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PROSPECTing the Moon:

A call for members of the User Group
of ESA's PROSPECT sampling and
sample analysis package for the Luna-
27 Moon lander mission



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1 SUMMARY

This is a call to seek applicants for membership of the PROSPECT User Group. PROSPECT is a drilling, sampling, sample handling, processing and analysis package under development by ESA for the Russian Luna-27 mission; scheduled for flight to the Lunar South Polar region in 2020. PROSPECT is under development as one of a number of activities in ESA which aim to secure roles for Europe, in international partnerships, in the coming era of lunar exploration.

PROSPECT will be operated at the lunar surface in the South Polar region of the Moon, where it is required to:

- Extract samples from depths of up to 2m.
- Extract water, oxygen and other chemicals of interest.
- Identify the chemical species extracted.
- Quantify the abundances of these species.
- Characterize isotopes such that origins and emplacement processes of these species can be established.

The PROSPECT User Group will be a group which represents the end users of PROSPECT and the data and lessons learned products that will result from its application at the lunar surface.

The tasks of the User Group during Phase B are described in the following sections and are summarised below:

- Review and update the PROSPECT science and other user objectives and requirements
- Validate science and other user requirements and advise on verification approaches
- Provide user support to Development Model test campaigns
- Support the establishment of operational scenarios at the lunar surface
- Represent a broad User Community for the data products that will be produced

It is also expected that the User Group will provide on-going support through later mission phases including during operations at the lunar surface, and will ultimately lead the analysis and exploitation of the data that is produced.

Key Dates & Information:

- Call for membership proposals: **18 May 2015**
- Responses received: **30 June 2015**
- User Group selection: **31 July 2015**
- KO Meeting: **October 2015**.
- Responses and enquiries shall be sent by e-mail to explorationcall@esa.int

Responses shall arrive no later than 30th June 2015.

2 SCOPE OF THE CALL

This is a call to seek applications for membership of the PROSPECT User Group. PROSPECT is a drilling, sampling, sample handling, processing and analysis package under development by ESA for the Russian Luna-27 mission (also called “Luna-Resource Lander”); scheduled for flight to the Lunar South Polar region in 2020. PROSPECT is one of a number of lunar exploration activities being undertaken by ESA with a view to securing a comprehensive role for Europe, through international cooperation, in the coming era of lunar exploration.



The PROSPECT User Group will be a team of scientists, technologists and lunar explorers who will support the project throughout its lifetime, beginning as the project enters Phase B. Participation of the User Group in Phase B shall be confirmed following this call. Participation in later phases is contingent upon the approved continuation of the project to full Phase C, D & E, which is expected by end of 2016. The User Group will support the on-going definition of the project, provide support to test campaigns and associated scientific activities as well as provide a focal point for a broader lunar exploration community with an interest in the project. Ultimately the User Group will provide support to the planning and operation of PROSPECT at the surface of the Moon and lead the way in the analysis of data and exploitation of results.

3 BACKGROUND

The Moon is an important exploration destination for the European Space Agency (ESA), together with Low Earth Orbit and Mars. The Moon, and in particular the Lunar South Polar region, is seen as a stepping stone for human exploration further into the Solar System and as an important destination in its own right. More detailed information on this is provided in the ESA Space Exploration Strategy. The South Pole also presents a uniquely challenging operational environment for robotic missions and for human explorers with significant unknowns in terms of surface conditions, as well as important potential in the form of possible resources. ESA's work is focussing on accessing this environment, and exploiting the materials and conditions that are found at the surface.

To realise its ambitions in lunar exploration within current and foreseen budgetary constraints in Europe, ESA's first step is to develop core exploration products, which can be provided to the missions of partners for flight before the end of the decade. It is in this context that a cooperation with Russia has been pursued.

Lunar exploration is a high priority in the Russian space programme, with a sequence of robotic missions planned in the course of the next ten years. This includes orbiting, landing and sample return missions targeting the unexplored regions of the lunar poles. In the context of a broad cooperation between ESA and Roscosmos for exploring the Solar System, both Agencies have a particular interest to join efforts in lunar exploration and have been establishing together a cooperation based on complementarity of technology and science.

Following detailed discussions with Roscosmos and other Russian entities, ESA intends to contribute to the Russian-led Luna-27 lander mission with its "PILOT" product for precise and safe landing and its "PROSPECT" product for investigating potential resources. This will pave the way for more ambitious missions in the future, including Lunar Polar Sample Return, which is currently under investigation.

At the ESA Council Meeting at Ministerial level held in Luxembourg in December 2014 it was decided that the preparatory lunar activities would be integrated with the ISS Exploitation Programme. Following this decision the Phase B development of these products for the Russian Luna-27 mission will begin during the course of 2015.

A Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is under development by ESA for application at the lunar surface on the Russian Luna-27 mission planned for 2020. During the course of 2015 an extensive set of Phase B activities for PROSPECT will begin. These activities will include definition, design, test activities and campaigns using development models.

ESA is establishing a PROSPECT User Group to provide representation within the project of the end users of PROSPECT, the data it will generate, and the lessons and experience that will be gained for future missions through its operation and development. The User Group is the equivalent of a conventional science team, but with the potential for broader scope, to recognise the range of interests and benefits associated with exploration. It is through the scientific and other users of PROSPECT's products that the benefits of the project will be realised. It is thus essential that the users are represented from the beginning of the project and throughout its lifetime.

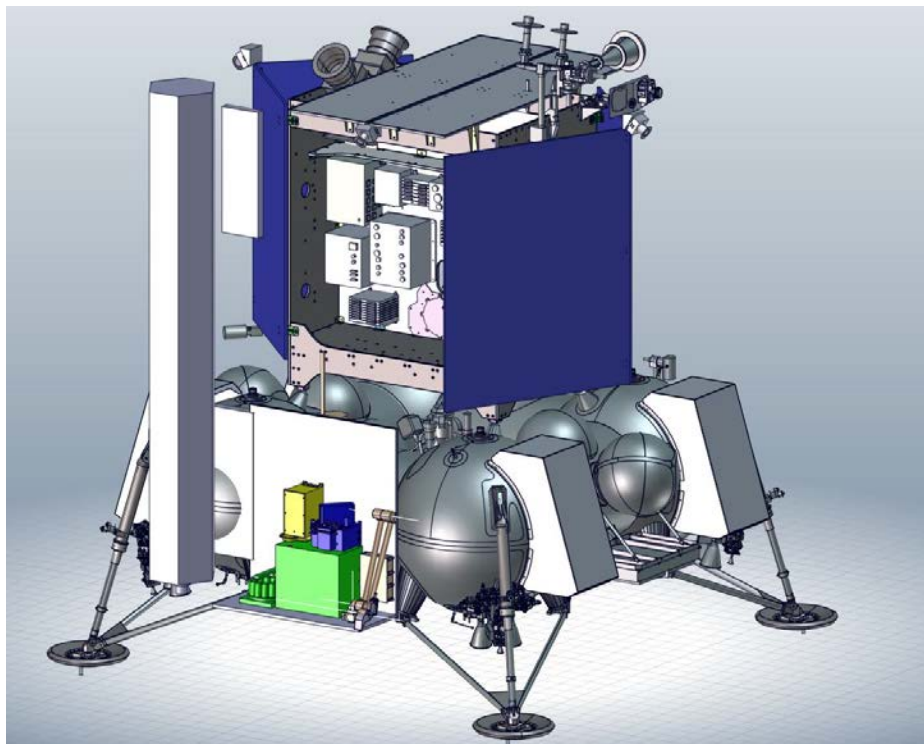


Figure 1. The Russian Luna-27 lander planned for 2020 to the lunar South Polar Region, including the PROSPECT drill (ProSEED) and laboratory (ProSPA) along with Russian led sample analysis instruments.

4 CONTENT OF THE DOCUMENT

This document describes the scope of the activities that will be undertaken by the PROSPECT User Group, with an emphasis on the activities to be undertaken during Phase B and the interface between the User Group and the project. The PROSPECT product is currently approved for activities up to the end of Phase B, from autumn 2015 until mid-2017. The budget for continuation to full Phase C, D & E is expected to be confirmed by end of 2016.

The document also describes the process for selection of the members of the User Group and the support that will be offered to the selected members as they participate to the work of the group. The document also outlines the future expected roles of users in PROSPECT, post Phase B.

5 PROSPECT OVERVIEW

Establishing the utilisation potential of resources found in-situ on the Moon may be key to enabling sustainable exploration in the future. PROSPECT has been defined to support the identification of potential resources, to assess the utilisation potential of those resources and to provide information to help establish their broader distribution. PROSPECT will also perform investigations into resource extraction technologies that may be applied at larger scales in the future and provide data with important implications for fundamental scientific investigations on the Moon related to Solar System history, astrobiology and the origins of terrestrial volatiles.

The development of PROSPECT should generate a number of benefits for future exploration by:

- Securing Europe’s position as the partner of choice of in key areas for future international missions in the areas of:
 - Drilling
 - Sampling
 - Sample handling and processing
 - Sample analysis;
- Generating knowledge which addresses unknowns for:
 - Resource utilisation and the potential use of lunar resources to support future exploration
 - Fundamental scientific questions related to the Moon, the history of terrestrial volatiles and the origins of life enabling chemistry;
- Engaging and increasing public and stakeholder interest and understanding of lunar exploration and its benefits;
- Providing a drill that meets Russian requirements and expectations and ensure that Europe benefits from the provision of that drill.

To achieve these goals PROSPECT will be operated on the lunar surface in the South Polar region of the Moon, where it will be required to:

- Extract samples from depths of up to 2m.
- Extract water, oxygen and other chemicals of interest that may be present.
- Identify the chemical species extracted.
- Quantify the abundances of these species.
- Characterize isotopes so that the origins and emplacement processes of these species can be established.

PROSPECT is divided into two main elements, a drill (PROSPECT Samples Excavation and Extraction Device: ProSEED) and a chemical laboratory (PROSPECT Sample Processing and Analysis system: ProSPA). PROSPECT builds on heritage and experience obtained during the development of Rosetta/Philae, Beagle 2 and Exomars in the areas of drilling, sampling, sample handling and sample analysis. In the lunar polar regions PROSPECT is able to target water ice, if present at the landing site, and chemicals that may be contained within that ice. At all locations on the Moon PROSPECT is able to extract volatiles released from regolith by heating. These include physisorbed, chemisorbed and solar wind implanted volatiles. Oxygen extraction from minerals shall also be performed through candidate resource extraction processes. Details are provided in the current version of the science objectives and requirements definition document, whose review will be the subject of the initial work of the User Group.

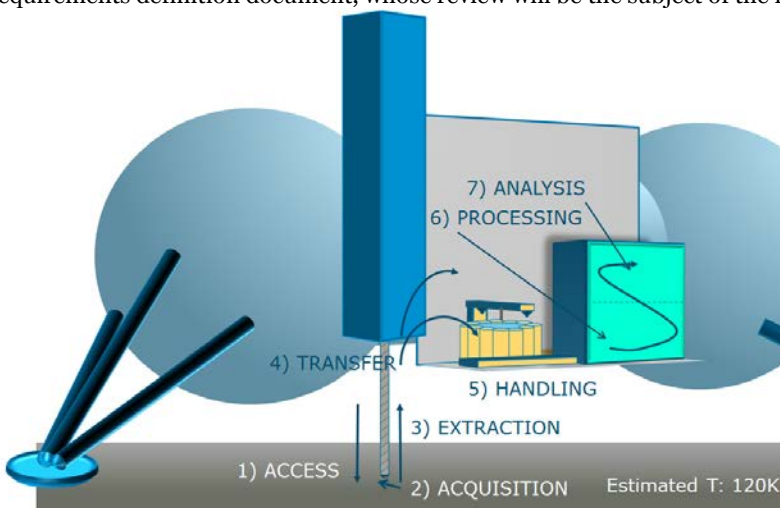


Figure 2. Illustration of the functions of the PROSPECT end-to-end sample chain.



Below are summaries of the functions of the PROSPECT package. A schematic diagram of the ProSPA chemical laboratory, which will process and analyse solid samples provided by the ProSEED drill, is shown in Figure 3.

Drilling and sampling: PROSPECT includes a drill that is required to provide access to the subsurface to depths of up to 2m. Once at the required depth a sampling tool removes small regolith samples, whilst preserving sample volatile content. Samples must then be extracted and handled whilst minimizing alteration and contamination, including losses of volatiles due to thermal effects. Samples are then transferred to ovens where they are sealed for chemical extraction.

Sample heating and thermochemical extraction processes: Samples are sealed in ovens and heated to temperatures as high as $\sim 1000^{\circ}\text{C}$. Heating in vacuum extracts ices, chemisorbed volatiles and solar wind implanted volatiles. Reacting gasses may also be introduced to the ovens to extract additional chemistry of interest. A number of techniques are under investigation, based on a combination of flight heritage and laboratory investigations. These include combustion with oxygen, oxidation using fluorine and reduction using hydrogen or methane.

Chemical composition and abundance analysis: Evolved gasses are measured to determine their chemical compositions and to establish the abundance of the chemicals which are evolved. This evaluation is performed using a combination of gas pressure determination and mass spectroscopy.

Gas chemical processing: The evolved chemicals require processing in order for their isotopic characteristics to be determined by a dedicated mass spectrometer. Preparations can thermally separate chemical species for analysis based on sublimation properties and convert chemical species into those which are better suited to introduction to a magnetic sector mass analyser or to remove isobaric interferences. The preparation is performed in a chemical processing system through a combination of refinement and chemical conversion.

Isotopic analysis: Isotopes of the elements of interest are separated for detection using a magnetic sector mass analyser and measurements are then made and compared with real time measurements of standards. Using this technique accurate analysis is achieved, allowing direct comparison with laboratory measurements on Earth, of both existing lunar samples and meteorites.

Supporting measurements: Instrumentation is under consideration to monitor the drilling and sampling process, to support operations, to provide measurements early in the sample chain and to establish the effects of the chain on samples. Measurements emphasise monitoring operations, assessing mineralogy and investigating water content and dynamic processes occurring during the drilling and sampling. Measurements may include optical imaging, infrared spectroscopy, temperature and electrical permittivity.

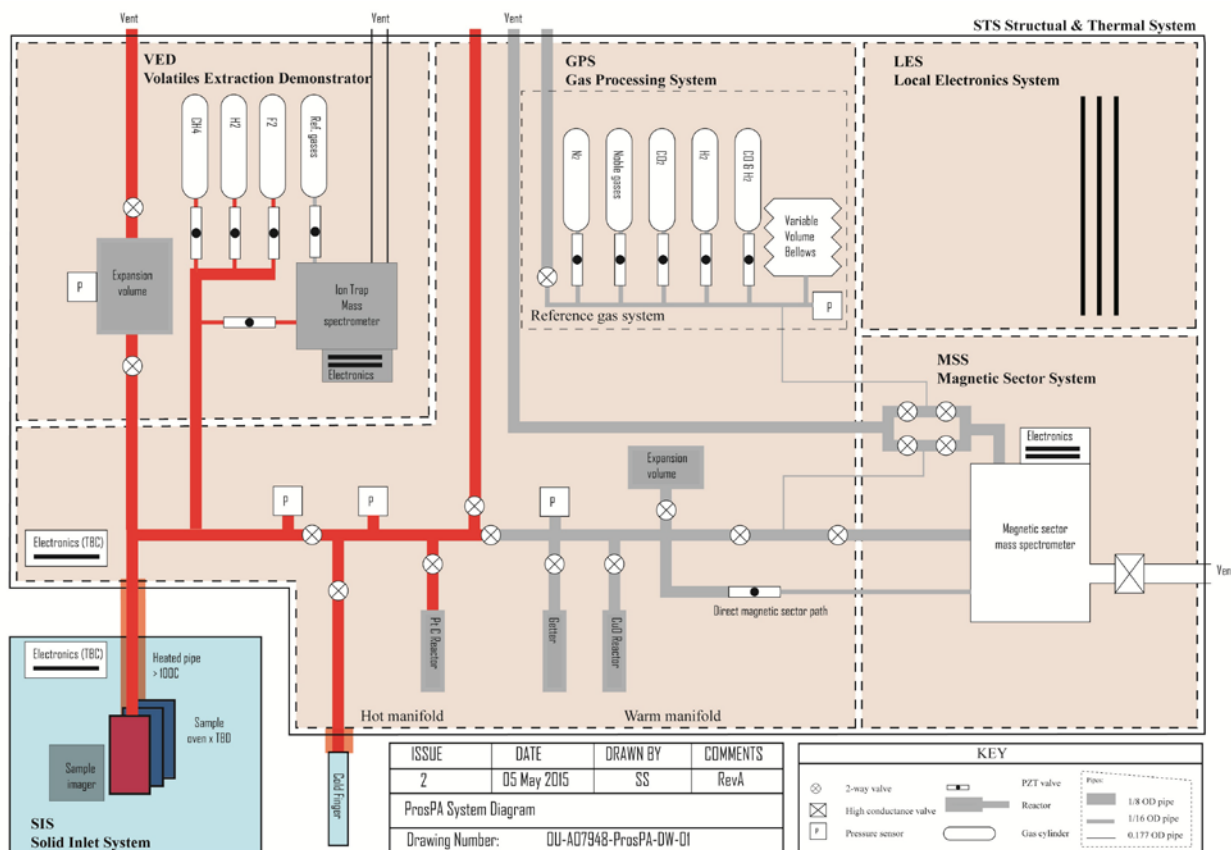


Figure 3. System elements of the PROSPECT chemical laboratory.

6 PROSPECT USER GROUP OBJECTIVES AND PROFILE

The PROSPECT User Group will be a group which represents the end users of PROSPECT and the data and lessons learned products that will result from its application at the lunar surface. The products are envisaged in the following domains:

- **Scientific and engineering data products** which can be analysed to generate new knowledge of the Moon, its resources and the operation of systems at the surface
- **Experience and lessons learned products** which can be used to ensure that knowledge and experience gained during the project is transferred to later missions
- **Communications products** which can be used to engage the general public and other stakeholders in the project and increase awareness and interest in lunar exploration.

The User Group may be considered to be the equivalent of a conventional science team, with an enhanced scope to include additional expertise relevant to exploration. In Phase B the User Group is there to define and validate the user (science) objectives and requirements for the project, and to support the definition of validation and verification approaches for those requirements. The User Group will also support the preparations for operations and testing activities.

The User Group membership will include scientists and other experts from a range of disciplines, whose host institution is based in an ESA Member State. The User Group will also provide ESA with access to expertise,



capabilities and facilities that may be applied to support the validation of requirements. The members will be present in a personal capacity but should be able to represent the interests of their host organisations and the broader community associated with their area of expertise.

Expertise sought through this call includes:

- Resource Prospecting
- Material properties and excavation
- Chemical resource extraction processes
- Future resource utilisation systems
- Planetary sciences
- Cosmochemistry
- Astrobiology

In addition a demonstrated expertise in the following areas is also welcomed from applicants:

- Feed forward to future exploration missions including in areas such as technology development, system architectures, operations
- Communication, public engagement, formal and informal education.

The User Group will include additional ESA experts in areas relating to technology and communications.

Throughout the project ESA remains as the only authority with regard to the definition and modification of User requirements.

Membership of the User Group is open to potential users from organisations that have an interest in participating in the development of PROSPECT as part of an industrial consortium. However individuals participating in the User Group shall not be personally financially supported by those activities and will be required to register any commercial or financial interests they have in the development or outcomes of the PROSPECT. Personal conflicts of interest may prevent participation in either the User Group or an industrial consortium.

7 PHASE B USER GROUP TASKS

The tasks of the PROSPECT User Group during Phase B are described in the following sections and are summarised below:

- Review and update the PROSPECT science and other user objectives and requirements
- Validate science and other user requirements and advise on verification approaches
- Provide user support to Development Model test campaigns
- Support the establishment of operational scenarios at the lunar surface
- Represent a broad User Community for the data products that will be produced

Throughout the PROSPECT development the User Group members shall be supported in developing a familiarity and understanding of the system, such that they are equipped to provide support to the project, to their own communities and to lead the exploitation of data.

7.1 PROSPECT objectives and requirements definition

The User Group will be responsible for ensuring that the objectives of the package and the requirements placed on it to achieve those objectives are consistent with the needs of the users of the output data. Requirements defined by the group will refer to the functions and performance of PROSPECT as well as possible landing sites for the mission. In



the case of landing site these are considered as inputs for consideration as part of a joint landing site selection with Russia.

A preliminary set of objectives and requirements has been generated by ESA, in cooperation with the Topical Team on Exploitation of Local Planetary Materials and through discussion with the Russian partners, and applied during the Phase A activities. These shall be reviewed at the start of Phase B and updated by the User Group. These requirements will then become applicable to the PROSPECT project. Requirements shall be under review continuously throughout the Phase B activities, based on the results of technical activities, and shall be frozen at PDR.

7.2 Requirements validation and verification

During the Phase B activities the User Group shall identify needs for activities related to the validation of requirements and advise on approaches to the verification of those requirements. These activities may be analytical, require detailed modelling efforts or experimental and test activities to generate robust requirements justified on the basis of real data. The group is then tasked with elaborating a comprehensive plan of activities to be performed, for recommendation to the Agency, who will then decide if and how to fund them.

Examples of envisaged activities are described below.

7.2.1 Material compositional analogues definition

A significant number of PROSPECT requirements are linked to the measurement performance for composition or errors associated with isotopic measurements. These requirements must ultimately be defined and verified against analogues that are appropriate in terms of composition and can be sourced reliably and with reproducible characteristics. The User Group will be tasked with identifying candidate analogue materials and defining laboratory tests to confirm the properties of those analogues before their selection is confirmed as the basis for PROSPECT requirements.

7.2.2 Sublimation from samples

A significant number of PROSPECT requirements are related to volatile (e.g. water) losses from samples due to sublimation. The process of losses from ice bearing regolith samples is poorly constrained but is a major driver for the system. Experimentation and modelling activities are required to define the sensitivity of volatile loss due to temperature. This work is a precursor to the system level assessment activities to be performed using the PROSPECT Development Model. The User Group will be tasked with identifying candidate analogue materials for testing and defining laboratory testing and modelling approaches to quantify the sublimation processes and their implications for requirements.

7.2.3 Oxygen extraction processes

The PROSPECT requirements include those for the extraction of oxygen from regolith through thermochemical reactions. The specified reactions are possible ISRU relevant processes, which the ProSPA chemical laboratory may be able to demonstrate. However there is limited experience of performing these reactions with a view to resource extraction specifically, or with respect to the constraints of the laboratory and Luna-27 mission. It is important to investigate these reactions in a laboratory setting to determine the practicality of their implementation on PROSPECT and the parameters of greatest importance for related measurements in-situ. The User Group will be tasked with defining the appropriate measurements and requirements and determining an approach to making the appropriate measurements.

7.3 Support to test campaigns

During Phase B it is planned that a series of Development Models will be developed. These Development Models will be used to perform test campaigns in laboratories and on field campaigns. The purpose of these activities is to investigate the performance and behaviour of the systems in analogous environments. This will validate



requirements, verify key aspects of the designs and mitigate risks by allowing the design to be informed by work performed with hardware in the field to identify issues that cannot be identified by any other means. The User Group will provide end user support to these activities, and in the process develop a fluency with the systems, their operation and their utilisation that can later be applied at the lunar surface and to the analysis of data products.

7.4 Operational scenario definition

During Phase B the group shall generate notional operational scenarios to inform the maturation of operational scenarios for planning and the system design. These activities shall also benefit from the experience gained during the development model test campaigns.

7.5 Representing a broader user community

The User Group are representatives of a broader user community. As such they should be contact points for the communities associated with their own specialisms and should collect inputs on needs and expectations from those broader communities such that they can be seen to represent these broader interests. They should promote the utilisation of the data sets and products generated.

User Group members will be expected to provide representation of PROSPECT at relevant meetings, conferences and symposia as well as participate in the preparation of articles for peer reviewed scientific publications. One specific task during Phase B will be the organisation of a PROSPECT User Workshop.

7.5 Risk Analysis

During Phase B the group shall help ESA identify development and operational risks along with possible mitigation actions that will inform future development of the PROSPECT package. These activities shall also benefit from the experience gained during the development model test campaigns.

8 POST PHASE B USER ACTIVITIES

After Phase B there will be a continuing need for User Group involvement in PROSPECT. Users will be required to participate in responding to technical developments in the project, calibration, testing, field campaigns, preparations for operations, real time operational “back room” support and ultimately the utilisation and exploitation of PROSPECT data products. It is envisaged that the PROSPECT User Group as selected following this call will provide the core of any user engagement in later phases.

During Phase B the specific requirements and process for user participation post Phase B will be determined. These shall be included in the definition of the PROSPECT project detailed planning for post Phase B.

9 INTERFACES

The User Group shall interface with the project via the assigned ESA personnel, referred to here as the ESA Project Scientist.

The User Group shall communicate with each other regularly via monthly Webex meetings and face meetings, chaired by the ESA Project Scientist. For details see schedule below.



10 FINANCIAL SUPPORT FOR USER GROUP MEMBERS

User Group applicants shall provide a letter of support from the entity which will provide financial support for the time spent supporting the work of the Group. This would nominally be their National Agency but could be an alternative funding body or the host institution. The time required is likely to vary for different group members and at different times during the project. However as a nominal average allocation of around one to two days per month is expected for most User Group members.

The Agency will support the costs of travel and related expenses relating to attendance at User Group meetings, which are expected to take place three to four times a year.

11 USER GROUP SELECTION PROCESS

The User Group is expected to consist initially of up to ten external members to be selected following this call. Submissions are encouraged from younger investigators and seasoned professionals alike. The aim is to generate a team which represents a breadth of experience and encourages the transfer and sharing of knowledge and skills with a view to ensuring it is secured for the future.

The received applications will be reviewed by an independent selection panel with relevant scientific and exploration competence taken from the ESA advisory structure. The appraisal of received applications will be undertaken with a view to ensuring a competent, well-integrated, functional, suitably diverse and representative team.

Following this review the chair of the selection panel will provide a recommendation to ESA on the membership of the User Group. A final decision on the composition of the User Group will be made by ESA and applicants will be notified of the outcome. Successful applicants will then be invited to join the User Group. Upon accepting this invitation User Group members undertake a commitment to support the User Group activities for the duration of the current Phase B activities, which are expected to run until mid-2017, with a view on the following Phase C, D & E until 2021.

12 NOMINAL SCHEDULE

The following preliminary schedule is envisaged for user group activities

- Responses received: **30 June 2015**
- User Group selection: **31 July 2015**
- KO Meeting: **October 2015**.
 - Project briefing, objectives and requirements review, identification of validation and verification related activities. Identification of project support needs and other user related activities.
- Second Meeting: **December 2015**.
 - Detailed definition of validation and verification activities. Requirements confirmation, iteration with system activities and establishment of further validation actions.
 - Preparation for development model test campaigns.
 - Preparations for user community workshop
- Initiation of validation and verification activities: **February 2016**.
- Third meeting: **March 2016**.
 - Reporting on validation and verification activity progress, review of requirements, detailed planning of support to DM test campaigns.
 - Finalisation of requirements and validation inputs to SRR.
- DM test campaign support initiation: **March 2016**.
- User Community workshop: **May 2016**.



- Fourth Meeting: **September 2016.**
 - Reporting on all activities and final analysis and conclusions of validation and verification support activities.
 - Requirements review and update on that basis.
 - Review of lessons learned from DM test campaigns.
 - Preparations for Phase C/D.
- Fifth meeting: **January 2017.**
 - Wrapping up of Phase B activities.
 - Final formulation of requirements and inputs for PDR.
 - Planning for Phase C/D.

13 RESPONDING TO THIS CALL

Responses to this call shall include the following information:

- Name
- Position
- Institution
- Background and relevant experience
- Areas of interest with respect to PROSPECT
- Potential contributions to the activities of the User Group during Phase B
- Longer term interests for post Phase B and data exploitation
- Relevant competencies and facilities within the host institute
- Possible access to relevant resources, laboratories and experience in support of User Group activities
- Additional relevant information
- Letter of support from the entity providing financial support to the respondent
- Statement of commercial interest in the development or outcome of the PROSPECT mission.

Up to ten pages is suggested as a guideline for the length of responses.

Responses and enquiries shall be sent by e-mail to explorationcall@esa.int

Responses shall arrive no later than 30th June 2015.

The selected members of the User Group shall be informed before the end of September 2015 following consultation with the ESA Member States through the Programme Board for Human Spaceflight Microgravity and Exploration.