ExoMars

3rd Landing Site Selection Workshop

Final Report

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		Date
Prepared	**LSSWG, J. L. Vago, D. Rodionov**	18 December 2015
Agreed		
Approved		

ESTEC, 20–21 October 2015

FINAL REPORT

EXECUTIVE SUMMARY

On 20–21 October 2015 seventy international scientists, project, and industry engineers gathered at ESTEC, in Noordwijk (NL) for the third ExoMars 2018 Landing Site Selection Workshop (LSSW#3).

The workshop was co-organised by ESA and IKI/Roscosmos with the support of the ExoMars 2018 Landing Site Selection Working Group (LSSWG). The goal of the meeting was to review and discuss the merits and challenges of the four candidate landing locations remaining —Mawrth Vallis, Oxia Planum, Hypanis Valles, and Aram Dorsum— and recommend two final candidate landing sites for further detailed study and certification.

Description of Activities

The morning of Day 1 started with ESA/IKI describing the workshop organisation (please see attached agenda in Annex 1). ESA/IKI explained that, following detailed science overviews of each landing site by its proposing team and engineering assessment presentations from ESA and Industry, participants would be invited to express their preference by voting in writing. The results of this voting would constitute an important input to the LSSWG deliberations. However, ESA/IKI clarified that it was the LSSWG's responsibility to produce the final recommendation and that its science and engineering experts may have good reasons to deviate from the vote outcome. ESA/IKI introduced the spreadsheet and weighting factors to be used for tallying up the votes. They also presented a Summary Slide to capture the salient science and engineering attributes of the four candidate landing sites (Annex 2). After each presentation the Summary Slide would be updated to ensure it was as accurate and complete as possible. The Summary Slide would be displayed as a reminder during the voting.

Thereafter the landing site proposing teams delivered their science presentations (available at ESA's Robotic Exploration web site) organised in the following manner:

- Introduction to the landing site: Location, general age, and ellipses for both the 2018 and 2020 launch opportunities.
- Science diversity: Geological context, depositional history and age of the major units; mineralogical and morphological evidence for sustained low-energy aqueous activity; biosignature preservation potential (unit deposition, water, burial and exhumation history); types of high-priority scientific targets.
- Science accessibility: Distribution of high-priority targets within the landing ellipse(s); including a graphic depiction of the possibility to reach a high-priority target after 1-km, 2-km, and 4-km rover traverses.
- Locomotion analysis: Discussion of the presence of soft soils and dunes that could be problematic for the rover.
- Mission example: Presentation of one or two examples of possible, ~3-km rover exploration missions to showcase the site's science variety and interest.

Mawrth Vallis and Oxia Planum were addressed in the morning; Hypanis Valles and Aram Dorsum in the afternoon. The participants asked questions, discussed the candidate landing sites' potential in view of the ExoMars mission objectives and rover capabilities, and updated the contents of the Summary Slide after each presentation.

The second block of presentations in the afternoon of Day 1 began with a discussion of the Entry, Descent, and Landing (EDL) Corridor Analysis results. For each landing site Industry performed Montecarlo simulations taking into account the elliptical dispersion around the desired atmospheric entry point, the atmospheric conditions, the landing site properties, and the spacecraft's aerothermodynamic performance to check if the mission could satisfy engineering constraints with the required (3-σ) probability of success (please refer to Landing Site Analysis presentation). The main findings are summarised hereafter:

- For a 2018 launch Oxia Planum and Hypanis Valles satisfy the preliminary EDL engineering constraints. Aram Dorsum allows just a marginal entry corridor. No safe entry corridor exists for Mawrth Vallis. Landing on either of these two higher-elevation-sites at this time of the year (arrival at Ls = 324º) would be challenging due to the effect of strong high altitude winds. Simulations show that these winds do not always allow the parachute system to achieve the required quasi-vertical attitude (≤ 15º off vertical) —necessary for the radar to operate correctly— by the prescribed 1.5-km elevation over the local terrain. The team explored a number of options to improve the landing safety for these sites but the results were not encouraging. Industry concluded that for the 2018 launch scenario the margins for Aram Dorsum and Mawrth Vallis are insufficient, resulting in excessive risk.

- Conversely, for a 2020 launch case, the entry corridors (landing at Ls = 19º) provide higher margins for most EDL constraints. In particular the parachute verticalisation requirement no longer constitutes a limiting factor. However, for all sites, the dispersion at the Mars atmospheric entry point is larger than for the corresponding 2018 launch case. Without exceeding the 10 g maximum deceleration load, only Aram Dorsum fully complies with the entry corridor requirements using a 100-km major axis ellipse. Appropriate entry corridors could also be defined for the other three sites by enlarging the landing ellipses' major axis to 120 km.

Day 1 ended with a presentation of manual (and some automatic) rock counting results computed over the summer at Leicester University for several sub-regions at each landing site.

The morning of Day 2 started with presentations on: 1) Rock Automatic Detection (RAD) algorithm development status at the International Research School on Planetary Science (IRSPS), Pescara (ITA); 2) Landing site compliance with latitude, elevation, slope, thermal inertia, and rock abundance requirements (on the entire ellipse), and with egress and mobility requirements (analysis performed on a few 256 m x 256 m geologically representative spots); 3) Landing Site Engineering Constraints (LSEC) present compliance and possible evolution; 4) Dust coverage index for the various sites based on TES and OMEGA data; and 5) Discussion on the presence of clay deposits at the four sites and on their distribution and accessibility. Each proposing team then took 15 minutes to summarise the main features of their candidate landing site.

Thereafter, according to the procedure explained on Day 1, the LSSWG requested workshop participants to express their preference by listing in descending order of priority the four candidate landing sites. Participants provided their inputs in folded, anonymous forms provided by the LSSWG.

Voting Results

Fifty-two votes were tallied immediately after lunch in the following manner:

1. Weighted Scoring: Assigning 5 points to the first choice, 3 points to the second, 1 point to the third, and 0 points to the fourth. This method puts in evidence sites appearing more often in the first positions.

2. Even Scoring: The two top sites received 1 point regardless of their priority. This allows identifying which two sites achieved a wider consensus, i.e. they appeared more often in people's list of preferred locations.

The results of this consultation were (in all cases, the higher the score, the better):

Site	Weighted Score
Oxia Planum	162
Aram Dorsum	124
Mawrth Vallis	122
Hypanis Valles	96

Site	Even Score
Oxia Planum	37
Mawrth Vallis	28
Aram Dorsum	26
Hypanis Valles	21

The scores clearly show that the participants preferred Oxia Planum. Aram Dorsum and Mawrth Vallis tied for second place.

LSSWG Recommendation

LSSW#3 Outcome

The participants to the 3rd ExoMars 2018 Landing Site Selection Workshop present at ESTEC on 20–21 October 2015 have considered the four candidate landing sites: Aram Dorsum, Hypanis Valles, Oxia Planum, and Mawrth Vallis. The ExoMars 2018 Landing Site Selection Working Group (LSSWG) tasked with making a recommendation for the down selection of landing sites would like to state:

1. The LSSWG thanks the proposing teams for the excellent sites proposed and the impressive work performed to characterise them.

2. The LSSWG strongly encourages all proposing teams to join up in the analysis of the recommended landing sites and bring to bear their considerable expertise for the benefit of ExoMars and its scientific return.

3. Based on the participants' presentations, discussions, and voting the LSSWG recommends:

    a. Oxia Planum as the candidate landing site for the baseline 2018 launch opportunity.

    b. Oxia Planum as one of the two candidate landing sites, with a second to be selected from Aram Dorsum and Mawrth Vallis, for the backup 2020 launch opportunity.

For the baseline 2018 launch case, only Oxia Planum could be proposed as the other two sites presented technical problems preventing their further consideration for an arrival in 2019.

For a backup launch scenario with arrival in 2021 the LSSWG did not establish a merit ranking among the three recommended sites. Based on the presently available information, all could be considered viable for selection as the final landing site. Oxia Planum will benefit from the detailed characterisation work —part of the landing site certification process— to be performed in the framework of the baseline mission preparations. It is important that additional detailed analysis be conducted on Aram Dorsum and Mawrth Vallis so the LSSWG can make an informed recommendation regarding the second landing location to be certified. The LSSWG would propose to select the second site —among Aram Dorsum and Mawrth Vallis— at an upcoming Landing Site Selection Workshop, probably in late 2016.

Next Steps

The LSSWG would like to evaluate the three remaining sites in a systematic way, *i.e.* comparing specific criteria between the three sites. This effort should start soon to be in a position to react in case unforeseen certification issues are found with Oxia Planum.

Whereas the EDL Entry Corridor Analysis information has been deemed sufficient to accomplish the workshop objectives, the LSSWG considers that all three recommended landing sites require more in-depth surface analysis: Rock counting, surface roughness, presence of soft terrains, and slope characterisation are needed. The LSSWG intends to form a subgroup from within its members to lead the process —working with site proposers, the agencies and Industry— of checking site characteristics.

In addition, the LSSWG would like to explore why and how each of the three remaining sites is particularly well suited to accomplish the mission's scientific objectives —especially the search for evidence of past life— using the rover payload.

ANNEX 1

3rd LSS Workshop – AGENDA: 20–21 October 2015
Who: Mars Science Community, Project, Industry Erasmus Auditorium, ESTEC

Tue 20 Oct 2015 Sol 1:

09:00 Welcome and brief intro (15 min) — J. Vago/D. Rodionov

09:15 **Landing site science updates** (4 x 60 min) — Proposing Teams
—Please plan 45 min for the presentation and roughly 15 min for questions—

- 09:30 Mawrth Vallis
- 11:00 Oxia Planum

Please organise your presentation as follows:

- Site refresher: Where is the site (Context, HRSC/MOLA, CTX scale images);
- Science diversity: Identify specific high-priority scientific targets: geological context, age, mineralogy, water activity, and biosignature preservation potential;
- Accessibility: show your preferred touchdown point. 1) Colour in your landing ellipse the parts for which you are never more than 1 km away from a prime target. 2) Do the same for those parts never more than 2 km away. 3) Same for 4 km away. Please see Aram Dorsum's presentation of 2nd LSSW (slides 61 & 62).
- Locomotion: Analyse the presence of soft soils and dunes that may be problematic.
- Mission example: Present one or two instances of 3-km traverse missions that you could conduct in the ellipse to showcase its science variety and interest.

13:15 Lunch @Cantine (90 min)

- 14:15 Hypanis vallis
- 15:30 Aram Dorsum

16:15 Break (15 min)

17:00 **Landing site engineering analysis** (90 min)

- 17:00 Entry corridor analysis (45 min) — F. Calantropio (TAS-I)/A. Zashchrinskiy (LAV)
  - Oxia Planum
  - Hypanis Vallis
  - Aram Dorsum
  - Mawrth Vallis

  Explain technical details of how the analysis was done;
  Discuss constraints and any possible flexibility used in the analysis;
  Which sites are doable, which need more work, which are too dangerous?

- 18:15 Results of manual rock counting (30 min) — E. Sephton Nash

19:00 End of Sol 1

Wed 21 Oct 2015 Sol 2:

09:00 Introduction (agenda) — J. Vago

09:15 **Site Characterisation**

- 09:15 Slopes & rock distribution (30 min) — F. Calantropio, A. Merlo (TAS-I)/A. Aboudan, A. Pacifici (IRSPS)
- 09:45 Update of Landing Site Engineering Constraints (15 min) — L. Lorenzoni
  Summary and next steps
- 10:00 Dust coverage index (15 min) — D. Loizeau
- 10:15 Clay context/comparison for all sites (15 min) — J. Carter
- 10:30 Discussion (15 min) — All

11:00 Coffee Break (15 min)

11:15 **Summary of each site's findings from the day before** (60 min)

- Aram Dorsum (15 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA
- Hypanis Vallis (15 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA
- Oxia Planum (15 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA
- Mawrth Vallis (15 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA

12:15 Voting (30 min)
Participants will be asked to rank the four sites in order of preference, from first to last, taking into account the scientific and engineering information. The voting analysis will follow a format similar to that used in LSSW1.

12:45 Lunch @Cantine (90 min)

14:00 **Landing Site Selection Working Group Meeting in Db 124** (3 hrs)
LSSWG counts votes, analyses outcome, discusses results, formulates recommendation and prepares to inform participants.

17:00 **LSSWG Recommendation:** LSSWG announces voting results and explains the reasons for their recommendation —which may or may not be in agreement with the voting

17:30 Discussion (30 min)

18:00 End of Sol 2

ANNEX 2

Candidate Landing Site Summary Slide

Property	Mawrth Vallis	Oxia Planum	Hypanis Vallis	Aram Dorsum
Age (Ga)	Early Noachian to early Hesperian	Middle to late Noachian (clays) Hesperian (delta)	Early Hesperian delta deposits	Middle Noachian
Aqueous sediments	Mainly pedogenic & local fluvial clays. Clay variety	Pedogenic/detrital. Less clay variety than Mawrth	Detrital distal fine material (possibly mudstone)	Detrital (fluvial), multiple episodes
Duration of aqueous event	Various events over 400 Ma	Various events over 400 Ma	~1 Ma	???
Biosignature preservation: Fine grain size	Yes, soft, easy to drill. Many windows.	Yes, many layers, polygonal clays and also in delta fan	Yes, on plains	Yes, on flood plains Coarser on river
Biosignature preservation: Rapid burial	Probable	Probable for clays Yes for delta fan	Yes. Rapid continuous deposition.	Yes
Biosignature preservation: Recent exhumation	Yes. Most recent at foot of cap units	Yes. Most recent at foot of volcanic & delta units	Better at foot of eroded butes. Exhumation age ?	Yes, about 0.5 Ga ago. Better at foot of eroded butes.
Prime targets: Area coverage for 1, 2, 4-km traverse	92%, 95%, 100%	93%, 98%, 100%	98%, 99%, 100%	80%, 91%, 98%
EDL 2018	Does not fulfil 3-σ verticalisation req.	Feasible-100 km	Feasible-100 km	Feasible-100 km (less margin)
EDL 2020	Feasible-120 km	Feasible-120 km	Feasible-120 km	Feasible-100 km
Dune coverage	Some sand patches	Some sand patches	Almost no TARs	Very few TARs
Dust coverage	Very little	Very little	Some	Some
Rock coverage (spot evaluation)	Relatively better	Relatively better	Medium	Medium
Slopes (spot evaluation)	Acceptable	Better	Medium	Better
Planetary Protection	OK	OK	OK	OK

LIST OF PARTICIPANTS

Andrew Coates	UCL/MSSL (UK)	PanCam	a.coates@ucl.ac.uk
Craig Leff	UCL/MSSL (UK)	PanCam	c.leff@ucl.ac.uk
Ernst Hauber	DLR, Berlin (D)	PanCam, LSSWG	ernst.hauber@dlr.de
Sanjeev Gupta	Imperial College London (UK)	PanCam, Hypanis	s.gupta@imperial.ac.uk
Andrey Ivanov	IKI (RUS)	ISEM	aivanov@iki.rssi.ru
Stephen Clifford	Lunar and Plan. Inst. (USA)	WISDOM	clifford@lpi.usra.edu
Nicolas Mangold	LPG Nantes, CNRS (FR)	WISDOM	nicolas.mangold@univ-nantes.fr
Svein-Eric Hamran	FFI (NO)	WISDOM	she@ffi.no
Sergey Nikiforov	IKI (RUS)	ADRON	nikiforov@l503.iki.rssi.ru
Jean_luc Josset	Space Exploration Inst. (CH)	CLUPI, PanCam	jean-luc.josset@space-x.ch
Frances Westall	CNRS-Orléans (FR)	CLUPI, LSSWG	frances.westall@cnrs-orleans.fr
Marie Josset	Space Exploration Inst. (CH)	CLUPI, PanCam	marie.josset@space-x.ch
Simone De Angelis	IAPS-INAF (IT)	Ma_MISS	simone.deangelis@iaps.inaf.it
Jean-Pierre Bibring	IAS (FR)	μΩ, LSSWG	jean-pierre.bibring@ias.u-psud.fr
Fernando Rull	Uni. Valladolid/CAB (ES)	RLS	rull@fmc.uva.es
Howell Edwards	Uni. Leicester (UK)	RLS, LSSWG	H.G.M.Edwards@bradford.ac.uk
Ian Hutchinson	Uni. Leicester (UK)	RLS	ibh1@star.le.ac.uk
Alian Wang	Washington Uni. (USA)	RLS	alianw@levee.wustl.edu
Will Brinckerhoff	NASA GSFC (USA)	MOMA	william.b.brinckerhoff@nasa.gov
Walter Goetz	MPS (DE)	MOMA	goetz@mps.mpg.de
John Bridges	Uni. Leicester (UK)	LSSWG	j.bridges@leicester.ac.uk
Becky Williams	Planetary Science Inst. (USA)	LSSWG	williams@psi.edu
Stephanie Werner	Univ. of Oslo (NO)	LSSWG	stephanie.werner@geo.uio.no
Christian Satre	Univ. of Oslo (NO)		christian.satre@geo.uio.no
Henning Dypvik	Univ. of Oslo (NO)		henning.dypvik@geo.uio.no
Damien Loizeau	Uni. Lyon (FR)	LSSWG	damien.loizeau@univ-lyon1.fr
Lyle White	McGill Uni. (CAN)	LSSWG	lyle.whyte@mcgill.ca
Cathy Quantin	Uni. Lyon (FR)	Oxia Planum	cathy.quantin@univ-lyon1.fr
Jessica Flahaut	Uni. Lyon (FR)	LSSWG	jessica.flahaut@ens-lyon.org
Peter Fawdon	The Open Uni. (UK)	Aram/Hyp/Mawrth	peter.fawdon@open.ac.uk
Matthew Balme	Open University (UK)	Aram/Hyp/Mawrth	matt.balme@open.ac.uk
Lucy Kissick	Durham Uni. (UK)	Aram/Hyp	lucy.kissick@durham.ac.uk
Peter Grindrod	Uni. College London (UK)	All sites	p.grindrod@ucl.ac.uk
Elliot Sefton-Nash	Birbeck, Uni. London (UK)	All sites	e.sefton-nash@ucl.ac.uk
Joel Davis	Uni. College London (UK)	Hyp/Aram	joel.davis.09@ucl.ac.uk
Alberto Fairén	Centro de Astrobiología (ES)	LSSWG	agfairen@cab.inta-csic.es
Gian Gabriele Ori	IRSPS (IT)	LSSWG	ggori@irsps.unich.it
Alessio Aboudan	IRSPS (IT)	Rock Maps	aboudan@irsps.unich.it
Andrea Pacifici	IRSPS (IT)	Slope Maps	pacifici@irsps.unich.it
François Poulet	IAS (FR)	Mawrth	francois.poulet@ias.u-psud.fr
Brigitte Gondet	IAS (FR)	Mawrth	Brigitte.gondet@ias.u-psud.fr
John Carter	IAS (FR)	Oxia/Mawrth	john.carter@ias.u-psud.fr
Joe Michalski	Nat. History Museum (UK)	Mawrth	j.michalski@nhm.ac.uk
Christoph Gross	FU-Berlin		christoph.gross@fu-berlin.de
Nikolaus Kuhn	Uni. Basel (CH)	Clays, PP	nikolaus.kuhn@unibas.ch
Karen Reyes	Uni. Nac. Mexico (MEX)		ka.reyes@hotmail.com
Bram Mooij	VU Amsterdam (NL)		b.j.a.@vu.nl
Anna van Soest	VU Amsterdam (NL)		a.f.vansoest@vu.nl
Mélissa Martinot	VU Amsterdam (NL)		m.martinot@vu.nl
Fabio Calantropio	TAS-I	EDL	fabio.calantropio@thalesaleniaspace.com
Andrea Merlo	TAS-I	Rover Ops	andrea.merlo@thalesaleniaspace.com
Bernard Foing	ESA	Science	bernard.foing@esa.int
Andrew Ball	ESA	Instruments	andrew.ball@esa.int
Frédéric Haessig	ESA	Instruments	frederic.haessig@esa.int
Albert Haldemann	ESA	Payload & AIV	albert.haldemann@esa.int

Luc Joudrier	ESA	Rover Operations	luc.joudrier@esa.int
Pantelis Poulakis	ESA	Rover locomotion	pantelis.poulakis@esa.int
Leila Lorenzoni	ESA	EDL	leila.lorenzoni@esa.it
Joachim Strenge	ESA	EDL	joachim.strenge@esa.int
Adam Williams	ESOC	Operations	adam.williams@esa.int
Tiago Loureiro	ESOC	Operations	tiago.loureiro@esa.int
Dave Heather	ESAC	Data Archive	dave.heather@esa.int
Karen O’Flaherty	ESA	Outreach	karen.o’flaherty@esa.int
Emily Baldwin	ESA	Outreach	emily.baldwin@esa.int
Sandy Carnell	ESA	MicroARES	sandy.carnell@esa.int
Olivier Witasse	ESA	JUICE	olivier.witasse@esa.int
Håkan Svedhem	ESA	LSSWG	hakan.svedhem@esa.int
Luigi Colangeli	ESA	Science Coord.	luigi.colangeli@esa.int
Rolf de Groot	ESA	Exploration Coord.	rolf.de.groot@esa.int
Daniel Rodionov	IKI	LSSWG	rodionov@iki.rssi.ru
Jorge L. Vago	ESA	LSSWG	jorge.vago@esa.int