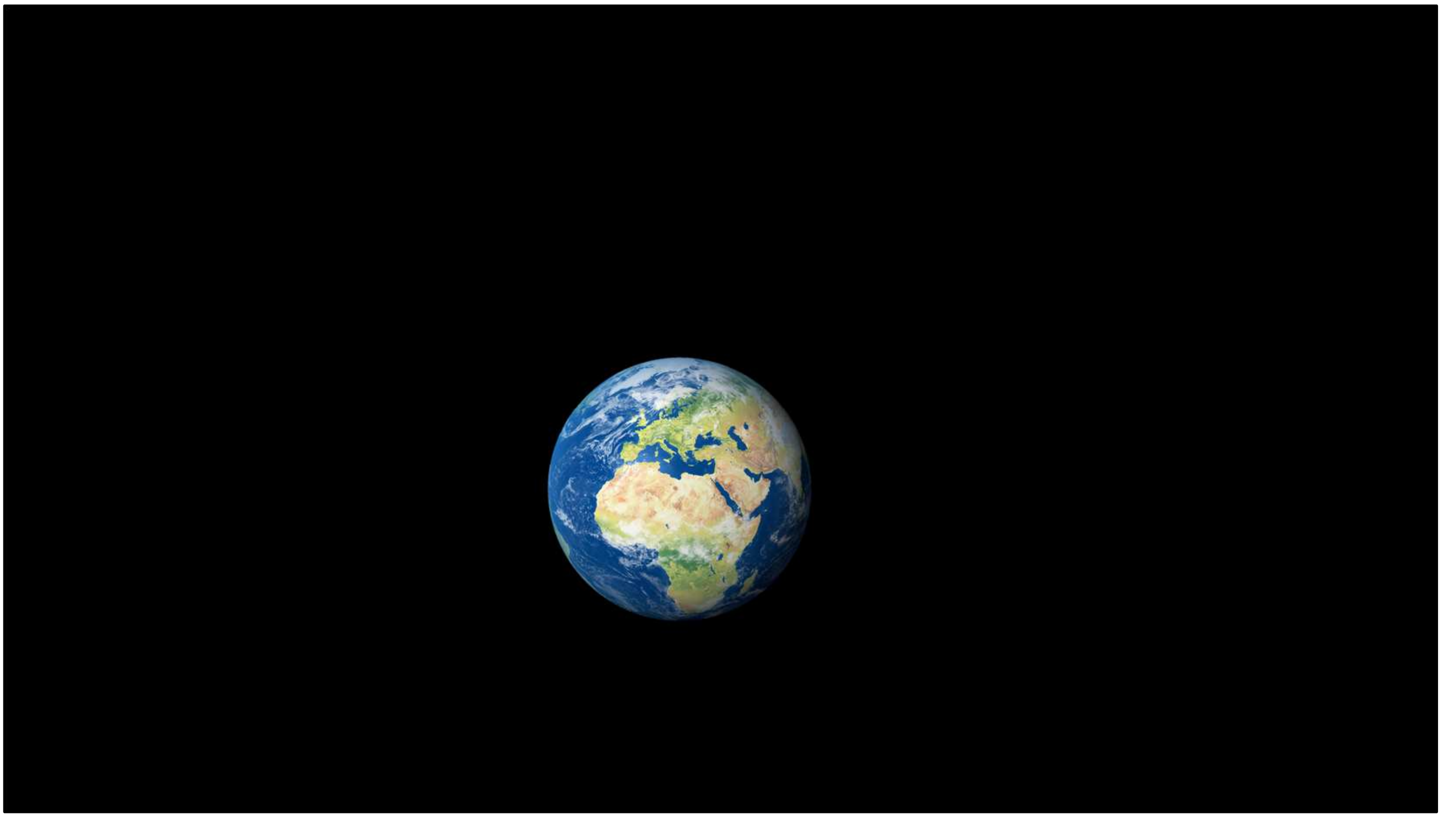
THE STRATEGIC RESEARCH CLUSTER IN SPACE ROBOTICS TECHNOLOGY

This video will introduce you to the Strategic Research Cluster in Space Robotics Technology

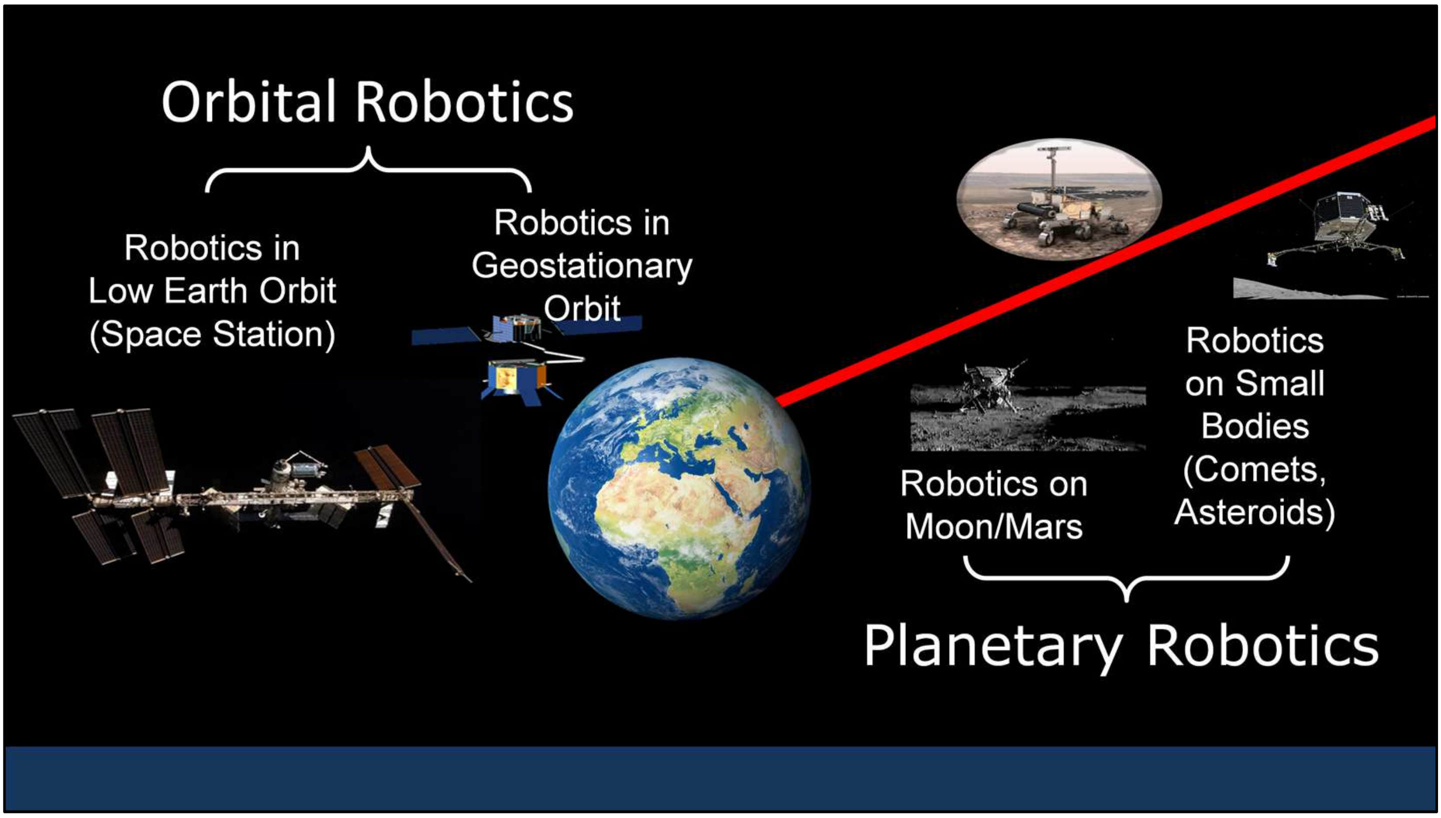
A Strategic Research Cluster is a coordinated effort of individual research and development grants that aim at producing a significant demonstration of a specific technology

We are talking here of
Space Robotics Technology

A Strategic Research Cluster (SRC in abbreviation) is a a particular way of coordinating the efforts of different consortia (that will receive EC operational grants).
The final aim of the SRC is to produce at the end of a period a major demonstration of technology. The technology subject of this video is space robotics



Space robotics is fundamental for Space exploration and utilisation.
Lets look at the expansion of human activities from earth to space.
The red arrow represents an increasing distance from Earth into space



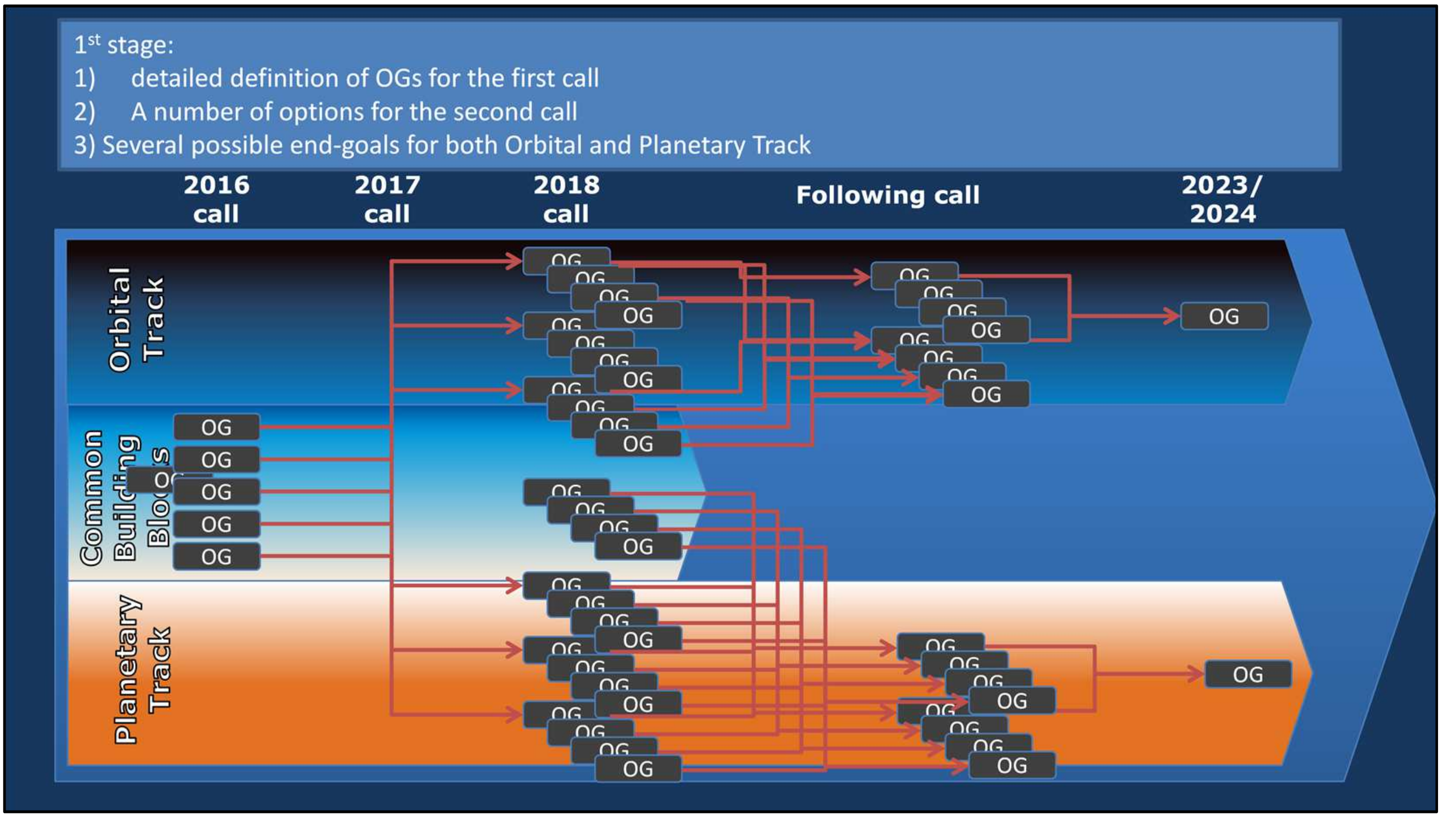
In low Earth orbit we find the first human infrastructure: the international space station. It has been built by means of robots. More robots will be used for future infrastructure.

Higher up, several robot servicing concepts have been proposed to increase the capability and efficiency of geostationary satellites

Robots built to operate in absence of gravity, atmosphere and exclusively on man made objects serve these orbital applications.

Further away we have robots on the Moon, and Mars to initially explore and later support colonisation

Finally another category of robots is exploring the small bodies of the solar system. Planetary robots work in presence of gravity (possibly very small) interacting mostly with the natural environment



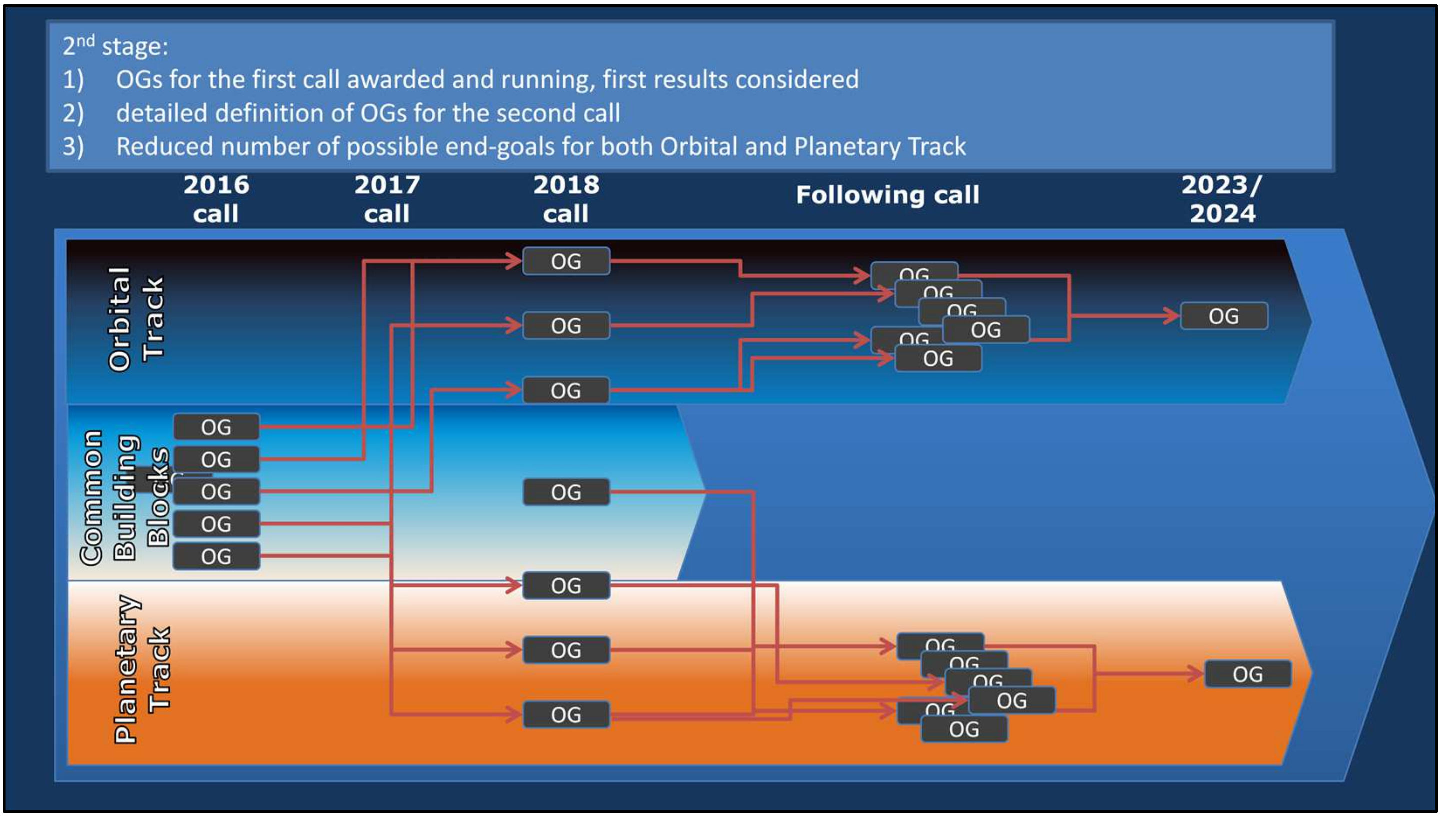
The space robotics SRC will develop its activities in five years of the programme by structuring its work in three development tracks.

One planetary Track, One orbital track and a track that will focus on common building blocks used by both orbital an planetary applications.

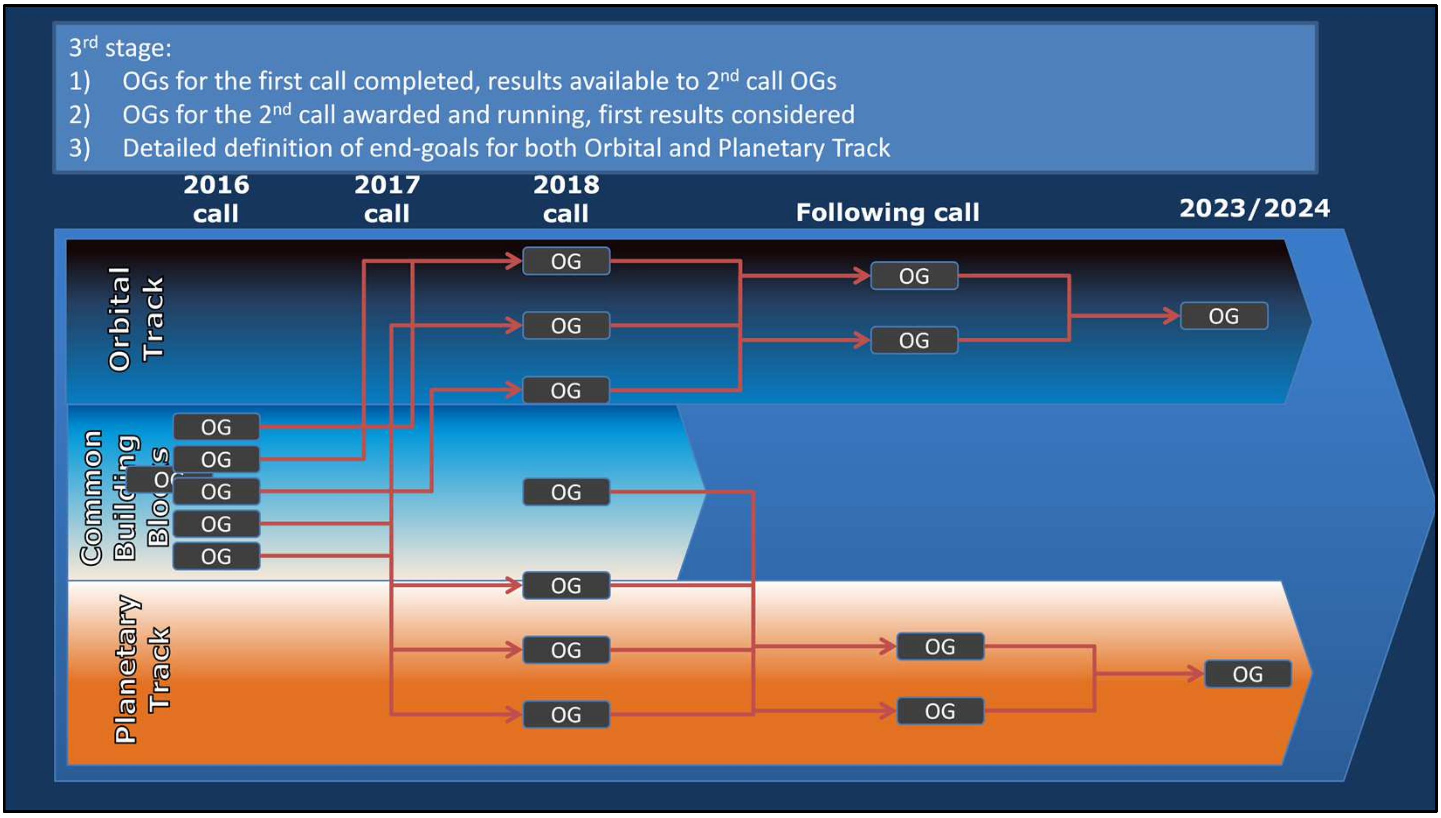
In three sequential calls, the tracks will rely on operational grants with specific subjects defined by a roadmap. The grants will progressively prepare technology towards final high profile flight demonstrations intended for the 2023-24 timeframe.

In the course of the H2020 this roadmap will be revised two times following the needs that emerge and the achievements of concluded operational grants.

So the roadmap will have three stages. Each stage will have a better definition of the final demonstration and hence more focus on specific technologies subject of the operational grants



Once the operational grants of the present call will have been awarded, a new revision of the roadmap will detail and focus the topics for the second call.



Finally in the last stage of the roadmap, the mission studies preparing for the final demonstrations will be defined in time for the last call of the SRC

The Space Robotics Technology Strategic Research Cluster offers an unique opportunity to carry out a foundation-making programme of research and development of high impact and high consistency.

The roadmap describes a programme to implement a set of long-lasting community-building developments that not only will serve the initial purpose of the SRC, i.e. demonstration of space robotics technology, but could allow future institutional missions in the field of space robotics.

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COHERENCE COMPLEMENTARITY AND COORDINATION IN THE SRC

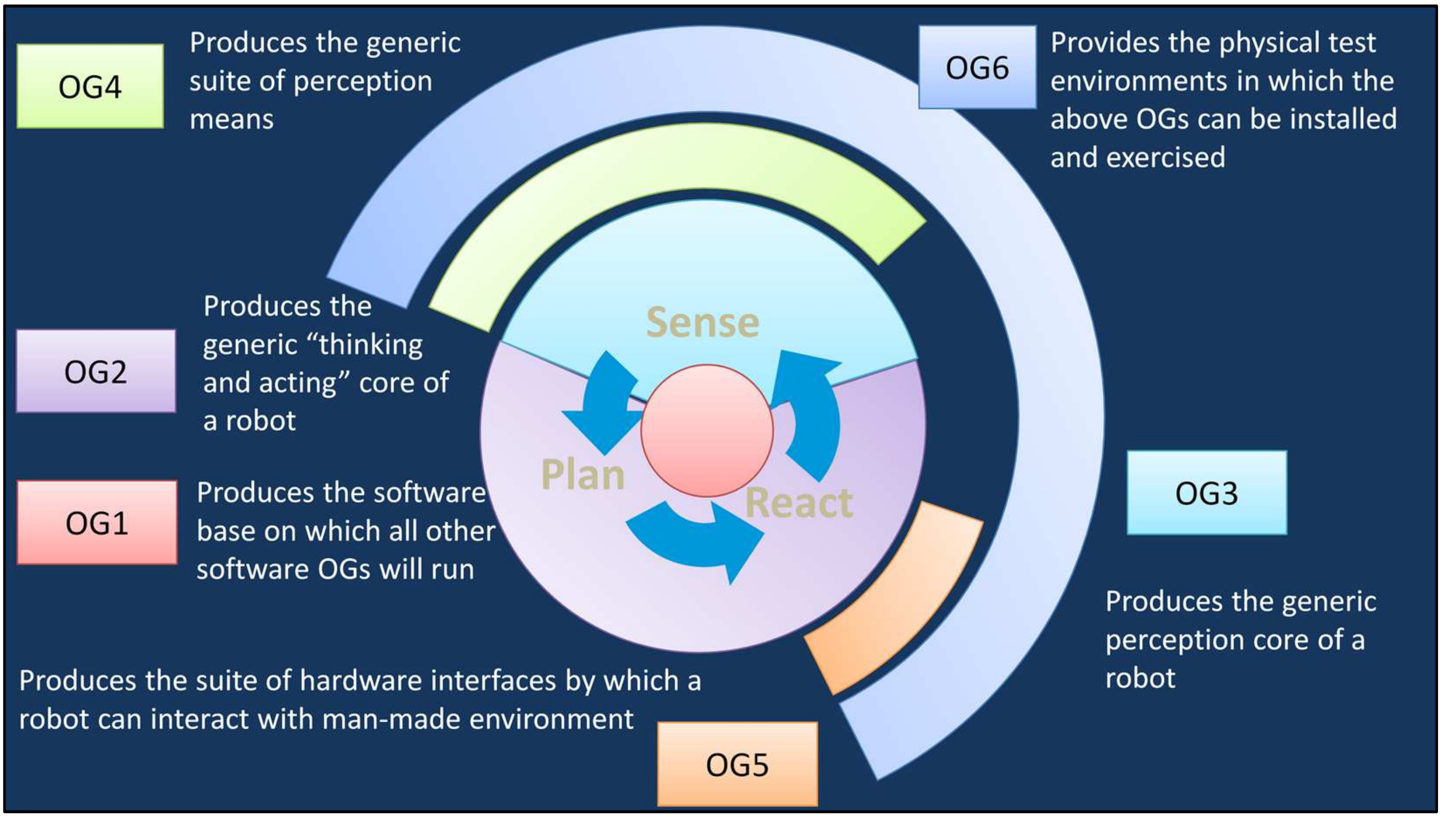
Without enforcing coherence, complementarity and coordination of the Operational Grants, the step-by-step roadmap cannot be implemented and the final success of the SRC is in danger.

Coherence and complementarity are realised by the detailed specification of operational grants.

Each OG deals with different aspects of a robot systems

Each OG has a carefully defined scope and set of deliverables

Unlike many EC calls the calls in the Space Robotics SRC will need to be very descriptive in order to realise the necessary coordination between concurrent OGs.
Also in order to optimise the communication and coordination between OGs, each OG is highly complementary to all concurrent OGs.



To guarantee complementarity, the different OGs have not overlapping subjects. We can see this from an onion diagram showing the capabilities of a space robot.

Most robots rely on the sense-plan-react cycle. OG3 will implement the generic perception core of a robot

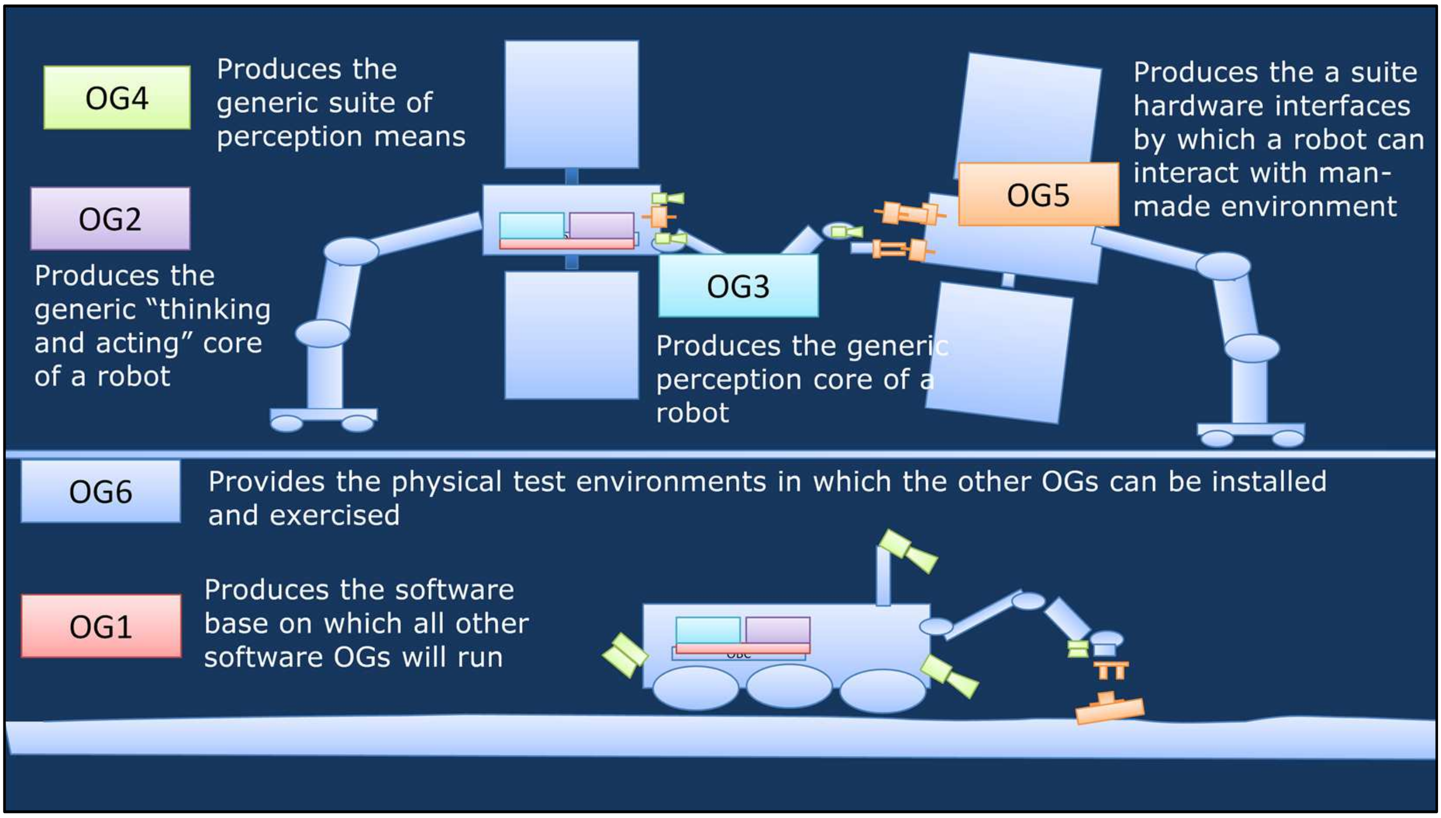
While OG2 will cover the planning and acting capability

OG1 will produce the standard software framework to generate robot controllers

With OG4, a standard suite of perception means will be created

OG5 will address the interfaces for interacting with man-made objects

Finally OG6 will provide the high-quality physical test environment in which all other OG products will be validated.



Eventually all OGs will contribute to demonstrations addressing the orbital and planetary applications.

Let's see how:

- OG6 will provide test platforms and environments for demonstrating: Orbital applications and Planetary Applications.
- OG1 will test in these platforms the basic software layers to allow: The perception core produced by OG3 and the thinking and acting core produced by OG2, to run seamlessly
- OG4 will test with the platforms a generic suite of perception means
- Finally OG5 will implement and test interfaces that allow the platforms to manipulate objects

Coordination is implemented by means of:

Commonly defined and agreed requirements and interfaces

cross-delivery among OGs of partial results

Common meetings

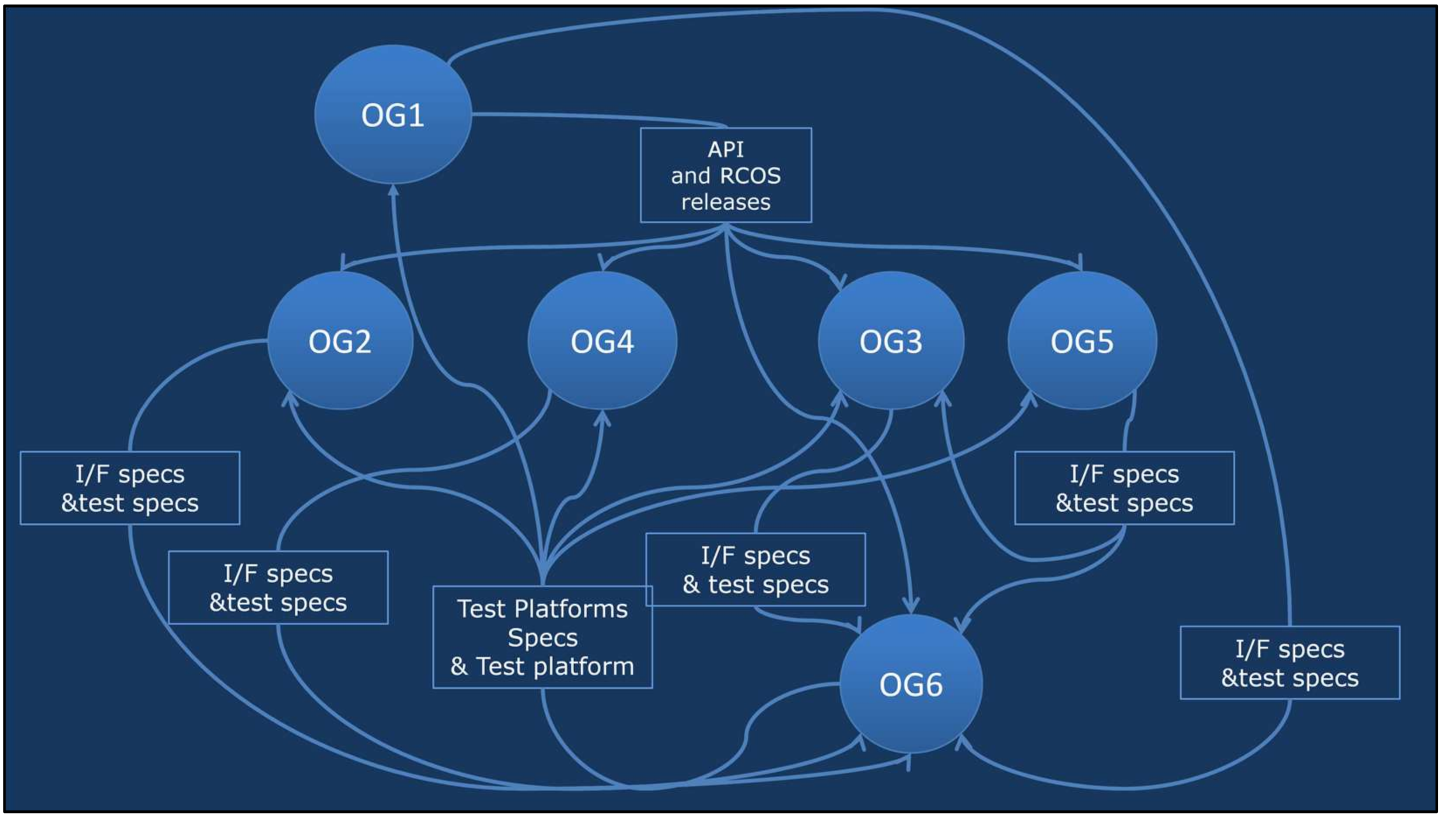
The operational grants will run concurrently to produce deliverables that must integrate among themselves.

Coordination is capital to achieve that.

All OGs will contribute in the definition of common requirements, interface and test specifications.

When development advances the OGs will also exchange intermediate products.

Common meetings of all OGs participants are also foreseen



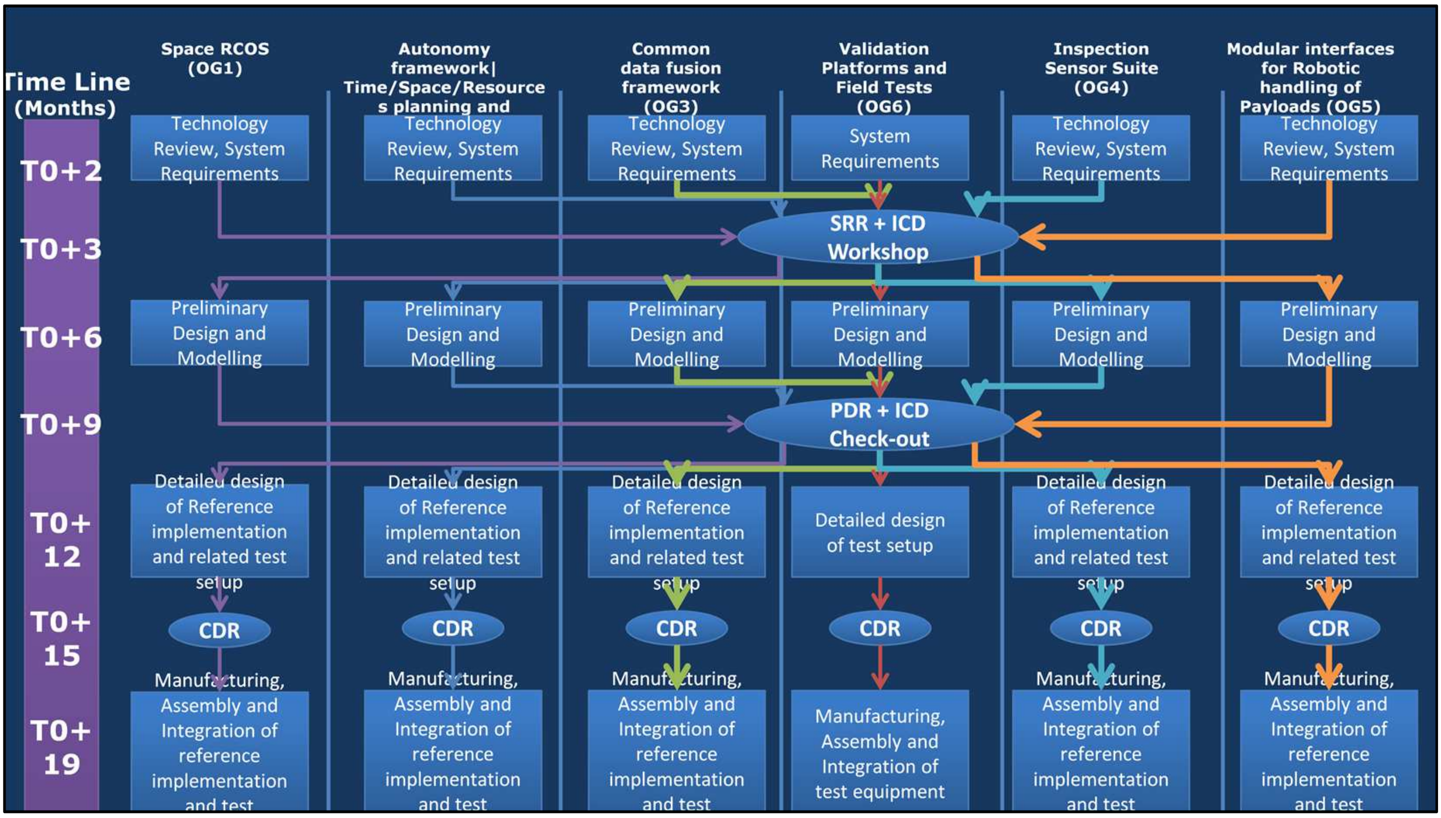
(Only OG1 connections are shown)

At the beginning, all Ogs will exchange and concur on common interfaces and test specifications.

OG6 will provide to all other OGs the specifications of their test platforms.

In the course of the development all OGs will share development snapshots through a common repository site.

In the diagram this is only shown for OG1, for clarity.



Programmatically, All OGs will run on a common schedule that foreseens common workshops for agreement of requirements, and interfaces Check-out and refinement of interface consistency

The development will run for two years, with all OGs completing their products and testing them individually

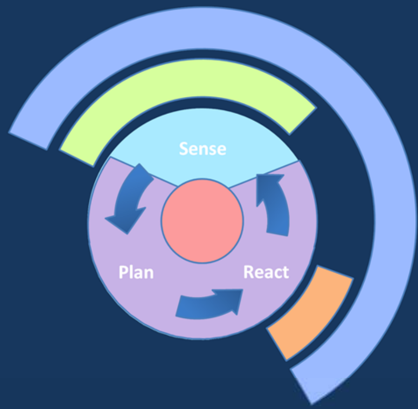
Finally all OGs will demonstrate their achievement on common high quality demonstration platforms.

The validation approach

- Stages of validation
  - Each OG realize and independent verification and validation
  - Validation in common test platforms (Orbital & Planetary)
  - Validation of fully integrated OGs (next stage)
- Objectives
  - A good interaction and coordination between all OGs is vital for the future integration
  - The validation tests shall be coherent with the demonstration scenarios and the Roadmap goals.
  - The result and deliverables of the OGs must be consistent with the SRC_Guidelines_Space_Robotics_Technologies (COMPET-4-2016)

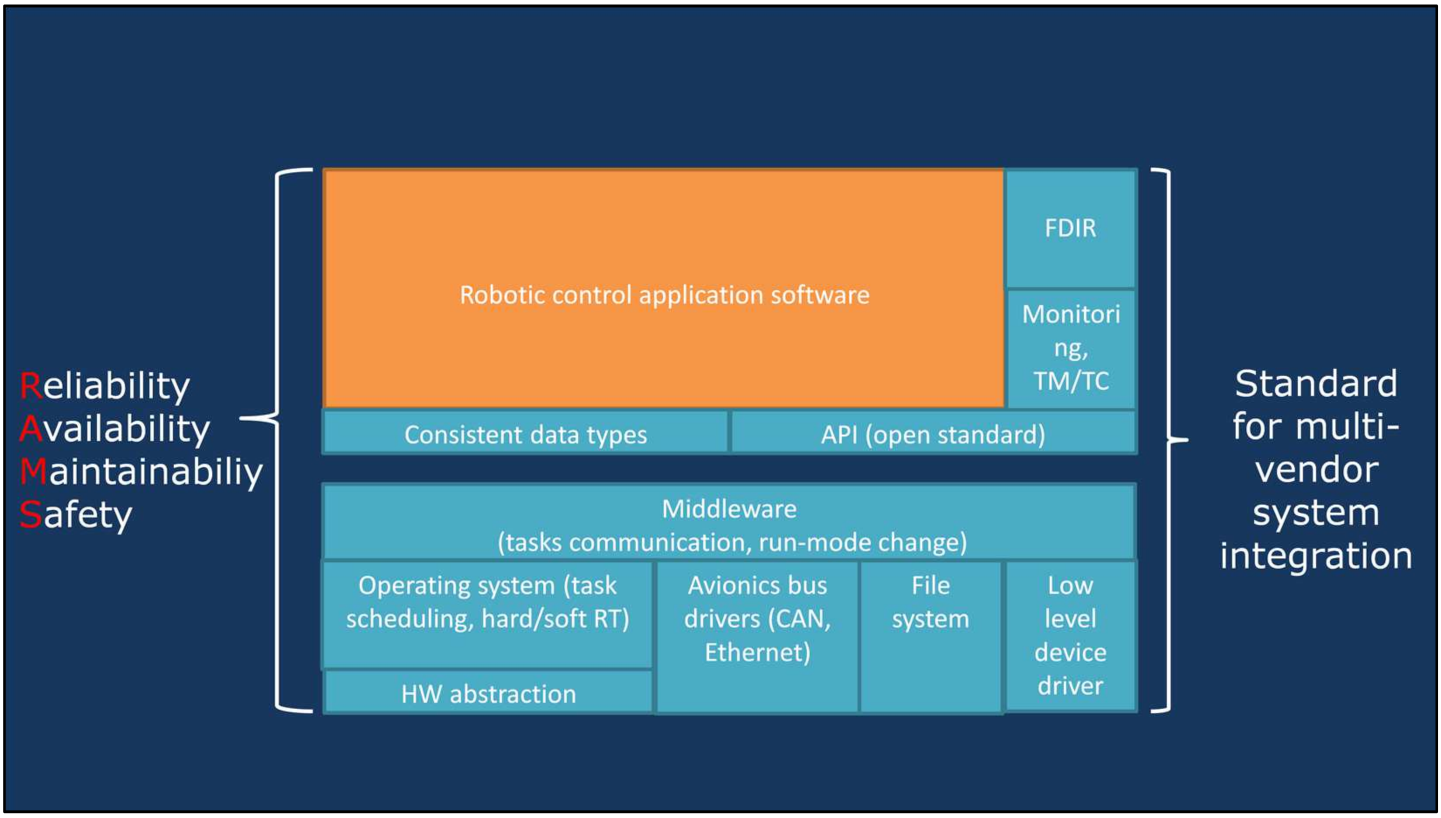
As the Space Robotics SRC aims at achieving effective demonstration for dependable space robotics applications, the validation of the products of the OGs is capital.
Each OG will entertain in: first in Independent validation, with own means and finally, validation on the high quality platforms provided by OG6.

SPACE ROBOT CONTROL OPERATING SYSTEM (OG1)



Lets now have look at the subjects treated by each OG.

OG1 deals with the means that allow development of Robot Controller Software



Robot developers implement software specific to the specific target application. To allow re-use of modules across applications, their code need to rely on:

- consistent data types
- a standard application programming interface

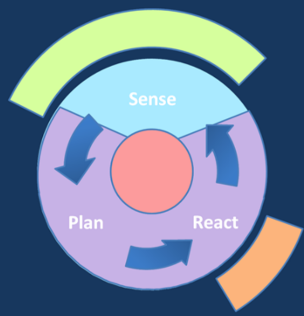
Also, as space robots operate remotely, they need:

- standard means for remote monitoring and control
- and for dealing with with Failure Detection Isolation and Recovery

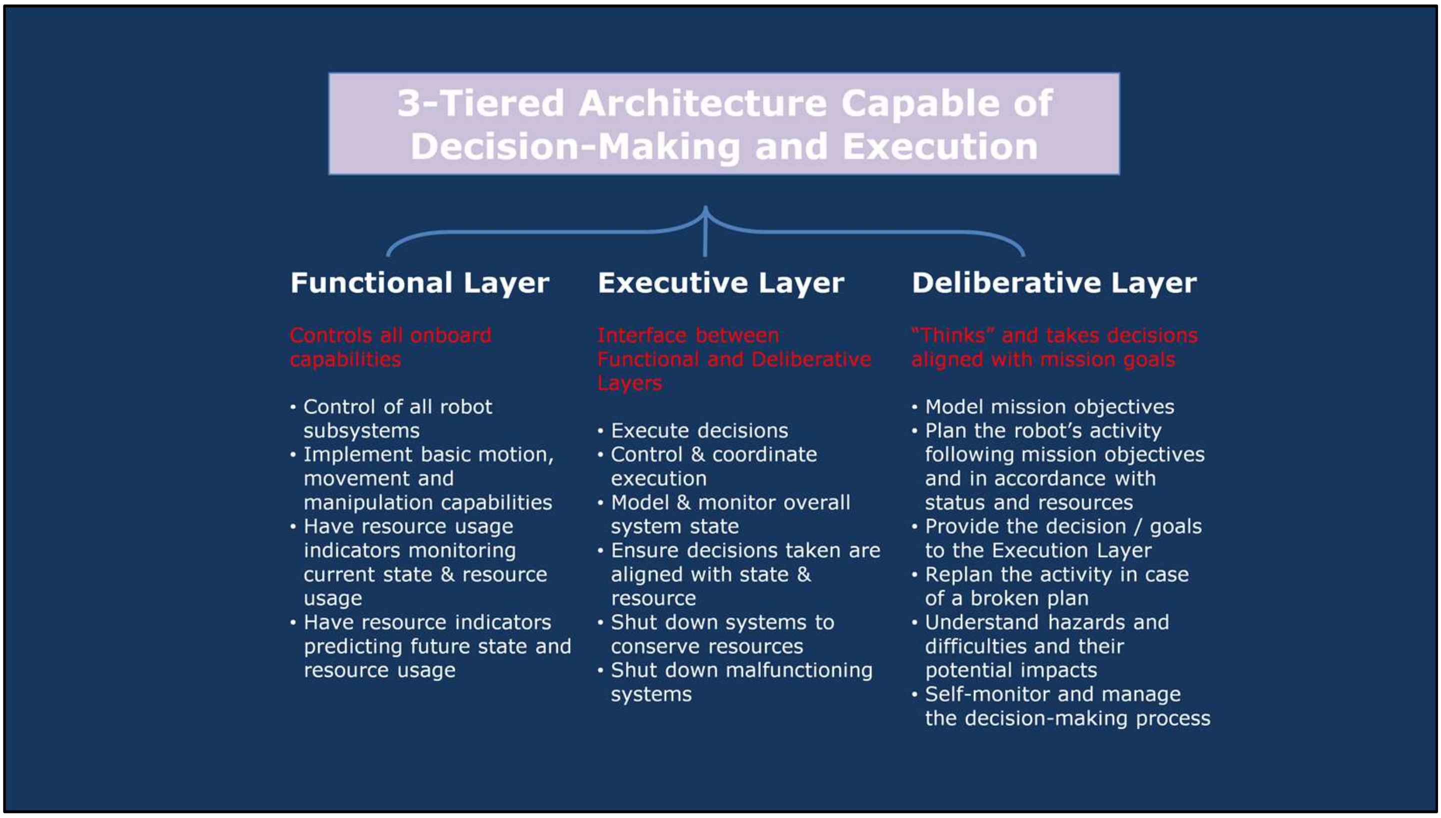
Robot software is made of several tasks:

- hence a middleware is needed to coordinate these tasks.
- Robot control software also requires strict real-time behaviour,
- access to the robot hardware and communication and data storage means"

All this maintaining the highest Reliability Availability Maintainability and Safety quality required by space applications.
OG1 will also need to respect the fact that space hardware varies depending on the vendor chosen



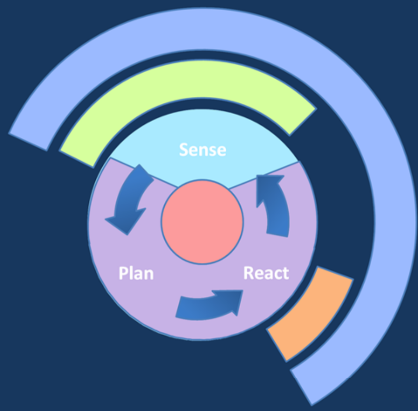
AUTONOMY FRAMEWORK: TIME/SPACE/RESOURCES/PLANNING/SCHEDULING (OG2)



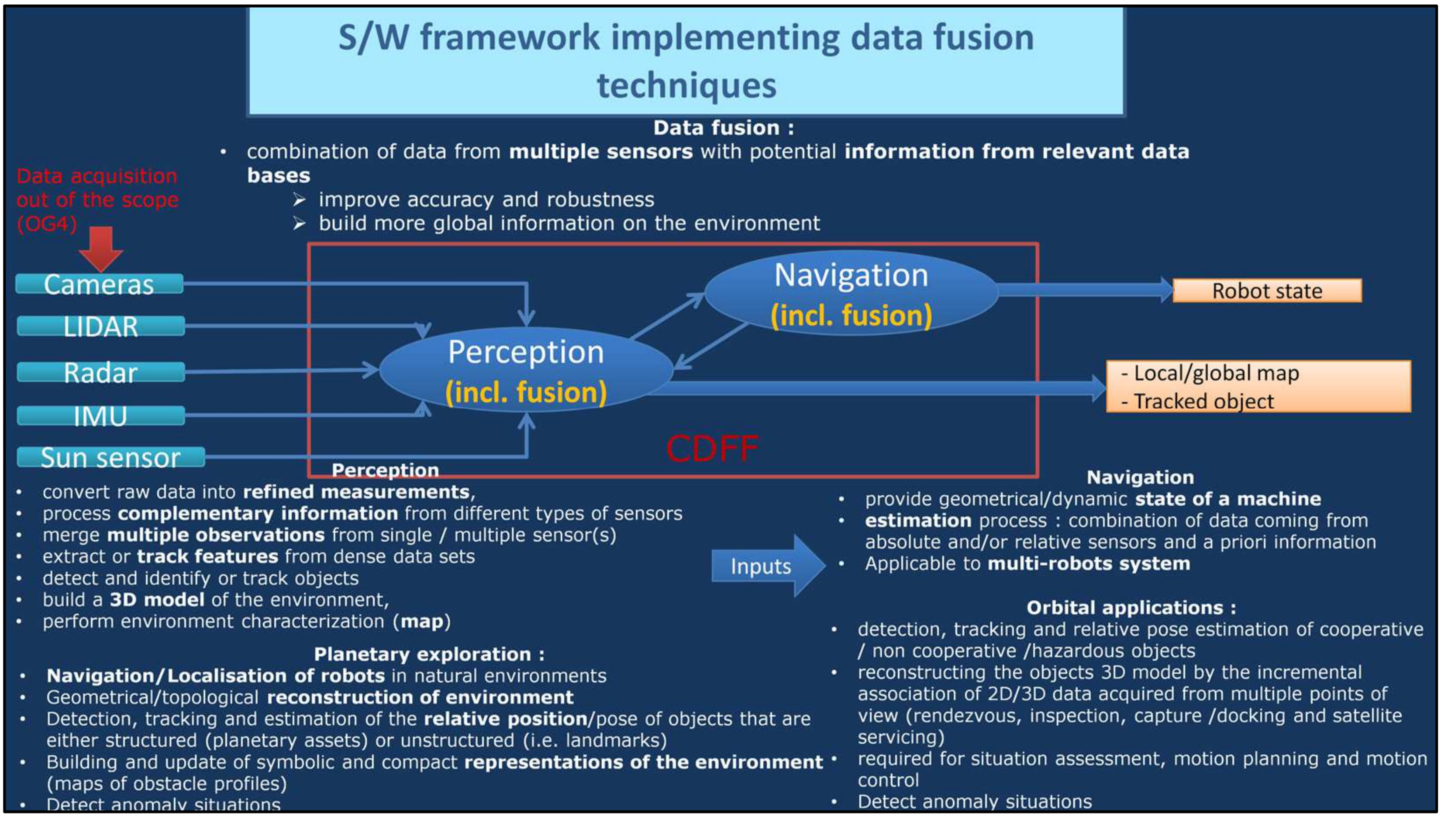
The Autonomy Framework sits at the heart of the robotic system and is responsible for making decisions and the necessary planning to execute those decisions in alignment with mission objectives and goals, and also the robot's onboard resources and status. It interfaces directly with the Inspection Sensor Suite and the Common Data Fusion Framework, and relies upon the software language of the RCOS.
The AF will adopt a three-tiered hierarchical architecture: functional, executive, and deliberative layers.

- The **Functional Layer** controls all onboard capabilities of the robotic system. It comprises an object-oriented hierarchy capturing the granularity of the system, where individual objects represent the equipment, systems and instrumentation responsible for robotic capabilities such as movement, sensing, manipulation, and all other controllable functions. The functional layer is therefore responsible for the following functions (Control of all robot subsystems; Implement basic motion, movement and manipulation capabilities; Have resource usage indicators monitoring & estimating state & resource; Have resource indicators predicting future state and resource usage)
- The **Executive Layer** is the interface between the other two layers: it receives the plans from the deliberative layer in the form of task trees, or sequences of actions to be completed. It does not possess any planning ability itself – it's purely reactive, but coordinates and controls the tasks to be undertaken by the functional layer. The Executive Layer has the following functions (Execute decisions; Control & coordinate execution; Model & monitor overall system state; Ensure decisions taken are aligned with state & resource; Shut down systems to conserve resources; Shut down malfunctioning systems)
- The **Deliberative or decision layer** takes decisions based upon input from the sensors, fused by the data fusion framework, in alignment with mission goals and objectives – it's therefore event and goal-driven. It may also be discriminatory, asking particular sensors for particular slices of information in order to best formulate its decisions and tasks to be undertaken. The Deliberative Layer has the following functions (Model mission objectives; Plan the robot's activity following mission objectives and in accordance with status and resources; Provide the decision/goals to the Execution Layer; Replan the activity in case of a broken plan; Understand hazards and difficulties and their potential impacts; Self-monitor and manage the decision-making process)

The diagram shows the flow of information inside the Autonomy Framework, and also the interface points between the Autonomy Framework and the other Operational Grants.



COMMON DATA FUSION FRAMEWORK (OG3)

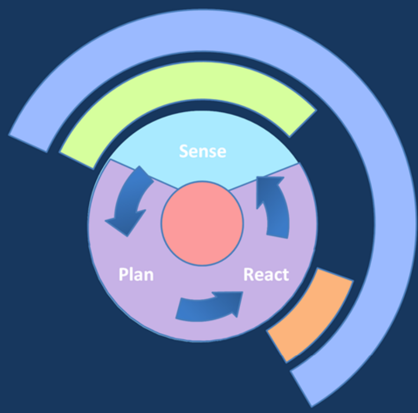


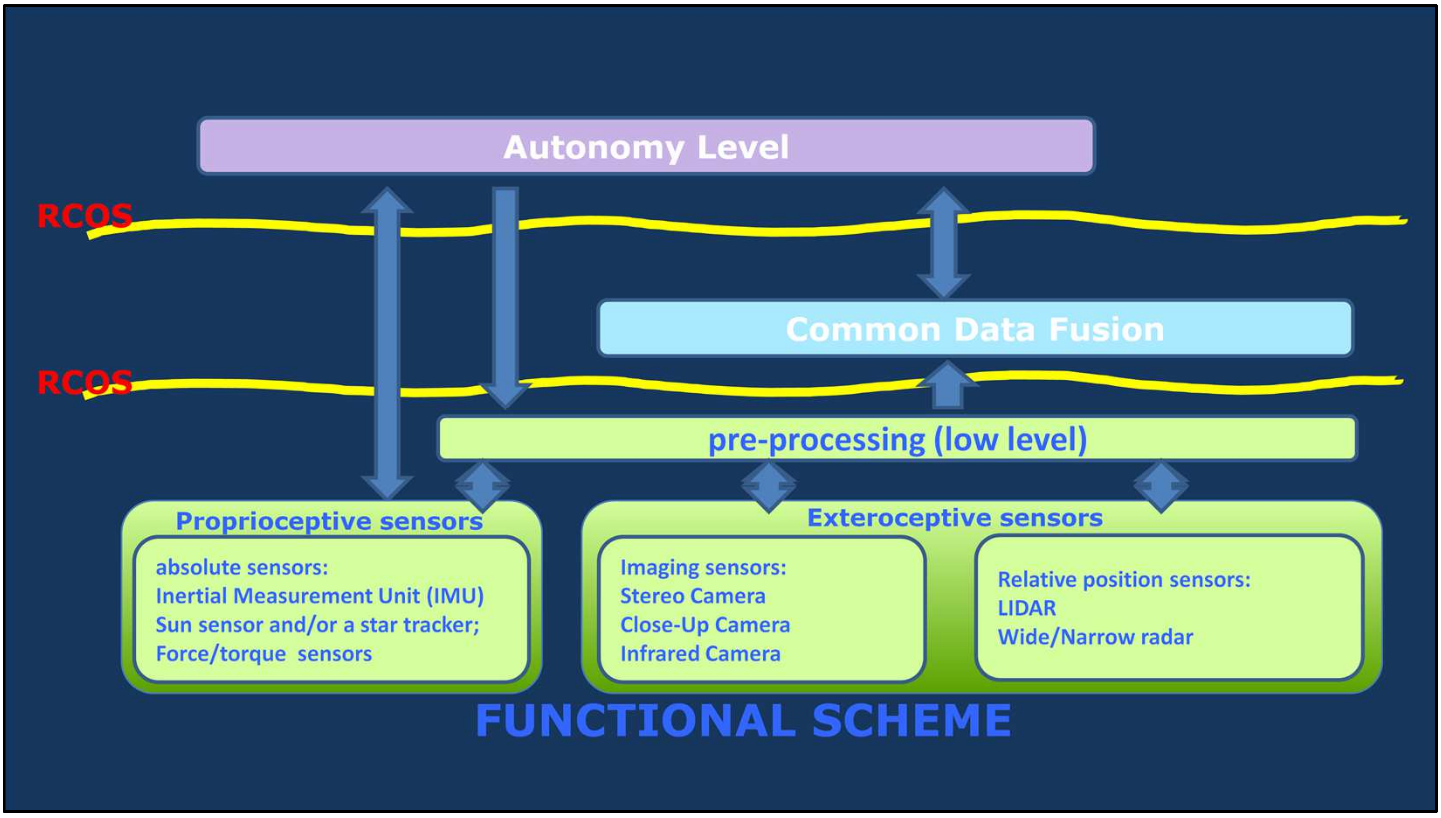
This OG satisfies the needs of perception and localisation for both planetary exploration and orbital systems. Data fusion is necessary to achieve a satisfactory level of performance and robustness than no single sensor would be able to provide.
This OG shall consist in developing a software framework designed for embedded systems and implementing data fusion techniques for various sensors.
Beyond performance and robustness, data fusion will allow to acquire a global knowledge of the environment
The inputs will come from the different sensors involved in the perception process. The processing of these data through the CDFF shall result in the vehicle's localisation state and models of the environment.

The common data fusion framework, or CDFF to be developed includes the functionalities of **Perception** and **Navigation** applicable to robotic systems in both Orbital and Planetary tracks.

- The Perception functionalities include the conversion, merging and fusion of data from the sensors, detection and tracking of features and objects, construction and charactrerisation of 3D maps.
- The Navigation functionality provides the geometrical and dynamic state of the robot through a process of estimation that includes several sensors in the rover. Navigation function must also consider and take advantage of the presence of other rovers.
- In the Orbital track, the targeted applications are : rendezvous, inspection, capture /docking and satellite servicing. The information produced by the CDFF is required for situation assessment, motion planning and motion control.
- For Planetary scenarios, the CDFF targets autonomous science, long range traverse and rendezvous with other planetary assets.

COMMON INSPECTION SENSOR SUITE (OG4)



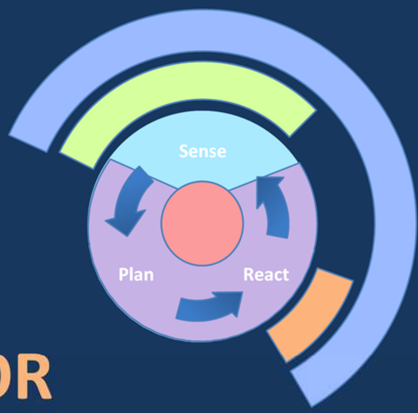


The Inspection Sensor Suite provides for all senses of the robotic system. It consists in a set of perception sensors that together with the products of OG2 and OG3 allows to: detect and identify objects in the operational environment, define position and attitude of the autonomous vehicle while moving in space or on a planetary surface reconstruct the environment geometry and build maps gather further information e.g. appearance, color, temperature, in order to characterize the environment around the vehicle.

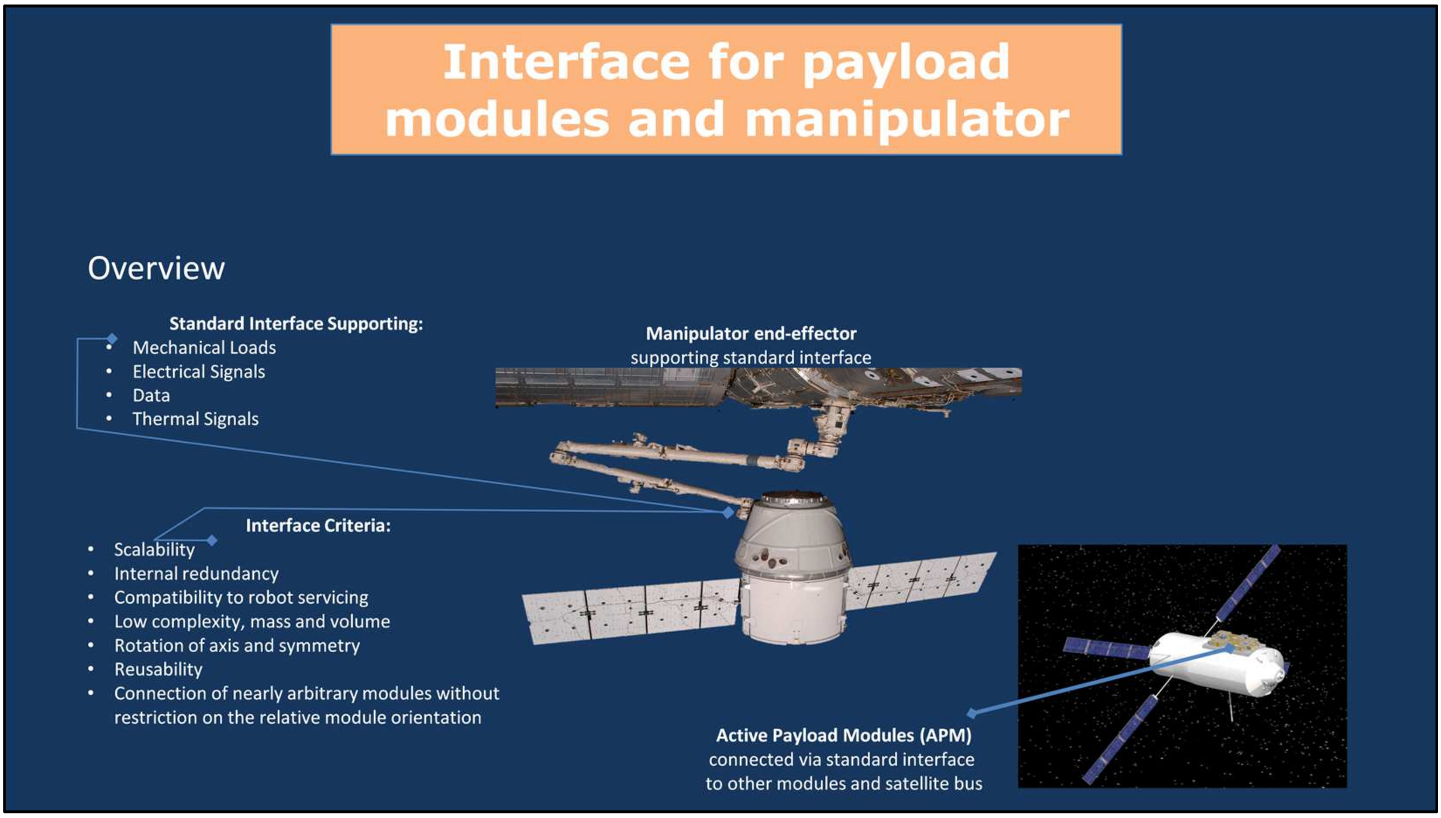
The sensor suite is composed of two types of sensors:

- Proprioceptive sensors, which are responsible for measuring the vehicle position, attitude and dynamics while an inspection task is executed.
- Exteroceptive sensors are used to investigate and thus acknowledge the operational environment.

The raw data are pre-processed and sent, through the means of the Robot Control Operating System (RCOS), to the common data fusion framework. The common data fusion framework, upon a specific request, provides the autonomy level with data, through RCOS. The Proprioceptive sensors can interface directly with the autonomy level. The same autonomy level can send a request directly to the Inspection Sensor Suite while the response is returned through the common data fusion framework.



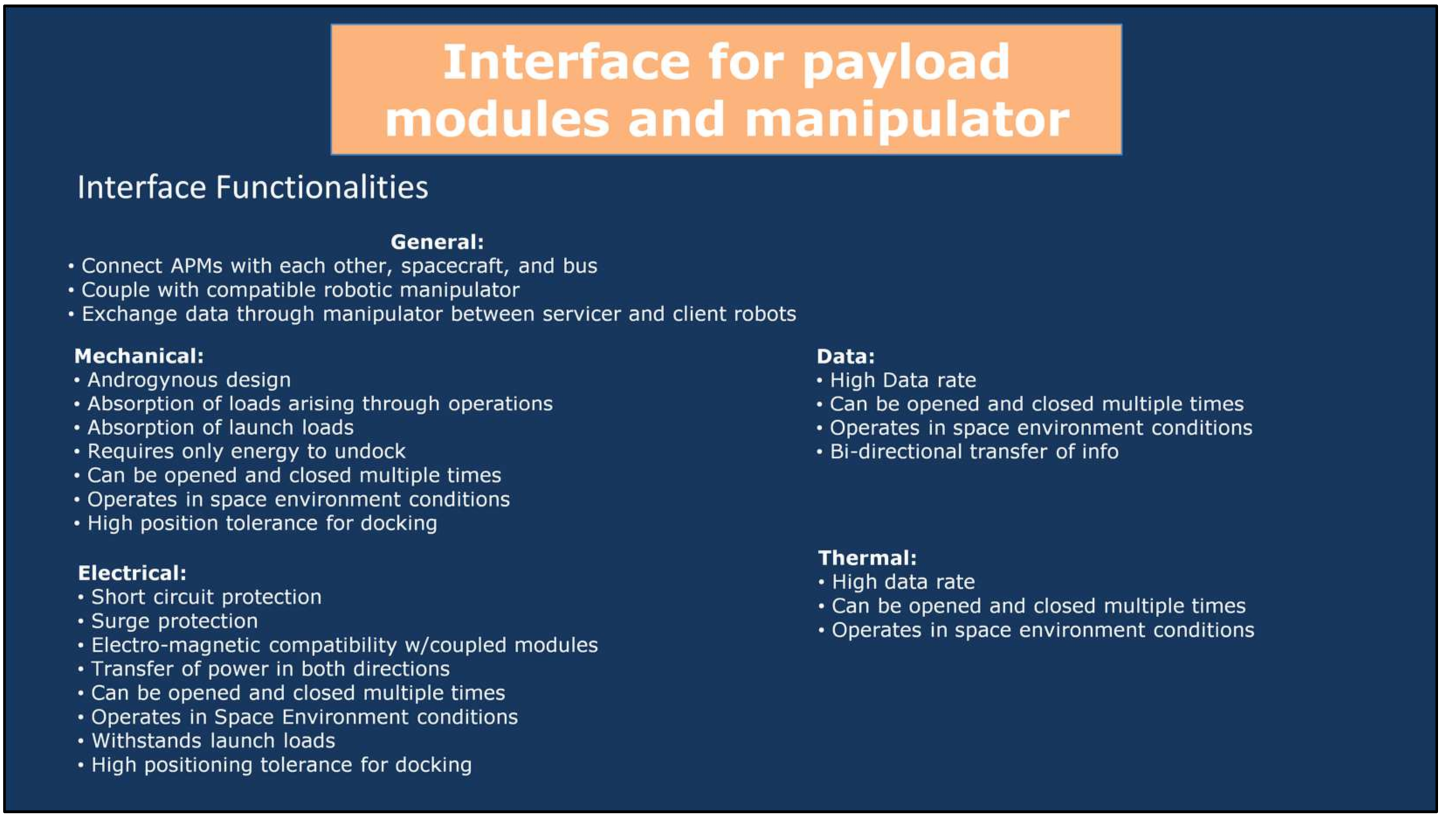
MODULAR INTERFACES FOR ROBOTIC HANDLING OF PAYLOADS (OG5)



The driver for this OG is the desire for a standardised form of an interface allowing the coupling of spacecraft modules. A *standard interface* in this context is defined as a combination of devices that allow to couple active payload modules. or APM, to a manipulator, among themselves and to spacecraft. It shall allow transferring of mechanical loads, electrical signals and data as well as thermal flux between the coupled modules.

APMs are containers with integrated subsystem or payload components, which can be used to fulfil a certain task. Additionally a servicing robot can “communicate” with module attached through its manipulator due to the data transfer capability of the interface.

The *standard interface* may be realised in an integrated form (where mechanical, thermal, electrical, data connections are combined) or a separated form. In any case, the *standard interface* shall allow building up large clusters of modules. The interfaces for modular compatible spacecraft for this OG should be designed to a few specific criteria, in order to use it for various applications in space, as listed on this slide." "By assembling clusters of modules of different functions is possible to realise highly modular spacecraft.

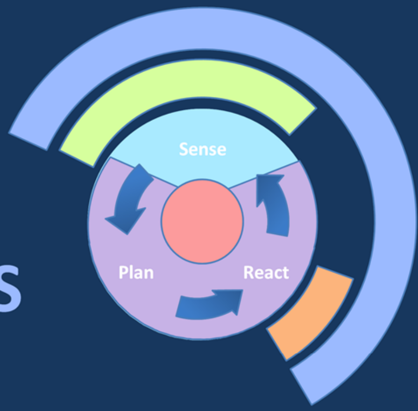


A standardisation of the interface and spacecraft elements (modules) is necessary to increase the capacity and capability of robotics usage in space, as used in manufacturing. Modularity will extend the usability and maintainability of spacecraft. This OG asks for the development of a suitable design of interface, test modules and proper end-effector for a robotic manipulator.

The interfaces for modular compatible spacecraft for this OG should be designed to a few specific criteria, in order to use it for various applications in space, as listed on this slide While there are some general functionalities that the modular interfaces will be expected to demonstrate, there are also expected functionalities specific to the type of transfer that will be enabled: mechanical, electrical, data and thermal.

The proposed interface design must cover all functionalities. However, if it is technically not possible to meet all requirements, a compromised solution must be found.

VALIDATION PLATFORMS AND FIELD TESTS (OG6)



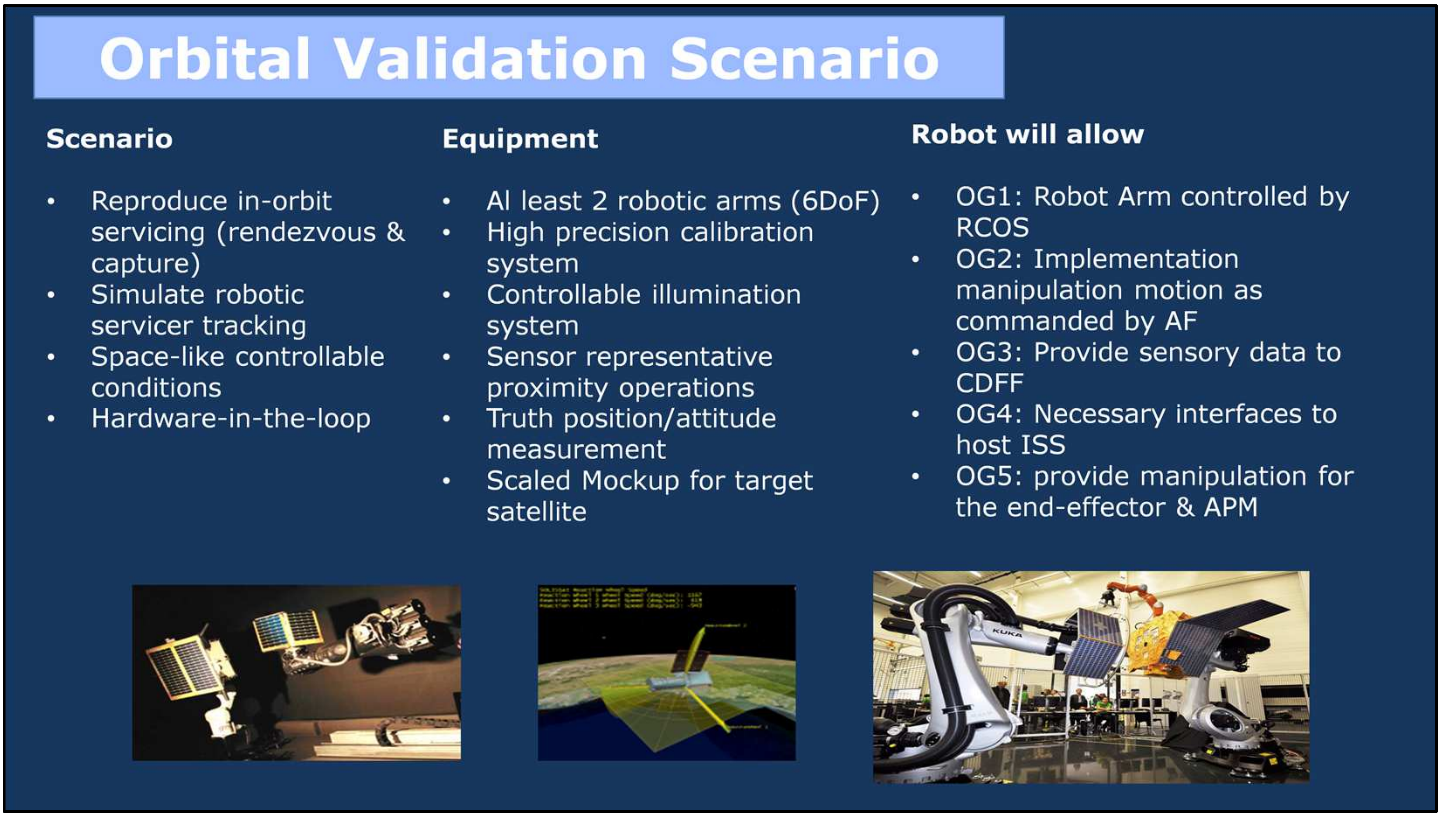
OG6

- Shall support validation of the common building blocks in the most relevant environment
- Must cover both scenarios Planetary Exploration and Orbital Servicing
- Must be able to validate ALL OGs in BOTH Scenarios
- Shall rely on European reference Network of Test Facilities
- does not include design of the facilities, only adaptation for the OGs validation.
- Shall provide the necessary facilities (Already existing laboratories, only small adaptations intended)
- Shall provide the necessary: Platforms, specifications, interfaces, models, datasets & monitoring
- Shall assist and give on-site support to validation, but validation tasks are outside the scope of this activity

The **validation platforms** shall assist the validation (in representative environments with different degree of fidelity) of all technologies developed within the SRC.
OG6 shall identify and prepare the facilities to assist the validation of the above listed SRC technologies, building on a set of already existing laboratories across Europe, by creating a network of validation platforms/test facilities.

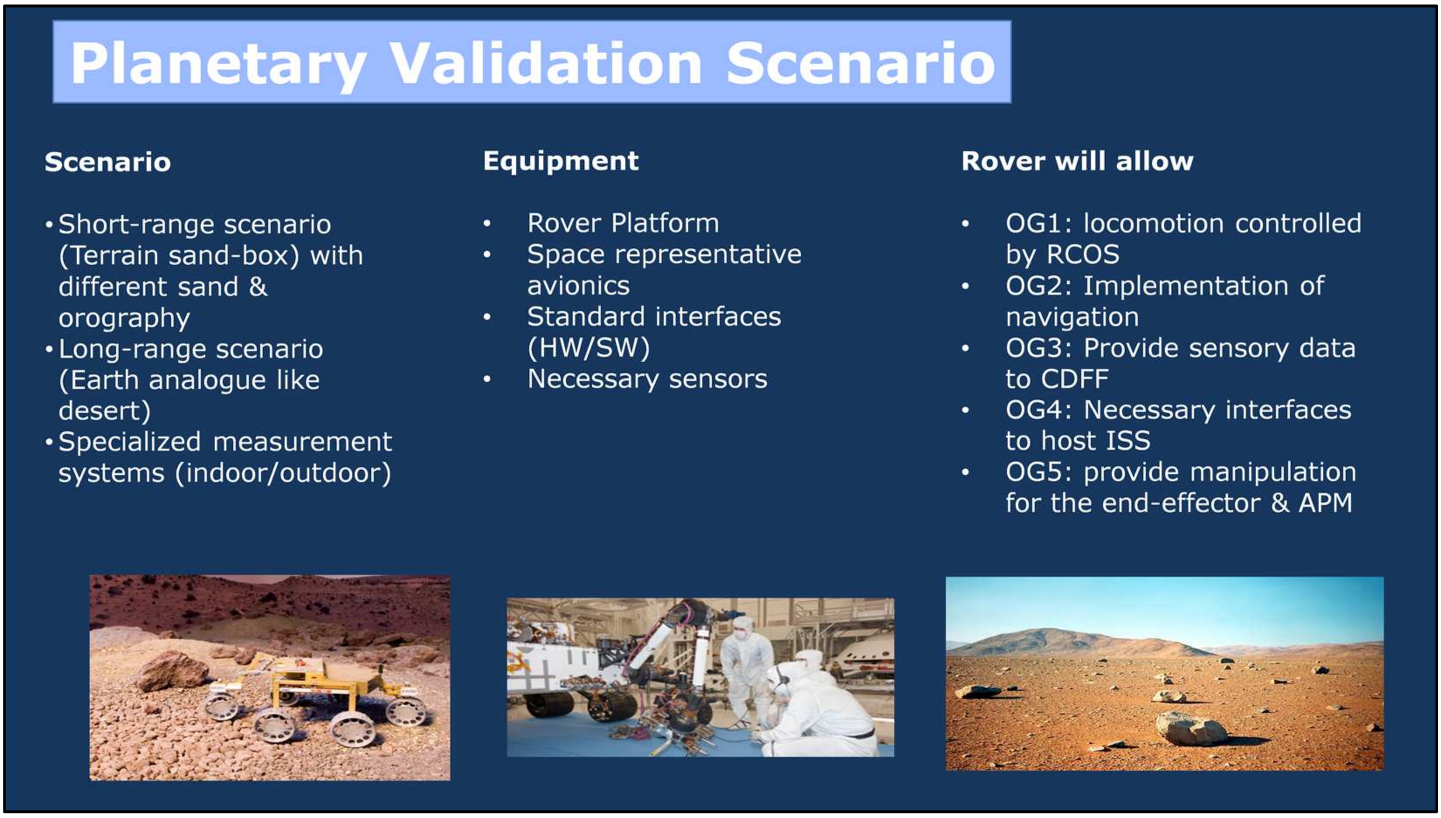
This activity shall also allocate the resources needed to assist the on-site support needed by the facilities and platforms for the validation of SRC activities. The validation tasks of the SRC technologies are outside the scope of this activity (except for the above mentioned on-site support).

- Must cover both scenarios Planetary Exploration and Orbital Servicing
- Must be able to validate ALL OGs in BOTH Scenarios
- OG6 does not include design of the facilities, only adaptation for the OGs validation.
- This task do not include the validation activities, only the Support to validation activity



ORBITAL For the validation of building blocks in the orbital scenario OG6 shall make available, to all OGs, a ground simulation facility based on robotic systems able to reproduce in-orbit servicing applications such as rendezvous and capture scenarios or manipulation of payloads.
Moreover, the system shall be able to reproduce space like controllable conditions. A high precision calibration system, compatible with scaled scenarios, shall enable the validation of the tests.

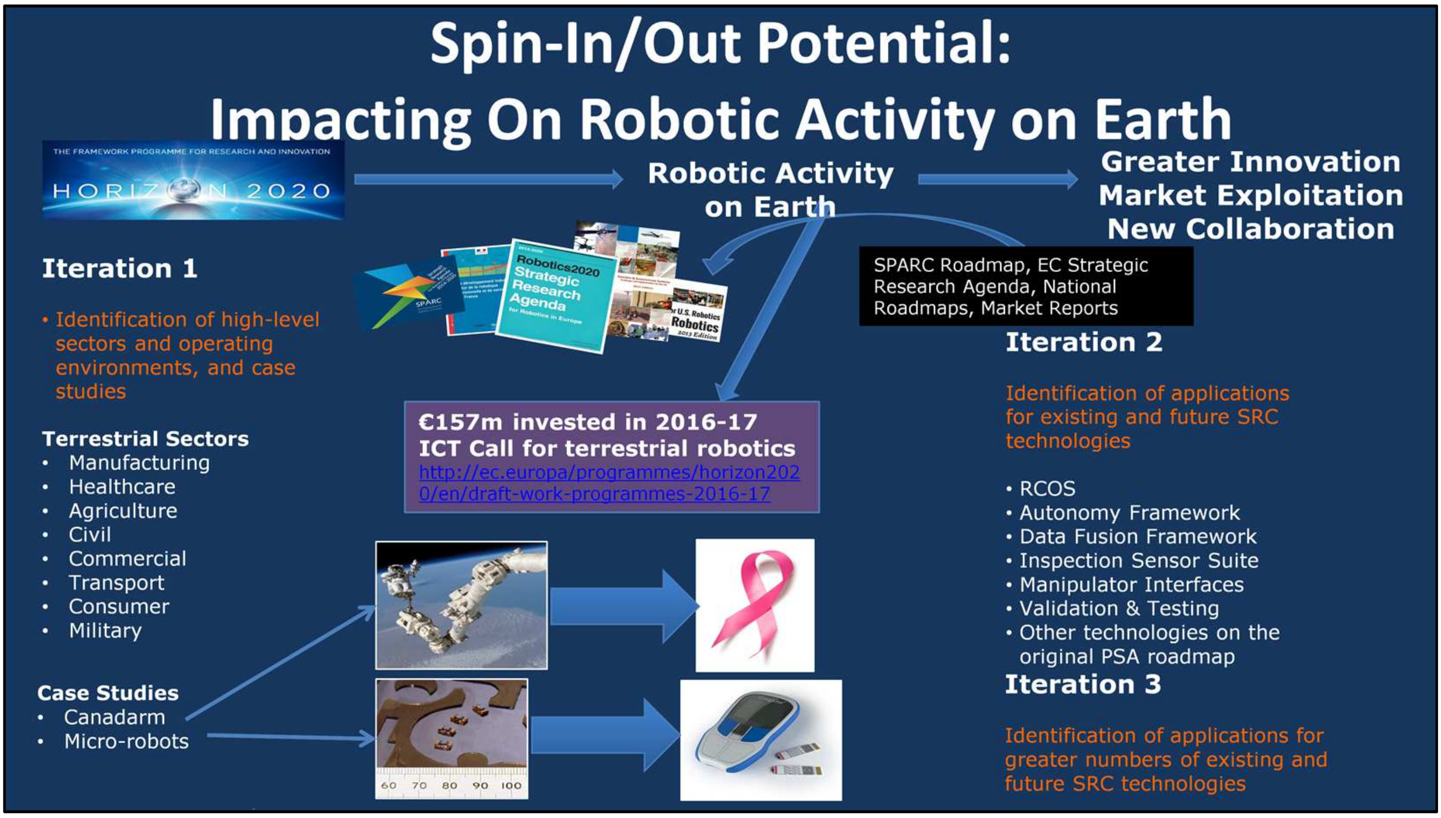
The system shall be composed of the following elements: At least two 6-DOF robotic arms that will simulate chaser and target, one of which mounted on a rail, in order to add an additional DOF, A controllable illumination system, Sensors representative of RVD and proximity operations, A ground truth position and attitude measurement system for all moving subjects, A control system for the robotic arms in that can move the two robot arms to reproduce simulated spacecraft motion, Force torque sensors to allow contact dynamics and Scaled mock-ups for target spacecrafts and payloads to be inspected.



PLANETARY The planetary demonstration scenario final goal is to verify and validate the hardware and software products, developed in each OG in a representative planetary environment. Two validation sites have been identified:

- A short range planetary exploration scenario, that will consist of a Mars-yard-like terrain (small/medium size terrain "sandbox") filled with different sizes of sand, gravel and rock with different orography (crater, boulders, dunes, gravy slopes etc) address a short range locomotion and manipulation case.
- A long range planetary exploration scenario, to be implemented in a earth analogue scenario. Address a long range locomotion situation

For both sites specialized measurement systems (indoor and outdoor) are required: ground-truth localisation system for rover and objects and ground-truth terrain measurement system.
Also, a rover platform shall be made available. This rover, equipped with space-representative avionics, shall offer standard interfaces that are compatible with all OGs technologies.

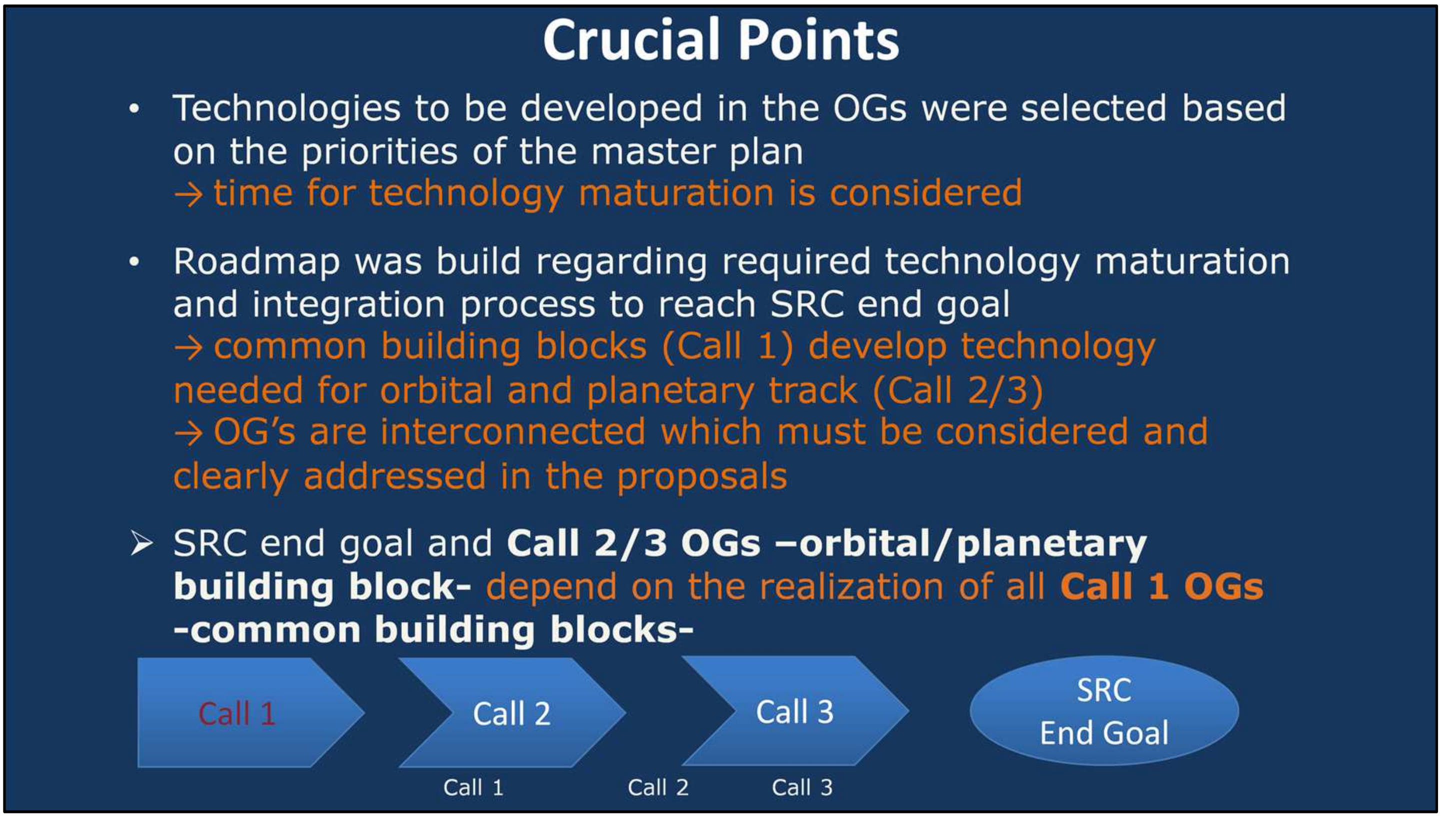


The roadmap has also been designed with the attention at identifying how and where the results of the Strategic Research Cluster may be appropriated and applied in terrestrial sectors. Because the funding for this space robotics programme comes through the Horizon twenty-twenty programme, there is an obligation to ensure that other, commercial and/or terrestrial applications, are identified where the SRC technologies could be applied. This is of great importance so as to enable greater innovation, market exploitation and collaboration. Through consulting a number of existing reports into the trends, drivers and applications of robotics technologies, the PSA, using the taxonomy provided by the EU Robotics' SPARC roadmap, we can see that the potential applications lie in the sectors listed here, and in the operating environments listed below. The Spin-In / Out Assessment also provided case studies where space robotics capabilities have already been applied with great success in other sectors, including how technologies developed for Canadarm, and microrobots developed for inspection and maintenance, have been re-appropriated for the healthcare sector.

The next iteration of this process will capture the existing potential applications for those operational grants, and also other technologies appearing on the roadmap, while a third iteration may also seek to update and mature this process.

Consortia are therefore encouraged to consider where the technology being developed within their SRC Operational Projects may be applied in terrestrial scenarios, how that may be achieved, and what impact that may potentially achieve.

There is also a great amount of activity happening elsewhere in Horizon twenty-twenty with respect to robotic activity on Earth. For example, for the 2016-2017 I see tea Call, €157m are being invested into terrestrial robotic activity. It is therefore highly encouraged that synergies between the two areas are exploited.



The SRC in space robotics technology aims at the maturation of the key technology, that space robotics needs in the next decade. The evaluation process of the proposals submitted to this first call is crucial to the success of the SRC.

The technology needed, has been identified within a selection process resulting in a roadmap . This roadmap, with due consideration to the SRC end goals, and to the current status of technology, has determined priorities for development and assigned them to OGs

The priority of all OGs of call 1 has been found to be very high. These OGs are required to provide the basic common technology for further SRC activities in the orbital and planetary track.

As the development of this technology is split in several OGs, it must be harmonised in order for the final result to operate smoothly. So these OGs have been designed, technically and programmatically, to be interconnected with each other. It is essential that the proposals reflect the interaction and interfacing among OGs.

At the same time it is very important that all OGs are allocated to consortia. A missing OG means a gap in a key technology in the roadmap which results in a very high risk of failure of the SRC.