IV&V of the Canadian-provided International Space Station Mobile Servicing System (MSS) Displays

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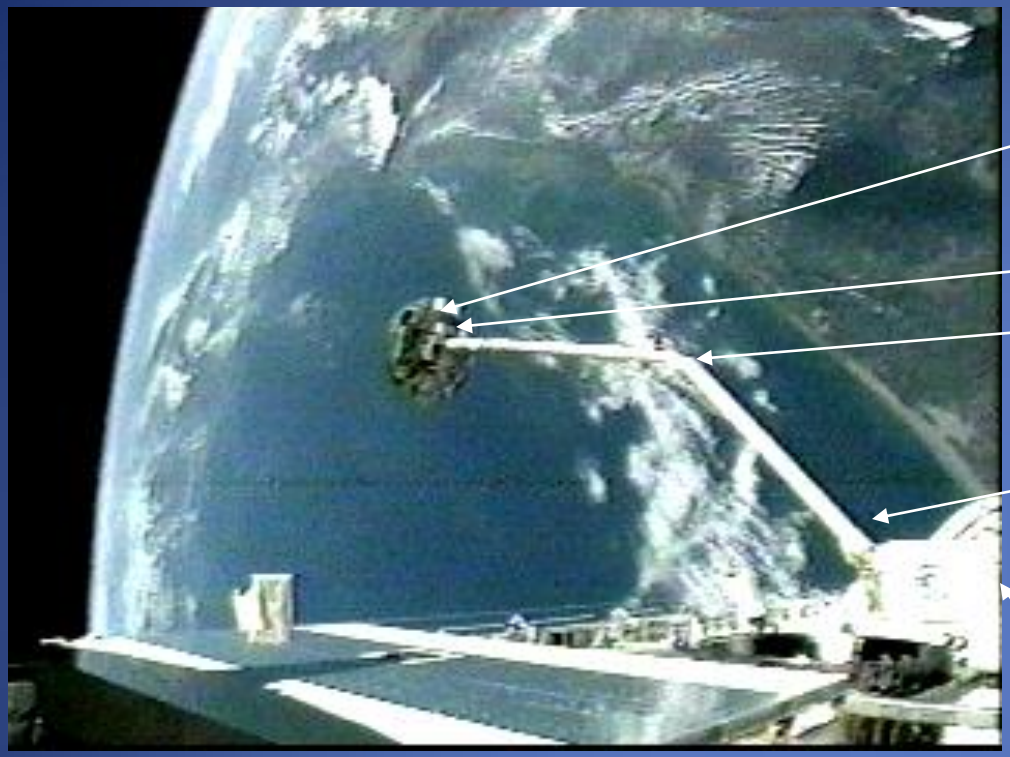
The Heritage of the Space Shuttle Remote Manipulator System

In the 1970's, NASA contracted with SPAR, in Brampton, Ontario, for the development of a payload deployment system for the Shuttle.

The highly successful Remote Manipulator System resulted.

SPAR was bought by McDonald-Detweiler Robotics, which later became MD Robotics.

Shuttle Remote Manipulator System

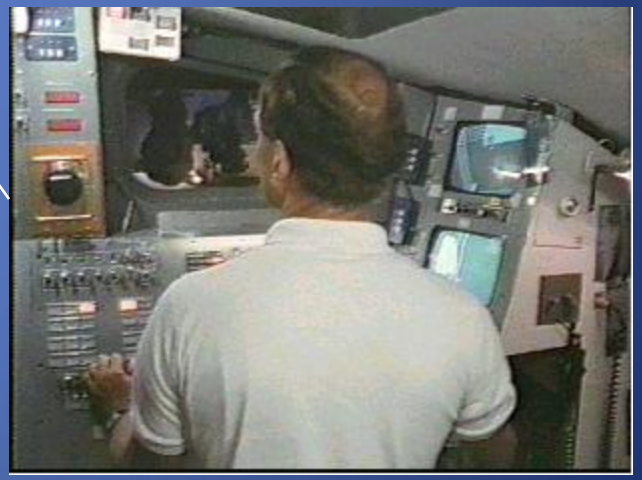


Payload on
End Effector

Wrist (3 DOF)
Elbow (1 DOF)

Shoulder (2 DOF)

The RMS is 50 feet long
Weighs 1,000 pounds
and can move 150,000 pound payloads.



Astronaut operating the RMS from the aft Flight Deck

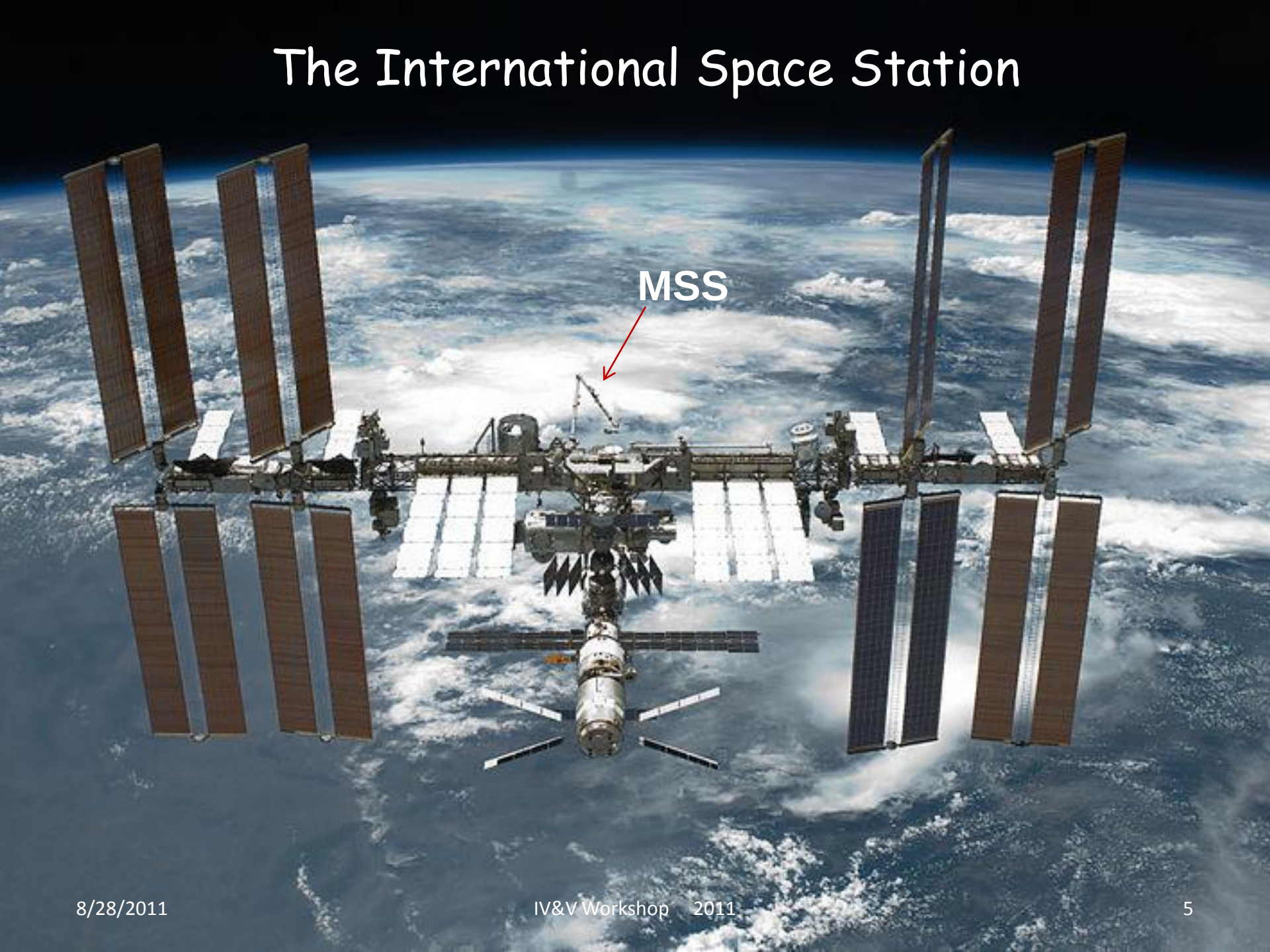
RMS control modes include hard wired and computer-augmented.

Partner nations of the International Space Station contribute services in return for access or other services onboard the ISS.

Canada provided the Mobile Servicing System to the ISS as its contribution.

As a second generation robot with capabilities exceeding that of the Shuttle RMS, the MSS set the standard for robotics for human spaceflight.

The International Space Station

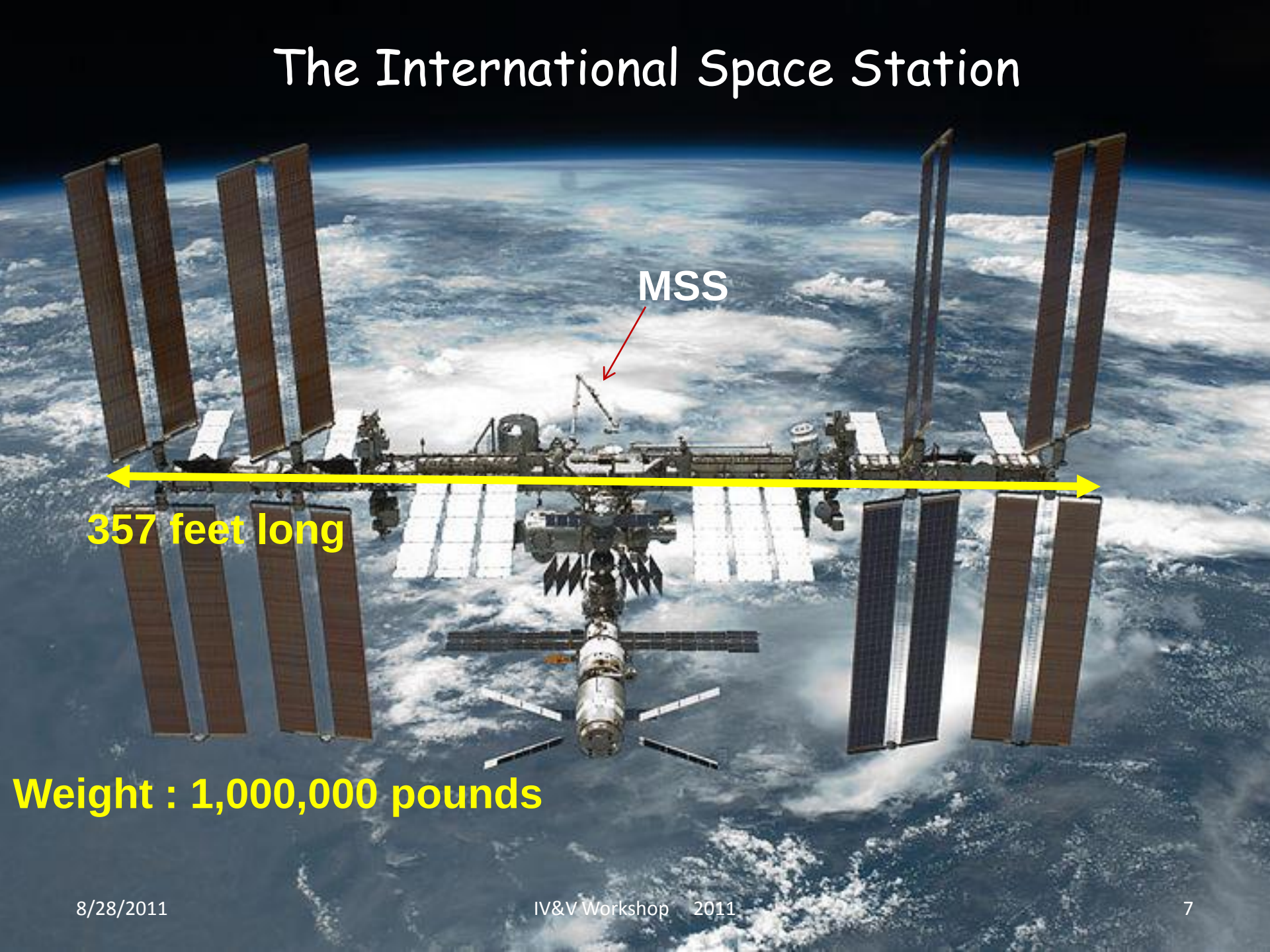


The MSS provides transportation, power, and data connectivity of ISS components, equipment, and EVA astronauts for assembly and maintenance.

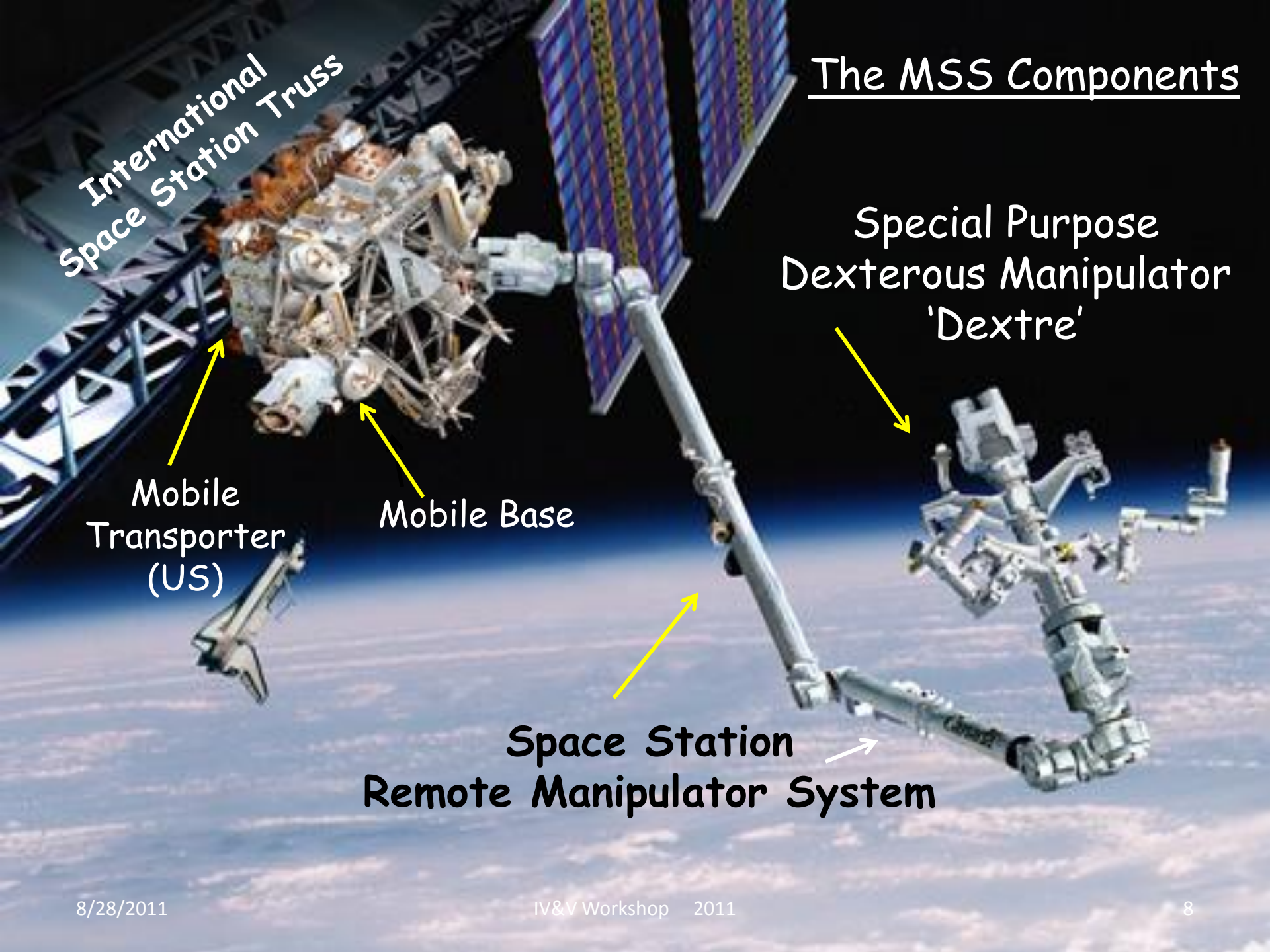
(2001) SSRMS –Space Station Remote Manipulator System
(2002) MBS – Mobile Base System
(2002) MT -- Mobile Transporter (US provided)
→ these contributed pivotally to assembly of the ISS:
100 EVAs 43 shuttle payloads 20 assembly operations
10 logistics ops & captured two free-flying spacecraft H-II

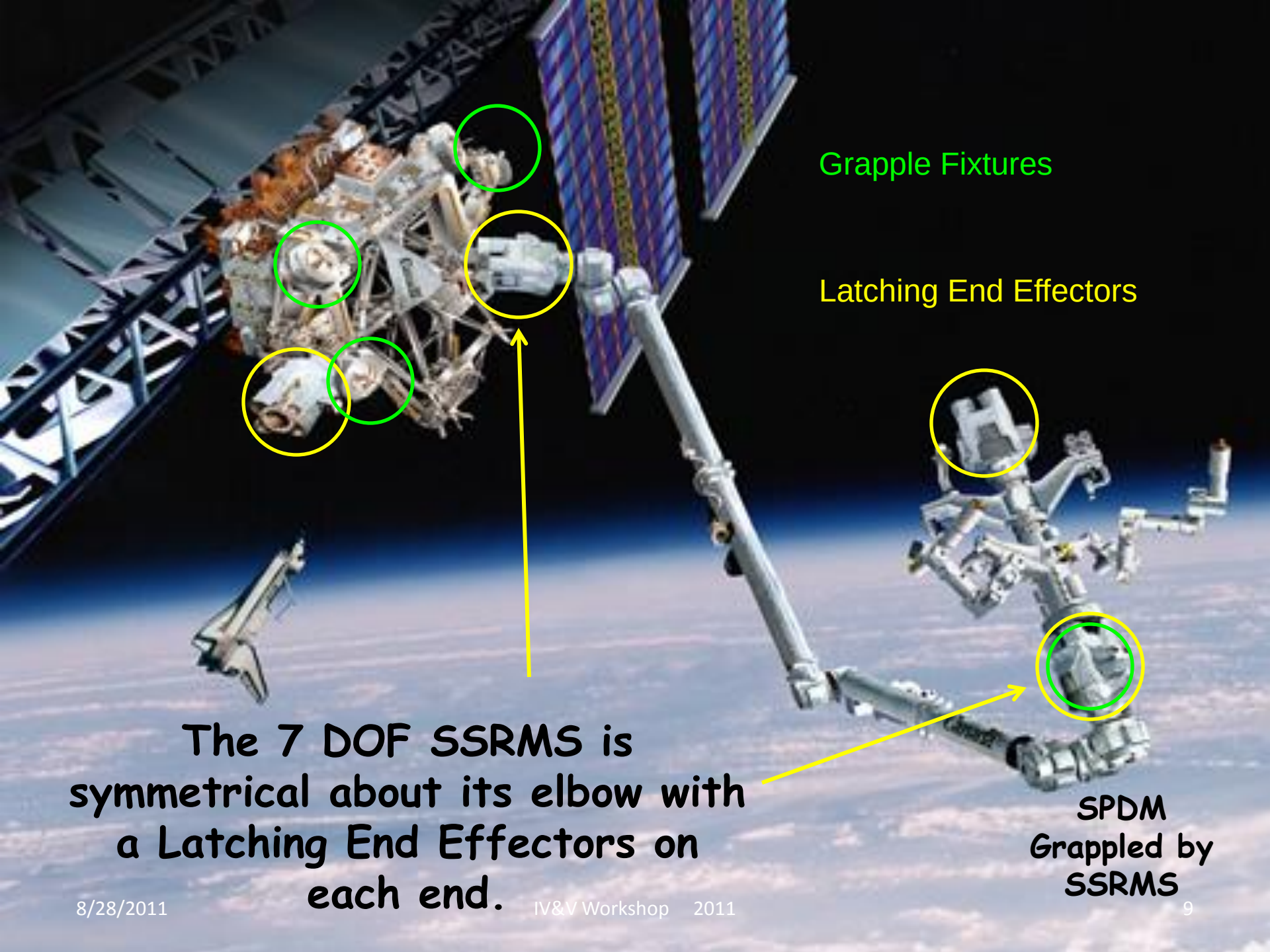
(2010) SPDM -- Special Purpose Dexterous Manipulator
→ performs 'EVR' maintenance—the robotic approximation of astronaut EVA

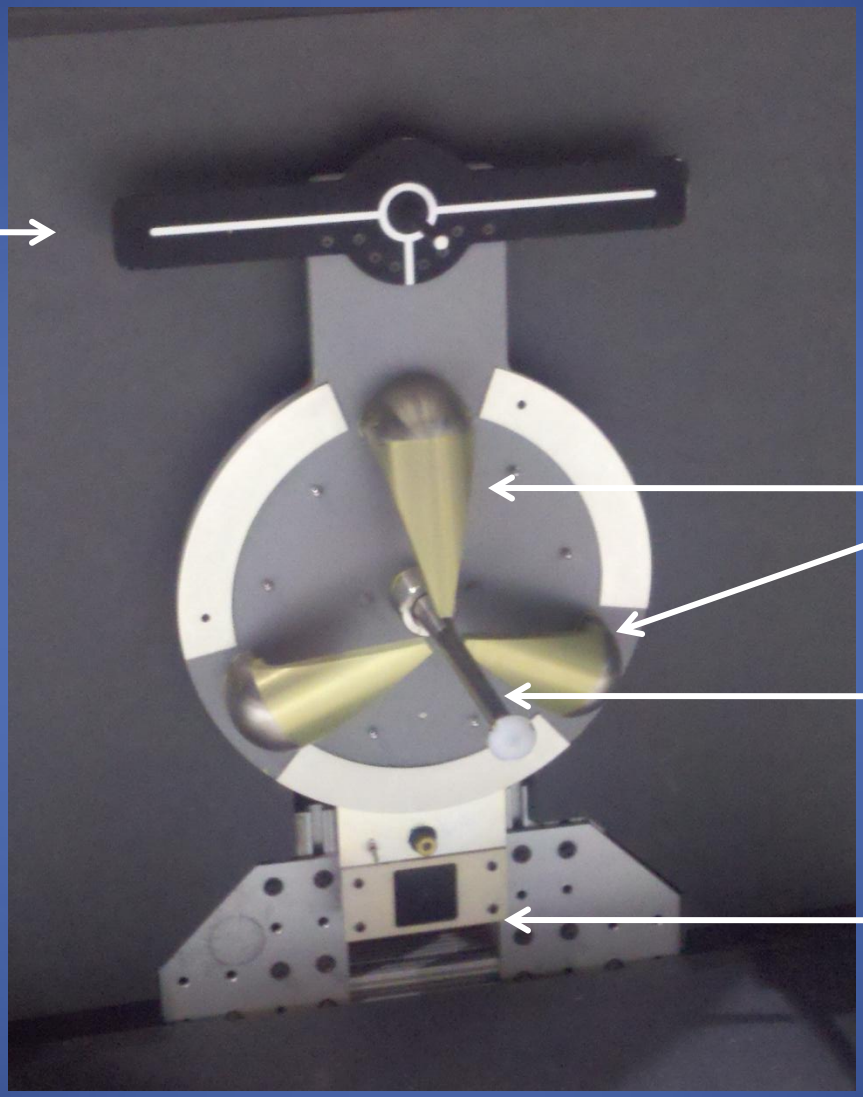
The International Space Station



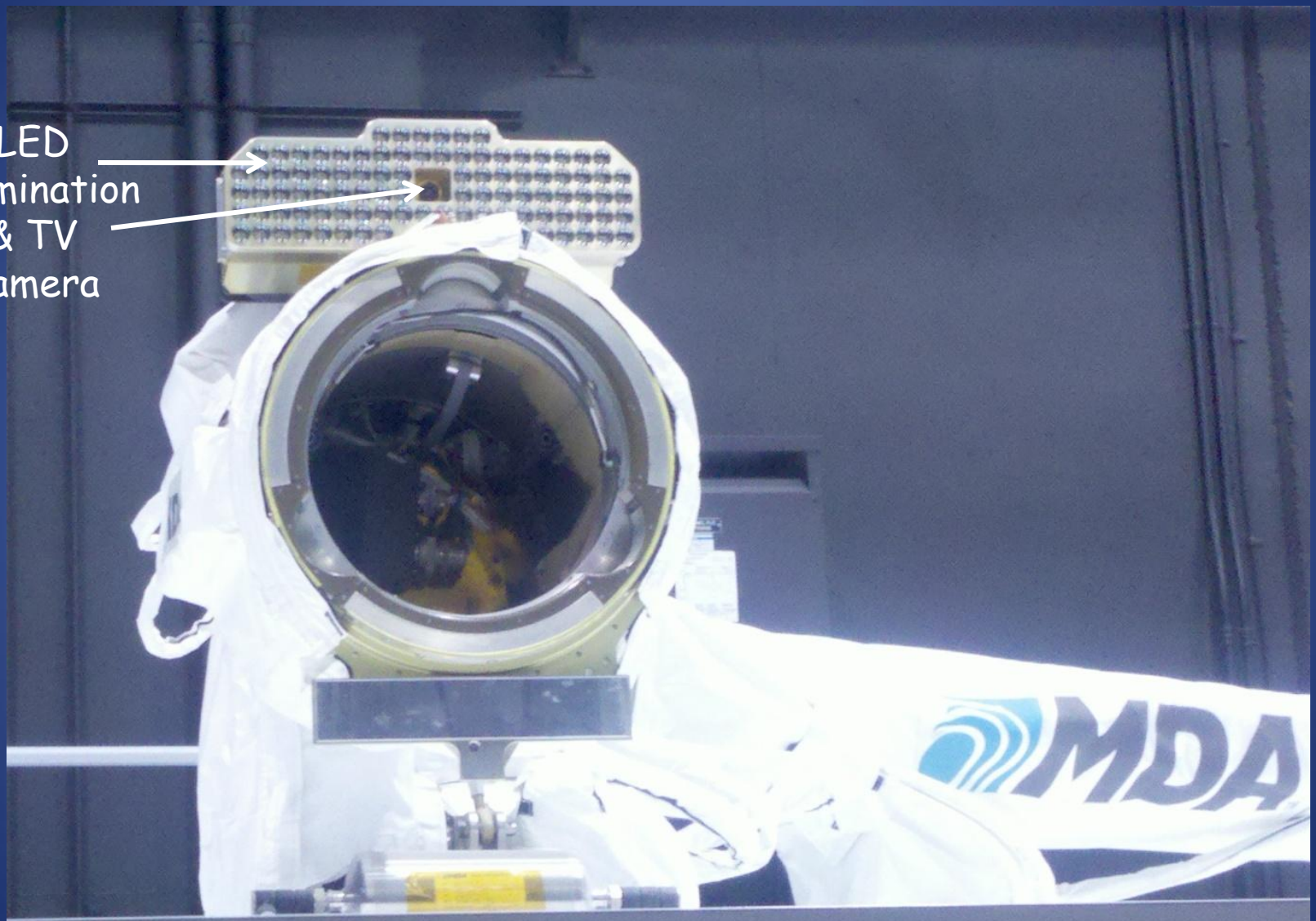
The MSS Components



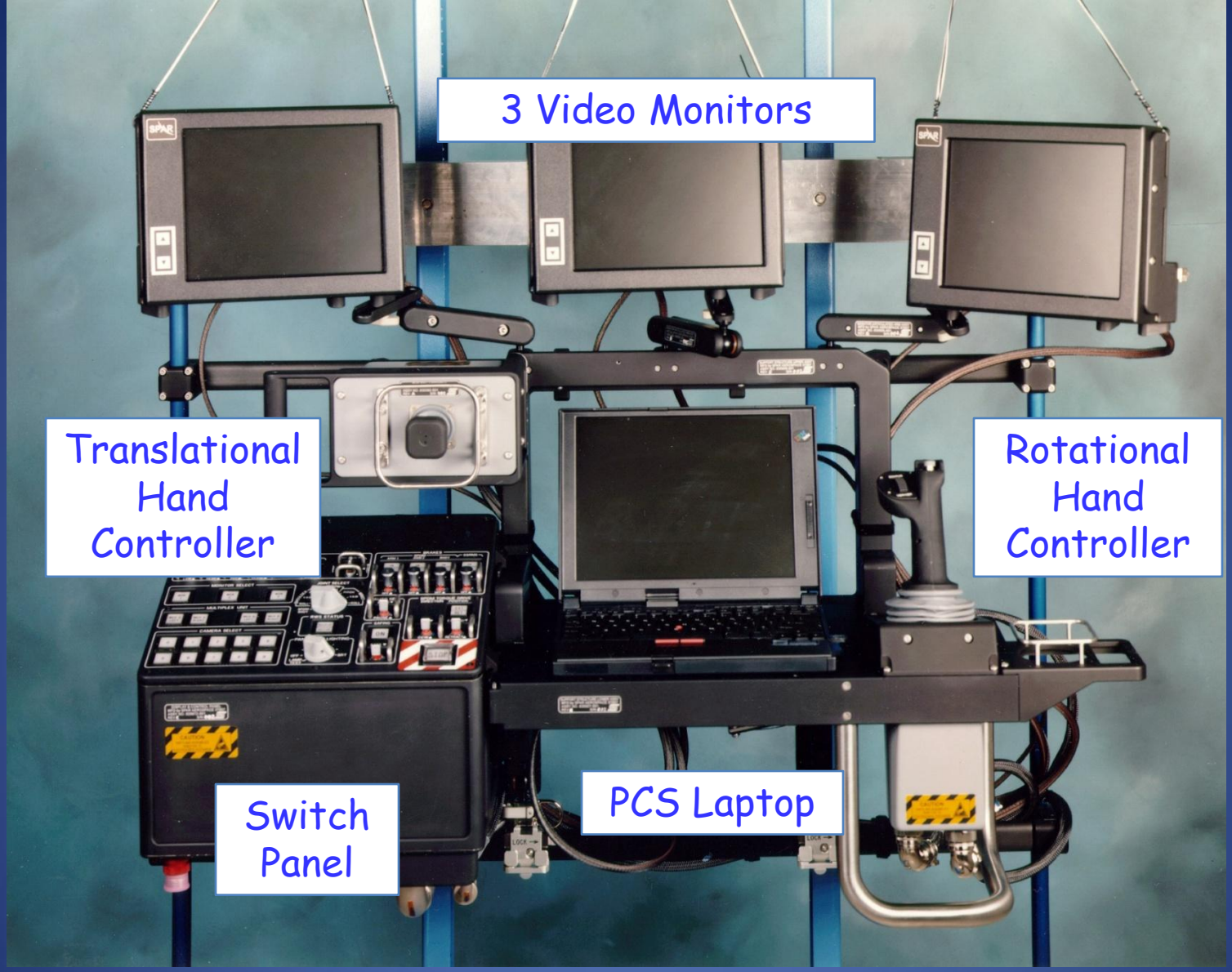

Grapple Fixtures
Latching End Effectors
The 7 DOF SSRMS is symmetrical about its elbow with a Latching End Effectors on each end.
SPDM Grappled by SSRMS



ISS MSS Power Data Grapple Fixture Ground Mockup



ISS SSRMS End Effector Ground Mockup



ISS Robotic Work Station is used to control the MSS over the ISS data network.
The MSS can also be controlled from the ground.

Canadian Astronaut Julie Payette operating the ISS Robotic Work Station in a ground laboratory.

US Astronaut Leroy Chou operating the Robotic Work Station onboard the ISS.

Pause for Insight

Safety for astronauts & spacecraft dictates very careful mission planning of all paths of movement of a manipulator and its payload.

This is typically begun with kinematic analysis of the manipulator and its workspace configuration using high definition computer graphics models.

These procedures are refined through the use of dynamic engineering simulations.

Flight procedures are wrung out in Systems Test Facilities & Crew Trainers such as full cockpit Simulators, Neutral Buoyancy, and Virtual Reality immersion trainers.

Post flight crew debriefs provide feedback on process.

All MSS software was developed by Canada with no NASA IV&V performed until 2008, when 3 displays requirements documents (~3,000 pages total) for the MSS were transferred to NASA responsibility.

IV&V reviews all changes to the 3 documents.

- Software Change Requests
- Redlines to the documents

IV&V also supports reviews of

- Unit Tests of the changes,
- Formal Qualification Testing (FQT)
- Change request prioritization for the Portable Computing System software builds

Requirements Change Drivers:

- Functional Errors
- ISS Configuration Changes
- Planned Improvements
- Documentation Updates

Nature of Issues Found IV&V:

- Text 'typos' & contextual content
- Incomplete or incorrect graphic figures
- Missing footnotes, & graphic figures
- Non-deleted requirements, figures, & footnotes
- Incorrect expected test values

MSS displays are in the Portable Computing System (PCS).

Currently consist of 382 windows

Each window has textual and graphic requirements for

Function &

Size, colors, text and icon format, and screen locations for

- Labels
- Graphic figures
- Status data fields
- Command buttons
- Navigation buttons (to & from other windows).

Each window has tabular specs for context of all

- Status data
- Command signals

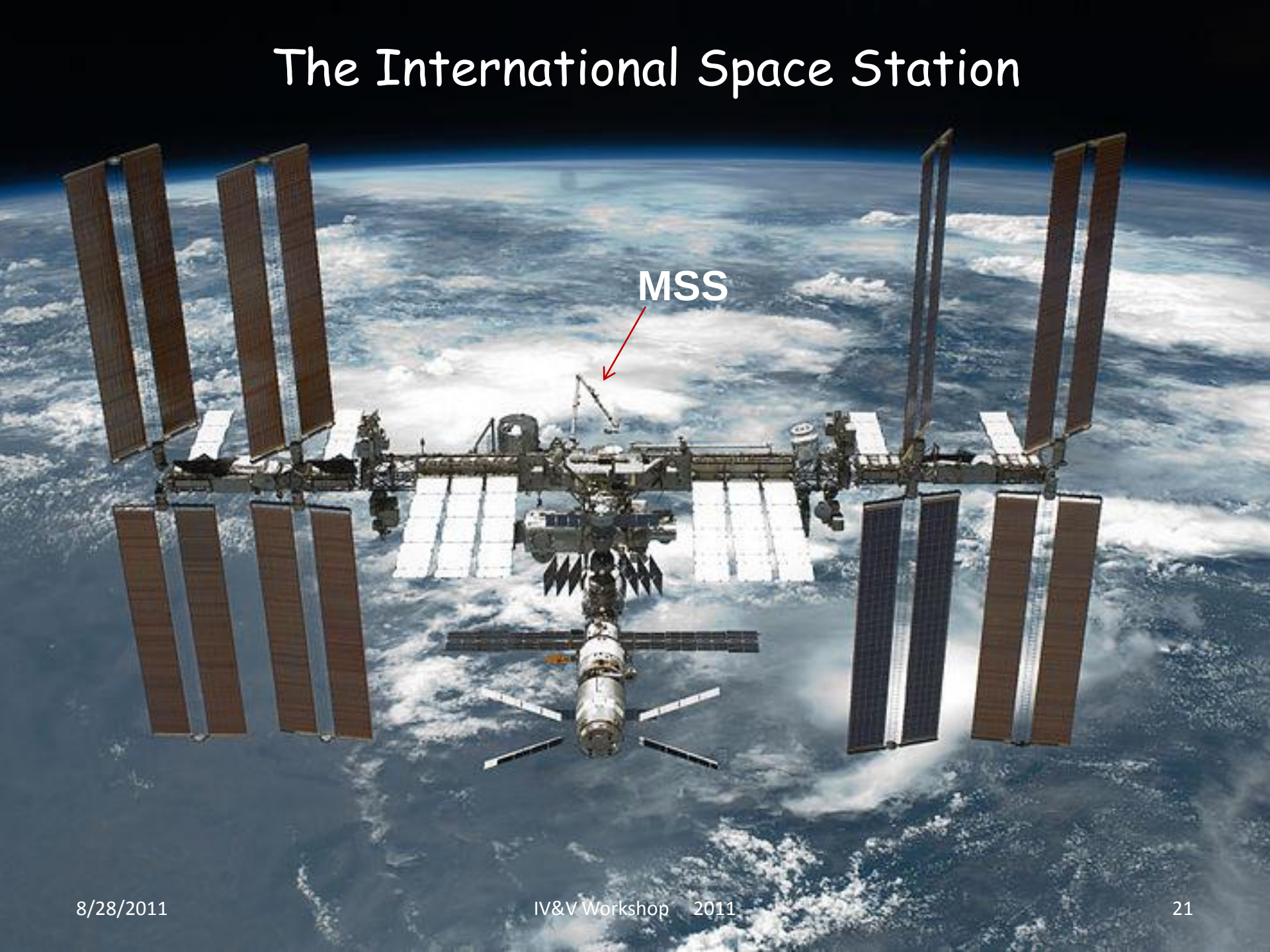
(Each of which has a unique identification number.)

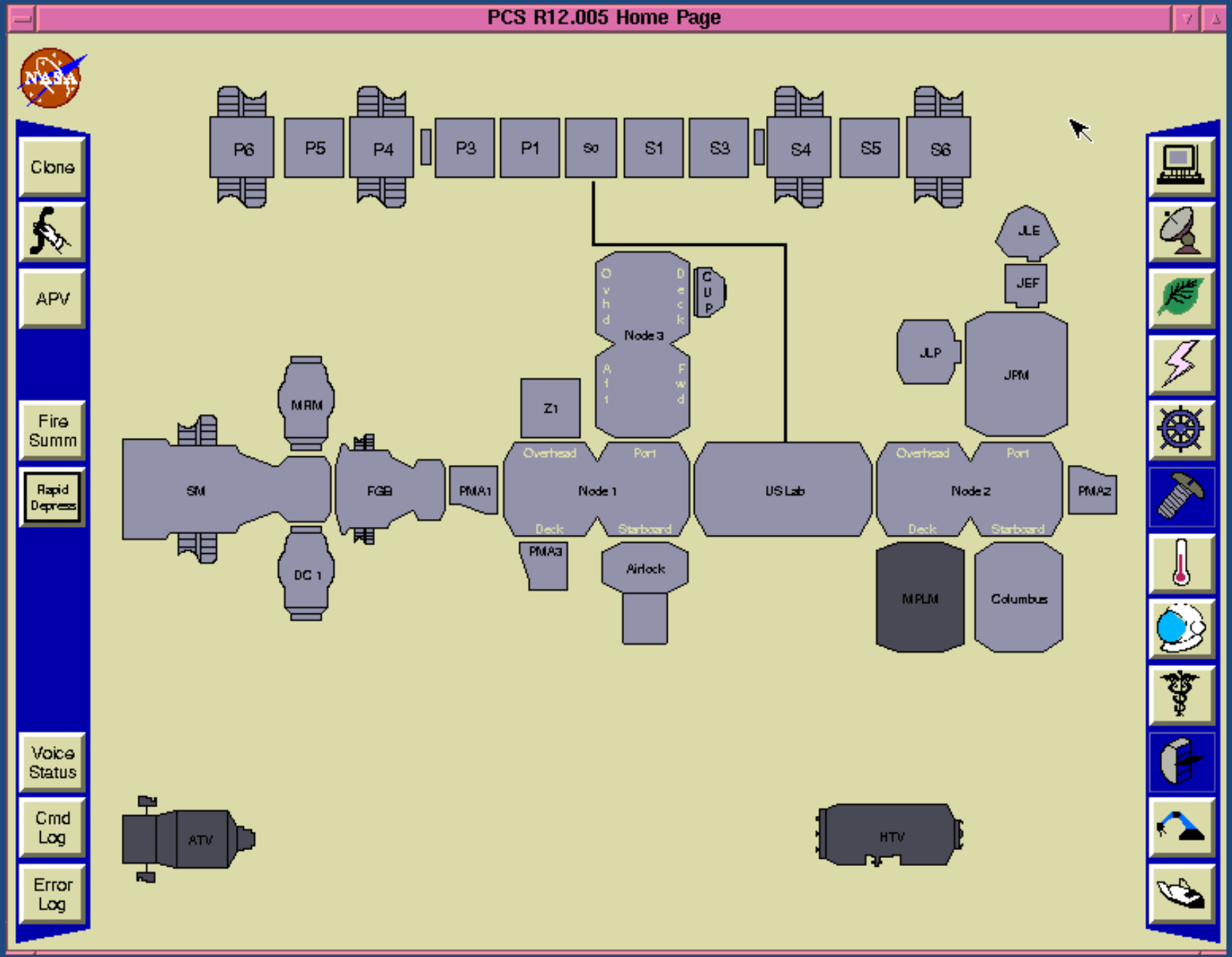
The MSS Displays & Parameters Summary

	Display Pages	Status Data	Command Signals	Total Parameters
MT/MBS	79	486	1221	1707
SSRMS	121	1751	2535	4286
SPDM	182	n/a	n/a	n/a

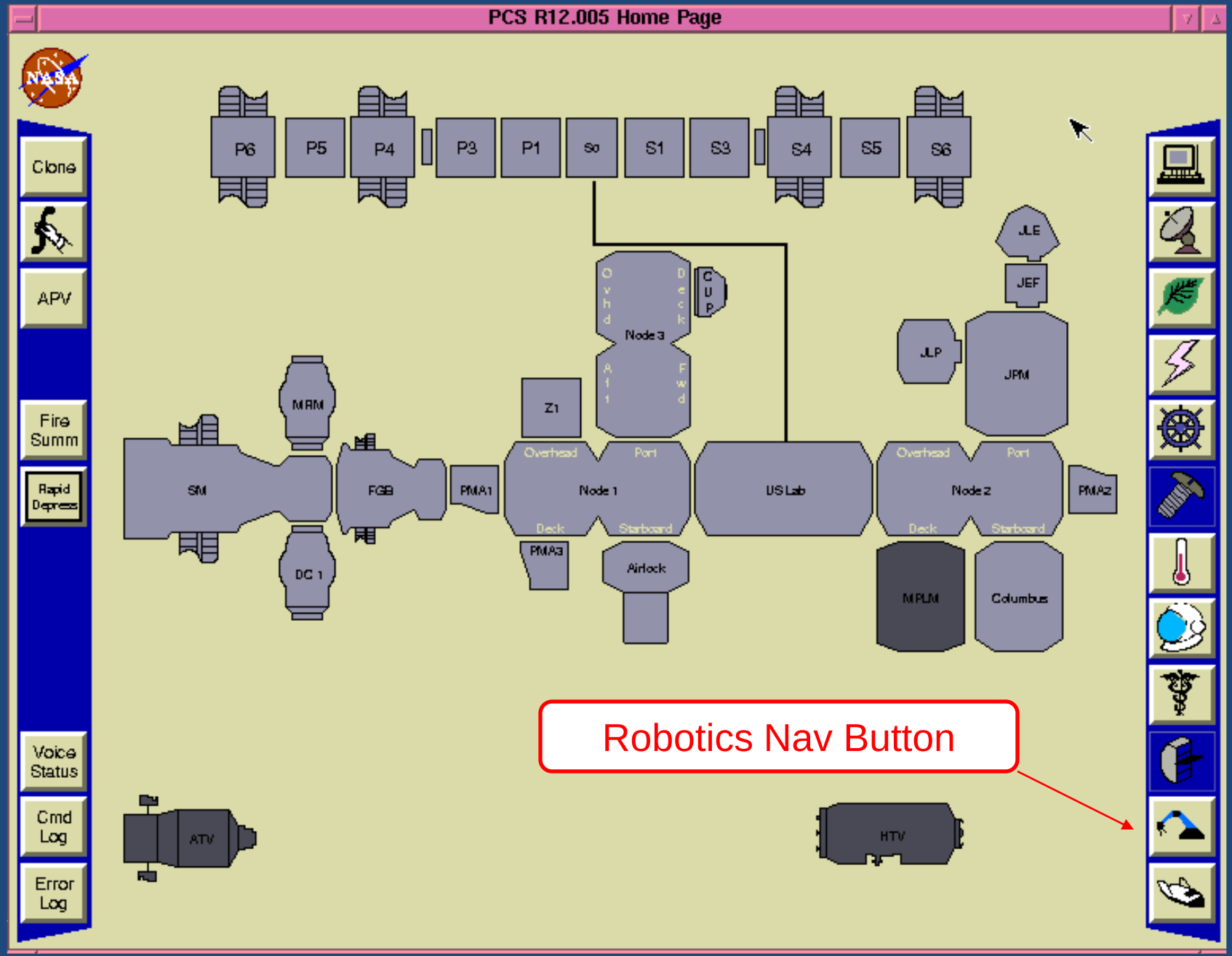
ISS MSS SCRs Reviewed by IV&V (issues reported)	2008	2009	2010	2011
MT		3 (3)		1
MBS	2	2 (2)		
SSRMS		13 (4)	9 (1)	18
SPDM		11 (7)	1	2
Totals 62 (17)	2	29 (16)	10 (1)	21
Unit Tests			7 (3)	2
Formal Qualification Tests			6	6
Build Prioritizations				12
Totals 33 (3)	0	0	13 (3)	20

The International Space Station

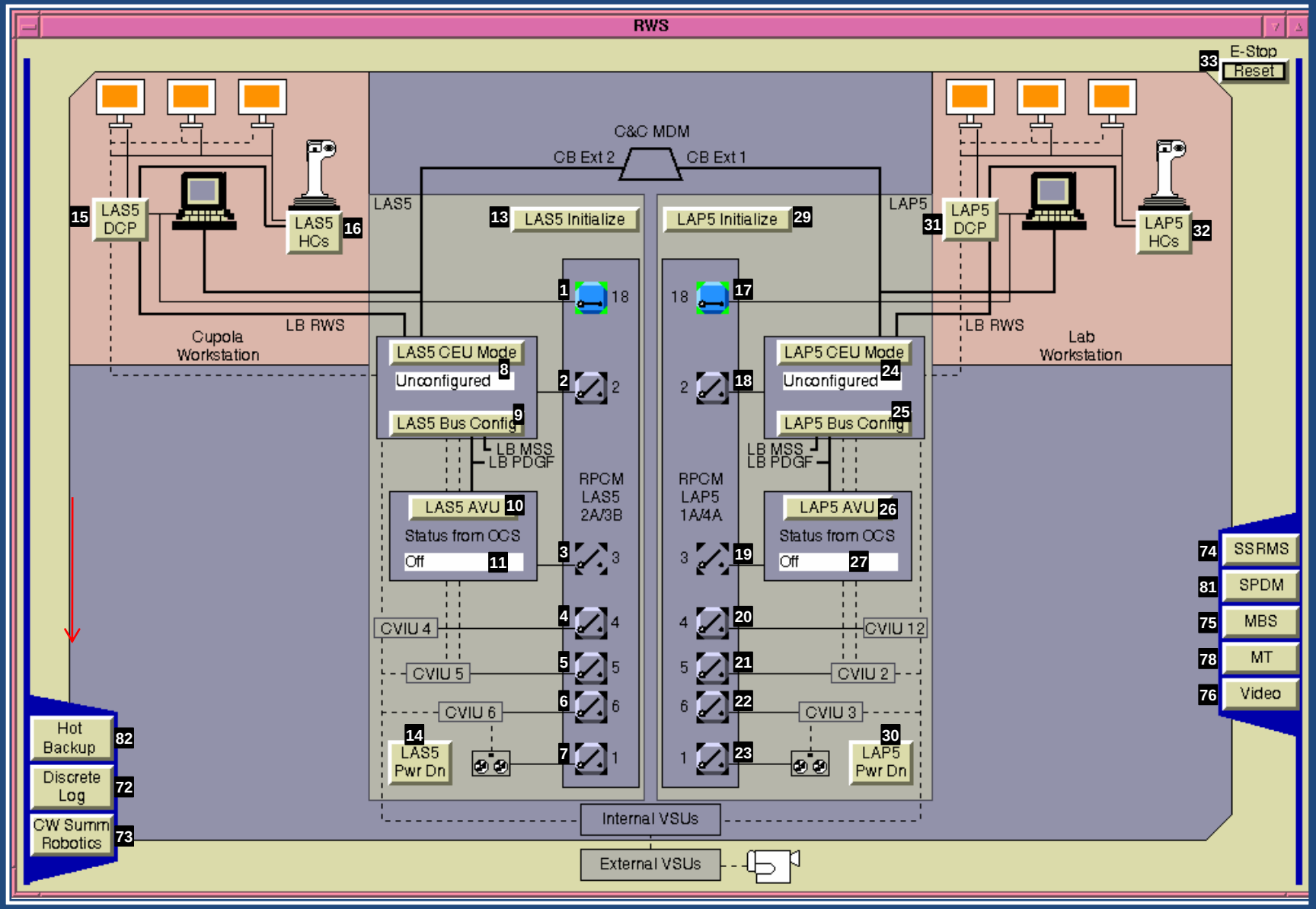




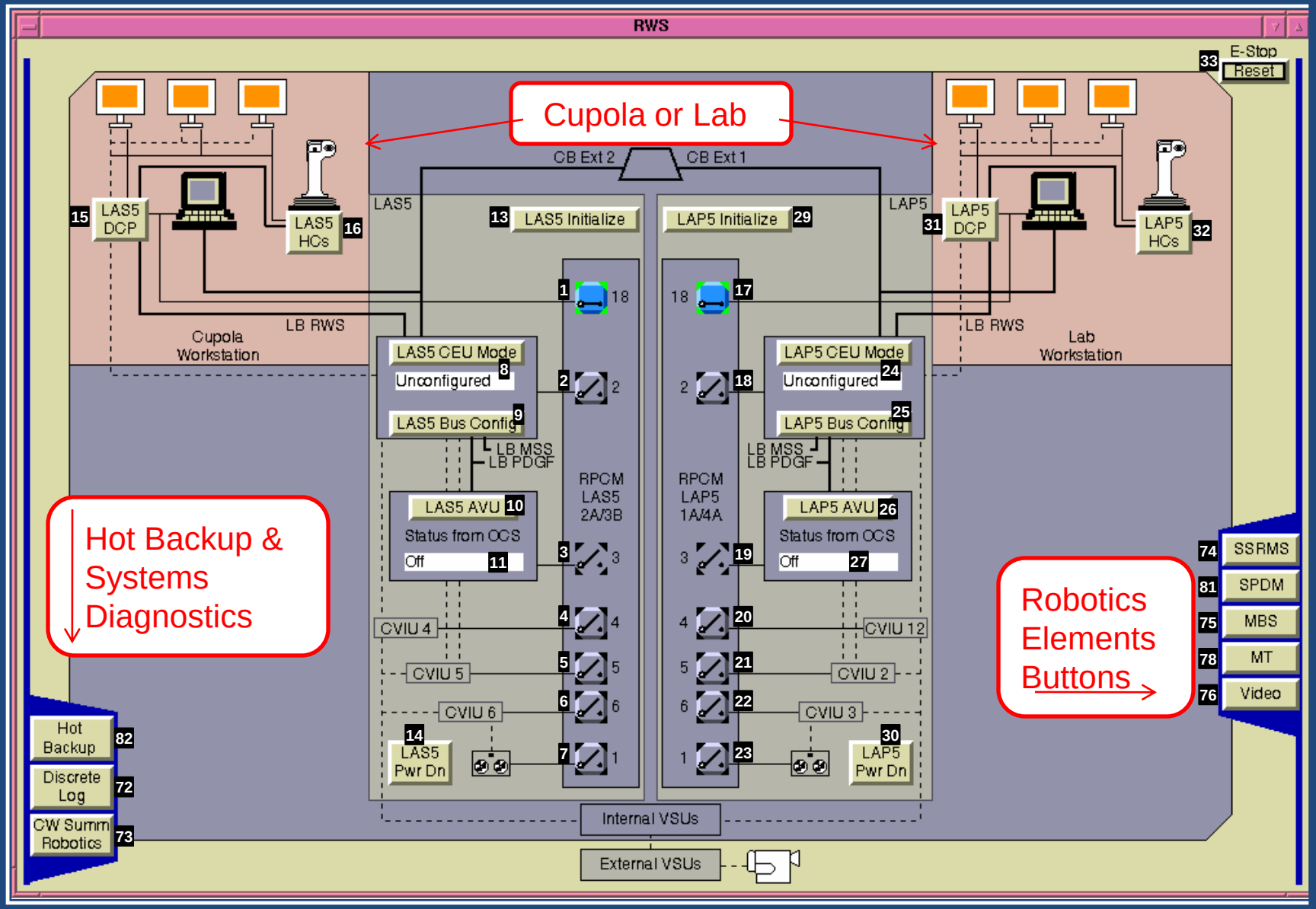
ISS Home Page window



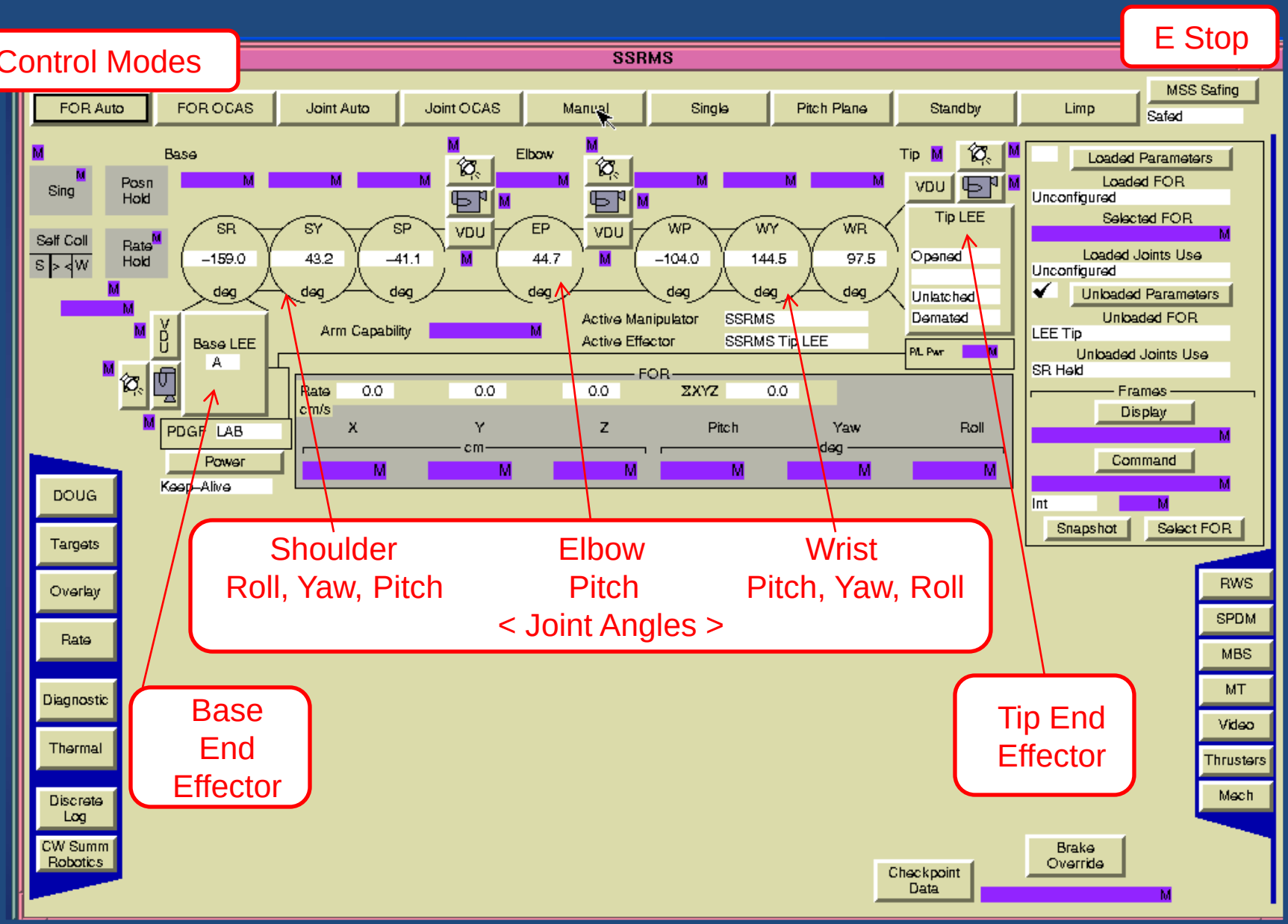
ISS Home Page window



ISS Robotics Work Station window



ISS Robotics Work Station window



ISS SSRMS window

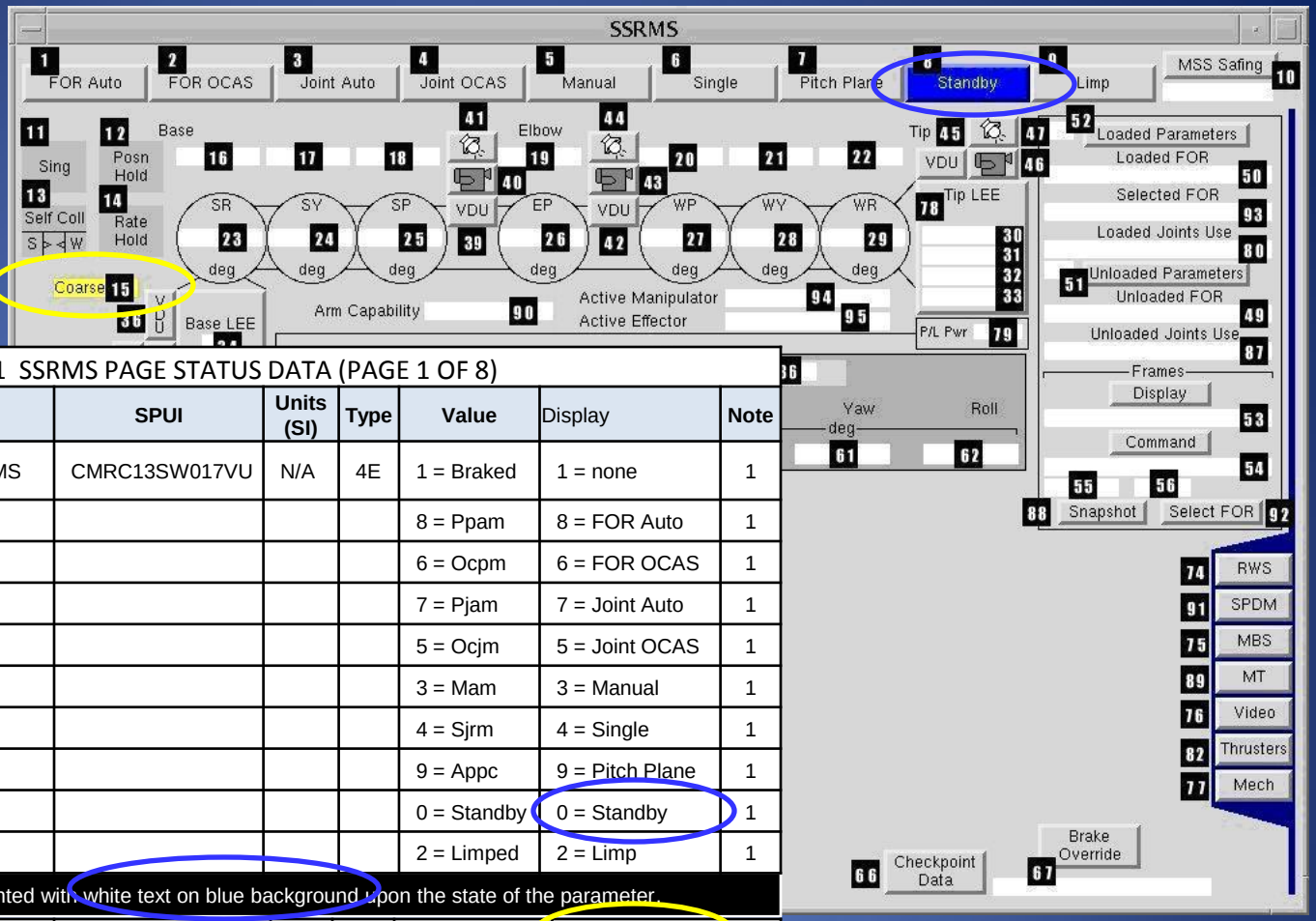
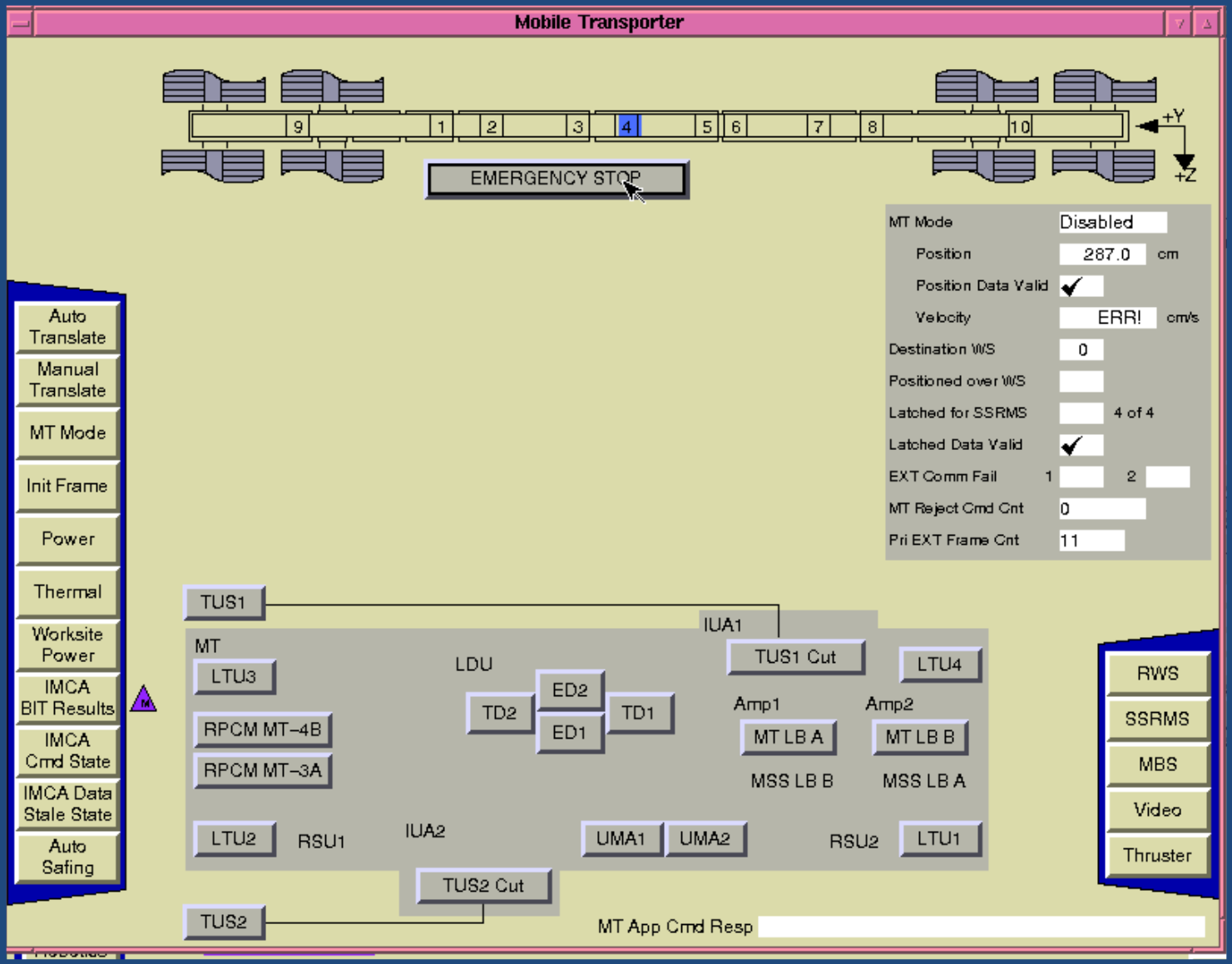


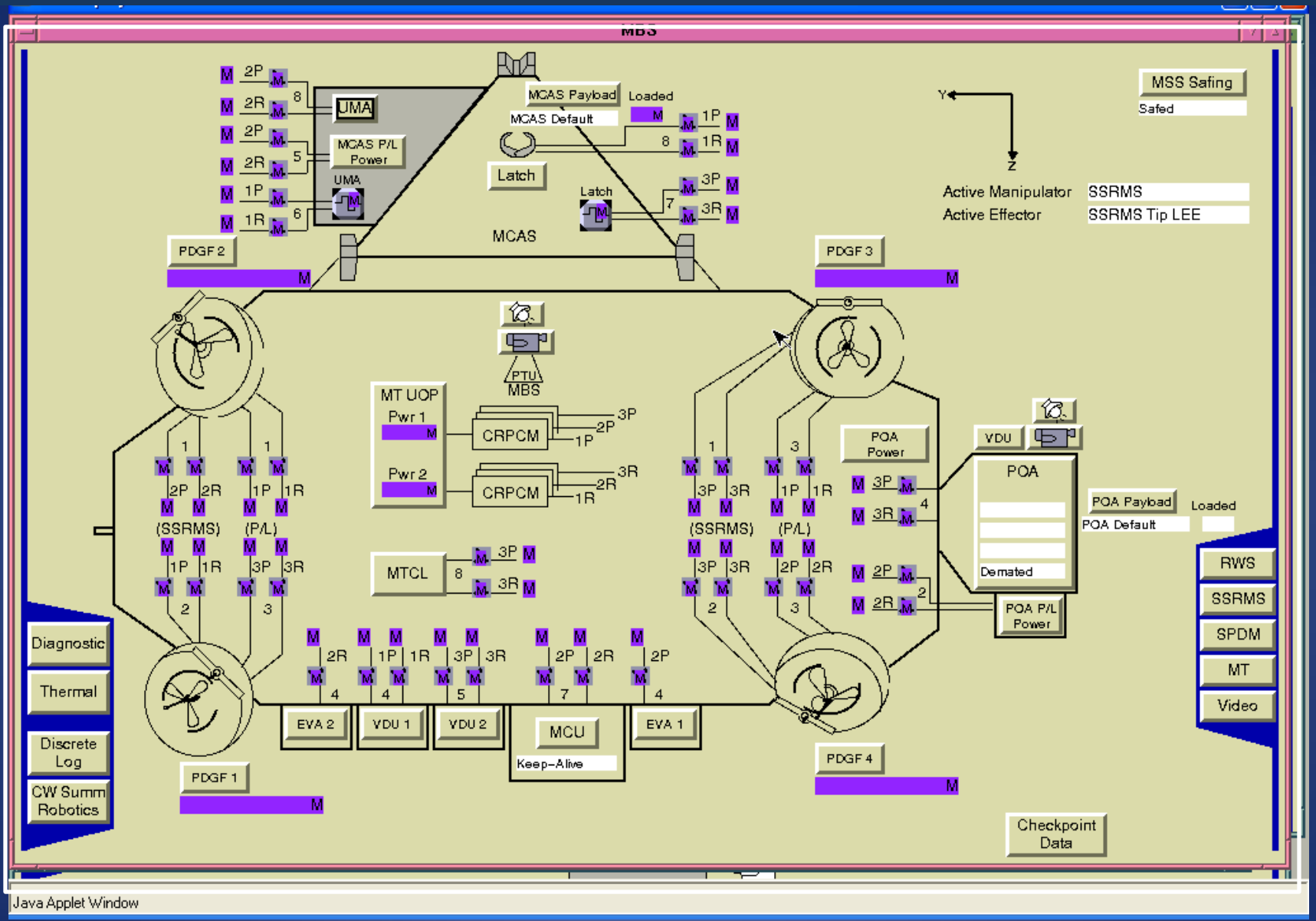
TABLE 3.3.1.2-1 SSRMS PAGE STATUS DATA (PAGE 1 OF 8)

Device Identifier	Ops Name	SPUI	Units (SI)	Type	Value	Display	Note
	MSS_OCS_Manipulator_Mode_SSRMS	CMRC13SW017VU	N/A	4E	1 = Braked	1 = none	1
1					8 = Ppam	8 = FOR Auto	1
2					6 = Ocpm	6 = FOR OCAS	1
3					7 = Pjam	7 = Joint Auto	1
4					5 = Ocjm	5 = Joint OCAS	1
5					3 = Mam	3 = Manual	1
6					4 = Sjrm	4 = Single	1
7					9 = Appc	9 = Pitch Plane	1
8					0 = Standby	0 = Standby	1
9					2 = Limped	2 = Limp	1
Note 1. The appropriate mode button is highlighted with white text on blue background upon the state of the parameter.							
15	SSRMS_JEUs_Vernier_Bus	CMRC13SW00MKU	N/A	1E	0 = Coarse	0 = "Coarse"	13
					1 = Vernier	1 = "Vernier"	
	SSRMS_Invalid_Vernier_Coarse_Selection	CMRC13SW0B6SJ	N/A	1E	0 = False	0 = "Coarse" or "Vernier"	
						1 = "Invalid"	
					1 = True		
Note 13. The background color is yellow when SSRMS_JEUs_Vernier_Bus is Coarse or SSRMS_Invalid_Vernier_Coarse_Selection is True. If SSRMS_Invalid_Vernier_Coarse_Selection is True, "Invalid" is displayed; otherwise, SSRMS_JEUs_Vernier_Bus determines the text displayed.							

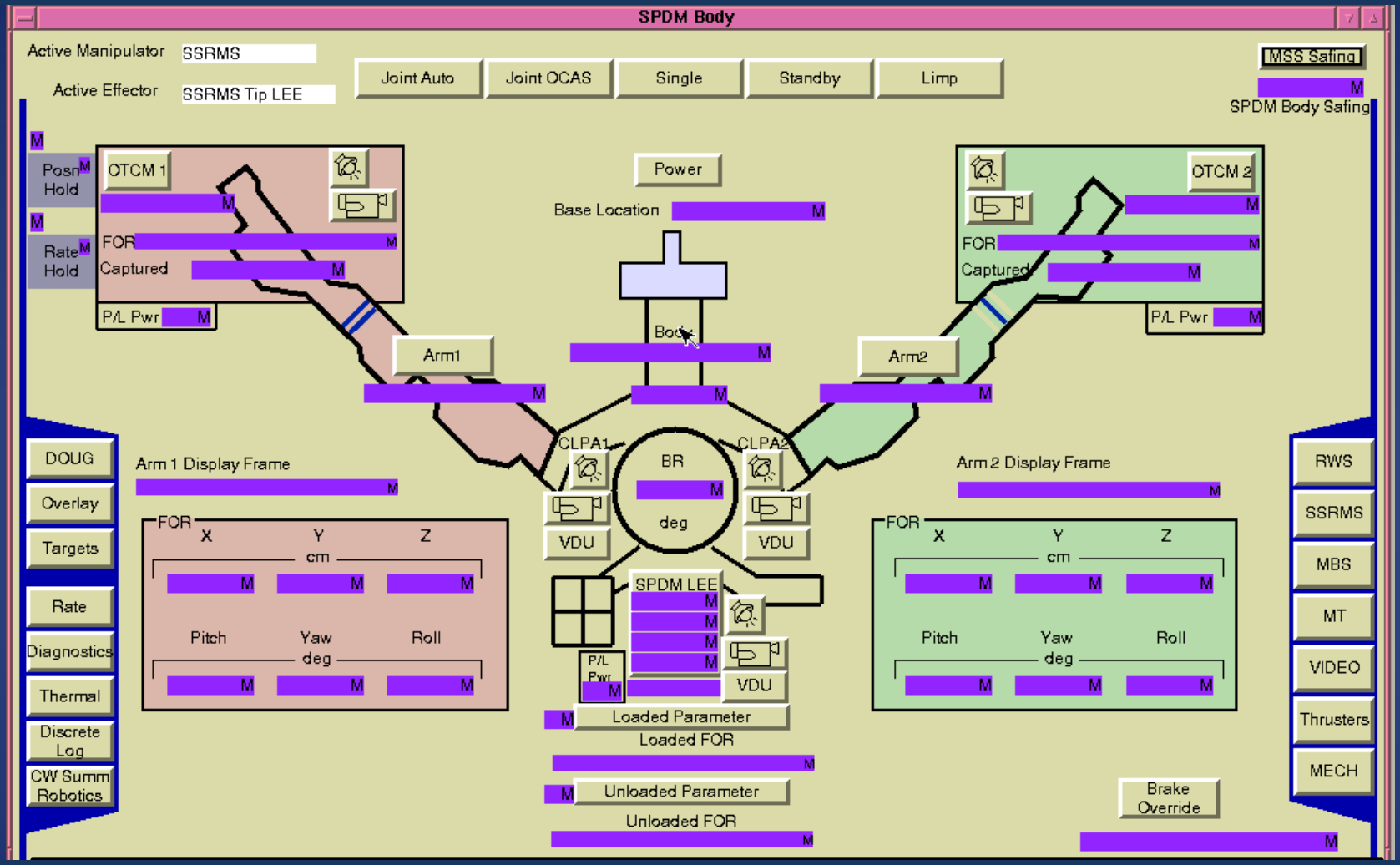
ISS SSRMS window and Status Data table excerpt from SSP 50337-01-ANX PCS R13



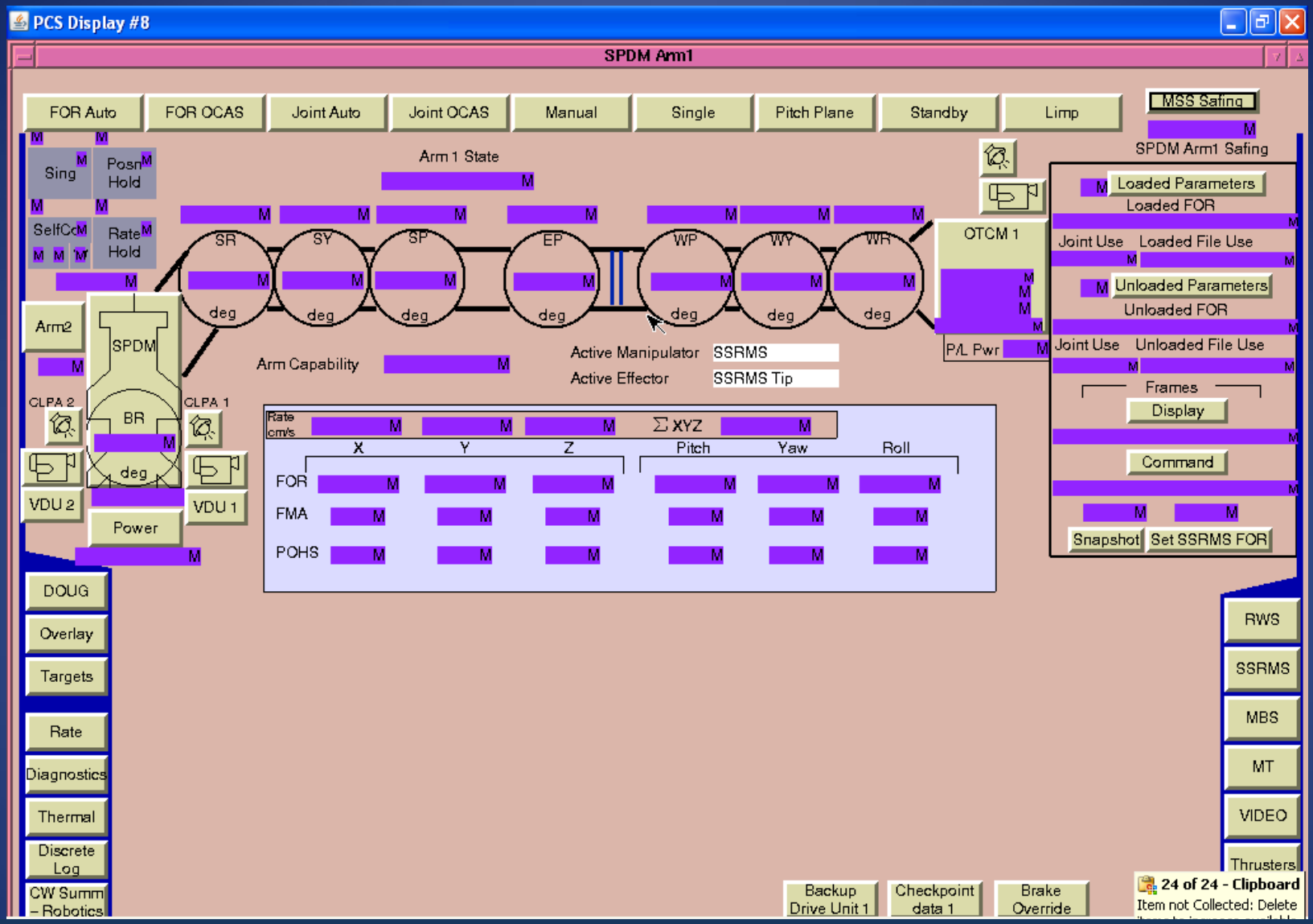
ISS Mobile Transporter window



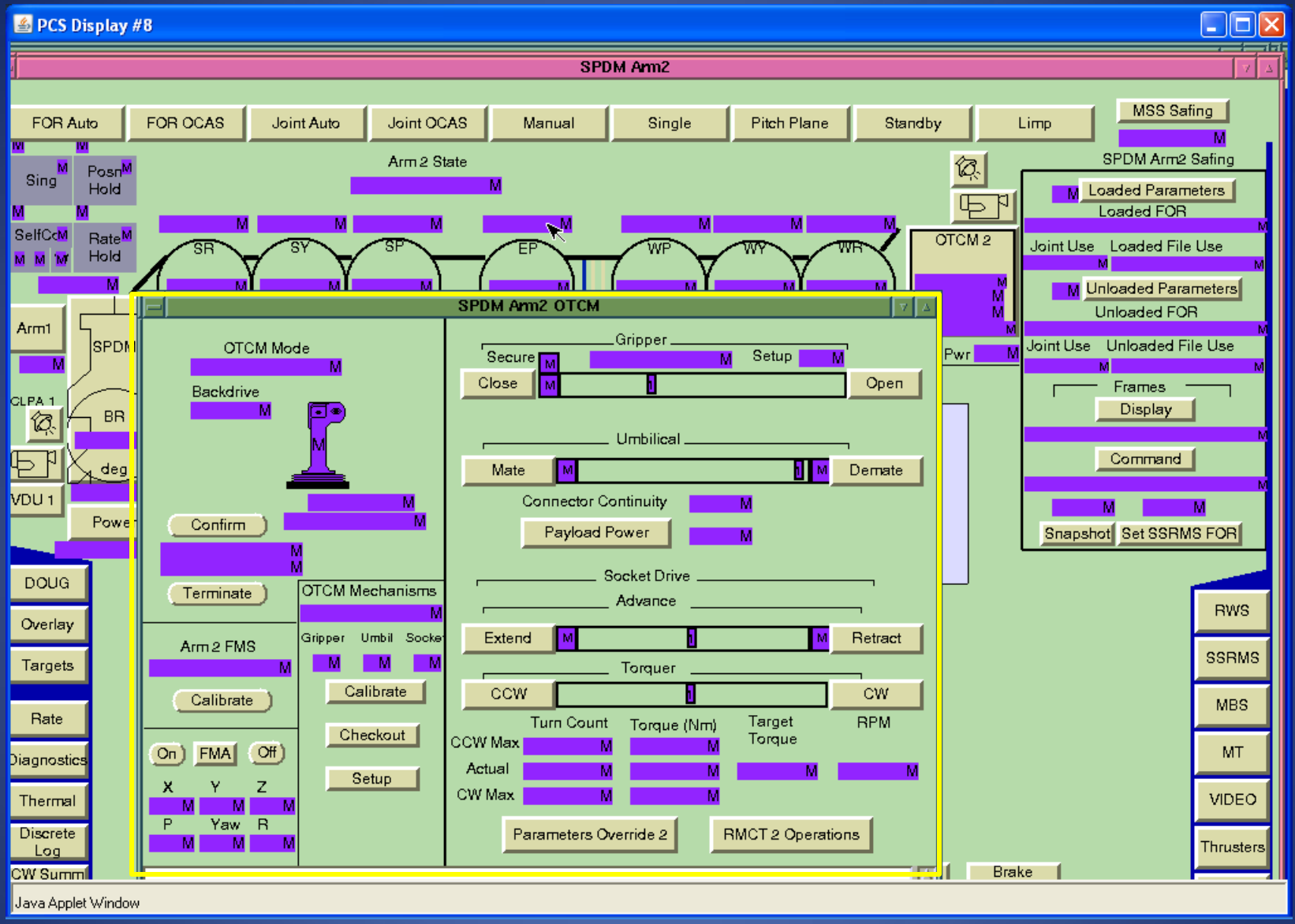
ISS Mobile Base System window



ISS SPDM Body window



ISS **SPDM Arm1** window



ISS **SPDM Arm 2** window with **OTCM** popup invoked

ISS Assembly operations have been exceptionally successful by having onboard astronauts execute scripted moves of payloads using the SSRMS.

Recently-initiated Maintenance operations with the SPDM (DEXTRE) have successfully used ground issued sequence commands.

It is likely that the number of onboard SPDM displays will be reduced.

IV&V of the Canadian ISS MSS onboard displays has been presented.

Scope is limited to 'one end' of the MSS, but is critical for system integrity.

State of the art for operational robots for manned spaceflight.

Illustrates how complex these systems are.

Questions ?