EUROPEAN SPACE AGENCY

ROBOTIC EXPLORATION TECHNOLOGY PLAN

Programme of Work 2009-2014

SUMMARY

This document presents the currently proposed activities in the Technology Research Programme (TRP), the Exploration Technology Programme (ETP, funded by MREP) that are supporting the implementation of ESA's Robotic Exploration Programme from 2009-2014.

This document is provided for information only and is subject to future updates.

March 2013

This page is left intentionally blank.

1- Background and scope

The MREP-2 programme (Mars Robotic Exploration Preparation-2, ESA/PB-HME(2012)56, rev.1) was subscribed at the 2012 ESA Council at Ministerial 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.

The general approach is to consider a MSR mission as a long-term objective and to progress step-by-step towards this objective through short and medium-term MSR-related technology developments, which are validated during intermediate missions and by developing Long Term enabling technologies, such as Novel Power Systems (NPS) and Propulsion engines.

Two proposed candidate intermediate missions are based on previous MREP activities:

- The Mars Moon Sample Return mission, also called PHOOTPRINT, aiming at returning a sample from a moon of Mars, nominally Phobos.

- The Network Science mission, also called INSPIRE, aiming at delivering a network of probes on the surface of Mars to perform simultaneous seismic and meteorological measurements.

Both have substantial study heritage, are considered top-class scientific and technological missions providing high visibility, and are also recognized as intermediate steps towards MSR - according to the recommendation of advisory bodies, the Solar System Exploration Working Group (SSEWG) and the Human Spaceflight and Exploration Science Advisory Committee (HESAC) (given in Annex B and C of ESA/PB-HME(2012)56, rev1.) Both candidate missions are credible for launch opportunities from 2024 onwards and will be further prepared by the General Studies Programme (GSP) funded Phase A studies. The outcome of these studies will be presented to the Human Spaceflight, Microgravity and Exploration Programme Board. In addition, discussions with international partners are also ongoing regarding their potential participation in the programme and in particular for the potential MSR mission architecture and collaboration scheme.

This first MREP-2 technology work plan is focusing on the longer term developments and preparation of MSR, which are not precluding any decision on the candidate mission that could be implemented in the 2024 timeframe. Some of the activities under these themes are naturally also relevant to the candidate intermediate missions. As for MREP-1, the work plan will be updated on a regular basis, enabling to take into account the outcome of discussions with potential partners and/or PB-HME.

Note that this workplan shows only those new MREP-2 activities for which approval is requested for 2013/2014 implementation. For details on the MREP-1 activities, please refer to ESA/IPC(2011)138, ESA/IPC(2012)79 79 and ESA/PB-HME(2013)6.

In application of Council decisions contained in ESA/C(2012)104, 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 IPC.

2- Work Plan Elaboration and Implementation

- **Definition of the activities**

The programme of work presented here was defined using the ESA End-to-End process as described in ESA/IPC(2005)39, involving a TECNET (TEChnology NETwork) of technical and mission experts from ESA. 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 work plan makes use essentially of MREP-2 Exploration Technology Programme (ETP) and TRP budgets, complemented possibly with the Strategic Initiative budget.

For the practical implementation of ESA TDAs, all the proposed activities are intended to be initiated in 2013. However, where the budgets for 2013 and 2014 are shown for an activity, this indicates that contractual phasing is intended, with the annual commitments shown in the respective yearly columns. In such cases, approval is sought in this TDP for the entire activity, covering the years 2013-2014. It is planned to revisit the MREP-2 Technology Plan on a regular basis and update the plan with the results of discussions with Member States and international partners, system studies and ongoing activities.

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 IPC and PB-HME fully informed of the work plan implementation.

- **ESA Technology Development Activities: role of TRP and ETP**

ESA MREP-2 technology activities mainly rely on MREP-2 and TRP technology 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 3). 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 will be used to fund robotic exploration-related activities at any TRL level. However, it focuses on TRL >3, building on earlier developments funded through TRP.

For ETP, the activities will be implemented so as to meet a geographical distribution reflecting the Participating States subscriptions.

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. Articles 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. Article 14.1.A,C ESA Procurement Regulations) * See ESA/IPC(2005)87, rev4., Industry has been informed, through 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 equipments 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 equipments/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

Annex 1:
List of ESA MREP-2 Programme Technology Development Activities

List of activities seeking approval for 2013/14

Prog.	IPC Appr.	ESA Ref.	Activity Title	Budget				PP	C'try	SW Clause applicab.	Remarks
				2011	2012	2013	2014				
Mars Sample Return											
TRP	N/A	T906-001ET	Next generation uplink coding techniques	0	0	450	0	C		N/A	
TRP	N/A	T916-003MM	Planetary communication system based on modulated retro-reflection	0	0	300	0	C		N/A	
TRP	N/A	T906-002ET	Software Defined Radio Proximity-1 Link Communications Package design study	0	0	300	0	C		N/A	
ETP	IPC	E901-003ED	Miniaturized Integrated Avionics for planetary landers	0	0	500	1000	C(2)		N/A	Phase 1 (500K), Phase 2 (1000k)
TRP	N/A	T912-001GS	Improvement of Delta-DOR performances for 1 nrad accuracy for precise landing support	0	0	250	0	C		N/A	
TRP	N/A	T913-011MM	Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT (COMPASS)	0	0	200	0	DN/C	ES	N/A	
ETP	IPC	E914-001QI	Sterilisation limits for sample return planetary protection measures	0	0	300	1000	C(3)		N/A	Phase 1 (300K), Phase 2 (1000k)
ETP	IPC	E913-010MM	Manipulation systems for sample handling in a Sample Receiving Facility	0	0	300	700	C(1)		N/A	Phase 1 (300K), Phase 2 (700k)
ETP	IPC	E918-003MP	ERC dynamic stability via balloon drop tests	0	0	1000	0	C		N/A	
TRP	IPC	T918-004MP	Catalytic properties of Ablators	0	0	500	0	C		N/A	
TRP	N/A	T903-012EP	Solar Power Regulator Breadboard	0	0	300	0	C		N/A	Replaced E903-012EP from previous plan.
Long Term – Nuclear Power											
ETP	IPC	E903-015EP	European Isotope Production Phase 2	0	0	2000	0	DN/C	UK	N/A	
Total of all activities				**0**	**0**	**6400**	**2700**				

Budget summary tables

Application/Mission	Progr.	2011	2012	2013	2014	Total
MSR						
	ETP (4)			2100	2700	4800
	TRP (7)			2300		2300
Total				**4400**	**2700**	**7100**
Long Term						
	ETP (1)			2000		2000
Total				**2000**		**2000**
Grand Total TRP				**2300**		**2300**
Grand Total ETP				**4100**	**2700**	**6800**
Grand Total ESA				**6400**	**2700**	**9100**

Annex 2:

Detailed Descriptions of ESA MREP-2 Programme

Technology Development Activities

MSR

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					

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:

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**	>2016

				Need/Date:	
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.					

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 a 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, datapackage.			

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).					

Improvement of Delta DOR performances for 1 nrad accuracy for precise landing support			
Programme:	TRP	**Reference:**	T912A-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 accurcay 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) Trade off 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:

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.

Sterilisation limits for sample return planetary protection measures			
Programme:	ETP	**Reference:**	E914-001QI
Title:	Sterilisation limits for sample return planetary protection measures		
Total Budget:	1300		

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.
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 activity is proposed with the following tasks: Phase 1: 1. Identification and description of representative biological samples based on latest ESF report, identification and characterisation of representative sample preparation and conditioning, including matrix material, for the heat/radiation inactivation tests, identification of material (non-vesicular picritic basalt for most tests, martian meteorites for confirmation tests) and characterisation (chemistry and pore space using tomography) of projectile and targets for the hypervelocity impact tests, identification of the criteria for biological inactivation, 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, identification of the test and measurement approach (produce a test plan), including high speed cameras, flash X-rays, in-situ tracers and chemical analysis of the pressure and heat affecting the projectile for the hypervelocity impact tests, This task will conclude the Phase 1 of this activity, at which point COSPAR will be consulted in order to agree the way forward with respect to the testing to be done in the Phase 2. Phase2 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, statistical approach for all tests to achieve a confidence interval in the 95-99% range, develop hydrodynamic simulations and material models to extrapolate the hypervelocity impact test results. 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
Description of preparation and characterisation of the samples, projectiles and target materials, description of criteria for biological inactivation, description of experimental set-up for heat/radiation inactivation tests and impact tests, TRRs, test reports for the different tests, hydrodynamic simulations and material models for impact tests, recommendations for inactivation levels.

Current TRL:	N/A	**Target TRL:**	N/A	**Application Need/Date:**	Q3 2014
Application Mission:	MSR, Phootprint		**Contract Duration:**	16	

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 kEuros for 12 months to consolidate the requirements, provide a preliminary design iteration & trade off, description of a development program 800 kEuros 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:					

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 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 Mission:	MSR, Phootprint and Marco Polo-R		**Contract Duration:**	24	
S/W Clause:	N/A		**Reference to ESTER**	T-8101, T-7904	
Consistency with Harmonisation Roadmap and conclusion:					
ATD Harmonisation 2012					

Catalytic properties of Ablators			
Programme:	TRP	**Reference:**	T918-003MP
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 cataliticity, emissivity is another important surface properties to be determined. Also, for ablating thermal protection materials, accurate measurement of the recession rate is a critical task for the characterization and proper modelling 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, an 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 cataliticity estimation will be performed. The study would also involve an 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 modelling 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:					

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; - trade offs 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:**	2013
Application Mission:	Network Science		**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					

Long Term – Nuclear Power

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 aforementioned 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 2000kEuros 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:					

Annex III

Justification for Proposed Tendering Procedure

Justification for Proposed Tendering Procedure: DN/C
Industrial Policy Committee

ESA Reference	Title	Firm Fixed Price (Keuro)	Proposed Bidder
T913-011MM	Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT (COMPASS)	200	GMV (ES)

Justification:

Supplementary tasks to on-going work in MREP Spartan and SEXTANT activities (E913-001MM and E913-005MM).

Justification for Proposed Tendering Procedure: DN/C
Industrial Policy Committee

ESA Reference	Title	Firm Fixed Price (Keuro)	Proposed Bidder
E903-015EP	European Isotope Production Phase 2	2000	National Nuclear Laboratory (UK)

Justification:

This is a Phase 2 of a long-term activity with the UK National Nuclear Laboratory for development of nuclear isotope material.