EUROPEAN SPACE AGENCY

MARS ROBOTIC EXPLORATION PREPARATION -2 PROGRAMME

TECHNOLOGY PLAN

Programme of Work for 2016 and relevant Procurement Plan

SUMMARY

This document presents the proposed activities to be initiated in 2016 in the Exploration Technology Programme (ETP, funded by MREP-2). It also summaries the current state of MREP-2 Programme's technology programme as a whole, providing an overview of all running and proposed Technology Development Activities supporting the implementation of the Programme.

This document is provided for information only and may be subjected to future updates.

December 2015

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1 Background and scope

The MREP-2 programme (Mars Robotic Exploration Preparation-2, ESA/PB-HME(2012)56, rev.1) was subscribed at the C/MIN 2012, with the objective to reinforce Europe's position in Mars robotic exploration and prepare for a European contribution to a future international Mars Sample Return (MSR) mission.

This document provides the programme of work defining the activities to be initiated in 2016. This programme of work is aimed at completing the industrial commitment of the MREP2 programme funding that was subscribed at the C-MIN(2012) and supplemented by Member States at the C-MIN(2014). Furthermore, the document serves as a self-standing overview and record of all the currently running activities within the MREP-2 programme as well as a selection of activities identified as valuable to be considered for future implementation after 2016.

Most of MREP-2 budget (> 80%) will be committed through the previously approved work plans. The new activities that are proposed in this work plan are mainly addressing the additional subscription that was made at the C-MIN(2014). It is intended that this will be the last update of the MREP-2 Technology plan prior to the next C-Min.

2 Work Plan Elaboration and Implementation

2.1 – Definition of the activities and budgets

The overall programme of work presented here was defined using the ESA End-to-End process as described in ESA/IPC(2005)39, involving the TECNET (TEChnology NETwork) Service Domain 9 (SD9), who is specifically in charge of Robotic Exploration and constituted of technical and mission experts from many ESA Directorates. The process ensures coordination with activities planned in other Directorates, in particular in HSO, and makes the best use of the industrial and internal studies achieved so far for Mars future missions.

The specific activities presented here for approval, followed by implementation in 2016, have been defined taking in account Member State's interests as well as in coordination with relevant experts from the ESA Technical Directorate.

The work plan makes use essentially of MREP-2 (ETP) and TRP budgets. The TRP budget is devoted to initial technology developments, leading to an experimental feasibility verification of critical functions or to a validation at breadboard level in laboratory environment (TRL 4). In case of components this might be extended to e.g. radiation hardening, since otherwise a proof of feasibility is not possible.

The ETP (Exploration Technology Programme) is constituted of technology activities that are directly funded by the MREP-1 and/or MREP-2 programmes. It is used to fund robotic exploration-related activities at any TRL level. However, it focuses on TRL >3, building on earlier developments funded through TRP.

The GSTP (General Support Technology Programme) budget is used mainly for activities at a high TRL level (TRL 4 or higher) to complement the availability of ETP funding. Note however that while the GSTP activities shown in this work plan have been defined and internally agreed through the SD9 TECNET process, they are only provided here for information and not for approval. Approval for all GSTP activities will be submitted to the IPC in dedicated GSTP work plans.

2.2 – Implementation Aspects

For the practical implementation of ESA TDAs, all the newly proposed activities seeking approval are to be initiated in 2016.

The baseline approach is to have a single contract for each activity, unless otherwise stated in the work plan. In case of specific interest for the Programme - e.g. risk reduction, investigation of different technical solutions, or for enabling competition on critical hardware in the future phases - the Executive may envisage placing parallel contracts provided that good quality offers are received and subject to budget compatibility. In such a case, the parallel contract will be reflected in the regular update of the work plan, which occurs as a minimum on a yearly basis, for keeping the PB-HME and IPC fully informed of the work plan implementation.

For ETP, the activities will be implemented so as to meet a geographical distribution reflecting the Participating States subscriptions to MREP-2. For that purpose, the implementation plan and the geo-return requirements for each activity will be carefully monitored for meeting the programme-level geo-return requirements, in close coordination with the Participating States for satisfying as far as possible their technology priorities. Furthermore, the Agency reserves the right, following competitive tenders, to take specific corrective measures for meeting MREP-2 geo-return requirements.

Furthermore, in application of Council decisions contained in ESA/C(2014)110, the Executive undertakes to identify technological activities capable to support the integration of New Member States and of under-returned countries, in view of a structural effect. Some procurement policies could therefore be adapted, and reported to the IPC.

2.3 - Annexes and detailed information

Annex 1 provides the summary tables for the new activities to be implemented in 2016, and the corresponding detailed description sheets.

Annex 2 provides the update of MREP-2 Programme technology roadmaps, reflecting the latest developments and enabling a visual understanding of the logic underlying the proposed activities.

Annex 3, 4 and 5 provide additional background information.

Annex	Title	Content
Annex 1	Definition of 2016 activities (for approval)	Summary tables and description for new activities to be implemented in 2016, under ETP (MREP-2) and TRP funding.
Annex 2	Update of MREP technology roadmaps (for information)	The following technology roadmaps have been updated: Phobos Sample Return, Mars Precision Lander, Mars Sample Return and Long term enabling technologies (Nuclear Power Systems and Propulsion) Notes on the Roadmaps: 1. MREP-1 TDAs are only shown where relevant and are specifically labeled as such. All other TDAs are from MREP-2 work plans only. 2. In the figures, the starting point and length of the TDA blocks refer to the expected Kick-off date and duration of the respective activities.
Annex 3	Summary description of future Mars missions (for information)	Summary of current definition of future Mars missions: - PHOOTPRINT (Phobos Sample Return) - INSPIRE (Network science mission) - Mars Precision Lander (MPL) - Mars Sample Return (MSR)
Annex 4	Summary of Technology Development Activities (for information)	Summary tables and detailed descriptions of activities from the current and previous MREP work plans. The tables include: completed MREP-1 activities, removed/replaced activities from previous work plans, running activities; approved activities under preparation; and activities to be possibly implemented after 2016 are presented.

Table 1- List and content of the Annexes

KEY TO TABLES

Each activity is given a programmatic reference, which will remain unchanged until completion. Additional planning elements associated with each of the activities are:

Programme:	Programme budget foreseen for the activity
Reference:	Unique ESA generated reference for TDA
Activity Title:	Title of the proposed TDA
Budget:	The total Contract Authorisation (CA) values are given in KEURO, at yearly economic conditions. The year for which the budget is intended is specified.
Procurement Policy (PP):	Procurement Types: C = Open Competitive Tender; (Ref. Article 13.1 ESA Procurement Regulations) C(1)* = Activity restricted to non-prime contractors (incl. SMEs). C(2)* = A relevant participation (in terms of quality and quantity) of non-primes (incl. SMEs) is required. C(3)* = Activity restricted to SMEs & R&D Entities C(4)* = Activity subject to SME subcontracting clause C(R) = Competition is restricted to a few companies, indicated in the "Remarks" column; (Ref. Article 13.2 ESA Procurement Regulations). DN/C = Direct Negotiation/Continuation; the contract will be awarded in continuation to an existing contract; (Ref. Article 14.1.D ESA Procurement Regulations) DN/S = Direct Negotiation/Specialisation; the contract will be awarded by direct negotiation in implementation of a defined industrial policy or resulting from a sole supplier situation; (Ref. Articles 14.1.A,C ESA Procurement Regulations) * See ESA/IPC(2005)87, rev.4. Industry has been informed, through the EMITS "News", of the content of that document.
SW clause applicability:	Special approval is required for activities labelled: either *“Operational Software”* or *“Open Source Code”*, for which the Clauses/sub-clauses 42.8 and 42.9 (“Operational Software”) and 42.10 and 42.11 (“Open Source Code”) of the General Clauses and Conditions for ESA Contracts (ESA/REG/002), respectively, are applicable.
Objectives:	The aims of the proposed TDA.
Description:	Overview of the work to be performed.
Deliverables:	Provides a short description of the tangible outcome e.g. breadboard, demonstrator, S/W, test data. **A final report is standard for every activity.**
Current TRL:	Describes the current Technology Readiness Level of the product that is going to be developed in this activity.
Target TRL:	The TRL expected for the product at the **end of the activity**. For equipment, TRP usually concludes with TRL 3, ETP at TRL 5/6. However in the case of components target TRL in TRP could be higher. It is also understood that TRLs do not apply to S/W and tools. For these cases description of SW

	quality, i.e.: architecture, beta version, prototype, or full operational, achieved at the end of the activity.
Application Need/Date:	Describes the required TRL and date for the technology development of which the respective activity is part of on the base of the maturity required by the application. The general rule is that a requirement specifies the need date for a product. For equipment/payloads this is in general TRL **5/6, -** the level generally required for **Phase B of a project.** The exceptions are components, where TRL 8 (flight readiness) should be achieved. For S/W and tools separate readiness levels are defined below
Technology Readiness Level	TRL1 - Basic principles observed and reported TRL2 - Technology concept and/or application formulated TRL3 - Analytical and experimental critical function and/or characteristic proof-of-concept TRL4 - Component and/or breadboard validation in laboratory environment TRL5 - Component and/or breadboard validation in relevant environment TRL6 - System/subsystem model or prototype demonstration in a relevant environment (ground or space) TRL7 - System prototype demonstration in a space environment TRL8 - Actual system completed and "flight qualified" through test and demonstration (ground or space) TRL9 - Actual system "flight proven" through successful mission operations
Technology Readiness Levels for S/W and tools	Algorithm: Single algorithms are implemented and tested to allow their characterisation and feasibility demonstration. Prototype: A subset of the overall functionality is implemented to allow e.g. the demonstration of performance. Beta Version: Implementation of all the software (software tool) functionality is complete. Verification & Validation process is partially completed (or completed for only a subset of the functionality). S/W Release: Verification and Validation process is complete for the intended scope. The software (software tool) can be used in an operational context.
Application Mission:	Possible mission application/follow-on.
Contract Duration:	Duration of the activity in months.
Reference to ESTER:	Identifies the related requirement in the ESTER database
Consistency with Harmonisation Roadmap and conclusion:	Identifies the related Harmonisation Roadmap Requirement

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Annex 1:

1. Summary table of 2016 activities for approval
2. Budget summary
3. Detailed descriptions of 2016 activities for approval

Summary of all new activities seeking approval for 2016

1	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
Phobos Sample Return											
MREP-2/TRP	IPC	E918-012FT	Phobos Sample Return plume and plume-surface interaction characterisation	0	0	700	0	DN/S	GB	N/A	DN with Fluid Gravity (GB) and using DLR facilities (TRP budget). Co-funded 350kE:350kE between ETP:TRP. This activity replaces previously approved activity E918-010MP. Intended as a CCN to E918-011FT.
Mars Precision Lander											
MREP-2	IPC	E905-023FM	Validation of the EAGLE simulator tool	0	0	500	0	C		N/A	Competition open to MREP participating countries to the extent of their available budgets
SFR, Robotics and Mechanisms											
MREP-2	IPC	E913-016FT	Exomars-like rover and science operations simulation through field-trials	0	0	1000	0	DN/S	GB	N/A	DN with Airbus (GB)
Mars Sample Return											
MREP-2	IPC	E926-003FM	Starting a Sample Analogue Curation Facility for Future Exploration Missions	0	0	1200	0	DN/C	GB	N/A	DN with NHM (GB)
Long term											
MREP-2	IPC	E919-012MP	Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)	3045	0	2500	0	DN/C	GB	N/A	DN with Moog (GB). Phase 2b is intended as a CCN to the running Phase 2a contract.
Total of all 2016 MREP-2 activities seeking approval				**0**	**0**	**5550**	**0**				
Total of all 2016 TRP activities seeking approval				**0**	**0**	**350**	**0**				
Total of all 2016 ETP and TRP activities seeking approval				**0**	**0**	**5900**	**0**				

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Application/Mission	Progr.	2014	2015	2016	2017	Total
9-01 Phobos Sample Return						
	ETP /TRP	0	0	700	0	700
Total		**0**	**0**	**700**	**0**	**700**
9-02 MPL						
	ETP	0	0	500	0	500
Total		**0**	**0**	**500**	**0**	**500**
9-03 SFR Robotics and Mechanisms						
	ETP	0	0	1000	0	1000
Total		**0**	**0**	**1000**	**0**	**1000**
9-05 MSR						
	ETP	0	0	1200	0	1200
Total		**0**	**0**	**1200**	**0**	**1200**
9-06 Long Term						
	ETP	3545	0	2500	0	6045
Total		**3545**	**0**	**2500**	**0**	**6045**
Grand Total TRP		**0**	**0**	**350**	**0**	**350**
Grand Total ETP		**3545**	**0**	**5550**	**0**	**9095**
Grand Total ESA		**3545**	**0**	**5900**	**0**	**9445**

Budget summary table per commitment year

Detailed descriptions of 2016 ETP/TRP activities

Phobos Sample Return

Phobos Sample Return thruster plume and plume-surface interaction characterisation					
Programme:	ETP		**Reference:**	E918-012FT	
Title:	Phobos Sample Return thruster plume and plume-surface interaction characterisation				
Total Budget:	700				
Objectives					
The objective of this activity is to characterize the expected contamination of the Phobos surface at the PhSR landing site by the lander descent thrusters, using representative thrusters and regolith simulant in an existing test facility.					
Description					
Thruster plume-surface interaction characterization are critical to the PhSR mission objectives, as the effects of the landing plumes on the regolith of Phobos can lead to contamination of the collected sample. An initial study is running with the following objectives: 1) To characterize the physical mechanisms of Phobos regolith when subjected to gas-surface interactions; 2) To determine the method for estimating the contamination levels due to thruster plume impingement on the Phobos surface; 3) To develop the numerical tools for plume-surface interactions in rarefied flows and pre-validate this model with existing data. Another outcome will be the identification of a suitable test facility where the exhaust plume of the PhSR thruster and its plume-surface interactions can be characterized. In order to complete the validation of the numerical models developed, it is necessary to perform a hot-fire test-based activity for scaled thrusters with off-axis configurations (e.g. increasing angles from the plume stream axis). The choice of thrusters to be tested shall be representative of the possible selection for PhSR, i.e. one mono-propellant and one bi-propellant thruster. The characterization of chemical thruster plumes in rarefied atmospheres and the plume-surface impingement effects will enable the Agency to better understand and assess the likely contamination levels on Phobos due to the PhSR thrusters. Some particles emitted from the thrusters before the spacecraft's free fall are expected to contaminate the landing site. This event has science implications as chemical contamination of the sample is not wanted. In order to consolidate the system trade between altitude of free fall and sample contamination by thrusters, characterization in vacuum of regolith contamination from thrusters at several heights is needed, as well as correlation with the numerical models, in order to allow making reliable predictions of soil contamination for several thruster and altitude configurations. The outcome will be the contamination distribution on the Phobos surface, i.e. the lateral extent and depth of regolith contamination, computed for the "real" scenario of the PhSR mission. This activity will include the following tasks: - Preparation of a suitable test facility and instrumentation; - Characterization of the thruster exhaust plume in vacuum conditions (low-density chamber). This will allow to collect the species distributions and thermodynamic data (pressure and temperature) in the plume at a number of streamwise locations downstream the nozzle trailing edge; - Plume-regolith interaction characterization in order to obtain the sticking coefficients of the thrusters species and force measurements on the regolith surface; - Update of numerical models with test data and validation of the predicted contamination levels at different heights in the spacecraft landing phase; - Repeat of the above with the second thruster type.					
Deliverables					
Technical Notes, numerical simulation data, experimental test data and assessment of the results.					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	Phootprint (all planetary landing/take-off exploration missions)		**Contract Duration:**	15	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Aerothermodynamic Tools (2012), roadmap activity B8.					

MPL

Validation of the EAGLE simulator tool			
Programme:	ETP	**Reference:**	E905-023FM
Title:	Validation of the EAGLE simulator tool		
Total Budget:	500		
Objectives			
The objective is to mature the validation status of the EAGLE simulator suite before its integration within the Harwell Robotics and Autonomy Facility (HRAF).			
Description			
During several ESA activities a simulator tool for Entry Descent and Landing phases has been developed, called EAGLE. As a simulator suite, it consists of a set of mathematical models, each related to either specific mission subsystems (e.g. parachute, camera) or specific physical modeling of the EDL environment such as atmosphere/landing site topography. The tool has evolved to encompass both lunar and Mars specific library models, which have not necessarily reached the same level of validation. Therefore comparing results when switching library elements for a given mission concept is rather difficult. As part of a first consolidation exercise, a requirements gathering process has taken place during the Phase 1 of the HRAF Pilot 1 activity. This process (SRR) led to a consolidated set of EAGLE requirements needed to mature the EAGLE simulator suite. These requirements should lead to the full validation of the various EAGLE models relevant to the EDL scenarios of future MREP missions. This activity shall focus on two main aspects currently needed to mature EAGLE before it can be considered for integration as a tool within the HRAF Core Architecture. - The first is the definition of validation approaches for the requirements that are linked to some mandatory mission scenarios. Taking into account the current status of validation of the affect models, the validation approach shall be detailed from model level up till complete mission level simulation. - The second part of the activity shall implement (part of) the previously defined validation approach, as agreed with the Agency. Both elements of the activity may need software code modifications, which shall be fully tested and debugged prior to entering the validation phase.			
Deliverables			
Documentation Software algorithms as needed			

Current TRL:	3	**Target TRL:**	4/5	**Application Need/Date:**	
Application Mission:	MPL and other Mars landers		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

SFR Robotics and Mechanisms

Exomars-like rover and science operations simulation through field-trials.

Programme:	ETP	**Reference:**	E913-016FT
Title:	Exomars-like rover and science operations simulation through field-trials.		
Total Budget:	1000		

Objectives

To undertake field trials of simulated Exomars rover and science operations, including drilling, in support of preparation for the 2018 mission.

Description

In preparation for Exomars science operations during the 2018 mission, simulated operations under realistic conditions, including rover and instrumentation in the field are required to be performed to provide training to mission planners, rover operators as well as science instrument teams to work together as seamlessly as possible. The previous ESA TRP activity SAFER, has successfully conducted in 2013, field trails directly relevant to the Exomars 2018 mission. The objectives of the SAFER activity were to bring together three Exomars instrument models (PANCAM emulator, CLUPI emulator and WISDOM prototype) on a rover platform capable of autonomous operations, and to test in a representative Mars environment, the strategies necessary for successful science target identification, approach, and investigation, including drilling (albeit manually).

This MREP2 activity proposes to undertake enhanced field trail campaigns in both 2017 and again in 2018, building on the experience and lessons learned from the SAFER campaign, by increasing the level of realism and extending the science instrument suite, as well as including the participation of relevant control centres in the operations. In this way, maximum benefit is obtained by re-using very recent expertise and knowledge gained by the teams involved in setting up and conducting the trials as well as the science teams that participated in them. These campaigns are expected to include:

1) An existing Exomars drill breadboard or equivalent, mounted on the rover platform or other suitably representative mount.
2) An existing Exomars-like rover mobile platform housing the instruments and possibly the drill.
3) The Exomars rover navigation system for flight-like autonomous rover mobility operations.
4) Existing prototypes or breadboards of the WISDOM, Pancam and CLUPI instruments, plus other COTS replacements of rover instruments (E.g. Raman Spectrometer and MicroOmega infrared spectrometer) for which no existing hardware is available for use in the field trial.
5) Remote rover and science operations, using Harwell or the Altec Rover Control Centre or both.
6) Science operations that are based on the Exomars Reference Experiment Cycle.

The science and engineering dataset generated during the field campaign will be included into the database at the ESA Harwell Robotics & Autonomy Facility to support future ESA activities.

The proposed work fits within the larger context of on-going preparations for Exomars operations across Europe. Based on previous experience with field trials for rovers as well as sampling systems, it is expected that this activity could also benefit from a joint participation of CNES and the Italian Space Agency, ASI.

Deliverables

Any breadboards developed. Technical and video documentation. All engineering and scientific data generated during the trials

Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2017

Application Mission:	EXM 2018	**Contract Duration:**	18
S/W Clause:	N/A	**Reference to ESTER**	

Consistency with Harmonisation Roadmap and conclusion:

MSR

<table>
<tr><th colspan="6">Starting a Sample Analogue Curation Facility for Future Exploration Missions</th></tr>
<tr><td>Programme:</td><td colspan="2">ETP</td><td>Reference:</td><td colspan="2">E926-003FM</td></tr>
<tr><td>Title:</td><td colspan="5">Starting a Sample Analogue Curation Facility for Future Exploration Missions</td></tr>
<tr><td>Total Budget:</td><td colspan="5">1200</td></tr>
<tr><td colspan="6">Objectives</td></tr>
<tr><td colspan="6">The objective is to enhance the initial Sample Analogue Collection and curatorial database, acquire lab equipment to perform basic sample characterisation and sub-sample preparation and develop standard characterisation protocols for incoming acquisitions. This activity is funded by the ESA MREP-2 programme and supported by UKSA.</td></tr>
<tr><td colspan="6">Description</td></tr>
<tr><td colspan="6">Future exploration missions are intended to land on various target bodies: besides Mars also Phobos and Asteroids are identified as potential mission destinations. Landing and possible subsequent dynamic exploration of the planetary body entails a direct contact between spacecraft systems and scientific instruments. The challenge of proper characterisation and validation of that physical interaction with the "unknown" material can be helped with the use of sample analogues, i.e. simulants of the target body material that replicate the specificities of the expected application environment.

Through MREP-2 activities E926-001FM and E926-002FM an initial Collection of Analogue Samples for Phobos/Deimos/ Asteroids, Mars and the Moon has been characterised and curated. Through this new activity the Collection will be enlarged with specimens generated/procured during ESA supported technology development activities, ESA supported field trials as well as with other similar collections and initiatives. The curatorial database will be updated wrt. to the enhanced Sample Analogue Collection, the various preparations and usage of the specimen preparations. A first set of standard characterisation protocols for new incoming acquisitions and preparation protocols for sub-samples will be defined and validated. An assessment will be made on the available and accessible analytical equipment on the Harwell Campus and missing analytical equipment needed to execute these protocols will be procured.

This activity will:
- enhance the initial Sample Analogue Collection with specimens generated/procured during ESA supported technology development activities, ESA supported field trials as well as with other similar collections and initiatives;
- log the sample preparation protocols for all analogues in the database.
- define and execute (as needed) a set of standard characterisation protocols for incoming acquisitions;
- acquire lab equipment to perform basic sample characterisation, sub-sample preparation and quality inspection thereof;
- keep the curatorial database up-to-date and valid wrt. the enhanced Sample Analogue Collection and preparations;</td></tr>
<tr><td colspan="6">Deliverables</td></tr>
<tr><td colspan="6">Documentation
Enhanced Sample Analogue Collection
Enhanced Sample Analogue Collection Curation Database
Laboratory Equipment</td></tr>
<tr><td>Current TRL:</td><td>2/3</td><td>Target TRL:</td><td>4</td><td>Application Need/Date:</td><td></td></tr>
<tr><td>Application Mission:</td><td colspan="2">MSR, Phootprint, Inspire & various</td><td>Contract Duration:</td><td colspan="2">18</td></tr>
<tr><td>S/W Clause:</td><td colspan="2">N/A</td><td>Reference to ESTER</td><td colspan="2"></td></tr>
<tr><td colspan="6">Consistency with Harmonisation Roadmap and conclusion:</td></tr>
<tr><td colspan="6">N/A</td></tr>
</table>

Long Term

Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)					
Programme:	ETP		**Reference:**	E919-012MP	
Title:	Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)				
Total Budget:	6045				
Objectives					
This activity will continue the development, to a generic qualification level, of a High Thrust Apogee Engine for the Robotic Exploration Programme.					
Description					
The MREP-funded Combustion chamber and Injection technology development activity was a first phase aimed at defining a high thrust apogee engine (HTAE) that was a specific fit to Agency requirements for planetary missions and orbit insertion. The HTAE phase 1 targeted an ITAR-free design and examines high performance injector design and cost effective high temperature materials developments. The definition of a flow control valve was also included to complete the equipment definition. The phase 1 activity concluded in 2013 with an Intermediate PDR (I-PDR) for the injector, chamber and valve. The follow on Phase 2, is aimed at: - Completion of design Definition. o Final loop of injector, chamber and valve development testing as identified in Phase 1B will be performed to finalise injector down-selection for the design of the HTAE including any further optimisations identified. o PDR. - Detailed design. o CDR. - Generic Qualification. o Manufacture of EM (generic qualification) batch 2 test hardware. o Process qualification for injectors, chamber manufacture and if relevant, chamber material coating process. o HTAE Valve development activity - design and manufacture of a qualification model for engine qualification programme. o Qualification program of engine(s) to TBC specification (generic qualification requirements). The Phase 2 is split into two parts, Phase 2a and Phase 2b as shown below: - Phase 2a (3545kEuros) started 2014 for a duration of 18 months until CDR. - Phase 2b (2500kEuros) starting 2016, for a duration of 24 months until completion. This proposal is for the implementation of Phase 2b in 2016, assuming a successful CDR at the end of Phase 2a.					
Deliverables					
Documentation, development models, engineering model engine and valve assemblies.					
Current TRL:	3	**Target TRL:**	5/6	**Application Need/Date:**	2016
Application Mission:	INSPIRE, Phootprint, MSRO and other future Mars missions		**Contract Duration:**	42	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Annex 2 (for information only):
Update of MREP technology roadmaps

1. Phobos Sample Return
2. Mars Precision Lander
3. SFR, Robotics and Mechanisms
4. Mars Sample Return
5. Long term technologies

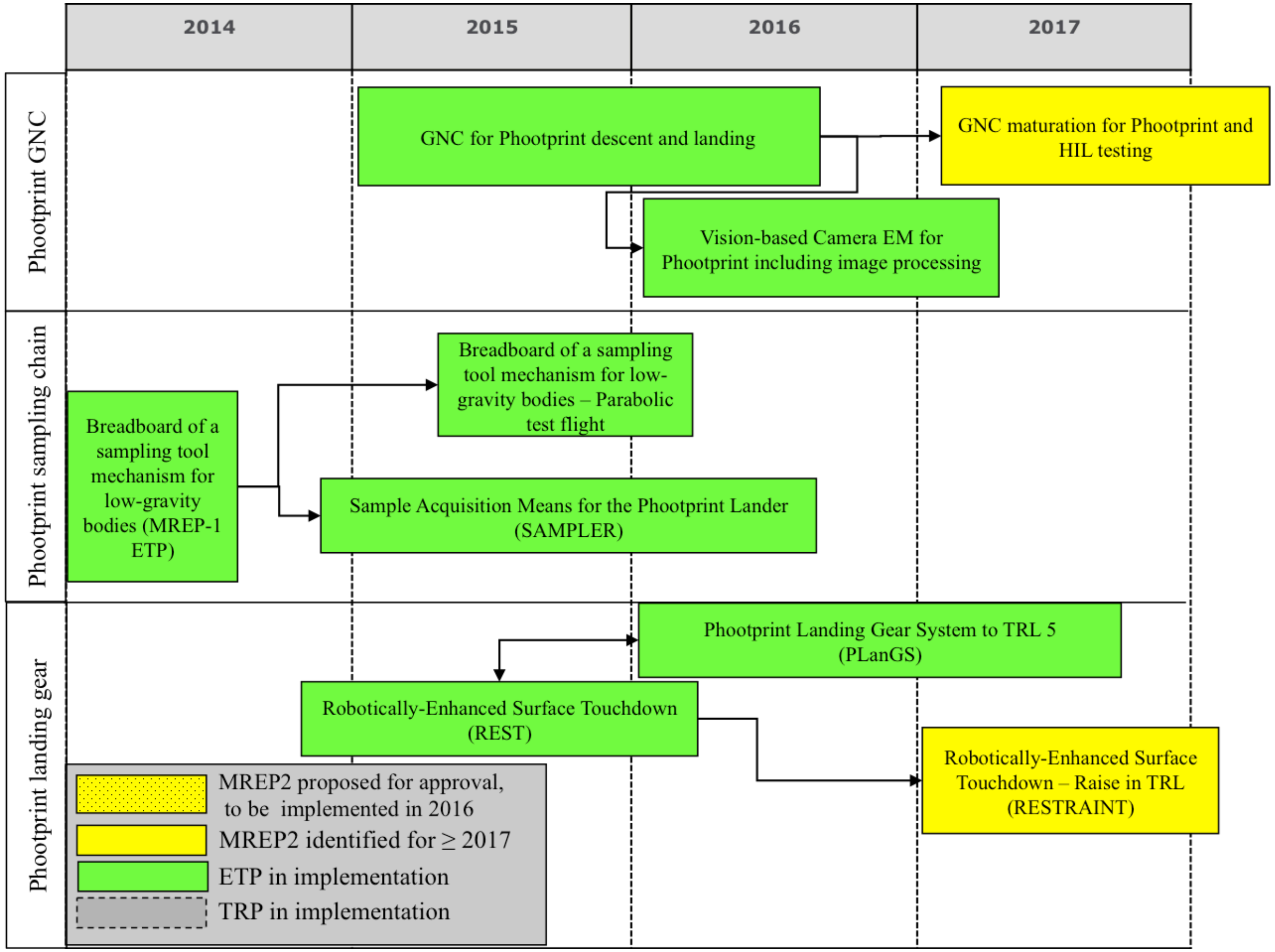

Figure 1: Phobos Sample Return technologies roadmap 1./3

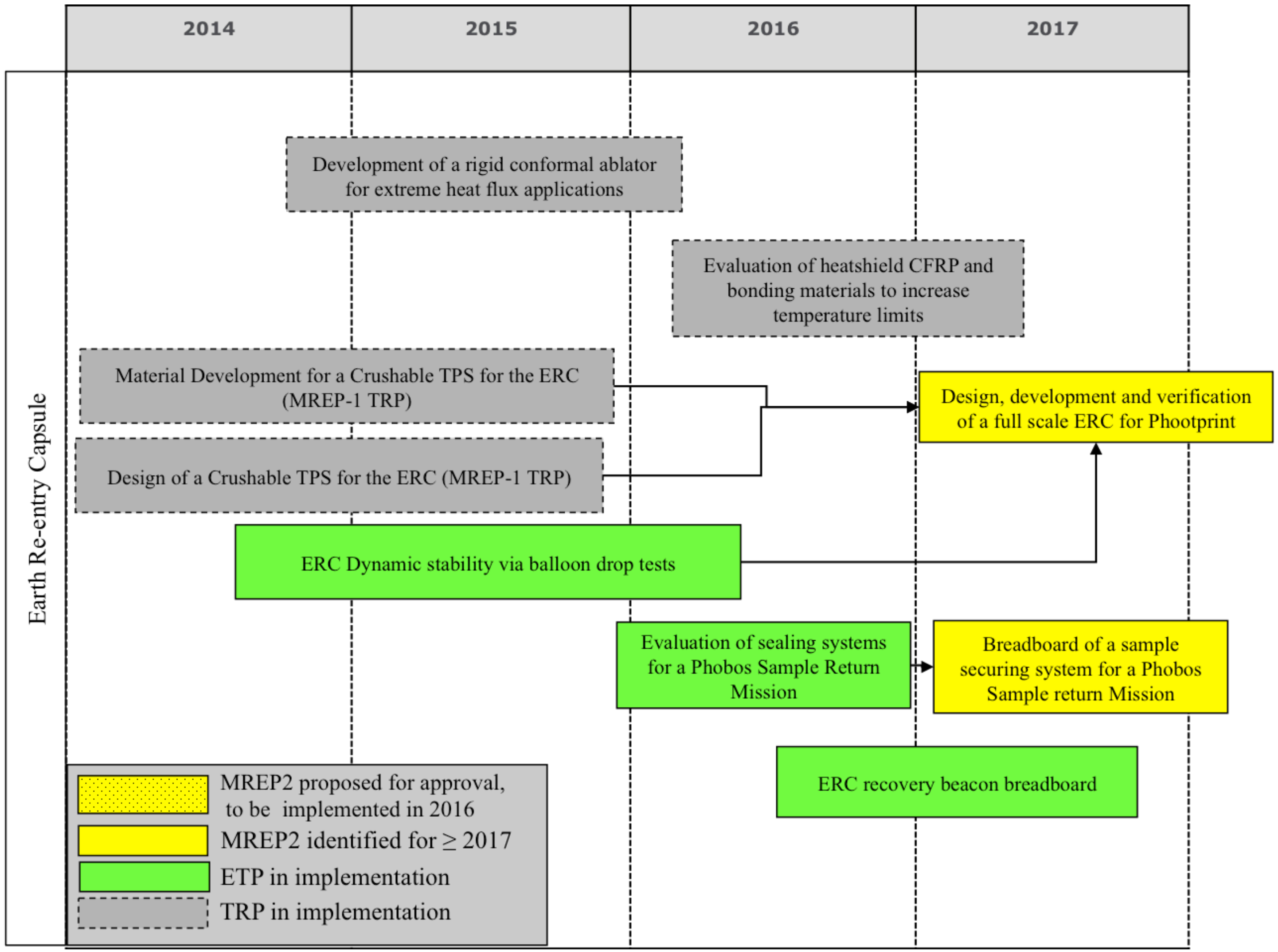

Figure 2: Phobos Sample Return technologies roadmap 2./3

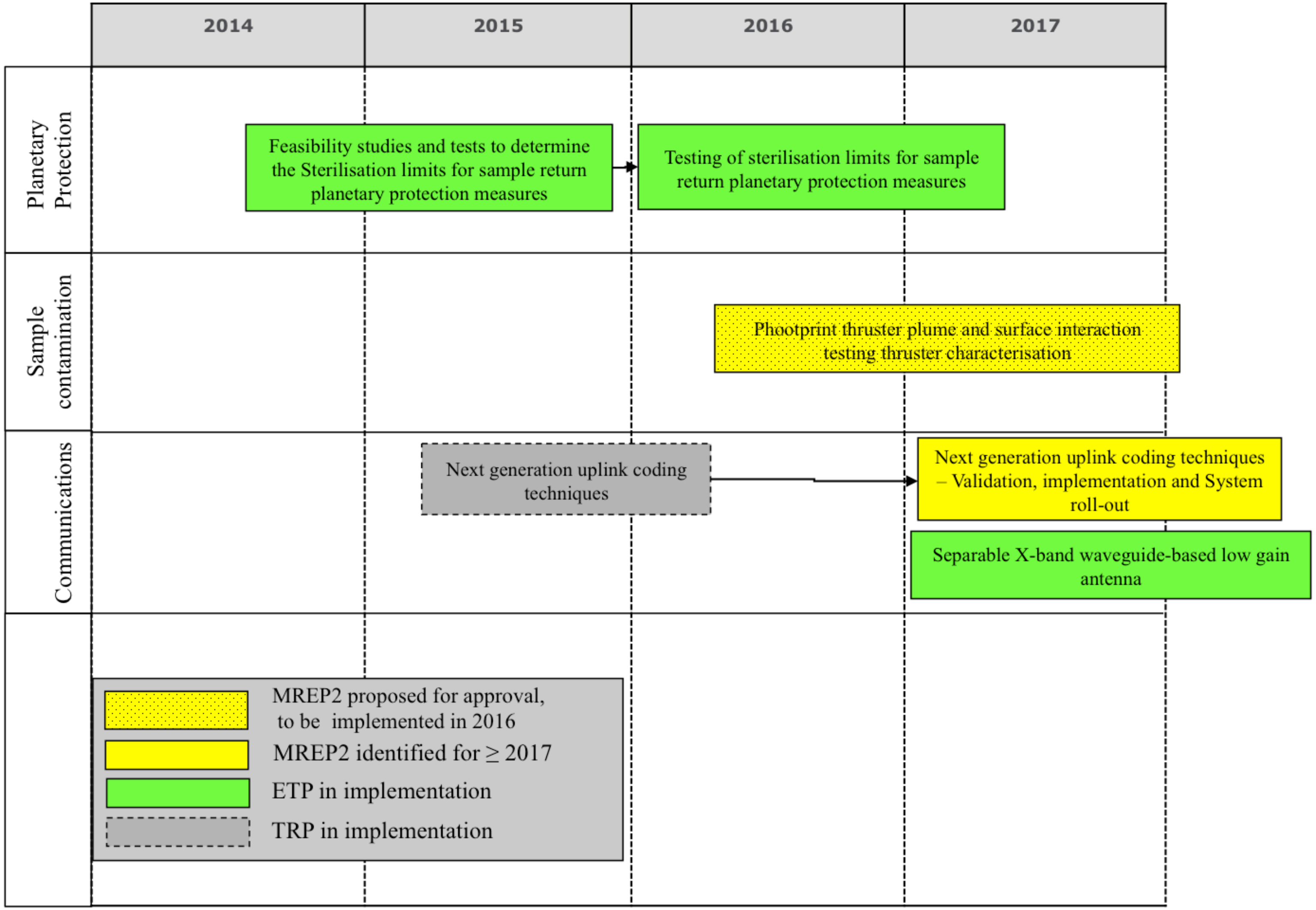

Figure 3: Phobos Sample Return technologies roadmap 3./3

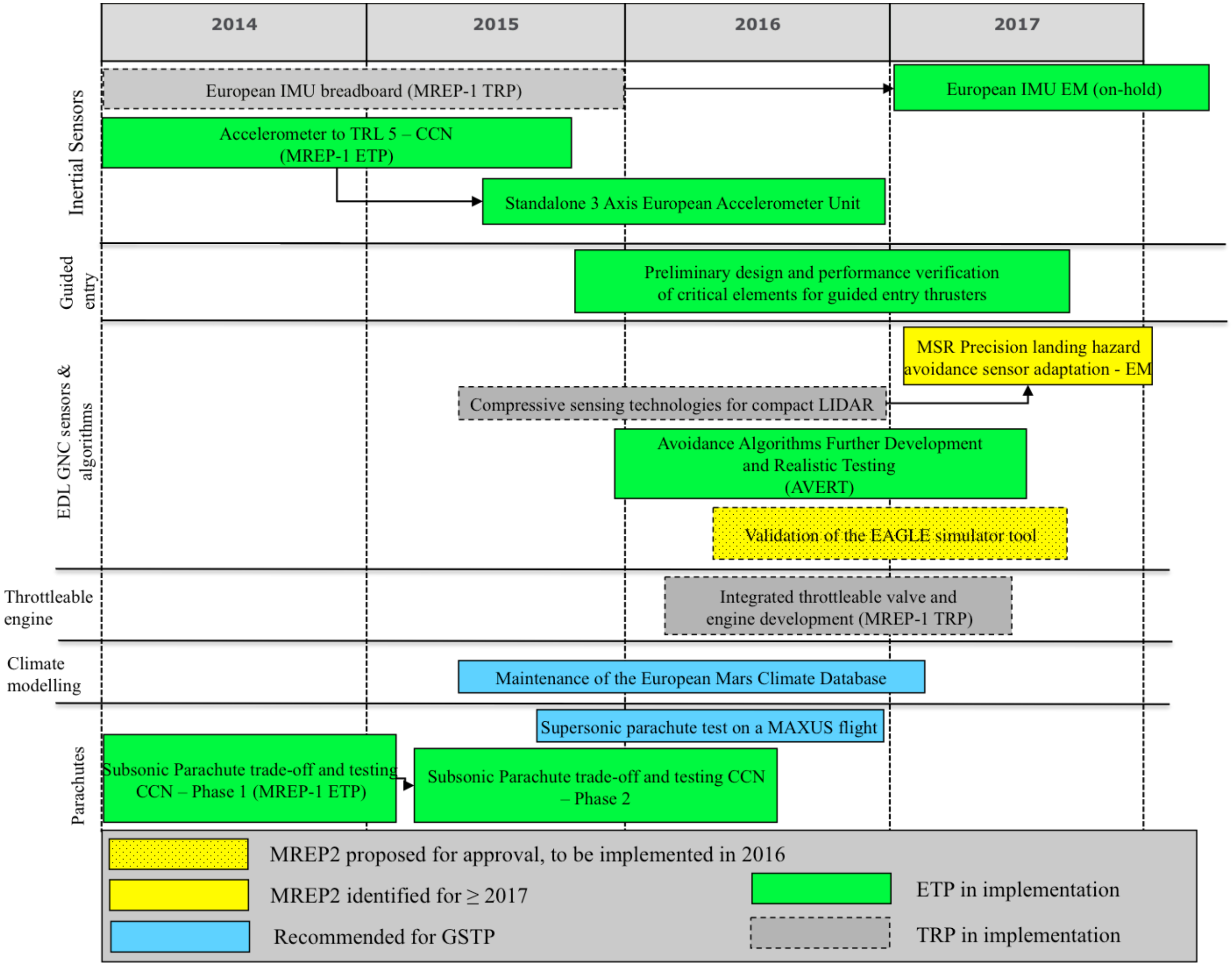

Figure 4: Mars Precision Lander technologies roadmap 1./2

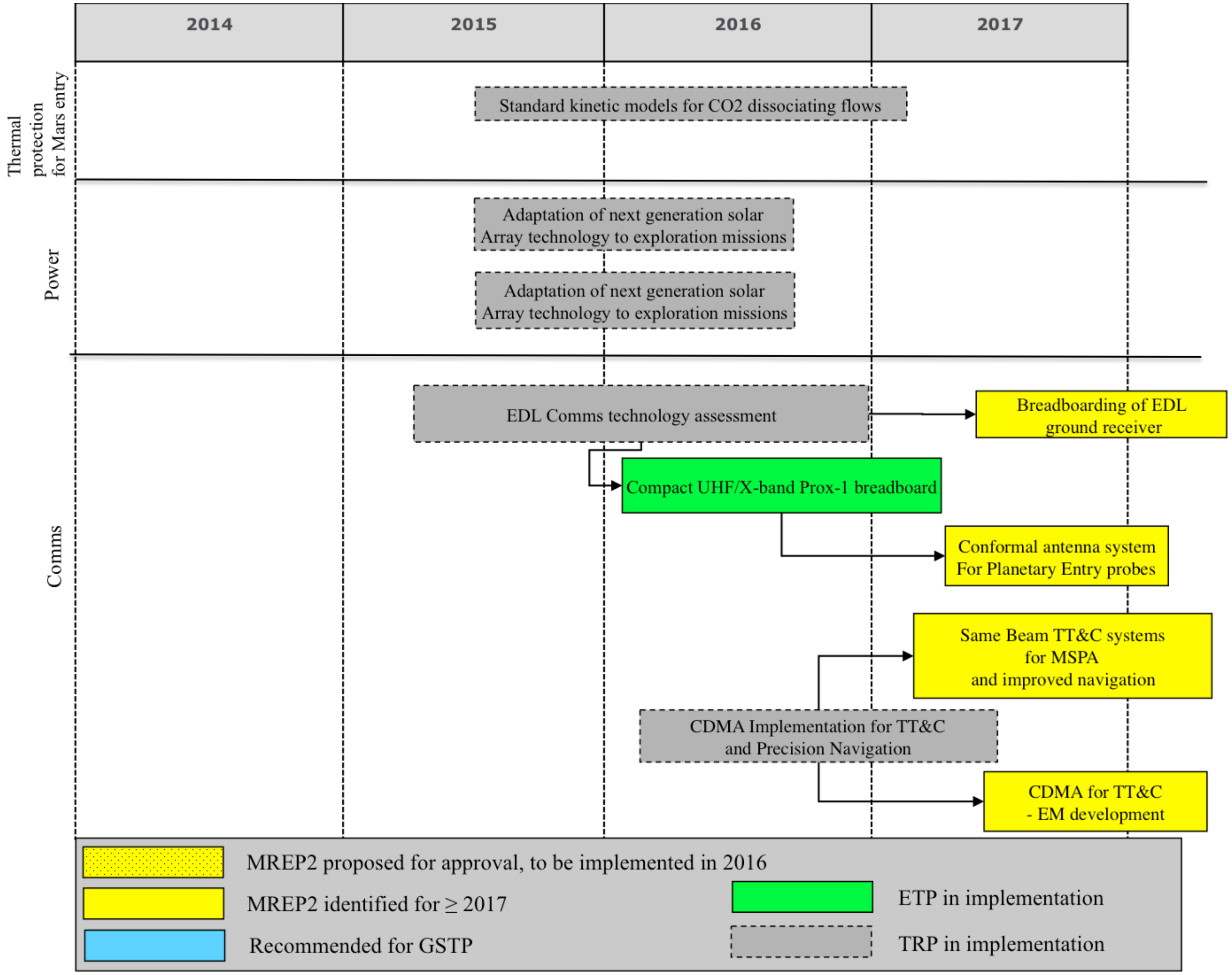

Figure 5: Mars Precision Lander technologies roadmap 2./2

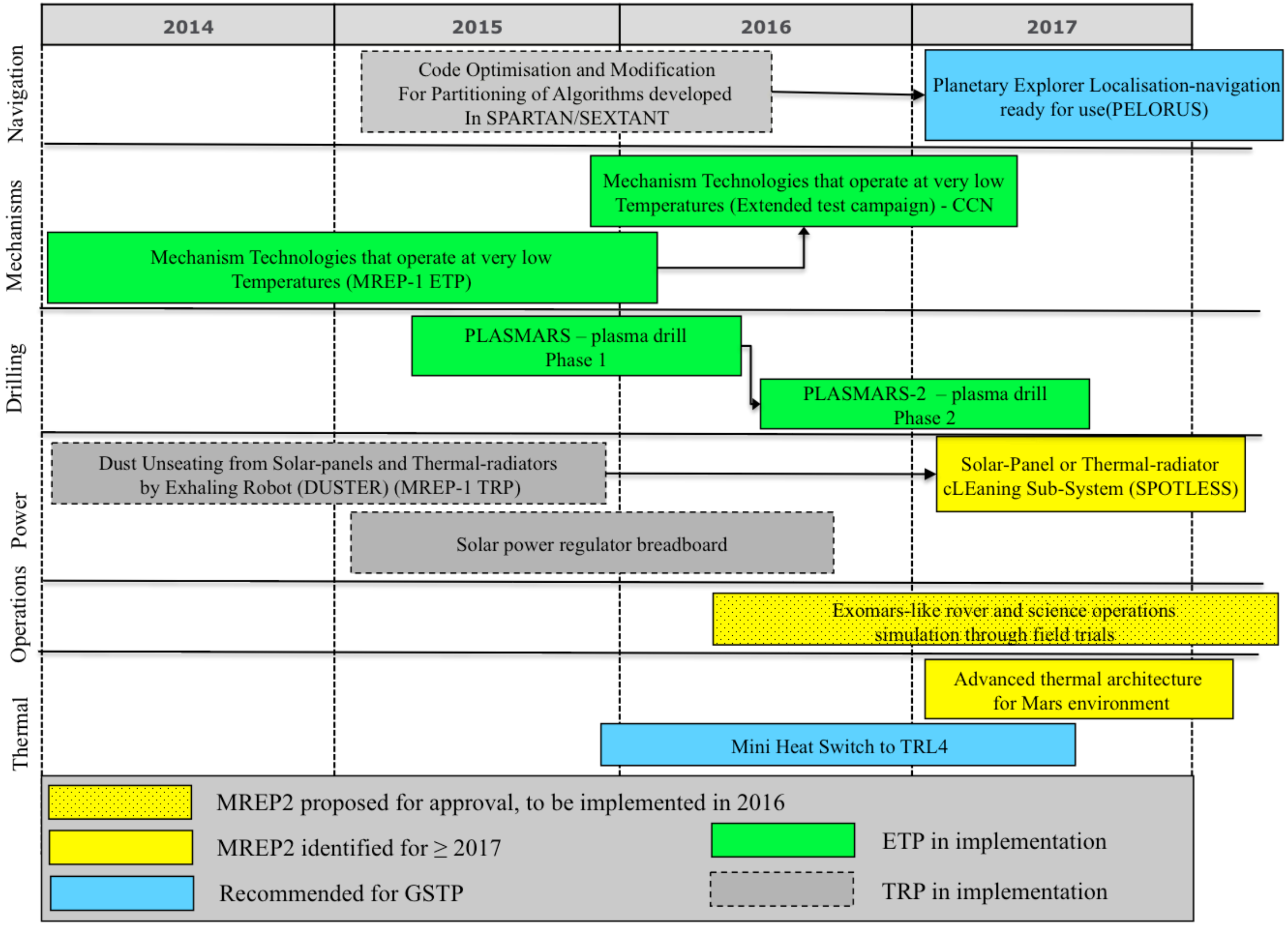

Figure 6: SFR Robotics and Mechanisms technologies roadmap

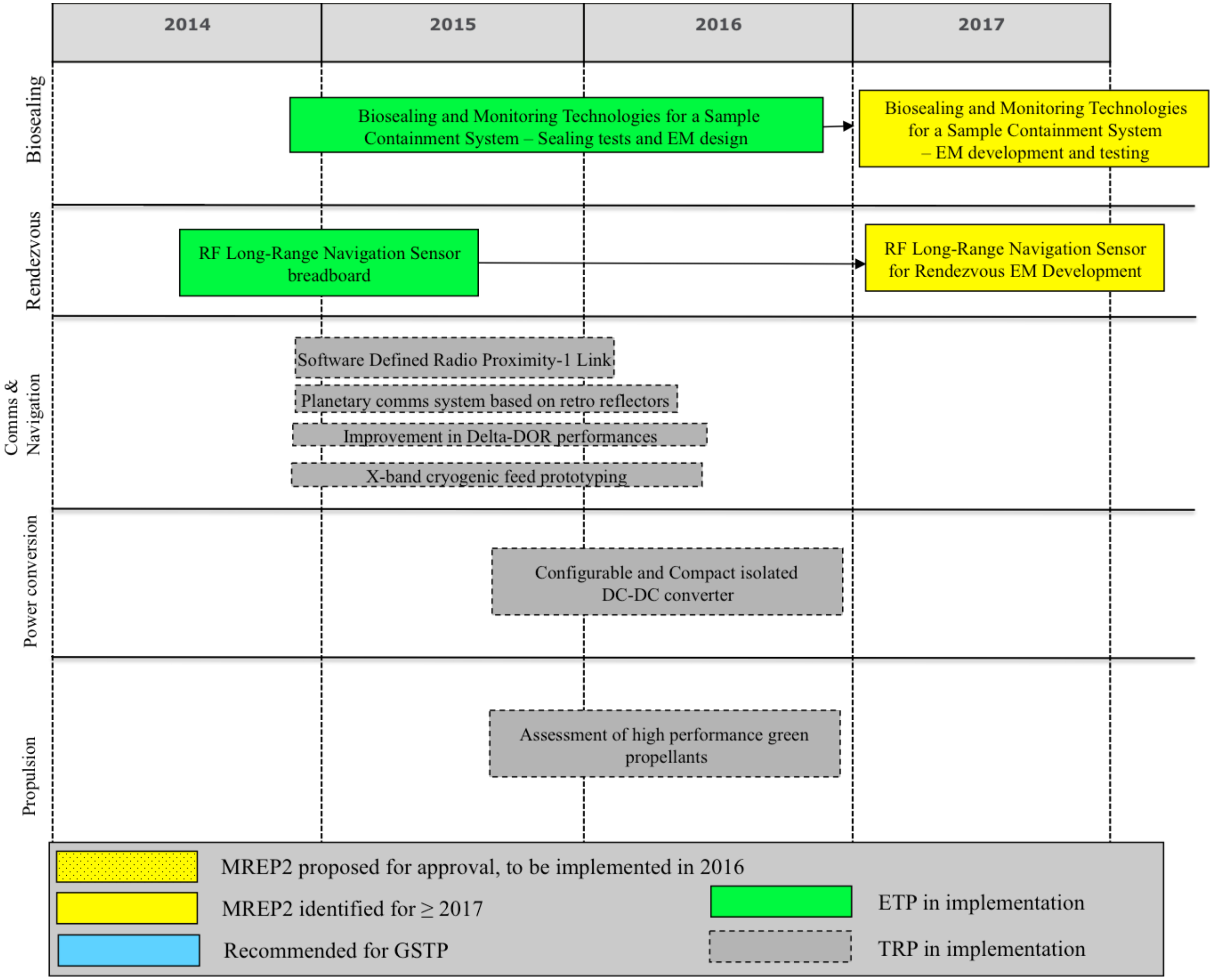

Figure 7: Mars Sample Return technologies roadmap 1./2

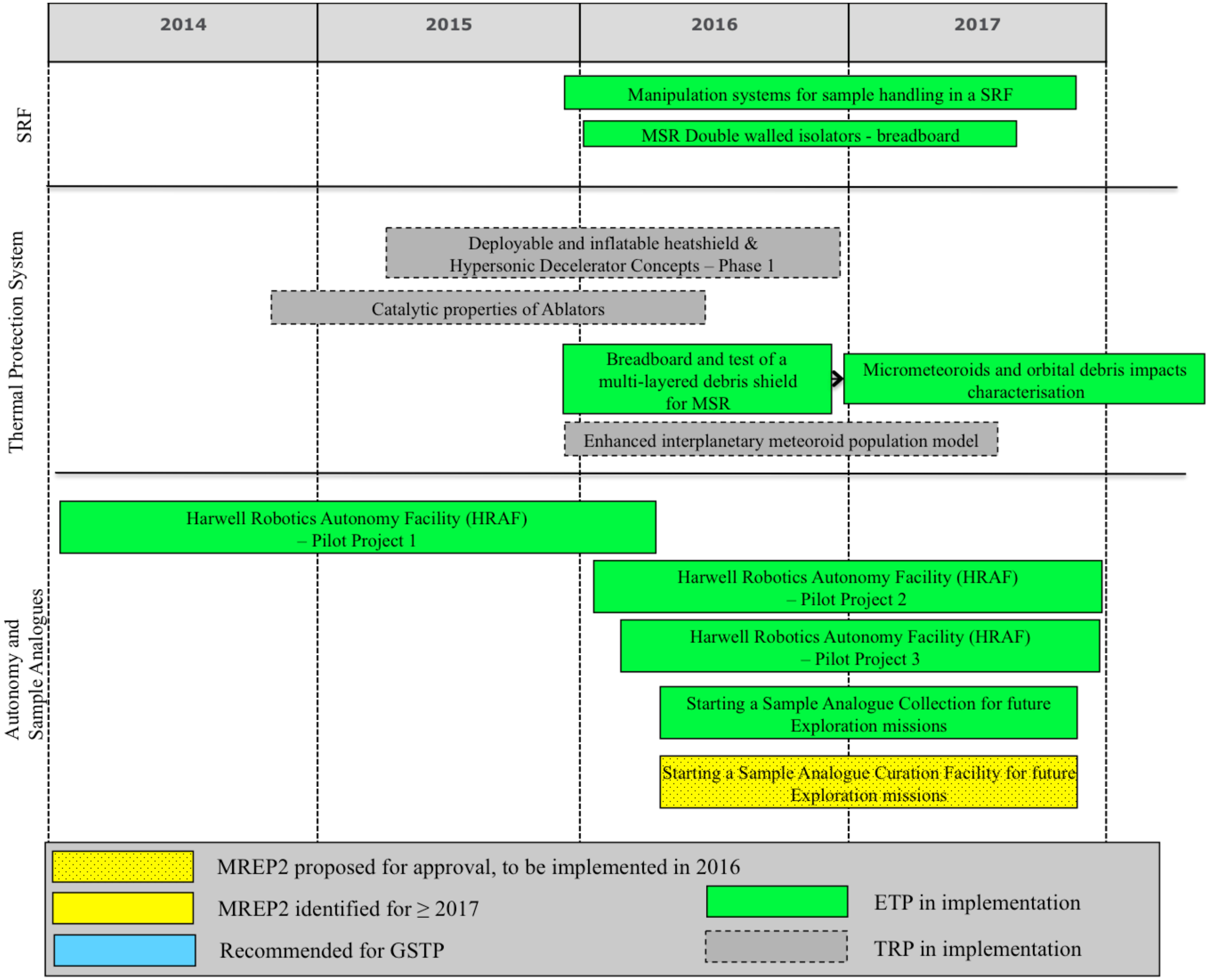

Figure 8: Mars Sample Return technologies roadmap 2./2

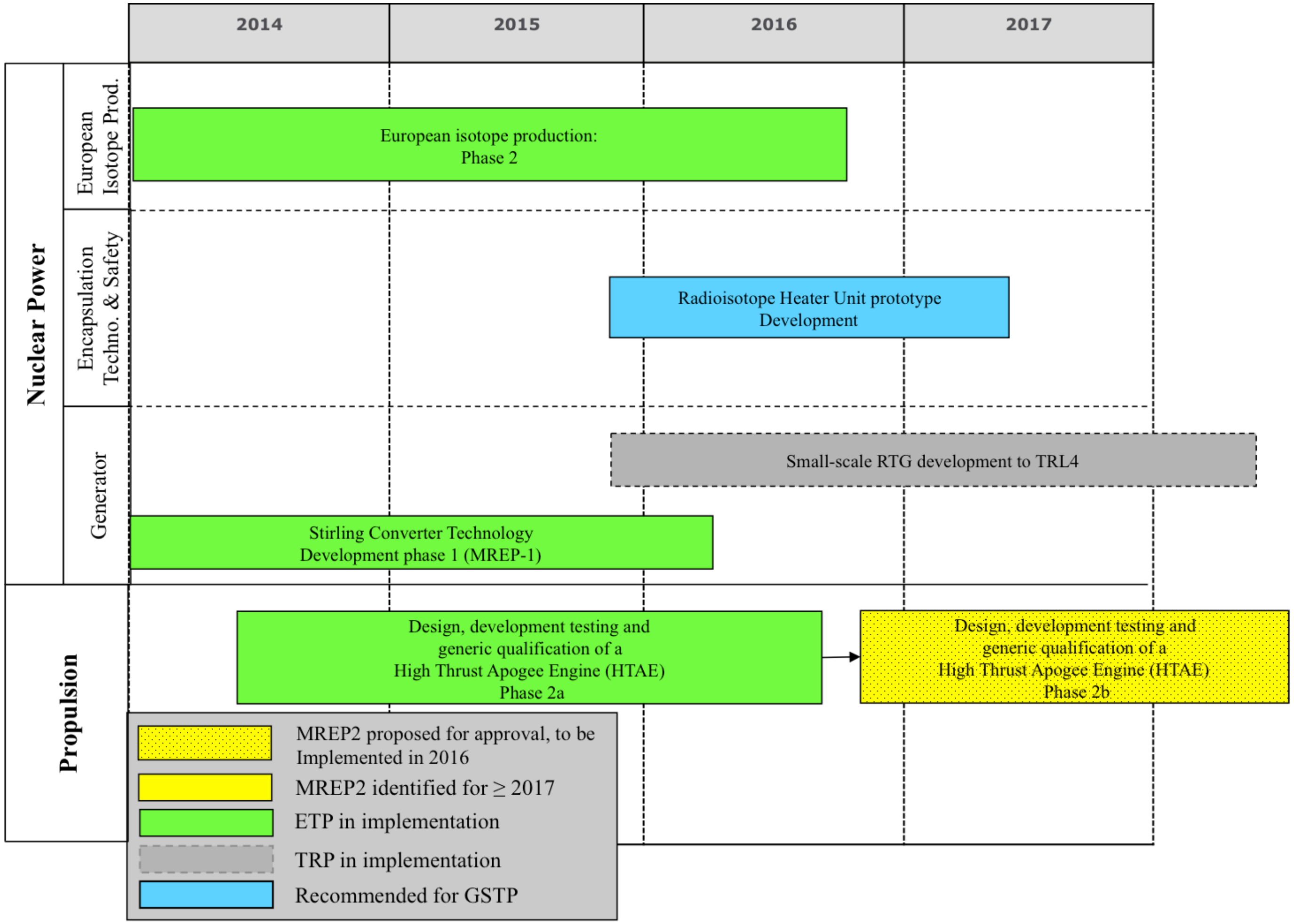

Figure 9: Long term technologies roadmap

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Annex 3:
Summary description of post-ExoMars candidate missions
and
Mars Sample Return

A4.1 The Phootprint mission

PHOOTPRINT will return a sample from the Mars moon Phobos. It is launched by Ariane 5 (or similar launcher) into direct escape to Mars in 2024. The spacecraft composite is made of three main elements:

- A lander carrying the ERV/ERC, performing the transfer to Mars, the Mars orbit insertion and operations around and on Phobos including landing and sampling
- An Earth Return Vehicle (ERV) performing Mars escape, transfer back to Earth and ERC release few hours before re-entry
- An Earth Re-entry Capsule (ERC) with hard landing on Earth
- Possibly a Propulsion Module (PM) that performs the transfer to Phobos and is jettisoned at Phobos (in that case the lander module does not include any propulsion system, and the near-Phobos manoeuvres are performed by the ERV)

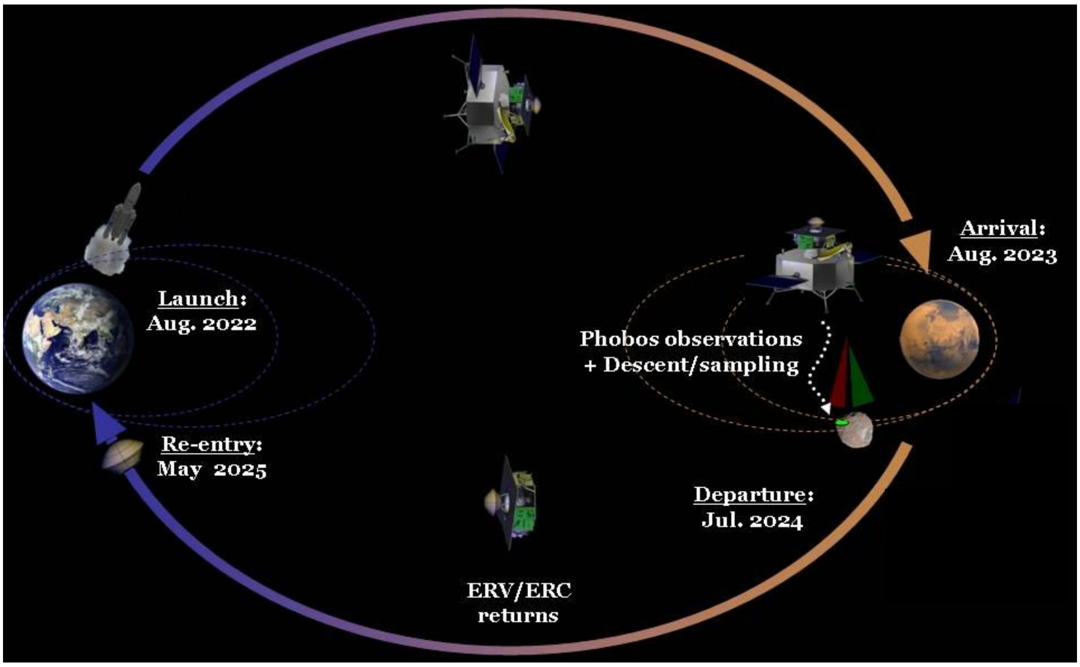


Figure 10: PHOOTPRINT mission scenario (note that foreseen launch date is now 2024)

The composite will transfer to Mars during 11 months. A number of burns will bring the spacecraft to a 6500 km circular Mars orbit near Phobos, where it will stay for about a year. Throughout this year, Phobos will be characterised and potential landing sites will be identified using its onboard instrumentation. First observations will take place from a remote distance of a few hundreds of km, then closer at to 50 to 100 km. After this characterisation and the selection of a scientifically interesting and technically suitable and safe landing site, the composite will descent towards Phobos and perform a soft landing on its surface.

Eventually, the spacecraft will stay on Phobos for a number of day/night cycles to allow iterations with the ground team to select a sampling spot. The 2-meter robotic arm will deploy a sampling tool to collect 100 gram samples on the chosen spot. If the soil is not appropriate for sampling the robotic arm can be repositioned to another location. As the surface gravity is extremely low (2 to 8 mm/s^2), thrusters will be continuously fired during the sampling operation to push the lander on the surface and ensure stability when sampling occurs.

After confirmation of a successful sampling procedure, the sample will be transferred to the re-entry capsule and sealed. The ERV/ERC-composite will take-off from Phobos and transferred into a Mars escape orbit to perform from there the Mars escape manoeuvre and transfer back to Earth. After 8 months return trip the ERC will be released a few hours before Earth arrival and re-enter the atmosphere at 12 km/s.

	Value	**Unit**
Launch mass	~ 4000	kg
Total Delta V	~ 4200	$m \cdot s^{-1}$
Mass around Phobos (Lander/ERV/ERC)	~ 1700	kg
Mass returned to Earth (ERC)	~ 30	kg
Re-entry velocity	~12	$km \cdot s^{-1}$
Earth landing site	Woomera test Range	
Mission duration	< 3	year

Table 1: Key mission parameters

A4.2 The Mars Precision Lander (MPL) with Small, Science Rover (SFR) mission

The mission objective is to perform a soft precision landing on Mars with precision of 10 km (3 sigma) and to deliver a ~100kg rover to the Martian surface. The mission is launched by a Soyuz Fregat from Kourou either into a GTO orbit, or into a direct escape followed by an Earth fly-by. The spacecraft composite is made of three main elements:

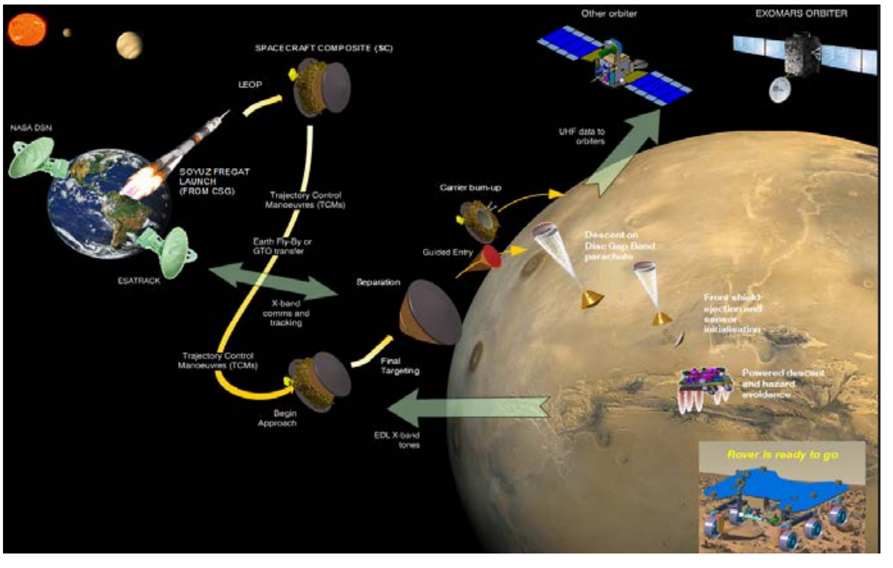
- A carrier to support the lander during the cruise phase and deliver it to Mars. After release of the lander about 15 minutes before Mars entry, the carrier will break up and burn up in the Martian atmosphere.
- A lander performing the precision entry, descent and landing including hazard avoidance
- A 100 kg class highly-mobile rover for extended-range scientific exploration, which would also demonstrate the fast roving capability required for the MSR (Sample Fetch Rover),
- 

Figure 11: Mars Precision Lander mission scenario

Once safely landed, the rover will start its surface mission for over 180 sols, exploring a landing site normally not accessible without the precision landing capability. The technology to land more precisely on Mars directly offers a substantial increase in the number of available landing sites on the surface that could be targeted by future missions. As an example, without precision landing only 1 out of 12 last candidates landing sites from the MSR and MSL would be accessible. It should be noted that a data relay orbiter is required to support the rover operations.

	Earth Fly-By (EFB) + dropship	**GTO + conventional lander**
Launcher capability	1625 kg	3180 kg
Possible launch dates	November 2025 (or later)	October 2024 or November 2026
Mars arrival	September 2025 or August 2027	
Delta-v for transfer	No DSM, 70 m/s navigation delta/v	1.6 -1.9 m/s
Total launch mass including adapter	1391 kg	3240 kg
Landing sites	Latitude : -15° to +30°, Longitude : Any Altitude: <0 km MOLA	

Table 2: Key mission parameters

A4.3 The INSPIRE mission

The INSPIRE mission aims at delivering a network of landers on the surface of Mars with Direct-to-Earth capabilities to perform simultaneous seismic, radio science and meteorological measurements for a full Martian year lifetime.

Mission Overview

The mission concept is based on a Soyuz-Fregat launch from Kourou into GTO with the interplanetary escape performed by carrier with the MREP High Thrust Engine (1.1kN). Launch date timeframe is 2024 to 2028. The total transfer duration is 7-9 months to 1.5 years depending on the interplanetary transfer (direct escape to Mars or with an Earth Gravity assist maneuver in order to reduce the deltaV). At the end of the transfer, the 3 probes are sequentially released from the arriving hyperbolic trajectory and the Carrier performs an avoidance maneuver (CAM) before Entry Insertion Point (EIP) to avoid to crash on Mars and comply with Planetary protection requirements.

Lander release

Tens of days before arrival at Mars, the tracking campaign of the spacecraft will become more intense as preparations take place for the release of the landers. The first probe will be released about 11.5 days before arrival at Mars followed by further tracking (deltaDOR) and retargeting maneuvers to release the second lander a few days later. In nominal conditions, the last probe is released 5.5 days before EIP, however in case of failure, the current release strategy allows margin for contingency management for both, the Ground Segment and the one safe mode recovery.

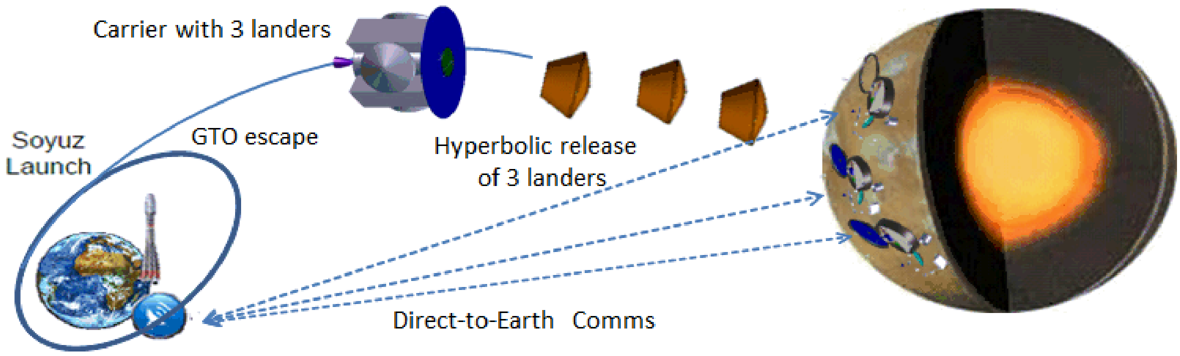


Figure 12: Proposed INSPIRE Mission Architecture

Total Composite dry mass	**1862 kg**
Carrier dry mass	**686 kg**
Propellant mass	**1205 kg**
Probe mass	**391kg**
Total wet mass (2026)	**3193kg**
Launch margin (2026)	**1.8%**
Lander mass	**145 kg**
Diameter of the lander	**1.1m**

Table 3: Main characteristics of the mission.

Entry, Descent and Landing (EDL)

The probes enter the Martian atmosphere performing a ballistic entry protected by its heatshields. At the appropriate conditions, the supersonic disc-gap-band parachute is opened, further decelerating the probes. This is followed by a brief retro propulsion phase, a short freefall and finally a semi-soft landing using unvented (bouncy) airbags. Throughout this phase, critical event data is downlinked to Earth. A similar EDL strategy has been proven successfully by Mars Pathfinder (MPF) and Mars Exploration Rover (MER) missions.

Surface operations

After the lander has come to rest, the airbags are jettisoned to allow the clamshell to open and the solar panel will be deployed. The lander proceeds with check-outs and communications direct-to-earth are established. High-resolution, colour panoramic pictures of the landing sites are then taken for relay to earth providing an early opportunity to visualise the immediate surroundings of the lander for operational, scientific and especially public outreach purposes. The following days will see the deployment of the different payloads: the meteorological boom is unfolded and the mole and seismometer will be placed onto the surface by the robotic arm. The mole will start its hammering process to dig itself into the surface whilst making scientific measurements. Once fully deployed, the landers will become long term (goal of > 1 Martian year) seismic, radio science and atmospheric monitoring stations taking simultaneous measurements without the need for complex operational planning and cost.

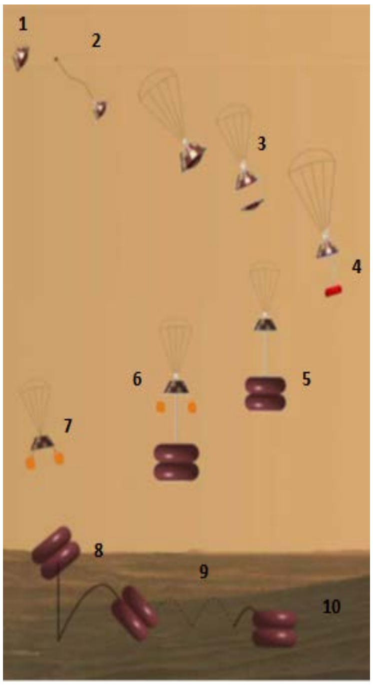


Figure 13: Entry, Descent and Landing chain

A4.4 The Mars Sample Return mission

The summary presented here focuses on the MSR-Orbiter (MSR-O) mission that has been studied by ESA with two industrial teams. The entire MSR reference mission campaign, as resulting from i-Mars report and ESA/NASA joint effort in 2009-2011, is shown and described in the following figure. This reference mission campaign is subject to evolution, since the International Mars Exploration Working Group (IMEWG) has recently decided to re-initiate the work on MSR architecture, by extending the participation new partners such as Roscosmos.

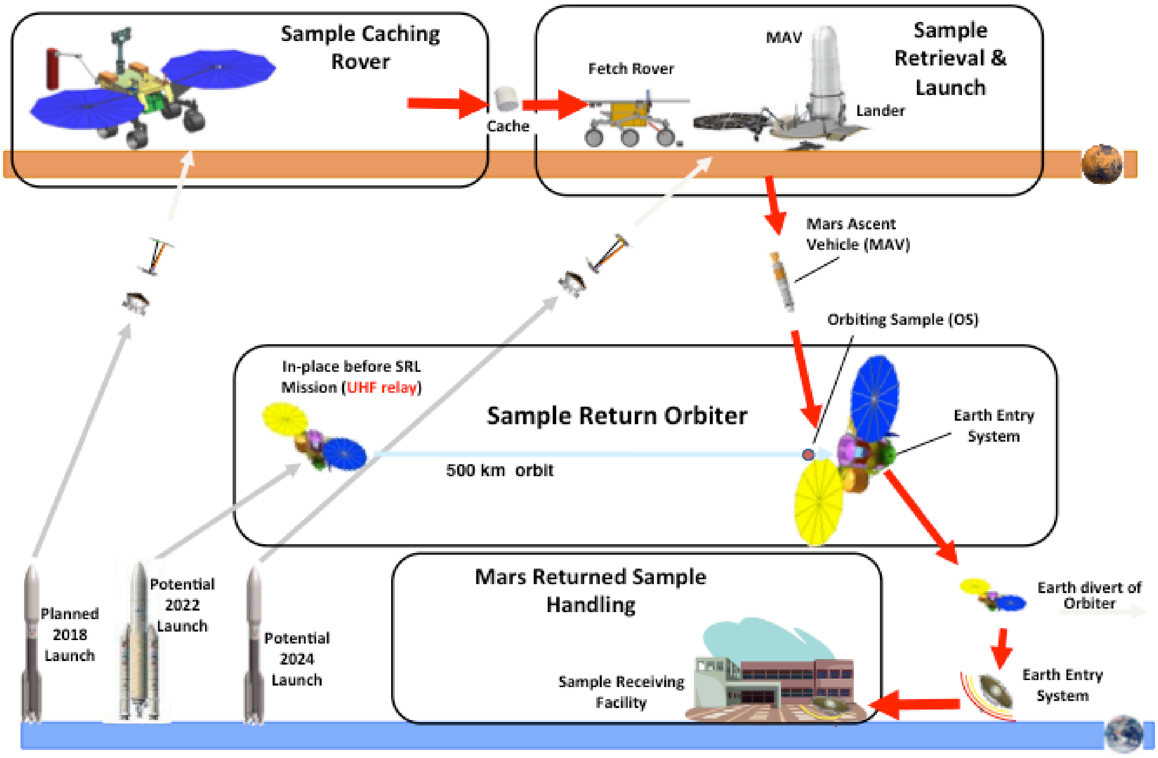


Figure 14: The four elements of the MSR campaign: The caching rover selects the samples and places them in a cache. The sample retrieval and launch mission retrieves later the pre-stored cache with a sample fetch rover, places it in the orbiting sample container, which is launched in low Mars orbit by the Mars Ascent Vehicle. The MSR-O searches, rendezvous and captures the OS, seals it and returns it to the Earth. Finally the Earth Re-entry Capsule enters the Earth atmosphere and lands on the surface. Note: All launch dates are now delayed to late 2020s/early 2030s.

The baseline launcher for MSR-O is an Ariane 5, assuming late 2020's or early 2030's as launch dates. Two major injection strategies have been analysed: (1) direct injection to Mars and (2) injection into a high elliptical orbit (HEO) followed by an Earth escape performed by the propulsion module. This second strategy allows for increased mass delivered to Mars at the cost of a large propulsion module and some increased operational risk. Other alternatives, like Earth swing-by or long transfers have been also analysed. In general these lead to higher mass at Mars at the cost of longer transfer duration. The baseline is focused on short transfers (typically 10 months) to minimise the overall mission lifetime and to provide a solid margin for covering the arrival of the MSR-R element, intended to be launched 2 years after MSR-O.

At Mars the spacecraft performs the Mars Orbit Insertion (MOI), followed by an apocentre lowering manoeuver and jettison of the propulsion module. Aerobraking is used to save around 1.000 m/s delta-v for further lowering of the orbit apocentre down to parking orbit altitude of around 500 km. In the parking orbit MSR-O waits for the MSR-R descent module arrival to cover its entry, descent and landing on Mars. MSR-O serves also as communication relay for all operating MSR surface elements (lander and MAV, fetching rover) for a duration of 6 months. During this period the sample fetching rover is deployed, transfers to the pre-stored sample cache, and returns it back to the lander, where the cache is put into the Orbiting Sample (OS) container, ready to launch with the Mars Ascent Vehicle (MAV). MSR-O follows the MAV launch and in particular the OS release, performs an orbit estimation of the OS, to size end execute the rendezvous manoeuvres up to the final capture of the OS. The rendezvous and capture phase nominally lasts less than 10 days.

The OS is placed inside the bio-container (BC) after capture and sealed according to planetary protection requirements. Once bio-sealed, the BC is transferred into the Earth Re-entry Capsule (ERC). The OS handling system is no longer needed and is jettisoned to reduce the Orbiter mass.

MSR-O escapes from Mars to an Earth transfer leg of around 10 months. At Earth arrival the ERC is released for re-entry at ~12 km/s, followed by a hard landing (no parachute is used for reliability reasons) in Utah or Australia. The Mars samples are retrieved and transferred to the Sample Receiving Facility (SRF) for further storage and analysis.

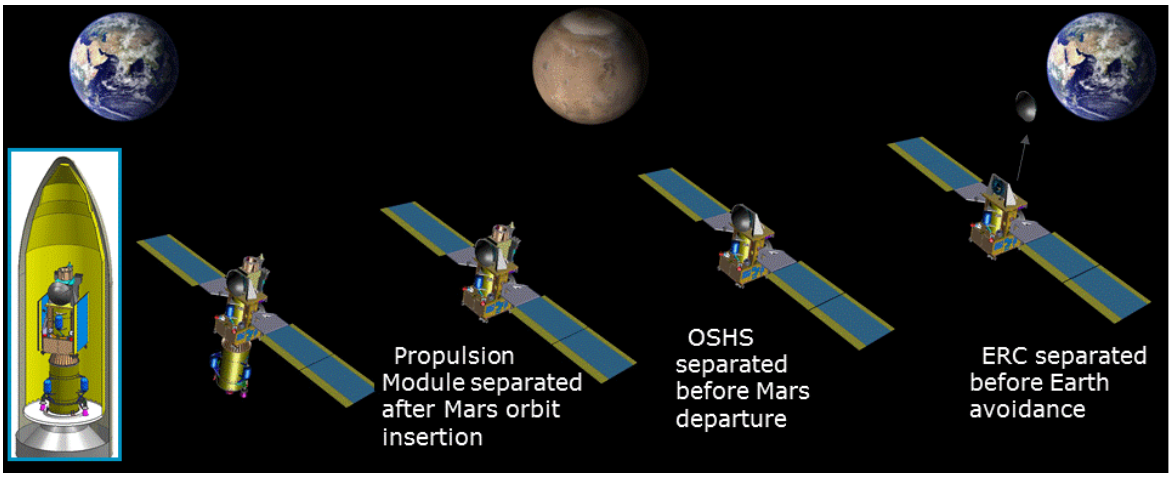


Figure 15: The MSR-O staging strategy is optimised for mass performance

MSR-O design is dominated by the high overall demanded delta-v, driven by the following major manoeuvres for typical direct escape scenario:

- Deep space manoeuver (DSM) of ~500 m/s
- Mars orbit insertion (MOI) of ~700 m/s followed by an aerobraking phase
- Mars escape orbit acquisition of ~1200 m/s and a Mars escape of ~1000 m/s

Numerous additional smaller manoeuvres are necessary. In the case of HEO injection additional ~800 m/s are needed for Earth escape.

Annex 4 (for information only):

1. List of completed MREP-1 Programme activities
2. List of Removed/replaced activities from previous MREP programme work plans
3. Summary tables and detailed descriptions of all running, approved or proposed activities from the MREP-1 and MREP-2 Programmes

Completed MREP-1 Programme activities (ETP, TRP, ACP)

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2013	2014	2015	2016	PP	C'try	SW Clause applicab.	Remarks
ETP	Y2011	E915-003MS	Breadboard of a sampling tool mechanism for low-gravity bodies	0	0	0	0	C	IT	N/A	
TRP	Y2008	T304-038EE	Maintenance of Martian Atmospheric circulation models (large scale, mesoscale, upper atmosphere) and continued validation of Martian Climate database	0	0	0	0	DN/C	FR	N/A	
ETP	Y2009	E905-006EC	End to end Optimisation and GNC design for High Precision Landing on Mars	0	0	0	0	C	FT	N/A	
ETP	Y2011	E905-016EC	Accelerometer component to TRL5	0	0	0	0	C	CH	N/A	
ETP	Y2012	E905-017FT	Accelerometer to TRL5 - CCN	0	0	0	0	DN/C	CH	N/A	
ETP	Y2009	E905-007EC	Camera-aided Mars Landing and Rendezvous navigation system	0	0	0	0	C	FR	N/A	
TRP	Y2010	T905-008EC	Sensor Data Fusion for Hazard Mapping and Piloting	0	0	0	0	C	FR	N/A	
ETP	Y2009	E905-007EC-B	Camera-aided Mars Landing and Rendezvous navigation system	0	0	0	0	C	IT	N/A	
ETP	Y2010	E905-008EC	Sensor Data Fusion for Hazard Mapping and Piloting	0	0	0	0	C	PT	N/A	
TRP	Y2007	T309-002HS	Innovative Rover Operations Concepts- Autonomous Planning (IRONCAP)	0	0	0	0	C	DE	Operational Software	
ETP	Y2009	E913-001MM	SPAring Robotics Technologies for Autonomous Navigation (SPARTAN)	0	0	0	0	C	ES	N/A	
ETP	Y2011	E913-005MM	Spartan EXTension Activity - Not Tendered (SEXTANT)	0	0	0	0	DN/C	ES	N/A	
ETP	Y2009	E913-002MM	Study of a Sample Fetching Rover for MSR	0	0	0	0	C	GB	N/A	
TRP	Y2010	T913-004MM	Surface-Wheel Interaction modeling for Faster Traverse (SWIFT)	0	0	0	0	C(1)	CH	N/A	
ETP	Y2009	E913-002MM-B	Study of a Sample Fetching Rover for MSR	0	0	0	0	C	IT	N/A	
ETP	Y2011	E913-006MM	EXperimental Production of data/Evidence on Rover Tractive performance In Soils relevant for Exploration (EXPERTISE)	0	0	0	0	C	CH	N/A	
ETP	Y2011	E913-007MM	Shock Mitigation Operating Only at Touch-down by use of minimalist/dispensable Hardware (SMOOTH)	0	0	0	0	C	IT	N/A	
TRP	Y2011	T924-002QT	High specific stiffness metallic materials	0	0	0	0	C(3)	AT	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2013	2014	2015	2016				
TRP	Y2008	T305-031EC	Robust Autonomous Aerobraking Strategies	0	0	0	0	C	FR	N/A	
TRP	Y2008	T305-031EC-B	Robust Autonomous Aerobraking Strategies	0	0	0	0	C	FR	N/A	
ACP	Y2012	A923-001FI	Extremely low power timer board EM for landers - CCN	0	0	0	0	DN/C	AT	N/A	
ETP	Y2009	E901-001ED	Extremely low power timer board EM for landers	0	0	0	0	C(1)	AT	N/A	
ETP	Y2009	E901-002ED	Tailored On-Board Computer EM for planetary landers	0	0	0	0	C	SE	Operational Software	
SI	Y2009	S901-001ED	Extremely low power timer board EM for landers	0	0	0	0	C(1)	DK	N/A	
TRP	Y2009	T918-001MP	Subsonic Parachute Trade-Off and Testing	0	0	0	0	C(2)	GB	N/A	
TRP	Y2009	T905-003EC	Assessment and breadboarding of a planetary Altimeter	0	0	0	0	C(1)	PT	N/A	
ETP	Y2010	E920-001MS	Airbags for small landers - Breadboard and Test	0	0	0	0	C	IT	N/A	
ETP	Y2009	E905-002EC	EDLS GNC Optimisation and Technology Specification for small Mars landers	0	0	0	0	C(1)	ES	N/A	
ETP		E906-003FI	SPEX (Spectro-Polarimeter for Planetary Exploration) Characterization Program	0	0	0	0	DN/S	NL	N/A	
TRP	Y2009	T319-035MC	Airbags for small landers - Design	0	0	0	0	C(1)	GB	N/A	
TRP	Y2011	T903-014EP	Characterisation of space and terrestrial cells for future Mars lander/rover missions	0	0	0	0	C(1)	DE	N/A	
TRP	Y2010	T911-001GR	Simulation tool for breakup/burnup analysis of Mars orbiters	0	0	0	0	C	DE	Operational Software	
TRP	Y2008	T306-044ET	Lander Compact Dual UHF/X-band Frequency Communication Package Study	0	0	0	0	C(2)	GB	N/A	
ETP	Y2009	E914-001MM	MSR biocontainment system sealing and monitoring technologies - development and validation	0	0	0	0	C(2)	IT	N/A	
TRP	Y2008	T314-033MM	Evaluation of Encapsulated Bioburden on Flight Hardware	0	0	0	0	C(2)	DE	N/A	
TRP	Y2011	T914-005MM	MSR Double walled isolators - feasibility concept study	0	0	0	0	C	GB	N/A	
ACP	Y2007	CG80	RF Long Range Navigation Sensor Breadboard	0	0	0	0	C	ES	N/A	
ETP	Y2009	E905-010EC	Integrated GNC solution for Autonomous Mars Rendezvous and Capture	0	0	0	0	C	ES	N/A	
ETP	Y2007	E906-004ET	RF Long Range Navigation Sensor Breadboard	0	0	0	0	C	ES	N/A	
ACP	Y2007	CG50	Sample Canister Capture Mechanism Design and	0	0	0	0	C	IT	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2013	2014	2015	2016				
			Breadboard								
ETP	Y2011	E915-005MS	Sample canister capture mechanism parabolic flight test	0	0	0	0	DN/C	IT	N/A	
ETP	Y2010	E921-002PA	Delta-development of TPS for high heat loads	0	0	0	0	C	FR	N/A	
ETP	Y2011	E921-003PA	Adaptation of TPS materials of High-density for High Heat load (AT3H) re-entry applications	0	0	0	0	C	FR	N/A	
ETP	Y2014	E926-001FM	Starting a sample analogue collection for exploration missions	240	0	0	0	DN/S	GB	N/A	
ETP	Y2009	E919-011EP	Combustion chamber and injection technology development	0	0	0	0	C	GB	N/A	
ETP	Y2009	E903-001EP	European isotope production: Phase 1, samples and testing. (Including safety provisions)	0	0	0	0	C(1)	GB	N/A	
TRP	Y2008	T303-039EP	European Nuclear Isotope Evaluation, Selection and Feasibility Study	0	0	0	0	C(1)	GB	N/A	
TRP	Y2008	T303-039EP-B	European Nuclear Isotope Evaluation, Selection and Feasibility Study	0	0	0	0	C(1)	FR	N/A	
TRP	Y2009	T303-040EP	Nuclear fuel capsule and aeroshell design study	0	0	0	0	C(2)	GB	N/A	
TRP	Y2008	T203-006EP	Stirling Engine Radioisotopic Power System Requirement Study	0	0	0	0	C	GB	N/A	
ETP	Y2010	E903-003EP	Nuclear Power Systems architecture study for safety management and fuel encapsulation prototype development.	0	0	0	0	C(2)	FR	N/A	
TRP	Y2009	T903-006EP-B	Thermoelectric converter system for small-scale RTGs (to ~TRL3/4)	0	0	0	0	C	FR	N/A	
TRP	Y2009	T903-006EP	Thermoelectric converter system for small-scale RTGs (to ~TRL3/4)	0	0	0	0	C	GB	N/A	
ACP	Y2007	CA10	On-Line Reconfiguration Control System and Avionics Technologies (ORCSAT)	0	0	0	0	C	GB	N/A	
ACP	Y2007	CE60	Validation of Aerothermodynamics Experimental and Computational Tools for the Support of Future Mars Missions	0	0	0	0	C	BE	N/A	
ACP	Y2007	CG10	GNC Maturation and Validation for Rendezvous in Elliptical Orbit (GNCOMAT)	0	0	0	0	DN	PT	N/A	
ACP		CG20	Automated Orbit Determination Techniques for	0	0	0	0	C(R)	PT	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2013	2014	2015	2016				
			Rendezvous (AODER)								
ACP		CG40	Worst Case & Safety Analysis Tools for Autonomous Rendezvous System	0	0	0	0	C	ES	N/A	
ACP	Y2007	CG60	Virtual Spacecraft Image Generator Tool	0	0	0	0	DN	GB	N/A	
ACP	Y2007	CK10	Bioburden and biodiversity evaluation in spacecraft facilities and lifetime test of rapid spore assay	0	0	0	0	C	DE	N/A	
ACP	Y2007	CK20	Extension of Dry Heat Sterilisation Process to High Temperature	0	0	0	0	C	DE	N/A	
ACP	Y2007	CK30	Development of a Complementary Low Temperature Sterilisation Method	0	0	0	0	C	GB	N/A	
ACP	Y2007	CK50	Definition of Functional Requirements for a MSR Biological Containment Facility	0	0	0	0	C	CH	N/A	
ACP	Y2007	CR10	Mars Surface Sample Transfer / Manipulation	0	0	0	0	C	GB	N/A	
ACP	Y2007	CG70	PRISMA-HARVD Experiment	0	0	0	0	DN	ES	Operational Software	

Removed/replaced activities from previous MREP work plans

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2013	2014	2015	2016				
Phootprint											
MREP-2	N/A	E914-001QI	Sterilisation limits for sample return planetary protection measures	300	1000	0	0			N/A	Replaced by new activities E914-002QI (running) and E914-003QI (for approval for 2015)
MREP-2	N/A	E918-005MP	Characterisation of Phootprint landing site contamination from descent thrusters	0	0	500	0			N/A	Replaced by new proposal for 2015 (E918-010MP)
MREP-2	Y2014	E918-010MP	Phootprint thruster plume and surface interaction testing facility development and thruster characterisation	0	700	500	0			N/A	Replaced by new running TDA (E918-011FT) and proposal for 2016 (E918-012FT)

MPL											
MREP-2	N/A	E905-019EC	Laser Planetary Altimeter Engineering Model	0	0	1500	0			N/A	Covered by running activity in Cosmic Vision
MREP-2	N/A	E905-009EC	Ground Testing of Precision Landing navigation system	0	0	500	0			N/A	Removed until needed (>2016)
MREP-1	Y2011	E915-001MS	Lowering system Breadboard for Mars landers	0	0	500	0			N/A	No mission priority
MREP-2	N/A	E906-009ET	Compact Dual UHF/X-band Proximity-1 Communications Package EQM	0	0	0	2500			N/A	Replaced by new proposal E906-010ET
MREP-2	N/A	E906-010GS	Breadboarding of EDL Ground Receiver	0	0	0	300			N/A	Replaced by new proposal T912-006GS
MREP-2	N/A	E918-009MP	Mars guided entry thruster system to TRL5	0	0	0	1000			N/A	Removed until needed (>2016)
MREP-2	N/A	E919-003MP	Design, development and testing of a throttleable monopropellant engine for soft landing	0	0	0	4000			N/A	Removed until needed (>2016)
INSPIRE											
MREP-2	N/A	E905-005EC	Ground Testing of the EDLS Navigation Chain for small Mars landers	0	0	500	0			N/A	No mission priority
MREP-2	N/A	E919-001MP	Retro Rockets for Mars landing	0	0	0	4000			N/A	No mission priority
MREP-2	N/A	E920-003MS	Airbags for Small Landers: Extended testing of the landing system with a large variety of impact parameters	0	0	1500	0			N/A	No mission priority
MREP-2	N/A	E907-007EE	UHF/X-band back-shell antenna system for Mars entry vehicles	0	0	0	800			N/A	Replaced by new proposal E907-009EE
MSR											
MREP-2	N/A	E905-012EC	End to end ground testing of GNC solution for Autonomous Mars Rendezvous and Capture	0	0	800	0			N/A	Removed until needed (>2016)
MREP-1	Y2011	E905-001EC	Aerobraking Flight Representative Demonstrator	0	0	350	0			N/A	Removed until needed (>2016)
MREP-2	N/A	E906-007ET	Software Defined Radio Proximity-1 Link Communications Package design EQM	0	0	0	2500			N/A	Removed until needed (>2016)
Long term											
MREP-2	N/A	E903-004FP	Nuclear Power Systems architecture study for safety management and fuel encapsulation NPSAFE (phase	0	0	1000	0			N/A	No funding available

			2)								
MREP-2	N/A	E903-007FP	Small-scale RTG development to TRL 5	0	0	1000	0			N/A	Replaced by new proposal T903-015EP
MREP-2	N/A	E903-020FP	Radioisotope Heater Unit development (RHU-DEV1)	0	0	1000	0			N/A	Replaced by new proposal G903-001EP
MREP-2	N/A	E903-005EP	Safety and aggression tests & demonstrations	0	0	0	2000			N/A	Removed until needed (>2016)
MREP-2	N/A	E903-008EP	Thermoelectric converter system for small-scale RTGs (to ~TRL6)	0	0	0	3000			N/A	No funding available
MREP-2	N/A	E903-010EP	Stirling converter development phase 2 to TRL6	0	0	0	3300			N/A	No funding available

All running, approved and proposed activities from MREP-1 and MREP-2 (including TRP, MREP-2 and GSTP)

PHOBOS SAMPLE RETURN

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
MREP-1/MREP-2	Y2011	E915-003MS-B	Breadboard of a sampling tool mechanism for low-gravity bodies	0	0	0	0	C	ES	N/A	Approved 2012 for 750kEuros. First phase of 450 kEuros, completed with AVS (ES). Phase 2 (300k) running as CCN under MREP 2:2 funding.
MREP-2	Y2013	E913-012MM	Sample Acquisition Means for the Phootprint Lander: Experiments and first Realisation (SAMPLER)	1500	0	0	0	C	GB	N/A	Running activity with Airbus (GB) Phased contract (Phase 1, 700kEuros)
MREP-2	Y2013	E905-017EC	Guidance, Navigation, and Control (GNC) for PHOOTPRINT descent and landing	400	0	0	0	C(R)	PL	N/A	Running activity with GMV (PO)
MREP-2	N/A	E905-018EC	Guidance, navigation and control (GNC) maturation for PHOOTPRINT and hardware in the loop (HIL) testing	0	0	0	600	C		N/A	
MREP-2	Y2014	E905-020EC	Vision-based navigation camera EM for PHOOTPRINT including image processing	0	1000	0	0	C		N/A	
MREP-2	Y2013	E920-005MS	Phootprint Landing Gear System to TRL5 (PLanGS)	1500	0	0	0	C(2)		N/A	Intended phased contract (Phase 1, 400kEuros)
MREP-2	Y2013	E913-013MM	Robotically-Enhanced Surface Touchdown (REST)	430	0	0	0	C(1)	RO	N/A	Running activity with GMV (RO)
MREP-2	N/A	E913-014MM	Robotically-Enhanced Surface Touchdown - RAise In TRL (RESTRAINT)	0	0	0	800	C		N/A	
TRP	N/A	T906-001ET	Next generation uplink coding techniques	450	0	0	0	C	PT	N/A	Running activity with Deimos (PT)
MREP-2	N/A	E906-006ET	Next generation uplink coding techniques - Validation, Implementation and System Roll-Out	0	0	0	800	C		N/A	
MREP-2	Y2014	E914-002QI	Feasibility studies and tests to determine the Sterilisation limits for sample return planetary protection measures	450	0	0	0	DN/S	GB	N/A	Running activity with Open University (GB)
MREP-2	Y2014	E914-003QI	Testing of sterilisation limits for sample return planetary protection measures	0	850	0	0	DN/C	GB	N/A	Intended as a CCN to E914-002QI. Original contract value: 450kEuros.
MREP-2	Y2015	E918-011FT	Phobos regolith assessment and thruster plume-surface interaction modeling	0	100	0	0	DN/S	GB	N/A	Initiated in mid-2015. Running activity with Fluid Gravity (GB)
MREP-	IPC	E918-012FT	Phobos Sample Return thruster plume and plume-surface	0	0	700	0	DN/C	GB	N/A	DN with Fluid Gravity (GB) and using

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2014	2015	2016	2017	PP	C'try	SW Clause applicab.	Remarks
2/TRP			interaction characterisation								DLR facilities (TRP budget). Co-funded 350kE:350kE between ETP:TRP. This activity replaces previously approved activity E918-010MP Intended as a CCN to E918-011FT.
MREP-2	Y2014	E907-008EE	Separable X-band waveguide-based low gain antenna	0	450	0	0	C		N/A	
TRP	N/A	T924-004MT	Evaluation of heatshield CFRP and bonding materials to increased temperature limits	0	400	0	0	C		N/A	
TRP	Y2013	T921-004MT	Development of a rigid conformal ablator for extreme heat flux applications	400	0	0	0	DN/S		N/A	
MREP-2	Y2013	E918-003MP	ERC dynamic stability via balloon drop tests	1000	0	0	0	C	GB	N/A	Running activity with Vorticity (GB)
MREP-2	N/A	E920-004MS	Design, development and verification of a full scale Earth Return Capsule for Phootprint	0	0	0	1800	C		N/A	
MREP-2	Y2014	E906-011FP	ERC RF recovery beacon breadboard	0	400	0	0	C		N/A	
MREP-2	Y2014	E915-007FT	Evaluation of sealing systems for a Phobos Sample Return Mission	245	0	0	0	DN/S		N/A	Running activity with Comoti (RO) as Special Measure to RO.
MREP-2	Y2014	E915-008FI	Breadboard of a sample securing system for a Phobos Sample return Mission	0	700	0	0	DN/C		N/A	Intended as a CCN to E915-007FT
Total Phobos Sample Return				**6375**	**3900**	**700**	**4000**				

MPL

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2014	2015	2016	2017	PP	C'try	SW Clause applicab.	Remarks
MREP-2	IPC	E905-023FM	Validation of the EAGLE simulator tool	0	0	500	0	C		N/A	Competition restricted to the GB
TRP	Y2011	T904-001EE	Extension and validation of Mars atmospheric and dust environment models	0	0	0	0	DN/C	FR	N/A	Approved 2011 for 150kEuros. Running activity with LMD (FR). CCN of 75kEuros contracted in 2014.
GSTP	N/A	G619-003EE	Maintenance of the European Mars Climate Database	0	0	300	0	DN/C		N/A	Proposed to GSTP
TRP	Y2011	T905-014EC	European IMU breadboard	0	0	0	0	C	FR	N/A	Approved 2011 for 800kEuros. Running activity with Airbus (FR).

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
MREP-2	Y2014	E905-015EC	European IMU EM	0	2000	0	0	DN/C		N/A	
MREP-2	Y2013	E905-021EC	Stand Alone 3 Axis European Accelometer Unit	500	0	0	0	C(1)	GB	N/A	Running activity with TAS-UK (GB)
MREP-2	Y2015	E905-022EC	AVoidance algorithms Extended development and Realistic Testing (AVERT)	0	750	0	0	DN/C		N/A	Follow-on MREP-2 activity for Portugal. Comprised of 400kEuros from MREP-2, 250kEuros from the SME budget for Portugal and 100kEuros from the SME budget for Greece.
MREP-2	N/A	E916-003MM	MSR Precision landing hazard avoidance sensor adaptation - Engineering Model	0	0	0	1000	C		N/A	
TRP	N/A	T916-004MM	Compressive Sensing Technologies for compact LIDAR systems	475	0	0	0	C(3)	CH	N/A	Running activity with CSEM (CH)
GSTP	Y2014	G619-007MP	Supersonic parachute test on a MAXUS flight	500	0	0	0	C		N/A	Proposed to GSTP
TRP	N/A	T906-008ET	Entry, Descent and Landing Communications technology assessment	350	0	0	0	C	IT	N/A	Running activity with TAS-I (I)
MREP-2	Y2014	E906-010ET	Compact Dual UHF/X-band Proximity-1 Communications Package breadboard	0	1000	0	0	C		N/A	
MREP-2	N/A	E907-009EE	Conformal antenna system for Planetary Entry probes	0	0	0	500	C		N/A	
TRP	N/A	T906-014GS	Same Beam TT&C systems for MSPA and improved navigation: Architecture definition and breadboarding of critical components	0	0	0	500	C		N/A	
TRP	N/A	T906-012ET	CDMA Implementation for TT&C and Precision Navigation	0	400	0	0	C		N/A	.
MREP-2	N/A	E906-013ET	EM development - CDMA for TTC and RadioScience	0	0	0	1500	C		N/A	
TRP	N/A	T912-006GS	Breadboarding of EDL Ground Receiver	0	0	0	300	C		N/A	
MREP-2	Y2013	E918-008MP	Preliminary design and performance verification of critical elements for guided entry thrusters	800	0	0	0	C		N/A	
TRP	Y2011	T919-001MP	Integrated throttleable valve and engine development for Mars landings	650	0	0	0	C		N/A	
TRP	Y2014	T918-006MP	Standard kinetic models for CO2 dissociating flows	0	500	0	0	DN/S	PT	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
TRP	N/A	T903-016EP	Adaptation of next generation commercial solar array technology to exploration missions	0	100	0	0	DN/S		N/A	
TRP	N/A	T903-016EP-B	Adaptation of next generation commercial solar array technology to exploration missions	0	100	0	0	DN/S		N/A	
Total MPL				**3275**	**4850**	**800**	**3800**				

SFR Robotics and Mechanisms

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
MREP-2	IPC	E913-016FT	Exomars-like rover and science operations simulation through field-trials.	0	0	1000	0	DN/S	GB	N/A	DN with Airbus (GB)
TRP	N/A	T913-011MM	Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT (COMPASS)	200	0	0	0	DN/S	ES	N/A	Running activity with GMV (ES)
TRP	Y2010	T913-003MM	DExtrous LIghtweight Arm for exploratioN (DELIAN)	0	0	0	0	C	IT	N/A	Approved 2010 for 800kEuros. Running activity with Selex-Galileo (IT).
TRP	Y2011	T913-008MM	Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)	0	0	0	0	C(1)	GB	N/A	Approved 2011 for 450kEuros. Running with MagnaParva (GB).
TRP	N/A	T913-008MM-B	Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)	0	0	0	0	C(1)	GR	N/A	Approved 2011 for 450kEuros. Running activity with HTR (GR).
MREP-2	N/A	E913-015MM	Solar-Panel Or Thermal-radiator cLEaning Sub System (SPOTLESS)	0	0	0	1200	C(1)		N/A	
MREP-1	Y2010	E915-002MS	Mechanisms technologies that operate at very low temperatures	0	0	0	0	C	IT	N/A	Approved 2010 for 475kEuros. Running activity with Tecnomare (IT).
MREP-2	Y2013	E915-004FP	Mechanisms Technologies that operate at very low temperatures (Extended test campaign) - CCN	350	0	0	0	DN/C	AT	N/A	Running activity with Tecnomare (IT) and AAC (AT).
MREP-2	N/A	E921-006MT	Advanced Thermal Architecture for Mars Environment	0	0	0	1000	C		N/A	
MREP-2	Y2013	E901-003ED	Miniaturized Integrated Avionics for planetary landers	500	1000	0	0	C(2)	SE	N/A	Running activity with RUAG (SE).
TRP	N/A	T903-012EP	Solar Power Regulator Breadboard for Mars Surface Missions	300	0	0	0	C	PT	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2014	2015	2016	2017	PP	C'try	SW Clause applicab.	Remarks
MREP-2	Y2009	E903-013EP	Development of a low temperature Lithium ion battery and survivability tests	0	0	0	0	C(1)	GB	N/A	Approved 2009 for 450kEuros. MREP-1 activity completed with ABSL (GB). CCN (22kEuros) under MREP-2 placed in Dec 2014.
MREP-2	Y2014	E915-006FT	Feasibility study of a plasma drill for Mars exploration (PLASMARS)	245	0	0	0	DN/S	NO	N/A	Running activity with Zaptec (NO) as Special Measure to NO.
MREP-2	Y2014	E915-009FT	Breadboarding and testing of a plasma drill for Mars exploration (PLASMARS-2)	0	500	0	0	DN/C	NO	N/A	Intended as a CCN to E915-006FT. Original contract value: 245kEuros.
Total SFR Robotics and Mechanisms				**1595**	**1500**	**0**	**2200**				

INSPIRE

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2014	2015	2016	2017	PP	C'try	SW Clause applicab.	Remarks
TRP	Y2010	T921-001QE	Adaptation of Aerogel Materials for thermal insulation	0	0	0	0	C(1)	PT	N/A	Approved 2010 for 300k. Running activity with AST (PT).
MREP-2	Y2012	E918-001MP	Subsonic parachute trade-off and testing - CCN	0	0	0	0	DN/C	GB	N/A	Approved 2012 for 350kEuros. First phase (130k) funded under MREP-1 and completed with Vorticity (GB). Phase 2 (220k) to be funded by TRP (175kEuros) and MREP-2 (45k).
Total INSPIRE				**0**	**0**	**0**	**0**				

MSR

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget 2014	2015	2016	2017	PP	C'try	SW Clause applicab.	Remarks
MREP-2	Y2013	E914-004QI	Biosealing and Monitoring Technologies for a Sample Containment System - Sealing tests and EM design	1000	0	0	0	DN/C	IT	N/A	Running activity with Selex Galileo (IT)
MREP-2	N/A	E914-005QI	Biosealing and Monitoring Technologies for a Sample Containment System - EM development and testing	0	0	0	2000	DN/C	IT	N/A	
MREP-	Y2014	E914-005MM	MSR Double walled isolators - breadboard	0	800	0	0	DN/C	GB	N/A	

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
2											
MREP-2	Y2013	E913-010MM	Manipulation systems for sample handling in a Sample Receiving Facility	0	300	700	0	C(1)		N/A	
MREP-2	Y2014	E906-005ET	RF Long-Range Navigation Sensor further breadboarding and EM detailed design	0	800	0	0	C(R)		N/A	Competition restricted to Spain
TRP	N/A	T912-001GS	Improvement of Delta DOR performances for 1 nrad accuracy for precise landing support	250	0	0	0	C	IT	N/A	Running activity with Sapienza Uni (IT)
TRP	N/A	T916-003MM	Planetary communication system based on modulated retro-reflection	300	0	0	0	C	GB	N/A	Running activity with Qinetiq (GB)
TRP	N/A	T916-003MM-B	Planetary communication system based on modulated retro-reflection	300	0	0	0	C	CH	N/A	Running activity with Synopta (CH)
TRP	N/A	T904-003EE	Enhanced interplanetary meteoroid population model	0	300	0	0	DN/C		N/A	
MREP-2	Y2014	E920-006FT	Breadboard and test of a multi-layered debris shield for MSR	245	0	0	0	DN/S	RO	N/A	
MREP-2	Y2014	E904-004FP	Micro Meteorids and Orbital Debris (MMOD) impacts characterisation and protection for the MSR Earth Re-entry Capsule (ERC)	0	700	0	0	C		N/A	
TRP	Y2010	T919-036MC	Design of a crushable TPS for the ERC	0	0	0	0	C	FR	N/A	Approved 2010 for 370kEuros. Running activity with MECANO (F).
TRP	Y2010	T920-002QT	Material development for a crushable TPS for the ERC	0	0	0	0	C	GB	N/A	Approved 2010 for 350kEuros. Running activity with Magna Parva (GB).
GSTP	N/A	G619-009MT	Ablative TPS Numerical Test Cases - Mathematical Code Assessment & Improvement	0	0	300	0	C		N/A	Proposed to GSTP
TRP	N/A	T921-005MT	Deployable & Inflatable Heatshield & Hypersonic Decelerator Concepts - Phase 1	400	0	0	0	C		N/A	
TRP	Y2013	T918-004MP	Catalytic properties of Ablators	0	0	0	0	C	BE	N/A	Running activity with VKI (BE)
TRP	N/A	T906-002ET	Software Defined Radio Proximity-1 Link Communications Package design Study	0	0	0	0	C	LU	N/A	Running activity with EMTronix (LU)
TRP	Y2013	T912-005GS	X-Band cryogenic feed prototyping	0	600	0	0	C(1)	FR	N/A	Running activity with Callisto (FR)
MREP-2	Y2013	E904-005EE	Modelling of the Mars Environment for Future Missions	400	0	0	0	C(2)	GB	N/A	Running activity with STFC (GB)
MREP-2	Y2013	E908-001FP	Harwell Robotics Autonomy Facility (HRAF) - Pilot project 1	0	0	0	0	DN/C	GB	N/A	Running activity with Scisys (GB)

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
MREP-2	Y2014	E908-002FP	Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 2	0	1500	0	0	C(R)	GB	N/A	
MREP-2	Y2014	E908-003FP	Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 3	0	1500	0	0	C(R)	GB	N/A	
TRP	Y2014	T903-017EP	Configurable and Compact isolated DCDC-converter (CC-DCDC)	0	500	0	0	C		N/A	
TRP	N/A	T919-013MP	Assessment of high performance green propellants	0	150	0	0	C		N/A	
MREP-2	Y2014	E926-002FM	Starting a Sample Analogue Collection for future Exploration missions - Phase 2	0	550	0	0	DN/C	GB	N/A	Running activity with the Natural History Museum (GB)
MREP-2	IPC	E926-003FM	Starting a Sample Analogue Curation Facility for Future Exploration Missions	0	0	1200	0	DN/S	GB	N/A	DN with NHM (GB)
Total MSR				**2895**	**7700**	**2200**	**2000**				

Long Term

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2014	2015	2016	2017				
MREP-2	IPC	E919-012MP	Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)	3545	0	2500	0	DN/C	GB	N/A	DN with Moog (GB). Phase 2b is intended as a CCN to the running Phase 2a contract. Phase 2a (3545kEuros) contracted in 2014, which includes 500k STRIN (IE) and 37k GSTP (IE). Total MREP-2 for Phase2a only 3008kEuros.
MREP-2	Y2013	E903-015EP	European Isotope Production Phase 2	0	0	0	0	DN/C	GB	N/A	Running activity with NNL (GB).
MREP-1	Y2009	E903-009EP	Stirling Converter Technology Development phase 1	0	0	0	0	C	GB	N/A	Approved 2009 for 2000kEuros. Running activity with SEA (GB).
TRP	Y2014	T903-015EP	Small-scale RTG Development to TRL 4	0	500	0	0	DN/C	GB	N/A	
GSTP	Y2015	G619-012EP	Radioisotope Heater Unit Prototype Development	0	300	0	0			N/A	
Total Long Term				**3545**	**800**	**2500**	**0**				

Full descriptions of ESA MREP-2 Programme Technology Development Activities

Phobos Sample Return

Breadboard of a sampling tool mechanism for low-gravity bodies					
Programme:	ETP		**Reference:**	E915-003MS-B	
Title:	Breadboard of a sampling tool mechanism for low-gravity bodies				
Total Budget:	750				
Objectives					
Design Modeling, Breadboarding and validation of a sampling tool in order to reduce the risk related to the very unknown nature of asteroids' surfaces which are targets of future science and exploration mission candidates (Phobos/Deimos sample return, asteroid sample return)					
Description					
In future exploration missions (e.g. of a Mars moon or a near-Earth asteroid) it is planned to collect tens of grams of regolith (dust but also cm-sized stones) and return them to Earth for further ground-based analysis. Several sampling tools (samplers) have been proposed, such as a rotating corer (as baselined in the previous Marco Polo assessment study) or counter-rotating brushes (as proposed in the new MarcoPolo-R science mission proposal for Cosmic-Vision M3). For the exploration mission candidate Phobos/Deimos sample return, a sampler identical to the one that will be used in MarcoPolo-R can be assumed as the requirements are almost identical in terms of mass and type of soil to be collected. There is no single sampling technology for low-gravity bodies that has undergone a rigorous engineering assessment, aiming at proving the ability of the sampler to collect material in any envisaged situation. This is the purpose of the subject activity. Phase 1 of this activity shall consist of: 1) refinement of the requirement specifications produced in ESA CDF studies, 2) trade-off of possible sampling concepts and preliminary design of the two best candidate sampling systems 3) dynamic modelling of soil-sampler interaction (considering micro-g level and composite soil expected for Asteroid/ Phobos/Deimos) to perform sensitivity analyses to different soil physical characteristics 4) detailed design of the best performing sampler and definition of test campaign/equipment 5) breadboarding of the best performing sampler and production of test equipment 6) ground testing The nature of the soil on asteroids is poorly known so a laboratory (ground) testing campaign which covers a large range of soil simulants with various soil properties (in terms of compressive strength, density, grain size, shape, cohesiveness) shall be undertaken in adequate environmental conditions. Phase 2 of this activity shall consist of: 1) Parabolic flight testing 2) Additional modifications to the breadboard if required The proposed technology development shall allow assessing: - the amount of collected sample as a function of soil properties, - the type of sample that can be realistically collected, - the resulting forces and torques induced on the spacecraft, - the most suitable interface with the transfer system, - the extent of cross-contamination in case of multiple sampling. Note. 1. It is not foreseen to perform the detailed design or breadboarding of the transfer and containment system, but the constraints/interfaces associated to it will strongly be taken into account when producing the design of the sampling tool itself.					
Deliverables					
Breadboard, Design justification file, tests results					
Current TRL:	2	**Target TRL:**	4/5	**Application Need/Date:**	TRL 5 by 2014
Application Mission:	Moon of mars sample return		**Contract Duration:**	21	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Sample Acquisition Means for the Phootprint Lander: Experiments and first Realisation (SAMPLER)			
Programme:	ETP	**Reference:**	E913-012MM
Title:	Sample Acquisition Means for the Phootprint Lander: Experiments and first Realisation (SAMPLER)		
Total Budget:	1500		

Objectives

The activity addresses the robotic sampling operation of the PHOOTPRINT mission. The activity shall 1) experimentally assess the detailed requirements of the sampling operation 2) specify, 3) design, 4) realise and 5) test (in relevant environment) a breadboard of
the operation.

Description

Background:

Sampling operations in low-gravity (as on Phobos) for extended time (as in the case of PHOOTPRINT) are poorly understood. The dynamic motion induced by the sampling operation (to be expected in a non-homogeneous material) couples with the dynamic properties of the lander, its legs and even thrust or anchoring mechanism. For the total system to remain stable and for the sampling tool to effectively sample the surface, the total dynamic motion must be damped significantly. Possible provisions for damping dynamics can be realised on the sampling-tool, on the arm and on the lander. However these provide different performance and imply different costs. Experiments on the whole sampling operation are needed to ascertain the need/extent/implementation of damping provisions in the sampling chain (arm and sampling tool).

Programme of work: The programme of work is divided in two phases that deliver products and results with incremental TRL. The first phase intends to increase the understanding of the dynamic behavior of the sampling chain by delivering a simulator, validated through tests.
In the second phase the focus shifts into the development of high fidelity breadboard of the complete sampling chain and its demonstration trough test.

- Phase 1
i. Requirements specification
ii. Design of a number of sampling-tools as well as sampling strategies. Realisation of breadboards of the chosen tools.
iii. Design and development of a parametric test campaign (using an air bearing table) for testing the chosen sampling tools/strategies with a range of representative soil analogues.
iv. Development of dynamic model and related simulator
v. Execution of the test campaign and correlation of the test data with the model produced at iv.

- Phase 2
i. Trade-off and design the complete sampling chain (supported by the validated simulator).
ii. Develop a real-scale breadboard of the sampling chain, a mockup of platform with representative dynamics and a test environment to exercise them. The test environment shall allow testing of the breadboard against different soil types.
iii. Perform tests
iv. Evaluate results from the tests

Deliverables

- Project documentation
- Mathematical model/simulator
- Breadboards
- Software
- Test rig
- Data archive containing both raw and processed data from all tests

Current TRL:	1	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	Phootprint		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-9012	

Consistency with Harmonisation Roadmap and conclusion:

The activity was not addressed by the 2012 harmonisation exercise on A&R, as the PHOOTPRINT mission had not yet been manifested

Guidance, Navigation, and Control (GNC) for PHOOTPRINT descent and landing			
Programme:	ETP	**Reference:**	E905-017EC
Title:	Guidance, Navigation, and Control (GNC) for PHOOTPRINT descent and landing		
Total Budget:	400		

Objectives					
The objective of the activity is to design and develop the GNC for PHOOTPRINT up to TRL 4. This shall include the mission vehicle management (MVM) and the FDIR for the PHOOTPRINT mission with Model In the Loop (MIL) full testing, and preliminary real time checks on a Processor in the Loop (PIL) environment.					
Description					
The aim of the activity is to design and develop the critical GNC algorithms needed for the PHOOTPRINT mission during proximity operations, descent, landing and departure. Moreover, in this activity it shall be defined the mission vehicle management (MVM) for this PHOOTPRINT mission taking into account the GNC system, the operating modes and the Failure Detection, Isolation and Recovery (FDIR) system. The MVM is responsible for selecting the GNC modes providing scheduling service and FDIR functionalities. The system shall be robust to safely achieve the required performances in the presence of possibly large uncertainties. The following tasks shall be performed: - Consolidation of functional, operational, performance and environment requirements for the PHOOTPRINT mission taking into account the mission objectives and constraints. - Definition of the GNC architecture, including sensor suite trade-off. - Detailed analysis and definition of the GNC algorithms, including MVM, FDIR. - Implementation of a Model In the Loop simulator with the complete GNC system architecture, FDIR and MVM. - Validation of the simulator and performance tests for the PHOOTPRINT landing. - Update of PANGU for the specific case of the PHOOTPRINT mission. - Implementation of the modification of the MIL to perform autocoding for the PIL - Implementation of a Processor In the Loop in a RASTA-like environment: test bench consisting on the assembly of the modified MIL and a flight representative motherboard. - GNC verification and validation with the PIL.					
Deliverables					
- Technical notes - Model in the loop simulator, including the GNC, MVM, and FDIR - Processor in the loop test bench software					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2015
Application Mission:	PHOOTPRINT		**Contract Duration:**	15	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Guidance, navigation and control (GNC) maturation for PHOOTPRINT and hardware in the loop (HIL) testing			
Programme:	ETP	**Reference:**	E905-018EC
Title:	Guidance, navigation and control (GNC) maturation for PHOOTPRINT and hardware in the loop (HIL) testing		
Total Budget:	600		
Objectives			
The objective of this activity is to maturate the GNC for PHOOTPRINT (coming from a previous activity) and test it in a close loop control in hardware in the loop (HIL) environment. In particular, this test-bed shall use of a robotic test bench to fully test the PHOOTPRINT proximity operations, including descent, landing in closed loop control.			
Description			
For the real-time validation and verification of a GNC system it is required to test the GNC design in a closed loop real-time simulation with sensor hardware in the loop and a representative test bed environment with robot arms and translation devices. This tests will allow to understand the interaction of sensors in the complete GNC subsystem, measure the processing times to gather data from sensors and understand the overall GNC response to failures including sensors in the loop. This acitivity shall, first of all, consolidate and mature the GNC design for PHOOTPRINT Entry, Descent, Landing and Departure (coming from a preceding activity) including the Mission Vehicle management (MVM) and the Failure Detection, Isolation and Recovery (FDIR). Moreover this activity shall test the GNC for PHOOTPRINT in a real-time environment aiming to fully validate and verify the Entry, Descent and Landing mission arcs in European facilities. This end-to-end GNC test benching shall include all navigation sensors (including hardware), the guidance algorithms, and the control loops. The test bench shall consist of the assembly of a processor in the loop (PIL) and the flight representative set of sensors to form a closed loop controlled system. The ability to simulate failure injection and contingency operations shall be covered in the scope of			

this test environment. The PIL to be assembled in the HIL shall be taken from previous development activities (MREP2 "GNC for PHOOTPRINT descent and landing"). In the frame of this activity the following tasks shall be performed: - Consolidation and maturation of the GNC design including the MVM and the FDIR for PHOOTPRINT Entry, Descent, Landing and Departure. - In-depth analysis and selection of the most suitable European facility and detailed evaluation of its suitability for the planned mission, including the feasibility of both real-size and scaled-down simulations. - If needed, the selected facility shall be upgraded and validatied. - Definition and development of a real-time test bench (HIL) to be used for GNC verification and validation. - On the base of previous development activities, the test bench shall allow for tetsing the GNC, the Mission Vehicle Manager (MVM), and the FDIR in the end-to-end test-bed. - Functional and performance validation of the GNC, MVM, and FDIR in the real-time facility.					
Deliverables					
GNC maturation GNC, MVM, and FDIR End-to-End tesing. Full technical documentation shall be delivered, covering software specifications, architecture, design and justification, testing, verification, and validation					
Current TRL:	4	**Target TRL:**	6	**Application Need/Date:**	2017
Application Mission:	PHOOTPRINT		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Vision-based navigation camera EM for PHOOTPRINT including image processing					
Programme:	ETP		**Reference:**	E905-020EC	
Title:	Vision-based navigation camera EM for PHOOTPRINT including image processing				
Total Budget:	1000				
Objectives					
The objective of this activity is to develop an engineering model (EM) of a vision-based camera for PHOOTPRINT. This activity shall also include the image processing algorithms.					
Description					
The features of Phobos differ from those in a planetary environment (gravity, regolit composition, orbital environment). The aim of the activity is to adapt existing navigation cameras (NPAL, VisNAV, etc) to meet the needs of the PHOOTPRINT mission in its arc of descent and landing. PHOOTPRINT needs an accurate navigation to correctly guide the spacecraft in its descent and touch-and-go trajectory towards Phobos. Current cameras are being developed for vision-based navigation in planetary entry, descent and landing applications, that can be adapted for the specific case of PHOOTPRINT. The camera shall then be able to perform autonomous vision-based navigation using feature landmark recognition. Image-processing algorithms shall be developed and implemented into a NPAL-like camera to perform vision-based navigation around and towards Phobos. Furthermore the activity shall assess the environment characteristics to which the camera will be subjected for the PHOOTPRINT mission (temperature variations, radiation, vibration environment, contamination,?) and captured in a technical note in the form of requirements to create an EM of the camera. The activity shall be divided in three parts. The first part shall perform: - the incorporation of the requirements created during the design of the GNC for PHOOTPRINT. - the incorporations of the experience and development performed for the NPAL camera - the detailed design, including miniaturisation, of the EM The second part shall consist of building an engineering model of the camera. The third part of the activity shall concentrate on testing the camera to verify its performance in a representative environment.					
Deliverables					
- Full technical documentation (CDR datapackage) shall be delivered, covering software specifications, architecture, design and justification, testing, verification, and validation. - Camera EM					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2017

Application Mission:	PHOOTPRINT	**Contract Duration:**	18
S/W Clause:	N/A	**Reference to ESTER**	T-8071
Consistency with Harmonisation Roadmap and conclusion:			
Yes with AOCS Sensors and Actuators (2009): Optical Navigation Sensors - Aim A: Multi Mission Navigation System with Descent and Landing capability			

Phootprint Landing Gear System to TRL5 (PLanGS)					
Programme:	ETP		**Reference:**	E920-005MS	
Title:	Phootprint Landing Gear System to TRL5 (PLanGS)				
Total Budget:	1500				
Objectives					
The objective is to develop an optimised landing gear system capable of providing safe landing on the surface of Phobos (micro-gravity conditions) and ensuring the required attitude and stability to allow surface operations (i.e. sample acquisition and robotic arm motion).					
Description					
In the context of the Phootprint mission, the landing phase of its lander of 1000 to 1500kg (with CoG at 1m above the base of the S/C) will end with a free fall without using the braking thrusters, from 15m (TBC) above the surface and with a landing velocities range of <0.6 m/s vertical and < 0.15m/s horizontal. Therefore the landing gear design, including the foot-pad and possibly anchoring system (TBC) and breadboard, needs to be fully representative of the flight system with respect to its dynamic behaviour in the landing configuration for the final touchdown and surface operations. This activity shall also aim at the minimization of the mass of the landing gear system considering the use of CFRP components for the main structural elements (i.e. main and secondary struts) or other lightweight technological solutions. The need of damping of the shock transferred to the spacecraft at touchdown has to be considered in frame of the activity and simple solutions (possibly passive systems such as crushable materials, foams) shall be implemented and validated by test. Moreover, the possibility of implementing load limiting capabilities (i.e. collapsible load limiters) at the interfaces of the landing gear with the spacecraft need to be considered. In the frame of this activity, the functionality of the landing gear system shall also include provisions for deployment, latching and touchdown sensors. The activity will consist on two (2) contractual phases: Phase 1 (400 kEuros, 9 months) with the following main tasks to be implemented - Review of the state of the art of configurations, design solutions and materials; - Analysis of mission/system requirements and definition of the requirements for the landing gear subsystem; - Perform characterisation tests on possible crushable materials and landing pads (the latter for friction coefficient characterisation) - Establish the design concept of the complete landing gear system including all active (e.g. actuators) and passive (e.g. damping systems) solutions and including provisions for sampling handling and operations in micro-gravity conditions; - Establish a dynamic model for landing simulations, using previous characterisation tests results for correlation, and identify by analysis the worst cases among the landing scenarios; - Define the requirements for the manufacturing and validation of a landing gear demonstrator; - Define the demonstrator verification approach considering all the environmental conditions and the relevant operational approaches. Phase 2 (1100 kEuros, 15 months) with the following main tasks to be implemented - Design the landing gear demonstrator on the basis of the requirements and verification approach established during phase 1; - Breadboard manufacturing and verification plan. Establish the test procedures; - Design, manufacturing and assembly of the landing test setup; - Manufacturing of the breadboard components and assembly; - Execution of the landing tests on the demonstrator					
Deliverables					
Demonstrator(s), Dynamic model, and Technical Notes including test Reports					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2016
Application Mission:	Phootprint		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

<table>
<tr><th colspan="6">Robotically-Enhanced Surface Touchdown (REST)</th></tr>
<tr><td>Programme:</td><td colspan="2">ETP</td><td>Reference:</td><td colspan="2">E913-013MM</td></tr>
<tr><td>Title:</td><td colspan="5">Robotically-Enhanced Surface Touchdown (REST)</td></tr>
<tr><td>Total Budget:</td><td colspan="5">430</td></tr>
<tr><td colspan="6">Objectives</td></tr>
<tr><td colspan="6">Develop a prototype of an actively compliant landing gear for low-G environment using robotics derived technology</td></tr>
<tr><td colspan="6">Description</td></tr>
<tr><td colspan="6">Background:
Landing in low-g environments provides for some difficult issues for conventional landing gears but also for opportunity to implement smarter and more flexible landing gears. Essentially the issues are related to the possibility of rebounding due to the residual elasticity of the landing gear (which is impossible to eliminate completely), and the difficulty of leveling the platform once lading is achieved. The opportunities come from the fact that impact/settling forces and velocities during landing are minimal and hence compatible with the capabilities of electromagnetic actuators. Therefore it is possible to conceive an active landing gear that uses linear (or rotational) DC brushless motors to implement 1) deployment of the landing legs, 2) impedence-controlled absorption of the impact/settling forces and compensation of residual elasticity, 3) re-levelling of the lander platform, 4) rejection of vibration induced by sampling devices. To note, the use of impedence-control schemes for brushless DC motors is common in robotics in order to allow robotic joints to simulate virtual mechanical properties (i.e mass, damping and elasticity). The use of motor-driven absorption of forces at landing is not new: the PHILAE lander in the ROSETTA mission uses a capstan actuator

Programme of work:
1) requirement definition
2) design of prototype
3) manufacturing and assembly 4) test on air bearing table
5) closure</td></tr>
<tr><td colspan="6">Deliverables</td></tr>
<tr><td colspan="6">? standard project documentation
? technical notes,
? prototype hardware
? videos</td></tr>
<tr><td>Current TRL:</td><td>1</td><td>Target TRL:</td><td>3/4</td><td>Application Need/Date:</td><td>2015</td></tr>
<tr><td>Application Mission:</td><td colspan="2">PHOOTPRINT,</td><td>Contract Duration:</td><td colspan="2">18</td></tr>
<tr><td>S/W Clause:</td><td colspan="2">N/A</td><td>Reference to ESTER</td><td colspan="2">T-8937</td></tr>
<tr><td colspan="6">Consistency with Harmonisation Roadmap and conclusion:</td></tr>
<tr><td colspan="6">The activity was not addressed by the 2012 harmonisation exercise on A&R. To be noted the PHOOTPRINT mission at that time was not manifested yet.</td></tr>
</table>

<table>
<tr><th colspan="4">Robotically-Enhanced Surface Touchdown - RAise In TRL (RESTRAINT)</th></tr>
<tr><td>Programme:</td><td>ETP</td><td>Reference:</td><td>E913-014MM</td></tr>
<tr><td>Title:</td><td colspan="3">Robotically-Enhanced Surface Touchdown - RAise In TRL (RESTRAINT)</td></tr>
<tr><td>Total Budget:</td><td colspan="3">800</td></tr>
<tr><td colspan="4">Objectives</td></tr>
<tr><td colspan="4">Increase the readiness level (up to TRL5) of an actively compliant landing gear for low-G environment</td></tr>
<tr><td colspan="4">Description</td></tr>
<tr><td colspan="4">Background
The Robotically-Enhanced Surface Touchdown (REST) activity, aims at the implementation of an active landing gear that by means of a smart actuator system can perform 1) deployment of the landing legs, 2) impedence-controlled absorption of the impact/settling forces and compensation of residual elasticity, 3) re-levelling of the lander platform, 4) rejection of vibration induced by sampling devices. The REST activity will produce a prototype of such landing gear, just implementing (and testing experimentally) critical functions and other characteristics for an initial proof-of-concept (TRL3)

The RESTRAINT activity shall continue the development of the active landing gear so that at the end of it a landing gear breadboard will be validated in a relevant environment (TRL 5).

Programme of work:
1) requirement definition</td></tr>
</table>

2) design of prototype 3) manufacturing and assembly 4) test in relevant environment 5) closure					
Deliverables					
- standard project documentation - technical notes, - prototype hardware - videos					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2015
Application Mission:	PHOOTPRINT		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8937	
Consistency with Harmonisation Roadmap and conclusion:					
The activity was not addressed by the 2012 harmonisation exercise on A&R. To be noted the PHOOTPRINT mission at that time was not manifested yet.					

Next generation uplink coding techniques					
Programme:	TRP		**Reference:**	T906-001ET	
Title:	Next generation uplink coding techniques				
Total Budget:	450				
Objectives					
For exploration missions, powerful coding techniques need to be studied in order to enable high rate communication uplinks directly from Earth as well as to extend the supported maximum distance, despite the constraint of limited received power. In the frame of CCSDS NASA has already proposed some techniques to this purpose. Current constraints seen by exploration missions, such as the need to ensure commanding at distances up to 2.7 AU, make the introduction of new uplink coding techniques a must.					
Description					
A system study is required to assess the impact of different coding techniques for the TC uplink of exploration missions, in order to enable the use of high rate uplink directly from Earth as well as to extend the supported maximum distance, particularly for emergency situations. As seen in current Mars Robotic Exploration missions under study or preparation, spacecraft commanding through the LGA (Low Gain Antenna) can be rather challenging, once distances of up to 2.7 AU are considered and reliance of the NASA 70m ground station antenna cannot be assumed any longer. The use of uplink coding, possibly in combination with low data rates (7.8 bps or lower), will provide the additional margin needed to ensure commanding for these challenging scenarios. At the same time, new coding techniques are expected to mitigate to a great extent the problems due to the introduction of higher uplink data rates, dictated by payload calibration as well as operational needs, i.e. use of CFDP with high rate telemetry downlink, which poses serious constraints to the designers. This is even more critical once fail safe RFDU architectures are employed where switches in the receiver chain are replaced by 3-dB hybrids. The study should first consider coding techniques already proposed in the frame of CCSDS, i.e. LDPC codes, and to investigate other alternative coding schemes, including non-binary codes. Besides other figure of merits, the undetected error performance will be prominent in the assessment and decoding algorithms suitable to maintain low undetected errors will be implemented. The study shall assess the impact of the new coding techniques towards higher layer protocols, i.e. TC or AOS, as well as towards the physical layer, i.e. the impact on the demodulator due to the lower SNR allowed by the coding gain. Finally, the study shall address the impact on the architecture of the overall O/B receiver, considering in particular the complexity, power consumption and flexibility required. Suitable decoding algorithms will be studied, proposing the relevant trade-offs between performance and O/B resource utilization. A bread-board shall complete the activity, in order to minimize the risk for future missions adopting the new coding techniques, as well as to promote such techniques in the proper standardization bodies, e.g. CCSDS and ECSS. This activity is highly relevant to the associated ETP activity entitled "Compact Dual UHF/X-band Proximity-1 Communication EQM".					
Deliverables					
End to end system study on next generation uplink coding for Mars exploration missions and a hardware proof of concept (breadboard).					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2022-2024

Application Mission:	MSR, INSPIRE, PHOOTPRINT	**Contract Duration:**	14
S/W Clause:	N/A	**Reference to ESTER**	N/A
Consistency with Harmonisation Roadmap and conclusion:			
Harmonization Dossier "TT&C Transponders and Payload Data Transmitters," 2012			

Next generation uplink coding techniques - Validation, Implementation and System Roll-Out			
Programme:	ETP	**Reference:**	E906-006ET
Title:	Next generation uplink coding techniques - Validation, Implementation and System Roll-Out		
Total Budget:	800		
Objectives			
For exploration missions, powerful coding techniques are needed in order to enable high rate communication uplinks directly from Earth as well as to extend the supported maximum distance. Current constraints seen by Mars missions, such as the need to ensure commanding at very high distances (up to 2.7 AU) and for emergency communications make the introduction of new uplink coding techniques and the corrensponding adaptation of the spacecraft receiver a mission driver. An End-to-End validation in a realistic operational environment shall be conducted as part of this activty.			
Description			
A previous TRP activity will have completed the associated system study in order to assess the impact of different coding techniques for the uplink of exploration missions in order to enable the use of high rate uplink directly from Earth as well as to extend the supported maximum distance. As seen in current Mars Robotic Exploration missions under study or preparation, spacecraft commanding through the LGA (Low Gain Antenna) can be rather challenging, particularly at the max Earth-Mars distance 2.7 AU are considered. The use of uplink coding, possibly in combination with low data rates (7.8 bps or lower) will provide the additional margin needed to ensure spacecraft commanding for these challenging scenarios which have a very low signal to noise ratio. This ETP activity will take the results from the previous TRP activity and define the operational implementation and Sytem Roll-out aspects in a consolidated way. The previous TRP study will have selected and validated the most appropriate TC uplink codes for operational useage. This ETP activity will then optimise the algorithms, trade-off architectural implementations to be used for both the ground segment and the space segment and build and validate the end to end system demonstrator based on representative ground station assets (e.g. Mission Control System) and flight representaitve TT&C receivers and TC uplink decoding units. The TC uplink decoding blocks could reside within either the TT&C unit/receiver itself or in the O/B data handling unit, depending upon the mission scenario. The selected detailed implementation shall address the impact on the architecture of the overall O/B receiver by considering in particular the complexity, power consumption, reliability and flexibility. The activity shall also define a roadmap and phased schedule for implementing the TC uplink codes in the ESOC ground stations and any associated delta developments required for the on-board TT&C/ data handling subsystems. An End-to-end validation of TC upling encoding and decoding in a realistic environment shall be conducted by making use of representative ground segment and TT&C flight representative assets.			
Deliverables			
Technical Notes, End to end system validation of TC uplink coding for high data rate uplinks, Roadmap for operational implementation.			

Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2018

Application Mission:	INSPIRE, PHOOTPRINT, MSR	**Contract Duration:**	24
S/W Clause:	N/A	**Reference to ESTER**	T-7725
Consistency with Harmonisation Roadmap and conclusion:			

Feasibility studies and tests to determine the Sterilisation limits for sample return planetary protection measures			
Programme:	ETP	**Reference:**	E914-002QI
Title:	Feasibility studies and tests to determine the Sterilisation limits for sample return planetary protection measures		
Total Budget:	450		
Objectives			
The objective of this activity is to perform feasibility studies and tests to allow the later production of a test dataset in order to			

derive sterilisation limits (i.e. heat, radiation, pressure) for backward planetary protection measures essential to support MSR mission studies (e.g., MSR-O and ERC) and related technology developments (e.g., containment system) and to confirm the Phootprint planetary protection category in light of recent studies indicating substantial material transfer from Mars to Phobos.					
Description					
Backward planetary protection (i.e. protection of the Earth's biosphere from potentially harmful extraterrestrial material) is a key issue for any sample return missions and in particular MSR. Moreover, the Phootprint mission assumption (for planetary Protection) of an unrestricted return needs to be confirmed with relevant tests and analyses. In order to identify the limits of heat, radiation and pressure whereby sterilisation is expected to occur (which impacts, for example, the design of the MSR biosealing system, the earth return capsule etc.), this activity is proposed with the following tasks: 1. Identification and description of representative biological samples based on latest ESF report, 2. identification and characterisation of representative sample preparation and conditioning, including matrix material, for the impact/heat/radiation inactivation tests, 3. identification of material and characterisation of projectile and targets for the hypervelocity impact tests, 4. identification of the criteria for biological inactivation, 5. identification of the test and measurement approach to evaluate the heat and radiation inactivation covering a dynamic range with each method up to and including a SAL-6, 6. identification of the test and measurement approach (produce a test plan), 7. preparation of test equipment (including e.g. high speed cameras), 8. demonstration of the capability of the test facilities to meet all test requirements, 9. identification of the impact/thermal/radiation simulation tools, and demonstration of their capability to meet requirements.					
Deliverables					
1. Description of preparation and characterisation of the samples, projectiles and target materials, 2. description of criteria for biological inactivation, 3. description of experimental set-up for heat/radiation inactivation tests and impact tests, 4. test report demonstrating the capability of the test equipment, 5. simulation report demonstrating the capability of the simulation tools.					
Current TRL:	N/A	**Target TRL:**	N/A	**Application Need/Date:**	Q3 2014
Application Mission:	MSR, Phootprint		**Contract Duration:**	6	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Testing of sterilisation limits for sample return planetary protection measures			
Programme:	ETP	**Reference:**	E914-003QI
Title:	Testing of sterilisation limits for sample return planetary protection measures		
Total Budget:	850		
Objectives			
The objective of this activity is to produce test data in order to derive sterilisation limits (i.e. heat, radiation, pressure) for backward planetary protection measures essential to support MSR mission studies (e.g., MSR-O and ERC) and related technology developments (e.g., containment system) and to confirm the Phootprint planetary protection category in light of recent studies indicating substantial material transfer from Mars to Phobos. After a first activity devoted to feasibility tests (E914-002QI), the objective of this activity is to perform full tests and the simulations campaigns, as well as associated statistical analyses required for Phobos categorisation.			
Description			
Backward planetary protection (i.e. protection of the Earth's biosphere from potentially harmful extraterrestrial material) is a key issue for any sample return missions and in particular MSR. In order to identify the limits of heat, radiation and pressure whereby sterilisation is expected to occur (which impacts, for example, the design of the MSR biosealing system, the earth return capsule etc.), this Phase 2 activity is proposed with the following tasks: 1. Perform inactivation tests using separately heat and gamma radiation in ambient and vacuum environment, 2. Perform hypervelocity impact tests in the velocity range of 0.5- 4.5 km/sec with particles in the micron to millimetre range and a target with a bulk density of 1 g/ccm and a size distribution in the 50-100 micron range, 3. Perform hydrodynamic, thermal and radiation simulations (incl. material modelling), to extrapolate tests results as required", 4. Perform statistical analyses using tests and simulations results in order to verify inactivation limits and Phobos Planetary Protection category.			

The statistical approach shall allow for all tests to achieve a confidence interval in the 95-99% range. Experimental work requires a dedicated heat-kill set-up, a cobalt 60 radiation source with about 2 Gy/sec, a two-stage light gas gun facility and capabilities for handling and preparing biological samples (microbes, viruses and phages) and geological samples.					
Deliverables					
TRRs, test reports for the different tests, simulations models and results, recommendations for inactivation levels, recommendations for Phobos categorisation.					
Current TRL:	N/A	**Target TRL:**	N/A	**Application Need/Date:**	Q3 2014
Application Mission:	MSR, Phootprint		**Contract Duration:**	8	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Phobos regolith assessment and thruster plume-surface interaction modelling					
Programme:	ETP		**Reference:**	E918-011FT	
Title:	Phobos regolith assessment and thruster plume-surface interaction modelling				
Total Budget:	100				
Objectives					
The objective of this activity is to investigate the interaction between thrusters and regolith at a fundamental / analysis level, in support of future test-based activities for scaled flight vehicles including multi thrusters and off-axis configurations (e.g. increasing angles from the plume stream axis).					
Description					
In order to achieve the objective of this activity, the analysis of representative regolith characteristics in the Phobos environment shall be undertaken. In addition to the characterization of the Phobos surface details, it is necessary to define and model the physical mechanisms that may occur during the plume-surface interaction. The outcome of this study will enable the Agency to better understand and assess the likely contamination levels on Phobos due to the PhSR thrusters during descent, and possibly during sampling operations where thrusters should be used to generate a hold-down force counter-acting the tool-to-soil reaction forces. In the long term, the strategy is to test a single thruster under representative conditions and use the experimental data to validate numerical models, which will then be used to compute the ?real? scenario for the PhSR mission. Such work has not yet been conducted and therefore an additional objective of this study is to develop the method, tools and apparatuses required to properly undertake such activity. In summary, this activity will: - Characterize the physical mechanisms of Phobos regolith when subjected to gas-surface interactions; - Determine the method for estimating the contamination levels due to thruster plume impingement on the Phobos surface; - Develop the numerical tools for plume-surface interactions in rarefied flows and pre-validate this model with existing data.					
Deliverables					
Technical Notes, plume-surface interaction model results for PhSR simulation case.					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	Phootprint (all planetary landing/take-off exploration missions)		**Contract Duration:**	5	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Phobos Sample Return thruster plume and plume-surface interaction characterisation				
Programme:	ETP	**Reference:**	E918-012FT	
Title:	Phobos Sample Return thruster plume and plume-surface interaction characterisation			
Total Budget:	700			
Objectives				

The objective of this activity is to characterize the expected contamination of the Phobos surface at the PhSR landing site by the lander descent thrusters, using representative thrusters and regolith simulant in an existing test facility.
Description
Thruster plume-surface interaction characterization are critical to the PhSR mission objectives, as the effects of the landing plumes on the regolith of Phobos can lead to contamination of the collected sample. An initial study is running with the following objectives: 1) To characterize the physical mechanisms of Phobos regolith when subjected to gas-surface interactions; 2) To determine the method for estimating the contamination levels due to thruster plume impingement on the Phobos surface; 3) To develop the numerical tools for plume-surface interactions in rarefied flows and pre-validate this model with existing data. Another outcome will be the identification of a suitable test facility where the exhaust plume of the PhSR thruster and its plume-surface interactions can be characterized. In order to complete the validation of the numerical models developed, it is necessary to perform a hot-fire test-based activity for scaled thrusters with off-axis configurations (e.g. increasing angles from the plume stream axis). The choice of thrusters to be tested shall be representative of the possible selection for PhSR, i.e. one mono-propellant and one bi-propellant thruster. The characterization of chemical thruster plumes in rarefied atmospheres and the plume-surface impingement effects will enable the Agency to better understand and assess the likely contamination levels on Phobos due to the PhSR thrusters. Some particles emitted from the thrusters before the spacecraft's free fall are expected to contaminate the landing site. This event has science implications as chemical contamination of the sample is not wanted. In order to consolidate the system trade between altitude of free fall and sample contamination by thrusters, characterization in vacuum of regolith contamination from thrusters at several heights is needed, as well as correlation with the numerical models, in order to allow making reliable predictions of soil contamination for several thruster and altitude configurations. The outcome will be the contamination distribution on the Phobos surface, i.e. the lateral extent and depth of regolith contamination, computed for the "real" scenario of the PhSR mission. This activity will include the following tasks: - Preparation of a suitable test facility and instrumentation; - Characterization of the thruster exhaust plume in vacuum conditions (low-density chamber). This will allow to collect the species distributions and thermodynamic data (pressure and temperature) in the plume at a number of streamwise locations downstream the nozzle trailing edge; - Plume-regolith interaction characterization in order to obtain the sticking coefficients of the thrusters species and force measurements on the regolith surface; - Update of numerical models with test data and validation of the predicted contamination levels at different heights in the spacecraft landing phase; - Repeat of the above with the second thruster type.
Deliverables
Technical Notes, numerical simulation data, experimental test data and assessment of the results.

Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	Phootprint (all planetary landing/take-off exploration missions)		**Contract Duration:**	15	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Aerothermodynamic Tools (2012), roadmap activity B8.					

Separable X-band waveguide-based low gain antenna			
Programme:	ETP	**Reference:**	E907-008EE
Title:	Separable X-band waveguide-based low gain antenna		
Total Budget:	450		
Objectives			
The objective of this activity is to provide a breadboard waveguide antenna that offers the best performance before and after stacked elements are separated, applicable to Phootprint and Inspire current needs			
Description			
Background Phootprint current baseline design is targeting a composite spacecraft consisting of several stacked elements which have a centralized communication architecture (Lander and Earth Return Vehicle (ERV)). An optimization of the RF path between the ERV and the lander could be implemented by using a waveguide separation design based on an open-ended choked horn design. In this configuration when the ERV and the Lander are mated, the antenna acts as a waveguide path between the ERV RF distribution network and the Lander antennas. However, when the ERV separates from the Lander, since it has virtually no friction, this open waveguide acts as an ERV nadir pointing Low Gain Antenna for the return trip to Earth.			

A similar architecture has also been considered in Inspire descent module design in order to allow Direct-to-Earth (DTE) communication during Mars Entry Descent and Landing, following the approach taken by the NASA Mars Science Laboratory mission (MSL). Even though US technologies are available, European capability for such antenna architectures are currently at very low TRL level and therefore the need for the development has been identified. This technology would be of direct interest for current Phootprint communication architecture optimization and also applicable to develop European capabilities for DTE communications during future planetary Entry Descent and Landing phase as indicated by Beagle 2 recommendation. Description: This activity will start with a critical look at the requirements of Phootprint and INSPIRE missions and will perform a trade-off between different combined horn antenna solutions that, in particular for the Phootprint case, consist of two parts, one attached to the lander, and a waveguide part that is used as antenna attached to the ERV. For each mission application (Phootprint and INSPIRE), a preliminary design will be performed paying special attention to the gain and radiation pattern of the waveguide antenna and the separation mechanism between the two parts. After the selection of the best solution, critical breadboarding activities will be carried out. Using these results, a detailed design will be performed, followed by building of the full antenna. A full test campaign will be performed and conclusions drawn. A development plan will be established to bring the technology to flight readiness.
Deliverables
Study report and breadboard

Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	Phootprint and INSPIRE		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Evaluation of heatshield CFRP and bonding materials to increased temperature limits			
Programme:	TRP	**Reference:**	T924-004MT
Title:	Evaluation of heatshield CFRP and bonding materials to increased temperature limits		
Total Budget:	400		
Objectives			
The objective is to screen, trade-off and characterise existing CFRP substrate materials (including honeycomb structures) as well as bonding materials and processes suited for the attachment of an ablative TPS for an increased temperature limit of at least 250degC at the TPS/structure interface.			
Description			
OOne important constraint in the sizing process of an ablative TPS for atmospheric entry vehicles is the temperature limit of the supporting heatshield structure and of the bonding material used to attach the TPS. This temperature limit is typically in the range of 150-180degC. For the CFRP the limiting factor is typically the resin. New resin materials (like cyanate ester or bismaleimide) have commercially become available in recent years and relevant CFRP materials been qualified towards higher temperature limits for other space applications (like solar arrays or antenna reflectors). Such increased limits would allow to reduce the required TPS thickness and therefore to reduce the mass of the TPS. The objective of the activity shall be achieved through the following steps: - Perform a market research of advanced CFRP based on relevant new resin materials as well as bonding materials for the attachment of the TPS suited for increased temperatures - Perform a trade-off (including relevant screening tests) - Develop and test a selected CFRP material as well as a TPS bonding material to achieve an operational temperature of at least 250degC, while meeting atmospheric entry vehicle requirements.			
Deliverables			
Study report and material samples			

Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	Sample return missions.		**Contract Duration:**	15	
S/W Clause:	N/A		**Reference to ESTER**	T-8142	
Consistency with Harmonisation Roadmap and conclusion:					
No existing THAG harmonisation dossier but consistent with D/TEC Exploration Technology Roadmap					

Development of a rigid conformal ablator for extreme heat flux applications					
Programme:	TRP		**Reference:**	T921-004MT	
Title:	Development of a rigid conformal ablator for extreme heat flux applications				
Total Budget:	400				
Objectives					
Based on the existing ASTERM material, a European rigid conformal ablative heatshield material shall be developed and characterised for application on the Earth re-entry capsule of sample return missions (e.g. Mars, comets, asteroids). A material demonstrator with a representative size and geometry shall be manufactured.					
Description					
The ASTERM ablative heatshield material has recently been developed (under Astrium R&D and TRP-DEAM) and is currently in pre-qualification (under MREP-DEAM2). This development is specifically tailored for application on the Earth return capsule of sample return missions. The material is a low-density carbon-phenolic ablator and is produced by impregnating a low density rigid graphite felt with a phenolic resin. Recent developments by NASA have demonstrated that by replacing the rigid graphite felt in the manufacturing process by a flexible felt can lead to a significant improvement of the material performance: Internal thermo-mechanical stresses are reduced making the material more robust to loads and deflections; thermal performance is improved leading to lower required thickness and therefore lower mass; manufacturable unit sizes are increased which might more easily allow to produce the ERC heatshield as one single piece avoiding interface issues.					
Deliverables					
Study reports Material samples and demonstrator					
Current TRL:	2	**Target TRL:**	5	**Application Need/Date:**	2016
Application Mission:	Sample return missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8947, T-8142	
Consistency with Harmonisation Roadmap and conclusion:					
Consistent with D/TEC technology roadmap					

ERC dynamic stability via balloon drop tests					
Programme:	ETP		**Reference:**	E918-003MP	
Title:	ERC dynamic stability via balloon drop tests				
Total Budget:	1000				
Objectives					
To provide a full end-to-end dynamic stability tests to validate an Earth re-entry capsules					
Description					
Sample return missions such as MSR, Phootprint, Marco Polo-R etc., foresee a capsule re-entering the earth atmosphere at high velocity (typically ranging from 11 to 14 km/s) without the usage of a supersonic parachute as an aerodynamic decelerator; as such, the dynamic stability of the ERC during the entry phases is essential in this situation. An assessment is presently running to investigate and trade-off different re-entry capsule shapes (identifying pros and cons concerning accommodation capability, stability, CoG positioning, thermal exposition, and landing conditions) and preliminary characterize the dynamic stability in the transition phase from supersonic to subsonic velocity of a few selected configurations. In this proposed activity, a full end-to-end dynamic stability assessment to validate the ERC shape shall be carried out by means of balloon drop tests at high altitude. A detailed aerodynamic characterization of a number of selected ERC configurations shall be obtained via these free flight tests. Within the activity, the contractor shall also design and implement the inertia metrology package needed for attitude and position data acquisition (and storage). Wind tunnel test and CFD simulations can be foreseen if needed.					
Deliverables					
Reports, results of tests (and calculations), databases, instrumented models, synthesis, recommendations on methodologies					
Current TRL:	3	**Target TRL:**	6	**Application Need/Date:**	2023
Application	MSR, Phootprint and Marco Polo-R		**Contract Duration:**	24	

Mission:			
S/W Clause:	N/A	**Reference to ESTER**	T-8101, T-7904
Consistency with Harmonisation Roadmap and conclusion:			
ATD Harmonisation 2012			

Design, development and verification of a full scale Earth Return Capsule for Phootprint			
Programme:	ETP	**Reference:**	E920-004MS
Title:	Design, development and verification of a full scale Earth Return Capsule for Phootprint		
Total Budget:	1800		

Objectives

The objective of this study is to undertake the design, development and verification of an Earth Return Capsule (ERC) which is capable of
bringing back safely till high velocity touch down, returned samples from the Martian moon Phobos.

Description

During the re-entry phase of the mission, the ERC is subjected to extreme heat and mechanical loads. To ensure the integrity of the returned samples, stringent thermal and mechanical requirements are set. The ERC is usually protected by TPS (Thermal Protection System) to minimise the heat load due to high surface heat fluxes at the early Earth entry phase and by high energy absorbent core material to limit the mechanical load (2000g max at sample level) upon the hard landing phase on Earth. To accomplish such requirements, the architecture of the ERC is as critical as what the performance of the protection materials can offer. The following activities are foreseen in this study :

- Review of Phootprint requirements for ERC
- Investigate the most optimal design solution based on the mission requirements. To achieve that, trade-off studies shall be performed using a combination of TPS material, crushable materials and other structural materials.The possibility of having a matrix of crushable materials of different density and mechanical behaviour, leading to gradual reduction of impact load at the bio-container, shall be examined. In addition, the outcomes from two ongoing ESA studies namely : T919-036MC "Design of a crushable TPS for the ERC" and T920-002QT "Material development for a crushable TPS for the ERC", shall be considered as potential inputs to the investigation.
- Design, analysis and verification by breadboard tests of one or multiple ERC concepts. The proposed design shall be able to offer maximum protection to accommodate payloads such as the returned sample bio-container, beacon, batteries, etc. Sample tests shall be performed to support the development.
- Manufacturing of full scale structural models of a selected ERC concept to be used in thermal and mechanical verification tests.

Deliverables

Documentation (Final Report, Summary Report, Technical Data Package including photograpic ducmentation)
Hardware (breadboard and full scale models)

Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	Phootprint		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

ERC RF recovery beacon breadboard			
Programme:	ETP	**Reference:**	E906-011FP
Title:	ERC RF recovery beacon breadboard		
Total Budget:	400		

Objectives

The objective of this activity is to develop and test a breadboard of a small size RF beacon aimed at easing the ERC recovery operations after landing.

Description

The ERC is a critical element of the Phootprint mission as being the one bringing back the samples for laboratories investigations. In order to secure its recovery after landing, it is currently foreseen to implement an RF beacon from which the signal can be easily recovered by ground facilities to guide them to the landing site.

The main requirements of this beacon are: - light mass, low power consumption, powered by a small battery hosted in the ERC (the battery is considered part of the beacon). - must operate during at least 4 hours after landing. - must endure high g-loads at ERC impact, in the order of 2000g. This activity shall design and build a beacon breadboard meeting the above requirements. The breadboard will then go through a test and validation campaign.					
Deliverables					
RF beacon breadboard, tests numerical data, technical reports					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	Phootprint		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Evaluation of sealing systems for a Phobos Sample Return Mission					
Programme:	ETP		**Reference:**	E915-007FT	
Title:	Evaluation of sealing systems for a Phobos Sample Return Mission				
Total Budget:	245				
Objectives					
Evaluation of existing concepts and design of sealing system(s) for the Earth Return Capsule of a Phobos Sample Return Mission.					
Description					
The ERC of a Phobos Sample Return requires a sealing system to contain the samples through all phases of the return flight to Earth and transfer to the sample receiving facility. The reliability requirements for containment are far less stringent than that of a Mars Sample Return mission due to the low planetary protection categorisation of Phobos (currently category II). Therefore, a much simpler sealing system is required than those that have been designed in other technology activities for a MSR return capsule. However, a key requirement that remains challenging is to ensure that the seal can withstand the hard impact during the Earth landing, having undergone the varied thermal environment on Phobos and long cruise back to the Earth. Therefore, designs that can combine simplicity and low mass together with robustness to temperature swings and shocks are to be investigated. This activity will include: 1- A review of existing designs from existing missions studies, suggested modifications and potentially the identification of one or more original concepts for the sealing system. 2 - Preliminary breadboarding and testing of relevant sealing technologies to de-risk the most risky concepts. 3- Impact analyses through non-linear Finite Element Modelling. 4 - A trade-off of all the concepts and downselection of one or more for breadboarding and testing in a follow-on activity. 5 - Production of a preliminary test plan for the proposed breadboards including a concept of specific test facilities that are required to undertake representative impact tests. 6- Production of a development plan to TRL5.					
Deliverables					
Technical data package including preliminary test plan and development plan.					
Current TRL:	1	**Target TRL:**	2/3	**Application Need/Date:**	2018
Application Mission:	PHOOTPRINT		**Contract Duration:**	9	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Breadboard of a sample securing system for a Phobos Sample return Mission			
Programme:	ETP	**Reference:**	E915-008FI

<table>
<tr><td>Title:</td><td colspan="5">Breadboard of a sample securing system for a Phobos Sample return Mission</td></tr>
<tr><td>Total Budget:</td><td colspan="5">700</td></tr>
<tr><td colspan="6">Objectives</td></tr>
<tr><td colspan="6">The development of a breadboard to demonstrate the function and survival of the Phobos sample return mission sample canister securing system after impact on Earth of the Earth re-entry capsule. This requires the design, manufacturing and test of such a securing system that can avoid compromising the scientific integrity of the sample. The design and test parameter shall be linked to the Phootprint system studies</td></tr>
<tr><td colspan="6">Description</td></tr>
<tr><td colspan="6">Collected sample material from non-terrestrial bodies are typically stored in a sample vessel which itself is mounted in the Earth re-entry capsule. If no further planetary protection rules apply (as for this activity) the applicable requirements are driven by the science requirements, rather than the protection of the Earth's biosphere. The focus is a potential contamination of the collected material both ways (in- and outside the sample vessel). During re-opening non contamination of the sample shall occur.

The securing system shall encapsulate a sample stored in the sample canister which was collected on the surface of Phobos. Other application to similar bodies like asteroids are possible. As key requirements the following two subjects were identified (a) no particle larger than 1 um shall escape and (b) the securing system shall survive the impact on the surface when returning to Earth. In a precursor 2014 activity (E915-007FT) candidate technologies will be analysed and modeled in depth and a conceptual design developed. Out of these concepts, 2 or more will be used for further analysis and breadboarding within this activity.

In this activity the chosen concept have to be designed and manufactured. The design option are accompanied by detailed modeling. The test facility(ies) especially those for the impact/shock test have to be adapted and set-up according specifications. Possible requirements with respect to the closure mechanism have to be taken into account. A trade-off between different materials (e.g. metal vs. polymeric) that can be used to secure the samples is expected. The breadboard(s) shall be built and extensively tested to reach a TRL 5.</td></tr>
<tr><td colspan="6">Deliverables</td></tr>
<tr><td colspan="6">Breadboards and test results</td></tr>
<tr><td>Current TRL:</td><td>3</td><td>Target TRL:</td><td>5</td><td>Application Need/Date:</td><td>2019</td></tr>
<tr><td>Application Mission:</td><td colspan="2">Phootprint</td><td>Contract Duration:</td><td colspan="2">24</td></tr>
<tr><td>S/W Clause:</td><td colspan="2">N/A</td><td>Reference to ESTER</td><td colspan="2"></td></tr>
<tr><td colspan="6">Consistency with Harmonisation Roadmap and conclusion:</td></tr>
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</table>

MPL

Validation of the EAGLE simulator tool					
Programme:	ETP		**Reference:**	E905-023FM	
Title:	Validation of the EAGLE simulator tool				
Total Budget:	500				
Objectives					
The objective is to mature the validation status of the EAGLE simulator suite before its integration within the Harwell Robotics and Autonomy Facility (HRAF).					
Description					
During several ESA activities a simulator tool for Entry Descent and Landing phases has been developed, called EAGLE. As a simulator suite, it consists of a set of mathematical models, each related to either specific mission subsystems (e.g. parachute, camera) or specific physical modeling of the EDL environment such as atmosphere/landing site topography. The tool has evolved to encompass both lunar and Mars specific library models, which have not necessarily reached the same level of validation. Therefore comparing results when switching library elements for a given mission concept is rather difficult. As part of a first consolidation exercise, a requirements gathering process has taken place during the Phase 1 of the HRAF Pilot 1 activity. This process (SRR) led to a consolidated set of EAGLE requirements needed to mature the EAGLE simulator suite. These requirements should lead to the full validation of the various EAGLE models relevant to the EDL scenarios of future MREP missions. This activity shall focus on two main aspects currently needed to mature EAGLE before it can be considered for integration as a tool within the HRAF Core Architecture. - The first is the definition of validation approaches for the requirements that are linked to some mandatory mission scenarios. Taking into account the current status of validation of the affect models, the validation approach shall be detailed from model level up till complete mission level simulation. - The second part of the activity shall implement (part of) the previously defined validation approach, as agreed with the Agency. Both elements of the activity may need software code modifications, which shall be fully tested and debugged prior to entering the validation phase.					
Deliverables					
Documentation Software algorithms as needed					
Current TRL:	3	**Target TRL:**	4/5	**Application Need/Date:**	
Application Mission:	MPL and other Mars landers		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Extension and validation of Mars atmospheric and dust environment models					
Programme:	TRP		**Reference:**	T904-001EE	
Title:	Extension and validation of Mars atmospheric and dust environment models				
Total Budget:	150				
Objectives					
To maintain and improve the capacity to predict the Martian atmospheric environment					
Description					
Extended validation of densities at lower thermospheric altitudes for aerobreaking Extended validation of mesoscale modeling and nesting and GCM subgrid-scale parametrisation schemes for precision landing. State of the art dust lifting and transport scheme for the mesoscale and large scale circulation models.					
Deliverables					
Validation reports					
Current TRL:	3	**Target TRL:**	4	**Application**	continuing

				Need/Date:	
Application Mission:	all Mars missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Maintenance of the European Mars Climate Database					
Programme:	GSTP		**Reference:**	G904-002EE	
Title:	Maintenance of the European Mars Climate Database				
Total Budget:	300				
Objectives					
To maintain and keep up-to-date Martian climate models which have been developed under TRP					
Description					
Under TRP comprehensive models of the martian atmopsheric environement have been developed and used to develop a generic data base of atmospheric data, used in EDL. This database is supplemented with additional models at progessively smaller scales to cover all aspects of mission design, including near ground environment (z<20 m). The boundary conditions for these models need to be continually upgraded as data from current Mars missions become available. New data is also used for upgrade and validation of physical parameterizations used in these models. It is anticipated that some of the effort will be devoted to the improved modelling of dust lifting and transport mechanisms, hence giving access to realistic dust spatial variability. The activity will be in two phases, with phase two activities being more tightly defined in the light of progress in phase developments, and new problems and requirements arising in scenario analyses.					
Deliverables					
Upgraded Martian general circulation model and documentation. Upgraded Martian mesoscale/microscale model and documentation. New version of Mars Climate Database (refined dust scenarios) and validation documentation. Technical notes on scenario studies.					
Current TRL:	4	**Target TRL:**	7	**Application Need/Date:**	2017
Application Mission:	All Mars missions		**Contract Duration:**	36	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

European IMU breadboard			
Programme:	TRP	**Reference:**	T905-014EC
Title:	European IMU breadboard		
Total Budget:	800		
Objectives			
Breadboard and demonstrate the performance of an IMU for Mars exploration			
Description			
There is a clear need of a European IMU for the Robotic exploration programme. This is considered a critical technology to enable the future exploration missions during cruise, Aerobraking, Entry, Descent and Landing and in-orbit Rendezvous. The available European gyro products are not optimised for the exploration requirements. Current low mass products have low performance while available high performance products have a hig mass. Furthermore, there is no European space qualified accelerometer (US space qualified off the shelf products are available) however a TRP-funded European accelerometer feasibility demonstrator has just been launched in 2010, and may form a basis for the European IMU development pending confirmation of its performance vs. MREP requirements. This activity intends to invite industry to propose an optimised IMU concept, based on an existing design, with gyro and accelerometer functions compliant with the MREP programme exploration needs. PDR stage shall be reached at the end of this activity with bread boarding to demonstrate the critical functions and performances. The activity would include: - analysis of the driving requirements and major constraints based on IMU specifications provided from the MREP High-precision			

landing GNC optimisation TDA (E905-006EC) and MREP Precision Lander system study. - main design modification trade-offs - detailed interfaces with the accelerometer and gyro preparatory work based on reuse of existing gyros building blocks and necessary delta-developments - early prototyping and testing of critical functions to demonstrate feasibility of meeting the key MREP performance requirements - development plan till EQM qualification and estimation of the recurring cost of the IMU
Deliverables
Technical Data pack - Test reports of IMU breadboard - Development plan of IMU to EQM H/W: Breadboard of IMU

Current TRL:	2	**Target TRL:**	3/4	**Application Need/Date:**	TRL5 by 2015
Application Mission:	Precision lander, MSR		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
AOCS sensors and actuators Gyros and IMUs. AIM E1					

European IMU EM					
Programme:	ETP		**Reference:**	E905-015EC	
Title:	European IMU EM				
Total Budget:	2000				
Objectives					
To develop and test to TRL5, an European IMU for Exploration.					
Description					
The activity shall develop an EM of an European IMU following from a previous breadboarding activity for the gyro and a separate accelerometer development activity. The IMU design shall be based on the gyro prototype architecture and the accelerometer component development. An EM shall be manufactured and tested in a relevant environment simulating its use on a Mars precision landing mission.					
Deliverables					
H/W: An IMU EM meeting MREP programme performance specifications					
Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2016
Application Mission:	All Mars missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
AOCS Sensors and Actuators harmonisation (2009) - Gyros and IMUs Aim E : Development of a low cost IMU					

Stand Alone 3 Axis European Accelometer Unit			
Programme:	ETP	**Reference:**	E905-021EC
Title:	Stand Alone 3 Axis European Accelometer Unit		
Total Budget:	500		
Objectives			
To develop and test an Engineering Model (EM) of a miniaturised 3 Axis European Accelerometer unit based on a European accelerometer detector already being developed and suitable for use on Rovers and EDL missions. The target for the unit would be for PHOOTPRINT, Mars Precision Lander and other future Mars lander missions.			
Description			
European accelerometer components are currently in development (Colibrys (CH) and ESS (GR)); this activity will result in the availability of a miniaturised stand alone 3 axis unit based on these components. The general characteristics of the unit are expected			

to be: < 350g < 60*60* 60mm < 2.5 W 28 Volt primary power supply with both +/-1g and +/-20g measurement ranges per axis. The activity will include the preliminary design, breadboarding, detailed design and EM manufacture and test. The tests will include performance and environmental testing (thermal and mechanical).					
Deliverables					
Unit EM, data package					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	All Mars missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

AVoidance algorithms Extended development and Realistic Testing (AVERT)					
Programme:	ETP		**Reference:**	E905-022EC	
Title:	AVoidance algorithms Extended development and Realistic Testing (AVERT)				
Total Budget:	750				
Objectives					
The goal of this activity is to further develop the fusion of sensor data for hazard avoidance and piloting initiated under the previous study with SpinWorks (E905-008EC). This activity brings the sensor data fusion techniques for hazard avoidance and piloting from a TRL 3 to TRL 4/5 through the implementation of the algorithms, along with an associated relative navigation scheme, on an avionics test bench with active sensor hardware, followed by flight testing of the algorithms and avionics on an UAV over representative terrain.					
Description					
Future solar system landing missions will be targeting regions of high scientific interest but with significant risk (e.g. craters, boulders, shadowed areas, slopes.) The availability of both cameras and active optical sensors (scanning Lidars, flash Lidar/3-D cameras) with their different characteristics in term of measurement type, rate and field-of-view led to the investigation of hazard detection algorithms that would fuse the data from these two sensor types (and additionally from inertial and altimetric sensors when available) to provide accurate hazard maps to the flight control software. Several sets of sensors pairs, fusion algorithm (fusing sensor data at low- or high level) and scenarios (Mars and asteroid) have been developed, implemented, simulated on a SIL platform and benchmarked within the frame of activity E905-008EC run by SpinWorks (PT). The logical next step is to further implement and test the best combination(s) performance in a PIL simulation test-bed with sensor hardware (2D and 3D cameras). The main tasks of this follow-up activity shall be : - to review the results of the two previous activities, including their conclusion on the relevance of the HDA algorithm to relative navigation and to select for both Mars and asteroid missions at most 2 sets of sensors/algorithms (specifically, the reliability of the method(s) in estimating local slope values and identifying dangerous areas with steep slopes shall be the primary selection criterion.) - to assess, through benchmarking and profiling, whether it is required to implement the HDA and/or relative terrain navigation algorithm(s) on a dedicated processor and develop the SW/HW partitioning architecture in this case. -to implement, in the first instance, the HDA and relative navigation algorithms on an a COTS avionics test bench with CPU (no dedicated processor) and with COTS hardware sensors such as 2D and 3D cameras. - to upgrade the avionics test bench by implementing the relevant portions of the algorithms on a dedicated processor (e.g. FPGA) and test it on a flight-representative test-bench as well as flight-testing on a UAV platform over representative terrain.					
Deliverables					
- Sensor data fusion algorithms, associated real-time software and avionics test bench - Technical documents, including test documentation					
Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2019
Application	Mars/asteroid landing missions		**Contract Duration:**	15	

Mission:			
S/W Clause:	N/A	**Reference to ESTER**	
Consistency with Harmonisation Roadmap and conclusion:			

MSR Precision landing hazard avoidance sensor adaptation - Engineering Model					
Programme:	ETP		**Reference:**	E916-003MM	
Title:	MSR Precision landing hazard avoidance sensor adaptation - Engineering Model				
Total Budget:	1000				
Objectives					
Based on the results and requirements of the End-to-End optimisation and GNC design study, this activity will further develop the hazard avoidance sensor(s) for MSR High Precision Landing, building on the pre-developments performed under the Aurora program. An elegant prototype shall be manufactured to demonstrate the successful incorporation of HW and SW modifications and to be used in the Mars precision landing field testing which is a next step.					
Description					
Optical-based navigation systems are required on several key stages of future exploration missions. Such systems allow autonomous navigation manoeuvres to be performed during the precise landing of a descent module in order to allow high precision landing and avoid hazards. This task can be performed by vision-based camera systems and LIDARs. Both systems have been explored and breadboards have been developed for demonstration purpose under other ESA activities, in particular the NPAL/VisNav breadboard for a vision-based navigation demonstration, and an imaging LIDAR breadboard. Other studies are planned to further define and refine the EDLS GNC for high-precision landing on Mars and the optimum methods of data fusion between different sensors to assist the Hazard mapping and subsequent avoidance piloting that ensure such landings can be performed safely and with a high reliability. These studies are expected to have impacts on the sensing hardware by refining the requirements on accuracy, resolution, update rate, range, power, mass and hardware to software (GNC s/w to Sensor hardware/s/w) interfaces. This updated information will be fed into the development of the sensor design, and the hardware and software of the sensors will be upgraded to meet them. The activity shall be executed in two phases: In Phase 1 the specifications for an elegant prototype shall be consolidated and the detailed design of the sensor shall be established. During Phase 2 an elegant prototype of the navigation sensor will be manufactured and validated by test, ready for its integration into the Mars Precision Landing Field testing which occurs in a future activity.					
Deliverables					
Mars Precision landing EDL Sensor elegant prototype					
Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2016
Application Mission:	MSR		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-7860	
Consistency with Harmonisation Roadmap and conclusion:					

Compressive Sensing Technologies for compact LIDAR systems			
Programme:	TRP	**Reference:**	T916-004MM
Title:	Compressive Sensing Technologies for compact LIDAR systems		
Total Budget:	475		
Objectives			
The objective of this activity is to assess and develop to TRL4, novel technologies for future compact imaging LIDARs based on compressive sensing techniques.			
Description			
Imaging LIDAR sensors are currently foreseen to be used in various space applications like during the descent and landing of planetary spacecraft or supporting the rendezvous operation between two spacecraft (with or without cooperative targets).			

Nowadays the major drawback of using traditional Imaging LIDAR sensors is still their high mass (>12Kg for the overall unit) and high power consumption (>80Watts). In addition these sensors, typically single element detectors using large mirror scanners, have limited performances for some of the space applications. For example for the planetary lander application the desired high number of image elements that the system has to scan, on a fixed field of view, to image the target full frame has a strong time constraint due to the dynamics of the landing. Several novel detector array technologies have emerged in Europe in the last years that can lead to the development of more compact Imaging LIDARs systems. However the current state of the art of these detector arrays in Europe is still far away (limited number of detector elements and fill factor) from the development of a fully flash type Imaging LIDAR system (no scanning). Recently a novel imaging technique, designated as compressive sensing, has been identified as a possible technique also for ranging applications. Since only a single element detector is required for the measurements (ranging and imaging) based on compressive sensing the current lack of high pixel resolution arrays in Europe could be overcome. In addition the system can be used, in the same application, or as a single element ranging system (like an altimeter) or as 3D imager, depending only on the illumination/imaging modulation technology used and on the implemented operational mode. Imaging LIDARs based on compressive sensing offer more compact systems, as they do not need mechanical scanners, and in addition the signal to noise ratio available for each measurement is much higher than when directly compared with flash type systems, thereby offering longer range/lower power operation than other techniques. Within this activity technologies for a Imaging LIDAR system based on compressive sensing shall be investigated, assessed, breadboarded and tested. A technology development plan for the performance optimization of the selected technologies shall be elaborated and executed. The technologies shall be integrated into a Imaging LIDAR technology demonstration breadboard and tested in laboratory conditions. As a result of this activity the feasibility of Imaging LIDAR systems based on compressive sensing shall be verified and assessed for different space applications.
Deliverables
Novel Imaging LIDAR technologies, Imaging LIDAR breadboard, data package

Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	MPL, MSR		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-7860	
Consistency with Harmonisation Roadmap and conclusion:					

Supersonic parachute test on a MAXUS flight			
Programme:	GSTP	**Reference:**	G918-007MP
Title:	Supersonic parachute test on a MAXUS flight		
Total Budget:	500		
Objectives			
The objective of this activity is to demonstrate the capability to test new supersonic parachute designs in representative conditions for space missions and reduce the reliance on existing non-European parachute systems by using European sounding rockets.			
Description			
As already proved feasible by the flight of the CIRA Sounding Hypersonic Atmospheric Re-entering Kapsule (SHARK) on the MAXUS-8 sounding rocket, the present activity shall make use of the spare payload volume, otherwise used for ballast, to perform a low cost flight test of a supersonic parachute on the MAXUS mission in 2015. Also, an initial internal feasibility study showed that there is possible to test a suitable sized parachute (1m diameter) in the available mass and volume constraints given by MAXUS, therefore there is a very good opportunity to develop state-of-the-art technologies for testing supersonic parachutes in Europe. The proposed activity includes: - the detailed design of the capsule, parachute and deployment system including instrumentation and avionics - the procurement (COTS)/development/manufacture of all items above - installation the payload on MAXUS - (launch) - post flight analysis The following minimum instrumentation is foreseen to obtain flight data for design: ? Timer to measure events from MAXUS separation (initiation) to touchdown ? Video of the deployment and steady state descent, ? Accelerations and Angular rates of the capsule, ? Axial force during deployment, and ? Pressure sensor(s) Further, since the capsule will be analysed by CFD to assess the wake, heating and the stability for the reference mission, there is also an opportunity to test future mission capsule shape dynamics in relevant conditions			
Deliverables			

Reports of detail designs, flight data and post flight analysis. Also flight hardware (all items procured/developed/manufactured under the present activity).					
Current TRL:	5	**Target TRL:**	7	**Application Need/Date:**	2018
Application Mission:	MREP		**Contract Duration:**	36	
S/W Clause:	N/A		**Reference to ESTER**	T-8101, T-8873, T-8940, T-7906	
Consistency with Harmonisation Roadmap and conclusion:					
ATD Harmonisation 2012					

Entry, Descent and Landing Communications technology assessment			
Programme:	TRP	**Reference:**	T906-008ET
Title:	Entry, Descent and Landing Communications technology assessment		
Total Budget:	350		
Objectives			
- To investigate and prepare for communication direct to Earth (DTE) allowing limited information (minimum redundant) about Lander health, position and its tracking during Entry Descent and Landing and - if necessary after landing - during robotic operations. - To carry out investigations for optimum output possible with given radio signals transmitted during EDL, exploiting large antennas on-ground if needed larger than 35 m. - To identify critical technologies for on-board and on ground hardware.			
Description			
After the Beagle failure it has been recommended that ESA missions implement a means of providing information of the events occurred during the critical entry, descent and landing (EDL) phase so it is possible to perform an investigation in case of failure. It is therefore required that future missions implement a communications system capable of transmitting information during the EDL phase. Moreover, since the existence or the visibility of an orbiter cannot be guaranteed, it is mandatory to investigate a solution compatible with the transmission of information directly to Earth during this phase. Increasing on-ground available aperture and combining different antennas in an interferometer (Very Long Baseline Interferometry) has proved to be extremely useful for detection and determination of the trajectory of Huygens when landing on Titan. The activity will be applicable to the entry, descent and landing phase on any planet or moon. Initially the Contractor shall analyse the corresponding mission scenarios and system requirements; considering among others the following systems aspects e.g. plasma environment, black-out effect, signal dynamics, etc. A Multiple Frequency Shift Keying (MFSK) X-band system has been implemented by NASA but its detection is a very demanding task for a receiver. Current investigations indicate that with a 35m G/S and the state of the art on board technology, the required C/No to receive specific MFSK tones is not fulfilled in all circumstances at the ground station receiver.. The Contractor shall investigate the following concepts: ?Define precise communication scenarios RF requirements for on-board hardware, noting EDL power limits. -Study different types of on-board antennas compatible with different EDL module configurations and analyse antenna patterns to provide a required Earth coverage at all times -Evaluate time accuracies needed and oscillator performances -Investigate other approaches for the transmission of data (e.g. coherent/non-coherent tones, modulation schemes, etc.) The Contractor shall investigate for such scenarios the possible ground system solutions: -Addition of apertures and VLBI/interferometer capabilities, cooperating with radio astronomy community. -Demonstrate how to arrive at accuracies like 100m rms, assisted by experiments. -Exploit latest capabilities of the radio-astronomy community and the ground segment community, including E-VLBI. -Cooperate with European VLBI Network as external service. -High bit-rate interconnect to central correlator will need to be adapted for SC tracking. -Exploitation of software code developed for Huygens trajectory determination as applicable. The contractor shall investigate the signal reception by a G/S receiver: -Consolidate the receiver requirements. -Study ways to improve the receiver architectures capable to detect the EDL signal under extreme conditions defined in the course of the activity with ESA 35m antennas.			
Deliverables			
-Propose different communication architectures and select the most promising one for an EDL receiver architectural concept identifying the critical technologies with subsequent breadboarding (proof-of-concept) required for high-risk developments; TN's, reports, Final Report			

Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2018
Application Mission:	INSPIRE, PHOOTPRINT, MPL		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8738	
Consistency with Harmonisation Roadmap and conclusion:					
Harmonization Dossier "TT&C Transponders and Payload Data Transmitters" 2012.					

Compact Dual UHF/X-band Proximity-1 Communications Package breadboard					
Programme:	ETP		**Reference:**	E906-010ET	
Title:	Compact Dual UHF/X-band Proximity-1 Communications Package breadboard				
Total Budget:	1000				
Objectives					
The aim of this activity is to develop and test breadboard of a compact dual frequency (UHF/X-band) communication package for Mars lander/rover missions					
Description					
The activity is a follow on of the completed TRP activity: Dual UHF/X-band communications package study This activity targets the design, development and testing of breadboard of a communications package for planetary probes/landers/rovers which is able to communicate both with an Orbiter (for data relay) and directly to the Earth from the surface of Mars. The design is flexible to cope with the different mission requirements, e.g. implementation of the UHF only capabilities, X-band functions o both while keeping compact unit dimensions and low mass. Mars missions typically implement a UHF proximity-link with a data-relay Orbiter as their primary link for returning science data. The use of relay links is attractive for reasons of power efficiency and higher possible data-rates compared to direct-to-Earth links. Nevertheless, in order to support communications during Entry Descent and Landing (EDL), for contingency cases or missions in which an orbiter cannot be guaranteed, the inclusion of a direct link to/from Earth in the X-band is required. The direct to Earth link will be implemented in the X-band Deep Space band frequency allocation. The direct link with Earth offers some advantages; it is not subject to the usual delay in operations due to the visibility of the orbiter from the Earth, allowing the possibility to upload operational commands in real time. This equipment could also be used besides the nominal surface operations, during the cruise phase, in emergency situations and for contingency operations, as well as during the entry, descent an landing (EDL) phase either by transmitting health status beacon tones or modulated telemetry. Instead of fitting two separate transponders into the constrained lander/rover, a single unit serving both UHF and X-band links would bring important savings in mass and volume without sacrificing functionality or mission safety.					
Deliverables					
Technical Notes, breadboard					
Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2026
Application Mission:	SFR, MSR		**Contract Duration:**	29	
S/W Clause:	N/A		**Reference to ESTER**	T-8738	
Consistency with Harmonisation Roadmap and conclusion:					
Harmonization Dossier "TT&C Transponders and Payload Data Transmitters," 2012					

Conformal antenna system for Planetary Entry probes			
Programme:	ETP	**Reference:**	E907-009EE
Title:	Conformal antenna system for Planetary Entry probes		
Total Budget:	500		
Objectives			
To optimise and develop an conformal antenna system based on proven technological concepts for Entry, Descent and Landing phases for Robotic Exploration missions.			
Description			
Background After the Beagle 2 failure, one of the recommendations from the Commission of Inquiry concluded that future planetary entry			

missions should include a minimum telemetry of critical performance measurements and spacecraft health status during mission critical phases such as entry and descent. The implementation of this requirement is even more challenging for any mission concept which does not rely on a relay Orbiter for the entry, descent and landing (EDL) phases. The EDL is a very specific scenario for communications limited by several constraints: plasma formation mainly at UHF, aerodynamic disturbances due to protrusion from probe external mechanical profile, antenna exposure to high temperature, probe attitude, Earth angle coverage, etc. EDL antennas would likely used either UHF, X or dual UHF/X-band frequency. The optimum frequency to be used for such a phase, and hence for this activity, is currently being investigated in the frame of the TRP activity "EDL Communications technology assessment". However, the optimum technology for the antenna in order to guarantee the link and to cope with any possible angular movement of the descent module (DM) needs to be investigated. Different options considering a waveguide-based horn antenna attached to the back shell of the DM or single radiating elements have been previously proposed. The communication link using conventional omnidirectional antennas is often marginally capable of the required bit rate in the baseline scenarios. Furthermore, the pattern could be strongly affected by the DM and possible shadowing can occur in case only one element is used. Conformal antennas are considered a very good alternative in order to fulfil the aerodynamic and RF requirements. They will be integrated on the surface of the backshell and on the surface of the Lander after the backshell is released. This type of antenna will also allow to be highly performing independently of the attitude of the descent module and Lander. While the primary technology for radiating elements is available, the overall antenna system implementation needs to be optimised from the electrical, mechanical and mission operation point of view to ensure the necessary performances. Description This activity will start with a critical look at the requirements of the future Mars landing missions and will carefully consider the attitude of the Descent module and its impact on the view angle of the antenna. A preliminary design of a conformal antenna considering a realistic representation of the Mars Precision Lander descent and lander systems shall be performed. The critical components will be identified and critical breadboarding activities carried out. Using these results, a detailed design will be performed, followed by building of the full conformal antenna. A full test campaign will be performed and conclusions drawn. A development plan will be established to bring the technology to flight readiness.
Deliverables
Study report and breadboard

Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2019
Application Mission:	Mars lander missions		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Yes with the Array Antenna Harmonisation finalized in January 2012 [Activity D13 ?Antenna integrated in ballons/parachutes for EDL systems?					

Same Beam TT&C systems for MSPA and improved navigation: Architecture definition and breadboarding of critical components			
Programme:	TRP	**Reference:**	T906-014GS
Title:	Same Beam TT&C systems for MSPA and improved navigation: Architecture definition and breadboarding of critical components		
Total Budget:	500		
Objectives			
Architectural definition, technical specifications and prototype of critical components for a Same Beam Interferometry system for precise navigation and radio-science applications			
Description			
Same Beam operations can allow two objectives: 1) Multiple Spacecraft Per Aperture (MSPA) TT&C support 2) Improved navigation by means of Same Beam Interferometry (SBI) in the approach phase of an orbiter to a celestial body having other probes with well know orbits orbiting around it (e.g. a S/C approaching Mars where already other probes -ESA or other Agency- are orbiting) In the frame MSPA the adoption of a coherent link with the use of a spread spectrum signal structure such as CDMA (Code Division Multiple Access) is being proposed as a long-term solution for Deep Space missions to enable 2-way Earth/satellite links using the same frequency. In this scope the activity shall be a follow-on of the first part of the proposed activity T906-012ET, in which the investigation of the suitable CDMA codes for such application is undertaken. The breadboarding of the ground modem is proposed here, as the natural continuation of the aforementioned TRP activity. In terms of ground systems, the more critical part of the system is the CDMA receiver, which needs to cope with the reception of a signal with interference from the other CDMA users, plus the low signal levels, typical of a Deep space scenario. This technique would also enable the Radio-Science use of SBI for improved planetary geodesy.			

In its use for navigation, SBI can be seen as complementary to Delta-DOR for improved plan-of-sky relative measurements between two (or more) S/C using as on-board TT&C the current generation of Deep Space Transponders (DST). In this context, the objectives of the study are: 1) To define the best suitable architecture for multiple S/C signal reception on ground and subsequent signal processing 2) To breadboard the critical component of the ground system. A typical use case of SBI for navigation could be envisaged in the context of ExoMars 2018 mission or for Mars Precision Lander/Phootprint. The proposed study logic is as follows: 1) MSPA with CDMA ? Define the on-ground architecture to cope with both navigation and RSE needs (with inputs from ESTEC study) ? Produce technical specification and architectural design for a CDMA ground modem. ? Design and develop the breadboard of the complete CDMA ground modem with emphasis on the critical technologies. ? Full test and validation of the breadboard Rx development using realistic signal characteristics. ? Test of the CDMA breadboard Rx with the Tx breadboard resulting from the activity at ESTEC (if available) 2) SBI for navigation ? Define the SBI error budget for navigation use ? Produce the specifications and the architectural design of the signal processing tool for SBI used for navigation, ? Produce the breadboard of the signal processing tool for SBI-navigation ? Test by signal simulation and by tracking data (if available) of the breadboard of the signal processing tool for SBI-navigation
Deliverables
Error budgets, produced specifications, simulation software and all breadboarded hardware and software components

Current TRL:	2	**Target TRL:**	5	**Application Need/Date:**	2019
Application Mission:	Precision lander/Phootprint		**Contract Duration:**	20	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

CDMA Implementation for TT&C and Precision Navigation			
Programme:	TRP	**Reference:**	T906-012ET
Title:	CDMA Implementation for TT&C and Precision Navigation		
Total Budget:	400		
Objectives			
Study and investigation of the CDMA codes for TT&C and precision navigation, preliminary transponder design and breadboarding of the receiver			
Description			
CDMA is being considered in the ESA mission INSPIRE to support Radio Science Experiment (RSE) based on Same Beam Interferometry (SBI) technique. This technique uses a single Earth antenna to track simultaneously and differentially two or more landers. Additionally, CDMA has been proposed as a possible long-term solution for Multi Spacecraft Per Aperture in support of Near Earth and/or Deep Space missions in order to optimise the number of Deep Space antennas required to support ESA missions and thereby minimise the infrastructure investments. The activity shall cover 1. Study and investigation of the suitable CDMA codes taking into account the performance characteristics and impacts of the spacecraft transponder and ground station equipment in terms of acquisition and synchronization aspects, tracking capability in the presence of doppler and doppler rate and the interference robustness together with the signal dynamics such as frequency (Doppler) and amplitude variations. The Link Performances shall be analyzed for typical missions to Mars in order to assess EIRP, operating point of the amplifier, G/T, data rates and coding schemes. In this frame the overall subsystem requirements focusing on on-board and on ground units shall be derived as well. 2. Analysis of the transponder architecture and frequency plan taking into account the following points: - Optimization of the transponder performances in terms of phase stability. - Implementation of different requirements for classical TT&C Communication links and Radio Science (based on SBI). The impact of a Dual Mode Transponder (implementing the CDMA codes but configurable also in Standard Mode using the current ECSS/CCSDS requirements) shall be analyzed also in terms of RSE performances, complexity, mass, power and operational implications 3.Bread-boarding of the on-board receiver: A breadboard of the receiver including the front end and the transponder Digital Signal Processing based on a FPGA device(s) will be developed, it shall include the selected spread spectrum codes for the CDMA applications, in addition to the standard processing.			

Deliverables					
Technical Notes, Final Report and receiver breadboard					
Current TRL:	2	**Target TRL:**	3/4	**Application Need/Date:**	2019
Application Mission:	INSPIRE, future Mars missons		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

EM development - CDMA for TTC and RadioScience					
Programme:	ETP		**Reference:**	E906-013ET	
Title:	EM development - CDMA for TTC and RadioScience				
Total Budget:	1500				
Objectives					
Development and test of an EM model implementing standard TMTC and CDMA codes					
Description					
CDMA is being considered in the ESA mission INSPIRE to support Radio Science Experiment (RSE) based on Same Beam Interferometry (SBI) technique. This technique uses a single Earth antenna to track simultaneously and differentially two or more landers using the same frequency. Additionally, CDMA has been proposed for Muti Spacecraft Per Aperture to control simultaneously from the same G/S two or more S/C's minimising RF coordination issues . The activity shall cover 1. The design and development of the EM model including the RF and digital signal processing . The unit shall include the selected spread spectrum codes, in addition to the standard TMTC. 2. Testing of the EM with adequate lab equipment. In particular the transponder performances in terms of phase stability are very critical. 3. Compatibility tests via RF (at X-band) with the ground station receiver when feasible.					
Deliverables					
Technical Notes, including design description, test procedure and test results. EM hardware and control equipment					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2019
Application Mission:	INSPIRE, future Mars missions		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Breadboarding of EDL Ground Receiver			
Programme:	TRP	**Reference:**	T912-006GS
Title:	Breadboarding of EDL Ground Receiver		
Total Budget:	300		
Objectives			
- Based on the results of the previous activity (T906-008ET) that defined the systems for Direct-to-Earth (DTE) communication to the landers during Entry, Descent and Landing (EDL) phases, this activity will produce the architectural design of the EDL receiver, -identify the critical technologies for the ground receiver, -Breadboard and validate the EDL ground receiver, incorporating the developments made of the critical technologies.			
Description			
After the Beagle failure it has been recommended that ESA missions implement a means of providing information of the events occurring during critical EDL phase, to allow an investigation in case of failure. An activity is started in under TRP (T906-050ET) to assess and define the architecture of a communications system capable of transmitting information during the EDL phase. Moreover, since communications by an orbiter cannot be guaranteed, the solution shall allow transmission of information directly to Earth during EDL phases.			

A Multiple Frequency Shift Keying (MFSK) X-band system has been implemented by NASA but its detection is a very demanding task for a receiver. Current investigations indicate that with a 35m antenna and the state of the art on board technology, the required C/No to receive specific MFSK tones is not fulfilled in all circumstances at the ground station receiver. The architecture of a receiver able to deal with the signal received during EDL phase, will be drafted in the previous TRP activity, in order to allow the communication system assessment. The receiver architecture will be finalised and a breadboard produced and validated under this activity. Based on the results of the previous TEC-ET activity the Contractor shall: - Consolidate the requirements of the ground receiver capable to detect the EDL signal under the extreme conditions previously identified, with ESA ESTRACK 35m antennas; - Produce the architectural design of the EDL receiver, - Identify the critical technologies. - breadboard (proof-of-concept) required for the high-risk developments; - Design and develop the breadboard of the complete EDL Ground receiver (BB EDL Rx) - Full Test and validation of the breadboard receiver development using realistic signal characteristics.
Deliverables
TN's, reports, high-risk developments and EDL receiver breadboard (BB EDL Rx) as implied by above Description; Final Report2

Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2018
Application Mission:	Exomars, Phootprint, Inspire		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	Yes, T8738	
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Preliminary design and performance verification of critical elements for guided entry thrusters			
Programme:	ETP	**Reference:**	E918-008MP
Title:	Preliminary design and performance verification of critical elements for guided entry thrusters		
Total Budget:	800		
Objectives			
Preliminary design and performance verification of critical elements for thrustes guided entry on Mars			
Description			
For a precision landing (on Mars) it is strictly required to guide and control the capsule in the first part of the entry. Indeed the most importance source of dispersion is the hypersonic flight. The NASA Phoenix capsule was designed aiming at a controlled and guided entry but a more detailed analysis of the interaction of the jets of the Reaction Control System (RCS) and the flow at hypersonic and supersonic conditions suggest a significant interference capable to reduce the efficiency of the thrusters or even produce control reversal. The hypersonic guidance was finally removed from the Phoenix EDL architecture in 2005. The activity shall focus on 3 sequential aspects: - the preliminary design of a RCS capable to control and guide a reference entry probe of the ESA?s Mars Precision Lander mission. To this end the contribution of the RCS to forces and moments in low density flow have to be estimated taking into account the heat fluxes on the capsule surfaces due to the impingement of the hot gases. DSMC-CFD calculations (and ad-hoc preliminary tests if necessary) shall be foreseen. The jet flow interaction shall be assessed in view of system (propulsion, accommodation, performance, flight mechanics?) implications/aspects. - derive the requirements for a test campaign (in an aerodynamics rarefied facility) to verify the performance of the designed system. Particular importance shall be given to appropriate duplication of flight conditions and accurate measurement techniques. - Prepare (and eventually modify/upgrade) the selected facility and measurement techniques where to performed the test campaign note: This activity prepares the actual test campaign of Mars guided entry thrusters system to TRL 5 in a following activity.			
Deliverables			
Reports and databases. Computational (and experimental) data. Test campaing requirements. Preparation (modification/upgrade) of the selected facility			

Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2019
Application Mission:	MPL		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-8101, T-8940, T-8093	

Consistency with Harmonisation Roadmap and conclusion:
ATD Harmonisation 2012

Integrated throttleable valve and engine development for Mars landings					
Programme:	TRP		**Reference:**	T919-001MP	
Title:	Integrated throttleable valve and engine development for Mars landings				
Total Budget:	650				
Objectives					
Further development of an all European 2.5-3.5 kN throttleable valve for use as part of an all European Martian Entry Descent and Landing System (EDLS) To include close coupled testing in a flight like configuration with a mono propellant rocket motor.					
Description					
The MSR mission (and any proposed landing on the Martian surface with a large payload) requires a soft landing. The precision of this landing is also of increasing importance as site selection becomes a driver for science. Automatic hazard avoidance also becomes desirable. Both these requirements are best met with a propulsion system with a capacity for thrust modulation. Any exploration robotic missions requiring a soft landing such as MSR and its precursors will require dedicated engines that represent a clear case for European independence. In general, throttleable mono-propellant solutions are required due to landing site contamination considerations. Further, the relative simplicity of the mono-propellant solutions leads to a more mass efficient propulsion subsystem. A running activity on throttlable valve development shows promise that this capability can be acquired within Europe. This testing under the TRP program is to be limited to flow path development of the valve and obtaining metrics for flow quality and repeatability on a development model. Only simulants are to be used and the valve will not be coupled with an engine (though the contractor has been asked to consider thermal and structural constraints in the development) The activity proposed herein is to take the previous work at valve level and examine the issues of coupling the valve to a flight engine. The activity scope is to include: - Further development of the development model (DM) valve to include a flight like interface. - Design development and manufacture of throttle valve elegant breadboard DM - Design and manufacture of valve driver electronics elegant breadboard DM - Demonstration of combined valve and controller in conjunction with battleship/existing chamber and catalyst bed. - Valve development and verification based on existing mono-propellant hardware - Verification of engine thermo-mechanical behaviour and catalyst performance in throttled conditions - Preliminary requirements definition on a throttleable engine of 2.5-3.0kN rated thrust with a deep throttling capability - Preliminary design definition and justification of a mission specific chamber and catalyst bed A European product development in this area can be based on initial know-how built in the past by European industry and needs to be front loaded to cover throttle valve development which is an essential component of the overall engine design. Engine chamber technology already exists at a stand alone TRL of 5, however, the combined TRL is at best 3.					
Deliverables					
DM engine, valve and drive electronics models Valve PDR data pack (based on a generic URD) Engine PRR datapack					
Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	TRL 5 by 2016
Application Mission:	Mars Precision Lander, MSR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
C3: 1-3 KN Throttable Engine(s) The decent engine is likely to require mono-propellant for Mars applications (though bi-propellant remains an option for lunar landing)					

Standard kinetic models for CO2 dissociating flows			
Programme:	TRP	**Reference:**	T918-006MP
Title:	Standard kinetic models for CO2 dissociating flows		

Total Budget:	500				
Objectives					
The objective of this activity is to provide an ESA standard model for Mars entry chemistry. As a first step, the study will focus on pure CO2 reactions, including relaxation of internal degrees of freedom (vibration,...)					
Description					
Mars atmosphere consists in a mixture of CO2 (approximately 95%), N2, Ar and traces of other species. When a probe enters Mars atmosphere at hypersonic speed, the atmospheric gas mixture is heated and chemical reactions occur (dissociation, ionisation...). The design of the heat shield requires the knowledge of the distribution of heat flux, pressure and shear stress at its surface, that depends on the chemical and physical state of the surrounding gas. Chemical and vibrational rates are needed for the numerical prediction of the flow properties. They are best provided by processing results of numerous tests in kinetic shock tubes. ESA has developed a facility dedicated to this problem. The work shall focus on CO2 pure gas, but the influence of the presence of N2 and Ar shall also be preliminary assessed. It is expected to involve mostly experimental work in shock tube(s), but also numerical and analytical work shall be required: Part of the work shall be to perform by emission/absorption measurements in a shock tube giving ground state and most important excited states populations at high temperature. LIF (Laser Induced Fluorescence) measurements shall also be investigated, for their applicability in such short duration flows. The electronic densities and temperatures shall also be measured. A two spectrometer approach for the emission spectroscopy is recommended, so to identify the important bands, and to investigate particular bands at high resolution. Ab initio calculations (Molecular Dynamics/Schr?dinger if required) shall be performed for the most critical chemical rates. The results of the shock tube tests and of ab-initio calculations shall be collected, to develop a high-fidelity chemical and vibrational kinetic scheme for CO2 mixture. Different levels of modelling shall be included in the standard kinetic model developed within this activity, including Collisional Radiative (excited state specific) and State to State (vibrational state specific) data. The final result of the activity is the recommendation of standard chemical kinetics schemes for CO2, with the associated reaction rates and assessment of confidence/uncertainties.					
Deliverables					
Reports. Experimental data in electronic format (Data Base) and numerical data and associated models also in electronic format to allow future comparisons and/or benchmark tests. ESA standard kinetic models for CO2 mixtures chemistry, ionisation and vibrational relaxation.					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2023
Application Mission:	MREP		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-8090, T-8089	
Consistency with Harmonisation Roadmap and conclusion:					
ATD Harmonisation 2012					

Adaptation of next generation commercial solar array technology to exploration missions			
Programme:	TRP	**Reference:**	T903-016EP
Title:	Adaptation of next generation commercial solar array technology to exploration missions		
Total Budget:	100		
Objectives			
Examine the scope for application of next generation solar array technology for commercial earth orbit applications to exploration missions. Definition of delta developments for exploration missions			
Description			
Since the last meeting of TECNETSD9 in 2013, planning for development of next generation solar array technologies at prime contractors (in particular at TAS-F and Airbus D) has matured significantly. Scope for the incorporation of next generation solar cell technology and significant further reduction of structural mass have been identified as part of the same system level trade-offs. A preliminary study for the Inspire mission (ref. INSPIRE-TASF-ENG04-100639806R08/07/2014) identified scope to apply, for Mars surface missions, next generation solar array technology which is already under development for commercial earth orbit missions. This study will investigate the applicability / benefit of next generation commercial technology to exploration missions, including PHOOTPRINT, INSPIRE and other reference Mars surface lander and rover applications, and define the delta-developments needed to bring these technologies to TRL 6 for different exploration mission scenarios. Compatibility with dust removal systems / combined system level optimisation will be included. This approach is likely to be very cost effective because the probability that the technology developments will reach TRL6 for commercial missions is very high and the delta cost to achieve TRL6 for exploration missions is likely to be a small fraction of the overall development cost. A similar approach has successfully been adopted for characterisation of commercial solar cells for Mars surface applications in			

order to derive the maximum benefit from available technology while minimising the need for dedicated new developments.					
Deliverables					
Study report(s) and roadmap for delta developments to achieve TRL6 for exploration missions					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	all		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Yes with Solar Generators and Solar Cells RM [D11 ? Solar generator development optimized for ultra-thin multi junction cells]					

Adaptation of next generation commercial solar array technology to exploration missions					
Programme:	TRP		**Reference:**	T903-016EP-B	
Title:	Adaptation of next generation commercial solar array technology to exploration missions				
Total Budget:	100				
Objectives					
Examine the scope for application of next generation solar array technology for commercial earth orbit applications to exploration missions. Definition of delta developments for exploration missions					
Description					
Since the last meeting of TECNETSD9 in 2013, planning for development of next generation solar array technologies at prime contractors (in particular at TAS-F and Airbus D) has matured significantly. Scope for the incorporation of next generation solar cell technology and significant further reduction of structural mass have been identified as part of the same system level trade-offs. A preliminary study for the Inpsire mission (ref. INSPIRE-TASF-ENG04-100639806R08/07/2014) identified scope to apply, for Mars surface missions, next generation solar array technology which is already under development for commercial earth orbit missions. This study will investigate the applicability / benefit of next generation commercial technology to exploration missions, including PHOOTPRINT, INSPIRE and other reference Mars surface lander and rover applications, and define the delta-developments needed to bring these technologies to TRL 6 for different exploration mission scenarios. Compatibility with dust removal systems / combined system level optimisation will be included. This approach is likely to be very cost effective because the probability that the technology developments will reach TRL6 for commercial missions is very high and the delta cost to achieve TRL6 for exploration missions is likely to be a small fraction of the overall development cost. A similar approach has successfully been adopted for characterisation of commercial solar cells for Mars surface applications in order to derive the maximum benefit from available technology while minimising the need for dedicated new developments.					
Deliverables					
Study report(s) and roadmap for delta developments to achieve TRL6 for exploration missions					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	all		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Yes with Solar Generators and Solar Cells RM [D11 ? Solar generator development optimized for ultra-thin multi junction cells]					

SFR, Robotics and Mechanisms

Exomars-like rover and science operations simulation through field-trials.					
Programme:	ETP		**Reference:**	E913-016FT	
Title:	Exomars-like rover and science operations simulation through field-trials.				
Total Budget:	1000				
Objectives					
To undertake field trials of simulated Exomars rover and science operations, including drilling, in support of preparation for the 2018 mission.					
Description					
In preparation for Exomars science operations during the 2018 mission, simulated operations under realistic conditions, including rover and instrumentation in the field are required to be performed to provide training to mission planners, rover operators as well as science instrument teams to work together as seamlessly as possible. The previous ESA TRP activity SAFER, has successfully conducted in 2013, field trails directly relevant to the Exomars 2018 mission. The objectives of the SAFER activity were to bring together three Exomars instrument models (PANCAM emulator, CLUPI emulator and WISDOM prototype) on a rover platform capable of autonomous operations, and to test in a representative Mars environment, the strategies necessary for successful science target identification, approach, and investigation, including drilling (albeit manually). This MREP2 activity proposes to undertake enhanced field trail campaigns in both 2017 and again in 2018, building on the experience and lessons learned from the SAFER campaign, by increasing the level of realism and extending the science instrument suite, as well as including the participation of relevant control centres in the operations. In this way, maximum benefit is obtained by re-using very recent expertise and knowledge gained by the teams involved in setting up and conducting the trials as well as the science teams that participated in them. These campaigns are expected to include: 1) An existing Exomars drill breadboard or equivalent, mounted on the rover platform or other suitably representative mount. 2) An existing Exomars-like rover mobile platform housing the instruments and possibly the drill. 3) The Exomars rover navigation system for flight-like autonomous rover mobility operations. 4) Existing prototypes or breadboards of the WISDOM, Pancam and CLUPI instruments, plus other COTS replacements of rover instruments (E.g. Raman Spectrometer and MicroOmega infrared spectrometer) for which no existing hardware is available for use in the field trial. 5) Remote rover and science operations, using Harwell or the Altec Rover Control Centre or both. 6) Science operations that are based on the Exomars Reference Experiment Cycle. The science and engineering dataset generated during the field campaign will be included into the database at the ESA Harwell Robotics & Autonomy Facility to support future ESA activities. The proposed work fits within the larger context of on-going preparations for Exomars operations across Europe. Based on previous experience with field trials for rovers as well as sampling systems, it is expected that this activity could also benefit from a joint participation of CNES and the Italian Space Agency, ASI.					
Deliverables					
Any breadboards developed. Technical and video documentation. All engineering and scientific data generated during the trials					
Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	EXM 2018		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT (COMPASS)			
Programme:	TRP	**Reference:**	T913-011MM
Title:	Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT (COMPASS)		
Total Budget:	200		
Objectives			
Enhance TRL of SPARTAN/SEXTANT computer vision cores, for navigation, towards flight			
Description			

? Background: The SPARTAN and SEXTANT activities have implemented in VHDL logic a series of computer vision algorithms necessary to implement navigation systems for planetary probes. Starting from their mainly sequential description, the algorithms have been turned into vectorial and pipelined cores so that they can con work in the latest FPGA devices. However, these devices are not currently qualified for space use and even when they will be so, they will be subject to US export restrictions. The subject activity proposes to re-engineer the SPARTAN/SEXTANT cores so that they can be partitioned and ported from the present single-FPGA into networks of smaller FPGA devices thus allowing the possibility of using European-sourced FPGAs.. ? Programme of work: 1. preliminary design of system and validation setup 2. detailed design 3. Manufacturing, assembly and unit testing 4. Testing 5. Closeout					
Deliverables					
? standard project documentation ? technical notes, ? FPGA cores ? demonstrators					
Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2015
Application Mission:	MSR, PHOOTPRINT, future rovers		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8937	
Consistency with Harmonisation Roadmap and conclusion:					
The activity was not addressed by the 2012 harmonisation exercise on A&R, although its precursor activities were presented.					

DExtrous LIghtweight Arm for exploratioN (DELIAN)					
Programme:	TRP		**Reference:**	T913-003MM	
Title:	DExtrous LIghtweight Arm for exploratioN (DELIAN)				
Total Budget:	800				
Objectives					
Development of a breadboard of robot arm (including annexed tool exchange device) capable of implementing 1) deployment and operation/application of scientific instruments/tools on surface soil/rock, 2) escavation/trenching/scooping of granular soil 3) support for coring 4) transfer of samples within and in/out of the arm base platform.					
Description					
The activity is a follow-on from a previous system study on a Sample Fetching Rover for MSR. The activity shall: 1) further detail the system requirements related to the robotic arm produced by the SFR system activity, include additional requirements that will be provided by the SOW, define verification requirements 2) re-visit the conceptual design on the basis of the updated requirements 3) design and validate by simulation the design 4) Manufacture, assemble and integrate the arm 5) test and demonstrate the breadboard 6) provide recommendations on technology development The breadboard is needed: 1) to verify attainable performance and identify technological issues, 2) to provide a platform for integrated testing of sampling tools, sampling procedures, and the overall system.					
Deliverables					
Documentation: System Requirement Document, Detailed Design Document, User Manual, test report, video describing the development and documenting the tests Hardware: breadboard of robot arm Software: executable code to enable use and testing					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2013
Application Mission:	IM		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-2, T-7717	
Consistency with Harmonisation Roadmap and conclusion:					

<table>
<tr><th colspan="6">Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)</th></tr>
<tr><td>Programme:</td><td colspan="2">TRP</td><td>Reference:</td><td colspan="2">T913-008MM</td></tr>
<tr><td>Title:</td><td colspan="5">Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)</td></tr>
<tr><td>Total Budget:</td><td colspan="5">450</td></tr>
<tr><td colspan="6">Objectives</td></tr>
<tr><td colspan="6">Breadboarding and validation of a robotic system for cleaning solar arrays and thermal radiators, using the only proven-to-work-on-Mars dust removal principle.</td></tr>
<tr><td colspan="6">Description</td></tr>
<tr><td colspan="6">MER operations showed that wind, in the form of dust-devils, was a very efficient way to clean the rover solar panels. The proposed R&D activity aims at implementing the "air-cleaning" principle with simple robotic means that can blow dust off of critical surfaces. The manipulator, placed in a suitable location on the rover can puff air from its tip. The manipulator moves its tip on a pattern designed to progressively blow off the dust from the inner surfaces to the edges.

The main advantages of this solution are:
1) that it uses the only cleaning principle known to certainly work on Mars,
2) that it can be independent of the geometry and configuration of solar array and thermal radiators,
3) it does not impose extra hardware on these already densely populated surfaces, and,
4) it could potentially clean other surfaces (e.g. optics of instruments).

The activity shall:
1. address the design, development of the three main elements of air-puffing system being 1) an ultra-lightweight stick manipulator including the bellow-duct technology to route the air in the joints, 2) a Martian-air compressor, 3) a puffing nozzle
2. define the optimal configuration for their placement on the deck of a planetary rover (SFR could be considered a study case) and the optimal operational use
3. Validate the system through testing of a breadboard in representative Martian environment

The stick manipulator shall (and can) be extremely light as being just made of air ducts and simple joints having no demanding positioning/orientation accuracy. The compressor is assumed to be best placed at the manipulator base. Potentially also all actuators can be placed at the base of the manipulator. In the case that another arm is present on the rover (e.g. DELIAN) the control electronics can be shared between the two systems.

Overall the activity shall aim at implementing the design of the DUSTER within very constrained mass envelope (few hundred grams) and with minimalist stowage and packing. A functional system demonstrator shall be produced. The activity finally shall also produce breadboard(s) to validate the DUSTER system and characterise its performance by tests in a simulated Martian environment.</td></tr>
<tr><td colspan="6">Deliverables</td></tr>
<tr><td colspan="6">1. DUSTER system functional demonstrator
2. DUSTER breadboard(s)
3. Test results.</td></tr>
<tr><td>Current TRL:</td><td>1</td><td>Target TRL:</td><td>3</td><td>Application Need/Date:</td><td>TRL5 by 2014</td></tr>
<tr><td>Application Mission:</td><td colspan="2">INSPIRE, SFR</td><td>Contract Duration:</td><td colspan="2">18</td></tr>
<tr><td>S/W Clause:</td><td colspan="2">N/A</td><td>Reference to ESTER</td><td colspan="2"></td></tr>
<tr><td colspan="6">Consistency with Harmonisation Roadmap and conclusion:</td></tr>
<tr><td colspan="6"></td></tr>
</table>

<table>
<tr><th colspan="4">Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)</th></tr>
<tr><td>Programme:</td><td>TRP</td><td>Reference:</td><td>T913-008MM-B</td></tr>
<tr><td>Title:</td><td colspan="3">Dust Unseating from Solar-panels and Thermal-radiators by Exhaling Robot (DUSTER)</td></tr>
<tr><td>Total Budget:</td><td colspan="3">450</td></tr>
<tr><td colspan="4">Objectives</td></tr>
<tr><td colspan="4">Breadboarding and validation of a robotic system for cleaning solar arrays and thermal radiators, using the only proven-to-work-on-Mars dust removal principle.</td></tr>
<tr><td colspan="4">Description</td></tr>
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surfaces. The manipulator, placed in a suitable location on the rover can puff air from its tip. The manipulator moves its tip on a pattern designed to progressively blow off the dust from the inner surfaces to the edges. The main advantages of this solution are: 1) that it uses the only cleaning principle known to certainly work on Mars, 2) that it can be independent of the geometry and configuration of solar array and thermal radiators, 3) it does not impose extra hardware on these already densely populated surfaces, and, 4) it could potentially clean other surfaces (e.g optics of instruments). The activity shall: 1. address the design, development of the three main elements of air-puffing system being 1) an ultra-lightweight stick manipulator including the bellow-duct technology to route the air in the joints, 2) a Martian-air compressor, 3) a puffing nozzle 2. define the optimal configuration for their placement on the deck of a planetary rover (SFR could be considered a study case) and the optimal operational use 3. Validate the system through testing of a breadboard in representative Martian environment The stick manipulator shall (and can) be extremely light as being just made of air ducts and simple joints having no demanding positioning/orientation accuracy. The compressor is assumed to be best placed at the manipulator base. Potentially also all actuators can be placed at the base of the manipulator. In the case that another arm is present on the rover (e.g. DELIAN) the control electronics can be shared between the two systems. Overall the activity shall aim at implementing the design of the DUSTER within very constrained mass envelope (few hundred grams) and with minimalist stowage and packing. A functional system demonstrator shall be produced. The activity finally shall also produce breadboard(s) to validate the DUSTER system and characterise its performance by tests in a simulated Martian environment.
Deliverables
1. DUSTER system functional demonstrator 2. DUSTER breadboard(s) 3. Test results.

Current TRL:	1	**Target TRL:**	3	**Application Need/Date:**	TRL5 by 2014
Application Mission:	INSPIRE, SFR		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Solar-Panel Or Thermal-radiator cLEaning Sub System (SPOTLESS)			
Programme:	ETP	**Reference:**	E913-015MM
Title:	Solar-Panel Or Thermal-radiator cLEaning Sub System (SPOTLESS)		
Total Budget:	1200		
Objectives			
The activity shall further develop the most promising dust removal system that has been proven in previous early technology development activities and test in relevant environment to increase the end-to-end system TRL.			
Description			
The proposed activity will build upon the most successful dust removal principle demonstrated in previous TDAs (e.g. T913-008MM DUSTER or previous Aurora SAMM study concepts). The system design shall be revisited with the scope to increase the TRL and develop a full E(Q)M of the dust removal system, tailored to the candidate MREP2 mission needs. The activity will look at SPOTLESS as a lander/rover subsystem (using INSPIRE or Small Rover as reference cases), where interfaces and lander/rover accommodation issues will be thoroughly investigated and incorporated in the design, as much as the lander/rover design maturity allows. The end-to-end control of the dust cleaning system will be designed as well as the detailed specification of dust-removal operational scenarios targeted to the INSPIRE/SFR missions will be outlined. Finally the system will be tested in a Martian environmental simulator both for validation and for overall characterization of performance metrics (w.r.t. resources, cleaning efficiency of operational scenarios, etc.) Programme of work: 1. requirement specification 2. preliminary design of apparatus and validation setup 3. detailed design 4 Manufacturing, assembly and unit testing			

5. Testing 6. Closeout					
Deliverables					
- project documentation - technical notes, - SPOTLESS hardware & software - test data					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2015
Application Mission:	SFR, MSR		**Contract Duration:**	20	
S/W Clause:	N/A		**Reference to ESTER**	T-1, T-9012	
Consistency with Harmonisation Roadmap and conclusion:					
The activity was not addressed by the 2012 harmonisation exercise on A&R, although its precursor activity was presented					

Mechanisms technologies that operate at very low temperatures					
Programme:	ETP		**Reference:**	E915-002MS	
Title:	Mechanisms technologies that operate at very low temperatures				
Total Budget:	475				
Objectives					
Development of mechanisms technologies (e.g. solid lubrication, surface treatments, bearings etc) that allow mechanisms to have safe operating temperatures below -40C, and as low as -100C (with flight allowable temperatures even lower than that) to allow the operation of rover locomotion systems, robotic arms, and other such deployable systems without significant pre-heating.					
Description					
The current pre-heating requirements of deployable mechanisms on Mars landers and rovers can require a considerable power budget if operation is needed from the early morning on a Martian sol, even at equatorial latitudes. The MERs were rated to safely operate at -55C while the Beagle 2 arm was rated to -40C. On small rovers and landers, the constraints on battery and solar array size limits the power available for mechanism preheating as the available power has to be shared with locomotion and robot arm operations. Mechanisms (including actuators with motors and gearboxes, etc) that have safe operating temperatures below -40C, and as low as -100C (with flight allowable temperatures even lower than that) are in need of development to allow the operation of rover locomotion systems, robotic arms, and other such deployable systems without significant pre-heating. This activity proposes the development of technologies (using inputs from an earlier system study that would identify required technology developments in this area) that would enable mechanisms to operate at very low temperature.					
Deliverables					
Qualified technologies that allow mechanisms used in landers/rovers to operate at very low temperatures.					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2013
Application Mission:	SFR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Mechanisms Technologies that operate at very low temperatures (Extended test campaign) - CCN			
Programme:	ETP	**Reference:**	E915-004FP
Title:	Mechanisms Technologies that operate at very low temperatures (Extended test campaign) - CCN		
Total Budget:	350		
Objectives			
The objective is to undertake a more comprehensive testing campaign within the ongoing MREP "Cold mechanisms" activity (E915-002MS) in order to achieve a higher TRL and reliability.			
Description			

In the activity, MREP Mechanisms Technologies that operate at very low temperature, the rover locomotion subsystem was identified as one of the main critical mechanism onboard a Mars surface element (Rovers/Lander) that would impose the most challenging requirements in terms of low temperature (benefits from early start-up operations at -80C) and total lifetime (Sample Fetching Rover (SFR) application 21km ground track). Among other parts of the locomotion subsystem, this imposes that the drive mechanism is expected to achieve more than 100 million cycles on the motor, more than 6 million cycles on the planetary gearbox and around 63,000 cycles on the harmonic drive (all intended at output shaft). These two requirements are far from been achievable with the current mechanisms technologies used for Mars exploration; on one hand, the liquid lubricants (i.e. Braycote) due to the low extreme temperature, and on the other hand, the solid lubricants (i.e. sputtered MoS2) due to the long lifetime. In the course of the activity, during the trade-offs and preliminary testing (i.e. Pin-On-Disc and fretting tests) of the most promising non-space and space mechanisms technologies, several solutions have shown interesting results: - 4 solid lubricants based on MoSx/WC and MoS2+Sb2O3 have preliminary demonstrated an increase in the lifetime by a factor of a 100 versus sputtered MoS2. - 2 liquid lubricants with specific additives have shown similar friction coefficients to Braycote601EF at -80C however they remain more promising since their viscosity at -80C is significantly lower. On top of this, it has been estimated that different Harmonic Drive configuration designs could be promising e.g. the type specifically designed for dry lubrication (by maximising synergies with the harmLES project (EU)) with the option of reducing the preload on the teeth (TBC). Also new materials, such as ceramics for the planetary gears or a breakthrough concept based on contactless magnetic transmission were found promising. Considering all these promising findings and the limited resources of the initial activity in regards to the testing campaign (i. e. only first ranked solutions, only two components selected from the full drive chain, HD and PG, will be tested) it is believed that there is a need for extending the test campaign. This way will substantiate the final outcome by increasing the reliability of the results and/or by increasing the range potential solutions, including hybrid (according to a consolidated "best practice" approach) and/or even extend to other components of the kinematic chain of a drive mechanisms by covering also, the bearings, hall sensors and motors. Collateral effect of an adequate implementation of this extended test campaign will be the minimisation of the cost and design efforts. Coordination and synergies with other European projects (i.e. harmLES) and ESA activities (Dry lubricated Gearbox) will also be maximised.
Deliverables
Technical notes, breadboards, qualified technologies that allow mechanisms used in Lander and Rovers to operate at very low temperatures,

Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2015
Application Mission:	Sample Fetching Rover, Phootprint and Inspire		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Advanced Thermal Architecture for Mars Environment			
Programme:	ETP	**Reference:**	E921-006MT
Title:	Advanced Thermal Architecture for Mars Environment		
Total Budget:	1000		
Objectives			
The objective is to develop an advanced thermal architecture for a warm compartment used for Mars surface operation. Several key thermal components, as stand-offs, insulation, convection baffles and harness feedthroughs, need to be enhanced in order to minimize the heat loss to the environment.			
Description			
Typically, a warm compartment of a Rover or Lander on the surface of Mars will lose its internal heat though the insulation. Nevertheless, mechanical stand-offs as well as harnesses will also contribute to between 1/3 to 1/2 of these heat losses. There are some development activities currently on-going concerning the Aerogel insulation. This proposed activity would be a follow-on to these Aerogel development activities, covering a full scale warm compartment. Even though several technologies for stand-offs harness feedthroughs are currently available, they are mostly not optimised for low thermal conductivity. Therefore, within this activity, a standardized and thermally optimised stand-off shall be developed and tested. In addition, low-conductive feed-throughs			

for harnmesses and electrical or sensor wires shall be developed and tested, in order to reduce the parasitic heat losses. Finally, as the warm compartment may have several large volumes that could trigger natural convection, the uses of baffles can be of advantage to suppress natural convection. After the development and test (at sample/subsystem level) of these three technologies, a representative warm compartment shall be designed, manufactured and tested, implementing these technologies and the insulation technology currently being developed.					
Deliverables					
Full scale warm compartment breadboard Trade-off, Design, Analysis & Test Documentation					
Current TRL:	3-4	**Target TRL:**	6	**Application Need/Date:**	2019
Application Mission:	SFR, MSR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-8839	
Consistency with Harmonisation Roadmap and conclusion:					
No existing THAG harmonisation dossier but consistent with D/TEC Exploration Technology Roadmap					

Miniaturized Integrated Avionics for planetary landers					
Programme:	ETP		**Reference:**	E901-003ED	
Title:	Miniaturized Integrated Avionics for planetary landers				
Total Budget:	1500				
Objectives					
Design and Development of a miniaturized OBC-PCDU for planetary landers					
Description					
Planetary landers and rovers, require avionics that are low mass, low power and miniaturised as much as possible. Based on the outcomes of the activity Tailored On-Board Computer EM for Planetary Landers, the proposed activity aims to design and develop an integrated and miniaturized all-in-one avionics solution that will provide the functionalities of data handling, command and control, data storage , landing phase control and power management, conversion and distribution for planetary landers. The inclusion of parts of the communication system shall also be addressed. Several precursors or parallel relevant activities include: - The Tailored On-Board Computer EM for planetary Landers (ITT AO/1-6718/11/NL/EK) activity, which develops a single lane planetary landing data processing unit composed by a Processing module and a Power module; these items represent two of the elementary building blocks that will compose the future miniaturised avionics system. - The Solar Power Regulator Breadboard for Mars Surface Missions (E903-012EP) activity, which will develop the most suitable solar array power regulator for the planetary lander purposes. - Aurora Avionics Architecture System Definition that was completed in 2005. The proposed activity is split in two phases: Phase 1 - Requirements Definition, Architectural Trade-off (which subsystems to be included), Architectural Design Phase and Interface Definition (500 kEuros) Phase 2 - Detailed Design and Development of an elegant breadboard of the avionics (1000 kEuros) Requirements for the integrated avionics for Planetary landers in particular for Digital and Power functions and interfaces (type and number) shall be defined. The requirement definition activity shall be concluded with a System Requirement Review and followed by an architectural design activity. Also the mechanical interfaces of such an integrated unit shall be analyzed in order to later have the possibility to procure such boards from different subcontracting companies (according to their best competence, for example OBDH, solar array power conversion, power management and distribution, etc.). A redundancy concept for the integrated avionics unit tailored for planetary landers shall be proposed and analyzed. The avionics shall be based on a modular design that will allow adaptability and easy upgradeability of functions and performances. The Phase 1 will be concluded with an Architectural Design Review. The Phase 2 will be started after a positive conclusion of Phase 1 and shall involve company(ies) with proven experience in D&D of OBC/CDMU/PCDU products. An elegant BB shall be designed, developed and tested accordingly to a set of agreed test plan and procedures.					
Deliverables					
Elegant Breadboard of a miniaturized avionics system, data package.					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2015

Application Mission:	MSR, INSPIRE, future lander/rovers.	**Contract Duration:**	30
S/W Clause:	N/A	**Reference to ESTER**	T-7795, T-7799, T-7753, T-8614
Consistency with Harmonisation Roadmap and conclusion:			
A miniaturized OBC-PCDU is consistent with the trends identified in the technical dossier on Data Systems and On-Board Computers (issue 3, 2012) and on Power Management and Distribution (2008).			

Solar Power Regulator Breadboard for Mars Surface Missions					
Programme:	TRP		**Reference:**	T903-012EP	
Title:	Solar Power Regulator Breadboard for Mars Surface Missions				
Total Budget:	300				
Objectives					
The main objective is the optimisation of power system topologies and control to achieve the maximum photovoltaic power transfer to the platform and the payload for Mars Surface Missions.					
Description					
Solar Arrays on the Mars Surface face harsh, non-homogenous and highly unpredictable environments due to suspended dust in the atmosphere, dust deposition, occurrence of dust storms, high daily thermal excursion and sun incidence evolution during the daytime. Compared to conventional shunt switching regulators, regulators based on Pulse Width Modulation (PWM) converters and Maximum Power Point (MPP) Trackers (MPPTs) would enable a significant increase of photovoltaic power transferred by the conditioning electronics to the platform and the payload. In the TEC-EP power laboratory, specific power topologies are currently being studied and tested which should allow efficiency and mass/size improvements over more conventional designs. The existing MPPT tracking algorithms are not well suited for Mars due to their inability to differentiate a local MPP to the absolute MPP, and other principles can be investigated and plugged into the conditioning electronics to be able to track maximum solar array power in any condition. This activity consists of 4 main tasks: - system analysis to identify the most promising power conditioning designs and MPPT solutions; - tradeoffs and simulations for the identification of the most suited Solar Array Regulators and MPPT designs; - detailed design of the innovative Solar Array Regulators and MPPT; - breadboarding & testing of the selected design.					
Deliverables					
Breadboards, test results and study reports					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2015
Application Mission:	Inspire		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	None	
Consistency with Harmonisation Roadmap and conclusion:					
consistent with Harmonisation Power Management and Distribution second semester 2008					

Development of a low temperature Lithium ion battery and survivability tests			
Programme:	ETP	**Reference:**	E903-013EP
Title:	Development of a low temperature Lithium ion battery and survivability tests		
Total Budget:	450		
Objectives			
Development and life test of a Li ion battery at low temperature, after selection of cells by characterisation tests; and Assessment of the possibility of the Li ion battery recovery after storage at very low temperature (-50C or colder)			
Description			
In applications such as landers and rovers, the battery has to deliver high energy at low temperature. ABSL Space products (UK) evaluated in 2007 the best COTS Li ion cells operating at -20?C for Exomars. A cell was selected and a battery was assembled and tested at Estec. Li ion cells are evolving quickly, due to terrestrial market needs (electronics, automotive,...) and new cells with higher specific energy are now available and should be evaluated at low temperatures. Some manufacturers are also developing Li			

ion cells for low temperatures conditions; such cells could be of interest if they offer sufficient specific energy. After characterisation of available cells, the survivability of the cells in extreme temperatures will be assessed. In case of malfunction, or dust storm on Mars leading to loss of power and loss of thermal management, the Li ion battery could be exposed to very low temperatures. The recovery of a battery after exposure to temperatures below freezing point of the electrolyte, is not known. The proposed activity will include two phases: Phase1 - Thorough evaluation of high specific energy COTS cells at low temperature, and of available prototype of cells optimised for low temperatures, - Selection of the best candidates, - Battery design and assembly, - Life-test at low temperature. Phase 2: - Very low temperature storage Test: storage at very low temperature at different state of charge, for different durations; - Test of different recovery scenarios (i.e. Charge conditions; rate, minimum temperature required).					
Deliverables					
Technical Notes, characterisation tests results, Battery breadboard, battery tests results, recovery plan					
Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2012
Application Mission:	INSPIRE, SFR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	None	
Consistency with Harmonisation Roadmap and conclusion:					
Yes. Follow-on from Battery roadmap issue 1 revision 3 September 24 2006. Activity D1					

Feasibility study of a plasma drill for Mars exploration (PLASMARS)					
Programme:	ETP		**Reference:**	E915-006FT	
Title:	Feasibility study of a plasma drill for Mars exploration (PLASMARS)				
Total Budget:	245				
Objectives					
The main objective of this activity is to assess the feasibility and effectiveness of plasma drilling technology for use in Mars exploration.					
Description					
The ability to drill into the Martian surface is a key technology of interest to ESA, as demonstrated by the development of the drill system for the Exomars rover that has been on-going for many years and it’s central role in the mission to acquire samples from 1-2 metres depth. This conventional drill system is limited however to relatively shallow depths due to the considerable mass and volume that would be required for a system that could reach down to much greater depths; something that is not feasible on a relatively small rover. As it is of strong scientific interest to be able to acquire samples from even greater depths on the Martian surface, in particular in the search for extant life, technologies that offer the ability to reach 5m or more within the same resource envelop of the Exomars drill are of considerable interest to the programme. One such technology is based on plasma drilling which has seen terrestrial applications in the areas of deep drilling for geothermal and oil and gas. This technology may offer advantages over conventional rotary drilling techniques in allowing greater drilling depths using the same limited resources available on small lander and rover platforms. This activity is intended to undertake the following tasks: ➢ Perform a literature survey, review ESA’s high-level technical requirements and elaborate a set of preliminary requirements for a plasma-drilling system suitable for drilling on the Martian surface. ➢ Design at a conceptual level, a plasma-drilling system for the Mars application ➢ Design, manufacture and test simple breadboards of components of the drilling system to investigate, for example, feasibility of the concept under Martian conditions, resources required and scientific integrity of the material that can be accessed from within the drill hole. ➢ Elaborate a technology development plan with ROM costing for a development until TRL5.					
Deliverables					
Technical Data package, breadboards of drill components					
Current TRL:	2	**Target TRL:**	3-4	**Application Need/Date:**	2020
Application Mission:	MSR, Phootprint		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		

Consistency with Harmonisation Roadmap and conclusion:
N/A

Breadboarding and testing of a plasma drill for Mars exploration (PLASMARS-2)					
Programme:	ETP		**Reference:**	E915-009FT	
Title:	Breadboarding and testing of a plasma drill for Mars exploration (PLASMARS-2)				
Total Budget:	500				
Objectives					
The objective of this activity is to develop a breadboard of a complete plasma drilling system and test it.					
Description					
The ability to drill into the Martian surface is a key technology of interest to ESA, as demonstrated by the development of the drill system for the Exomars rover that has been on-going for many years and its central role in the mission to acquire samples from 1-2 metres depth. This conventional drill system is limited however to relatively shallow depths due to the considerable mass and volume that would be required for a system that could reach down to much greater depths; something that is not feasible on a relatively small rover. This activity is intended to serve as a follow-on to a feasibility study activity on plasma drilling technology for Mars exploration, funded by the MREP-2 programme and initiated in 2014 (see E915-006FT Feasibility study of a plasma drill for Mars exploration (PLASMARS)). This activity would undertake the following tasks: - Based on the outcomes of the feasibility study, elaborate a set of detailed technology requirements for a plasma-drilling system suitable for drilling on the Martian surface. - Design at a preliminary level, a plasma-drilling system for the Mars application - Perform a detailed design of the plasma drill. - Manufacture and test a full-scale breadboard of a plasma drill system under realistic drilling conditions for Mars and/or Moon of Mars. - Produce a development plan with ROM costing.					
Deliverables					
Technical Notes, test results, breadboard H/W.					
Current TRL:	3	**Target TRL:**	4/5	**Application Need/Date:**	2019
Application Mission:	Planetary missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

INSPIRE

Adaptation of Aerogel Materials for thermal insulation					
Programme:	TRP		**Reference:**	T921-001QE	
Title:	Adaptation of Aerogel Materials for thermal insulation				
Total Budget:	300				
Objectives					
Develop and test of multifunctional aerogel for Mars exploration (landers and rovers) to reduce mass of the thermal insulators.					
Description					
Aerogel are produced by sol-gel processing and are the lightest solids known (with density down to 3times that of air). It has been shown in the past that they outperform MLI as a thermal insulation in a low pressure environment as existing on Mars. The objective of the study is to tune the properties of a suitable Aerogel such that also other desirable properties (flexibility, damping) can be achieved. By controlling the pore size and distribution such materials will outperform both MLI as well as classical foams in a low pressure environment. This can be achieved by adapting the materials processing window and by incorporating for instance hybrid compounds into an inorganic Aerogel network. After that key functional properties shall be evaluated and performance improvement shall be quantified.					
Deliverables					
Trade-off and selection of target properties, material processing, tuneable property assessment, test plans, test reports, test samples and technical notes					
Current TRL:	2/3	**Target TRL:**	3/4	**Application Need/Date:**	2013
Application Mission:	INSPIRE, SFR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	None	
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Subsonic parachute trade-off and testing - CCN					
Programme:	ETP		**Reference:**	E918-001MP	
Title:	Subsonic parachute trade-off and testing - CCN				
Total Budget:	350				
Objectives					
Development of a particle imaging velocimery (PIV) system for enhanced subsonic wind tunnel testing and testing campaign with additional subsonic parachute designs for Mars missions.					
Description					
This CCN to the running TRP activity (T918-001MP) is intended to develop a system for Particle Imaging Velocimetry at the Canadian National Research Council (CNRC) subsonic wind tunnel, in order to enhance the quality of the test data that could be achieved for the development of subsonic parachutes for Mars EDL. The activity is divided into two phases: Phase one: Co-development (with CNRC) of the PIV for the subsonic wind tunnel. Phase two: Production of a few parachute(s) with existing designs but using a material which changes color with strain to visualize the stress distribution, and test in CNRC (where the PIV will be available). Further tests (including design and manufacture) with different parachute type(s) than the one presently foreseen in the subsonic test campaign shall also be included.					
Deliverables					
Fully functional PIV system, scale-model parachutes, test data and documentation					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2015
Application Mission:	Mars surface missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

MSR

Biosealing and Monitoring Technologies for a Sample Containment System - Sealing tests and EM design

Programme:	ETP		**Reference:**	E914-004QI	
Title:	Biosealing and Monitoring Technologies for a Sample Containment System - Sealing tests and EM design				
Total Budget:	1000				
Objectives					
Based on the previous results of the MREP-1 activity "Biosealing and Monitoring Technologies for a Sample Containment System", the objective of this TDA is to perform additional, already identified, tests on critical components of the sealing system, adapt the design of the container accordingly, perform necessary breadboarding and produce a design of an EM of the biosealing and monitoring system.					
Description					
This mission enabling technology development for MSR is a continuation of a 2.5 year 1500 kEuro contract completed in June 2013 to develop a flight biosealing and monitoring system for a MSR mission. Phase 1: Based on the previous study and test results, the following additional tests on critical components of the sealing system are necessary: -Aging of polymeric seals -Further development of metal energized seals, incl. change from internal to external compression, seal mating surface -Optimisation of the Nanofoil application for the breaking-the-chain lid -Continuation of the particle penetration tests (sealing system performance validation) in line with PRA and updated metal seal application -Optimisation of monitoring system -Update of PRA -Opening process Some of these tests will introduce a design modification of the container (e.g., stiffening to better support the metal seal) and the sealing system and therefore will also result in new breadboards. -Design of Engineering Model Manufacturing and tests need to be under strict PA/QA control for Phase 1 to meet the schedule and ensure that the conclusions are relevant.					
Deliverables					
Updated breadboards for the sealing and for the containment system, design of EM updated PRA, DDVP for QM and FM.					
Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2017
Application Mission:	MSR		**Contract Duration:**	20	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Biosealing and Monitoring Technologies for a Sample Containment System - EM development and testing					
Programme:	ETP		**Reference:**	E914-005QI	
Title:	Biosealing and Monitoring Technologies for a Sample Containment System - EM development and testing				
Total Budget:	2000				
Objectives					
Based on the previous MREP-2 activity of biosealing and monitoring system development, manufacture an EM and perform end-to-end integrated tests.					
Description					
In this follow-on activity, the following work is envisaged: -Manufacturing of EM, representative of all interfaces, material and processes, incl. internal (aluminum) and external (titanium) container, CBL with Nanofoil and C-seals, lid for internal and external container, monitoring system -Integrated end-to-end test Manufacturing and tests need to be under strict PA/QA control meet the schedule and ensure that the conclusions are relevant.					
Deliverables					
Engineering Model and test reports, data package.					
Current TRL:	4	**Target TRL:**	5	**Application**	2017

				Need/Date:	
Application Mission:	MSR		**Contract Duration:**	16	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

MSR Double walled isolators - breadboard					
Programme:	ETP		**Reference:**	E914-005MM	
Title:	MSR Double walled isolators - breadboard				
Total Budget:	800				
Objectives					
Design, breadboard and validate double walled isolators to receive and analyse MSR samples in clean and ultra clean environment.					
Description					
The challenge of the MSR containment facility is to comply with planetary protection requirements of a category V, restricted Earth return, mission and hence prevent any backward contamination and generation of false positive and negative results in the life detection and biohazard tests. To maintain a clean, contained environment for curation and analysis of returned Mars samples, the MSR biological containment facility parallel studies (ESA contracts Nr 21431, 22226) have identified a potential solution, e.g. a double walled isolator (DWI). A detailed feasibility study for a DWI concept, including a demonstration by test or analysis of critical functions has been proposed before entering a second phase of a detailed design and breadboarding activity. This proposal addresses this second phase: The DWI must provide a primary containment level at least equivalent to a Biological Safety Cabinet (BSC) class III. Interfaces need to be available to pass the samples into and out of the isolator. The isolator must be capable of housing a robotic manipulation system and interfacing with a range of analytical instrumentation. In addition, the control of terrestrial contamination and cross contamination between samples and the recovery of martian material following handling processes is of high importance. The compatibility with decontamination/cleaning processes needs to be taken into account and validated for the DWI. This process shall: - Recover solid materials from surfaces - Clean all equipment in contact with the MSR hardware and samples - Sterilise all equipment in contact with the MSR hardware and samples - Be administered by robotic means, to minimise human interaction with the sample - Be able to be verified after operation (either by direct verification or process qualification)					
Deliverables					
Technical Data Package including Detailed design, and functional breadboard.					
Current TRL:	2	**Target TRL:**	5	**Application Need/Date:**	TRL5 by 2018
Application Mission:	2020+		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Manipulation systems for sample handling in a Sample Receiving Facility					
Programme:	ETP		**Reference:**	E913-010MM	
Title:	Manipulation systems for sample handling in a Sample Receiving Facility				
Total Budget:	1000				
Objectives					
Identify and demonstrate feasibility for a micro manipulation system interfaced to an isolation system for samples returned from Mars respecting the requirements for sample manipulation under containment, contamination control and maintaining sample quality.					
Description					
To handle returned Mars samples for biological hazard assessment, whilst maintaining the science contained within them, it will be necessary to make use of remote manipulation systems to remove contaminating humans as much as possible from the process. These systems will need to be able to: - Handle the samples and sub samples (order of grams down to micro grams)					

- Operate in a freezer temperature (~250K), ambient or low pressure, dry nitrogen environment - Produce a minimum of contamination into the sample environment from the materials and lubricants used in their construction. - Be able to be sterilised decontaminated via a qualified process prior to installation in the containment area - Be able to operate for a minimum of 6 months with a minimum of planned servicing - Operate in a double walled isolator with minimal through wall intrusion Activity in 2 phases: 200 k€ for 12 months to consolidate the requirements, provide a preliminary design iteration & trade off, description of a development program 800 k€ for 24 months for design and performing breadboard testing.
Deliverables
Requirements, preliminary design, development plan, detailed breadboard design, TRR, breadboard test report, recommendation for future activities.

Current TRL:	0	**Target TRL:**	4	**Application Need/Date:**	2015
Application Mission:	MSR and other sample return missions		**Contract Duration:**	36	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

RF Long-Range Navigation Sensor further breadboarding and EM detailed design			
Programme:	ETP	**Reference:**	E906-005ET
Title:	RF Long-Range Navigation Sensor further breadboarding and EM detailed design		
Total Budget:	800		
Objectives			
The definition of an Engineering Model of a sensor able to provide long range sample canister location during MSR rendezvous, as well as associated breadboarding activities			
Description			
The MSR canister of samples (target vehicle) will be launched from the Martian surface and injected in a stable orbit, with severe limitations on payload capacity and resources. Injection accuracy relative to the target vehicle waiting in orbit will be limited by the navigation means of the ascent stage, its surface location, timing and the target vehicle navigation. The target vehicle shall be then detected and tracked by an orbiter (chaser) that will subsequently performed the corresponding rendez-vous manoeuvres. In the detection of the target vehicle, a significant dispersion is expected, which will require therefore in-orbit navigation means from up to thousands of kilometers. Previous studies at mission analysis level and preparatory work for the Aurora Core Programme activity CG80 "RF Long-Range Navigation Sensor Breadboard" has shown that RF-based sensors in chaser and target vehicles are the optimal approach in order to achieve navigation across long ranges. Activity CG80 is now near to completion. 2 parallel contracts have been awarded which will allow comparing the respective performance of 2 RF sensor architectures (one way or two ways). The next logical step is the definition an engineering model in the proposed activity - supported by proper analyses - together with some breadboarding activities allowing to increase the level of confidence on the sensor performances and robustness. The proposed activity will allow reaching TRL 4. The objective of this activity is the definition of the Engineering Model based of the RF Long-Range sensor based on the results of the previous Aurora CG80 activity, together with some breadboarding and test (e.g. antenna suitable to the sample canister accommodation constraints, miniaturised power system, ...). Proper analyses (considering - among others - the sample canister accommodation constraints and the sensor robustness) will support the EM definition. The engineering Model comprises two units. One to be installed in the chaser and the other to be installed in the target vehicle. Both units will be architecturally very different due to different nature of the platforms (chaser and target vehicle).			
Deliverables			
Definition package for an Engineering Model of the long-range RF sensor (two units: one to be on-board of orbiter and the other to be on-board of sample container vehicle) ; breadboards and tests results			

Current TRL:	3/4	**Target TRL:**	4/5	**Application Need/Date:**	2018
Application Mission:	MSR		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

FF Radio Frequency Metrology. Technical Dossier and Roadmap. TEC-ETN/2007.64

Improvement of Delta DOR performances for 1 nrad accuracy for precise landing support					
Programme:	TRP		**Reference:**	T912-001GS	
Title:	Improvement of Delta DOR performances for 1 nrad accuracy for precise landing support				
Total Budget:	250				
Objectives					
The main objectives are 1) To evaluate the technological enhancements needed to improve the accuracy of the Delta-DOR system to the 1 nrad level, either by enhancing the current Delta-DOR system or by using alternative satellite signal structure (e.g. spread-spectrum technique to increase the similarity between the satellite downlink signal and the quasar calibrator) to perform the measurement. 2) To define the proper on-board and ground architectures 3) To simulate critical components of the system (on-board TT&C and on ground correlator) for spread spectrum signal.					
Description					
The precise knowledge of the S/C state at separation from the lander on MSR imposes strict navigation requirements especially on Delta-DOR. The target angular accuracy would be in the order of 1 nrad in the satellite localisation in the plane of sky. The feasibility of such level of accuracy has been partially investigated in the frame of a previous GSP activity (" Interdisciplinary study on enhancement of end-to-end accuracy for spacecraft tracking techniques"). Here it is proposed to address specifically the possibility to reach 1 nrad accuracy (in X- and Ka-band) with either technological improvements on the current systems or via development of alternative technologies in terms of S/C signal structure to be used for Delta-DOR measurements. The study shall therefore: 1) Evaluate the technological developments needed to enhance the current Delta-DOR system to the 1 nrad level 2) Evaluate possible alternatives on the S/C signal structure that could lead to the same (or better) level of accuracy. One of the solutions proposed in the previous GSP activity was to have the spacecraft transmitting a spread spectrum DOR signal over a bandwidth broadened to 152 MHz in the 34.2-34.7 GHz band (Ka-Band). This choice makes the spacecraft and the quasar signals very similar, thus maximizing the noise canceling effect of the interferometry measurement. Moreover, by adopting a spread spectrum DOR signal, the group delay ripple is reduced by a factor of 10, without the necessity of any particular calibration technique. In this case the DDOR correlator software has to be able to handle the de-spreading of the spread spectrum range signal. As part of the study the selection for the most appropriate spread spectrum modulation scheme will be traded off based on performance as well as available technology in the on-board domain. Simulations of the on-board and on-ground process shall be undertaken to demonstrate the feasibility of the concept and identify critical areas in the development 3) Tradeoff between solutions shall be provided with the final recommendation					
Deliverables					
* Technical documentation (design, trade-off) * Simulators of on-board and on-ground enhanced Delta DOR systems.					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2018
Application Mission:	MSR, Precision landing missions		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Planetary communication system based on modulated retro-reflection			
Programme:	TRP	**Reference:**	T916-003MM
Title:	Planetary communication system based on modulated retro-reflection		
Total Budget:	300		
Objectives			
The objective of this activity is to develop a laser communication system in which one partner terminal is extremely miniaturised in terms of size, mass and power consumption by using modulated retro-reflection of the light received.			
Description			
A low-power principle of laser communications between a Mars lander and an orbiter can be applied optically by modulating the reflectivity of a corner-cube or cat's-eye retro-reflector situated on the lander. This type of optical communication system enables one terminal to be extremely small and lightweight with very low power			

consumption (required only for the modulation system). The outgoing laser beam can also be modulated (at a different frequency) enabling bidirectional communications. However, the maximum link distance is only in the order of a couple of hundred km, because the link budget drops with the fourth power of distance, which also limits the achievable data rate. Retro-reflectors require no pointing system, but for hemispherical coverage a retro-reflector array is necessary. Several institutes are investigating the use of modulated retro-reflection systems for laser communication applications in asymmetrical link arrangements, where one partner terminal is located on a platform on which mass, volume and power consumption must be minimised, such as on planetary landers/rovers or sample-return missions. The Contractor needs to have experience with modulated retro-reflector systems, but shall first investigate the latest results from literature. In addition he will identify the space missions/applications for which such a system could be beneficial. He shall then design an optimised system and develop a breadboard prototype and test it in a relevant environment.					
Deliverables					
Breadboard of a transceiver and a retro-reflection system for low-power communication					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	MSR, INSPIRE		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Planetary communication system based on modulated retro-reflection					
Programme:	TRP		**Reference:**	T916-003MM-B	
Title:	Planetary communication system based on modulated retro-reflection				
Total Budget:	300				
Objectives					
The objective of this activity is to develop a laser communication system in which one partner terminal is extremely miniaturised in terms of size, mass and power consumption by using modulated retro-reflection of the light received.					
Description					
A low-power principle of laser communications between a Mars lander and an orbiter can be applied optically by modulating the reflectivity of a corner-cube or cat's-eye retro-reflector situated on the lander. This type of optical communication system enables one terminal to be extremely small and lightweight with very low power consumption (required only for the modulation system). The outgoing laser beam can also be modulated (at a different frequency) enabling bidirectional communications. However, the maximum link distance is only in the order of a couple of hundred km, because the link budget drops with the fourth power of distance, which also limits the achievable data rate. Retro-reflectors require no pointing system, but for hemispherical coverage a retro-reflector array is necessary. Several institutes are investigating the use of modulated retro-reflection systems for laser communication applications in asymmetrical link arrangements, where one partner terminal is located on a platform on which mass, volume and power consumption must be minimised, such as on planetary landers/rovers or sample-return missions. The Contractor needs to have experience with modulated retro-reflector systems, but shall first investigate the latest results from literature. In addition he will identify the space missions/applications for which such a system could be beneficial. He shall then design an optimised system and develop a breadboard prototype and test it in a relevant environment.					
Deliverables					
Breadboard of a transceiver and a retro-reflection system for low-power communication					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	MSR, INSPIRE		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Enhanced interplanetary meteoroid population model					
Programme:	TRP		**Reference:**	T904-003EE	
Title:	Enhanced interplanetary meteoroid population model				
Total Budget:	300				
Objectives					
The main objective of the activity is the development of an enhanced meteoroid environment model that can be used for impact risk assessments for space missions in near-Earth and interplanetary space (applicable for heliospheric distanced of 0.05 to 10AU with main application being Near-Earth space from approx. 0.7 to 2AU). The model shall compute number density, impact flux/ fluency, velocity (heliocentric and relative to spacecraft), impact angle distribution, and imparted linear momentum as a function of meteoroid mass. It shall cover the mass range 10-15 g to 100 gram.					
Description					
Every spacecraft in orbit is impacted by meteoroids. Because of their high velocity (10-70 km/s) even sub-millimetre sized particles can damage spacecraft parts and potentially disable spacecraft functions. Existing meteoroid flux models that can be applied outside of Erath orbit are only at prototype state and have uncertainties of the flux at a given mass of a factor 5-10 even for the Mars distance. Such an uncertainty can lead to overdesign or an unacceptable large risk. The interplanetary meteoroid environment consists of 3 main populations: The sporadic or background population, the stream population, and the interstellar population For most orbits and times the sporadic population is dominant. In recent years new data have become available, mainly radar and optical observations, have become available and the production process of meteoroids (mainly from comets) has been better understood. The new data and understanding should now allow producing an enhanced interplanetary meteoroid population model. The new observational data shall be analysed, preprocessed and assessed for consistency and suitability as input for a new model. This data reduction shall consider the experience gained during the IMEX study (ESA contr. 4000106316) which addresses meteoroid streams. In a second step a computer based model shall be developed that predicts the meteorid fluxes for user specified interplanetary orbits, mission durations, target orientations and size and velocity ranges. The model shall include all known meteoroid populations.					
Deliverables					
Software and related documentation of the developed enhanced interplanetary meteoroid model					
Current TRL:	SW	**Target TRL:**	SW	**Application Need/Date:**	2015
Application Mission:	Interplanetary missions from Mercury to Saturn		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Yes with TD4 Space Environments & Effects Roadmap [Section 3.a: microparticles/environment models]					

Breadboard and test of a multi-layered debris shield for MSR			
Programme:	ETP	**Reference:**	E920-006FT
Title:	Breadboard and test of a multi-layered debris shield for MSR		
Total Budget:	245		
Objectives			
Breadboarding and testing of an active, multi-layered debris shield for protection of the thermal protection system of the MSR Earth Return Capsule from micrometeoroidal impacts during the return journey to Earth.			
Description			
The Earth Return Capsule for the MSR mission will undertake a long cruise journey back to the Earth with the Martian samples and during this time, there is a risk that hypervelocity particles of natural origin may impact the ERC and in particular the heatshield, thus compromising its ability to protect the ERC during re-entry in the earth's atmosphere. As such, debris sheilding is required to protect the heatshield and both single and multilayered options may be considered. Moreover, detection of critical size particles getting through the protection shield and impacting the heat shield is probably also required. This activity proposes to further investigate the feasibility of the concept already studied by Romanian industry under STAR2012 funding called "Active Micro-Shields System", in the frame of the Mars Sample Return mission. This concept offers the possibility of not only detecting the impact of particles, but also in estimating the distance travelled through the shield and whether the shield is punctured or not, exposing the sensitive thermal protection layer beneath. The proposed programme of work includes: 1) Design of a debris shield for the MSR ERC, taking into account the latest micrometeoroid environmental models, the reference mission design and MSR mission reliability requirements. System aspects shall be considered and trade-offs made between single and multi-layered shield designs. 2) Research into suitable materials (such as Aerogel) to make up the multi-layered shield structure, considering the ESA			

requirements. 3) Investigation of novel production techniques for the multilayered structure, such as 3D printing. 4) Manufacture and test (with hypervelocity particle impacts) the shield concept together with particle detection and localisation capability.					
Deliverables					
Breadboard and test results					
Current TRL:	2-3	**Target TRL:**	3-4	**Application Need/Date:**	2022
Application Mission:	MSR		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Micro Meteorids and Orbital Debris (MMOD) impacts characterisation and protection for the MSR Earth Re-entry Capsule (ERC)					
Programme:	ETP		**Reference:**	E904-004FP	
Title:	Micro Meteorids and Orbital Debris (MMOD) impacts characterisation and protection for the MSR Earth Re-entry Capsule (ERC)				
Total Budget:	700				
Objectives					
The objectives of this activity are: - to characterise MMODs impacts on the ERC Thermal Protection System (TPS) and define associated impact equations - to verify the thermal behavior of impacted TPS - to develop a Micrometeorids detection and protection system breadboard to be incorporated on the ERC TPS,					
Description					
The ERC is a critical element of the MSR mission since a failure during re-entry or landing would lead to a possible release of Martian particles into the Earth biosphere, which is unacceptable for Planetary Protection. Consequently a very high reliability must be demonstrated, including for the TPS which is a single point failure. Previous studies have shown that MMOD impacts are a critical event for the TPS performance. This activity focuses on MMOD impact mitigation and is divided in 2 phases: Phase 1: - perform high velocity impact tests with MMOD-like particles (mean micrometeorids velocity being about 15 Km/s) on TPS samples of 1 or 2 sorts (low density and high density). Some tests shall include an ERC debris shield simulator (this cover is foreseen to protect the ERC from the less energetic micrometeorids) - derive impact equations to be used in future studies - perform high enthalpy tests on impacted TPS samples to assess their performance, and from there refine the requirements on critical MMODs Phase 2: - starting from the phase 1 results, derive requirements for a micrometeorid (MM) detector/shield system (MDS) in order to protect against lower energy particles and detect the higher energy MM that perforate the TPS despite the ERC shield. This detection capability allows reducing the mass of the ERC shield to an acceptable level, while fulfilling the Planetary Protection requirements with a very low probability of mission los. - design and build an MDS breadboard - verify the MDS breadboard performance using MM impact tests					
Deliverables					
TPS samples, MDS breadboard, tests numerical data, technical reports					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2018
Application Mission:	MSR		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Design of a crushable TPS for the ERC			
Programme:	TRP	**Reference:**	T919-036MC
Title:	Design of a crushable TPS for the ERC		
Total Budget:	370		
Objectives			
The objective of the proposed activity is to investigate ways of building a multifunctional structure, that acts as a heatshield for planetary re-entry (supporting Thermal Protection System, TPS), but also brings damping capability for hard landing.			
Description			
For the re-entry phase, the TPS is sized to limit the temperature on the inner side of the lander, i.e. a thermal insulation is needed between the external surface and the inside "cold" structure and payload. During the hard landing phase, mechanical decoupling is needed between the external surface that hits the ground at high velocity and the inner payload for which deceleration load shall be limited. This dual thermal/mechanical insulation need leads to the idea of using one single structure, possibly a composite made of several materials, e.g. CFRP foam, honeycomb or the titanium hollow spheres to be developed, to achieve both isolation functions. Such a multifunctional structure would allow simplifying the lander architecture, reducing the number of sub-assemblies and thus reducing the mass and complexity. - Review of the MSR requirements for heatshield and earth impact after re-entry. - Investigate solutions to combine the structural/thermal and impact damping functions of the heatshield. Identify the material characteristics needed and potential candidates, including foams, honeycomb and hollow spheres. Trade-off the solutions. - Provide a material specification as input for the activity on low conductivity/high temperature crushable material using hollow spheres - Design and analyses of a MSR integrated heatshield and earth impact damping structure, possibly using titanium hollow spheres if this material proves best suited and sufficiently mature. - Manufacturing and impact tests of a breadboard (several might be needed for several destructive tests).			
Deliverables			
Documentation (Final Report, Summary Report, and Technical Data Package, incl. Photographic Documentation). Hardware (breadboard).			

Current TRL:	1	**Target TRL:**	3	**Application Need/Date:**	2012
Application Mission:	NEXT, MSR (>2016)		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	High Speed Earth Re-Entry of Sample Capsules: Advanced Heat Shield Concepts	
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Material development for a crushable TPS for the ERC			
Programme:	TRP	**Reference:**	T920-002QT
Title:	Material development for a crushable TPS for the ERC		
Total Budget:	250		
Objectives			
To establish manufacturing technology and scale-up of crushable hollow-sphere made of Ti alloy for use in a crushable TPS for Earth landing during an MSR mission. To characterise the static and dynamic mechanical properties of the material, as well as the physical and chemical properties. To develop and characterise joining techniques of the Ti alloy hollow-sphere to conventional materials used in space applications.			
Description			
The crushable materials are today either honeycomb or polymeric (or carbon) foams. The honeycomb can sustain only compressive stresses and loses its effectiveness when stressed in the nominal direction, the foam are limited to low temperature or procured outside Europe. In this activity, the pure Ti hollow-sphere technology (contract 18167) will be transferred to a high performance Ti alloy. The mechanical and physical characteristics of the material will be established at high and room temperature, the technologies for joining the Ti hollow-sphere to other materials will be developed and characterised. This material is theoretically far better than any existing ones for such passive landing applications as it combines high specific stroke properties with high in-service temperature (about 600C) and a low thermal conductivity.			
Deliverables			
Technical notes - Test samples - Test reports - Breadboard - industrial development roadmap			

Current TRL:	2/3	**Target TRL:**	3/4	**Application Need/Date:**	2012
Application	MSR		**Contract Duration:**	18	

Mission:			
S/W Clause:	N/A	**Reference to ESTER**	T-8148
Consistency with Harmonisation Roadmap and conclusion:			

Ablative TPS Numerical Test Cases - Mathematical Code Assessment & Improvement					
Programme:	GSTP		**Reference:**	G921-007MT	
Title:	Ablative TPS Numerical Test Cases - Mathematical Code Assessment & Improvement				
Total Budget:	300				
Objectives					
To assess the reliability of the mathematical codes used to size the thickness of ablative TPS on entry heatshields; to refine and possibly reduce the related uncertainties; and to identify relevant areas to improve the codes.					
Description					
In the frame of the European Ablation Working Group, several simplified numerical ablation test cases have been defined and were used by different partners to assess the performance of available codes for ablative TPS sizing. Those test cases were based on literature data which, however, turned out to be incomplete and in several aspects not consistent. Missing data had to be complemented by assumptions, which strongly limited the suitability of the derived test cases to assess the performance of the mathematical codes used for ablative TPS sizing. In recent years a new European lightweight ablative material has been developed (TRP-DEAM, MREP-DEAM2) specifically tailored for the Earth return capsule of sample return missions. Also for this new material, now called ASTERM, material and test data cannot be made openly available due to industrial confidentiality aspects. However, a similar material exists, called AQ61, which in its physical composition and performance is very similar to ASTERM, but due to its more complicated manufacturing process is not considered as candidate for relevant flight applications. Within a previous TRP (Thermal Response Characterisation of Reference TPS Material) a dedicated set of plasma tests has been performed which are intended to be used now to establish numerical test cases based on real test data. While also a basic set of material characteristics of AQ61 is available, material characterisation will have to be completed as part of this activity. In order to rebuild the numerical test case, an integrated solution for charring ablators (including thermo-chemistry), is needed. This can be achieved by the coupling (exchange by files or on the fly evaluation of properties) of a response code for charring ablators with a code for equilibrium chemistry calculations. In order to rebuild the plasma test, the thermal response code must be capable of modeling the test specimen (an axis-symmetric model), and the chemistry code must have the capabilities to model the charring materials used in real ablators (like AQ61, MONA, ASTERM, ...). The following work is to be conducted in this activity: ? Establish a booklet with a set of numerical ablation test cases based on available plasma test results of the AQ61 material ? Where necessary the available data shall be complemented by relevant additional material characterisation ? Coupling of a response code for charring ablators with a code for equilibrium chemistry calculations ? Model and run the above test cases with at least three of the ablative TPS sizing codes available in Europe ? Compare the results with the available plasma test data, assess the code/model performance and identify the weaknesses of the used codes ? Derive relevant uncertainties based on the test cases and extrapolate these uncertainties to relevant entry analysis ? Identify relevant code improvements and code delta-development The booklet shall be established in progressive steps, starting from a simple test case which is iteratively increasing in complexity. E.g. the ablation-chemistry coupling would be an element of an advanced iteration.					
Deliverables					
- Booklet with the definition of a set of numerical test cases. -Technical Notes on material characterisation, test case results and code assessment					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2016
Application Mission:	Sample return missions;		**Contract Duration:**	20	
S/W Clause:	N/A		**Reference to ESTER**	T-8282, T-8277	
Consistency with Harmonisation Roadmap and conclusion:					
Activity identified in D/TEC technology roadmap					

Deployable & Inflatable Heatshield & Hypersonic Decelerator Concepts - Phase 1					
Programme:	TRP		**Reference:**	T921-005MT	
Title:	Deployable & Inflatable Heatshield & Hypersonic Decelerator Concepts - Phase 1				
Total Budget:	400				
Objectives					
To review the European capabilities in terms of deployable and inflatable heatshield and hypersonic decelerator technologies and to assess the potential which such technologies might bring to enable new mission concepts for Mars exploration. Eventually to initiate development of the main technological elements of the concept identified as most suited for Europe.					
Description					
Europe has previously invested in early development of inflatable decelerator technology which resulted in a partially successful flight demonstration (IRDT). This technology has strong potential for enabling new Mars mission concepts and is therefore proposed for further investigation. Very significant effort was spent by NASA in recent years on related technologies (hypersonic inflatable decelerators, mechanically deployable structures, multi-functional carbon fabrics for deployable heatshields, etc.). It is not viable for Europe to embark on similar developments in all of these fields; therefore it is recommending initiating first a technology assessment to downselect the most promising concepts for future missions. The objectives of this activity shall be achieved through the following steps: - Identify and study different inflatable and deployable heatshield & hypersonic aerodynamic decelerator concepts for atmospheric entry probes, and to assess their potential benefits for potential future Mars exploration missions. In particular, it shall be identified which missions such technologies could enable which are today considered not feasible. - Review the related technological elements available in Europe, and assess their maturity for a relevant mission application. The required key technologies shall be identified, existing solutions be assessed and any required delta-development be identified. The expected technological limits shall be identified. - Perform a trade-off on the various concepts considering the expected benefit/interest for future missions and the required development effort and risks. - At system level the following aspects will have to be considered: Packing, configuration, aerodynamic stability, potential separation strategies. - The technologies to be specifically assessed shall include high temperature fabrics, deployment and inflation mechanisms and integration of the TPS material. The heatshields used so far for entry probes of planetary exploration missions are based on a thermal protection system on a rigid structure. The heatshield typically also acts as hypersonic decelerator. While its dimension is typically limited by geometrical constraints, like e.g. the fairing of the launcher, enlarging the hypersonic decelerator would allow to significantly reduce the ballistic coefficient and thereby the loads experienced by the heatshield during the atmospheric entry. Deployable and inflatable heatshield concepts have therefore moved in the focus of interest in recent years. Such technology might enable future planetary exploration missions which are not feasible today, e.g. increased landed P/L masses or currently unreachable (higher altitude) landing sites on Mars.					
Deliverables					
Study reports (technological review, mission & application assessment, trade-off)					
Current TRL:	1-2	**Target TRL:**	3-4	**Application Need/Date:**	2018
Application Mission:	Future planetary exploration missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8079, T-7906, T-7879, T-8142	
Consistency with Harmonisation Roadmap and conclusion:					
Consistent with D/TEC technology roadmap					

Catalytic properties of Ablators			
Programme:	TRP	**Reference:**	T918-004MP
Title:	Catalytic properties of Ablators		
Total Budget:	500		
Objectives			
The objective of this activity is to determine the catalytic properties of ablators materials in the VKI Plasmatron facility and to			

derive corresponding physical models for implementation in CFD codes.					
Description					
Ablative thermal protection materials are the most critical parts of the thermal protection systems for hypersonic applications that face high velocity (7~10 km/s) atmospheric entry. The thermal protection systems experience very complex interconnected phenomena during a re-entry flight. Their design and improvement require suitable ground testing associated with dedicated measurement techniques. One of the most important measurement techniques is the accurate measurement of material temperature. Further, together with catalycity, emissivity is another important surface property to be determined. Also, for ablating thermal protection materials, accurate measurement of the recession rate is a critical task for the characterization and proper modeling of the ablative materials. Here is proposed to use optical techniques (such as high speed and/or high-definition cameras) and associated post- processing techniques to calculate the recession rate of the ablative samples exposed to plasma flow. Finally, uncertainty quantification will be performed of both the enthalpy reconstruction and the whole loop enthalpy reconstruction + catalycity identification. An identification of parameters which have a critical impact on the catalycity estimation will be performed. The study would also involve uncertainty quantification on the gas reaction. In this case the rate constants would be the uncertainty parameters. The existence of correlations between the gas reactions and how the enthalpy or catalycity are influenced by change in the reaction rate coefficients is of large interest. Also, the influence of the diffusion modeling on the identification of the catalytic properties of the material shall be investigated. The models employed in the computer codes will be upgraded based on the results of the present investigation.					
Deliverables					
Reports including test plan, test data, numerical reconstruction and assessment of the results. Experimental data in electronic format (Data Base) and numerical data and associated models also in electronic format to allow future comparisons and/or benchmark tests.					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2023
Application Mission:	MSR, Phootprint and Marco Polo-R		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-7902, T-7897, T-8094, T-8090	
Consistency with Harmonisation Roadmap and conclusion:					

Software Defined Radio Proximity-1 Link Communications Package design Study			
Programme:	TRP	**Reference:**	T906-002ET
Title:	Software Defined Radio Proximity-1 Link Communications Package design Study		
Total Budget:	300		
Objectives			
The objective of this activity is to investigate the implementation of a flexible and multimission data-relay communication package based on CCSDS Proximity-1 protocol using software defined radio as the enabling technology.			
Description			
The current European proximity-link transceivers (as developed in the previous ESA missions, for instance Beagle) are limited in flexibility as they are based on a low level of integration between the RF and the digital part. Using the Software Defined Radio technology (similar to that implemented by NASA/JPL for the Electra transceiver) allows a higher level of flexibility with the possibility of unit reconfiguration. Using the software defined approach provides the capability to add/change functionality by simply changing the software version. This software upload (software patch) can be done pre-launch or in orbit, which makes the unit very flexible and provides the capability to support multiple missions. This multimission approach is particularly interesting in case of an Orbiter with data-relay capabilities and a long lifetime (such as Mars Express). This way it can support different lander missions (European, American and other international space agencies) even the ones it wasn't intended to serve in the first place. Allowing post-launch reconfigurability of the protocol and signal processing functions over the Orbiter lifetime supports protocol updates and provides the possibility to respond to unanticipated mission scenarios. Secondly, by ensuring a standardised and interoperable data-relay infrastructure allows any lander to make use of multiple data-relay assets, thereby increasing the science return while at the same time reducing mass and power requirements on the lander. The ultimate goal would be to equip every science Orbiter with a standardised relay package, taking away some of the technology burden of small lander missions. The scope of the activity is to study the implementation of a reprogrammable Proximity-1 transponder based on a software defined radio architecture. The transponder shall support the Proximity-1 protocol in its entirety including support for full duplex operation. The transmit and receive carrier frequencies shall be programmable (by software uploads) to any frequency in the range used by the Proximity-1 protocol (i.e. 390 - 450 MHz). The transponder shall be designed in a modular manner that allows tailoring of the basic			

transponder to future missions. The proximity-link transponder to be developed shall implement different modes, e.g. only sampling, demodulation, etc. to support the EDL and rendezvous and capture mission modes, it shall also support higher data-rates than those currently available on European hardware, in order to increase the science return. Consideration shall be given to the architecture proposed in order to reduce mass, power and volume envelopes as much as possible. The contractor shall implement the most critical functionalities in a breadboard.					
Deliverables					
TN's, Final Report, breadboard					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	>2016
Application Mission:	MSR, future exploration missions		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8744	
Consistency with Harmonisation Roadmap and conclusion:					
Harmonization Dossier "TT&C Transponders and Payload Data Transmitters" 2012.					

X-Band cryogenic feed prototyping					
Programme:	TRP		**Reference:**	T912-005GS	
Title:	X-Band cryogenic feed prototyping				
Total Budget:	600				
Objectives					
To design an innovative X-Band cryogenic feed to be installed in the future in the Deep Space antennas. G/T in X-Band will be maximised by an integrated design of the feed (receive and transmit in X band) and the cryo- cooled LNA sub- systems					
Description					
The reception performances of the Deep Space Ground Stations are limited by the noise generated in the front end. Any reduction of this noise will allow to increase the data transmitted or to reduce the required mass and power on the spacecraft transmitter. X band is presently used for the telemetry of all deep space missions and will still be the preferred frequency band for future Mars exploration missions. The existing feed and LNA systems have been designed separately. Therefore, the feed system is operated at room temperature while the LNA is operated at 12 K. The overall system noise temperature is therefore suboptimal due to the insertion loss of the waveguide connection and passive elements at room temperature. In order to increase the mission data return, it would be extremely beneficial improving the present G/T by more than 1 dB. This will be achieved by reducing the loss of the feed system and trying to cryo-cool as much as possible the passive components of the receiver front end (diplexer, polarizer, waveguides, tracking coupler...). The interconnection of the feed and LNA subsystems will be optimised and the cryo-cooler subsystem will be designed to guarantee a maximum availability and redundancy. The same feed is going to be used for the uplink at 20 kW. A proper study will be conducted to minimise the effect of the high power uplink on the cryogenic subsystem.					
Deliverables					
A prototype of X-Band cryo-feed subsystem.					
Current TRL:	2	**Target TRL:**	4	**Application Need/Date:**	2016
Application Mission:	All future missions in X band		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Modeling of the Mars Environment for Future Missions			
Programme:	ETP	**Reference:**	E904-005EE
Title:	Modeling of the Mars Environment for Future Missions		
Total Budget:	400		
Objectives			
To develop user-oriented, integrated tools to analyse aspects of the Mars environment required for mission design, including atmosphere, dust, regolith, and radiation.			
Description			
Various studies have analysed aspects of the Martian environment, including climate data derived from global circulation models,			

radiation data derived from monte-carlo studies of cosmic ray propagation in the atmosphere and regolith, and various dust investigations. This activity will review the available models, and develop tools around them that allow easier use in engineering. This avoids that the engineer will have to work with complex tools whose subtleties require considerable effort to work with. Requirements will be established for both the underlying physical modeling, and the engineering tools.					
Deliverables					
Engineering tools and associated documentation.					
Current TRL:	3	**Target TRL:**	37	**Application Need/Date:**	2017
Application Mission:	All Mars missions		**Contract Duration:**	36	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Harwell Robotics Autonomy Facility (HRAF) - Pilot project 1					
Programme:	ETP		**Reference:**	E908-001FP	
Title:	Harwell Robotics Autonomy Facility (HRAF) - Pilot project 1				
Total Budget:	1200				
Objectives					
The objective is to implement the HRAF core infrastructure and demonstrate, through a pilot project, the value of the facility for the validation of autonomous systems and technologies. This activity is the first in a long-term programme and is funded by the UK through the ESA MREP-2 programme and supported by UKSA.					
Description					
The development of complex autonomous robotic systems will be critical for future planetary exploration missions. At a minimum, elements of the MSR mission such as Sample Fetch Rover, landing with high precision (and hazard avoidance), autonomous sampling and sample transfer or sample container rendezvous and capture will all require ECSS level-3 autonomy and higher. Although the related technology developments are progressing strongly within Europe, there remains a lack of critical infrastructure to allow validation, verification and integration of autonomy components at the mission level. The aim of this activity is to setup a facility that supports the validation of autonomous systems and associated technologies to enable the TRL of technologies to be raised, confidence in performance to be gained, cost estimates to be more credible, and eventually missions to be validated. These will require the use of specialist test facilities including mock planetary surfaces, software-based simulation environments and physical field trials in representative environments to provide ground truth. The aim of this activity is: Phase 1: - Define underlying requirements (including prime, academic and Agency input) - Validation Process Definition - Define the architecture of the facility (S/W, H/W environment, tools...) Phase 2: - Start of Component Engineering - Integration of core infrastructure elements (including maturation of the EAGLE software tool) - Prepare and execute a pilot project The activity is split into 2 phases: Phases 1 ends with a PDR. A successful PDR is the prerequisite for the execution of phase 2. The pilot project will be based on and use results and data from the SEEKER activity and EAGLE simulator development (ESA C21286(2007)).					
Deliverables					
Documentation Software (Middleware components) EAGLE update					
Current TRL:	1	**Target TRL:**	3	**Application Need/Date:**	2015
Application Mission:	MSR, Phootprint, Inspire & various		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 2					
Programme:	ETP		**Reference:**	E908-002FP	
Title:	Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 2				
Total Budget:	1500				
Objectives					
The objective is to progress the implementation of the HRAF core infrastructure capabilities with extensive field trials of rover technologies. This activity is the second one of a long-term programme and is funded by the ESA MREP-2 programme and supported by UKSA.					
Description					
The aim of HRAF is to support the integration, verification and validation of autonomy systems and associated technologies from unit up to mission level. This requires the use of specialist test facilities including mock planetary surfaces, software-based simulation environments and physical field trials in representative environments to provide ground truth. The first step in the implementation of the HRAF Core infrastructure is being performed through the Pilot Project 1 (E908-001FP), which simulates long-range rover navigation based almost entirely on Visual Localisation using stereo cameras in support of mission concepts such as the SFR or long-range science rover. The Pilot 2 activity aims to progress to the next step in rover technology readiness by performing a set of field trials to test ESA-developed technologies for long-range and fast navigation (SPARTAN/SEXTANT). The accumulation of realistic field-test data during these trials will feed directly into extended validation of recently developed rover-locomotion simulation tools such as SWIFT (developed under TRP for Mars missions). The inclusion of newly-developed ground system operations software for rover operations (e.g. IRONCAP) can also be envisaged. This will allow the extended validation of ESA's investments in state-of-the-art rover technologies in representative environments, therefore providing much increased confidence in the technologies to be adopted for use in future ESA missions. The HRAF Pilot Project 2 will: - perform extended validation of recently ESA-developed rover technologies through field trials using an SFR-like scenario; - develop further the HRAF data archive to handle more different types of autonomy related data sets and support validation of existing simulation tools;					
Deliverables					
Documentation Software algorithms and middleware components as needed Ground truth data from field trials					
Current TRL:	2	**Target TRL:**	3/4	**Application Need/Date:**	2016
Application Mission:	MSR, Phootprint		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 3			
Programme:	ETP	**Reference:**	E908-003FP
Title:	Harwell Robotics and Autonomy Facility (HRAF) - Pilot Project 3		
Total Budget:	1500		
Objectives			
The objective is to progress the implementation of the HRAF core infrastructure capabilities with both hardware and algorithm demonstration cases for robotic arm as well as EDL technologies. This activity is the third one of a long-term programme and is funded by the ESA MREP-2 programme and supported by UKSA.			
Description			
The aim of HRAF is to support the integration, verification and validation of autonomy systems and associated technologies from unit up to mission level. This requires the use of specialist test facilities including mock planetary surfaces, software-based simulation environments and physical field trials in representative environments to provide ground truth. The EDL phases of future ESA missions such as Phootprint and Mars Precision Lander require significant autonomous systems			

with complex behavior in unknown and unpredictable environments, especially during the final landing phase. This activity will contribute to further validation of ESA-developed EDL technologies (e.g. vision, lidar and data fusion algorithms and GNC sensor hardware) potentially using flying testbeds based on quadcopters/UAVs or other types of flying testbeds. A second development proposed through this Pilot 3 activity is the safe and autonomous deployment and operation of a robotic arm for instrument deployment and/or sample collection such as it will be required for SFR and Phootprint. It is proposed to use both the ESA developed DELIAN arm (to be completed in mid-2015) and the UKSA developed LARAD arm in 'field trials' to simulate and validate operations of potential robotic arm designs and compare their respective performances. It is also proposed to include within this activity, in a later phase, the robotic arm breadboard to be developed in the SAMPLER activity to be started in Q4 2014. For this latter solution, only the Phootprint environment will be applicable.
Deliverables
Documentation Software algorithms and middleware components as needed EDL systems test data Robotic arm test data

Current TRL:	2	**Target TRL:**	3/4	**Application Need/Date:**	2016
Application Mission:	MSR, Phootprint, Inspire & various		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Configurable and Compact isolated DCDC-converter (CC-DCDC)			
Programme:	TRP	**Reference:**	T903-017EP
Title:	Configurable and Compact isolated DCDC-converter (CC-DCDC)		
Total Budget:	500		
Objectives			
Development of a compact and configurable isolated DCDC-converter to be deliverable as an IP product (PCB layout and schematic), to be used for low power units and payloads.			
Description			
Isolated and regulated voltage supplies are needed for supply instruments/payloads. As the design of the power supply is not the main task of the payload designer, off the shelf converter modules are often used for this purpose. However, these are often unnecessarily bulky and more powerful than the required power level. It is also often difficult to get design details from the manufactures, in case they are needed for system/WCA analysis. The proposed CC-DCDC shall provide a galvanically isolated voltage which is set by the user. The CC-DCDC shall operate from and up to 28V bus voltage. The CC-DCDC shall be able to provide typically up to 10W (TBC) of power. The CC-DCDC shall be simple, miniaturised, modular and reconfigurable, and possibly based on rad-hard ICs as switching devices to achieve miniaturisation. The CC-DCDC shall be deliverable as an IP product consisting of PCB layout and schematic which can be added to the IP users design without modification.			
Deliverables			
CC-DCDC layout and schematic: IP product.			

Current TRL:	3	**Target TRL:**	5	**Application Need/Date:**	2017
Application Mission:	all		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
Yes with Power Management & Distribution RM [B28 ? Study of simplified DC to DC converters for low power applications]					

Assessment of high performance green propellants			
Programme:	TRP	**Reference:**	T919-013MP

Title:	Assessment of high performance green propellants				
Total Budget:	150				
Objectives					
Identify and assess chemical propellant candidates with low toxicity and potential for high performance that could meet exploration needs and requirements					
Description					
To date, a large majority of space propulsion systems have relied on conventional mono- and bi-propellants, hydrazine, MMH and MON. The toxicity level of these propellants has demanded special measures to reduce safety risks (e.g. SCAPE suits, limited testing with propellants, extra mechanical barriers, restriction on air transport, etc.). These measures can have significant impact to cost and schedule for ground operations. In 2011, Europe's Registration Evaluation Authorisation and Restriction of Chemicals (REACH) added hydrazine to their candidate list of substances of very high concern (SVHC), due to its toxicity. With this step, there is an associated risk that REACH will make hydrazine obsolescent (restrict or prohibit its use) in the near to mid-term. This risk also exists for hydrazine derivatives MMH or UDMH and, to a lesser extent, Nitrogen Tetroxide (or MON). The SVHC list is updated on a regular basis (i.e. two times per year). This risk places further and more immediate emphasis on the need for alternatives to conventional chemical propellants. Further, there is a need for / interest in propulsion systems with a better performance to mass ratio. Currently, there are propellants with the potential to meet these lower toxicity and higher performance needs (e.g. high energy density materials HEDM, CNES high performance monopropellant, ...). This activity will: - Identify and assess these propellants to determine their feasibility for use on space platforms through literature review. - Characterise propellant (e.g. physical properties, toxicity, safety, material compatibility, etc.) - Down select to 1 or 2 key propellants - Possible small scale testing (e.g. decomposition test) - Perform a system study to assess the impact/benefits of these propellants for exploration platforms.					
Deliverables					
Propellant assessment report, system study report. Down-selected propellant(s) and associated thrusters would be developed further in a follow-on activity.					
Current TRL:	1	**Target TRL:**	2	**Application Need/Date:**	2022
Application Mission:	Exploration Missions		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
This is part of activity D4-High Performance Green Propellant Development in the approved Harmonisation Chemical Propulsion Green Propulsion roadmap.					

Starting a Sample Analogue Collection for future Exploration missions - Phase 2			
Programme:	ETP	**Reference:**	E926-002FM
Title:	Starting a Sample Analogue Collection for future Exploration missions - Phase 2		
Total Budget:	550		
Objectives			
The objective is to define and build a first Sample Analogue Collection in support of Robotic Exploration missions to Mars, Phobos, Deimos and to a lesser extent Asteroids and the Moon. This activity is funded by the ESA MREP-2 programme and supported by UKSA.			
Description			
Future exploration missions are intended to land on various target bodies: besides Mars also Phobos and Asteroids are identified as potential mission destinations. Landing and possible subsequent dynamic exploration of the planetary body entails a direct contact with the target body between spacecraft systems and scientific instruments. The challenge of proper characterisation and validation of that physical interaction with the "unknown" material can be helped with the use of sample analogues, i.e. simulants of the target body material that replicate the specificities of the expected application environment. Through an initial MREP-2 contract (E926-001FM) a catalogue of geological characteristics for selected and/or intended landing/touch down areas and surrounding regions currently identified for future exploration missions is being produced. The requirements to which analogue sample material should comply with in order to be an acceptable representative of the target body's material will be prepared together with a suitable set of identified specimen fulfilling these requirements. Both natural and artificial analogues are considered. This activity will, for an agreed downselection of the proposed sample analogue catalogue: - localise and acquire the downselected sample analogue material to constitute an initial Sample Analogue Collection;			

- characterise and verify the various requirements for each of the acquired specimen; - start the associated curation database for the Sample Analogue Collection;					
Deliverables					
Documentation Sample Analogue Collection Sample Analogue Collection Curation Database					
Current TRL:	1	**Target TRL:**	3	**Application Need/Date:**	2016
Application Mission:	MSR, Phootprint, Inspire & various		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Starting a Sample Analogue Curation Facility for Future Exploration Missions					
Programme:	ETP		**Reference:**	E926-003FM	
Title:	Starting a Sample Analogue Curation Facility for Future Exploration Missions				
Total Budget:	1200				
Objectives					
The objective is to enhance the initial Sample Analogue Collection and curatorial database, acquire lab equipment to perform basic sample characterisation and sub-sample preparation and develop standard characterisation protocols for incoming acquisitions. This activity is funded by the ESA MREP-2 programme and supported by UKSA.					
Description					
Future exploration missions are intended to land on various target bodies: besides Mars also Phobos and Asteroids are identified as potential mission destinations. Landing and possible subsequent dynamic exploration of the planetary body entails a direct contact between spacecraft systems and scientific instruments. The challenge of proper characterisation and validation of that physical interaction with the "unknown" material can be helped with the use of sample analogues, i.e. simulants of the target body material that replicate the specificities of the expected application environment. Through MREP-2 activities E926-001FM and E926-002FM an initial Collection of Analogue Samples for Phobos/Deimos/ Asteroids, Mars and the Moon has been characterised and curated. Through this new activity the Collection will be enlarged with specimens generated/procured during ESA supported technology development activities, ESA supported field trials as well as with other similar collections and initiatives. The curatorial database will be updated wrt. the enhanced Sample Analogue Collection, the various preparations and usage of the specimen preparations. A first set of standard characterisation protocols for new incoming acquisitions and preparation protocols for sub-samples will be defined and validated. An assessment will be made on the available and accessible analytical equipment on the Harwell Campus and missing analytical equipment needed to execute these protocols will be procured. This activity will: - enhance the initial Sample Analogue Collection with specimens generated/procured during ESA supported technology development activities, ESA supported field trials as well as with other similar collections and initiatives; - log the sample preparation protocols for all analogues in the database. - define and execute (as needed) a set of standard characterisation protocols for incoming acquisitions; - acquire lab equipment to perform basic sample characterisation, sub-sample preparation and quality inspection thereof; - keep the curatorial database up-to-date and valid wrt. the enhanced Sample Analogue Collection and preparations;					
Deliverables					
Documentation Enhanced Sample Analogue Collection Enhanced Sample Analogue Collection Curation Database Laboratory Equipment					
Current TRL:	2/3	**Target TRL:**	4	**Application Need/Date:**	
Application Mission:	MSR, Phootprint, Inspire & various		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Long Term

Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)			
Programme:	ETP	**Reference:**	E919-012MP
Title:	Design, development testing and generic qualification of a High Thrust Apogee Engine (HTAE)		
Total Budget:	6045		
Objectives			
This activity will continue the development, to a generic qualification level, of a High Thrust Apogee Engine for the Robotic Exploration Programme.			
Description			
The MREP-funded Combustion chamber and Injection technology development activity was a first phase aimed at defining a high thrust apogee engine (HTAE) that was a specific fit to Agency requirements for planetary missions and orbit insertion. The HTAE phase 1 targeted an ITAR-free design and examines high performance injector design and cost effective high temperature materials developments. The definition of a flow control valve was also included to complete the equipment definition. The phase 1 activity concluded in 2013 with an Intermediate PDR (I-PDR) for the injector, chamber and valve. The follow on Phase 2, is aimed at: - Completion of design Definition o Final loop of injector, chamber and valve development testing as identified in Phase 1B will be performed to finalise injector down-selection for the design of the HTAE including any further optimisations identified. o PDR - Detailed design o CDR - Generic Qualification o Manufacture of EM (generic qualification) batch 2 test hardware o Process qualification for injectors, chamber manufacture and if relevant, chamber material coating process o HTAE Valve development activity - design and manufacture of a qualification model for engine qualification program o Qualification program of engine(s) to TBC specification (generic qualification requirements) The Phase 2 is split into two parts, Phase 2a and Phase 2b as shown below: - Phase 2a (3545kEuros) started 2014 for a duration of 18 months until CDR - Phase 2b (2500kEuros) starting 2016, for a duration of 24 months until completion This proposal is for the implementation of Phase 2b in 2016, assuming a successful CDR at the end of Phase 2a.			
Deliverables			
Documentation, development models, engineering model engine and valve assemblies.			

Current TRL:	3	**Target TRL:**	5/6	**Application Need/Date:**	2016
Application Mission:	INSPIRE, Phootprint, MSRO and other future Mars missions		**Contract Duration:**	42	
S/W Clause:	N/A		**Reference to ESTER**		
Consistency with Harmonisation Roadmap and conclusion:					

European Isotope Production Phase 2			
Programme:	ETP	**Reference:**	E903-015EP
Title:	European Isotope Production Phase 2		
Total Budget:	2000		
Objectives			
The precursor activity European Isotope Production Phase 1 resulted in the submission of a fully costed 7-year plan leading to the commencement of Am241 radioisotope fuel production at the UK National Nuclear Laboratory. This Phase 2 activity covers the first year of the "Development" task in the 7-year plan.			
Description			
Overall objectives of the 7-year plan are as follows: - To complete the engineering development of the previously proposed Am241 production plant at Sellafield in Cumbria, England. The outstanding development areas are: plutonium dissolution, plutonium solvent extraction, americium solvent extraction, plutonium finishing, americium finishing, evaporator operation and solvent management. - To develop the previously produced concept design into a fully complete and detailed preliminary design, to be taken through the HAZOP1 safety review process, to a point suitable for immediate use in (future) pre-fabrication design/blueprinting.			

- To continue the evolution of the plant safety case and security (nuclear material safeguards) planning, including continued real-time liaison and iteration with the regulatory authorities. Specifically, this 200kEuros Phase 2 activity covers the initial stage of the DEVELOPMENT task which entails: 1. Specification, design and procurement of equipment needed for full-scale inactive testing. 2. Development of chemical models (computer) for each sub-process. 3. Perform maloperations investigations for the solvent extraction processes.					
Deliverables					
Deliverables to ESA will be documentary (not hardware), but in many cases will derive from the execution of nuclear engineering trials and experimental rig manufacture/procurement within the NNL Central Laboratory. Detailed deliverables are TBD in the contractor's proposal and subsequent negotiation process.					
Current TRL:	4	**Target TRL:**	5	**Application Need/Date:**	2016
Application Mission:	INSPIRE and other future Mars missions		**Contract Duration:**	12	
S/W Clause:	N/A		**Reference to ESTER**	T-8933	
Consistency with Harmonisation Roadmap and conclusion:					

Stirling Converter Technology Development phase 1					
Programme:	ETP		**Reference:**	E903-009EP	
Title:	Stirling Converter Technology Development phase 1				
Total Budget:	2000				
Objectives					
To develop a breadboard model of a Stirling cycle power converter system for use with radioisotopic heat sources.					
Description					
This contract covers the initial development of a Stirling cycle power converter system for space applications, considering use with radioisotopic heat sources. Electrical output in the ~100 W range. A breadboard will be developed and tested in laboratory conditions (using a simulated, non-nuclear, heat source).					
Deliverables					
Consolidated requirements and design documentation. Breadboard model with test reports.					
Current TRL:	2	**Target TRL:**	3	**Application Need/Date:**	2013
Application Mission:	Outer Planets, Mars exploration, (>2018)		**Contract Duration:**	27	
S/W Clause:	N/A		**Reference to ESTER**	T-8534	
Consistency with Harmonisation Roadmap and conclusion:					
Consistent with nuclear power dossier					

Small-scale RTG Development to TRL 4			
Programme:	TRP	**Reference:**	T903-015EP
Title:	Small-scale RTG Development to TRL 4		
Total Budget:	500		
Objectives			
Continued development of small scale RTG, building upon the conclusions of the successful precursor TRP activity, to result in TRL4 for the full RTG system including optimised heat source design.			
Description			
The precursor activity T903-006EP resulted in the manufacture of an RTG breadboard using bismuth telluride thermoelectric modules (TEGs) which were based on established COTS technology, enhanced and optimised for the RTG application. The test performance of the breadboard (4W at 5% efficiency) was better than foreseen, and provides a clear and confident indication of a highly promising direction for the development of a European RTG using Am241 radioisotope fuel. Extra work scope performed			

under CCN resulted in an engineered design for a flight-like 10W RTG system, with mass budget of 10kg. The precursor activity took the TRL of the RTG system to a solid TRL3. The heat source (fuel encapsulation system) design was the subject of other activities and is lower at TRL2. This proposed activity will take the TRL to 4 in both cases, resulting in a full European RTG capability at TRL4. Detailed objectives are: - Further development of the (existing) breadboard thermal management system to provide steady state operation over extended periods - The long duration testing (in the existing breadboard system) of bismuth telluride TEGs and devices manufactured with composite p- type material. - Further incremental improvements to TEG materials and production of associated modules. - Development of processes and procedures for testing, characterisation and selection of TEGs for flight application. Development of a thermal model of the 10W RTG system. - Development of the existing heat source encapsulation system design, resulting in an engineering design underpinned by thermal, mechanical (impact) and aerothermodynamic (re-entry) modeling. - Manufacture of the elegant breadboard, including a non-nuclear but otherwise fully flight-representative heat source. - Testing of the elegant breadboard in a representative environment. - Mechanical testing of the elegant breadboard. - Consolidated and finalised system design.
Deliverables
Electrically heated RTG prototype built to TRL4 "elegant breadboard" level, including heat source encapsulation system (but excluding nuclear materials). All associated design, manufacture and test data and reports.

Current TRL:	3	**Target TRL:**	4	**Application Need/Date:**	2021
Application Mission:	Future Mars / Moon/ Outer solar system		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-8933	
Consistency with Harmonisation Roadmap and conclusion:					
N/A					

Radioisotope Heater Unit Prototype Development			
Programme:	GSTP	**Reference:**	G903-001EP
Title:	Radioisotope Heater Unit Prototype Development		
Total Budget:	300		
Objectives			
- To design and manufacture an (electrically heated) RHU prototype. The cladding and aeroshell materials and structures would also be applicable to larger heat source applications (e.g. for RTGs and Stirling radioisotope power systems). - To perform standard environmental testing e.g. vibration, thermal cycling, system level functional testing in a representative environment. - To design and manufacture a simulant radioisotope pellet (using surrogate non-active material).			
Description			
BACKGROUND: The development of radioisotope heater units (RHUs) is critically important as a key enabling technology for future planetary and deep space missions. These devices reduce the need to use electrical power to keep systems within nominal temperature ranges, save on using electrical power in power-constrained missions and reduce electromagnetic interference generated by electrical heating systems. The design and development of RHUs was originally planned to be part of the MREP activity "Nuclear power systems architecture and safety study for safety management and fuel encapsulation prototype development" (SRE-PAP/E903-003EP), which was completed in late 2013. However, this element was de-scoped from the study due to budget constraints. Therefore, the development of RHUs is an aspect of the ESA nuclear power development programme that is falling behind the targeted progression. In parallel, the University of Leicester has developed a design concept for an RHU, which was funded by a UK Space Agency study. This design built upon work performed in an earlier ESA TRP contract ("Nuclear fuel capsule and aeroshell design study" 4000102120/12/NL/AF) that was completed in 2012. PROPOSED WORK SCOPE: 1. Consolidate and critically review the existing RHU design arising from the earlier ESA TRP and UKSA work. 2. Refine and modify the RHU design as necessary, using computer modeling techniques to determine predicted performances. 3. Manufacture a RHU prototype, not containing nuclear materials but utilising suitable surrogate pellets materials and electrical heating systems.			

4. Test the RHU prototype under appropriate environments (vibration and thermal cycling at minimum). Accident scenario, e.g. impact testing is TBC.

INTERFACE AND SYNERGY WITH ASSOCIATED ACTIVITIES:
ESA CTP activity C203-001FT "Design and breadboarding of an automated clad welding system for Radioisotope Heater Units" is approved by IPC and under preparation. This CTP activity was first conceived to involve iridium alloy, which is no longer relevant due to technical developments. This CTP activity will benefit from the design work in this GSTP activity to determine the material and architecture of the inner metallic encapsulation.

Deliverables					
RHU prototype (non nuclear). All associated design, manufacture and test data and reports.					
Current TRL:	2-3	**Target TRL:**	4	**Application Need/Date:**	2021
Application Mission:	Future Mars / Moon / Outer solar system		**Contract Duration:**	18	
S/W Clause:	N/A		**Reference to ESTER**	T-8933	
Consistency with Harmonisation Roadmap and conclusion:					
N/A					