ExoMars

4th Landing Site Selection Workshop

Final Report

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		Date
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Agreed		
Approved		

ESTEC, 27–28 March 2017

FINAL REPORT

EXECUTIVE SUMMARY

On 27–28 March 2017 approximately seventy international scientists, project, and industry engineers gathered at ESTEC, in Noordwijk (NL) for the fourth ExoMars 2020 Landing Site Selection Workshop (LSSW#4).

The workshop was co-organised by ESA and IKI/Roscosmos with the support of the ExoMars 2020 Landing Site Selection Working Group (LSSWG). The goal of the meeting was to review and discuss the merits and challenges of the three remaining candidate landing locations—Mawrth Vallis, Oxia Planum, and Aram Dorsum—and recommend either Aram Dorsum or Mawrth Vallis as the additional candidate site to accompany Oxia Planum 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 participants would be invited to express their preference by voting in writing, following introduction presentations, engineering assessment deliveries from ESA and Industry, and detailed science overviews of each landing site by its proposing team. The results of the participants' 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 could 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 Summary Slides to capture the salient science and engineering attributes of the candidate landing sites. After each presentation the Summary Slides would be updated to ensure they would be as accurate and complete as possible. The Summary Slides would be displayed as a reminder during the voting.

The first talk discussed general aspects of terrains and biosignatures during the Noachian—the era believed to hold the highest promise for the potential existence of life on Mars, and that corresponding to the landing sites' age. This was followed by a presentation covering rover operations. Thereafter the sites' engineering constraints for landing and locomotion were addressed. In particular, from the point of view of Entry and Descent, the project team clarified that the three sites were considered feasible.

During the afternoon the landing site proposing teams delivered their science presentations organised in the following manner:

- Introduction to the landing site: Location, general age, and ellipses for the 2020 launch opportunity.
- 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.

The morning of Day 2 started with a presentation on surface density and roughness, as gleaned from SHARAD radar measurements (SHARAD is the ground penetration radar on NASA's Mars Reconnaissance Orbiter). Each proposing team then took 20 minutes to summarise the main features of their candidate location. Some of the sites' attributes are highlighted in the Summary Table (Annex 2), with an emphasis on the two sites under evaluation.

Thereafter, according to the procedure explained on Day 1, the LSSWG requested workshop participants to express their preference by stating in writing whether they would prefer Aram Dorsum or Mawrth Vallis to join Oxia Planum to become the two final candidate sites. Participants provided their inputs in folded, anonymous forms provided by the LSSWG. They included six ExoMars Science Working Team (ESWT) members, the mission Principal and Co-Principal Investigators working on the provision of the nine rover instruments.

Voting Results

Forty-six votes were tallied immediately after lunch in the following manner:

Site	Votes
Aram Dorsum	20
Mawrth Vallis	26

The scores show that a majority of the participants preferred Mawrth Vallis. Six ESWT members were present; five preferred Mawrth Vallis and one Aram Dorsum.

LSSWG Recommendation

LSSW#4 Outcome

The participants to the 4th Landing Site Selection Workshop, present at ESTEC on 27–28 March 2017, have reviewed the latest information regarding the three candidate landing sites: Aram Dorsum, Mawrth Vallis, and Oxia Planum.

The ExoMars 2020 Landing Site Selection Working Group (LSSWG) has been tasked with recommending one additional location —from among Aram Dorsum and Mawrth Vallis— to accompany Oxia Planum as candidate landing site for the mission. The two sites being considered present slight maximum elevation non-compliances that are recognised by the LSSWG and will be evaluated as part of the landing site certification process.

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

2. The LSSWG strongly encourages all proposing teams to combine 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 the following:

   Mawrth Vallis as the additional candidate landing site to be considered together with Oxia Planum for the 2020 launch opportunity.

Next Steps

The LSSWG would like to help evaluate the remaining sites in a systematic way, *i.e.* comparing specific criteria between the sites. The recommended landing sites require more in-depth surface analysis: Rock counting, surface roughness, presence of soft terrains, and slope characterisation are needed. This analysis is done by Industry as part of their task to assess the landing sites compatibility to the engineering constraints. The LSSWG intends to form a subgroup from within its members to support the process of checking site characteristics, working in collaboration with site proposers, the agencies, and Industry.

ANNEX 1

4th LSS Workshop – AGENDA: 27–28 March 2017
Who: Mars Science Community, Project, Industry Erasmus Auditorium, ESTEC

Mon 27 Mar 2017 Sol 1:

09:30 Welcome and brief intro (10 min) — J. Vago/D. Rodionov/F. Spoto

09:40 Workshop objective and organisation (10 min) — J. Vago

09:50 **Terrains and biosignatures** (10 min) — J. Vago
Surface conditions during the Noachian —how much water, where, how cold the surface, how hot the subsurface. Types of environments that could support what type of life/microorganisms and relative abundance of biosignatures.

10:00 **Rover operations strategy** (15 min) — Luc Joudrier
What we can do and what we cannot —landing, locomotion, and drilling strategy.

10:15 **Engineering constraints for landing and locomotion**
Summarise what we have learned about the various sites.

- 10:15 LSSWG work on TARs, loose soils, and rocks (45 min)
  J. Bridges, D. Loizeau, E. Sefton-Nash
- 11:00 Oxia Planum Certification —work in progress— (15 min)
  F. Calantropio, A. Merlo (TAS-I)/A. Aboudan, A. Pacifici (IRSPS)
- 11:25 DM status and update of EDL analysis (15 min) — LAV
- 11:40 Update of Landing Site Engineering Constraints (20 min) — L. Lorenzoni
  Summary and next steps

12:00 Lunch (90 min)

13:30 Mawrth Vallis (90 min) — Mawrth Team

Please organise your site presentations as follows:

- Site refresher: Where is the site (Context, HRSC/MOLA, CTX scale images); **NEW** please show the site with superimposed landing probability model for your ellipse (GIS products available on LSSWG web page – see 'Resources' section).
- Science diversity: **NEW** Provide your best interpretation model of the regional geological depositional and alteration history and describe the depositional environment(s) at the site. Identify specific high-priority scientific targets: geological context, age, mineralogy, water activity, and the potential for biosignature formation, concentration and preservation. How much variety is there in potential targets?
- **NEW:** Specifically address candidate ponded water sites and/or low-T hydrothermal settings — how old are they, where does the water come from?
- Accessibility: show your preferred touchdown point. 1) Colour-code the landing ellipse based on the regions that are never more than 1000 m from a prime target (corresponding to 20 sols of 50 m/sol driving) 2) Do the same for those parts never more than 60 sols driving (2000 m) and 90 sol (4500 m) away.
- Locomotion: Present the distribution of terrains that might be problematic for the Rover to travel across. such as areas of dense secondary impact cratering, rugged bedrock, aeolian bedforms (ripples and dunes) and soft soils,
- Mission example: Present one or two instances of 3-km traverse missions that you could conduct. What are the chances of finding physical and chemical biosignatures? Where? How easy is it to move around?

15:00 Discussion and complete Summary Sheets (20 min) — All

15:20	**Aram Dorsum** (90 min)	Aram Team
16:50	Discussion and complete Summary Sheets (20 min)	All
17:10	**Oxia Planum** (90 min)	Oxia Team
18:40	Discussion and complete Summary Sheets (20 min)	All
19:00	End of first day. LSSWG splinter meeting in Db124 (30 min)	
20:00	Social dinner in Noordwijk	

Tue 28 Mar 2017 Sol 2:

09:30 Introduction (5 min) — J. Vago

09:35 Surface density and roughness from SHARAD radar (10 min) — G. Morgan

09:45 **Summary of each site's findings** (60 min)

- Aram Dorsum (20 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA
- Mawrth Vallis (20 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA
- Oxia Planum (20 min) — Science: Proposing Team; Engineering: TAS-I/LAV/ESA

Check the information on the "Sites' Summary Sheets" —recalling all scientific and engineering aspects of each candidate location— to ensure they are as complete and accurate as possible.

10:45 **Discussion of all sites** (45 min) — All

11:30 **General voting** (30 min)

Please note: To vote you need to have been there for all presentations!!!
The "Sites' Summary Sheets" will be flashed on the screen as a reminder.

Participants will be asked to rank Aram Dorsum and Mawrth Vallis in order of priority taking into account the available scientific and engineering information. This input will be used to identify the relative preference of the two locations.

ESWT voting

We would also like to learn what the ExoMars Science Working Team (the PIs and Co-PIs of the nine rover instruments) have to say about the second site to be recommended. They have invested many years of hard work in preparing the rover instruments and will need to run their experiments on the location we will land on. It is fair that we listen to what they have to say.

Combined with the above but specifically requesting the inputs from the rover's ESWT.

The voting results will be used by the LSSWG as an important input to help identify which site, Aram Dorsum or Mawrth Vallis, gathers the highest preference to accompany Oxia Planum as candidate landing site. However, the responsibility for the final recommendation is the LSSWG's, who may decide to deviate (for good reasons) from the voting results.

12:00 Lunch @Cantine (90 min)

13:30 **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.

Vote counting (60-90 min)	Becky, Lyle, Jorge
Creation of Pros and Cons table	All
Evaluation and discussion based on pros and cons	All
Formulation of a written recommendation	All
Concluding remarks	All

16:30 **LSSWG Recommendation:** LSSWG announces voting results and explains the reasons for their recommendation —which may or may not be in agreement with the voting.

17:00 Discussion (30 min)

17:30 End of Sol 2

RESOURCES

Selected information and GIS products relevant to landing site characterisation are available on the Landing Site Selection Working Group webpage:

https://www.cosmos.esa.int/web/exomars/2020-lsswg

ANNEX 2

Candidate Landing Site Summary Slides

Property	Aram Dorsum	Mawrth Vallis	Oxia Planum
Age span (Ga)	Older than late Noachian to early Hesperian	Early-Middle to late Noachian	Middle to late Noachian
General nature of aqueous sediments	Detrital (alluvial), multiple episodes	Sedimentary material requiring sustained water that include multiple aqueous environments. End of stratigraphy likely ended by pedogenic process. Fluvial activities. Extremely diverse mineralogy (clays, sulfates, ferrous phases)	Pedogenic/detrital. Less clay variety than Mawrth
Duration of aqueous events	Various events over 400 Ma	Various events over 400 Ma	Various events over 400 Ma
What are the most interesting targets (their age in Ga)?	Flood plains >3.8 Ga	4.0–3.7 Ga	4.0–3.7 Ga
How much of the ellipse is occupied by interesting targets?	97%	>90% at 1 km drive	
Are interesting targets small and far apart? Or distributed all over?	Extensive areas in centre of ellipse, possible inliers exposed in pits throughout ellipse	Distributed all over, land-on. Also the capping unit has erosional windows providing access to targets.	
Prime targets: Area coverage for 1, 3, 5-km traverse from centre	80%, 91%, 98%	92%, 95%, 100%	93%, 98%, 100%
Rock and mineral variety over short distances	Variety of geological units in ellipse, plus regional diversity from large fluvial catchment	Very high for clay units (greatest on Mars, together with Nili region)	
What is not high priority targets, is it interesting?	Local overburden, comprises impact-excavated materials of potential interest	Cap rock material, but still interesting for past igneous processes	
Ponded water areas	Yes	Yes, sulfate deposits and fluvial/ponding features	
Signatures of possible low-T hydrothermal systems	Uncertain. Possibly sampled in catchment and deposited.	Yes, numerous mineralized fractures/veins. Also possible induced-impact fractures in crater rims.	
Biosignature preservation: Fine grain size	Yes, on flood plains Coarser on river	Yes, soft, easy to drill. Many windows.	Yes, many layers, polygonal clays and also in delta fan
Biosignature preservation: Rapid burial	Yes	Yes due to sedimentary process and by capping unit deposition.	Probable for clays Yes for delta fan
Biosignature preservation: Recent exhumation	Yes, better at foot of eroded butes.	Yes. Very recent at foot of capping unit. Also actively eroding scarps and erosional windows in capping unit.	Yes. Most recent at foot of volcanic & delta units

Property	Aram Dorsum	Mawrth Vallis	Oxia Planum
EDL 2020	Feasible-100 km	Feasible-120 km	Feasible-120 km
Elevation: % of whole ellipse area below –2000 m MOLA	95.3 %	94.3 %	100 % (100 %)
Elevation: % of (90%) ellipse below –2000 m MOLA	?	?	100 % (100 %)
Slopes: % compliance ≤3° at 2000 m base-length	98.8 %	98.3 %	99.1 %
Slopes: % compliance ≤8.6° at 330 m	98.9 %	97.7 %	98.8 %
Slopes: % compliance ≤12.5° at 7 m	98.9 %	88.2 %	93.7 %
Slopes: % compliance ≤15° at 2 m	94.2 %	92.4 %	94.9 %
Crater density:	1.55 crater per sq. km		
TAR coverage (% and where)	1.4 %	10.8 %	4.4 % (concentrated E of ellipse centre)
Clean bedrock coverage (%, where)	3 % (float rocks and cliffs)	16 %	36 %
Spectral (OMEGA) dust coverage	Spectrally dusty	Least dusty	Somewhat dusty
Thermal inertia: % area > 150 TIU (from TES data)	99% ≥ 150 Jm-2s-0.5K-1	99% ≥ 150 Jm-2s-0.5K-1	100% ≥ 150 Jm-2s-0.5K-1
Albedo: % area in range 0.10–0.26 (from ? data)	100% 0.1 – 0.26	100% 0.1 – 0.26	100% 0.1 – 0.26
Manually-derived rock abundance factor ***k*** (best-fit to 1.5 - 2.25m objects)	0.176 (7.0 km^2 sampled)	0.122 (2.5 km^2 sampled)	0.138 (5.0 km^2 sampled)
Planetary Protection	OK	OK	OK

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