ESA AI and Robotics at iSAIRAS 2014

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Abstract

The paper provides 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 2014.

The paper will allow readers to see what are the links between individual technologies/ experiments presented at iSAIRAS and the missions they intend to serve.

1 Introduction

On the subject of organization, ESA differentiates the field of space exploration in human-oriented and otherwise non-human tended missions being undertaken respectively by the Science and Robotics Exploration (SRE) directorate and by the Human Spaceflight (HSO) directorate.

A new initiative, called CLEANSPACE targets the development of technology to realize a sustainable use of space. Besides technologies for "green" development, launch and operation of spacecraft, CLEANSPACE targets also technology to "clean up" orbits, i.e. Active Debris Removal (ADR).

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.

2 Science and Robotics exploration missions

The SRE directorate is currently readying the ExoMars programme. This consists of two missions, the 2016 and 2018 ones. The 2018 mission contains an important robotic contribution.

The SRE directorate aims at sending robotic probes to Mars every 2 years. According to this plan, the PHOOTPRINT and the Mars Precision Lander missions are being studied.

2.1 ExoMars 2016

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2.2 ExoMars 2018

Presently ExoMars (ESA) is the only European **funded mission** to make substantial use of A&R, in the form of an autonomous rover, an automated exobiology laboratory and robotised drilling system. The mission has suffered considerable changes since its inception. The mission is now being developed in cooperation with ROSKOSMOS and it will include a Russian-provided lander with the ESA provided rover, remained unchanged with respect to previous settings of the mission.

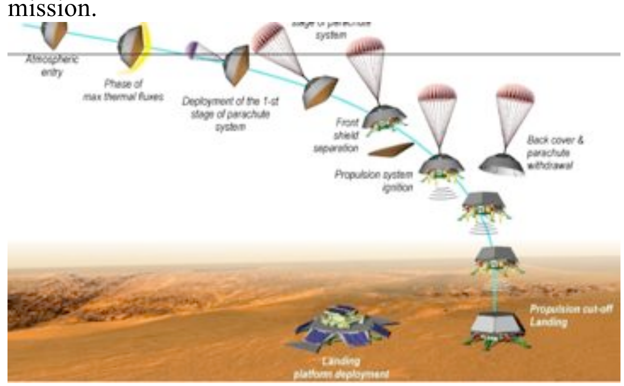

Figure 1: Scenario of ExoMars 2018 landing

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.

The rover is in advanced state of procurement and contracts for phase C of major subsystems have been awarded.

There are also some technology development activities that intend to provide contribution to the programme. At iSAIRAS the paper on "Wheel-Soil Interaction Data

Generation and Analysis on Characterised Martian Soil Simulants" will be presented. This documents an activity that is developing experimental knowledge on soil that will be valuable for the operation of the rover.

Figure 2: Lunokhod ramp at the Lavotchkin museum

The latest field test run by ESA in the Atacama desert, with an ExoMars rover model equipped with most of the payload complement is documented in two papers "Demonstrating Autonomous Mars Rover Science Operations in the Atacama Desert" and SAFER: The promising results of the Mars mission simulation campaign in Atacama, Chile".

Finally, the paper "3D Rover Operations Control System: application to the ExoMars mission" documents the application of the 3DROV rover simulation framework to the mission

Figure 3: The BRIDGET rover equipped with ExoMArs payload during the SAFER tests in the Atacama desert of Chili

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

Figure 4: rendering of the Phootprint elements on Phobos. The Earth Return Capsule (ERC) is secured on the Earth Return Vehicle (ERV) which sits on the lander module. The lander module is quipped with a robot arm.

2.4 Mars Precision Lander

The Mars Precision Lander (MPL) mission is part of an international setting of missions that will realize a Mars sample return. The MPL will deliver an 85kg Sample Fetching Rover (SFR) close to assets already present on the Mars surface, including a sample cache. The SFR will pick-up the cache and deliver it to a Mars Ascent Vehicle (MAV), which in turn will place it in orbit around Mars. The MPL is required to have a landing ellipse size of 10 km (3s) or less, equally the SFR will need to have an operating range of about 15 km. This last requirement represents a 10 fold increase with respect to the capabilities of the present ExoMars rover. ESA has approached the requirement with the R&D activities aiming at increasing dramatically rover locomotion duty cycle and efficiency. As part of these activities ESA has ported many computer vision algorithms needed for rover navigation to computationally efficient Field Programmable Gate Arrays (FPGAs). Also the need to maintain the energy production of solar arrays across the mission has been approached with the investigation of a small robot that can blast away dust from the individual cells.

3 Human Spaceflight and Operation missions

The HSO directorate has instead continued the development of the ISS with its related robotic element (ERA). In preparation to return of humans to the Moon, HSF intends to cooperate with ROSKOSMOS in their Lunar exploration programme. Finally HSO sponsors also partially a technology experimental programme in telerobotics named METERON.

3.1 ERA

In its long ascent to orbit (the ERA robot arm has been ready to fly for the last 7 years) the ERA programme has suffered another delay of its launch date.

This time the delay has been caused by the 2013 Proton launch failure that has caused a moratorium of launches.

The main concern of ESA has been to keep alive the technical team, which has been working for so many years on the project, in order to be able to support flight operations in 2015.

3.2 Lunar Drill Development

Due to economic constraints, ESA has, for the time-being, put on hold the development of an own lunar lander. However it has decided to contribute to the Russian lunar exploration programme. Besides the contribution in science that was under development in the now suspended lunar-lander programme, ESA will provide a sampling drill that builds on the ExoMars drill development. 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.

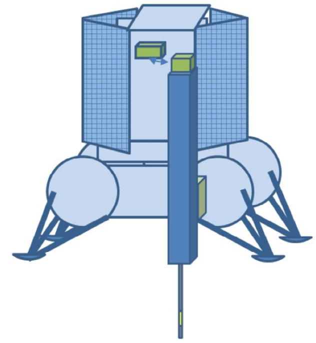

Figure 5: schematics of how the ESA drill will be accommodated on the ROSKOSMOS lunar lander

3.3 METERON

An intermediate step in the human exploration of Mars foresees humans orbiting around the planet, who will remotely control robotic assets on the surface. This approach will allow orbiting scientists to study Mars unaffected by the highly limiting Mars-Earth communication issues and at the same time remove one of the main cost/risk drivers of a human planetary mission (I.e. landing and taking off from the planet).

ESA is using the ISS to experiment on the efficacy and limitations of such setting. Robot command and monitoring interfaces have been uploaded to the ISS and are being used to control robots on-ground such us the Eurobot Ground Prototype (EGP).

The paper "Toward the first haptic force-reflection experiment on the International Space Station" address a first step in such experiments.

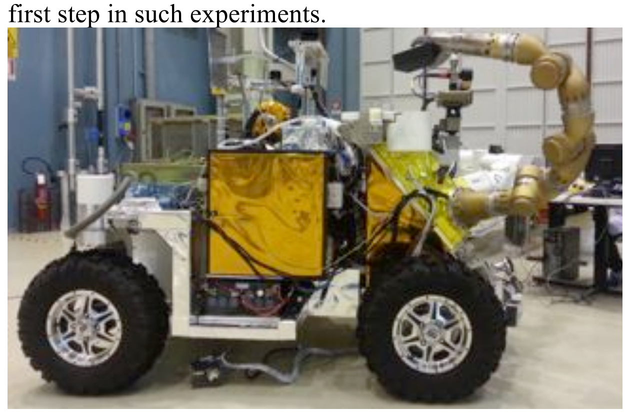

Figure 6: The Eurobot Ground development Prototype (EGP), equipped with the DEXARM robot arm, the CTED tool exchange device and the DEXHAND anthropomorphic gripper.

4 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:

- Eco-design
- Green technologies
- Space debris mitigation
- 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. For the more complex robot based grasping, ESA relies on technology developments being undertaken at DLR.

At iSAIRAS, papers on ESA funded activities are "Performing rigid-body simulations for engineering purposes using gaming physics engines", "Performing rigid-body simulations for engineering purposes using gaming physics engines", "Reliable and Efficient Simulation of Nets for Active Space Debris Removal Purposes" and "Validation of a Net Active Debris Removal simulator within parabolic flight experiment" all dealing with the ESA pioneered throw-net capture means. The paper "Concepts for Service-Based Active Space Debris Removal" deals with the economic sustainability of ADR as commercial service.

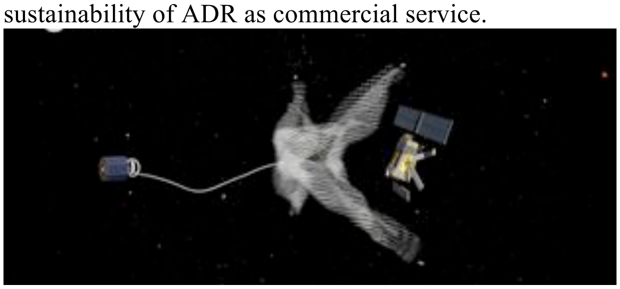

Figure 7: an e.Deorbit satellite capturing a debris (defunct spacecraft) with a throw net.

5 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, 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 iSAIRAS.

6 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.