Joint Mars Exploration Programme

ANNOUNCEMENT OF OPPORTUNITY:

EXOMARS ENTRY, DESCENT, AND LANDING DEMONSTRATOR MODULE (EDM) SCIENCE

Entry and Descent Science with Spacecraft EDL Engineering Sensors and Provision of a Surface Payload for the ExoMars EDM

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1 BACKGROUND

1.1 Programmatic Overview

In late 2008, ESA and NASA began investigating the possibility of combining resources to implement joint missions in a collaborative programme to explore Mars. Initial discussions focused on mission concept studies for the 2016 and 2018 Mars launch opportunities, however the programme's ultimate objective is the implementation of an international Mars Sample Return (MSR) effort.

The outcome of this initial process led to the definition of joint missions for the 2016 and 2018 opportunities.

The 2016 mission is ESA-led and launched by NASA. ESA will provide a Mars orbiter and an Entry, Descent and Landing (EDL) demonstrator.

The ExoMars Trace Gas Orbiter (TGO) will accommodate scientific instruments for the detection of atmospheric trace gases, the study of their temporal and spatial evolution, and the localization of their source regions. Additionally, the 2016 orbiter will provide surface telecommunications support for the 2018 mission and for other landed assets until 2022.

The ExoMars EDL Demonstrator Module (EDM) constitutes a technology platform whose main goal is to allow Europe to acquire a Mars landing capability. Although designed to demonstrate EDL technologies, the EDM offers limited, but useful, science capabilities.

1.2 Purpose of this Announcement of Opportunity (AO)

This is the second solicitation for payload proposals jointly organised by ESA and NASA in the framework of the Joint Mars Exploration Programme (JMEP) that both agencies plan to implement. However, there are some differences between this call and the one implemented for the ExoMars Trace Gas Orbiter (TGO):

1. ESA will release this AO; both agencies will take part in the proposal review process.
2. NASA will not fund hardware contributions, but will support US Co-Investigators (Co-I) participating in the selected proposals.

Review teams from ESA participating states and from the US will evaluate proposals received in response to this call. All reviewers will sign nondisclosure Agreements.

1.3 Responding to this AO

All proposals to participate in the opportunity described here must be submitted in response to this AO.

ESA will not fund the development and exploitation of scientific instruments for the ExoMars EDM. Under ESA coordination, the national agencies and research institutions taking part in ESA's Aurora Programme and submitting proposals to this opportunity will be responsible for funding any payload provisions selected in response to this Announcement.

NASA will consider supporting participation as individual Co-Investigators on EDL Surface Payload proposals and on EDM Entry and Descent Science proposals submitted from ESA participating states. NASA will not support hardware contributions.

Interested US scientists should affiliate themselves as a scientific Co-I with a proposal from an ESA participating state. In the event that this proposal is selected, NASA will invite a further proposal as a Participating Scientist.

Given that this mission is part of the ESA-NASA Joint Mars Exploration Programme, proposals having an international dimension are encouraged. In particular, participation is encouraged from scientists in countries contributing to ESA's Aurora Programme (Austria, Belgium, Canada, Denmark, France, Greece, Germany, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom) and in the US.

2 SCIENCE AND PROGRAMME OBJECTIVES

2.1 ESA ExoMars Science and Exploration Goals

The ESA objectives for the ExoMars Programme, which consists of the 2016 and 2018 mission opportunities, can be found in the ExoMars Science Management Plan (see the AO Library at the location given in Chapter 7 of this document).

The ExoMars technology objectives are:

- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars;
- Surface mobility with a Rover;
- Access to the subsurface to acquire samples; and
- Sample acquisition, preparation, distribution, and analysis.

The ExoMars scientific objectives are:

- To search for signs of past and present life on Mars;
- To investigate the water/geochemical environment as a function of depth in the shallow subsurface; and
- To study Martian atmospheric trace gases and their sources.

2.2 NASA Planetary Science and Mars Exploration Goals

The Scientific goals underlying NASA's Planetary Science program are articulated in the NASA Science Plan (http://nasascience.nasa.gov/about-us/science-strategy/):

- How did the Sun's family of planets and minor bodies originate?
- How did the solar system evolve to its current diverse state?
- What are the characteristics of the solar system that led to the origin of life?
- How did life begin and evolve on Earth and has it evolved elsewhere in the solar system?
- What are the hazards and resources in the solar system environment that will affect the extension of human presence in space?

In formulating the Mars Exploration Program within the Planetary Science Division, these science goals have been made more specific to Mars itself. These goals are:

- To search for evidence of life,
- To understand the history of the solar system, and
- To prepare for future human exploration.

2.3 Science Opportunities for the 2016 ExoMars EDM

The ExoMars EDM will land during the Martian statistical dust storm season. While there cannot be any certainty of encountering a dust storm, the expected state of the atmosphere during this period can best be described as "dust loaded." The EDM will have the opportunity to probe the Mars atmospheric environment under dust conditions that have not been well studied by previous missions.

The EDM mission offers two major science opportunities:

1. **Entry and Descent Science**: Data from the EDL Engineering Sensors (accelerometers, gyroscopes, radar altimeter, radio link, spacecraft sensors aimed at monitoring heat shield and parachute performance), and other auxiliary information (e.g. landing site ellipse, probe aerodynamic parameters, etc.) can be used by the proposers to derive **atmospheric profiles for density, temperature, pressure, and maybe wind** along the entry and (to a lesser degree) parachute descent trajectory. Measurements of this type have been performed on other Mars landers, but **the mission provides a unique opportunity to try this for the first time during the dust storm season.** This "extreme case" science could prove very valuable for climate modellers and atmospheric scientists. Better knowledge of the Martian atmosphere and EDL performance characteristics under dust-rich conditions could help optimise future probe design.
2. **EDM Surface Payload (SPL)**: It is possible to perform a variety of brief scientific measurements using small sensors that are compatible with the EDM's accommodation limitations. Sensors can be housed within the lander's warm compartment (e.g. pressure sensor), or mounted on the exterior (e.g. camera and environmental sensors). This landing opportunity is specially suited for pursuing **science goals associated with a dust-**

loaded atmosphere. Such measurements are intrinsically interesting, complement entry and descent science, support the technology verification of the landing success, and may provide a useful surface data set for the 2016 ExoMars Trace Gas Orbiter and 2018 Rover missions.

The following is a list of **general environment science objectives to which the EDM results could contribute**. Please note that due to: 1) the overriding technology objectives of EDL, and 2) the limited surface mission duration, it will not be possible to fully address these objectives. The list also includes example measurements; these are not meant to be the only measurements possible.

1. Improve our understanding of temporal (diurnal, seasonal) and spatial (vertical, regional) variability within the Martian atmosphere:
   - Determine atmospheric profiles for key parameters (density, T, P, wind...) from high altitude to the surface, with fine spatial resolution;
   - Characterise the atmospheric state during a period of high dust storm probability;
   - Extend existing *in situ* datasets to help resolve discrepancies in remotely sensed data and models.
2. Provide *in situ* experimental constraints on key physico-chemical properties and processes in the near-surface environment, with relevance to dust, water, organics, and trace gases:
   - Study dust physical properties;
   - Investigate dust-related surface-atmosphere processes (e.g. dust loading, transport, electrical charging and discharging);
   - Characterise organic degradation agents (UV, oxidants, radiation);
   - Determine volatile exchange between the subsurface and lower atmosphere.
3. Conduct measurements that can improve or complement the scientific outcome of the 2016 Trace Gas Orbiter and the 2018 Rover missions.

3 PROPOSAL OPPORTUNITIES AND SCHEDULE

3.1 EDM Surface Payload

From a project implementation point of view, the EDM Surface Payload is conceived as a single, integrated entity that includes a number of elements or functions:

- Central Electronics Unit (analogue and digital electronics, power distribution, timer, memory, data processing and interface);
- Power Source (primary battery);
- Interconnecting harness;
- Sensor #1 … Sensor #N.

With this AO, ESA solicits proposals for the provision of fully integrated payloads (i.e. containing all the elements described above), but will also consider submissions proposing individual sensors. In this manner, as indicated in the ExoMars Science Management Plan (SMP), teams will have the possibility to propose either fully integrated payloads or individual sensors.

Submitted Proposals, whether for the entire payload or for individual sensors, will be subjected to the same level of scrutiny. ESA and NASA experts will conduct a technical, management, and funding commitment evaluation. An independent, anonymous peer review will be used to arrive to a science recommendation.

Please note that, compatible with the available resources, ESA and NASA intend to fly the best possible EDM Surface Payload. This may require combining elements from different proposals. Though teams are free to propose complete or partial payloads, it is possible that only parts of their proposal are retained. Based on the outcome of the technical and science reviews, the Agencies will finalise the composition of the selected EDM Surface Payload.

IMPORTANT: It is assumed that one complete SPL, containing all necessary elements and functions, can be selected. If this were not to be the case, for example in case only individual sensors are proposed, then ESA will not implement a Surface Payload in the EDM.

The ExoMars project team requires a single point of contact to ensure an efficient technical implementation. It is therefore expected that the selected EDM Surface Payload's Principal and Co-Principal Investigators (PI and Co-PI, respectively) will have authority to discuss and agree interfaces between the entire EDM Surface Payload and the EDM —the formal appointment of the PI and Co-PI will be addressed with the relevant Lead Funding Agency (LFA) following the completion of the selection process. Other scientists will be considered EDM Surface Payload Co-Is; a lead Co-I should be identified for each sensor/element. This lead Co-I is expected to interact with the PI rather than ESA. Please see also Chapter 6 of the E-PIP.

ESA and NASA will present the results of the evaluation and the payload recommendation to the Solar System and Exploration Working Group (SSEWG). Thereafter, ESA will submit the recommended payload for approval to the Human Spaceflight and Exploration Programme Board (PB-HME).

3.2 EDM Entry and Descent Science

This AO also requests proposals to compose a science team to conduct scientific analyses of the EDM Engineering Sensors' data. It is important to understand that these are not scientific sensors; their objective is to allow the project team to evaluate the spacecraft's technical performance. This AO does not solicit additional EDL sensors.

A preliminary indication of the data expected from the EDM Engineering Sensors can be found in Chapter 8. Please note that the number, type, location, and performance of these sensors are not yet fully determined. For the purpose of preparing their proposal, teams should assume receipt of the specification of the EDL Engineering Sensors according to the draft schedule indicated in Chapter 4.

Proposing teams interested in making use of this opportunity will need to construct a science analysis scenario based on the information that is available at the time of issuing this call and on similar types of analyses conducted on previous missions, e.g. Huygens, MER and Phoenix.

In case more than one EDM Entry and Descent Science proposal were to be selected, the agencies will request that a single science team be constituted, under one PI and Co-PI. Such coordination action would be undertaken together with the selected teams and the relevant Lead Funding Agencies.

A single Principal Investigator (PI) shall be ESA's point of contact for the EDL Science investigation. In case more than one EDM Entry and Descent Science proposal were to be selected, ESA will request that a single science team be constituted. The PI shall bear the primary responsibility for ensuring that the EDL Science activities meet their objectives and are implemented within the programmatic framework determined at selection. It is expected that the PI shall be assisted by up to two Co-PIs and a team of Co-Investigators (Co-Is). The PI retains ultimate responsibility for the investigation, but may choose personnel to have lead responsibility for specific activities.

3.3 Schedule

The following schedule applies to this call:

- No pre-proposal teleconference is planned as part of this solicitation. Further information will be available in the AO Library at the location given in Chapter 7.
- Please address questions concerning any portion of this document to the Points of Contact given in Chapter 7, as appropriate. The period for questions will close four weeks before the proposal due date.
- A Notice of Interest (NOI) to propose to this announcement is extremely valuable to ESA and NASA, and, therefore, is encouraged. NOIs are due on the date given in Chapter 7.
- All proposals are due on the date provided in Chapter 7. Proposal submission requirements are outlined in Chapter 5.
- For individual scientists to be funded by NASA, funding will begin as soon as appropriate funding vehicles can be put in place; commonly this is four to eight weeks following a successful NASA Participating Scientist selection (please refer to Section 1.3 of this document).
- For proposals to be funded through ESA participating states, funding for selected proposals will begin as soon as the appropriate agreements can be put in place, following ESA Programme Board (PB-HME) approval.

4 REQUIREMENTS AND CONSTRAINTS

4.1 Opportunity Requirements

This opportunity solicits proposals for science investigations that include <u>a complete SPL</u> to be included in the ESA-led 2016 ExoMars EDM.

This call will also consider proposals for science investigations that include a sensor to be accommodated as part of a complete SPL to be included in the ESA-led 2016 ExoMars EDM. Regardless of their science merit, the feasibility of accommodating sensors proposed individually will be largely determined by their compatibility with the selected payload's architecture. For this reason, teams are encouraged, if possible, to make arrangements to propose as part of a complete SPL proposal.

Finally, this announcement also requests proposals from science teams to conduct scientific analyses of data acquired by the EDL Engineering Sensors.

4.1.1 Surface Payload PI Responsibilities

As detailed in the E-PIP, the selected EDM Surface Payload PI is responsible for conducting the SPL science investigation. This includes, but is not limited to, delivering all elements of the complete SPL and implementing any necessary capabilities to prepare the SPL mission timeline. The PI shall also be responsible for analysing the data, preparing and archiving the data products, and reporting the results of the science investigation in the science literature.

4.1.2 Entry and Descent Science PI Responsibilities

The selected EDM Entry and Descent Science PI is responsible for analysing the engineering sensors' data, preparing and archiving the data products, and reporting the results of the science investigation in the science literature. EDM Entry and Descent Science proposals shall: 1) specify a PI, a Co-PI, and all Co-Is; 2) describe the role of each team member; and 3) justify the necessary nature of their role.

The EDM Entry and Descent Science PI shall:

1. Be the investigation's primary point of contact with other Project elements regarding the investigation's activities and schedule.
2. Represent the Entry and Descent Science team in relevant Project reviews.
3. Have overall responsibility for scheduling meetings and maintaining communications with the EDM Manager and ExoMars Project Scientist.
4. Participate in relevant meetings and associated working groups, providing inputs on topics including interaction with the Project during flight operations, interactions (if any) with the SPL, archiving and other topics. These inputs may require participation and deliverables from other members of the Entry and Descent Science team, to be coordinated by the PI.
5. Generate and maintain documentation as required.
6. Establish milestones and monitor and assure adequate progress towards achieving the goals of Entry and Descent Science.
7. Ensure that the Entry and Descent Science activity meets the Project-approved schedule.

8. Establish, as appropriate, the allocation of funds through negotiation with the responsible funding authority.
9. Demonstrate that the Entry and Descent Science investigation meets its agreed science requirements.
10. The PI is also responsible for data analysis, and overall conduct of the investigation.
11. Prepare, certify, and release data products to the Planetary Science Archive (PSA) and other archives according to the still-to-be-finalized ExoMars EDM data management and archival requirements.
12. Ensure that the reduction, analysis, reporting, and archival of the results of the investigation meet with the highest scientific standards and completeness, consistent with budgetary and other recognized constraints.
13. Ensure development and readiness of tools and services that are required for scientific analysis of the EDL data.
14. Ensure the timely provision to the Project of each deliverable.

4.2 Cost and Schedule Constraints

The appropriate national funding institution, in coordination with ESA, will finance EDM Surface Payload elements and EDM Entry and Descent Science teams from countries that participate in ESA's Aurora Programme. <u>Proposals from teams in ESA participating states must provide letters of financial endorsement from the relevant funding sources</u>.

NASA expects to fund up to three investigators as Participating Scientists in proposals submitted by teams from ESA participating states in response to this AO.

4.2.1 Surface Payload Schedule

The opportunities described in this AO request proposals for EDM Surface Payloads that shall be consistent with the mission schedule as described in the E-PIP. Proposers to the opportunities described in this AO should refer to the E-PIP available at the URL listed in Chapter 7.

4.2.2 Entry and Descent Science Schedule

Proposals for the Entry and Descent Science shall assume the draft schedule, deliverables, and receivables listed in Table 1.

Table 1: Preliminary overall phasing for the EDL Science activity.

Q2 2011	**Selection of EDL Science investigation**
Phase 0: Task Identification and Justification Q2 2011 to Q2 2012	Inputs: AO and E-PIP. Output: PI delivers draft Entry and Descent Science Implementation Plan to PS and Project Manager (updated proposal).
Phase 1: Algorithm Development Q2 2012 to Q4 2013	Input: ESA delivers draft EDL Engineering Sensors Description to Entry and Descent Science PI. Activity: Establishment of reconstruction code(s). Output: PI delivers Issue 1 of Entry and Descent Science Implementation Plan, including reconstruction codes, to ESA.
Q4 2013	**EDM Critical Design Review**
Phase 2A: Algorithm Test and Validation Q1 2014 to Q1 2015	Input: ESA delivers Issue 1 of EDL Engineering Sensors Description containing quantitative description of the engineering sensors, plus existing representative datasets. Output: PI delivers Issue 2 of Implementation Plan using EDM simulated data.
Q1 2015	**EDM Flight Acceptance Review**
Phase 2B: Algorithm Test and Validation Q1 2015 to landing (Oct 2016)	Input: ESA delivers Issue 2 of EDL Engineering Sensors Description containing an updated description of the engineering sensors, plus existing representative datasets. Output: PI delivers Issue 3 of Implementation Plan using EDM simulated data.
EDM Entry, Descent and Landing (Oct 2016)	
Phase 3: Data Analysis Landing + 1 month to Landing + 7 months	Inputs: ESA delivers flight data following landing and initial post-flight report to PI. Outputs: PI deliveries to ESA: • Delivery 0 using navigational information and best available atmospheric model. • Delivery 1 using actual flight data. • Delivery 2 six months after landing – refined analysis, maximally consistent with the available information.
Phase 4: Archival Receipt of Data + 6 months	Outputs: PI delivers data products to PSA compliant with ESA data management and archiving requirements.

4.3 Technical Requirement Constraints

More complete details of the technical requirements and constraints can be found in the E-PIP. This section provides a brief overview.

The EDM Surface Payload (SPL) will be able to start its 4-sol nominal science mission soon after landing. The ExoMars Trace Gas Orbiter (TGO) will provide data relay services for the EDM.

It is the intention of ESA and NASA to select an EDM Surface Payload that does not exceed the following constraints:

- Total mass allocation for the complete SPL: ≤ 3.0 kg (including maturity margins).
- Total data volume allocation: ≤ 50 Mbit (over the entire SPL mission).

IMPORTANT: Please note that the above constraints have been established for the baseline mission scenario under the assumption of a landing site in the equatorial region, as described in the E-PIP. Depending on the latitude and environmental conditions of the final landing site that the mission will be able to target, the EDM lifetime on the surface of Mars could be shortened (e.g. for the case of a winter landing at higher latitudes). This could result in reductions to the SPL lifetime and data return. Were this to be the case, the project team will work with the selected SPL team to determine the feasibility to (partially) recover the science.

As a guide to proposers, the E-PIP provides mass indications for the EDM Surface Payload support functions (e.g. Central Electronics Unit, etc.).

EDM Surface Payload sensors are expected to be simple, body-mounted units that do not require deploying mechanisms. They may be accommodated at different locations on the lander. The internal harness between units will be considered part of the EDM Surface Payload's mass budget.

Please note that the launch approval process established for this mission does not allow the use of either Radioactive Heating Units (RHUs) or Radioactive Thermal Generators (RTGs).

The selected EDM Surface Payload must meet the applicable planetary protection requirements for a Mars landed mission. (See E-PIP requirements in the AO library).

4.4 Special Conditions applying to this AO

1. Proposal must be submitted electronically; please see Section 5.3 of this document.
2. The notification process will be coordinated between ESA and NASA, as described in Section 6.6.1.
3. Data policies for investigations selected in response to this call will follow the guidelines specified in the ExoMars Science Management Plan. However, proposals should quantify the brief validation period after which the data will be placed in a publically available

archive. It is expected that this brief period should be less than six calendar months. Please note that ESA and NASA reserve the right to direct or conduct processing and release of data needed for mission or program planning and also to support public engagement.

4. Proposers will be required to coordinate their communications and outreach plan with ESA and NASA. Proposers should include funding for these activities in their proposals.

5 PROPOSAL PREPARATION AND SUBMISSION

5.1 Notice of Interest (NOI)

The NOI should include a preliminary list with the proposing team members, their affiliation and e-mail contact information, and an abstract (one page maximum) describing the contemplated investigation. Please refer to the NOI Template included in the AO Library to provide the requested information.

The NOI must be submitted electronically, in Word (.doc) format. Please refer to the NOI Template provided in the AO Library.

5.2 Proposal Content Requirements

5.2.1 Proposal Content

Proposal content must conform to the guidelines set forth in this AO and in the applicable E-PIP. Proposals must include:

1. An informative title such that by reading the title a person should understand the goal of the proposed investigation; plus a one-word name or acronym for the proposal.
2. A (one page maximum) summary of the proposal's scientific objectives and the means to address them.
3. The detailed coordinates of every member in the proposing team. There is no limit on the number of Co-Investigators that may take part in a proposal, provided all team members have a well-defined scientific and/or technical role.
4. A brief outline (one short paragraph per person) of the expertise that each investigator will contribute to the proposed investigation.

   Proposals for a complete EDM Surface Payload must identify a PI, a Co-PI and all Co-Is, describe the role of each team member, and justify the necessary nature of their role. A lead Co-I should be designated for each sensor/element. The process for confirming the final EDM Surface Payload PI and Co-PI is explained in Section 3.1.

   Proposals for EDM Surface Payload individual sensors must identify all Co-Is, describe the role of each team member, and justify the necessary nature of their role. A lead Co-I should be identified for each sensor.

Proposals for EDM Entry and Descent Science must identify a PI, a Co-PI and all Co-Is, describe the role of each team member, and justify the necessary nature of their role.

5. The proposed investigation's scientific and technical description, including heritage and maturity, as applicable (twenty pages maximum).
6. The proposed investigation's implementation, management, collaboration arrangements, work breakdown structure, cost table, and basis for estimate (twenty pages maximum).
7. Letters of financial commitment from the proposal's Lead Funding Agencies —only from applicable ESA participating states, not necessary from NASA.
8. A section containing curricula vitae for all team members (maximum 2 pages per person), including up to 10 recent and/or relevant publication references.

Please refer to the Proposal Template provided in the AO Library.

5.2.2 Limit on Size of Electronic Proposals

Proposals must be submitted electronically, as a single PDF file not exceeding 15 MByte.

5.3 Submission Requirements

5.3.1 Electronic Submission of NOIs

The Notice of Interest must arrive electronically no later than the date given in Chapter 7. NOI must be submitted as an attachment, in Word (.doc format). Instructions and forms to submit an NOI can be found at:

http://exploration.esa.int/EDM-AO

Please use as filename for the NOI attachment: (Investigation Name)—NOI.

ESA will confirm the reception of NOIs by e-mail.

5.3.2 Electronic Submission of Proposals

Complete proposals must arrive electronically no later than the date given in Chapter 7. Proposals must be submitted as an attachment, in PDF format. Instructions and forms to submit a proposal can be found at:

http://exploration.esa.int/EDM-AO

Please use as filename for the proposal attachment: (Investigation Name)—PROPOSAL.

ESA will confirm the reception of proposals by e-mail.

5.4 Questions

Questions concerning the content provided in this document, or in the E-PIP, should be sent to the e-mail addresses for questions listed in Chapter 7. Questions and answers deemed to be of interest to all proposers will be posted in the AO Library.

The latest date for receipt of questions is four weeks prior to the proposal due date listed in Chapter 7.

6 PROPOSAL EVALUATION, SELECTION, AND APPROVAL

6.1 Evaluation Process

All proposals will be initially screened to determine their completeness and compliance to requirements and constraints of this AO. Proposals found to be incomplete or non-compliant can be rejected without further review.

Complete, compliant proposals addressing the science opportunities identified in Chapter 3 of this AO will be assessed against the evaluation criteria described in this Chapter by panels of anonymous peer reviewers. Reviewers will be instructed to evaluate all proposals independently and not to compare investigations. Review panels may be augmented through the solicitation of non-panel (mail-in) assessments, which the panels have the right to accept in whole or in part, or to reject.

Proposers should be aware that during the evaluation and selection process, the Agencies might request clarifications on specific points of a proposal. Such a request, and the proposer's response shall be in writing.

6.2 Categorisation Process

An *ad hoc* Categorisation Committee, composed entirely of ESA and NASA staff, will convene to consider the peer review results. This committee will categorise the proposals according to the following definitions:

Category I: Well conceived and scientifically and technically sound investigations pertinent to the goals of the programme and to the AO objectives, offered by a competent investigator from an institution capable of supplying the necessary support to ensure that any essential flight hardware, or other support, can be delivered on time, and that data can be properly reduced, analysed, interpreted, and published in a reasonable time. Investigations in Category I are recommended for acceptance and normally can be displaced only by other Category I investigations.

Category II: Well conceived and scientifically or technically sound investigations, which are recommended for acceptance, but at a lower priority than Category I.

Category III: Scientifically or technically sound investigations, which require further development of an instrument or a spacecraft subsystem. Category III investigations maybe recommended for further development by participating states and may be reconsidered at a later time for the same or other opportunities.

Category IV: Proposed investigations that are recommended for rejection for the particular opportunity under consideration, whatever the reason.

6.3 Selection and Approval Process

ESA and NASA will review the results of the evaluation and categorisation to prepare a selection recommendation. This selection recommendation will be presented to the ESA Solar System and Exploration Working Group (SSEWG) who is tasked with verifying that the recommended investigations can adequately address the mission's objectives and that the selection process has been conducted according to ESA's practices. Thereafter the selection recommendation is presented to the ESA Director of Science and Robotic Exploration and to the NASA Associate Administrator for the Science Mission Directorate. The final step in the selection process at ESA is the approval by the ESA Programme Board for Human Spaceflight and Exploration (PB-HME).

6.4 Evaluation Criteria

Proposals will be evaluated according to the following evaluation criteria:

- Scientific merit of the proposed investigation;
- Implementation merit and feasibility of the proposed investigation;
- Technical, management, and financial commitment of the proposed investigation, including compatibility with the ExoMars EDM as specified in the E-PIP.

For Entry and Descent Science proposals, the evaluation will also assess whether the proposing team demonstrates:

- Relevant experience in atmospheric (re-)entry and descent profile reconstruction;
- Evidence of scientific excellence in planetary (especially Martian) atmospheric science;
- Ability to establish and manage an EDL Science team able to meet the investigation's objectives and commitments;
- Capacity to deliver quality data products for submission to the Planetary Science Archive (PSA).
- Commitment from relevant LFA(s) to support the EDL Science activities.

6.4.1 Scientific Merit of the Proposed Investigation

Each proposed investigation will be evaluated for its scientific merit as expressed in terms of specific major and minor strengths and weaknesses. To evaluate intrinsic merit, the goals and objectives of the proposed investigation will be assessed to determine the impact of the investigation on one or more of the science objectives identified in the AO and relevant ESA and

NASA programme documents. For science investigations, this evaluation will include how well the investigation fills gaps in the understanding of science and thereby provides for progress in one of the science research programmes, and/or how well the proposed investigation synergistically supports other ongoing science missions related to research programmes sponsored by the Agencies. A major element in the assessment of scientific merit will be whether the data that to be gathered will be sufficient to complete the proposed investigation. Merit will be evaluated for the baseline proposed investigation. Science enhancements beyond the baseline investigation will not contribute to the assessment of the merit of the proposed investigation.

The evaluation of scientific merit will also assess the extent to which the proposed investigation addresses high priority scientific objectives defined in this AO.

This evaluation will result in narrative text, as well as an appropriate rating.

6.4.2 Implementation Merit and Feasibility of the Proposed Investigation

Each proposed investigation will be evaluated for its scientific implementation merit, including feasibility, resiliency, and the probability of success as expressed in terms of specific major and minor strengths and weaknesses. Implementation merit and feasibility will be evaluated by assessing the degree to which the investigation will address the proposed scientific or technical goals and objectives, the degree to which the proposed SPL or sensor(s) can be built using the proposed methods, the degree to which the proposed SPL or sensor(s) can provide the necessary data. Areas requiring critical technology development of the SPL for flight readiness will be identified and the plan for completing technology development will be assessed. Considerations in the evaluation of the data analysis (i.e., calibration/validation) and archiving plan will include an assessment of planning adequacy and evidence of plans for well documented, high level products and software usable by the entire community, an assessment for adequacy of resources for physical interpretation of data and reporting scientific or technical results in refereed journals, and the proposed plan for the timely release of the data to the public domain. Should a new technology that represents an untested advance in the state of the art be proposed for use, an assessment will be made of the likelihood of its success. The probability of success will be evaluated by assessing science team roles, experience, expertise, the organisational structure of the science team, and the technical risk associated with the overall mission design and/or instrument set. The roles of the PI, Co-PI, and each Co-I will be evaluated for necessary contributions to the proposed investigation; the inclusion of Co-Is who do not have a well defined and necessary role will be considered a weakness of the proposal.

The evaluation of scientific implementation merit will also assess:

- The extent to which the proposed investigation is compatible with the EDM design, as given in the E-PIP.
- The maturity of the proposed investigation's design or the demonstration of a clear path to achieve the necessary TRL on the schedule given in the E-PIP.

This evaluation will result in narrative text, as well as an appropriate rating.

6.4.3 Technical, management, and financial commitment of the proposed investigation

Each proposed investigation will be evaluated for its technical, management, and financial commitment, as expressed in terms of specific major and minor strengths and weaknesses. The technical and management approaches will be evaluated to assess the likelihood that the investigation can be implemented as proposed. This includes an assessment of risk of completing the investigation within the proposed schedule. The evaluation will consider, as appropriate, implementation factors such as the complete SPL or sensor(s) design and design margins; communication needs; and the proposers' understanding of the processes, products, and activities required to accomplish development and integration of all elements (flight elements, ground and data systems, etc.). This assessment will also consider the adequacy of the proposed organisational structure, the roles and experience of the known partners, the management approach, the commitments of partners and contributors, and the team's understanding of the scope of work (covering all elements and phases of the mission, including contributions). The relationship of the work to the schedule, the mission's interdependencies, and associated schedule margins will also be evaluated. Proposal development resiliency (the flexibility to recover from problems) will also be evaluated. This will include an assessment of the approach to descope the Baseline Investigation in the event that development problems force reductions in scope. Investigations proposing new technology, i.e., technologies having a TRL less than 5, will be penalised for risk if adequate backup plans to ensure success of the investigations are not described.

The risk management approach the science investigation team intends to use will be assessed, as will any risk mitigation plans for new technologies, any long-lead items, and the adequacy and availability of any required manufacturing, test, or other facilities.

The role, qualifications, and experience of the PI will be assessed, as will the commitment, spaceflight experience, and past performance of the PI and his or her implementing institution, against the needs of the investigation.

The role, qualifications, and experience of the Project Manager (PM) (if assigned separately from the PI) will be assessed, as will the commitment and past performance of the PM and his or her implementing institution, against the needs of the investigation.

The plans for managing the risk of contributed critical goods and services will be assessed, including the commitment of every partner as documented in letters of commitment and the adequacy of contingency plans for coping with the failure of a proposed cooperative arrangement.

This evaluation will result in narrative text, as well as an appropriate adjectival rating.

6.5 Selection Factors

Proposals will undergo a joint ESA-NASA review process. The results of the proposal evaluations, based on the evaluation criteria described above, and the subsequent proposal categorisation will be considered in the selection process.

The Selection Officials may take into account a number of programmatic factors in deciding whether or not to select any proposal, including, but not limited to, available funding and maintaining a programmatic and scientific balance across the sponsoring ESA and NASA programmes.

The overriding consideration for the final selection of proposals submitted in response to this AO will be to maximise scientific return and to minimise implementation risk within the available budget and technical constraints applicable to the EDM mission element.

6.6 Implementation Activities

Selected, approved proposals from ESA participating state investigators will be implemented according to ESA procedures.

Participation of NASA funded investigators in selected, approved proposals from ESA participating state investigators will be subject to the instructions and constraints indicated in Sections 1.2 and 4.2.

6.6.1 Notification of Selection

Notification of selection for all proposals will be via formal written notification from ESA.

Proposers of investigations not selected will also be notified in writing by ESA.

All proposing teams will receive a written report detailing their proposal's evaluation results.

6.6.2 Approval of Investigations

Investigations selected from this competition will be presented for approval to the ESA Programme Board for Human Spaceflight and Exploration (PB-HME). However, throughout the project implementation phase, the selected investigations will be subject to a number of reviews and technical requirements detailed in the E-PIP. Failure to comply in a timely and satisfactory manner could ultimately result in a recommendation for deselection.

7 SUMMARY OF KEY INFORMATION

Funding available for selected investigations from ESA participating states	To be arranged with the investigation's national Lead Funding Agency (LFA)
Funding available for NASA participating scientists	Please refer to Section 4.2
Due Date for NOI	15 January 2011
Due Date for Proposals	1 March 2011
EDM AO Library Site (E-PIP and all AO documents)	http://exploration.esa.int/EDM-AO
Submission Medium	Electronic copies only; please see Section 5.3
ESA and NASA points of contact concerning this AO	Dr. Jorge L. Vago ExoMars Project Scientist ESA/ESTEC (SRE-SM) Noordwijk The Netherlands Tel: +31 71 565 5211 E-mail: jorge.vago@esa.int Dr. Philippe Crane Planetary Science Division Science Mission Directorate NASA Headquarters Washington, DC 20546-0001 Tel: +1 202-358-0716 E-mail: philippe.crane@nasa.gov
For questions:	Please submit questions electronically to: jorge.vago@esa.int philippe.crane@nasa.gov albert.haldemann@esa.int Thierry.blancquaert@esa.int

8 GENERAL DESCRIPTION OF THE EDL ENGINEERING SENSORS

A general description is given in Table 2.

1. Please specify and justify the minimum measurements that will allow you to reconstruct the environment (density, T, P, wind, dust, etc.) in a manner sufficient for Industry to verify the performance of the EDM during EDL.
2. Please specify the measurements that would allow you to maximise the scientific return from the set of measurements described in this AO (sampling rate, sensitivity, geometry, operation).

Table 2: EDM System Data, Engineering Sensors and Auxiliary Information. Please note that the number, type, location, and performance of these sensors are not yet fully determined.

Data Source		**Description**
Inertial Measurement Units (IMUs) at 2 locations (on surface platform approx. 0.6 m from the probe axis)	Gyroscopes	Each IMU has a 3-axis gyroscope sampled at 100 Hz.
	Accelerometers	Each IMU has a 3-axis accelerometer sampled at 100 Hz.
Radar Doppler Altimeter (RDA)		Velocity and altimetry relative to terrain sampled at 20 Hz, from an altitude ~3 km above the surface (altimetry available from ~6 km).
Timing information		Timing of triggered events, e.g. parachute deployment, FS separation, BCV separation, touchdown.
Front Shield		Pressure sensors: 1 at stagnation point, 1 at each of 3 radial locations (N.B. these measure pressure in the hypersonic / supersonic flow environment, not the natural atmospheric pressure)
		7 thermal plugs (embedded in the TPS; each with 3 thermocouples)
Back Shield		Sun sensors (×2) for attitude determination prior to entry
		3 thermal plugs (embedded in the TPS; each with 2 thermocouples)
Main Parachute		Measurement of the inflation loads (TBC)
Camera		Downward-looking images, at intervals between Front Shield separation and touchdown
Aerodynamic database		Drag coefficient vs. Angle of Attack and Mach num-

	ber, for free molecular flow and continuum regime, with associated uncertainties.
Probe Mass history	Predicted mass history of the vehicle through the EDL sequence, with associated uncertainties
Probe Moment of Inertia (MoI)	MoI tensor, with associated uncertainties
Probe CoM history	Predicted position of the Probe CoM through the EDL sequence, and associated uncertainties
Position and orientation of IMUs	In EDM co-ordinate frame.
State Vector at Entry Interface Point	Position, velocity and attitude at a particular time prior to entry, and associated uncertainties
Landing Site Ellipse	Post-separation prediction from Navigation

9 DEFINITION OF TECHNOLOGY READINESS LEVELS (TRL)

Instruments and spacecraft subsystems are classified by ESA according to a "Technology Readiness Level" (TRL) on a scale of 1 to 9. Levels 1 to 4 relate to creative, innovative technologies before or during mission assessment phase. Levels 5 to 9 relate to existing technologies and to missions in definition phase. These are summarised in Table 3.

Table 3: ESA Technology Readiness Level Summary.

TRL	Level description
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical & experimental critical function and/or characteristic proof-of-concept
4	Component and/or breadboard validation in laboratory environment
5	Component and/or breadboard validation in relevant environment
6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)
7	System prototype demonstration in a space environment
8	Actual system completed and "Flight qualified" through test and demonstration (ground or space)
9	Actual system "Flight proven" through successful mission operations