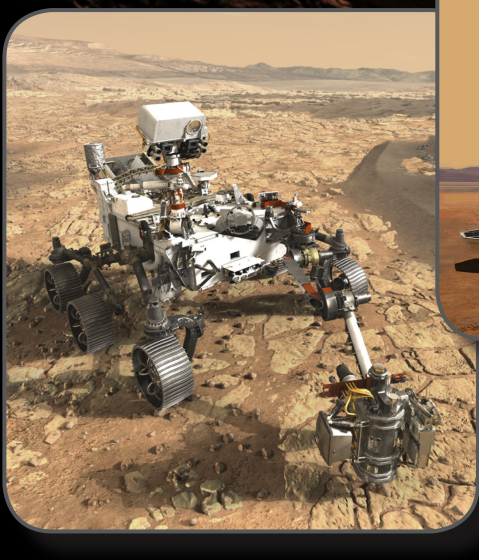
2018 INTERNATIONAL MARS SAMPLE RETURN CONFERENCE BERLIN



2018

INTERNATIONAL

MARS

SAMPLE RETURN

CONFERENCE

BERLIN

Welcome

It is with pleasure that I welcome you to the Second International Mars Sample Return Conference here in Berlin, organised by ESA, NASA and DLR. For me, Mars Sample Return (MSR) is a tantalising but achievable vision that lies at the intersection of the many good reasons to explore space.

There is no question that for a planetary scientist, the chance to bring pristine, carefully chosen samples of the Red Planet back to Earth for examination by the best brains using the best facilities is a mouth-watering prospect. Reconstructing the history of Mars and answering questions of its past and present habitability are only two areas of discovery that will be dramatically advanced by such a mission.

But MSR also demands that engineers solve a myriad of technical and operational challenges. Beyond traditional spacecraft engineering, it will drive innovation in unexpected but valuable areas such as materials, micro-biological protection and autonomous systems.

This complexity of these challenges also demand that they are addressed by an international and commercial partnership - the best of the best. At ESA, with our 22 member states and further cooperating partners, international cooperation is part of our DNA.

And the fascination and creativity of such an undertaking will surely create world-wide excitement. Early on, we should think about how to seize the exciting opportunities to communicate the value of science, technology engineering and mathematics for new generations through a Mars Sample Return expedition and embed this in our plans.

We should also not under-estimate the cultural and artistic potential of linking the Blue Planet and the Red Planet with the first “round trip” voyage of discovery. For example, it will reinforce the simple but often forgotten message of how dependent life on Earth is upon our cocooning atmosphere and magneto-sphere – luxuries which Mars has almost completely lost. And by acting as a “scale model” of an eventual human mission to Mars, it will bring that tantalising prospect a step closer to reality.

Here at ESA, we have been preparing MSR technology and concepts for a decade. More recently, we have combined our robotic and human exploration vision into a single programme E3P – the European Exploration Envelope Programme. Ten years on from the first International Mars Sample Return conference hosted by CNES in July 2008, it is the right time for the international science and technology community to review the state of the art in Mars science and exploration, reflect on what we have learnt in the past decade and measure our global readiness to launch an MSR campaign in the 2020’s.

For me, the key question is: are we ready for the challenge?
I hope that, together, we will discover the answer.

David H. Parker

David Parker
Director of Human and Robotic Exploration
European Space Agency

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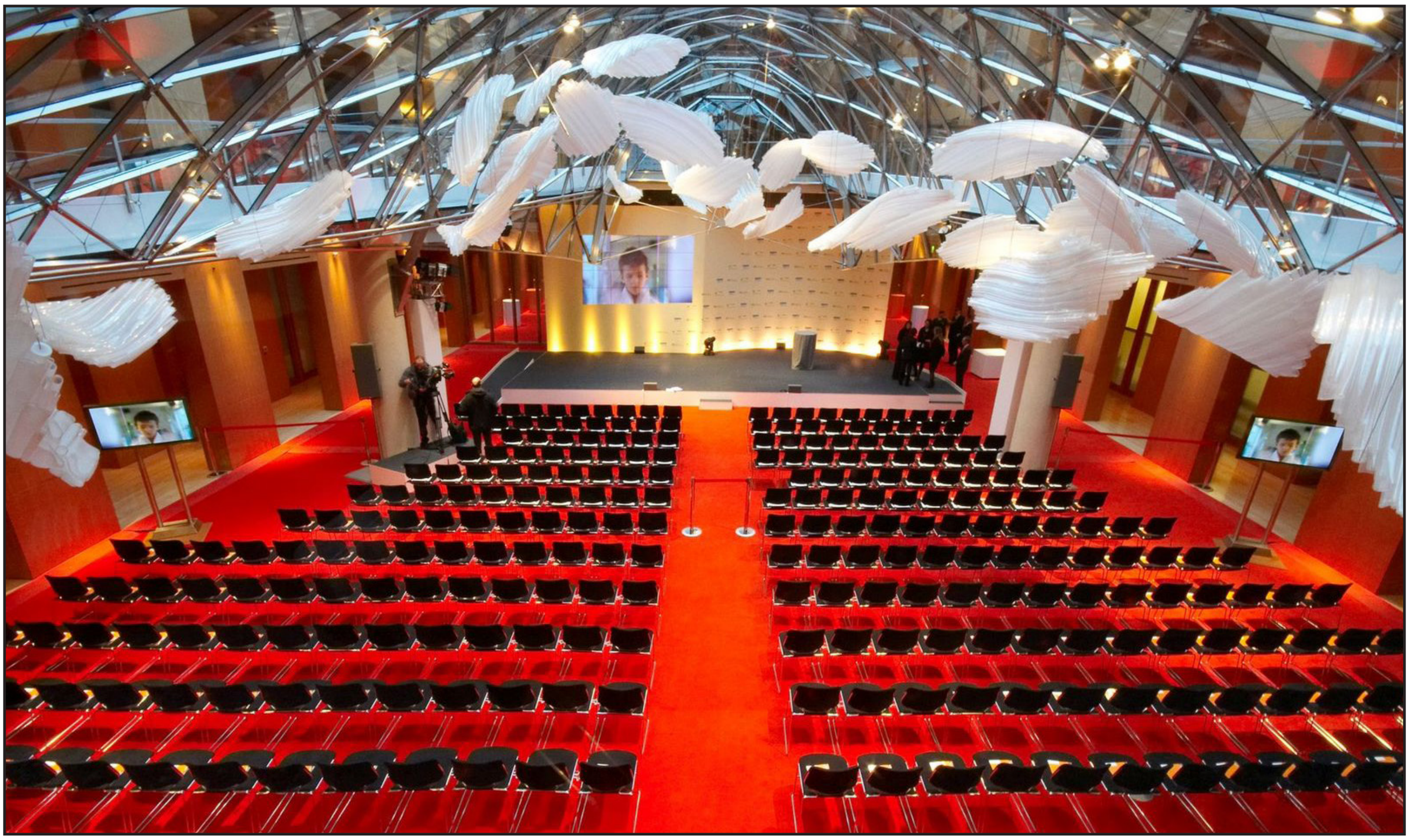
Dark Materials on Olympus Mons

Venue

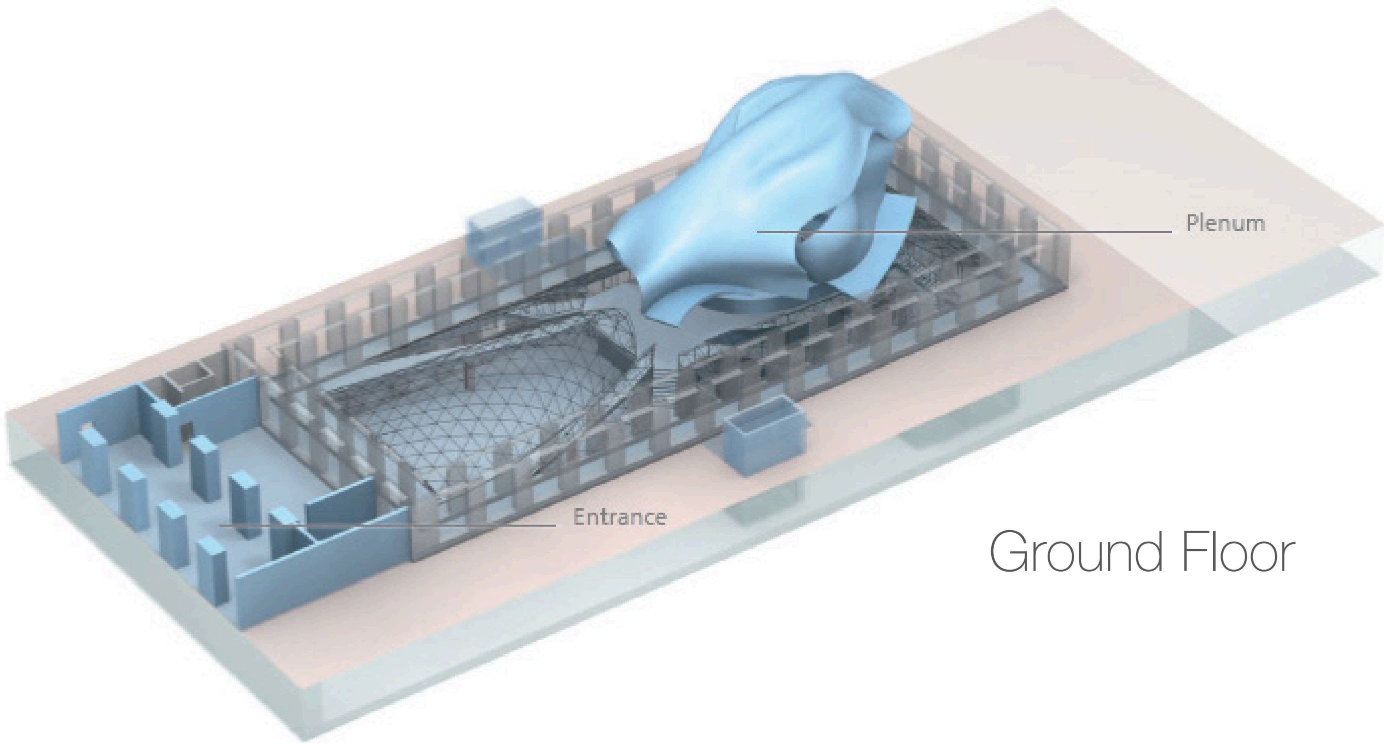
The AXICA Convention Center, Berlin

AXICA is located at Pariser Platz right next to the Brandenburg Gate, one of Berlin's great landmarks.The renowned architect Frank O. Gehry has created an architectural masterpiece that enhances the status of the location. The stark, classical façade opens onto the entrance area to reveal a spatial sculpture of biomorphic forms, lavish materials and a spectacular, dynamic geometry. A place for meeting and communicating, space for finding new prospects and inspiration.

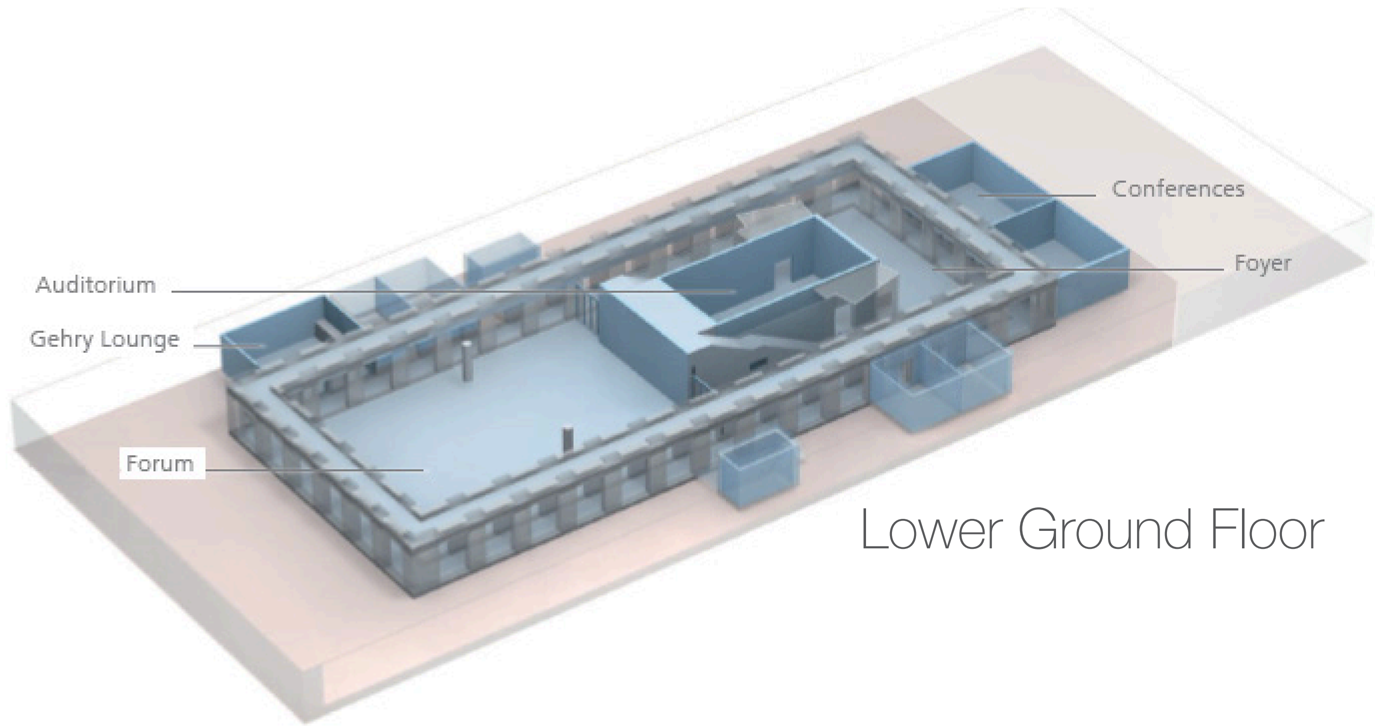


Wi-Fi Information

Network: MSR2018 | Password: MSRconf2018



Ground Floor



Lower Ground Floor

Committees

Institutional Support
European Space Agency
CNES
German Aerospace Center
National Aeronautics and Space Administration
International Mars Exploration Working Group
Lunar and Planetary Institute
Universities Space Research Association

Program Committee
Stefaan De Mey, European Space Agency
Chad Edwards, Jet Propulsion Laboratory, USA
Ernst Hauber, DE DLR
Chris Herd, University of Alberta, Canada
Jörn Helbert, DLR
Vicky Hipkin, Canadian Space Agency
Gerhard Kminek, European Space Agency
Christian Lange, Canadian Space Agency
Scott McLennan, SUNY Stony Brook, USA
Jack Mustard, Brown University, USA
Lisa Pratt, University of Indiana, USA
Elliot Sefton-Nash, European Space Agency
Caroline Smith, Natural History Museum, UK
Eileen Stansbery, NASA Johnson Space Center, USA
Micheline Tabache, European Space Agency

Organizing Committee
David Beaty, Jet Propulsion Laboratory, USA
Sanjay Vijendran, European Space Agency
Michael Meyer, NASA Headquarters, USA
Brandi Carrier, Jet Propulsion Laboratory, USA
Yael Asher, European Space Agency
Thiag Kumaraswamy, European Space Agency


The White Cliffs of ‘Rover’

Schedule at a Glance

Wednesday, April 25

<table>
<tr><td colspan="2">Registration and Morning Refreshments 9:30 a.m. – 10:00 a.m.</td></tr>
<tr><td rowspan="3">Welcome and Introductory Remarks
10:00 a.m. – 10:55 a.m.</td><td>Parker</td></tr>
<tr><td>Zurbuchen</td></tr>
<tr><td>Suchet</td></tr>
<tr><td rowspan="4">Mars Exploration: What Have We Learned Recently?
10:55 a.m. – 12:15</td><td>McLennan</td></tr>
<tr><td>Jaumann</td></tr>
<tr><td>McSween</td></tr>
<tr><td>Westall</td></tr>
<tr><td colspan="2">Discussion 12:15 p.m. – 12:30 p.m.</td></tr>
<tr><td colspan="2">Lunch 12:30 p.m. – 1:30 p.m.</td></tr>
<tr><td rowspan="8">Mars Returned Sample Science:
Report of the International Mars Sample Return Objectives and Samples Team (iMOST) Study
1:30 p.m. – 3:10 p.m.</td><td>Beaty and Grady</td></tr>
<tr><td>Mangold</td></tr>
<tr><td>Campbell</td></tr>
<tr><td>Siljeström</td></tr>
<tr><td>Des Marais</td></tr>
<tr><td>Kleine</td></tr>
<tr><td>Swindle</td></tr>
<tr><td>Lightning Talks</td></tr>
<tr><td colspan="2">Discussion 3:10 p.m. – 3:30 p.m.</td></tr>
<tr><td colspan="2">Break 3:30 p.m. – 3:50 p.m.</td></tr>
<tr><td rowspan="5">Mars Returned Sample Science:
Specific Samples and/or Investigation Strategies (1 of 2)
3:50 p.m. – 5:05 p.m.</td><td>Freissinet</td></tr>
<tr><td>Gangidine</td></tr>
<tr><td>Fornaro</td></tr>
<tr><td>McMahon</td></tr>
<tr><td>Siljeström</td></tr>
<tr><td colspan="2">Discussion 5:05 p.m. – 5:15 p.m.</td></tr>
<tr><td colspan="2">Break 5:15 p.m. – 5:30 p.m.</td></tr>
<tr><td colspan="2">Hors D'oeuvre / Poster Session / Tech Demos / Exhibits
5:30 p.m. –7:30 p.m.</td></tr>
</table>

Thursday, April 26

Morning Refreshments 8:00 a.m. – 8:30 a.m.	
Opening Remarks 8:30 a.m. – 8:35 a.m.	
Mars Returned Sample Science: Specific Samples and/or Investigation Strategies (2 of 2) 8:35 a.m. – 9:20 a.m.	Jakosky
	Thieme
	Brenker
Discussion 9:20 – 9:25 a.m.	
Keynote Talks: Lasting Legacy of Apollo Samples 9:25 a.m. – 10:05 a.m.	Sio
	Anand
Break 10:05 a.m. – 10:25 a.m.	
Mars 2020, Candidate Landing Sites, ExoMars and Their Relationship to Mars Sample Return 10:25 a.m. 11:15 a.m.	Williford
	Schulte
	Vago
Discussion 11:15 a.m. – 11:25 a.m.	
Concept for a Mars Sample Return Architecture, Flight Mission Elements, and Subsystems (1 of 3) 11:25 a.m. – 12:30 p.m.	Vijendran and Edwards
	Muirhead
	Duvet
	Hipkin
Lunch 12:30 p.m. – 1:30 p.m.	
Concept for a Mars Sample Return Architecture, Flight Mission Elements, and Subsystems (2 of 3) 1:30 p.m. – 2:05 p.m.	Vijendran
	Parrish
Discussion 2:05 p.m. – 2:15 p.m.	
ILA Mars Event Live Stream 2:15 p.m. – 3:00 p.m.	
Concept for a Mars Sample Return Architecture, Flight Mission Elements, and Subsystems (3 of 3) 3:00 p.m. – 3:35 p.m.	Perino
	Kminek
Discussion 3:35 p.m. – 3:50 p.m.	
Break 3:50 p.m. – 4:10 p.m.	
Mission Elements, Subsystems, and Technologies for Mars Sample Return 4:10 p.m. – 5:55 p.m.	Haldemann
	Ocon
	Fulford
	Bergemann
	Fumagalli
	Pellacani
	Marinova
Discussion 5:55 p.m. – 6:10 p.m.	
Break 6:10 p.m. – 6:30 p.m.	
Buses to Dinner 6:30 p.m.	
Conference Dinner	

Friday, April 27

Morning Refreshments 8:00 a.m. – 8:30 a.m.	
Opening Remarks 8:30 a.m. – 8:35 a.m.	
iMARS-2 8:35 a.m. – 9:05 a.m.	Haltigin and Smith
Discussion 9:05 a.m. – 9:15 a.m.	
Planning for Sample Receiving Facility(ies), Curation, and Analysis Facilities (1 of 2) 9:15 a.m. – 10:00 a.m.	Meyer Brucato McCubbin
Discussion 10:00 a.m. – 10:10 a.m.	
Break 10:10 a.m. – 10:30 a.m.	
Planning for Sample Receiving Facility(ies), Curation, and Analysis Facilities (2 of 2) 10:30 a.m. – 12:00 p.m.	Berthoud Vrublevskis Harrington Schoonen Simionovici Helbert
Discussion 12:00 p.m. – 12:10 p.m.	
Lunch 12:10 p.m. – 1:10 p.m.	
Concepts for Mars Sample Return Public Outreach 1:10 p.m. – 1:40 p.m.	Heward Klug Boonstra
Discussion 1:40 p.m. – 1:55 p.m.	
Mars Sample Return - Integration and Next Steps 1:55 p.m. 3:00 p.m.	Vijendran and Meyer Discussion Panel
Adjourn at 3:00 p.m.	

Layers and Dark Dunes

The Program

Wedneday, April 25

Welcome and Introductory Remarks

Introduction and historical context of the conference.

Chairs: David Beaty (Mars Program Office, JPL/Caltech, USA) and Sanjay Vijendran (ESA)

9:30 a.m. Registration and Coffee in Foyer

10:00 a.m. Welcome and Introductory Remarks
David Parker (ESA) and Thomas Zurbuchen (NASA Headquarters, USA)

10:40 a.m. 1st International Mars Sample Return Conference 2008: CNES Historical Perspective
Lionel Suchet (CNES)

Mars Exploration: What Have We Learned Recently?

This session summarizes recent results from the exploration of Mars. This is the scientific context within which we need to evaluate the scientific importance of Mars Sample Return.

Chairs: Jack Mustard (Brown University, USA) and Elliot Sefton-Nash (ESA)

10:55 a.m. Recent Accomplishments in Mars Exploration: The Rover Perspective [#6034]
Mobile rovers have revolutionized our understanding of Mars geology by identifying habitable environments and addressing critical questions related to Mars science. Both the advances and limitations of rovers set the scene for Mars Sample Return.
McLennan S.M. (The State University of New York at Stony Brook, USA)
McSween H.Y.

11:15 a.m. Mars Exploration Recent Accomplishments: Orbital Perspective [#6030]
All known geological processes are active on Mars and water played a major role all over its history.
Jaumann R. (DLR, Germany)

11:35 a.m. Martian Meteorites: What Have We Already Gleaned from Samples, and What are We Missing? [#6017]
Martian meteorites have been critical in understanding the planet's geologic processes and history, but biased sampling and lack of geologic context have limited what can be learned from them.
McSween H.Y. (University of Tennessee, USA)
Herd C.D.K.; Humayun M.; Beaty D.

11:55 a.m. The Search for Life on Mars: Latest Results [#6117]
A discussion of the current state of the search for life on Mars.
Westall F. (CNRS, France)

12:15 p.m. Discussion

12:30 p.m. Lunch

Mars Returned Sample Science: Report of the International Mars Sample Return Objectives and Samples Team (iMOST) Study

Report of the International Mars Sample Return Objectives and Samples Team (iMOST) analysis.

Chairs: Benjamin Weiss (Massachusetts Institute of Technology, USA) and Stephanie Werner (University of Oslo, Norway)

1:30 p.m. Introduction to the 2018 iMOST Study [#6120]

An overview of the 2018 iMOST study on the science potential of Mars Sample Return.

iMOST Team: Beaty D.W. (Mars Program Office, JPL/Caltech, USA); Grady M.M. (Open University, UK); McSween H.Y.; Sefton-Nash E.; Carrier B. L.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mackelprang R.; Mangold N.; Mayhew L.E.; McCoy J.T.; McCubbin F.M.; McLennan S.M.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

1:40 p.m. Seeking Signs of Life on Mars: The Importance of Sedimentary Suites as Part of Mars Sample Return [#6045]

Sedimentary, and especially lacustrine, depositional environments are high-priority geological/astrobiological settings for Mars Sample Return. We review the detailed investigations, measurements, and sample types required to evaluate such settings.

iMOST Team: Mangold N. (University of Nantes-LPG, France); McLennan S.M.; Czaja A.D.; Ori G.G.; Tosca N.J.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

1:52 p.m. Seeking Signs of Life on Mars: A Strategy for Selecting and Analyzing Returned Samples from Hydrothermal Deposits [#6046]

The iMOST hydrothermal deposits sub-team has identified key samples and investigations required to delineate the character and preservational state of potential biosignatures in ancient hydrothermal deposits.

iMOST Team: Campbell K.A. (University of Auckland, New Zealand); Farmer J.D.; Van Kranendonk M.J.; Fernandez-Remolar D.C.; Czaja A.D.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Carrier B.L.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

2:04 p.m. The Search for Life's Organic Carbon in Returned Samples from Mars [#6052]

This is a provisional report from the iMOST sub-team on the objective of seeking the signs of life, identifying key samples, and measurements needed to understand martian organic carbon.

iMOST Team: Siljeström S. (RISE Research Institutes of Sweden, Stockholm, Sweden); Sephton M.A.; Glavin D.P.; Brucato J.R.; Raulin F.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Shaheen R.; Shuster D.L.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

2:16 p.m. Seeking the Signs of Life: Assessing the Presence of Biosignatures in the Returned Sample Suite [#6102]

Biosignatures are objects, substances, and/or patterns whose origins require life. They occur as organic compounds, stable isotope patterns, minerals, and morphologies. Each type requires particular modes of preservation and analytical measurements.

iMOST Team: Des Marais D.J. (NASA Ames Research Center, USA); Grady M.M.; Shaheen R.; Steele A.; Westall F.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

2:28 p.m. What Could be Learned About the Geochronology of Mars from Samples Collected by M-2020 [#6041]
A discussion of the objectives for geochronology of returned martian samples collected by M-2020, principally calibration of cratering, dynamo, and climate histories.
iMOST Team: Kleine T. (University of Münster, Germany);
Humayun M.; Amelin Y.; Borg L.E.; Herd C.D.K.; Moser D.E.; Moynier F.; Shuster D.L.; Wadhwa M.; Werner S.C.; Zipfel J.; Altieri F.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Horgan B.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Septhon M.A.; Shaheen R.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Weiss B.P.; Westall F.; Wheeler R.M.; Zorzano M.P.

2:40 p.m. Constraining Our Understanding of the Actions and Effects of Martian Volatiles Through the Study of Returned Samples [#6054]
Volatiles play a key role in the evolution of Mars' atmosphere, hydrosphere, and geosphere, and returned samples of the atmosphere, sedimentary rocks, regolith, and secondary minerals will inform our understanding of that evolution.
iMOST Team: Swindle T.D. (University of Arizona, USA);
Altieri F.; Busemann H.; Niles P.B.; Shaheen R.; Zorzano M.P.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Campbell K.A.; Carrier B. L. Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.

2:52 p.m. Lightning Talks
Brief presentations of other iMOST objectives from the poster session.

3:10 p.m. Discussion

3:30 p.m. Break

Mars Returned Sample Science: Specific Samples and/or Investigation Approaches (1 of 2)

The presentations in this session describe either specific samples of interest or specific measurements/investigations for Mars Sample Return. Please be sure to visit the poster session for more of these ideas.

Chairs: Vinciane Debaille (Université Libre de Bruxelles, Belgium) and Ernst Hauber (DLR, Germany)

3:50 p.m. Sample Analysis at Mars (SAM) and Mars Organic Molecule Analyzer (MOMA) as Critical In Situ Investigation for Targeting Mars Returned Samples [#6044]
SAM (Curiosity) and MOMA (ExoMars) Mars instruments, seeking for organics and biosignatures, are essential to establish taphonomic windows of preservation of molecules, in order to target the most interesting samples to return from Mars.
Freissinet C. (LATMOS-IPSL, France);
Glavin D.P.; Mahaffy P.R.; Szopa C.; Buch A.; Goesmann F.; Goetz W.; Raulin F.; Science Teams SAM and MOMA

4:05 p.m. Developing a Trace Element Biosignature for Early Earth and Mars [#6018]
Due to metamorphism and diagenesis, determining the biogenicity of ancient fossils is difficult and often contentious. Using trace element concentrations, we propose a novel biosignature independent from organic and morphological preservation.
Gangidine A. (University of Cincinnati, USA);
Czaja A.D.; Havig J.

4:20 p.m. Preparation, Characterization, and UV Irradiation of Mars Soil Analogues Under Simulated Martian Conditions to Support Detection of Molecular Biomarkers [#6057]
We present laboratory activities of preparation, characterization, and UV irradiation processing of Mars soil analogues, which are key to support both in situ exploration and sample return missions devoted to detection of molecular biomarkers on Mars.
Fornaro T. (Carnegie Institution of Washington, USA);
Brucato J.R.; ten Kate I.L.; Siljeström S.; Steele A.; Cody G.D.; Hazen R.M.

4:35 p.m. How Can We Look for Fossils on Mars? [#6078]
Mars 2020 should target fine-grained sediments, which on Earth preserve biosignatures more reliably and consistently than other settings identified on Mars. Taphonomic experiments will show how oxychlorine compounds may affect preservation.
McMahon S. (University of Edinburgh, UK);
Bosak T.; Grotzinger J.P.; Briggs D.E.G.; Hurowitz J.; Tosca N.; Petroff A.; Summons R.E.; Weiss B.P.

4:50 p.m. Spatial Mapping of Organic Carbon in Returned Samples from Mars [#6104]
To map organic material spatially to minerals present in the sample will be essential for the understanding of the origin of any organics in returned samples from Mars. It will be shown how ToF-SIMS may be used to map organics in samples from Mars.
Siljeström S. (RISE Research Institutes of Sweden, Sweden);
Fornaro T.; Greenwalt D.; Steele A.

5:05 p.m. Discussion

5:15 p.m. Break

5:30 p.m. Poster Session Area

Posters: Mars Sample Return Engineering

The Designing of the Mission to Mars for the Siol Delivery by the Electric Propulsion Spacecraft [#6004]
The effectiveness of the mission to return soil from Mars depends on design and trajectory parameters.The problem of comprehensive optimization of the low-thrust mission Earth-Mars-Earth is formulated and solved in this paper.
Starinova O.L.; Gao Ch.; Kurochkin D.V.; Yudong H.

Engineering Challenges for a Sample Fetch Rover [#6011]
The Sample Fetch Rover is a key element of the Mars Sample Return mission architecture. This presentation will focus on the engineering challenges that must be overcome to achieve the mission goals.
Wayman A.; Meacham P.; Williams M.

Mars Sample Return Orbiter Architecture Options — Results of the ESA Mars Sample Return Architecture Assessment Study [#6015]
This paper presents the identified most promising chemical and electric propulsion architecture options of the Mars Sample Return (MSR) orbiter identified during the recent ESA MSR Architecture Assessment Study.
Derz U.; Joffre E.; Perkinson M.C.; Huesing J.; Beyer F.; Sanchez Perez J.M.

Orbiting Sample Capture and Orientation Technologies for Potential Mars Sample Return [#6027]
Technologies applicable to a potential Mars Sample Return Orbiter for orbiting sample container capture and orientation are presented, as well as an integrated MArs CApture and ReOrientation for a potential NExt Mars Orbiter (MACARONE) concept.
Younse P.; Adajian R.; Dolci M.; Ohta P.; Olds E.; Lalla K.; Strahle J.W.

Drill Concept for a Future Mars Sample Return Mission [#6032]
The return to the Earth of samples of high astrobiological interest is one of the main objectives of the future martian exploration programs.
Fumagalli A.; Pilati A.; Sangiovanni G.; De Sanctis M.C.; Mugnuolo R.; Altieri F.; Ammannito E.; Pirrotta S.; Gily A.; Durrant S.

Mars Sample Return as a Key Step Before Manned Missions [#6050]
A Mars Sample Return mission is in the roadmap of a manned mission if and only if it participates to the qualification of the entry, descent, and landing systems.
Salotti J.M.

In Situ Pre-Selection of Return Samples with Bio-Signatures by Combined Laser Mass Spectrometry and Optical Microscopy [#6059]
The University of Bern developed instrument prototypes that allow analysis of samples on Mars prior to bringing them back to Earth, allowing to maximize the scientific outcome of the returned samples. We will present the systems and first results.
Wiesendanger R.; Wurz P.; Tulej M.; Wacey D.; Neubeck A.; Grimaudo V.; Riedo A.; Moreno P.; Cedeño-López A.; Ivarsson M.

OHB's Exploration Capabilities Overview Relevant to Mars Sample Return Mission [#6064]
The presentation will give an overview to all the OHB past and current projects that are relevant to the Mars Sample Return (MSR) mission, including some valuable lessons learned applicable to the upcoming MSR mission.
Jaime A.; Gerth I.; Rohrbeck M.; Scheper M.

Antarctic Testing of the European Ultrasonic Planetary Core Drill (UPCD) [#6067]
An overview of a series of field testing in Antarctica where the Ultrasonic Planetary Core Drill (UPCD) architecture was tested. The UPCD system is the product an EC FP7 award to develop a Mars Sample Return architecture based around the ultrasonic technique.
Timoney R.; Worrall K.; Li X.; Firstbrook D.; Harkness P.

TU Berlin Rover Family for Terrestrial Testing of Complex Planetary Mission Scenarios [#6074]
The TU Berlin has developed a family of planetary rovers for educational use and research activities. The paper will introduce these cost-effective systems, which can be used for analogue mission demonstration on Earth.
Kryza L.; Brieß K.

Re-Entry: Inflatable Technology Development in Russian Collaboration (RITD) [#6079]
Technology has been developed specifically for launching spacecraft into the planet's atmosphere. The technology is based on the concept of using inflatable braking device, which was originally developed for landing in conditions of Mars.
Koryanov V.V.; Kazakovtsev V.P.; Harri A.M.; Da-Poian V.

Mars Sample Return Orbiter Rapid Architecture Study [#6098]
An overview of rapid systems analysis (mass, risk, and schedule) on 1000s of MSRO configurations to understand key technologies and feasible options. Can we generate enough power? Can we aerobrake in time? Are some technology elements just too risky?
Godfrey A.; Johnson M.; Stroud C.

The Potential Impact of Mars' Atmospheric Dust on Future Human Exploration of the Red Planet: Mars Sample Return Considerations [#6105]
To aid early engineering and mission design efforts, the NESC held a workshop on the atmospheric dust and its impact on the human exploration of Mars. Of great interest is the possible Mars Sample Return contribution that will help to answer pertinent questions.
Winterhalter D.; Levine J.S.; Kerschmann R.; Beaty D.W.; Carrier B.L.; Ashley J.W.

CNES Rover Autonomous Navigation and Its Potential Application to Mars Sample Return Fetch Rover [#6126]
This paper presents the work achieved by CNES to meet some of the challenges of autonomous traverse capabilities throughout its R&D activities and participation to Exomars.
Delpech M.; Rave X.; Rastel L.

From Exomars to Mars Sample Return: Thales Alenia Space Experience and Know-Hows
Ferri A.; Billot C.; Garcés de Marcilla D.

Posters: Mars Sample Return Science, Analogue Studies, and Potential Landing Sites

Sample Quality Standards for Returned Martian Samples [#6056]
Summary of sample quality standards for Mars Sample Return as defined by the Mars 2020 Returned Sample Science Board.
Returned Sample Science Board: Beaty D.W.; McSween H.Y.; Carrier B.L.; Czaja A.D.; Goreva Y.S.; Hausrath E.M.; Herd C.D.K.; Humayun M.; McCubbin F.M.; McLennan S.M.; Pratt L.M.; Sephton M.A.; Steele A.; Weiss B.P.

Introduction to the 2018 iMOST Study [#6089]
An introduction to the 2018 International Mars Sample Return Objectives and Samples Team (iMOST) study, and a preliminary report of the scientific objectives of Mars Sample Return.
iMOST Team: Beaty D.W.; Grady M.M.; McSween H.Y.; Sefton-Nash E.; Carrier B.L.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mackelprang R.; Mangold N.; Mayhew L.E.; McCoy J.T.; McCubbin F.M.; McLennan S.M.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

High Priority Samples to Characterize the Habitability of Groundwaters and Search for Rock-Hosted Life on Mars [#6051]
Discussion of the strategies required to understand the geologic context and habitability of martian groundwater aquifers and to search for evidence of life in the martian subsurface using samples.
iMOST Team: Ehlmann B.L.; Mayhew L.E.; Mustard J.F.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

Potential High Priority Subaerial Environments for Mars Sample Return [#6043]
The highest priority subaerial environments for Mars Sample Return include subaerial weathering (paleosols, periglacial/glacial, and rock coatings/rinds), wetlands (mineral precipitates, redox environments, and salt ponds), or cold spring settings.
iMOST Team: Bishop J.L.; Horgan B.; Benning L.G.; Carrier B.L.; Hausrath E.M.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Herd C.D.K.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; Mccoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

The Use of Returned Martian Samples to Evaluate the Possibility of Extant Life on Mars [#6053]
The astrobiological community is highly interested in interrogating returned martian samples for evidence of extant life. A single observation with one method will not constitute evidence of extant life — it will require a suite of investigations.
iMOST Team: ten Kate I.L.; Mackelprang R.; Rettberg P.; Smith C.L.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mayhew L.E.; McCoy J.T.; McCubbin F.M.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Spry J.A.; Steele A.; Swindle T.D.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

The Importance of Mars Samples in Constraining the Geological and Geophysical Processes on Mars and the Nature of its Crust, Mantle, and Core [#6055]
We present the main sample types from any potential Mars Sample Return landing site that would be required to constrain the geological and geophysical processes on Mars, including the origin and nature of its crust, mantle, and core.
iMOST Team: Herd C.D.K.; Ammannito E.; Anand M.; Debaille V.; Hallis L.J.; McCubbin F.M.; Schmitz N.; Usui T.; Weiss B.P.; Altieri F.; Amelin Y.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Harrington A.D.; Hausrath E.M.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Van Kranendonk M.J.; Wadhwa M.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

The Importance of Returned Martian Samples for Constraining Potential Hazards to Future Human Exploration [#6049]
Thorough characterization and evaluation of returned martian regolith and airfall samples are critical to understanding the potential health and engineering system hazards during future human exploration.
iMOST Team: Harrington A.D.; Carrier B.L.; Fernandez-Remolar D.C.; Fogarty J.; McCoy J.T.; Rucker M.A.; Spry J.A.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Beaty D.W.; Benning L.G.; Bishop J.L.; Borg L.E.; Boucher D.; Brucato J.R.; Busemann H.; Campbell K.A.; Czaja A.D.; Debaille V.; Des Marais D.J.; Dixon M.; Ehlmann B.L.; Farmer J.D.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Kleinhenz J.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Niles P.B.; Ori G.G.; Raulin F.; Rettberg P.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Wheeler R.M.; Zipfel J.; Zorzano M.P.

The Relevance of Mars Samples to Planning for Potential Future In-Situ Resource Utilization [#6042]
Discussion of objectives related to in-situ resource utilization that could be met using returned martian samples, including what types of samples would be useful for meeting these objectives.
iMOST Team: Kleinhenz J.; Beaty D.W.; Boucher D.; Dixon M.; Niles P.B.; Wheeler R.M.; Zorzano M.P.; Altieri F.; Amelin Y.; Ammannito E.; Anand M.; Benning L.G.; Bishop J.L.; Borg L.E.; Brucato J.R.; Busemann H.; Campbell K.A.; Carrier B.L.; Czaja A.D.; Debaille V.; Des Marais D.J.; Ehlmann B.L.; Farmer J.D.; Fernandez-Remolar D.C.; Fogarty J.; Glavin D.P.; Goreva Y.S.; Grady M.M.; Hallis L.J.; Harrington A.D.; Hausrath E.M.; Herd C.D.K.; Horgan B.; Humayun M.; Kleine T.; Mangold N.; Mackelprang R.; Mayhew L.E.; McCubbin F.M.; McCoy J.T.; McLennan S.M.; McSween H.Y.; Moser D.E.; Moynier F.; Mustard J.F.; Ori G.G.; Raulin F.; Rettberg P.; Rucker M.A.; Schmitz N.; Sefton-Nash E.; Sephton M.A.; Shaheen R.; Shuster D.L.; Siljeström S.; Smith C.L.; Spry J.A.; Steele A.; Swindle T.D.; ten Kate I.L.; Tosca N.J.; Usui T.; Van Kranendonk M.J.; Wadhwa M.; Weiss B.P.; Werner S.C.; Westall F.; Zipfel J.

Martian Regolith for Plant-Based Life Support [#6005]
As plants could play key roles in future long-term life support systems on Mars, it is crucial to know whether in situ resources such as martian regolith are suitable for seed germination and subsequent growth of a wide variety of plant species.
Visscher A.M.; Seal C.E.; Pritchard H.W.

The Use of Terrestrial Analogues to Inform Mars Sample Return [#6007]
Terrestrial Mars analogue sites can provide insights into rover-based biosignature detection, types of biosignatures present in different Mars-relevant terrains, biosignature preservation, and location of biosignature hot spots.
Cloutis E.A.

Impact Craters and Impactites as Important Targets for Mars Sample Return Missions [#6016]
Research conducted over the past few years reveals that meteorite impact craters provide substrates and habitats for life. We propose that craters and their products should be reconsidered as high priority targets for Mars Sample Return missions.
Osinski G.R.; Cockell C.S.; Pontefract A.; Sapers H.M.; Tornabene L.L.

The CanMars Analogue Mission: Lessons Learned for Mars Sample Return [#6068]
We present an overview and lessons learned for Mars Sample Return from CanMars — an analogue mission that simulated a Mars 2020-like cache mission. Data from 39 sols of operations conducted in the Utah desert in 2015 and 2016 are presented.
Osinski G.R.; Beaty D.; Battler M.; Caudill C.; Francis R.; Haltigin T.; Hipkin V.; Pilles E.

Astrobiological In-Situ Investigations as Part of a Mars Sample Return Mission [#6022]
Proposal to include in a Mars Sample Return mission an in-situ component to make sure that active life is not missed, both because of planetary protection ramifications and scientific value.
Schulze-Makuch D.; Airo A.

Landing Sites for a Mars Sample Return Mission in Arabia Terra [#6033]
We are characterizing the geology of several areas in Arabia Terra as possible Mars Sample Return mission landing sites. Arabia Terra presents several interesting sites regarding the search for past traces of life on Mars.
Salese F.; Pondrelli M.; Schmidt G.W.; Mitri G.; Pacifici A.; Cavalazzi B.; Ori G.G.; Glamoclija M.; Hauber E.; Le Deit L.; Marinangeli L.; Rossi A.P.

The Planetary Terrestrial Analogues Library (PTAL) [#6060]
The Planetary Terrestrial Analogues Library project aims to build and exploit a spectral data base for the characterisation of the mineralogical and geological evolution of terrestrial planets and small solar system bodies.
Werner S.C.; Dypvik H.; Poulet F.; Rull Perez F.; Bibring J.P.; Bultel B.; Casanova Roque C.; Carter J.; Cousin A.; Guzman A.; Hamm V.; Hellevang H.; Lantz C.; Lopez-Reyes G.; Manrique J.A.; Maurice S.; Medina Garcia J.; Navarro R.; Negro J.I.; Neumann E.R.; Pilorget C.; Riu L.; Sætre C.; Sansano Caramazana A.; Sanz Arranz A.; Sobron Grañón F.; Veneranda M.; Viennet J.C.; PTAL Team

Western Eos Chaos on Mars: A Potential Site for Future Landing and Returning Samples [#6065]
Introducing Eos Chaos as a potential area for collecting samples. Eos Chaos contains a number of aqueous minerals. We have detected zoisite — a least reported low-grade metamorphic mineral from this area.
Asif Iqbal Kakkassery; Rajesh V.J.

PTAL Database and Website: Developing a Novel Information System for the Scientific Exploitation of the Planetary Terrestrial Analogues Library [#6069]
The PTAL website will store multispectral analysis of samples collected from several terrestrial analogue sites and pretend to become a cornerstone tool for the scientific community interested in deepening the knowledge on Mars geological processes.
Veneranda M.; Negro J.I.; Medina J.; Rull F.; Lantz C.; Poulet F.; Cousin A.; Dypvik H.; Hellevang H.; Werner S.C.

Plans for Selection and In-Situ Investigation of Return Samples by the Supercam Instrument Onboard the Mars 2020 Rover [#6072]
The SuperCam instrument onboard Rover 2020 still provides a complementary set of analyses with IR reflectance and Raman spectroscopy for mineralogy, LIBS for chemistry, and a color imager in order to investigate in-situ samples to return.
Wiens R.C.; Maurice S.; Mangold N.; Anderson R.; Beyssac O.; Bonal L.; Clegg S.; Cousin A.; DeFlores L.; Dromart G.; Fisher W.; Forni O.; Fouchet T.; Gasnault O.; Grotzinger J.; Johnson J.; Martinez-Frias J.; McLennan S.; Meslin P.-Y.; Montmessin F.; Poulet F.; Rull F.; Sharma S.

Searching for Biosignatures in Martian Sedimentary Systems [#6076]
We present experiments designed to simulate an inhabited martian lacustrine system analogous to Gale Crater. We describe the microbes found to thrive in this simulated environment and identify issues detecting biomarkers in this context.
Stevens A.H.; McDonald A.; Cockell C.S.

X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) for In Situ Surface Characterization and Triage of Cached Samples [#6077]
In situ X-ray diffraction and fluorescence instruments in development will be presented. Capabilities to elucidate provenance, inform cache/discard decisions, and document a sample's original state in the context of sample return will be discussed.
Walroth R.C.; Blake D.F.; Sarrazin P.; Bristow T.; Thompson K.

APXS Data from Mars and MSR Samples: How Can They Be Combined and Benefit from Each Other? [#6080]
The APXS has returned the chemical composition of more than 1000 samples on four rover missions along the combined traverse of >70km. Combining Mars data with terrestrial lab results of martian samples will be important, but it has to be done right.
Gellert R.

Towards Mars — Stratospheric Balloons as Test-Beds for Mars Exploration [#6083]
The abstract deals with the possibilities to use stratospheric balloons for Mars science and technology needs, especially with the opportunities offered by the new European infrastructure project HEMERA, recently selected by the European Commission.
Dannenberg K.

Combining Non–Destructive Magnetic and Raman Spectroscopic Analyses for Mars Sample Return — Powerful Tools In Situ and in Laboratory [#6086]
Very sophisticated, high-end techniques are requested for the investigation of pristine particles from a planetary surface, such as Mars, in situ or in our laboratories, in case of martian meteorites or even returned samples from (future) missions.
Hoffmann V.H.; Kaliwoda M.; Hochleitner R.; Mikouchi T.; Wimmer K.

Martian Methane Cycle and Organic Compounds from Martian Regolith Breccia NWA7533 by Orbitrap Mass Spectrometry [#6088]
We compare the organic mixture of a carbon rich martian meteorite and carbonaceous chondrites. The major difference lies in the absence of polymeric patterns in NWA7533. We interpret this as a destruction of exogenous polymers under Mars conditions.
Orthous-Daunay F.R.; Thissen R.; Flandinet L.; Bonal L.; Vuitton V.; Beck P.; Hashiguchi M.; Naraoka H.

Spectral Characterization of H2020/PTAL Mineral Samples: Implications for In Situ Martian Exploration and Mars Sample Selection [#6090]
We present combined analysis performed in the framework of the Planetary Terrestrial Analogues Library (H2020 project). XRD, NIR, Raman, and LIBS spectroscopies are used to characterise samples to prepare ExoMars/ESA and Mars2020/NASA observations.
Lantz C.; Pilorget C.; Poulet F.; Riu L.; Dypvik H.; Hellevang H.; Rull Perez F.; Veneranda M.; Cousin A.; Viennet J.C.; Werner S.C.

Seeking Signs of Life Preserved in Martian Silica [#6093]
Hot spring nodular silica deposits on Earth, which resemble those discovered with the Spirit rover, preserve concentrated organics and fine-scale structures that could be searched for on Mars with the Mars 2020 rover and in returned samples.
Ruff S.W.; Farmer J.D.; Van Kranendonk M.J.; Campbell K.A.; Djokic T.; Damer B.; Deamer D.W.

Downselection for Sample Return — Defining Sampling Strategies Using Lessons from Terrestrial Field Analogues [#6094]
We detail multi-year field investigations in Icelandic Mars analogue environments that have yielded results that can help inform strategies for sample selection and downselection for Mars Sample Return.
Stevens A.H.; Gentry D.; Amador E.; Cable M.L.; Cantrell T.; Chaudry N.; Cullen T.; Duca Z.; Jacobsen M.; Kirby J.; McCaig H.; Murukesan G.; Rader E.; Rennie V.; Schwieterman E.; Sutton S.; Tan G.; Yin C.; Cullen D.; Geppert W.; Stockton A.

The Rosetta Stones of Mars — Should Meteorites be Considered as Samples of Opportunity for Mars Sample Return? [#6096]
We summarize insights about Mars gained from investigating meteorites found on Mars. Certain types of meteorites can be considered standard probes inserted into the martian environment. Should they be considered for Mars Sample Return?
Tait A.W.; Schröder C.; Ashley J.W.; Velbel M.A.; Boston P.J.; Carrier B.L.; Cohen B.A.; Bland P.A.

Mineralogical Control of Organic Matter Thermal Alteration: Implications for Biosignature Preservation in Returned Martian Samples [#6100]
Raman spectroscopy, which will be used by Mars 2020, can identify organic carbon and can assess the level of thermal alteration experienced by organic fossils. This study provides evidence that lithology can also influence apparent thermal alteration.
Czaja A.D.; Osterhout J.T.; Gangidine A.J.

Ultrasonic Sorter for Handling and Collecting Dust or Soil Particles Separated by Size/Density [#6103]
A new device is proposed consisting of an endless screw attached to a small sorter actuated by ultrasounds where particles collect from soil or dust to be separated and collected in different reservoirs for their return to the Earth.
Gonzalez I.; Pinto A.

Hydrated Minerals and Evaporites as Key Targets for a Mars Sample Return Mission [#6111]
Here we focus on hydrated minerals and evaporites as paleo-environment indicators with preservation capacity. Thus, samples from these materials would increase our knowledge about the past aqueous activities of Mars and its habitability potentials.
Adeli S.; Hauber E.; Jaumann R.

The Nature, Origin, and Importance of Carbonate-Bearing Samples at the Final Three Candidate Mars 2020 Landing Sites [#6113]
All three candidate Mars 2020 landing sites contain similar regional olivine/carbonate units, and a carbonate unit of possible lacustrine origin is also present at Jezero. Carbonates are critical for Mars Sample Return as records of climate and biosignatures.
Horgan B.; Anderson R.B.; Ruff S.W.

Advanced Analytical Methodologies Based on Raman Spectroscopy to Detect Prebiotic and Biotic Molecules: Applicability in the Study of the Martian Nakhlite NWA 6148 Meteorite [#6114]
Advanced methodologies based on Raman spectroscopy are proposed to detect prebiotic and biotic molecules in returned samples from Mars: (a) optical microscopy with confocal micro-Raman, (b) the SCA instrument, (c) Raman Imaging. Examples for NWA 6148.
Madariaga J.M.; Torre-Fdez I.; Ruiz-Galende P.; Aramendia J.; Gomez-Nubla L.; Fdez-Ortiz de Vallejuelo S.; Maguregui M.; Castro K.; Arana G.

Examination of Laser Microprobe Vacuum Ultraviolet Ionization Mass Spectrometry with Application to Mapping Mars Returned Samples [#6115]
Laser microprobe of surfaces utilizing a two laser setup whereby the desorption laser threshold is lowered below ionization, and the resulting neutral plume is examined using 157nm Vacuum Ultraviolet laser light for mass spec surface mapping.
Burton A.S.; Berger E.L.; Locke D.R.; Lewis E.K.; Moore J.F.

On Size of Meteorites from Surface of Mars for Mars Sample Return Mission [#6116]
Couple ideas on size of meteorites from surface of Mars for Mars Sample Return mission.
Yakovlev G.A.; Grokhovsky V.I.

Posters: Sample Receiving Facilities, Curation, and Planetary Protection

Description of European Space Agency (ESA) Double Walled Isolator (DWI) Breadboard Currently Under Development for Demonstration of Critical Technology Foreseen to be Used in the Mars Sample Receiving Facility (MSRF) [#6009]
The need for biocontainment from Planetary Protection Policy and the need for cleanliness for scientific investigation requires that the samples returned from Mars by the Mars Sample Return (MSR) mission must be handled in a Double Walled Isolator (DWI).
Vrublevskis J.; Berthoud L.; McCulloch Y.; Bowman P.; Holt J.; Bridges J.; Bennett A.; Gaubert F.; Duvet L.

Description of European Space Agency (ESA) Remote Manipulator (RM) System Breadboard Currently Under Development for Demonstration of Critical Technology Foreseen to be Used in the Mars Sample Receiving Facility (MSRF) [#6010]
In order to avoid the use of "double walled" gloves, a haptic feedback Remote Manipulation (RM) system rather than a gloved isolator is needed inside a Double Walled Isolator (DWI) to handle a sample returned from Mars.
Vrublevskis J.; Duncan S.; Berthoud L.; Bowman P.; Hills R.; McCulloch Y.; Pisla D.; Vaida C.; Gherman B.; Hofbaur M.; Dieber B.; Neythalath N.; Smith C.; van Winnendael M.; Duvet L.

It's Time to Develop a New "Draft Test Protocol" for a Mars Sample Return Mission (or Two....) [#6012]
A Mars Sample Return (MSR) will involve analysis of those samples in containment, including their safe receiving, handling, testing, and archiving. With an MSR planned for the end of the next decade, it is time to update the existing MSR protocol.
Rummel J.D.

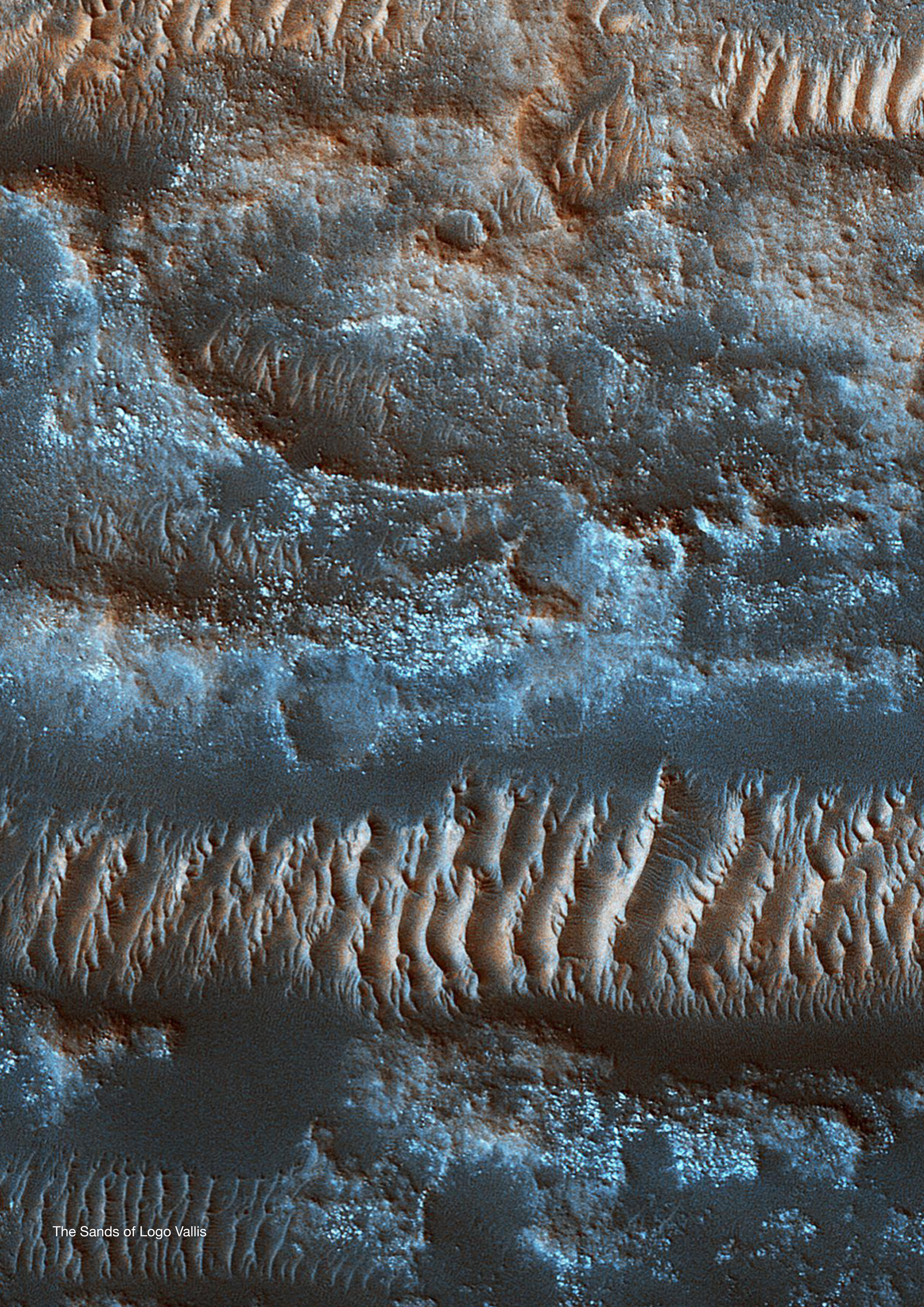
Mars Sample Return as a Feed-Forward into Planetary Protection for Crewed Missions to the Martian Surface [#6108]
PP implementation is a required part of crewed exploration of Mars. Determining how PP is achieved is contingent on improved knowledge of Mars, best obtained in part by analysis of martian material of known provenance, as part of a Mars Sample Return mission.
Spry J.A.; Siegel B.

Experimental Study of an Assembly with Extreme Particulate, Molecular, and Biological Requirements in Different Environmental Scenarios from Quality Point of View [#6063]
The presentation will cover results from an ESA supported investigation to collect lessons learned for mechanism assembly with the focus on quality and contamination requirements verification in exploration projects such as ExoMars.
Müller A.; Urich D.; Kreck G.; Metzmacher M.; Lindner R.

EURO-CARES: Recommendations for the Design of a Mars Sample Return Facility [#6082]
The EURO-CARES team presents the final design and infrastructure for a receiving and curation facility for restricted samples.
Hutzler A.; Ferrière L.; Bennett A.; Russell S.S.; Smith C.L.; EURO-CARES Consortium

Impact of Planetary Protection and Contamination Control on a Life Detection or Sample Return Mission [#6095]
ExoMars as one of the few life detection missions can be an example of how planetary protection and contamination control influence of the development of flight hardware. A few lessons learned can be drawn from the mission even before launch.
Steininger H.

Facility or Facilities? That is the Question. [#6109]
The management of the martian samples upon arrival on the Earth will require a lot of work to ensure a safe life detection and biohazard testing during the quarantine. This will induce a sharing of the load between several facilities.
Viso M.


The Sands of Logo Vallis

Thursday, April 26

Mars Returned Sample Science: Specific and/or Investigation Approaches (2 of 2)

The presentations in this session describe either specific samples of interest or specific measurements/ investigations for Mars Sample Return. Please be sure to visit the poster session for more of these ideas. Refreshments will be available before the session begins.

Chairs: Janice Bishop (SETI Institute, USA) and Jörn Helbert (DLR, Germany)

8:30 a.m. Opening Remarks

8:35 a.m. Scientific Value of a Returned Sample of Martian Atmosphere [#6071]
A returned sample of unaltered martian atmosphere would have considerable scientific value for understanding the evolution of Mars and its climate and the potential for life.
Jakosky B.M. (University of Colorado, Boulder, USA);
Zurek R.W.; Atreya S.K.; Mahaffy P.R.; Zahnle K.; Toon O.B.; Tolbert M.; Mumma M.J.

8:50 a.m. Elemental Composition of Mars Return Samples Using X-Ray Fluorescence Imaging at the National Synchrotron Light Source II [#6024]
NSLS-II at BNL provides a unique and critical capability to perform assessments of the elemental composition and the chemical state of Mars returned samples using synchrotron radiation X-ray fluorescence imaging and X-ray absorption spectroscopy.
Thieme J. (Brookhaven National Laboratory, USA);
Hurowitz J.A.; Schoonen M.A.; Fogelqvist E.; Gregerson J.; Farley K.A.; Sherman S.; Hill J.

9:05 a.m. Non-Destructive Trace Element Tomography Using Europe's Brightest Synchrotron Sources (ESRF-Grenoble, DESY-Hamburg) — Towards a Better Understanding of Martian Samples [#6110]
Synchrotron sources are valuable tools to measure the main and trace element content of extraterrestrial samples. The non-destructive measurements will allow to identify important geological processes within the martian mantle and crust.
Brenker F. E. (Goethe University, Germany);
Vincze L.; Vekemans B.; de Poulle E.

9:20 a.m. Discussion

Keynote Talks: Lasting Legacy of Apollo Samples

One of the things we have learned from our experience with the Apollo samples is that sample-based research can continue for decades after first receipt of samples. Samples are the gift that keeps on giving.

Chairs: Janice Bishop (SETI Institute, USA) and Jörn Helbert (DLR, Germany)

9:25 a.m. Long Term Value of Apollo Samples: How Fundamental Understanding of a Body Takes Decades of Study [#6040]
Fundamental understanding of a body evolves as more sophisticated technology is applied to a progressively better understood sample set. Sample diversity is required to understand many geologic processes.
Sio C.K. (Lawrence Livermore National Laboratory, USA);
Borg L.E.; Gaffney A.M.; Kruijer T.K.

9:45 a.m. The Continuing Legacy and Major Scientific Advances Enabled By Returned Lunar Samples [#6118]
The availability of lunar samples returned by Apollo missions almost 50 years ago remain a vital and valuable resource to the sample science community.
Anand M. (Open University, UK)

10:05 a.m. Break

Mars 2020, Candidates Landing Sites, ExoMars and Their Relationship to Mars Sample Return

This session will present a status report on the Mars 2020 sample-caching rover, its candidate landing sites, the Exomars rover mission, and the relationship of all of these to Mars Sample Return.

Chairs: Victoria Hipkin (Canadian Space Agency, Canada) anfd Briony Horgan (Purdue University, USA)

10:25 a.m. The NASA Mars 2020 Rover Mission
The NASA Mars 2020 rover mission will explore an astrobiologically relevant site to characterize its geology, evaluate past habitability, seek signs of ancient life, and assemble a returnable cache of samples. An overview of technical capabilities and scientific strategy in development will be presented with a focus on the role envisioned for Mars 2020 in a possible Mars sample return campaign.
Williford K. (Jet Propulsion Laboratory, California Institute of Technology, USA)

10:45 a.m. The Mars 2020 Rover Mission Landing Site Candidates [#6026]
The number of suitable landing sites for the Mars 2020 rover mission has been narrowed to three leading candidates: Jezero Crater, NE Syrtis, and Columbia Hills. Each offers geologic settings with the potential for preservation of biosignatures.
Schulte M. (NASA Headquarters, USA);
Meyer M.; Grant J.; Golombek M.

11:00 a.m. ExoMars Contributions to Mars Sample Return [#6021]
Each of the two ExoMars missions has the potential to make discoveries that could inform and perhaps influence our collective strategy for a future Mars Sample Return mission.
Vago J. L. (European Space Agency);
Svedhem H.; Sefton-Nash E.; Kminek G.; Ruesch O.; Haldemann A.F.C.; Rodionov D.; ExoMars Science Working Team

11:15 a.m. Discussion

Concept For a Mars Sample Return Architecture, Flight Mission Elements, and Subsystems

This session provides an introduction to the overall flight architecture of the Mars Sample Return campaign, and then analysis of each of the primary flight elements.

Chairs: Paul Fulford (MDA Robotics and Automation, Canada) and Gianfranco Visentin (ESA)

11:25 a.m. Mars Sample Return Architecture Overview [#6058]
NASA and ESA are exploring potential concepts for a Sample Retrieval Lander and Earth Return Orbiter that could return samples planned to be collected and cached by the Mars 2020 rover mission. We provide an overview of the Mars Sample Return architecture.
Edwards C.D. Jr. (Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, USA) and Vijendran S. (European Space Agency)

11:40 a.m. Mars Sample Return Lander Mission Concept [#6119]
This talk will provide information on the current concepts and options for the architecture and design of the Mars Sample Return Lander.
Muirhead B.K. (Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, USA)

12:00 p.m. ESA Sample Fetch Rover: Heritage and Way Forward [#6122]
The Sample Fetch Rover (SFR) is one of the key elements of the Mars Sample Return (MSR) campaign architecture. We will present the SFR heritage as well as a way forward identified to address this engineering challenge.
Duvet L. (European Space Agency);
Beyer F.; Delfa J.; Zekri E.

12:15 p.m. MSR Fetch Rover Capability Development at the Canadian Space Agency [#6123]
Describes Fetch Rover technology testing during CSA's 2016 Mars Sample Return Analogue Deployment which demonstrated autonomous navigation to "cache depots" of M-2020-like sample tubes, acquisition of six such tubes, and transfer to a MAV mock up.
Hipkin V. (Canadian Space Agency, Canada);
Picard M.; Gingras D.; Allard P.; Lamarche T.; Rocheleau S.G.; Gemme S.

12:30 p.m. Lunch

1:30 p.m. Mars Sample Return — Earth Return Orbiter Mission Overview [#6124]
An overview of the Earth Return Orbiter mission concept.
Vijendran S. (European Space Agency);
Huesing J.; Beyer F.; McSweeney A.

1:50 p.m. Mars Orbiting Sample (OS) Capture and Containment Technology Development [#6125]
A presentation of one potential approach to orbiting sample (OS) capture and bio-containment for Mars Sample Return.
Parrish J.C. (Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, USA);
Gershman R.; Hendry M.; Younse P.J.

2:05 p.m. Discussion

2:15 p.m. Break to watch live stream of the ILA Berlin Air Show Mars Event

3:00 p.m. A Maturing Earth Entry Vehicle Concept for Potential Mars Sample Return [#6127]
This presentation describes the most recent efforts by JPL's Mars Formulation Office to mature an Earth Entry Vehicle concept that could be used on a potential Mars Sample Return campaign.
Perino S. V. (Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, USA);
Lobbia M.; Parrish J.

3:15 p.m. Planetary Protection Associated with Mars Sample Return [#6075]
This presentation will cover the various planetary protection aspects related to a Mars Sample Return campaign, in terms of requirements, independent oversight, and sample analysis protocol.
Kminek G. (European Space Agency)

3:35 p.m. Discussion

3:50 p.m. Break

Mission Elements, Subsystems, and Technologies for Mars Sample Return

This session contains a portion of the ideas submitted to this conference related to the engineering of Mars Sample Return. Please be sure to see additional ideas in the poster session.

Chairs: Joseph Parrish (Mars Program Office, JPL/Caltech, USA) and Marie-Claire Perkinson (Airbus, UK)

4:10 p.m. Lessons from ExoMars for MSR [#6107]
After ExoMars, ESA is considering participation in Mars Sample Return. The lessons learned from the development of ExoMars 2016 and 2020 will enable contributions to the international effort.
Haldemann A. (European Space Agency);
Alary C.; Baglioni P.; Ball A.; Bayle O.; Bayon S.; Bethge B.; Blancquaert T.; Braghin M.; Chiusano F.; Cislaghi M.; Dellantonio D.; Denis M.; Didot F.; Durrant S.; Gianfiglio G.; Gould G.; Goulty D.; Haessig F.; Joudrier L.; Kasper M.; Kminek G.; Laneve V.; Lindner R.; Lorenzoni L.; Malyshev. M.; McCoy D.; Mitschdoerfer P.; Monteiro D.; Ott S.; Pereira J.; Poulakis P.; Rasse B.; Sangiorgi S.; Schmitz P.; Spoto F.; Svedhem H.; Temperanza D.; Vago J.; Walloschek T.; Winton A.; Yushtein Y.; Zekri E.

4:25 p.m. An Architecture for Autonomous Rovers on Future Planetary Missions [#6084]
This paper proposes an architecture for autonomous planetary rovers. This architecture combines a set of characteristics required in this type of system: high level of abstraction, reactive event-based activity execution, and automous navigation.
Ocon J. (GMV Innovating Solutions, Spain);
Avilés M.; Graziano M.

4:40 p.m. A Rover Mobility Platform with Autonomous Capability to Enable Mars Sample Return [#6087]
The next step in understanding Mars is sample return. In Fall 2016, the CSA conducted an analogue deployment using the Mars Exploration Science Rover. An objective was to demonstrate the maturity of the rover's guidance, navigation, and control.
Fulford P. (MDA Robotics and Automation, Canada);
Langley C.; Shaw A.

4:55 p.m. Overview of OHB Expertise on Mars Planetary Exploration Missions [#6066]
The first part provides an overview of the design and testing of the ExoMars SPDS. Lastly, lessons learned obtained from the sample testing are presented showing how operational procedures can optimize the system and solve occurring problems.
Thiel M. (OHB System AG, Germany);
Bergemann C.; Muehlbauer Q.; Paul R.; Jaime A.

5:10 p.m. Design, Development, and Preliminary Validation for a BioContainment System for MSR [#6031]
A bio-containment system was conceived, designed, and tested by Leonardo S.p.A. and partners under ESA development contract. Results achieved so far are presented, including reports of the several tests performed on development hardware.
Fumagalli A. (Leonardo S.p.A, Italy) and Spagnoli B. (Leonardo S.p.A, Italy);
Terribile A.; Indrigo D.; Romstedt J.; Vjendran S. Kminek G.

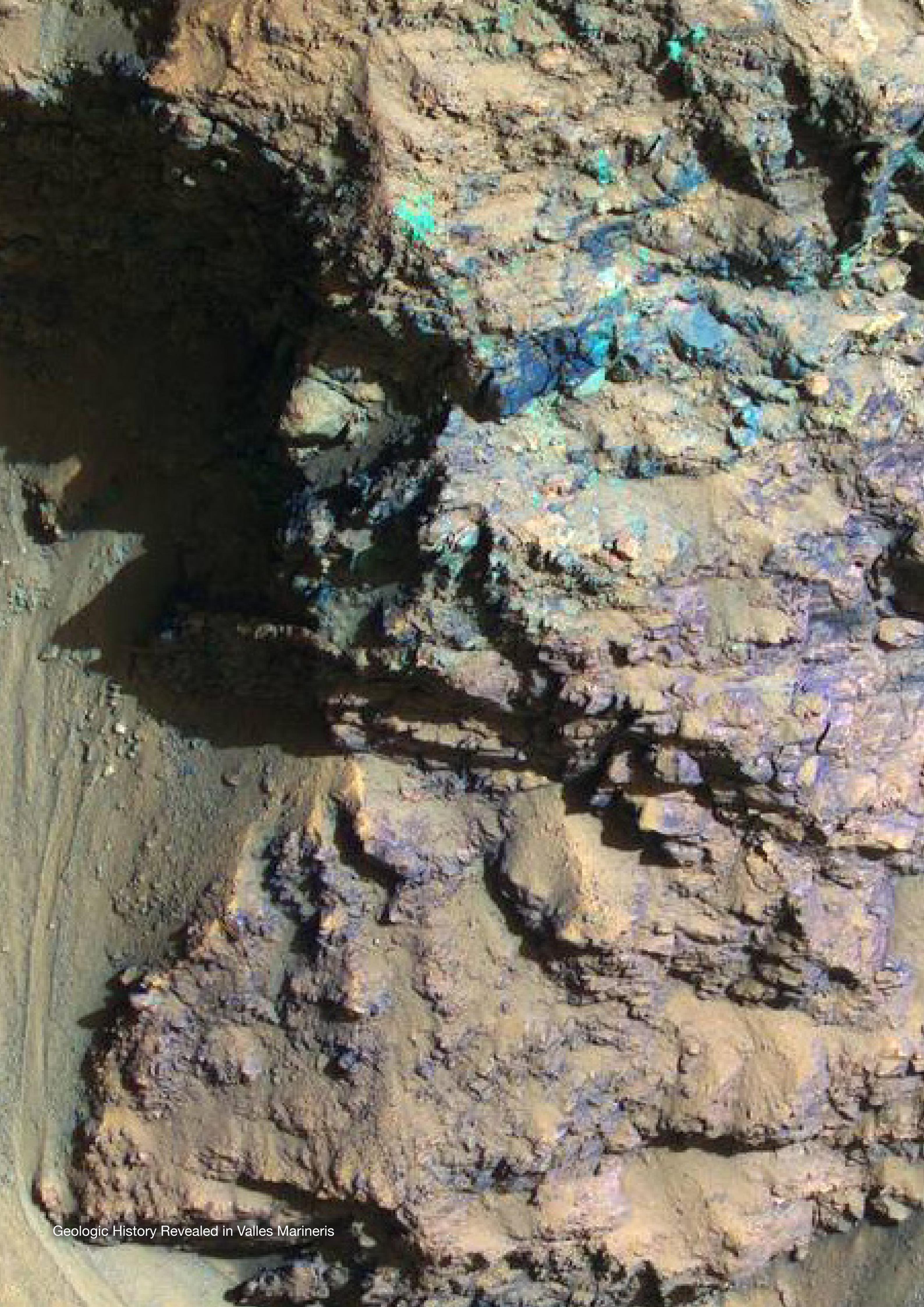
5:25 p.m. Roadmap of Advanced GNC and Image Processing Algorithms for Fully Autonomous MSR-Like Rendezvous Missions [#6085]
GMV extensively worked in many activities aimed at developing, validating, and verifying up to TRL-6 advanced GNC and IP algorithms for Mars Sample Return rendezvous working under different ESA contracts on the development of advanced algorithms for VBN sensor.
Pellacani A. (GMV Innovating Solutions, Spain);
Strippoli L.S.; Gonzalez-Arjona D. G.

5:40 p.m. Commercial Capabilities to Accelerate Timeline and Decrease Cost for Return of Samples from Mars [#6112]
An overview of SpaceX capabilities of relevance to sample return and other Mars missions.
Marinova M. M.(SpaceX, USA);
Wooster P.; Brost J.

5:55 p.m. Discussion

6:10 p.m. Break

6:30 p.m. Buses leave to dinner



Geologic History Revealed in Valles Marineris

Friday, April 27

Planning for Sample Receiving Facility(ies), Sample Curation, and Sample Analysis Facilities (Part 1)

Discussions of potential planning for different aspects of the Sample Receiving Facility(ies), sample curation, and sample analysis facilities. Please be sure to visit the poster session for more of these ideas. Refreshments will be available before the session begins.

Chairs: Lucy Berthoud (Bristol University, UK) and Ludovic Ferriere (Natural History Museum Vienna, Austria)

8:30 a.m. Opening Remarks

8:35 a.m. A Draft Science Management Plan for Returned Samples from Mars: Recommendations from the International Mars Architecture for the Return of Samples (iMARS) Phase II Working Group [#6038]
This paper summarizes the findings and recommendations of the International Mars Architecture for the Return of Samples (iMARS) Phase II Working Group, an international team comprising 38 members from 16 countries and agencies.
Haltigin T. (Canadian Space Agency, Canada) and Smith C. (Natural History Museum, UK);
Lange C.; Mugnuolo R.

9:05 a.m. Discussion

9:15 a.m. Mars Sample Handling Functionality [#6106]
The final leg of a Mars Sample Return campaign would be an entity that we have referred to as Mars Returned Sample Handling (MRSH.) This talk will address our current view of the functional requirements on MRSH, focused on the Sample Receiving Facility (SRF).
Meyer M. (NASA Headquarters, USA);
Mattingly R. L.

9:30 a.m. EURO-CARES as Roadmap for a European Sample Curation Facility [#6061]
EURO-CARES is a three-year multinational project funded under the European Commission Horizon2020 research program to develop a roadmap for a European Extraterrestrial Sample Curation Facility for samples returned from solar system missions.
Brucato J.R. (INAF-Astronomical Observatory of Arcetri, Italy);
Russell S.; Smith C.; Hutzler A.; Meneghin A.; Aléon J.; Bennett A.; Berthoud L.; Bridges J.; Debaille V.; Ferrière L.; Folco L.; Foucher F.; Franchi I.; Gounelle M.; Grady M.; Leuko S.; Longobardo A.; Palomba E.; Pottage T.; Rettberg P.; Vrublevskis J.; Westall F.; Zipfel J.; EURO-CARES Team

9:45 a.m. Planning Related to the Curation and Processing of Returned Martian Samples [#6101]
Many of the planning activities in the NASA Astromaterials Acquisition and Curation Office at JSC are centered around Mars Sample Return. The importance of contamination knowledge and the benefits of a mobile/modular receiving facility are discussed.
McCubbin F.M. (NASA Johnson Space Center, USA);
Harrington A.D.

10:00 a.m. Discussion

10:10 a.m. Break

Planning for Sample Receiving Facility(ies), Sample Curation, and Sample Analysis Facilities (Part 2)

Discussions of potential planning for different aspects of the Sample Receiving Facility(ies?), sample curation, and sample analysis facilities. Please be sure to visit the poster session for more of these ideas.

Chairs: Monica Grady (Open University, UK) and Rachel Mackelprang (California State University Northridge, USA)

10:30 a.m. Sample Transport for a European Sample Curation Facility [#6025]
This work has looked at the recovery of Mars Sample Return capsule once it arrives on Earth. It covers possible landing sites, planetary protection requirements, and transportation from the landing site to a European Sample Curation Facility.
Berthoud L. (Thales Alenia Space, UK);
Vrublevskis J.B.; Bennett A.; Pottage T.; Bridges J.C.; Holt J.M.C.; Dirri F.; Longobardo A.; Palomba E.; Russell S.; Smith C.

10:45 a.m. Description of European Space Agency (ESA) Concept Development for a Mars Sample Receiving Facility (MSRF) [#6008]
This presentation gives an overview of the several studies conducted for the European Space Agency (ESA) since 2007, which progressively developed layouts for a potential implementation of a Mars Sample Receiving Facility (MSRF).
Vrublevskis J. (Thales Alenia Space, UK);
Berthoud L.; Guest M.; Smith C.; Bennett A.; Gaubert F.; Schroeven-Deceuninck H.; Duvet L.; van Winnendael M.

11:00 a.m. Preserving Samples and Their Scientific Integrity — Insights into MSR from the Astromaterials Acquisition and Curation Office at NASA Johnson Space Center [#6039]
Rigorous collection of samples for contamination knowledge, the information gained from the characterization of reference materials and witness plates in concurrence with sample return, is essential for MSR mission success.
Harrington A.D. (NASA Johnson Space Center, USA);
Calaway M.J.; Regberg A.B.; Mitchell J.L.; Fries M.D.; Zeigler R.A.; McCubbin F.M.

11:15 a.m. Examining Returned Samples in their Collection Tubes Using Synchrotron Radiation-Based Techniques [#6014]
Synchrotron radiation-based techniques can be leveraged for triaging and analysis of returned samples before unsealing collection tubes. Proof-of-concept measurements conducted at Brookhaven National Lab's National Synchrotron Light Source-II.
Schoonen M.A. (Brookhaven National Laboratory, USA);
Hurowitz J.A.; Thieme J.; Dooryhee E.; Fogelqvist E.; Gregerson J.; Farley K.A.; Sherman S.; Hill J.

11:30 p.m. QESA: Quarantine Extraterrestrial Sample Analysis Methodology [#6081]
Our nondestructive, nm-sized, hyperspectral analysis methodology of combined X-rays/Raman/IR probes in BSL4 quarantine, renders our patented mini-sample holder ideal for detecting extraterrestrial life. Our Stardust and Archean results validate it.
Simionovici A. (ISTerre, Grenoble Alpes University, France);
Lemelle L.; Beck P.; Fihman F.; Tucoulou R.; Kiryukhina K.; Courtade F.; Viso M.

11:45 p.m. Planetary Sample Analysis Laboratory at DLR [#6020]
Building on the available infrastructure and the long heritage, DLR is planning to create a Planetary Sample Analysis laboratory (PSA), which can be later extended to a full sample curation facility in collaboration with the Robert-Koch Institute.
Helbert J. (Institute for Planetary Research, DLR, Germany);
Maturilli A.; de Vera J.P.

12:00 p.m. Discussion

12:10 p.m. Lunch

Concepts for Mars Sample Return Public Outreach

An important aspect of Mars Sample Return is our strategies for engaging the public. How can we involve them in the adventure?

Chairs: Sanjay Vijendran (ESA) and Michael Meyer (NASA)

1:10 p.m. Concepts and Planning for MSR Public Outreach [#6091]
The Mars Sample Return (MSR) community now has an opportunity to build support through outreach to policy makers, the media, the public, teachers, and students. This presentation aims to start a dialogue on concepts and planning for MSR outreach.
Heward A. R. (Open University, UK)

1:25 p.m. Mars Sample Return: The Critical Need for Planning a Meaningful and Participatory Public Engagement Program [#6092]
The Mars Sample Return campaign offers the prospect of an historical leap forward in the understanding of the science of Mars, and an unprecedented opportunity to engage our citizenry in one of the enduring questions of humanity, "Are we alone?".
Klug Boonstra S. (Arizona State University, USA)

1:40 p.m. Discussion

Discussion Panel: Mars Sample Return – Integration and Next Steps

The purpose of this panel is to draw together the primary messages of the conference and to begin planning for the next steps.

Moderators: Michael Meyer (NASA) and Sanjay Vijendran (ESA)

Panel Members: Bernardo Patti (ESA); Jim Watzin (NASA); Victoria Hipkin (CSA); Monica Grady (Open University, UK); Scott McLennan (The State University of New York at Stony Brook, USA)

1:55 p.m. Summing Things Up
Michael Meyer (NASA) and Sanjay Vijendran (ESA)

2:10 p.m. Panel Discussion

2:55 p.m. Concluding Remarks

3:00 p.m. Conference Adjourns

Social Dinner

Thursday, April 26

6:45 p.m. – 10:00 p.m.

Hofbräu Tavern Berlin

Experience a piece of Bavarian culture in the heart of the capital.

Located in Alexanderplatz, the restaurant offers hearty meals, original Hofbräu beer from Munich, live music and waiters in real costumes. From original Munich white sausages over roast pork to original Austrian and Swabian delicacies – you will be served fresh dishes and cold beer!

Arrival: Buses will depart from Axica to Hofbräu Tavern Berlin at 6:30 p.m.

Departure: Guests are free to leave the dinner location when they wish and will arrange their own transportation back to the hotels. Taxis will also be available at guests expense.

Bus Information

Thursday, April 26

Buses will depart from Axica to Hofbräu Tavern Berlin at 6:30 p.m.

Friday, April 27

Bus will depart to Schönefeld Airport at 3:30 p.m.

Bus to Berlin Tegel Airport at 3:30 p.m.

Should you be interested in making use of the shuttle bus to the airport, please list your name at the registration desk.

All passengers are requested to go on the bus five minutes prior to the indicated time.

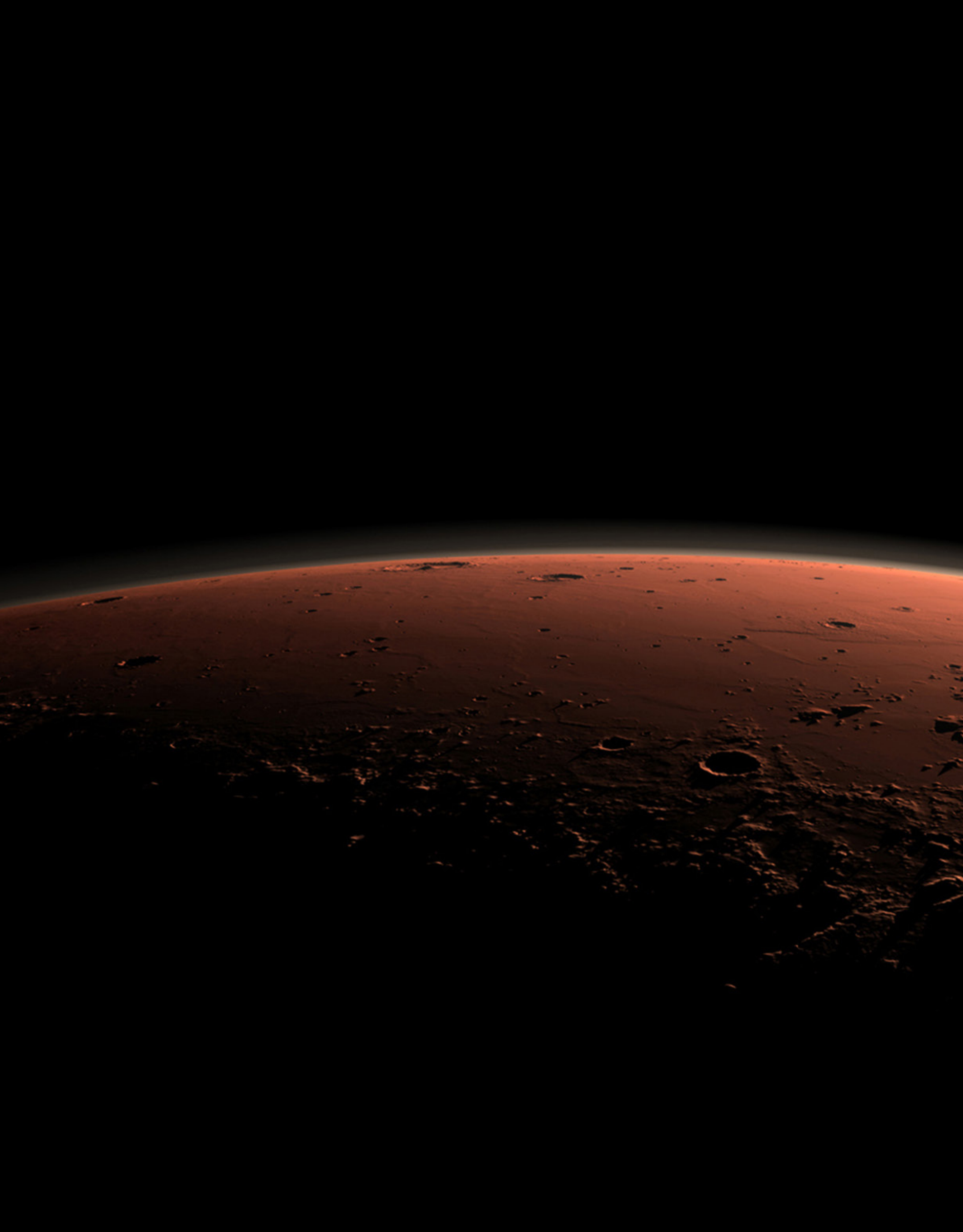

Victoria Crater

Notes

Notes

For more information on the conference,
please refer to https://tinyurl.com/2018-msr-conf

Thank you for coming!



CONTENTS

Hydrated minerals and evaporites as key targets for a Mars sample return mission. S. Adeli[1], E. Hauber[1], and R. Jaumann[1,2], [1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institute for Planetary Science, Berlin, Germany (Solmaz.Adeli@dlr.de), [2]Freie Universität zu Berlin, Institute of Geosciences, Berlin, Germany.

Introduction: The early Mars climate and surface conditions are two major questions still under debate. There is clear morphological evidence of liquid surface water on early Mars, such as: large crater lakes, valley networks, and alluvial fans [e.g., 1, 2]. Moreover, there is widespread evidence of thick layers rich in aqueous minerals, i.e., phyllosilicates, which indicate the abundant presence of liquid water during their formation. It is nevertheless still unclear whether the early Mars climatic conditions were “warm and wet” [3], “cold and wet” [4], or even “cold and icy” [5]. The aqueous minerals and evaporites offer a paleo-environmental record of their formation and subsequent modification. Thus, investigating direct samples from these materials would increase our knowledge about the past geology of Mars as well as its astrobiological potential.

Hydrated minerals: Here we focus on two groups of minerals found widely on Mars, which have the potential of preserving traces of past life; phyllosilicates (clay minerals) and evaporites.

Phyllosilicates: Phyllosilicate-bearing materials are characterized by their light-toned appearance, polygonal fractures, and late Noachian-early Hesperian formation age [6, 7]. They are the major products of chemical weathering of mafic silicate minerals [8]. In several outcrops, a stratigraphic relation between various kind of phyllosilicates has been detected, in which Fe/Mg-phyllosilicates (mainly Fe/Mg-smectite, saponite, nontronite) form the bulk of the deposit and the upper superficial part have been altered into Al-phyllosilicates (kaolinite, montmorillonite, Al-smectite). This stratigraphical relation indicates a major change in the chemical environment of the deposit, since formation of the Fe/Mg-phyllosilicates are believed to be linked to abundance presence of liquid water, which prevailed during early Mars in neutral to alkaline environments [e.g., 7] whereas alteration towards Al-phyllosilicates is the result of a top-down leaching process due to limited surface runoff [e.g., 9].

Phyllosilicates have been hypothesized as a major element in the chemical evolution resulting in the origin of life on Earth, because of their ability to concentrate and catalyze complex organic molecules, and to protect against UV radiation [10]. Smectitic clays have a reactive surface able of absorbing considerable amounts of organic compounds in the mineral structure, and if buried they have a preservation capacity [11]. Therefore, the phyllosilicate-bearing deposits on Mars have been investigated as a potential target for the investigation of past habitable sites.

Evaporite minerals: The main evaporite minerals detected on the highlands of Mars are sulfates and chloride salts. They are mainly found in local depressions and appear within light-toned deposits ranging in width from a few tens of meters to a few kilometers, with polygonal fractures. Their formation has been interpreted as precipitation in brines as result of water accumulation in ponds [12], and the source of water is most likely surface runoff. The deposits rich in evaporites are found in proximity to phyllosilicate-bearing deposits and are overlying them. This stratigraphic relationship indicates that the salts were deposited at a later time, thus by a later water activity. This late-stage water activity may have been the last major local water activity as it is suggested by the presence of the undegraded, uneroded, and unaltered chloride-rich layer.

On Earth, evaporites and salts form in alkaline and/or acidic conditions, and they can preserve traces of life, e.g., salt crystals which can preserve amino acids for 4-40 Ma [13] and biosignatures found in sedimentary evaporitic layers in dry Rio Tinto [14]. Analogue studies in the Atacama desert show that even highly saline environments may offer temporary habitable conditions to certain types of bacteria [15].

Conclusion: The widespread presence of water involved in the deposition of phyllosilicates, in addition to their chemical and molecular structure, make them a potentially favorable environment to host life. Therefore if life has ever developed on Mars, its traces have to be searched within ancient phyllosilicate-rich material. This material, however, must have been well preserved since its formation time (early Mars) until now on the surface or shallow subsurface. Hence, where phyllosilicate-rich materials are covered and preserved by evaporates, may be prime locations for sampling and further lab analysis.

References: [1] Cabrol, N.A. and E.A. Grin. Lakes on Mars. , 2010. [2] Carr, M.H. (1995), *JGR 100*. [3] Craddock, R.A. and A.D. Howard. (2002), *JGR 107*.[4] Fairén, A.G. (2010), *Icarus*. *208*. [5] Wordsworth, R., et al. (2013), *Icarus*. *222*(*1*). [6] Bishop, J.L., et al. (2008), *Science*. *321*. [7] McKeown, N.K., et al. (2009), *JGR 114*. [8] Poulet, F., et al. (2005), *Nature*. *438*. [9] Le Deit, L., et al. (2012), *JGR117*. [10] Wattel-Koekkoek, E.J.W., et al. (2003), *Europ. J. Soil Sci*. *54*(*2*). [11] Kennedy, M.J., et al. (2002), *Sci*. *295*. [12] Osterloo, M.M., et al. (2008), *Sci*. *319*. [13] Aubrey, A., et al. (2006), *Geol.*. *34*(*5*). [14] Fernández-Remolar, D.C., et al. (2005), *EPSL*. *240*(*1*). [15] Jänchen, J., et al. (2015), *Int. J. Astrobiology*. *15*(*2*).

ELECTROMAGNETIC SPACECRAFT PROPULSION MOTOR AND A PERMANENT MAGNET (PM-DRIVE) THRUSTER. Author: Balashirin Ahmadov , Affiliation: Engineer at Baku High-tech Park, Address: Nizami str. 129E, Baku, Azerbaijan, e-mail: balashahmadov@box.az

Introduction: As it is well-known there are ion thrusters, which are designed to be used for realisation the future interplanetary missions. The competing space travelling technologies that can be alternative to modern ion thrusters are; nuclear and photon thrusters, electromagnetic spacecraft propulsion motors, microwave drive engines and etc. I am an engineer and inventor from Baku, Azerbaijan and engage in the creation and improvement of the new electromagnetic spacecraft propulsion motor within last 10 years.

Electromagnetic spacecraft propulsion motor. I present to MSR Conference my own-designed new electromagnetic propulsion motor as an interplanetary travelling engine that can be successfully used for realization the Mars Sample Return missions. Note that, my new electromagnetic motor creates hundreds times stronger propulsive force rather than ion thrusters, that is, the new motor is efficient than ion thrusters for many-many times. So that, in the new motor the propulsive force is created by means of the electromagnets that are weighing ten kilograms. But in ion thrusters as a propellant was used inert gases weighing few milligrams, that is why their propulsive force is very low. As remarked above in the new electromagnetic motor the propulsive force is creating by the means of the heavy electromagnets, so that, two similar (with the same sizes) electromagnet, which have the shape of ring segments are independently installed inside the body, parallel to each other and were kept in starting positions via springs. These electromagnets are moving under influences of the magnetic fields which are appeared between them by energy of a power source. By hitting parallel elastic blows to the forward wall of the body these electromagnets push the whole motor system forward. The frequency of the blows can be 50-100 blows per second. So, the new electromagnetic propulsion motor in the operation process only consumes electrical power and its propellant, solid electromagnets, never leaving inside of the motor, create propulsive force using unique combination of the interacting forces.

The new motor consumes electrical power in the form of the periodically interrupted short pulses, because the power only is needed to energize the electromagnets at the starting positions and after the short acceleration power must be switched off and then electromagnets pass remain trajectories completely freely. So, this unique feature creates wide possibility for energy saving and as a result efficiency of the new motor can be extremely high. At the same time, the new electromagnetic propulsion motor has very simple construction, so that, it comprises only semi-circle shaped body in which was installed two independent electromagnets and these electromagnets are kept in the starting positions via springs.

I installed the video of the new electromagnetic propulsion motor on Youtube. You can watch that video by entering the key phrase **Ahmadovsumd** into YouTube's search window. In that video I showed the early variant of my electromagnetic propulsion motor in both tests; on the floor and in a suspended state. In that experiment power is switching on/off to the motor circuit by me, but it can be done automatically with controller mechanism, then the work of the motor will be continues and straight. Besides, a perfect and precise made variant of the motor won't have those deficiencies that you can find in the experimental motor. How these processes happen and configuration of the interacting forces among the electromagnets and body of the motor are explained in my International patent application. Note that, in last 3 years I cardinally improved the new motor and now the top variant of the motor becomes perfect than previous constructions.

The application area of the new electromagnetic propulsion motor won't be limited by the space mission's technologies. It can be successfully used in airplanes, helicopters, electric vehicles, robots, sea boats and etc., because the new motor has great potential in both; in creation of the new modes of motion and in high energy efficiency.

PM-Drive: I present to MSR Conference my next (very important) propulsive technology, which I had discovered 6 months ago. I named that technology PM-Drive (a permanent magnet drive), so that, the new device mainly consists of permanent magnets and doesn't use any propellant and electrical energy for generation propulsive force. It has no mechanical parts, but has very simple construction. I am going to show this sensational technology in MSR Conference and by few simple experiments demonstrates its propulsive force.

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THE CONTINUING LEGACY AND MAJOR SCIENTIFIC ADVANCES ENABLED BY RETURNED LUNAR SAMPLES. M. Anand[1,2], [1]School of Physical Sciences, The Open University, Milton Keynes, UK (Mahesh.Anand@open.ac.uk), [2]Department of Earth Sciences, The Natural History Museum, London, UK.

Introduction: The six Apollo and three Luna sample return missions to the Moon heralded a new era in Planetary Science research. As we approach the 50th anniversary of the first human landing (Apollo 11; July 1969) on the Moon and subsequent return of the first batch of lunar rocks and soil samples, we continue to make major scientific advances based on work being carried out on these lunar samples in terrestrial laboratories. Of the 382 kg of Moon samples that were collected by the six Apollo missions, a significant proportion remains available to the scientific community as a result of careful planning and curation of these precious extraterrestrial samples at the NASA Johnson Space Centre in Houston, Texas. Here, I provide a few examples of major findings that have been made through continuing analysis of lunar samples from Apollo collections. The main aim here is to highlight the importance of returned samples in advancing the field of Planetary Sciences and to demonstrate the staying power of samples as a 'gift that keeps giving'.

Origin of the Moon: Based on similarities between primarily mantle-derived rocks from the Earth and the Moon for a number of stable isotope systems (e.g., O, Cr, Ti), the origin of the Moon via a high-energy impact between the proto-Earth and a sizeable impactor, followed by large scale re-equilibration between the Earth-Moon system has been proposed [1-2]. However, a number of recent high-precision oxygen isotope studies appear to present contradictory evidence concerning the nature of this impact event [3-4]. Without the continuing availability of Apollo samples for such high-precision measurements, it wouldn't have been possible to make these strides in our understanding of the origin of Earth-Moon system.

Lunar Magma Ocean (LMO): It was the mineralogical and geochemical investigations of Apollo 11 samples that led to the identification of almost 4.5 Ga old pure anorthosites, the presence of which was interpreted in terms of a large scale magma ocean differentiation in the aftermath of the impact-origin of the Moon. The concept of LMO has largely withstood the test of time although several variations of the original LMO model have been proposed recently based upon continuing re-investigation of Apollo samples [5-6].

Cratering chronology and the impact-flux in the inner Solar System: Samples of impact-melt formed during basin-forming impact events were also represented in the Apollo collections and as a result age-dating of those samples in terrestrial laboratories allowed establishment of a cratering curve for the Moon. This lunar cratering curve has been widely used to age-date craters on other bodies such as Mercury and Mars. Besides, the preponderance of ~3.9 Ga ages reflected in impact-melt samples collected during Apollo missions led the development of a Late Heavy Bombardment (LHB) or lunar cataclysm hypothesis [7]. Recent work combining radiometric ages of the youngest lunar basins, geochemical data on Apollo samples and numerical modelling, however, argues against a monotonic decline in impact flux since 4.5 Ga, challenging the LHB hypothesis [8].

Lunar volatiles: Perhaps the most exciting recent developments enabled by the availability and re-analysis of returned lunar samples is the finding that that the lunar interior contains appreciable quantities of water and other associated volatiles. The dominant source for lunar water appears to be carbonaceous chondrite-type material with a minor contribution from cometary objects [9-10]. It has become apparent that the Moon has received volatiles from multiple sources at different stages of its geological history. Unravelling this history will require further research on existing lunar samples, but also 'new' samples from regions of the Moon not sampled previously.

Conclusion: The availability of lunar samples returned by Apollo missions almost 50 years ago remain a vital and valuable resource to the sample science community. New discoveries and insights related to the fundamental processes in the Solar System are routinely made through re-analysis of Apollo samples using latest analytical techniques and instruments that weren't available previously, highlighting the importance and value of return samples.

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ABSTRACT – AN OVERVIEW OF A REGENERATIVE FUEL CELL CONCEPT FOR A MARS SURFACE MOBILE ELEMENT (MARS ROVER)

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Introduction This paper outlines an overview of a regenerative fuel cell system concept for a Mars Rover. The objectives of the system are discussed as well as the enabling technologies to build a competitive system. Furthermore, design aspects of the Mars Rover are highlighted to allow maximum benefits of a regenerative system. Finally, how to gain technological heritage before the Mars mission is a very important design factor.

Overview of Regenerative Fuel Cell The paper discusses how the fuel cells is divided into a number of modules and how the mounting concept of these modules is designed. The hydrogen and oxygen fuel cell system based on mass integration of very small and thin fuel cells combine electrical power generation and active thermal control of structures and equipment in a very efficient way. This performance can be very useful for a Surface Mobility Element (Rover) to survive a Mars night. Furthermore, additional fuel cells mounted on surfaces with heat radiation capabilities will also allow the system to provide electrical power to the rover's operational modes. This feature will provide high flexibility to execute the operational modes during lunar day or during lunar night.

The active control of the fuel cell modules is also discussed. The inclusions of advanced MEMS technology for flow control units, isolation valves and pressure transducers, dedicated assemblies of small thin fuel cells mounted directly on structures and equipment or embedded into chassis can be specifically designed for various operational cases. Each assembly is divided into a number of subassemblies. All components are controlled in real-time via an embedded S/W in the Rover's on-board computer.

The reloading of hydrogen and oxygen by water splitting is performed by the power of solar anel in standby day light mode. The electryser used for the watersplitting is of the same type of technology as for the fuel cell but operated in reversed mode. The modules of the electrolyser are mounted directly on various surfaces to radiate excessive heat.

Highly reliable and efficient electrochemical compressors for both hydrogen and oxygen allow storage of gases up to 700 bar, which restrict the volume of storage gas tanks to reasonable and acceptable sizes.

This paper also outlines how the critical masses of the oxygen and hydrogen tanks based on proven technology can be minimised. The possibility to manufacture the tanks in new technology like graphene is also briefly discussed.

Typical Performance The characteristics of the typical performance are presented for a proposed regenerative fuel cell system and its impacts on the Rover design.

Technological Heritage Method How this technology can be used and proven on a Lunar Rover before a more critical mission to Mars has to be addressed in order to obtain the proven reliability as required before the actual mission to Mars. Since there are obvious differences between Mars and Lunar missions the designs of the enabling technolgies have to be scalable.

Partners All major Technologies are SoA and partners for the system are: OHB Sweden, Sweden AB, MyFC, Sweden, Royal Institute of Stockholm, Sweden, MT Aerospace, Germany and Hydrogen Efficiency Technologies (HyET), Netherland, in cooperation with University of Berkeley, USA.

Magnetic Mars Dust Removal Technology

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Introduction:

It is known that Mars atmosphere contains a large load of suspended dust. Saltation process or the settlement of atmospheric dust onto the surface of solar arrays can affect the utility on solar power on any Mars mission, and specially for long term operation. This can be a special issue for the case of a future 6-months Sample Fetching Rover (SFR) mission where the current baseline architecture contemplates the use of solar array instead. For this relatively 6-months long operation dust storms can jeopardize the entire mission, not only in the supply of energy for locomotion but for the communication with the Mars Ascent Vehicle (MAV). For instances, it was early calculated that the power loss of solar array caused by settled dust for mission on Mars can be around 52.2 % to 89 %,**[1].** Dust is expected to be adhered to the array by Van der Waals adhesive forces which can be very strong for the dust particles sizes. Today, available dust-removal techniques can be classified into four categories, **[2],** namely: -natural, -mechanical, -electromechanical, and -electrostatic. Natural dust removal relies in the possible capability of surface martian wind for cleaning the solar array which seems not to be applicable for horizontal arrays at locations with wind conditions similar to those found at the Viking landing site. Mechanical-removal is based in the use of mechanical wiping, blowing, or removable covers, however, the constraint in weight for a SFR mission makes this a not very reasonable approach. Electromechanical-removal comprises shaking the array, or using sound to break dust adhesion, however, besides to have the problem of weight, also it would be necessary another supplementary system to carry the dust away after adhesion is broken. Finally, electrical-removal is based in inducing electrostatic forces. For this last method, if the array surface is charged and conductive enough, dust particles will accumulate a charge the same as the array, and then repelled from the array. Nevertheless, for this method -which so far has been stated as the best approach, they also, as in the electromechanical removal, will require and supplementary system, wind or tilting the array to carry the dust away.

In this work we propose a new approach as a result of the recent information recorded from the last years on Mars. This approach is as follows:
From the recorded data from recent Mars missions, there are substantial evidence that the dust of Mars is strongly magnetic. In fact, almost all dust particles in the Martian atmosphere are magnetic, according to new data obtained by NASA´s Mars Exploration Rover Spirit containing mostly the strong magnetic mineral magnetite (Fe_3O_4). If so, the magnetic properties of the martian dust can be harnessed as a new removal technique. It is well known that a particle with magnetic properties (magnetic dipole, as is the case for magnetite Fe_3O_4) when is under the action of a magnetic field gradient, the magnetic dipoles are attracted/repelled into regions of higher magnetic field, in other words there will be a net magnetic force acting on the magnetic particle.
Now it istraightforward to envisage the significance of this phenomena for Mars-dust removal technology. By generating a localized magnetic feld, it could be possible to vertically push dust particles away from, say, the solar array. The principle behind of this technique which is conspicuous by its simplicity and roustness, also, deserves special consideration because the easiness for application. In fact, a simple, almost weightless hollow tube wrapped by copper wire (a sort of solenoid) will be enough, or the use of a permanent magnet. Besides of dust magnetic cleaning of solar arrays, or the samples, also, the same principle can be used experimentally to know the fraction of dust which is actually magnetized.

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WESTERN EOS CHAOS ON MARS: A POTENTIAL SITE FOR FUTURE LANDING AND RETURNING SAMPLES. Asif Iqbal Kakkassery[1], V. J. Rajesh[1], [1]Department of Earth and Space Sciences, Indian Institute of Space Science and Technology, Valiamala P.O., Thiruvananthapuram 695 547, India (asifiqbalka@gmail.com; rajeshvj@iist.ac.in)

Introduction: Scientific analyses of rocks and minerals using diverse techniques are essential for understanding the origin and evolution of a rocky planetary body. Rocks and minerals of Martian surface have to be analysed in detail as our knowledge of surface evolution and composition of Mars is mostly confined to the interpretation of the results from payloads in orbiters, landers and rovers. The surface and subsurface samples of Martian surface, if available, could be analysed, dated and interpreted in scientific means in order to further understand the origin and evolution of Mars.Though the nature of tectonism is a debatable topic for Martian researchers many scientists consider that the Valles Marineris is a structural remnant of tectonic activity which had been prevailed on Mars[1]. Abundant mineralogical and structural evidences for past fluvial activities have been noticed from Valles Marineris region. As northern lowlands were preferred landing sites for the missions that accomplished the aim of landing on Mars, the knowledge regarding Southern Highlands and Valles Marineris is only through the orbital data. Landing on Valles Marineris and subsequent analysis of rock samples can address important scientific aspects of tectonics and aqueous processes.

Eos Chaos is a potential location on Eastern part of Valles Marineris. It is evident that the Eos chaos along with other eastern segments of Valles Marineris have experienced fluvial processes for a considerable period [2,3].

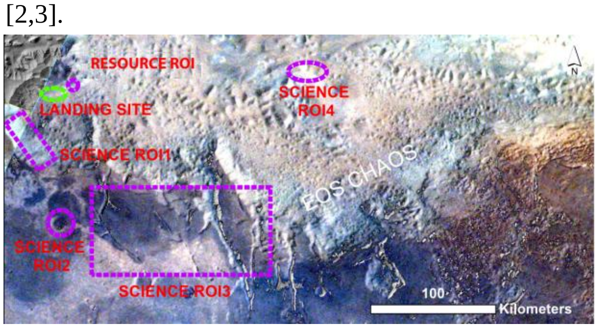

Figure 1: A MCC-CTX mosaic of Eos chaos showing proposed landing site with comparatively less abundant rocks for safe landing. Other selected regions of interests with moderately abundant rocks are also shown. Resource ROI shows presence of hydrated and low grade metamorphic minerals. Science ROI1 contain channels that shed light to past aqueous processes and possible life signatures. Science ROI 2 is an impact crater and ejecta blanket. ROI 3 contains a number of grabens from which past tectonic activity can be explored. Science ROI 4 contains light toned layered deposits, landslides and vertical tectonic structure.

Data sets and methodology: Mars Color Camera (MCC) data from ISRO's Mars Orbiter Mission (MOM 1) and Context camera (CTX) imageries, Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) hyperspectral data from NASA's Mars Reconnaissance Orbiter mission are the preliminary tools employed for this study.

Results and discussions: Low-grade metamorphism has been identified from a few areas on Mars and presence of metamorphic minerals such as prehnite, chlorite, hydrated silica and analcimite have been identified from restricted environments such as breccia blocks, isolated outcrops and eroded debris. [4,5,6] Presence of low-grade metamorphic minerals such as prehnite and chlorite indicates a distinct temperature (~250-380 ^{o}C) compared to the surface and a rich aqeous environment. Prehnite and chlorite minerals form in prehnite-pumpellyite facies to lower green schist facies. Zoisite, a hydrous mineral in epidote group often associated with prehnite and chlorite, is rarely reported from Mars. We report an occurrence of zoisite in S-W trending slope of Eos chaos. Hydrothermal fluid interaction with host rocks in subsurface conditions (temperatures ranging from ~250-380 ^{o}C) may have produced zoisite and later brought to the surface. The lower Al_2O_3 contents of Martian surface prevents the formation of zoisite in surface conditions [6].

Conclusion: Landing of a rover and further analyses of returned samples from Eos Chaos can shed light on past aqueous activities in this region. As zoisite is detected from Western Eos Chaos, chemical analyses of subsurface materials can lead to a better understanding of low grade metamorphic conditions prevailed in Martian subsurface. Grabens, light toned layered deposits, landslides etc. are some of the features on this area that help us to understand the structural and compositional evolution along with any evidences for the past life existed.

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OVERVIEW OF OHB EXPERTISE ON MARS PLANETARY EXPLORATION MISSIONS

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Introduction: Due to its high scientific return on investment, a Mars sample return mission is often described as one of the most important and significant robotic space missions. OHB System AG Munich has been assuming a leading role in instrumentation for Moon and Mars missions. In addition, space robotics with applications ranging from small rovers to on-orbit manipulation are key technological competences of the company.

SPDS: Sample handling on Mars imposes unique and stringent requirements on mechanism design calling for special solutions that satisfy not only the challenging space environments upon arrival on Mars. They also need to consider the presence of dust and be compatible to varying subsoil material as well as to meet the demanding planetary protection requirements.

One elaborate example for this is the Sample Preparation and Distribution System (SPDS, [1]) which has been developed and qualified by the OHB System AG as equipment of the Analytical Laboratory Drawer (ALD) on board the ExoMars 2020 Rover. The ExoMars Rover and Surface Platform Mission, planned for launch in 2020, is a large international cooperation between the European Space Agency and Roscosmos with a contribution from NASA.

The SPDS equipment is formed by a mechanism chain consisting of four different sub-units that convey Martian sub-soil samples provided by the rover-mounted drill into an ultra-clean environment for crushing, dosing and distribution to the instrument payloads for scientific analysis. OHB is in charge of the entire mechanical detailed design, including the actuators and sensors as well as the equipment level testing.

Content: The first part of the presentation provides an overview of the design and testing of the four ExoMars SPDS sub-units, of which three have already completed the flight model acceptance test campaign at mechanism level. Different features and solutions are presented that help to implement planetary protection and cleanliness measures into the mechanism design, which are needed due to high sensitivity of the instruments that are intended for finding traces of past or present life on Mars. Furthermore, it is demonstrated how reliable mechanism operations can be conducted in an extremely dusty environment during the sample handling activities, minimizing sample loss and possible cross-contamination between subsequent samples. Lastly, lessons learned obtained from the sample testing are presented which show how operational procedures and constraints can optimize the system and solve occurring problems.

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SAMPLE TRANSPORT FOR A EUROPEAN SAMPLE CURATION FACILITY.

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Aims

The aim of this work was to propose methods for the recovery and transport of Mars samples from the sample return landing site to a European Sample Curation Facility (ESCF). It was carried out as part of the EURO-CARES project (European Curation of Astromaterials Returned from Exploration of Space) - an EU Horizon 2020 funded project to create a roadmap for the implementation of the ESCF.

Methodology

To learn from previous sample return missions, a review of sample return recoveries for the Genesis [1], Stardust [2] and Hayabusa-1 [3] missions was performed with the aid of relevant experts. Plans for the future recovery of OSIRIS-REx [4] were also examined. Current information on designs for Mars Sample Return missions was collected and presented.

Possible landing sites for a Mars Sample Return mission were compared, including Utah Test and Training Range (UTTR) [5], White Sands, Wallops, Woomera, Kazahkstan and Esrange. A preliminary look at nominal and non-nominal capsule landing scenarios was performed. Then a process of recovery and initial inspection of the Mars samples was proposed, including the recovery of spacecraft parts, portable laboratories, the challenges of handling and the public perception of risk.

Results

Six potential sample recovery landing sites were considered and it was shown that the mission architecture and engineering of the Earth Return Capsule has a bearing on selection. A NASA-led sample return mission may well use the UTTR facility, as with previous missions. However, future missions could be led by other agencies or commercial entities, with Europe as a partner, or lead. The Esrange Space Centre in Sweden is therefore an attractive option with the potential to provide Europe with a recovery option to support future missions.

A list of requirements was developed for the recovery process. The recovery and inspection infrastructure and functional flow for restricted missions was developed and the different elements of the necessary infrastructure were described in product breakdown structures.

Ground recovery of intact and non-intact samples and the possibility/necessity for a portable containment facility were discussed, as well as containment within a suitable transportation box. Analysis of existing technology and current regulations led to the definition of the basic structure of a suitable transportation box. This was based on a layered configuration to adhere to World Health Organisation IATA guidelines for the transport of potentially hazardous samples.

Planetary protection considerations for the landing site were considered and these also included the selection of staff members, their training and health surveillance. Technologies and techniques that could be employed for dealing with a non-nominal landing, specifically where the containment of the ERC has failed and sample material has been released to Earth, were proposed and recommendations made. The critical areas for future innovation were also established.

Conclusions

This work has looked at the recovery of an Earth return capsule from a Mars Sample return mission once it arrives on Earth. It covers possible landing sites, planetary protection requirements and transportation from the landing site to a European Sample Curation Facility. It includes consideration of the recovery infra-structure, training of personnel and preservation of the integrity of the sample.

Acknowledgements

This project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 640190. The information and views are those of the authors and do not necessarily reflect the official opinion of the European Union or of Thales Alenia Space.

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LONG TERM VALUE OF APOLLO SAMPLES: HOW FUNDAMENTAL UNDERSTANDING OF A BODY TAKES DECADES OF STUDY L.E. Borg[1], A.M. Gaffney[1], T.K. Kruijer[1], and C.K. Sio[1] [1]Lawrence Livermore National Laboratory, 7000 East Ave. L-231, Livermore CA 94550; borg5@llnl.gov.

Introduction: Approximately 2415 samples weighing 381 kilograms were returned to Earth during the Apollo missions. This collection is the basis for most of what we know about the origin, history, and evolution of the Moon, and can elucidate how samples returned from Mars would clarify our understanding of this most Earth-like body. Scientific results of investigations completed on this collection serve to illustrate how progressively more sophisticated insights into the geologic history of a body follow from decades of study and concomitant development of analytical capability. The evolution of ideas associated with the age of the Moon based on measurements made on samples from 1971 to 2018 provide such an example.

Early days: The first isotopic analysis of Apollo samples clearly indicated that the Moon was ancient. $^{87}Sr/^{86}Sr$ ratios measured in 1971 on soils and rocks were only slightly elevated from values determined from Allende CAIs and basaltic meteorites implying they formed near the beginning of the Solar System at ~4.6 Ga [1]. Several ancient ages were determined from plutonic rocks of the Mg-suite samples that were interpreted to have been intruded into the anorthositic crust. Some of the most influential ages were absolute ages determined in 1975 and 1976 on Mg-suite samples 72417 of 4.55±0.10 Ga [2] and 76535 of 4.61± 0.07 Ga [3]. These strongly supported the hypothesis that the Moon formed at the beginning of Solar System history. At about the same time, petrogenetic studies led to the development of the magma ocean model. This provided a framework for directly determining the age of the Moon by dating anorthosite rocks interpreted to represent a primordial solidification product of a once molten Moon. However, isotopic investigations in the 1970's and early 1980's were unable to obtain ages using contemporary techniques.

Middle days: Significant progress was made in understanding the age of the Moon between 1979 and 1999. The first age on anorthosite sample 60025 of 4.42±0.04 Ga was determined in 1988 [4], followed by ages on anorthosites 67215 of 4.562±0.068 Ga in 1994 [5] and 62236 of 4.29±0.06 in 1999 [6]. The ability to measure the ages was predicated upon the development of the Sm-Nd isotopic system and the understanding that portions of individual samples were disturbed by secondary impact processes and needed to be physically removed before ages could be determined. Model ages of magma-ocean cumulates were also measured from 1979 to 1995 on suites of whole rock samples. They yielded ages ranging from 4.36±0.06 to 4.42±0.07 [7-8]. The range of measured ages, however, led to significant confusion, providing evidence for proponents of both an ancient and a young Moon. Nevertheless, an age near the beginning of the Solar System was no longer in vogue.

Today: Two factors have led to the modern view of the age of the Moon. Traditional chronometric techniques have been refined and short-lived isotopic systems were developed. Application of multiple chronometers to the same mineral separates is now commonly used to identify fallacious ages that might record mixing, rather than crystallization, processes. Re-measuring lunar sample ages between 2008 to present demonstrates that all of the most ancient ages are likely erroneous. The improved precision and accuracy of these measurements also demonstrates that a vast majority of lunar materials, from crustal rocks and minerals to cumulates of the lunar magma ocean, yield a limited range of ages between 4.30 and 4.38 Ga [9]. This range is supported by the application of two short-lived chronometers on suites of mare basalts. One chronometer, ^{182}Hf-^{182}W is dead indicating the Moon cannot be older than 4.50 Ga [10]. The second chronometer is ^{146}Sm-^{142}Nd and yields ages of cumulate formation averaging 4.334 ±0.018 Ga [10]. This implies that the Moon is significantly younger than was initially believed in 1971.

Implications for Mars Sample Return: The most important lessons from Apollo are:

1. Fundamental understanding of a body evolves as more sophisticate technology is applied to a progressively better understood sample set.
2. Only a small proportion of samples in a suite are suited to any specific question. ~0.7% (17/2415) of the samples collected during Apollo are suitable to directly measure the age of the Moon.
3. Sample diversity is required to understand many geologic processes. Lunar model ages are derived from analysis of sample suites. A petrogenetic framework is necessary to interpret measured ages.

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NON-DESTRUCTIVE TRACE ELEMENT TOMOGRAPHY USING EUROPE´S BRIGHTEST SYNCHROTRON SOURCES (ESRF-GRENOBLE, DESY-HAMBURG) – TOWARDS A BETTER UNDERSTANDING OF MARTIAN SAMPLES. F.E. Brenker[1], L. Vincze[2], B. Vekemans[2], and E. de Poulle[2], [1]Geoscience Institute / Mineralogy, Goethe University Frankfurt, Altenhoeferallee 1, 60438 Frankfurt am Main, Germany, f.brenker@em.uni-frankfurt.de, [2]Department of Chemistry, Ghent University, Krijgslaan 281, S12, B-9000 Ghent, Belgium, laszlo.vincze@ugent.be.

Introduction: Martian rock samples (meteorites and returned samples) represent an important source of detailed petrological and geochemical information. About 200 meteorites classified as Martian meteorites of various rock types are already available for studies in Earth [1]. These so-called SNC – meteorites are a unique group of magmatic rocks originally formed on Mars and separated from their source planet through a series of large asteroid impacts on the planetary surface. Their relation to Mars is confirmed via oxygen isotopic data [2,3], trapped atmospheric gas [2], a similar trend in Mn-Fe ratios in olivine and pyroxene [2,3] and more recently due to comparison with chemical measurements of various rover missions on the surface of planet Mars [4].

One of the scientifically most valuable find of a Martian meteorite within the last decade is sample NWA 7034 and related pairings (like NWA 8171) or better known with its synonym "Black Beauty" [5]. This group of meteorites is officially classified as Martian breccia and represents the first and only Martian sedimentary rocks for detailed study in laboratories on Earth. A high diversity of different rock fragments were recently reported ranging from Si-poor chemistries, to basaltic, to more Si-rich magmatic fragments. However, although a breccia is a sedimentary rock per definition and will give important information on the crustal evolution, it´s rock components are magmatic in origin.

Thus a large part of the Martian crust including chemical sediments and clays are still not available for studies with modern analytical techniques in laboratories on Earth. As these rocks are crucial to understand the processes and evolution of the planetary surface, including climatic variations, and the origin of Life, sample return will be of primary interest of any scientist working on the evolution of terrestrial planets.

Due to it´s immense importance these valuable samples should be treated with extreme care. Thus, any non-destructive analytical approach should be the first choise. However, non-destructive measurement techniques, like low dose SEM, ESEM, synchrotron XRD and XRF, are scarce.

Synchrotron Techniques: Synchrotrons around the globe were used to study tiny particles of cometary [6, 7] and interstellar sources [8, 9, 10] collected during NASAs Stardust mission. It was demonstrated that synchrotron sources are valuable tools to measure the main and trace element content of even the tiniest extraterrestrial particles. The development of new analytical approaches to measure REE-patterns in sub-micron inclusions applying confocal XRF set-ups and energy-dispersive X-ray imaging detectors [11] represent ongoing work in the framework of a long-term project of our group at the PETRA-III synchrotron facility (Hamburg, Germany) and is already applied to various sample types including asteroidal as well as Martian sample material.

Rare Earth Elements: The non-destructive, quantitative measurements of REE patterns from mineral species in rock fragments will allow to identify important processes associated with the formation of the Martian crust. The detailed study of samples returned fro the Martian surface will help to better understand the conditions and chemical variability on the ancient surface of planet Mars. REE-patterns are especially useful as they may record changes in oxygen-fugacity, temperature, fluid content and chemical reservoirs, especially if combined with isotopic studies on the same samples. Important information on the rare earth element fractionation, especially at late stage high temperature crystallization and low temperature surface alteration could be obtained from these samples. Also information about Eu-anomaly, the relative enrichment of light REE versus heavy REE and ultimately the overall pattern distribution could be retrieved with the high-energy XRF spectroscopy measurements.

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EURO-CARES AS ROADMAP FOR A EUROPEAN SAMPLE CURATION FACILITY.

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Introduction: EURO-CARES (European Curation of Astromaterials Returned from Exploration of Space) was a three year (2015-2017), multinational project, funded under the European Commission's Horizon2020 research programme to develop a roadmap for a European Extra-terrestrial Sample Curation Facility (ESCF). Such an ESCF was designed to receive and curate samples returned from Solar System exploration missions to asteroids, Mars, the Moon, and comets. So far, there are only two facilities dedicated for unrestricted returned samples: the NASA Johnson Space Centre in Houston (USA) and the JAXA Hayabusa curation facility in Sagamihara (Japan). Previous studies of an ESCF were either country-specific (e.g., [1]) or mission/target specific (e.g., MarcoPolo-R [2]). With the EURO-CARES project we proposed to move onwards from these specific studies, using experience accumulated at NASA, JAXA, and in various laboratories and museums curating meteorites, in combination with expertise from biosafety laboratories, cleanroom manufacturers, electronics and pharmaceutical companies, nuclear industry, etc. Long-term curation of extra-terrestrial samples requires that the samples are kept as clean as possible to minimize the risk of detrimental contaminants, at the same time ensuring that Martian samples remain contained in case of biohazards. The requirements for a combined high containment and ultraclean facility will naturally lead to the development of a highly specialized and unique facility that will require the development of novel scientific and engineering techniques. We report here a summary of the EURO-CARES study. **The project:** EURO-CARES project was organized around five technical Work Packages (WP), led by scientists and engineers from institutions from all over Europe. **Planetary Protection:** Planetary protection requirements and implementation approaches were determined by the best multidisciplinary scientific advice according to international policy [3] and recommendations from the European Science Foundation [4]. Biohazard and Life Detection protocol were assessed. The existing sterilization methods and techniques were reviewed under new discoveries of phenomena associated with terrestrial microbial extremophiles. **Facilities and Infrastructure:** All the aspects, from building design to storage of the samples were covered. The facility should be composed of a receiving laboratory, a cleaning and opening laboratory, a bio-assessment laboratory, a curation laboratory, and a storage room. The facility will have to be easily adaptable. Long-term curation of samples is a challenging aspect, especially because the pristine nature of the samples should be preserved. **Instruments and Methods:** The methodology of characterization of returned samples and the instrument base required at the ESCF was determined. The analyses should provide an appropriate level of characterization while ensuring minimal contamination and minimal alteration of the sample. Instrumentation will also be required to monitor contamination levels within the facility. **Analogue Samples:** Analogue proxies are necessary in a curatorial facility for testing sample handling, preparation techniques, storage conditions, planetary protection measures as well as to validate new analytical methods. For practical reasons, it may be necessary for the curation and analytical facility to have its own collection of analogue samples. The selection of analogues will be constantly evolving to take into account the rapid changes in the understanding of different Solar System bodies that result from current and future space missions, e.g., Curiosity, Hayabusa 2 and OSIRIS-REx. **Portable Receiving Technologies:** The Earth re-entry capsule from a sample return mission is targeted at a specific landing ellipse on Earth, possibly at considerable distance from the ESCF. A portable receiving facility may be used to inspect, document, and package the sample container(s). It will then be transported to the ESCF using a safe and secure method. In addition, methods for the transport of samples from the facility to the outside institutions were studied, to ensure security and non-contamination of the samples.

More information is available on the project website: **www.euro-cares.eu**

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Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 640190.

EXAMINATION OF LASER MICROPROBE VACUUM ULTRAVIOLET IONIZATION MASS SPECTROMETRY WITH APPLICATION TO MAPPING MARS RETURNED SAMPLES .
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Introduction: It is projected that in the Mars 2020 sample return there will be 20 samples containing approximately 15 grams each of martian rock and regolith. Because each sample will be unique and irreplaceable, sample analysis techniques must be optimized or designed to to consume the least amount of material necessary to make a measurement. We are currently developing a novel two-laser microprobe mass spectrometry setup utilizing vacuum ultraviolet (VUV) post-ionization for applications to surface mapping using a minimal ionization threshold from micron sized sample voxels.

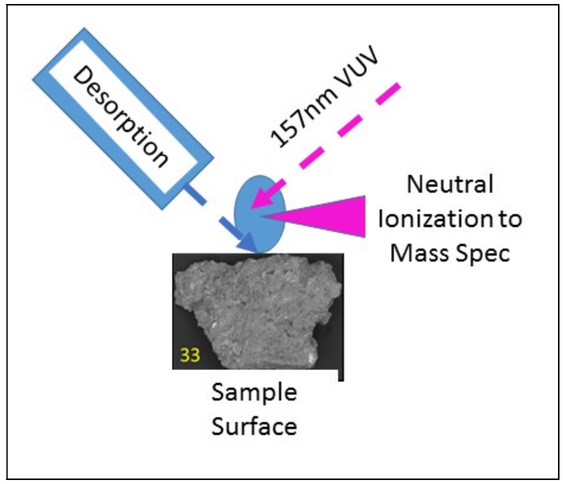
Two laser surface microprobe using VUV post-ionization is a candidate for maximizing the ionization of neutral species typically not measurable in mass spectrometry [1]. Ionization of the neutral plume provides a significant increase in the useful yield (number of molecules detected vs removed from the sample), and at the same time minimizes the amount of material that has to be removed from a surface in order to make a molecular map. Specifically, because the desorption threshold of a physical solid is separate from the ionization threshold of the molecules in that material, the desorption laser can be significantly reduced in intensity to the point where no ions are formed, but neutrals are gently lifted from the surface. This enhances the sensitivity of the technique by minimizing the amount of molecular degradation during volatilation of the organics, reducing the amount of mass required for analysis, which would help maximize the scientific return of samples returned from Mars.

Amino acids are particularly interesting molecules to target in Mars samples because they are essential to life as we know it, they can be made by abiotic processes as well as biotic ones, and they have been observed previously in trace amounts in a martian meteorite [2].

Methods: Laser microprobe with vacuum ultraviolet ionization mass spectrometry was used to analyze femto and picomole quantities of amino acids doped onto inorganic substrates to demonstrate the potential for mapping and quantitative analysis of returned samples. Small samples of geologic structures of interest such as meteorites are tested and surface examined before and after sample analysis to determine how the surface is effected even at low laser thresholds for the desorption of neutrals to be post-ionized.

General Schematic:

Shown below is a general schematic whereby the neutrals are ionized separate from the laser desorption upon a simulated meteorite surface.



Results: Preliminary tests on previous carbon coated surfaces using C60 as a calibrant have demonatrated that threshold control from desorption and post-ionization are well defined as the photonic coupling is well defined. Mapping of meteorite surfaces coated with a known amino acid will provide a preliminary proof of concept demonstration.

Future Work: We will apply our optimized techniques to the analysis of martian meteorites to evaluate the effectiveness of those techniques on actual samples from Mars.

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PRESERVING SAMPLES AND THEIR SCIENTIFIC INTEGRITY – INSIGHTS INTO MSR FROM THE ASTROMATERIALS ACQUISITION AND CURATION OFFICE AT NASA JOHNSON SPACE CENTER.

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Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC), in Houston, TX (henceforth Curation Office) manages the curation of all past, present, and future extraterrestrial samples returned by NASA missions and shared collections from international partners, preserving their integrity for future scientific study while providing the samples to the international community in a fair and unbiased way. The Curation Office also curates flight and non-flight reference materials and other materials from spacecraft assembly of sample return missions that would have the potential to cross-contaminate a present or future NASA astromaterials collection. These materials are primarily collected during the assembly, test, and launch operations (ATLO) phase and after flight during the recovery and curation phase. In addition, the Curation Office curates non-flight, flight-like, and flown witness plates for sample return missions. These reference materials and witness plates provide the scientific community with the fundamental ability to reconstruct the contamination/alteration history of the sample collection through the course of the mission, with the overall goal of strengthening the scientific conclusions drawn from the study of returned materials.

Contamination Knowledge: The information gained from characterizing the physical, biological, inorganic, and organic chemical properties of reference materials and witness plates is defined as the Contamination Knowledge (CK) of the sample collection. Unlike the data collected for Contamination Control (CC) and Planetary Protection (PP), CK is exclusively concerned with preserving reference materials and witness plates for study by future scientists upon sample return. Although data collected for CC and PP purposes can be complementary to CK, they are two separate data sets with distinct objectives. A robust collection of samples for CK is necessary to allow the martian material in a returned sample to be distinguished from terrestrial contamination.

Biological Investigations Broaden Collection's Requirements: Unlike other sample collections, Mars Sample Return (MSR) requires the curation of samples for biological investigation. The addition of biological experimental endpoints to sample return campaign objectives broadens the requisite range in preservation environments (e.g. inert ultra-pure nitrogen gaseous environment at 18°C versus <-80°C) and types of CK samples. Some of the types of biological CK samples the Curation Office requires include, but are not limited to:

1) Un-analyzed swabs and wipes in sterile containers stored at ≤ -80°C.
2) All recirculation filters from the clean rooms used for rover and rover hardware assembly and all filters from the laminar flow benches used to assemble sample intimate hardware. Packaged in sterile Teflon bags and frozen at -80°C.
3) Witness plates collecting airborne contamination within the assembly cleanrooms stored at ≤ -80°C.

Collecting and curating unanalyzed samples will minimize the possibility that current analysis and extraction techniques destroy or alter the samples or otherwise inhibit yet to be developed measurements. It has been Curation Office policy since the Apollo missions to preserve as many pristine samples as possible for future scientific research [1,2].

Conclusions: Although CK is required to be collected for all stages of the MSR campaign, the CK for the Mars 2020 mission is the most critical for understanding contamination in the returned samples given the intimacy between the samples and the Mars 2020 hardware. Rigorous collection of CK and derived blanks for all possible contamination sources and pathways particularly those in the SCS, is essential for mission success.

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MARS SAMPLE RETURN ARCHITECTURE ASSESSMENT STUDY. S. Centuori[1], P. Hermosín[1], J. Martín[1], G. De Zaiacomo[1], S. Colin[2], A. Godfrey[2], J. Myles[2], H. Johnson[3], T. Sachdev[3], R. Ahmed[3], [1]DEIMOS Space S.L.U. (Ronda de poniente 19, 28760 Tres Cantos, Spain, simone.centuori@deimos-space.com), [2]Lockheed Martin UK Ampthill (Reddings Wood, Ampthill, Bedford MK45 2HD, UK, colin.a.stroud@lmco.com), [3]MDA Corporations (9445 Airport Rd, Brampton, ON L6S 0B6, Canada, Holly.Johnson@mdacorporation.com).

The current paper aims to present the results of the ESA funded activity "Mars Sample Return Architecture Assessment Study": its objective is to identify the critical parameters of the MSR mission, perform the relevant trade-offs at both mission and system level, evaluate different mission scenarios and select the best candidates to be then furtherly.

The study has been carried-out by an industrial consortium composed by

- DEIMOS Space S.L.U. as prime contractor and responsible for the mission design
- Lockheed Martin UK Ampthill as responsible of the system design, mass budget and risk analysis
- MDA Corporation as responsible of the payload mechanisms

Mars Sample Return is a joint collaborative project of ESA and NASA aimed at bringing to Earth several surface samples from the Red Planet. The mission is considered a major milestone to enable Mars human exploration, because it will allow scientists to better understand the characteristics of Mars and, based on this information, to design the infrastructure that will receive the first astronauts travelling to the Red Planet.

Such complex objective envisages several mission phases, from the Earth-Mars transfer to the Mars orbital phase, the descent and landing on the Martian surface, the ascent from the Red Planet, the inbound leg towards Earth and the entry in the terrestrial atmosphere followed by the landing on our planet of the capsule containing the astrobiological sample. And such a complex mission opens the door to a wide spread of solutions for the mission architecture, but all of the sharing three critical modules:

- A sample caching rover, to be launched in 2020, which will acquire the samples on the surface and cache them in a defined depot for subsequent collection.
- A surface element launched in 2026 or 2028, containing the Mars Ascent Vehicle (MAV) and a sample fetching rover, which will collect the samples from its depot and return them to the MAV, where they will be stored in the Orbital Sample (OS) element. This spherical OS will be launched by the MAV into a nominally circular orbit above the surface of Mars.
- A spacecraft launched in 2024 or 2026 that will rendezvous with the orbital sample element, collect the surface sample and come back to Earth.

The identified parameters allow to fully define the mission scenarios by using a combination of them. The first parameter to be considered is the launcher, which is injecting the spacecraft into the interplanetary trajectory. Another critical element is the type of propulsion employed during the interplanetary legs, i.e. chemical or electric. Then, several parameters are defined when considering the Mars orbit design after the outbound leg, in particular the strategy used for the orbit acquisition and the parking orbit prior to the rendezvous with the OS. Finally, the selection of the landing site on Earth is made in order to identify the constraints on the inbound trajectory and on the Earth atmospheric entry.

Several trade-offs of all these parameters have been deeply studied during the course of the activity in order to evaluate the mission feasibility and its sensitivity to the most critical design drivers: the combination of candidate propulsion systems (1 chemical and 4 electrical) together with the consideration of all possible staging scenarios and the possibility of performing a full or partial aero-braking for Mars orbit acquisition, leaded to the analysis of more than 500 mission scenarios. An extensive analysis has then been conducted at both mission and system level to verify the fulfilment of the mission goals including: the full definition of the transfer trajectories and Rendezvous operations, the entry corridor in the Earth return together with the dispersion at Earth landing site, the mission risk assessment and the payload mechanisms definition.

The most promising options foresee full chemical propulsion or a mixed system joining the chemical thrusters with the powerful ARM electrical engine. In both cases the mission will rely on the use of aerobraking and staging to reduce the spacecraft wet mass..

This work would not have been possible without the support of ESA, whose team members have always demonstrated a fruitful collaboration and a productive attitude along all the project development. We want then to thank them for their cooperation that was fundamental for the outcome of the project.

THE USE OF TERRESTRIAL ANALOGUES TO INFORM MARS SAMPLE RETURN. E. A. Cloutis[1]. [1]Dept. of Geography, University of Winnipeg, Winnipeg, MB, Canada R3B 2E9; e.cloutis@uwinnipeg.ca.

Introduction: Terrestrial analogues of Mars terrains relevant to landed missions, and likely to sample return missions, can provide valuable operational experience for, and geological insights into, these future missions. The Canadian Space Agency (CSA) has long supported activities at terrestrial Mars analogue sites. Here we report on current and future activities for a number of terrestrial analogue sites.

The goals of work by the University of Winnipeg at these analogue sites has converged to focusing on two main goals: (1) How can instruments on past, current, and future Mars landed missions be applied to recognizing biosignatures? (2) What is the relationship between different terrains and biosignatures?

Current and ongoing investigations:

1. Quebec Ophiolite Belt, QC, Canada. Serpentinites in S. Quebec have been used for previous rover trials [1]. Their geology (e.g., serpentinite, carbonates) is relevant to a number of areas on Mars with similar geology. Work at these sites allows us to understand methane generation associated with serpentinization and its detection [2], and microbiological variations as a function of lithology [3]. Open pit mines in the area also allow for testing of biosignature-detection instruments and exploration strategies [1].

2. Hanksville, UT, USA. This site consists of anastamozing inverted and exhumed fluvial channels, relevant to some ExoMars 2020 rover landing sites [4]. CSA-sponsored rover trials were conducted at the site in Nov. 2016 [5]. Field activities included determining whether biosignature hot spots could be predicted [6].

3. East German Creek, MB, Canada. This site consists of hypersaline springs and spring-associated carbonate mounds with various microbiological communities and microbially induced sedimentary structures (MISSs) [7], the latter of which share similarities with controversial MISS identified in Gale crater [8]. Activities undertaken at this site include studies of biosignature preservation [9] and bio-geo-hydrology relationships [7]. Nearby quarries provide a valuable third dimensional view of the subsurface system feeding these springs [10]. Such environments may have served as "last refuges" for life on Mars [11].

4. Lake St. Martin (LSM) impact structure, MB, Canada. LSM is an ~20 km wide impact crater hosting a variety of shocked lithologies (carbonates, granites) and extensive evaporite (mostly gypsum) deposits [12]. It has been investigated for understanding gypsum-biological interactions [13], endolith survival [13], and post-impact depositional mechanism [14], and because gypsum is present in Martian craters [15, 16].

5. Iceland. Recent activities in Iceland include studying fluvial- and aeolian-reworked basaltic sediments, hydrothermally-altered basalts, and microbial community-hosting hot springs and fumaroles, with a focus on biosignature detection.

Future investigations: As future rover landing sites are further narrowed down, we plan to target additional relevant terrestrial analogue sites in terms of geology, geomorphology, habitability, astrobiology, and sample return. Future deployments include:

Modern, Phanerozoic, and Archean stromatolites and MISS: how stromatolites are fossilized and how can they be recognized with increasing age.

Channeled scablands and anastamozing channels in Iceland and Washington state and massive glacial outflow features from Lake Agassiz, Canada: how such features are associated with biosignature hot spots.

Archean deep mines with isolated groundwater systems: the nature of microbe-groundwater-geological interactions in such environments and what biosignatures are formed and preserved.

No one terrestrial analogue site is fully relevant to Mars. However, by targeting a range of analogue sites, each with unique characteristics, our understanding of the evolution of Mars, its habitability, biosignature potential, gradually improves. This knowledge also informs best practices for Mars sample return (e.g., recognition of biosignatures in diverse environments.

Summary: Our results to date show that some biosignatures are persistent, and the biosignature hot spots can be predicted in some environments.

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Acknowledgements: This work has been supported by CSA, CFI, MRIF, NSERC, and the University of Winnipeg.

PLANETARY QUARANTINE FACILITY FOR THE DEEP SPACE GATEWAY.
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Introduction: A leading candidate for the next major program for human spaceflight may be the Deep Space Gateway (DSG), a space station in orbit around the Moon. Depending on the design of the orbital trajectory, the DSG could offer advantages for staging missions to Mars and for receiving spacecraft returning from Mars or the Asteroid belt. These trajectory advantages also make the DSG a potentially ideal location for planetary protection to install and operate a Planetary Quarantine Facility (PQF) to receive and perform initial analysis of returned Mars samples.

Off-Planet Quarantine Facilities: NASA first began studying an orbital quarantine facility with the Antaeus Report (1981) that placed the PQF in low Earth orbit in a manner similar to then-current space station concepts [1]. During the following two decades, the Exobiology Branch and the Center for Mars Exploration at NASA Ames Research Center evaluated the various challenges of receiving and handling extraterrestrial samples with biological potential. One focus was on developing a sample-handling chamber that could contain the samples without the risk of leakage or escape of materials. This chamber would incorporate a "vacuum jacket" through which any leakage of gas would pass through an autoclave, destroying any organism that escaped. This system became referred to as BSL-4+ or BSL-5 to describe it as advanced beyond the Centers for Disease Control's existing highest standard of "Biosafety Level 4." [2, 3]

One of the key realizations to emerge in the late 1990s was that the Bioisolation technology and operations might not be the most challenging part of the Mars Sample Return mission. Instead, the most challenging aspect might be "writing the environmental impact statement to locate a MRSH laboratory on Earth." One participant's not entirely sardonic solution was to return Mars samples to an orbital storage module, until such time as it was possible to complete construction of the BSL–5 Mars sample receiving and handling facility. Estimates for the completion of the Earth-based facility ranged up to three times as long as the entire Mars sample return mission itself, from project start to sample return to an orbiting "short stop."

Further studies applied both system engineering and urban and regional planning methods to identify the appropriate landing site on Earth and where to transport the samples from there to a permanent curatorial facility. [4,5]. However, the lead author came to the then unpublishable conclusion that the original Antaeus Mission was the best idea and most correct from a system analysis perspective. It would be far more efficient, economical, and safe to process and analyze Mars returned samples in a space-based laboratory.

The Deep Space Gateway: The DSG would afford the ideal space-time coordinates for the Mars returned sample science receiving lab. It provides the essential Bioisolation from Earth to prevent back contamination. Surgical robots are now sufficiently advanced to provide all the capabilities a scientist could need to manipulate, slice, dice, and assay a Mars sample. The two-second time latency to Earth from the distant retrograde orbit of the Deep Space Gateway might be slightly annoying, but far less of an obstacle than sending commands to the Mars surface with up to 40 minutes latency. Finally, it would be feasible for scientist-astronauts to work directly on Mars samples at the Deep Space Gateway, in concert with remote researchers.

Planetary Sample Receiving Lab: The baseline requirements for the PSRL at the DSG include a dedicated module equipped with BSL-4+ grade containment systems and telerobotics. A dedicated sample airlock to pass returned samples directly into the PSRL, without need to pass other through pressurized portions of the DSG station, would greatly simplify control of potential back-contamination. The PSRL would attach to the DSG station via a dedicated airlock, with decontamination capability, including showers and evacuation to vacuum. The operational design for the PSRL mission would concentrate on teleoperated or autonomous operation of the analytical capabilities, while being crew tended in terms of sample selection, loading, unloading, and packaging for return of sterile samples to Earth.

Surgical Robotics and Telerobotics: A critical component of the PSRL will be the implementation of microsurgical robots that researches use with microscopes to study the Mars samples. These robots operate inside the Bioisolation chambers, so that the entire assay process is safely contained.

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MINERALOGICAL CONTROL OF ORGANIC MATTER THERMAL ALTERATION: IMPLICATIONS FOR BIOSIGNATURE PRESERVATION IN RETURNED MARTIAN SAMPLES. A. D. Czaja[1], J. T. Osterhout[2], and A. J. Gangidine[1], [1]Department of Geology, University of Cincinnati, Cincinnati, OH, 45221-0013, USA, [2]Department of Earth, Planetary, and Space Sciences, University of California-Los Angeles, Los Angeles, CA 90095, USA. andrew.czaja@uc.edu.

Introduction: Organic matter preserved in ancient rocks (kerogen) is one of the primary sources of information about the earliest life on Earth and would provide strong evidence for past life on other planets, such as Mars. Raman spectroscopy is a common tool used to identify the presence of organic carbon in ancient rocks and is one of the methods of organic detection used by the SHERLOC instrument that will be deployed by the Mars 2020 rover. It is also typically used to assess the level of thermal alteration experienced by organic fossils and their encompassing geologic units as indicated by the molecular structure of kerogen [e.g., refs 1, 2, 3]. Previous studies, however, have each focused on a single lithology. This study provides evidence for variable molecular structures of kerogen on millimeter scales within primary lithologies composed of different minerals. This evidence comes from both naturally occurring kerogen and experimentally thermally altered organic matter.

Methods: For this study, samples of Mesoproterozoic kerogen-bearing chert-carbonate microbialites from the Middlebrun Bay member of the Rossport Formation of Ontario, Canada were analyzed. This unit was previously studied by Raman spectroscopy to measure the effect of thermal alteration on the carbon isotope composition of the kerogen by a local igneous intrusion [4]. Slabs of chert-carbonate were placed in a tube furnace and heated up to 400ºC for various lengths of time. Thin sections were made from the central portion of each slab. The molecular structure of the kerogen within individual microbialite layers was studied via Raman spectroscopy and the apparent level of thermal maturity was determined via standard spectral parameters such as D/G band intensity ratios, D-band FWHM, and Raman Index of Preservation (RIP) [1, 2, 3].

Results and Discussion: Kerogen preserved in the least altered cherts and carbonates have similar molecular structures as measured by Raman spectroscopy. The more thermally altered samples possess kerogen with molecular structures that vary with lithology/mineralogy. The measured molecular-structural variations are possibly the result of bonding of the kerogen with the various minerals that differentially shield the kerogen from thermal alteration.

Conventional wisdom states that a difference in perceived thermal alteration between a kerogenous object and the rest of the host rock is an indicator that they are not syngenetic [e.g., refs. 3, 5]. The results reported here, however, imply that this is not necessarily true and any scale used to measure Raman thermal alteration (e.g., geothermometry, RIP) for kerogen must be calibrated to the host mineral composition. These findings have implications for the potential of various lithologies to preserve organic biosignatures on Mars, the understanding of which is an important priority of Mars sample science [6]. The Mars 2020 SHERLOC instrument will use UV Raman spectroscopy to search for and identify organic matter in martian sedimentary rocks, and the PIXL instrument can provide geologic and lithologic context. Therefore, data from these two instruments in conjunction with an understanding of lithologic control of Raman signatures of organic matter could be used to prioritize any returned samples for analysis on Earth.

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TOWARDS MARS - STRATOSPHERIC BALLOONS AS TEST-BEDS FOR MARS EXPLORATION

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Introduction: Stratospheric balloons are well-known platforms for various research and technology needs such as atmospheric studies and monitoring, validation of satellite data, astrophysics and other fields. Typical balloon flight duration varies from a few hours to several weeks, depending on the choice of season, launch site and flight trajectory. The altitudes are usually between 20 and 40 km. Balloons of various sizes are available and can carry payloads from a few kg to several tons. As to atmospheric studies, the balloons offer opportunities of in-situ measurements at given altitudes for self-standing studies and/or validation of satellite measurements. In case of astrophysics, the balloons enable measurements from higher levels of stratosphere,, i.e. above clouds and thicker layers of atmosphere thus improving sensitivity and quality of observations compared to ground-based measurements.

Balloons for Mars exploration: Stratospheric balloons are also suitable analogues for Mars exploration as the conditions at typical flight altitudes are quite similar to those on the Mars surface. Due to this fact, the instruments developed for Mars missions can be conveniently tested during a balloon flight before heading to the red planet.

In addition to the in-situ tests of scientific instruments, balloons can also be used as lifting bodies to perform drop tests from high altitudes to test and validate e.g. parachute systems or re-entry bodies. Such tests have been done for several planetary probes and are also planned for the ESA/Roscosmos mission ExoMars.

Balloon flights are carried out from several sites, e.g. Esrange in Northern Sweden, Timmins in Canada and occasionally from Svalbard. Smaller balloons can also be launched from Aire Sur L'Adour in France. Launches from e.g. Esrange enable long-duration flights from Sweden to e.g. Northern Canada, allowing 5-6 days of scientific measurements on a zero pressure balloon.

Possibilities within the HEMERA project: Recently, a new balloon infrastructure project called HEMERA has been selected by the European Commission within its programme Horizon 2020. One of the objectives of the HEMERA project is to enlarge user community within research and technology related to stratospheric balloons and to coordinate activities within the field. The project is coordinated by the French space agency CNES and involves 13 partners from various European entities as well as the Canadian Space Agency, CSA. The project was kicked-off in late January and will be executed during 2018-2021.

Six balloon campaigns are foreseen within HEMERA offering free balloon flights to users and scientists from various science fields and/or for technology tests. The launch sites will be Esrange in Sweden, Timmins in Canada and Aire Sur L'Adour in France. In order to assess user needs, a Call for Ideas will be organized in February with a deadline in April 2018. The ideas received will be carefully analyzed by the HEMERA consortium and used to define the scope of the Call for Proposals (to be issued in July 2018) and to schedule upcoming balloon campaigns. In additional to the campaigns, various outreach and education activities are foreseen such as workshops and summer school for students.

The Mars community is kindly invited to submit their ideas in response to the HEMERA Call for Ideas and subsequent Calls for Proposals. More information about HEMERA and possibilities for science community will soon be available on a dedicated HEMERA website (currently under development).

Balloon launch from Esrange in Sweden, photo K. Dannenberg

CNES ROVER AUTONOMOUS NAVIGATION AND ITS POTENTIAL APPLICATION TO MARS SAMPLE RETURN FETCH ROVER. M. Delpech, X. Rave, L. Rastel. [1]Centre National d'Etudes Spatiales (CNES), 18 Avenue Edouard Belin, 31400 Toulouse, France - email: michel.delpech@cnes.fr

Introduction: Rovers on the Mars surface have relied over the years on navigation approaches with progressively higher autonomy However, the distance crossed by Curiosity today does not exceed several tens of meters per sol and the daily roving distance of ESA Exomars, expected to land in 2021, should be in the 100 m ballpark. The future MSR mission is now pushing this boundary with the concept of fetch rover which traverse capability should be increased by an order of magnitude to optimize samples retrieval [1]. This paper presents the work achieved by CNES to meet some of these challenges throughout its R&D activities and participation to Exomars.

CNES activities in AN : The history of CNES robotics team involvement in rover autonomous navigation dates back to the mid 90s with its participation to the Russia led Marsokhod project. CNES contribution comprised the stereo camera system and the Autonomous Navigation (AN) software package which optimization required intense effort due to the limited computing resource. AN algorithms were subsequently improved and matured through several years of R&D development and validation effort including field testing. This expertise was proposed to JPL during the first MSR project and experiments/demonstrations were performed in JPL Mars Yard in 2000 to show the potential of Autonomous Navigation versus the nominal Hazard Avoidance approach. Afterwards, CNES got involved in the ESA-led Exomars project through an active participation in the requirements phase, the in-kind delivery of its AN framework to the main actors along with its technical support[2]. Following the stall of the AN functionality due to budget constraints, CNES recently stepped forward to promote the re-introduction of AN in Exomars and is currently negotiating the accommodation of its own AN flight software along with the UK AN baseline solution. The CNES proposed functionalities go beyond the strict Exomars requirements and include capabilities that appear beneficial to future rovers with enhanced autonomy needs.

Regional Navigation: The typical structure of a Vision Based AN package relies on 3 sequential computational stages performed while the rover is stopped: (1) Stereo Correlation & DEM Generation, (2) Traversability Map Build & Update, (3) Path & Perception Planning. There, the environment representation used for short-medium range planning is built by merging the consecutive local maps taken at each stop and such a representation leads to range limitations due to obvious on-board memory constraints.

To increase the rover long traverse capability, CNES developed two additional features (Regional map build & update, Regional path planning) that rely on a more efficient and complementary representation of the environment. To optimize memory usage, the local traversability map generated at each perception cycle is compressed into an obstacle map that can be vectorized. Such a compact representation referred as regional map stores all identified obstacles along the way and provides a synthetic and global knowledge compatible with few kilometers traverses.

The regional map enables the rover to efficiently plan a reverse path if dead ends are encountered or a quick return is required. In addition, the regional map can be initialized with forbidden or undesirable areas labelled as such by ground operators. These functionalities that have a low impact in terms of memory usage and computational cost with respect to the typical 3 stages AN algorithms have been developed to comply with Exomars requirements. The computational time of the whole optimized AN package on the Exomars LEON2 processor is around 30 s for a sequence of 3 perceptions. These functionalities that can be activated or inhibited from ground are foreseen to be exercised during the nominal and/or extended mission to show their potential in the perspective of longer traverses. This AN technique has been intensively validated on a representative numeric simulator and tested on the field with ARTEMIS rover (Exomars-like rover platform). Further improvement is currently under study to exploit the regional map concept for relative localization.

Conclusion: This work describes a potential step to enhance the rover autonomous navigation that represents only one of the challenges to be faced by the MSR fetch rover. Besides the necessary ruggedization of the locomotion platform, the implementation of reliable perception approaches for the detection, the localization and the grasping of sample tubes will require significant effort.

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MARS SAMPLE RETURN ORBITER ARCHITECTURE OPTIONS – RESULTS OF THE ESA MARS SAMPLE RETURN ARCHITECTURE ASSESSMENT STUDY. U. Derz[1], E. Joffre[1], M-C. Perkinson[1], J. Huesing[3], F. Beyer[2], J. M. Sanchez Perez[2], [1]Airbus Defence and Space Ltd, Gunnels Wood Rd, SG1 2AS Stevenage, United Kingdom, [2]European Space Agency, Keplerlaan 1, PO Box 299, NL-2200 AG Noordwijk, The Netherlands, [3]RHEA for ESA, Keplerlaan 1, PO Box 299, NL-2200 AG Noordwijk, The Netherlands.

Introduction: In 2017 Airbus in the UK conducted the Mars Sample Return Architecture Assessment Study on behalf of ESA. It aimed in particular to:

- Quantify possible mission architectures of the international Mars Sample Return campaign
- Identify design envelopes of these possible architectures, for the elements that could be contributed by ESA
- Support identification and selection of ESA contributions to the campaign
- Provide inputs to the technology development planning

Bi-lateral discussions between ESA and NASA identified the Mars Sample Return Orbiter element as a very likely European led contribution. Hence the study entirely focused on architecture options of the orbiter.

Study Logic: In order to support architecture trade off and selection, a set of architecture constraints were defined by the customer at the beginning of the study. They covered aspects as launch and return dates, launcher performance, payload masses and communication relay provision in Mars orbit. In parallel a set of architecture "ideas" were generated by Airbus. They cover different options in terms of launch vehicle, propulsion type, number of stages and point(s) of stage separation as well as use of aerobraking.

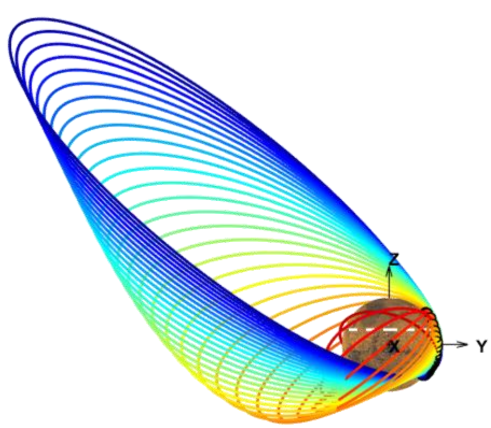

Figure 1: Sample intermediary orbits during aerobraking to low Mars orbit (separated by ~7 days)

An intensive mission analysis was carried out to support launch mass estimation and mission scheduling of each architecture. Due to the nature of the initial architecture ideas, mission analysis had to address besides conventional impulsive transfers also low thrust transfers as well as combinations of the above. Also the possibility of Earth and Venus gravity assists were studied.

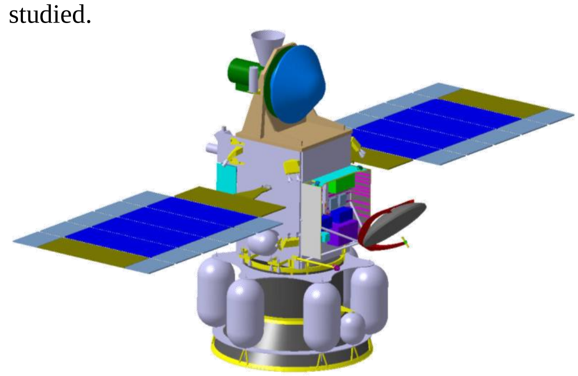

Figure 2: Airbus Mars Sample Return Orbiter phase A design

In a second step an architecture trade-off was conducted to reduce the number of options. Launch mass margin, return date, technology readiness and Earth Re-Entry Capsule atmospheric entry conditions were considered as criteria. The resulting three most promising architectures were investigated in more detail. In order to establish a first phase 0 spacecraft design, preliminary subsystem trade-offs were carried out, in particular in the area of propulsion and power subsystems. Furthermore the sensitivity to the payload mass was investigated. Finally the performance of each architecture was compared to the given architecture constraints.

Scope: This presentation outlines the used approach to define a Mars Sample Return Orbiter architecture. It presents the most promising architectures that were identified (both chemical and electric propulsion options) and compares their performance with the given constraints.

A MINIATURIZED SPECTROMETER FOR OPTIMIZED SELECTION OF SUBSURFACE SAMPLES FOR FUTURE MSR MISSIONS.

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Introduction: Here we present the concept of a miniaturized spectrometer for future Mars Sample Return (MSR) missions. The instrument is based on the design of the Ma_MISS (Mars Multispectral Imager for Subsurface Studies) experiment [1] on board the ExoMars 2020 Rover [2]. This instrument, coupled with a drill tool [3], will allow an assessment of the mineralogical composition of sub-surface terrains and optimize the selection of martian samples with a high astrobiological potential to be returned to the Earth.

Instrument description: The proposed instrument main requirement is miniaturization because it is embedded within drill parts. The spectrometer is accommodated in a box on the external wall of the drill box. The light from an integrated 5W lamp is collected and carried to the miniaturized Optical Head (OH) using an optical fiber bundle. The OH is within the drill tip. An anti-reflective coated Sapphire Window (SW) with high hardness and transparency on the drill tip tool protects the OH permitting the observation of the borehole wall. Different depths can be reached by the use of drill extension rods, for example 50 cm long, each containing optical fibers and a collimator. The first extension rod is connected to the non-rotating part of the Drilling System, hosted on the rover, through a Fiber Optical Rotating Joint (FORJ), that allows the continuity of the signal link between the rotating part of the drill and the spectrometer subsystem.

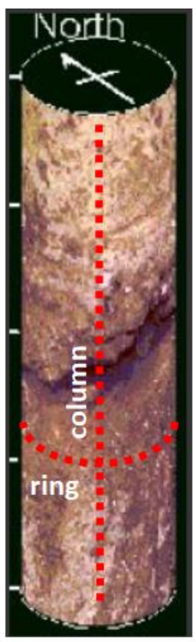

Fig. 1. Depiction of "column" and "ring" acquisitions (red spots) obtained in the bore hole with a vertical translation and with a 360° rotation of the drill tip, respectively.

Scientific objectives:

Making use of the drill's movement the instrument slit will scan rings and columns, build up hyperspectral images of the borehole (Figure 1) and accomplish the following goals:

Determine the composition of subsurface materials: spectral range and high spatial resolution will allow identifying differences in lithologies, and distinguishing between volcanic and sedimentary rocks. Analysis of band positions and shapes can be used to identify different types of mineralogical phases. Crystal field absorptions due to Fe^{2+}-Fe^{3+} (near 1 and 2 µm) and other transition elements in association with iron-bearing minerals can be used to identify many types of silicates, oxides, etc. [4]. The occurrence of OH^{-}/H_2O vibrational bands near 1.0, 1.4, and 1.9 µm is indicative of the hydration state of materials [5]. Carbonates also display overtones and combinations of vibrational features that are in principle observable in the 1.75–2.20 µm range [5].

Map the distribution of potential subsurface water and volatiles: Ice deposits in the Martian shallow subsurface have been inferred from remote-sensing detection of hydrogen based on neutron and gamma ray spectroscopy [6] and from permafrost evidences [7]. Detections of low latitude H_2O frost on pole facing slopes are consistent with a subsurface ice [8].

Characterize important optical and physical properties of materials (e.g. grain size): The study of spectral parameters, such as continuum reflectance level and slope can help to determine important physical parameters like the different dimensions of grains in materials to better assess the type and state of sediments in the subsurface.

Produce a model stratigraphic column to obtain clues about subsurface geological processes: Mars surface is rich in sedimentary outcrops that exhibit stratigraphic features at a range of spatial scales. On Earth, our understanding of the evolution of ancient climate and life development derives from the study of mineralogical, textural, and geochemical signatures preserved in the sedimentary rock record in stratigraphic sections. These insights could also have been preserved in Martian subsurface stratigraphy.

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The Moon: A 100% isolation barrier for Earth during exobiological examination of solar system sample return missions. *Barry E. DiGregorio, Buckingham Centre for Astrobiology, University of Buckingham, Buckingham MK18 1EG, United Kingdom*

Introduction: In the coming decades NASA and all other capable space faring nations will want to return samples of Mars, samples of ice from Jupiter's moon Europa and samples of the plumes of water emanating into space from Saturn's Moon Enceladus to look for any evidence of extraterrestrial biology. As exciting as these sample return missions are to astrobiologists, lingering questions on how best to safely examine these samples without accidental contamination of the Earth's biosphere remain problematic. For example, robotic sample return missions that are sent to the surface of the Earth or Earth orbit for laboratory analysis do not offer a 100% guarantee that some technological or other errors would not lead to an eventual exposure of these materials to Earth's biosphere. Even if examined in an Earth orbiting space station, a contamination event might render it uninhabitable, ultimately to reenter the Earth's atmosphere where sections of the spacecraft could survive intact and spread out over vast distances of our planet.

The only 100% guarantee of protecting Earth's biosphere from a hazardous back contamination event is to use the Moon as a sample return examination facility to qualify samples for eventual return to Earth. A well planned lunar quarantine laboratory as part of a larger lunar base would be perceived by the public and scientific community as another legitimate reason to reinvest in a return to the Moon.

Pros: The size of sample return payloads could be much larger because of the Moons 1/3 gravity. Aside from the Moon offering a 100% back contamination barrier to Earth, it also has enough gravity that would make working with extraterrestrial materials less difficult than working in a microgravity environment of an orbital space station or other orbiting module designed for such a purpose. The Moon's lack of an atmosphere with near vacuum conditions greatly reduces the possibility of the spread of a back contamination event to other areas of a lunar scientific outpost.

If putative extraterrestrial microorganisms are found in samples, a lunar planetary quarantine facility could be used to test a wide variety of terrestrial ecosystems in enclosed modules simulating various Earth environments.

Finally, other advantages would be experiments on the mutation rates of terrestrial microorganisms in the lunar radiation environment that might help how humans could best survive radiation exposure on Mars.

Cons: Cost. Obviously the establishment of a lunar quarantine facility as part of large scientific outpost would require the commitment and resources from a number of space faring partners.

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UN OOSA A/72/20. (2017) Report of the Committee on the Peaceful Uses of Outer Space (COPUOS 60th Session), para 332. United Nations, New York.

ESA SAMPLE FETCH ROVER: HERITAGE AND WAY FORWARD. L. Duvet[1,] F. Beyer[2], J. Delfa[1], E. Zekri[2], [1]European Space Agency, ECSAT, Fermi avenue, Harwell Didcot, Oxfordshire, OX11 0FD, United Kingdom; ;ludovic.duvet@esa.int, juan.delfa@esa.int, [2]European Space Agency - ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands, friederike.beyer@esa.int, eric.zekri@esa.int

Introduction: The Sample Fetch Rover (SFR) is one of the key elements of the Mars Sample Return (MSR) campaign architecture. SFR will collect the sample tubes left by the Mars 2020 rover and bring them back to the Sample Return Lander where a dedicated robotic arm on the lander will transfer them to the Mars Ascent Vehicle. With a maximum mass of 120 kg, SFR will have to drive long distances autonomously, typically 20-30 km, while facing harsh conditions, in particular due to the dust storm season which will affect most of its nominal mission, starting presently in July 2027. SFR has been identified as a possible contribution from the European Space Agency to the NASA-led MSR campaign. In order to be ready for a launch in 2026, ESA aims at capitalizing on the ExoMars rover heritage while injecting new technologies developed by the Agency and other European programs. A dedicated phase A/B1 (i.e. up to System Requirements Review) will be initiated by ESA in spring 2018, aiming at consolidating the baseline concept, implementation specifications, cost and programmatics for the ESA ministerial meeting in December 2019, gate toward the implementation phase. We will present the SFR heritage as well as a way forward identified to address this engineering challenge.

Sample Fetch Rover:

The present architecture of the MSR campaign identifies the need to collect the RSTA (Return Sample Tube Assembly) cached by the Mars2020 rover and bring them back to the Sample Return Lander. This function will be primarily performed by the so called Sample Fetch Rover, a lightweight (<120 kg), fast (~200m/sol), autonomous (for navigation and fetching) rover platform carried on the Mars surface by SRL in July 2027. It is important to note that presently the use of Mars2020 for that function is kept as an option in order to provide robustness at campaign level while providing the possibility of a lean approach for SFR.

For one of the three selected Mars2020 landing sites, Columbia Hill, Jezero Crater, and North East Syrtis, SFR will drive up to 30 km (depending on the optimum path) in a maximum duration of 150 sols (or 230 in case of severe dust storm conditions).

The autonomous navigation capability, coupled to a resource effective operation planning and intense on-ground characterization of the cache depot (for precise tube location), will be the key to achieve the mission in time. Similarly to the driving, the fetching phase will require a high level of autonomy in order to fit the 36 RSTA pick-up in a typical 10 days window. Vision-based algorithms, for navigation and fetching will be the baselined capabilities of the rover. These processing capabilities will require resource effective on-board computing to cope with the limited power. The locomotion system will also need to comply with the limited mass and power while offering the best performances in terms of traversed distance per day. Maximizing the traversed distance per day will be the result of a system trade-off between rover speed, energy consumption and availability, and capability to start in cold conditions.

These aspects have been covered by ESA over the past years by different internal and industrial studies (MarsREX, MarsFAST, SFR pre-phase A) with evolving assumptions as the MSR campaign architecture was maturing. All of these concepts however relied strongly on the ExoMars rover design and experience available at that time, taking into account new technologies where required. The most critical technologies were considered for implementation as part of the SFR technology roadmap, with the objective to achieve TRL5/6 by the end of the upcoming phase A/B1, now foreseen by spring 2020. In parallel, ESA has identified the importance of performing field trials for SFR and an end-to-end campaign will take place in 2019.

MARS SAMPLE RETURN ARCHITECTURE OVERVIEW. C. D. Edwards[1] and S. Vijendran[2], [1]Jet Propulsion Laboratory, California Institute of Technology, M/S 321-690, 4800 Oak Grove Dr, Pasadena, CA 91109, USA; chad.edwards@jpl.nasa.gov, [2]European Space Agency - European Space Research and Technology Centre (ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands, sanjay.vijendran@esa.int.

Introduction: NASA and ESA have maintained a continuous robotic presence at Mars since the arrival of NASA's 2001 Mars Odyssey orbiter and ESA's 2003 Mars Express Orbiter. A series of subsequent orbital (MRO, MAVEN, ExoMars/TGO) and landed (MER, Phoenix, MSL) missions has redefined our understanding of the Red Planet, revealing clear evidence of a warmer, wetter ancient Mars and providing insight into Mars as a system in terms of its geology, climate, and habitability. Over time, a broad consensus has emerged in the Mars science community that the logical next step in advancing our understanding of Mars is to return a scientifically selected set of Martian samples, for investigation in terrestrial laboratories. Such a strategy would enable an unprecedented breadth and depth of scientific investigations, far beyond the capabilities of in situ instruments.

MSR Baseline Architecture: The most recent planetary science decadal survey [1] strongly endorsed the scientific rationale for returning samples from Mars. Among flagship mission concepts, the committee placed top priority on the Mars Astrobiology Explorer-Cacher (MAX-C), as the first element of a notional three-mission NASA-ESA Mars Sample Return campaign. MAX-C has since evolved into NASA's Mars 2020 mission, scheduled for launch in Jul-Aug 2020, and tasked to collect and cache a scientifically selected set of samples for potential retrieval and return to Earth by a subsequent mission, with a capability to collect and cache at least 20 samples during the rover's 1.5-Mars-year primary science mission.

NASA and ESA are currently exploring concepts for the subsequent missions that could enable the return of the samples collected by Mars 2020. The first of these mission concepts, the Sample Return Lander, would deploy a landed platform at the Mars 2020 landing site, from which a small Sample Fetch Rover would egress and retrieve the cached samples. After returning to the lander, the samples would be transferred to an Orbiting Sample (OS) canister and loaded into a Mars Ascent Vehicle (MAV), which would launch the OS into low Mars orbit.

There, an Earth Return Orbiter (ERO) would rendezvous with the OS and capture it. After secure biocontainment, the contained OS would be transferred to an Earth Entry Vehicle (EEV), and the ERO would leave Mars orbit and return toward Earth, where the EEV would be released on a trajectory to land at a designated Earth landing site. After landing, the returned samples would be transferred to a secure Sample Receiving Facility for evaluation and, ultimately, extensive science investigation.

This presentation will serve as an introduction to the current baseline MSR architecture, to be followed by a series of more detailed presentations on the various proposed MSR elements. The information provided about possible Mars sample return architectures is for planning and discussion purposes only. NASA has made no official decision to implement Mars sample return.

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Acknowledgment: A portion of the research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

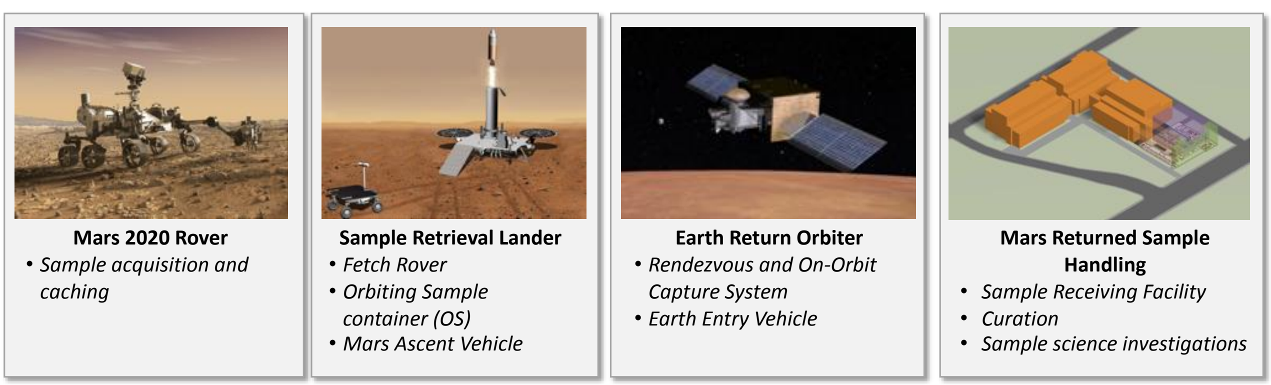

Figure 1: Notional Mars Sample Return architecture, with three flight elements and one terrestrial element.

PREPARATION, CHARACTERIZATION AND UV IRRADIATION OF MARS SOIL ANALOGUES UNDER SIMULATED MARTIAN CONDITIONS TO SUPPORT DETECTION OF MOLECULAR BIOMARKERS. T. Fornaro[1], J. R. Brucato[2], I. L. ten Kate[3], S. Siljeström[4], A. Steele[1], G. D. Cody[1] and R. M. Hazen[1], [1]Geophysical Laboratory, Carnegie Institution for Science, 5251 Broad Branch Rd NW, Washington, DC 20015, USA - tfornaro@carnegiescience.edu, asteele@carnegiescience.edu, gcody@carnegiescience.edu, rhazen@carnegiescience.edu, [2]INAF-Astrophysical Observatory of Arcetri, L.go. E. Fermi 5, 50125 Firenze, Italy - jbrucato@arcetri.astro.it, [3]Earth Sciences Department, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands - I.L.tenKate@uu.nl, [4]RISE Research Institutes of Sweden, Drotting Kristinas väg 45, 114 28 Stockholm, Sweden - sandra.siljestrom@ri.se.

Introduction: Laboratory simulations of the Martian environment are essential to support both *in situ* exploration and sample return missions devoted to detection of molecular biomarkers on Mars [1-7]. Indeed, they may provide important information about the processing experienced by potential biomarkers in the harsh Martian conditions, which helps to: inspect the conditions for the preservation of signs of past or present life on Mars, correctly interpret data collected on the ground, and develop suitable life detection methods and technologies for analyses both on the ground and in terrestrial laboratories.

Ultraviolet (UV) radiation and perchlorates are among the main degradation agents on Mars [8-10], whose effect on the stability and reactivity of possible biomarkers embedded into the Martian soil strongly depends on the protective or catalytic properties of the mineral matrices [11-12]. A systematic study of the effects of UV radiation and the presence of perchlorates on a variety of possible Mars soil analogues is key to figure out which mineral deposits are more suitable to preserve potential biomarkers on Mars, developing models for their degradation at geological timescales. This would be particularly helpful to select the future landing sites on Mars for collecting samples to return to Earth. Moreover, the characterization of Mars soil analogues through various non-destructive techniques allows to assay the sensitivity of different laboratory instruments to detect diagnostic features of molecular biomarkers [13,14].

Accordingly, we present laboratory activities of preparation, characterization and UV irradiation processing of Mars soil analogues. In more detail, we have prepared Mars soil analogues by doping natural and synthetic minerals with organic compounds considered as biomarkers using an equilibrium adsorption method. Subsequently, we have employed Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS), micro-Raman imaging, and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) to gain insight into specific molecule-mineral interactions. Furthermore, we have investigated the effects of UV radiation on the molecule-mineral complexes under Martian-like conditions through UV irradiation experiments inside a Martian simulation chamber.

These studies highlight the complementarity of different techniques for detecting diagnostic features of biomarkers adsorbed on minerals, which can be crucial for the interpretation of data collected on the ground during mission operative periods.

Moreover, the results of the UV irradiation experiments allow us to compare the photoprotective/photocatalytic behavior of a variety of minerals relevant to Mars mineralogy and make predictions for the mineral deposits that have the highest preservation potential on Mars.

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SAMPLE ANALYSIS AT MARS (SAM) AND MARS ORGANIC MOLECULE ANALYZER (MOMA) AS CRITICAL *IN SITU* INVESTIGATIONS FOR TARGETING MARS RETURNED SAMPLES.

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Introduction: One of the biggest concerns for the detection of organics on extraterrestrial environment is the preservation potential of the molecules at the surface and subsurface given the harsh radiation conditions and oxidants they are exposed to. The SAM and MOMA instruments, respectively onboard NASA Mars Science Laboratory 2011 and joint ESA/RosCosmos ExoMars 2020, are both analytical laboratories that seek *in situ* organic molecules and potential biomarkers in the martian subsurface, and thus establish taphonomic windows of preservation of those molecules. This is critical for making a wise choice of Mars samples to return to Earth.

Current and future in situ analyzes: SAM has been analyzing Mars' regolith since 2012, with 16 scooped or drilled locations under investigation. SAM discovered chlorohydrocarbons indigenous to a mudstone drilled sample, Cumberland (CB) [1]. The discovery of chlorohydrocarbons in the martian surface means that reduced material with covalent bonds has survived despite the severe degrading conditions. Organic compounds in this ancient sedimentary rock could haver formed on Mars from igneous, hydrothermal, atmospheric, or biological processes or, alternatively, delivered directly to Mars via meteorites, comets, or interplanetary dust particles. The implication of these results are twofold. Firstly, CB sample is composed of 20 % of smectite [2]. The detection of up to 300 part per billion of organic compounds in this sample suggests that clays are good candidates for accumulating and preserving organics over geological timescales. This has previously been postulated considering clays' high surface area, negatively charged interlayers and cation associated with water in the interlayers that retards water flow. Secondly, organics are prone to degradation under the high-energy radiation exposure through the thin Mars atmosphere. Preserved samples are thought to be buried < 2-3 m but the CB sample is only 65 mm-deep. The CB sample was found to have a surface exposure ages of 78 +/- 30 million years [3], which suggests recently exposed rocks could contain preserved organic matter and should be targeted for sample return.

The MOMA instrument onboard ExoMars 2020 should increase the detected abundance and diversity of organic molecules in Mars subsurface [4]; by drilling a sample down to 2 meters, it will access more preserved area. The detection of oxychlorines at two very different locations (Phoenix: polar [5] and Curiosity: equatorial [6] sites) support the hypothesis that those compounds may be widely distributed at the surface of Mars. The drill cores of sedimentary rocks obtained and analyzed from the uppermost 2 m of the martian surface by ExoMars will thus be highly valuable to assess the unknown gradient of oxychlorine vs. depth within the martian regolith. Returning samples from a depth where oxychlorine is less abundant or even absent will provide the potential for better organic preservation and facilitate search for biosignatures in Earth-based laboratories.

Feeds forward to Mars sample return: The ability to detect organic compounds in martian sedimentary rocks is a function of their initial abundance and entrainment as the rock formed, the extent of subsequent degradation during diagenesis, exhumation and exposure to the surface and near-surface radiation - including the new conditions the sample is exposed to after caching and before returning it. *In situ* investigations provide significant progress toward mapping out potential windows of preservation for chemically reduced organic compounds, by providing important constraints on the types of rock samples (mineralogy, radiation exposure) to target for future examination and for sample return missions.

This view into ancient Mars begins to provide a context for habitable environments and is a first step toward understanding the presence and diversity of possible prebiotic or biotic molecular signatures. *In situ* investigation is a necessary first step before sample return. The current and future state of knowledge of simple and complex organics preservation, revealed by SAM and MOMA investigations, provide a critical source of information for understanding the returned samples that can be analyzed on Earth with the cutting-egde technologies available in our laboratories.

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A ROVER MOBILITY PLATFORM WITH AUTONOMOUS CAPABILITY TO ENABLE MARS SAMPLE RETURN. P. Fulford[1], C. Langley[1] and A. Shaw[1], [1]MDA Robotics and Automation (paul.fulford@mdacorporation.com ; 9445 Airport Road, Brampton, Ontario, Canada, L6S 4J3).

Introduction: It is widely accepted that the next step in understanding Mars is to bring samples of Mars to Earth. This will allow Mars samples to be analyzed by scientists in laboratories across the world and by scientists who are not yet born using instruments that have not yet been invented. Like the Apollo samples that continue to be analyzed today, the samples brought to Earth by our current Mars Sample Return efforts will continue to be analyzed for decades to come. Here we discuss protoype activities for a rover system that can acquire Mars samples and deliver them to an ascent vehicle, in the first step of their journey to Earth.

In fall of 2016 the CSA conducted a Mars Sample Return Analogue Deployment (MSRAD 2016) [1,2] using the Mars Exploration Science Rover (MESR). MSRAD 2016 is the highest-fidelity rover deployment for Canada to date, and a direct follow-on from the 2015 Mars-analogue deployment [3]. The two deployments were conducted in the same site in Utah (see Figure 1), with mission operators located remotely in Quebec and the Science Team located at the University of Western Ontario. The goal of the deployment in 2016 was the execution of an end-to-end analogue mission demonstrating working concepts for a future Mars "Fetch Rover" mission.

One of the objectives of this analogue mission was to demonstrate the maturity of the rover's onboard autonomous guidance, navigation, and control (GNC), which allows operators to simply command goal locations for the traverse. The rover avoids local hazards and intelligently selects short-range waypoints which maximize traverse safety. If a low-resolution digital elevation map is available, the rover also avoids getting trapped in dead-ends. Absolute heading estimation and gravity correction help to reduce drift in the rover's relative navigation estimate.

Autonomous traversing for sample fetching was tested in this Mars-like environment and under the realistic conditions of a sample return mission. During MSRAD 2016, MESR travelled a total distance of 1 km in fully autonomous mode by establishing its own routes and avoiding obstacles to reach its destinations using onboard GNC functions. No emergency stop command was ever issued by the field safety personnel, nor operators at CSA headquarters. . This is a good indication that MESR successfully and safely executed its tasks. More details on MSRAD 2016 can be found in [4].

The deployment has successfully shown that many of the rover technologies needed for Mars sample return are mature, and capable of performing in a challenging relevant environment.

Acknowledgements: Thank you to the CanMars team and the CSA. This work was funded by the CSA.

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Figure 1: MESR rover during the 2016 Mars Sample Return Analogue Deployment.

DRILL CONCEPT FOR A FUTURE MARS SAMPLE RETURN MISSION. A. Fumagalli[1], A. Pilati[1], G. Sangiovanni[1], M.C. De Sanctis[2], R. Mugnuolo[3], F. Altieri[2], E. Ammannito[3], S. Pirrotta[3], A. Gily[4], S. Durrant[5], [1]Leonardo S.p.A., Viale Europa s.n.c., Nerviano (MI), 20014, Italy, [2]INAF/IAPS, via del Fosso del Cavaliere 100, 00133 Rome, Italy, [3]Agenzia Spaziale Italiana, ASI, Italy, [4]Thales Alenia Space Italia, Strada Antica di Collegno, 253, 10146 Torino, Italy; [5]European Space research and TEchnology Centre (ESTEC), Keplerlaan 1, PO Box 299, 2200 AG Noordwijk, The Netherlands.

Introduction: The return to the Earth of samples of high astrobiological interest is one of the main objectives of the future Martian exploration programs. Due to the very tenuous atmosphere of the planet, ultraviolet and ionizing radiations could have degraded or destroyed potential chemical bio-signatures at or in the vicinity of the Martian surface. Radiation effects decrease with depth, hence the access to the Martian sub-surface is mandatory to collect samples that better preserve possible bio-signatures.

Here we describe the concept of a Drill for future Mars Sample Return (MSR) missions with the goal of collecting and storing samples from the Martian subsurface based on the design of the drill on board the ExoMars 2020 Rover [1]. The proposed drill foresees an integrated miniaturized spectrometer to better evaluate the sub-surface layers from which the samples should be collected [2, 3] and a tool to collect the samples for the return.

Drill Concept: One of the aims of the ExoMars mission is to search for signs of past or present life on Mars and to investigate soil composition at depths down to 2 meters. The ExoMars Drill has the main purpose of collecting the samples at these depths and delivering them at the onboard instrumentation for analysis.

Although able to drill 2-meter-deep holes, the Drill is compact – less than 1-meter-long – thanks to its multi-rod, extendable drill string design.

Indeed, the first rod is in fact the drill tool (the drilling/cutting item), equipped with its internal sampling mechanism that allows collecting, retaining and releasing the sample to/from the given depth. The Drill is also equipped with a redundant drill tool that can be used (in case of need) after abandoning the main one. The redundant drill tool has the same capabilities of the main one. Other three rods are included in the Drill; at launch they are safely stored inside it and the mandrel is connected directly to the drill tip. During operations one or more rods can be installed between the drill tip and the mandrel, by means of threaded junctions, to extend the drilling capabilities up to 2 meters.

The Drill also incorporates the Ma_Miss spectrometer [3] which is capable of performing scientific analysis of the drilled borehole.

Being one of the mission aims the search of life, all the ExoMars hardware is under strict Planetary Protection requirements, especially the part of the Drill that go into contact with the Martian samples. To reach them, special cleaning treatments and sterilization are applied; also, it is specified that particular garments – including sterile gloves and more – must be worn by anyone in contact with the hardware.

The Drill mechanisms are supplied and controlled by a Central Electronics Unit, located in the ExoMars Rover. Operations are performed automatically with aid of Control SW and minimum input required from Earth.

Nominal mission: For the Drill, the nominal mission on Mars consists of 2 vertical surveys and 6 experiment cycles. The aim of the "vertical survey" is to drill a 2-meter-deep hole collecting a sample every 50 cm, namely at surface, 0.5 m, 1 m, 1.5 m and 2 m depth. In one "experiment cycle" two samples are collected, one at surface and one at 1.5 m depth.

In late 2017, a simulation of the nominal mission has been completed successfully in the frame of the Drill qualification campaign. The environmental test campaign has been performed using a dedicated facility designed and built at CISAS (University of Padova), reproducing the Mars-like conditions in terms of temperature, atmospheric composition and pressure; a sample container filled with Mars-representative rocks is also included. The successful completion of this part of the qualification campaign is a very important result: it has been proved that the Drill is able to perform its mission in a representative environment.

Other qualification tests, including functional testing, sterilization compatibility verification, vibration, shocks, thermal testing, EMC have been completed successfully in 2017, prior to the nominal mission simulation. The end of the qualification testing is planned for mid-February 2018, with the mechanism lifetime completion.

The Drill concept presented here is a mature technology for collecting samples of Mars from depths which are of great scientific interest. The technology is ready to be used for future Mars Sample Return.

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DESIGN, DEVELOPMENT AND PRELIMINARY VALIDATION FOR A BIOCONTAINMENT SYSTEM FOR MSR

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In the framework of a potential international Mars Sample Return (MSR) mission, a Bio-Containment system was conceived, designed, breaboarded and deeply investigated by Leonardo S.p.A. (formerly Selex ES) and Eniprogetti (formerly Tecnomare) under European Space Agency development contracts funded by the Mars Robotic Exploraiton Preparation (MREP) Programme. This abstract presents the results achieved in the development phase, started in 2011, and reports the results of several tests performed on the breadboards. A road map for the full development of the system is also presented.

MSR foresees to collect and transport a set of soil samples from the Martian surface back to the Earth. Once collected, each sample will be stored into a dedicated canister (Orbiting Sample, OS), which will be launched into Mars orbit and captured by a Mars-Orbiting spacecraft. This spacecraft will be equipped with a robotic system capable of sealing the Orbiting Sample into a Bio-Containment system. The Biocontainment system is then returned to Earth, transported by a dedicated Earth Return Vehicle. The final stage of the return is the release of the Earth Return Capsule, carrying the biocontainment system, into the Earth's atmosphere for an entry, descent and hard landing on the surface. The objective of the Biocontainment system is to meet the backward Planetary Protection requirements which are to avoid any particle larger than 10nm to escape from the cointainer itself, thus preserving the Earth's Biosphere from contamination of particles coming from Mars. The biocontainer concept consists of a double vessel with three levels of sealing, sterilization capability and sealing failure detection. The overall system, including handling elements, is capable to position the OS into the Bio-Container, to "break the chain with Mars" through a specific sterilization process, to provide a tight sealing of the OS for its safe return. The Biocontainer will be closed with two levels of gasket based sealings with each sealing level including three gaskets of different types. One of the two containment compartments is pressurized in order to enable a monitoring system to detect possible major failures by pressure measurements. During the whole return phase the pressurized compartment of the Bio-container will be constantly monitored for leaks to allow for a final decision on Earth re-entry.

During the workshop, the architectural design of the Biocontainment system will be presented. Extensive presentation of the most recent activities focused on investigating and testing of possible technological solutions to implement the design baseline will also be provided. In particular, results on investigation of the sealing issue based on gaskets of different types will be discussed. In this respect, four different polymeric gaskets have been tested through a test campaign aiming at subjecting the polymers to an ageing process/performance degradation due to environmental conditions related to the mission scenario (i.e. radiation, vacuum, thermal ageing) and to finally test the two best candidates performing an 'operative' test with the gaskets individually installed in a breadboard of the container and of its lid. The test campaign led to the selection of two different polymeric gaskets, that proved to be promising both in terms of resistance to representative environmental conditions and in terms of sealing performance. Concerning the third seal, of metal type, a thorough experimental investigation has finally led to the selection of a configuration based on a metal seal with axial compression. This solution has proved to provide the required level of sealing compatibly with a reasonable compression force.

The technology for the sterilization to break the chain with Mars has also been investigated and tested. The sterilization is achieved by bringing the surface of the Biocontainer interface potentially contaminated by the OS to a temperature of 500°C for at least 1 s. Results of these activities will also be presented at the workshop.

The original Bio-Container System concept has been validated and consolidated through a significant experimental test campaign performed at breadboard level. The proposed next step is the development and test of a more complete and representative Engineering Model of the system, to turn a concept into a concrete possibility.

DEVELOPING A TRACE ELEMENT BIOSIGNATURE FOR EARLY EARTH AND MARS. A. Gangidine[1], A. D. Czaja[1] and J. Havig[2]. [1]Department of Geology, University of Cincinnati (agangidine@gmail.com, andrew.czaja@uc.edu) [2]Department of Earth Sciences, University of Minnesota (jeffhavig@gmail.com).

Introduction: Impending missions focusing on the search for life outside of our planet require the development of robust and conclusive biosignatures. Due to metamorphism and diagenesis, determining the biogenicity of ancient fossils on Earth is difficult and often contentious (1, 2). Some of the oldest evidence for life on Earth comes from hydrothermal silica deposits (3, 4), which may also exist on the surface of Mars (5, 6, 7, 8) in at least one of the candidate landing sites for the Mars 2020 mission. We report here our initial results and plan to further develop a novel biosignature for ancient terrestrial and extraterrestrial life based on trace elements sequestered by life and preserved in the rock record. Preliminary data from modern organisms preserved in terrestrial hydrothermal silica-depositing environments indicate that enrichments of certain trace elements are spatially associated with biological material relative to the surrounding mineral matrix. Samples were collected from Steep Cone in Yellowstone National Park, a 9-m-tall active, alkaline, hot spring that has layers of silica precipitate exposed along the side of the cone by a stream cut. The silica-rich water flowing from the hot spring preserves the native microbial life in sinter. Samples taken from various levels of the strata allow for the microbes to be observed in multiple stages of silicification/diagenesis. Samples were analyzed via biological secondary ion mass spectrometry (BIOSIMS) for primary and trace elements (Figure 1). Using BIOSIMS, we can determine the concentration and spatial location of trace elements in each sample on a micron scale across biological structures and into the surrounding silica matrix. Most of the measured trace elements (Fe, As, Al, Cr, and Mn) are found to be co-localized with preserved organics, while Ga is found to be co-localized with siliceous coatings that surrounded the microbes during life and were subsequently preserved. By developing this novel biosignature and combining it with multiple techniques for establishing biogenicity, we can find more robust evidence of life. Based on the observation that trace elements are sequestered in silica associated with microbes and not in the surrounding silica matrix, it is possible that these elemental distributions can be used as a biosignature that exists independently from organic and morphological preservation. This technique is performed using thin sections and each analysis requires the ablation of a volume of material on the order of 10^{-5} mm^3 and is thus minimally invasive and minimally destructive. Therefore, this technique may prove to be a valuable tool for the search for extraterrestrial life in precious samples, particularly from those collected by the upcoming Mars 2020 mission.

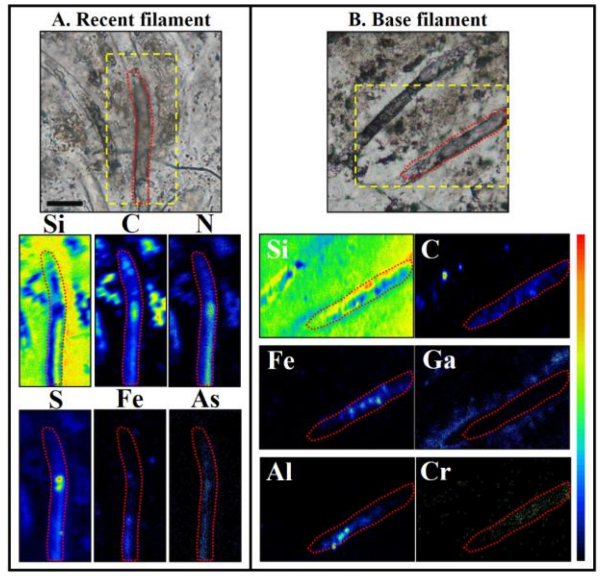

Figure 1: A sample of BIOSIMS analyses of silicified filaments from Steep Cone. A) Plain light photomicrograph of a sample taken from the top of Steep Cone. The dotted yellow boxes in A & B show the areas analyzed via SIMS in subsequent images to the right of A & B, and the dotted red outlines surround the area of the filaments bisecting the surface (and thus analyzed by the BIOSIMS) of each thin section. Subsequent images show SIMS data for each noted element. B) Plain light photomicrograph of a sample taken from the base of Steep cone. Subsequent images show SIMS data for each noted element. Color bar on right shows relative values from low (blue) to high (red). The scale bar in panel A = 20 µm and applies to all images.

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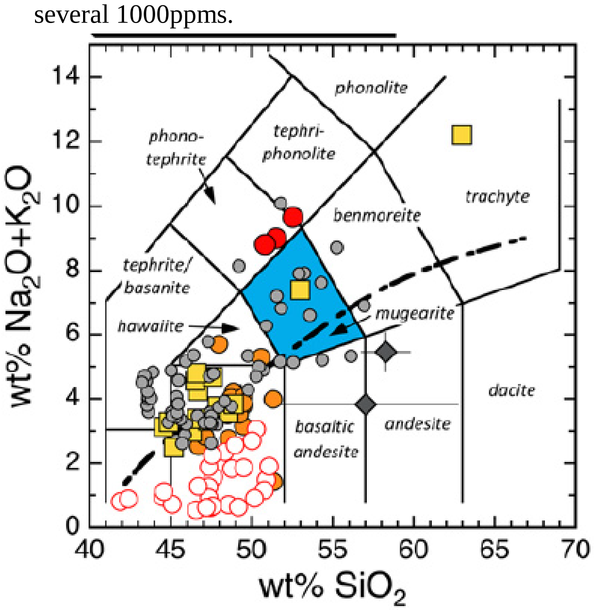
APXS DATA FROM MARS AND MSR SAMPLES: HOW CAN THEY BE COMBINED AND BENEFIT FROM EACH OTHER? R.Gellert, Univ. of Guelph (Guelph, ON, N1G2W1, Canada; rgellert@uoguelph.ca)

Introduction: Three generations of the Alpha-Particle-X-ray-Spectrometer (APXS)[1][2] have been part of the science suite on all Mars rovers. The chemical composition of more than 1000 samples along the combined traverse of >70km on Mars provided a remarkable diversity of igneous and altered sedimentary bedrock and soil.

Method: The APXS measures x-ray emission after irradiation with x-rays and alpha particles. The sample diameter is ~2cm for MSL and ~4cm for MER with penetration depths from ~2–100 micrometer. 16 standard elements are reported, including Ni, Zn and Br with detection limits down to ~50-20 ppm. Elevated levels of Cu, Ga, Ge, As, Se, Rb, Sr, Y, Pb were detected and quantified for some samples.

Results: Bulk chemistry is a powerful and versatile tool to determine the origin and relation of igneous rocks and to indicate various alteration processes. APXS data are often used in TAS plots like below from [3] to relate the four landing sites with Martian meteorites (open circles in graph). Usual Martian soil is very similar at all sites and often used as an average Mars composition. Very dissimilar to the original SNC group, it matches closely the bulk composition of the newer brecciated NWA 7034 meteorite [4].

APXS data are used to compare rocks along the traverse and to assess a common formation process or geologic relationships at larger scales. Alteration processes can be implied by the salt content (S, Cl, Br), the ubiquitous Fe/Mn ratio of ~50 of igneous rocks and especially by the content of trace elements. Adirondack type basalts at Gusev, Bounce Rock at Meridiani and JakeM at Gale all have Ni and Zn at or below ~100ppm, while sedimentary bedrock can have up to several 1000ppms.



Implications for Sample Return: APXS element trends that indicate large scale fluid interactions found at multiple landing sites might be visible in future samples returned from Mars. The Burns Formation is characterized by ~25% SO_3 content and the Murray Formation has lower Mg, Ca, elevated K and ubiquitous high Ge of 100ppm [5]. Even higher Ge values have been identified in isolated samples at the Rim of Endeavour Crater. Elevated Si, often correlated with Ti, Cr and K has been identified at Gale and Gusev Crater. $CaSO_4$ veins have been found at Gale Crater and Meridiani. Various other sulfates can be implied by elemental correlations.

MSR selection on Mars: Ideally, returned samples should be characterized well before selection. If alteration trends similar to other missions are encountered, these samples should have elevated priority for return.

Proposed Lab Work for MSR: Returned samples should be characterized in terrestrial labs with special consideration of the conditions and limitations of the science suite of instruments on the rovers. For the APXS this means averaged bulk composition of a dime sized spot with all APXS detectable elements quantified. Ideally this should be done with an APXS equivalent lab setup or XRF and PIXE methods mimicking the sample size. Additional knowledge of Martian minerals present would allow a refined analysis of previous mission data, benefitting the accuracy. As found in [6], the analysis of APXS data is limited in accuracy by the assumption of homogeneous samples. Feeding in known mineralogy would increase the achievable accuracy of APXS analyses over the required homogeneous sample assumptions so far.

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Acknowledgements: The MSL APXS is managed and financed by the Canadian Space Agency, with MDA as prime contractor to build the instrument. The MER APXS was developed and built in the Department of Cosmochemistry in Mainz, mainly funded by the Max Planck Society and, in part, by the German Space Agency (DLR). This work was made possible through the CSA contract for the MSL APXS 9F052-14-0592. The unwavering support of dedicated engineers at JPL during development and operations of the rovers is greatly appreciated and acknowledged.

Abstract Title: Mars Sample Return Orbiter Rapid Architecture Study

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Abstract: The Mars Sample Return Orbiter (MSRO) is a key element of the MSR Mission, responsible for the rendezvous, capture and return of an Orbital Sample (OS) from Mars to Earth. To assess the feasibility of the MSRO, ESA commissioned an architecture assessment study with a consortium of companies; including Deimos Spain, Lockheed Martin UK (LMUK) and MDA Canada. These companies have performed mission analysis, spacecraft systems engineering and payload systems engineering activities, respectively. This work acts to support an ESA decision to downselect baseline/backup mission architectures for further development.

Mission analysis first identified architecture options feasible from a timeline perspective, looking at aspects such as thruster options and computing delta-v budgets. LMUK then evaluated each mission architecture for feasibility using spacecraft systems engineering. Mass budget analysis (on thousands of possible permutations) was performed using a tool developed by LMUK to identify spacecraft architectures that would meet ESA launcher (Ariane 62/64) requirements. From this analysis key technological drivers of mass were identified; including the use of large solar arrays (>100m^2) for high power electrical propulsion systems (e.g. ARM engine). A similar analysis was performed to determine the volume configuration within the launcher shroud; options with large solar arrays will require particular attention in its stowed configuration to ensure fitting within the shroud. Each architecture option was assessed to understand their relative risk values and impact to the nominal schedule. The highest risk values typically pertained to options that are at the lowest TRL, and the findings should support ESA in exploring the early development of these technologies. As an example, flexible solar array technology, which was investigated during this study due to its high power output and low mass, does not exist in Europe. Hence this would require a full development/qualification programme. The key conclusions of these analysis activities, alongside the mission/payload analysis undertaken, were delivered in early February 2018.

LMUK have performed four key tasks within this MSRO study:

- Mass budget analysis
- Spacecraft configuration design
- Risk/opportunity analysis
- Identification and development strategy for critical technologies

The spacecraft systems engineering performed as well as the key spacecraft/technological conclusions output from this study, will be the focus of this presentation.

ULTRASONIC SORTER FOR HANDLING AND COLLECT DUST OR SOIL PARTICLES SEPARATED BY SIZE/DENSITY. I. González[1] and A. Pinto[1] [1]Institute of Physical Technologies, Group of Ultrasonic Resonators RESULT, National Research Council of Spain CSIC, Serrano 144, 28006 Madrid (Spain) iciar.gonzalez@csic.es

Introduction: The ability of ultrasound to manipulate differently sized particles has been extensively demonstrated in aerosols and liquid suspensions, eiher in macro-scale chambers exposed to high power standing waves or microfluidic devices at low power amplitudes [1-3].

Here, we propose a simple device consisting of an endless screw attached to a small sorter where particles collected from soil or dust are sorted by some of their physical properties that make them susceptible to the acoustic waves.

The particles circulate inside the chamber of acoustic treatment once introduced by an endless screw that collect the samples from the soil (regolith) or the dust environment, which remains continuously rotating during the process for the sample collection.

The chamber, with a rectangular geometry suitable for the acoustic actuation, has one inlet and various outlets for the particles extraction, which are collected separately by size or density in different reservoirs for their trip to the Earth.

Method and Procedure: The acoustic sorter works based on a three steps performance to consecutively extract three different particle populations enriched along the central axis of the chamber length by the action of the ultrasounds. It is a continuous process of particle separation and collection in the external reservoirs. The chamber has a cross section with dimensions of the order of half wavelength applied, allowing the establishment of a plane standing wave with a pressure node along its center. Particles exposed to the acoustic wave in this cavity during their flow motion (continuously induced from the rotating endless screw) experience different entrainment effects generated by a radiation force acoustically induced within the chamber associated to their different size or density. This force is due to a nonlinear interaction between the incident wave and that one scattered by each particle with a volume V_p and compressibility β_p much smaller than the acoustic wavelength λ of the wave applied. It can be expressed as [4]:

$$F^{rad} = -\frac{\pi P_0^2 V_p \beta_0}{2\lambda}\varphi(\rho,\beta)\sin(2kx) \qquad (1)$$

where $\varphi = \frac{5\rho_p - 2\rho_0}{2\rho_p + \rho_0} - \frac{\beta_p}{\beta_0}$ is the acoustic contrast factor, P_0 the incident wave pressure amplitude, ρ_0 and β_0 the density and compressibility coefficients of the fluid respectively, and "x" the distance from the particle to the nearest node of pressure in the standing wave. According to this equation, the particles collect in parallel bands perpendicular to the sound wave direction, separated by a half wavelength distance ($\lambda/2$). The sign of ϕ indicates the motion of the particles either toward the nodes ($\phi > 0$) or to the antinodes in the standing wave ($\phi < 0$). In this way, acoustic forces can then be used to separate particles (acoustopheresis) based on processes of particle enrichment/collection governed by the radiation force.

Resume: Our device encloses three consecutive particle enrichment processes isolating in a particles with certain three-step size ranges or densities, enabling a rapid sorting process. This technique does not present requirements of specific properties of the samples, such as magnetic particle susceptibility to be collected separately by the current techniques on Mars.

Our ultrasonic sorter is a low cost of manufacturing device whose size can be scaled as desired or required by the payload requirements, providing different ranges of size/density actuation that agree with the frequency of work.

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LESSONS FROM EXOMARS FOR MSR. A. Haldemann[1], C. Alary[1], P. Baglioni[1], A. Ball[1], O. Bayle[1], S. Bayon[1], B. Bethge[1], T. Blancquaert[1], M. Braghin[1], F. Chiusano[1], M. Cislaghi[1], D. Dellantonio[1], M. Denis[2], F. Didot[1], S. Durrant[1], G. Gianfiglio[1], G. Gould[1], D. Goulty[1], F. Haessig[1], L. Joudrier[1], M. Kasper[1], G. Kminek[1], V. Laneve[1], R. Lindner[1], L. Lorenzoni[1], M. Malyshev[1], D. McCoy[1], P. Mitschdoerfer[1], D. Monteiro[1], S. Ott[1], J. Pereira[1], P. Poulakis[1], B. Rasse[1], S. Sangiorgi[2], P. Schmitz[2], F. Spoto[1], H. Svedhem[1], D. Temperanza[1], J. Vago[1], T. Walloschek[1], A. Winton[1], Y. Yushtein[1], E. Zekri, [1]European Space Agency (Noordwijk, the Netherlands), [2]European Space Agency (Darmstadt, Germany).

Introduction: ESA's ExoMars 2016 and ExoMars 2020 missions are carried out jointly with the Russian Space Agency, Roscosmos. The first sent the Trace Gas Orbiter (TGO) with an Entry, Descent and Landing Demonstrator Module (EDM), named Schiaparelli. The second mission combines a Carrier Module (CM) and Descent Module (DM) to cruise to Mars, where the DM places a Surface Platform (SP) and Rover on the Martian surface. Both the SP and Rover have scientific instrument complements. The Rover's Pasteur Payload (PPL), coupled with a 2-meter subsurface Drill will explore the geological and (bio)geochemical environment of the landing site.

After ExoMars, ESA is considering participation in Mars Sample Return (MSR). The ExoMars 2020 Rover's PPL will inform scientific strategies for Mars Sample Return [1]. The lessons learned from the development of ExoMars 2016 and 2020, from the Assembly, Integration and Test (AIT) of those missions, and from Operations, support MSR contributions such as a Fetch Rover, an In-Orbit Rendezvous spacecraft, and/or an Earth return spacecraft.

General Status: EDM was assembled at the Thales Alenia Space (TAS) Italy in Torino during 2014 through early 2015. TGO was assembled at TAS-France facilities in Cannes in the same period. Both spacecraft had their environmental and functional testing carried out at TAS-F in Cannes, and were shipped to Baikonur Cosmodrome in late 2015. TGO and EDM arrived at Mars on 19 October, 2016. Schiaparelli's Entry, Descent and Landing (EDL) was not successful, while TGO established its orbit nominally and has been successfully aerobraking into its science orbit.

The ExoMars 2020 Rover Structural and Thermal Model (STM) will be tested in the first half of 2018. The Rover Proto-Flight Model (PFM) assembly runs from mid-2018 through Q1 2019, followed by environmental testing. The DM will have mechanical testing in mid-2018, and thermal tests in the second half of the year. The DM FM assembly will start in third quarter 2018 with environmental testing mid-2019, leading to a launch campaign in April 2020.

Lessons from ExoMars 2016 for MSR: 2016 AIT was carried out under strict Planetary Protection control. This included a dedicated ISO7 Highly-Controlled cleanroom at TAS-I, and an ISO7HC tent inside the ISO8 facility at TAS-F. The clean tent was in Baikonur with a bio-sampling laboratory to maintain planetary protection requirements during the launch campaign. This same approach will be used for ExoMars 2020: Europe's aerospace industry can fully and successfully implement planetary protection.

Schiaparelli. Although the ExoMars EDM did not land safely to complete its surface mission, it successfully transmitted telemetry via UHF relay to TGO during EDL, it's parachute deployed fully, and the Radar Doppler Altimeter operated. The comprehensive investigation [2] led to recommendations that have already been implemented for the 2020 mission.

TGO Aerobraking and Relay Operations. Although aerobraking of TGO was not a programmatic objective per se, it represents ESA's first operational use of the technique. The final implementation required refinements of the TGO on-board software to ensure safe operations during the automated dips into the Martian atmosphere, with proper preparations to allow for recovery should anomalies on the spacecraft occur. The know-how is now available for managing the orbits of large spacecraft at Mars.

Lessons from ExoMars 2020 for MSR: The final lessons from the AIT of 2020 are yet to be learned, however several ExoMars Rover subsystems offer feedforward to MSR. For example the external electronics on the Rover are required to passively survive Martian diurnal thermal cycles. So-called cold-electronics will have been qualified for the PanCam instrument and Rover's drive electronics. The Loop Heat Pipe technology developed for the Rover will be proven in the system testing of the Rover during 2018.

Conclusion: ExoMars developments will be reported at the conference, along with the tests planned in 2018 and 2019, prior to the ESA Council of Ministers in 2019, and which demonstrate technical readiness of ESA and European industry to participate fully in MSR.

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A DRAFT SCIENCE MANAGEMENT PLAN FOR RETURNED SAMPLES FROM MARS: RECOMMENDATIONS FROM THE INTERNATIONAL MARS ARCHITECTURE FOR THE RETURN OF SAMPLES (iMARS) PHASE II WORKING GROUP. T. Haltigin[1], C. Lange[1], R. Mugnuolo[2], and C. Smith[3]. [1]Canadian Space Agency, 6767 Route de l'Aeroport, Saint-Hubert, QC, CANADA, J3Y 8Y9 (timothy.haltigin@canada.ca, christian.lange@canada.), [2]Agenzia Spaziale Italiana (raffaele.mugnuolo@asi.int), [3]Natural History Museum, UK (caroline.smith@nhm.ac.uk),

Background: In 2006, the International Mars Exploration Working Group (IMEWG) chartered Phase I of the international Mars Architecture for the Return of Samples (iMARS) Working Group (WG). This group was tasked to outline the scientific and engineering requirements for an internationally-sponsored and -executed Mars Sample Return (MSR) campaign [1].

While significant efforts have since been dedicated to defining the technical elements of how samples could be returned successfully from Mars, somewhat less attention has been focused on how the samples will be managed after their return.

In 2014, IMEWG thus chartered Phase II of the iMARS WG, comprising two panels of experts – Engineering and Science/Earth Operations – with the aim of providing: (a) a status report on technical planning for an MSR campaign, and; (b) recommendations for progressing towards campaign implementation, including a proposed sample management plan. Here, we report on the deliberations, findings, and recommendations pertaining to the latter.

Science Management Plan - Considerations: Over the course of the Phase II work, two guiding principles for sample science management emerged: open competition for access to samples, and public transparency and engagement in returned sample handling and scientific results.

Moreover, the overlap of sample safety considerations with scientific inquiry was prevalent. In recommending avoidance of the "stuck in containment sample scenario", an emergent philosophy guiding the development of the sample management plan was to 'perform world-class science as safely as necessary.'

Report Structure and Topics: Building upon the iMARS Phase I outcomes [1], the Phase II team proposed the development of an international MSR Science Institute to oversee sample governance. Three central themes were defined and developed:

(i) Science Implementation. Ground-based MSR operations will require 'rules of the road' to define guidelines for sample access and distribution and publication rights and obligations. In doing so, it will be imperative that peer-reviewed processes and procedures are in place well in advance of the samples being returned, and that those procedures are periodically reviewed and adjusted as necessary.

(ii) Sample Management Structure. The proposed Institute operates at three levels: (a) a distributed Executive responsible for overall decision-making; (b) Science, Safety, and Curation teams collocated at the Sample Return Facility (SRF), and; (c) virtual science teams composed of internationally-recognized experts. External advisory boards would then ensure that local and interational interests and regulations are met.

(iii) Curation Plan: While safety considerations add a level of complexity to sample storage, distribution, and tracking of samples, experience with existing extraterrestrial sample collections and sensitive biological materials provide a solid foundation for an MSR curation plan. Leveraging that experience, it will be imperative that adherence to planetary protection protocols and prevention of cross-contamination drive the curatorial approach.

Key Recommendations: In total, the iMARS Phase II WG provided 21 recommendations under the broad headings of Technology, Programmatics, and Sample Management. Of these, three have emerged as being most critical to the advancement of MSR:

(i) International Coordination. To advance development of the MSR architecture, interested international partners must declare their interests, define a cooperation framework, and determine their contributions.

(ii) MSR Science Institute. MSR campaign partners should establish an international MSR Science Institute as part of the campaign's governance structure upon approval to return samples from Mars.

(iii) Planetary Protection Protocol. An internationally-tasked and -accepted planetary protection protocol for MSR should be produced as soon as possible, as this protocol will have technical and programmatic implications for the mission architecture.

Report Publication: At the time of writing this abstract, the iMARS WG is pursuing publication of its report with the journal Astrobiology. It is anticipated that an open access version will be available in Spring 2018, and will be made available in parallel on the MEPAG website. Comments from the broader MSR community will be welcomed.

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Planetary Sample Analysis Laboratory at DLR. J. Helbert[1] , A. Maturilli[1] and J.P. de Vera[1], [1]Institute for Planetary Research, DLR, Germany, (joern.helbert@dlr.de)

Introduction: Building on the available infrastructure and the long heritage DLR is planning to create a Planetary Sample Analysis laboratory (PSA), which can be later extended to a full Sample Curation facility. The step-wise extension follows the successful development approach used for the Planetary Spectroscopy Laboratory (PSL) and Astrobiology Laboratories and the recommendations of EuroCares.

Introduction: Global reconnaissance of Mars can only be obtained by remote sensing methods. It is playing a key role in determining surface mineralogy, texture, weathering processes, volatile abundances etc. and informs the site selection for in-situ measurements and ultimately sample return. The synergies between in-situ, sample return and global remote sensing are key to understand the evolution of Mars. This motivates the planned extension of PSL with a PSA laboratory by support of the Astrobiology Laboratories.

Current facilities: The Planetary Spectroscopy Laboratory (PSL) at DLR (http://s.dlr.de/2siu) feature several unique capabilities. Two identical spectrometers (one UV-vis and one IR optimized) allow bi-directional and hemispherical reflectance of samples from 70K to 290K as well as transmission measurements from UV to far-infrared. Emissivity can be measured from the near to the far infrared, with an external planetary simulation chamber attached to the spectrometer allowing to achieve sample temperatures from 270-900K. It is the ground reference laboratory for the MERTIS thermal infrared spectral imager on the ESA BepiColombo mission [4, 5]. Members of the PSL group are team members of the MarsExpress, VenusExpress, ExoMars, MESSENGER and JAXA Hayabusa 2 mission [6]. In addition PSL has been used extensively in support of the ESA Rosetta and NASA DAWN missions. The samples analyzed at PSL ranged from rocks, minerals, to meteorites and Apollo lunar soil samples.

In addition the institute is operating a Raman micro-spectrometer lab (http://s.dlr.de/e49q) as part of the Astrobiology Laboratories with a spot size on the sample in focus of <1.5 µm. The spectrometer is equipped with a cryostat serving as a planetary simulation chamber which permits simulation of environmental conditions on icy moons and planetary surfaces, namely pressure (10^{-6} hPa – 1000 hPa), atmospheric constituents, and temperature (4K – 500K). The samples, which are analyzed in the laboratory range from minerals, Martian analog materials, meteorites, biological samples (e.g. pigments, cell wall molecules, lichens, bacteria, archaea and other) to samples returned from the ISS (BIOMEX) [7, 8, 9] and the asteroid Itokawa (Hayabusa sample).

PSA: In a first step PSA will focus on spectroscopy on the microscopic scale and geochemical and geo-microbiological analysis methods to study elemental composition and isotopic ratios in addition to mineralogy to derive information on the formation and evolution of planetary surfaces, search for traces of organic materials or even traces of extinct or extant life and inclusions of water. The DLR PSA will be operated as a community facility (much like PSL in the EuroPlanetRI http://www.europlanet-2020-ri.eu/), supporting the larger German and European sample analysis community.

The current facilities are operating in climate-controlled rooms and follow well-established cleanliness standards. The PSA will be housed in an ISO 5 clean room, with one or two supporting clean rooms for sample handling, preparation and storage. The cleanrooms are equipped with glove boxes to handle and prepare samples. All samples will be stored under dry nitrogen. DLR in Berlin is already operating similar several clean rooms for (optical) instrument development.

Based on current planning the sample analysis laboratory would be operational and ready for certification by mid of 2021. Analysis of first Hayabusa 2 samples will start by beginning to mid of 2022.

Outlook: Following the approach of a distributed European sample analysis and curation facility as discussed in the preliminary recommendations of EuroCares (http://www.euro-cares.eu/) the PSA facility at DLR can be expanded to a curation facility. The timeline for this extension will be based on the planning of sample return missions. The details will depend on the nature of the returned samples. Through the BIOMEX project a collaboration has been established with the Robert-Koch Institute (RKI) (http://www.rki.de) for question of samples that might pose a bio-hazard. RKI is operating BSL 4 facilities, which might be used as part of a future DLR Mars sample curation facility.

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Constraining the Source Craters of the Martian Meteorites: Implications for Prioritiziation of Returned Samples from Mars.

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Introduction: As the only samples available for laboratory study, the analysis of the >100 known Martian meteorites have resulted in a number of major science advances [1]. However, with the exception of one, the Martian meteorites sample only igneous units [1]. This is because of the inherent bias in the sample delivery method towards young, igneous rocks [e.g., 2]: over 80% of all Martian meteorites are shergottites 575-175 Ma in age [3], some ~14% are nakhlites and chassignites ~1300 Ma [3], and only ~1% are augite-rich shergottites ~2400 Ma [4, 5]. As such, the meteorites are fairly representative of Amazonian igneous activity [1], and could be used to provide pinning points to the relative chronology of Mars based on crater size-frequency distributions [6]. However, a fundamental limitation of the meteorites is that they are randomly sampled from unknown igneous units.

Finding the Meteorite Source Craters: Ejection ages indicate that the martian meteorites were produced by ≤8 impact events between 0.7 and 20 Ma [3]. Attempts at identifying the source craters for these meteorites using spectral matching [e.g., 7] have met with limited success, primarily because the youngest igneous terrains (e.g., Tharsis) are largely obscured by dust [e.g., 8]. The study by [9] was among the first integrated approaches to this problem; however, these authors assumed ages of 4.1-4.3 Ga for the shergottites, a postulation which has since been proven incorrect [e.g., 10]. The identification of rayed craters – indicative of high ejection velocities and young ages – on predominately Amazonian igneous surfaces has provided the best potential candidates [11], although the visibility of rays is also dependent on dust cover.

We have utilized existing remotely-sensed datasets coupled with new modeling of the meteorite delivery process to “rule in” or “rule out” candidate source craters from among a database of the best-preserved craters on Amazonian igneous terrains. Details of the approach, modeling, and initial results can be found in [12]. The main advance we have made is the ability to model the permissible range of crater size for a given meteorite from the shock damage preserved within it.

Results: We selected four martian meteorites which cover the range of petrologic types, Amazonian ages, and conditions and timing of impact ejection: Zagami, Tissint, Chassigny, and NWA 8159 [12]. Cross-reference of the range of permissible crater diameters with our crater database, and selecting for Amazonian-age igneous units and the best-preserved craters, results in a relatively small number of possible craters for each meteorite. All potential source craters except one are < 30 km diameter, consistent with expectations that large, young craters are rare. Eight of the craters could be the source craters for all four meteorites; however, considerations of the differences in petrogeneses and ejection ages of the four meteorites shows that each of these meteorites is likely derived from its own crater [12]. Work is onging to further refine the potential source craters for each meteorite to a relatively small number [12] (ideally one).

Implications: Uncertainties in the relative chronology of Mars, especially for mid- to late-Amazonian terrains, are up to 2-3 times their actual radiometric ages [6]. Linking the Martian meteorites to their source igneous units will assist in reducing this uncertainty. The priority of MSR can then be on the sampling of Noachian and Hesperian rocks [1], in order to answer fundamental questions related to the geologic evolution of Mars over time [13, 14].

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Concepts and Planning for MSR public outreach. A. R. Heward[1,2], [1]Europlanet 2020 Research Infrastructure (The Open University, Walton Hall, Milton Keynes MK7 6AA, UK, anita.heward@europlanet-eu.org), [2]Science Office (Rua, Luso Celuloide nº 488, r/c direito, 4500-819, Espinho, Portugal)

Introduction: Mars Sample Return (MSR) sets a challenge for humanity that has the capacity to inspire and engage people around the globe. The broad mix of themes addressed within MSR, including exploration, cross-disciplinary cutting-edge science, technological innovation, robotics and AI, philosophical questions about the origins of life and humanity's future, as well as ethical questions about planetary protection, provides multiple facets to engage different audiences with different interests and priorities. At a time of growing concerns about globalization, nationalism and public confidence in "experts", MSR could offer a very positive example of collaboration on an international scale. Nonetheless, MSR requires large investments over long periods. This means that that there is a need for proactive and strategic engagement to build support for MSR in a wide range of stakeholder groups, including policy makers, the media, the general public, teachers and students (who will be the next generation of scientists and engineers). A collaborative effort within the MSR community will help create a coherent narrative and make the most of outreach opportunities deriving from scientific and technical achievements, mission events and milestones, resources, human stories and role models. Early 2018, with major ESA and NASA missions coming up in 2020, is an ideal time to discuss opportunities for international collaboration on engagement with a wide range of audiences. This presentation, alongside that by Sheri Klug Boonstra, aims to raise questions and start a dialogue on concepts and planning for MSR outreach.

Areas for consideration:

Potential partners: An effective international outreach strategy for MSR will need a broad network of partners at an international, national, regional and local scale. These could include space agencies, funding agencies, research institutions, industry, research infrastructures, societies and associations. They could also include museums, science centres, planetaria, educational networks, charities and citizen science projects. Identifying key partners will be an important first step in discussions.

Timeline: As well as major mission events and milestones, ongoing research and activities, e.g. analogue field trips, can provide richness and continuity in the timeline building towards MSR. How can events on large and small scales be highlighted and incorporated within the MSR story at a level that is achievable by the multiple players involved?

Tools: There is an ever-increasing range of tools available for outreach. The media, social media, webinars, MOOCs, citizen science projects, exhibitions, live events, teacher training and educational resources can all be effective tools when well-designed and targeted at the right audience. However, many organisations rely on limited resources or volunteer effort, so need to focus activities. How can we use different channels of communication most effectively and share best practice and resources?

Accessibility, diversity and inclusion: How can we make the wider community feel part of the MSR endeavour? The multiple languages and cultural differences across continents and countries can provide a significant challenge for outreach at an international level. How can be resources be most effectively adapted and translated to reach diverse audiences and minimise barriers? How can those that are under-represented or would not normally consider science as "for them" be engaged? Can we find diverse role models and methods of communication to ensure that we are not "preaching to the choir"?

Risks: What are the potential areas for backlash or negative stories? How can these be addressed and risks minimised?

Training: Does the community require training to support outreach efforts? If so, what kind of training is most needed and what is the best way of meeting this need?

Evaluation: How can we effectively evaluate the impact of outreach efforts? How can we include formative evaluation in developing programmes and resources to ensure that they meet the highest standards of quality and accessibility? What metrics are required to measure short-term outcomes and longer-term behavioural changes resulting from outreach initiatives?

Related stories: How should/could MSR outreach strategy intersect with other fields of exploration, such as development of a lunar village or space mining? Where are the areas of overlap and possible collaboration? Where is there divergence? What are the potential causes of confusion or conflicting messages, and how should these be addressed?

COMBINING NON–DESTRUCTIVE MAGNETIC AND RAMAN SPECTROSCOPICAL ANALYSES FOR MARS SAMPLE RETURN – POWERFUL TOOLS IN SITU AND IN LABORATORY. V.H. Hoffmann[1,2], M. Kaliwoda[3], R. Hochleitner[3], T. Mikouchi[4], K. Wimmer[5]. [1]Fac. Geosciences, Dep. Geo- and Environmental Sciences, Univ. Munich, [2]Dep. Geosciences, Univ. Tübingen, Germany; [3]Mineralogical State Collection, Munich, Germany, [4]Dep. Earth Planet. Science, Univ. Tokyo, Japan. [5]Ries Crater Museum, Nördlingen, Germany. Email contact: vh.hoffmann@web.de

Introduction

Very sophisticated, high end techniques are requested for the investigation of pristine particles from a planetary surface, such as Mars, in situ or in our laboratories, in case of Martian meteorites or even returned sample from (future) missions. Within our projects we have developed and successfully tested specifically magnetic and Raman spectroscopic techniques for that purpose.

Within our projects, a large series of Martian meteorites have been investigated by magnetic means in order to unravel and better understand the formation history of the planet Mars, for example the potential existence of an early dipole magnetic field. Further, specific magnetic techniques allow studying the magnetic record of extraterrestrial materials even under space conditions, at very low temperatures, in our laboratories – in situ conditions on planetary surfaces such as Mars. It is generally accepted that a strong magnetic dipole field represents one of the major preconditions for the development and continuous existence of a stable dense atmosphere, and later liquid water, generally life formation conditions as on our Earth.

Several years ago we have started to develop an extended database on magnetic and Raman Spectroscopic signature of natural terrestrial and meteoritic glasses. Background and focus were the findings of the Mars Phoenix mission, namely numerous in part highly magnetic spherules of still unclear origin and formation. A likely impact or volcanic background was hypothesized.

The most important result of was the clear requirement of extended databases based on specific sets of properties of natural glasses: magnetic signature of natural glasses was never investigated systematically, and we decided to significantly extend in parallel our existing database on Raman Spectroscopic characteristics.

Pparallel projects within a more general approach have been focused on LASER Micro Raman Spectroscopy which is perfectly suited for identifying and discriminating (extra-) terrestrial mineralogy, with a number of unique advantages: (a) fully non-destructive (repeated experiments possible on one and the same spot under variable conditions), (b) investigations with high sensitivity and in parallel high resolution, optionally in 3 dimensions, (c) as a major advantage experiments on pristine material without any preparation or coating, so in situ, and (d) mineral polytypes (eg diamonds) can be well discriminated. Variable LASER frequencies allow to optimize and fine-tune the Raman system to specific sample and experiment requirements. High resolution scanning can produce very detailed distribution maps of selected mineral phases. Micron- or even nano-sized particles such as various diamond polytypes can be detected in this way.

Within our Hayabusa sample analyses project we have successfully applied LASER Micro Raman Spectroscopy on several individual Itokawa particles.

Generally, the carbon-phase mineralogy has not really been investigated systematically in extraterrestrial materials. The main focus was on ureilites and certain carbonaceous chondrites, and priority was set on graphitic components and diamonds. The presence of very rare carbonaceous phases such as graphenes, fullerenes or nanotubes which can be expected in a number of extraterrestrial material types has not been investigated to our best knowledge. The same applies to prebiotic signatures or traces of extinct or extant life on Mars. Therefore we have started detailed and systematic investigations on the carbon-phase mineralogy of a larger set of various stony meteorite types and other extraterrestrial materials.

In our contribution we will demonstrate on selected examples the high end capabilities of both, fully non-destructive techniques, specifically focusing on the combination of both [1-5].

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THE NATURE, ORIGIN, AND IMPORTANCE OF CARBONATE-BEARING SAMPLES AT THE FINAL THREE CANDIDATE MARS 2020 LANDING SITES. B. Horgan[1], R. B. Anderson[2], and S. W. Ruff. [1]Purdue University, West Lafayette, IN (briony@purdue.edu), [2]U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ. [3]School of Earth and Space Exploration, Arizona State University.

Introduction: The Mars 2020 mission will collect samples for possible Mars Sample Return at one of three final candidate landing sites: (1) Jezero Crater, a crater lake containing two or more carbonate deposits; (2) NE Syrtis, an exposure of altered Noachian crust including carbonates; and (3) the Columbia Hills in Gusev crater, a hydrothermal system with nearby carbonate-bearing sediments. Here we discuss new results [1] for carbonate units at Jezero and compare the carbonate unis at the three sites as targets of potential Mars sample return.

Carbonates in Jezero crater: We find that the carbonate units within Jezero [2-6] are more spectrally variable than previously reported. All of the carbonate units exhibit Mg-carbonate, hydration, and mafic CRISM signatures, but the relative strengths of these parameters vary and correlate with morphology.

The *"Mottled Terrain" (MT)* is a regional unit [2-6] with a texture of small (10-100s m) ridges, often with a NE/SW orientation. At finer scales, the MT is generally fractured with a highly variable texture. The MT exhibits strong hydration bands, often along with weaker carbonate and olivine bands than other carbonate units.

The *Light-Toned Floor (LTF)* unit is present in the basin floor, and usually lacks the larger ridges and fractures characteristic of the MT. The LTF more typically has a "pock-marked" texture. The LTF exhibits Mg-carbonate and olivine signatures, where strong olivine signatures correlate with aeolian cover. The olivine-bearing sand appears to be sourced from the LTF itself [2,4].

The *"Marginal" carbonates (MC)* occur on the NW inner margin of the crater. These carbonates exhibit much stronger carbonate bands and often weaker olivine and hydration signatures than other units. The MC lack the erosional textures of the MT and LTF, appearing heavily fractured and blocky at HiRISE scale. Similar outcrops occur along the base of much of the western crater rim, restricted to between ~ -2300 and -2400 m.

Comparison to NE Syrtis and Gusev carbonates: The NE Syrtis landing site just south of Jezero includes a regional "Fractured Unit" [7] that appears to be stratigraphiclly and spectrally equivalent to the Mottled Terrain. At Gusev, Spirit detected Mg-Fe carbonates in the Comanche outcrops [8], which also contains olivine, an unknown amorphous silicate, and a hydrated phase [9-11]. Comanche is hypothesized to be an altered version of the nearby olivine-bearing Algonquin outcrop, and may be a subset of a texturally similar unit that extends throughout S Gusev crater [9]. From orbit, the area resembles the ridged texture of the Mottled Terrain.

Possible origins for olivine/carbonate units: The Columbia Hills units lack layering but drape topography, consistent with pyroclastics or impact ejecta; however, low Ni may argue against ejecta [13]. A pyroclastic origin could be consistent with the properties of the olivine units in Jezero/NE Syrtis, including moderate thermal inertia [8,12], a sand source, and draping topography [7], but they have also been proposed to be Isidis ejecta or lava flows [e.g., 9]. The Comanche carbonates have been proposed to be hydrothermal in origin [8], but their chemistry is more consistent with a low-T process, such as weathering, diagenesis, or evaporation [9]. Both high- and low-T origins have also been proposed for the NE Syrtis/Jezero carbonates [2-7,12-14]. The similarity of the regional carbonate units at the three sites suggests that they represent a major Noachian rock type, and sample return from these units could provide key insights into the geology of Noachian Mars.

The "marginal" carbonates in Jezero have somewhat different properties compared to the regional units. In addition, the restricted elevation of the MC (-2300 to -2400 m) is comparable to the upper stand (-2260 m) and minimum elevation (-2395 m) for a Jezero paleolake reported by [15], suggesting that the MC could be associated with precipitation at the paleolake margins [1].

Significance of carbonates for MSR: Noachian carbonates are a major target for MSR because they record past climate and aqueous processes, and isotopic analysis of carbonates could constrain the evolution and fate of the early Mars CO_2 atmosphere [16]. Carbonate precipitation is an excellent biosignature preservation mechanism, especially in subaqueous settings, where carbonate deposits are commonly biologically mediated [17]. If the "marginal" carbonates at Jezero are indeed shoreline deposits, they would thus be a very high priority target for MSR.

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Habitation Module Technology for Mars Sample Preservation and Return.
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Introduction: Lunar and Mars sample return is of tremendous interest to the space community such as NASA, ESA, and private industry. Collected samples of Mars need to be preserved and properly treated in returnable cache, packed to stop back-contamination prior to the return mission.

ASMS, Inc.'s Space Utility Module (SUM) allows sample collection by means of a tracked robot to travel around the surface of Mars from a variety of locations. The collected samples could initially be tested in-situ in the scientific SUM for the case of volatiles, and then packed for return to Earth for further research. In-situ resources could be fabricated into mission critical components within the SUM.

The SUM is a self-contained unit, for various applications such as manufacturing, habitation, and scientific research [1], [2], [3], [4], [5], The Space Utility Preserve Sample Module & Rover Figure 1. It is the ideal habitation laboratory unit in support of the Mars Sample Return (MSR) mission [6]. The SUM allows a tracked rover robot with drilling and pick-and-place to excavate the surface or rocky terrain to collect samples on Mars [7] Lunar-Mars Tracked Rover Robot prototype in Figure 2. A robotic arm could drill and pick up the samples of interest off the surface. The tracked rover robot would then return the sample to the SUM [8]. The double doors would permit the rover to exit over a ramp to perform its exploration and sample collection. In the SUM, the sample could be tested with the available scientific instruments, for chemical and physical analysis to meet the science community's requirements. The SUM will have the available capability to preserve the sample, avoiding any exposure to contaminants, and in the case of volatiles, would be prepared by a robot to transport for a low temperature journey to Earth [9]. The SUM has many unique features [10]. The double doors are equipped with the International Berthing Docking Mechanism (IBDM) allow for ease of access to the module and allow for reconfigurability and upgradability with the use of the slideable platform on rollers for efficient delivery and installation of scientific equipment for transport of samples for a later date.

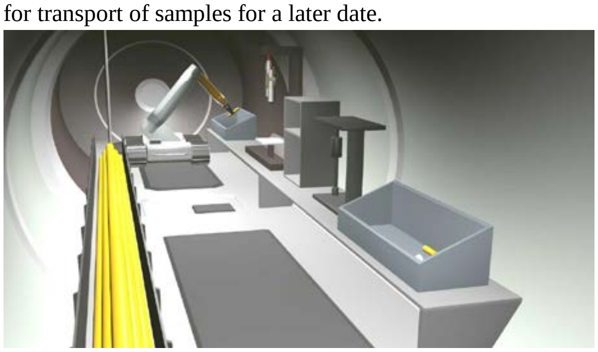

Figure 1- Space Utility Preserve Sample Module & Rover

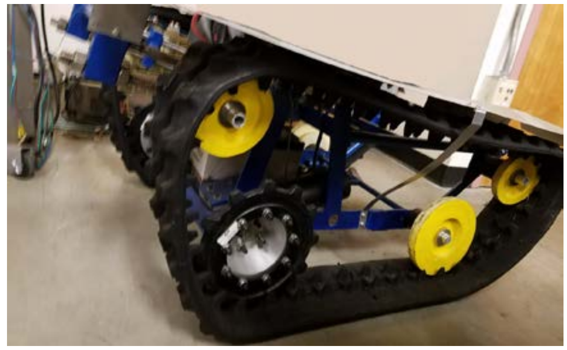

Figure 2- Lunar-Mars Tracked Rover Robot prototype

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EURO-CARES: Recommendations for the Design of a Mars Sample Return Facility. A. Hutzler[1], L. Ferrière[1], A. Bennett[2], S. S. Russell[3], C. L. Smith[3], and the EURO-CARES Consortium, [1]Natural History Museum, Burgring 7, A-1010 Vienna, Austria, [2]Public Health England, Salisbury, SP4 0JG, UK, [3]Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK (aurore.hutzler@gmail.com).

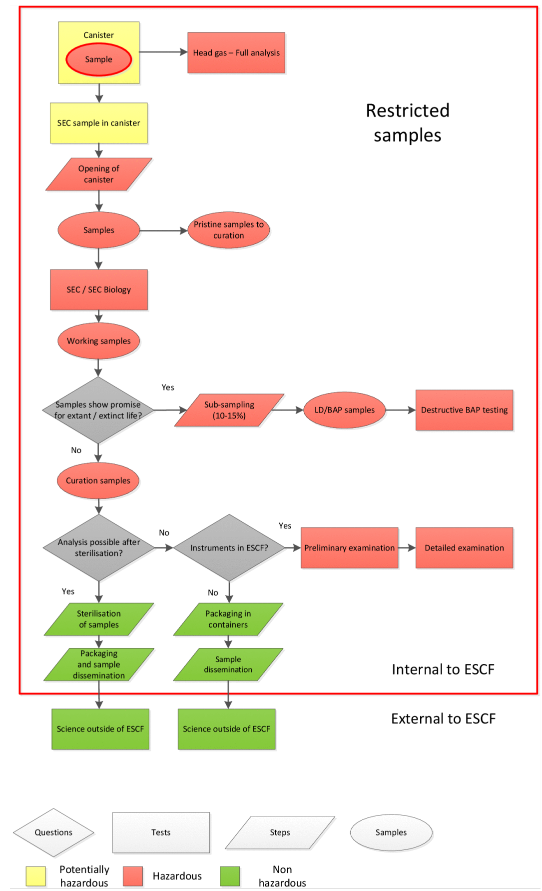
Introduction: EURO-CARES (European Curation of Astromaterials Returned from Exploration of Space) was a three year (2015-2017) multinational project funded under the European Commission's Horizon 2020 research programme. The objective of EURO-CARES was to create a roadmap for the implementation of a European Extra-terrestrial Sample Curation Facility (ESCF) suitable for the curation of samples from all possible return missions, likely over the next few decades, to the Moon, asteroids, Mars, and other bodies of the Solar System (i.e., for both unrestricted and restricted samples).

Here we summarize the main conclusions of the final report of the project regarding the design and infrastructure requirements for curation of samples from restricted bodies such as Mars.

Restricted Functional Units: We first identified the different activities that would take place in a Mars Sample Return (MSR) facility. We describe a Sample Receiving Facility (SRF), where the Earth Return Capsule would be received, assessed and opened. We describe then a Sample Curation Facility (SCF), where the sample(s) would be characterized, curated and stored. The SCF would also include the suite of instruments necessary to Biohazard Assessment Protocol and Life Detection. The figure below shows the sample flow we compiled. Workflows of activities and layouts have been developed during a collaboration with architects from Merrick & Co. (Canada) [1].

Cleanliness and Containment: A MSR facility needs to integrate both cleanliness and containment principles. We recommend to use primary enclosures similar to the ones in BSL-4 laboratories, or Double-Wall Isolators [2]. Laminar flow cleanrooms is recommended for limiting cross-contamination while allowing flexibility in the future.

Location and Cost Drivers: Because of the European nature of the project, our first location requirement was for the facility to be in Europe. Other parameters, such as limited natural hazards, countries with histories of bsl-4 laboratories and space exploration projects, would need to be also taken into consideration. Owing to so many uncertainties, it is impossible to evaluate a precise financial cost for such a facility, however we estimate that a fully fitted MSR facility could cost around 200 m€. Location, use of robots, cleanroom regime, instrumentation capacities, etc. are amongst the parameters that can drive the costs for the initial construction, and during the life of the facility.



Timeline: We estimate that a minimum of 7 to 10 years would be necessary to define the requirements, design, construct, and test a functional MSR facility. It is highly probable that such a facility will have various funding partners (space agencies, institutions, countries, etc.); a complex financial arrangement takes time to come to completion. In view of the timeline of sample return missions from Mars, it is imperative to move forward with this project as soon as possible.

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Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no 640190.

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Introduction: The analysis in Earth laboratories of samples that could be returned from Mars is of extremely high interest to the Mars exploration community, and on an international basis. IMEWG (the International Mars Exploration Working Group) is currently exploring options to involve the international community in the planning for returned sample science, including the potential analysis of the returned samples. Given that the Mars 2020 rover will collect and store samples for possible return by a future mission, the need for planning for such Earth-based study is critical and more "real" now than it has ever been. The Mars 2020 samples, if returned, would provide the basis for performing a variety of Earth-based experiments, including ones related to the search for the signs of life.

Why Now?: There are two main reasons why an updated analysis of the science potential of MSR is now appropriate:

1. The last major analysis of the specific scientific objectives of MSR, and how they translate to sample types and sample quantities was the MEPAG E2E-iSAG (End-to-End International Science Analysis Group) analysis carried out in 2010-11 (and published in early 2012). Since then, there have been advances on several different fronts that may change our perception of the scientific priorities for MSR:

- The number of Mars meteorites in our collections on Earth has now grown to over 100 (this number was 55 in 2011), and includes one brecciated sample that has a different age from all the other martian meteorites, and is thus presumably representative of a different region of Mars. What has changed from our investigations into this set of samples?
- The Curiosity rover landed on Mars (Aug. 2012) after E2E completed its work, and has since operated successfully for more than five years. It has analyzed a number of solid samples (both rocks and regolith) as well as the martian atmosphere. In addition, scientific output from the wealth of data returned by orbiter missions since 2011, such as NASA's Mars Reconnaissance Orbiter and Mars Odyssey, as well as ESA's Mars Express, has been fundamentally important in shaping and improving our understanding of the martian surface. Do any of these discoveries change the priority of Mars returned sample science?
- Research on terrestrial analogs, especially in the general field of astrobiology, has blossomed. We have a better understanding of the relationship of life to its environment, and of changes with time.
- There have been substantial improvements in our ability to handle and analyze very small samples. A highly visible example is the work that has been done on the Hayabusa samples (JAXA), and many instrumentation developments around the world. Does this meaningfully change what can be learned from returned martian samples of constrained size?

2. As part of the planning for the potential investigation of the samples after they arrive on Earth, we need a systematic analysis of which measurements would need to be made on the samples. This information can be used by successor teams to derive an instrument list and the logical sequencing of analyses. This is key input into planning for one or more sample receiving facilities (and its/their functionalities), for one or more curation facilities, and for certain key operational decisions.

Results: We have constructed a framework of six primary objectives related to the analysis of martian samples. For the life-related objective, four environmental divisions were made (hydrothermal, sedimentary, sub-aerial, and rock-hosted), because the strategies and kinds of samples are very different. For each objective, a logical set of sub-objectives and/or investigations has been derived. For each of those, we have mapped out the kinds of samples desired/required to achieve the stated objective/sub-objective, as well as the essential measurements to be made on the samples. Interim results are presented for discussion/feedback in the form of a set of objective-oriented abstracts, which will be followed after the conference by a full report.

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POTENTIAL HIGH PRIORITY SUBAERIAL ENVIRONMENTS FOR MARS SAMPLE RETURN.

iMOST Team (J. L. Bishop[1] B. Horgan, L. G. Benning, B. L. Carrier, E. M. Hausrath, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, C. D. K. Herd, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljestrom, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano). [1]SETI Institute (Mountain View, CA; jbishop@seti.org)

Subaerial environments of interest for potential Mars Sample Return include surface or near-surface sites not covered by a body of water, but having direct access to water from precipitation, snow melt, or ambient-temperature groundwater [1]. This includes soils, wetlands, ephemeral ponds, cold springs, and periglacial/glacial environments, with paleosol profiles as a high priority collection site. Such soils can be topped by aqueously deposited sediments and precipitates from wetlands, ephemeral ponds, and springs. The composition and morphology of paleosols preserve evidence of past climate, aqueous conditions, and life. Key topics addressed by samples collected from subaerial environments include:

1) Constrain the duration of interaction with liquid water by investigating a weathering profile from the surface to unaltered parent material.
2) Assess the characteristics of past liquid water, and how it has changed through time.
3) Investigate weathered materials such as soils, paleosols, sediments, weathering rinds or rock coatings to assess past climate.
4) Examine characteristics of past aeolian and atmospheric processes.

Types of Environments Considered: The three highest priority subaerial environments considered for sample return are: weathering environments, wetlands, or cold spring settings. Subaerial weathering includes alteration preserved in paleosols, periglacial or glacial environments, and rock coatings/rinds. The wetlands category encompasses rocks formed under a variety of redox conditions as well as sediments exhibiting chemically active near-surface zones. Cold springs are subaerial environments where ambient-temperature water emerges from the subsurface onto the surface.

Subaerial Weathering. This category includes suites of rocks or soils/paleosols representative of the range of depth and weathering, from most-altered to least-altered/unaltered parent material [e.g. 2], as well as rocks containing coatings or rinds [e.g. 3] formed through alteration, precipitation or biogeochemical reactions. Examples of terrestrial subaerial weathering are present at the paleosol sequence at John Day Fossil Beds National Monument [2] and at the Painted Desert at the Petrified Forest National Park [4,5]. Alternating horizons of clays, iron oxides (FeOx) and sulfates document changes in climate and redox conditions.

Periglacial/glacial. Near-surface changes in chemistry and mineralogy have been observed in the Antarctic Dry Valleys (ADV) that are attributed to an active zone at a few cm depth [e.g. 11,12]. Despite the cold and dry surface conditions, chemically active and inhabited soil/sediment horizons are present there just below the surface. These active zones are identified in ADV sediments through changes from anhydrite to gypsum, from amorphous aluminosilicates to montmorillonite, and through elevated NaCl levels [11,13].

Wetlands. Rocks containing evidence for sedimentation or mineral precipitation under reducing conditions are of high relevance. This category also includes salt ponds and brine-rich systems where high salt contents and microbes are influencing the types of minerals that precipitate, as well as sediments altered in desert environments where terrestrial microbes inhabit chemically active zones just below the surface.

Ephemeral ponds. The shallow, acid brine lakes in Western Australia are rich in microbial life, have variable pH, and have unique mineral assemblages (clays, FeOx, sulfates, and Cl salts) that could be representative of ancient habitable environments on Mars [6]. The possibility of acid waters was first proposed due to elevated S and Cl in the soil on Mars [7], followed by the suggestion of clay-sulfate-FeOx assemblages related to gossan-type environments in Western Australia [8], well before jarosite was detected on Mars [9,10].

Cold Springs. Mineral deposits precipitated from ambient springs have the potential to trap a variety of biosignatures, and would be important for sample return, especially those with evidence for long-term buildup. Examples include ferrihydrite precipitating from runoff on tufas in Iceland [14] and carbonates precipitating at Mammoth Spring at Yellowstone National Park [15].

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SEEKING SIGNS OF LIFE ON MARS: A STRATEGY FOR SELECTING AND ANALYZING RETURNED SAMPLES FROM HYDROTHERMAL DEPOSITS.

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Introduction: Highly promising locales for biosignature prospecting on Mars are ancient hydrothermal deposits, formed by the interaction of surface water with heat from volcanism or impacts [1-3]. On Earth, they occur throughout the geological record (to at least ~3.5 Ga), preserving robust mineralogical, textural and compositional evidence of thermophilic microbial activity [e.g., 3-5]. Hydrothermal systems were likely present early in Mars' history [6], including at two of the three finalist candidate landing sites for M2020, Columbia Hills [7-9] and NE Syrtis Major [10 & refs. therein]. Hydrothermal environments on Earth's surface are varied, constituting subaerial hot spring aprons, mounds and fumaroles; shallow to deep-sea hydrothermal vents (black and white smokers); and vent mounds and hot-spring discharges in lacustrine and fluvial settings. Biological information can be preserved by rapid, spring-sourced mineral precipitation [1,2,9], but also could be altered or destroyed by post-depositional events [5,11,12]. Thus, field observations need to be followed by detailed laboratory analysis to verify potential biosignatures.

Selection of Cached Samples: Exploration of a Martian hydrothermal deposit for signs of past life requires establishment of geologic context, identification of constraints on past habitability, and assessment of potential for biosignature capture and preservation [13]. Utilization of a spatially integrated framework of overlapping orbital, to outcrop, to micro- and geochemical scale observations, and application of predictive facies models from Earth-analog hydrothermal systems, will optimize selection of cached samples that are most likely to yield biosignature information in subsequent Earth-based laboratory investigations.

Key Samples and Investigations: The iMOST hydrothermal deposits sub-team (within the Seeking the Signs of Life Objective for a potential Mars sample return) has identified key samples and investigations required to delineate the character and preservational state of potential biosignatures, thus paving the way to ultimately confirm their essential nature as either abiological or biological in origin. Returned samples would ideally include representative examples of primary hydrothermal facies formed by cooling and degassing of discharge fluids away from vent-point sources, in which variably adapted microbial components would be expected. Such samples, selected from rover mapping of lateral/vertical facies distributions and spectral identification of hydrothermal sediments, would be subjected to Earth-based textural, mineralogical, elemental and isotopic analyses to potentially reveal thermal gradients, flow rates, duration of thermal outflow, and evolution of the hydrothermal system over time, including reconstruction of a fluid history that may have affected the types, as well as quality of preservation of biosignatures. Returned samples would also enable lab tests for consistency with biotic processes, via microscale mapping and study of bioessential elements/minerals; measurement of mineral and isotopic proxies involved in redox coupling relevant to biogeochemical cycling; and high-resolution interrogation of oxidized and reduced carbon by methods only available in Earth-based laboratories.

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SEEKING THE SIGNS OF LIFE: ASSESSING THE PRESENCE OF BIOSIGNATURES IN THE RETURNED SAMPLE SUITE. iMOST Team (D. J. Des Marais[1], M. M. Grady, R. Shaheen, A. Steele, F. Westall, and F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, D. L. Shuster, S. Siljeström, C. L. Smith, J. A. Spry, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, R. M. Wheeler, J. Zipfel, M. P. Zorzano, [1]Exobiology Branch, NASA Ames Research Center, MS 239-4, Moffett Field, CA 94035, U. S. A., David.J.DesMarais@nasa.gov.

Introduction: A biosignature (a "definitive biosignature" or DBS) is an object, substance and/or pattern whose origin specifically requires a biological agent [1]. One category of DBS are complex organic molecules and/or structures whose formation and abundances relative to other compounds are virtually unachievable in the absence of life. A potential biosignature (PBS) is an object, substance and/or pattern that might have a biological origin and thus compels investigators to gather more data before reaching a conclusion as to the presence or absence of life. The usefulness of a PBS is determined not only by the probability that life created it but also by the improbability that nonbiological processes produced it. Because habitable planetary environments create nonbiological features that can mimic biosignatures, these environments must be characterized to the extent necessary to provide a context that is essential for confirming the presence of DBS. Environmental conditions [2] also must have allowed biosignatures to be preserved and amenable to detection. Categories of biosignatures and their measurement requirements are indicated below.

Carbon compounds: Carbon compounds constitute the chemical framework of living systems due in part to their enormous molecular diversity and chemical versatility. But life utilizes only a relatively small number of compounds that meet its requirements for functionality and efficiency. These compounds can be distinguished by measuring their particular molecular structures, relative abundances and molecular weight distributions [2,3]. Potentially diagnostic compounds include certain normal and branched alkanes, fatty acids, porphyrins, hopanes, steranes, amino acids, and other heteroatomic (N-, O-, P-, and S-bearing) compounds. Measurements should be able to detect subpicomole quantities and distinguish between terrestrial contaminants and any components indigenous to Mars.

Patterns of stable isotopic abundances: Biochemical processes can affect the stable isotopic compositions of reactants and products in ways that differ from those caused by nonbiological processes. Such differences form a basis for distinguishing between biosignatures and products of other processes. Stable isotopic compositions (e.g., of C, H, N, O and S) should be measured in individual compounds or minerals in the context of known isotopic reservoirs to seek patterns inconsistent with abiotic processes [4,5].

Minerals: Biological activity has greatly expanded the known repertoire of minerals on Earth, in part by creating chemical conditions for their stability that would not exist otherwise [6]. Measurements should detect and map the spatial arrangement of minerals that, on Earth, are compositionally and morphologically associated with biological activity or catalytic activity (e.g., Fe-oxides, C- and S-bearing minerals) relative to rock textures and the presence of organic carbon.

Morphologies (objects and fabrics): Microbial cells have characteristic size and shape distributions [7]. Microbial biofilms can alter sedimentary fabrics and physical properties [7]. Measurements should seek microscale or macroscale rock or mineral fabrics and structures that are consistent with formation or fossilization of biological entities and inconsistent with chemical or abiotic processes. Mineral surfaces and interiors should be imaged to search for physical evidence of metabolic activity (e.g., pits and trails), especially where associated with redox gradients.

Preservation and degradation: Deposits should be sought that are particularly conducive to biosignature preservation, e.g., phosphates, carbonates, sulfates, and phyllosilicates [2]. Samples least altered by oxidation, heating and radiation are preferred.

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HIGH PRIORITY SAMPLES TO CHARACTERIZE THE HABITABILITY OF GROUNDWATERS AND SEARCH FOR ROCK-HOSTED LIFE ON MARS. iMOST Team (B.L. Ehlmann[1], L. E. Mayhew, J. F. Mustard, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljeström, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano) [1]California Institute of Technology (ehlmann@caltech.edu).

Introduction: Objective 1.1 of the iMOST sample return objectives is to establish the geologic context, interpret the potential habitability, and evaluate the potential for biosignature preservation in samples from an environment hypothesized to have had elevated potential for Martian life [1]. Here, we describe the strategies required to understand the geologic context and habitability of Martian groundwater aquifers and to search for evidence of life in the Martian subsurface using samples.

Why samples recording groundwaters are important: Radiation, cold temperatures, low water activity, and atmospheric pressure were challenging to life over most of Mars history, including time-equivalent periods on Earth [2,3]. Mineralogic evidence from the Opportunity and Curiosity landed missions [4,5], from orbit [6], and thermophysical modeling suggest ancient groundwaters on Mars that may even persist to the present [7]. Because the terrestrial subsurface is inhabited [8-9], similar mafic and ultramafic igneous and sedimentary aquifers on Mars should be interrogated to understand their geologic characteristics, habitability, and search for rock-hosted life.

Key investigations: To interrogate samples from groundwater-altered rocks, the rover will first search for features indicative of groundwater flow. A non-exhaustive list includes: mineralized fractures or ridges, diagenetic concretions, zones with color change indicating leaching and/or cements. Key phases include Fe and Mn oxides, phyllosilicates, silica, sulfates, carbonates, and other salts. Samples should be selected to:

Determine the physical-chemical conditions of water-rock interaction and assess habitability. Key water properties can be derived by identification of mineral assemblages and include temperature, pH, Eh, aH_2O, and ion activities as indicated by mineral phases.

Determine the source of fluids. Mineral phases and H, C, S, O and metal isotopes can be used to understand the relative contributions from different fluid sources (atmospheric, groundwater, magmatic).

Determine the time-evolution of the groundwater system and chemical reactions. Petrological relationships (overgrowths, cross-cutting relationships) can used to time-order the formation and dissolution of phases, thereby understanding changes in groundwater properties due to changing sources or fluid evolution.

Characterize organics to evaluate sources. Organics, if present, may be observed in situ with SHERLOC fluorescence. Detailed characterization of location and structure at nanometer-scale will inform endogenous abiotic, biotic, vs. meteoritic origin.

Evaluate evidence for biosignatures: Initial signatures are likely chemical/mineralogic as the products of life tend to be more volumetrically significant than life itself. Nanometer-scale investigations will investigate isotopic signatures of phases and mineral-organic associations.

Samples: Samples from groundwater aquifers with evidence for redox interfaces (because redox disequilibria drives metabolism), lithologic interfaces (because permeability focuses fluid flow), and sites of mineralization (which indicate active chemistry and the potential for entrapment of cells/organisms) are specifically sought. A non-exhaustive, unprioritized list of high-priority samples includes rocks with (1) organics associated with mineralized fractures or voids, (2) Fe oxide or Fe sulfide precipitates (e.g., framboids), (3) Fe or Mn redox fronts, (4) fractures, vugs, vesicles, or pore space filled with precipitated minerals (carbonates, silica, sulfates, clays, oxides), (5) zones enriched in minerals formed by leaching or in situ transformation, (6) textures suggestive of microtubules possibly present at smaller spatial scales.

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THE IMPORTANCE OF RETURNED MARTIAN SAMPLES FOR CONSTRAINING POTENTIAL HARZARDS TO FUTURE HUMAN EXPLORATON. iMOST Team (A. D. Harrington[1], B. L. Carrier, D. C. Fernandez-Remolar, J. Fogarty, J. T. McCoy, M. A. Rucker, J. A. Spry, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljeström, C. L. Smith, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano, [1]Astromaterials Research and Exploration Science (ARES) Division, NASA Johnson Space Center, Houston, TX 77058, USA (Andrea.D.Harrington@NASA.gov).

Introduction: Mars has been a prime target for future human exploration for decades. However, even after the many successes of orbital, lander, and rover missions, there are still an array of unknowns in the martian environment that pose potential physical, chemical, and biological hazards to human health. Mars sample return represents a vital potential next step in understanding these hazards and mitigating the risks to both the explorers and the inhabitants of Earth.

NASA's Mars 2020 rover will collect, seal, and store samples on Mars. The regolith and drill core samples to be cached by the rover could be returned to Earth by a future mission for thorough analysis. One of the key objectives of Mars 2020 includes contributing to the preparation for human exploration of Mars, which includes constraining the nature of potential hazards [1].

The two main human health risk categories that drive the strong desire for returned samples are engineering and biological/toxicological [2]. The engineering risks pertain to the terrain morphology of the landing operation zones (e.g. safe landing and human/rover locomotion) as well as possible mechanical failures due to environmental stressors. The biological and toxicological risks are broader in that they concern the health of both the explorers and life on Earth (e.g. backward contamination). Given the complexity of the hazards, the following sub-objectives were created. The foundation of each sub-objective is a thorough examination of the returned sample's physical features (e.g. grain size, shape) and bulk composition including: inorganic (e.g. bulk chemistry, mineralogy), organic, and biological. This is a provisional report from the iMOST Human Health Hazard Objective sub-team identifying key samples and techniques needed to understand the human hazards of martian surface exploration and possible ways to mitigate these risks.

Human Health Hazards Sub-objectives:

1. *Determine if biological hazards exist in the martian environments to be contacted by humans* that might have adverse effects on the crew if they were exposed while on Mars, and/or on other terrestrial species if uncontained martian material returned to Earth.

2. *Assess risks to crew health and performance* and inform the setting of appropriate permissible exposure limits by characterizing the potential acute and chronic toxicity resulting from exposure to martin dust.

3. *Characterize martian regolith and airfall samples in order to prepare high-fidelity martian regolith and dust simulants*. This includes, but is not limited to: understanding the major and minor differences in geochemistry that correlate with grain/particle size, shape, and aerodynamic diameter, as well as local versus global dust. The characterization of an array of samples would allow for the manufacturing of large quantities of simulants for use in engineering testbeds and large scale toxicological evaluations.

4. *Determine the efficacy of utilizing martian regolith as a radiation shield for humans on the surface from a solar particle event*. This would determine the types and quantity of radiation that can be shielded and the degree to which other biologically relevant particles are formed after passing through the substrate.

Recommended Samples: Although understanding the properties of drill core samples would inform engineering models and biological/toxicological hazard assessments, regolith and airfall samples would be the most valuable for initial determination of human health hazards. The two types of regolith samples required are: 1) bulk samples representative of "typical" surface material for the engineering models and 2) respirable (<10μm minimum; <2.5μm ideal) regolith and airfall samples for biological/toxicological evaluation. Furthermore, while not within the scope of the Mars 2020 mission, airfall samples would also be vital to assess the most likely human and mechanical exposure hazard.

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THE IMPORTANCE OF MARS SAMPLES IN CONSTRAINING THE GEOLOGICAL AND GEOPHYSICAL PROCESSES ON MARS AND THE NATURE OF ITS CRUST, MANTLE, AND CORE.

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Introduction: *In situ* compositional and mineralogical measurements on the Martian surface, combined with analyses of Martian meteorites, indicate that most igneous rocks are lavas and volcaniclastic rocks of basaltic composition and cumulates of ultramafic composition [1]. Alkaline rocks are common in Early Hesperian terranes and tholeiitic rocks dominate younger Amazonian martian meteorites [1]. Very uncommon feldspathic rocks represent the ultimate fractionation products, while granitoid rocks have not been identified [1]. The impact-driven delivery mechanism for the Martian meteorites [2] biases in favor of more competent samples – young, igneous rocks [e.g., 3] – and against rocks that are more representative of the Martian crust [e.g., 4]. Comparisons of rock types found among the meteorites to those documented by landed missions demonstrates this bias unequivocally [1]; furthermore, of the over 100 martian lithologies represented by the martian meteorites, only one (NWA 7034 and pairs) is a regolith breccia [e.g., 1, 5].

While the meteorites provide important insights into the nature of the silicate portion of Mars, including the origin of mantle components with differing geochemical characteristics [e.g., 6], they do not provide information on the composition of the original crust Mars, nor the nature of the mantle sources from which rocks at the Martian surface have been derived (e.g., igneous rocks at Gusev and Gale craters). Thus, there is much to be learned from the study of carefully selected samples from the martian surface.

Sub-Objectives (in no priority order) for any potential MSR landing site:

a) Determine the diversity of igneous rocks and the mechanisms for that diversity; the relationship of those rocks to other igneous rocks of Mars; and the makeup of breccias.
b) Determine the long-term production of igneous liquids on Mars, and use this to quantitatively constrain the composition and evolution of the martian mantle
c) Constrain the long-term geodynamical evolution of Mars, from core segregation to crustal differentiation, and the existence of chemically distinct mantle reservoirs
d) Determine the nature of the early martian crust, and the processes that caused its early alteration to form widespread hydrous minerals
e) Improve our understanding of cratering as a process for modifying the martian surface, including the development of shock-related rocks and mineral assemblages, impact-induced melts, impact-related hydrothermal alteration, and impact-deposited sediments
f) Constrain the processes that lead to weathering, erosion, transport, deposition, and lithification of sedimentary rocks on Mars
g) Constrain the composition, physical properties, and origin of globally transported martian dust
h) Constrain the strength and orientation of the ancient martian magnetic field

Samples: Addressing this objective requires samples that record igneous compositional diversity (in major, minor and trace elements and isotopes) reflecting differences in mantle source characteristics and/or igneous fractionation processes; samples that capture the nature of the processes that formed and affected the primitive crust of Mars; samples that provide insights into the nature of cratering on Mars; and samples that constrain the processes of weathering, transport and deposition of older rocks to form younger sediments (including global dust) and sedimentary rocks. This objective also requires oriented samples which record the evolution of the Martian dynamo.

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WHAT COULD BE LEARNED ABOUT THE GEOCHRONOLOGY OF MARS FROM SAMPLES COLLECTED BY M-2020.

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Introduction: Based on meteoritic evidence, Mars accreted as early as 2 Ma after the formation of the first solids in the solar system [1] from material with an O-Ti-Cr-Ni isotopic provenance distinct from the Earth-Moon system [2]. It likely formed a magma ocean within ~100 Ma after solar system formation [3], from which the martian core last equilibrated with its mantle at pressures of ~14 GPa [4]. The formation of most of the mass of the Martian crust is constrained to have occurred by 4.35 Ga [5,6]. Remanent magnetization in martian meteorite ALH 84001 demonstrates a dynamo had initiated on Mars at or before 4.1 Ga [7]. Sample return is necessary because meteorites lack geologic context and their orientation with respect to the paleomagnetic field is not known [8].

The M-2020 mission is designed to collect and cache drill cores obtained by an instrumented rover. These cores could subsequently be returned to Earth for analysis in terrestrial laboratories, from sites either near the Isidis basin or Gusev crater. The key objectives, summarized elsewhere [9], include potential for major astrobiological insight and recovery of histories of climate and dynamo activity. Geochronological investigations will provide temporal context for each of these objectives. This is an interim report from the M-2020 Objectives team regarding progress towards identifying key materials and techniques needed to optimize the recovery of temporal constraints on Martian history.

Geochronology Subobjectives:

1. Calibrate the Martian cratering chronology by radioisotope dating a surface with well defined cratering statistics, and calibration of the bombardment history by radioisotope dating of impact melts and breccias. Martian crater chronology models are calibrated against the lunar cratering record [10]. However, the earliest (4.2-3.9 Ga) lunar bombardment history still is debated [11], application of which to Mars potentially introduces uncertainties of hundreds of millions of years [12], addressable with sample return.

2. Determine the thermal/magnetic history of Mars to interpret mantle convection and dynamo history (including the timing of magnetic field cessation), with implications for atmospheric escape. Oriented samples of *in situ* igneous or sedimentary rocks would be required, ideally from stratigraphic sections.

3. Determine the evolution of the Martian hydrosphere, including the transition to habitability, using combined $\delta^{18}O$ and U-Pb dating of zircon or other U-rich accessory phases, and the timing of water/rock interaction processes (e.g., hydrothermal alteration).

4. Determine the timing attributes of a martian sedimentary system, including the various aspects of source-to-sink analysis with detrital zircon chronology.

5. Improve our understanding of the timing (e.g., Hf-W, Sm-Nd) *and processes* (nucleosynthetic anomalies and stable isotope fractionation of lithophile and siderophile elements) involved in the accretion and early differentiation of Mars, particularly from Noachian sediments.

6. Determine the history of surface exposure, including the timing and rates of crustal uplift/erosion and burial on Mars by U-Th-He and cosmogenic nuclide (^{3}He, ^{21}Ne, ^{10}Be, ^{26}Al) dating of surface rocks.

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THE RELEVANCE OF MARS SAMPLES TO PLANNING FOR POTENTIAL FUTURE IN-SITU RESOURCE UTILIZATION. iMOST Team (J. Kleinhenz[1], D. W. Beaty, D. Boucher, M. Dixon, P. B. Niles, R. M. Wheeler, M. P. Zorzano, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, L. G. Benning, J. L. Bishop, L. E. Borg, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, D. J. Des Marais, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljeström, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, J. Zipfel.) [1]NASA Glenn Research Center, 21000 Brookpark Rd. MS: 86-8 Cleveland, Ohio, USA 44135.

Introduction: Considerable recent planning has focused on the potential importance of Mars *in-situ* resources to support future human missions. While atmospheric CO_2 provides a source of oxygen [1], the regolith offers other potential resources [2]. The most significant surface asset is water, which could be used for propellant generation [3], life support, habitat sustainment, and agriculture [4]. In regard to the latter, the regolith could also provide a source of nutrients to supplement terrestrial fertilizers and/or act as a substrate to buffer plant roots. Local material could also be used as feedstock for construction, including for structures, roads, and additive manufacturing [5]. Native salts (e.g. perchlorates or chlorides) in the Martian regolith could be used as water absorbents for closed loop life support systems or for capture of the limited atmospheric water.

Any of these *in-situ* processes would require definition of the resources to influence equipment design and resource budgeting. Exploration via orbital and landed surveys as well as technical demonstrations would be necessary. Mars sample return could play a key role in supporting this planning, especially when considering possible long-term human presence.

The goal of the International MSR Objectives & Samples Team (iMOST) is to define the objectives that could be met using returned martian samples, and identify the types of samples needed to meet those objectives. In-Situ Resource Utilization (ISRU) is one of the six iMOST objectives, and this document summarizes the needs specified therein.

ISRU Objectives: The primary surface resource of interest for Mars ISRU is water. (Although the presence of subsurface ice deposits [6] is of great interest to ISRU, the candidate landing sites for Mars 2020 were chosen in part to avoid near-surface ice, due to planetary protection concerns.) The amount and form of water in Mars surface material will heavily impact potential production processes. Therefore the first two ISRU-related objectives of studying Mars samples on Earth would be to; 1) Determine the concentration of water, its mineralogical basis, and its variation, and to identify contaminants that may negatively impact either production or end-use processes. Some of these contaminants (e.g. perchlorates) may also be usable resources; 2) Characterize the physical and thermophysical properties of martian surface materials to influence the design of possible ISRU surface systems and to develop high-fidelity regolith simulants for engineering test beds 3) The third ISRU-related objective focuses on assessing the presence and quantity of any elements/minerals (especially water-soluble attributes) that are essential for plant growth, as well as elements/minerals that can be toxic to plants and/or a microbiome.

The final ISRU-related objective is to identify and characterize high-value metallic resources. The potential presence of ore deposits would be of value both for ISRU and economic considerations. However, this type of collection would be considered a "sample of opportunity": not specifically sought out, but if encountered, should be considered worthy of a sample return.

Recommended Samples: We have identified five samples that would be useful for meeting ISRU objectives. Three samples could be used to fulfill ISRU objectives 1 and 2. These are 1) a "typical" surface sample, representative of abundant loose material, 2) a subsurface regolith sample from the same location that is isolated from diurnal heat cycling, and 3) a core sample of sedimentary rock that displays the strongest signature of hydration in the landing zone. Two additional samples to fulfill the agriculture objective are: 4) a sample of sand-sized basaltic dune material, and 5) a sample of bright fine-grained dune material. Two optional samples would be an ore-rich sample of opportunity, and an airborne dust sample for filtration concerns.

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SEEKING SIGNS OF LIFE ON MARS: THE IMPORTANCE OF SEDIMENTARY SUITES AS PART OF MARS SAMPLE RETURN. iMOST Team (N. Mangold[1], S. M. McLennan, A. D. Czaja, G. G. Ori, N. J. Tosca, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, L., F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljeström, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano, [1]LPG-Nantes, CNRS, Université Nantes, Nantes, France (nicolas.mangold@univ-nantes.fr).

Introduction: Seeking the signs of life on Mars is often considered the "first among equal" objectives for potential Mars sample return [e.g., ref. 1]. Among the geological settings considered to have the greatest potential for recording evidence of ancient life or its prebiotic chemistry on Mars are lacustrine (and marine, if ever present) sedimentary depositional environments. This potential, and the possibility of returning samples that could meaningfully address this objective, have been greatly enhanced by investigations of an ancient redox stratified lake system in Gale crater by the Curiosity rover [2].

Lacustrine (and marine) environments are typically the ultimate repository of "source-to-sink" sedimentary systems [3]. In order to extract the maximum amount of information from such systems, and place that information into the context of the geological and climatological history of Mars, it is necessary to evaluate all pre-, syn- and post-depositional processes that may influence the compositions of sedimentary rocks.

Detailed Investigations: The iMOST team has established a list of detailed investigations designed to achieve the overall goal of characterizing the aqueous portion of a Martian sedimentary system:

1. *Investigate physical and chemical sedimentary processes in ponded water to better understand sustained, widespread liquid surface water on Mars, including the examination of evaporites;*
2. *Investigate sediment diagenesis, including processes of cementation, dissolution, authigenesis, recrystallization, redox, and fluid-mineral interaction;*
3. *Investigate mechanisms by which sediment is/was generated on Mars, by understanding the weathering and erosional processes;*
4. *Investigate provenance of sediment in the sedimentary system, including variation in lithology, tectonic association, and paleoclimate;*
5. *Investigate the nature of subaqueous (or subglacial) transport regimes that cut channels and valleys, including whether they were persistent or episodic, the size of discharge, and the climatic conditions and timescales of formation;*
6. *Characterize physical properties of aeolian materials to understand aspects of the surface processes and climate history.*

Critical Measurements: Many parts of these investigations can/will be accomplished by synergistic evaluation of combined rover *in-situ* and orbital measurements, and such data will further provide the fundamental context for returned sedimentary samples. However, many critical measurements can only be obtained on returned samples. The iMOST team has further identified more than twenty such measurements that cover the full range of stratigraphic, sedimentological, petrological, geochemical and isotopic characterization of the sediment suites and their various internal constituents.

Required Samples: Samples required to accomplish these measurements fall into nine (not all mutually exclusive) categories:

1. *Suite of sedimentary rocks representative of the stratigraphic section;*
2. *Suite of sedimentary rocks showing a range of lithification intensity and style;*
3. *Rocks of any type showing a range of weathering styles and intensity, including weathering rinds;*
4. *Sedimentary rocks with a variety of grain compositions;*
5. *Modern regolith, especially if locally derived;*
6. *Relatively coarse-grained sedimentary rocks;*
7. *Suite of sedimentary rocks representative of stratigraphy within an ancient stream channel;*
8. *Sample of modern aeolian sediment;*
9. *Sample(s) of lithified aeolian sedimentary rock.*

References: [1] McLennan S.M. et al. A. (2012) *Astrobiol, 12,* 175-230. [2] Hurowitz J. A. et al. (2017) *Science, 356,* doi:10.1126/science.aah6849. [3] Grotzinger J. P. (2013) *In: S. J. Mackwell et al. (Eds.) Comparative Climatology of Terrestrial Planets,* pp. 439-472, Univ. Arizona Press.

THE SEARCH FOR LIFE'S ORGANIC CARBON IN RETURNED SAMPLES FROM MARS. iMOST Team (M. A. Sephton[1], S. Siljeström, D. P. Glavin, J. R. Brucato, F. Raulin, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, G. G. Ori, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, R. Shaheen, D. L. Shuster, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano.) [1] Earth Science and Engineering, Imperial College London, SW7 2AZ; m.a.sephton@imperial.ac.uk.

Introduction: Evidence of habitability and habitation of Mars may be forthcoming if samples from Mars were returned to Earth in the future [1]. Clear objectives and associated choices of samples is essential to maximize the opportunities that may be presented by returned samples. In the context of the solar system, the relative similarity of Earth and Mars generates an expectation of biochemical harmony for the two planets. We can confidently predict that any biochemical scaffolding on Mars would be based on carbon and any biochemical solvent would be based on water. To expect otherwise would require planetary conditions and chemistries [2] that differ dramatically from those of either Earth or Mars. Reduced carbon is therefore a beacon for the potential discovery of evidence of life in a sample. Yet the presence of reduced carbon alone is not sufficient to indicate life. Many non-biological processes produce concentrations of reduced carbon and even when present in organic structures the involvement of life is not conclusively indicated. Organic carbon-rich meteorites are good examples of the widespread nature of non-biological organic chemistry in the solar system [3]. Any reduced carbon detected in samples from Mars should, therefore, have features that provide the ability to discriminate between non-life and life sources and, preferably, between an origin on Earth and Mars [4]. For detecting life, the usefulness of organic carbon to biochemistry is in its ability to form complex and specific organic structures. Recognizing the organic signatures of life is therefore an achievable goal [5]. For discriminating provenance on Earth and Mars, detailed environmental adaptions must be sought. Although based on carbon and water the biochemical similarities between organisms on Earth and Mars would not be expected to be exact. Our terrestrial examples of environmental adaptations reveal substantial biochemical variations that reflect the challenges and opportunities presented by the host environment [6].

This is a provisional report from the iMOST subteam on the objective of Seeking the Signs of Life, identifying key samples and measurements needed to understand Martian Organic Carbon.

Organic Carbon sub-objectives:

1) Determine the presence and nature of carbon in multiple valence states on Mars. To measure inorganic carbon, reduced carbon, simple organic molecules and polymers, organic matter features, correlation with mineral catalysts and the cosmogenic nuclides to determine exposure age. Key samples would be organic-rich rocks, unaltered igneous rocks and regolith.

2) Determine stable isotopic composition (e.g., of C, H, N, O, S) of organic matter and compare it to carbon-bearing minerals such as carbonates, water, organic compounds or minerals. Key samples would be car-bon-rich in nature.

3) Establish whether chemical relationships could indicate biological processes. To seek evidence of chemical equilibria or disequilibria that are inconsistent with abiotic processes, and thus which would be indicative of biological activity. Suitable samples would contain appropriate mineral assemblages, especially those which contain organic carbon in concentrations significantly above average.

4). Identify any aspects of the environment conducive to the existence and preservation of prebiotic chemistry. To identify components of pre-biotic chemistry, evidence for hydrothermal activity, presence of mineral catalysts, cosmogenic nuclides. Suitable samples would be rocks of any type which have been recently exposed and especially those whose formation age predates the cessation of the planetary magnetic dynamo.

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CONSTRAINING OUR UNDERSTANDING OF THE ACTIONS AND EFFECTS OF MARTIAN VOLATILES THROUGH THE STUDY OF RETURNED SAMPLES.
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Introduction: Volatiles have clearly played a key role in the evolution of Mars' atmosphere, hydrosphere and geosphere, with effects ranging from the geomorphological evidence for outflow channels and valley networks early in Mars' history to formation of alteration products in rocks to the current seasonal changes in the polar caps. It is clear that the absolute and relative abundances of various volatiles have changed through time via volcanic degassing, atmospheric loss, and interactions with the crust.

In addition to studying the current Martian atmosphere and ancient trapped gases in Martian sedimentary, igneous and impact samples, there is considerable knowledge to be gained by examining the compositions of sedimentary rocks, regolith and secondary minerals that are especially sensitive to climatic influences such as obliquity-driven changes. For example, results from the Curiosity rover indicate that it is possible to obtain high resolution chemostratigraphic climate records from rhythmically bedded sedimentary rocks using in situ measurements [1]. Analysis of selected returned samples from such in situ records would be extremely important in confirming and fully understanding such records. In addition, there is growing capability of applying a variety of radiometric techniques to dating of the time of sedimentation and obtaining such dates from climate-sensitive sedimentary sequences would greatly help to tie down the timescales of past climate changes.

This is a provisional report from the iMOST subteam on key samples needed to understand volatiles.

Volatiles sub-objectives:

1) Determine the original source(s) of the planet's volatiles, and the initial isotopic compositions of the constituent gases in the atmosphere. Determining the original composition is complicated by the processes that occurred on the planet during its history, but there are some isotopes (such as the triple-isotope system of O in rocks [2]) that are expected to change modestly and be highly diagnostic of their origin.

2) Understand crustal-atmospheric interactions and feedbacks, especially for C, O, S, N, Cl, and H, in order to interpret present and past geochemical cycling on Mars. Although present conditions are much different than those earlier in Mars' history, many of the crustal-atmospheric interactions are expected to be similar, so quantifying the current interactions would provide constraints on the past history of volatiles.

3) Quantify the history of the composition of the atmosphere, and the history of contributions from the interior (e.g. H, C, N, O, noble gases and radiogenic products). Changes in the Martian atmosphere with time are clearly coupled to changes in the Martian environment. Outgassing (most likely volcanic, but perhaps related to impact) is the primary source of volatiles for contributions to the atmosphere, and it should be possible to put constraints on the amount of outgassing by determining the history of the composition, elemental, molecular, and isotopic, of the Martian atmosphere trapped in rocks and secondary minerals. There are still significant questions about the evolution of noble gases [3]

4) Assess temporal variations in the composition of the present-day atmosphere. CO_2, Ar, N_2, O_2, H_2O, CO, and other compounds that have been measured in-situ to vary during the year [4,5,6]. The amount, variability and role of heterogeneous catalytic reactions with the regolith of oxidizing volatiles such as H_2O_2 are unknown. Measure the oxidation capacity of the atmosphere by constraining the odd oxygen cycle (O_3-O) using oxygen triple isotopes and determine the role of peroxy radicals in the removal of organic matter in the soil and regolith [7,8].

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THE USE OF RETURNED MARTIAN SAMPLES TO EVALUATE THE POSSIBILITY OF EXTANT LIFE ON MARS.
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Introduction: The formal life-related objective of the Mars 2020 sample-collecting rover is to seek the signs of ancient life. The rover will not enter 'special regions' on Mars where Earth life may replicate or extant Martian life forms are likely to exist. Therefore, returned samples will not specifically be chosen for the purpose of discovering extant life unless something unexpected is encountered in the field. Regardless, the astrobiological community is highly interested investigating whether or not there is extant life in/on these samples.

Sampling: As far as we are aware, the proposed M-2020 mission landing sites lack distinguishing features that would favor one over another as an environment condunsive to the survival of extant life. Thus, for the purpose of this analysis, we assume that all samples collected by the M-2020 rover be selected for other reasons.

Investigations Required to Test for Extant Life:

So far, no detailed methods and procedures for the detection of extant extraterrestrial life forms have been defined. A draft protocol for the identification of biohazards in Martian samples was formulated in 2002 [1] and a workshop report about life detection in Martian samples was published in 2014 [2]. There are several approaches for assessing the presence of extant life, which are presented in the order of impotance and likelihood of success.

Physico-chemical analyses: This examination has some overlap with Objectives 1.2 & 1.3 (identify candidate biosignatures as evidence of extinct life) in that a subset of the biomarkers targeted these objectives may also speak to the presence of extant life. Specifically, groups of organic molecules that are unlikely to be formed abiotically but are rapidly degraded. Proteins and DNA-like genetic material are stable for thousands to millions of years [3, 4]—a short period in the context of the presence and evolution of life—and are thus a primary target of this objective. Both the presence and size of DNA molecules are of particular interest. In the absence of the repair machinery that exists in a living cell, DNA is damaged and fragmented [5,6]. Therefore, large intact DNA molecules would be strong evidence of recent life.

Physio-chemical analyses should start with non-destructive and non-invasive methods and proceed towards more and more destructive methods. First insights can be obtaind using different microscopic methods such as Raman, UV-, IR-, and VIS spectroscopy. Besides aiding in detecting biosignatures, they will enable direct detection of cells and biofilms. More destructive techniques include electron microscopy, nano- and ToF-SIMS as well as combinations of mass spectrometry and liquid or gas chromatography techniques. These methods enable the detection and identification of complex organic compounds and put them in the structural and compositional context of their sample matrix.

Genetic analysis: If life on Mars and Earth share a common origin and thus share DNA as genetic material, another approach to discovering extant life would be to use a genetic-based analyses. Metagenomics, the processes of isolating and sequencing all DNA from an environment, is the most viable option for this as it can be performed with trace amounts of DNA and does not require culturing. Low DNA-yield samples are susceptible to contamination, so scientific investigations must have sufficient resources to eliminate contamination as a possible explantion for the data.

Culture experiments: Success in cultivating organisms from Martian samples would be the ultimate proof of exant life. However, even on Earth we can only culture a few percent of all microbes from an environmental sample. The probability of finding the right cultivation conditions is negligible. These types of analyes would also need to be conducted in the sample receiving facility for planetary protection reasons. Culture attempts are not recommended unless evidence of extant life is identified though other independent means.

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OHB's Exploration Capabilities Overview Relevant to Mars Sample Return Mission

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OHB System AG is one of the three leading space companies in Europe. It belongs to the listed high-tech group OHB SE, where around 2,200 specialists and executives work on key European space programs. With two strong sites in Bremen and Munich and more than three decades of experience, OHB System specializes in high-tech solutions for space, science and industry.

Within its core business *Space Business*, the areas of Exploration and Science play a key role for the company.

The presentation will give an overview to all the OHB past and current projects that are relevant to the Mars Sample Return Mission, including some valuable lessons learned applicable to the upcoming MSR mission.

During the presentation we will give an overview of all the know-how available in Europe and in Germany at OHB, that is directly applicable and relevant to the MSR mission (systems engineering, mission arquitecture, planetary protection, robotics and mechanisms, sample handling) showcasing some examples of hardware and studies performed in the past and currently.

The main highlight of the presentation will be the lessons learned from the OHB contributions to the ExoMars 2016 and 2020 projects.

The Trace Gas Orbiter, the Sample Processing and Distribution System, the Analytical Laboratory Drawer, the High Resolution Camera and the Carrier; all elements designed and developed at OHB for the ExoMars missions will be presented with an emphasis on how the work done and the processes learned the can be applied to the upcoming MSR.

SCIENTIFIC VALUE OF A RETURNED SAMPLE OF MARTIAN ATMOSPHERE. B. M. Jakosky[1], R. W. Zurek[2], S. K. Atreya[3], P. R. Mahaffy[4], K. Zahnle[5], O. B. Toon[1], M. Tolbert[1], and M. J. Mumma[4]. [1] University of Colorado at Boulder, [2] NASA/Jet Propulsion Laboratory, [3] University of Michigan, [4] NASA/Goddard Space Flight Center, [5] NASA/Ames Research Center. (Corresponding author, bruce.jakosky@lasp.colorado.edu)

Introduction: A returned sample of unaltered Martian atmosphere would have considerable scientific value for understanding the evolution of Mars and its climate and the potential for life. Collecting such a sample is not currently incorporated into the Mars 2020 rover mission, except as essentially unusable amounts of "head space" gas along with individual rock and regolith samples. Such a capability could easily be incorporated into an anticipated "fetch" rover that would collect the samples and package them for return to Earth.

In light of recent measurements from the *Mars Science Laboratory* and the *MAVEN* mission, and anticipated results from the *Trace Gas Orbiter*, we wanted to revisit the scientific value of returning a sample of atmosphere. The *MSL Sample Analysis at Mars* (*SAM*) instrument suite has obtained high-precision measurements of the composition of the present-day Mars atmosphere. These include isotopic measurements of key gases and abundances of certain trace gases. *MAVEN* observations of the composition and structure of the upper atmosphere provide fundamental information on how to interpret some of the results relative to atmospheric loss through time.

Scientific objectives: Measurements of the present-day atmosphere that would be made on a returned sample would provide information that allows us to understand key aspects of Mars evolution:

(i) Isotope ratios of the noble gases tell us about the sources of gas in formation of the atmosphere and its subsequent evolution. Of particular interest, and requiring more-precise measurements than currently available, are the isotopes of Xe (that may be indicative of ongoing processes within the regolith and surface-atmosphere exchange) and Kr (that relate to supply and loss of gas to the atmosphere through time).

(ii) Trace gas abundances tell us about ongoing geological and biological processes in the Martian regolith.

(iii) Isotope ratios in trace gases (such as $^{13}C/^{12}C$ and D/H in methane, CH_4, and ethane, C_2H_6, and D/H in H_2O for comparison) can tell us about their chemical formation processes, possibly including biology.

(iv) Samples of airborne dust that could be included in an atmospheric sample will allow us to understand factors controlling the present-day climate and atmospheric cycles and the chemical evolution. The current sample-collection schemes will not obtain samples of airborne dust, and it is not necessarily a given that surface dust would be present everywhere that is being sampled or that it would have properties similar to dust in the atmosphere.

(v) A sample of the atmosphere provides important boundary conditions on exchange of gas between the surface and atmosphere and on related chemical processes. Of particular importance are regolith materials such as perchlorates that can reflect surface-atmosphere interactions; understanding the implications of such compounds in the regolith will require knowledge of the composition of the atmosphere.

(vi) An unaltered sample of atmospheric gas is necessary for evaluating possible contamination of the geological samples. Samples from the interior of rocks may not ever have been in contact with the atmosphere, and may be altered by drilling and sample collection. Measurement of the atmospheric composition will help to understand changes that might have taken place.

(vii) An atmospheric sample can serve as "ground truth" for in situ verification of atmospheric abundances derived from the *Trace Gas Orbiter* or, if *TGO* measurements are not available, can provide key measurements.

Sample collection: An atmospheric sample could be obtained from a simple, mostly passive collector that would not require the complexity of a compressor. A scrubber/getter system could remove the active gases (CO_2, O_2, N_2, and H_2O), allowing the remaining gases to fill a previously evacuated container; both the scrubber and the gas container would be returned to Earth. The volume of even the trace noble gases collected in this procedure far exceeds the volume needed for multiple measurements with the sensitive mass spectrometers on Earth. The technology for this type of system is well developed and understood.

Conclusions: Mars sample return is intended to explore all aspects of a complex and interconnected Mars environment. Given the role of the atmosphere in driving our understanding of climate and the potential for life, it is necessary that we obtain an atmospheric sample as part of the collection. As sample collection would be done on a not-yet-designed fetch rover, now is the appropriate time to begin development of the concept for incorporation into rover planning.

Mars Exploration Recent Accomplishments: Orbital Perspective. R. Jaumann[1,2]; [1]German Aerospace Center (DLR), Inst. of Planetary Research, Berlin, Germany, Ralf.Jaumann@dlr.de, [2]Freie Universitaet Berlin, Inst. of Geological Geosciences, Berlin, Germany.

Introduction: Numerous spacecrafts orbited Mars and observe its surface, subsurface, atmosphere and environment including Mars Odyssey, Mars Express, Mars Reconnaissance Orbiter, Mars Orbiter Mission, ExoMars Trace Gase Orbiter and Maven, which are still active. Cameras, spectrometers, laser altimeters, and radar experiments enabled investigations of geological processes, interactions of the interior with the surface as well as of the surface with the atmosphere and the exosphere. The spatial resolution of image data reaches ~10 cm/pixel in places [1,2], the global coverage reaches even up to ~98% with a resolution better than 20 m/pixel in color [3,4]. Topographic data reach ~10 m/pixel with stereo imaging [3,4] and laser altimetry [5]. Spectral observations in the visible and infrared spectral range yield compositional information about the surface and atmosphere [*e.g.*,6,7,8,9] as well as information on thermal surface properties [10,11] and shallow water by gamma ray measurements [12]. Radar provided access to the subsurface [13,14] down to ~4 km depth. **Accomplishments:** Geomorphological analyses of the Martian surface indicate major modifications by endogenic and exogenic processes on all scales. Endogenic landforms (e.g., tectonic rifts and basaltic shield volcanoes) were found to be very similar to their equivalents on Earth, suggesting that no unique processes are required to explain their formation. Volcanism may have been active up to the very recent past or even to the present, putting important constraints on thermal evolution models [e.g.,15,16,17,18]. Dark dunes contain volcanic material and are evidence for the significantly dynamic surface environment, characterized by widespread erosion, transport, and redeposition [e.g., 19,20,21]. The analysis of diverse landforms produced by aqueous processes revealed that surface water activity was likely episodic. The amount of liquid water, however, reduced from ancient large paleolakes and valley networks to local outflow channels existed in the recent past (late-mid Amazonian) [e.g.,15,16,22,23]. Particularly important are prominent glacial and periglacial features at polar regions and mid-latitudes, including debris-covered glaciers [e.g.24,25,26]. The identification of hydrated minerals and their geological context has enabled a better understanding of paleoenvironmental conditions and pedogenetic processes [e.g.,26,27]. External processes, affected the evolution and vigor of the martian hydrologic cycle and influenced the distribution and state of water on, and within, the planet's crust [e.g.18] with progressively shrinking reservoirs of groundwater [28]. Various phyllosilicates formed by aqueous alteration very early in the planet's history and are found in the oldest, Noachian-aged terrains; sulfates, on the other hand, are indicative of an acidic environment and were formed later [26,29]. Beginning about 3.0 billion years ago, the Amazonian Epoch is dominated by the formation of anhydrous ferric oxides in a slow superficial weathering, with limited and short-lasting surface liquid water across the planet [26]. While the planet's first billion years, with differentiation, hydrodynamic escape, volcanism, large impacts, erosion, and sedimentation rapidly modified the atmosphere and crust [e.g.,18] geological processes in the following epochs ceased but still had the power to change the surface. In addition, remote sensing of Mars has revealed that the surface is continually changing [e.g., 30-33] by modifications due to exogenic processes, including aeolian activity, mass movements, the growth and retreat of the polar caps, and crater-forming impacts. Although it could be confirmed from orbit that all known geological processes are active on Mars and water played a major role all over its history small-scale geochemical and possible biochemical processes are not accessible by remote-sensing from orbit but need in-situ and sample analyses.

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MARS SAMPLE RETURN: THE CRITICAL NEED FOR PLANNING A MEANINGFUL AND PARTICIPATORY PUBLIC ENGAGEMENT PROGRAM. S. Klug Boonstra[1], [1]Arizona State University, Mars Space Flight Facility, 201 E. Orange Mall, Moeur Bldg. Rm 131, Box 876305, Tempe, AZ 85287-6305, sklug@asu.edu

Introduction: The Mars Sample Return Campaign (MSRC) offers planetary science the prospect of an historical leap forward in the understanding of the geology and habitability of the red planet. In addition to this important science return, MSRC also offers an unprecedented opportunity to engage the citizenry of this planet in one of the enduring questions of humanity, "Are we alone?"

Important Considerations: The National Academy defines public engagement as "seeking and facilitating the sharing and exchange of knowledge, perspectives, and preferences between or among groups who often have differences in expertise, power, and values." [1]

MSRC will involve a set of complex steps that will occur over a long timeframe and will necessitate the development of outreach strategies that will enable the public to fully engage, dialogue, and meaningfully participate with the science community during this endeavor.

A new *Interplanetary Initiative* at Arizona State University has formed a group of interdisciplinary scholars to explore a question that has implications related to MSRC: "How will humankind react to the discovery of life off Earth?" They acknowledge that "while both scientists and the public at large have prepared for encountering extraterrestrial life through preparing to encounter extraterrestrial intelligence, it seems much more likely that humanity will directly encounter alien life first through some form more akin to microorganisms. *This in turn raises the likelihood that extraterrestrial life will not announce itself but rather will be announced — through a cloud of science and policy actions that are already acknowledged to be shifting and fraught with challenges.*" (emphasis added) [2]

To build a trustworthy dialogue with the public, it will be important for MSRC to: 1) be highly communicative to the public about the mission plans, timetables, and the rigorous planetary protection protocols and safeguards that will be in place; and 2) offer pathways for the public to engage as participants in the mission. By keeping the public informed and giving them the opportunity to become stakeholders and contributors, MSRC will be able to optimize their outreach efforts and effectively engage the public to better understand the scientific and technological value and benefits of MSRC.

Preparing and Engaging the Public As Participants in the Mars Sample Return Campaign: In the last decade, NASA has successfully designed and implemented a wide range of outreach strategies to grow public interest. With the likelihood of technology advances continuing, new strategies must keep pace to capitalize on ways to engage broad audiences in participatory exploration. A multi-decade strategy to engage the public in Mars missions was proposed [3] in 2009 and included ways for the public to participate through multiple pathways. In this framework, individuals could "level-up" - taking on more complex projects by attaining more skills, knowledge, and providing reliable science return to the science community from mission data analysis. Citizen science activities such as this and The Mars Student Imaging Project [4,5,6] are valuable models for sustaining long-term interest of participants. This type of activity provides strong interfaces with the mission science, interaction with Mars community scientists, and provide meaningful learning through deep, authentic science experiences.

With the considerable timeline available prior to a return of Mars samples estimated to be in the mid-to-late 2020s, MSRC has the lead time to develop innovative and effective plans to involve the public as partners for this remarkable time in Human history.

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PLANETARY PROTECTION ASSOCIATED WITH MARS SAMPLE RETURN. G. Kminek[1], [1]European Space Agency, Keplerlaan 1, 2200 AG Noordwijk; gerhard.kminek@esa.int.

Scope: A Mars Sample Return (MSR) campaign falls under the COSPAR Planetary Protection Category V, restricted Earth return [1]. The associated COSPAR Planetary Protection Policy & Requirements are in place to guide compliance with article IX of the United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space [2], i.e. to avoid adverse changes in the environment of the Earth from the introduction of extraterrestrial matter [3] [4].

This presentation will cover the various planetary protection aspects related to a MSR campaign, including the leading requirements to achieve a high level of assurance for the safety of the Earth [4], including independent oversight [3], and initiatives to formulate a sample test protocol that takes into account the scientific and safety issues [5] [6].

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RE-ENTRY: INFLATABLE TECHNOLOGY DEVELOPMENT IN RUSSIAN COLLABORATION (RITD).

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Introduction

To study the Mars is supposed to use the space landing vehicles (LV) to determine the parameters of the atmosphere and the soil characteristics of the Mars surface. Dimensions and weight of the landing vehicle limited capacity of launch vehicles.

Main Idea

As a device for braking is proposed to use the inflatable braking device (IBD). Folded landing vehicle has small dimensions. Before entering the atmosphere of a celestial body inflatable braking device deployed slight overpressure. Then axisymmetric landing vehicle with an inflatable braking device receives a small angular velocity of rotation about the longitudinal axis.

Thus landing vehicle was a landing vehicle MetNet for Mars sample return mission [1]. MetNet uses two inflatable braking device. Primary inflatable braking device (PIBD) is a frontal inflatable screen that parries the main heat load while moving of the landing vehicle in the upper and middle layers of the atmosphere. Additional inflatable braking device (AIBD) is set on final descent, and is intended for additional braking system. In this project the technology is applied braking throughout the descent: Entry, Descent and Landing System (EDLS) in the atmosphere of Mars.

The main objective of this project is to evaluate and develop a conceptual design of such a system for launching the appropriate range of conditions from Mars atmosphere in the Earth's atmosphere [2], [3]. As expected, there may be additional perturbations of the Earth's atmosphere during the entry, descent and landing. This technology provides the ability to deliver a payload weight 4-8 kg to deliver a low-Earth orbit.

Studies have shown that this technology with the use of inflatable braking devices, originally developed for the descent into the conditions of the Martian atmosphere, can be applied to Earth conditions. The preliminary results are opening a very good perspective, showing that the current design for the Mars landing vehicles can be used for the Earth. The studies were conducted for 120 different types of conditions of entry and descent into the Earth's atmosphere.

Conclusion

Investigation of the possibility of application of this technology for the descent into the Earth's atmosphere dedicated project RITD. This project analyzes the motion of the landing vehicle to hyper-, transonic and subsonic flight.

Project participants: Finnish Meteorological Institute, Lavochkin Space Association, Bauman Moscow State Technical University, National Institute for Aerospace Technology, Madrid.

This research was supported by the European Commission Seventh Framework Programme FP7/2007-2013 under grant agreement n° 263255 RITD.

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TU Berlin Rover Family for Terrestrial Testing of Complex Planetary Mission Scenarios. L.Kryza and K.Brieß, Technische Universität Berlin, Chair of Space Technology (contact: lennart.kryza@tu-berlin.de)

Planetary mission scenarios grow more complex with an increasing number of scientific requirements and potential operations on celestial surfaces. Major challenges are posed by a number of factors: Environmental conditions, communication delays, blackouts, required technological level and the complexity of mission scenarios. Sample return missions (SRM) to Mars are composed of all the given requirements and thus require well developed mission architectures. Space systems for SRM need to perform a wide range of tasks at least semi-autonomously in order to be able to reliably operate despite the given communication delay to Earth and during potential blackouts when no data transmission is possible.

The Chair of Space Technology at the Technische Universität Berlin has developed a family of educational planetary robots which allow researching various mission concepts that require planetary robots to work on their own or as a team. The space rover projects at the Chair have utilized the scope of robotic competitions in order to derive requirements for these terrestrial testbeds. This paper introduces these space rover systems which have been developed for the SpaceBot Cup, organized by the German Aerospace Center (DLR) and the European Rover Challenge organized by the European Space Foundation. They include the mobile rovers SEAR (Small Exploration Assistant Rover), SEAR2 and BEAR (Berlin Exploration Assistant Rover) as well as the stationary robot POLARIS (Planetary Orbiter – Landing ARea Interface System).

SEAR and its successor SEAR2 have been developed in order to navigate very rough terrain consisting of rocks, sands, slopes and other obstacles completely autonomously. It simultaneously crosses unknown areas, localizes itself and maps its surroundings (SLAM). Furthermore it is capable to autonomously identify obstacles and different objects. SEAR will then make decisions according to its mission objectives and plan paths around obstacles in order to reach the desired objects and grasp them. These are the main tasks of the SpaceBot Cup, in which SEAR successfully competed in 2013 and 2015. It can be seen on the competition field in figure 1.

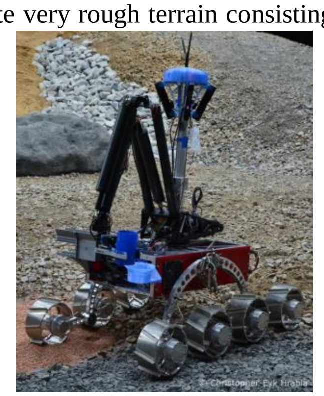

Figure 1: SEAR on Lunar Testbed in 2015 [1]

BEAR was developed as a versatile platform to use various different subsystems. In its initial form it will be equipped with a sample retrieval device, a manipulator and various sensors to gather environmental data.

POLARIS is a support system for the rovers and serves as designated communication access point and processing hub. Its main design driver is to be a supportive monitoring system for one or several rovers.

The given systems are designed as autonomous terrestrial testbeds for planetary robotics and share common underlying architectures across all robots. This paper will introduce cost-effective approaches regarding various subsystems, including communication, sensors and on-board computers. Presented setups create a robot with the same capabilities as they are needed during an actual mission but enable faster development using current technologies. Furthermore it will be presented, how Mars mission restrictions in regard to communication challenges, can easily be simulated.

References: [1] Image by: Christopher-Eyk Hrabia (2015).

Spectral characterization of H2020/PTAL mineral samples: Implications for in situ martian exploration and Mars sample selection. C. Lantz[1], C. Pilorget[1], F. Poulet[1], L. Riu[1], H. Dypvik[2], H. Hellevang[2], F. Rull Perez[3], M. Veneranda[3], A. Cousin[4], J.-C. Viennet[2], and S.C. Werner[2]. [1]Institut d'Astrophysique Spatiale, CNRS/Univ. Paris-Sud, France (Bât. 121, 91405 Orsay Cedex ; cateline.lantz@ias.u-psud.fr), [2]Department of Geosciences, Univ. of Oslo, Norway, [3]Department of Condensed Matter Physics, Univ. of Valladolid, Spain, [4]Institut de Recherche en Astrophysique et Planétologie, CNRS/Université Paul Sabatier, France.

Introduction: Space exploration on Mars is driven by the search of the ingredients for the planet habitability like hydrated and organic materials. To achieve this goal, upcoming in-situ missions will use several analysis techniques that have never been brought together to Mars surface yet.

The PTAL project [1] aims at building and exploiting a database [2], the *Planetary Terrestrial Analogues Library,* in order to characterize the mineralogical evolution of terrestrial bodies, starting with Mars. Natural Earth rocks (~100) have been collected on selected locations around the world to get the best analogues for martian geology. Each sample will be characterized with XRD and thin sections (Oslo University), NIR (Paris-Sud University), Raman (Valladolid University), and LIBS (Toulouse University) spectroscopies. These techniques are similar to the instruments on board of current and forthcoming martian missions (Fig. 1). Such combined analysis will give the opportunity to prepare and understand ExoMars/ESA and Mars2020/NASA observations.

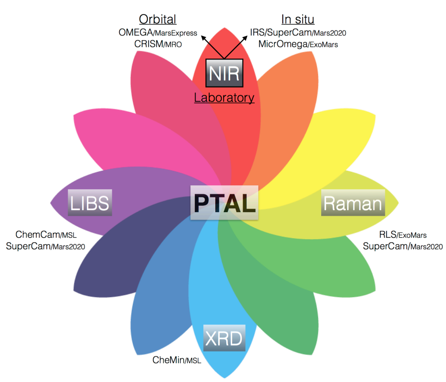

Figure 1: Overview of project PTAL.

Techniques: In a first step, samples are characterized with thin section and XRD analyses to obtain the main rock classification and the preliminary lithological description, including natural alteration products. We remind that XRD is a part of the Curiosity payload.

Then, NIR spectroscopy is used according to two techniques. We have a FTNIR spectrometer that mimics spectral characterization of IRS/Mars2020 (a point spectrometer performing NIR observations with spots of ~500 µm [4]) and a spare model of MicrOmega (a NIR hyper spectral microscope with spatial resolution of 20 µm over 5 mm^2) to analyse PTAL samples. The point spectrometer is used on powders (two grain sizes for comparison), while MicrOmega is very useful to highlight mineralogical heterogeneity of bulk samples (Fig. 2).

Raman spectroscopy is performed and offers a unique complementarity to the NIR as some compounds are better detected with Raman. It also gives information on the crystalline/amorphous state.

The last step is the LIBS (using a spare model of ChemCam) that provides the elemental composition.

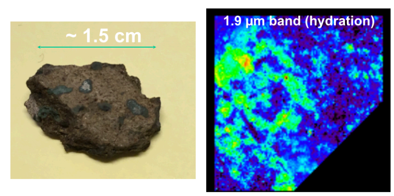

Figure 2: Example of an altered sample with olivine inclusions (bulk on left picture) seen by MicrOmega (right; mapping of the 1.9 microns hydration band).

Current status of measurements: Measurements of several tens of samples have started. Preliminary results will be presented at the time of the conference. A comparison emphasizing the complementarity of the techniques (XRD, NIR, and Raman first) will be discussed. We will also highlight the link between macroscopic and microscopic scale to perform NIR multiscale analysis of martian analogue samples combining identification and quantification as this technique is a part of the orbital and in situ payloads. This will help coordinated analyses of the martian surface from both orbital and landed platforms.

PTAL investigations and the later released database will provide insightful informations for landing site selection and sample collection for a further sample return.

References: [1] Werner et al. (2018) *this issue*. [2] Veneranda et al. (2018) *this issue*. [3] Wiens et al. (2016) *LPSC, No. 1903*, 1322.

Acknowledgements: This project is financed through the European Research Council in the H2020-COMPET-2015 programme (grant 687302).

"Mars Sample Return"

A longstanding top priority of CNES and the French scientific community

Jean-Yves Le Gall
CNES President
1st January 2018

CNES has extensive expertise in the field of missions to Mars, as illustrated by its participation in the U.S. Mars Science Laboratory (MSL), InSight and Mars 2020 missions. CNES is also participating in several sample return missions, on Japan's Hayabusa 1 and 2 (including the MASCOT lander, set to arrive mid-2018 on the asteroid Ryugu) and on the MMX project to Phobos.

CNES and the French scientific community are already on board the "Mars Sample Return" mission, since they are participating in NASA's Mars 2020 mission. It is expected that the Mars 2020 rover will select and store samples that will then be brought back to Earth later on. The crucial sample selection step will be relying heavily on the SuperCam camera provided by France.

CNES is therefore closely involved in the preparation of the "Mars Sample Return" mission and fully supports the international initiative that will lead to the return and analysis of the first Martian samples. Once these samples are brought back to Earth, they will have to be analysed, and here again France can play a central role thanks to its internationally renowned teams and scientific equipment for this analysis.

"Mars Sample Return" will also imply rigorous planetary protection actions. The organization put in place, most probably between ESA and NASA, must allow 100% secure and fair access to the samples for all scientists of the countries involved in the mission.

The next step for Europe, France and CNES in this very ambitious project will be the end-2019 ESA Ministerial Conference, which will obviously be a key milestone in the "Mars Sample Return" mission roadmap.

* * *

COMMERCIAL MARS SAMPLE RETURN ARCHITECTURE. R.X. Lenard, President and CEO Zodiac Planetary Services, 16 Dunkin Road Edgewood, NM, rxlenard@gmail.com

Introduction: Zodiac Planetary Services is a newly formed company with unique intellectual property (patent pending # 62/523432, Celestial Object Sample Return System) which can revolutionize the acquisition and transport of celestial samples, either in scientific quantities or in bulk amounts. Zodiac has formed cooperative arrangements with two local Universities who are working with ZPS designs for one of the key sample acquisition and return subsystems. The Zodiac approach can enable the acquisition of multiple samples from effectively any location on celestial objects using multiple end effectors. For locations such the Moon or Mars, a long-rod penetrator, capable of collecting intact core samples to depths of ~2 meters with a sample mass of ~ 1 kg are feasible; such samples provide an exceptional perspective into various celestial object surface and below surface regions. At present ZPS is member financed; we are internally supporting a design and hardware demonstration of one of the key subsystems. We have submitted several proposals to NASA toward maturing key technologies. Finally, our expectation is to obtain special financing from the U.S. Treasury which would be repaid via sales of samples to various space agencies, commercial entities and private individuals. At present we would anticipate collecting ~ 20 Mars core samples for a sales price of ~ $150M-$200M. This compares very favorably with a single sample from the present Mars Sample Return Mission. The ability to collect samples from multiple locations provides a very profound understanding of many sample sites without having to select a single one.

ADVANCED ANALYTICAL METHODOLOGIES BASED ON RAMAN SPECTROSCOPY TO DETECT PREBIOTIC AND BIOTIC MOLECULES: APPLICABILITY IN THE STUDY OF THE MARTIAN NAKHLITE NWA 6148 METEORITE.

J. M. Madariaga*, I. Torre-Fdez, P. Ruiz-Galende, J. Aramendia, L. Gomez-Nubla, S. Fdez-Ortiz de Vallejuelo, M. Maguregui, K. Castro, G. Arana, Department of Analytical Chemistry, University of the Basque Country (UPV/EHU), Barrio Sarriena, s/n, 48940 Leioa, Spain (juanmanuel.madariaga@ehu.eus).

Introduction: The important contribution of organic materials arriving in the comets and asteroids that impacted Mars (creating impact craters) and other bodies in the Solar System has been suggested. We should expect simple chemical precursors (CO_2, O_2, N_2, SO_x, etc.), simple molecules (methane, acetylene, etc.) and complex compounds (amino acids, hydrocarbons, etc.) trapped in the Martian materials as such chemicals have been found in meteorites arriving Earth.

To detect such prebiotic and abiotic molecules the scientific community has two broad family of analytical methodologies, the ones based in the destructive pretreatment of the samples and those based in non-destructive instrumental techniques. These methodologies are complementary because relevant information is retrieved from both approaches. As samples are expected to be small and scarce, the non-destructive methodologies should be used first, and then those based in destructive steps.

Raman spectroscopy is one of the most promising analytical technique among the non-destructive methods because inorganic and organic compounds containing covalent bonds are sensitive to this vibrational spectroscopy technique. We must remind that the prebiotic and abiotic molecules will be present in a matrix of inorganic nature.

Advanced Raman Spectroscopy Methodologies: Among the different configurations of Raman spectroscopy, we suggest to use three different configurations: optical microscopy coupled to confocal micro-Raman spectroscopy, the hyphenated Raman-SEM/EDS instrument (also called SCA, Structural and Chemical Analyzer), and High Resolution Raman imaging:

Optical microscopy coupled to confocal micro-Raman spectroscopy. The Raman spectrometers that incorporate confocal microscopes allow us to search by optical microscopy where to perform the analysis at micrometer level. The instrument offers the possibility to perform as many Raman measurements as different morphological microstructures are present in the sample to the naked eye. This is recommended when "known" samples are under study (see Figure 7 in ref. [1] where O_2(g), C≡N bond and N_2(g) were detected).

Hyphenated Raman-SEM/EDS. For completely unknown samples or for very complex samples, the SCA configuration is very helpful. First, the SEM images are obtained in a given area searching for cavities, inclusions and bubbles where the prebiotic and abiotic compounds are likely trapped in the inorganic matrix. Then the EDS maps are obtained searching for areas where the carbon image is not superimposed with any metal. In such structures, the Raman analysis is performed to confirm if there is an organic molecule or a combination of organic molecules (see Figure 1).

High Resolution Raman Imaging. Once the area with the positive response to organic molecule has been located, High Resolution Raman Imaging can be performed to define the form of the structure containing the organic molecule (see Figure 1).

Applicability to the search of organic compounds in the NWA 6148 Nakhlite: The NWA 6148 Martian meteorite was studied for its geochemical composition [2]. Using that knowledge, the suggested methodology was applied to search for organic compounds in the cavities, inclusions and bubbles of the NWA 6148 Martian meteorite. Figure 1 shows the organic signatures over a clear Raman spectrum of olivine together with the High Resolution Raman Image depicting the form of the bubble.

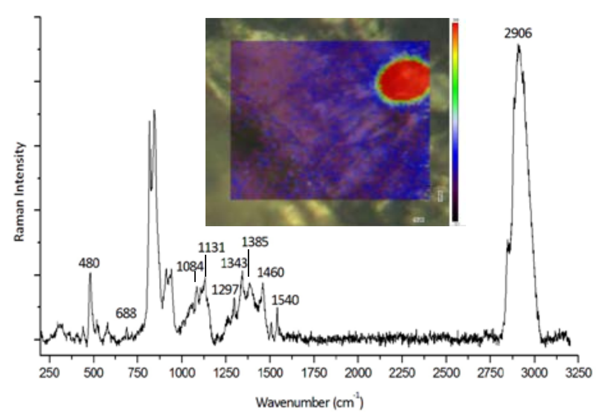

Figure 1.- Raman spectrum of an aliphatic compound, over the Raman signature of an olivine matrix, and the Raman image of the bubble.

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PLANNING RELATED TO THE CURATION AND PROCESSING OF RETURNED MARTIAN SAMPLES. Francis M. McCubbin and Andrea D. Harrington, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058. francis.m.mccubbin@nasa.gov.

Introduction: The Astromaterials Acquisition and Curation Office (henceforth referred to herein as NASA Curation Office) at NASA Johnson Space Center (JSC) is responsible for curating all of NASA's extraterrestrial samples. Under the governing document, NASA Policy Directive (NPD) 7100.10E "Curation of Extraterrestrial Materials", JSC is charged with "the curation of all extraterrestrial material under NASA control, including future NASA missions." The Directive goes on to define Curation as including "…documentation, preservation, preparation, and distribution of samples for research, education, and public outreach." Here we describe some of the ongoing planning efforts in curation as they pertain to the return of martian samples in a future, as of yet unplanned, mission.

Advanced Curation at NASA JSC: Part of the curation process is planning for the future, and we refer to these planning efforts as "advanced curation" [1]. Advanced Curation is tasked with developing procedures, technology, and data sets necessary for curating new types of collections as envisioned by NASA exploration goals. We are (and have been) planning for future curation, including cold curation, extended curation of ices and volatiles, curation of samples with special chemical considerations such as perchlorate-rich samples, curation of organically- and biologically-sensitive samples, and the use of minimally invasive analytical techniques (e.g., micro-CT, [2]) to preliminarily examine and/or characterize samples. Many of these efforts will be critical for successful curation of returned martian samples. However, to improve our ability to curate the astromaterials collections of the future and to provide maximum protection to any returned samples, it is imperative that curation involvement commences at the time of mission inception.

Importance of Contamination Knowledge: When curation involvement is at the ground floor of mission planning, it provides a mechanism by which the samples can be protected against project-level decisions that could undermine the scientific value of the returned samples. A notable example of one of the benefits of early curation involvement in mission planning is in the acquisition of contamination knowledge (CK). CK capture strategies are designed during the initial planning stages of a sample return mission, and they are to be implemented during all phases of the mission from assembly, test, and launch operations (ATLO), through cruise and mission operations, to the point of preliminary examination after Earth return. CK is captured by witness materials and coupons exposed to the contamination environment in the assembly labs and on the space craft during ATLO. These materials, along with any procedural blanks and non-flight, flight-like, and flown hardware, represent our CK capture for the returned samples and serves as a baseline from which analytical results can be vetted. Collection of CK is a critical part of being able to conduct and interpret data from organic geochemistry and biochemistry investigations of returned samples. The CK samples from a given mission are treated as part of the sample collection of that mission, hence they are part of the permanent archive that is maintained by the NASA Curation Office.

The Mars 2020 mission may represent the first step in a larger Mars Sample Return campaign. Consequently, we must treat the ATLO portion of that mission as any other sample return mission. Specifically, we will collect and curate CK samples so that contaminants can be distinguished from indigenous martian materials within the returned samples. The efforts to collect and curate CK related to Mars 2020 are ongoing, and details regarding the CK efforts are outlined in Harrington et al., [3].

Mars Sample Curation Facility: In the past, there has been a distinction made in the literature between a sample receiving facility and a sample curation facility [e.g., 4]; however, advances in technology over the last decade have demonstrated that the receiving facility may be a mobile facility that is deployed to the planned landing site (e.g., Utah Test Range). A mobile/modular BSL-4 receiving facility can meet all current standards and protocols, including redundant systems and critical biological containment/pressurization requirements [5]. This facility could serve as the containment facility for initial life-detection studies and preliminary examination of the samples. This mobile facility could be transported directly to the curation facility for permanent storage and processing once the samples are released. Future studies of sample receiving facilities that require BSL-4 containment may wish to include a comparison review of modern mobile/modular labs as an alternative construction option.

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RECENT ACCOMPLISHMENTS IN MARS EXPLORATION: THE ROVER PERSPECTIVE.

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Introduction: Four rovers have successfully operated on the surface of Mars: Sojourner (1997), Spirit (2004-2010), Opportunity (2004-present) and Curiosity (2012-present), and their investigations have revolutionized our understanding of Mars geology [1-3]. Nevertheless, even with their remarkably sophisticated analytical capabilities – that with Curiosity stretches the boundaries of what is capable by robotic explorers – it is clear that many of the critical scientific questions related to Mars science cannot be fully addressed by rover *in situ*, laboratory and remote sensing, even when combined with orbital analyses, and that samples from Mars must be examined in terrestrial laboratories.

Sedimentary Environments and Habitability: Rovers provide a testament to the likelihood that if ancient life and/or its prebiotic chemistry ever took hold on Mars, knowledge of it can be extracted from the geological record. Thus, rovers have identified and characterized habitable environments in sedimentary, surficial hydrothermal and deeper hydrothermal settings. Spirit identified opaline silica-rich rocks and soils with similarities to modern microbial-bearing hot spring deposits and Noachian outcrops composed of Mg-Fe-carbonates interpreted as near-surface hydrothermal precipitates or evaporites. Opportunity identified Hesperian-aged aeolian-playa sedimentary rocks, although textures and mineralogy indicate low water activity diagenetic regimes of limited habitability. Opportunity also characterized Noachian(?) impact deposits that include features consistent with deeper seated hydrothermal activity (Ca-sulfate veins, highly elevated Zn, bleached and altered fracture zones). Curiosity explored Hesperian fluvio-lacustrine sedimentary rocks and provided thorough sedimentological-stratigraphic-geochemical documentation of an ancient redox stratified lake. Curiosity's payload further identified organic molecules and minerals that provide both the building blocks of life (C, H, O, N, S, P) and energy sources required to sustain chemoautotrophic microbial metabolism (Fe, Mn, S redox pairs).

Igneous History and Geochronology: Rovers have documented an unexpected highly diverse igneous history for Mars, including recognition of alkaline igneous provinces and rare highly differentiated magmatic rocks. Indeed, one of the most important rover findings has been that the mostly young igneous SNC meteorites are not representative of the ancient (pre-Amazonian) crust. While petrological and isotopic studies of SNC meteorites on Earth have provided great insights into the composition and evolution of the Martian crust-mantle system, it remains a highly incomplete view without laboratory analyses of the full range of igneous compositions and ages.

Radiometric age dating is a necessary constraint on many critical questions for Mars and a remarkable accomplishment of Curiosity has been the first *in situ* surface exposure ages (He, Ne, Ar) and whole rock radiometric ages (K-Ar) on Mars. Nevertheless, uncertainties in interpreting such ages merely reinforce the need for samples where multiple methods and experiments can be applied to resolve such complexities.

Mars atmosphere: Spirit and Opportunity have documented seasonal variations in Martian atmospheric Ar content over many years. Curiosity has analyzed the chemical and isotopic composition of the atmosphere, greatly extending and refining our understanding of its evolution. Among the major new findings are low but variable methane contents and better refined models of atmospheric loss over geological time.

Discussion: There will continue to be a role for rovers in the exploration of Mars for the forseeable future; planned missions by NASA (Mars2020), ESA (ExoMars) and China will continue to study the surface of Mars. But we are now at a point where many of the highest priority science questions require returned samples in order to make significant further progress. In addition to exploring habitable settings and characterizing remarkable geological diversity, rovers also have provided the necessary experience for developing exploration strategies that will be invaluable for any MSR sampling/caching campaign, regardless of landing site (i.e., geological setting). Thus, approaches will be different for sedimentary rocks, where stratigraphy is key, and hydrothermal settings, where mapping geological relationships will be required. Rover missions have provided experience in documenting geological and stratigraphic context of sample location sites, coordinating rover activities with orbital observations, documenting geological diversity through study of both outcrops and components in fragmental rocks and, most importantly, developing sample selection strategies/priorities.

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HOW CAN WE LOOK FOR FOSSILS ON MARS? S. McMahon[1], T. Bosak[2], J. P. Grotzinger[3], D. E. G. Briggs[4], J. Hurowitz[5], N. Tosca[6], A. Petroff[7], R. E. Summons[2], B. P. Weiss[2] [1]UK Centre for Astrobiology, University of Edinburgh, UK, sean.mcmahon@ed.ac.uk, [2]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, [4]Department of Geology and Geophysics, Yale University, New Haven, CT 06520, [5]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794, [6]Department of Earth Sciences, Oxford University, Oxford, UK, [7]Department of Physics, Clark University, Worchester, MA 01610.

Introduction: The Mars 2020 mission seeks to collect samples with a high potential to preserve signatures of past life. The emerging field of comparative planetary taphonomy aims to guide this search and identify optimal targets.

Insights from Earth show that environments with fine-grained sediments are likely to yield fossils. In contrast, other settings, such as serpentinizing environments or deep aquifers on Earth, have a poor potential to preserve fossils and would require very large samples to reliably yield any biosignatures. Recent discoveries by Mars missions have revealed paleoredox boundaries, precipitated Fe-Mg clay minerals, Fe oxides and Fe-Mg carbonates in environments with much greater potential to harbor and preserve abundant life [1]. Notable is the high abundance of oxychlorine compounds unique to Mars that complicate the detection of organic compounds. Experiments that integrate insights from fossil preservation on Earth with chemical conditions relevant for Mars can guide the identification of sampling targets and improve detection techniques as well as our understanding of processes that yield false positive biosignatures.

Exceptional preservation: Exceptionally preserved fossils in iron-, silica- and sulfur-rich sediments on Earth provide the framework for comparative planetary taphonomy. Regardless of environmental context, organisms are fossilized when the original organic material resists decay, or when early precipitation of authigenic minerals replicates morphological details. This does not happen often: most bacteria, archaea and organic-walled unicellular eukaryotes, and about 60% of macroscopic marine animals, are soft-bodied and decay within weeks, before they can become fossilized. Thus, Mars 2020 should target environments that may have harbored abundant life and experienced rapid mineral precipitation.

Fossilization and organic preservation on Mars: Laboratory experimental studies provide process-oriented understanding of fossilization and can address planet-specific differences. Environments where secondary minerals form rapidly during authigenesis and early diagenesis, such as those recognized in Gale crater [2], are most likely to preserve potential biosignatures on both early Earth and Mars. Modeling constrained by rover-based observations can provide better constraints on rates of sediment transport and authigenic mineral formation on Mars.

Oxychlorine compounds: A major gap in our understanding of organic preservation on Mars arises from the high abundance of oxychlorine compounds which obstruct the detection of organic compounds by the *Sample Analysis at Mars* (SAM) instrument's pyrolysis approach. These compounds appear to be a ubiquitous component of rocks at Gale crater, present at ~1 wt.% concentrations in most sedimentary rocks examined by Curiosity [3]. We do not know how soluble oxychlorine compounds were incorporated into Martian sedimentary rocks, why they are distributed uniformly within Gale crater, and what implications they have for Martian taphonomy.

We hypothesize that: 1) these compounds were incorporated by adsorption and/or co-precipitation with early authigenic and early diagenetic mineral phases; and 2) their presence may have affected fossil and organic preservation. Taphonomic experiments can test these hypotheses by characterizing the distribution of soluble oxychlorine compounds in organic matter and authigenic mineral phases. The results will have direct implications for fossilization on Mars and could lead to new approaches for *in situ* characterization of Martian organic matter.

False positives: Abiotic water-rock interactions, redox gradients and diagenetic processes can form silica sinter on altered volcanic rocks [4, 5], hydrothermal textures in sediments, and accompanying elemental distributions that mimic traces of life. Thus, the search for biosignatures on Mars must: 1) recognize abiotic processes that produce silica- and iron-rich structures with morphologies similar to examples on Earth and Mars; and 2) rigorously estimate the probability that a given sample is the result of an abiotic process. We address this by developing experimental systems that mimic hot springs and other hydrothermal settings where silica-saturated solutions evaporate quickly in a low-pressure atmosphere similar to that on Mars (<10 mbar).

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MARTIAN METEORITES: WHAT HAVE WE ALREADY GLEANED FROM SAMPLES, AND WHAT ARE WE MISSING? H. Y. McSween[1], C. D. K. Herd[2], M. Humayun[3], and D. Beaty[4]. [1]Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN, USA, mcsween@utk.edu, [2]Department of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Canada, [3]Department of Earth, Ocean & Atmospheric Sciences, Florida State University, Tallahassee, FL, USA, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Accessible (and Free) Martian Samples: A Mars source for the shergottite, nakhlite, and chassignite meteorites, proposed almost 4 decades ago, has been documented by shock-implanted gases in them that precisely match the unique martian atmosphere [1]. More than a hundred of these meteorites have now been recognized and studied [2]. All are mafic or ultramafic in composition and, with the lone exception of one regolith breccia, are igneous rocks (basalts and cumulates).

Accomplishments of Mars Sample Science to Date: Martian meteorites have played pivotal roles in complementing remote-sensing data to understand Mars' geologic processes and history [e.g. 3], and in defining exploration goals and capabilities for past and future missions. Some major science advances include:

- geochemical and isotopic constraints on the planet's bulk composition and volatile inventory,
- the basaltic composition of the crust and its trace element abundances,
- complete mineralogies of rocks, including phases not detected by remote sensing,
- distinctive oxygen isotopic signature,
- documented ongoing igneous activity spanning more than 4 billion years,
- compositionally different and isolated mantle source regions and temporal evolution of magma compositions,
- absence of mantle mixing or crustal recycling through plate tectonics,
- basaltic protoliths for sediments and soils, and limited chemical weathering,
- pervasive shock metamorphism of surface rocks,
- current atmospheric composition and information on planetary outgassing and atmospheric loss mechanisms.

Limits on the Meteorite Collection: Except for 4.1-Ga ALH 84001 and 4.4-Ga NWA 7533/7034, the martian meteorites are all young (crystallization ages of <2.4 Ga, with most <0.2 Ga). However, most of the martian surface is ancient; the biased meteorite age sampling probably reflects the difficulty in launching non-coherent rocks like those pounded over millennia by impacts. Clustering of cosmic-ray exposure ages suggest the meteorites derive from perhaps 8-10 sites [3], with each site providing a specific rock type. However, no launch sites for specific meteorites have been confidently identified, although rayed craters are likely the best candidates [4].

What Martian Meteorites Do Not Tell Us: The geologic units on Mars interpreted as fluvial, lacustrine, evaporative, hydrothermal, aeolian, or pyroclastic have not been sampled by meteorites. These kinds of rocks are most likely to contain significant prebiotic or even biotic organic matter. The lone (but paired) regolith breccia meteorite, NWA 7533/7034, represents the only sedimentary sample in the collection [5]. However, it is mineralogically distinct from most martian soils and does not reveal information about the environmental conditions that yielded clays, amorphous phases, and evaporites on ancient Mars. Despite much ado about possible evidence for martian life in ALH 84001 [6], subsequent analyses indicate that its intriguing microscopic morphologies, minerals, and organic matter had abiotic origiins. (This controversy has, however, has sharpened the astrobiological tools to be used on future returned samples and prompted a Mars exploration program focused on the search for life.) Although Amazonian igneous activity is fairly well represented in the meteorite collection, magmatism in Hesperian and Noachian times is almost unsampled. Because the meteorites' launch sites and stratigraphic context are unknown, radioisotope chronology cannot be used to underpin a planetary chronology based on crater size-frequency distributions.

Mars has joined the Earth and Moon as the best characterized solar system objects, in large part because we have samples to study in the laboratory. However, bias in sampling of different rock types and ages and the absence of geologic context for martian meteorites demonstrate the critical need for return of carefully selected Mars samples to Earth.

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MARS RETURNED SAMPLE HANDLING FUNCTIONALITY. M.A. Meyer[1] and R. L. Mattingly[2], [1]NASA Headquarters, 300 E Street, SW, Washington, DC 20546, [2]Mars Program Office, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109

Introduction: A Mars Sample Return (MSR) campaign with the goal of returning samples before 2030 is under consideration. The Mars 2020 Rover mission currently in development would perform the sample collection and caching for potential return. Following 2 more missions, the final leg of the campaign would be an entity that we have referred to as Mars Returned Sample Handling (MRSH), which includes the activities between the landing of samples on Earth and initial sample analysis. This talk will address our current view of the functional requirements on MRSH, focused on the Sample Receiving Facility (SRF).

MRSH notionally has three components of functionality. Initially Ground Recovery Operations (GRO) would be responsible for safing the entry capsule with the samples, and safely transferring the capsule to a SRF while protecting the samples. The operations in the SRF include acceptance of the returned space hardware and samples, perform preliminary sample evaluation and assess the safety of samples while also ensuring strict containment and contamination control. Samples confirmed to be non-hazardous or rendered “safe” by sterilization would be placed in long-term curation in a Mars Curation Facility (MCF) while maintaining individual sample integrity with controlled access to outside labs.

Genesis of requirements: In the early 2000s, an MRSH Working Group was established, to define the functionality and provide oversight of industry studies. The results of these studies are summarized in a 2009 research article in Astrobiology [1]. Since then;

M2020: In the development of the Mars 2020 Rover Mission, several activities were organized to assure samples will be of the quality required for effective analysis (science and planetary protection) if returned.

- Returned Sample Science Board, defining sample quality requirements
- Planetary Protection requirements details.
- Starting curation of pre-launch organic and inorganic contamination knowledge artifacts.

MSR Internationization: A renewed interest in an international MSR emphasizes the need for remote access to samples and analysis. International sample management was subject of the iMARS-II study [2].

Challenges: A few of the key challenges:

1. The samples and other Mars material must remain in quarantine containment until proven safe by analysis or sterilization.
2. The samples must remain pristine through-out, to enable world-class science, and life and hazard assessment.
3. International access and international management and oversight are required. This is an international endeavor and effects the world.
4. Both cost and risk need to be minimized to fit within a reasonable program implementation.
5. Maintaining preflight contamination-knowledge artifacts over a decade to be available for returned sample analysis.

Input Needed: several of the many areas need to be addressed to adequately understand the requirements:

1. What investigations need to be performed on the samples. The iMOST study is updating current requirements with an international view-point.
2. What measurements have to be made on samples while under containment and what investigations can be performed on sterilized samples. The current thinking is that the SRF is for analysis while under quarantine, and sufficient to characterize the samples and demonstrate sample safety. Remaining measurements can be performed in outside laboratories. In addition, how much flexibility is needed to introduce additional instrumentation responsive to discovery? Is access to other facilities (like a synchrotron) needed while samples are in containment?
3. Testing protocol [3] to certify samples are safe needs to be updated. Animal/plant challenge testing required may be outdated. A strategy should be developed that the science performed within the SRF informs planetary protection adequately such that separate testing (and sample use) is not needed.

Summary: This talk will discuss concepts for the SRF and our current view of the functional requirements on MRSH. If samples are to be returned by 2030, over the next year we need your expert input to help formulate an international SRF.

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(iMARS) Phase II (2016)

MARS SAMPLE RETURN LANDER MISSION CONCEPT. B. K. Muirhead[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

This talk will provide an overview of current concepts and options for the architecture and design of a Mars Sample Return Lander (called Sample Return Lander, SRL). Key mission objectives and the overall baseline mission design will be described, including the mission's concept of operations and a notional timeline from launch to entry, through surface operations, to delivery of the samples to Mars orbit.

The overall lander vehicle concept will be described, including current options being evaluated. Key lander element options will be discussed, including the Mars Ascent Vehicle (MAV), Fetch Rover, Orbiting Sample container (OS), and tube transfer robotics systems.

Specific challenges and approaches for addressing those challenges will be discussed, including key technical margins and planetary protection. Major trade studies and implementation approaches and a proposed schedule will also be discussed.

The information provided about possible Mars sample return architectures is for planning and discussion purposes only. NASA has made no official decision to implement Mars sample return.

LANDING SITE SELECTION ON MARS IN IAPYGIA QUADRANGLE. Saumitra Mukherjee, Priyadarshini Singh, Deepali Singh, and Nidhi Roy, Remote Sensing Applications Laboratory, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, 110067, India. (saumitramukherjee3@gmail.com)

Introduction: The study area centred at 56.233ºE and 7.787ºS lies in the Iapygia quadrangle of Mars flanked by Schroeter crater in the north and Huygens crater in the south (Fig. 1.). The extraction of the palaeo-drainage network within the region suggests that it is a flat terrain with a depression of ~500m covering an area of around 20,000 square kilometres. Several streams of the drainage network end into this basin making it a reservoir of several deposits brought in by these channels.

Data sets and Methodology: We have utilized CTX images (6m/pix) and other global datasets including basemaps of THEMIS day IR (100 m/pix), HRSC and MOLA Blended Digital Elevation Model (200m/pix). Each basemap was imported into ArcGIS 10.1 and THEMIS map was overlaid on HRSC MOLA Blended DEM to study morphological features inside the basin.

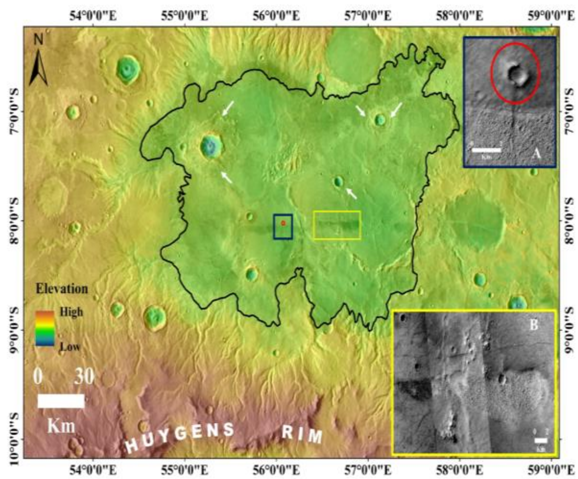

Fig. 1. Study area is outlined in black. Note the difference in ejecta morphology of rampart craters (white arrows) towards the eastern and western side of the basin. Deformed crater rim [inset A]; Dike system and parallel flow deposits [inset B].

Discussion: Following reasons suggest that the proposed area can be a prospective landing site for exploration:

(a) Morphology: Rampart craters having ejecta morphologies ranging from radial to single and double layered with comparable crater sizes have been observed [1]. The eastern side of the basin has single layered circular and pancake type ejecta layer whereas the western side has double layered hummocky ejecta implying that there is higher volatile concentration in that side (Fig. 1.). An extension of a dike network reported by [2] is seen in high resolution CTX image mosaic of the area (Fig. 1. inset B). Further, similar studies on Mars as well as Earth show emplacement of such structures in volatile rich deposits [2]. Parallel to the dike, flow deposits are visible running from east to west as inferred from DEM (Fig. 1. inset B). This is consistent with the depositions seen in the western and northern side of the basin further confirming flow towards the topographically low western region. In addition, deformation of a crater rim is observed along a lineament running from north to south (Fig. 1. inset A). Similar features indicating recent subsurface fault activity in the region may further be explored.

(b) Biosignature preservation: Central to presence of life on Mars is the concept of habitability, the set of conditions that allow the emergence of life and successful establishment of microorganisms in any one location. While the environmental conditions may have been conducive to the appearance of early life in Martian history, habitable conditions were always heterogeneous on a spatial scale and in a geological time frame. Ponding of water can also provide a prime setting for harbouring life and preserving it during adverse climatic conditions [3,4].

(c) Regional Geology: The study area has been mapped as a part of Late Noachian highland unit extending upto lava flows of Syrtis Major in the northeast region [5]. The area has some olivine deposits, indicative of effusive magma events, as well as high-calcium pyroxene abundance [6] both of which contribute to high thermal inertia. Aqueously altered minerals including hydroxylated silicates are also present on the north-western periphery of the basin.

Conclusion: Sampling done in the vicinity of the dike system makes this site suitable for the collection of representative samples of deeper crustal/mantle materials. Evidence of aqueous sedimentation increases the probability for preservation of biosignatures thereby making it a prospective sampling site. Moreover, a permanent sampling station can also be established within this relatively flat basin with diverse morphological features.

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Experimental study of an assembly with extreme particulate, molecular and biological requirements in different environmental scenarios from quality point of view

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Projects such as EXOMARS 2020, Juice, Mars Sample Return and any other planned project with dedicated planetary protection constraints, lead to new challenges due to simultaneously achieving extreme levels of particulate, molecular and biological cleanliness levels. The presentation will cover results from an ESA-supported investigation to collect lessons learned for mechanism assembly with the focus on quality and contamination requirements verification, which is particularly important for the subcontractor management.

The heritage of OHB is based on the direct contribution from the High Resolution Camera, the Sample Processing and Distribution System (SPDS), the optical harness and the Analytical Laboratory Drawer (ALD) developments for the ExoMars2020 mission. The contributions cover the full range of cleanliness deliverable status from visible clean components to be finally cleaned by the Customer, up to components integrated in the ultra clean zone.

An additional source of experience was gained by exchange and support from and for other suppliers. In this regard, aspects from manufacturer to customer covering material compatibility, cleaning, sterilization and verification, documentation had to be covered.

To cover these open challenges, OHB and IPA Fraunhofer experts signed a cooperation agreement. The combination of non-space application heritage and the laboratory infrastructure at IPA Stuttgart has initiated several valuable impulses, developments and systematic studies.

One study covers the assembly of a representative mechanism in different environments, including the judgement on particulate, molecular and biological requirements achievement. The main objectives of the study were risk assesment, logistics effort, duration and quality aspects.The results will be summarized in the presentation. The possibility to extract system engineering and design guidelines is currently in preparation at OHB and will be briefly outlined.

This project was cofounded by ESA and OHB.

Furthermore, the presentation will address the difficult interaction of performance driven requirements, within achievable values and the transparent break down into subcontractor requirements, always maintaining a consistent verification philosophy. Finally, we will discuss the challenge of defining for every single part, the cross-over point of high precision cleaning / sterilization, when the effort of contamination control has to be shifted from parts control to process, infrastructure and facility control.

The cooperation of IPA and OHB System reported in the presentation, focussing on cleanliness, cleaning process development and verification methods is supported by ESA.

AN ARCHITECTURE FOR AUTONOMOUS ROVERS ON FUTURE PLANETARY MISSIONS. Ocón, J [1], Avilés, M[1], Graziano,[1] M. [1]GMVAD, Isaac Newton, 11, PTM Madrid, 28760,

Introduction: The Mars Sample Return (MSR) mission consists of bringing to Earth a number of Martian samples for thorough analysis in Earth laboratories, without the time, budget, and space constraints of a space mission. Irrespectively of the final mission architecture, it is widely accepted that the MSR mission will feature at least two surface elements, specifically a lander hosting a Mars Ascent Vehicle (MAV) and a Sample Fetching Rover (SFR).

The SFR will collect samples from the surface/subsurface of Mars, or pick up cached samples from a previous mission and return them back to the MAV.

One of the main challenges that is required in rover planetary missions is the need for on-board autonomy. Three autonomy levels are defined in the ECSS Space Segment Operability standard: preplanned (E2), adaptive (E3) and goal oriented (E4). An autonomous operations concept, that can be considered a combination of adaptive and goal oriented, requires the following characteristics:

- **High level of abstraction** of the on-board activities. A closed control loop that uses sensor feedback enables commanding at a high level of abstraction, commanding via goals.
- The autonomous operations are achieved by **considering the ground control system as part of the end-to-end Rover control architecture** where the deliberative tasks, and in particular planning, are shared between on-board software and software on ground.
- **Reactive event-based activity execution**. This means that the rhythm of execution of the activities is driven by the occurrence of events that indicate that a given situation has been detected
- **Autonomous navigation**. The Rover will be able to autonomously navigate the surface of Mars given a target point. Therefore, emphasis must be given to a reasonable mobility of the rover, which must be at least in the range of future precision landing ellipse dimensions (< 10km) in the case of the SFR collecting cached samples or even up to 20 km in the scenario where the SFR will have to also do the sampling.

The architecture that we will describe in this paper is aimed to tackle these characteristics. This architecture is being/has been developed and tested by GMV in ongoing projects (GOTCHA) as well as previous projects (SPARTAN, SEXTANT, COMPASS)

Within the proposed architecture, a **single agent or controller** is in charge of performing the traditional deliberative and executive layers of a three-layer architecture. The first two characteristics mentioned before: **high level of abstraction and on-board deliberation**, are provided by the agent that can be commanded from ground based on a set of high-level commands or goals (i.e. "during this sol goto a given site to take a sample"). Goals are decomposed on-board by a planner, and the plan is executed by the agent. In parallel, quick **reactive event-based activity execution** is also provide by maintaining a set of event-action tables that are updated periodically from ground, and guarantee the survivability of the rover in a harsh environment.

Similarly, a long traverse **autonomous navigation system** is needed to allow faster traversals compared to current rovers, which only travel around 100 meters per sol. Basing navigation on computer vision is attractive owing to the passive mode of operation, simple hardware, small form factor and low power consumption of camera sensors. However, vision based techniques are computationally demanding, which becomes a particularly challenging problem considering the limited computational resources available on board such rovers.

Our navigation solution relies on an **optimized, hardware embedded vision-based system** for long traverse autonomous navigation of planetary rovers meeting the high demands of future missions where large and fast traversals are required. The system is a SW/HW co-design combining the high computing power and low power consumption of an FPGA together with the higher floating point accuracy and flexibility of a processor. The choice of employed algorithms was based not only on their raw performance in terms of accuracy or robustness, but also on their suitability for being implemented in a FPGA. This allows a much more efficient system in terms of computing power, memory footprint, communication needs, energy use, speed and configurability. The hardware logic has been optimized to fit into current space-grade FPGA devices but also into networks of smaller devices comparable in size and performance to the next generation European space-grade FPGA devices co-funded by ESA (i.e., the BRAVE family of FPGAs). The SW elements of the design were implemented on a LEON processor running RTEMS, thus resulting into a space ready navigation component.

MARTIAN METHANE CYCLE AND ORGANIC COMPOUNDS FROM MARTIAN REGOLITH BRECCIA NWA 7533 BY ORBITRAP MASS SPECTROMETRY. F. R. Orthous-Daunay[1], R. Thissen[1], L. Flandinet[1], L.Bonal[1], V. Vuitton[1], P. Beck[1], M. Hashiguchi[2] and H. Naraoka[2] frod@ujf-grenoble.fr. [1]Institut de Planétologie et d'Astrophysique de Grenoble, Univ. Grenoble Alpes/CNRS, F-38000 Grenoble, France. [2]Research Center for Planetary Trace Organic Compounds, Kyushu University.

Introduction: Exploration of Mars is partly motivated by the question of its habitability and the timing of a possible origin of life like on Earth. This lead to the study of the most blatant life markers that are organic molecules. Due to lack of meteoritic sample very little is known about Martian organic matter with respect to carbonaceous chondrites'. The most simple organic molecule, methane, has been detected in the Mars atmosphere at steady state [1]. This implies the existence of an organic carbon cycle given the quick destruction of methane in this planetary environment. UV photodegradation of exogenous chondritic-like organics delivered to Mars by impacts is thought to be a sustainable source of methane [2]–[4]. Recent measurements of the methane content variability in the Mars atmosphere [5] raised new interest upon the origin of this unstable organic molecule.

NWA7533 is a Martian regolithic breccia wich multiple lithologies described in [6]. It bears clasts with Ir and Ni contents comparable to lunar soils, interpreted as exogenous CI-like material for up to 5wt%. This unique sample possibly carries residues of chondritic organics that underwent the processes related to the CH_4 cycle.

We applied our Orbitrap method to NWA7533 and Murchison. We propose to use the SOM diversity as a proxy of transformation processes occurring on Mars assuming samples are representative of their parent bodies history.

Method: The preparation requires direct physical access to the sample in open air at room pressure. Twice 30 milligrams of NWA7533 were ground and soaked in 6mL of Methanol/Toluene (1:2) solvents for maceration during. Glassware was washed in ethanol with caustic soda and baked at 250°C for 12 hours to eliminate contamination. The sample amount needed depends directly on the organic content. For carbonaceous chondrites, down to 1 mg is enough.

Mass spectra were acquired with a Thermo LTQ Orbitrap XL at its highest resolving power (120000 at m/z = 400). Ions are produced with Electrospay ionization (ESI), both for cations and anions.

Very high resolution mass spectrometry enables a statistical analysis of the molecular diversity. In favorable cases, differential chemistry is described by few consistent "molecular patterns". The identification of a process is achieved by finding a signature distribution among the molecular families with a given pattern. Molecular formulas can be computed from each exact mass by a combination algorithm that takes into account stoichiometric rules.

Results: Martian extracts are slightly simpler than the chondritic mixture. Considering only the cations, the molecular density is lower (~2000 compound for NWA7533 vs. ~2600 for Murchison in the 150-500 m/z range). The Martian extract cations have m/z up to 800 whereas chondritic cations are extremely rare above m/z = 650 with respect to the instrument dynamic range. Martian cations have systematically much lower mass defect than Murchison's. This is due to higher oxygen content, probably in the organic structure, and to the presence of Na adducts.

Repetitive patterns in the NWA7533 are combinations of C, H and O. The most frequent pattern in NWA7533 is CH_2. This group is also very frequent in the carbonaceous chondrites extracts. The mass distribution in carbonaceous chondrites is consistent with polymeric molecular growth whereas it is absolutely not the case for NWA7533. The two other major patterns in NWA7533 are C_2H_2 and the $C_3H_6O_{-1}$ permutation. Where oxygen is part of several other patterns in the Martian extract, it does not appear in the chondritic mixture. The CH_4 pattern is noticed but is not a major one. The absence of signature polymeric distribution in the Martian sample is interpreted as a destruction of an existent mixture similar to the carbonaceous chondrites one. Recent experiment on the irradiation of Murchison organics indicate UV photons can destroy chains effectively [7]. We conclude that the organic matter in this Mars sample was not synthetized on place and is likely to be exogenic chondritic matter that underwent extreme UV irradiation and/or heating on the Mars surface.

Perspective: As the amount of returned sample is very limited, liquid extraction is not guaranteed. Desorption ionization at millimeter scale is currently developed to ionize molecules in dry conditions [8].

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THE CANMARS ANALOGUE MISSION: LESSONS LEARNED FOR MARS SAMPLE RETURN. G. R. Osinski[1,2,3], D. Beaty[4], M. Battler[1,3], C. Caudill[1], R. Francis[4], T. Haltigin[5], V. Hipkin[5], E. Pilles,[1], L. L. Tornabene[1], K. Williford[4] and the CanMars team. [1]Centre for Planetary Science and Exploration / Dept. of Earth Sciences, University of Western Ontario, Canada. [2]Dept. of Physics and Astronomy, University of Western Ontario, Canada. [3]Dept. of Electrical and Computer Engineering, University of Western Ontario, Canada. [4]Jet Propulsion Laboratory, California Institute of Technology, USA. [5]Canadian Space Agency, Canada (gosinski@uwo.ca)

Introduction: In the lead up to a potential Mars Sample Return (MSR) mission [1], simulated "analogue missions" at scientifically relevant sites on Earth provide important opportunities to develop and test technologies, software and operations architectures, and to train personnel [2, 3]. The CanMars analogue mission represents the highest fidelity and longest MSR-focused simulated mission to date and the results and lessons learned for MSR are detailed herein.

CanMars Overview: The current scenario being considered for a future potential MSR activity is a series of three missions: cache, retrieval (fetch-MAV), and transport to Earth. The NASA Mars 2020 mission could represent the first cache mission and was the focus of the CanMars analogue mission. CanMars was conducted over two weeks in November 2015 and continued over three weeks in October and November 2016 at a field site in Utah, USA, that was unknown to the mission control team located at Western, London, Ontario, Canada. The objectives for CanMars included: i) comparing the accuracy of selecting samples remotely using rover data versus a traditional human field party, ii) testing the efficiency of remote science operations with periodic pre-planned strategic traverse days, iii) assessing the utility of realistic autonomous science capabilities to the remote science team, and iv) investigating the factors that affect the quality of sample selection decision-making in light of returned sample analysis.

Both the 2015 CanMars mission, which achieved 11 sols of operations, and the first part of the 2016 mission (sols 12–21), were conducted with the Mars Exploration Science Rover (MESR; [4]) and a series of integrated and hand-held instruments designed to mimic the payload of the Mars 2020 rover. Part 2 of the 2016 campaign (sols 22–39) was implemented without the MESR rover and was conducted exclusively by the field team as a Fast Motion Field Test (FMFT) with hand-carried instruments and with the equivalent of three sols of operations being executed in a single actual day.

This operations architecture for CanMars was based on previous planetary exploration and analogue missions with the Mission Control Team being divided into Planning and Science sub-teams. In advance of the 2015 operations, the Science Team used satellite data, chosen to mimic datasets available from Mars-orbiting instruments, to produce a predictive geological map for the landing ellipse and a set of hypotheses for the geology and astrobiological potential of the landing site.

Science Objectives and Overview: A detailed Science Plan was drawn up that described constrained science objectives in order to focus science team decision-making and help derive lessons from the operations tests, and with direct relationship to Mars 2020 objectives. These objectives were: i) To advance understanding of the habitability potential of sub-aqueous sedimentary environments: learn how to seek, identify and characterize samples containing high organic carbon; and ii) to advance understanding of the history of water at the site. An explicit goal was to return the sample that the science team expected to have the highest total organic carbon (TOC) content.

Lessons learned for MSR: A variety of lessons learned for both future analogue missions and planetary exploration missions are provided, including: i) dynamic collaboration between the science and planning teams as being key for mission success; ii) the more frequent use of spectrometers micro-imagers having remote capabilities rather than contact instruments; iii) the utility of strategic traverse days to provide additional time for scientific discussion and meaningful interpretation of the data; iv) the benefit of walkabout traverse strategies (cf., [5]) along with multi-sol plans with complex decisions trees to acquire a large amount of contextual data; and v) the availability of autonomous geological targeting (cf., [6]), which enabled complex multi-sol plans gathering large suites of geological and geochemical survey data. Further implications of CanMars for a potential MSR mission will be discussed.

Acknowledgements: Thank you to the entire 2015 and 2016 CanMars teams, whose hard work and dedication made this mission a success. This work was funded by the Natural Sciences and Engineering Research Council of Canada's CREATE program and the Canadian Space Agency.

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IMPACT CRATERS AND IMPACTITES AS IMPORTANT TARGETS FOR MAR SAMPLE RETURN MISSIONS.
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Introduction: In determining the science priorities for Mars Sample Return (MSR), the MEPAG Next Decade Science Analysis Group [1] called for 4 primary, high-priority suites of rock to be sampled (sedimentary, hydrothermal, weathering, and igneous). "Impact products" appear under a final, lower priority "Other" category" and "as samples of opportunity".

Meteorite impact craters have featured prominently in the surface exploration of Mars; typically highlighted as sites offering unique bedrock exposure (e.g., Victoria Crater during the MER Opportunity's expeditions) or as sedimentary basins providing unique climate records (e.g., Gale Crater, landing site for the MSL Curiosity rover). However, we propose that in addition to providing exposure and records of infilling, impact craters represent prime astrobiology exploration targets for MSR missions. As outlined below, impact craters could have provided conditions for the emergence of life on Mars through the production of both substrates for prebiotic chemistry and critical habitats for the emergence and survival of life. We thus respectfully propose that impact craters and their products ("impactites") should be reconsidered as high priority targets for MSR.

Substrates for prebiotic chemistry: One of the major advancements in recent years regarding the origins of life has been the recognition of the important role of mineral substrates [2]. Specifically, it has been proposed that minerals may have been a key factor in the formation of organic molecules. Clay minerals, and in particular montmorillonite, have been shown to catalyze a variety of organic reactions, in particular the formation of RNA [3, 4].

Clays and other hydrated minerals have been widely documented on Mars, and are preferentially associated with the heavily cratered highlands; although some lowland exposures, exclusively in impact craters, have also been found [5]. The interpretation for this association of clays with impact craters has generally been that the craters have exposed pre-existing clays. However, it is important to note that impact events can also generate primary clays through impact-generated hydrothermal alteration [6, 7] and through the devitrification of hydrous impact melt products. Thus, clays within impact craters may be pre-impact (i.e., excavated), syn-impact (i.e., impact-generated), or post-impact (i.e., impact crater lakes) [7]. Regardless of the origin, clays, widely held as being important for prebiotic chemistry, are prevalent within impact craters on Mars.

Habitats for emergence and evolution of life: On Earth, one of the most widespread theories for the origin of life is that it originated in hot, aqueous environments [8]. Volcanic heat sources drive nearly all active hydrothermal systems on Earth today, however, it has been shown that most large impact events on Earth and Mars likely generated hydrothermal systems [6] that based on numerical modeling may have persisted for hundreds of thousands of years [9]. Thus, hydrothermal systems generated by the impact craters themselves may have provided habitats for the emergence of life on Mars.

In addition to hydrothermal systems, impact craters also generate other important habitats: 1) impact-processed crystalline rocks that have increased porosity and translucence compared to unshocked materials, improving microbial colonization [10, 11]; 2) impact glasses that can provide bioessential elements and preserve microbial trace fossils [12]; and 3) impact crater lakes that form protected sedimentary basins with various niches and that increase the preservation potential of fossils and organic material [13].

Summary: In addition to providing locations where all the 4 high-priority MSR suites (sedimentary, hydrothermal, weathering, and igneous) could be sampled, we suggest that given the astrobiological potential of impact craters, an Impact Products suite be considered a high priority for MSR.

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MARS ORBITING SAMPLE (OS) CAPTURE AND CONTAINMENT TECHNOLOGY DEVELOPMENT.

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Introduction: Part of any notional Mars Sample Return scenario [1] is the need to return the collected samples from the Martian surface safely back to the Earth. This function has been studied for a large number of potential mission architectures, with most MSR architectures approaching the return as a rendezvous and capture of the Orbiting Sample (OS) in low Mars orbit, followed some type of encapsulation and/or sterilization (containment) of the OS for planetary protection purposes, then a Mars-to-Earth transit followed by a direct atmospheric entry in an Earth Entry Vehicle (EEV) to a landing on the Earth's surface. This paper describes one such approach to the OS capture and bio-containment.

Orbiting Sample Capture: In this approach, the MSR OS would be captured and prepared for Earth return as part of a sample orbiter mission. The key requirements include: (1) the need to *capture the OS* based on a range of potential closing velocities and positional/angular offsets, which drives the capture subsystem design, (2) the need to *orient the OS* for eventual placement into the EEV, which drives the orientation subsystem design, (3) the need to *encapsulate and/or sterilize the OS* so that no uncontained and unsterilized Mars material would be allowed to be released into the Earth's biosphere, which drives the containment susbsystem design, and (4) the need to *place and secure the contained OS* into the EEV, which drives the contained transfer subsystem design. All of these functions must be performed under remote monitoring and control, except for the capture function, which requires autonomous activation to satisfy the dynamic timing requirements of the OS rendezvous.

Potential technology solutions for these operational challenges are described, and an integrated design concept that satisfies the capture, orient, containment, and transfer functions is presented.

Containment: Any potential MSR mission must assure a very low probability of inadvertent release of Mars material into the Earth's biosphere in order to provide protection against the extremely unlikely possibility of biological hazards in the returned material [2]. Backward planetary protection (aka containment assurance) requires breaking the chain of contact with Mars: any Mars material reaching Earth must be inside a robustly sealed sample container. In addition, the integrity of the sample container must be maintained (with an unprecedented degree of confidence) until delivered to a secure receiving facility on Earth.

Potential planetary protection requirements and potential challenges to containment are discussed, plans to assess and mitigate these challenges are outlined, and corresponding technology development is described.

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[1] National Research Council (U.S.). Committee on the Planetary Science Decadal Survey. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. Washington, D.C.: National Academies Press; 2011.

[2] Planetary Protection Provisions for Robotic Extraterrestrial Missions, *NPR 8020.12D*. Washington, D.C.: NASA Headquarters; 2011.

Acknowledgment: A portion of the research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The information provided about possible Mars sample return architectures is for planning and discussion purposes only. NASA has made no official decision to implement Mars sample return.

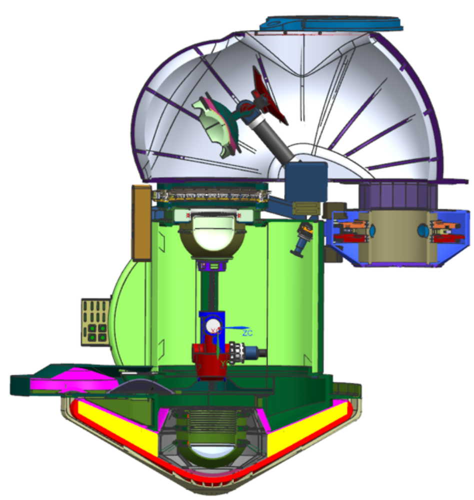

Figure 1: Notional OS capture and containment system concept, including Earth Entry Vehicle (EEV).

A Maturing Earth Entry Vehicle Concept for Potential Mars Sample Return.

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Introduction: Part of any notional Mars Sample Return Mission [1] is the need to return the collected samples from the Martian surface safely back to the Earth. This function has been studied for a large number of potential mission architectures, with most MSR architectures approaching the return as a rendezvous and capture of the Orbiting Sample (OS) in low Mars orbit, followed some type of encapsulation and/or sterilization (containment) of the OS for planetary protection purposes, then a Mars-to-Earth transit followed by a direct atmospheric entry in an Earth Entry Vehicle (EEV) to a landing on the Earth's surface.

Abstract:

This presentation describes the most recent efforts by JPL's Mars Formulation Office to mature an EEV concept that could be used on a potential MSR campaign. Due to the overall complexity of MSR and challenging 'Earth return' planetary protection requirements, the EEV has been architected for simplicity, robustness, and exceptional reliability. The first EEV concept was developed by Mitcheltree et al. [2] for the original MSR project in the late 1990s. Since then a number of architectural assumptions and design requirements have changed, warranting new examination of the EEV design and trade space. The key changes influencing EEV design are 1) an increase in the size and baseline quantity of sample tubes, 2) a maturing orbiting sample container design, 3) a new on-orbit 'break-the-chain' containment approach, and 4) a higher than previously anticipated entry velocity needed for new potential return trajectories. As in the original EEV concept, the current reference concept shown in Fig. 1 is entirely passive and relies on high performance materials and a simple design to achieve the high level of robustness and reliability required for planetary sample return missions. The vehicle employs a ballistic entry, has no parachute system, has no active electronics or mechanisms, and relies entirely on aerodynamic drag during entry coupled with an impact absorbing structure during landing to reduce loads to levels were containment and survival of the encapsulated samples can be nearly guaranteed. The current EEV concept differs from earlier EEV concepts in several ways. The most notable & differentiating design features of the current concept are a carbon-carbon hot-structure heatshield and a carbon-phenolic wrapped stiff-shell 'containment assurance' module. A brief history of early EEV concepts, a discussion of the key design trades, and details of the current reference EEV concept will be presented.

References:

[1] National Research Council (U.S.). Committee on the Planetary Science Decadal Survey. Vision and Voyages for Planetary Science in the Decade 2013-2022. Washington, D.C.: National Academies Press; 2011.

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Acknowledgment:

A portion of the research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

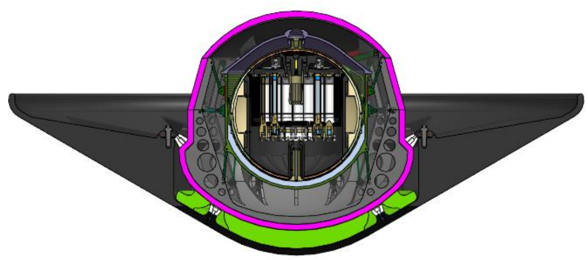

Figure 1: Section view of current reference hot-structure EEV concept.

MSR Fetch Rover Capability Development at the Canadian Space Agency. M. Picard[1], V. Hipkin[1], D. Gingras[1], P. Allard[1], T. Lamarche[1], S. G. Rocheleau[1], and S. Gemme[1], [1]Canadian Space Agency, 6767 Route de l'Aeroport, St Hubert, J3Y8Y9, Canada (Victoria.Hipkin@Canada.ca)

Introduction: The Canadian Space Agency (CSA) undertakes Planetary Exploration activities in international partnership and recognizes robotics as a Canadian strength. A significant early investment has been support for procurement, through ESA, of the 6-wheeled ExoMars Bogie Electro-Mechanical Assembly [1] from McDonald Dettweiler Associates, based in Brampton, Ontario. Later CSA investments supported the development of several ground prototypes of mobility systems for the moon and Mars. A multi-year campaign of technology development and test has followed, based on the Mars Sample Return architecture requirements developed under iMARS [2] , and culminating in CSA's 2016 Mars Sample Return Analogue Deployment at a Mars analogue site in Utah, USA. The 2016 campaign used the Mars Exploration Science Rover (MESR) platform in a high fidelity science operations simulation of a MSR Cache mission 'CanMars' conducted in partnership with University of Western Ontario [3] , followed by several days of tests related to a MSR Fetch Rover scenario. This paper describes the Fetch Rover scenario and tests which successfully demonstrated autonomous navigation to 'cache depots' of Mars 2020-like sample tubes lying on the ground, acquisition of 6 such sample tubes, and transfer to a Mars Ascent Vehicle (MAV) mock up.

Sample tubes: The sample tubes retrieved by the Fetch rover were 3D printed in plastics based on a 3D model of the Mars 2020's Returnable Sample Tube Assembly (RSTA) that was provided to the CSA team by NASA/JPL. These RSTA mockups featured an internal ballast so total mass would range from 100 g to 150 g. This is representative of an RSTA made in titanium and filled with 35 g of Martian material.

The Fetch Rover Scenario: The Fetch rover scenario was derived from an MSR architecture incorporating an adaptive caching strategy [4]. This scenario assumes 'cache depots' would contain RSTAs in a yet to be determined pattern and would likely be located on benign terrain, e.g., on fairly flat areas.

End to end operations: Fetch operations lasted 47 hours distributed over 6 sols from Sol 22-28 of the longer MSRAD campaign (Figure 1, bottom). On Sol 22 the rover successfully 1) egressed from its lander mockup, 2) traveled autonomously about 27 m to reach the closest cache depot, 3) captured and stored one RSTA, 4) droved another 27 m to get back to the lander, 5) inserted the retrieved RSTA into the Tube Orbiting Container (TOC) on the MAV. Over the entire MSRAD Fetch phase, the rover traveled a total of 613m in autonomous navigation mode. No emergency stop was triggered from the field safety officer. Autonomous navigation is reported in a companion paper [6].

Figure 1: The Fetch rover inserting a RSTA into the TOC using CSA's Mechanical RSTA Acquisition Tool (MecRAT)

Summary and Future Work: A simple and effective adaptive cache fetch rover concept was successfully demonstrated for the first time in 2016 at a Mars analogue site in Utah, USA, significantly reducing the risk associated with such an approach. Future technology development could include a next generation MecRAT prototype with development of an automatic RSTA detection and pose estimation using computer vision techniques to simplify operations even further. CSA plans a Fetch Rover concept study in 2018 which will revisit rover design with respect to accommodation within NASA lander concept, and consider what additional science or human exploration mission objectives might be met by an extended Fetch rover mission at the Mars 2020 landing site.

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Acknowledgments: This work was supported by the Canadian Space Agency. The MESR rover was built by MDA Corp.

RD860 AND RD860L ENGINES WITH DEEP THRUST THROTTLING AND A HIGH TECHNOLOGY READINESS LEVEL (TRL). O.O. Prokopchuk[1], V.A. Shul'ga[2], O.V. Dibrivnyi[3] and A.S.Kukhta[4], [1-4]Yuzhnoye State Design Office, 3, Krivorozhskaya str., 49008, Dniepropetrovsk, Ukraine, info@yuzhnoye.com.

Introduction: To solve the problems of delivering payloads to Mars surface and returning them to the orbit, liquid rocket engines, operating on storable propellants with deep throttling possibility, are needed, besides, having high energy-mass characteristics and an ability to provide multiple operational runs in flight. Another determining factor is the high reliability requirements for such engines, which can be achieved either by duplicating engine components and subsystems, or by high reliability of engine components, confirmed by a significant amount of development tests, and in the ideal case – by flight tests. The cost and time of development, for such an engine, are also important.

Taking the abovementioned into account allow, it is reasonable to use proven technical solutions and elements of existing serially produced engines, it will allow reducing the time and cost of development with a significant increase in reliability.

One of the alternatives may be the creation of such engine basing on the serially produced by SDO Yuzhnoye and Yuzhmash PA (VG143) main engine assembly, for the VEGA LV AVUM upper stage. For more than 5 years of operation, this engine proved to be very effective when working in flight conditions during 11 launches of Vega LV. Moreover, the combustion chamber of this engine (in different modifications) successfully operated as a part of YSDO engines (RD859, RD864, RD866, RD869) in a fairly wide range of thrust.

In this case, we are considering the possibility of creating a single chamber engine RD860 with thrust adjustment in a range from 250 to 500 kgf, and a three chamber engine 860L with thrust adjustment in a range from 250 to 1000 kgf. Providing such thrust adjustment will require changing engine combustion chamber pressure in a range from ~20 to ~41 kgf/cm^2. A high TRL level at the initial phase of work can be achieved by applying pneumopump propellant feed system, developed for operating with this combustion chamber within the scope of program on creating DU802 propulsion system.

Main advantages of pneumopump propellant feed system are: the ability of providing high energy-mass characteristics by increasing combustion chamber pressure (with low pressures at engine inlet), simple, and, consequently, more reliable pneumopump design in comparison with turbopump; high accuracy of providing a propellant mixture ratio ±1%, without using additional regulation units, and simplicity of providing multiple operational runs.

The report will present approaches on creating an engine with a pneumopump propellant feed system, on serially produced (VG143) main engine assembly, for the VEGA LV AVUM upper stage; layout and characteristics of RD860 and RD860L engines with pneumopump propellant feed systems. The estimated development time-frame and TRL levels for the engine and its parts and units will also be provided.

SAMPLE QUALITY STANDARDS FOR RETURNED MARTIAN SAMPLES. The Returned Sample Science Board (D. W. Beaty[1] and H. Y. McSween[2], co-chairs; B. L. Carrier[1], A. D. Czaja[3], Y. S. Goreva[1], E. M. Hausrath[4], C. D. K. Herd[5], M. Humayun[6], F. M. McCubbin[7], S. M. McLennan[8], L. M. Pratt[9], M. A. Sephton[10], A. Steele[11], and B. P. Weiss[12]), [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [2]University of Tennessee, Knoxville, TN, [3]University of Cincinnati, Cincinnati, OH, [4]Universitiy of Nevada, Los Vegas, NV, [5]University of Alberta, Edmonton, Canada, [6]Florida State University, Tallahassee, FL, [7]NASA Johnson Space Center, Houston, [8]Stony Brook University, Stony Brook, NY, [9]Indiana University, Bloomington, IN, [10]Imperial College, London, U.K., [11]Carnegie Institution, Washington, DC, [12]Massachusetts Institute of Technology, Cambridge, MA.

Introduction: The Mars 2020 rover will acquire and cache samples for possible return to Earth at some future date. Over approximately the last four years, sample quality standards have been established to ensure that the samples could address the planned scientific objectives within the necessary constraints of mission design and cost [1]. Some of these standards were formulated by the Mars 2020 Returned Sample Science Board (RSSB), while others came from other sources. Table 1 summarizes the full set of sample quality standards of which we are aware.

Table 1: Working Campaign-Level Science Requirements for Mars Samples

Organic Contamination	Tier 1 compounds <1 ppb Tier 2 compounds <10 ppb TOC <40 ppb
Inorganic Contamination	Group A <1% (see text) Group B <0.1% (see text) Pb <2 ng/g
Magnetics	Exposure to <0.5 mT Shock pressure <0.1 GPa Orientation to half-cone uncertainty of <5°
Fracturing	Size distribution in a single core of <20% by mass in pieces $\leq$2 mm, and >70% by mass in pieces with largest dimension >10 mm
Internal Movement	Minimize by preloading tubes compatible with X-ray CT imagine of core
Temperature	<60°C required, <40°C desired
Cross-Contamination	<150 mg per sample tube
Sealing	<1% water, translated to He leak rate for 20 y
Radiation	<100 krad over 20y

Earth-sourced contamination: Minimizing Earth-sourced contamination is critically important for geochemistry, isotope geochronology, and astrobiology investigations. Mars-sourced contaminants will be monitored by witness blanks.

Magnetics: These include limitations on exposure to a spacecraft magnetic fields (<0.5mT), shock intensity during launch and landing (<0.1 GPa), and accuracy to which orientation should be determined based on a surface features (to within 5°).

Mechanical Integrity: The fracturing of a rock sample does not directly affect its scientific utility, as long as the pieces stay together. Agreement was reached on a size-frequency distribution, which would have enough large pieces (>70%) to support the high-priority preparation of polished thin sections and orientable samples, enough medium-sized pieces (>20%) for many kinds of geochemical investigations, and would minimize the quantity of "fines" (<10%), which are far less useful.

Internal Movement: The movement of fragments of a rock relative to each other in the core is generally considered to be more damaging to science than fracturing itself. This is because a fractured but not jumbled rock can be reconstructed if the pieces are still in proximity.

Temperature: The RSSB conducted an intensive analysis of temperature constraints for 11 investigations where thermal excursions could affect the outcome. A maximum temperature of 60°C (20° above ambient temperature) was determined for samples within core tubes on the martian surface and during recovery on Earth. A lower temperature threshold of 40°C is desirable for investigations of organic matter, amorphous materials, hydrated sulfates and zeolites.

Mars-sourced contamination: Because the Mars 2020 rover will reuse drill bits and not have the ability to clean between their sampling uses, cross contamination between Mars samples is inevitable. A cross contamination limit of 1% is considered compatible with most kinds of geochemistry studies.

Sealing: Sealing of the tubes is critical for retaining volatiles so that the original volatile inventory would be measured and the original states of volatiles could be calculated from thermodynamic considerations and from dedicated atmospheric samples.

Summary: The selection, acquisition, storage, and possible return to Earth of Mars samples is challenging and expensive, and international partners must be assured that the scientific quality and integrity of samples can be ensured.

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SEEKING SIGNS OF LIFE PRESERVED IN MARTIAN SILICA. S. W. Ruff[1], J. D. Farmer[1], M. J. Van Kranendonk[2], K. A. Campbell[3], T. Djokic[2], B. Damer[4], and D. W. Deamer[4], [1]Arizona State University, steve.ruff@asu.edu, [2]University of New South Wales, [3]University of Auckland, [4]University of California at Santa Cruz

Introduction: The NASA Mars 2020 rover mission is the first since the Viking landers of the 1970s with a stated objective to seek signs of life, in this case, past life. The intervening decades of Mars exploration have shown that Mars indeed had settings habitable to life as we know it. During this same period, hypotheses have emerged that hydrothermal settings on early Earth likely were home to the first living cells. Among these, hot spring fields on land are strong candidates for the origin of life [e.g., 1]. The recent identification of microbial biosignatures in ~3.48 Ga hot spring/geyser silica deposits lends support to this hypothesis [2]. Taken together, these developments provide a compelling rationale for seeking signs of past Martian life among hydrothermal silica deposits, which have been unambiguously identified on Mars [3].

Martian Silica: Outcrops and soil composed of opaline silica (amorphous SiO_2•H_2O) discovered by the Spirit rover next to the "Home Plate" feature in the Columbia Hills of Gusev crater are manifestations of volcanic hydrothermal activity [3]. On Earth, opaline silica is a typical product of hydrothermal activity, occurring as a residue of acid leaching in the case of fumaroles, and chemical sedimentary deposits known as sinter in the case of hot springs and geysers. The stratiform expression of the Home Plate silica occurrences and sharp contact relationship with an underlying rock unit, along with textural details among individual silica rocks, are entirely consistent with a sinter deposit and inconsistent with silica residue [4]. Furthermore, the nodular and digitate morphology of many of the silica rocks, and their firm attachment to a substrate, mimic the expression of silica stromatolites found in hot spring discharge channels on Earth, most notably in the more Mars-like conditions near Chile's Atacama Desert [5; 6](Fig. 1).

The Columbia Hills site is among three remaining candidates for Mars 2020. The Home Plate silica deposits with stromatolite-like characteristics represent potential biosignatures [5], an obvious target for sample return. The rover is well equipped to investigate this possibility in situ, which could lead to major new discoveries during the mission, as described below.

Organic Preservation: On Earth, the sedimentary processes that produce nodular silica can trap and preserve biofilms, concentrating organics on surfaces and within finely laminated interior structures (Fig. 1c). Given the apparent lack of diagenesis of Home Plate silica [4], the preservation potential of any organic matter contained in or on these rocks would be largely a function of radiation damage. Solar UV radiation damage is unlikely given the shielding by silica, but solar and galactic cosmic rays could be highly destructive to ppb levels of organics as shown by modeling [7]. However, if the concentrated organics evident in terrestrial nodular silica were present on Mars, the potential for preservation could be high, as is found in the organic carbon in carbonaceous chondrites [7]. The identification of any organic compounds among Home Plate silica rocks would be a significant discovery. Furthermore, even if no organics are measured, the identification of finely laminated stromatolite-like structures would be significant. Finally, the observation of one or more of the many micro- to macro-scale textures associated with biosignatures in terrestrial hot spring/geyser facies [8] would likewise be a major discovery. Samples returned from such rocks could then be investigated for microfossils and organics in laboratories on Earth.

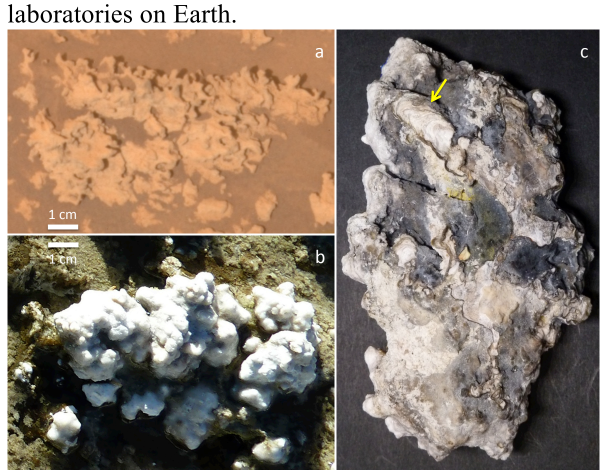

Figure 1. Nodular, digitate silica on Mars (a) and in a Tuja, Chile hot spring channel (b). (c) After chiseling out, the underside of piece in **b** (rotated) shows organics (dark gray) and stromatolite-like structure (arrow).

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IT'S TIME TO DEVELOP A NEW "DRAFT TEST PROTOCOL" FOR A MARS SAMPLE RETURN MISSION (OR TWO....). J. D. Rummel, SETI Institute, P.O. Box 2838, Champlain, NY 12919 USA, jrummel@seti.org

Introduction: In the late 1990s the development of a protocol to support the analysis of the samples in a containment facility was begun by NASA in cooperation with CNES. The result was a "Draft Test Protocol" (DTP) that outlined required preparations "for the safe receiving, handling, testing, distributing, and archiving of martian materials here on Earth" [1]. The protocol addressed, in a comprehensive fashion, various aspects of sample handling and of testing the samples that had been also been studied by others [e.g., 2].

For Mars sample return missions, NASA has long been committed to following the recommendations of the Space Studies Board (SSB) of the US National Academies in its reports on sample handling and testing [3, 4], many of which are now reflected in the COSPAR Planetary Protection Policy [5]. In particular, the 1997 SSB study *Mars Sample Return: Issues and Recommendations*, recommended that: 1) "samples returned from Mars by spacecraft should be contained and treated as potentially hazardous until proven otherwise," and 2) "rigorous physical, chemical, and biological analyses [should] confirm that there is no indication of the presence of any exogenous biological entity."

The first Mars Sample Handling Protocol (MSHP) Workshop that led to [1] was held in March 2000, and subsequent to the completion of the initial version of the DTP a stringent review and revision process took place, with a blue-ribbon review (Chaired by Joshua Lederberg of Rockefeller University and Lynn Goldman of Johns Hopkins University). After review and further revisions, the "Final" version of the DTP was published on 31 October 2002, representing a consensus understanding of what is required to meet planetary protection requirements for a Mars sample return mission.

Overall, the DTP addressed physical-chemical analyses and curation considerations for untested portions of the samples to ensure that controlled distribution of the samples outside of containment could be accomplished after the requirements of the DTP were met. Specific analyses noted in the DTP comprised a series of tests to detect a possible living entity ('life detection'), as well as tests to look for biological activity, even if a living entity were not detected ('biohazard testing'). The DTP was designed to be a top-level protocol that would rigorously analyze returned martian samples to determine that they are free from biohazards and/or extraterrestrial life forms. It included both required "science" opportunities (and a provision for other analyses) and biohazard tests to be conducted in containment, but the DTP did not envision doing all of the work of sample analysis within containment.

Why Now? Given the planned launch by NASA of a sample-caching rover in 2020, and with serious discussions of completing the first sample-return mission in subsequent launch opportunities, it is time to review and replace the DTP. Not only have there been numerous improvements and updates to the study of biology and extraterrestrial samples in the 15 years since it was published [e.g., 6], there have been several focused activities and studies that have occurred since the DTP was published [e.g., 7]. In particular, there has been an increased realization that a broad commonality exists between the analyses required to complete a biohazard and life-detection protocol and those necessary for an "early" characterization of returned martian samples. This has the potential to conserve a larger proportion of Mars material than would be possible if the two activities were not linked.

The current notional timeline discussed by NASA for a Mars sample return mission could bring a sample back to Earth as early as 2029 [8]. Based on the recommendations of the DTP [1], and the SSB [2, 3, 4] the planning for a Mars sample receiving facility (SRF) should therefore be started in 2018, or as stated in [4], "in the earliest phases of the Mars sample return mission." Such planning can refresh and broaden the participant base, make specific improvements to the existing DTP, and update it to reflect current analytical and biological research, while including early science and opportunities such as advanced robotics for a more effective and less contaminating protocol execution.

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LANDING SITES FOR A MARS SAMPLE RETURN MISSION IN ARABIA TERRA

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We are characterizing the geology of several area in Arabia Terra as possible Mars Sample return mission landing sites. Arabia Terra presents several interesting sites regarding the search for past traces of life on Mars. The long-lasting past presence of water, the flat floors and the low elevation of the intercrater plains in this region, represent excellent qualities when looking for possible sample return mission landing sites. We are investigating the stratigraphic and environmental setting of this region suggesting that different physiographic conditions, which interact with the groundwater, originated different sedimentary environments (deeper basins=clay bearing lacustrine conditions; shallower basins=sulphate-bearing evaporitic conditions).

The genesis of the layered deposits in this region has been attributed to different depositional processes and environments, many of them involving the presence of water either in surface or subsurface driven by hydrothermal processes and/or groundwater fluctuations [1,2,3]. Sulfate-bearing layered deposits formation have been related to a groundwater dominated hydrological system [2,3,4,5]. Additionally, fluid expulsion related processes have been increasingly invoked to explain the formation of some pitted cones and mounds within the light toned deposits in Arabia Terra [6,7]. The topgraphy of Arabia Terra is of particular interest because it shows gentle north-facing slopes over a wide area, thus favoring complex interactions with the groundwater table. The depth of several sites in this region, below -4000 m, has favored the prolonged presence of ponding water both on the surface and in the watery subsoil. Deep groundwater and spring/play deposits are both relevant for past life presence on Mars in different way. Deep groundwater is crucial for the presence of lakes and ocean, spring deposits and in general fluid expulsion-related environments (fissures, veins) are potentially suitable targets when searching for life or trace of life as it has been observed in many location on Earth [8].

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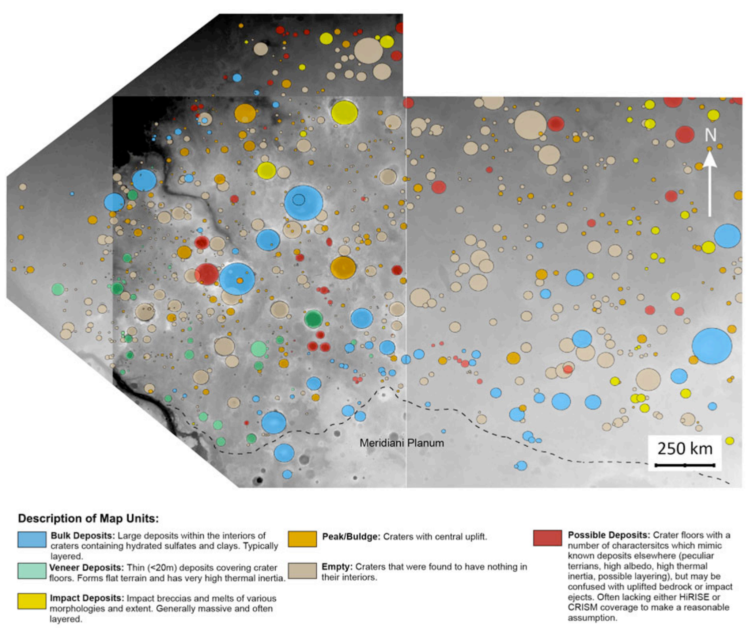

Figure 1 Arabia Terra (21°15′N 5°15′E) is a regional dichotomy boundary between the high- and lowlands of northern Mars, known for its densely cratered terrain and extensive distribution of water-altered deposits. Clay-bearing and sulfate-bearing light-toned layered deposits are widespread over the whole area [9] showing different morphological, sedimentological and mineralogical characteristics.

MARS SAMPLE RETURN AS A KEY STEP BEFORE MANNED MISSIONS.

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Introduction: In several papers and in a recent review from the International Academy of Astronautics, it is highly recommended to design the Mars Sample Return mission (MSR) in view of the future manned missions to the red planet [1,2]. As complexity is the main cost driver, several MSR studies and plans focused on the simplest and cheapest way to undertake that mission without considering in details how it could best fit in the preparation phase of manned missions [2,3]. It is proposed here to address that problem.

Overview: Many architectural elements or outputs of a MSR mission could be of interest in view of a manned mission (trajectory, Mars orbit rendezvous, in situ resource utilization, etc.). However, the risks, the complexity and the cost of a manned mission are driven by two important elements:

a) The availability and reliability of a heavy rocket to launch and send to Mars each module (habitable module, mars ascent vehicle, propulsion system of the return vehicle, etc.).

b) The availability and reliability of an entry, descent and landing (EDL) system for each heavy module that has to be sent to the surface.

Reliability of complex systems: For any system, there are different ways to determine the risk of failure. In the rocket domain, there are so many subsystems and procedures that the bottom-up approach is generally not considered. In order to be qualified, a system must be flight proven, but even after this step, as environmental conditions, subsystems and context of use always change, some failures may still be observed. The reliability of such complex systems may be estimated by means of a maturity curve. Such curves simply show that the probability of failure is decreasing with the number of consecutive successful uses. Experts will typically use similar curves to estimate the risks for the two complex elements of the manned Mars mission, the launcher and EDL systems.

Launcher: In order to minimize the risks of a manned mission, it is of particular importance to prove the reliability of the heavy launcher that will be used to send all modules to Mars. As can be currently observed with NASA Space Launch System, it is difficult to find relevant missions to test that launcher and improve its reliability. A MSR mission is one of the rare candidate missions that could make use of the heavy launcher. In order to clearly improve the maturity of the launcher, it is of a primary importance to design the MSR mission with a payload of the same mass as one of the module that will be sent to Mars for the manned mission. If another launcher is used, or if the configuration is very different (different mass, different trajectory, etc.), the MSR mission would not be a key preparatory mission and would miss one of its main objectives.

EDL systems: Entry, descent and landing on the surface of Mars has been identified by experts as one of the riskiest phase of the mission. At the moment, it is still not clear what is the best strategy and the best EDL systems to land a heavy payload on Mars. Once again, the reliability will be uncertain. The qualification will require at least one successful landing on Mars with the same exact configuration expected for the habitable module of the manned mission (same mass, same entry velocity, same angle of attack, same EDL systems, etc.). Without humans onboard, it would be a pity not sending several robots, or all the payload required for a MSR mission. Even if a first MSR mission is undertaken with totally different EDL systems, a heavy MSR mission would still be required to qualify EDL systems.

Conclusion: Considering the preparatory phase of a manned mission, it is clear that a specific MSR mission is on the roadmap. A heavy launcher will have to be used and the payload mass will be in the same order as the mass of the habitable module to qualify EDL systems. Such a mission will probably be unavoidable. As the budgets and strategies of space agencies depend on political decisions, a preliminary MSR mission that would not use the heavy launcher of the manned mission and would not test the EDL systems of the manned mission might be preferred, but it would be clearly a loss of time and efforts in view of the manned mission.

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MSR ESA EARTH RETURN ORBITER MISSION DESIGN TRADES. J. M. Sanchez Perez[1], G. I. Varga[1], J. Huesing[2] and F. Beyer[2], [1]ESA-ESOC, Roberth-Bosch-Str. 5, 64293, Darmstadt, Germany, [2]ESA-ESTEC, Keplerlaan 1, PO Box 299, NL-2200 AG Noordwijk, The Netherlands.

Contribution to the Mars Sample Return campaign with the Earth Return Orbiter (ERO) is under study by ESA. ERO will launch in 2026 on an Ariane 64 with the objective of bringing Mars samples back to Earth before the end of the 2020's. For this objective the ERO will be equipped with a sample handling payload (to capture and bio-seal the orbiting sample) and an Earth return capsule (ERC) that will be deployed from the hyperbolic approach to Earth.

Unlike previous ESA missions to Mars, the use of electric propulsion (EP) is being considered for the ERO. ESOC's Mission Analysis Section is supporting the ERO definition studies by exploring the vast mission design trade space of full-EP and hybrid Mars return missions, using a combination of EP and chemical propulsion (CP) to optimise the mission profile.

ERO's mission options consist of the following:

- launch and direct escape from Earth
- outbound transfer using EP
- possible Mars orbit injection manoeuvre using chemical engine (if hybrid architecture)
- target orbit acquisition spiraling down to low Mars orbit (LMO) using EP
- rendezvous and retrieval of the orbiting sample
- departure orbit acquisition spiraling up from LMO using EP
- possible Trans-Earth Injection manoeuvre to leave Mars using a chemical engine (if hybrid)
- inbound transfer to Earth using EP
- ERC delivery to the appropriate entry conditions for a landing in the Utah Test and Training Range.

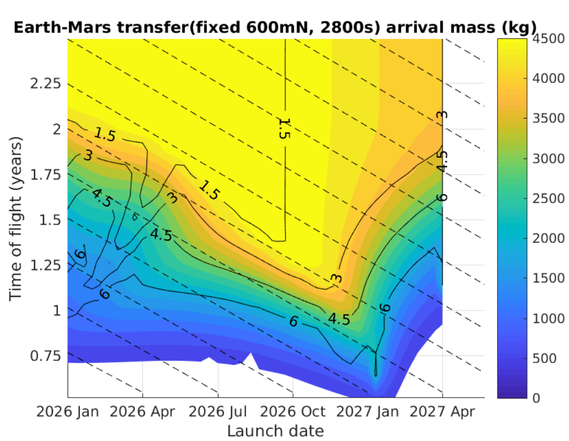

Figure 1: Sample outbound transfer plot. Colour coded: mass at Mars arrival, black-level-lines: Earth escape velocity, dashed lines: fixed arrival date.

The mission design process involves the generation of a database of optimal EP transfers, both outbound & inbound, for an extensive grid of departure dates and transfer durations. The outbound transfer optimisation is subject to the constraint imposed by the capability of the launcher and the Mars arrival velocity (assumed zero for full-EP missions). The optimal mass delivered to Mars can be represented in a plot (Fig. 1) together with the Earth escape velocity in order to analyse sensitivities with respect to launch date and duration.

Similarly the inbound transfer is optimised considering a fixed mass returned to Earth and for varying the Mars escape velocity. Similar plots for the inbound transfer allow the analysis of the sensitivities of transfer performance and Earth arrival velocity with respect to the departure and arrival dates.

For given launch and Earth arrival dates, the end-to-end mission design is analysed using the results from the transfers database and analytical models for the chemical burns and the phases in EP spiraling. An internal optimisation is performed to obtain the outbound and inbound transfer durations subject to different criteria. A figure of merit that increases mission success probability is the stay time in LMO that can be maximised subject to the feasibility of the mission in terms of mass arriving and departing from LMO.

Different EP technologies and power levels of the platform are being investigated by performing parametric analysis of the main parameters related to the EP system. The resulting information is being used to identify feasible architectures for the ERO.

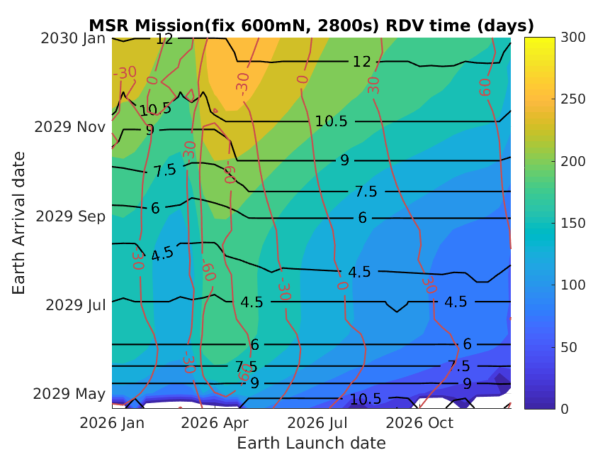

Figure 2: EP mission optimized LMO performance. Colour-coded: LMO stay time, black-level-lines: Earth arrival velocity, red-level-lines: LMO arrival epoch

Examining Returned Samples in their Collection Tubes using Synchrotron Radiation-based Techniques

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Introduction: High brightness synchrotron radiation facilities, such as the National Synchrotron Light Source-II (NSLS-II) at the Brookhaven National Laboratory, USA, provide a unique and critical capability to perform *in-situ* assessments of sample integrity (using X-ray tomography), mineralogy (using X-ray diffraction, XRD), and possibly chemical composition and elemental distribution (using X-ray Raman Scattering), once samples are returned to Earth, but before they are unsealed from their collection tubes.

Over the last two years, we have established a working group to evaluate how synchrotron radiation-based techniques can be leveraged for triaging and analysis of returned samples. Proof-of-concept measurements have been conducted at NSLS-II and next steps have been identified.

Proof-of-Concept Measurements: The capability to quantitatively assess the mineralogy of rock samples encapsulated in Ti-alloy tubes was demonstrated by conducting a set of measurements at the X-ray Powder Diffraction (XPD) beamline at NSLS-II. The tubes, shown in **Figure 1**, are prototypes of those that will be used during the Mars 2020 Rover mission to encapsulate rock and regolith samples. Six samples (each approx. 2cm long, 1.5cm diam) were collected using a coring drill prototype for the Mars 2020 Sample Caching System (SCS) at the NASA Jet Propulsion Laboratory (JPL). For most of our measurements, the sample tube was rotated continuously and translated laterally in ~2.5mm increments for exposing distinct sections of the tube to the X-ray beam (~1mm diameter beam of monchromatic X-rays; E=67.756 keV, λ=0.183 Å), yielding volume-averaged X-ray diffraction patterns at five positions in each sample. Each individual diffraction pattern was collected with a 60 second integration time. The measurements enable identification and phase abundance estimates despite the containment.

The capability to determine the structure of poorly crystalline or 'amorphous' materials was demonstrated by conducting an *in situ* Pair Distribution Function (PDF) analysis of a silica glass sample contained in the Ti-alloy tube. PDF analysis reveals the short-range ordering in 'amorphous' materials, constraining the materials structure and identity. As seen in Figure 2, it is possible to extract with high fidelity the PDF signal

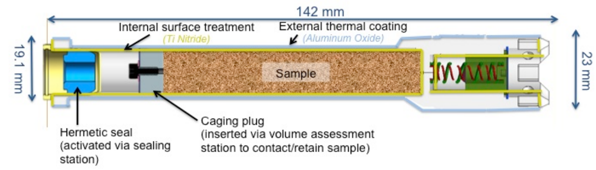

Fig. 1: Schematic illustration of a hermetically sealed Ti-alloy sample tube to be used for encapsulating samples on the Martian surface prior to Earth return.

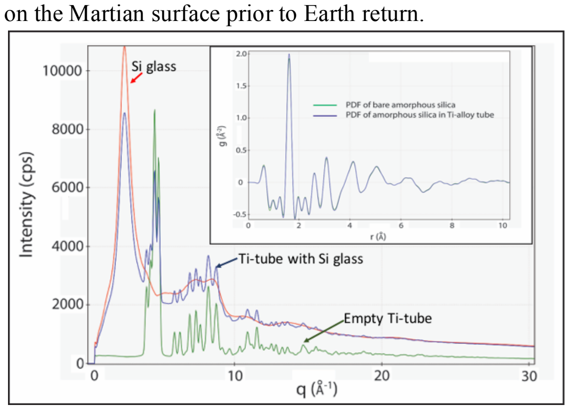

Fig. 2: PDF proof-of-concept measurement. PDF signals for Si glass only, Si glass contained in Ti-alloy tube and tube alone. Inset shows that by substracting the contribution from the tube, the PDF signal from the Si glass can be extracted with high fidelity.

contributed by the glass after subtraction of the signal contributed by the Ti-alloy tube.

Together, these two proof-of-concept experiments show that using synchrotron radiation-based techniques the mineralogy of contained samples can be determined.

Next Steps: Additional proof-of-concept measurements will be needed to determine the feasibility of diffraction-based tomography and X-ray Raman Scattering. X-ray tomography is already widely used, but experiments are needed to demonstate the feasibility of diffraction-based tomography. The application of X-ray Raman Scattering will require more extensive development work. In addition, the effect of X-radiation on organic matter and cellular material at the intensities and exposures used in these techniques needs to be evaluated. **Acknowledgements:** This work was funded by an SBU-BNL seed grant to JAH and JT and DOE, Office of Science, Basic Energy Science under contract DE-SC0012704.

THE MARS 2020 ROVER MISSION LANDING SITE CANDIDATES. M. Schulte[1], M. Meyer[1], J. Grant[2] and M. Golombek[3], [1]NASA Headquarters, 300 E St. SW, Washington, DC 20546; Mitchell.D.Schulte@nasa.gov and Michael.A.Meyer@nasa.gov, [2]CEPS, Smithsonian Institution, Air and Space Museum, 6th at Independence, Washington, DC 20560; grantj@si.edu, [3]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109; mgolombek@jpl.nasa.gov.

Introduction: The Mars 2020 rover mission, currently in development, is NASA's first step in returning samples from Mars. With a suite of instruments specifically chosen to rigorously document the geological context of the selected landing site, search for biosignatures of ancient life, and collect carefully selected and documented core and/or regolith samples for eventual return to Earth.

Based on these scientific goals, the choice of landing site for the mission has engendered significant attention and the project has made investigating the landing site candidates a priority. A variety of engineering considerations has limited the locations on Mars where the rover can be delivered to +/- 30° latitude, below 0.5 km elevation (relative to the MOLA geoid), areas with thermal inertias greater than 100 J m^{-2} $s^{-0.5}$ K^{-1}, albedo lower than 0.25, and radar reflectivities >0.01. However, even within those constraints, hundreds of landing sites are possible for the Mars 2020 rover mission.

The incorporation of new baselined technologies on the Mars 2020 mission, including range trigger for parachute deployment and terrain relative navigation (TRN), will allow a precision approach to landing within relatively narrow landing site ellipses (all on the order of ~11× 9 km), and will help the mission team achieve the stated goal of acquiring a number of samples within the duration of the prime mission (currently baselined as 1.25 Mars years or just over 800 sols).

After a series of three workshops to date, with a fourth planned for the second half of 2018, involving the scientific community, Mars 2020 project personnel, policy makers, and other stakeholders, the number of suitable landing sites has now been narrowed to three leading candidates: Jezero crater, NE Syrtis, and Columbia Hills.

Jezero Crater: Jezero crater, with a landing ellipse centered at 18.4386°N latitude and 77.5031°E longitude and at an elevation of -2.64 km, is interpreted to represent a delta formed in a crater lake [1]. The proponents of the Jezero crater site note that delivery of materials from a diverse set of environments that would be captured within the delta is an important feature of this location. Deltas on Earth are also known to provide sequestration and preservation of organic material, which would be valuable in the search for biosignatures from ancient terrains. There is evidence from CRISM data for the presence of hydrous minerals, including carbonates, with an Hesperian capping unit also within the area.

NE Syrtis: The NE Syrtis site with a landing ellipse centered at 17.8899°N latitude, 77.1599°E longitude and at -2.04 km elevation, represents a deep crustal setting in which water reacted with rocks, possibly providing a hydrothermal setting analogous to inhabited environments on Earth [2]. This ancient terrain contains evidence for igneous, hydrothermal and sedimentary environments. CRISM data indicate high mineralogic diversity, including phyllosilicates, sulfates, carbonates, and olivine in good stratigraphic context.

Columbia Hills: The Columbia Hills landing site, previously visited by the Spirit rover (where it remains, now inoperative), has its landing ellipse centered at 14.5478°N, 175.6255°E at an elevation of -1.93 km. Centimeter to decimeter-scale features observed by the Spirit rover are interpreted by the proponents of this site as being derived through precipitation from hot spring fluids, and it is suggested, by analogy with similar deposits on Earth [3], that the silica deposits could contain evidence of microfossils and/or microbially produced organic matter. The hot spring environment has also been suggested as one from which life on the early Earth may have emerged. Carbonate, sulfate, silica-rich outcrops, possibly hydrothermal in origin, with igneous outcrops of Hesperian age are in abundance nearby.

Summary: A fourth and final landing site workshop will be held in late summer or early fall of 2018, after which the final selection of the landing site for the mission will be made by NASA. The three remaining landing site candidates for the Mars 2020 rover mission represent diverse geological settings that all offer the potential for preservation of biosignatures should life have been present on Mars early in its history. The samples that would be returned from any of the final landing site candidates would represent an abundance of opportunities for sample scientists for generations.

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ASTROBIOLOGICAL *IN-SITU* INVESTIGATIONS AS PART OF A MARS SAMPLE RETURN MISSION. D. Schulze-Makuch[1] and A. Airo[1], [1]Center of Astronomy and Astrophysics, Technical University Berlin, Germany, email: schulze-makuch@tu-berlin.de

The Need for Including *In-Situ* Analysis: The focus of a Mars Sample Return (MSR) mission, as presently conceived, is a state-of-the-art analysis of Martian rocks, including the potential identification of fossilized Martian life. Hence, it is usually envisioned to collect sedimentary rocks that have been deposited under formerly aqueous, i.e. habitable, conditions, such as the deposits being investigated by the Curiosity rover at Gale Crater [1]. However, the most interesting collection sites for sample return are locations that are potentially habitable today or have been in the very recent past, such as sites showing putative hydrothermal activity [2], soils exhibiting Recurrent Slope Lineae [3], or areas close to lava tube caves or ice caves [4].

Irrespective of whether samples from presently or formerly habitable environments will be collected, it appears sensible to include in a MSR mission an *in-situ* component to make sure that active life is not overlooked. This is critical for two reasons. First, it would be a missed opportunity not to search for active life on Mars, considering that this would be the first time to do so since the Viking Landers in 1976 [5]. Secondly, not doing so could have serious planetary protection ramifications by bringing potentially active alien life back to Earth, which may endanger or interact with our own biosphere.

Martian life might be biochemically adapted to their environment in ways not known from Earth [6]. Even if not, if Martian organisms are at least as hardy as terrestrial desert dwellers there is reason for concern, since a recent study found soil microorganisms to be active in the driest core of the Atacama Desert after a rare rainfall event [7]. Although, no rain can fall from the Martian atmosphere today (8), liquid water near or at the surface could be present in the form of fog, nightly snow storms or ice microbursts, rising groundwater, and perhaps derive from structural water contained in minerals [7].

Proposal: Based on the above reasoning, we propose a MSR mission to include an *in-situ* analyses testing for the presence of active life, before sending the collected samples to Earth. Allegorically, such analysis could be done with a “tricorder”-type device, allowing to easily scan a sample for detecting life of any kind.

Previous studies on Martian analog environments on Earth, such as the high Canadian Arctic, have used three miniature low cost, low energy instruments to directly detect and characterize life forms in the field [9]. One of their life-detection methods employed a portable DNA sequencing device based on nanopore sequencing technology. However, despite the powerfulness of this tool on Earth, putative Martian organism might have such different biochemistry rendering this methodological approach as useless.

Thus, we are currently developing a device designed to detect the most general biosignatures, such as growth or metabolism, without needing to rely on a specific biochemistry for the analysis to work, as would be the case for sequencing technology. Sequencing would only be included for the purpose of ensuring that no forward contamination originating from Earth has occurred.

Testing samples on Mars for any signs of active life before returning them to Earth, would not only protect Earth from potentially detrimental contamination, but would also be valuable from a scientific viewpoint.

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SPATIAL MAPPING OF ORGANIC CARBON IN RETURNED SAMPLES FROM MARS. S. Siljeström[1], T. Fornaro[2], D. Greenwalt[3], A. Steele[2], [1]RISE Research Institutes of Sweden, Drottning Kristinas väg 45, 114 28 Stockholm, Sweden - sandra.siljestrom@ri.se, [2]Geophysical Laboratory, Carnegie Institution for Science, 5251 Broad Branch Rd NW, Washington, DC 20015, USA - tfornaro@carnegiescience.edu, asteele@carnegiescience.edu, [3]National Museum of Natural History, Washington, DC, 20013, USA - greenwaltd@si.edu.

The search for pristine organic molecules of Martian origin will be one of the major tasks in the investigation of any returned samples from Mars. To not just detect but also map this organic material spatially to any minerals and mineral catalysts present in the sample will be key to understand the abiotic and/or biotic processes that could have created this organic material present in the sample.

One technique, which is used for mapping organic material in geological samples is time-of-flight secondary ion mass spectrometry (ToF-SIMS). It is a surface sensitive technique, which uses energetic ions to generate secondary ions from the surface of a sample. These ions can then be detected in a mass spectrometer. In addition to mass spectra, ion images or chemical maps, which show the spatial distribution of the scanned surface area, are generated. The ability to map the distribution to extremely high spatial and spectral resolutions allows the simultaneous correlation of inorganic and organic species to be viewed. This is key in understanding the context of organic matter. Furthermore, due to the surface sensitivity of this technqiue it will yield valuable information on the fidelity of the sample in regards to process and collection contamination. This will greatly increase the fidelity of other "bulk" techniques that will be used to analyze the samples such as GC-MS or LC-MS/MS.

In this presentation several examples will be presented where ToF-SIMS has been used to map organic molecules in geological samples. Samples include Martian analogue samples, terrestrial fossils and Martian meteorites. The opportunities but also challenges in using ToF-SIMS in the analysis of any returned sample from Mars will be highlighted.

QESA: QUARANTINE EXTRATERRESTRIAL SAMPLE ANALYSIS METHODOLOGY

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Introduction: In view of the Sample Return missions, we have designed, tested and patented an extraterrestrial (ET) sample protocol of combined analyses and a miniature optimized sample holder under BSL4 quarantine conditions [1,2].

Previous analyses: The QESA protocol is the outcome of the last twenty years of X-ray hyperspectral analyses developed at the ID22/ID16B beamlines of the ESRF European synchrotron in Grenoble, to study at increasing nanometer spatial resolution, intermediate Z element traces – key issues in extraterrestrial mineralogy [3-5] and search for life [6, 7]. These analyses were successively used for probing extraterrestrial samples from NASA's Stardust cometary and interstellar mission [8, 9] as well as terrestrial Archean ones [10, 11] witnessing the inception of life 3.35 Gy ago, in the Barberton Greenstone Belt. Requirements for optimized high resolution fluorescence of fragile, rare samples as the MSR (Mars Sample Return) were scrutinized and specific protocols were designed.

Quarantine analyses : The QESA protocol combines Large Scale Infrastructure Facilities such as the ESRF with lab-based microscopy analyses of Raman/IR spectroscopies. Combining non-destructive X-rays, Raman/IR spectroscopies records information at atomic (XRF: X-Ray Fluorescence) and molecular levels (Raman, IR spectroscopies) as well as the macroscopic ones : crystallinity (XRD: X-Ray Diffraction) and speciation (XAS: X-ray Absorption Spectroscopy). Owing to focused X-rays, investigations are performed in the 20 nm - 1 µm range, while lab-based spectroscopies are intrinsically in the 1 - 10 µm range. An essential advantage of X-rays over other probes is the penetration depth in opaque samples of few hundred µm compared to the laser/IR ones of only few nm.

BSL4 Extraterrestrial Sample Holder (ESH) : Quarantine analyses are made in a dedicated sample holder, made of 3 nested containers, holding ET grains of sizes Ø 20-1000 µm, in a transparent spectroscopically pure silica capillary, at controlled N_2 pressures. The containers feature thin Be windows for X-ray sensitive analyses of least absorption and sapphire ones transparent to laser/IR beams. The 3 containers are permanently monitored by sensitive pressure and temperature sensors, guaranteeing their leak-proof capacity. This arrangement prevents release to Earth atmosphere of potential biohazards while also insuring insulation from toxic Earth agents such as O_2. A potential hull breach of a container's window is signaled by variations between the different partial N_2 pressures in the containers. A portable transport and storage vessel is associated to the sample holder and will be used for sterile disposal if needed.

Update: Our new 3-container ESH features a remote-controlled rotation piezo drive, for 3D morphology probing of grains by XCT: X-ray Computed Tomography, in absorption /fluorescence modes. Made by high resolution additive metal manufacturing techniques, from a spectroscopically pure alloy of high tensile strength, the ESH features fully leak-proof laser-welded seals.. This makes it more sensitive, safer and adapted to modern synchrotron requirements.

Goal: Our ESH is optimized for non-destructive elemental/molecular/mineralogical nano-analyses of bio-geological samples in a BSL4 environment. If Earth life is any guide to ET life, with µ-organisms of low Z element matrices but heterogeneous traces of intermediate Z ones, we are uniquely equipped for solving the crucial issue of identifying live or fossil ET traces on solid samples returned to Earth by future SRM operations. Closed-contour morphology, 100 nm to few µm, encased in selectively permeable membranes protects them from medium and controls their fluid exchanges. Speciation of intermediate Z key elements, camouflaged by low Z matrices, indicates the nature of local exchange chemistry pinpointing these active minuscule chemical actors called - LIFE.

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MARS SAMPLE RETURN AS A FEED-FORWARD INTO PLANETARY PROTECTION FOR CREWED MISSIONS TO THE MARTIAN SURFACE. J. A. Spry[1] and B. Siegel[2], [1]SETI Institute (Mountain View, CA 94043; aspry@seti.org), [2]NASA HQ (Washington, DC 20546).

Introduction: Stringent planetary protection requirements are currently imposed on robotic explorers sent to the red planet. The international consensus planetary protection policy obliges the nations sending these missions to comply with biological cleanliness levels for hardware that preserve the ability of future missions to do science at Mars unhindered by the contamination left behind by preceding missions [1].

However, this paradigm is incompatible with sending crewed missions to the martian surface. The decision to allow humans and their life support systems to visit the surface implies a level of contamination much beyond that permitted for robotic missions [2].

Still, the intent of the planetary protection policy remains the same; ensuring the conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants is not jeopardized, and protecting the Earth from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission (forward- and back-contamination, respectively) [3]. The question is therefore, how will this be achieved? Part of the decision making process would be the application of information generated from the scientific findings of a future Mars Sample Return (MSR) mission.

The Exploration Zone Concept: In its preliminary planning for crewed exploration at the surface of Mars, a NASA workshop was held in 2015, encouraging participants to envisage the science yield and ISRU available at sites across a wide swathe of Mars at latitudes up to 50° [4]. Over fifty locations with a notional 100km traverse limit from a central habitat location were proposed and discussed, across a wide variety of terrain types. Although planetary protection constraints were recognized and formed part of the overall discussion, they were not used as a discriminator in landing site prioritization at this point in time.

A Path to Planetary Protection Requirements: Part of the reason for not using planetary protection in prioritization of scientific targets is that our knowledge of Mars lacks the information to give quantitative requirements for crewed missions. While COSPAR policy [3] gives *guidelines* in approaches for crewed missions, numeric requirements equivalent to those used on robotic missions (e.g. $3x10^5$ spores per landed mission for landers at Mars; much less (30 spores) for missions performing life detection and/or targeting Special Regions at Mars [5]) are not given. More information is needed to develop those engineering requirements.

Progress to Addressing Knowledge Gaps: As part of the path to developing requirements, at an agency level, NASA drafted a NPI (NASA Policy Instruction, [6]) document, and then supported that with a workshop held in 2015, which identified three main areas for addressing knowledge gaps in planetary protection for crewed missions [7]:

Microbial and Human Health Monitoring where knowledge gaps were identified related to microbial and human health monitoring ;

Technology & Operations for Contamination Control which focuses on technologies needed for cleaning, sterilization and prevention of recontamination in spacecraft systems, and;

Natural Transport of Contamination on Mars where potential natural sterilization by Martian conditions, and environmental cleanup of terrestrial materials were considered.

Subsequently, a 2016 COSPAR workshop updated and prioritized the findings of the NASA workshop [8]. This presentation will discuss this and the work now proceeding to identify opportunities (including MSR) where the new information needed to close critical knowledge gaps can be generated.

Conclusion: Planetary protection implementation is a required part of future exploration efforts for Mars, including crewed missions. Determining how planetary protection should be implemented for crewed missions is contingent on improved knowledge of the Mars environment, some of which is best obtained by analysis of martian material of known provenance, as part of a MSR mission. Analyses from MSR samples will provide key information concerning both the forward and back contamination threat posed by crewed missions to the martian surface, enabling appropriate planetary protection constraints to be developed for future crewed missions to the martian surface.

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THE DESIGNING OF THE MISSION TO MARS FOR THE SOIL DELIVERY BY THE ELECTRIC PROPULSION SPACECRAFT. O. L. Starinova[1], Ch. Gao[2], D. V. Kurochkin[3] and H. Yudong[4], [1]Professor of Space Engineering Department, Samara National Research University, Russian Federation, solleo@mail.ru, [2]Accosiate professor of Harbin University of Technology, People's Republic of China, gaocs@hit.edu.cn, [3]Engineer of Space Engineering Department, Samara National Research University, Russian Federation, [4]Master student , Samara National Research University, Russian Federation.

Introduction: Mission to return soil from Mars is a typical kind of transfer with the return to the source orbit. The effectiveness of such a flight depends on many parameters describing the design scheme of spacecraft and the features of the trajectory. It is well known [1]-[4] that the electric propulsion spacecraft is the most useful for interplanetary flights at the present stage of space technology development.

The problem of comprehensive optimization of the trajectory and the ballistic parameters of a low-thrust mission Earth-Mars-Earth is formulated and solved in this paper.

Models and Methods: The problem of the Earth-Mars-Earth mission optimization is formulated with restrictions on the total mission duration and the distance to the Sun. Besides this, the heliocentric parts of trajectory are calculated by taking the ellipticity of planetary orbits into account. The aim of considering dynamic space maneuver is the payload transportation to the target areocentric orbit and returning its part to the initial geocentric orbit. The primary optimality criterion is a launching mass of spacecraft given the limited flight duration.

This problem formulation is a protracted process which requires the vast computing resources. Commonly, this problem is solved by either direct or indirect optimization methods using numerical integration [1], [2], [4] of the motion equations. This approach results in significant computational difficulties and doesn't allow to analyze the various design and ballistic parameters of the mission. However, the decision of optimization problem can be considerably simplified if the general problem is divided into the dynamic and the parametric parts. The basic idea of this division is the choice of such an intermediate criterion of optimization (the flight characteristics), which would allow one to determine the dependence of mission costs on the set of spacecraft design parameters.

This intermediate criterion may be different for different kinds of spacecraft, but in any case, it allows to split the problem into two components. The first one is the dynamic part of the optimization problem which consists in determining the control functions and the ballistic parameters providing for a minimum flight characteristic at fixed design parameters. The second one is the parametric part of the problem which allows choosing the design parameters corresponding to the minimum spacecraft launching mass.

The movement of the electric propulsion spacecraft is described by the system of the differential equations take into account the following assumptions. The spacecraft contemporaneously is subject to the gravitation of the one-body (a planet or the Sun). The gravitational field of all bodies isn't central. The Earth and Mars atmospheres are standard. The planet orbits relative to the Sun are known.

A design vector which uses to create the design scheme consists of the independent variables which significantly impact on the launched mass. A change in each of these variables leads to a different design of the spacecraft. In this study, we chose specific impulse and initial acceleration as design variables. The design model of the spacecraft can be obtained based on a mass balance equation in the parking orbit. This equation represents the initial mass as the sum of the masses of its general subsystems, the fuel, and the payload.

Results: With the use of the described technique, the results of the ballistic optimization of the missions to the Mars were received. A large number of the solved optimal control problems allowed to obtain the approximation dependences between the intermediary criterion and the design-ballistic parameters of the flights Earth-Mars and Mars-Earth [2]. These dependencies enable automating the process of optimizing the design scheme of spacecraft.The proposed method is especially useful on pre-conceptual design stages when the possibility of the fast analysis is more important than the accurate optimization on more complex and exact models.

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Impact of Planetary Protection and Contamination Control on a life detection or sample return mission. H. Steininger[1], [1]Max Planck Institute for Solar System Research (MPS), 37077 Göttingen, Germany (steininger@mps.mpg.de).

Introduction: The Mars Organic Molecule Analyzer (MOMA) is a combined pyrolysis gas chromatograph mass spectrometer (GC-MS) and laser desorption mass spectrometer (LD-MS). It will be the key instrument of the ESA Roscosmos ExoMars 2020 mission to search for extinct and extant life on Mars. Additionally the instrument should detect the organic background on Mars, e.g. the one caused by meteoritic influx. The drill system on board ExoMars is capable to provide a drill core from down to 2 m depth. The sensitivity of the instrument to organic contamination is high and even a small background of organic contamination would make the identification of Martian organics challenging. Contamination of biological origin could lead to a false positive life detection on Mars. This makes the Contamination Control one of the key points for the scientific success of the mission.[1]

Life detection mission: The ExoMars Mission is one of the few life detection missions. The planetary protection requirements for a life detection mission and a sample return mission with the goal of determining biological activity or extinct life are basically the same. The impact of planetary protection on instrument design, assembly, integration facilities and hardware delivery are severe. The same is true for the contamination control requirements needed to fulfil the science goals.

Planetary Protection: The spore load of the hardware is the governing number to verify the bioburden amount. The Viking post sterilization bioburden levels are hard to reach and even harder to maintain. The verification is mostly done by monitoring the bioburden before sterilization. The subsequent bioburden reduction reduces the bioburden by a determined factor. But this makes it impossible to verify any levels if contamination events arise during assembly or transport.

There are two extreme approaches for reaching the requirements. The one is post assembly sterilization the other is sterile integration. Mixed approaches are also possible. Both methods have different impacts on instrument development. The sterilization of the full instrument needs a carefully chosen set of materials and an assembled instrument with a non-operation temperature above 125°C. The sterile assembly on the other side makes a lot of operations very time consuming and this approach is strongly affected in case of contamination events.

Contamination Control: The approach of determining the levels for the requirement on contamination control should be governed by the analysis methods used by the instruments of the mission and therefore the science needs. For sample return this approach is impossible because it is not clear which methods will be available when the samples return. The analytical methods used to determine the contamination level must be simple enough that they are applicable at multiple locations and also for industry contractors.

The use of blanks and witness samples to determine the residual background of the instrument is a valuable approach taken in the ExoMars project.

Lessons learned: From the beginning to the delivery of flight hardware ExoMars can be seen as an example for how to deal with PP and CC. There are a few lessons which are different to missions with a less stringent PP and CC requirements, like Osiris-Rex and MSL.

The implementation of **all** necessary requirements and to communicate them to subcontractors is difficult. Late changes might be impossible or very costly. Misinterpretation of requirements should be avoided.

Implementation of a method to determine the contamination is essential. All involved parties must already be in a routine measurement mode when first hardware is available.

In most projects PP and CC requirements are easy to reach and have minimal impact on the system. To communicate that the impact of PP and CC is different in a sample return project and that every change should be considered with its impact on PP and CC is necessary.

The archived inventory of all materials used in the instruments in the assembly of the hardware is necessary. An analysis of that material with the identical instruments after samples returned will ensure maximum science output.

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Downselection for sample return – defining sampling strategies using lessons from terrestrial field analogues

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Introduction: Mars Sample Return (MSR) presents a unique opportunity for astrobiologists that comes with unique restrictions and may mean choosing a single sample to return from a planetary sized body. While other sample return missions have involved a certain amount of serendipity (e.g. Stardust) or have been less restricted in the amount of material able to be returned (e.g. Apollo), eventual MSR will have both the luxury of planetary-scale choice and the economy of severely-limited mass restriction. To increase the likelihood of choosing the most scientifically valuable sample possible, we must adopt sampling strategies for MSR that are more stringent than enforced on previous Mars missions.

Methods: The FELDSPAR (Field Exploration and Life Detection Sampling for Planetary Analogue Research) team has been exploring Mars analogue field sites in Iceland since 2012, using a range of physicochemical measurements and biomarker assays to assess the relative habitability of low-biomass volcanic environments. Using hierarchically nested spatial grids at 10cm, 1m, 10m, 100m and >1km scales, we have been able to characterize the spatial variability of various types of biomarkers in these environments, along with their correlations with each other and with various physicochemical parameters. By setting up a field lab with rapid turnaround analysis methods, using a variety of *in situ* analyses and sending samples back to institutional laboratories, we have also been able to assess various pipelines for sample downselection, analogous to what eventual MSR caching rovers will perform.

Results: Various statistical tests were used to quantify the spatial distribution and correlation of the biomarkers tested, and repeated expeditions to the same field sites allowed us to measure temporal trends. Generally, the assays used showed good correlation with each other. However, even at the smallest spatial scales all assays showed notable variability, though the sampling sites selected were as homogeneous as possible [1]. This implies that biomarker variation at the smallest scale must be considered in sampling strategies, requiring that careful decisions be made when performing different stages of downselection analysis, far beyond the broad strokes of sample location selection. Only a few centimetres could make the difference between conclusive or inconclusive results when analyzing samples back on Earth.

Figure 1: Four top level FELDSPAR field sites.

By using techniques with varying input requirements, turnaround times, and throughput synchronously in our field campaigns, we were also able to assess possibilities for sample triage and downselection. For example, the ATP bioluminescence assay, which can rapidly give an indication of the microbial activity in a sample, was used to inform which samples should be passed to more complex and time-consuming analysis (in our case, qPCR), which then informed which samples were prioritized for later, more detailed analysis in institutional laboratories [2].

Conclusions: Future expeditions as part of the FELDSPAR project will fold in further analysis techniques, including stand-off geochemical analysis, which will allow us to further develop the analytical pipelines we have developed and further constrain the environmental factors affecting the variability of biomarkers. This will allow us to inform future sample return exploration in the best ways to look for biomarkers in different locations and exactly where in those environments are most likely to lead to high quality science results.

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Searching for biosignatures in martian sedimentary systems A. H. Stevens[1], A. McDonald[2] and C. S. Cockell[1], [1]UK Centre for Astrobiology, University of Edinburgh, UK (adam.stevens@ed.ac.uk), [2]Bioimaging Facility, School of Engineering, University of Edinburgh, UK

Introduction: One of the prerequisites of Mars Sample Return will be the selection of a sample of significant enough scientific interest to send back. The Mars 2020 rover (and any subsequent caching rovers) will be equipped with a range of instruments to enable this selection. These instruments will seek to move beyond the capabilities of the Mars Science Laboratory in identifying potentially habitable environments and look for signs of life itself. Although the identification of biosignatures may not be definitive *in situ*, the higher the confidence at this stage of the mission, the greater the likelihood of selecting an appropriate target for sample return.

One of the most promising potential sampling sites are the numerous sedimentary areas on Mars such as those explored by MSL. As sedimentary systems have a higher relative likelihood to have been habitable in the past and are known on Earth to preserve biosignatures well, the remains of martian sedimentary systems are an attractive target for exploration by sample return caching rovers. If these systems hosted significant ecosystems in the past, we would expect it to be relatively easy to detect the signatures left behind, although the harsh martian surface conditions pose a problem for biosignature preservation. Yet if any ecosystems in Mars' past were marginal, these biosignatures would be even more difficult to find.

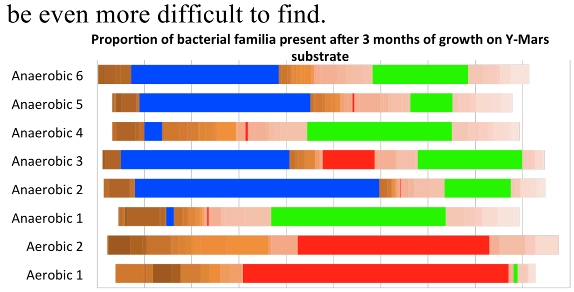

Figure 1: dominant bacterial families in inoculate after 3 months of growth, which for aerobic replicates were Oxalobacteraceae (Red) and for the anaerobic replicates were Chlorobiaceae (Blue) and Geobacteraceae (Green).

We used an analogue of a martian mudstone to investigate how best to look for biosignatures in these environments. The mudstone was inoculated with a relevant microbial community and cultured over several months under martian conditions to select for the most Mars-relevant microbes. We sequenced the final community to try and understand what functional types of microbes might be expected to exist in these environments and assess whether they might leave behind any specific biosignatures. We also prepared abiotic controls and samples with a single known species under the same conditions to assess detection limits for the techniques under investigation.

Since the Mars 2020 rover will carry two Raman spectrometers (and ExoMars another), we used a Raman instrument as our main biosignature detection technique. Here we present Raman analysis of our various samples. In the single species samples, with well characterized biological Raman bands to look for, it is difficult to find even marginally conclusive locations given the technical limitations of using Raman systems on environmental systems. While an instrument could serendipitously look in the right place, large, intensive rasters are required to look over even small areas. With no prior knowledge of the most appropriate Raman bands to look for, the process becomes even more difficult. This implies that without an extensive, well matured microbial ecosystem in place at burial, and the associated biogenic mineralisation, Raman instruments may struggle to find signs of life even in a substrate once peppered with microbes.

The clay rich substrate of these sedimentary systems also provides specific problems for Raman analysis, such as high background fluorescence, and many associated minerals have Raman peaks in locations that would interfere with identification of common biomarkers.

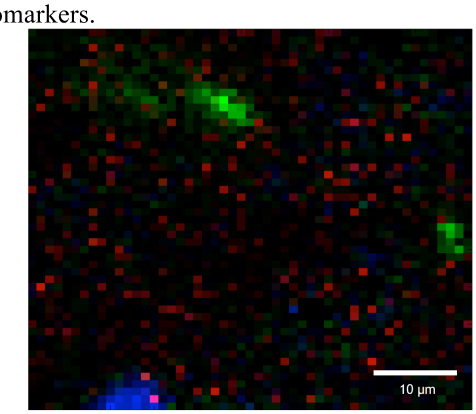

Figure 2: 100x100 µm Raman map of a mudstone mixed with a culture of Bacillus subtilis. Each colour is a known B. subtilis Raman peak. White pixels would suggesting the presence of the organism. Our map shows spatially distinct areas of individual peaks that could be clusters of cells, but none combined, meaning an inconclusive result.

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Roadmap of advanced GNC and image processing algorithms for fully autonomous MSR-like rendezvous missions. L. Strippoli[1] and D. Arjona[2], [1]GMV (lstrippoli@gmv.com), [2]GMV (dgarjona@gmv.com).

Introduction: During past years GMV extensively worked in many activities aimed at developing, validating and verifying up to TRL-6 advanced GNC and image processing algorithms for MSR rendezvous, e.g. [1, 2, 3, 4]. In addition, GMV is also currently working under different ESA contracts on the development of advanced algorithms for Vision-Based Navigation sensor with high Technology Readiness Level (TRL). These activities ([5], [6] and [7]) will provide useful outputs to minimize the costs of MSR-like missions, reducing the sensors suite while fulfilling the demanding performance requirements. The paper will present an overview of all these activities, presenting the main results obtained and providing an exhaustive roadmap of GNC technologies for MSR-like missions.

Advanced GNC algorithms for MSR-like missions: During iGNC activity [2], the GNC, robust FDIR and image processing algorithms for full autonomous rendezvous with a sample canister (since ~500 km long range to capture) have been validated at different levels (model in the loop, software in the loop, space-representative flight processor in the loop and hardware in the loop), assuming as mission inputs the information coming from MSRO study ([8]), and relying on high-fidelity environment models with realistic images generation. The activity has provided fundamental outputs and recommendations at system and mission level, including sensors/actuators baseline and capture performance consolidation, and has provided a full GNC solution and algorithms/SW prototype for MSR-like rendezvous missions, mostly reusable for the next MSR rendezvous mission whose detailed assessment has recently started.

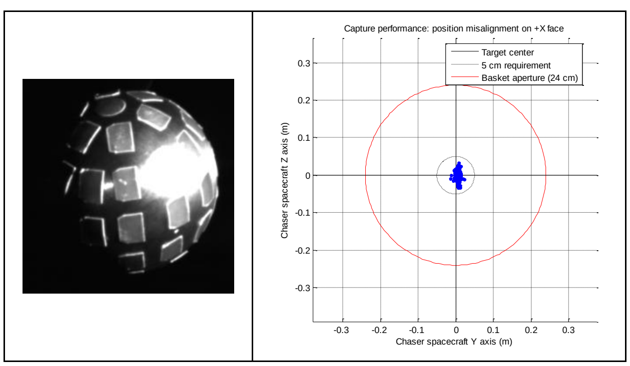

Figure 1: Sample container in iGNC HIL test bench (left), Capture performances obtained with iGNC simulator (right)

VBN Sensor Avionics:. Wide trade-off were performed over the optimal algorithms and hardware architecture based on high-fidelity, closed-loop simulation and benchmarking on representative flight hardware. Relative navigation based on image processing detection and feature tracking is implemented by GMV for Phobos Sample Return [5]. The implementation comprises the development of the high-performance avionics architecture Navigation Sensor. The Navigation Sensor instrument includes an Engineering Model (EM) of the Image Processing Board (IPB) and an Elegant BreadBoard (EBB) of the Camera Optical Unit (COU). Image processing is implemented on FPGAs as a HW accelerator providing performance improvement of 200x speed-up. PhobosSR phase A has confirmed the technical feasibility of a sample return mission to Phobos where critical technologies subject of dedicated technology development effort in the frame of MREP are developed by GMV with proved applicability to the Mars Sample Return mission. In the frame of the ESA's Asteroid Impact Mission (AIM, [6]), a lambertian sphere fitting image processing is implemented and evaluated by GMV on LEON2-FT processor with applicability to mid-range distances navigation to small spherical body, in application to a potential sample canister. And within HIPNOS [7], GMV provides a model-based tracking image processing implemented on SoC FPGA plus processor avionics for the close-range rendevouz and capture operations of the ESA's ENVISAT uncooperative target. The autonomous vision-based GNC avionics are tested in GMV's optical laboratory and dynamic robotic facility platform-art© simulating dynamic and kinematic representative conditions. These developments allows GMV to reach high TRL up to TRL6 enabling technology for current and future missions as in Mars Sample Return.

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[8] web: ESA s first step towards Mars Sample Return

THE ROSETTA STONES OF MARS – SHOULD METEORITES BE CONSIDERED AS SAMPLES OF OPPORTUNITY FOR MARS SAMPLE RETURN? A. W. Tait[1*], C. Schröder[1], J. W. Ashley[2], M. A. Velbel[3], P. J. Boston[4], B. L. Carrier[2], B. A. Cohen[5] and P. A. Bland[6], [1]Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK, *alastair.tait.maps@gmail.com, [2]Jet Propulsion Laboratory, Pasadena, CA, United States, [3]Michigan State University, East Lansing, MI, United States, [4]NASA Ames Research Center, Moffett Field, CA, United States, [5]NASA Marshall Space Flight Center, Huntsville, AL, United States, [6]Curtin University, Perth, WA, Australia.

Introduction: Many meteorites have been identified on the Martian surface by the MER rovers [1-4] and the Mars Science Laboratory (MSL) rover Curiosity [5-7]. These *Martian finds* are different from the SNC meteorites that are fragments of Martian crust found on Earth, and often referred to as *Martian meteorite*s. The Martian finds can significantly enhance understanding of geologic and atmospheric processes on the Red Planet because meteorite baseline composition is known with much higher precision from curated terrestrial falls than that of Martian rocks. Therefore any deviations in meteorite geochemical, mineralogical, and isotopic composition, while resident on Mars, would be the sole result of alteration by the Martian environment. Therefore, meteorites might act like a 'Rosetta stone', helping to decipher Martian surface history. This abstract is intended to facilitate a discussion of whether a weathered meteorite should be considered as a sample of opportunity for Mars Sample Return (MSR).

Insights Gained from Meteorites:

Atmosphere. Meteorite accumulation rates and the average size of meteorite fragments is to first order a function of the density of the atmosphere [8, 9]. For example, the martian iron-meteorite Block Island has been used to argue that the atmosphere was at least an order of magnitude denser when it fell [10], although, others argue this could be a recent fall under current conditions with a shallow entry angle [11].

Weathering. Metallic phases in meteorites make them extremely sensitive tracers to the presence of water [12]. None of the iron meteorites discovered on Mars so far show widespread signs of rust. They do, however, display patches of coating that is associated with iron oxidation [1,4,13]. This coating may have formed during periods of burial or ice exposure during high obliquity cycling [4]. Iron oxidation rates of stony-meteorites discovered by MER Opportunity are determined to be 1-4 orders of magnitude slower than the Antarctic weathering rate of similar materials [14].

Astrobiology. The search for life on Mars requires unambiguous biosignatures. The compositions of Ordinary chondrites (OC) are well known, making the detection of modifications by putative organisms easier to recognize [15]. In fact, ordinary chondrites make attractive habitats for terrestrial microorganisms in arid environments because they become hygroscopic and contain abundant metal and sulfur as energy sources [15].

Open Questions: Ordinary chondrites would be the most suitable targets to be considered as a sample of opportunity for MSR. They are the most common meteorite type found on Earth, and the same is expected for Mars [8]. So far, however, the observed Martian finds are dominated by iron and stony-iron meteorites [1-3], with only one candidate OC. Is this an observational sampling bias, or is there another environmental reason [6]? Indeed, how can OCs be identified by imagery and other remote sensing observations [e.g., 12]?

When considering a weathered ordinary chondrite for sample return, is there sufficient scientific value independent of exposure age? Given the potential upper limit of Noachian resident ages [10,14], can OCs not only survive but also preserve geochemical and isotopic signatures for billions of years?

These are some of the questions that should be addressed to assess the viability of OCs as samples of opportunity for MSR. A focused study of an ordinary chondrite candidate by either Opportunity or Curiosity, if encountered, would assist greatly with the assessment.

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ELEMENTAL COMPOSITION OF MARS RETURN SAMPLES USING X-RAY FLUORESCENCE IMAGING AT THE NATIONAL SYNCHROTRON LIGHT SOURCE II. J. Thieme[1], J. A. Hurowitz[2], M. A. Schoonen[1,2], E. Fogelqvist[3], J. Gregerson[2], K. A. Farley[4], S. Sherman[4], and J. Hill[1] [1]Brookhaven National Laboratory, PO Box 5000, Upton, NY 11973, USA, jthieme@bnl.gov, [2]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794, USA, [3]Eclipe Optics, SE-110 20, Stockholm, Sweden, [4]California Institute of Technology – Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

Background: The National Synchrotron Light Source (NSLS-II) provides a unique and critical capability to perform assessments of the elemental composition and the chemical state of Mars Return Samples using synchrotron radiation X-ray fluorescence imaging and X-ray absorption spectroscopy.

Materials and Methods: Six samples were collected using the coring drill prototype for the Mars 2020 Sample Caching System. These analog samples are Uniform Saddleback Basalt (USB), Bishop Tuff Intermediate (BTI), China Ranch Gypsum (CRG), Kramer Massive Mudstone (KMM), Napa Basaltic Sandstone (NBS), and Old Dutch Pumice (ODP). Parts of these samples were examined with the Sub-micron Resolution X-ray Spectroscopy beamline (SRX). The samples were raster-scanned through the focal X-ray spot, thus creating X-ray fluorescence (XRF) maps, which are collected by an energy dispersive detector.

XRF spectra were analyzed using the PyXRF software to determine elemental distribution and concentrations (Fig. 1). Maps were created showing the heterogeneity within these analogs (Fig. 2).

It can be envisioned to safely transfer the samples from their original collection tubes into highly X-ray transparent container. Therefore, maps and spectra have been obtained with an without such containers, showing no impact on the results.

Future Work: The upcoming SRX capability of mapping and spectroscopy at a spatial level of 100nm will be used to improve resolution. More chemical information for all samples will be collected with additional XRF maps, potentially using other beamlines at NSLS-II with different properties in addition. X-ray absorption spectroscopy is another SRX capability to be applied to these samples. XANES and EXAFS spectra from elements present in the samples reveal the local chemical speciation and coordination within the samples. Using micro-diffraction, the mineralogical structure of the samples can be probed.

Furthermore, additional proof-of-concept measurements will be conducted to determine the feasibility of phase contrast and XRF tomography. In addition, the effect of X-radiation on organic matter and cellular material at the intensities and exposures used in these techniques needs to be evaluated.

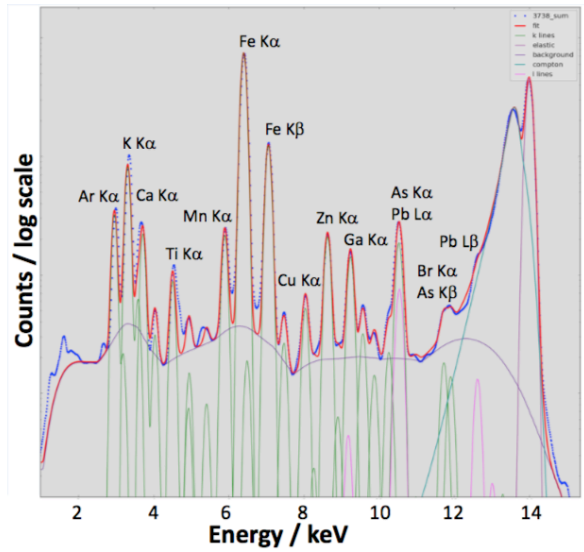

Fig. 1: X-ray fluorescence spectrum of BTI. Note that all elements are visible within just one scan, using here an incident X-ray energy of 14 keV. Main fluorescence peaks are labeled. Using the fitted peak area for each element gives rise to the elemental maps.

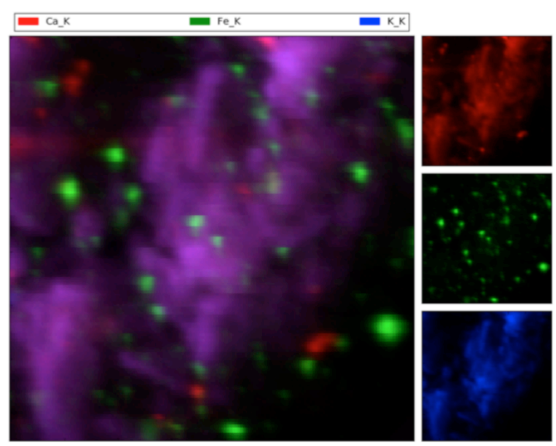

Fig. 2: RGB representation of Ca, Fe, and K in the BTI sample. Note the overlay of Ca and K in large parts. Size: 150x150 μm^2, focal spot = step size: 1 μm^2

Acknowledgements: This work was funded by an SBU-BNL seed grant to JAH and JT and DOE, Office of Science, Basic Energy Science under contract DE-SC0012704.

Antarctic Testing of the European Ultrasonic Planetary Core Drill (UPCD)

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Introduction:

The Ultrasonic Planetary Core Drill (UPCD) project, funded by a ~ €2.5M European Union Seventh Framework grant, has seen a consortium of European partners develop a sample acquisition and caching system for future exploration of terrestrial and icy planetary bodies. The ultrasonic/sonic drilling technique which forms the basis of the technology was pioneered by NASA JPL [1] at the turn of the 21st century. The University of Glasgow, principal investigators of the UPCD project, have worked towards optimizing the technique [2] and integrating the technology into an architecture which allows multi-drill bit coring and caching through a novel application of the bayonet connection method [3, 4].

The UPCD project culminated in a field trial at Coal Nunatak, Antarctic Peninsula, in the Antarctic summer 2016 (Figure 1). The presence of geology found only in the polar regions of Earth and Mars such as a permafrost, frost polygons and sloped lineae qualified the site as a suitable location for testing the hardware.

Figure 1: Coal Nunatak Field Site

The field test campaign allowed the team to push the complete UPCD architecture (Drill System, Sample Caching Carousel and Z-Axis Vertical Actuator, Figure 2) to the limits of its capability. The relatively unknown subsurface ensured that the team would be drilling blind, analogous to the conditions which are experienced by instrument teams on existing and future planetary missions. Testing the system in a Mars analog environment paves the way to achieving an advanced Technology Readiness Level (TRL) 5-6, further enhancing the complement of instrumentation available to the European and worldwide planetary science communities.

Lessons Learned from the Field:

The field site was chosen with guidance from the British Antarctic Survey (BAS) who operate within the British Antarctic Territories in which Coal Nunatak lies. The location is deemed to be analogous to the conditions which might be expected in other polar locations which are more commonly used as Mars analog sites (Antarctic Dry Valleys and the Haughton Impact Crater, Devon Island), though had never been utilised by instrumentation teams seeking to test their hardware. This provided the UPCD team with an exciting opportunity to work in a relatively unexplored environment coupled with the peace of mind afforded by relying on the operational and logistical expertise of BAS, a longstanding leader in polar exploration. Over the course of a ten-day expedition, the UPCD team was met with a number of challenges which it attempted to overcome in order to push the drill harder, exposing areas where the system was most robust and where the technology was lacking.

The terrain proved to be extremely challenging, providing the team with a breadth of lessons learned regarding, predominantly, the need for higher than anticipated drilling torques, amongst other findings which would only have been unearthed in a field test campaign. While the need for greater motor performance was identified, the system proved itself as having a notable robustness in the assembly of complete drill strings, and the subsequent disassembly and caching of these sample-containing core drill bits. This area of research is particularly novel, thus the results are highly encouraging and may confer an exciting and novel ability to future mission planners.

We at the University of Glasgow are eager to present our findings to the international Mars Sample Return community at this upcoming conference..

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CLUES ON PAST CLIMATIC ENVIRONMENTS AND SUBSURFACE FLOW IN MARS FROM AQUEOUS ALTERATION MINERALS FOUND IN NAKHLA AND ALLAN HILLS 84001 METEORITES

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Introduction: Until sample-return missions from Mars are achieved, the achondrite meteorites are the only Martian rocks available for study in our laboratories. Some of them contain evidence of water interaction at different times, and provide valuable information about current and ancient environmental conditions on the red planet [1]. Martian meteorites are so valuable because they have different crystallization ages and relevant information about their formation regions, although many of them remain unknown [1-2]. Here we focus in Allan Hills 84001 meteorite (hereafter ALH 84001) and Nakhla, which can be used for constraining conditions on early Mars because they formed ~4 and 1.3 Ga ago, respectively. Due to their long exposure to the Martian environment, both meteorites recorded processes of interaction with water. In the case of ALH 84001 we concentrate in Fe-Mg-Ca carbonates [2], and in Nakhla in the presence of iddingsite and magnetite.

Instrumental procedure: We have used SEM+EDX techniques to obtain X-Ray mappings to establish the mineralogical composition of the samples and identifying aqueous alteration minerals, particularly focusing here in the carbonate globules in NASA thin section ALH 84001,82 and magnetite in Nakhla. Quantitative chemical analyses were obtained using a JEOL JXA-8900 electron microprobe equipped with five wavelength-dispersive spectrometers at the UCM. Nakhla's sample is a fresh appearance section with no evidence of rusting, being currently part of the IEEC-CSIC meteorite collection repository.

Results: The petrographic features and compositional properties of these two Martian meteorites provide clear evidence for continuous action of water in Martian subsurface. A clear example are the complex carbonates that we have studied in ALH 84001, which are consequence of pervasive action of water. Detailed mineralogical growing patterns indicate that a Mg- and Fe-rich solution saturated the rock, leading to their precipitation in at least 2 or 3 different episodes [2-4]. This is supported by the presence of distinct chemical trends indicating that these carbonates grew in two or more stages. In conclusion, about 4 Ga ago carbonate globule formation occurred when a fluid soaked the host rock of ALH 84001, and it was affected by chemical variations probably associated with atmospheric changes and volcanic outgassing.

On the other hand, Nakhla achondrite is dominated by olivine and augite, but also contains metallic inclusions that often contain magnetite, and iddingsite, two products of aqueous alteration.

Conclusions: Given the well-known geochemical processes that formed both meteorites, we can say that they were significantly affected by water. The presence of aqueous alteration minerals in Nakhla reveals that it was affected by water during or shortly after its crystallization age. Then, it is evidence for quasi-contemporaneous presence of water in Mars' crust. No surprising given the detection of salty fluids emanating from permafrost-like layers in crater borders [4].

Having into account that the crystallization age of Nakhlites and Chassignites can be rounded to 1.3 Ga, and that both types of meteorites are somehow related, a comparison with crater count chronology of different regions suggested that Nakhlites formed on the large volcanic construct of either Tharsis Elysium, or Syrtis Major Planum, being ejected from Mars around 10.75 million years ago by an asteroid impact [5]. The subsurface of some of these regions could be significantly affected by hydrothermal processes.

Conclusions: The presence of distinctive aqueous alteration minerals in Mars like e.g. carbonates and magnetite, could be of great interest to distinguish water sources and identify potential habitats for human exploration and sample-return. Remote-sensing studies could concentrate in rocks with similar mineralogy to obtain valuable clues on the long-standing action of water on the Martian environment.

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EXOMARS CONTRIBUTIONS TO MARS SAMPLE RETURN J. L. Vago[1], H. Svedhem[1], E. Sefton-Nash[1], G. Kminek[1], O. Ruesch[1], A. F. C. Haldemann[1], D. Rodionov[2], and the ExoMars Science Working Team, [1]European Space Agency (Noordwijk, the Netherlands) [2]Space Research Institute of the Russian Academy of Sciences—IKI (Moscow, Russia).

The first ExoMars mission was launched on 14 March 2016 and arrived at the red planet on 19 October 2016. It included two elements: 1) the Trace Gas Orbiter (TGO) to study atmospheric trace gases and subsurface water with the goal to acquire information on possible on-going biological or hydrothermal rock alteration processes; and 2) Schiaparelli, a European entry, descent, and landing (EDL) demonstrator. Unfortunately, the lander was lost during the last minute of its EDL sequence. TGO is performing well and in March 2018 will complete its one-year aerobreaking phase to reach its science orbit, from where it will also provide data communication services for landed missions, nominally, until end 2022.

The second ExoMars mission is scheduled to launch on 24 July 2020. It will deliver to the martian surface an instrumented landing platform and a 310-kg rover having nominal mission durations of one Earth year and 218 sols, respectively.

After the rover will have egressed, the platform will carry out environmental and geophysics measurements at the landing site.

The rover will be equipped with a drill to collect samples from outcrops and below the surface, reaching down to 2 m. Such depth range has never been probed on Mars before. ExoMars' subsurface sampling capability may provide the best chance yet to access and analyse well-preserved sedimentary deposits, possibly containing molecular biosignatures [1].

The rover accommodates a suite of instruments—the Pasteur payload—for characterizing the landing site's geological context [2,3,4,5,6] and for analyzing the mineralogy [7,8,9] and organic composition [10] of the collected samples.

Each ExoMars mission has the potential to make discoveries that could inform and perhaps influence our collective strategy for future Mars Sample Return (MSR) missions: (1) TGO may detect methane and/or other atmospheric trace organic species in association with certain regions or seasons; and (2) the ExoMars rover could confirm our hypothesis that organic molecules can be found in a better state of preservation against the ravages of ionizing radiation at depth [11,12]. A new organics extraction and analysis technique—that seems not to suffer from the presence of oxychlorinated species in the sample material [10]—will allow discriminating between meteoritic delivered organic compounds and those having a possible biogenic interest.

The second ExoMars mission's two remaining candidate landing sites—Oxia Planum and Mawrth Vallis—were proposed based on their strong potential for past habitability and for preserving physical and chemical biosignatures (as well as abiotic/prebiotic organics). Both locations are ~4.0 Ga old, include evidence of long duration aqueous activity, and will provide access to deposits of an age no longer available for study on our own planet. The absence of global plate tectonics on Mars increases the probability that rapidly buried, ancient sedimentary rocks (possibly hosting microorganisms) may have been spared thermal alteration and been shielded from ionizing radiation damage until denuded relatively recently. The geological properties of Oxia Planum and Mawrth Vallis are substantially different from those of previous Mars landed missions. Thus, ExoMars has the potential to deliver a new understanding of the petrological, mineralogical and chemical record hosted on layered, phyllosilicate-rich areas of Mars. This knowledge may also influence the selection of materials for sample return.

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PTAL database and website: developing a novel information system for the scientific exploitation of the Planetary Terrestrial Analogues Library.

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Introduction: In recent years, orbiters and exploration rovers identified the presence of several hydrated mineral phases (i.e. phyllosilicates, sulphates) on the Martian surface, proving a wide range of past aqueous activity [1, 2].

This scientific finding has given a renewed impetus to research lines dedicated on understanding the geological evolution of Mars and on assessing its habitability during past global climatic eras. In this context, the study of terrestrial analogues became an essential tool for defining geological or biological processes that could have been occurred on Mars and other extraterrestrial bodies.

In spite of the critical importance of this field of study, the many results collected so far are still dispersed across the scientific literature. To overcome this limitation, this work aims to introduce the Planetary Terrestrial Analogues Library (PTAL) website that is being developed in the framework of the PTAL project (see Figure 1) [3, 4].

PTAL database and website: The PTAL website will deliver an extended multi spectral database of materials collected from several terrestrial analogues sites, which have been selected on the basis of their congruence to well-known Martian geological and environmental contexts. The collected samples are being characterized by near-infrared (NIR) [5], laser-induced breakdown (LIBS) and Raman spectroscopies by using both commercial and dedicated spacecraft instrumentation. Spectroscopic data are also supported by X-ray crystallography (XRD) analysis and other complementary techniques. As a whole, the multi analytical study will provide a comprehensive view of the geochemical and mineralogical composition of the samples and their geological context. The information system will also include data collected from artificial samples (replicating Martian protoliths composition) altered in the laboratory under controlled physical-chemical conditions (gas pressures, aqueous salinity, temperature etc.). Hence, essential inputs to develop and/or confirm chemical and thermo dynamical models of Martian alteration processes will be also provided.

Furthermore, the database will be integrated with a platform with several tools for advanced spectra processing. These tools include intensity normalization, baseline correction, instrument response correction and lineal combination of spectral data.

Finally the web-based platform will also implement a novel functionality that provides to users the possibility of requesting physical access to analogues and synthesized materials. In this way, it will be offered the opportunity to combine the data contained in the PTAL library with further analysis in the laboratory.

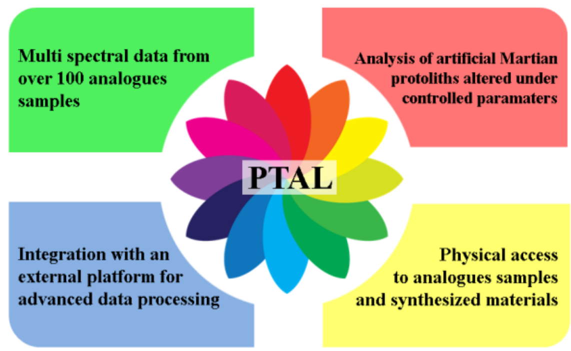

Figure 1: Overview of the main services provided by PTAL database and website

Conclusions: The PTAL website aims to become a cornerstone platform for the scientific community interested on deepens the understanding of geological aspects and processes of solar system planets and other extraterrestrial bodies. Considering that terrestrial and synthesized materials have been selected due to their congruence to Martian geological and environmental contexts, this platform could be also an important resource for the selection of samples to be collected on Mars and returned to Earth.

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Acknowledgements: This project is financed through the European Research Council in the H2020-COMPET-2015 programme (grant 687302).

MARS SAMPLE RETURN – EARTH RETURN ORBITER MISSION OVERVIEW. S. Vijendran, J. Huesing, F. Beyer, A. McSweeney, European Space Agency - European Space Research and Technology Centre (ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands, sanjay.vijendran@esa.int.

Introduction: The international Mars Architecture for the Return of Samples (iMARS) report, published in 2008, detailed elements of a multi-mission campaign that would for the first time return to Earth a set of rigorously documented samples collected from Mars. Since the publication of the first iMARS report, NASA and ESA have together been exploring mission concepts for the delivery of such a campaign. In 2012, the Mars 2020 rover mission was approved by NASA with the goal of caching and depositing on Mars a scientifically valuable set of samples for eventual return to Earth. Two subsequent missions working in tandem are currently foreseen to achieve this next step .First, the Sample Return Lander mission, which deploys a landed platform to the Mars 2020 landing site, from which a small Sample Fetch Rover egresses and retrieves the cached samples. After returning to the lander, the samples would be transferred to an Orbiting Sample (OS) canister and loaded into a Mars Ascent Vehicle (MAV), which launches the OS into low Mars orbit.

The second mission foreseen is the Earth Return Orbiter (ERO) which locates, rendezvous with and captures the OS in Mars orbit and seals it into a biocontainer before inserting it into an Earth Entry Vehicle (EEV). The ERO would leave Mars orbit and return to Earth, releasing the EEV on an Earth-impacting trajectory before performing an Earth avoidance maneuver itself. The EEV then lands at a designated site and is transferred to a Sample Receiving Facility for storage, opening and evaluation.

ESA has conducted extensive industrial pre-Phase A studies on sample return mission concepts in recent years as part of the Mars Robotic Exploration Preparation (MREP) Programme. These activities, as well as two architectural assessment studies conducted in 2017 will form the basis of an upcoming parallel Phase A/B1 industrial study of the ERO mission. ESA aims to prepare a programme proposal for an implementation decision at the next Council of Ministers meeting, expected in December 2019.

This presentation will serve as an overview of the Mars Sample Return - Earth Return Orbiter mission and how it fits into the overall MSR campaign architecture, as well as discuss previous and recent studies that have highlighted the key challenges and criticalities of this mission.

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Acknowledgment: ESA is grateful to NASA and the Jet Propulsion Laboratory for contributing to the work described in this abstract. The research by the Jet Propulsion Laboratory, California Institute of Technology, was performed under a contract with the National Aeronautics and Space Administration.

FACILITY OR FACILITIES? THAT IS THE QUESTION. M. Viso [1]Centre national d'études spatiales (CNES), 2 place Maurice Quentin, 75001 Paris Cedex 01, France.

Introduction: Retrieving samples from Mars and sending them to Earth to achieve scientific studies it's a technical challenge. The science which would be performed with such samples will be, without any doubt, an enormous step forward in the knowledge of the formation and evolution of the planet and would give some clues about the possibility that a prebiotic chemistry or a form of life emerged on this planet.

For these reasons, most if not all the space agencies, are categorizing this Mars Sample Return Mission, using the COSPAR Planetary protection Nomenclature [1] as Category V mission, in a subcategory defined as "restricted Earth return".

Categorization: Within the recommendations issued by the COSPAR, such a categorization imply several constraints in the development of the various steps of the space segments. This implies also stringent constraints on the Earth segment which will manage the samples. Since the work performed by the Space Studies Board of the National Research Council in the USA [2] the recommendations from the COSPAR are detailed and refined through various documents from the space agencies and the COSPAR. From these works several functions have to be fulfilled upon the arrival on earth of those samples which could be summarized as Receiving the samples, identifying the samples, protecting the samples from the earth atmosphere and biosphere, and protecting the release of any particle of the samples in the earth biosphere, performing biohazard testing and life detection, hen performing a curation and possibly the distribution of the samples.

From a single facility to several facilities: All these functions could be performed in a single facility the Mars Sample Receiving Facility. But the workload and the associated cost will be high. The risks of catastrophic event which could lead to the loss of all the samples would be concentrate on a single point. Finally, while the Mars sample return mission will be an international joint effort for the space segment, naturally, the partners will intend to contribute as well at the ground segment. This leads to define clearly the type of facilities and the functions that they will fulfill.

Sample Receiving Facility. Assuming that the samples will arrive on Earth in a single sealed and tight container this facility will have to ensure the proper isolation to open the return container, retrieve the individual Mars Sample Containers, identifying each one and testing their tightness. After these tests the container could be transferred for the characterization of the samples and the quarantine.

Sample Quarantine Facilities. The individual Mars sample Containers will be spread in the appropriate quarantine facility where they will be open, samples will be identified, characterized and split in several aliquots: for life detection and biohazard testing, for short and long term curation. The approved and certified facilities will perform the jointly agreed and approved testing protocol as described in the Draft protocol [4] (updated)

Sample Curation Facilities During the quarantine the samples dedicated to the curation will be sorted, identified and described in order to be further analyzed by the end of the quarantine, by the selected science teams. The curation will continue "forever" as it is done in the USA for the lunar samples.

The quarantine facilities will have the highest level of containment to prohibit any release of Martian material in the terrestrial biosphere. Up to the possible release of the Quarantine, the curation facilities will have the same level of containment and protection of the samples.

The Sample distribution: Independently of the place they will curate or investigate, the Martian samples will part of a single set of samples and will be managed according with a sample management plan agreed between the partners and under the auspices of a single joint committee. Their distribution for the science investigation will be subject to the now classical selection process based on the best science.

Conclusion: The Mars Sample Return Mission is challenging. The management of the returned samples will require joint efforts to mobilize all over the world the best scientists either to certified their planetary protection status (safe/unsafe), to ensure the best possible curation and to maximize the scientific return of thei ambitious missions.

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MARTIAN REGOLITH FOR PLANT-BASED LIFE SUPPORT. A. M. Visscher[1], C. E. Seal[1] and H. W. Pritchard[1], [1]Department of Comparative Plant and Fungal Biology, Royal Botanic Gardens, Kew, Wellcome Trust Millennium Building, Wakehurst Place, Ardingly, RH17 6TN, West Sussex, United Kingdom: a.visscher@kew.org; c.seal@kew.org; h.pritchard@kew.org.

Human beings are uniquely qualified to undertake key scientific investigations in the space environment, ranging from life and physical sciences research in microgravity, to geological and biological fieldwork on planetary surfaces [1]. For human mission durations that extend beyond one or two years, resupply of large volumes and masses of food, water, and atmospheric gases becomes unrealistic [2]. Therefore, long-duration future habitation of space involving great distances from Earth and/or large crew sizes (for example a lunar outpost or a Mars base) will require a controlled ecological life-support system to simultaneously revitalize atmosphere (liberate oxygen and fix carbon dioxide), purify water (via transpiration), and generate human food (in the form of cereals, legumes and oilseeds) [3].

Photosynthetic higher plants are able to provide key roles in several of these essential processes, including atmosphere regeneration, wastewater recycling and food production. For larger and longer-term habitats on the Moon or Mars, additional benefits from plants include construction materials, fabrics, medicines, dyes, lubricants, biofuels, well-being and aesthetics. A first attempt to design and research larger-scale life support systems was made in Arizona in 1991. For two years, the Earth-based closed ecological system Biosphere 2 supported over 3000 documented species of plants and animals in a number of ecosystems patterned after natural biomes (e.g. rainforest, savanna, desert, freshwater and salt-water marsh and coral reef oceanic systems) as well as an intensive agriculture system and a human habitat [4, 5].

Since plants will play several key roles in long-term life support systems on other planetary surfaces, it is crucial to know how they should be grown in such systems. The use of *in situ* regolith as a seed germination and plant growth substrate may have several advantages over hydroponic systems, such as the immediate bioavailability of plant essential ions, low-tech mechanical support for plants, and easy access to *in situ* materials once on the surface [6, 7]. However, the growth of certain plant species may be reduced by phytotoxic substances present in the regolith, such as high levels of soluble magnesium sulphate minerals found in various locations on Mars [8].

Although no sample return missions have ever taken place for Mars to date, approximately 380 kg of lunar material was collected and returned to Earth during the Apollo spacecraft era. A review of the subsequent experiments performed with some of this material shows that none of the studies accomplished so far have used pure lunar substrates for seed germination and plant growth analyses [9]. In all tests, seeds and plants were grown “in contact with” rather than “in” lunar samples [9]. Based on these findings we can conclude that future research addressing the use of *in situ* regolith for plant growth on the Moon or Mars is dependent on access to sufficient amounts of planetary material.

By using a future Mars mission as an enabling platform, we propose to investigate the plant growth potential of pure Martian regolith samples that could be collected and returned to Earth from several locations on Mars differing in geochemical composition. Our aim is to assess potential differences in responses to Martian regolith between plant species by selecting a range of species representing wide taxonomic diversity, climatic zones, habitats, life forms, seed characteristics and plant uses. We would do this by drawing on our scientific expertise in comparative seed and plant biology, in combination with access to >30,000 species available as seed through Kew’s Millennium Seed Bank Partnership. The expected results could lead to conclusions regarding the suitability of Martian regolith as a substrate for seed germination and plant growth in biodiverse life support systems on Mars. Information of this kind is essential to the design and technical requirements of long-term Mars bases, as it may impact the decision to include *in situ* resources such as Martian regolith, and, if so, for what processes (seed germination and/or plant growth) and what plant species (in case species vary in their performance). In addition, it may influence the location of a potential Mars base (depending on differences found between regolith samples of varying geochemical composition).

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DESCRIPTION OF EUROPEAN SPACE AGENCY (ESA) CONCEPT DEVELOPMENT FOR A MARS SAMPLE RECEIVING FACILITY (MSRF). John Vrublevskis[1], Lucy Berthoud[1], Michael Guest[1], Caroline Smith[2], Allan Bennett[3], Francois Gaubert[4], Hilde Schroeven-Deceuninck[5], Ludovic Duvet[5], Michel van Winnendael[4], [1]Thales Alenia Space UK Limited, Building 660, Bristol Business Park, Bristol, BS16 1EJ UK john.vrublevskis@thalesaleniaspace.com, [2]The Natural History Museum, Cromwell Road, London SW7 5BD UK C.L.Smith@nhm.ac.uk, [3]Public Health England, Porton Down, Wiltshire SP4 0JG UK allan.bennett@phe.gov.uk, [4]ESA-ESTEC, Keplerlaan 1, Postbus 299, 2200 AG Noordwijk NL Francois.Gaubert@esa.int, [5]ESA-ECSAT, Fermi Avenue, Harwell Campus, Didcot, Oxfordshire, OX11 0FD UK Michel.van.Winnendael@esa.int

Introduction: This presentation gives an overview of the several studies conducted for the European Space Agency (ESA) since 2007 which progressively developed layouts for a potential implementation of a Mars Sample Receiving Facility (MSRF) primarily for the purpose of identifying low TRL equipment critical for the operation of the MSRF. From this chain of analysis (some of which is based on assumptions of uncertain or unknown information) it was discovered that the five major drivers for an MSRF layout are 1. Biocontainment, 2. Cleanliness, 3. Returned Sample Type, 4. Hardware used to contain the returned sample and 5. Instruments used for scientific analysis. A change to any one of these drivers would result in a different MSRF layout and possibly a change to the technology used.

The initial ESA study conducted by Thales Alenia Space in the UK for an MSRF was started in 2009 and developed an initial set of top level requirements which were discussed and used at a multi-disciplinary workshop. After the requirements study a follow-on ESA DWI feasibility study examined the available technology options for the DWI. The subsequent 'DWRTP MSRF' layout reflected the need for Double Walled Rapid Transfer Port (DWRTP) containers to remove single point failures and to give operational flexibility. The latest update to the layout resulted from a 'consolidated inventory' of scientific investigations developed at a ESA working group in February 2015.

As a consequence of this development ESA have used the results to initiate two 'breadboard' developments to demonstrate the key technologies used in the DWIs and the RM system. It should be noted that MSRF will be an international facility and whereever the location of the MSRF is the high cost low TRL equipment being developed currently can be used as a very significant contribution of Europe to the MSRF, comparable to an instrument for a ground based telescope.

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Description of European Space Agency (ESA) Double Walled Isolator (DWI) Breadboard currently under development for Demonstration of Critical Technology foreseen to be used in the Mars Sample Receiving Facility (MSRF) . John Vrublevskis[1], Lucy Berthoud[1], Ysatis McCulloch[1], Portia Bowman[1], John Holt[2], John Bridges[2], Allan Bennett[3], Francois Gaubert[4], Ludovic Duvet[5], [1]Thales Alenia Space UK Limited, Building 660, Bristol Business Park, Bristol, BS16 1EJ UK john.vrublevskis@thalesaleniaspace.com, [2]Space Research Centre, Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH UK jmch1@leicester.ac.uk, [3]Public Health England, Porton Down, Wiltshire SP4 0JG UK allan.bennett@phe.gov.uk [4]ESA-ESTEC, Keplerlaan 1, Postbus 299, 2200 AG Noordwijk, The Netherlands Francois.Gaubert@esa.int, [5]ESA-ECSAT, Fermi Avenue, Harwell Campus, Didcot, Oxfordshire, OX11 0FD UK Ludovic.Duvet@esa.int

Introduction: The need for biocontainment from COSPAR's Planetary Protection Policy and the need for cleanliness for scientific investigation requires that the sample returned from Mars by the Mars Sample Return (MSR) mission must be handled in a Double Walled Isolator (DWI); an isolator that provides simultaneous biocontainment and cleanliness.

The layout and architecture of a Mars Sample Receiving Facilty (MSRF) is determined by the DWIs used and demonstrating the technology used in DWI is critical to the development of the MSRF. Hence the European Space Agency (ESA) initiated a feasibility study to investigate technologies unique to a DWI followed by breadboard demonstrator hardware that would determine the performance and suitability of the critical technologies.

A presentation of the results of the DWI feasibility study will be made followed by early results from the manufacture and early technology demonstrations of the DWI Breadboard.

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Description of European Space Agency (ESA) Remote Manipulator (RM) System Breadboard currently under development for demonstration of Critical Technology foreseen to be used in the Mars Sample Receiving Facility (MSRF). John Vrublevskis[1], Steve Duncan[1], Lucy Berthoud[1], Portia Bowman[1], Russell Hills[1], Ysatis McCulloch[1], Doina Pisla[2], Calin Vaida[2], Bogdan Gherman[2], Michael Hofbaur[3], Bernhard Dieber[3], Narendrakrishnan Neythalath[3], Caroline Smith[4], Michel van Winnendael[5], Ludovic Duvet[6], [1]Thales Alenia Space UK Limited, Building 660, Bristol Business Park, Bristol, BS16 1EJ UK john.vrublevskis@thalesaleniaspace.com, [2]Technical University of Cluj-Napoca, Research Center for Industrial Robots Simulation and Testing, 28, Memorandumului, Cluj-Napoca, 400114 Cluj, Romania doina.pisla@mep.utcluj.ro, [3]Joanneum Research Forschungsgesellschaft mbH, Institute for Robotics and Mechatronics Lakeside B08a, 9020 Klagenfurt am Wörthersee, Austria, [4]The Natural History Museum, Cromwell Road, London SW7 5BD UK, [5]ESA-ESTEC, Keplerlaan 1, Postbus 299, 2200 AG Noordwijk, The Netherlands Michel.van.Winnendael@esa.int, [6]ESA-ECSAT, Fermi Avenue, Harwell Campus, Didcot, Oxfordshire, OX11 0FD UK Ludovic.Duvet@esa.int

Introduction: In order to avoid the use of 'double walled' gloves an haptic feedback Remote Manipulation (RM) system rather than a gloved isolator is needed inside a Double Walled Isolator (DWI) to handle a sample returned from Mars by the Mars Sample Return (MSR) mission. The recent widespread introduction of collaborative robots ('Cobots') into manufacturing environments has resulted in an increase in availability (with a decrease in price) of industrial robotic arms equipped with force sensors that can be used for haptic feedback control. Also 'device agnostic' software environments are being introduced for haptic feedback robotic arm control that allows extensive reuse of software.

The layout and size of any DWI used is determined by the robotic arm & tools required to handle the returned sample & hardware used to contain the returned sample as well as any scientific instrument interfacing to a DWI. Hence the European Space Agency (ESA) first initiated a feasibility study to investigate technologies required for RM systems followed by breadboard demonstrator hardware that would determine the performance and suitability of the critical technologies.

Commercial Off The Shelf (COTS) hardware is being employed to demonstrate cuurent technology sample handling capabilities at a macro level and micro level of handling. This hardware will be controlled by custom, device agnostic software that is expected to be fully reusable. A presentation of the results of the RM systems feasibility study will be made followed by early results from the manufacture and early technology demonstrations of the RM systems Breadboard.

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X-RAY DIFFRACTION (XRD) AND X-RAY FLUORESCENCE (XRF) FOR *IN SITU* SURFACE CHARACTERIZATION AND TRIAGE OF CACHED SAMPLES. R. C. Walroth,[1] D.F. Blake,[1] P. Sarrazin,[2] T. Bristow[1] and K. Thompson[2] [1]Exobiology Branch, MS 239-4, NASA Ames Research Center, Moffett Field, CA 94035 (richard.c.walroth@nasa.gov), [2]SETI Institute, Mountain View, CA 94043.

Introduction: Sample return from the Martian surface or its moons poses a high degree of science risk and mission cost. An optimized sample return strategy should include contextual information to establish the provenance of a sample as well as sample triage during caching [1]. *In situ* X-ray based methods can elucidate provenance (e.g., past/present habitability), inform cache/discard decisions for individual samples, and document a sample's original mineralogy should changes occur during its return to Earth.

X-ray Diffraction (XRD): Because XRD probes the structural arrangements of atoms, it can definitively identify crystalline materials from first principles. The quantitative abundance and chemistry of minerals in a complex mixture can be determined through Rietveld refinement [2]. Isochemical phase transformations, undetectable by elemental analysis techniques, can be determined with great certainty using XRD.

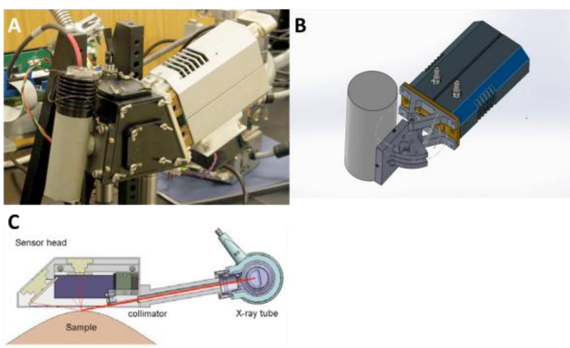

Figure 1. A) XTRA prototype demonstrating reflectance geometry. B) Guinier prototype in reflectance geometry. C) Schematic illustrating components of an arm-mounted Hybrid XRD.

CheMin: The CheMin XRD on Mars Science Laboratory has provided unique insight into the ancient environments of Mars, including evidence of habitability [3]. While CheMin has demonstrated the value of *in situ* XRD measurements, the instrument requires that samples be ground and sieved prior to analysis. We are developing next-generation XRD instruments that relax or remove these requirements.

XRD Instruments in Development: The Extraterrestrial regolith analyzer (XTRA) can characterize as-received regolith without sample preparation (Fig. 1A). A Guinier geometry XRD is in development that will provide high resolution data with faster collection times in a smaller footprint (Fig. 1B). Finally, the Hybrid XRD is an arm-mounted instrument capable of characterizing rocks and soil without either sample preparation or collection. Depending on the nature of the rover sent to collect samples, these instruments may serve as viable alternatives to a CheMin like instrument for *in situ* XRD analysis.

X-ray Fluorescence Mapping: XRF mapping can provide spatially-resolved elemental information at a scale commensurate with microbial life or its processes. The Mapping X-ray fluorescence spectrometer (MapX) is a full-field imaging spectrometer capable of providing elemental composition information at the 100 μm scale [4]. MapX has no moving parts and a demonstrated depth-of-field of 10 mm, allowing for rough untreated surfaces to be imaged with minimal loss of resolution. By employing ^{244}Cm as an excitation source, MapX can detect concentrations of biogenic elements such as C and N and O.

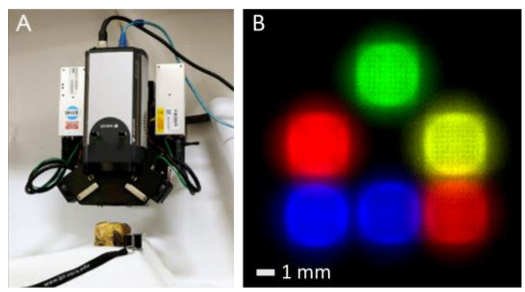

Figure 2. A) MapX-II prototype employing two X-ray tubes, a micro-pore optic X-ray lens and a commercial CCD camera. B) Mesh grid targets demonstrating spatial resolution and element identification. Cu in red, Ti in blue, Fe in green, and Ni in yellow.

Summary: An optimized sample return strategy should include *in situ* analysis capabilities such as XRD and XRF mapping that provide contextual information (provenance), inform sample triage, and establish the original mineralogy of returned samples.

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Acknowledgements: The authors are grateful for support from NASA's PICASSO and MatISSE programs, as well as NASA postdoctoral support to RCW.

ENGINEERING CHALLENGES FOR A SAMPLE FETCH ROVER.
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Introduction: Through 2017 plans for an international Mars Sample Return (MSR) mission have progressed, with a target launch in 2026. As part of this the European Space Agency (ESA) is exploring the possibility of contributing a Sample Return Orbiter as well as a Sample Fetch Rover (SFR).

In parallel to ESA's planning, Airbus has investigated the challenges associated with the rover surface mission requirements. This presentation will focus on these engineering challenges associated with the design and operation of the SFR.

The SFR is a key element of any Mars Sample Return mission. Landing with the Mars Ascent Vehicle (MAV), it is required to rapidly retrieve samples from their remote cached location and return them to the MAV for transfer to orbit. Due to its critical role in the mission, high reliability is also a key driver for the SFR.

Previous Work: In 2011 Airbus performed an assessment (Phase 0) study for an SFR mission [1]. It called for a 60kg rover vehicle to traverse 20km within 110 sols. The majority of the surface mission occurred prior to the Martian dust storm season, allowing the operations to be performed in benign optical conditions.

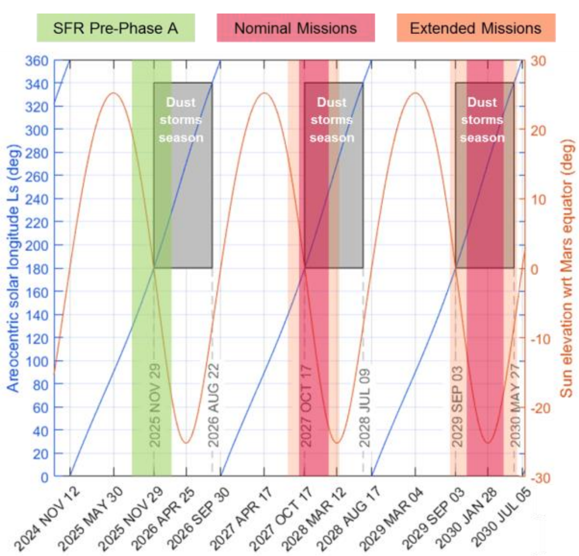

Figure 1: The SFR surface missions shown with the dust storm seasons

Current Mission: The new MSR misstion architecture places a number of challenging requirements on the SFR, extending beyond those in the assessment study. It requires a 125kg rover vehicle to traverse up to 30km within 155 sols. This paper will focus on these new requirements and the challenges they place on the SFR mission, and how they will drive the rover design. These key challenges can be broadly split into three domains: power and energy, mass and total distance traversed. These three domains are coupled and an optimization between them is required to achieve the mission.

Power and Energy. The mission concept studied for the Phase 0 enabled a significant portion of the the SFR surface mission to occur before the Martian dust storm season. As such, the rover was not required to operate or survive during the high optical depths. In contrast, the start of the SFR surface mission in the new mission architecture coincides with the Martian dust storm season, as is shown in Figure 1. This leads to the SFR having to both operate and survive at much higher optical depths. This presents a significant challenge for the SFR power and energy budgets. A constraint on the amount of energy available also constrains the traverse distance the SFR can achieve in a single sol. Additional energy could be achieved through a larger solar array and battery, but the size of these is constrained by several factors including the available mass.

Mass. The SFR is delivered to the surface along with the MAV. Because of this, the total mass available for the SFR is limited to c.125kg. This is approximately one third of the mass of the ExoMars Rover Vehicle, presenting a significant challenge when a similar level of mobility, higher speed and higher total traverse is required.

Total Traverse. The total required traverse has increased by 50% from the Phase 0 study, to 30km. This requires the SFR to traverse further each sol. In contrast, the ExoMars Rover Vehicle is designed to traverse 4km in just over 200 sols. Increasing the daily traverse requires significantly more energy per sol, the amount of which available is constrained by both the available mass and the atmospheric conditions.

This paper will address these challenges and how to meet them whilst still achieving a launch in 2026.

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PALEOMAGNETIC STUDIES OF RETURNED SAMPLES FROM MARS. B. P. Weiss[1] and the Returned Sample Science Board (D. W. Beaty[2], H. Y. McSween[3], B. L. Carrier[2], A. D. Czaja[4], Y. S. Goreva[2], E Hausrath[5], C. D. K. Herd[6], M. Humayun[7], F. M. McCubbin[8], S. M. McLennan[9], L. M. Pratt[10], M. A. Sephton[11], A. Steele[12]), [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 54-814, 77 Massachusetts Avenue, Cambridge, MA 02139, bpweiss@mit.edu, [2]Jet Propulsion Laboratory, Pasadena, CA, [3]University of Tennessee, Knoxville, TN, [4]University of Cincinnati, Cincinnati, OH, [5]Universitiy of Nevada, Los Vegas, NV, [6]University of Alberta, Edmonton, Canada, [7]Florida State University, Tallahassee, FL, [8]NASA Johnson Space Center, Houston, [9]Stony Brook University, Stony Brook, NY, [10]Indiana University, Bloomington, IN, [11]Imperial College, London, U.K., [12]Carnegie Institution, Washington, DC.

Introduction: The red planet is a magnetic planet. Mars' iron-rich surface is strongly magnetized, likely dating back to the Noachian epoch when the surface may have been habitable. Paleomagnetic measurements of returned samples could transform our understanding of the Martian dynamo and its connection to climatic and planetary thermal evolution and provide powerful constraints on the preservation state of biosignatures in the samples.

Although Mars presently does not have a core dynamo magnetic field, but the discoveries of intense magnetic anomalies in the ancient southern cratered terrane by the Mars Global Surveyor mission [1] and remanent magnetization in Martian meteorite ALH 84001 [2] provide strong evidence for a Martian dynamo during the Noachian epoch. The time of origin and subsequent decline of this field are poorly constrained but have critical implications for planetary thermal and tectonic history [3] and the evolution of the Martian atmosphere and climate [4].

Science from paleomagnetic studies: When magnetic minerals crystallize, cool, or are aqueously deposited in the presence of a magnetic field, they will magnetize in the direction of the local magnetic field with an intensity that scales with the field intensity. As a result, paleomagnetic studies of rocks yield two main pieces of information: the paleointensity and the paleodirection of past fields.

Because the original orientations in which all Martian meteorites and returned samples acquired their magnetizations are unknown, all paleomagnetic studies on Martian samples to date have only been able to infer the field paleointensity. By comparison, paleomagnetic studies of returned, oriented samples afford: (a) the first opportunity to infer the paleodirection of Martian paleofields; (b) geologic context; (c) the opportunity to obtain semicontinuous time sequences of paleomagnetic measurements; and (d) measurements of samples unaffected by shock processing associated with planetary ejection of meteorites.

A recent community-based study [5] produced a ranked list of key science objectives that could be achieved using paleomagnetic studies of returned Mars samples and that are linked to the leading Mars science objectives identified by the End-to-End International Science Analysis Group (E2E-iSAG) [6]. The top 6 objectives identified were:

1) Determine the intensity of the Martian dynamo
2) Characterize the dynamo reversal frequency and conduct magnetostratigraphy
3) Constrain the effects of heating, aqueous alteration, and radiolysis on the samples
4) Test the hypotheses that Mars experienced plate tectonics and/or true polar wander and constrain the tectonic and deformational history of the landing site
5) Determine the major mineral carriers of Martian crustal magnetization
6) Constrain sediment sourcing, fluid flow, and the depositional environment using environmental magnetism studies.

Sampling and curation strategy. The ideal targets for paleomagnetic studies are oriented samples acquired from bedrock with well-defined paleohorizontal indicators and lacking complex metamorphic, aqueous alteration, and shock histories. Samples should ideally be acquired from a time spanning the estimate lifetime of the Martian dynamo (pre-Noachian to Noachian Periods) During and following sampling, key sample quality criteria for ensuring the success of the magnetism science objectives are: (a) no exposure to fields >200 μT, (b) no exposure to temperatures >100 °C, (c) no exposure to pressures > 0.1 GPa, and (d) samples absolutely oriented with respect to bedrock with a half-cone uncertainty angle of <5°. On Earth, samples should be stored in a magnetically-shielded environment to prevent remagnetization in the Earth's field. Our recent tests of the Mars 2020 testbed drill indicate that all criteria are likely to be met, with the possible exception that some cores may experience unconstrained azimuthal rotations.

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The Planetary Terrestrial Analogues Library (PTAL). Werner, S.C.[1], H. Dypvik[1] , F. Poulet[2], F. Rull Perez[3], and the PTAL team. [J.P. Bibring[2], B. Bultel[1], C. Casanova Roque[3], J. Carter[2], A. Cousin[4], A. Guzman[3], V. Hamm[2], H. Hellevang[1], C. Lantz[2], G. Lopez-Reyes[3], J. A. Manrique[3], S. Maurice[4], J. Medina Garcia[3], R. Navarro[3], J. I. Negro[3], E.R. Neumann[1], C. Pilorget[2], L. Riu[2], C. Sætre[1], A. Sansano Caramazana[3], A. Sanz Arranz[3], F. Sobron Grañón[3], M. Veneranda[3], J.-C.Viennet[1]]. [1]CEED/GEO, University of Oslo, Norway (Stephanie.Werner@geo.uio.no), [2]University Paris-Sud, France, [3]University of Valladolid, Spain, [4]University of Toulouse, France.

The Planetary Terrestrial Analogues Library project aims to build and exploit a spectral data base for the characterisation of the mineralogical and geological evolution of terrestrial planets and small Solar System bodies. Basis for the library is our collection of natural field-collected and artificial planetary (often Martian) analogue materials as well as materials, which have been altered in laboratory experiments. Under controlled conditions and documenting rock alteration of analogue materials, the impact of varying environmental conditions (e.g., gas pressure, temperature, pH-value) can be quantified. All collected, and produced samples of rocks and their alteration / weathering products will be first characterised by XRD, thin sections as base and as input for the spectral library with standard commercial and dedicated spacecraft instrumentation (NIR, RAMAN, LIBS, XRD, thin sections) under laboratory conditions, and where possible on in-situ field campaigns at Earth analogue sites.

All data will be published and fed to the data base, which will allow users to jointly interpret laboratory results and newly gathered in-situ or remote sensing data using instruments (LIBS, NIR, Raman) on board of current and future space missions (e.g., Hayabusa-2, Curiosity, ExoMars, Mars2020). The main aim of the database is the use of spectra stored for purposes related to comparison, identification, quantification and spectral calculation when spectroscopic instruments such as NIR, Raman and LIBS operate in planetary missions and/or analysing materials in the field or in the laboratory.

Techniques: *Mineral Alteration Experiments:* Natural and artificial analogue materials have been altered in reaction bombs in aqueous solutions under various controlled experimental conditions to analyse alteration pathways with already first results, e.g. [1].

Near-Infrared Hyperspectral Imaging can be performed both on satellite and landed platforms, and is a non-destructive technique to detect most potential constituents: silicates, oxides, salts, hydrated minerals, ices and frosts, as well as organic compounds, discriminating between specific members in each family (e.g. low and high Ca pyroxenes, forsterite and fayalite, Mg and Al rich phyllosilicates, aliphatic and aromatic compounds), presented in [2].

Raman Laser Spectroscopy is a powerful technique used in a wide range of applications from mineralogy to biosciences or industry. The Raman spectrum shows very sharp bands, which allow unambiguous molecular identification of materials, presented in [3].

Laser-Induced Breakdown Spectroscopy is an active analytical technique that makes use of a laser pulse to analyse materials of interest at a distance by producing short-lived plasma with atoms in an excited state. Spectral analysis of the emitted light makes it possible to identify elements present in the sample from their characteristic emission lines of major elements (O, Na, Mg, Al, Si, K, Ca, and Fe), and additional minor and trace elements.

Synergy – Joint Inversion: The terrestrial analogue sites and their materials are useful for testing technology and instruments for planetary exploration, such as the evaluation of combined analytical conditions, to test standards and portable instruments, and to define the Planetary Terrestrial Analogues Library spectral input data. Because of the complementarity of their selection rules, Raman and IR spectroscopy are ideal to be combined for analysis of minerals and organic compounds. All natural, artificial and alteration product samples will be characterised by each of the sensing methods compare [2,3].

PTAL – The spectral library The goal of the Planetary Terrestrial Analogues Library database is to allow the use of spectra stored for purposes related to comparison, identification, quantification and spectral calculation when spectroscopic instruments such as NIR, Raman and LIBS operate in planetary missions and/or for analysing materials in the field or in the laboratory. The spectra are classified in close correlation with the well charcterised (XRD, thin sections) samples, from which they were obtained.

This data base features spectral tools allowing for the spectral data treatment implementation plans are the integration of the database management and algorithms in an end-user platform with graphical interfaces for the use of the data and analysing tools. The public release of the Planetary Terrestrial Analogues Library will be at the end of year 2020.

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Acknowledgements: This project is financed through the European Research Council in the H2020-COMPET-2015 programme (grant 687302).

The search for life on Mars: latest results. Frances Westall, CNRS-Centre de Biophysiaue Moléculaire, Orléans, France (frances.westall@cnrs-orleans.fr)

Introduction: Mars has long interested we humans from the point of view of its habitability and inhabitants and two major observations of the last century have had enormous effects on the search for life on Mars. The first concerned the results of the Viking landers in 1976, and the second was the paradigm-changing publication of McKay et al., [1] describing possible signatures of life in a meteorite from Mars. Both stimulated enormous controversy – and enormous advances in our understanding of life, its nature, limitations, and how and where to find it on Mars, paving the way for the MSL and ExoMars missions.

The Viking mission: The Viking landers produced enigmatic evidence for or against life on the planet and, although there is still debate, it is widely believed that the results of the various life detection experiments were negative. Lack of detection of organic carbon by the GC-MS experiment [2] may have been due to oxidation of possible organics in the martian soil by photochemically-produced oxidants. Note that perchlorates, detected by TEGA on the Phoenix mission [3], could broken down by photochemical reactions to produce powerful oxidants.

The ALH84001 meteorite: The Astrobiology discipline and missions to search for life on Mars (e.g. ExoMars [4,5]) were provided with significant stimulous from the 1996 publication of D. McKay et al. [1] which described geochemical and morphological evidence for fossil life in fractures in a meteorite dating from the Noachian period. Importantly, the authors recognised the necessity of using a number of lines of evidence to document the fossil traces, including mineralogical context evidence for formation of the biosignatures at temperatures conducive to life and the presence of bacteriomorph-like structures, potential biominerals and reduced carbon. Each one of these signatures has been contested and alternative abiotic means of production advocated. The spate of experimental and analytical studies provoked by this study has enormously improved our understanding of the characteristics of fossil bacteria (e.g. [6]), biominerals (e.g. [7]), or the nature of reduced martian carbon (e.g. [8]).

Organic molecules on Mars: The Viking and Phoenix missions threw up profound questions concerning analyses of organics on Mars and the consequences for the search for organic biosignatures. By comparison with the “rain” of abiogenic organics that continue to arrive on Earth in micrometeorites and carbonaceous chondrites [9], this should also be the case with Mars. Reduced carbon of probable endogenous, abiotic origin occurs in martian meteorites [8] and chlorinated organic compounds were detected finally by the SAM instrument on Curiosity [10], despite the technological difficulties. This work will be continued by the ExoMars 2020 instrument MOMA [5]. In addition, methane has been tantalisingly detected episodically in the martian atmosphere and at Gale Crater [11]. Methane could be formed abiotically and/or biogenically. The ExoMars Trace Gas Orbiter will make a concerted inventory of the phenomenon [12].

Search for life on Mars: Summons et al. [13] made an excellent review of possible biosignatures from the point of view of the MSL mission, listing morphology, biofabrics, organic molecules, isotopic signatures, biomineralisation and bioalteration features, chemical patterns and biogenic gases. Subsequent to the 1996 McKay paper [1] there have been numerous studies related to extreme habitats and extremophiles and our understanding of the limits of life continues to increase, with the effect that Special Regions have been defined in which life could flourish even today on Mars, including methane sources, RSL, gullies, pasted on terrains, caves etc. [14].

Importantly, understanding of the constraints of heterogeneous and limited habitability on the nature of potential martian life throughout the history of the planet is refining the search towards (necessarily anaerobic) primitive life forms, such as chemotrophs [15,16].

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MARS ASCENT VEHICLE NEEDS TECHNOLOGY DEVELOPMENT WITH A FOCUS ON HIGH PROPELLANT FRACTIONS. J. C. Whitehead, PO Box 73343, Davis, California, 95617, USA, jcw@dcn.org

Introduction: Launching geology samples from Mars to orbit requires a miniature launch vehicle, to provide a combination of velocity and acceleration beyond the capability of known spacecraft propulsion technology. The ultimate development challenge for a Mars ascent vehicle (MAV) is to achieve an unusually high propellant mass fraction for one or more tiny rocket stages. Reducing stage inert mass offers high leverage for the cost of Mars Sample Return (MSR).

MAV design studies and development efforts have mostly emphasized propellant selection and thrust generation, so a renewed emphasis is needed for creating unusually lightweight hardware.

Mass budgets: A MAV needs to be roughly 75 percent propellant at Mars departure, with approximately enough thrust to lift itself in Earth gravity [1]. A MAV propulsion stage without its payload needs to be 80 percent propellant or more. As shown in Figure 1, a stage propellant fraction of 85 percent permits a single-stage MAV to be about half as heavy as for 80 percent. Despite this steep dependence, most publications suggesting MAV designs have not highlighted mass data.

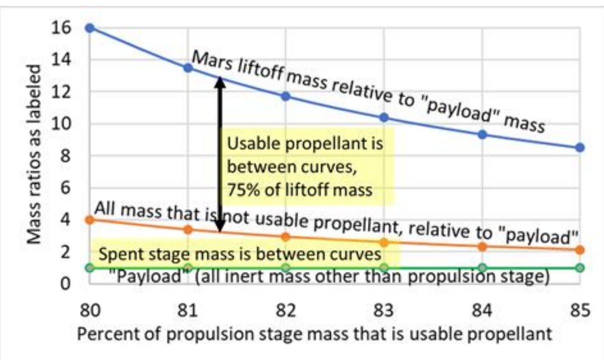

Figure 1. MAV mass relative to payload mass.

Stages of Earth launch vehicles are more than 90 percent propellant, which is made possible by using low tank pressures to permit thin structures, along with much higher combustion pressures so that engines can be compact and relatively lightweight. It is a huge challenge to do the same on a sufficiently small size scale for a MAV (hundreds of kg), although 85 percent propellant is a worthy goal. While the propulsion research community has done well to maintain continuity of expertise in propellants and combustion, there is no apparent pipeline of expertise for building small tanks, engines, pressurization systems, and directional control systems that must weigh far less than on satellites.

MAV design studies: Recent efforts at NASA JPL in particular offered new propellant ideas and insights for possible MAV designs [2-5]. However, mass calculations were only theoretical, for the sake of comparative propellant analyses. Aggressive component mass reduction is not noted as an opportunity, and mass growth does not appear on a list of risk items [2]. Mass is treated as a separate concern from propulsion functionality in a discussion of advancing TRL [3].

A dozen years ago, the NASA Mars Program funded the author's testing of miniature reciprocating pumps, discontinued despite encouraging results [6]. Subsequently, tiny turbopumps were tested by another group, recently acknowledged in one JPL MAV paper as probably not the answer for scaling down launch vehicles [4]. Electric pumps were found to offer only a slight advantage over pressure-fed propulsion, perhaps due to battery mass. The author has thus been inspired to refine concepts for miniature piston pumps.

Over a dozen years ago, the author's trajectory simulations quantified the disadvantages of a solid propellant MAV and the advantages of single-stage liquid [7]. For tiny solid rockets, excess thrust results in high atmospheric drag and requires heavy directional control parts, while leaving little time for steering corrections.

For many years, the notion of a solid propellant MAV was favored at NASA, so it is a step forward that the author's 2005 explanations were repeated more recently, along with a trajectory graph nearly identical to Figure 4 in reference 7 [5].

The full paper will show supporting details, including equations for Figure 1. The primary intent is to raise awareness in the MSR community that a new kind of space propulsion expertise is needed, with detailed physical insight into why things are heavy or not, with brainpower applied to aggressive mass reduction for a MAV and its components.

Regardless of what MAV design ultimately works, there is an urgent need to cultivate specialized team expertise for this unique application. By analogy, consider the uniqueness of Mars rovers and the decades that were required to develop working rovers while growing and maintaining appropriate expertise.

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Plans For Selection And In-Situ Investigation Of Return Samples By The Supercam Instrument Onboard The Mars 2020 Rover. R.C. Wiens[1], S. Maurice[2], N. Mangold[3], R. Anderson[4], O. Beyssac[5], L. Bonal[6], S. Clegg[1], A. Cousin[2], L. DeFlores[7], G. Dromart[8], W. Fischer[9], O. Forni[2], T. Fouchet[10], O. Gasnault[2], J. Grotzinger[9], J. Johnson[11], J. Martinez-Frias[12], S. McLennan[13], P.-Y. Meslin[2], F. Montmessin[14], F. Poulet[15], F. Rull[12], S. Sharma[16], and the SuperCam team. [1]LANL, Los Alamos, USA (rwiens@lanl.gov); [2]IRAP, Toulouse, France (sylvestre.maurice@irap.omp.eu); [3]LPG-Nantes, CNRS and Univ Nantes, France (nicolas.mangold@univ-nantes.fr); [4]USGS, Flagstaff, USA; [5]IMPMC, Paris, France; [6]IPAG, Grenoble, France; [7]JPL, Pasadena, USA; [8]LGLTPE, Lyon, France; [9]Caltech, Pasadena, USA; [10]LESIA, Meudon, France; [11A]PL/JHU, Laurel, USA; [12]UVA-CSIC, Valladolid, USA; [13]StonyBrook Univ., USA; [14]LATMOS, Guyancourt, France; [15]IAS, Orsay, France; [16]HIGP, Hawai'i, USA.

Instrument Capabilities and Objectives. SuperCam, which will be on board the Mars2020 rover, is a suite of four co-aligned instruments that remotely provide critical mineralogical and elemental compositions and textural observations via Laser Induced Breakdown Spectroscopy (LIBS), Raman spectroscopy and time-resolved fluorescence (TRF), visible and near-infrared spectroscopy (VISIR), and high resolution color imaging (RMI) [1, 2, 3, 4]. The LIBS, VIS, and RMI capabilities rely heavily on the ChemCam instrument on Curiosity/MSL while Raman and IR capabilities are new, providing a complementary set of observations for texture, mineralogy and elemental chemistry that can provide information on the various aspects of the 2020 mission [5] (Fig. 1). The main objectives for the 2020 mission are to search for signs of ancient life and to assemble a returnable cache of samples. SuperCam is built to help both objectives by providing detailed remote observations of surface targets, especially their mineralogy and chemistry, including potential organic material by the Raman technique, therefore helping in the choice of samples to be analyzed in-depth by contact instruments, and cached and eventually returned to Earth for some of them. SuperCam is the only instrument to provide chemical and mineral observations down the drill hole walls.

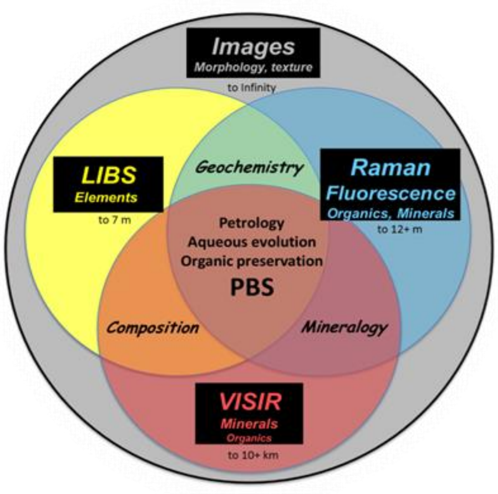

Fig. 1. SuperCam investigations contributing together to the detection of Potential Biosignatures (PBS).

Remote Sensing & Sampling Scales. Each investigation has its range of distances to target, from 2 m to 7 m for LIBS, up to 12 m for Raman and TRF, up to the horizon for VISIR and RMI (Fig. 2). In this way SuperCam will make thousands of pin-point measurements within and well beyond the arm workspace. Each investigation has its own sampling scale. The LIBS analysis area is 300 – 600 µm in diameter. Single laser shots probe typically a few µm in depth. When operated in a depth profile mode (hundreds to a thousand laser shots), the vertical sampling can go down to ~500 µm in rocks, depending on the nature of the target. The Raman, TRF, and VIS analysis footprints are similar, at 0.67 mrad (1.3 mm at 2 m distance), and 1.2 mrad for the IR. The imaging field of view is 20 mrad and the pixel FOV is 20 µrad (40 µm at 2 m). We expect arm-mounted instruments (PIXL, SHERLOC) to provide finer-scale measurements of the targets analyzed by SuperCam [5].

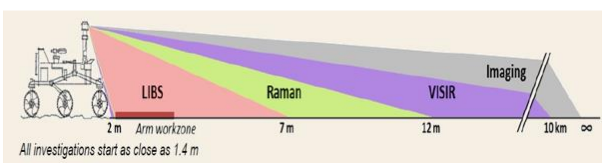

Fig. 2: Observation modes and analytical distance ranges of the SuperCam instrument.

Management. SuperCam is a multi-national instrument. The US contribution is funded by NASA. The US contribution is funded by NASA; the project is led from Los Alamos National Laboratory. The French contribution is funded by CNES and led from the Institut de Recherche en Astrophysique et Planetologie (IRAP). The U. Valladolid (UVA) in Spain is responsible for the on-board calibration targets. Other nations have contributed to the calibration-target effort, including France, Denmark, and Canada.

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IN SITU PRE-SELECTION OF RETURN SAMPLES WITH BIO SIGNATURES BY COMBINED LASER MASS SPECTROMETRY AND OPTICAL MICROSCOPY R. Wiesendanger[1], P. Wurz[1], M. Tulej[1] D. Wacey[2], A. Neubeck[3], V. Grimaudo[4], A. Riedo[5], P. Moreno[4], A. Cedeño López[4] and M. Ivarsson[6],
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Introduction: Sample return missions are among the most complex and cost intensive endeavours of planetary science. Only a small amount of sample material can be brought back to Earth for analysis in terrestrial laboratories. Careful selection and detailed pre-analysis of suitable samples on the Martian surface is therefore an important and necessary step to maximize the scientific output of the returned material. Especially the identification of bio-markers requires a multi-criteria approach, including element, isotope and optical analysis of the putative fossil and its host [1-4].

The LMS Instrument Suite: We developed a dedicated, compact instrument suite that fulfils the severe requirements of a sample return mission as well as the scientific performance for such an endeavour with high accuracy and reliability [5]. The suite consists of a high vacuum compatible microscope with micrometre resolution [8] and a mass spectrometer able to detect and quantify trace elements and isotopes down to the ppb level and permill accuracy [6, 7]. The instrument suite is designed to fit on typical planetary landers. We built a flight prototype and we will present its architecture and design features, as well as its key performance factors.

Analysis of the gunflint chert serving as a Mars analogue Sample: Using the 1.9 billion year old gunflint chert as an analogue sample for the search of fossils on the Martian surface, we demonstrate how different types of microbial fossils and the host regions on the sample can be distinguished and selected for chemical analysis. We will present the results of the chemical and imaging analysis of the selected locations and assign the sampled locations to known groups of fossilized bacteria.

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THE POTENTIAL IMPACT OF MARS' ATMOSPHERIC DUST ON FUTURE HUMAN EXPLORATION OF THE RED PLANET: MARS SAMPLE RETURN CONSIDERATIONS D. Winterhalter[1,2], J.S. Levine[3], R. Kerschmann[4], D.W. Beaty[1], B.L. Carrier[1], and J.W. Ashley[1]
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Introduction: With the increasing focus by NASA and other space agencies on a crewed mission to Mars in the 2039 time-frame, many Mars-specific environmental factors are now starting to be considered by NASA and other engineering teams. Learning from NASA's Apollo Missions to the Moon, where lunar dust turned out to be a significant challenge to mission and crew safety, attention is now turning to the dust in Mars' atmosphere and regolith. To start the process of identifying possible dust-caused challenges to the human presence on Mars, and thus aid early engineering and mission design efforts, the NASA Engineering and Safety Center (NESC) Robotic Spacecraft Technical Discipline Team organized and conducted a Workshop on the "Dust in Mars' Atmosphere and Its Impact on the Human Exploration of Mars", held at the Lunar and Planetary Institute (LPI), Houston, TX, June 13-15, 2017. The workshop addressed the following general areas:

1. What is known about Mars' dust in terms of its physical and chemical properties, its local and global abundance and composition, and its variability.
2. What is the impact of Mars atmospheric dust on human health.
3. What is the impact of Mars atmospheric dust on surface mechanical systems (e.g., spacesuits, habitats, mobility systems, etc.).

We present the top priority issues identified in the workshop. Of great interest is the possible MSR contribution that will help to answer the questions.

COMMERCIAL CAPABILITIES TO ACCELERATE TIMELINE AND DECREASE COST FOR RETURN OF SAMPLES FROM MARS. P. Wooster[1] , M. M. Marinova[1], and J. Brost[1], [1]Space Exploration Technologies (SpaceX), 1 Rocket Rd, Hawthorne, CA 90250 (paul.wooster@spacex.com).

Introduction: Mars Sample Return has been a key objective of the Mars science community for decades, including being identified by the most recent Planetary Sciences Decadal Survey [1] as the top priority large mission. While the Mars 2020 rover mission will begin the process of collecting carefully chosen samples with well-understood geologic context from the selected landing site [2], the timely return of samples is in part limited by the cost associated with the systems required to retrieve samples, perform Mars ascent, and return the samples to Earth. Being able to return the samples at significantly decreased cost can accelerate the timeline for the first return of samples from Mars while also opening opportunities for the return of samples from multiple sites on Mars in an affordable fashion.

Cost-Effective Launch: SpaceX was founded in 2002 to revolutionize space technology, with the ultimate goal of making life multi-planetary. Fundamental to achieving this goal is to vastly decrease cost and improve the reliability of access to and transport through space. The commercial development of the Falcon 9 and Falcon Heavy launch vehicles and our successes in introducing launch vehicle and spacecraft reusability offer increased launch capability at reduced cost [3]. We have also initiated development of the Big Falcon Rocket (BFR) launch and in-space transportation system [4], which will become available in the 2020's and provide Mars transportation capabilities well in excess of those currently available or being developed elsewhere, while continuing to decrease transportation costs by being fully and rapidly reusable.

With the largest payload capability of any operational launcher since the Saturn V, the Falcon Heavy provides significant trans-Mars injection mass delivery at a very affordable price point which can be quite valuable in the context of near-term Mars sample return missions. This capacity allows a single-launch sample retrieval mission, providing capability to deliver a lander with fetch rover and Mars ascent vehicle, along with an Earth return vehicle. Whether employing Viking- and MSL-style landing approaches, or using a new lander that could leverage capabilities SpaceX has been developing and demonstrating such as supersonic retro-propulsion, the overall useful mass delivered to the surface of Mars can be in excess of a metric ton, while simultaneously allocating launch mass for a capture and return orbiter and Earth entry vehicle. In addition to demonstrating technologies relevant for human-scale missions, the new lander option could open opportunities for providing a direct Earth-return capability, with the potential to further decrease operational complexity and overall cost relative to a Mars orbit rendezvous architectural approach.

The large landed mass on Mars directly increases the mass of material returned to Earth, allowing for multiple samples – rocks, subsurface, atmosphere – to be returned for further study and for more analyses to be performed. The lower price point has the potential to make it affordable to perform missions to multiple sites in a timely fashion, thus increasing the breadth of scientific understanding.

Future Developments: In the mid-2020's, the BFR system will start to offer the delivery of vastly increased Mars payload masses, enabling sample return capabilities well in excess of those considered as part of Mars program planning to date. With a fully reusable launch system, Earth orbit propellant transfer, and a fully-propulsive Mars landing, BFR is capable of delivering over 100 metric tons of useful mass to the surface of Mars in an affordable fashion. In the context of human missions, through use of in-situ propellant production the system is capable of returning over 50 tons of useful mass from Mars to Earth. In addition to returning with a BFR flight, opportunities also would exist for using the significant trans-Mars injection payload mass to transport sample retrieval-specific hardware. This approach could enable additional options for robotically-collected samples from a wider diversity of sites, complementing the in-depth sampling which would be conducted as part of human exploration in the vicinity of the initial Mars outpost site.

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ON SIZE OF METEORITES FROM SURFACE OF MARS FOR MARS SAMPLE RETURN MISSION. G. A. Yakovlev and V. I. Grokhovsky, Institute of Physics and Technology, Ural Federal University, Mira St., 19,Ekaterinburg, 620002, Russian Federation. E-mail: yakovlev.grigoriy@gmail.com.

The arrival of cosmic matter to Earth continues to the present day. Iron meteorites are important part of this flux, but terrestrial conditions start weathering processes, and this relatively rare type of meteorites begin to loose scientific value in point of pristine chemical composition. Meanwhile, an analysis of the meteorite candidates identified on Mars clearly showed that the conditions on the planet at the present time support their long-term preservation [1]. Given the composition and pressure of the Mars's atmosphere, one can assume that meteoroid do not experience significant changes, as well as chemical composition of this celestial body. These factors contribute to the growth of interest in the delivery of meteorites from the surface of Mars. However, same atmospheric parameters cause formation of crater even in case of small meteoroids [2].

Samples with changes of initial meteoroid structure due to impact event are undesirable, if pristine structure is of interest. Withal, pieces of small masses are likely to reach the Martian surface at survivable impact velocities [3]. The combination of the probability of finding meteorites on surface of Mars (which is high in comparison with areas of Earth outside the accumulation zones) and small masses of spalled-off fragments of large impactor, make them a good choice for Mars Sample Return Mission.

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Acknowledgement: This work was support by Ministry of Education and Science of Russian Federation (Project 5.3451.2017 / 4.6).

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ORBITING SAMPLE CAPTURE AND ORIENTATION TECHNOLOGIES FOR POTENTIAL MARS SAMPLE RETURN. P. Younse[1], R. Adajian[1], M. Dolci[1], P. Ohta[1], E. Olds[2], K. Lalla[1], and J. W. Strahle[1]. [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109 USA, paulo.j.younse@jpl.nasa.gov, [2]Sierra Lobo, Inc., 365 N. Halstead, Pasadena, CA 91107 USA.

Introduction: Making significant progress towards Mars Sample Return was recommended as one of the highest-priority goals for the decade 2013-2022 by the 2011 Planetary Decadal Survey [1]. A notional architecture for sample return is described in [2], which is composed of the Mars 2020 rover to acquire the samples, a Sample Return Lander (SRL) to recover the samples and launch them into Mars orbit within an Orbiting Sample (OS) container using a Mars Ascent Vehicle (MAV), and a Sample Return Orbiter (SRO) to retrieve the OS from Mars orbit and deliver it to Earth within an Earth Entry Vehicle (EEV). This research focuses on assessing technologies applicable to the OS capture and orientation functions of the SRO. Effective on-orbit OS capture is required for SRO OS retrieval, and manipulation of the OS into an upright orientation relative to the EEV at landing is needed to preserve the sample science. It should be recognized that all studies described here are preliminary results of work in progress and that no decisions on the design or implementation of a Mars Sample Return mission have been made by NASA.

Capture Technologies: Explored capture technologies include Bladed Capture, Capture Arm, and Flux Pinning (from left to right in Fig. 1). Bladed Capture uses a twin sets of blades that rotate inward to cage the OS within a capture cone. Capture Arm uses a three degree-of-freedom robotic arm to cage the OS within a capture cone. Flux Pinning uses cooled superconductors to pin the magnetic flux lines from magnets on the OS at a fixed position and orientation.

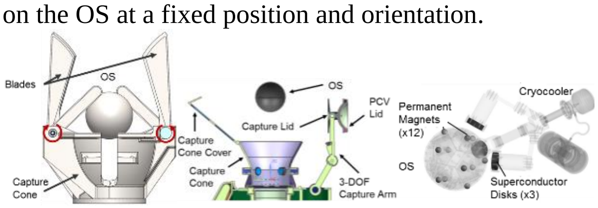

Figure 1: Capture technologies [2], [3], [4].

Orientation Technologies: Explored orientation technologies include Wiper Mechanism and Motorized Cups (from left to right in Fig. 2). The Wiper Mechanism orients the OS by rotating a moving wiper, which guides a pin on the OS along a fixed wiper until it settles in a groove at the final orientation. The Motorized Cups orients the OS by using contact friction between the OS and two sets of rotating cups arranged 90-degrees apart.

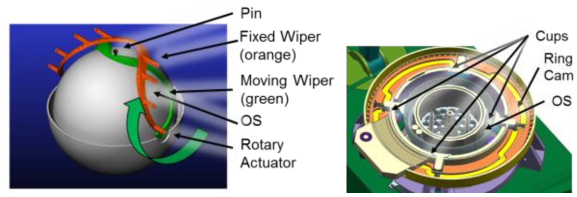

Figure 2: Orientation technologies [2], [3].

Integrated Capture and Orient Module: Fig. 3 shows the layout of a MArs CApture and ReOrientation for the potential NExt Mars Orbiter (MACARONE) concept that combines a sliding trap door for OS capture, a Motorized Cups Mechanism for OS orientation, and a two degree-of-freedom arm with a paddle for transferring the OS into a Primary Containment Vessel (PCV) for follow-up operations to seal off the OS for Earth return. System benefits include system modularity, development flexibility, testability in a 1G environment, analyzability without the need to simulate or test for 0G contact dynamics due to a "close before contact" strategy, encapsulation of potential Mars material on the outer surface of the OS due, and ability to be ejected from the spacecraft following completion of operations.

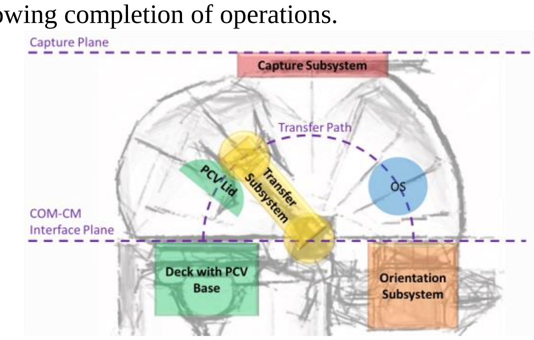

Figure 3: Capture and Orient Module MACARONE concept layout [2].

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SAMPLE RETURN IN PREPARATION FOR HUMAN MISSION ON THE SURFACE OF MARS

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Introduction: Through the 1st workshop(2014), the 2nd workshop(2015) and the 3rd workshop(2017) for Mars 2020 rover landing site, scientists including myself selected the three landing site candidates for collecting scientifically valuable samples for Earth return, assessing past and present habitability, and investigating geologic and environmental processes such as water-rock interaction and alteration of rocks: Jezero Crater, NE Syrtis, and Columbia Hills.[1] The Mars 2020 Landing Site Steering Committee and the Mars 2020 Project Science Group believe that lakebed deposit of chemical precipitates in Jezero Carter, crustal settings showing water-rock interaction in NE Syrtis, and surficial hot springs in Columbia Hills represent environments favorable for detecting past microbial life on Mars.[2] Furthermore, Mars 2020 will investigate water ice and/or water-bearing minerals for the potential use for future Mars human missions. Returned samples of Martian rocks and soils are expected to enhance significantly our understanding potential past and present Martian life as well as possible health hazards such as Hexavalent Cromium (CrVI) known as a carcinogen, and resources for food production-related chemicals, water, metal and silicon for human exploration on the surface of Mars. [3],[4]

Figure 1. Mars 2020 landing site candidates (a) Jezero Crater (b) NE Syrtis (c) Columbia Hills (Credit: NASA)

Homogeneity of Martian soils: The samples of regolith that were collected at the three distanced locations on Mars by Spirit, Opportunity, and Curiosity suggest that the chemical composition of Martian soils is somewhat homogenous throughout the planet.[5] The Martian dust storms both regional and global over a long period time seem to be a major factor for the similar chemical distribution of Martian soils. Thus, the top soils from Jezero Crater, NE Syris, and Columbia Hills are expected to have a similar chemical composition. Returned samples from any of the three sites are expected to deepen our understanding Martian soil composition.

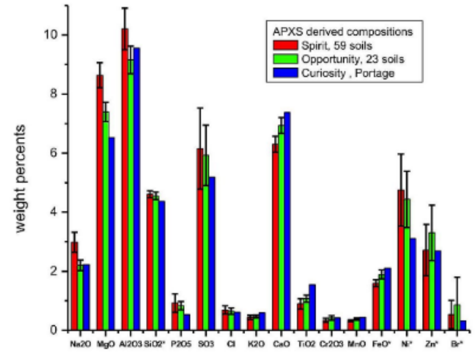

Figure 2. Comparison of Martian soils sampled by Spirit at Columbia Hills, Opportunity at Meridiani Planum, and Curiosity at Gale Crater (Credit: NASA)

Human Exploration on the Surface of Mars: The Mars Human Landing Site Workshop was held at the Lunar Planetary Institute in Houston, Texas in October 2015. More than forty potential landing sites for human mission on the surface of Mars, tentatively scheduled in 2030's, were discussed. The landing sites need to satisfy science criteria in astrobiology such as past and present habitability and potential for organic matters, atmospheric science such as meteorological diversity, and geoscience such as igneous rocks in different times as well as in situ resource utilization and civil engineering criteria in water resource, food production and metal/silicon resource.[3] Returned samples of Martian regolith will help science community make an informed decision in choosing the final human landing site and develop a better human mission plan to meet science criteria and IRSU & civil engineering criteria.

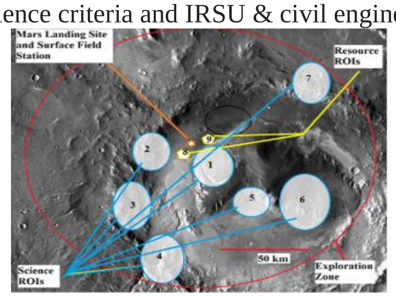

Figure 3. Gale Crater, a potential human landing site on the surface of Mars (Credit: NASA)

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