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The Canadian Mobile Servicing System for Space Station Servicing

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Abstract

The Mobile Servicing System (MSS) concept is being developed as the Canadian contribution to the Space Station Program. The MSS is a major element of the servicing architecture in the Space Station Program and complements the role of U.S. developed Servicing Facility on the Station. This paper describes the servicing functions performed by MSS. These functions include servicing of attached payloads as well as assembly and maintenance of the Station. Robotic servicing requirements have also been addressed. The architecture and concepts of MSS and its constituent systems are described.

1.0 Introduction

The Canadian contribution to the Space Station program is planned to be a Mobile Servicing System (MSS) on the Station. The MSS will be a major element of the servicing architecture in the Space Station program complementing other elements of this architecture which include the Servicing Facility, the Flight Telerobotic Servicer and the Space Shuttle Orbiter with its Remote Manipulator System.

Requirements analysis and concept development activities for MSS have been undertaken so far in the program (Phase B). Detail design and development activities will be started in the next phase of the program. This paper summarizes the requirements established for MSS and describes the MSS concept.

2.0 Mobile Servicing System (MSS) Functions

The concept of the Mobile Servicing System (MSS) has been developed to perform assembly, maintenance and servicing functions in the unpressurized environment of the Station. Major functions supported by the MSS are:

a) Station assembly:
- truss assembly
- assembly of modules
- attachment of station system assemblies
- assembly of photo-voltaic and solar dynamic power system

b) Station operations
- berthing and deployment of the Orbiter,OMV and OTV
- loading and unloading the cargo bay of the Or biter
- exchanging Logistics Module on the Station

c) Attached payload servicing
- assembly
- exchange Orbit Replaceable Units (ORU's)
- make/break connections and interfaces
- inspection

d) Maintenance of the Station, including main tenance of MSS:
- exchange ORU's
- make/break connections and interfaces
- inspection

The MSS, being a mobile system, will service attached payloads at their operating locations, perform Station maintenance functions at different locations as necessary, berth and deploy vehicles operating in the vicinity (from suitable locations on the

Station), load and unload the Orbiter including exchange of the Logistics Module, and transport payloads and cargo externally around the Station. It is also used in the assembly of the Station during build-up to its Initial Operations Capability (IOC). MSS capabilities are phased-in during Station assembly to meet the needs of assembly, Station operations and maintenance, and servicing of attached payloads.

The functions of MSS are complementary to those of the Servicing Facility on the Station, to be developed by the U.S. The Servicing Facility is an enclosed facility fixed at one location on the Station with the capability for environmental control. It is to be used for servicing free-flyers brought to the Station by the OMV, servicing those attached payloads which cannot be serviced at their attached locations (due to the requirements of environmental control or specialized tasks), refuelling, storing ORU's and servicing equipment, and integrating OMV's with their payloads.

3.0 Robotics Requirements for MSS

In order to perform the assembly, maintenance and servicing functions, the MSS should have the capability to perform tasks involving controlled manipulation of objects, and controlled mechanical interaction between objects. Typical tasks to be performed are:

a) capture/release and berthing/deployment of large objects up to the size of an Orbiter

b) ORU exchange

c) utility connect/disconnect

d) connector mate/demate

e) interface attach/detach

h) surface cleaning

i) thermal covers and blankets removal/ installation

j) inspection

k) work area and EVA monitoring

The MSS should be capable of performing its functions within the constraints and objectives of the Space Station program which require that the use of EVA be minimized and crew productivity as well as crew automony from the ground be progressively increased. This implies the following requirements for the MSS:

i) capture/release and berthing/ deployment tasks should be performed by IVA

ii) mechanical-interactive tasks,including dextrous manipulation should be performed by IVA

iii) a capability for MSS autonomous operation under operator supervision will be required. This capability should allow the operator to define instructions from the actuator-level to the task level in a high level language (robot programming), to "teach" the system tasks and to execute these tasks automatically, taking corrective action if anomalies arise during execution

iv) automatic fault detection and isolation to the ORU level will be required

v) self-test and diagnostics capability will be required

vi) ability for the system to plan tasks and resources for a mission, within the overall Station planning framework, will be required.

4.0 The Mobile Servicing System (MSS)

The concept of a Mobile Servicing System (MSS) meets the functional and robotics requirements described above. The MSS consists of two elements on the Station: a Mobile Servicing Centre (MSC), and an MSC Maintenance Depot (MMD). The MSC comprises a Mobile Transporter (MT) and a Mobile Remote Servicer (MRS) and has the capability to move along the Station truss structure using the MT. The MRS consists of the following systems:

- Two Space Station Remote Manipulator Systems (SSRMS)
- Special Purpose Dextrous Manipulators(SPDM)
- Intra-vehicular activity (IVA) Control Station (EVA-WS)
- Extra-vehicular activity (EVA) Work Station (EVA-WS)
- Power Management and Distribution System (PMDS)
- Data Management System (DMS)
- Communications System (CS)
- MRS Base System (MBS)

The MMD has the following systems to support the maintenance of the MSC as well as the accommodation of MRS systems not carried on a particular mission of the MSC:

- MMD Base System (MDBS)
- Power Management and Distribution System (PMDS)
- Data Management System (DMS)
- Communications System (CS)

The MSS elements on the Station constitute the Space Segment of the MSS. Operations on the Station are supported by two facilities on ground: a Ground Operations Centre (GOC) and an Operations Management and Logistics Centre (OMLC). The ground segment provides the equipment for User and Mission support, integration and test, simulations, and engineering analysis. The simulations capability is provided by a Manipulator Development and Simulation Facility (MDSF).

The hierarchy of MSS elements and systems is shown in fig. 4-1. The architecture and interfaces are shown in fig. 4-2. A pictorial view of MSC and MMD, is shown in fig. 4-3 .

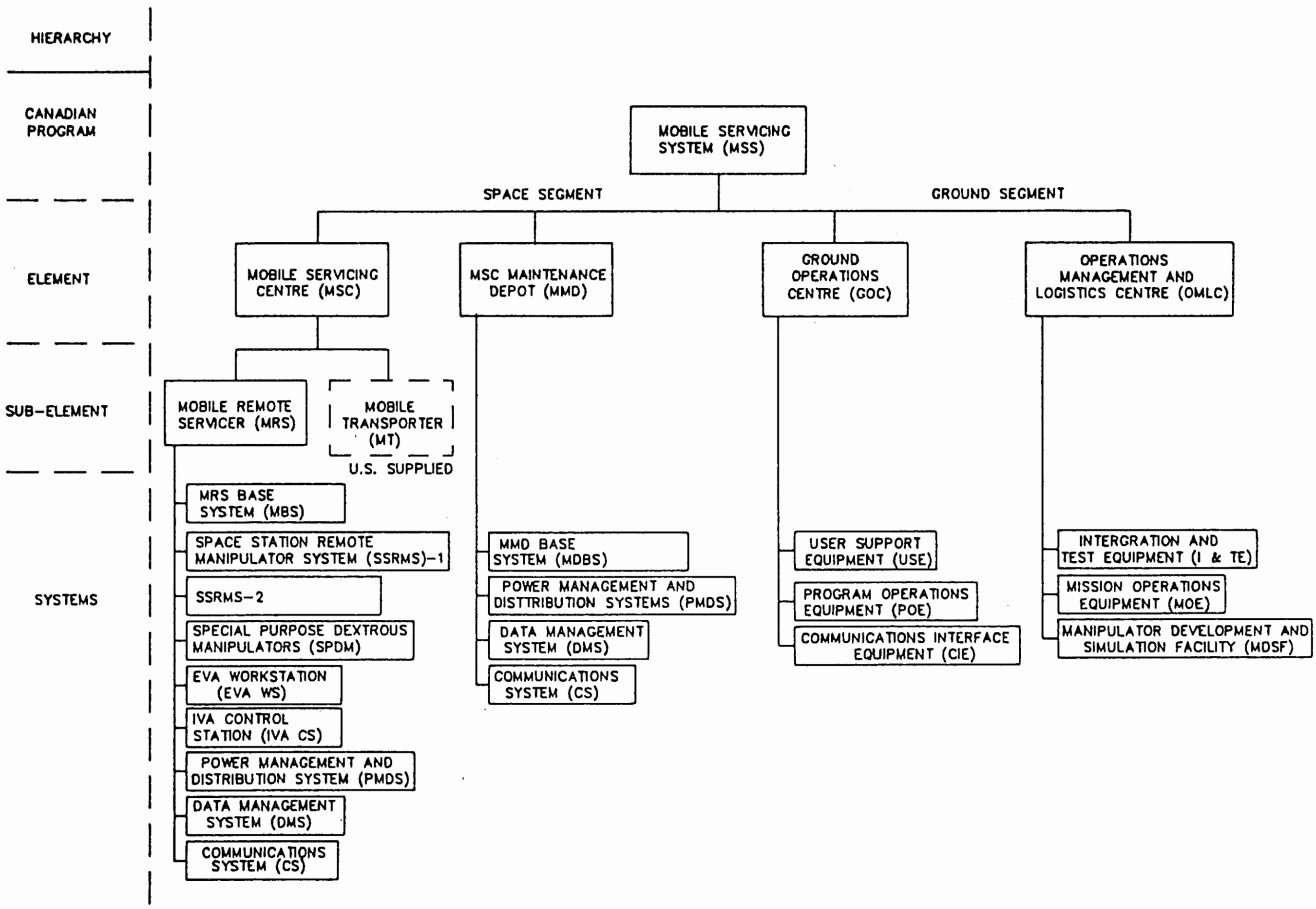

FIGURE 4-1 MOBILE SERVICING SYSTEM (MSS) HIEARCHY

The SSRMS is a large manipulator system, about 55 ft. (17 metres) long, with seven modular rotary joints. The manipulator configuration is symmetrical about the middle, and has an end effector at each end. The manipulator is relocatable and the symmetry enables either end to act as the "base" of the manipulator. The end-effectors have additional mechanisms to connect interfaces in order to transfer power, data and video. Force-moment sensors are incorporated at each end of the manipulator to provide force data which is used to provide feedback to the human operator as well to the manipulator control system for closed-loop control of the tip forces. Cameras are provided on the manipulator to provide viewing capability to the operator, and to provide inputs to a vision system. The vision system uses camera inputs to recognize targets and objects, and to provide range and attitude data for tracking by the manipulator, automatically or by operator control.

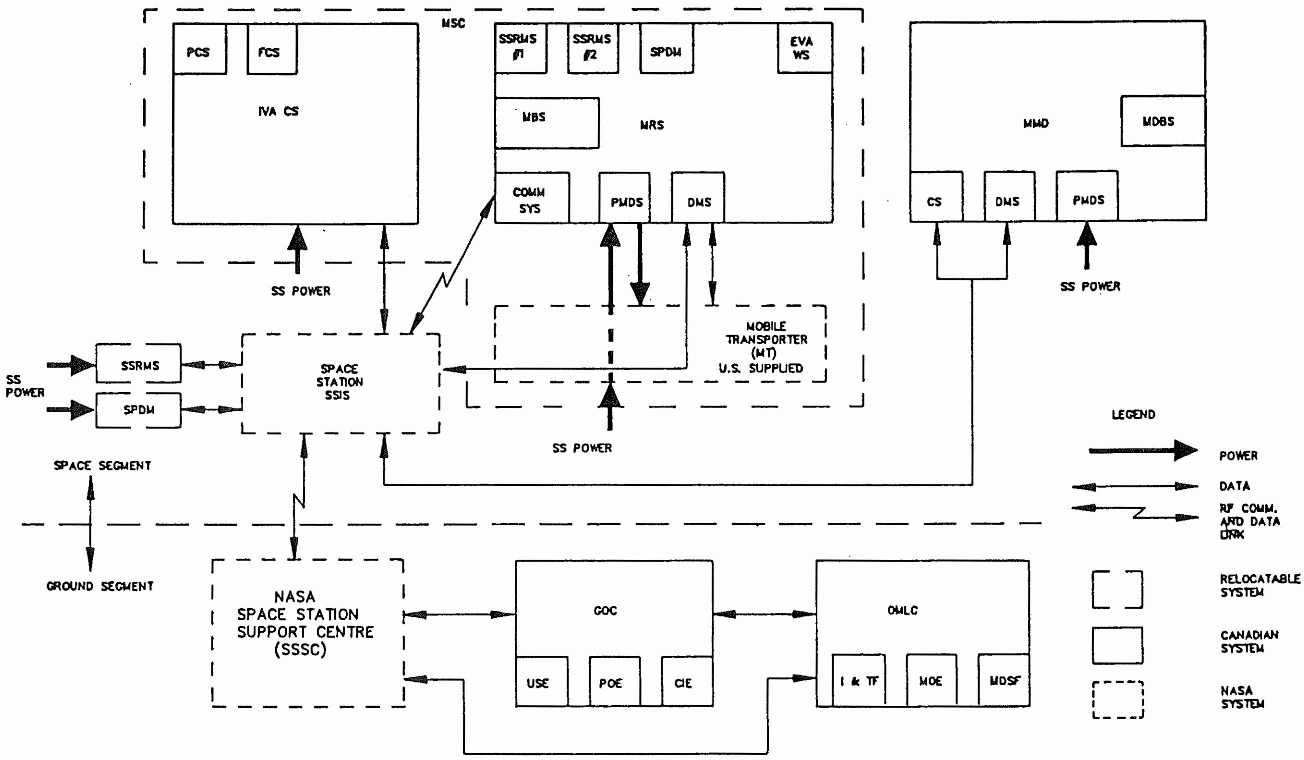

FIGURE 4-2 MSS ARCHITECTURE AND INTERFACES

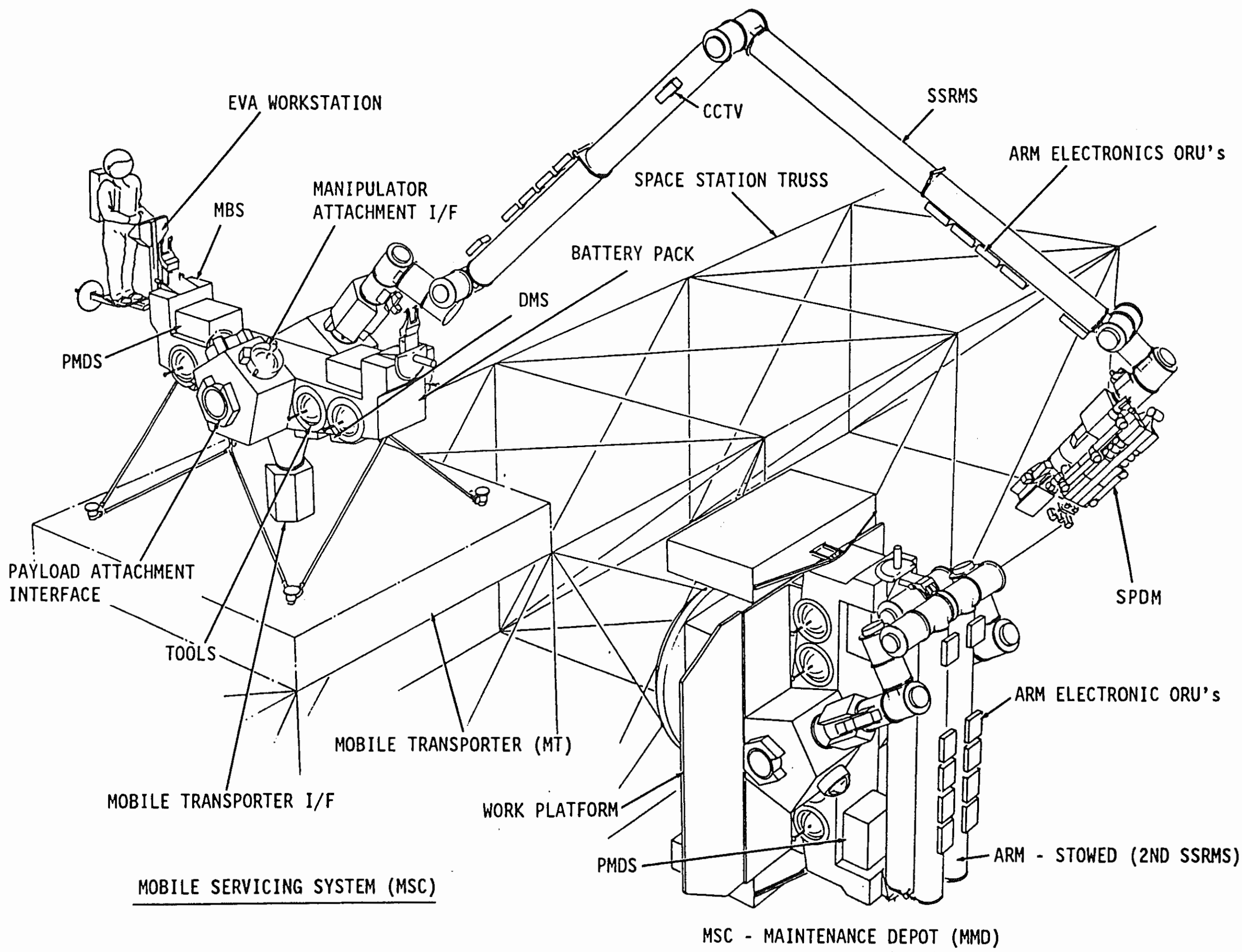

FIGURE 4.3 MSC & MMD ON THE SPACE STATION

The second SSRMS may position an astronaut close to a work area to perform some tasks in support of those being performed by the SSRMS. Assembly of the Solar Dynamic system, and assembly of Station modules and trusses, are examples of such tasks.

The SSRMS is used to handle large objects in assembly, maintenance, servicing, and operation functions of the MSS, including berthing and deployment of vehicles operating in the vicinity of the Station. It also performs servicing tasks requiring mechanical interaction using a set of tools which can be picked up by its end-effector. The physical size of the SSRMS manipulator arm, its force application capabability, flexibility, and control characteristics would make it unsuitable for performing some of the handling and interactive tasks which require dexterity and precision.

The SPDM of the MSS provides the capability to perform dextrous tasks in assembly, maintenance and servicing such as exchanging small ORU's, connecting/disconnecting utilities, mating/demating connectors, cleaning surfaces, removing/installing thermal blankets, etc. The SPDM consists of two small dextrous manipulators, each 4 to 6 ft. (1 to 2 metres) long, with vision systems, force-moment sensors, joints, electronics and a tool change-out mechanism at the tip of each manipulator arm. The dextrous manipulators are attached to the central body which provides accommodations for avionics, tools and other SPDM hardware. A vision system on the body provides overall views of the work place for the manipulators. The vision systems in the body and the manipulators are functionally integrated to provide the capability to perform tasks with increasing autonomy. A set of tools is provided in the body. These tools can be used by either manipulator. The body also provides accommodations to carry an ORU and to exchange it using the SPDM manipulators.

Attachment interfaces are provided on the central body to enable the SPDM to operate from the end of the SSRMS or from a fixed position on the MMD or the Station wherever a defined interface for power, data and video is provided. A pictorial view of the SPDM is shown in fig.4.4

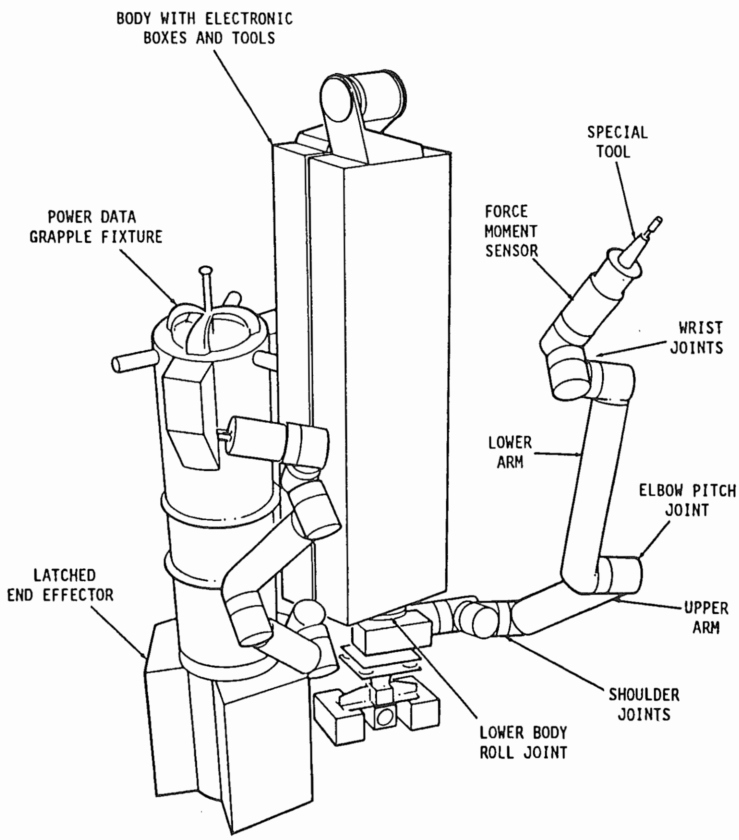

FIGURE 4-4 SPDM CONFIGURATION

The SSRMS, and the SPDM can be operated from the IVA-WS which is envisaged as the Station provided Multi-Purpose Access Console (MPAC), is fixed or portable, enhanced by the addition of an MSS specific display and control system including hand controllers to operate the MSS manipulator systems. Limited display and control capability is provided at an EVA Work Station.

In order to operate the MSC, SPDM and MMD, a complex Data Management System (DMS) is required. The DMS is a distributed system providing the hardware and software necessary to support data acquisition, storage, processing and communications needs of the systems. A Facility computer and an MSC control computer are provided by the DMS. The DMS provides the real-time local data busses, interfaced to the Station core network busses, for MSS data communications among the IVA-WS, MSC, MMD, EVA-WS, as well as SSRMS and SPDM when located away from the MMD. The DMS, Architecture block diagram is shown in fig. 4-5.

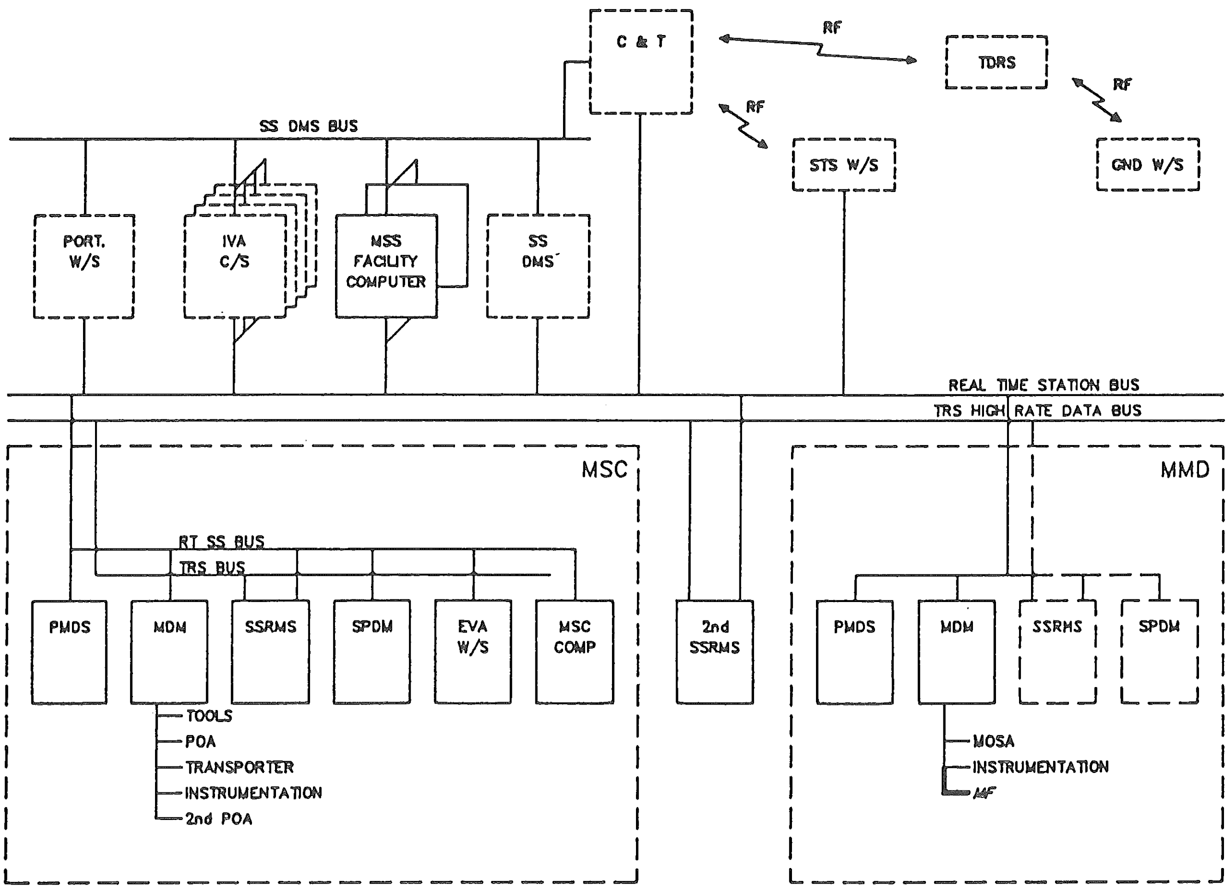

FIGURE 4-5 MSS DMS ARCHITECTURE

The operational and planning software for MSS is presently envisaged to have the following software functions:

- fault detection and diagnostic system
- on-orbit maintenance system
- task planning system
- resource management system
- integration and test system
- manipulator programming system
- collision avoidance
- multiple arm control

The PMDS converts and conditions the power available from the Station and distributes it to systems on the MSC and the MMD. It manages the MSS power utilization, including controlled offloading in support of Station power management, and provides a fault - tolerant architecture. An energy storage system (batteries) is provided on the MSC for operation during transportation between the utilities ports on the Station.

The Communications System consists of a video subsystem and an RF communications subsystem. The video system provides TV camera assemblies, pan and tilt units, lights, video bus interface units and video control units. The TV cameras interface with a Frequency Division Multiplex video bus on the MSC and the MMD. The RF communications system has a signal processor to process video and telemetery and command data, a transmitter/receiver, and an antenna. The communications system interfaces with the Station Communications & Tracking (C&T) System.

The MBS provides a stiff light-weight structure which attaches to the transporter and provides accommodations for attaching payloads (during transportation), SSRMS, APM, Tools, SPDM, PMDS, DMS and EVA-WS and Communications system. Thermal control provisions are provided for all the units carried on the MBS. Attachment interfaces are provided to carry payload-ORU pallets on the MBS for servicing missions. The structural configuration of MBS allows it to be packaged into the Orbiter bay for transportation to orbit.

The MMD provides a Base System (MDBS) similar to the MBS to provide attachment interfaces for SSRMS, APM, SPDM and EVA-WS. Accommodations for maintenance fixtures for MSC, storage of MSC- ORU's and provisions for EVA for maintenance are also provided on the MDBS. The PMDS, DMS and CS of the MMD are similar to the corresponding systems on the MSC. These systems support maintenance activities and subsequent test and check-out, from the IVA-CS. Maintenance tasks on the MSC can also be performed robotically on the MMD using SPDM and SSRMS.

5.0 Conclusion

The MSS architecture and concept has been developed as an effective implementation of a Station system to perform attached payload servicing as well as Station assembly, maintenance and operations functions. The system incorporates robotics and automation to minimize EVA and to progressively increase crew productivity and autonomy from ground. Since the Station will be a permanent facility designed for indefinite operation through on-orbit maintenance and refurbishment, the MSS will be designed to be space maintainable and to provide technology transparency. The MSS system design will be required to provide "hooks" and "scars" to allow addition of robotics and A.I. technologies which will become available after the system becomes operational.

6.0 Acknowledgements

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