PERASPERA

Space Robotics SRC Operational Grants
COMPET-4-2016:Space Robotics Technologies

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Presentation Outline

1. Why the SRC?
2. The Peraspera Roadmap
3. Demonstration Scenarios
4. The 2016-17 Call: SRC building Blocks
5. Further considerations

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Why the SRC?

The Space Robotics Strategic Research Cluster (SRC), under the steerage of Peraspera, 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.

↓

Integration

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

↓

Diversity

WHY?

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

↓

Impact

Why the SRC?

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

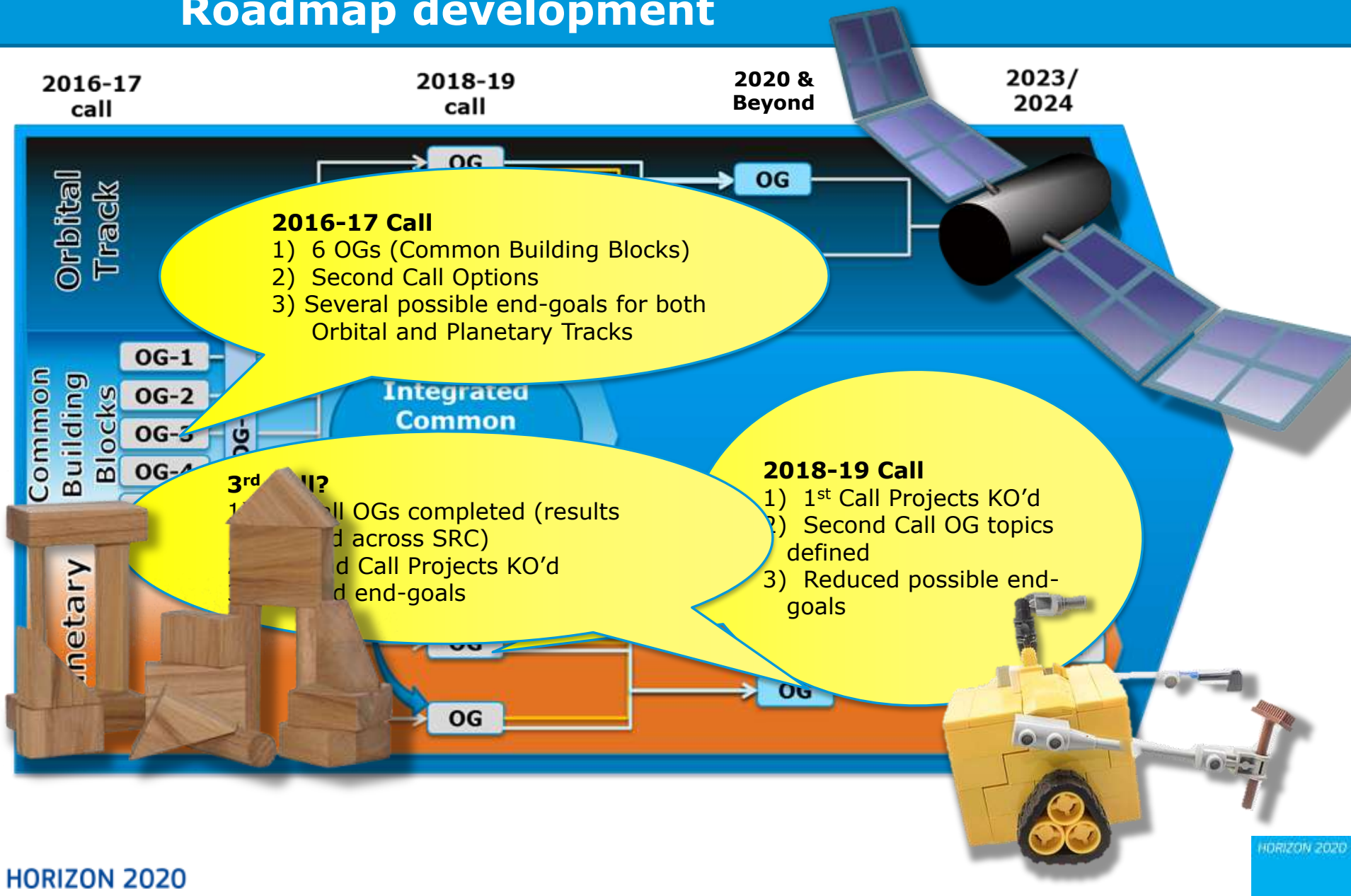
1. **Programme Support Activity (PSA)**:The main role of this PSA is to elaborate a roadmap and implementation plan for the whole SRC (referred to hereafter as the SRC roadmap) …
2. **Operational grants**: …The operational grants will address different technological challenges identified in the roadmap.

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 Roadmap

- 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:
  - Evaluation on the state of the art and needs of stakeholders
  - Definition and refinement of common conspicuous results
  - Planning of SRC activities towards the results
  - Technical evaluation and integration of intermediate SRC deliverables
  - Dissemination and education activities

Roadmap development



Demonstration Scenarios

Validation & Verification – Demonstration Scenarios

Planetary Scenario: The Martian Long Range Autonomous Scientist

1. Long daily traverses autonomously
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

1. APM Distributed data handling/processing.
2. Rendezvous & capture of cooperative target

a. Close perception for rendezvous operation
   - 3D spacecraft reconstruction
   - Pose estimation
   - Relative positioning and movement

b. Close range autonomous rendezvous

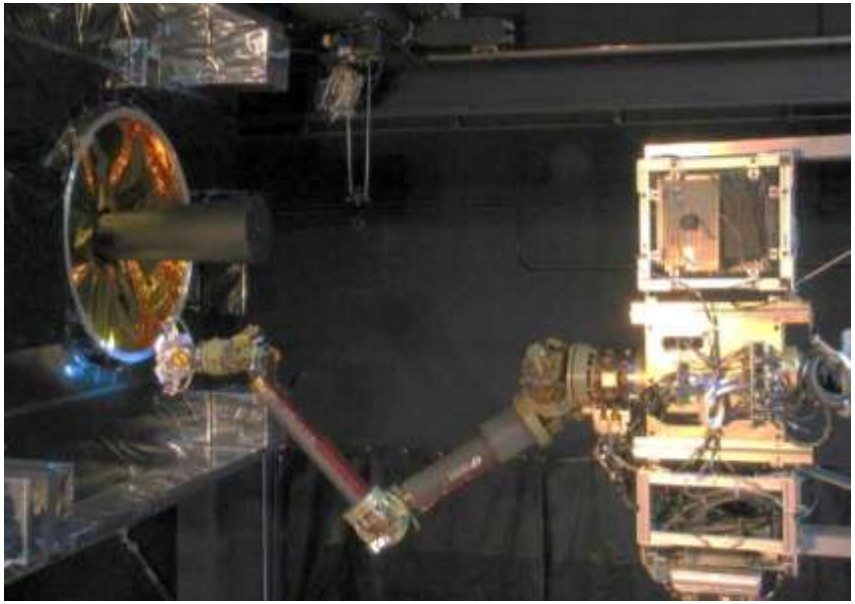
c. Perform inspection task on the "target satellite";

d. Docking/interlock mechanism/end-effector/grasping;

3. Exchange payload module, reconfiguring target system

a. Replace defective APMs using the standard I/F & dedicated end-effector with data transfer capability;

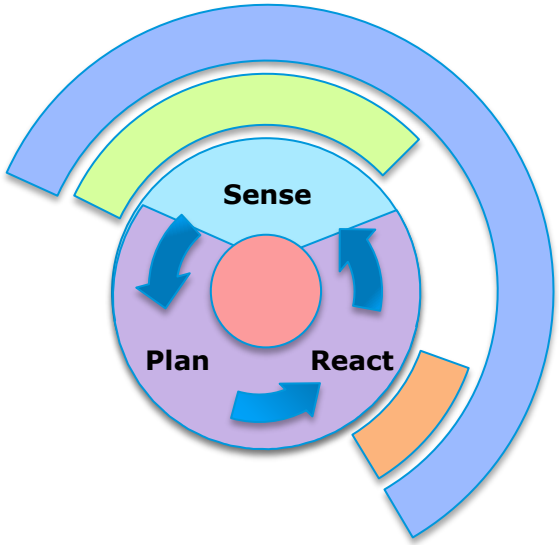
b. Re-configuration of target due to addition of a new APM.



2016-17 Operational Grants

Operational Grant Projects

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



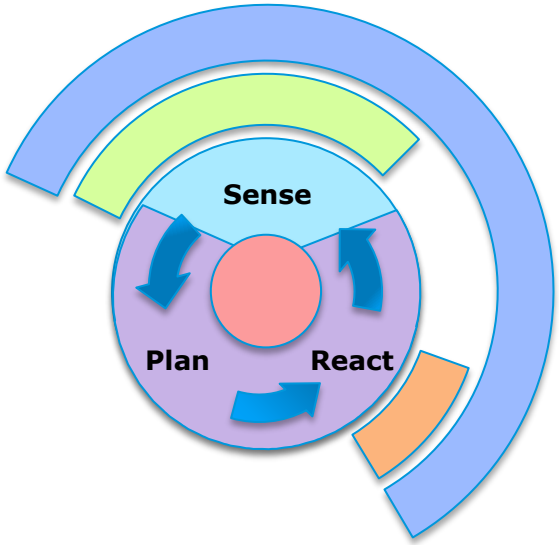
OG1: Open Source Robot Control Operating System

Overview

RCOS System

General Functions

- Enable creation of robot controllers
- Support the following robot controller engineering processes:
  - Architecture engineering
  - design and implementation,
  - verification,
  - validation,
  - management,
  - operation and maintenance
- Support the following processes
  - Modelling
  - Generation of code skeletons
  - Modelling of hardware & equipment
  - Model verification
  - Building the robot controller and downloading it to hardware
  - Monitoring and interaction with controller at runtime



OG1: Open Source Robot Control Operating System

Overview

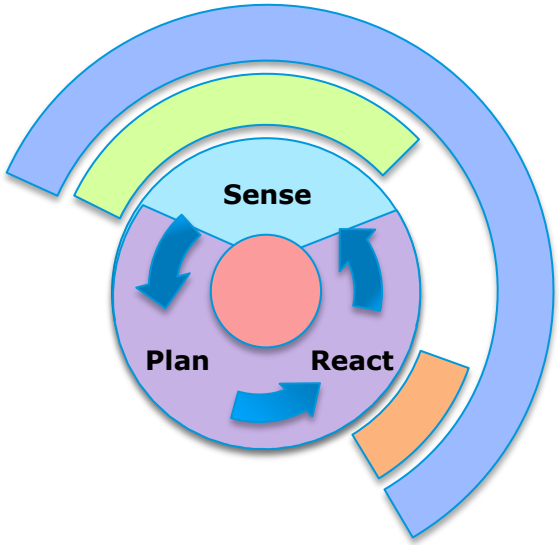
RCOS System

RCOS Target

- Hardware abstraction;
- Low-level device control;
- Scheduling of hard/soft real-time tasks;
- Task comms and sync
- Runtime-configuration management & monitoring;
- FDIR
- File system access & management
- Networking
- Consistent data types across operation;
- Logging/telemetry generation and command processing
- Application Programming Interface

RDEV

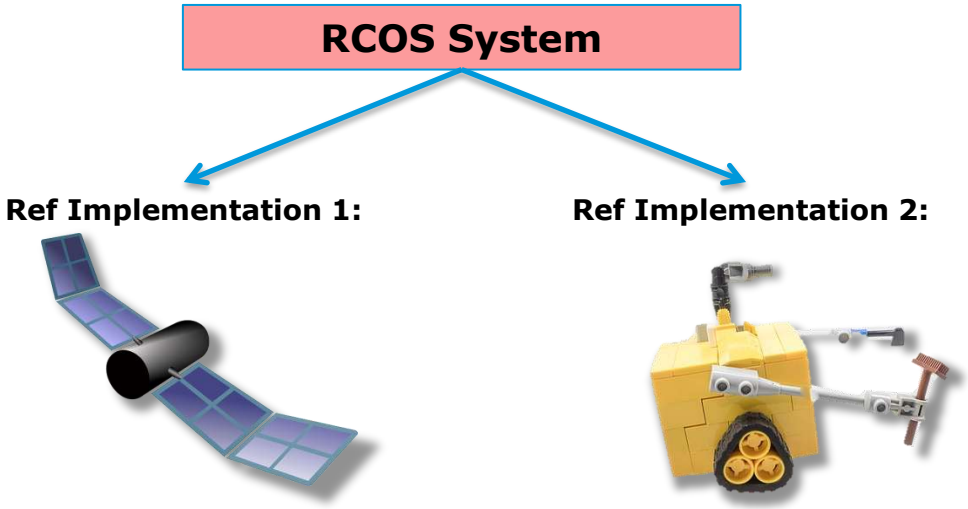
- Develop robot control applications within the RCOS target;
- Test robot control applications within the RCOS target;
- Maintain the robot control applications within the RCOS target;
- Validate the robot control applications within the RCOS target by characterising its Reliability, Availability and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

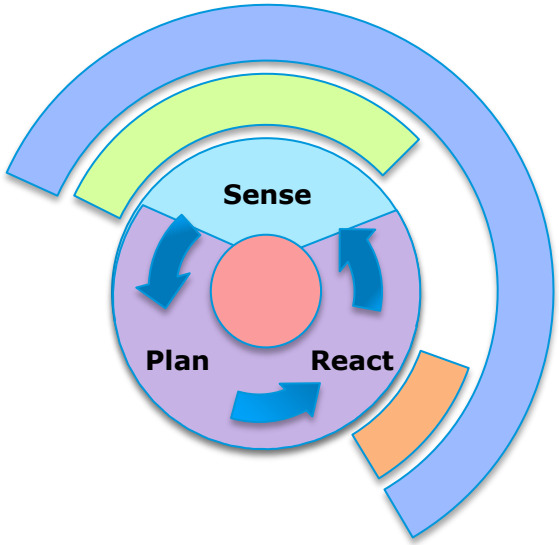


2016-17 Operational Grants

OG1: Open Source Robot Control Operating System

Overview





OG1 Key tasks:

- SOTA Assessment
- Preliminary Design
- Design of RI & Test Setup
- Coding & Manufacturing, Assembly and Integration
- Execution of Test

2016-17 Operational Grants

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

Overview

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

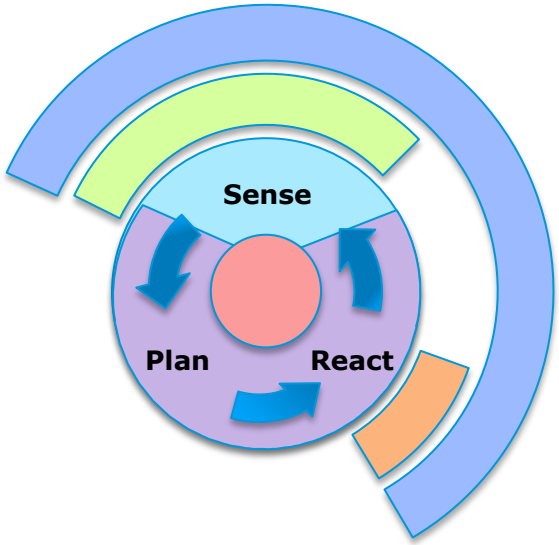
Interface between Functional and Deliberative Layers

- 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

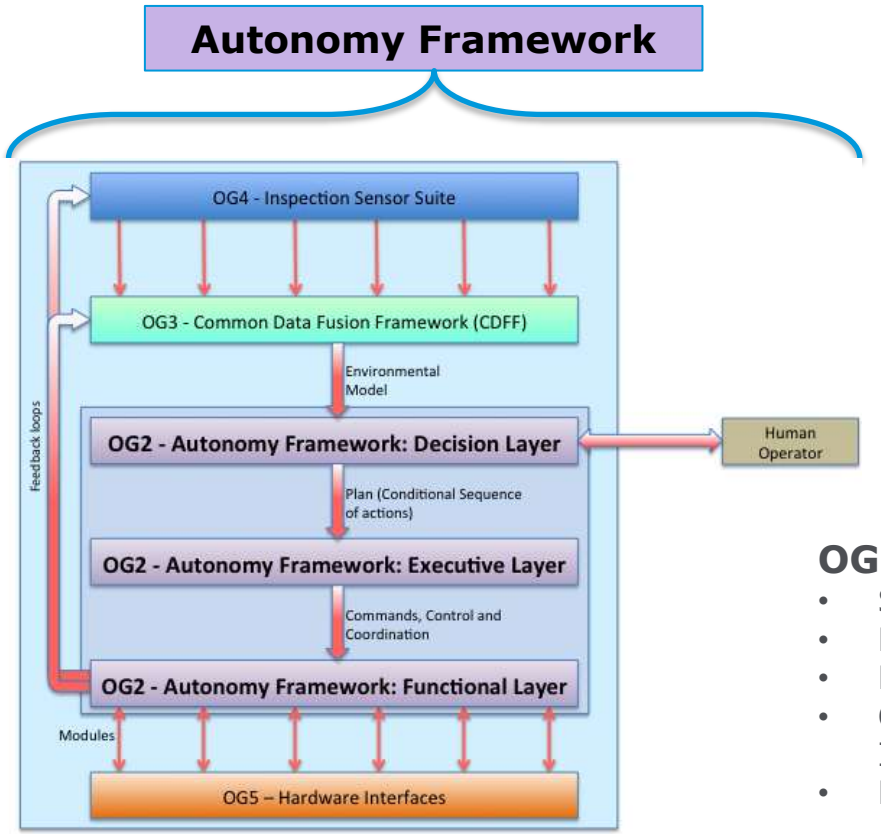
- Execute decisions
- Control & coordinate execution
- Model & monitor overall system state
- Ensure decisions taken are aligned with state & resource

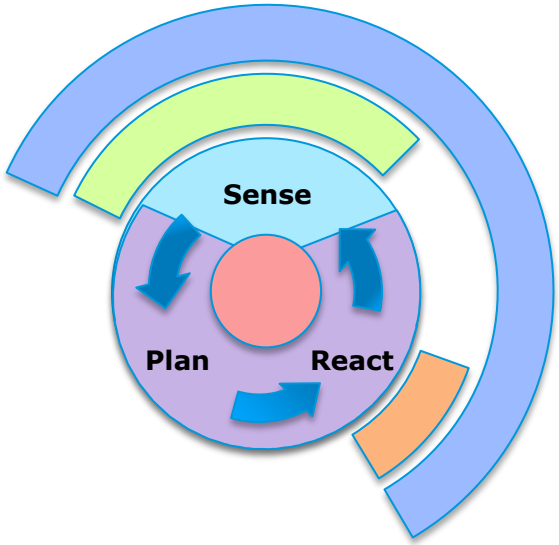


2016-17 Operational Grants

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

Overview





OG2 Key tasks:

- SOTA Assessment
- Preliminary Design
- Design of RI & Test Setup
- Coding & Manufacturing, Assembly and Integration
- Execution of Test

OG3: Common Data Fusion Framework

Overview

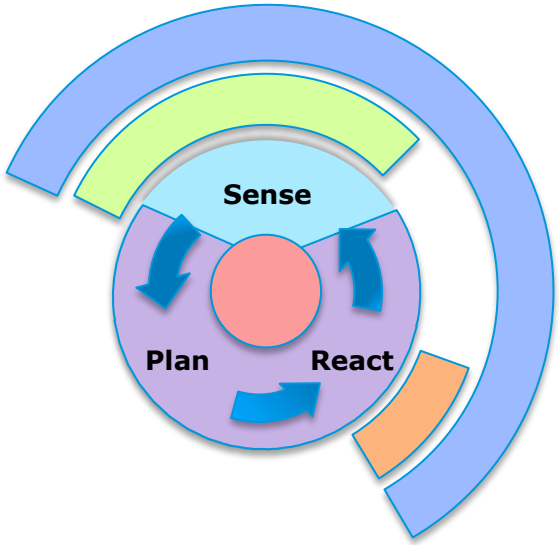
Common Data Fusion

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

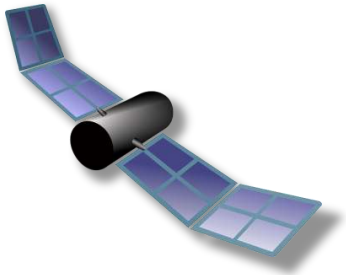
OG3: Common Data Fusion Framework

Overview

Common Data Fusion

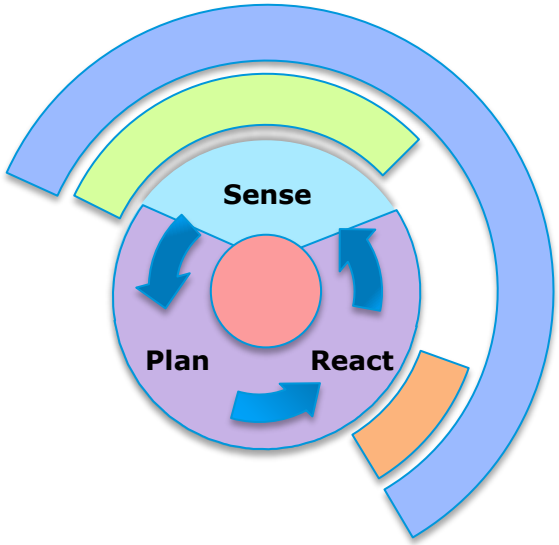
Functionalities (Orbital Track)

- 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



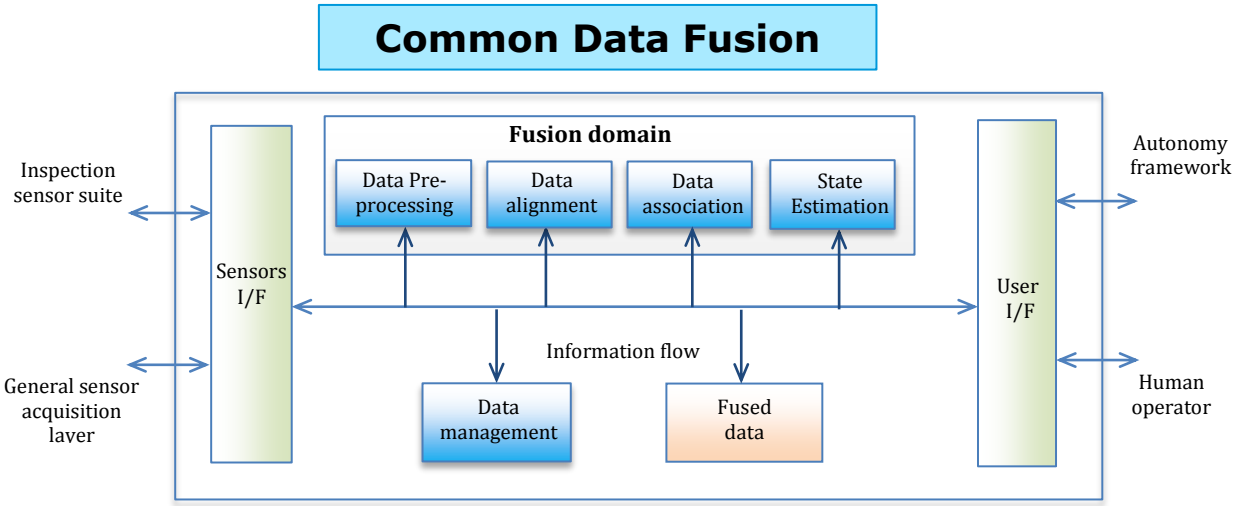
Functionalities (Planetary Track)

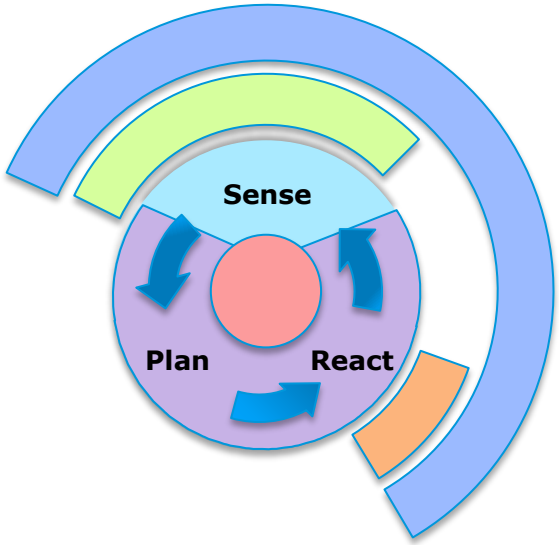
- Construction of panoramic images
- Incremental construction of terrain 3D models
- Detection and tracking of environmental objects
- Detection of structured objects ie assets, artefact, payloads
- Unexpected object identification
- Rover localisation
- Rover / manipulator localisation
- Map building



OG3: Common Data Fusion Framework

Overview





OG3 Key tasks:

- SOTA Assessment
- Preliminary Design
- Design of RI & Test Setup
- Coding & Manufacturing, Assembly and Integration
- Execution of Test

OG4: Inspection Sensor Suite

Overview

Inspection Sensor Suite

Exteroceptive

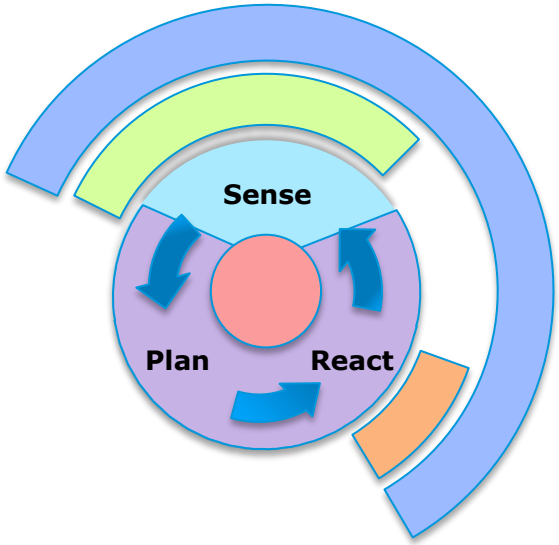
Looking at the outside world

- 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

Looking at internal status

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



2016-17 Operational Grants

OG4: Inspection Sensor Suite

Overview

Inspection Sensor Suite

Cooperative Scenarios

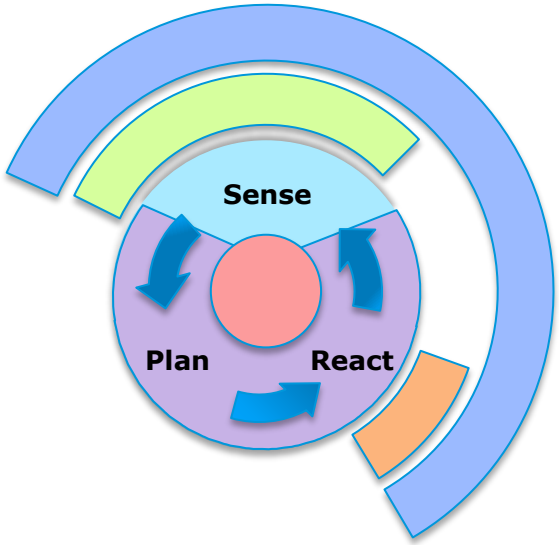
Orbital: on-orbit servicing of cooperative / operational satellites

- Optical markers
- Retro-reflectors or LEDs mounted onto target
- Combination of instruments on the inspector spacecraft (cameras, infrared detector) to help estimate attitude, relative position

Uncooperative Scenarios

Both orbital and planetary scenarios in unstructured environments

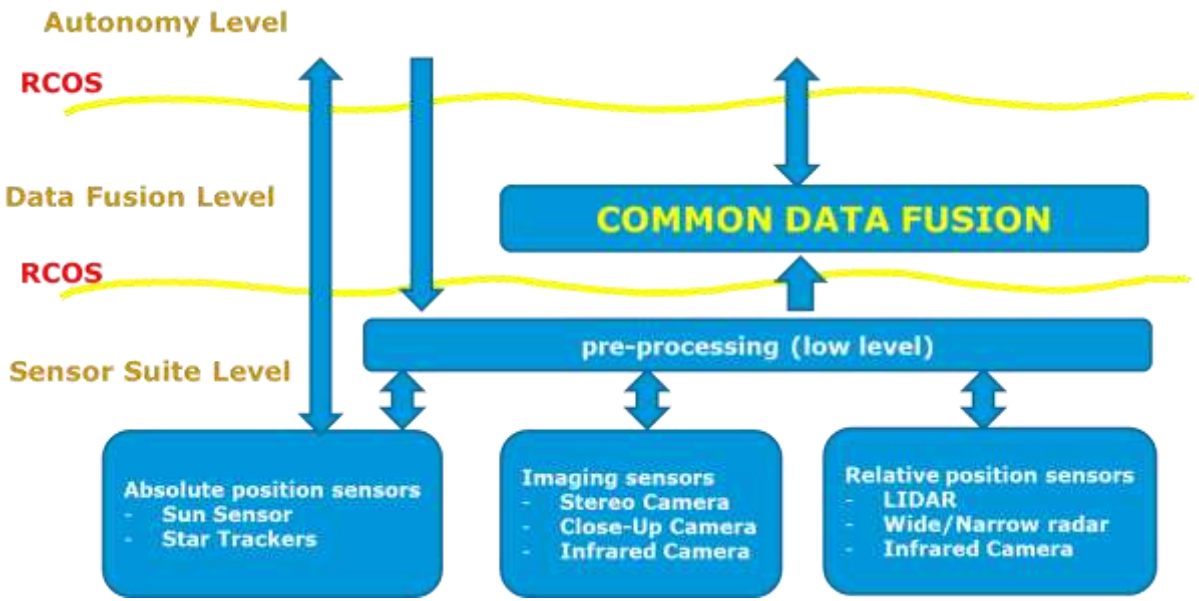
- Autonomous target identification, using:
  - Illumination Devices (lasers, LIDAR, LEDs, structured light)
- Combination of instruments:
  - Cameras, stereo cameras, LIDARs for environment mapping, surface characterisation, feature ID, IR detectors, ultrasound sonars

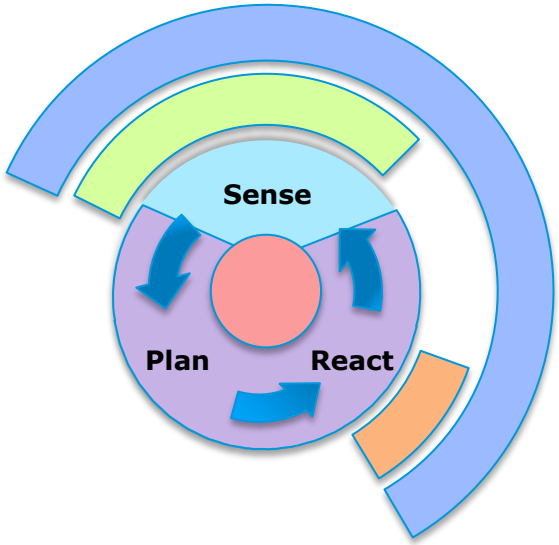


OG4: Inspection Sensor Suite

Overview

Inspection Sensor Suite





2016-17 Operational Grants

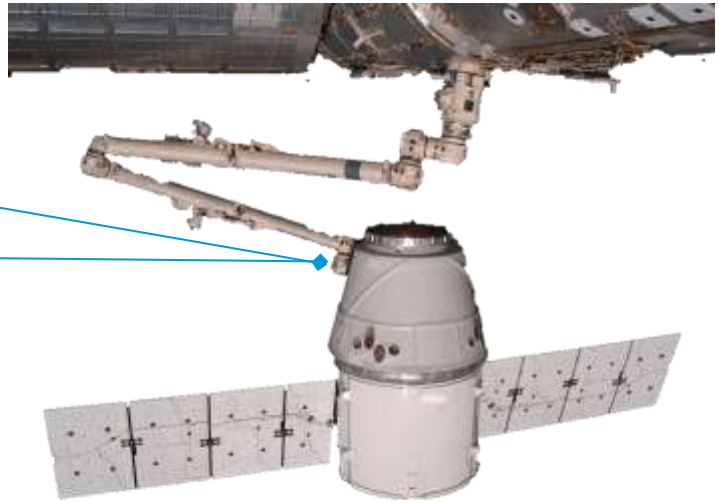
OG5: Modular Interfaces for Robotic Handling of Payloads

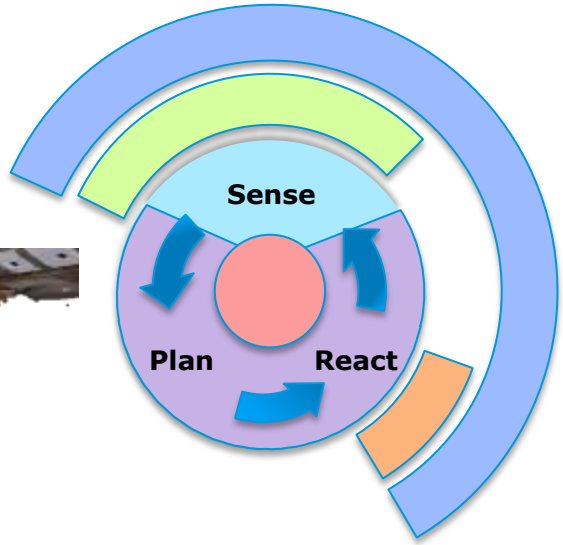
Overview

Manipulator Interfaces

Standard Interface Supporting:

- Mechanical Loads
- Electrical Signals
- Data
- Thermal Signals





Interface Criteria:

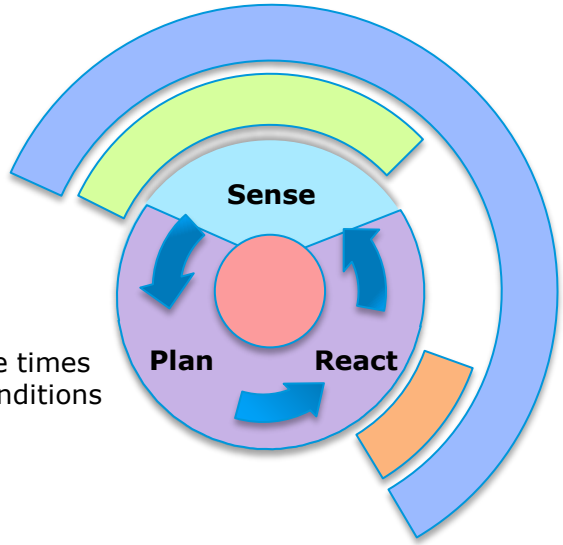
- Scalability
- Internal redundancy
- Compatibility to robot servicing
- Low complexity, mass and volume
- Rotation of axis and symmetry
- Reusability
- Connection of nearly arbitrary modules without restriction on the relative module orientation

OG5: Modular Interfaces for Robotic Handling of Payloads

Functionalities

Manipulator Interfaces

General:
- Connect APMs with each other, spacecraft, and bus
- Couple with compatible robotic manipulator
- Exchange data through manipulator between servicer and client robots



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

Overview

Validation Platforms

Other OG testing:

- OG1: Robot Operating Control System
- OG2: Autonomy Framework
- OG3: Common Data Fusion
- OG4: Inspection Sensor Suite
- OG5: Modular Manipulator Interfaces

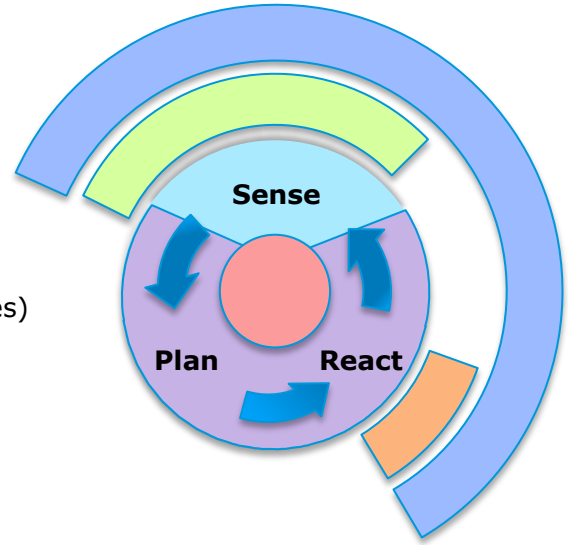
Different Levels of Support:

A European Network

- Unitary support (ISS)
- Integration level (CDFF, ISS, Interfaces)
- Avionics susbsystem level (RCOS)
- Mission level (AF)

Different Considerations:

- Earth analogues
- Modelling & Simulation
- Lab testing



2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

Planetary Validation Scenario

Scenario

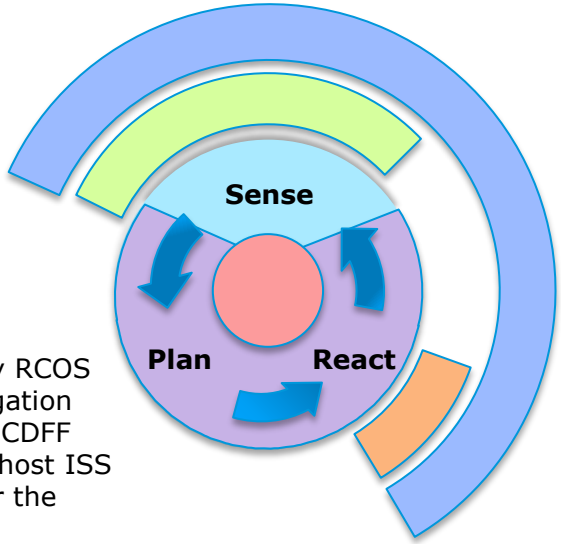
- Short-range scenario (Terrain sand-box) with different sand & orography
- Long-range scenario (Earth analogue like desert)
- Specialized measurement systems (indoor/outdoor)

Equipment

- Rover Platform
- Space representative avionics
- Standard interfaces (HW/SW)
- Necessary sensors

Rover will allow

- OG1: locomotion controlled by RCOS
- OG2: Implementation of navigation
- OG3: Provide sensory data to CDFF
- OG4: Necessary interfaces to host ISS
- OG5: provide manipulation for the end-effector & APM



2016-17 Operational Grants

OG6: Validation Platforms and Field Tests

Orbital Validation Scenario

Scenario

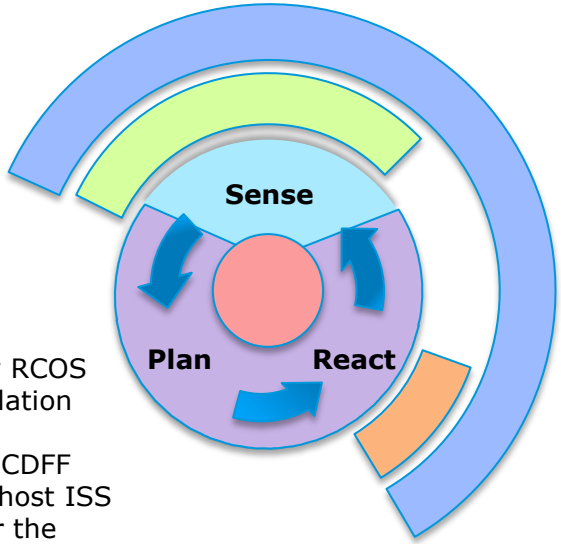
- Reproduce in-orbit servicing (rendezvous & capture)
- Simulate robotic servicer tracking
- Space-like controllable conditions
- Hardware-in-the-loop

Equipment

- Al least 2 robotic arms (6DoF)
- High precision calibration system
- Controllable illumination system
- Sensor representative proximity operations
- Truth position/attitude measurement
- Scaled Mockup for target satellite

Robot will allow

- OG1: Robot Arm controlled by RCOS
- OG2: Implementation manipulation motion as commanded by AF
- OG3: Provide sensory data to CDFF
- OG4: Necessary interfaces to host ISS
- OG5: provide manipulation for the end-effector & APM



Other Considerations

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 for Robotic Activity on Earth:

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 in ICT on terrestrial Robotics
- http://ec.europa/programmes/horizon2020/en/draft-work-programmes-2016-17
- ICT WP – Page 57

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.

Integration ***Diversity*** ***Impact***

Other Considerations

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