Appendix D to ANNEX A

MSS Camera Concept

1 List of Acronyms

Acronym	Definition
ACDB	Arm Control Data Bus
ACU	Arm Control Unit
AFRL	Air Force Research Laboratories
AR&D	Autonomous Rendezvous and Docking
BDU	Backup Drive Unit
C&C	Command & Control
CB	Control Bus
CCD	Charged Coupled Device
CCU	Camera Control Unit
CEU	Control Electronics Unit
CHU	Camera Head Unit
CLA	Camera and Light Assembly
CLPA	Camera/Light Pan/Tilt Unit Assembly
CPRCM	Canadian Power Remote Control Module
CSA	Canadian Space Agency, an Agency of the Government of Canada
CSCI	Computer Software and Configuration Item
CSOC	Common System Operating Cost
CSR	Camera Status Reader
CSSP	Canadian Space Station Program
CVIU	Common Video Interface Units
CVT	Current Value Table
DCP	Display and Control Panel
EEE	Electrical, Electronic, and Electromechanical
EFL	Effective Focal Length
ELC	Express Logistic Carrier
EM	Engineering Model
EVA	Extravehicular Activity
EVSU	External Video Switch
EWC	ELC Wireless Communications
FMEA	Failure Mode Effects Analysis
FOV	Field of View
FM	Flight Model
HD	High Definition
IR	Infrared
ISS	International Space Station
IVA	Inter-vehicular Activity
JEM	Japanese External Module
JOTI	Japanese External Module Orbital Replaceable Unit Transfer Interface
JSL	Joint Station LAN
LA	Light Assembly
LAB	Laboratory
LAN	Local Area Network
LB	Local Bus
LCS	Laser Camera System
LED	Light Emitting Diode
LEE	Latching End Effector
LEO	Low Earth Orbit

LiDAR	Light Detection and Ranging
M	Meter
MT	Mobile Transporter
MBS	Mobile Base System
MCC-H	Mission Control Center, Houston
MCDB	MBS Control Data Bus
MCU	Mobile Base System Computer Unit
MDM	Multiplexer/Demultiplexer
MRS	Mobile Remote Servicer
MSS	Mobile Servicing System
NASA	National Aeronautics and Space Administration
NTSC	National Television System Committee
OCS	Operations Control Software
OEU	OTCM Electronics Unit
ORU	Orbital Replaceable Unit
OTCM	Orbital Replacement Unit Tool Change-Out Mechanism
P/L	Payload
PCB	Printed Circuit Board
PDGF	Power and Data Grapple Fixture
PFM	Pulse Frequency Modulated
PFM	Proto-flight Model
POA	Payload and ORU Accommodation
PSU	Power Supply Unit
PTU	Pan/Tilt Unit
PWGSC	Public Works and Government Services Canada, a Department of the Government of Canada
QM	Qualification Model
RFI	Request for Information
RFP	Request for Proposals
RGB	Red, Green and Blue
RMCT	Robot Micro-Conical Tool
ROST	Robotic Offset Tool
RWS	Robotic Workstation
SACU	Synchronization and Control Unit
SCU	Sync & Control Unit
SET	Socket Extension Tool
SGS	Space to Ground Subsystem
SJEU	SPDM Joint Electronics Unit
SMI	Shared Memory Interface
SPDM	Special Purpose Dexterous Manipulator
SSP	Space Station Program
SSRMS	Space Station Remote Manipulator System
STDP	Space Technology Development Program
STEAR	Strategic Technologies for Automation and Robotics
TBC	Time Base Corrector
TDRS	Tracking and Data Relay Satellite
TUS	Trailing Umbilical System
TVC	TV Camera
VBSP	Video Baseband Signal Processor
VCS	Video Control Software
VDC	Volts, Direct Current
VDU	Video Distribution Unit
VGC	Video Graphic Card
VGS	Video Graphic Software
VSC	Video Signal Converter
VSU	Video Switching Units
VTR	Video Tape Recorder
WHS	Workstation Host Software
Wi-Fi	Technology that allows an electronic device to exchange data wirelessly

ZLA	Zoom Lens Assembly

2 Reference Documents

The documents identified in Table 2 provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document. These documents will be made only upon request from RFP respondents.

Table 1: Reference Documents.

MRD No.	Document Number	Document Title	Rev. No.	Date
RD-1.	D684-14957-01	International Space Station (ISS) ELC Wireless COMM (EWC) User Guide	Initial Release	11 May, 2012
RD-2.		Reference Guide to the International Space Station ftp://ftp.asc-csa.gc.ca/users/TRP/pub/ConceptStudies/2011/CS3A		November 2010
RD-3.	SSP 50892	Ethernet Requirements for Interoperability with the Joint Station LAN (JSL)	Baseline	June 2009
RD-4.	CSA-SS-PL-0047	Canadian Space Station Program (CSSP) Certificate of Flight Readiness (CoFR) Plan		
RD-5.	SN-C-0005	Space Shuttle Contamination Control Requirements	D	July 1998
RD-6.	SSP 30233	Space Station Requirements for Materials and Processes	H	August 2007
RD-7.	SSP 30237	Space Station Electromagnetic Emission and Susceptibility Requirements	T	February 2010
RD-8.	SSP 30240	Space Station Grounding Requirements	H	January 2010
RD-9.	SSP 30242	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility	K	January 2010
RD-10.	SSP 30243	Space Station Requirements for Electromagnetic Compatibility	N	January 2010
RD-11.	SSP 30256	Extravehicular Activity (EVA) Standard Interface Control Document	H	February 2007

MRD No.	Document Number	Document Title	Rev. No.	Date
RD-12.	SSP 30312	Electrical, Electronic, and Electromechanical (EEE) Parts Management and Implementation Plan for the Space Station Program	J	September 2004
RD-13.	SSP 30423	Space Station Approved EEE Parts List	K	July 2011
RD-14.	SSP 30425	Space Station Program Natural Environment Definition for Design	B	February 1994
RD-15.	SSP 30426	Space Station External Contamination Control Requirements	D	January 1994
RD-16.	SSP 30512	Space Station Ionizing Radiation Design Environment	C	June 1994
RD-17.	SSP 30558	Fracture Control Requirements for Space Station	C	August 2001
RD-18.	SSP 30559	Structural Design and Verification Requirements	D	July 2007
RD-19.	SSP 30560	Glass, Window, and Ceramic Structural Design and Verification Requirements	A	May 2003
RD-20.	SSP 30695	Acceptance Data Package requirements Specification	C	August 2010
RD-21.	SSP 30550	Robotic Systems Integration Standards, and DCN 002,003	C	October 2003
RD-22.	SSP 41167	Mobile Servicing System Segment Specification for the International Space Station Program	H	June 2010
RD-23.	SSP 41173	Space Station Quality Assurance Requirements	D	August 2006
RD-24.	SSP 41175-10	Software Interface Control Document	R	June 2010
RD-25.	SSP 42004	Mobile Servicing System (MSS) to User Interface Control Document	J	May 2011
RD-26.	SSP 50002	ISS Video Standard	A	Oct 2000
RD-27.	SSP 50005	International Space Station Flight Crew Integration Standard (NASA-STD-3000/T)	E	June 2006
RD-28.	SSP 50038	Computer Based Control System Safety Requirements – ISS	B	November 1995
RD-29.	SSP 50835	ISS Pressurized Volume Hardware Common Interface Requirements Document	C	November 2011

MRD No.	Document Number	Document Title	Rev. No.	Date
RD-30.	SSP 52051	User Electric Power Specifications and Standards, Vol 1	A	September 2005
RD-31.	ANSI-Z-136.1	American National Standard for Safe Use of Lasers[1]		March 2007
RD-32.	JSC-61XXX	User's Guide for the JEM ORU Transfer Interface (JOTI)	Draft	April 2012
RD-33.	SPAR-SS-TM-2657	MSS Camera/PTU TM Definition	B	October 1997
RD-34.	SPAR-SS-ICD-0462	MSS Common Internal ICD	F	September 2007

[1] Bidders need to obtain this document separately.

3 MSS Baseline Camera Requirements

3.1 Introduction

The baseline MSS cameras to be proposed must be designed so as to meet (or exceed) all existing MSS camera requirements for form, fit and function as these new MSS cameras will be verified to the existing mechanical, structural, power, thermal, data video, command/control/display and telemetry interfaces of the current MSS Video System. This includes providing an envelope that is well within the existing ORU envelope and does not violate any existing keep-out or EVA/EVR requirements. A very important factor of the seamless integration of the new cameras into the MSS Video System is that they must be 100% compatible with the existing MSS software and must not require any MSS software modifications.

In addition, since the MSS Video System is a key component of the SSRMS and critical to free-flyer capture, this unit must be space-qualified to ISS Criticality 3 level. This requires that the baseline camera address environmental requirements, such as radiation, vibration, shock and thermal.

To leverage installing any enhancements that the CSA may decide to pursue in the future as part of the Space Exploration Core program, the baseline MSS camera unit must provide scarring of a power connector and mechanical guides for a quick and simply IVA installation.

Adhering to this strategy for the baseline replacement cameras will be key to meeting the Canadian Space Station Programs goal to achieve integration and operation of the new camera by 2015.

3.2 Camera performance

The new camera should strive to offer improved performance, newer technologies should be considered for the MSS camera replacement in order to match or outperform in the following areas:

- power consumption;
- thermal survivability;
- mass and volume allowing additional functionality (MSS Enhancement Options) to be provided;
- sensor parameters: sensitivity, saturation, blooming resistance, radiation hardness, power consumption, frame rate and resolution.
- Compliance to the JAXA External Module (JEM) ORU Transfer Interface (JOTI) and IVA repairable
- Mechanical, Structural and electrical scarring for piggy-back, IVA plug-n-play enhancement units.

3.3 Single Unit vs Modular Camera Design

The new camera is not required to be implemented as 3 separate interconnected components, as is the existing camera (reference Section 13). For example, the camera could be implemented as a single unit that offers the same overall mechanical, electrical and thermal interfaces and adheres to the same power, mass and volume allocations. Another option would be to propose a modular design whereby each component would be replaceable by crew in the station. Components making up this modular design should be designed, in such a way, to optimize their interconnectivity so that crew time is minimal. It should be noted that the capability to pass ORUs from external to internal of the station for repair or modification, will exist via the Japanese External Module (JEM) ORU Transfer Interface (JOTI). Consequently, the replacement camera ORU external surfaces must be robust enough to withstand up to 20 lbs compression force on any side.

In this concept study, a trade-off of monolithic vs modular design should be performed with the pros and cons of design complexity, cost and schedule taking into consideration launch, storage (internal or external with FSE) and crew time for repair (per the technical report CDRL).

A CAD drawing and physical 3D model should be produced which can demonstrate the proposed concept for ISS IVA crew handling operations for camera repair and additions of plug-n-play proposed enhancement options. The model should be of sufficient detail to demonstrate the interconnectivity of any modular components and their ease of removal and installation by crew. The model should define the mechanical, structural and electrical interfaces, such as v-guides, unique keying, visual guides and redundant latching. Any no touch zones should be identified as well. The modules must be designed so as not to require tools and must have all fastening mechanisms be captive devices.

3.4 Light Assemblies

The light assemblies should propose newer space-proven technologies with better performance, less power consumption, lighter weight and longer life expectancy. A more reliable lighting design is desired, for instance using a light emitting diode (LED) array design. This unit should also be IVA replaceable in the event of failure.

3.5 Pan/Tilt Assembly

The pan/tilt (PTU) unit of the Camera Light Pan-Tilt Assembly (CLPA) unit provides a 350 degree pan and 184 degree tilt freedom of motion for the CLPA.

For the purposes of this study, 2 options could be considered. The first being a new design providing the same PTU capability that fits within the overall CLPA ORU volume. The second option is a re-use of the existing PTU assemblies on orbit to be refurbished and re-qualified with the MSS replacement camera.

3.6 Camera contamination protection

Camera lens covers have been installed on all MSS cameras to protect against contaminants being generated during attitude control firing of reaction control jets on all free flyers during robotic capture and release of these visiting vehicles. These camera covers were designed to fit the existing camera housings and can be installed by EVA or IVA.

Camera protective lens covers will need to be provided with the MSS replacement cameras. Shutters should not be implemented as cameras are critical components to the free-flyers' capture. The existing MSS Camera Lens covers should be considered for re-use and therefore, a trade-off should be done to compare schedule and cost for re-use (with possible impact to camera optics unit shroud) vs design of new camera covers.

3.7 Assumptions

For the purposes of this Concept Study, the following assumptions should be used:

1. All Flight Model (FM) units will be qualified as criticality 3 ISS standards.
2. An EM model will be delivered at CDR.
3. One unit from the FM build will be tested to qualification levels and then refurbished (if necessary) as a Flight Spare.
4. Electrical, Electronic, and Electromechanical (EEE) parts will be used and non-standard parts will be qualified for flight use.
5. Testing and qualification equipment and facilities are the responsibility of the contractor.
6. The CSA will provide the following Government Furnished Equipment:
   - (i) CLPA wedge interface and connector(s)
   - (ii) CLA connector(s)
   - (iii) Standard Dexterous Grasp Fixture (SDGF) and Dexterous Handling Target (DHT)
   - (iv) Launch (internal pressurized stow), on-orbit storage, crew IVA time and robotic manipulation costs will be covered under the CSA to NASA international agreement.

3.8 Baseline Camera Mandatory Requirements

The section contains the list of baseline camera minimum mandatory functional and performance requirements for the replacement camera. Since the baseline requirements are well understood, it is the objective of this Concept Study to propose a design as close as possible to a System Requirements Review level, with the intent to have a full SRR as soon as possible in the next phase. To this effect a requirements compliance matrix should be provided to the following requirements.

3.9 Camera Optical Properties

3.9.1 Must use bore-sight aligned optics.

3.9.2 Must provide color.

3.9.3 Must provide minimum 770 pixels by 500 pixels.

3.9.4 Must provide variable iris minimum range of f/2 to f/16.,

3.9.5 Must provide a minimum zoom ratio of 9.4:1.

3.9.6 Must provide a minimum Large Field of View (FOV) approximately 51.3 deg horizontal/ 39.3deg.

3.9.7 Must provide a narrow FOV less than 5.9 deg horizontal/4.4 deg vertical

3.9.8 Must have a focus range of 0.36 meters to 10 meters (infinity).

3.9.9 A camera lens cover must be provided that does not degrade optical performance. The existing camera lens cover can be used (reference to design ICD and drawings).

3.10 Camera Processor

3.10.1 Implementation and integration of the camera processor must not require modification to existing MSS control and command software.

3.10.2 Camera sync-input must allow for synchronization of the output video.

3.10.3 Camera commands must be provided via the input analog sync signal;

3.10.4 Output video to the RWS must be via Modified RS170A.

3.10.5 The camera must provide for loop-back of individual video lines from the analog sync signal to the camera output video signal (lines 15 and 19);

3.10.6 The camera must provide output video and sync pass-through capability;

3.10.7 The camera must have camera telemetry embedded in the output video.

3.10.8 The camera must provide connectivity with the Video Distribution Unit (VDU) (directly in the CLA configuration and indirectly through the PTU in the CLPA configuration).

3.10.9 On-board camera processing software or firmware must be modifiable and capabile of being up-linked.

3.11 Power

3.11.1 The camera optics, processor, lights/PTU and enhancement module must operate with120 VDC operation power provided by the MSS.

3.11.2 The camera optics, processor, lights/PTU and enhancement module must consume power ≤ 75 watts @ 127.5 Vdc;

3.12 Electrical, Mechanical and Structural Features

3.12.1 Mass must be ≤ 20.45 kilograms (45 lbs) for CLPA, <16.36 kilogram (36 lbs) for CLA. With the accommodation of an enhancement module the mass on each configuration could increase to +10%.

3.12.2 Overall Camera Head, Power/Processing Unit Volume must be ≤ 38.1cm depth x 22.86 height x 12.7cm width (15in x 9in x 5in).

3.12.3 The lights assembly can either be considered in the above volume or packaged within the overall CLA/CLPA ORUs' volume of 28.1cm depth x 22.86 height x 22.86cm width (15in x 9in x 9in) for CLA and 40.6cm diameter x 43.2cm height (16in x 17in) for CLPA.

3.12.4 The camera assembly base must match the current CLA and CLPA ICDs to MSS with respect to the mounting mechanical envelope, electrical connections and bonding and mounting surface(s) unique to MSS TVC cameras.

3.12.5 A PTU for the CLPA configuration must be provided with 350 degrees pan and 184 degrees tilt;

3.12.6 Implementation of a protective element or mechanism for the optics against contaminates or demonstration that this is not required. Re-use of existing camera covers is also an option (reference Camera Lens Cover, section 5.6).

3.12.7 Camera optics must be aligned with existing Robotic Workstation System (RWS) video overlays and displays (reference to the overlays and displays ICDs)

3.12.8 The CLA ORU configuration must be able to withstand 20lb compression force in any direction.

3.12.9 The CLA/CLPA ORU must be EVA, EVR and IVA compatible.

3.13 Logistics

3.13.1 Life (operational) must be ≥ 10 years. A shorter operational life can be considered but a trade-off must be provided to demonstrate the cost benefits per unit, accounting for launch, storage and IVA/EVR operational increases.

3.13.2 The camera system must be designed for graceful degradation. No single failure would prevent minimum operations.

3.13.3 The baseline camera must be space-qualified to criticality 3 level

3.13.4 The baseline ORU camera must be IVA repairable.

3.14 Environmental Testing

3.14.1 The MSS replacement camera must be fully Space-qualified, this includes verification testing activities, such as:

3.14.1.1 Vibration and shock testing

3.14.1.1.1 The ORU must be qualified for internal pressurized stow on Space-X Dragon, Soyuz, Progress or HTV launch vehicles.

3.14.1.2 Thermal cycling and TVAC testing

3.14.1.3 EMI/EMC testing

3.14.1.4 Radiation

3.15 Thermal Control

3.15.1 Survivability for > 3 hours unpowered

3.15.2 Survival temperature range of max ≥ 85C to minimum ≤ -50C.

3.16 MSS Camera lights minimum mandatory performance requirements:

3.16.1 Minimum luminance of 0.7 foot-candles minimum over a target diameter 32.8 feet (10m) at a distance of 32.8 feet with luminance uniformity must be better than 1.5:1;

3.16.2 Illumination uniformity over a target diameter of 39.4 inches (1m) at a distance of 39.4 feet must be no greater than 2:1, and similarly at 14 inches (0.356m);

3.16.3 Graceful degradation.

3.16.4 Thermal control.

4 MSS Camera Enhancement Options

4.1 Introduction

As part of the process of providing replacement MSS cameras, the CSA wants to investigate the technical options that could enhance MSS's capabilities for inspection, operations and and/or Autonomous Rendezvous and Docking (AR&D). This activity provides the opportunity to evaluate the feasibility of packaging showcase enhancement technologies easily on the MSS replacement cameras to provide new capabilities on the International Space Station (ISS).

Consideration should also be given to alternate design options which enhance reliability and redundancy.

4.1.1 Capabilities description

These enhancements will be introduced as single unit modular additions that would be "plug-and-play" mated to the MSS Camera modules by crew as part of an Intra-Vehicular Activity (IVA). The CSA is interested in using one or more of the following technologies, listed in the order of priority:

1. HD Camera
2. 3D Scanning Lidar
3. Infra red (IR) camera
4. Software based enhancements extending camera capabilities

These options will require Wi-Fi and on-board data storage and will be commanded and controlled via the ISS JSL network. Software Application Program Interfaces (APIs) for command and control must compatible with the JSL laptops (reference spec) and controllable by ground control.

Power for operations and thermal keep-alive states would be provided by the payload interface connector provided by the baseline MSS replacement camera.

4.1.1.1 Inspection capability

Given that the life of the ISS has been extended to 2020 and discussions have started to possibly extent it even further, the ISS operations may face some challenges such as its structural integrity because ISS was designed to 2015 and space debris is damaging the structure of ISS as evidenced by space shuttles. There is also evidence suggesting that the boom of Canadarm 2 had been hit by space debris. The structural life issue and space debris damaging cause the concern of safety and usability of ISS. Those are arguments in favour of developing an inspection capability on board the ISS. This capability has been identified by the CSA as the most important from a strategic point of view. The delivery of such technology would be applied to the CSA's Common System Operating Cost (CSOC) of the ISS.

4.1.1.2 AR&D capability

Since one of the ISS objectives is to be an low earth orbit (LEO) test-bed for the advancement of space technologies, the CSA wants to capitalize on the opportunity to evolve our robotics capabilities by developing and demonstrating functionalities such as, video servoing and autonomy. To achieve this would not only assist in on-going robotics operations (reducing operator time) and provide an additional offering for CSOC offset, but would assist in advancing Canada's position as a leader in space robotics.

4.1.2 Technology description

4.1.2.1 HD Camera

The ability to provide HD still or video capability on ISS is highly desirable to all parties as it can greatly increase inspection capability and can also provide high quality resolution video and pictures for public relations.

HD should be investigated as an enhancement unit or can be considered as the optical component of the baseline MSS replacement camera. If it is considered as part of the baseline camera unit, rationale should be provided identifying any technology risks (i.e. CCD/CMOS life vs radiation) and a mitigating action plan to ensure early delivery of the MSS replacement camera will not be impacted.

For an HD camera to function as the baseline MSS replacement camera, the design would have to describe compliance to transmitting video over NTSC 170A and identify how high-definition video would be processed and delivered, for example, with internal storage and Wi-Fi transmission to the ISS JSL network.

4.1.2.2 3D Scanning LiDAR based technologies

A strategic objective of the CSA's Exploration Core Program is to advance the technology of space-based LiDAR systems, which have important current and future applications for space exploration in Low Earth Orbit (LEO) and beyond. For more than two decades, the CSA has been funding incremental developments in space-based LiDAR under the Space Technology Development Program (STDP) & Exploration Core Program, which have led to several successful applications most notably the Laser Camera System (LCS) for on-orbit inspection of the thermal tiles on the Space Shuttle, a LiDAR for the Canadian Meteorological station on the Phoenix Mars Lander, and three successful TriDAR missions on the Space Shuttle to demonstrate rendezvous and docking with the ISS. See the CSA public website (www.asc-csa.gc.ca) for more details on these missions.

The CSA is interested in this technology as it can be applied to inspection and autonomous robotic operations.

4.1.2.3 Infra red (IR) camera

Infra red cameras (IR) have been in previous AR&D missions such as the TriDAR DTOs and Orbital Express. Infra red cameras can have many applications on the ISS, such as, inspection and tracking of visiting vehicles. IR data could also be collocated with LiDAR data to produce a textured point cloud. The IR technology the CSA is interested in is similar to the technology demonstrated during the Orbital Express mission. Specifically, a Microbolometer equipped with a vanadium oxide (VOx) detector to be used for ISS inspection.

4.1.2.4 Software based enhancements extending camera capabilities

While the mandatory requirement for the baseline cameras is to fit seamlessly in the existing MSS system and therefore not require any modification to MSS software, the CSA recognizes that there are several areas where software modifications could enhance or extend the life of a video system. To that intent, we have invite contractors to propose MSS software modifications with limited command/control impacts. Delivery (cost and schedule) should take into consideration individual features as well as logical and economical bundling of features.

4.2 Assumptions

The following are assumed for the enhancements portion of the MSS cameras:

- Communication between the hardware and the inside of the ISS will be through a wireless Ethernet link provided by the ELC Wireless Comm (EWC) infrastructure.
- No modifications to existing MSS telemetry will be required.
- Communication between ground and the ISS will be done through a remote desktop connection initiated from the Mission Control Center in Houston (MCC-H).
- Use of commercial parts will be permitted.
- Use of Electrical, Electronic, and Electromechanical (EEE) parts will be limited to interfaces only.
- Failure Mode Effects Analysis (FMEA) and parts de rating will be limited to error propagation only.
- Qualification will be performed to Proto Flight levels.
- There will be two copies of the hardware produced: an engineering model (EM) and a Proto Flight Model (PFM).
- Qualification will be performed on the PFM model.
- Launch of the proposed units should be assumed via internal pressurized stow on either Dragon or HTV launch vehicle. Cost of launch will come from the CSA/NASA negotiated budget for up-mass.

4.3 Requirements

The Contractor must develop and present an overall capability concept that would cover one or both of the two capabilities enumerated in Section 4.1.1, using one or more of the enhancement listed in Section 4.1.2. The concept should include a conceptual design of the new equipment, other hardware, software and instruments, qualification, implementation, launch and transportation to ISS, IVA installation, operations, command and data communications, ground station, science data analysis and utilization (if applicable) and disposal

The basic requirements are as follows:

- The proposed technology must last for a period of at least 2 years after installation, after which it must gracefully degrade, meaning that degradation must not induce failure to other subsystems.
- It must be possible to carry out the technology demonstration on the ISS no later than 2016.
- The development of the proposed concept must not involve modifications or integration to the MSS software, with the exception of the MSS Software Based Enhancements option.
- The proposed technology must use NASA EWC and JSL networks to MCC-H as a separate, non-critical command and control. An analysis must also be performed to recommend how to address limited wireless Ethernet coverage on the ISS (see RD-1 for details), especially on the Nadir side of the ISS (see Figure 4.1 and Figure 2).
- The proposed technology must be able to be mounted on the CLA and/or CLPA piggy-back interface and installable by IVA.
- Mass and volume must not exceed the mandatory camera volume requirements when mounted on the CLA or CLPA ORU.
- Power must not exceed the mandatory camera power requirements and must be provided via a power connector from the CLA/CLPA ORU.

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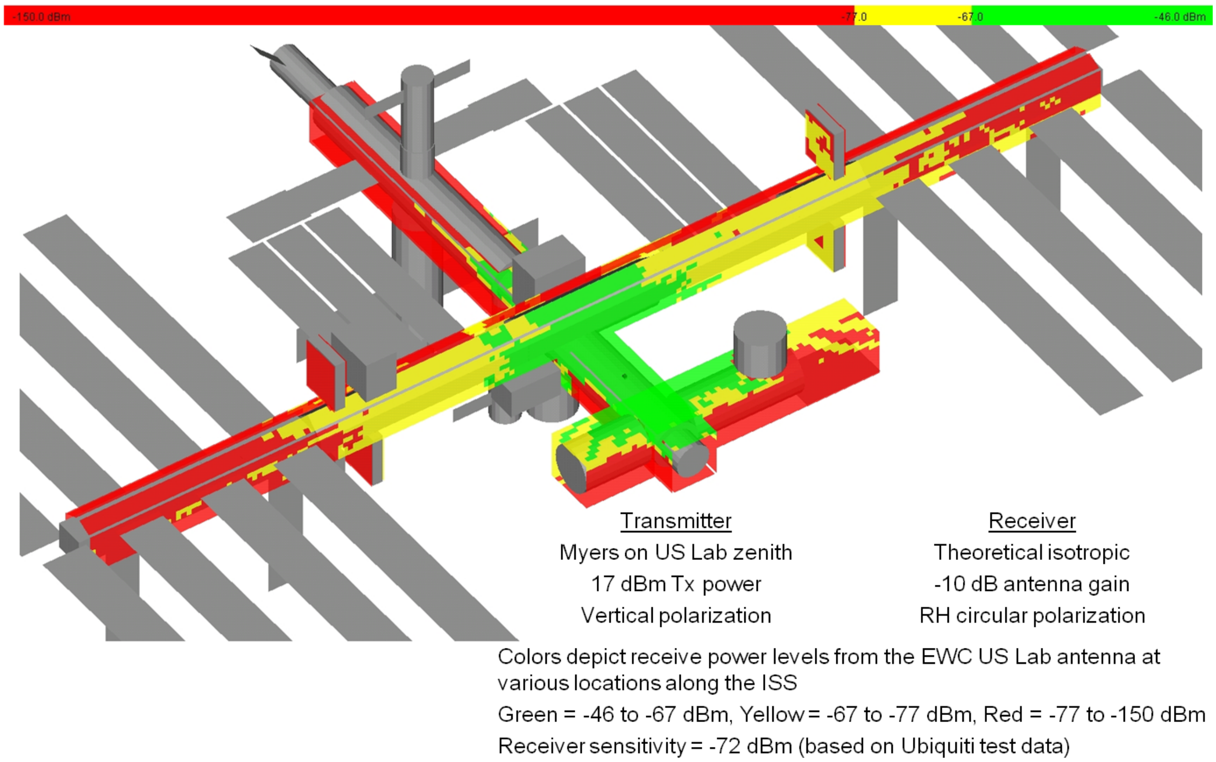


Figure 4.1 Received Power from EWC Antenna (Zenith View) (Credit: NASA)

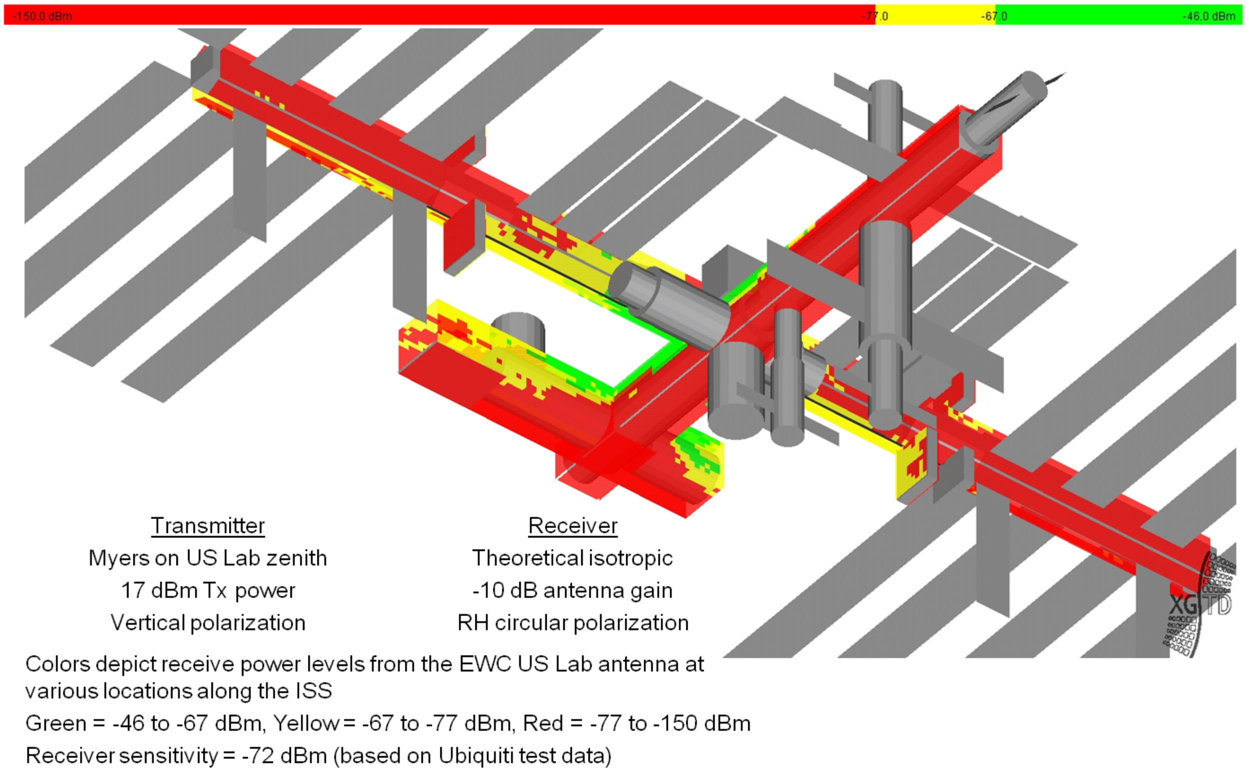


Figure 2 Received Power from EWC Antenna (Nadir View) (Credit: NASA)

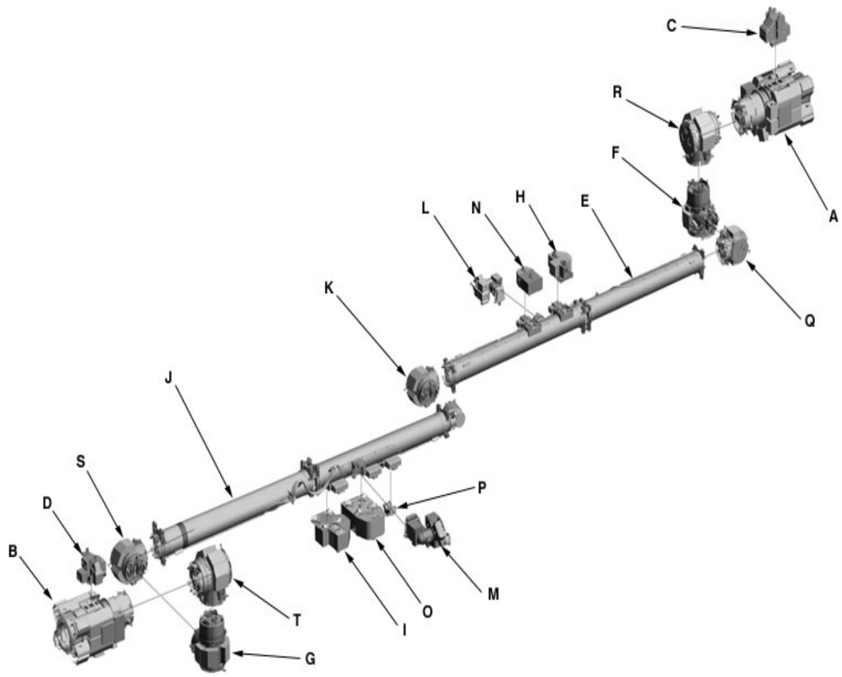
5 Description of Existing MSS Video System

5.1 Mobile Servicing System (MSS) Camera Locations

The Space Station Remote Manipulator System (SSRMS) (Figure 5.1) has two Camera/Light Pan/Tilt Unit Assemblies, (CLPAs) one on each boom, and two Camera and Light Assemblies (CLAs), one on each Latching End Effector (LEE).

Figure 5.1 – Space Station Remote Manipulator System (SSRMS) Configuration

Summary of SSRMS

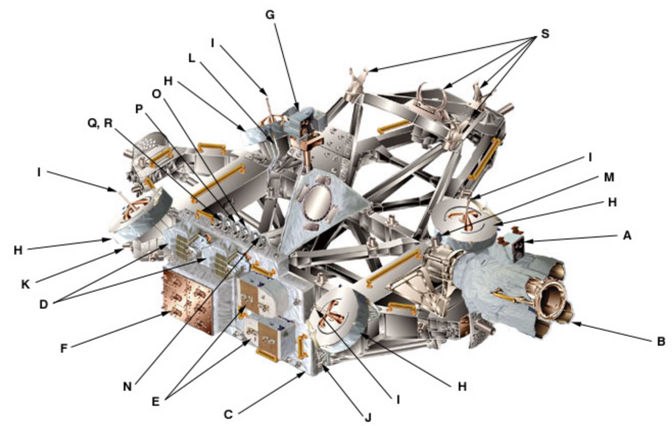


A) LEE - Latching End Effector (End A)	K) EJOD - Elbow Joint - Joint ORU #4
B) LEE - Latching End Effector (End B)	L) CLPA #1 - Camera, Light & Pan/Tilt Assembly (Boom B / End A)
C) CLA #1 - Camera & Light Assembly (End A)	M) CLPA #2 - Camera, Light & Pan/Tilt Assembly (Boom A / End B)
D) CLA #2 - Camera & Light Assembly (End B)	N) ACU - Prime - Arm Computer Unit (Boom Segment B2)
E) Boom Assembly B1/B2 (End A)	O) ACU - Redundant - Arm Computer Unit (Boom Segment A2)
F) EJOD - Yaw Joint - Joint ORU #2 (End A)	P) BRA - BDU Replacement Assembly (Boom Segment A2)
G) EJOD - Yaw Joint - Joint ORU #6 (End B)	Q) EJOD - Pitch Joint - Joint ORU #3 (End A)
H) VDU #2 - Video Distribution Unit (Boom Segment B2 / End A)	R) EJOD - Roll Joint - Joint ORU #1 (End A)
I) VDU #3 - Video Distribution Unit (Boom Segment A2 / End B)	S) EJOD - Pitch Joint - Joint ORU #5 (End B)
J) Boom Assembly A1/A2 (End B)	T) EJOD - Roll Joint - Joint ORU #7 (End B)

The Mobile Base System (MBS) (Figure 5.2) has one CLPA positioned on a mast in the center of the MBS and one CLA on the Payload and ORU Accommodation (POA).

Figure 5.2 – Mobile Base System (MBS) Configuration

Summary of MBS

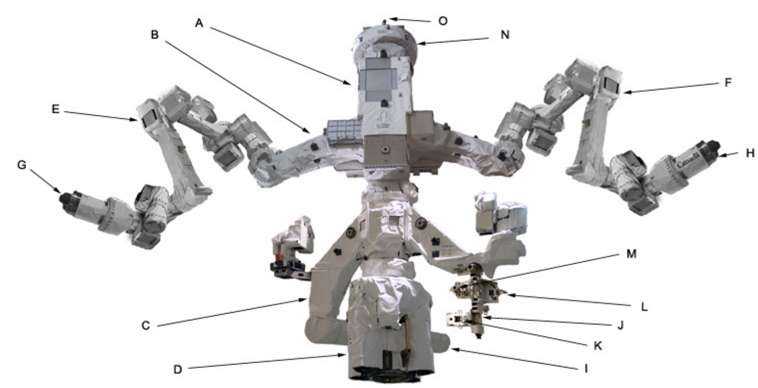


A) Camera & Light Assembly (CLA)	K) Cable Harness Assy W1, W2
B) Payload & ORU Accommodation (POA)	L) Cable Harness Assy W3, W4
C) ORU Base Assembly (OBA)	M) Cable Harness Assy W5, W6
D) Video Distribution Unit (VDU) x 2	N) Plate, Connector Assy W9, W10
E) MBS Arm Computer Unit (MCU) x 2	O) Cable Harness Assy, Camera W19
F) Canadian Remote Power Control Module (CRPCM) x 6	P) Harness Assembly W14
G) Camera, Light & Pan/Tilt Unit Assembly (CLPA)	Q) Panel, Electrical A, Assy W11
H) PDGF ORU Assembly x 4	R) Panel, Electrical B, Assy W12
I) PDGF Grapple Shaft x 4	S) MBS Common Attach System (MCAS)
J) Cable Harness Assy W7, W8	

The Special Purpose Dextrous Manipulator (SPDM) (Figure 5.3) has two CLPAs on outriggers and one CLA on the SPDM Latching End Effector (LEE).

Figure 5.3 – Special Purpose Dextrous Manipulator (SPDM) Configuration

Summary of SPDM



A) Body Assembly	I) Enhanced Orbit Replaceable Unit (ORU) Temporary Platform Assembly (EOTP)
B) Upper Body Assembly	J) Integrated Tool Holder Assembly (THA)
C) Lower Body Assembly	K) Robotic Offset Tool
D) Latching End Effector (LEE)	L) RMCT Assembly
E) Arm Assembly	L) RMCT Assembly (not shown)
F) Arm Assembly	M) Socket Extension Tool (SET)
G) ORU/TOOL Changeout Mechanism(OTCM)	N) PDGF ORU Assembly
H) ORU/TOOL Changeout Mechanism(OTCM)	O) Power Data Grapple Fixture (PDGF) Shaft

5.2 MSS Camera Description

There are two MSS camera Orbital Replaceable Unit (ORU) configurations. One configuration is the CLPA (Figure 5.4). The other configuration is the CLA (Figure 5.5).

Figure 5.4 - Camera/Light Pan/Tilt Unit Assembly (CLPA)

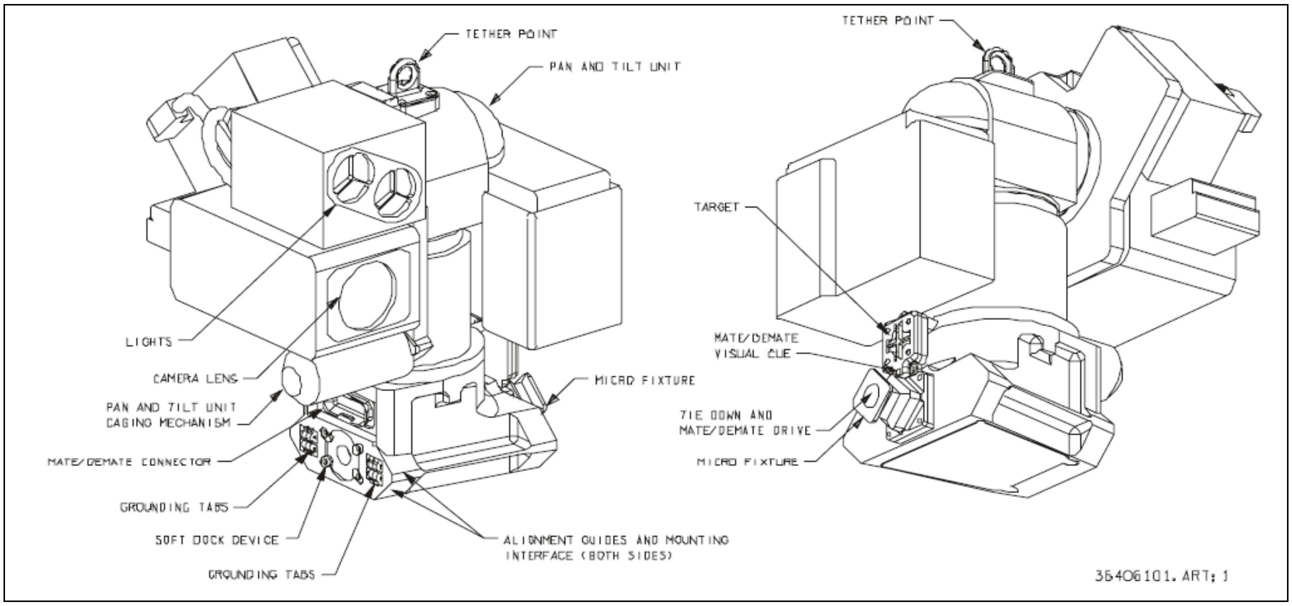
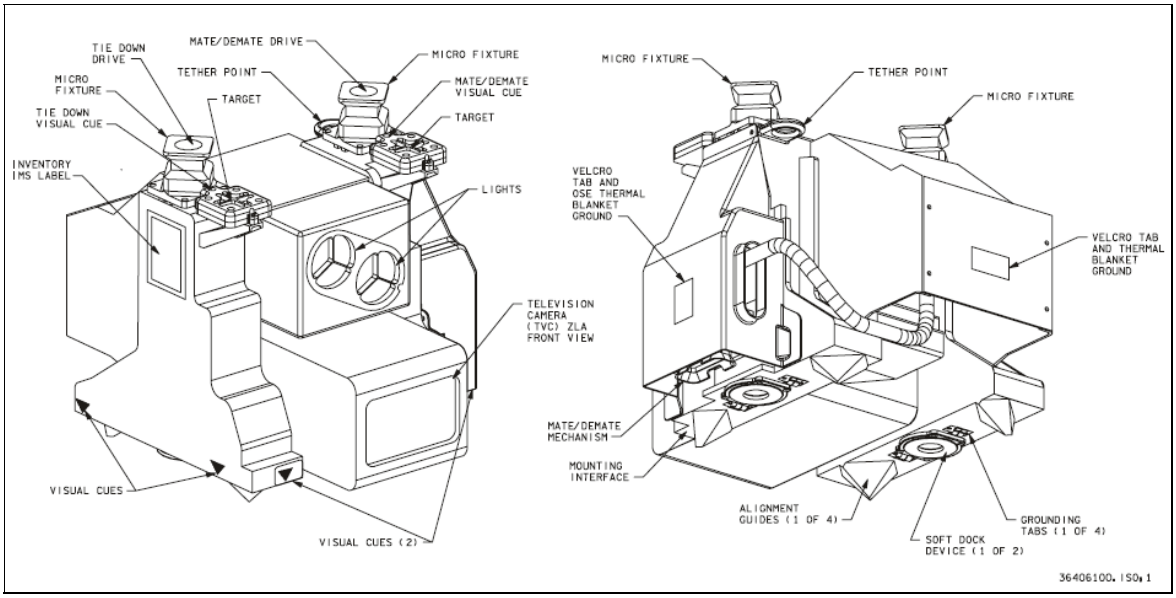


Figure 5.5 - Camera and Light Assembly (CLA)



Each MSS camera consists of three components: a Camera Control Unit (CCU), a Camera Head Unit (CHU), and a Zoom Lens Assembly (ZLA). The total mass of the camera is approximately 5.4 kg (12 lb).

5.2.1 Camera Control Unit (CCU)

The CCU contains only avionics. It receives/sends command signals for the CHU/ZLA and PTU from/to the VDU. The commands are sent from the VDU to the CCU in the sync signal. The CCU reads the sync signal for a location code to determine if the commands are meant for its CHU/ZLA or PTU. The CCU strips the commands off the sync signal and sends them on to the appropriate component. The CHU transmits the CCU status information on video settings, temperature limit information, and over/under voltage. The PTU sends the CCU pan and tilt limits, pan and tilt position, and temperature limit information. This information is returned to the VDU in the video signal that originates from the CHU.

The CCU is approximately 16 cm by 8 cm by 9 cm (6 in. by 3 in. by 3.5 in.) in size.

5.2.2 Camera Head Unit (CHU)

The CHU contains a color CCD image sensor. The CCD dimensions are 9.11 mm by 6.96 mm with a used area of 8.8 mm by 6.6 mm.

The CCD size is 770 pixels by 500 pixels. Each pixel has two photodiodes, each 5 μm by 4 μm. Image controls like sharpness and gain, for example, are controlled in the CHU. The CHU is connected to the CCU by a flexible cable.

5.2.3 Zoom Lens Assembly (ZLA)

The ZLA attaches to the front of the CHU and provides the capability for variable iris, zoom, and focus settings. The ZLA with the CHU is approximately 30.5 cm by 13 cm by 11 cm (12 in. by 5 in. by 4.2 in.) in size. The ZLA has a zoom ratio of 9.4:1. The maximum Field of View (FOV) is approximately 51.3 deg horizontal / 39.3deg, which corresponds to an Effective Focal Length (EFL) of approximately 9.0 mm. The minimum FOV is approximately 5.9 deg horizontal /4.4 deg vertical, which corresponds to an EFL of approximately 84.0 mm.

The minimum viewing distance is 36 cm (14 in.). The lens zoom function has two speed settings, but the rate switch on the Display and Control Panel (DCP) does not set them. At the start of a zoom command, the lens will zoom at the slower rate. After 2 seconds, the zoom rate will increase. There are no details available on the actual rates. However, the rates are set such that end-to-end travel is complete in 13 seconds. The zoom rate resets to the slow speed when the zoom command is terminated. Focus has a range of 0.36 meters to 10 meters (infinity). The commanding speed works in a similar fashion as zoom. The camera will adjust focus automatically when zoom is adjusted. This is done to assist the operator in acquiring optimum focus after a zoom operation is complete. The iris aperture has a range of f/2 to f/16. The commanding speed works in a similar fashion as zoom and focus, but the end-to-end travel for the iris is complete in 9 seconds.

A removable lens cover fitted to the existing camera housing has been added to all MSS cameras.

5.2.4 Light Assembly (LA)

The LA is used to provide illumination for close and distant viewing of MSS operations and inspections. For both the CLPA and CLA configurations, the LA is mounted directly above the camera. LA consists of two components: a lamp module and an electronics module. The lamp module holds two 65-W Tungsten Halogen lamps (2900o K color temperature). The electronics module receives the on/off command from the VDU. The LA has a mass of 2.3 kg (5.1 lb), and is approximately 11 cm by 13 cm by 13 cm (4 in. by 5 in. by 5 in.) in size. Each of the lamps can produce a 52° cone of illumination that provides an illumination level of 3.5 foot-candles at a distance of 10 meters (33 feet).

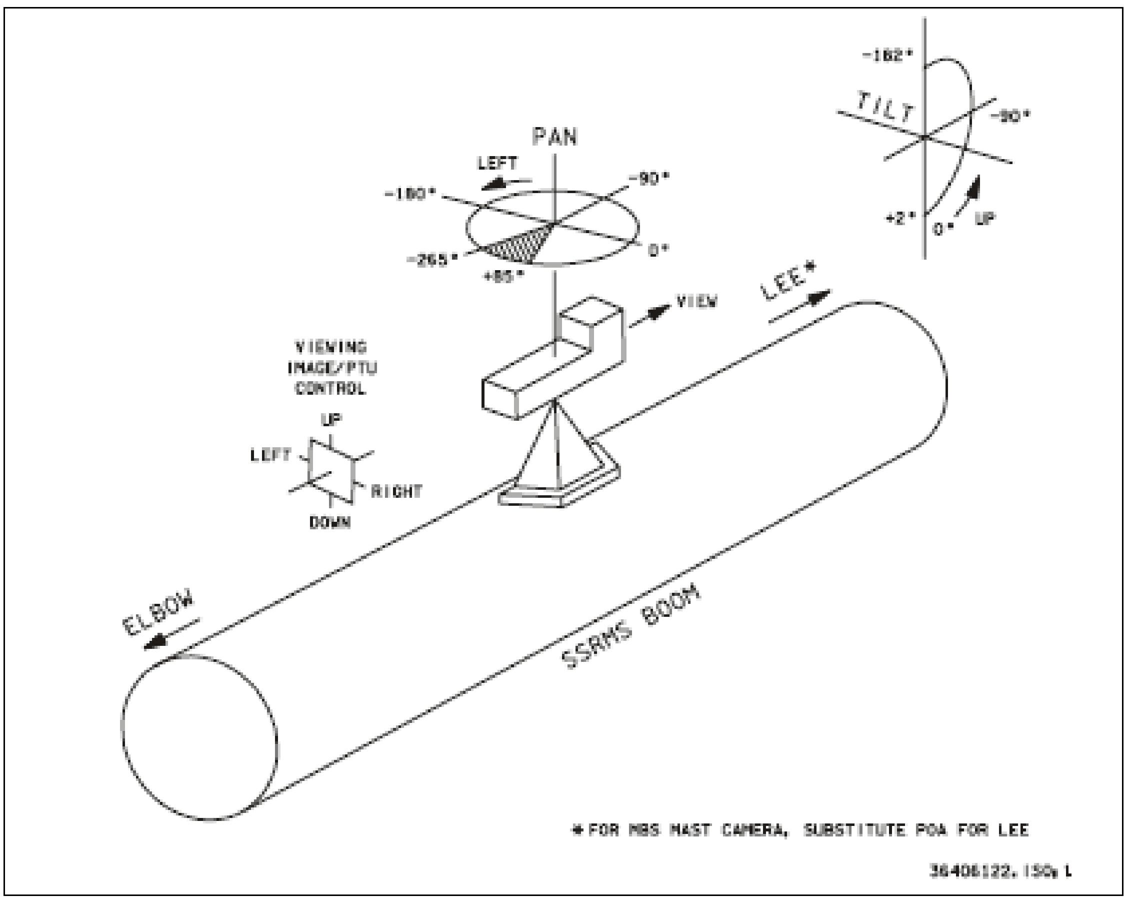
5.2.5 Pan/Tilt Unit (PTU)

The camera and LA mount directly to the PTU. The PTU plugs into the CLPA ORU Mate/Demate Assembly, which includes the CLPA ORU Mate/Demate Connector and Drive. For the purpose of discussing the CLPA, the CLPA ORU Mate/Demate Assembly and the PTU are considered one unit. The purpose of the PTU is to provide pointing capabilities for the camera and LA. The PTU provides the CLPA with the following freedom of motion.

- 350 deg pan
- 184 deg tilt

Figure 5.6 illustrates these pans and tilts ranges, and also shows the Camera Coordinate Frame. The PTU has fast (6 deg per second) and slow (1.2 deg per second) pan and tilt rates, and is equipped with limit switches that electrically inhibit actuator motion once a limit is reached. The PTU also has hard stops that physically stop the motion, but do not electrically inhibit the actuator from driving. The MSS camera defaults the pan and tilt speed to slow upon going operational.

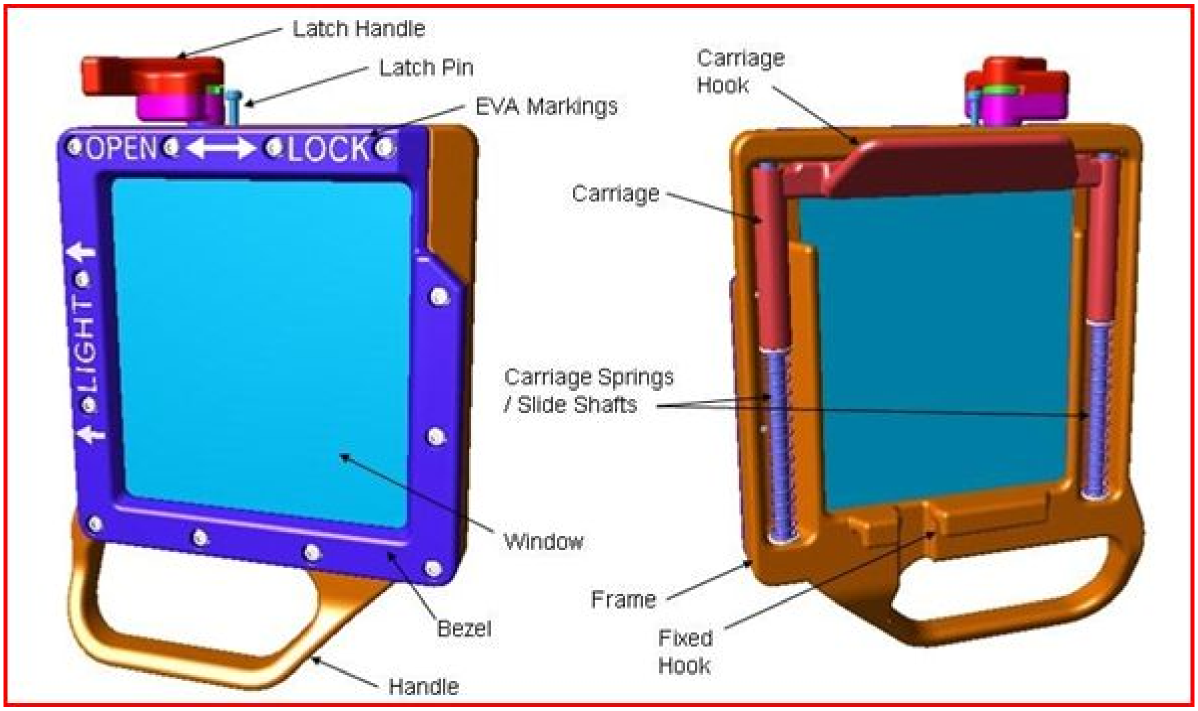
Figure 5.6 – PTU ranges and camera coordinate frame



5.2.6 Camera Lens Cover

More recently, camera lens covers (Figure 5.7) were installed on all MSS cameras to protect against contaminants being generated during attitude control firing of reaction control jets on all free flyers during robotic capture and release of these visiting vehicles. These camera covers were designed to fit the existing camera housings and can be installed by EVA or IVA. There are two (2) spare covers stored on-orbit today.

Figure 5.7 – Camera Lens Cover



5.3 MSS Camera Characteristics and Features Summary

The existing MSS Camera configuration (CCU, CHU, ZLA) function allocation, performance characteristics and features must be considered as minimum requirements. The Light Assembly and Pan & Tilt Unit are provided as reference because of the nature of their shared dependencies/interfaces. Dimensions identified in detailed sections below should be used as cumulative maximum dimension requirements.

Figure 5.8 – Mobile Servicing System (MSS) Camera Configuration

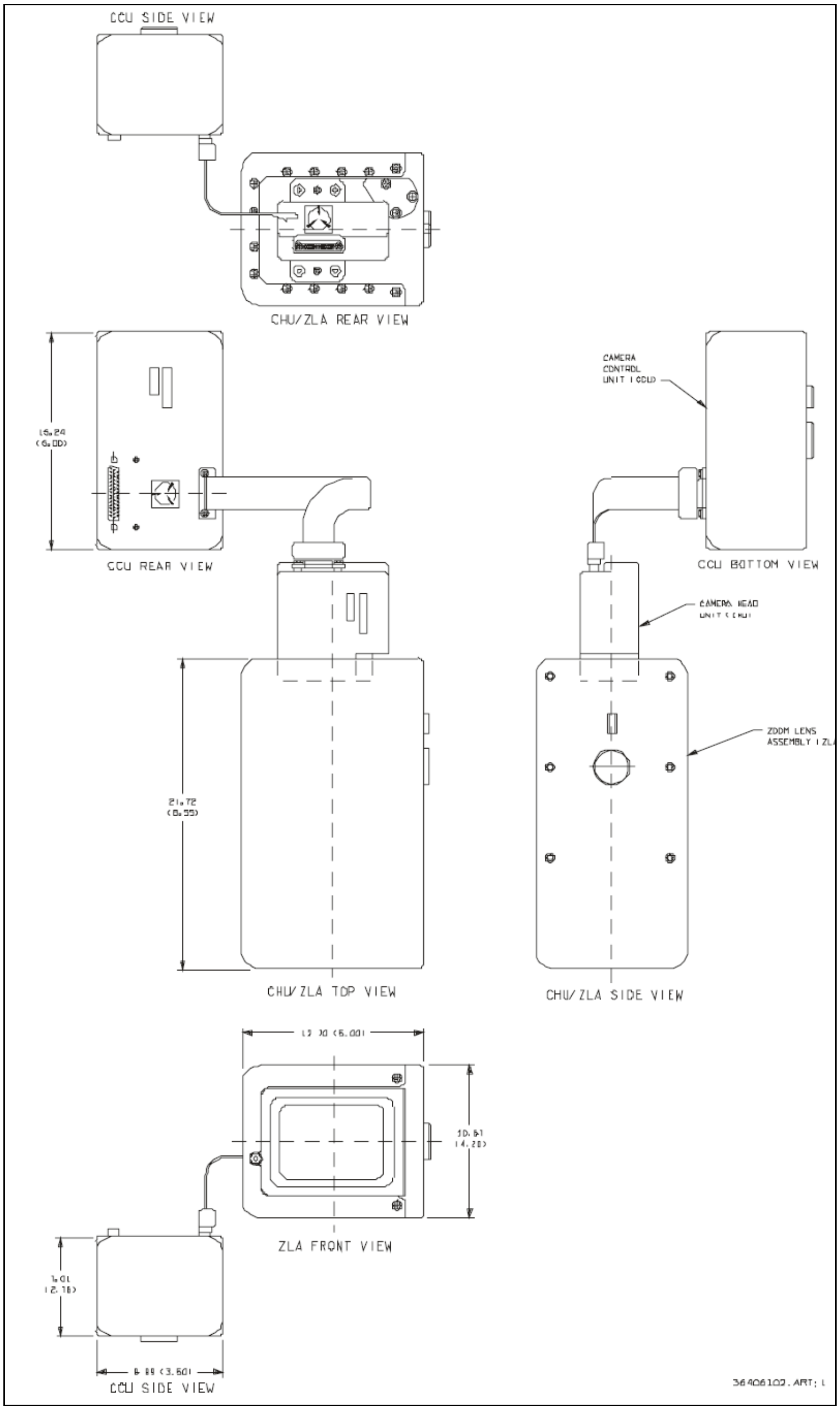
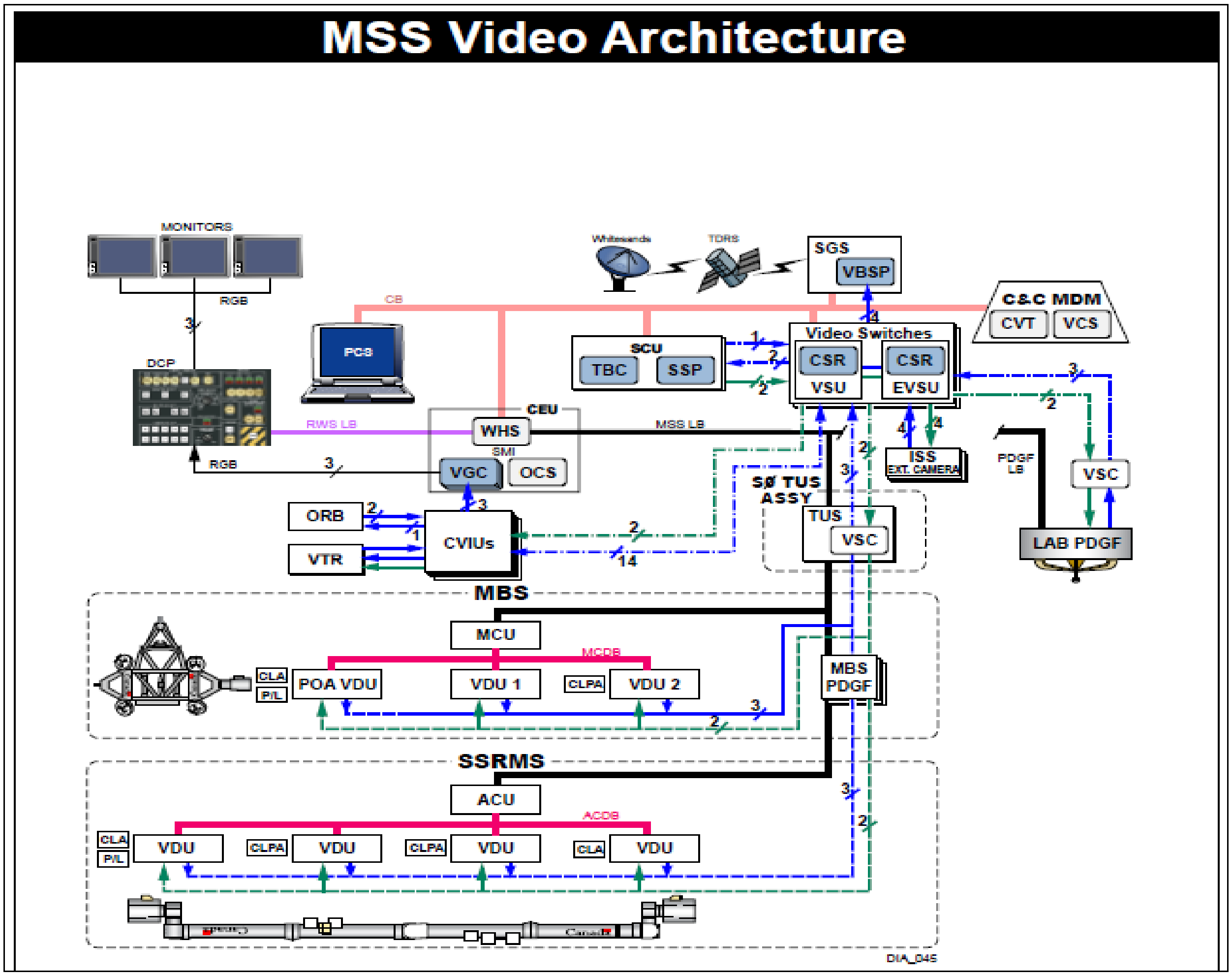


Figure 5.9 – MSS Video Architecture



Notes:

- Each VSU contains 1 CSR. Each EVSU contains 3 CSRs;
- VSUs interface with SCUs, CVIUs and VBSP;
- CVIUs provide 6 video lines to, and receive 8 from VSUs;
- EVSUs interface with M/T TUS, LAB PDGF VSC and ISS External Cameras;
- Each VGC includes Video graphics software (VGS).

All MSS cameras are located in the space environment, external to the pressurized ISS modules. However, the video must be distributed to the internally located Robotics Workstation. This is done via both the MSS and ISS Video Distribution Systems.

The overall MSS & ISS Video Distribution System is implemented as a complex distributed-switched network employing multiple video signal formats (baseband, PFM-modulation, RGB) and mediums (twisted shielded pair, coax, optical fiber) to interconnect the external cameras to the internally located Robotics Workstations

MSS Camera video (NTSC-RS-170A baseband) is passed to a MSS Video Distribution Unit (VDU), where it is Pulse Frequency Modulated (PFM) and “switched” onto one of three coaxial lines (channels). The video is then fed to a PDGF or along MBS Trailing Umbilical System (TUS) lines to an ISS Video Signal Converter (VSC) for conversion to optical fiber before being presented to a set of Video Switching Units (VSUs).

The VSUs feed Common Video Interface Units (CVIUs) that demodulate and convert to optical fiber to electrical signal format, before for presentation to the MSS Control Electronics Unit (CEU) Video Graphics Card (VGC). The VGC provides an RGB output to the appropriate RWS monitor. Note that the VSUs also provide video output to the ISS Space To Ground Subsystem (SGS) for transmission to the Ground.

MSS Camera commands are embedded into the vertical blanking interval of a centralized sync signal line that is generated by an ISS Sync & Control Unit (SCU) and distributed to all MSS cameras. Each camera location has a unique address that is present in the command header.

A command processor within each camera only executes the commands that are addressed to that specific camera.MSS camera telemetry is encoded into the vertical blanking interval (non-video portion) of the video signal, by the camera, and read by camera status readers within the ISS video switches. The telemetry is then overlaid onto the video image by the VGC.