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Eurobot Underwater Model

Testing the Co-operation between Humans & Robots

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1. Introduction

Upon its completion, the International Space Station or ISS will feature an assembly of about 30 large elements some of which pressurised. It will be the largest man made infrastructure orbiting around the earth, with dimensions of 100m long and 60 m wide, i.e. the size of football pitch. This home for human orbiting at approximately 430km around the earth will need preventive and / or corrective maintenance to keep flying during the coming decades. To allow in-orbit maintenance process, the ISS is made of hundred's of externally located equipment called "orbital replaceable units" which can be replaced either by human in Extra Vehicular Activity or by robotics.

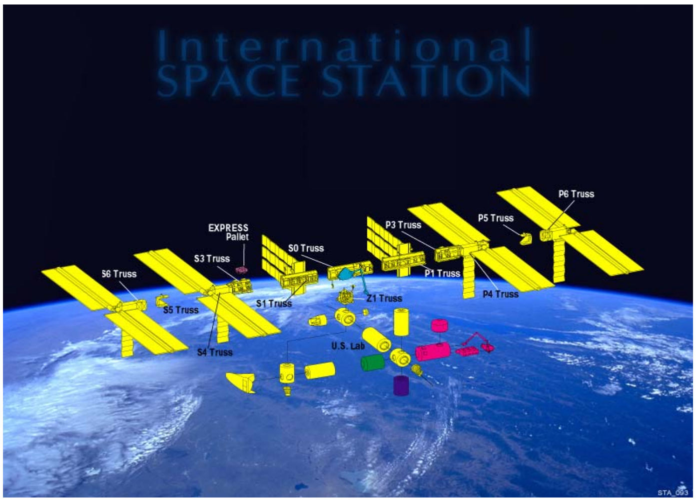

Figure 1; the ISS elements

Just on the ISS US segment alone, 300 ORUs will be mounted, ranging for small items like gyros to larger and heavier ones like battery.

2. Identified Needs for an EVA Assistant

Following disaster of Space Shuttle Columbia, NASA has decided to phase out the Shuttle by 2010. As a result the permanent on-board crew presence is limited to 2~3 now and will never be larger than 6.

Because crew presence on board ISS is scarce its usage shall be optimised to tasks for which the crew is essential, i.e. activities that require intelligence (e.g. science experiment, trouble shooting activities), time critical decision making, highly dexterous operations. Others activities which are routine or well defined and controlled can be assigned to automation and robotics means .

While the logistics tasks are well covered by current ISS robotics capabilities, there is a need to support the Extra Vehicular Activities performed by the crew (EVA) with better means during its sortie. The EVA sortie takes a significant portion of crew resource, due to preparation time required and rest needed for crew once the EVA has been executed. An on-board EVA assistant would help to maximise the number of tasks that may be carried out during an EVA sortie, possible resulting in fewer EVA sorties required.

3. Eurobot Tasks

EVA Sortie Support

In 2003, the European Space Agency proposed to develop an EVA assistant robot. This assistant would save EVA sortie time. This could be achieved by:

- Enabling to better prepare the sortie by performing at the intended worksite close up inspection, initial preparatory work
- By preparing the EVA sortie work in transferring tools and equipment needed at the worksite prior the sortie.
- During the EVA sortie, by assisting the astronaut during the work itself providing addition support restraints, viewing capabilities or powering means.
- After the EVA sortie by cleaning the worksite, storing away tools and equipment

As a result, more work could be done by the EVA

Tasks	Context	Ground	Crew Inside	Crew Outside
EVA Sortie Support	In preparation to the EVA sortie	Pick-up tools / equipment and bring it to the worksite		
	During the EVA sortie	*Monitoring of EVA sortie using Eurobot cameras/ lights*	Monitoring of EVA sortie using Eurobot cameras/ lights	Use Eurobot as handy man, stable platform for tools & equipment
	After the EVA sortie	Clean-up worksite		
Inspection tasks	Routine	Bring it to worksite and perform inspection		
	Off-nominal		Local pose close-up/ guidance	
Equipment replacement	Routine	Pick-up equipment and bring it to the worksite		
	Off-nominal		Investigate and perform manual operations	

Table 1; task allocation for Eurobot and Eurobot operator function of Eurobot task

crew during a single 6 hours sortie. Eurobot, acting as a Sherpa while the EVA crew concentrating on the repair activities themselves.

Small Equipment Replacement

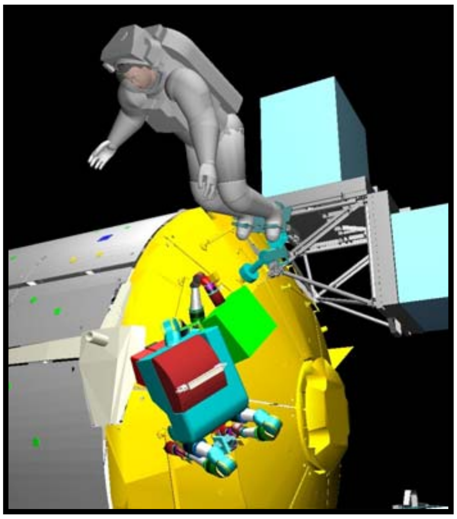

Figure 2; Eurobot assisting an EVA crew

While Eurobot can support the EVA sortie, it can also perform autonomously small equipment exchange. Upon its completion, up to 300 externally mounted equipment are designed for robotic exchange. Though systems already exists on ISS for such a task, Eurobot can serve as a useful complement to the existing infrastructure.

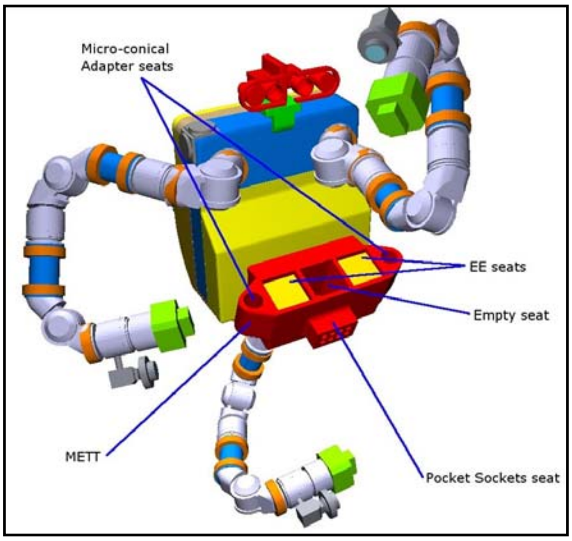

Figure 3; Eurobot Mobile Segment Overview

Inspection

External robots provide eyes for ISS crew. The Canadarm2 on ISS provides camera view to the station exterior. This capability, highly appreciated by crew and ground controllers needs to be completed with inspection close-up / high resolution capabilities. Eurobot will have the capability to access ISS areas not otherwise accessible e.g. a docking port. It will remove if required debris shield for behind panel inspection.

4. Eurobot WET (Weightless Environmental Test) Model

Because of the intimate close Human - Robot cooperation, technical but also operational aspects are challenging. To obtain an early feedback on operations / interaction aspects, an early prototype of Eurobot capable of operating in a wet environment i.e. "Neutral Buoyancy Facility", has been developed for ESA by a consortium led by Alcatel-Alenia Space Italy (AAS-I) including EADS.

The Objectives of the Eurobot Wet Model are:

- Early verification of operational concept for Eurobot
- Early feedback of use / merit from the crew
- Hands-on experience in advanced robotics technologies such as multi arm control / coordination aspects, vision recognition of non cooperative targets, control station for a mobile humanoid like robot

The Eurobot Wet Model Mobile Segment

The Eurobot Wet Model mobile segment is similar in size and configuration to the intended Flight Model. It consists of a central body structure with three identical arms, each with 7 joints are mounted. The arm length and strength are similar to those of a human. Each arm is equipped with a camera and an end-effector. The Eurobot Wet Model end-effector is however simplified, capable to grasp an EVA hand rail shape only. A head camera on a pan & tilt mechanism provides a global monitoring view of the worksite. Though the Eurobot wet model mobile

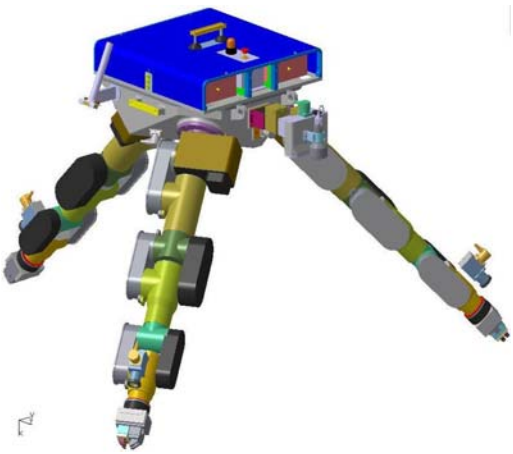

Figure 4; Eurobot Wet Model Configuration

segment has to be neutral buoyant, special effort has been made to keep the same " look and feel" compared to the intended Eurobot flight model. Figure 5 provides a comparison by juxtaposition of the two models.

Operator Control Station

The Eurobot Wet Model Operator Control Station will

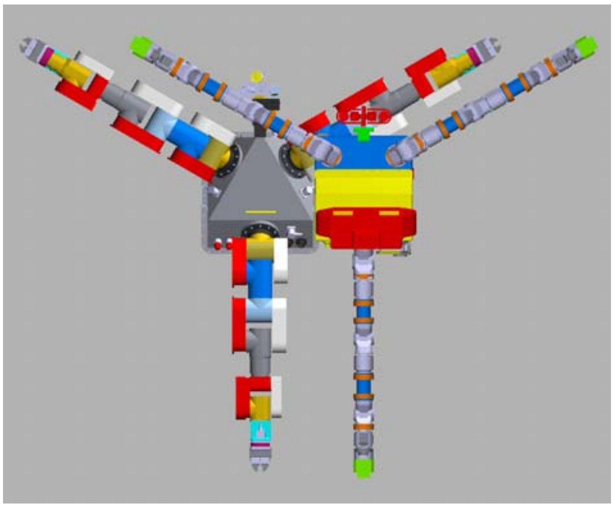

Figure 5; Eurobot Model / Wet FM Comparison

enable the operator to prepare, verify by simulation and command & monitor the Eurobot Wet Model tasks. More details on it can be found in RD1

5. Eurobot Wet Model Status

On the wet model side, the critical design review took place December 2005, the Eurobot wet model has been produced and assembled and the initial system level tested are being performed at AAS-I. The test campaign will be conducted in three major steps:

1. Dry test at AAS-I, wherein control performances will be evaluated, see Figure 6
2. Wet test in Altec(I), wherein initial performances in a water tank will be evaluated
3. Wet test in the European Astronaut Centre (EAC) in Cologne, Germany

Figure 6; Eurobot during "dry test"

The 3rd test step in EAC, in its neutral buoyancy facility will conclude the initial qualification phase of the Eurobot Wet Model programme. An end to end operational verification of autonomous ORU exchange and support to astronaut in EVA will be performed with the help of ESA astronauts.

6. Outlook of Exploration

Eurobot will be an enabling step for Europe towards developing service robots capabilities. Once its capabilities are demonstrated on the ISS, its concept will be re-used within the manned exploration programmes towards moon or mars wherein crew assistant is even more crucial.

7. Conclusion

The Eurobot will complement the ISS robotics system by providing cosmonaut assistance during EVA sortie, small equipment exchange capabilities and inspection close-up capabilities.

Due to the programme complexity, a step wise approach has been chosen to mitigate development risks. While technology developments are being pursued, in parallel a Wet Model of the Eurobot is developed to gain early operations expertise and feed-back. Eurobot technology will later be used in exploration.

8. Reference

RD1: Eurobot Control Station ECoS: The Control Station of the Eurobot Underwater Model; ASTRA 06, S. Estable (EADS) et al.

http://esaportal.esa.int/Xcel_export/TEC/Robotics/SEMBWA8LURE_0.html