In the proceedings of the 8th ESA Workshop on Advanced Space Technologies for Robotics and Automation
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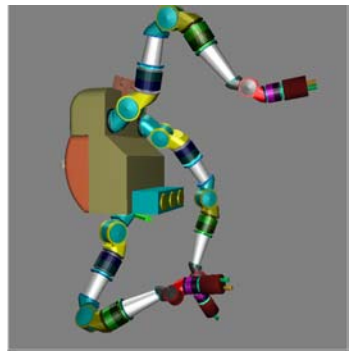

EUROBOT
EVA-assistant robot for ISS

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Presentation Overview

- EUROBOT Mission Objectives & Task Requirements
- Modes of Operation
- System Breakdown
- Mobile Segment Configurations Under Trade-Off
- Tools Panoply
- ORU & I/F Panoply
- Home Base
- Life after ISS … applications for Exploration…
- Project Schedule
- Conclusion

Objectives

- EUROBOT Motivations:
  - *Reduce the amount of crew time required for ISS external maintenance*
  - Reduce EVA sortie duration & numbers
  - Surgical model: human = surgeon, Eurobot = nurse

- EUROBOT Tasks Requirements:
  - EVA worksite preparation & closing tasks (2 EVAs in 1)
  - EVA co-operative task (2 EVAs in 1)
  - EVA sortie substitute:
    - Orbital Replacement Unit (ORU) installation / exchange
    - Payload servicing/ maintenance

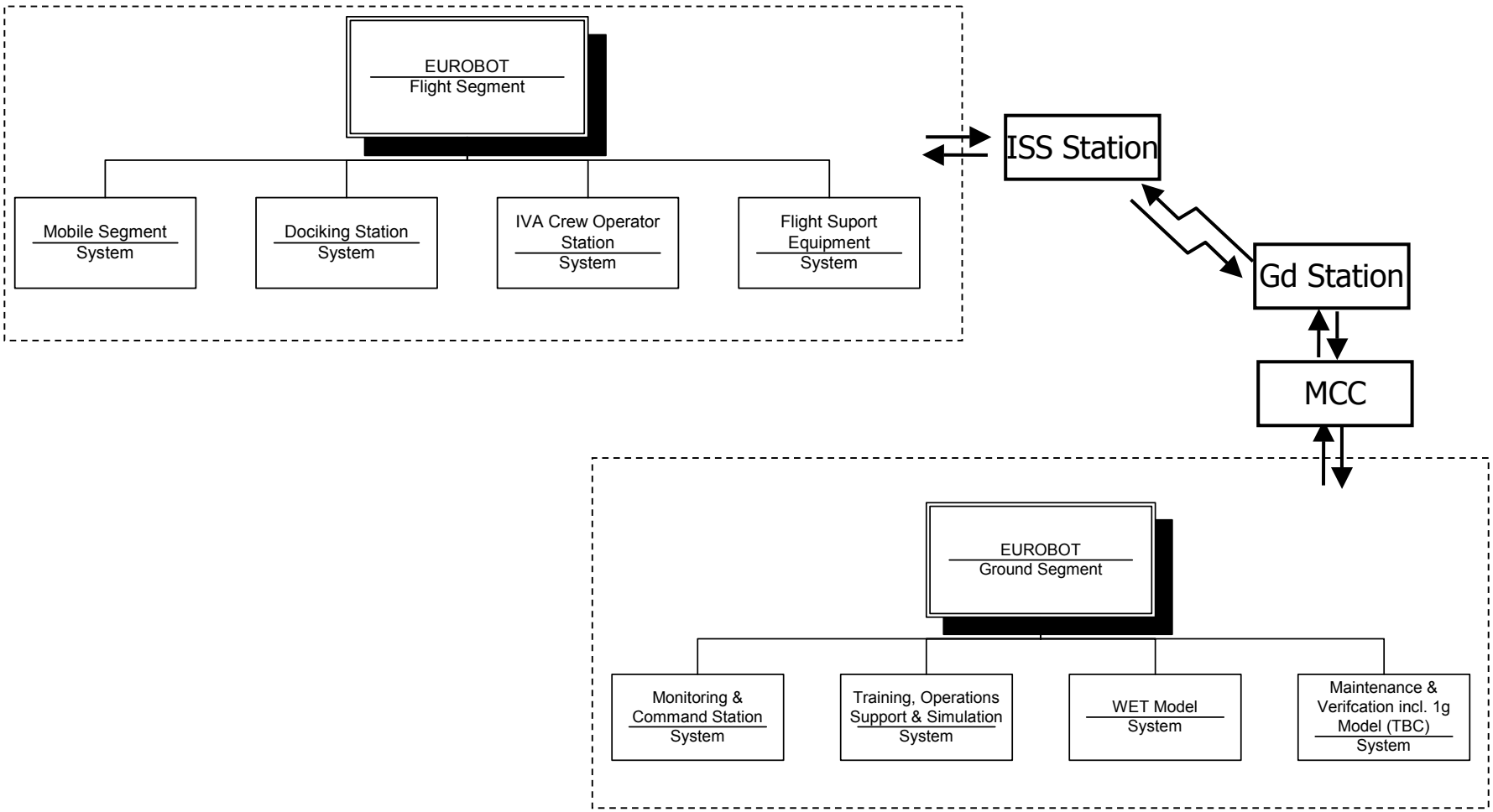
Tasks Requirements

- Deployment from Home-Base
- Locomotion & Transportation
  - self-RELOCATE to specified location (using handrails & / or other standard external ISS I/Fs)
  - TRANSPORT ORU/ payload (hold in 1 hand) while relocating
- Prepare EVA worksite
- Support EVA sortie (lighting worksite, monitoring, temporary stowage for ORUs, tools…)
- Close-up inspection and monitoring
- Safing / Keep-Alive / Maintenance
  - RECHARGE at Home-Base docking station
  - enter SAFE / STAND-BY / DORMANT state (stand-by & dormant at docking station)

Modes of Operation

- Modes of Operation:
  - *Autonomous* for all well structured/ repeatable/ tasks such as:
    - Deployment, locomotion & transportation to worksite
    - Worksite preparation prior to EVA sortie: foot-restraint installation, camera / lighting set-up, carrying tools-set
    - EVR compatible ORUs exchange
  - *Manual* for less structured/ predictable tasks:
    - EVA/ EUROBOT choreography while at worksite
    - Local inspection for troubleshooting

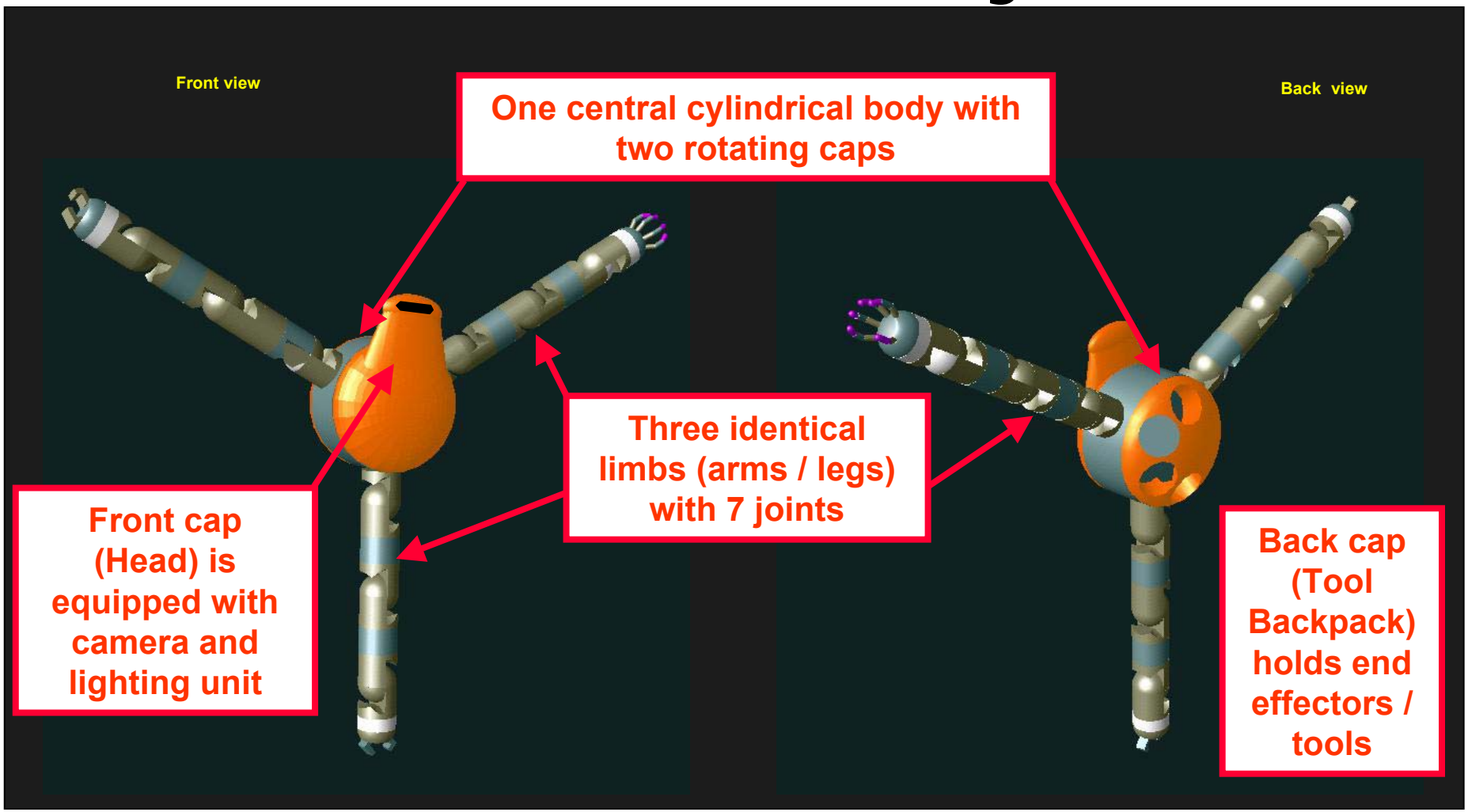
System Breakdown



System Configuration

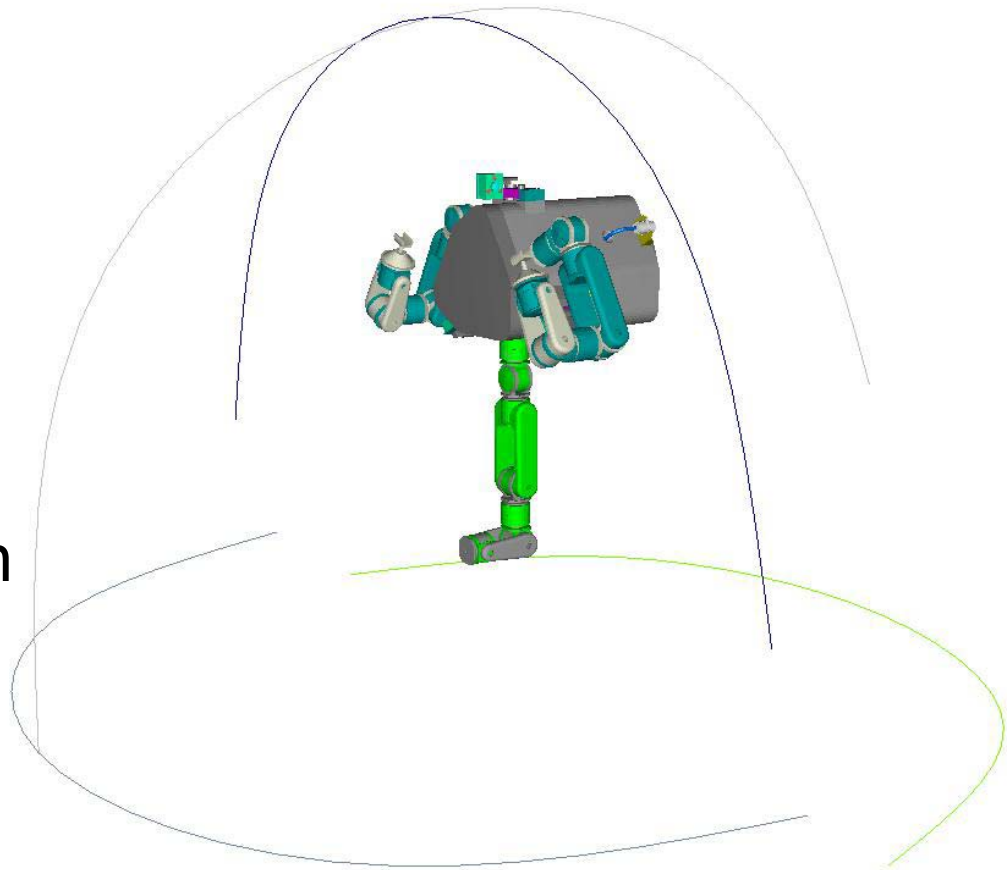
- Trade-off ongoing for different configurations
- Key issues
  - Large number of handling I/Fs to deal with
  - Large number of actuation I/Fs to deal with
  - Difficult to choose between many configuration options
  - Home base location
  - Charging station (TBC) location(s)
  - Wireless communications
  - Thermal
- Constraints
  - Ingress/egress through airlock

Initial ESA Baseline Configuration



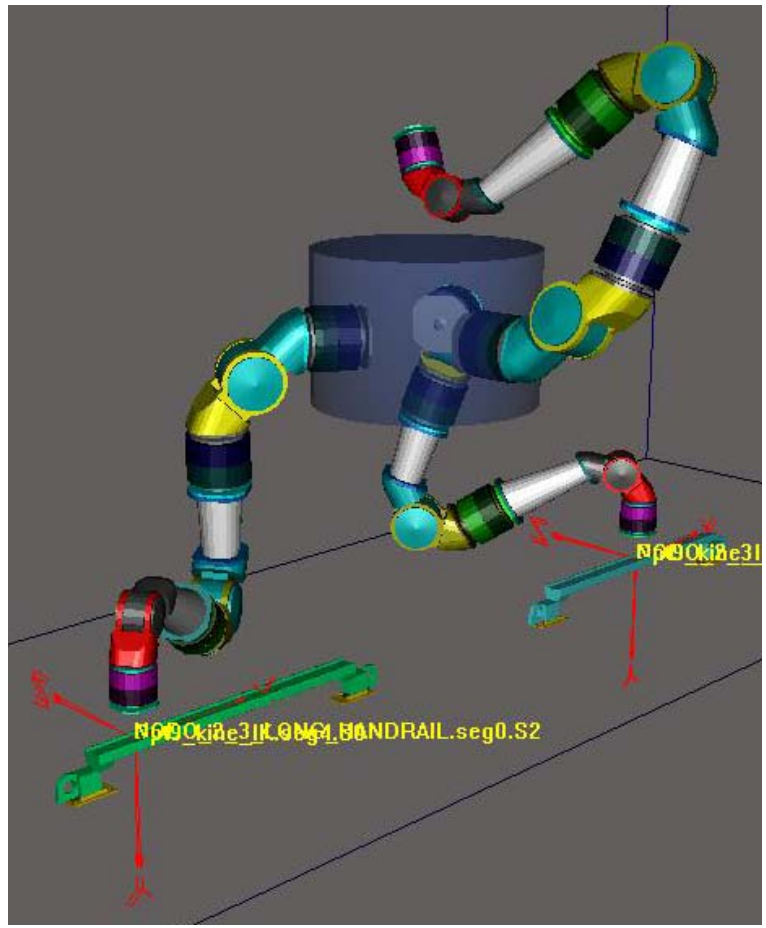
Configuration-1 Under Trade

- 3 identical arms of 1 meter each
- Each arm with 7 d.o.f
- Symmetrically mounted at 120 degrees around the body
- Initial PRR configuration



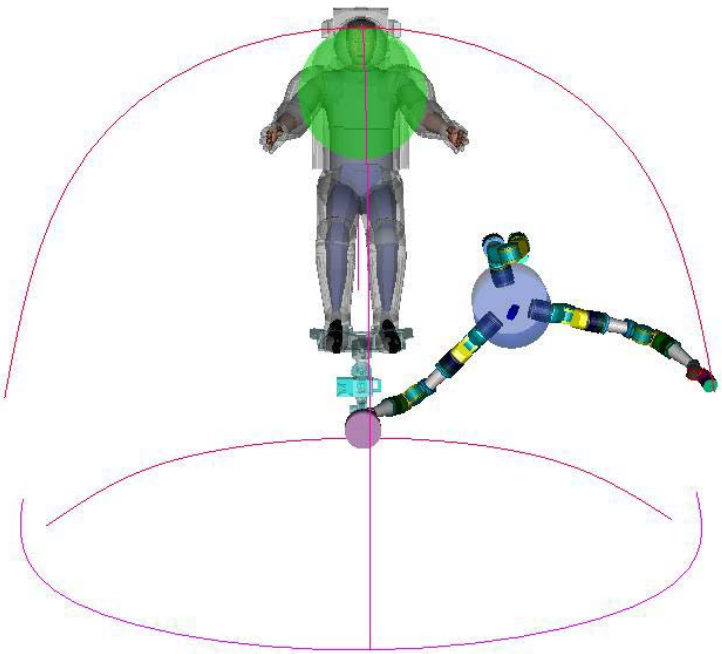
Configuration-2 Under Trade

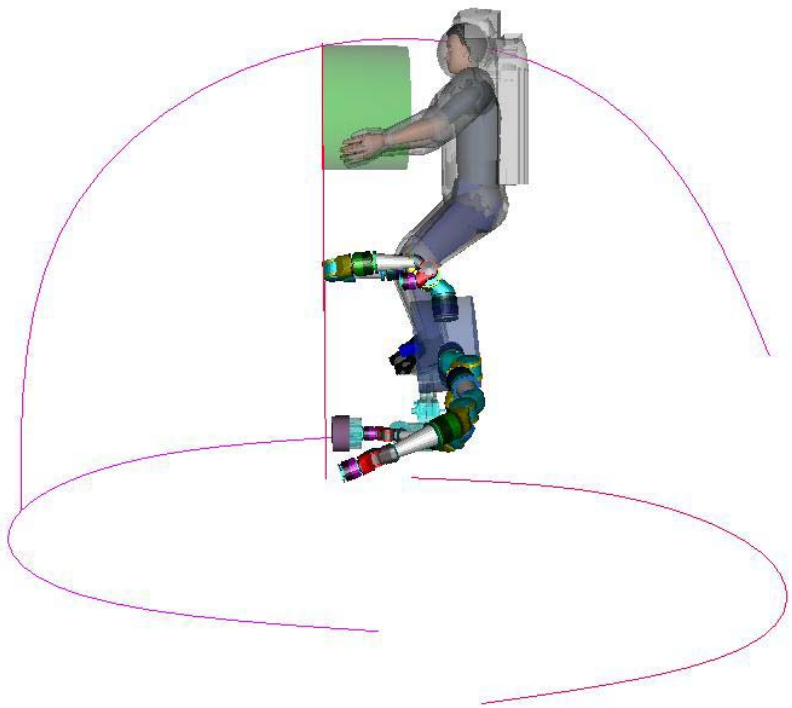
- 3 identical arms of 1 meter each
- Each arm with 7 d.o.f, with camera & lighting
- Symmetrically at 120 degrees around the body
- Set of cameras mounted (2 mono or 1 stereo) on pan & tilt unit on central body (not visible in picture)



Configuration-2 Under Trade

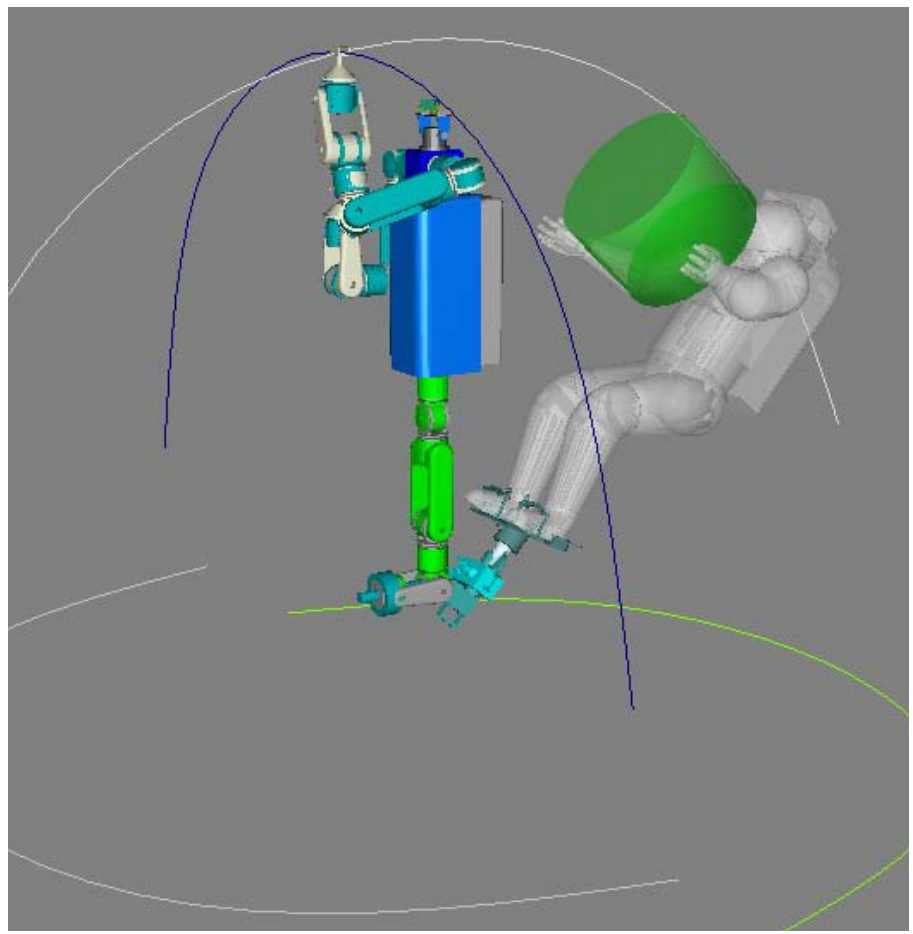
- EUROBOT size/reach compared to EVA





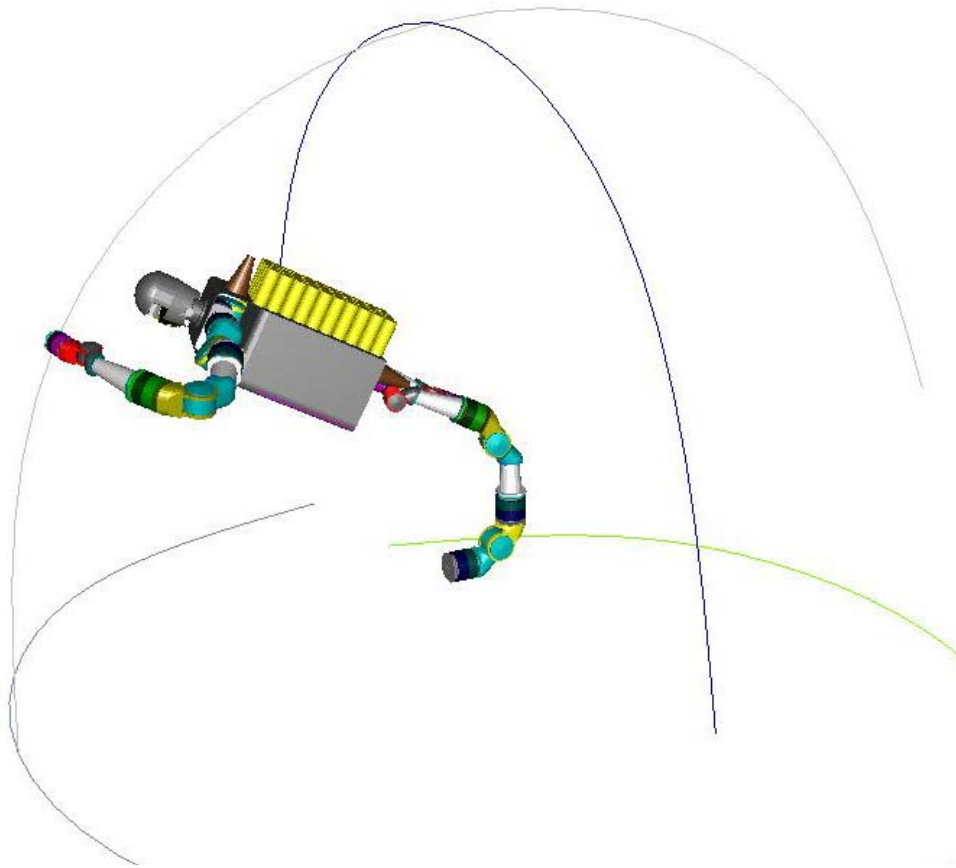
Configuration-3 Under Trade

- 2 identical arms of 1 meter each
- 1 stronger leg arm
- Each arm with 7 d.o.f
- 2 arms symmetrically mounted
- 2 cameras mounted on central body, on pan & tilt unit



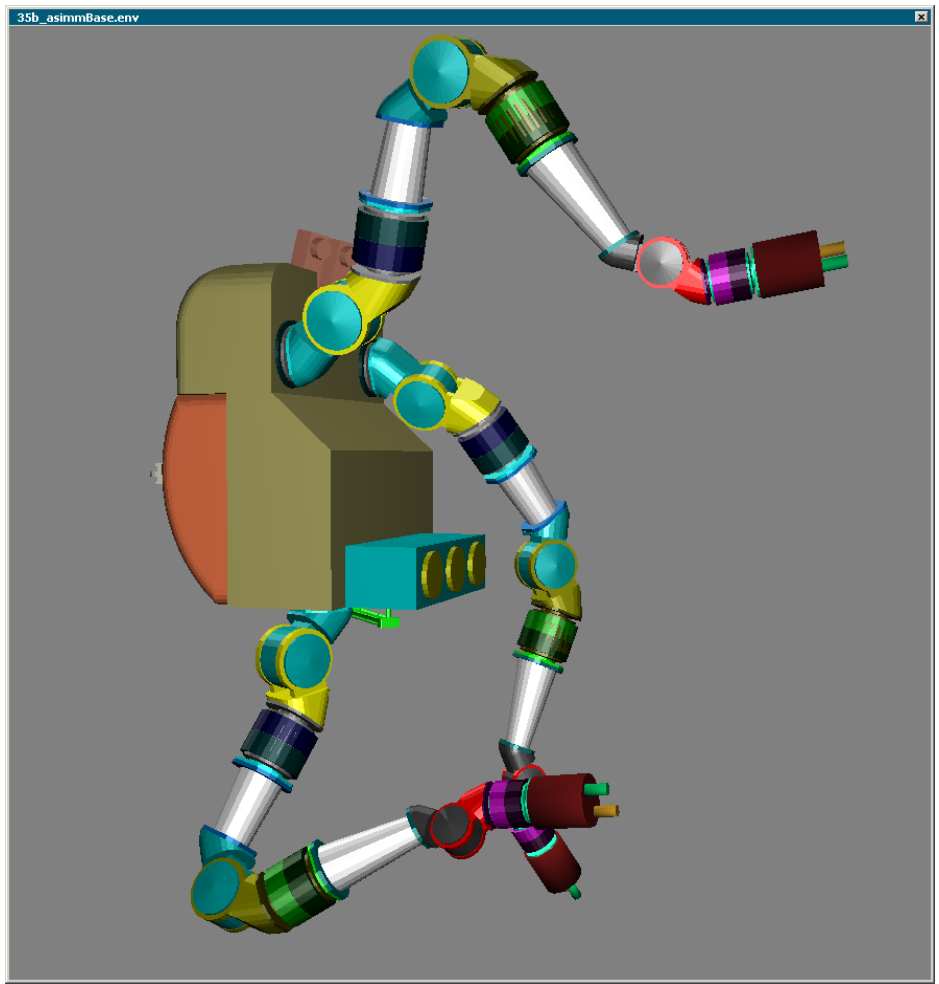
Configuration-4 Under Trade

- Identical arms of 1 meter each
- 1 stronger leg arm
- Each arm with 7 d.o.f
- 2 symmetrically mounted arms
- Same concept as –3- but different head and arms

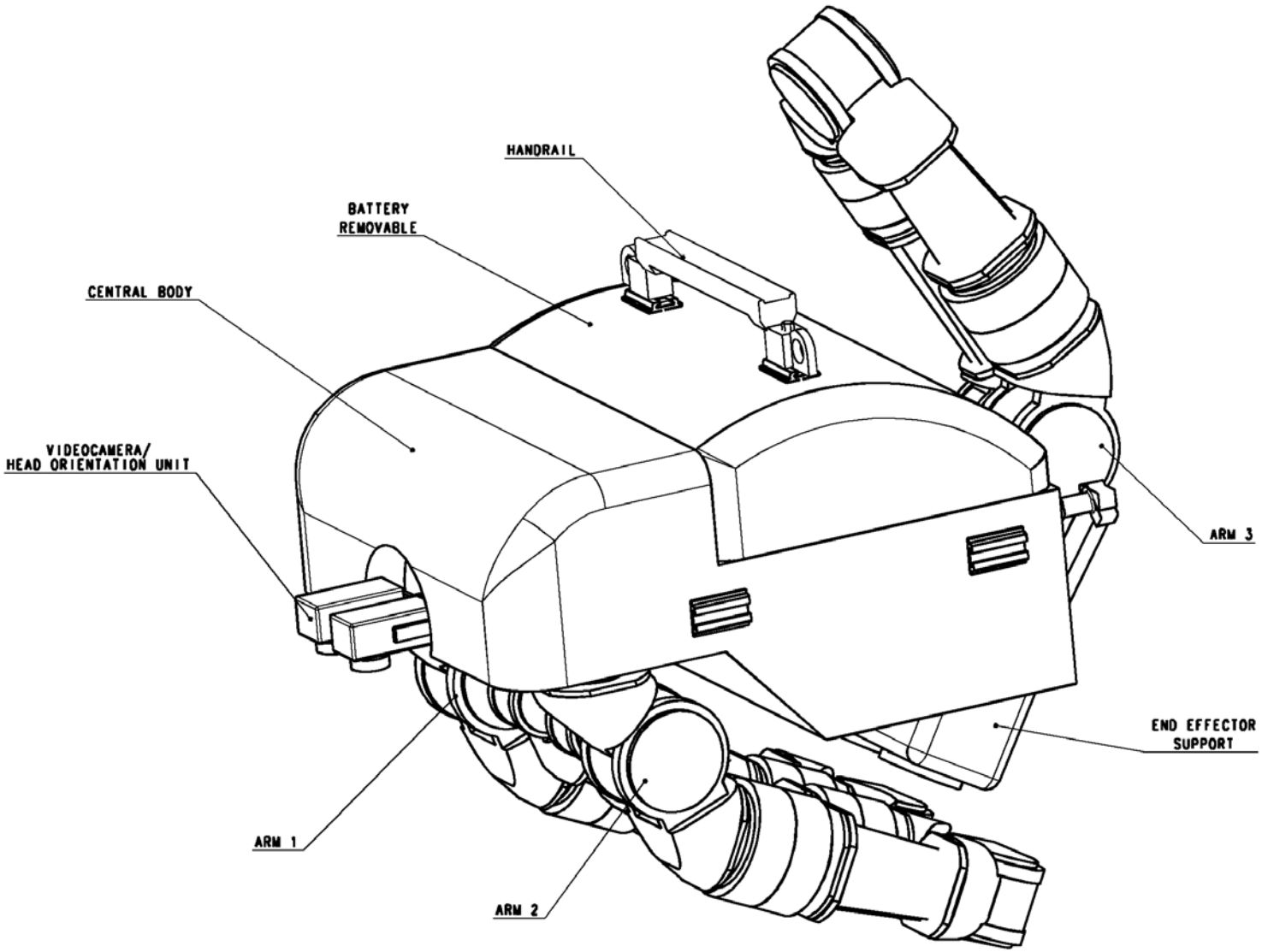


Configuration-5 Under Trade

- Identical arms of 1 meter each
- Each arm with 7 d.o.f
- 2 symmetrically mounted arms
- Camera on top
- End effector storage on “belly”
- Removable battery



Configuration-5 Under Trade



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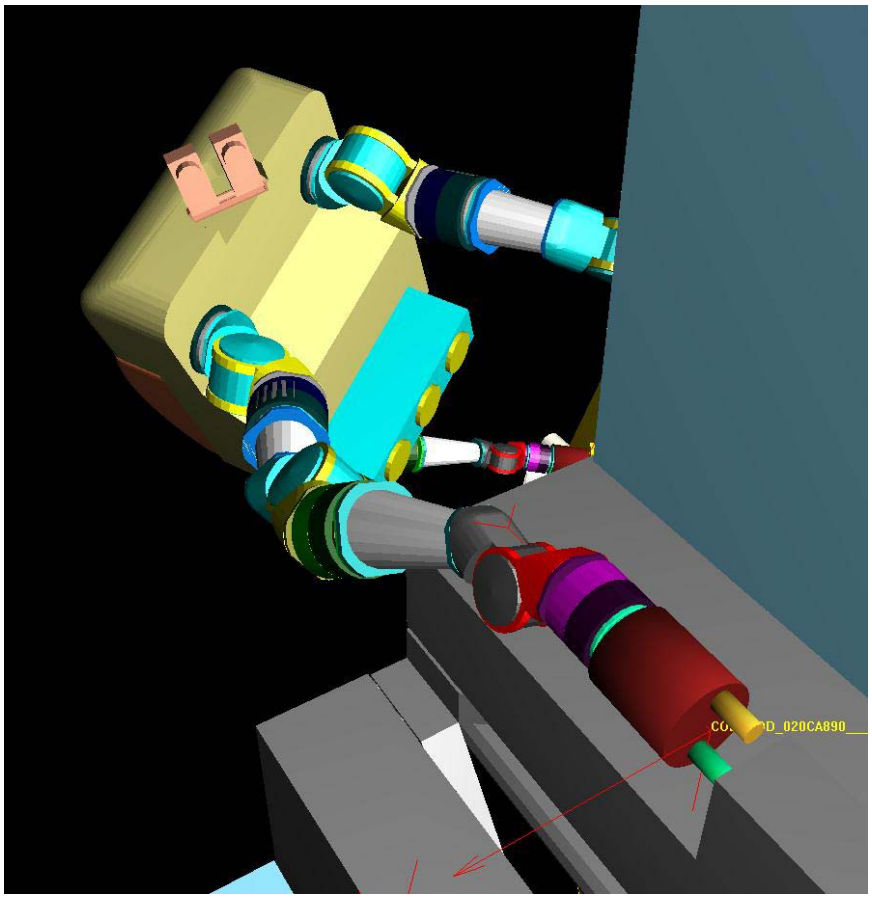
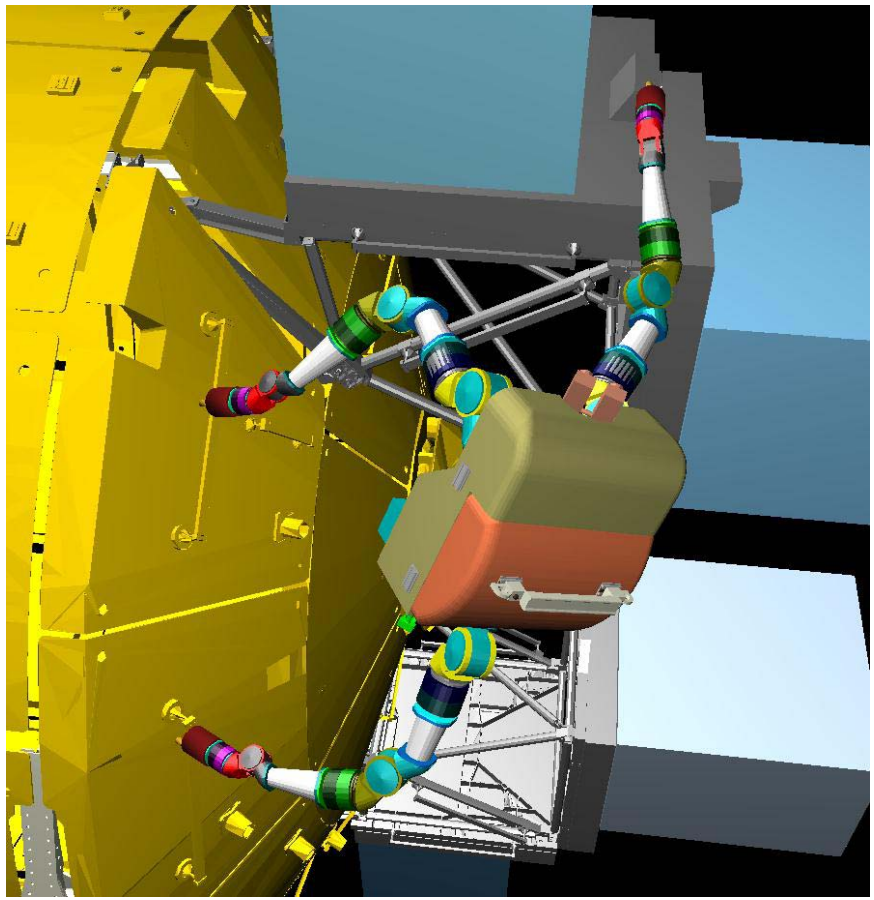
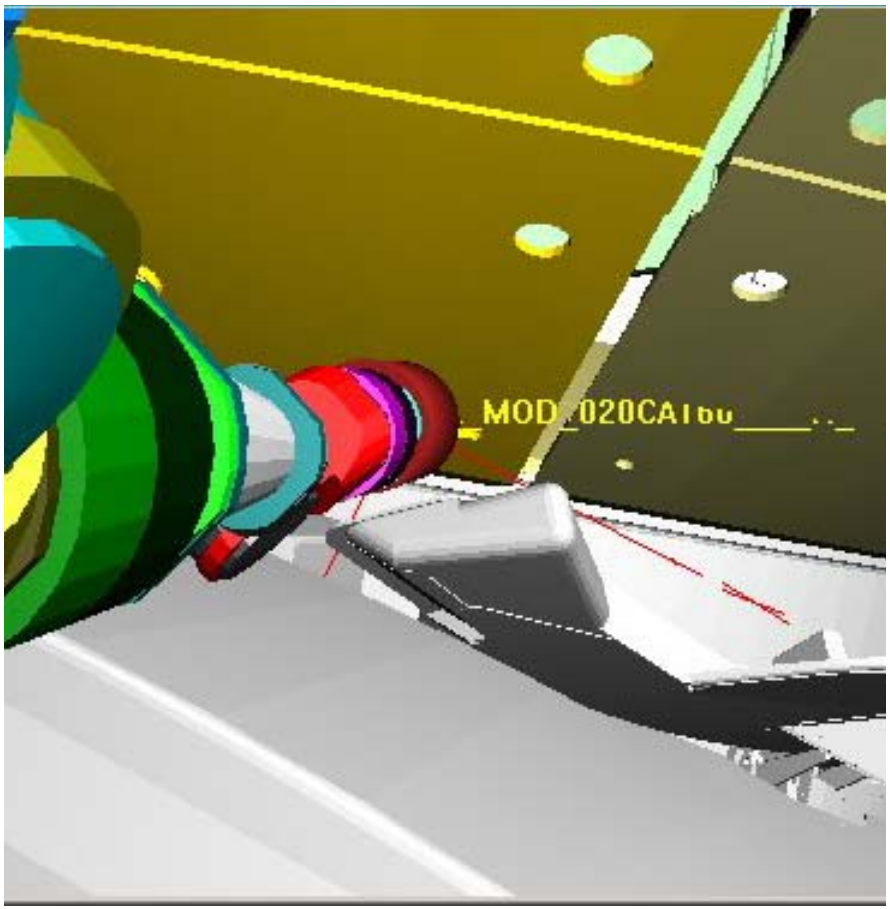
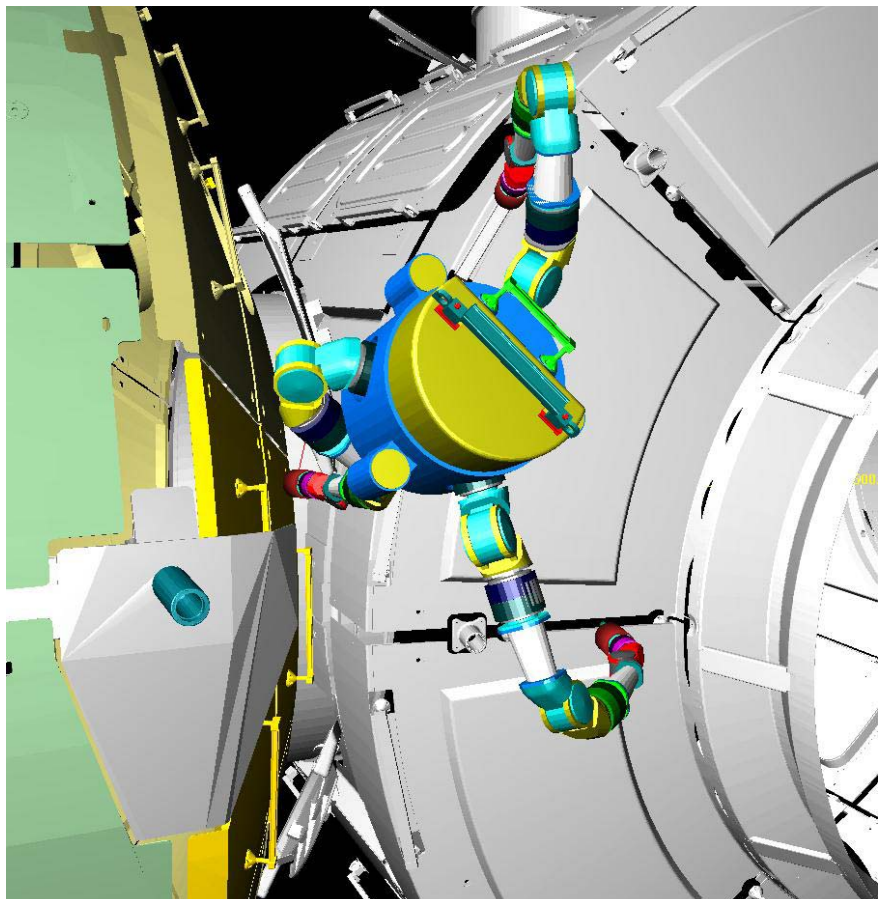
Configuration-5 at work on Columbus-EPF



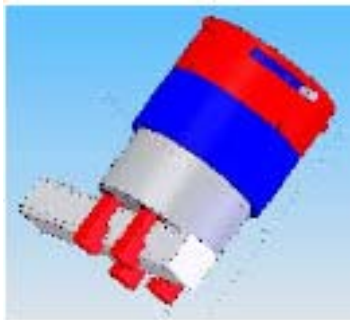


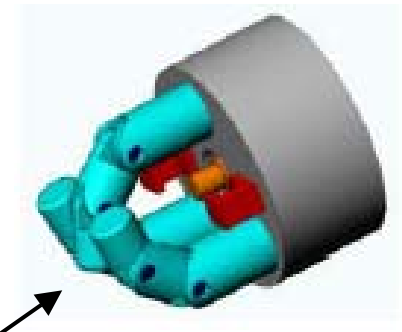
Stepping over Columbus-Node3



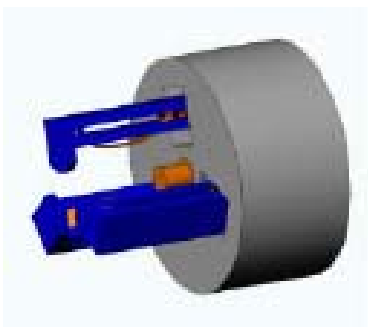


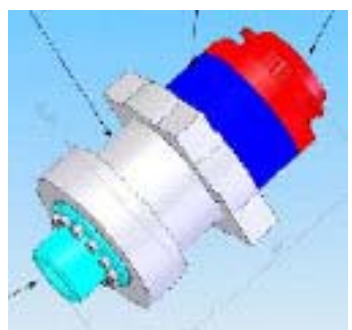
Tools Panoply



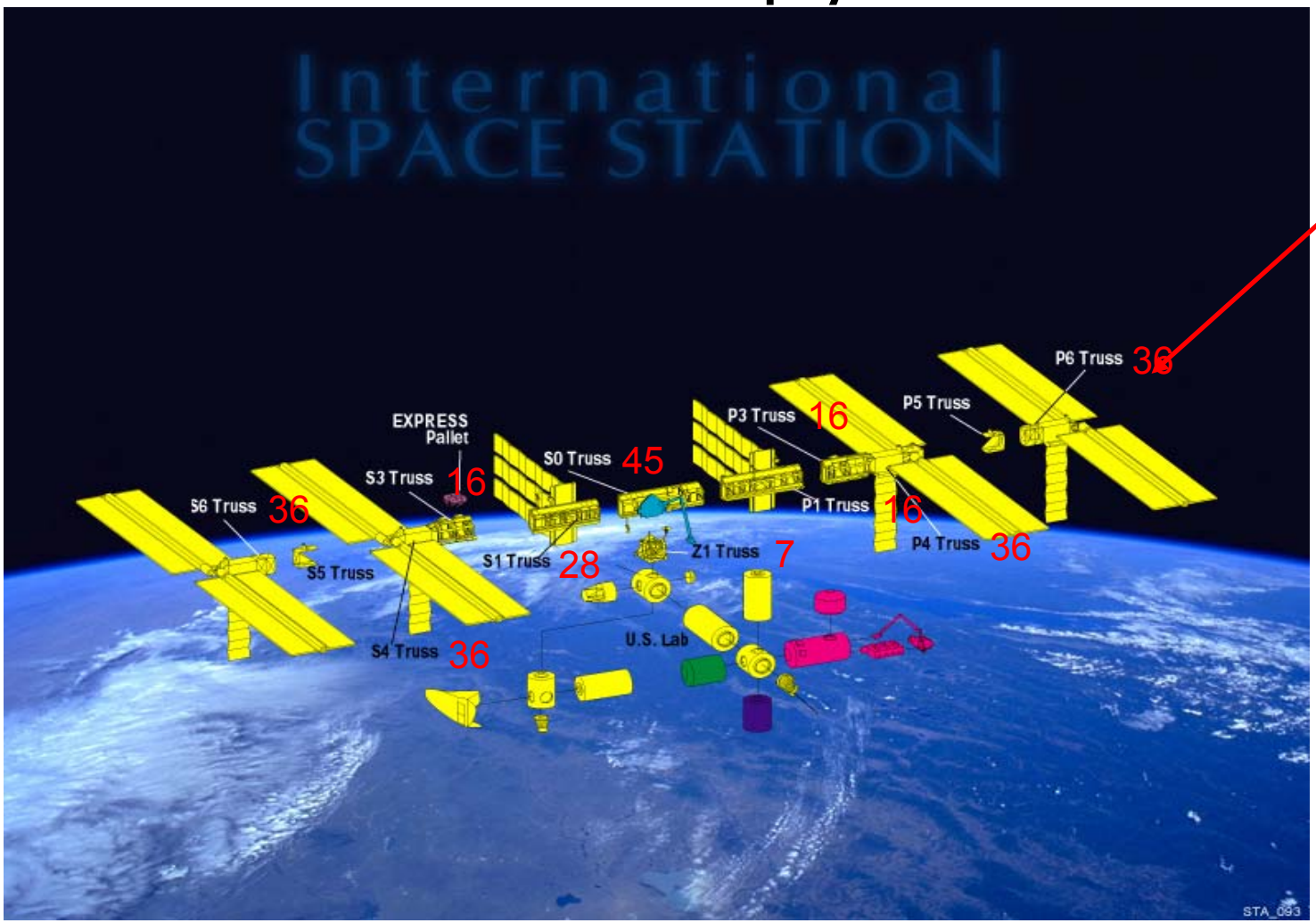


Hand-Rail End-Effector
Robotic I/F End-Effector
General Gripper End-Effector
Multi-Tool End-Effector
Specific Operation End-Effector



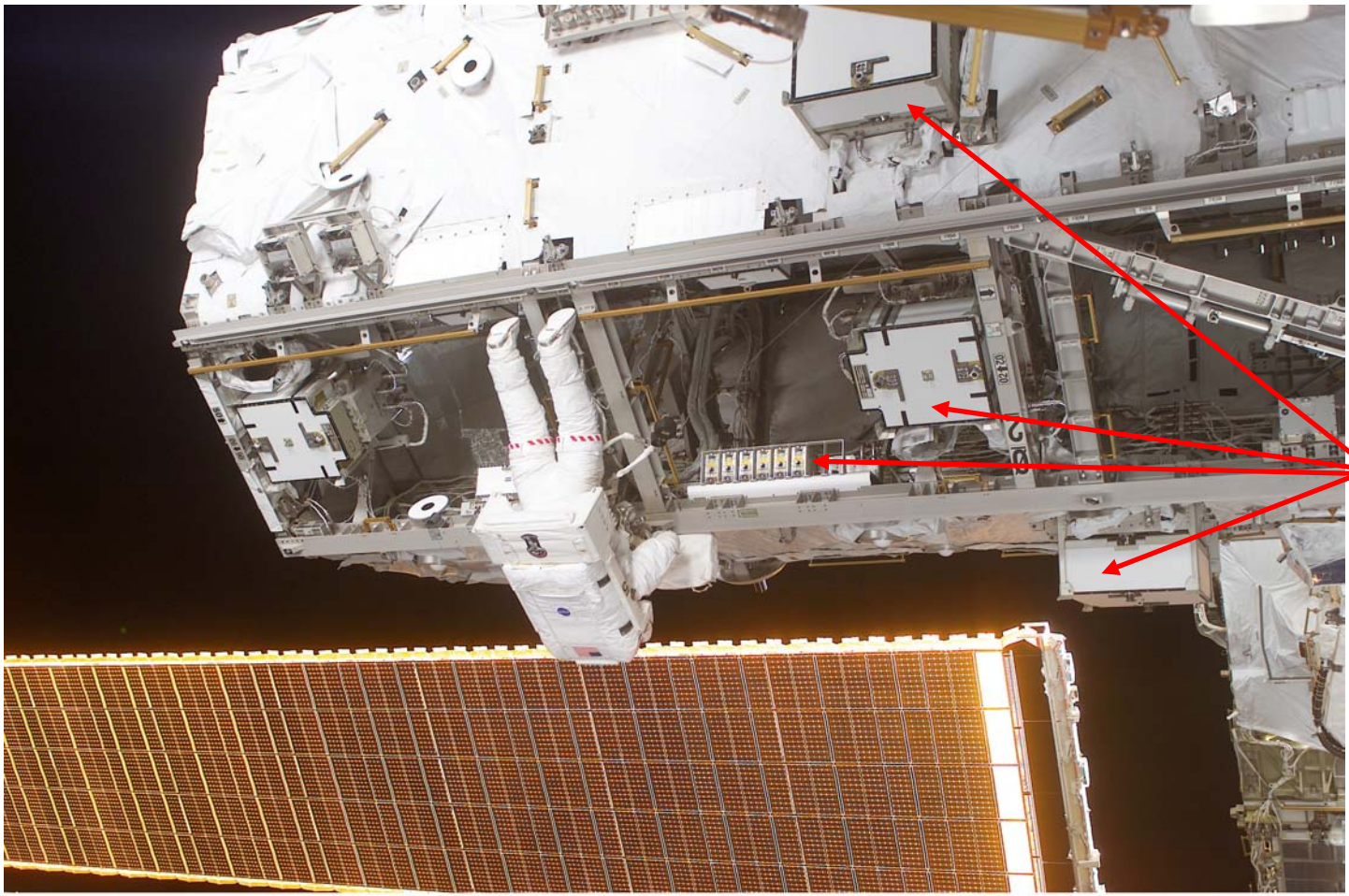


ORU Panoply in Brief

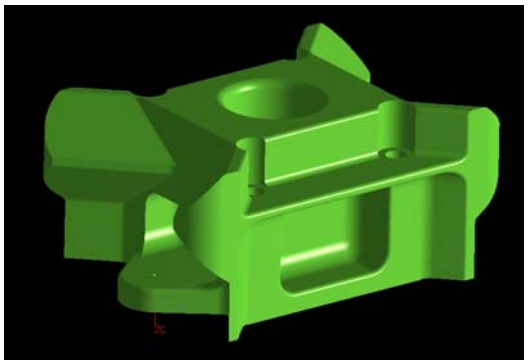


Example: US segment alone has large quantity of EVR ORUs (~300 already)

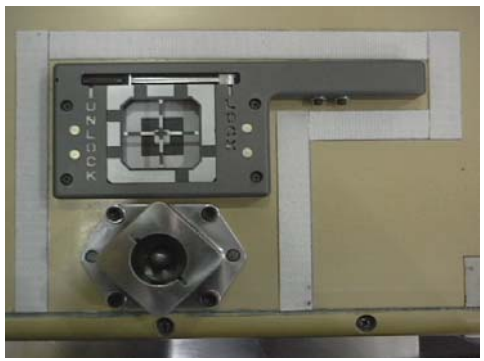
ORU Panoply: from Small (~1 kg) to Large (max 362 kg)



I/F Panoply



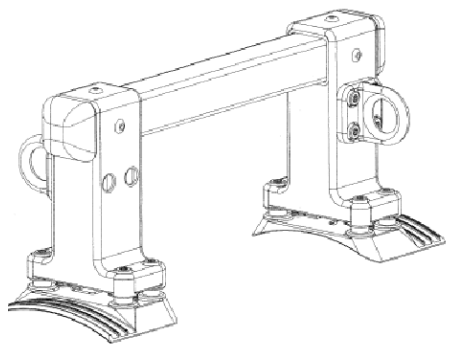
H-Fixture



Micro Square

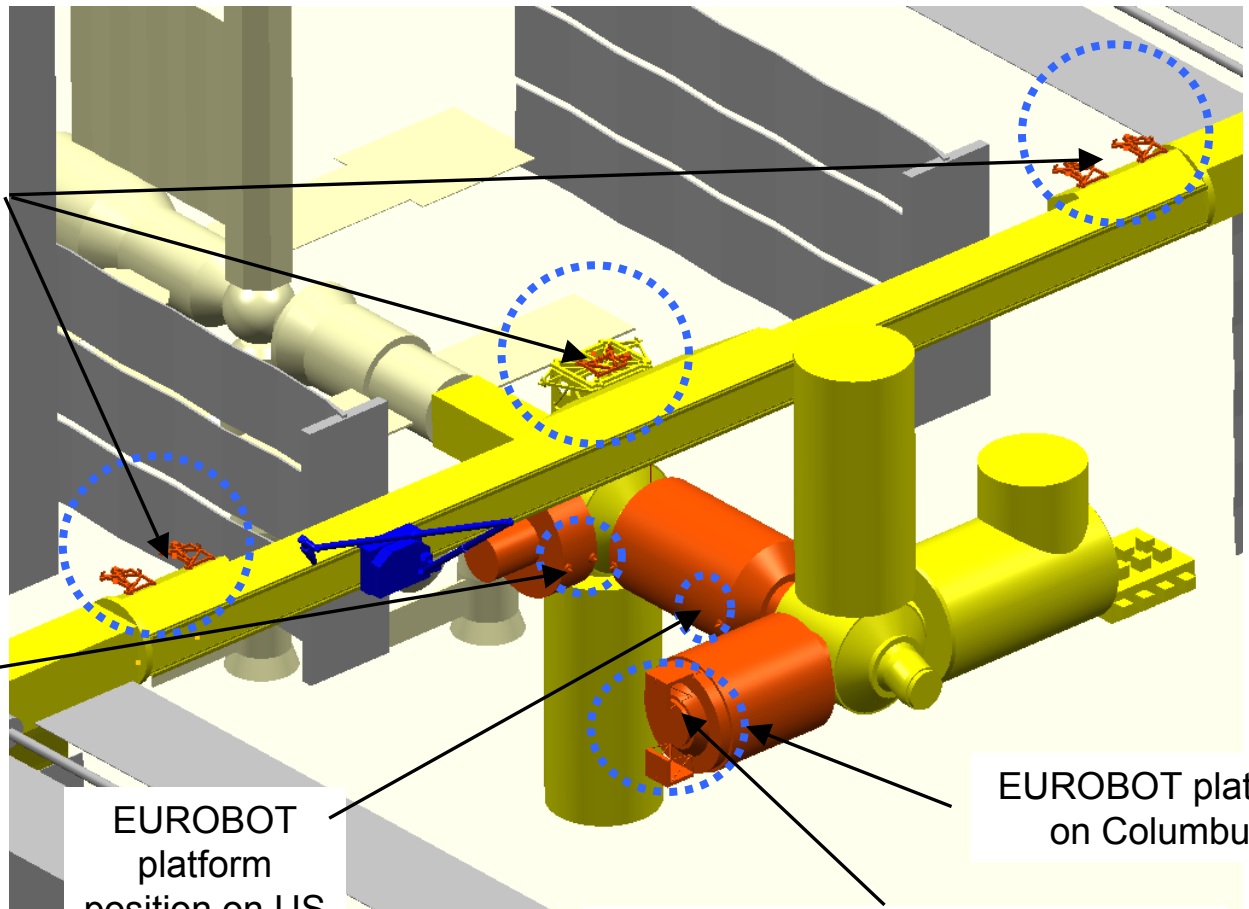
Micro Conical

US-Segment "Dog Bone"

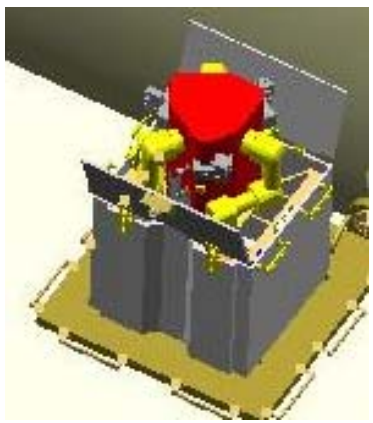


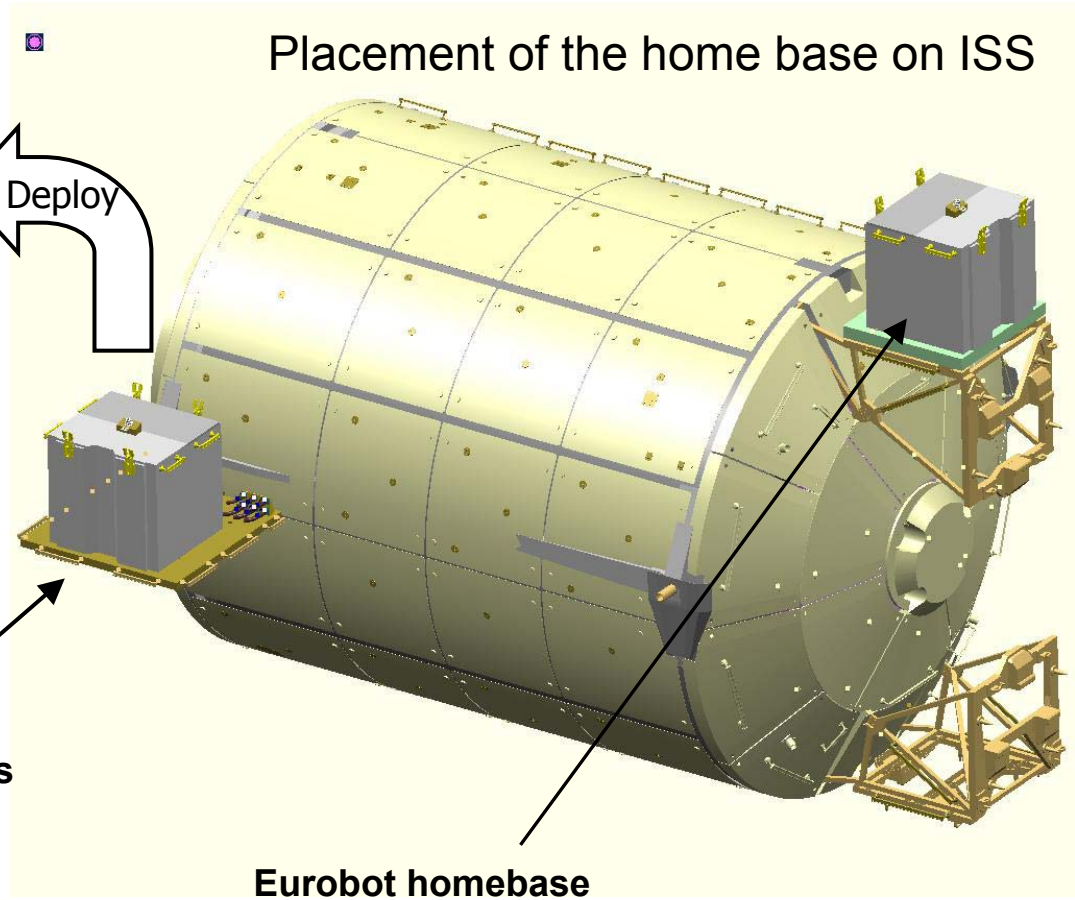
RS "Square"

Home Base Concept



Home Base Concept





Life After ISS …

- Humans will move beyond Earth orbit … back to the Moon & on to Mars
- Mobile **manipulator technologies** developed for EUROBOT project may be applied & developed further for Exploration programme
- Technologies used both in early robotic missions & later human missions
- Human missions may benefit from dedicated Mobile Manipulator System (MMS) in the role of EVA crew assistant

Manipulators in Space

Space Environment	Exploration Phase: Robotic Exploration	Human Arrival Imminent	Human Arrival	Long-Term Presence
Earth orbit	Test robotic/MMS technology & operations in LEO or on ISS	Test robotic/MMS technology & operations in LEO or on ISS	Use during potential on-orbit assembly of human mission modules	Use during potential on-orbit assembly of human mission modules
Interplanetary Space			Transfer vehicle maintenance; crew assistant	Transfer vehicle maintenance; crew assistant
Moon/Mars orbit	On MSR mission, use for sample handover from ascent vehicle to Earth-return vehicle	Maintenance of human mission modules sent in advance of human arrival	Orbit vehicle maintenance; crew assistant	Orbit vehicle maintenance; crew assistant

Manipulators on Moon/Mars Surface

Planetary Science	Site Scouting & Characterisation	Site Preparation & Infrastructure Deployment	Infrastructure Operation & Maintenance	EVA Support	IVA Support
Surface characterisation experiments	Imaging/mapping	Clearing landing site?	Operation & inspection of ISRU systems	Carry tools and hand them to astronauts	Routine greenhouse operations
Sample handling*	Travel to/through hostile terrain	Deployment of solar arrays	Inspection & monitoring of propellant & consumables storage tanks	"Eyes" for IVA astronaut	Process plants into ingredients
Imaging	Mobile "weather" station	Deployment & check-out of nuclear power systems	Inspection of nuclear facility	Emergency / back-up comms station	Telemedicine?
Astrobiology experiments (search for life)	Search for micro-climates, eg thru changes in volatiles	Deployment & check-out of ISRU units	Inspection of site damage after storm	Additional / mobile comms relay station	
Telescope/observatory operation	Determine present state, 3D distribution and cycling of water	Help make Lunar/Martian concrete/cement	NDI (Non-destructive Inspection) type testing of structures	Sample handling*	
Characterise surface-atmosphere interactions	Sample handling		Maintenance of solar arrays (eg wrt dust etc)	Robotic cameraman / journalist	
Determine pr regolith forma subsequent v Determine pr controlling dis dust, water, C determining l term events				Mobile computer / reference manual	
				"Record" EVA sessions ("diary-keeper")	
				Deployable navigation aid / emergency beacon	
				Additional/emergency lighting	
	(eg boundary layer) Determine electrical effects of atmosphere (Mars)			"Fetch & carry"	
				Emergency re-charge station for PLSS?	

Required Capabilities:
Instrument deployment & positioning
Soil manipulation
Science sample handling (acquiring, transferring, delivering & analysing)
Object & parts handling
Mechanism actuation
Tools handling and manipulation
Imaging
"Interface with surface systems, payloads & crew"

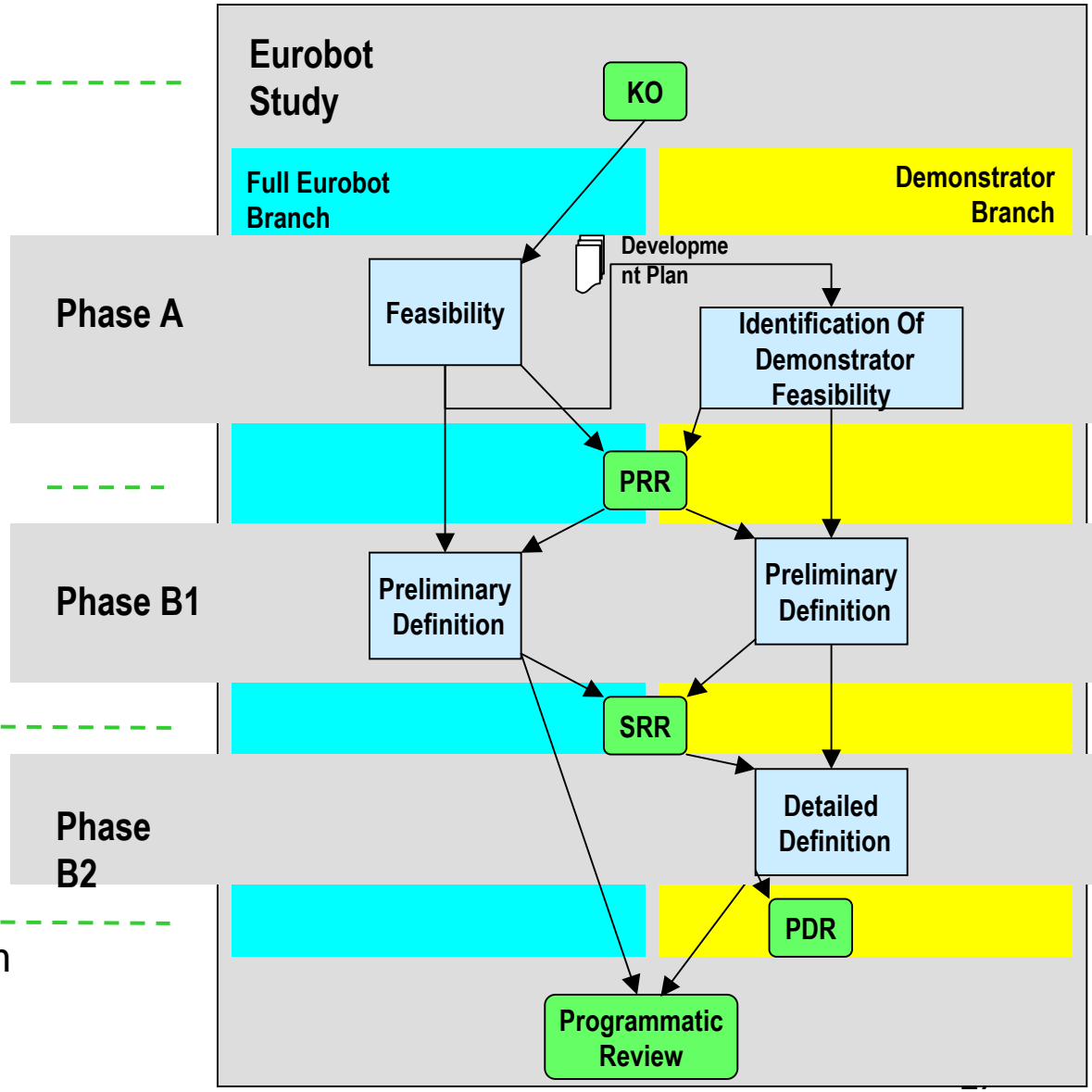
KO : April 04

PRR/dPRR: Mid Nov 04

SRR: Feb 2005

PDR: Jun 2005

PR: Jun 2005 input for C/Min



Conclusion

Eurobot presents a robotic solution to problems of EVA crew availability and hostile environments

ESA robotics studies harmonised to focus in same direction (arm/leg, hand, teleops, MMI)

Study aimed at getting a flight demonstrator on ISS before end of this decade