



Image Science and Analysis Group  
KX\Human Exploration Science Office  
KAARES



# ISS and Orion Inspection Capabilities and Challenges

NASA Johnson Space Center  
Astromaterials Research and Exploration Science (ARES)  
Image Science and Analysis Group (ISAG)  
Robert Scharf / Jacobs / XI4  
Randy Moore / XI4  
<http://isag.jsc.nasa.gov/>

January 2017



# ISS Inspection Camera Assets



## ➤ EXTERNAL

- **Mounted to structure**

- 4 standard definition TV cameras with lights on pan/tilt units
- 2 wireless Nikon DSLR cameras mounted to cameras above (2 more planned)
- 4 standard definition TV cameras on the JEM bulkhead and JEM Exposed Facility

- **Mounted to robotics**

- 4 standard definition TV cameras (2 with pan/tilt) on SSRMS
- 4 standard definition TV cameras (2 with pan/tilt) on SPDM
- 1 standard definition TV cameras with light and pan/tilt on MBS
- 3 standard definition TV cameras (2 with pan/tilt) on JAXA JEM EF arm

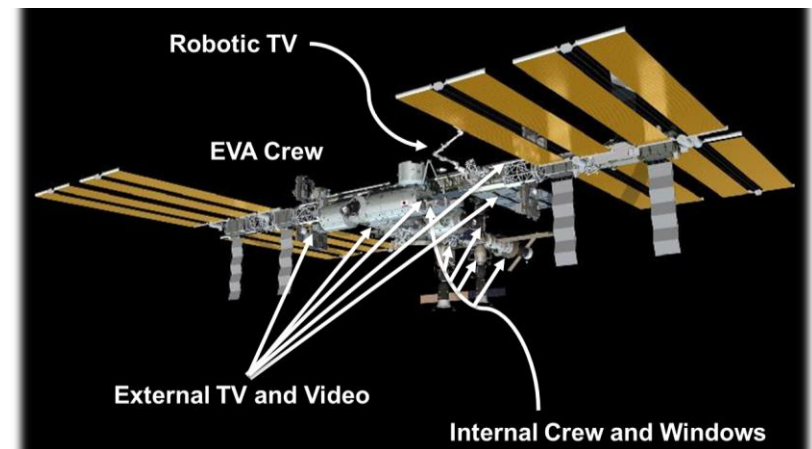
- **Crew equipment**

- 3 standard definition TV cameras with lights (wireless) on helmet
- Nikon digital SLR with selection of lenses and a flash unit
- GoPro Camera
- Infrared Camera

## ➤ INTERNAL

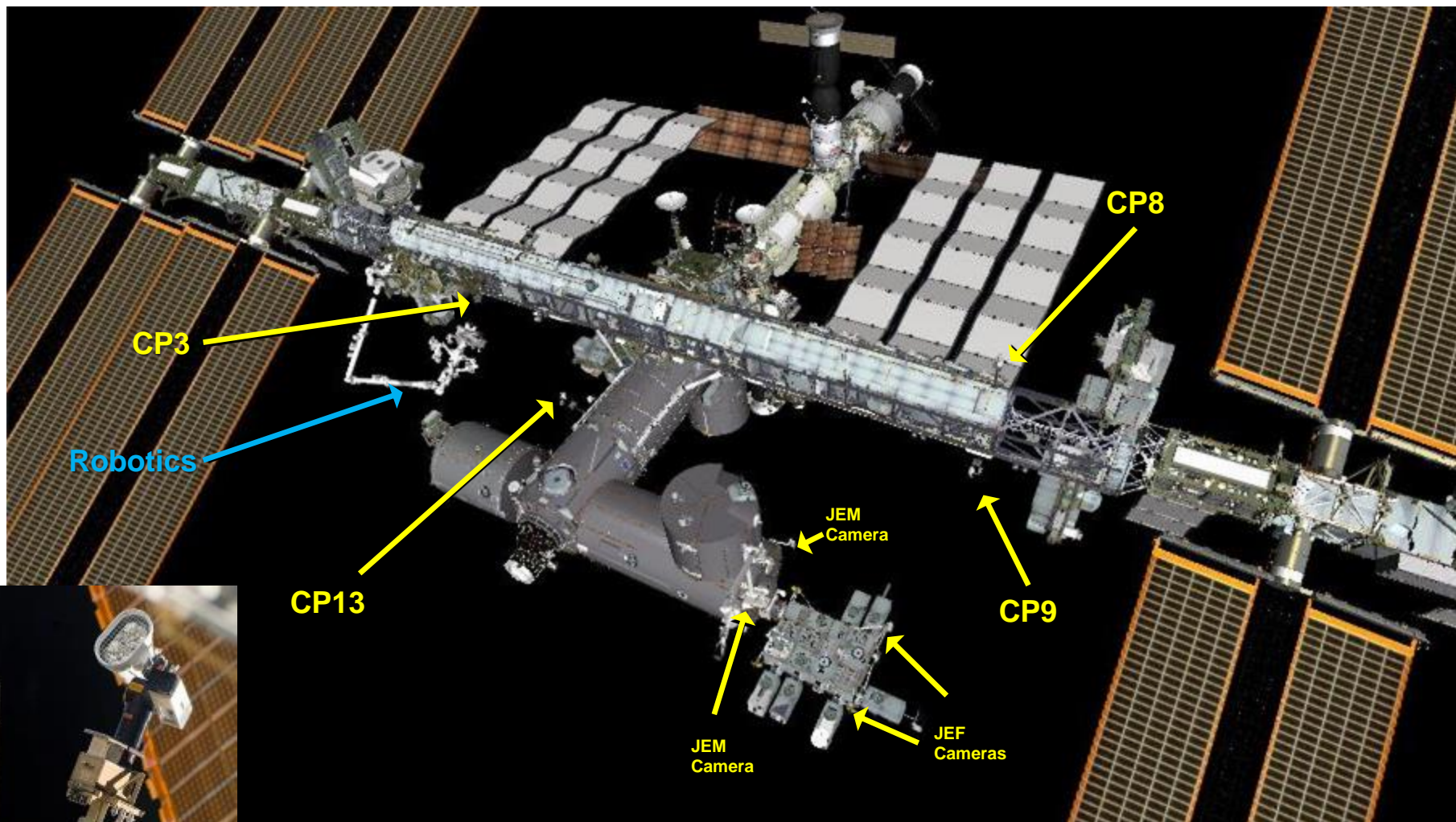
- **Crew handheld**

- Nikon D4 Digital SLRs, lenses
- 1 Nikon D3S modified for near-IR
- Selection of 2D and one 3D Video Camcorders
- Minicam with fiberscope





# External ISS Television Cameras



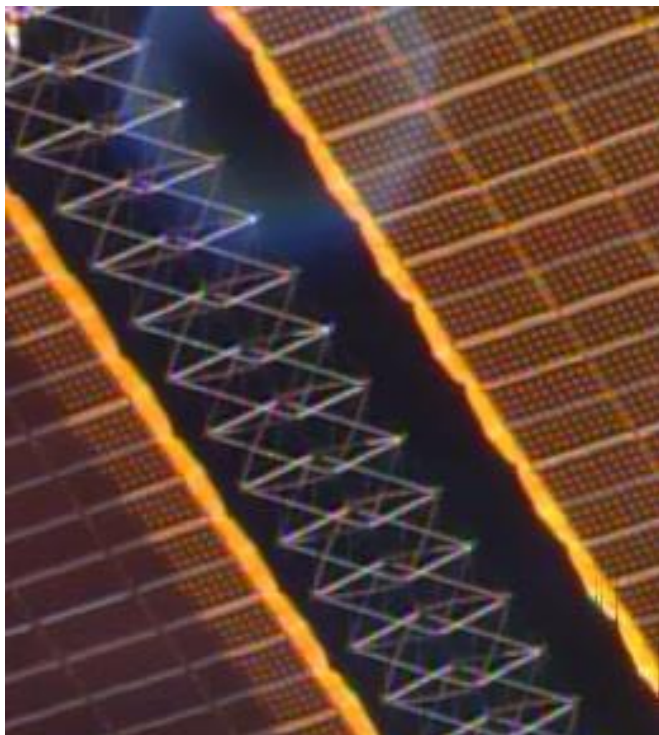
ETVCG – External TV Camera Group (4)  
 NTSC, 525 horizontal lines (USOS Standard)  
 CCD sensor  
 FOV: Max: 77x61 Min: 10x8°  
 Zoom ratio ~8:1

JEM EF – JAXA Experiment Module  
 Exposed Facility  
 NTSC, CCD

*Note: Nikon D4 DSLR/ with 56-600 equiv. zoom lens to be attached to each ETVCG (2016/2017)*



# External SD Television Cameras





# External HD Video and Still Cameras





# ETVCG Inspection Challenges



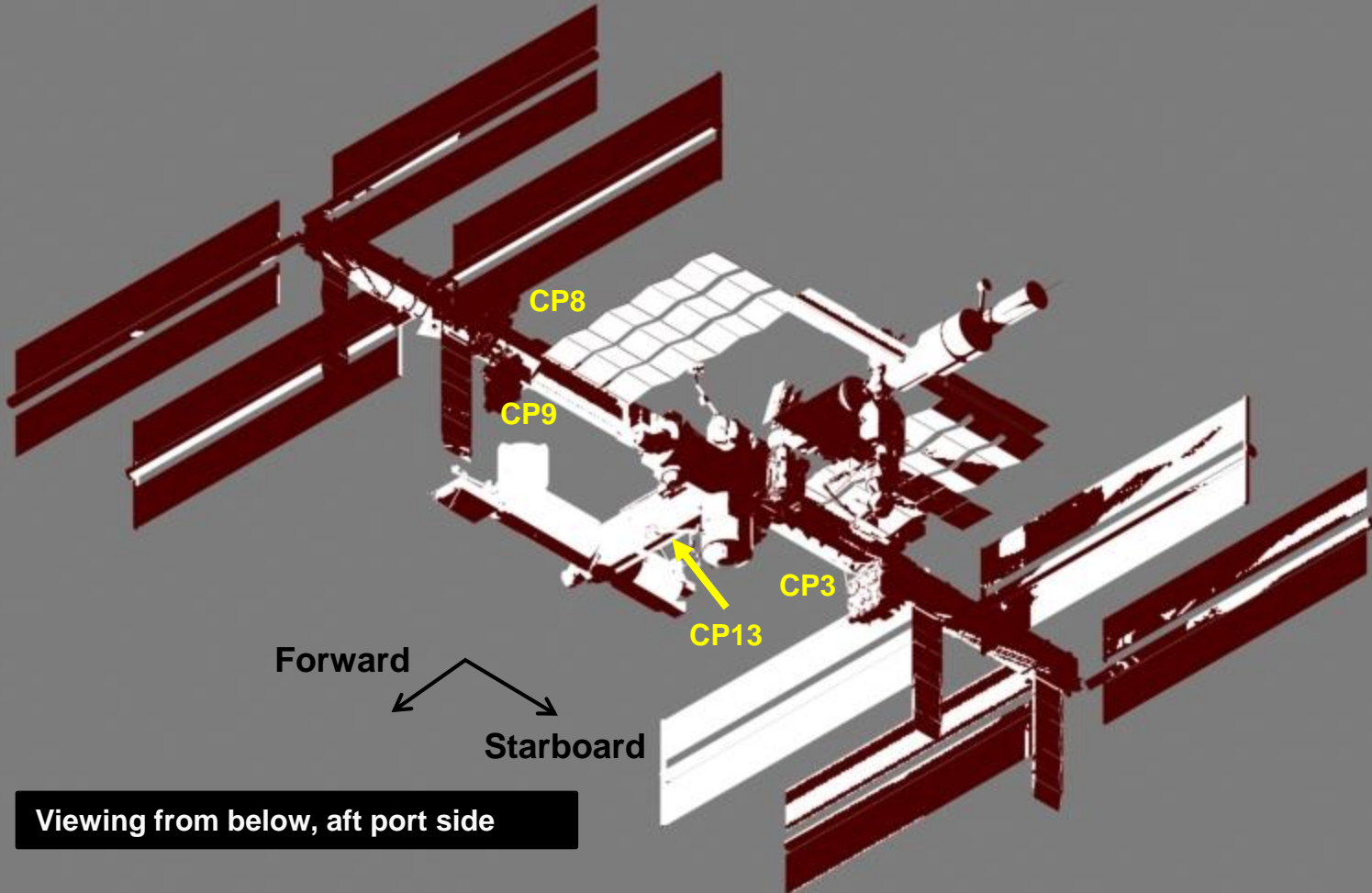
- **Limited camera installation locations, numerous blindspots**
- Resolution limitations – generally not adequate for detailed inspections
  - Standard definition TV
  - Compression of the video for downlink
  - Distance and high incidence viewing
  - *External high definition cameras planned for 2015 should dramatically improve capability*
- Hardware failure and degradation reduces capability
  - Three of four ETVCG cameras currently have issues (pink tint, intermittent stuck zoom and intermittent stuck iris)
  - Limited spares and opportunities to replace
- JEM cameras are not readily available
  - Camera operational time is minimized to conserve life
  - Pan and tilt via uplinked command script



# External TV Camera Coverage (ETVCGs (4) + JEM (4))



Brown shading shows current ETVCG and JEM cameras  
“blind spots”





# ETVCG Inspection Challenges



- Limited camera installation locations, numerous blindspots
- **Resolution limitations – generally not adequate for detailed inspections**
  - **Standard definition TV**
  - **Compression of the video for downlink**
  - **Distance and high incidence viewing**
- Hardware failure and degradation reduces capability
  - Three of four ETVCG cameras currently have issues (pink tint, intermittent stuck zoom and intermittent stuck iris)
  - Limited spares and opportunities to replace
- JEM cameras are not readily available
  - Camera operational time is minimized to conserve life
  - Pan and tilt via uplinked command script



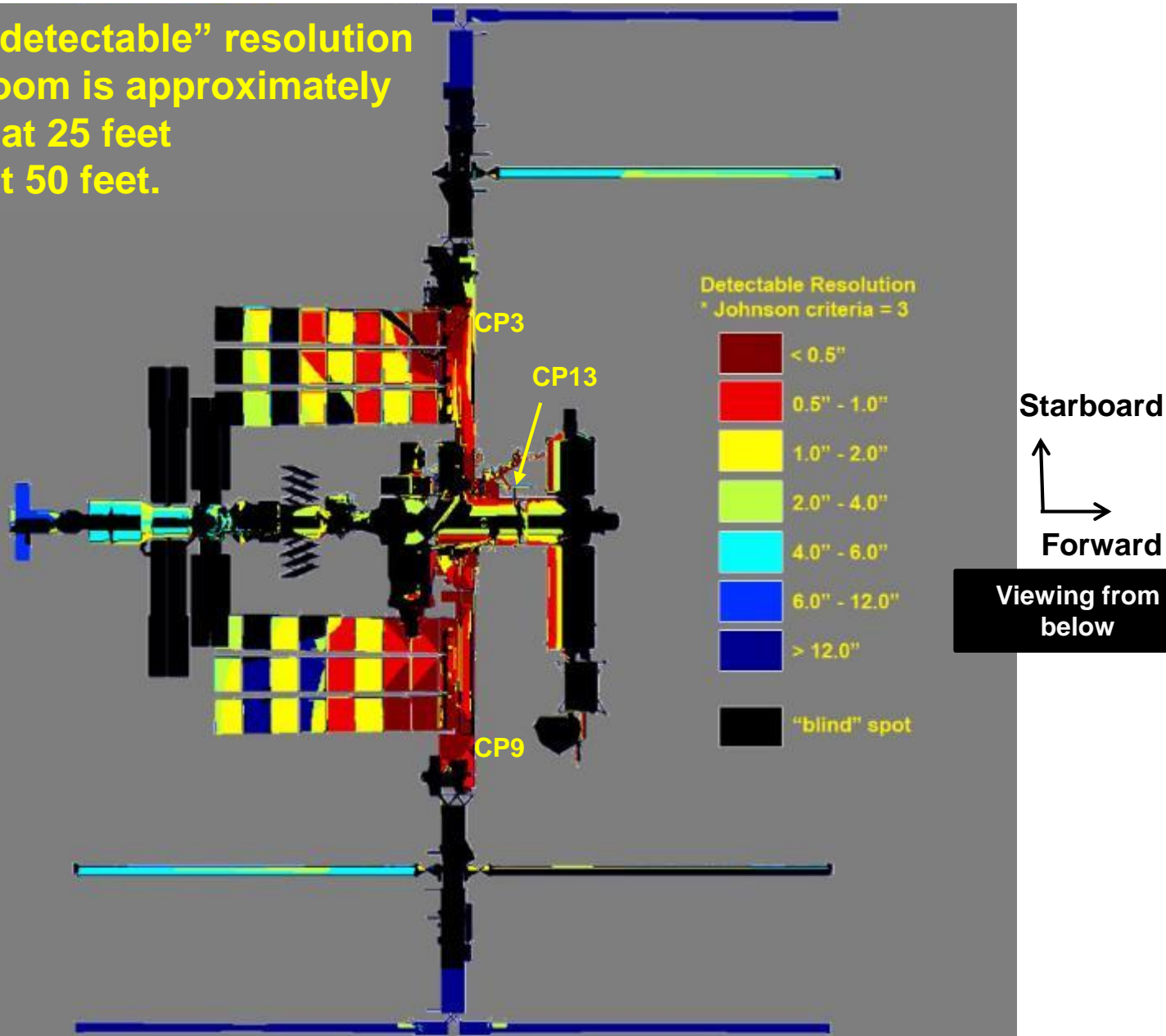


# External TV Cameras Resolution Analysis

## All ETVCGs Combined (4)



ETVCG "detectable" resolution at max zoom is approximately  
.25 inch at 25 feet  
.5 inch at 50 feet.





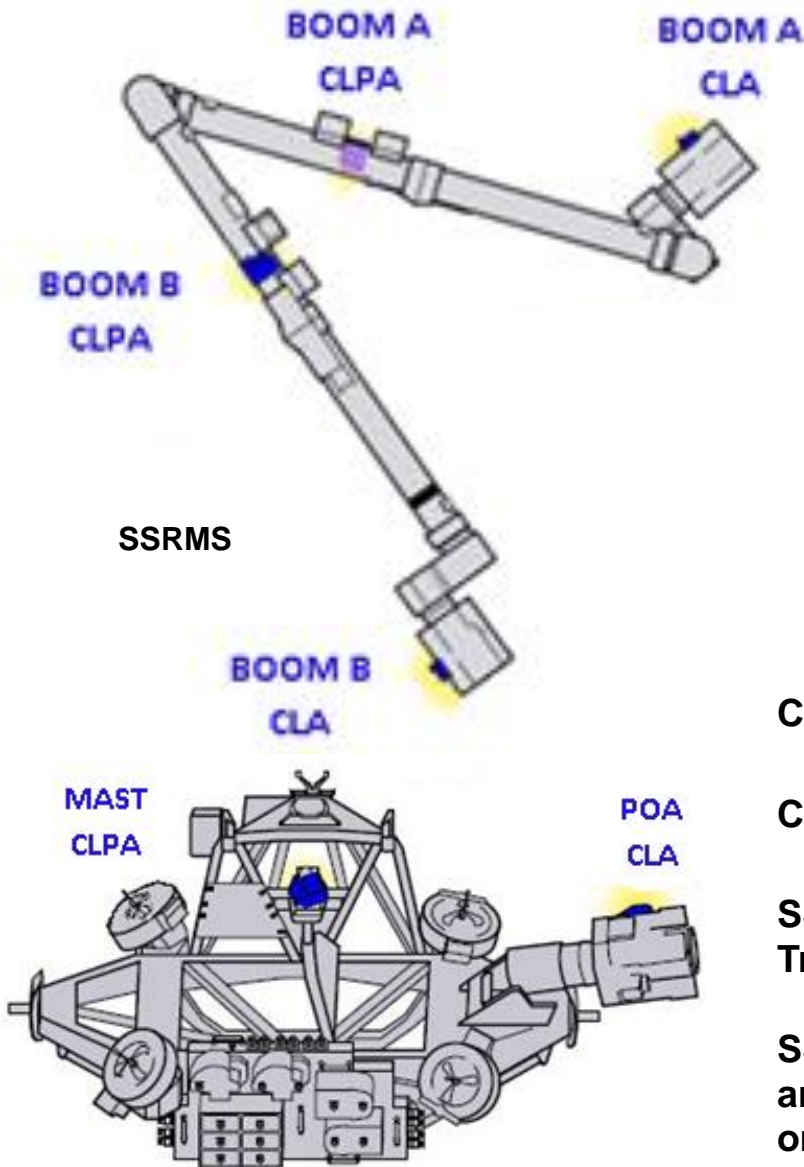
# External Mounted Video Inspection Challenges



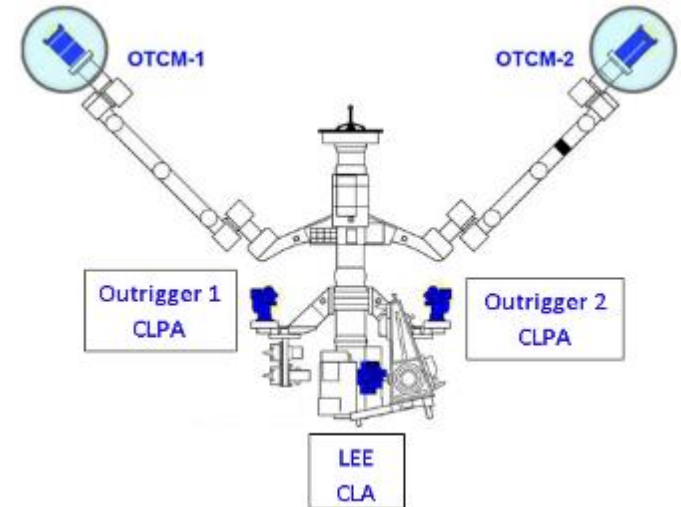
- Limited camera installation locations, numerous blindspots
- Resolution limitations – generally not adequate for detailed inspections
  - Standard definition TV
  - Compression of the video for downlink
  - Distance and high incidence viewing
  - *External high definition cameras planned for 2015 should dramatically improve capability*
- **Hardware failure and degradation reduces capability**
  - **Three of four ETVCG cameras currently have issues (pink tint, controller problem, and slow iris)**
  - **Limited spares and EVA opportunities to remove and replace**
- **JEM cameras are not readily available**
  - **Camera operational time is minimized to conserve life**
  - **Pan and tilt via uplinked command script**



# External Robotic Television Cameras (Mobile Servicing System)



Mobile Base System



Special Purpose Dexterous Manipulator (SPDM)/DEXTRE

CLA - Camera and Light Assembly (CLA)

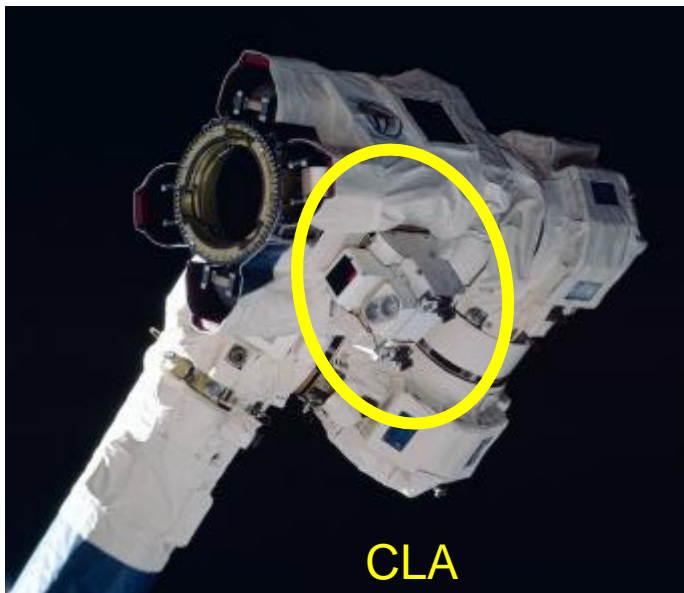
CLPA - Camera / Light / Pan-Tilt Unit Assembly

SSRMS moves along truss when attached to Mobile Transport/Mobile Base System (MT/MBS).

SSRMS is operational along truss at MT Worksites and Power and Data Grapple Fixtures (PDGF) located on USOS modules and Russian FGB.

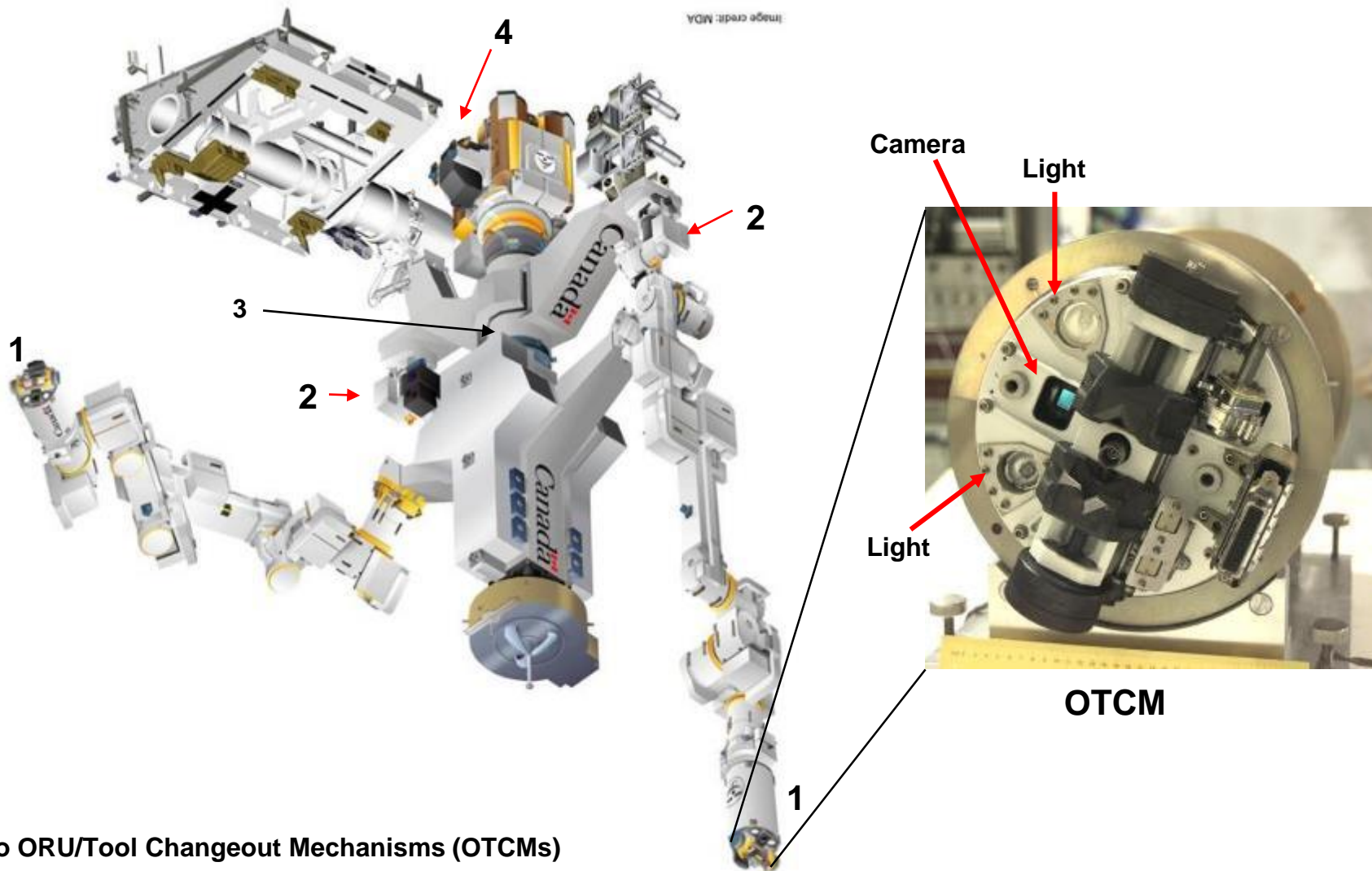


# External Robotic Television Cameras (Mobile Servicing System)



- Both CLA and CLPA utilize the same CCD camera and lights
- FOV Max ~ 52° x 40°, ~9mm focal length,  
Min ~ 6°x4° , ~84mm focal length
- Zoom ratio ~9:1
- The minimum viewing distance is 14 in.
- MSS camera “detectable” resolution at max zoom is approximately
  - ~.2 inch at 25 feet
  - ~.4 inch at 50 feet.
- Standard ETVCG and MSS frame rate: 30 fps

# SPDM (DEXTRE)



1. Two ORU/Tool Changeout Mechanisms (OTCMs)
  - 640x480, fixed focus, wide FOV, black/white
2. Two Camera/Light/Pan-Tilt Assemblies (CLPAs);
3. Body Roll Joint
4. SPDM Latching End Effector (LEE) with Camera/Light Assembly (CLA)



# Robotics Inspection Challenges



- **Robotic Operations are generally complex and require extensive planning.**
- **After planning joint angles/operations and then moving the manipulator to the inspection location, the viewing and resolution still might not be sufficient to resolve area of interest.**
- **Future inspection systems could plan to launch internally, but then go external through the JEM Airlock, however:**
  - **JEM Airlock usage is limited to a certain number of cycles per year**
  - **JEM Airlock usage requires use of limited IVA crew time**

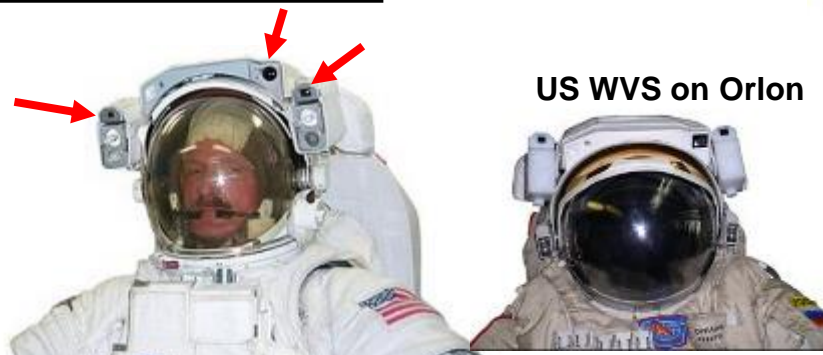


# EVA Crew Cameras



## Wireless Video System

- Three SONY XC-999 cameras
- HFOV = 85°, 56° and 30°
- Fixed depth of focus 12 inches to 25 feet.
- Detectable resolution .25-.5 inch at 10 feet.



## Digital SLR

- Nikon D4 DSLR
- Lens focal lengths 10.5-180mm

## GoPro

- Handheld EVA Video/Still Images





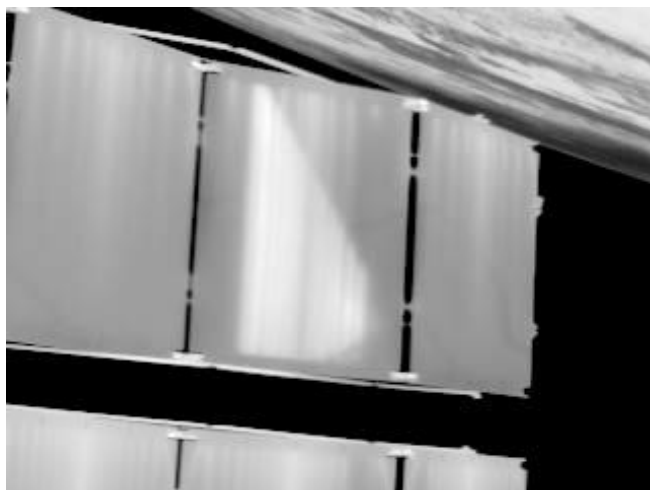
# External/Internal IR Camera



## Repackaged FLIR Systems ThermaCAM S60 Infrared Camera

Used for inspections of:

- Electrical components
- Radiators
- Solar Arrays
- Heaters



**Infrared View of Damaged Thermal Radiator  
(back-side surface)**







# Internal Crew Cameras



- Handheld still cameras provide the highest imaging resolution of any of the existing ISS imaging assets.

- Nikon D4 Digital Still Cameras
- Lenses ranging from 8mm to 1200mm
- One Nikon D3s modified for near IR photography/video

## High Definition Video



Canon XF305 – mounted and handheld.



Panasonic 3DA1 – 3D video capability



# Internal Crew Cameras



**Drift Ghost S Action Camera to be used for:**

- Obtaining HD video in tight spaces
- Over the shoulder views for ground situational awareness.



**Sony XC-999 Mini-cam**  
**Video camera with fiberscope**

## **Binoculars**

- 8x32
- 20x60



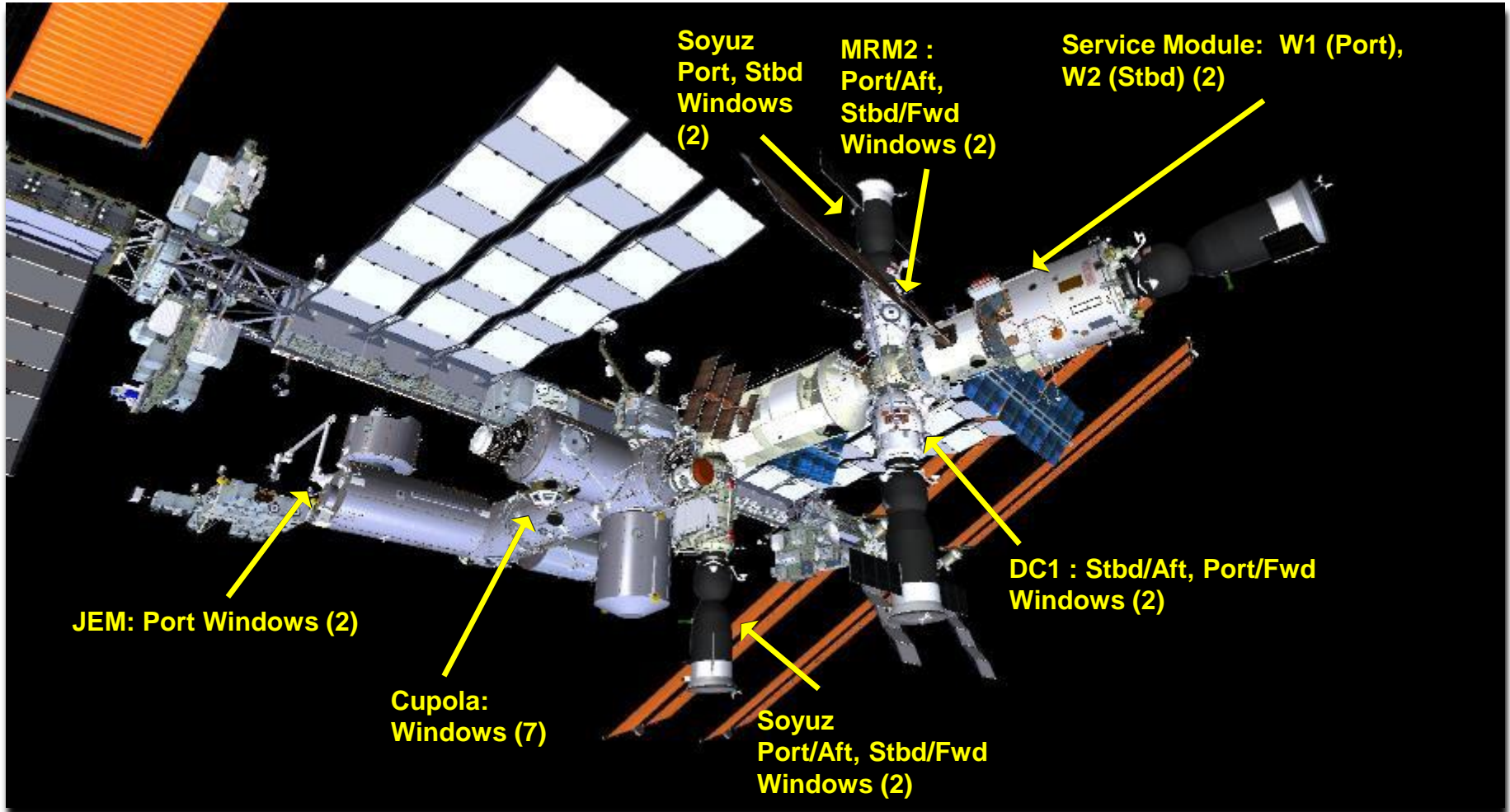
# Crew External Inspection Challenges



- **Limited windows, numerous blindspots**
  - **Distance and high incidence viewing**
- Protective plastic scratch panes installed over Cupola and JEM windows reduce image resolution but need justification for removal and the removal and reinstallation process is time consuming (Cupola ~4 hours).
- Limited crew time for imagery acquisition support (IVA and EVA)
- EVA – no time for dedicated surveys
  - Lens usually selected for large field of view



# Windows for External Surface Inspection



Russian segment and Cupola windows provide coverage of truss aft surfaces and JEM windows provide coverage of port, forward truss surfaces not visible in ETVCG blind spots.

Obstructed and Earth facing windows are not referenced.



# Example Views from ISS Windows

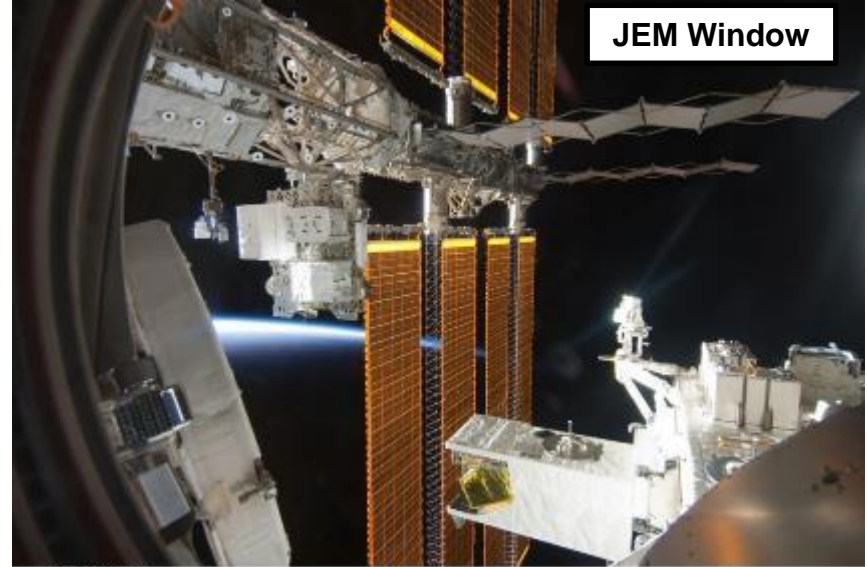


MRM2 Starboard/Forward Window



S129E007742

JEM Window

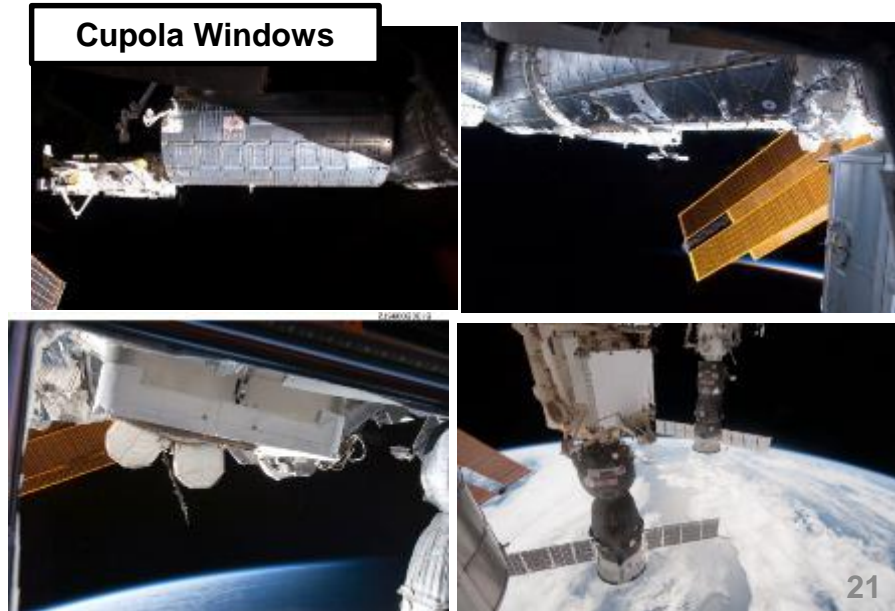


S133E008894

MRM2 Port/Aft Window



Cupola Windows

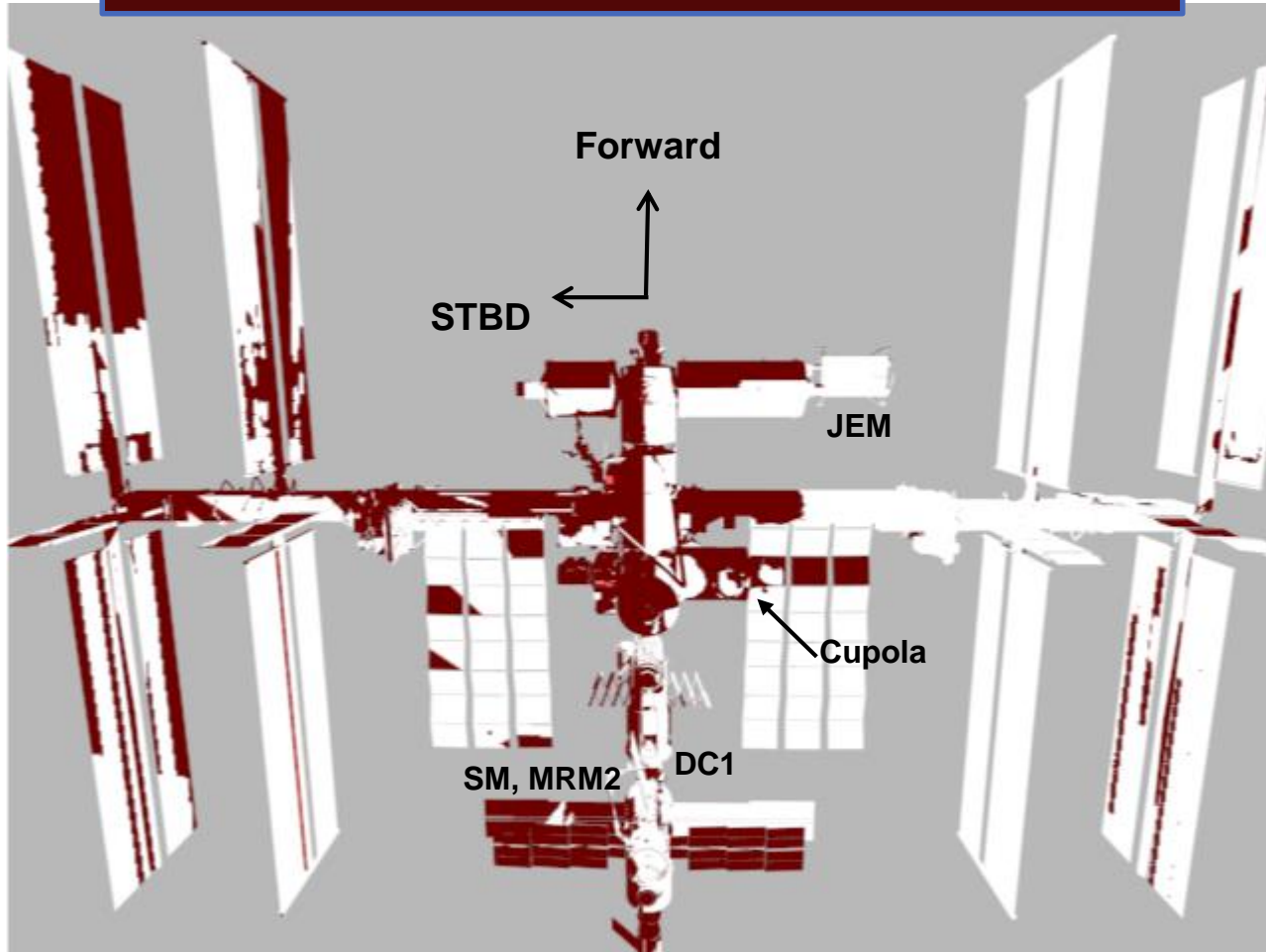




# ISS Window View Coverage



Brown shading shows window “blind spots”



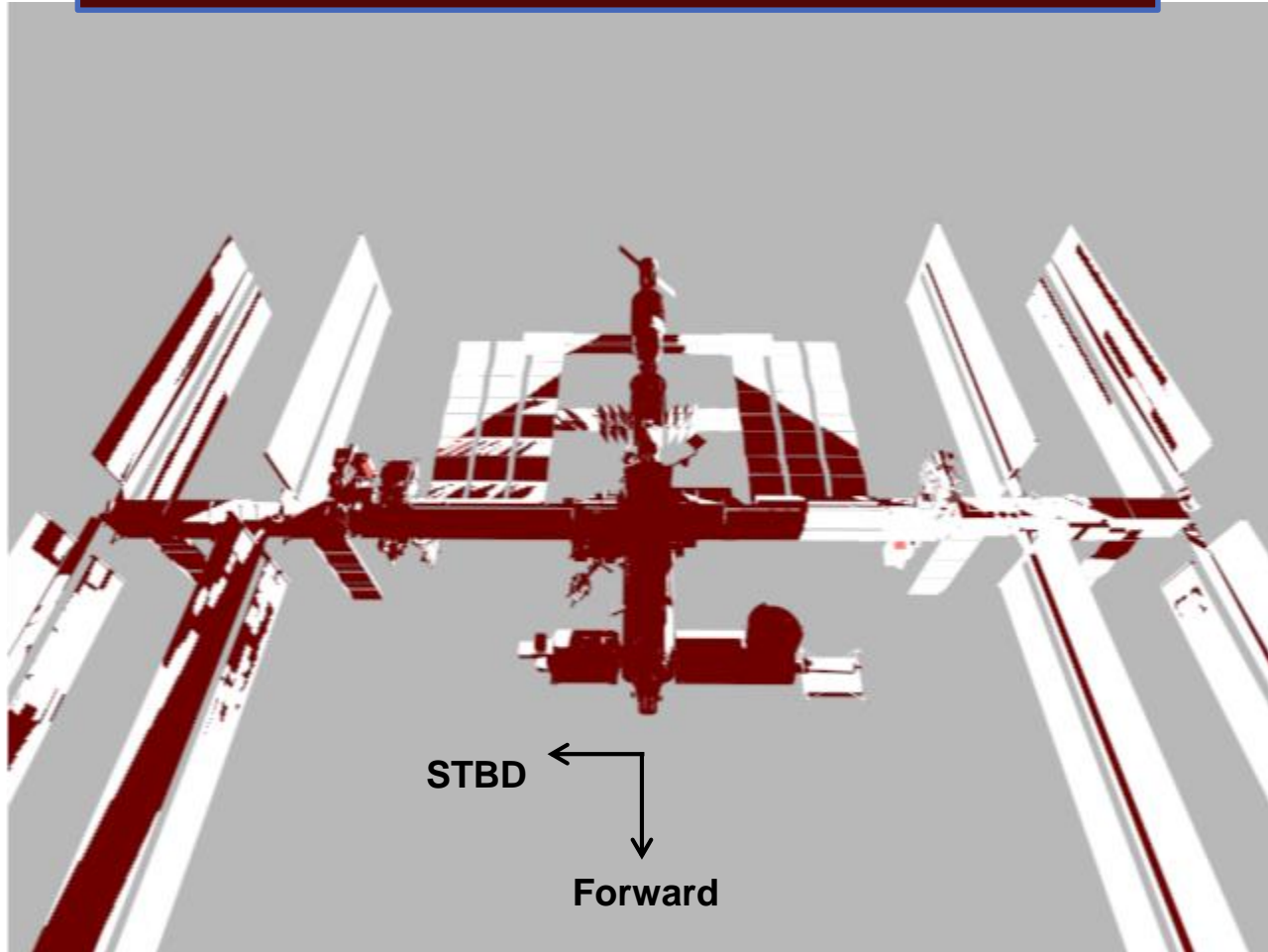
Viewing from below



# ISS Window View Coverage



Brown shading shows window “blind spots”



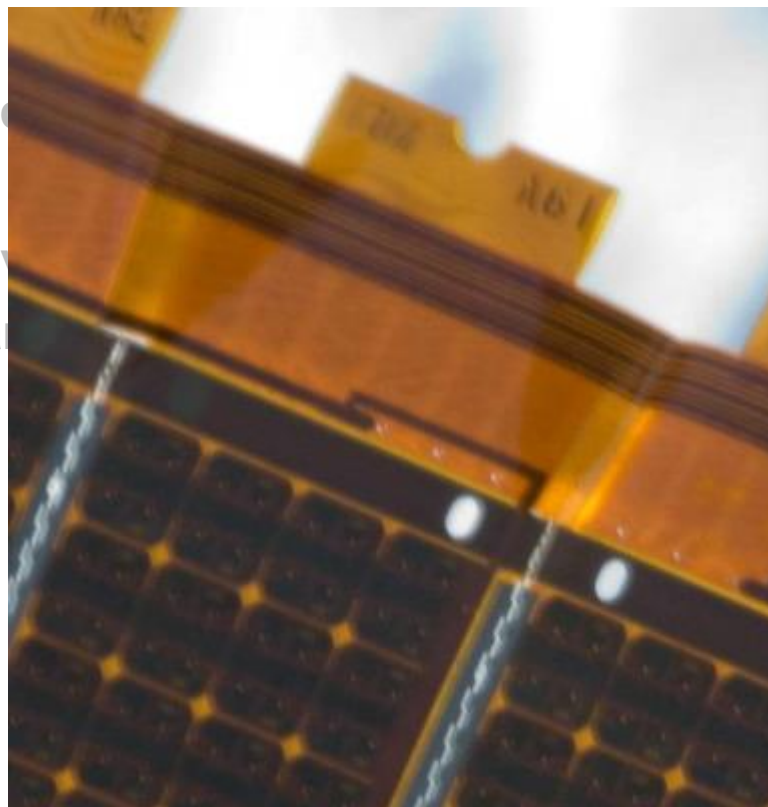
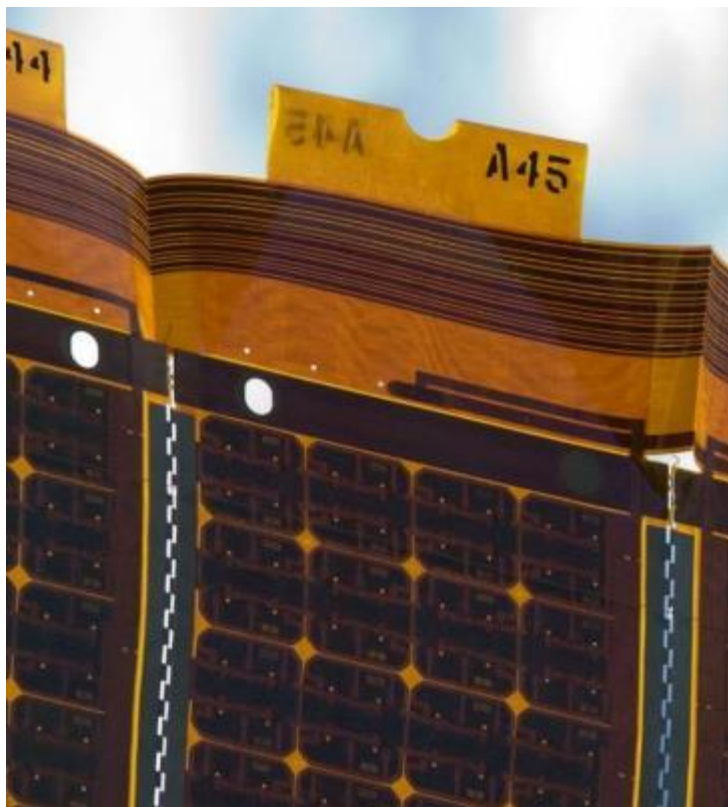
Viewing from above



# Crew External Inspection Challenges



- Limited windows, numerous blindspots
  - Distance and high incidence viewing
- **Protective plastic scratch panes installed over Cupola and JEM windows reduce image resolution but need strong justification for removal and the Cupola scratch pane removal and reinstallation process is time consuming (1- 4 hours).**







# Crew External Inspection Challenges



- Limited windows, numerous blindspots
  - Distance and high incidence viewing
- Protective plastic scratch panes installed over Cupola and JEM windows reduce image resolution but need strong justification for removal and the removal and reinstallation process is time consuming (Cupola 1-4 hours).
- **Limited crew time for inspection imagery acquisition (IVA and EVA)**
- **EVA – no time for dedicated surveys**
  - **Lens usually selected for large field of view**



# Other ISS Inspection Technologies



- **Handheld Ultrasonic leak detector**
- **Ammonia Mass spectrometer**



- **Challenges for Internal Inspection:**
  - **Stowage can be in the way**
  - **Crew time to rotate/reposition module racks can be hours**



# ISS Inspection Challenges Summary



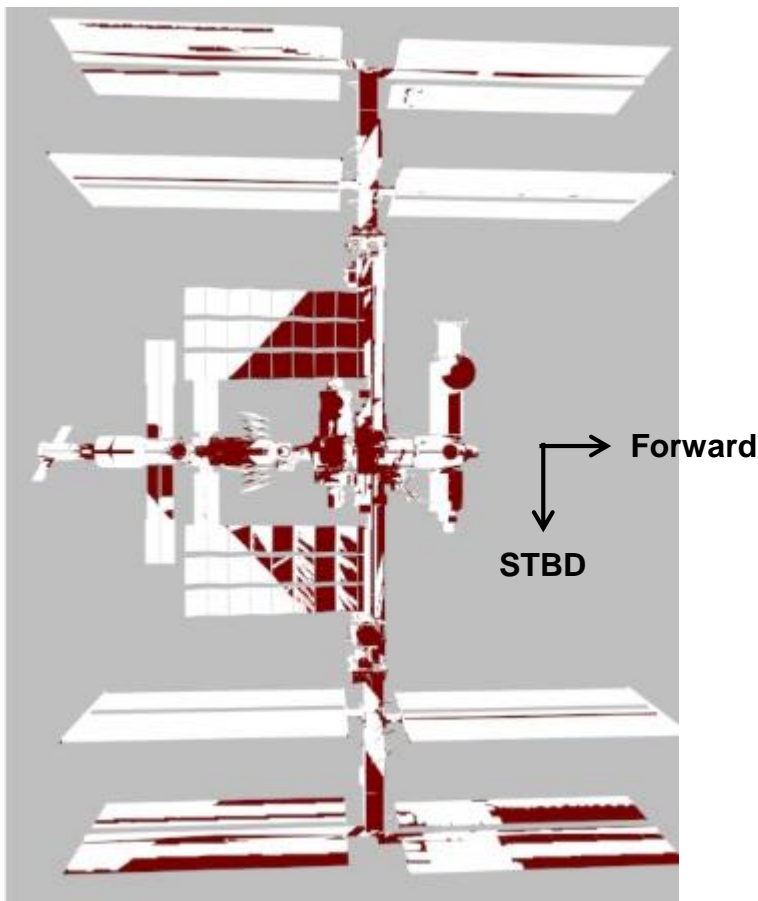
- **Regular, periodic inspection is limited to fixed line-of-sight views.**
- **Limited available IVA/EVA crew time**
  - **General ISS periodic inspection is lower priority to science and maintenance**
- **Scheduling ground controlled imagery surveys with mounted external cameras is not an issue, but they are low resolution and there are significant blind spots.**
- **Complex robotics operations inhibit using them for general purpose inspection surveys.**



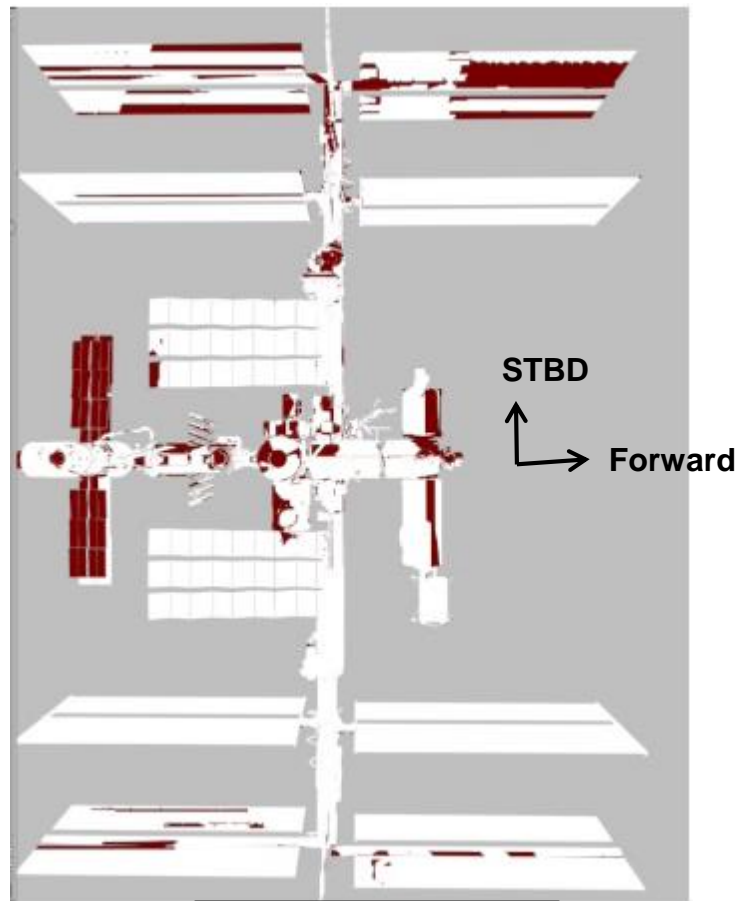
# ETVCG & JEM cameras and Windows Viewing Coverage



Brown shading shows combined window and external stationary camera “blind spots”



Viewing from above



Viewing from below



# ISS Visual Inspection Technology Needs



- **Fill in blind-spots and areas of low resolution resulting from fixed camera locations and windows**
  - Prefer crew not required to operate
- **Replace Shuttle fly-around imagery set which provided general ISS periodic inspection and views of overall ISS configuration**
- **Upgraded camera capabilities**
  - Better resolution – we lack a good close-up, inspection capability
    - Robotic SPDM attachments planned - VIPER-2 and DDVS
  - Color, stereo, 3D vision for better depth determination
  - Penetrating sensor technology (e.g. backscatter x-ray)
    - Observable MMOD impact surface damage is not indicative of underlying damage



Image Science and Analysis Group  
KX\Human Exploration Science Office  
KAARES



# Orion Inspection Capabilities and Challenges



# Orion Inspection Capabilities

- **There is no Orion Program requirement for inspection of the Orion crew module and service module exterior.**
- **However, cameras installed at the tips of the four solar arrays provide a capability to visually survey the exterior surfaces.**
- **An inspection using the solar array cameras is planned for EM-1 to:**
  - Evaluate an inspection capability
  - Provide situational awareness imagery



# EM-1/EM-2 Solar Array Cameras



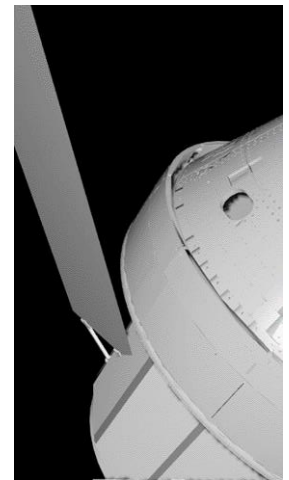
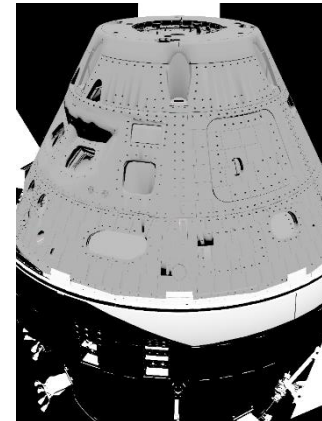
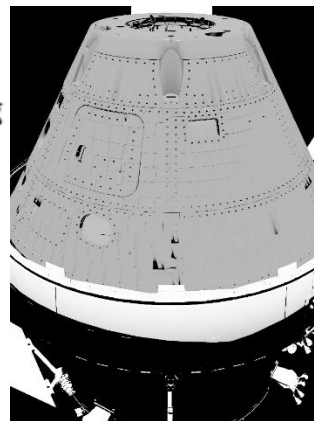
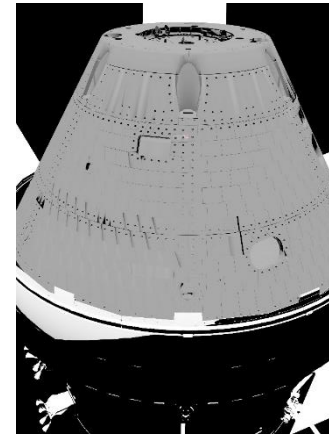
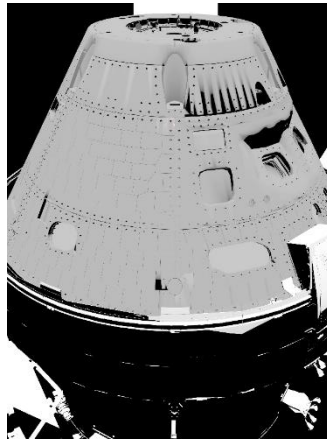
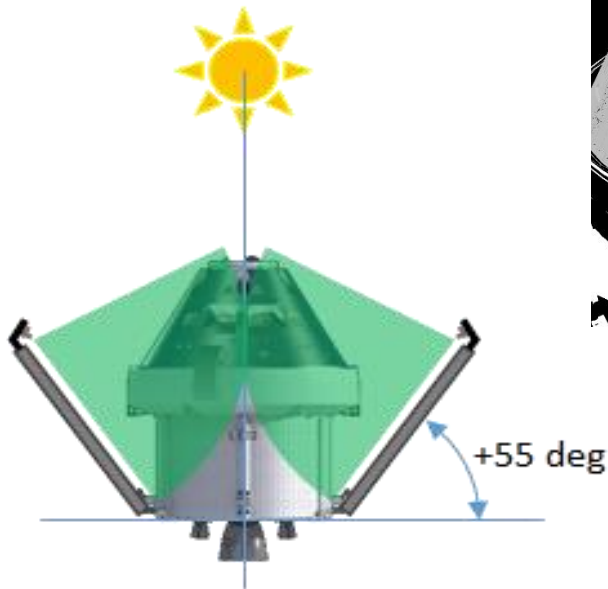
- **Solar Array cameras are modified GoPro Hero 4**
  - 12MP (4000 x 3000) CMOS Sensor
  - Streaming low resolution video via Wifi
  - Full resolution video and stills stored in camera microSD card for later WiFi transfer to vehicle comm system
    - Planned inspection modes: 12MP stills (Individual and Time Lapse)
    - Planned video rates (other events) of 4K @ 30 fps, 1080P @ 30 fps, Night Lapse





# Orion CM Surface Inspection

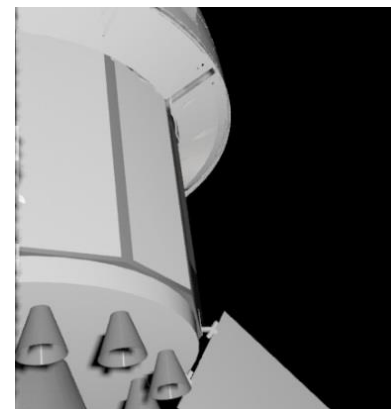
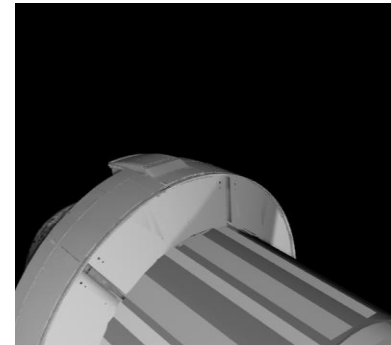
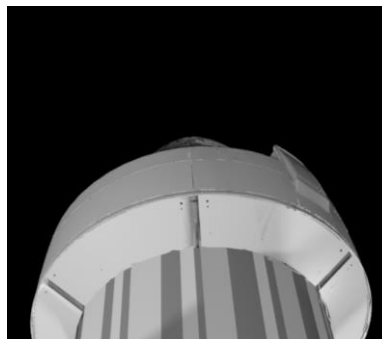
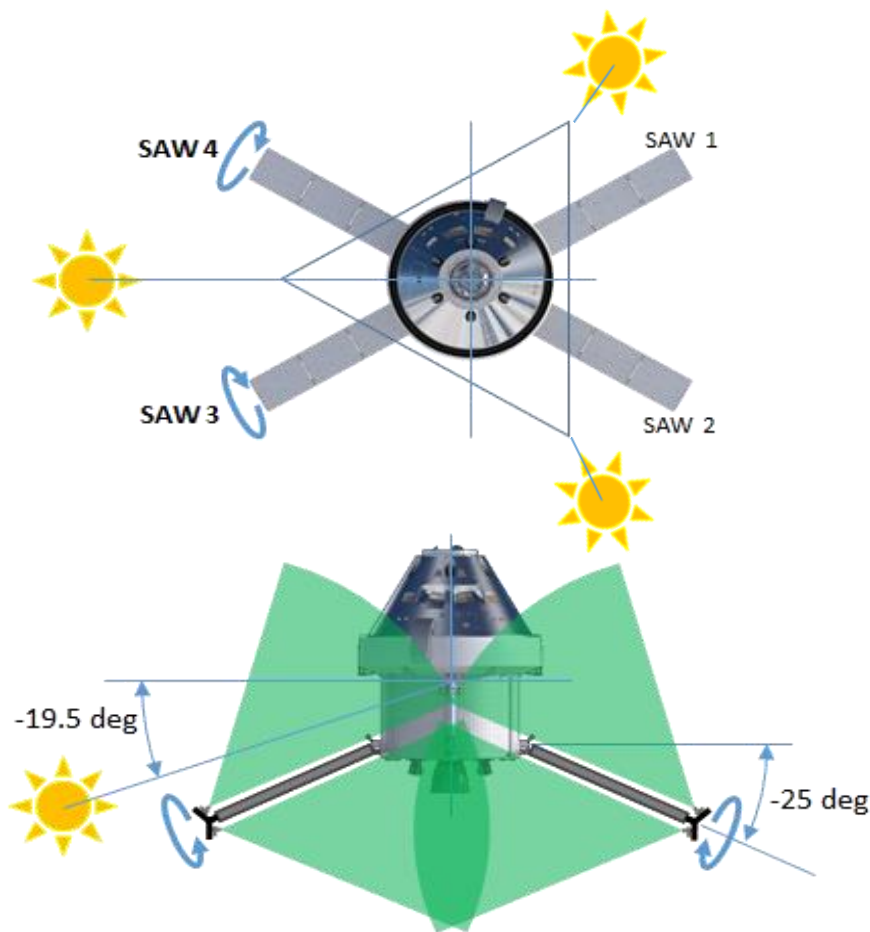
- Crew Module (CM) inspection
  - Orient Crew and Service Module (CSM) with sun on  $-X$  (i.e. centerline) axis.
  - Pitch SAW1 through SAW4 inner gimbal forward 55-deg and capture full resolution still images.
  - Capability to fill in any missing CM surface by pitching and rolling arrays and camera as needed if inner gimbal lowered to 25-deg.





# Orion SM Surface Inspection

- Service Module (SM) inspection
  - Orient CSM with the sun off to the side of the vehicle to avoid solar array shadows falling on CSM. Three separate SM imagery attitudes.
  - Pitch and roll solar arrays as needed and capture full resolution still images of SM surfaces.





# Orion Inspection Challenges

- **Desire to detect features as small as .25 inches.**
  - Very high-quality lenses have been chosen for the SAW cameras, based on possible need for MMOD inspection.
  - Lens Field of View and Focus distance chosen to meet the .25 inch detection goal.
- **Need favorable lighting for imagery**
  - Illumination and shadows will be controlled with vehicle attitude
- **CM surface reflectance**
  - The CM surface will be covered in highly reflective metal tape leading to issues of sun glint into the lens or surfaces reflecting the blackness of space.
  - With an MMOD impact, “volcano”-like features, rather than holes, would be expected due to metallic tape covering TPS.



# Solar Array Camera Inspection Imaging

## Anticipated Inspection Resolution for Arrays Swept Forward 55°



Off-angle lighting (e.g. reflection from the white plate on the right) helps illuminate volcano sides. The sun forward of the CM should perform good highlighting in this way (testing needed).

All five impacts clearly visible at normal incidence, with sufficient lighting.

45-deg incidence, contrast-stretched image. Impact detection diminished because look angle results in poor contrast (metallic "volcano" against metallic background, instead of black hole against metallic background as seen in left image). Low lighting also causes low signal-to-noise ratio (SNR). We need to re-image this configuration in sunlight.

Metallic "volcanos"

Impact test document image from a different camera