ESA AI and Robotics at iSAIRAS 2016

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Abstract

The paper will provide the programmatic context in which the European Space Agency (ESA) is and hence serves as orientation background, introduction and index to the several papers on ESA missions and ESA-sponsored technologies submitted to i-SAIRAS 2016.

The paper will provide an overview of these activities.

Research and development activities have progressed in the different branches of the ESA A&R technology tree. The paper will illustrate some achievements and new developments.

Finally ESA, on behalf of the European Union, leads a team of European space agencies that coordinate the next 5 years of space robotics developments under European Union funds. The paper will illustrate goals and steps of these developments.

Planetary Robotics Missions

On the subject of organization, the ESA differentiation between the field of space exploration in human-oriented and otherwise non-human tended missions has been removed with the attribution of all exploration activities to the Human and Robotics Exploration directorate.

The directorate is currently readying the ExoMars programme. This consists of two missions, the 2016 and 2020 ones.

ESA intends to send probes to Mars every 2 years. According to this plan, a Moon-of-Mars Sample return mission and a Mars Precision Lander missions have been studied. These will be illustrated. As well as with the technology developments that are associate to them.

In preparation to the return of humans to the Moon, ESA intends to cooperate with ROSKOSMOS in their Lunar exploration programme and it also intends to promote other Lunar missions such as the Lunar Volatile Prospector and other international missions that may benefit from cis-lunar orbiting station.

The ExoMars Missions

The ExoMars missions are developed in cooperation with the Russian Space Agency, ROSKOSMOS and were established to investigate the Martian environment and to demonstrate new technologies paving the way for a future Mars sample return mission in the 2020's. The first ExoMars mission was launched on 14 March 2016 on a Proton rocket and it is currently on route to Mars scheduled for landing on 19th of October. This first mission contains two elements: the Trace Gas Orbiter plus an entry, descent and landing demonstrator module, named Schiaparelli. Schiaparelli, the ExoMars entry, descent and landing demonstrator module will validate European technology for landing on the surface of Mars with a controlled landing orientation and touchdown velocity.

The Orbiter will perform detailed, remote observations of the Martian atmosphere, searching for evidence of gases of possible biological importance, such as methane and its degradation products.

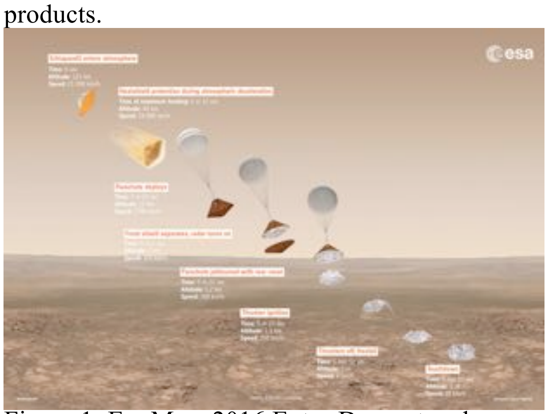

Figure 1: ExoMars 2016 Entry Descent and Landing sequence.

While these elements are not containing robotics technology, they are crucial for the success of the fully robotic mission ExoMars 2020. In fact the Orbiter will provide data-relay capability for Earth-Mars communication and the Schiaparelli will validate equipment (radar altimeter) and algorithms for Entry Descent and Landing for the ExoMars 2020 Lander.

The ExoMars 2020 mission (formerly scheduled for 2018) includes a Russian-provided lander with the ESA provided rover. The lander, a conventional parachute-rocket one, will deliver the 300 kg ExoMars rover on the surface of Mars by means of Lunokhod-type ramps.

While the Lunokhod was piloted to land on the Moon and it was placed on safe spot, ExoMars will rely on autonomous landing and may land in a spot that may create some operational concerns for egress.

Therefore ESA has been investigating the robustness of the egress operations and the efficacy of the situation-awareness means in the tests presented in the “Remote Rover Operations: Testing the ExoMars Egress Case” in session Session Remote Operation (1).

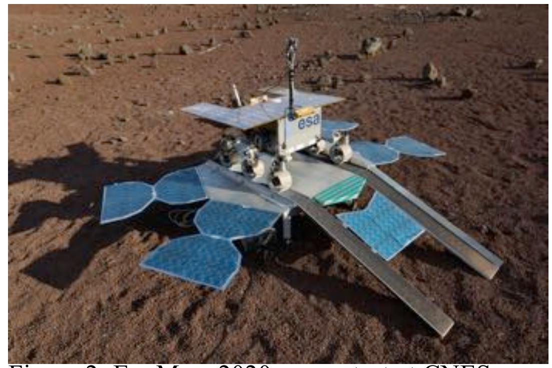

Figure 2: ExoMars 2020 egress test at CNES mars yard SEROM.

The ExoMars 2020 rover development is in full swing with elements approaching flight status as testified by the paper on “Actuator Development for the ExoMars Rover Bogie Electro-Mechanical Assembly” in session Space Components (1).

Phobos Sample Return (PHOOTPRINT)

For some time ESA has been contemplating a Phobos sample mission, which has been code-name PHOOTPRINT. The mission is presently subject of 2 Phase-A industrial studies that have both defined a common scenario in which a robot arm is used to collect samples from the Phobos surface and deliver them to a sample vessel placed into an Earth Return Capsule (ERC). ESA has been developing technology for the ultra lightweight robot arm, for different sampling mechanisms and for the reaction force control.

The paper “Regolith sampling and Deep Drilling in Low Gravity environment” in session Terrain assessment + Cooperative robotics illustrates some of these devices.

As Phobos has negligible gravity, every reaction force generated by contacting the surface tends to bounce the lander off the surface.

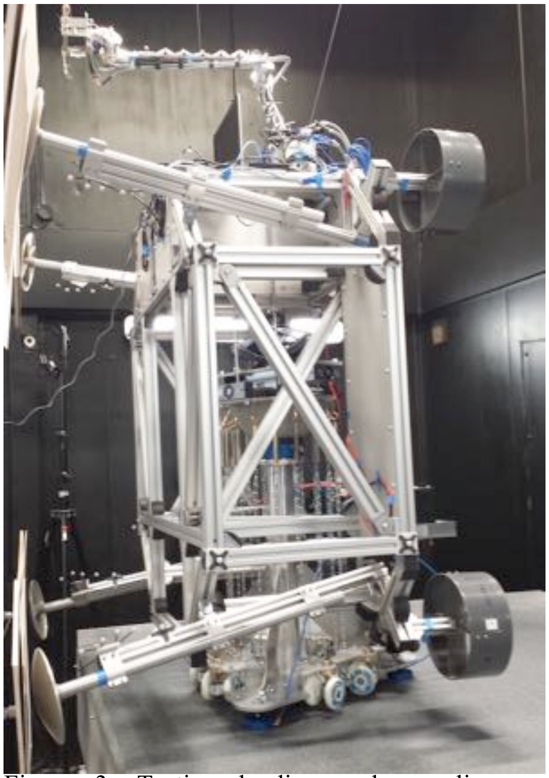

Figure 3: Testing landing and sampling on simulated Phobos gravity (courtesy of CBK-PAN)

Participation to the ROSKOSMOS Lunar-Resurs mission

ESA will provide key contributions to the Russian Lunar Resurs mission. These are named PILOT (a landing-hazard avoidance package), PROSPECT (a sampling drill that builds on the ExoMars drill development) and PROSPA (a scientific payload for the analysis of volatiles). Currently ESA runs activities for the development of a sampling and delivery tooltip compatible with icy regolith and for upgrading the ExoMars drill with percussion capability. The percussion system will be illustrated in the paper "Regolith sampling and Deep Drilling in Low Gravity environment" in session Terrain assessment + Cooperative robotics.

CLEANSPACE

With the Clean Space initiative, ESA intends to address the environmental impacts of its activities, both on Earth and in space by developing Clean technologies for space. These are being defined by ESA as those, which contribute to the reduction of the environmental impact of space programmes, taking into account the overall life-cycle and the management of residual waste and pollution resulting from space activities, both in the terrestrial eco-sphere and in space.

Clean Space activities are organised into four distinct branches:

1. Eco-design
2. Green technologies
3. Space debris mitigation
4. Technologies for space debris remediation.

It is in the last branch that robotics technologies for Active Debris Removal (ADR) are being developed. A variety of technologies for capturing debris are being addressed. Harpoons, "tentacles", and throw-nets are all investigated with technology development activities.

In particular the throw nets have been subject of a programme of development and validation that had several tests on parabolic flights.

ESA is also investigating concepts of grippers for coping with the capture of man-made debris by robot arm.

Another branch of CLEANSPACE that sees some robotics development is the one related to Space debris mitigation. One way to reduce the number of large spent satellites in orbit, is to allow them to be re-used as far as convenient.

For telecom satellites the principle reason of retiring a satellite is depletion of fuel. Therefore ESA has initiated the development of a refueling interface that will be proposed as international standard.

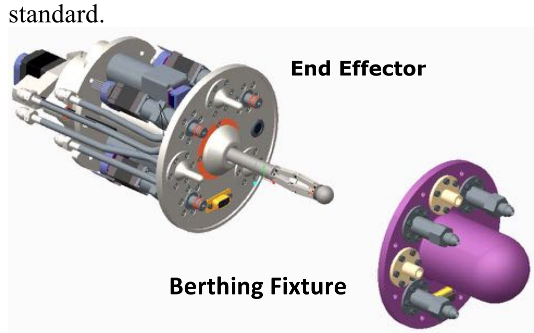

Figure 4: The ASSIST system, with its end-effector (to be mounted to a tanker satellite) and the berthing fixture (to be part of a serviceable satellite)

Whether a robot arm is used for grasping a non-cooperative object (such as debris) or a cooperative satellite (e.g. for refueling), the combined control of spacecraft platform and robot provides for issues as well as opportunities for optimization in the FDIR and redundancy of the robot+spacecraft system.
To this extent ESA has initiated the COMRADE R&D development activity that aims at developing the combined control system of a spacecraft equipped with a robot arm.

Generic A&R research and development
Not all ESA R&D is dedicated to missions (proposed or in development). ESA runs also R&D activities that are general in scope and may or may not be connected to missions. To this category belong the development of reliable robot autonomous controllers: the ESA project called SARGON is developing a robot control system development tool that will allow producing robot controllers for all space applications in an increasing level of quality. SARGON will allow to quickly develop robot application demonstrators for lab use and then, with some extra validation and verification effort, allow the transition of the same application code to the industrial quality level and to the space quality level.
An important asset for future planetary exploration will be the capability to navigate across large extent of planetary surface, maintaining accurate localization. ESA has produced a complete hardware system (FPGA based) for fast map-making and visual localization called COMPASS. Furthermore as for very large daily traverses dead-reckoning is very inaccurate, a system for global localization, using a-priori low resolution satellite maps, was developed and tested. The paper “HDPR: A Mobile Testbed for Current and Future Rover Technologies” in session Test Bed explains the testing.

Figure 5:The HDPR system on a 2km navigation run

In orbital robotics a problem encountered in grasping floating objects is the robustness of grippers and control systems against poorly understood contact dynamics. The papers “Recent Developments on ORBIT, a 3-DoF Free Floating Contact Dynamics Testbed” in session Test-beds, and the paper “A robotic testbed for low-gravity simulation” in session Simulation (1) describe different aspects of a facility recently developed at ESA for the accurate characterisation of behaviours at contact.

Figure 6: The ORBIT facility and the ROOTLESS platform, two means to recreate low-gravity

Further R&D is being carried out on autonomous science arbiters, miniaturized servo drive electronics for extreme environments, shape-changing wheels, rover teleoperation and programming ground stations, rf based precise localisation of objects.
Unfortunately these technologies could not be presented at i-SAIRAS 2016.

The H2020 strategic research cluster in space robotics technologies.
The European Union has in its Horizon 2020 framework programme (in short H2020) created the scheme of Strategic Research Cluster (SRC). 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. An SRC has been devoted to Space Robotics Technologies. ESA, together with the Italian Space Agency (ASI), the Spanish Space Centre (CDTI), the French Space Agency (CNES), the German Space Agency (DLR) and the UK Space Agency (UKSA) plans and coordinate the activities in the Space Robotics Technologies SRC.
The activities will unfold on a programme lasting till 2023 and preparing all for a high-level demonstration of an application of space robotics.

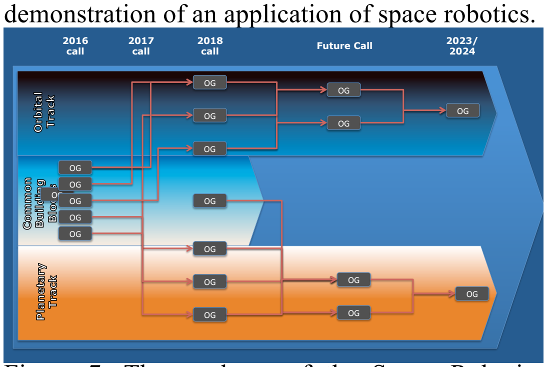

Figure 7: The roadmap of the Space Robotics Technologies SRC. The call in 2016 concentrates on basic building blocks. The call in 2018 will prototype robotics applications from building blocks. The call following will study the missions to be realised in the 2023

The operational grants (OG) currently being awarded cover basic building blocks needed for planetary and orbital applications.

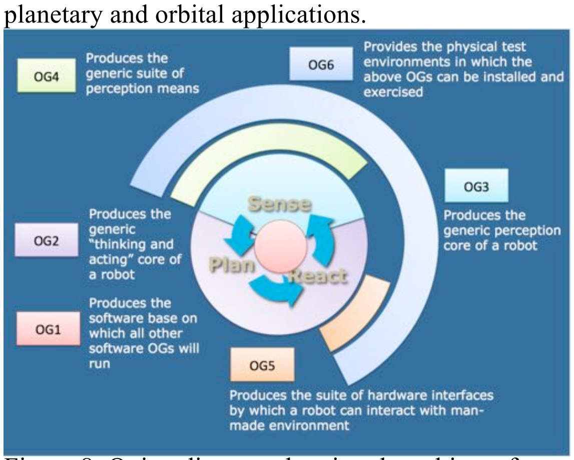

Figure 8: Onion diagram showing the subject of the first Operational Grants (OG) part of the SRC on Space Robotics Technologies

Conclusions
This paper has presented the overview of missions that ESA is currently pursuing, as background information for understanding the context and interrelation of individual developments being presented at iSAIRAS.