SPACE-27-TEC-2020: SRC - Space robotics technologies

Guidance Document for Horizon 2020 Work Programme 2018-2020

Final

25/10/2019
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<tr>
<td>APM</td>
<td>Active Payload Module</td>
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<td>ASM</td>
<td>Active System Module</td>
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<td>AURA</td>
<td>Association of Universities for Research in Astronomy</td>
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<td>CDR</td>
<td>Critical Design Review</td>
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<td>dRAS</td>
<td>demonstrator Robotic Assembly System</td>
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<td>dSMT</td>
<td>demonstrator Segmented Mirror Tiles</td>
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<td>ERGO</td>
<td>EUROPEAN ROBOTIC GOAL-ORIENTED autonomous controller (OG2 in the SRC)</td>
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<td>MDR</td>
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<td>OBC</td>
<td>On-Board Computer</td>
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<td>Operational Grant with xx [1-6] belonging to the call 2015 and xx [7-11] belonging to a call 2017</td>
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1 INTRODUCTION

1.1 OBJECTIVES OF THE DOCUMENT

This document constitutes the Technical Annex to the 2020 Call for the EC H2020 Strategic Research Cluster (SRC) in Space Robotics Technologies.

The document contains the detailed description of work, in terms of dependency on previous SRC activities, goals, achievements, programmatic aspects and the detailed specification of deliverables for each of the Operational Grants to be awarded in the call.

2 TOPIC OF THE 2020 CALL

The first activities in the SRC have addressed designing, manufacturing and testing of reliable and high performance robotic Common Building Blocks for operation in space environments (orbital and/or planetary). The specific challenge of the second call was to integrate the previously prepared Common Building Blocks into demonstrators on ground, towards applications of space robotics in the field of orbital and planetary use. These robotics applications address the future needs of exploration (advanced autonomy and robot cooperation relying on AI and other techniques) and commercial exploitation of space (on-orbit servicing, in-orbit assembly and reconfigurable satellites).

2.1 GENERAL CHALLENGE

The overall challenge of the strategic research cluster (SRC) is to enable major advances in space robotic technologies for future on-orbit missions (robotics and proximity rendezvous), and the exploration of the surfaces of the other bodies in our solar system.

The first activities in the SRC, awarded with the 2016 Call, have addressed designing, manufacturing and testing of reliable and high-performance common robotic building blocks for operation in space environments (orbital and/or planetary), which will be used for the activities subject to this call.

The specific objective of the 2018 call was to integrate the previously prepared common building blocks into demonstrators, on ground, towards applications of space robotics in the field of orbital and planetary use (phase 0/A studies). These robotics applications address not only the future needs of exploration and exploitation of space but also potential spin-off and spill-over effects to other areas of robotic activity on Earth, such as agricultural, automotive, mining, nuclear, or underwater.

The objective of the 2020 call is to prepare the technologies for demonstrators planned to be implemented in the 2023-2027 timeframe. The successful proposals shall validate relevant applications for both orbital and planetary scenarios relying on technologies derived from previous SRC activities.
3 RESEARCH WORK AND DELIVERABLE DESCIPTIONS FOR OG12/OG13

3.1 OBJECTIVES

The applications selected in the previous call contain enabling elements for enhancing and fostering commercialisation of space considering aspects of New Space and Industry 4.0. This momentum should now be transferred into an enabling orbital mission with high visibility to the larger public.

The in-orbit demonstration mission shall validate previous developments of the SRC for the purpose of simultaneously satisfying short-term (ie on-orbit inspection, life extension, de-orbiting) and mid-to-long-term (ie ORU exchange, reconfiguration, on-orbit assembly/recycling) horizons. It is required to connect these two different business cases in a single demonstrator. The proposed demonstrator shall represent a risk-taking, disruptive approach to enable new commercial opportunities in space.

The Orbital Mission Study shall provide a feasibility study relating to the demonstrator mission (Phase A) and a preliminary design of this mission (Phase B1) outlining system and technology requirements. In parallel to this, it shall be outlined which hardware and software technologies, as defined in the Mission Study, will be developed in order to achieve this level of technology maturation.

3.2 ASSUMPTIONS AT THE START OF THE WORK

Successful proposals are expected to provide a first iteration of the Conceptual Study, articulating the means to connect two different business cases (short term and mid-to-long term) in a single demonstrator. The proposed demonstrator shall represent a risk-taking, disruptive approach to enable new commercial opportunities in space in the shortest timeframe.

In parallel to this, successful proposals are expected to outline the plan of technology readiness enhancement for the technologies identified in this document.

As such, it is assumed that at the start of the work the following areas have been already addressed and defined in the successful proposals:

- **Global market & trend analysis:** The proposal shall dedicate a specific chapter detailing the business cases that will be enabled by the demonstrator and the new market opportunities that will be generated in the space sector in Europe.

- **Transition into the new paradigm:** The Proposal shall include a dedicated chapter to explain how the demonstrator will facilitate the smooth transition between the short-term market need and future commercial possibilities through the generation of new modular and reconfigurable, intelligent satellites. Furthermore, the proposed mission and system design shall allow the integration of other functional building blocks into the system at later phases (for example, Phases C and D) of the project. This shall demonstrate increased flexibility before launch compared to conventional systems.

- **TRL increase of critical systems:** The Proposal shall define re-use of the SRC building blocks, identify other critical hardware developments and any technology maturation needed to ensure the viability of
the demonstrator in the next phases. The proposal shall propose a plan to achieve for all these elements TRL 5-6 at the end of the activity.

- IPR and access rights shall be clearly justified, in particular for the building blocks used in the proposal (operative system, autonomy framework, Data-fusion framework, sensor suite & standard interfaces). In this justification, the use of building blocks on royalty-free basis (access rights, open design documentation and minimum TRL) shall be considered.

### 3.3 WORK DESCRIPTION

#### 3.3.1 WORK LOGIC AND SEQUENCING

The study has two separate streams of activities:

- Mission and system definition
- TRL increase of critical technologies

The two streams are meant to be running in parallel, with synchronisation events meant to update each stream with the progress of the other.

The activities are interlaced with 6 reviews/progress meetings:

- Mission Definition Review (MDR) at the end of Phase 0 to assess the baseline for the mission and the technology plan
- Progress Meeting 1 (PM1) in the middle of Phase A, to review the progress of the mission design
- Preliminary Requirement Review (PRR) at the end of Phase A
- Progress Meeting 2 and 3 (PM2 and PM3) during Phase B1 to assess the progress of detailing of the mission and the system design
- System Requirement Review (SRR) to examine the system requirements
3.3.2 TASK0: PHASE 0 MISSION ANALYSIS/NEEDS IDENTIFICATION

- Elaborate the mission statement in terms of identification and characterization of the mission needs, expected performance, dependability and safety goals and mission operating constraints with respect to the physical and operational environment.
- Develop the preliminary technical requirements specification.
- Identify possible mission concepts.
- Perform preliminary assessment of programmatic aspects supported by market and economic studies as appropriate.
- Perform preliminary risk assessment.

**Deliverables (dissemination level as per article 8 of the Collaboration Agreement):**

- All deliverables as requested by [AD15-20], with dissemination level CO-1
- Market and trend analysis & exploitation plan (Initial), with dissemination level CO-1
- State of the art & review previous OGs, with dissemination level PU
- Dissemination and communication plan, with dissemination level PU

3.3.3 TASK1: PHASE A FEASIBILITY

- Establish the preliminary management plan, system engineering plan and product assurance plan for the project.
- Elaborate possible system and operations concepts and system architectures and compare these against the identified needs, to determine levels of uncertainty and risks.
- Establish the function tree.
• Assess the technical and programmatic feasibility of the possible concepts by identifying constraints relating to implementation, costs, schedules, organization, operations, maintenance, production and disposal.
• Identify critical technologies and propose pre-development activities.
• Quantify and characterize critical elements for technical and economic feasibility.
• Propose the system and operations concept(s) and technical solutions, including model philosophy and verification approach, to be further elaborated during Phase B.
• Elaborate the risk assessment.
• Release of preliminary management, engineering and product assurance plans.
• Release of the technical requirements specification.
• Confirmation of the technical and programmatic feasibility of the system concept(s).
• Selection of system and operations concept(s) and technical solutions, including model philosophy and verification approach, to be carried forward into Phase B.

**Deliverables (dissemination level as per article B of the Collaboration Agreement):**

• All deliverables as requested by [AD15-20], with dissemination level CO-1
• Market analysis & exploitation plan (Update if needed), with dissemination level CO-1

### 3.3.4 TASK2: PHASE B PRELIMINARY DEFINITION (B1)

• Finalize the project management, engineering and product assurance plans.
• Establish the baseline master schedule.
• Elaborate the baseline cost at completion.
• Elaborate the preliminary organizational breakdown structure (OBS).
• Confirm technical solution(s) for the system and operations concept(s) and their feasibility with respect to programmatic constraints.
• Conduct “tradeoff” studies and select the preferred system concept, together with the preferred technical solution(s) for this concept.
• Establish a preliminary design definition for the selected system concept and retained technical solution(s).
• Determine the verification program including model philosophy.
• Identify and define external interfaces.
• Prepare the next level specification and related business agreement documents.
• Initiate pre-development work on critical technologies or system design areas when it is necessary to reduce the development risks.
• Initiate any long-lead item procurement required to meet project schedule needs.
• Prepare the space debris mitigation plan and the disposal plan.
• Conduct reliability and safety assessment.
• Finalize the product tree, the work breakdown structure and the specification tree.
• Update the risk assessment.
• Release of updated technical requirements specifications.
• Assessment of the preliminary design definition.
• Definition of operations concepts and business cases.
• Status of the technology development activities and plan for next phases
• Assessment of the preliminary verification program.

*Deliverables (dissemination level as per article 8 of the Collaboration Agreement):*

• All deliverables as requested by [AD15-20], with dissemination level CO-1
• Dissemination and communication Report, with dissemination level PU

### 3.3.5 TASK3: TECHNOLOGY MATURATION

The objective is to increase the TRL of critical technologies to TRL5-6 as required for the following B2 phase.

There are three groups of technologies here considered:

1. Common Building Blocks produced by the SRC
2. Technologies identified as critical in the Operational Grants of Application Call
3. New technologies developments identified in the mission study

As there will be 2 Operational Grants implementing competitively the mission studies, each proposal shall be responsible for the maturation of those technologies deemed to be required for the mission application(s) addressed therein, in accordance with the definitions above. Applicants should consider, that the part of their proposal related to Task 3 could be fine-tuned during the GAP phase. This ensures complementarity and avoid duplication between the two selected proposals.

With respect to points 1 and 2, the TRL increase effort shall start immediately. For group 3 it will follow the Technology Plan (delivered at the end of Task1).

*Deliverables (dissemination level as per article 8 of the Collaboration Agreement):*

• All deliverables as requested by [AD15-20], with dissemination level CO-1

### 3.4 DEFINITIONS AND SYSTEM BREAKDOWN

The application development OG7, OG8 and OG9 have focused on the possible short, mid and long-term scenarios in the use of robotics in orbital applications. The activity in subject shall consider a range of future mission scenarios, including those addressed by existing OGs, but not to the exclusivity of others. The activity must remain consistent to the long-term strategy of the proposers. In order to establish definitions that apply to all possible scenarios and mixes of them, the following breakdown of the mission elements is proposed. Proposals shall be obliged to devise a mission study that will not simply satisfy short-term market needs (for example, refueling, docking, station-keeping, orbit (de)raising, inspection, debris removal and deorbiting etc) unless it provides an innovative bridge to satisfying more long-term market requirements.
This breakdown is a superset of all elements of a system to be proposed:

- **Spacecraft equipped with manipulator:**
  - Platform
  - Payload
    - relocatable/replaceable/functional modules equipped with standard interconnects
  - Refuelling subsystem
    - Tank and piping
    - Grasping/refuelling tool
  - Robotic subsystem
    - At least one 6DoF manipulator equipped with a Standard Interconnect
    - a multi-purpose On-Board Computer (OBC)
    - robotic autonomous control system
    - a sensor suite equipped with all necessary sensors to fulfil its purpose
- **Spacecraft without manipulator:**
  - Platform
  - Payload
    - relocatable/replaceable/functional modules equipped with standard interconnects
    - Grasping/Refuelling Provisions

### 3.5 USER REQUIREMENTS AND CONSTRAINTS

#### 3.5.1 DEMONSTRATION REQUIREMENTS

R1 The demonstration shall allow building confidence on the feasibility of business based on-orbit servicing/assembly with high visibility for the larger public

R2 Demonstrate a mix of the applications studied in the OG7-OG9 including short to long term ones.

R3 Validate the SRC technologies with first time orbital use

R4 Achieve TRL9 for the technologies critical to the chosen application mix

#### 3.5.2 FUNCTIONAL REQUIREMENTS

R5 The demonstration shall be in full scale and immediately transferrable to the applications identified in OG7-OG9
R6 The demonstration shall implement autonomy capable to cope with a range of timing, spatial and environmental conditions representative of the uncertainty of a real mission.

R7 The duration of the demonstration shall allow for a minimum of 3 repetitions of the critical operations.

R8 The demonstrator shall validate modularity by means of upgrading the functionality of a platform assembling functional modules (e.g. ORU exchange).

R9 The proposed system design shall validate the increased flexibility introduced by modularity by allowing the integration of a functional module into the system at later phase of the project (Phase D) (addition of a functionality before launch).

3.5.3 IMPLEMENTATION CONSTRAINTS

R10 The demonstration shall be completed by 2025.

R11 The budget for the Demonstrator suggested by PSA is in the range of 50-100M€ including launch and operations costs. The proposal shall provide a first break-down for this costs in line with the mission and justification of cost/benefits/efficiency for future business cases.¹

R12 The demonstration shall make use of at least one 6 DOF robot manipulator.

R13 The Multi-purpose robot controller shall be implemented using the ESROCOS toolkit.

R14 Any robot motion/activity planning/scheduling system software in the multi-purpose robot controller shall be implemented using the ERGO framework.

R15 Any perception processing used in the system software shall be realised with the INFUSE framework.

R16 Sensor data pre-processing and aggregation shall be based on the I3DS design.

R17 Any modular assembly shall make use of the SRC Standard Interconnector (SI), SIROM. In the instance that a different Standard Interconnector is used, the chosen SI must provide the same access rights as described by Article 4.4 of the SRC Collaboration Agreement, equivalent TRL and make public the corresponding design documentation with respect to the other CBB(s).

R18 Any satellite grasping/refuelling means shall make use of the ASSIST system.

4 RESEARCH WORK AND DELIVERABLE DESCRIPTIONS FOR OG14

The purpose of this section is to define the scope of the work for Operational Grant 14 (OG14) in Advanced Robotics Planetary Exploration.

¹ "In-Orbit-Demonstration methodology and possible EU funding depends on future decisions and overall Horizon Europe budget.
4.1 OBJECTIVES

The objectives of OG14 are to investigate advanced robotic capabilities in the field of mobility and multi-robot cooperation in planetary surface exploration and implement the robot capability to collect, elaborate and share useful information from the scientific instruments onboard on it with the other explorer robots. The final result being sought is a demonstration showing that these capabilities allow teams of robots to explore regions of difficult accessibility (such as gullies, cliffs, craters and lava tubes), which are unreachable for present robotic systems and the cooperative multi-robot team is able to manage meaningful information for the target mission from a real time data retrieval.

The demonstration shall showcase the current capabilities in the exploration of difficult areas, and allow the identification of gaps in technology and knowledge, specifically in the areas of:

- Artificial Intelligence
- Sensing and modelling of complex environments
- Diverse means of locomotion
- Cooperative planning and decision-making.

The results of the successful project, coupled with the results of the previous SRC calls, will pave the way for future European activities in planetary exploration.

Specifically, the activity aims at:

- Defining the performance of the robotic explorers for a set of scenarios involving difficult access areas
- Defining the demonstrator in terms of the analogue site, the team of robots and the capabilities of the individual robots
- Identifying all critical technology and define a plan for technology development/adaptation/maturation to realize the architecture
- Define a Case Study for terrestrial exploitation of the technology to solve problems in terrestrial sectors and scenarios.
- Implement the technology plan
- Implement the demonstrator
- Perform a high visibility demonstration complete of at least one scientific research activity for which the collected data are elaborated in real time and shared among the explorer robot team and a Remote Monitoring Station

4.2 ASSUMPTIONS AT THE START OF THE WORK

It is assumed that the successful proposal has already performed a first iteration of Task 0, in order to define the capabilities required for the exploration of difficult areas.

It is assumed that the successful proposal has already performed a first iteration of Task 1, and it has identified the demonstrator to simulate hazardous and/or difficult extra-terrestrial terrain and test the technologies required to plan, navigate, traverse, investigate and share their results.
It is assumed that the consortium of the successful proposal has at its disposal robot explorers with diverse means of locomotion suitable to negotiate the target environments.

It is assumed that the successful proposal has already performed a first iteration of Task 2 and hence:

- identified (and have access to) state-of-the-art technology in artificial intelligence, sensing and modelling complex environments and capabilities in motion planning and execution,

- assessed the capability to collect, elaborate in real time and share meaningful information on the explored environment with the robot team and the Remote Monitoring Station useful for the target mission,

- assessed how results of the previous SRC Calls, both in terms of building blocks and of system design can be used in the demonstrator,

- collated a plan on how to develop and integrate the above technologies in the demonstrator.

It is assumed that the successful proposal has already performed a first iteration of Task 3 and hence it has defined a case study demonstrating how the same technology can be exploited on Earth to solve problems in terrestrial sectors and scenarios.

4.3 WORK DESCRIPTION

4.3.1 WORK LOGIC AND SEQUENCING.

![Diagram of activity logic and sequencing]

Figure 2: logic and sequencing of the activity. Tasks in blue, reviews in red

There are 6 reviews:
• Review 1 (R1) at the end of Task 0 for the assessment of the chosen exploration scenario
• Review 2 (R2) at the end of Task 1, to examine the design of the demonstrator
• Review 3 (R3) at the end of Task 2, to examine the State-Of-The-Art and the Analysis of Relevant Terrestrial Technologies & Capabilities
• Review 4 (R4) at the end of Task 3, to assess the plan for the development of the demonstrator and of the technologies
• Review 5 (R5) at the end of tasks 5 and 6 to assess the readiness of the technology implementation and the demonstrator and to review the progress of the terrestrial exploitation of Task 4
• Review 6 (R6) in conjunction with the high visibility demonstration, to finalise the activity

4.3.2 TASK 0: DEFINITION OF COLLABORATIVE ROBOTIC EXPLORATION SCENARIO

• Define a conceptual set of planetary exploration scenarios in which a team of robots works together to achieve exploration and investigation of hazardous terrain that is of high scientific interest, that would be otherwise inaccessible to a single robot.

• Identify how this scenario will be shaped into a demonstrator that will test the technologies required for a successful cooperative exploration and investigation of the site in question.

• Establish the expected performance requirements of the robotic explorers, as well as operating constraints with respect to the physical and operational environment.

• Develop the preliminary technical specification for the demonstration.

• Complete preliminary risk assessment

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

• Scenario Definition Document, with dissemination level PU
• Dissemination and communication plan, with dissemination level PU
• Preliminary risk assessment, with dissemination level PU

4.3.3 TASK 1: DEFINITION OF THE DEMONSTRATOR

• Provide a detailed definition of the demonstrator, including:
  o A description of the hazardous environs and/or difficult extra-terrestrial terrain which the robotic explorers will be expected to explore and investigate
  o A description of the types of facilities / locations to be used to execute the demonstration
  o A description of the team of robotic explorers, their individual and combined attributes and capabilities
  o A definition of the collaborative operations / functions that the robotic explorers will perform

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

• Demonstration definition document
4.3.4 TASK2: ANALYSIS OF THE STATE-OF-THE-ART

Provide:

- An analysis of existing capabilities and technologies within the space sector, including existing outputs of the Space Robotics SRC, shall be undertaken in order to identify technologies that will satisfy the performance requirements of the OG14 demonstrator.
- An analysis of terrestrial sectors shall also be undertaken to establish whether existing capabilities or technologies could be spun in from Earth-based sectors into OG14 in order to satisfy the performance requirements of the demonstrator, or could be developed within OG14 to the point of being able to do so.

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Analysis of Planetary Exploration State-Of-The-Art, with dissemination level PU
- Analysis of Relevant Terrestrial Technologies & Capabilities, with dissemination level PU

4.3.5 TASK3: IDENTIFICATION OF CRITICAL TECHNOLOGY & TECHNOLOGY PLAN

Provide:

- Identification of critical software and/or hardware technologies needed to enable the exploration of previously inaccessible areas on planetary surfaces.
- Identification of critical software and/or hardware technologies needed to enable the real time data elaboration to retrieve meaningful information to be shared among the robot explorer team (and the Remote Monitoring Station).
- A review of previous OGs to identify which SRC common building blocks shall be developed and matured for the demonstration
- Provide a description of the tests to which the technologies will be subjected in the various hazardous terrain outlined in the demonstrator definition document.

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Technology Development Plan, with dissemination level PU
- Demonstration definition document, updated with description of technology tests, with dissemination level PU

4.3.6 TASK4: TERRESTRIAL EXPLOITATION

Deliver:

- An exploitation plan that will consider various terrestrial scenarios which may make use of the robotic technologies developed & matured in OG14
- A full case study focusing on a terrestrial scenario of particular pertinence in which the technologies developed & matured in OG14 could be exploited to solve existing problems. An analysis of the socioeconomic benefits of using the technology in this scenario shall be incorporated.
Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Terrestrial Exploitation Plan, with dissemination level PU
- Full Case Study for Terrestrial Impact, with dissemination level PU

4.3.7 TASK5: TECHNOLOGY PLAN IMPLEMENTATION

Development and/or maturation of the technologies described in the Technology Development Plan

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Software and/or Hardware packages as prescribed in the Technology Development Plan, with dissemination level CO-1
- Design Definition Documentation, with dissemination level PU
- User Guidelines, with dissemination level PU
- Interface Control Documentation, with dissemination level PU

4.3.8 TASK6: DEMONSTRATOR IMPLEMENTATION

- Manufacture/procurement/production of the components, systems and platforms required to execute the demonstration
- Establishment and preparation of the test site(s) and facility(s) to be used in accordance with the technology development plan and demonstrator definition document
- Assembly, Integration and Testing of demonstrator
- Scheduling

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Demonstrator Design Definition Documentation, with dissemination level PU
- Test Plan & Schedule, with dissemination level PU

4.3.9 TASK7: DEMONSTRATION

Execution of the test(s) in accordance with previously established criteria

Deliverables (dissemination level as per article 8 of the Collaboration Agreement):

- Test results, with dissemination level PU
- Videos and media capturing demonstration, with dissemination level PU
- Final report & evaluation, with dissemination level PU

4.4 DEFINITIONS AND SYSTEM BREAKDOWN

The primary deliverable of OG14 is a demonstrator of the potential that robotic explorer agent and multi-agent can offer to future planetary exploration missions. The demonstration is intended to be performed in a Lunar or
Martian analogue scenario and shall make use only of space-sized HW, i.e. OBS performances, power availability and storage, etc.

In detail, the demonstrator shall put together:

1. An **ADvanced Robotic Explorer System (ADRES)** involving multiple **Robotic Explorer Units (REU)**, each one composed by the following main subsystems:
   - an existing robotic platform to be adapted/modified to achieve the OG goals
   - a sensor suite including all sensing and proprioceptive sensors needed to fulfil the mission tasks
   - a SW-HW framework manages:
     - autonomy and path planning
     - the real time elaboration of data from on board instruments,
     - the retrieval of meaning information for the targeted mission and sharing them among REU
     - cooperative decision making and tasks planning
   - a locomotion system (wheels, legs, caterpillars, etc...)
   - a robotic arm and an end-effector/tool (if required)

2. A **Testing Facility**, made available by the OG consortium, consisting of:
   - an analogue test environment, indoor or preferable outdoor, which would be representative of a terrain environment for topological and lighting conditions constraints.
   - an equipment suite providing ground truth (terrain model and robot reference localization)

3. A **Remote Monitoring Station (RMS)** responsible for monitoring the tests, acquiring RWAs’ state telemetry and interfacing with the **EST (Environment Simulation Tool)** from OG11 heritage, consisting of:
   - antennas for the telecommunication connections
   - HW/SW for the data storage and elaboration
   - telescopes for visual monitoring and telecommunication
   - HW/SW which use EST to manage the 3D and dynamic model representation and give model of the behaviour of the robot multi agents

4.5 **USER REQUIREMENTS AND CONSTRAINTS**

4.5.1 **DEMONSTRATION REQUIREMENTS**

R1 The demonstration shall confirm that hazardous and/or difficult extra-terrestrial terrain can be explored with state of the art, and therefore significantly increase the scientific return of Next-Gen exploration missions

R2 The demonstration shall prove the capability of the robotic team of performing specific operations, demonstrating capabilities and performances otherwise not achievable with a single robotic agent.

R3 The demonstration shall confirm that the identified gaps in technology and knowledge have been filled
R4  The demonstration shall confirm that TRL4 is reached for the technologies critical to the application

R5  The demonstration shall confirm that any technologies from terrestrial sectors identified in the course of the activity can be used in the planetary exploration context

R6  The demonstration shall confirm that any identified technology has sufficient robustness and usability to solve problems in terrestrial sectors and scenarios

R7  The demonstration shall prove the reuse and implementation of previous SRC products, both in terms of Building Blocks and applications

R8  the demonstration shall allow for a minimum of 3 repetitions of the critical operation (ascending/descending in different relevant environments)

4.5.2  FUNCTIONAL REQUIREMENTS

R9  The demonstration shall implement autonomous exploration capable to cope with a range of timing, spatial and terrestrially-feasible environmental conditions representative of the unknown of a real planetary exploration mission

R10  The demonstrator shall make use of REUs collaborating logically (i.e. by exchanging knowledge and coordinating actions and plans) and possibly physically (e.g. rappel crews)

R11  The ADRES system shall collect and retrieve 3D geographic information

R12  Each REU shall have the capability to host instruments to collect and to analyse scientific data

R13  Each REU shall be equipped at least of a scientific instrument and a SW/HW system enables it to analyze the measurements, retrieve in real time useful information for the target mission and share the results among REUs and RMS

R14  The ADRES system shall be able to cooperatively retrieve a 3D joint surface mapping, through its REUs

R15  The ADRES system shall be able to retrieve information from acquired data to cooperatively make decision in real time for moving or further investigate specific targets or/and areas, once received a specific task.

R16  The ADRES system shall be able to explore areas with a very complex structure, hard-to-reach or hard-to-traversed surfaces, with strong slopes, allowing at least one REU to perform multiple descend/ascend in a crater or a gully or lava tube or cave (Lunar or Martian), remaining in telecommunication with the other REUs

R17  The ADRES system shall be able to make autonomously decision on the approach in the exploration in real time, with the autonomy organization of the descending/ascending procedure
R18 The ADRES system shall have at least one of its REU qualified to move in vertical direction for ascending/descending exploration, a REU climber which is able in implementing an ad-hoc locomotion solution or changing its locomotion capability

R19 The suite of robots shall be able to cooperate to undertake exploring science by use of simultaneous measurements

4.5.3 IMPLEMENTATION CONSTRAINTS

R20 The demonstration shall be in full scale and representative of a realistic planetary exploration scenario (Lunar or Martian).

R21 The demonstration scenario must include a minimum of two (preferably three) cooperative Robotic Explorer Units and a Remote Monitoring Station

R22 The demonstration shall prove the re-use and implementation of previous SRC products, maximizing the re-use of the SRC Building Blocks

R23 The SW-HW framework that deal with autonomy and decision making in the REUs shall be implemented using the ESROCOS and ERGO toolkits

R24 Any REUs motion/activity planning/scheduling system software in the Multi-purpose robot controller shall be implemented using the ERGO framework

R25 Any perception processing used in the REUs shall be realised with the INFUSE framework

R26 Sensor data pre-processing and aggregation shall be based on the I3DS design