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Interactive comment on "The MetNet vehicle: A lander to deploy environmental stations for local and global investigations of Mars" *by* A.-M. Harri et al.

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Author's esponse to the review (Reviewer #1) of the manuscript

Title: The MetNet vehicle: A lander to deploy environmental stations for local and global investigations of Mars Author(s): A.-M. Harri et al. MS No.: gi-2016-19

Dear Reviewer and the Associate Editor,

Thank you very much for your valuable comments in reviewing this manuscript. We have taken into account your comments and recommendations, and most of them have resulted in modified and/or added text in the manuscript. This response is structured such that we have firstly responded to the major comments and then to minor com-

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ments. Our response treats all the reviewer's comments individually by introducing firstly the comment, then our response, and finally, the changes in manuscript are depicted in the end of this response as a supplemented file (in the form of a 'difference mansucript').

Note: text in bold is our response. Text in bold and in quotes is text that can be found in the updated paper (difference manuscript also in the end of this file).

The reviewer comments, not in bold, contains numbers in brackets. These numbers are the page and line numbers of the submitted manuscript that can be found online in the GI discussions section. Reviewer #1 may have received an earlier copy of the manuscript as his page and line numbers do not tie in with the published one in the discussions section. So we have added the correct page and line numbers to help guide the reviewer and ourselves.

Thank you very much for your valuable review effort, A.-M. Harri et al.

Response to reviewer #1 ===============

This paper deserves to be published once the comments below have been addressed. It promises to give a good overview of a mission concept of interest for flight initially as a demonstrator / piggyback and then as a full network deployment.

MAJOR COMMENTS

[MAJOR] p3 lines 184-185 and p16 lines 877-878, 888-889 (P5 116): Pyros are very reliable components, so surely these are not the major driver of overall reliability (show me an EDL failure attributed to a pyro failing...)... I would expect the reliability to be gauged rather by EDL outcome when parameters of the vehicle's entry state, physical characteristics, GNC approach and atmospheric conditions are dispersed over the expected ranges in a Monte Carlo simulation. In other words, one could have perfect pyro performance (or zero pyros) but still have an unreliable system!

Added text on page 5 line 122 (updated online manuscript):

"Our comparative reliability analysis showed that concept B was significantly more reliable than concept A. This was due to, amongst other things, the lower amount of pyrotechnique devices required by the concept B."

[MAJOR] p8 Figure 9 caption: The depths shown, are they for the natural, undisturbed surface materials, or do they take into account the thermal short circuit introduced by the presence of the lander (thermally conductive metal structure)? This makes an important difference to the temperature environment the equipment has to withstand.

It is now mentioned that the temperatures are for undisturbed material in the paper as follows.

Page 15 in the legend for figure 9:

"The range of temperatures experienced at different latitudes and depths on Mars over the Martian season in material undisturbed by the MNL."

Page 15 at line 304:

"Since the amplitude of the temperature variations tends to decline fairly rapidly with increased depth for undisturbed material (Fig. 9)."

Author comment to the reviewer:

The figure is for the natural, undisturbed surface materials. The figure caption and the text has been updated to make this clear. In reality it is expected that the metal casing will create a short circuit smoothing the temperature profile. Further work will need to be conducted to further assess the thermal environment around the lander. Colder but less variability.

[MAJOR] p9 lines 512-515 (P319 319): A preliminary power profile would be useful to illustrate the standby, measurement and data relay operations, and demands for heating, e.g. of battery and day vs. night.

Text has been added on page 17 and line 355:

"The MNL operations will be defined such that the average energy consumption does not exceed the energy provided by the solar panels. The main energy drain is the transmitter, which is used at such intervals that allow the charging of the battery in-between transmissions. The MNL components allow for such operational cyclograms to be defined."

[MAJOR] p13 lines 726-728 (P23 446): Does the comprehensive sterilisation of the entire lander include that of the batteries, which presumably have a max. non-op. T below that needed for sterilisation by DHMR? Please clarify bioburden control approach vs. AIT constraints.

Text has been added to page 24 line 497:

"The MNL decontamination will be performed via a combination of dry heating and hydrogen peroxide treatment. Dry heating is applied for humidity sensor devices."

[MAJOR] Please provide an estimate of the data volume that could be relayed. How often could a relay pass be supported, from an energy point of view?

Added text at page 16 line 324:

"The battery status monitor together with the system-related part of the software assures that enough energy remains available to perform the essential system tasks like telecommunication link during times of orbiter visibility, and time keeping. Surface to orbit link 16 kbps. The overall data transfer rate is expected to be low; about 0.25 to 0.75 Mb/day on the average, depending on the orbital configuration."

[MAJOR] Please clarify if the MNL is under normal circumstances expected to go dormant waiting for sufficient energy to charge its battery and start operations again, and thus has to wake up with no knowledge of the time. Does the MNL never know ahead of time when a relay pass is expected and thus relies on overlap of its 'link check' status with a relay pass of an orbiter? Given that this is presumably only for a few minutes each sol, doesn't the MNL waste quite some energy listening for a signal? Or is the

MNL always expected to keep track of the time and when the next relay passes are?

Added text at page 16 line 321:

"Operations are designed to make sure the transmitter does not drain the battery. The MNL goes into idle mode to save energy. The clock continues running. At preplanned times the lander waits for a hail signal from the orbiter before transmitting data."

I also suggest that some of the elements of the MNL and the configuration at each step of the EDL sequence could be clarified by the inclusion of a product tree or block diagram. This would help understanding section 3.

Updated figure 2 to more closely follow the configuration at each EDL step.

MINOR COMMENTS

1. Abstract, lines 5-6: I suggest 'simultaneous, distributed in situ measurements' (set of points rather than 2D spatial coverage).

Changed (page 1 line 3)

2. Mass breakdown: mass fraction of approximately 17% - does this include mass maturity margin and payload system margin?

Add text page 29 line 578:

"Hence a payload fraction of 17% based on Engineering Qualification Hardware is an excellent number . . ."

3. p1 line 24 (p1 15): savings on mass - Potentially, yes - but not only mass; depends on approach to thermal qualification. It might instead just give you a wider range of qualified components to choose from.

Updated the text page 1 line 12:

"As the payload bay will be embedded in the surface materials, the bay's temperature excursions will be much less than if it was fully exposed on the Martian surface allowing

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a reduction in the amount of thermal insulation and savings on mass."

4. p1 lines 29-31 and p2 lines 114-118: I suggest to cite Ralph Lorenz's relevant paper in these two places: doi:10.1016/j.asr.2011.03.033.

Added "Planetary penetrators: Their origins, history and future" paper reference on page 3 line 82 in the online discussions version of the paper (your p2 lines 114-118):

"A hard-lander, such as high-speed penetrators, typically impact the surface at speeds of around 100 m s-1, and experience high decelerations (1000s of gees) over short time periods during the penetration of the subsurface strata (Lorenz, 2011)."

5. p1 line 60 (p2 38): Seismology being another area (microseismometer).

Agreed, added seismology as an area of investigation. Added this at page 2 line 39:

"Meteorology, climate studies and seismology are areas of investigation that would benefit from a network of observations."

6. p1 line 69 (p2 43): 'efficiently' - yes, albeit not precisely. Actual burial depth and thus thermal environment will depend on the surface properties at the impact site.

Removed the word "efficiently".

7. p2 lines 78-79 (p2 50) : Reword and be more precise vs. the impact speeds foreseen for the Mars 96 and DS-2 designs.

Updated text page 2 line 48:

"This paper describes the MNL concept, a compact and lightweight vehicle designed to deliver a set of instruments to the surface of Mars. The MNL vehicle uses a combination of lightweight inflatable aerodynamic decelerators and a penetrator-like landing system that also give the correct operational attitude. MNL will impact the Martian surface at a relatively lower, and hence safer, speed of around 50 m/s compared to previous high-speed penetrator designs for Mars. For example the Mars 96 and DS2 penetrators had impact speeds of 80 and 190 m/s respectively, e.g. see Ball et al., (2009a)."

8. p2 lines 82-90 (p2 52): Reword based on the actual order of the sections and sub-sections that follow.

Edited text starting page 3 line 56:

"The paper is organised as follows. In the next section previous Mars landers and their Entry, Descent and Landing System (EDLS) are first reviewed in Section 2.1. MNL development is reviewed in Section 2.2. The selected MNL concept and its EDLS design are discussed and described in Section 2.3. Section 3 provides a more detailed description of the MNL mechanical and electrical systems. Potential mission types and scientific applications of the MNL design are outlined and discussed in Section 4. Future prospects are outlined and recommendations made in Section 5 with precursor missions are outlined in Section 5.1."

9. p2 line 95 (p3 60) : 'it payload' - change to 'its payload and critical systems'.

Changed. See page 3 line 66.

10. p2 lines 114-118 (p3 73): Also mention MarsNet hard lander/penetrator as first European study of such a vehicle? See yellow book, Chicarro, A., Coradini, M., Fulchignoni, M., Liede, I., Lognonne, F., Knudsen, J.M., Scoon, G.E.N., Wanke, H. MARSNET Assessment Study Report, ESA Publication SCI(91)6, European Space Agency, Noordwjik, The Netherlands, January 1991.

Added reference to MarsNet at line 26 page 2.

11. p3 lines 185-186 (p5 115) : 'control commands' - What's meant here? EDL on-board control steps (e.g. time based or event-triggered)?

Edited text (page 4 line 124) and have removed reference to 'control commands'.

"Our comparative reliability analysis showed that concept B was significantly more reliable than concept A. This was due to, amongst other things, the lower amount of pyrotechnique devices required by the concept B."

12. p3 lines 186-189 (p5 116): Again, mass is just one impact of reduction in T range reqt. - see comment above for p1 line 24.

Added text to page 5 line 126:

"Penetration into the Martian regolith results in the vehicle experiencing reduced diurnal temperature variations. This could help reduce the thermal protection requirement, reducing mass, and in addition permit a wider range of qualified components for use in the vehicle."

13. p3 lines 195-196 (P6 124): Relative or inertial entry speeds? Does this limit the interplanetary trajectories that can be used?

It is the relative entry speed. For higher speeds the MetNet needs to be adjusted slightly to allow for higher entry speeds.nAdded text at page 5 line 132:

"The selected MNL Entry, Descent and Landing System (EDLS) was designed to cope with relative entry speeds of slightly over 6 km/s for the current design configuration. Higher entry speeds are possible with some adjustments to the aerodynamics."

14. p3 line 223 (P6 141): estimates of what?

Mass, text has been updated on page 6 line 151 as below:

"The mass estimates were given with a margin of 10-20%."

15. p4 line 258 (p7 line 163): 'deployed during the entry phase' - triggered how, e.g. at what g load or Mach no.?

Edited text at page 7 line 177 page 7:

"The inflatable heat shield is used during the entry phase to stabilise, decelerate the lander and protect it against excessive heat. The heat shield is inflated using a timer after release from the carrier spacecraft."

16. p4 line 260: +18 FPA is a rising, not descending trajectory! Check!

Thanks, corrected. See page 7 line 177.

17. p4 line 262 & p5 line 273 (P7 165 171): altitude above what level? 0km MOLA or (as perhaps indicated by line 273) pressure-defined?

Yes pressure defined. Updated text. See line 179 page 7.

"The inflatable heat shield diameter is 1 m which decelerates the vehicle down to a Mach number of about 0.85 at an altitude of 4.5-11.0 km above the Martian datum, i.e. the point of zero elevation on Mars equivalent to the altitude where the pressure is 610 Pa, and a dynamic pressure of 95-130~Nm-2 (both altitude and dynamic pressure depending on the angle of entry)."

18. p5 line 282-283 (p7 173): I assume this 500g load is limited by the piston-like shock-limiting mechanism and its stroke length. What loads are experienced by the external shell?

Updated text at page 7 line 187:

"Peak deceleration of the MNL payload bay during the impact will be <500 g, with the outer shell experience about twice the load on the payload, and the total impact time is 20 ms."

19. p5 lines 307-309 (p8 193) : Unclear wording... the forebody is stowed, ... once deployed...?

Updated text page 8 line 208:

"The forebody is stowed inside the surface module cylindrical structure. When the forebody is deployed the empty space provides room for the deceleration of the equipment compartment along a set of crushable rods during the impact with the surface."

20. p5 lines 345-348: What is the rigid TPS material used? Only that of the flexible

TPS is mentioned.

The rigid TPS material, i.e Rigid Aerodynamic Shielding (RAS), can be found in section 3.1.1 Entry and descent related systems.

21. p6 Figure 3 caption: add legend for the numbered labels.

Updated legend:

"A schematic of MetNet showing the section of the heat protection sections of the inflated aeroshell. Section I covers the rigid frontal structure and inflated torus that supports the outer part of the heat shield. Section II covers the rear of the MNL with section III covering the very back."

22. p7 Figure 4: (b) seems to be covering up something 842mm wide in (a)?

Updated figure to remove the hidden image.

23. p8 Figure 9 caption: 'The light grey bars...' - Surely the other way round, as per legend? The light grey ranges are smaller.

Yes corrected.

24. p8 line 476 (P15 300): REFERENCE missing.

Added reference.

25. p8 line 493: (P15 311) DEFINition missing.

Added definition: "JTAG (Joint Test Action Group)"

26. p11, line 648 (P20 406): 'temperatures up to 1500 K' - What's the peak heating experienced (W/cm2)?

Updated text line page 23 line 471 with peak heating rate:

"The maximum surface temperature of the rigid TPS surface during the steepest trajectory has been calculated to be 523 K and a heat flux of 190 kW m-2 which is well below the short-term tolerance of the rigid TPS."

27. p11, line 679 (P22 427): 4586 m/s - isn't this too slow for hyperbolic entry? Please check.

Yes this is orbital. Updated text at page 23 Line 467:

"This is assuming a ballistic coefficient of 20 kg m-2, an entry altitude of 120 km and an orbital entry speed of 4586 m s-1."

28. p13 lines 739-741 (P23 460): I think the Pascal Mars Scout mission proposal (Haberle et al., 2000) deserves inclusion in this list.

Added reference page 26 line 506.

29. p16 line 956 (P30 598): REFs missing.

Deleted as references are included previously.

Some typos for correction:

Abstract, line 2: phenomena, plural DONE Abstract, line 9: 'number of launches' rather than 'amount of launchers'. DONE p1 line 20: orient DONE p2 line 123 (P3 L77): mission, singular. DONE p2, line 125 (P3 L78): Mars 96 was never meant to achieve a *stable* Earth orbit, I don't think, only a temporary orbit before the Earth escape burn. Better to say 'failed to achieve Earth escape trajectory'. DONE p5 line 319 (P8 L202):: unit, not unity. DONE p8 Figure 9 caption: modelled, not modellied. DONE p9 line 518: telescopic, not telescope. DONE p11, line 644 (P20 L404): Fig. 13, not 12, I think. Yes, DONE.

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Modified Manuscript with changes tracked

provided as a supplement file

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Please also note the supplement to this comment:
http://www.geosci-instrum-method-data-syst-discuss.net/gi-2016-19/gi-2016-19-AC1-supplement.pdf

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2016-19, 2016.