Peraspera SRC Operational Grants in the H2020 2016-17 Call

National Space Info Day, Pavilhão do Conhecimento, Alameda dos Oceanos, Lisboa
29 October 2015

Daniel Jones, UK Space Agency

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [Number]
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Presentation Outline

About the SRC and PSA

1. The SRC
2. The PSA
3. Work Logic

Building Blocks

1. Roadmap
2. Validation and Verification (Testing) Scenarios
3. Operational Grants 1-6
4. Spin-out considerations
5. Call Details

What is the SRC?

SRCs will be implemented through a system of grants connected among them and consisting of:

1. **Programme Support Activity (PSA)**:The main role of this PSA is to elaborate a roadmap and implementation plan for the whole SRC (referred to hereafter as the SRC roadmap) …
2. **Operational Projects (OPs)**: …The operational projects will address different technological challenges identified in the roadmap.

The objective of this system of grants is that the expected results of each individual grant would, when taken together, achieve the overall objective of the SRC.

The SRC will be bound by a Collaboration Agreement (note: not the same as a *consortium agreement!*)

Why the SRC?

The Peraspera SRC, under the steerage of the PSA Board, will be tasked with increasing competitiveness in the European space industry in both space and terrestrial sectors where highly advanced robotics solutions have been identified as strategically important.

HOW?

1. Enables a fully systems-engineering approach to integration, by maturing a suite of technologies and capabilities required by platform to undertake mission-specific tasks.

2. Brings on board a wide range of expertise from industry and academia, beyond the scope of a single consortium, to solve an specific and integrated set of problems

WHY?

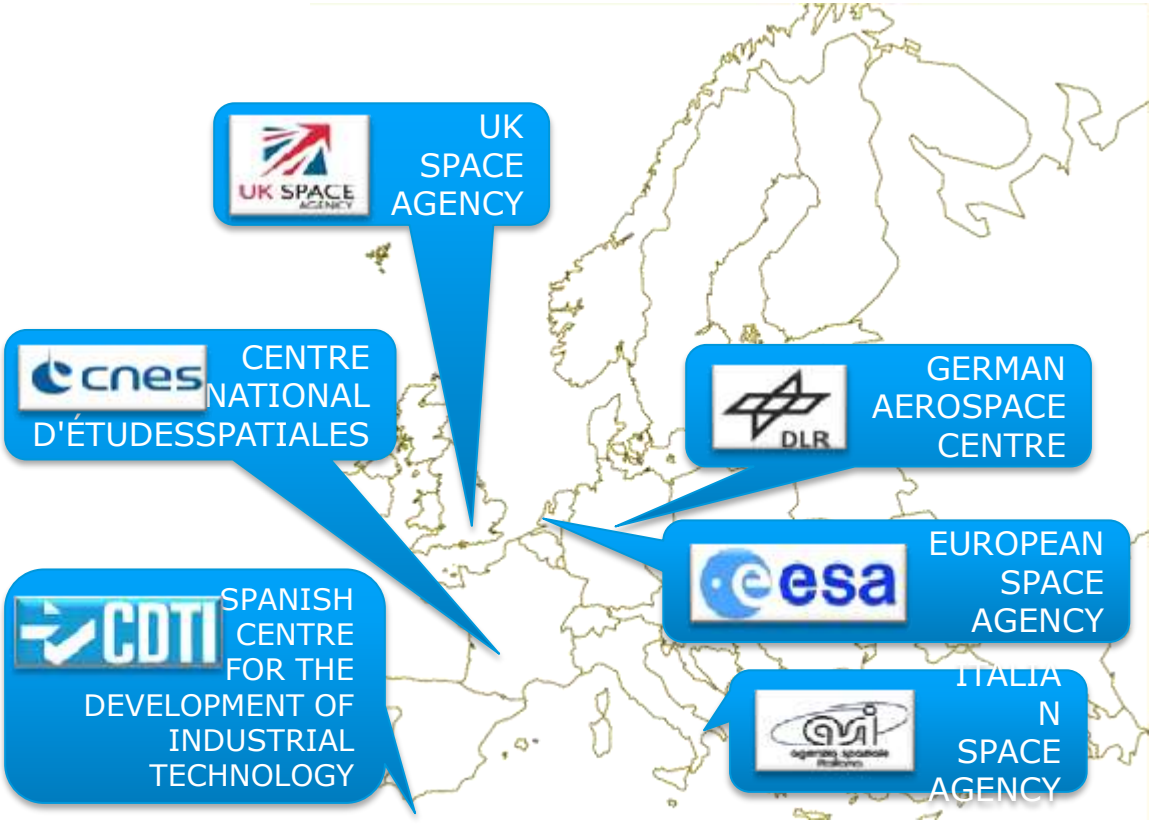
3. The background work being done by the PSA will align the SRC scope and targets to performance demands not only in the space sector, but terrestrial, commercial sectors also with clear socio-economic benefits

What is the PSA?

"***PER ASPERA (ad ASTRA)***" = "Through hardships to the stars"

Coordinator: ESA

Participants:
ASI
CNES
CDTI
DLR
UKSA



What is the PSA?

- PERASPERA will plan and accompany the SRC to attain its overall objective to deliver, within the 2023/2024 framework, **key enabling technologies and demonstrate autonomous robotic systems at a significant scale as key elements for on-orbit satellite servicing and planetary exploration**
- As such the PERASPERA activity will ran for 5 years and produce in this time a number of deliverables that will allow:
  - Evaluations on:
    - The State-Of-The-Art
    - Stakeholder Needs
    - Spin-Out (Commercial) potential
  - Definition and refinement of common conspicuous results
  - Planning of SRC activities towards the results
  - Evaluation and integration of intermediate SRC deliverables
  - Dissemination and education activities

This work will be reiterated and updated throughout the lifecycle of the project.

PSA Work

1. State-Of-The-Art
    a. Capture State of the art in developments in Space A&R across Europe according to the PERASPERA technology tree (an enlarged version of the Automation & Robotics (A&R) branch of the ESA technology tree)
2. Stakeholders' Needs
    a. Capturing the needs of end users, developers and operators of Space A&R systems
3. Spin-Out Potential
    a. Where space robotics technology could be commercially applicable

This was undertaken by "implicit" consultation: e.g. requirements within the European Space Technology Requirement database (ESTER), Agency-level roadmaps, International WG roadmaps, Industrial associations roadmaps and Company R&T roadmaps

European Commission

PERASPERA

Space Robotics Building Blocks: Operational Grants in the H2020 2016-17 Call

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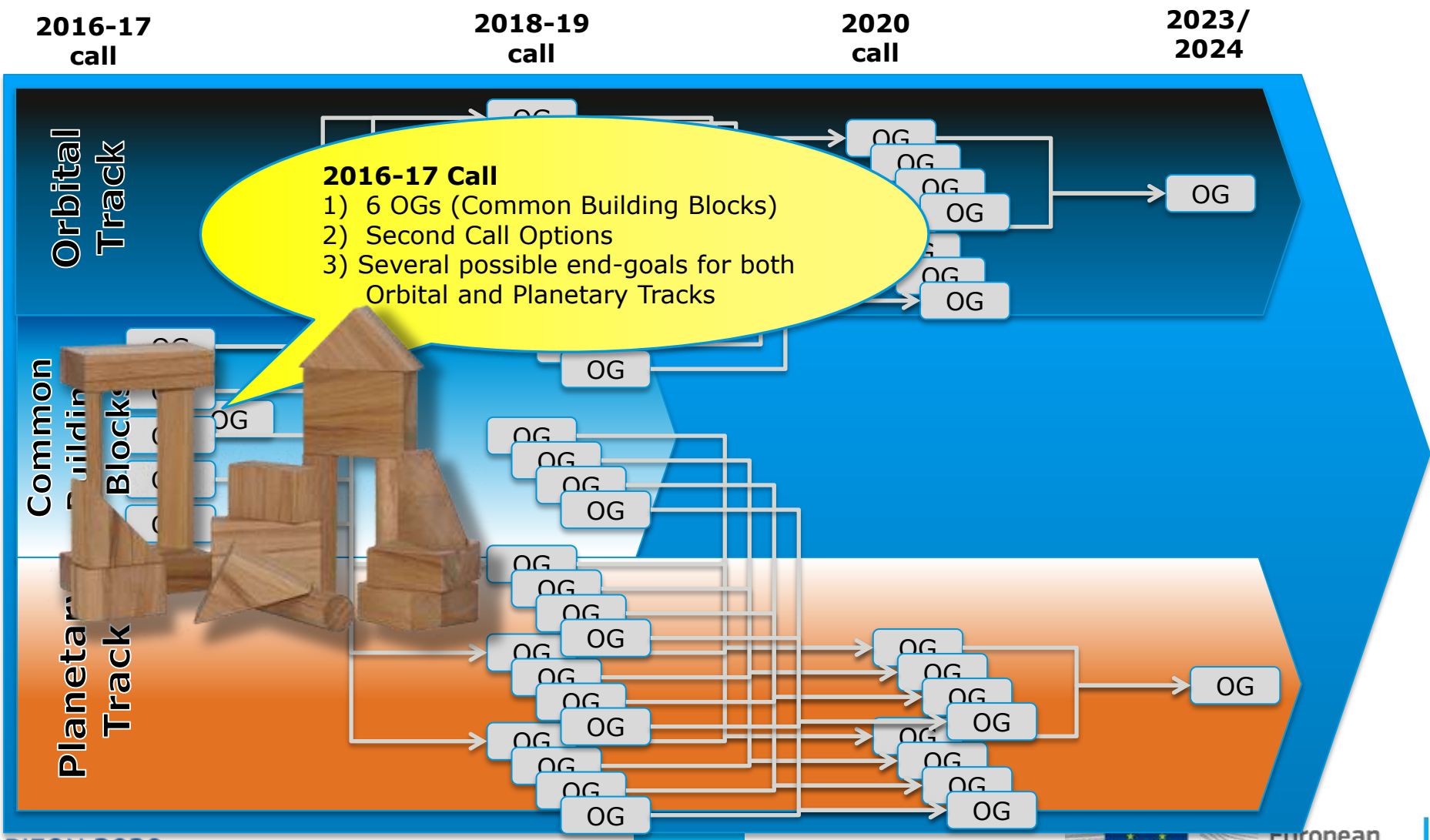
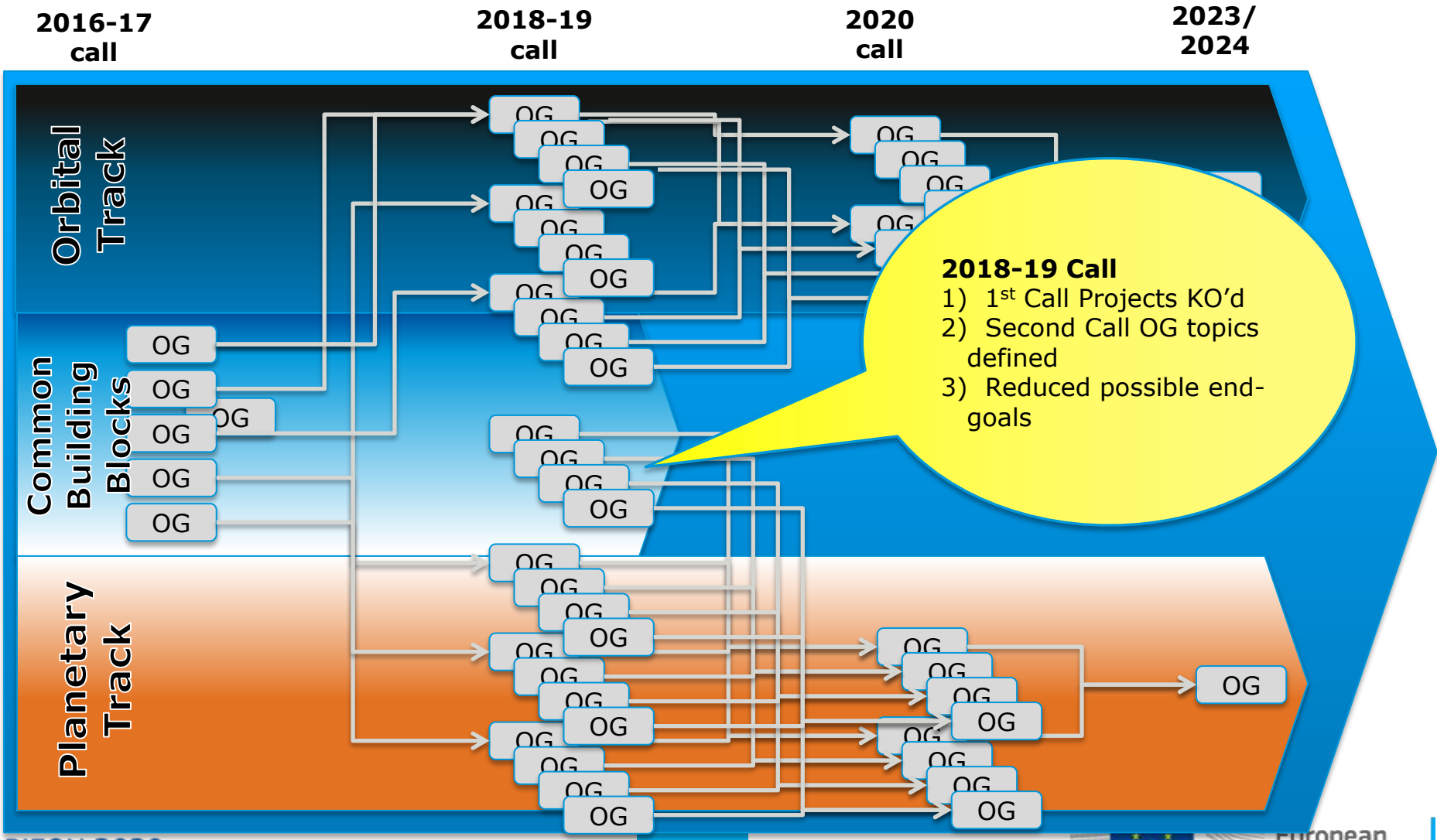
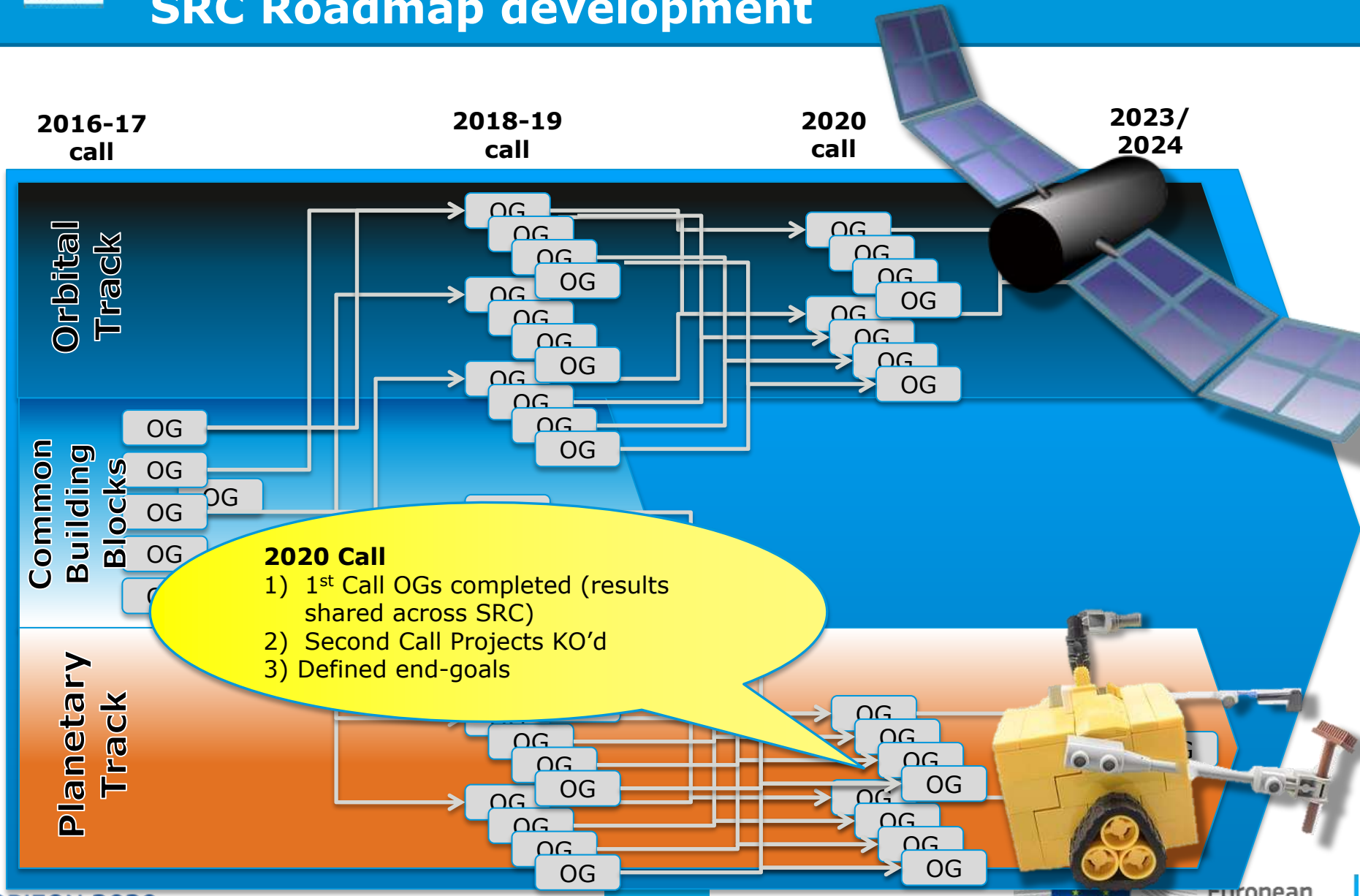
SRC Roadmap development



SRC Roadmap development



SRC Roadmap development



Demonstration Scenarios

Validation & Verification

2-Stage Process

1. Individual, stand-alone tests and methods
2. Partially-integrated tests and test methods in conjunction with OG6 (V&V)
    a. Planetary Scenario Demonstration
    b. Orbital Scenario Demonstration

Demonstration Scenarios

Planetary Scenario: The Martian Long Range Autonomous Scientist

Long traverse over Martian / Lunar surfaces

Long periods *incommunicado*

Demonstration Scenarios

Planetary Scenario: The Martian Long Range Autonomous Scientist

During the long Traverse, the Rover must:

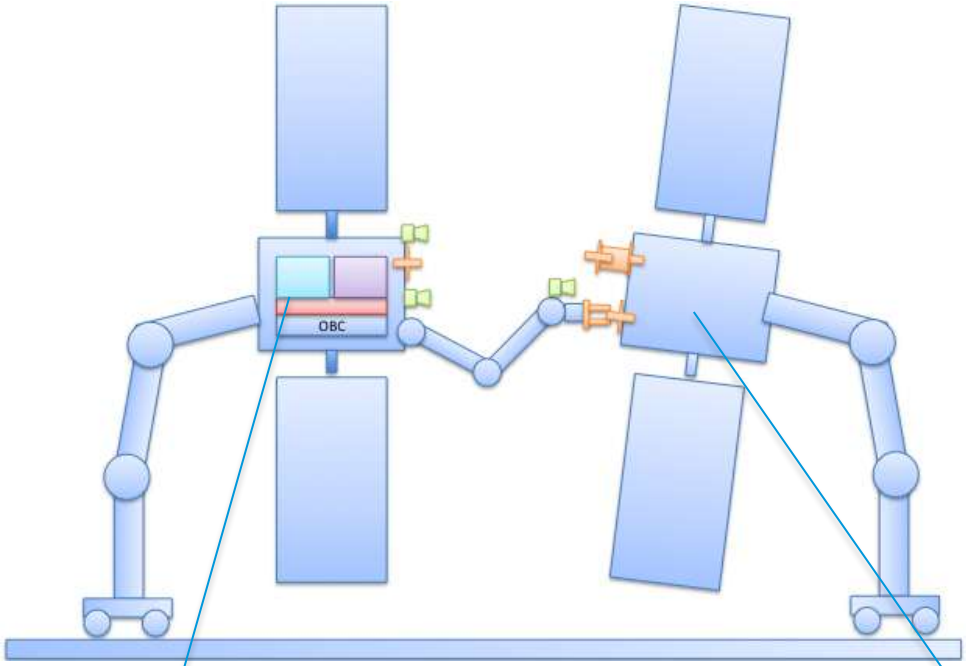
1. rendezvous with another planetary asset and achieve a final relative configuration that is compatible with the transfer of the module/sample to the desired destination by the manipulator arm. The demonstration is achieved when the module/sample is properly connected to the base.
2. return autonomously detected science in some opportunistic fashion. This new concept requires planning (and re-planning) capabilities, in addition to the ability to perform in-situ experiments and analyse the results.

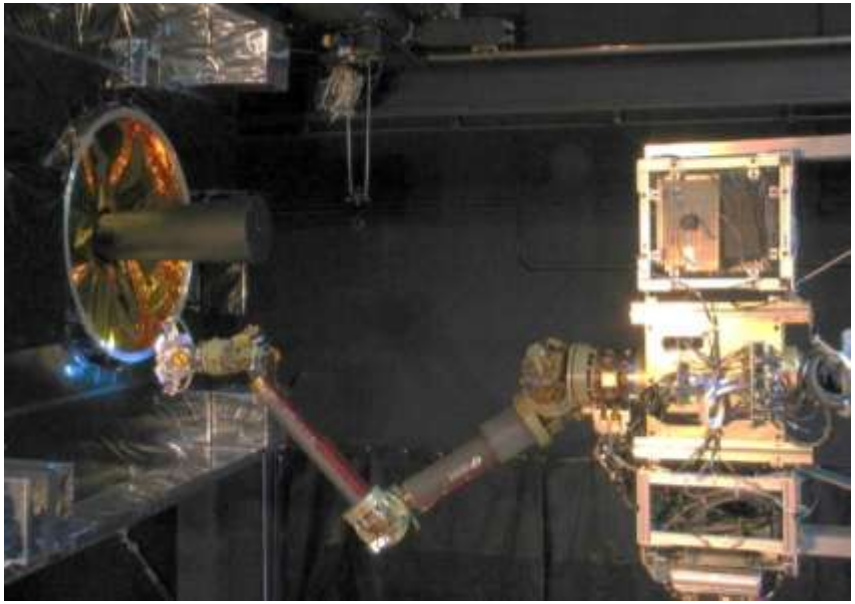
Capabilities to be Tested

1. Long daily traverses autonomously (1km+)
2. Visual / Flight-Time Autonomous Navigation
3. Path planning w/on-board resources
4. Relative localization w/data fusion
5. Landmark tracking at various ranges
6. Efficient Decision & Executive layer
7. Autonomous Nav: different autonomy grades
8. Rendezvous between two planetary assets
9. Fine relative positioning
10. Opportunistic science
11. Module/sample handling & storage
12. In-situ experiments/handling & decisions

Demonstration Scenarios

Validation & Verification: Orbital Scenario: ModSatServicing





Servicer satellite

Target Satellite: Damaged in LEO

Demonstration Scenarios

Validation & Verification: Orbital Scenario: ModSatServicing

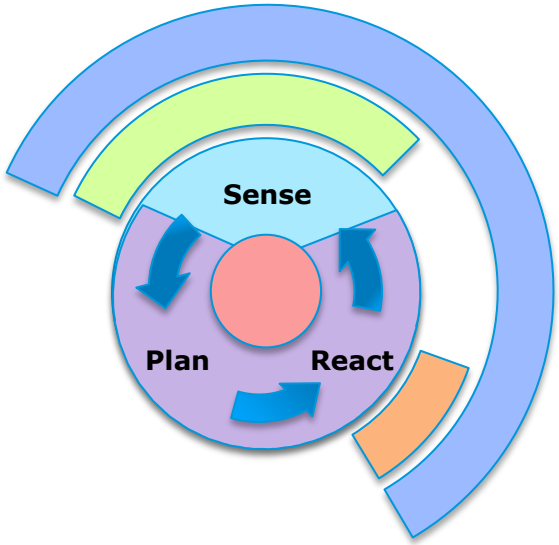
Capabilities to be Demonstrated:

1. Performs on-board experiment with equipped APMs
    a. Experiment: Distributed data handling/processing by the plugged APMs and the system bus via **standard I/F.**
2. Rendezvous and capturing "in LEO" of cooperative target satellite
    a. **Close perception for a rendezvous operation (20m)**: 3D spacecraft reconstruction, pose estimation, relative positioning and movement etc.,
    b. Close range **autonomous rendezvous** operation with different **levels of autonomy and collision avoidance**, **perform inspection** task on the "target satellite";
    c. **Docking**/interlock mechanism/end effector/grasping;
3. Exchange payload module and reconfiguration of the target system
    a. **Payload exchange:** Replace defective APMs and addition of at least one APM with function by using the standard I/F and a dedicated end-effector with data transfer capability;
    b. **Re-configuration of target satellite** due to addition of a new APM.

2016-17 Operational Grants

System Integration & Interfaces

- **OG1: RCOS System**
- **OG2: Autonomy Framework**
- **OG3: Common Data Fusion**
- **OG4: Inspection Sensor Suite**
- **OG5: Manipulator Interfaces**
- **OG6: Validation Platforms**



2016-17 Operational Grants

System Integration & Interfaces

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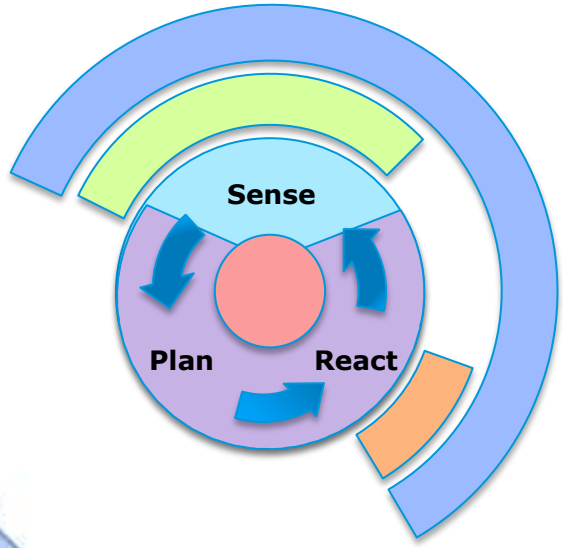

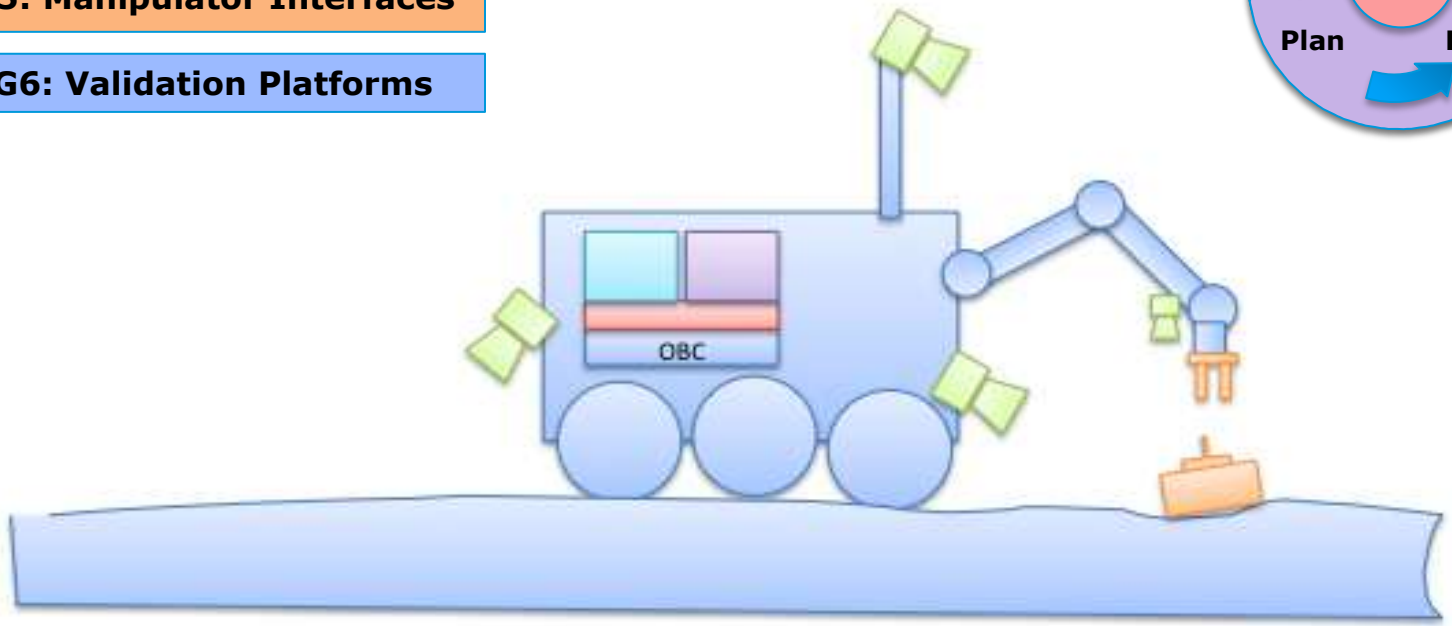

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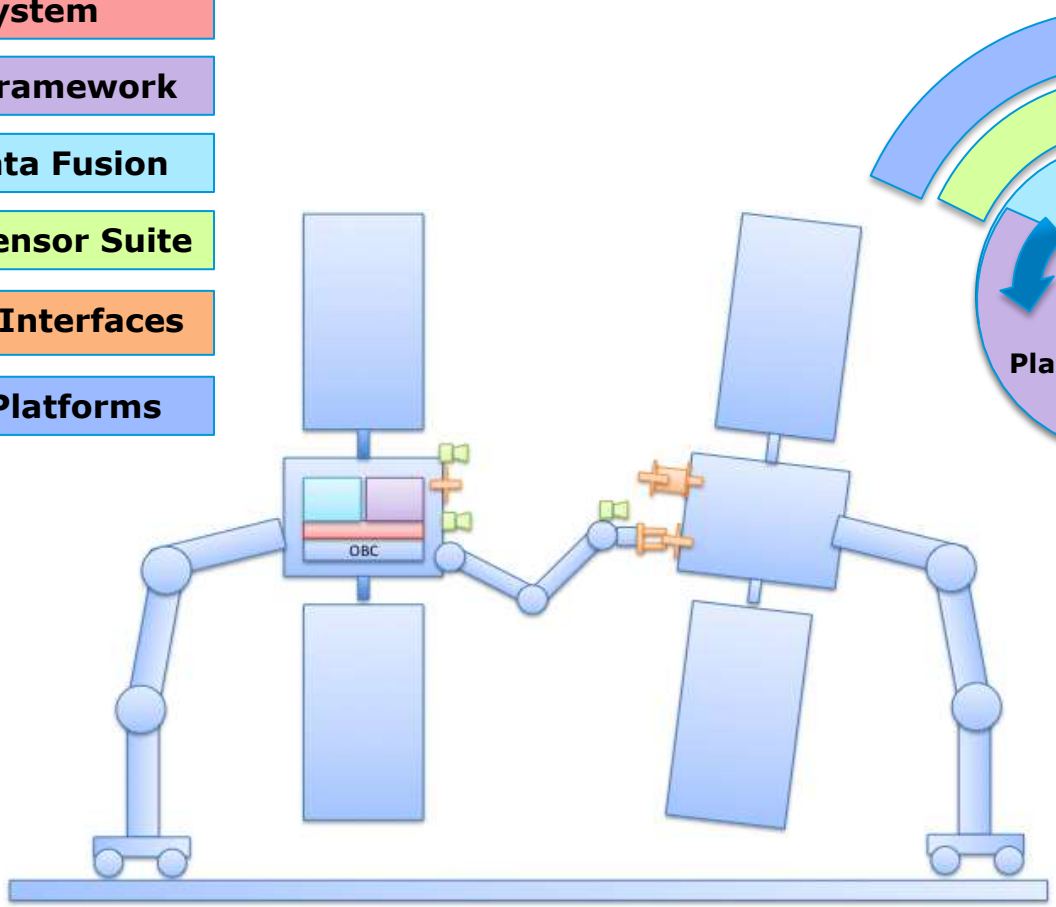
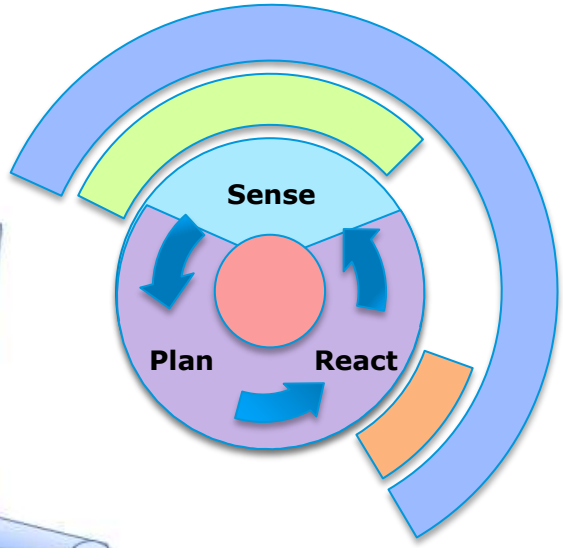




2016-17 Operational Grants

OG1: Open Source Robot Control Operating System

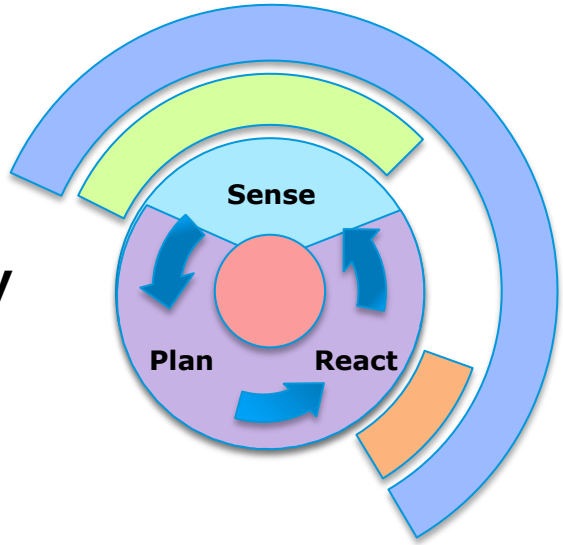
RCOS

RCOS System → **2 Reference Implementations**

RCOS Target
- Hardware abstraction
- Low-Level Device Control
- scheduling of hard/soft real-time tasks;
- Comms and sync between tasks;
- runtime-configuration management and monitoring;
- FDIR
- filesystem access & management;
- networking;
- consistent data types
- logging/telemetry generation & command processing;
- Application Programming Interface (API) for the above functions.

RCOS RDEV
- Develop robot control applications within the **RCOS Target**;
- Test robot control applications within the **RCOS target**;
- Maintain the robot control applications within the **RCOS Target**;
- Validate the robot control applications within the **RCOS Target** by characterising its Reliability, Availability and Safety.

Orbital **Planetary**



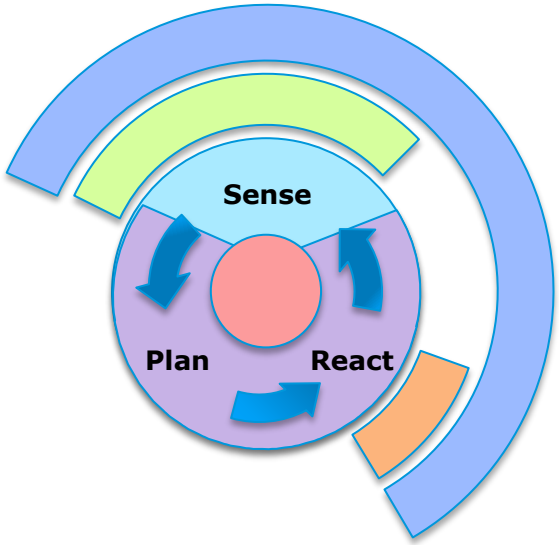
2016-17 Operational Grants

OG2: Autonomy Framework: Time/Space/Resources Planning & Scheduling

Autonomy Framework

Responsible for:

- Interpretation of data
- Executing tactical decisions
- Executing strategically important decisions aligned to mission objectives;
- Collating resource and usage information



2016-17 Operational Grants

OG2: Autonomy Framework: Time/Space/Resources Planning & Scheduling

Autonomy Framework

Functional Layer

Controls onboard capabilities

- Control of all robot subsystems
- Implement basic motion, movement and manipulation capabilities
- Have resource usage indicators monitoring & estimating state & resource

Executive Layer

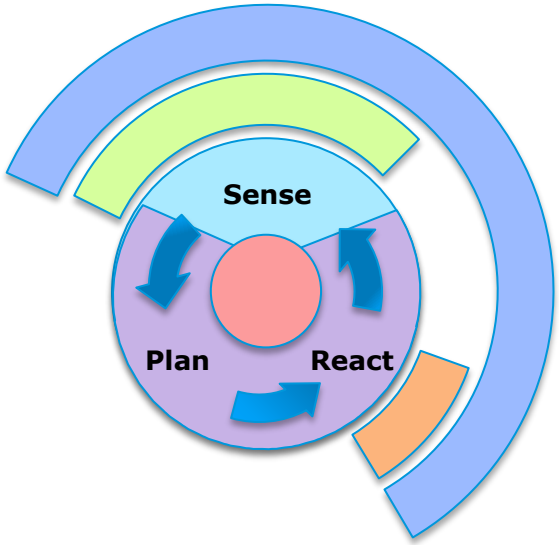
Interface between Functional and Deliberative Layers

- Execute decisions
- Control & coordinate execution
- Model & monitor overall system state
- Ensure decisions taken are aligned with state & resource

Deliberative Layer

"Thinks" and takes decisions aligned with mission goals

- Execute decisions
- Control & coordinate execution
- Model & monitor overall system state
- Ensure decisions taken are aligned with state & resource



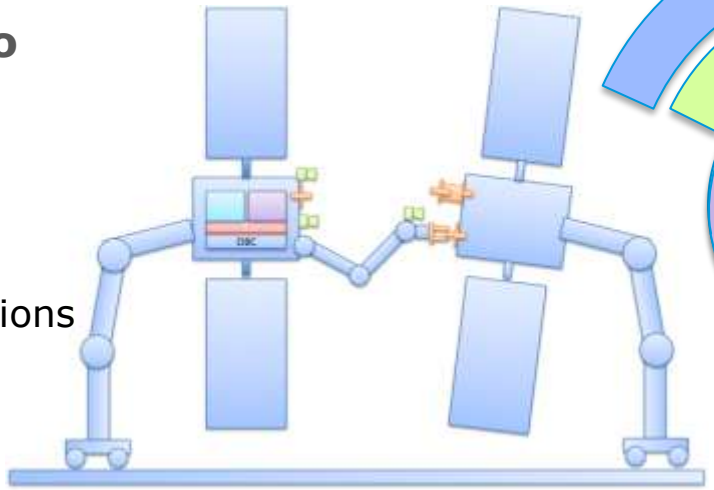
2016-17 Operational Grants

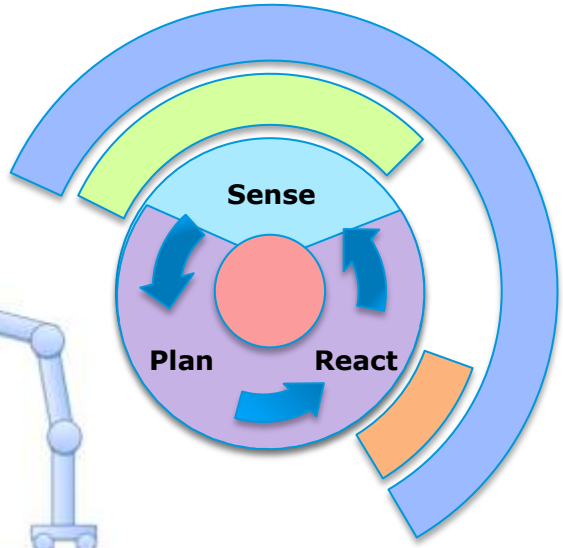
OG2: Autonomy Framework: Time/Space/Resources Planning & Scheduling

Autonomy Framework

AF in Orbital Scenario

- Delivering commands to:
  - Rendezvous
  - Interact
  - Remove
  - Avoid
- Scheduling /prioritising decisions in accordance with state
- Human-In-The-Loop





AF in Planetary Scenario

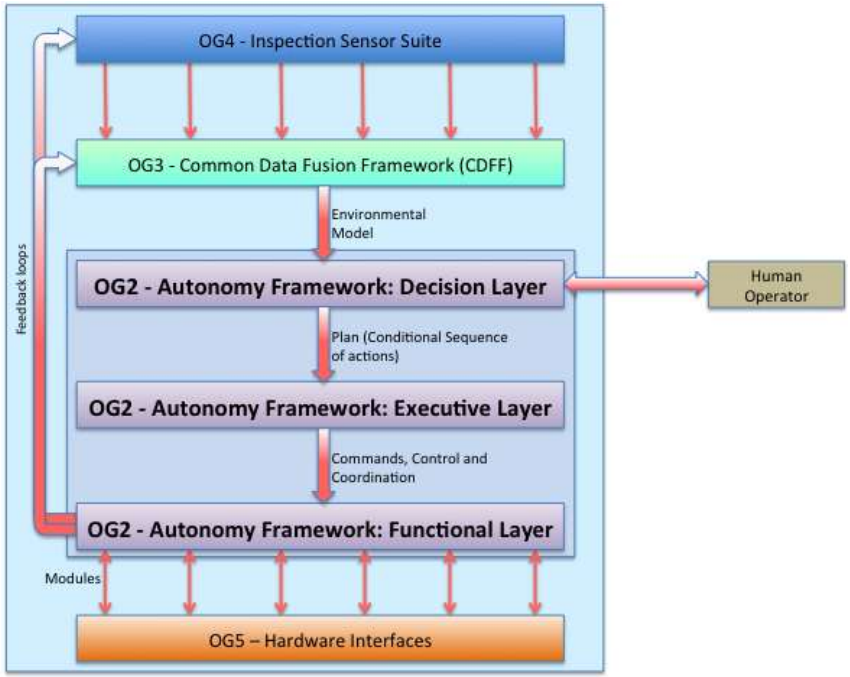
- Modelling the environment semantically
- Understanding of status and situation
- Understand resource consumption and system health

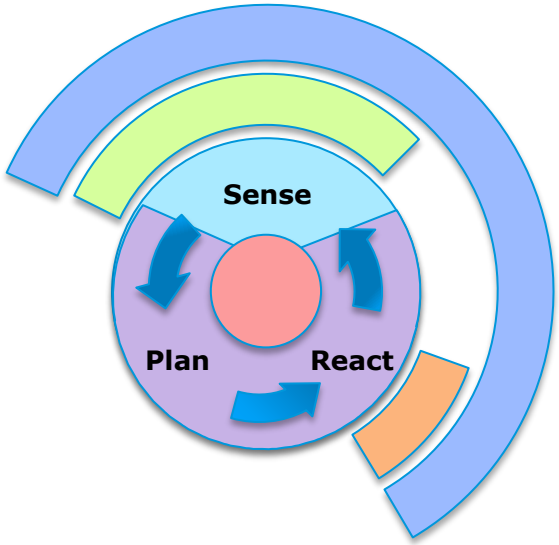
2016-17 Operational Grants

OG2: Autonomy Framework: Time/Space/Resources Planning & Scheduling

Overview

Autonomy Framework





2016-17 Operational Grants

OG3: Common Data Fusion Framework

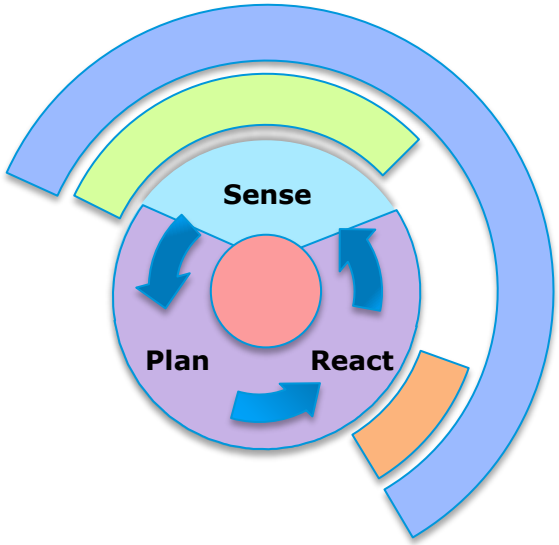
Common Data Fusion

Perception

- Convert raw data into refined measurements,
- Extract or track features from dense data sets (images, point clouds)
- Detect and identify or track an object from a set of features
- Build a 3D model of the environment,
- Perform a characterization of the environment (i.e. build a map)

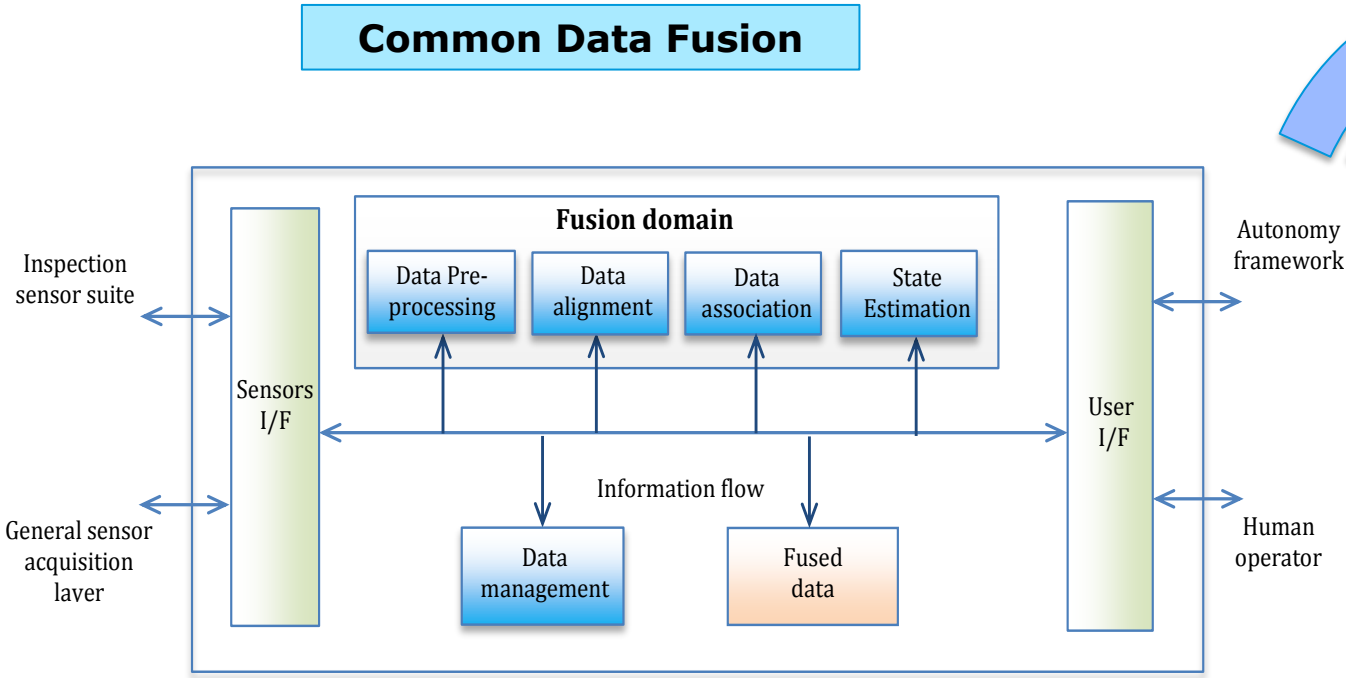
Navigation

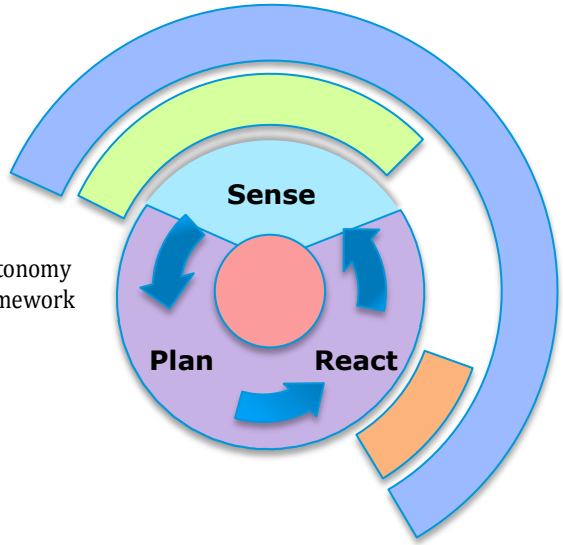
- Provides geometric state of robot respectful of frames of reference
- Provides series of estimates based upon:
  - processed data from relative and/or absolute sensors
  - A priori info (models etc)
- Can deliver states of several machines where system comprises several robotic agents



2016-17 Operational Grants

OG3: Common Data Fusion Framework





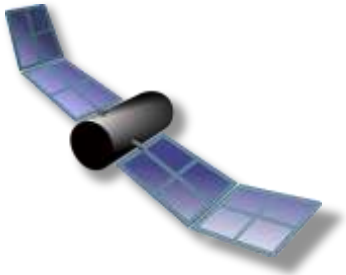
2016-17 Operational Grants

OG3: Common Data Fusion Framework

Common Data Fusion

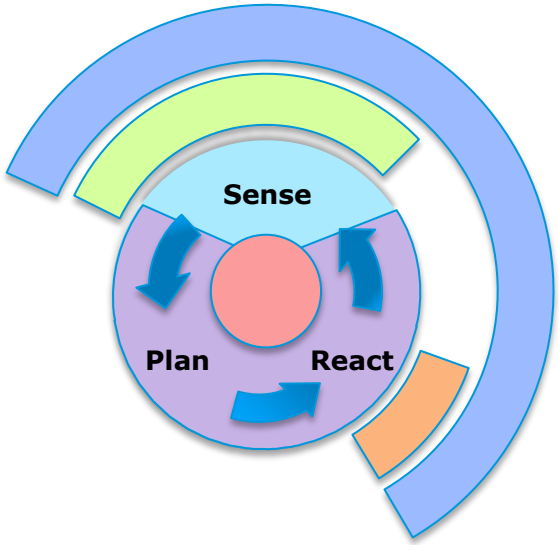
Functionalities (Orbital Track)

- Long range orbital object detection
- Object localisation in robot FoR
- Unexpected object detection and localisation
- Object 3D model reconstruction
- Estimation of object's orbital parameters after long-range detection
- Estimation of robot relative state



Functionalities (Planetary Track)

- Construction of panoramic images
- Incremental construction of terrain 3D models
- Detection and tracking of environmental objects
- Detection of structured objects ie assets, artefact, payloads
- Unexpected object identification
- Rover localisation
- Rover / manipulator localisation
- Map building



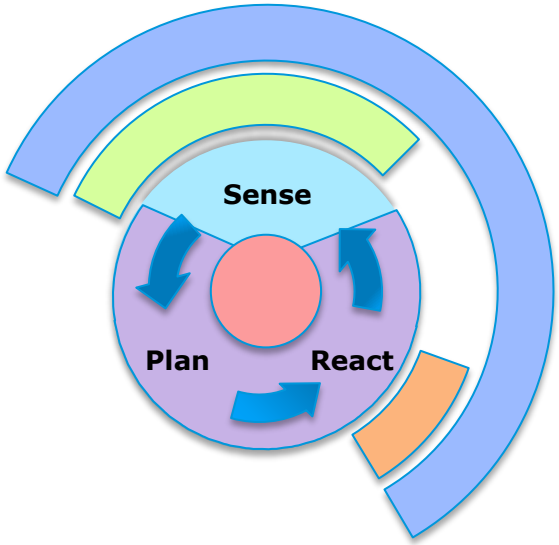
2016-17 Operational Grants

OG4: Inspection Sensor Suite (ISS)

Inspection Sensor Suite

Exteroceptive
Looking at the outside world

Proprioceptive
Looking at one's self



- **Low-Level Data preprocessing**
- **Software interface module**
- **High modularity**
  - **Self-consistent**
  - **Standard interfaces**

2016-17 Operational Grants

OG4: Inspection Sensor Suite (ISS)

Inspection Sensor Suite

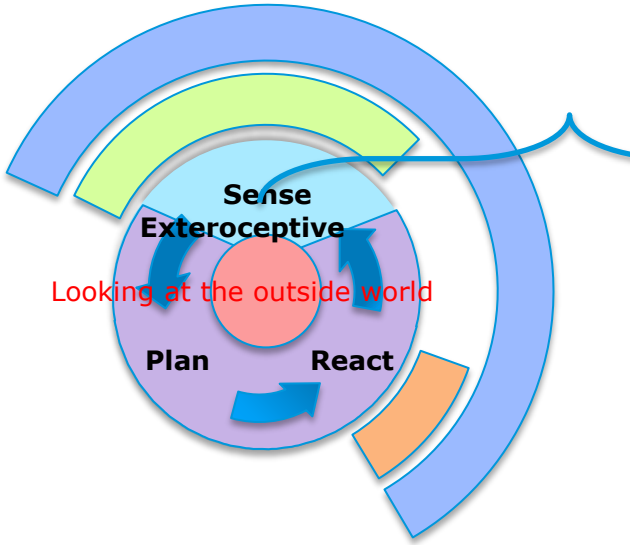
Exteroceptive

- Stereo Camera imaging systems
- Close-Up Hi-Res Camera
- Laser range finder
- Narrow / wide angle radar
- Ultrasound distance sensors for lab applications
- Contact sensors / mechanisms

Proprioceptive

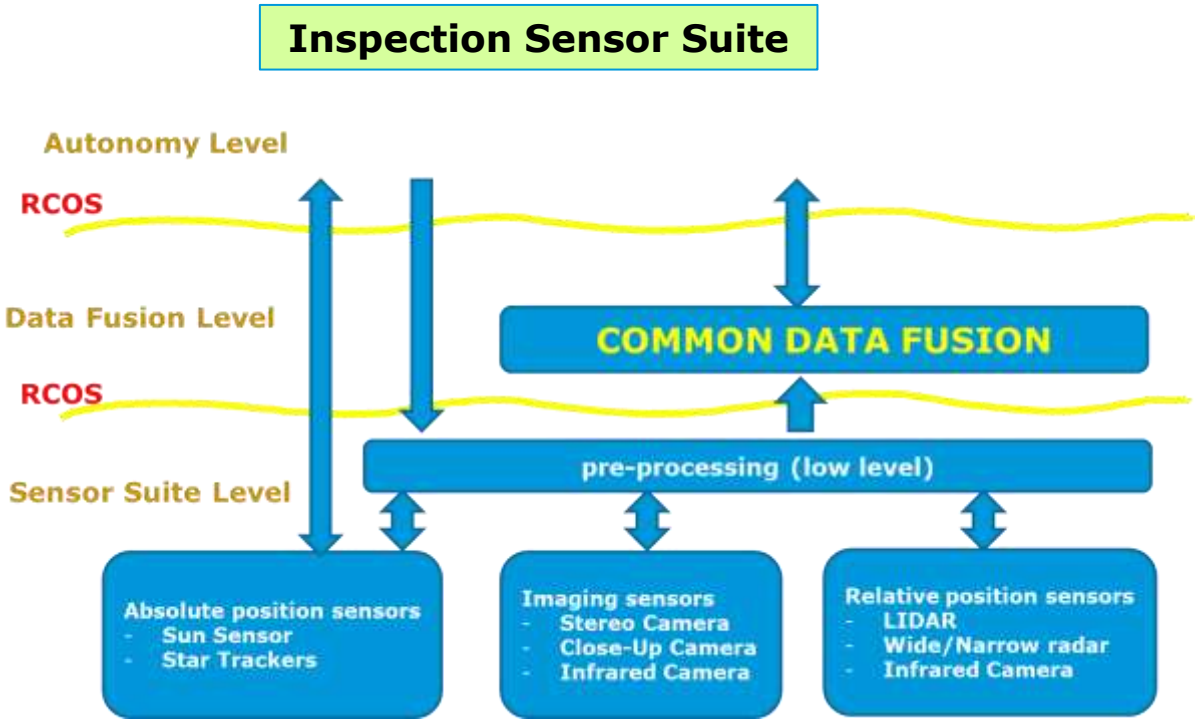
- Inertial Measurement Unit (IMU)
- A sun sensor and / or star tracker
- Force / Torque sensors

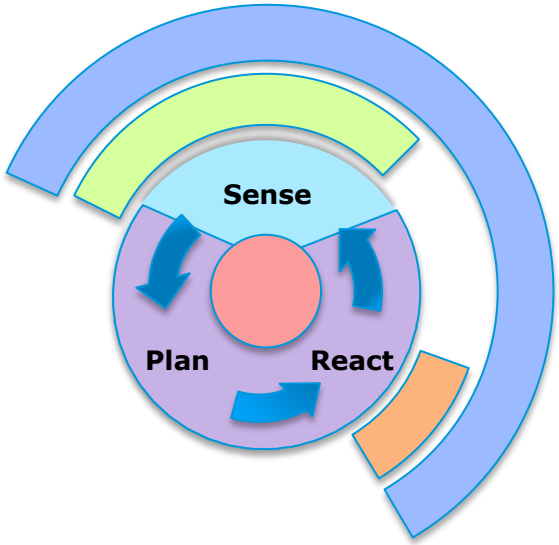
Illumination System



2016-17 Operational Grants

OG4: Inspection Sensor Suite





2016-17 Operational Grants

OG5: Modular Interfaces for Robotic Handling of Payloads

Manipulator Interfaces

Standard Interface:

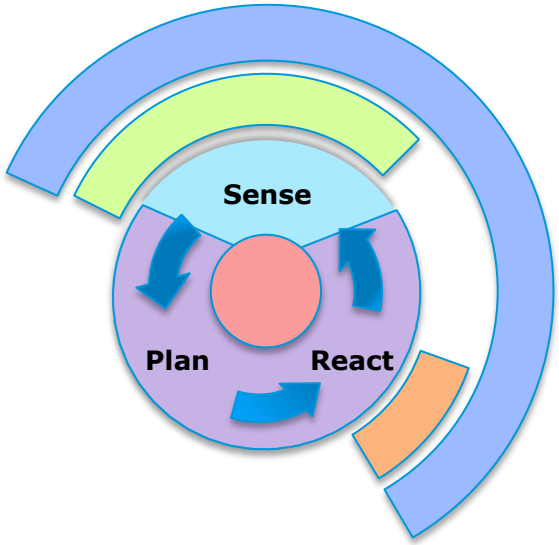
- Allows coupling between APMs and manipulators, platforms, other APMs
- Allows transfer of loads (mechanical, Electrical, data, thermal)

APMs:

- Container with onboard subsystem
- Used for particular tasks
- Allows communication between spacecraft and itself
- **Two** required
  - Two interfaces per module
  - Different equipment inside
  - Reusability
  - Max. weight

Manipulators:

- Demonstrate coupling
- Test-compatible
- Compliant with the interface being developed (mechanical, data and electrical)



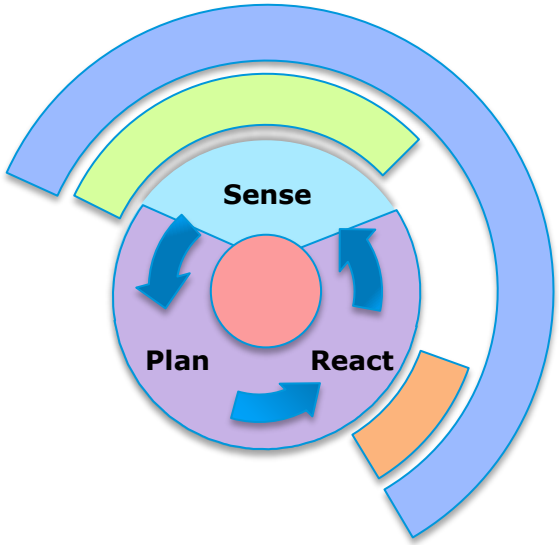
2016-17 Operational Grants

OG5: Modular Interfaces for Robotic Handling of Payloads

Manipulator Interfaces

Specific Criteria:

- Scalability
- Internal redundancy
- Compatibility to robot servicing
- Low complexity, mass and volume
- Rotation of axis and symmetry
- Reusability
- Connection of nearly arbitrary modules without restriction on the relative module orientation



2016-17 Operational Grants

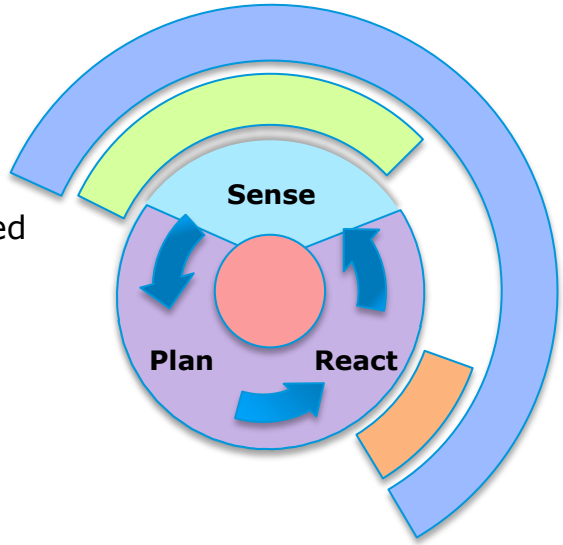
OG5: Modular Interfaces for Robotic Handling of Payloads

Functionalities

Manipulator Interfaces

Mechanical:
- Androgynous design
- Absorption of loads arising through operations
- Absorption of launch loads
- Requires only energy to undock
- Can be opened and closed multiple times
- Operates in space environment conditions
- High position tolerance for docking

Data:
- High Data rate
- Can be opened and closed multiple times
- Operates in space environment conditions
- Bi-directional transfer of info



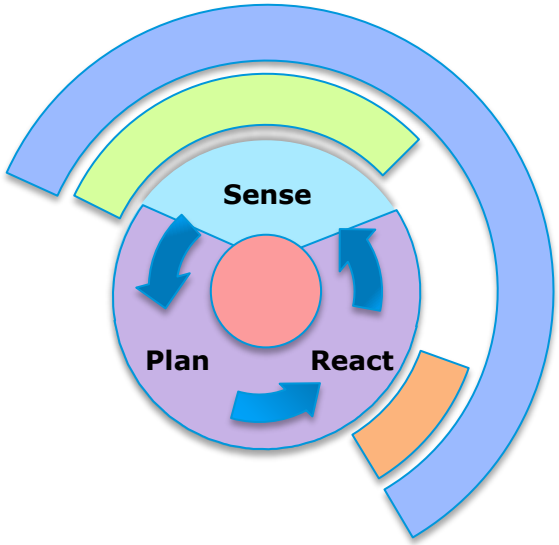
Electrical:
- Short circuit protection
- Surge protection
- Electro-magnetic compatibility w/coupled modules
- Transfer of power in both directions
- Can be opened and closed multiple times
- Operates in Space Environment conditions
- Withstands launch loads
- High positioning tolerance for docking

Thermal:
- High data rate
- Can be opened and closed multiple times
- Operates in space environment conditions

2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

Validation Platforms



2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

Validation Platforms

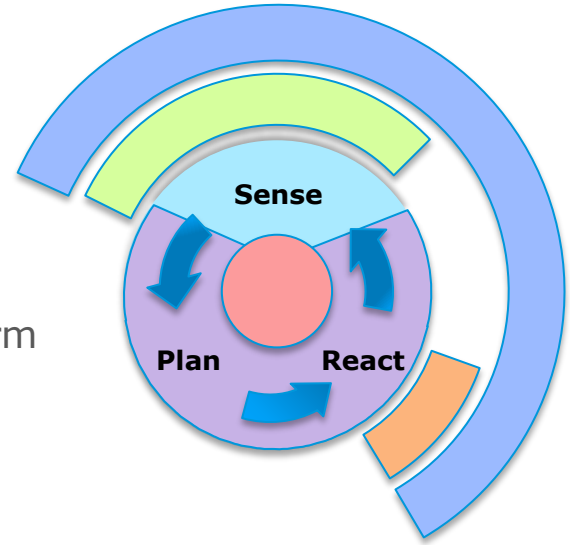
Network of test facilities & Validation Platforms

Different Support Levels

- Unitary Level (OG4)
- Integration Level (OG3, OG4, OG5)
- Avionics subsystem (OG1)
- Mission level (OG2)

Features & Requirements

- Provision of all types of test platform
  - Robot platforms mock-ups
  - Load mock-ups for OG5
  - Avionics test benches
  - Mission level test scenarios
  - Modularity and reusability
- Calibrated appropriately
- Meet monitoring & telemetry needs
- Representative datasets



2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

	Tests Needed	Facilities for Planetary Track	Facilities of Orbital Track
Inspection Sensor Suite (OG4)	Inspection suite sensor in realistic operational conditions	Rover locomotion platform in Planetary scenario (e.g. Mars-yard-like) representation to be used for sensors validation tests Dusty environment with sun/shadow illumination conditions Dataset generation capability for planetary inspection	Orbital infrastructure mockups with relevant features to be inspected Space-representative dynamic motion capability and repeatability Controlled space-representative illumination Dataset generation capability for orbital inspection
CDFF (OG3)	Localisation, map & detection capabilities of SW+sensors suite in natural and man-made environment		
Modular Interfaces (OG5)	Coupling interfaces (mechanical, electrical, data...)	Rover locomotion platform with (TBC) robotic arm	Nx6/7DOF testing platforms for short-range applications
RCOS (OG1)	Tests using space representative processor. RCOS shall also control robot systems	Space representative processor taking control of rover actuators and sensors through representative communication means	Space representative processor taking control of in-orbit manipulator and sensors through representative communication means
Autonomy Framework (OG2)	Test goal oriented autonomy framework with realistic plan in non-controlled environment.	Rover locomotion platform able to host SRC technologies identified sensors suites with data fusion framework and Avionics solution able to host the highly autonomous mission management/control SW. The platform and Avionics shall provide fault injection capabilities. Unitary and short-range tests in Marsyard–like labs; Long term, outdoor autonomous campaign	Optical test benches for long-range applications Nx6/7DOF testing platforms for short-range applications (e.g. close range rendezvous and capturing operations). Space-representative dynamic motion capability and repeatability Scalability Space-representative illumination conditions Fault injection capabilities

2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

Validation Platforms

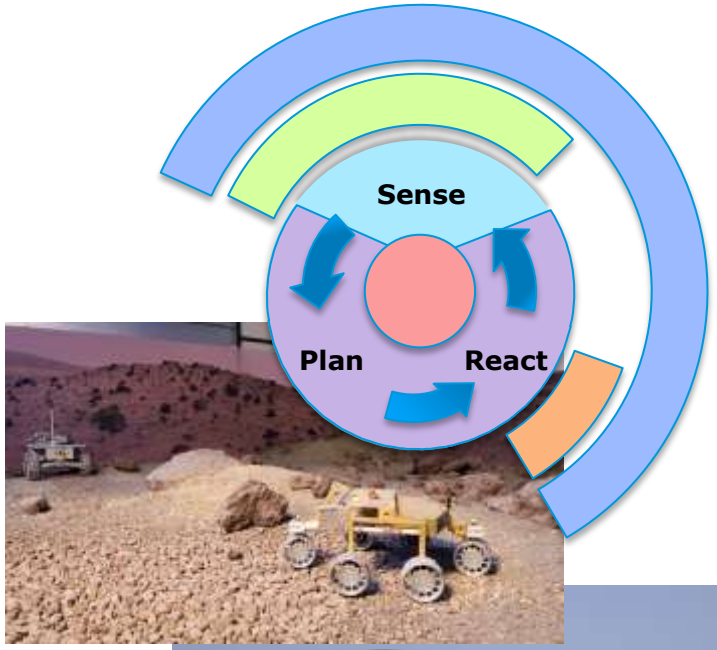
Planetary Validation Scenario

Short-range exploration **Long-range exploration**

(Mars-Yard terrain) **(Desert)**

Requirements

- Specialist Measurement Systems
- Rover
  - Standard SW, HW interfaces
  - OG compatible
    - RCOS controllable
    - RTEMS Space Avionics
    - Locomotion
    - Manipulator
    - Host the CDFF & algorithms
    - Load interfaces
    - Localisation



2016-17 Operational Grants

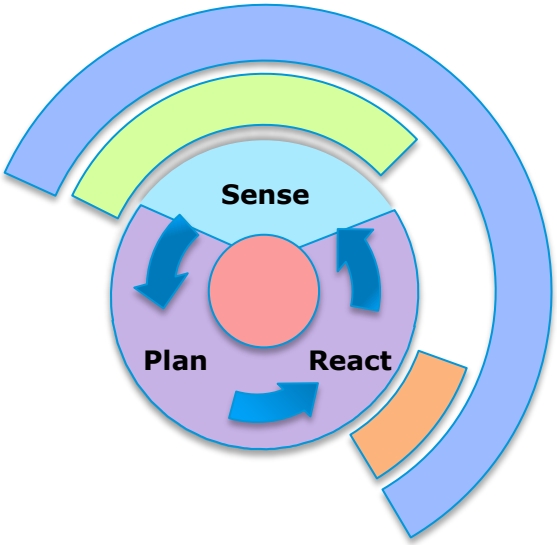
OG6: Validation Platforms and Field Tests

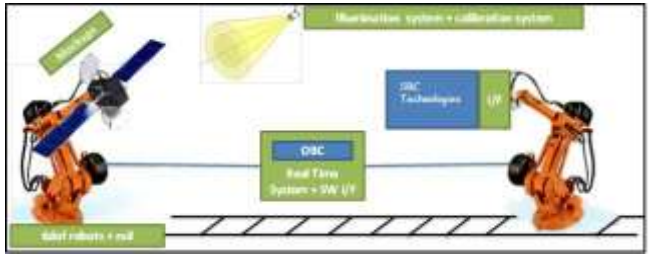
Validation Platforms

Orbital Validation Scenario

Ground simulation facility

- Hardware-In-The-Loop system
  - Simulate servicer & target satellites
  - Accurate
- Space-like conditions.
- High precision calibration system
  - Two robot arms (6DoF, rail-mounted)
  - Controllable illumination system
  - Precise calibration system
  - Real-time system
  - Force / torque sensors
  - Scaled mockups
  - Standard interfaces





Spin-Out Potential

The Peraspera SRC, under the steerage of the PSA Board, will be tasked with increasing competitiveness in the European space industry in both space and terrestrial sectors where highly advanced robotics solutions have been identified as strategically important.

Spin-In/Out Potential:

Terrestrial Sectors

- Manufacturing
- Healthcare
- Agriculture
- Civil
- Commercial
- Transport and Logistics
- Consumer
- Military

Operating Environments

- In the air
- On the ground
- Underwater
- In space
- In the human body

EC Activity

- €157m in 2016-17 ICT Call on terrestrial robotics
- http://ec.europa/programmes/horizon2020/en/draft-work-programme-2016-17

Call Details

COMPET-4-2016: SRC - Space Robotics Technologies

Research & Innovation action

- A minimum of one proposal will be selected for funding
- OG1, OG2, OG3, OG4, OG5
    - EU Contributions of €3-3.5m may be requested
- OG6 (Validation)
    - EU Contribution of ~€1m may be requested

Dates:

Call publication: NOW

Call Submission Window opens: Monday 9 November 2015

Call Submission Window closes: 6 March 2016

European Information Day: 9-10 November 2015, Hotel La Plaza Brussels - <LINK>

Other Considerations

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