Dextre-Deployable Vision Sensor (DDVS)

In-Space Inspection Workshop
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Space Exploration Development

Overview

- Objective
- Identifying needs and solutions within our reach
- Mapping CSA Technologies (short term and future)
- The Concept
- The Concept of Operations
- Benefits
- Forward work – further concept development

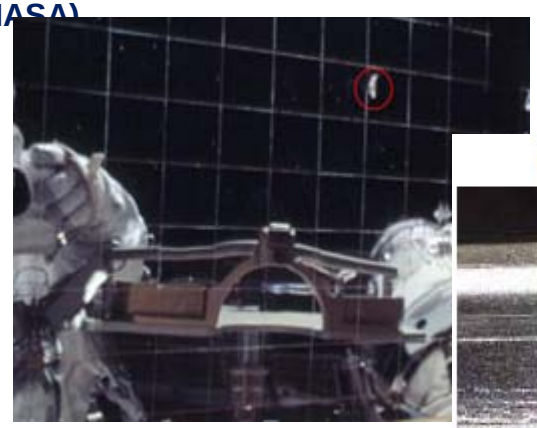
Objective

- **Maximize benefits between developing technologies for Canadian key industrial capabilities, and supporting ISS**

- **Considerations**
  - Support or increase MSS capability and services
  - Focus on mature technology to comply with urgency to launch as quickly as possible
  - Provide service to ISS through 2020+
  - Advance technology needed for future space exploration missions and multiple destinations
  - Demonstrate return on investment to the Government of Canada

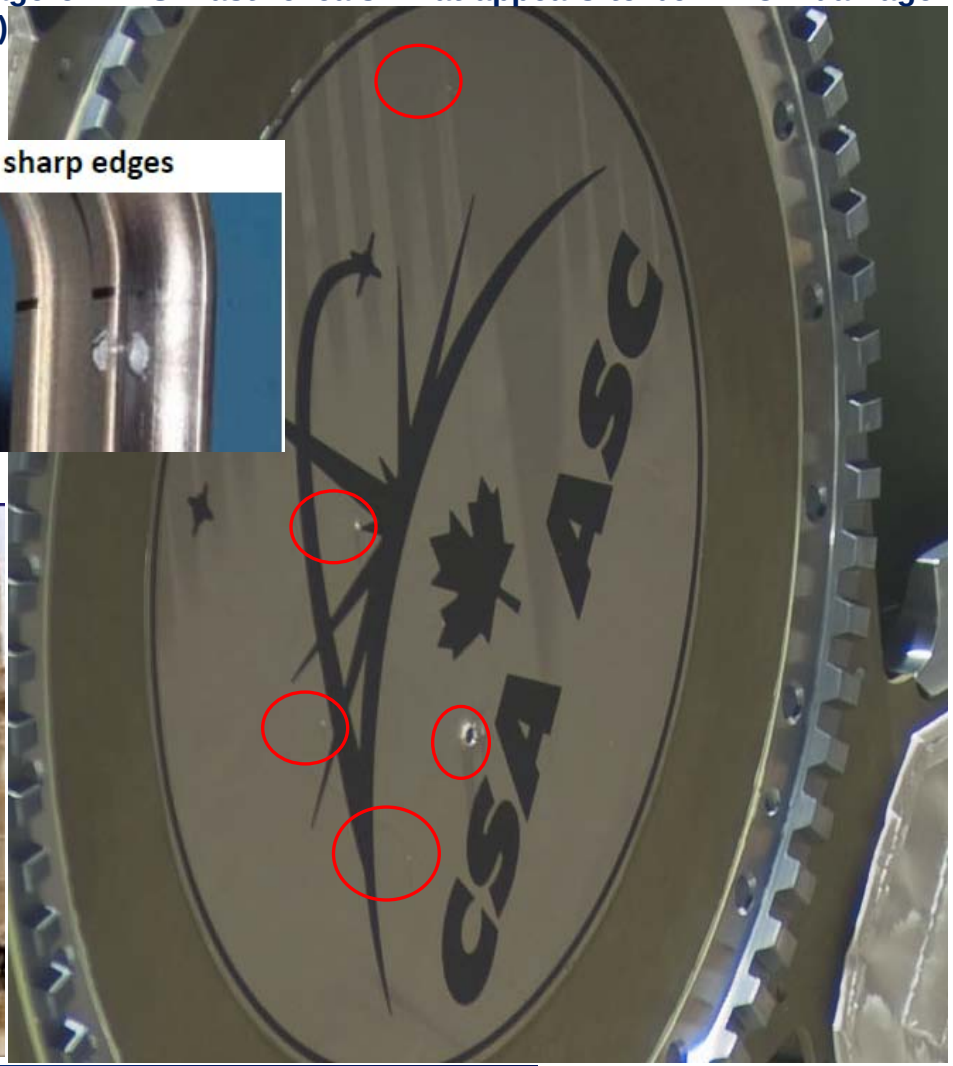
Past Events - ISS Inspection

ISS Radiator damage – MMOD (Credit: NASA)



Credit: NASA)

April 2010 image of MBS Mast reveals what appears to be MMOD damage (Credit: NASA)

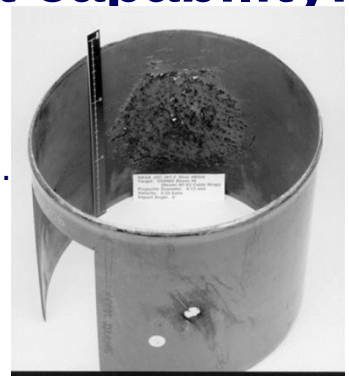


EVA Handrail Impacts - sharp edges

Progress Collision with MIR, 1997 – solar panel damage (Credit: NASA)

Inspection Requests - MSS

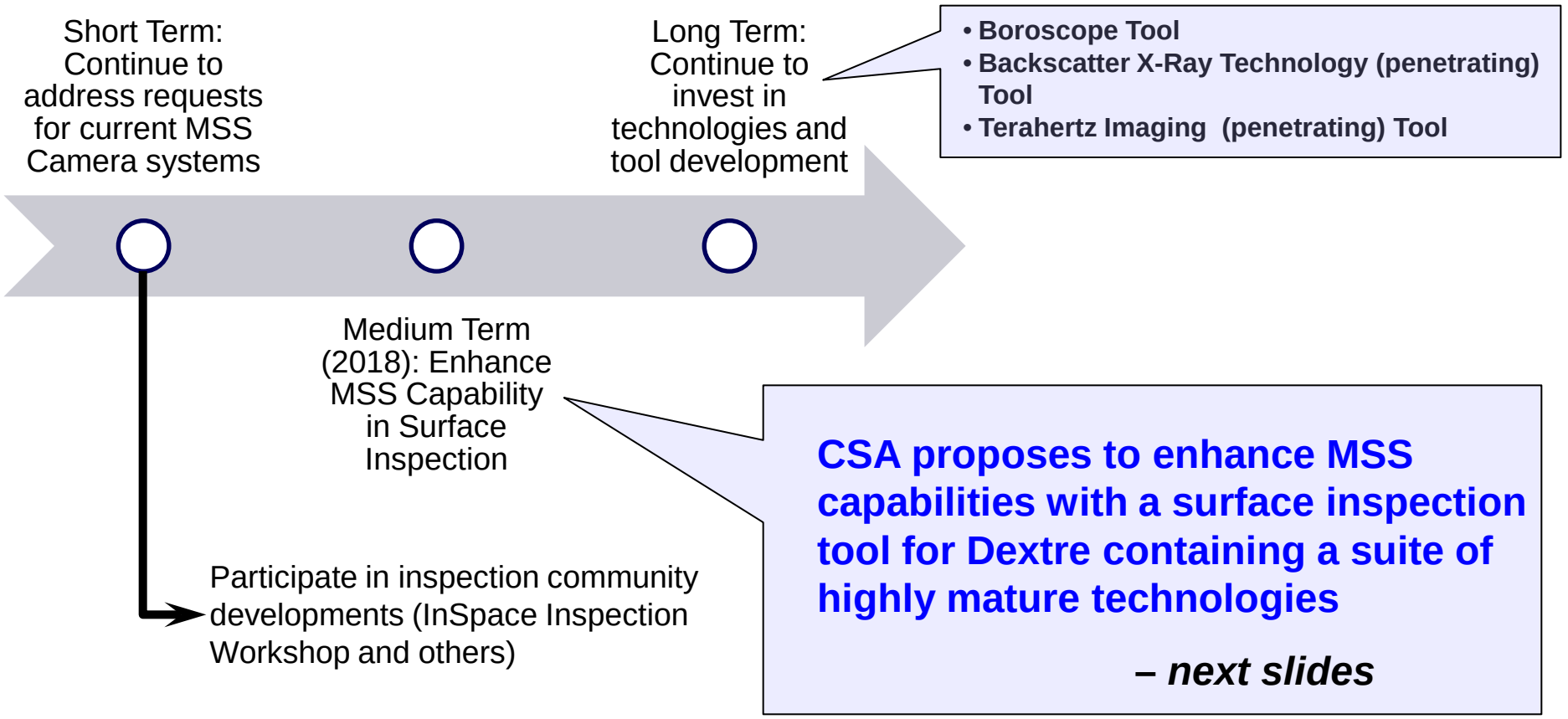
- **MSS is currently involved in the following inspection activities:**
  - Berthing interface survey, payload surveys, vehicles
  - LEE Snare cable photography
    - Currently done by Crew from Cupola
  - Configuration checks
    - Make sure ground tools match with on-orbit config, e.g. Dragon trunk
- **Areas where CSA may contribute and augment capability:**
  - Reduce Crew time required for imagery support
  - MMOD Impact Damage Inspection
    - Pressurized Modules, Primary Systems, ORUs, Window, Re-entry TPS, etc.
    - ORDEM 3.0 (new Orbital Debris Model) may raise new concerns
  - System Trouble-shooting
    - Mechanisms, Leaks (e.g. ammonia) and Corrosion
  - Periodic surveys of external ISS surfaces
    - Blind spots not visible from ISS IVA
    - Previously accomplished by Shuttle, 2+ yrs since last survey – CAIB report suggests yearly
  - Future Visiting Vehicles
  - Automation of Inspection
    - Both for operations, and in post-processing of data for damage detection



Credit: NASA)

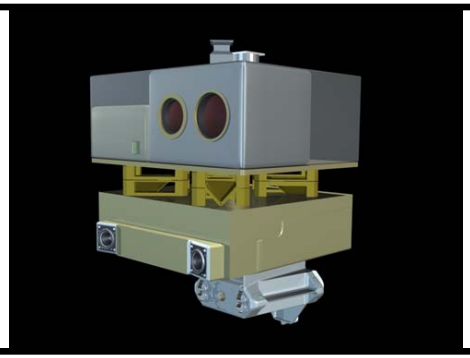
Inspection Needs

➲ **No silver bullet: a variety of solutions needed, now and in future**



Canadian Space Agency | Agence spatiale canadienne

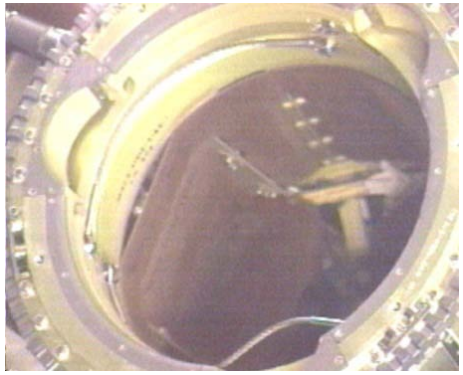
Concept Overview



A surface inspection tool for Dextre containing a suite of highly mature technologies

Current MSS Cameras:

- Standard Res camera & lights
- RCAMS upgrade to LED lights

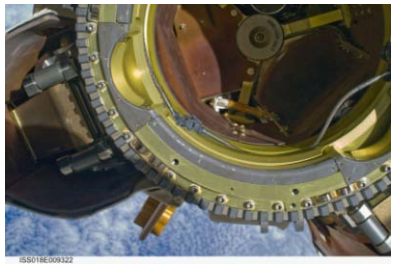


MSS Camera: 640x480 (Credit: NASA)

Dextre Deployable Vision System Overview

✓High Definition (HD) camera & lights

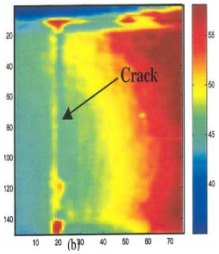
- **25Mpixel sensors, Zoom, 3D capability**



Credit: NASA)

✓Infrared (IR) camera

- Detects changes in heat flow using sun or laser source



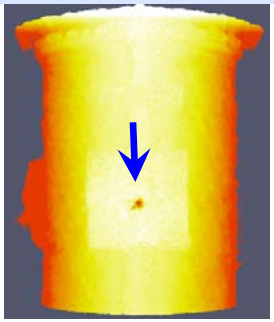
(Credit: Laval University)

✓Coarse Inspection or Workspace 3-D Scans

- Standoff distance 3-10 meters
- Millimeter resolution
- Detect under any lighting condition

✓Focused Inspection

- Sub millimeter resolution
- Standoff distance up to 3m
- Textured 3-D point cloud



(Credit: Neptec)

✓Automation of Inspection

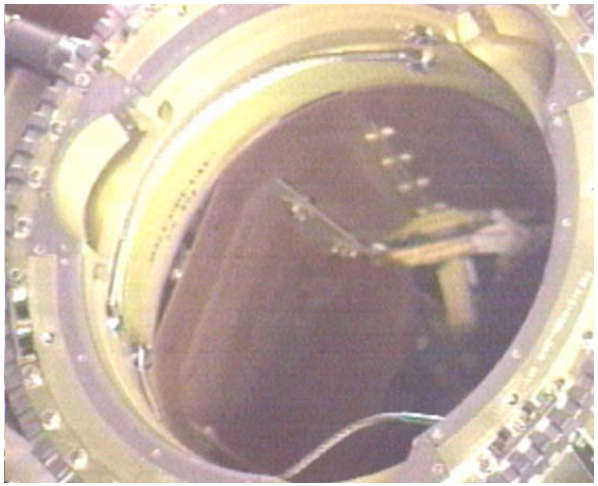
- Both for operations, and post-processing data to detect damage

Canada

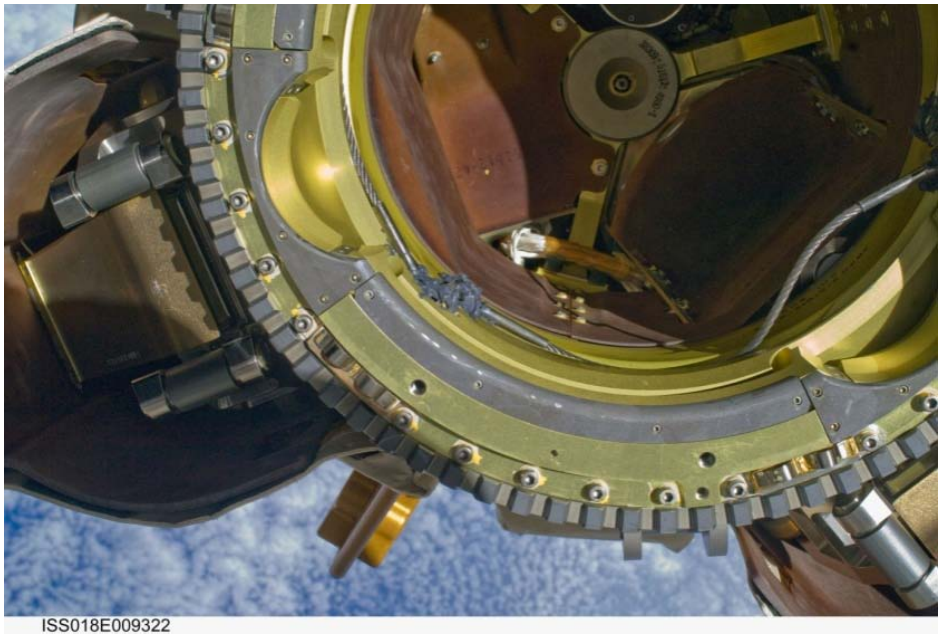
Mapping Mature Canadian Technology to Inspection Tool

Mature technologies and their merits for Surface Inspection:

- ✓ **High Definition (HD) camera & lighting**
  - 25Mpixel sensors, 50µm pixel resolution
  - Zoom capability
  - 3D capability
    - 3-D SFM (structure from motion)
    - Stereo imaging with 2 HD cams



MSS Camera: 640x480

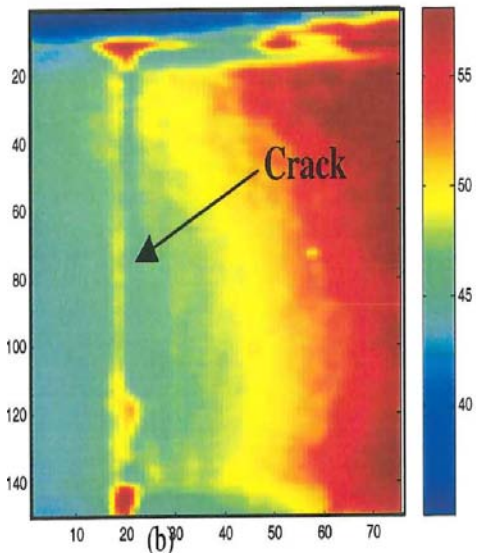


HD Camera (Example, photo from Cupola)

Mapping Mature Canadian Technology to Inspection Tool

Mature technologies and their merits for Surface Inspection:

- ✓ **Infrared (IR) camera**
  - Currently only EVA has an IR camera
  - Capable of detecting changes in heat flow due to damage, voids or cracks and can be pointed for a long period of time. Heat sources can be:
    - Sun
    - Laser
  - Potential to develop algorithms for unambiguous detection



IR imaging on tile crack (laboratory). (Credit: Laval University)

Picture using the IR camera during the Shuttle DTO (Credit: Neptec)

Example of an IR application:

- Lighter lines are shut-off solar array strings (getting hotter)
- As they are shut off in a known order, damage detection could be identified on failed strings
- Other potential applications

Mapping Mature Canadian Technology to Inspection Con't

Mature technologies and their merits for Surface Inspection:

Example images on next slides...

- ✓ **Active (Laser) coarse inspection sensor**
  - Unaffected by orbital lighting conditions
  - Long range inspection capability
  - Workspace 3-D mapping (Dragon trunk, Station surveys)
  - Robotic clearance (collision) monitoring capability - step towards autonomy
  - Added benefit: can be used for VV tracking as a technology demo.
- ✓ **Active (Laser) focused inspection sensor**
  - Unaffected by orbital lighting conditions
  - Sub millimeter resolution in all three directions
  - Standoff distance up to 3m
  - Produces point cloud, automated image processing

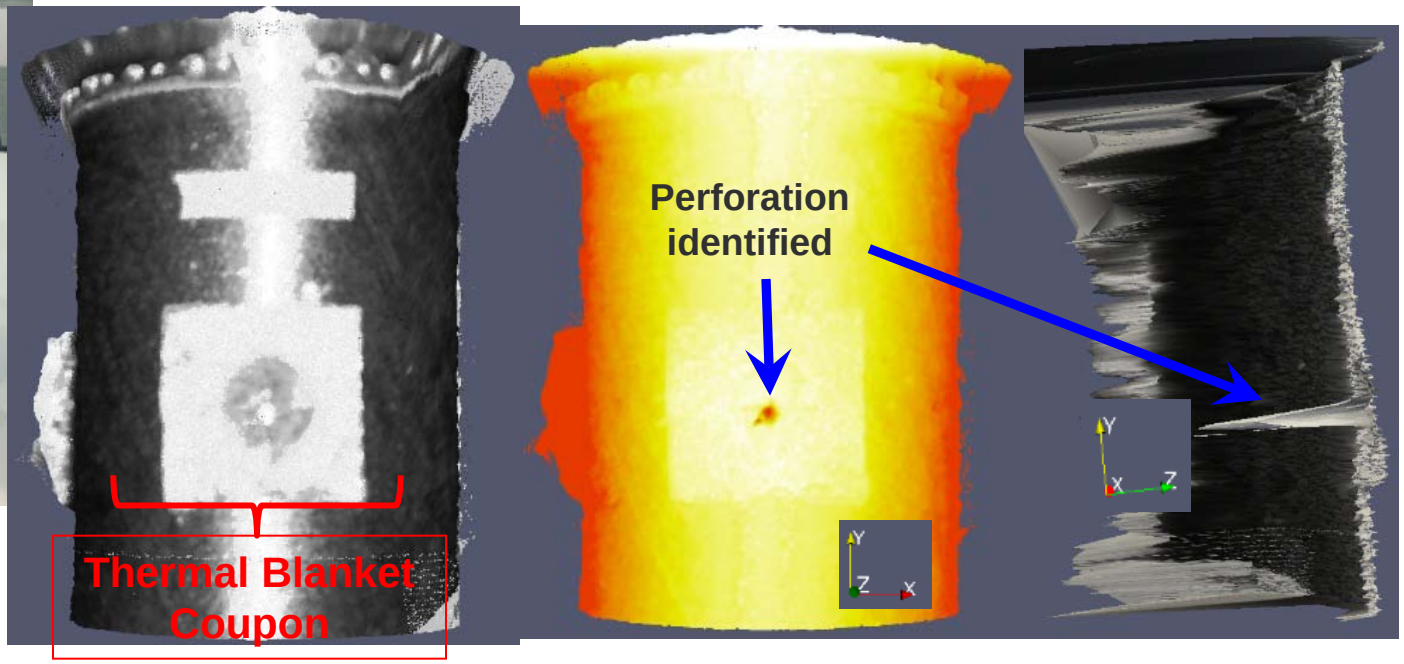
Coarse Inspection

Image Above: boom test segment

When damage is detected, a coarse inspection is performed by the LiDAR:

- **Standoff distance of roughly between 3-10 meters**
- **Detect MMOD damage under any lighting condition**

➔ *There are currently boom impacts that should be inspected*

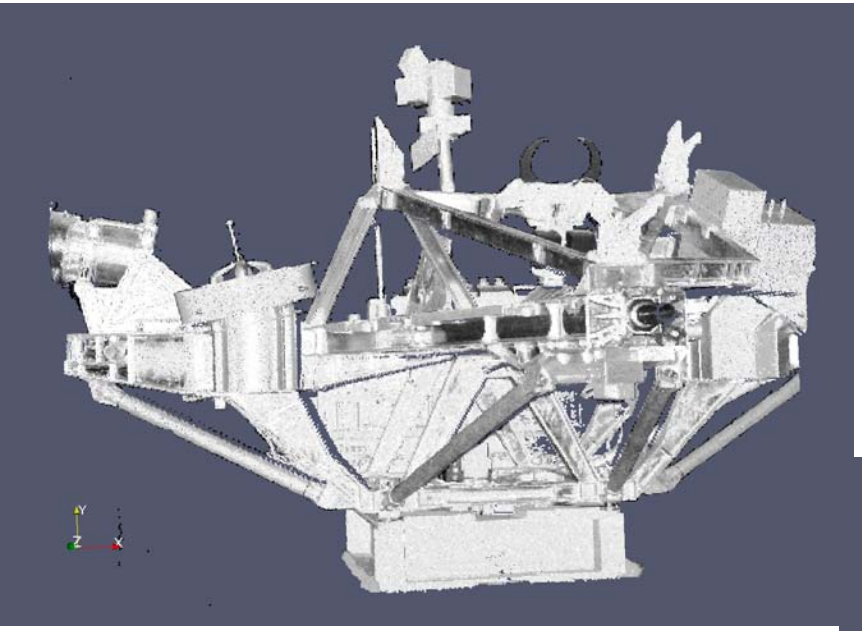


Example above: MSS test boom segment bombarded by debris @7km/s causing 5mm hole. LiDAR scan at 7.6 m standoff distance

Right: Colour coded depth image from LiDAR scan showing MMOD damage

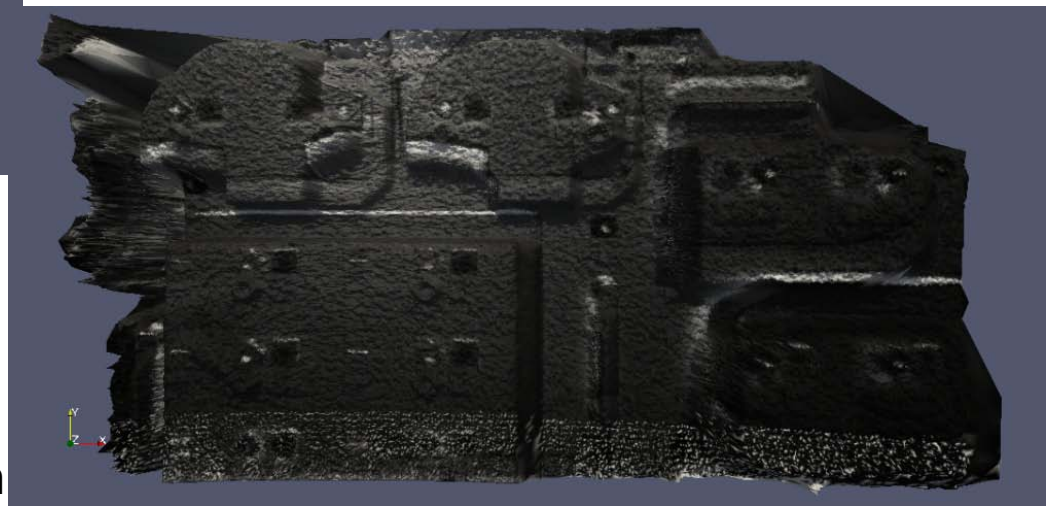
Coarse Inspection Con't

Image Below: Coarse scan of MBS mock-up at CSA



Enabled Capabilities:

- Pre-motion Surveys
- VV Cargo space survey
- Robotic Clearance Detection



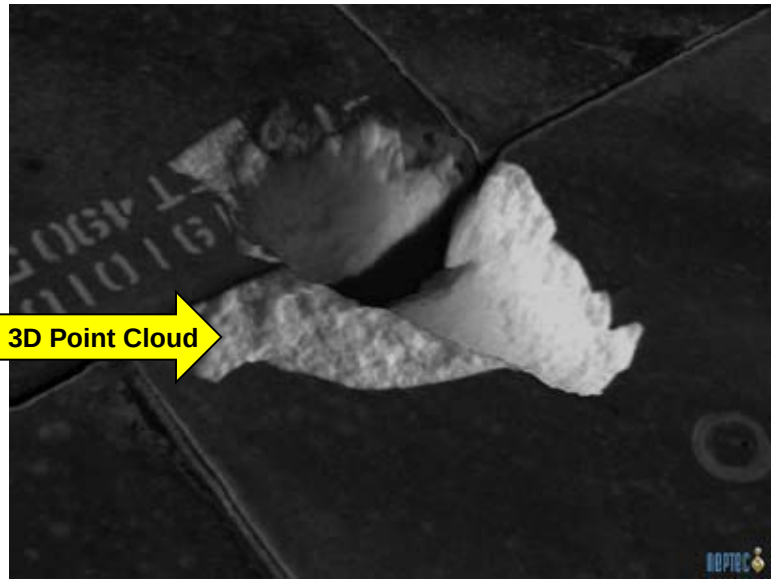
Above image: Video Example of MSS Workspace survey (3-D pdf)

Benefits to operations:

- Faster planning
- Faster operation (automated)
- Potentially reduce wear&tear on H/W

Focused Inspection

- **Sub-millimeter resolution using active (Laser) sensor**



Above – thermal tile damage scanned with 3D textured point cloud (laboratory image) (Credit: Neptec)

Above – examples of windshield and handrail impact damage (Credit: NASA)

Focused inspection would be performed from a close range, at 3 meters or less.

Its target is to characterize the damage, and hopefully get a certain amount of subsurface data without touching the surface.

Options for fine inspection are:

- ✓ **HD Stereo Camera, could be in the order of 25 Mpx with lighting**
- ✓ **Active (Laser) solution**
- ➔ ***Together – textured 3D Point Cloud***

Benefits to operations:

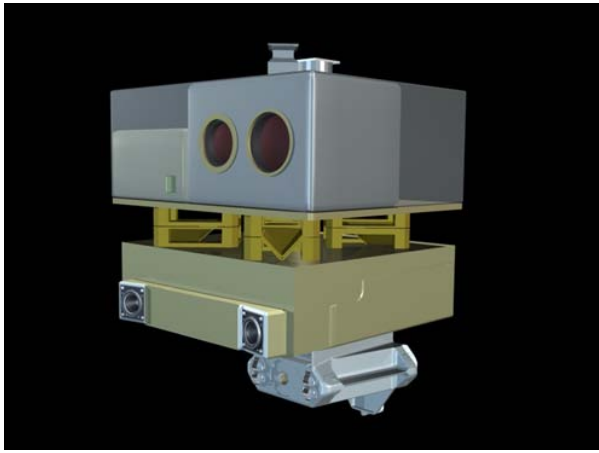
- **Increase resolution at greater standoff distance**
- **Faster operation (automated), less effort**

The Concept - DDVS

The Dextre-Deployable Vision Sensor (DDVS) is a surface inspection tool concept for the ISS, using IR, HD and LiDAR.

- Launch 2018 pressurized, deploy through JEM airlock (will comply to volume)
- Install and stow on MTRA
- Dextre tool with ops support from CSA
- Requires use of Station WiFi, downlink to ground support station

Tool Concept (Artist image only)



(Credit: MDA)

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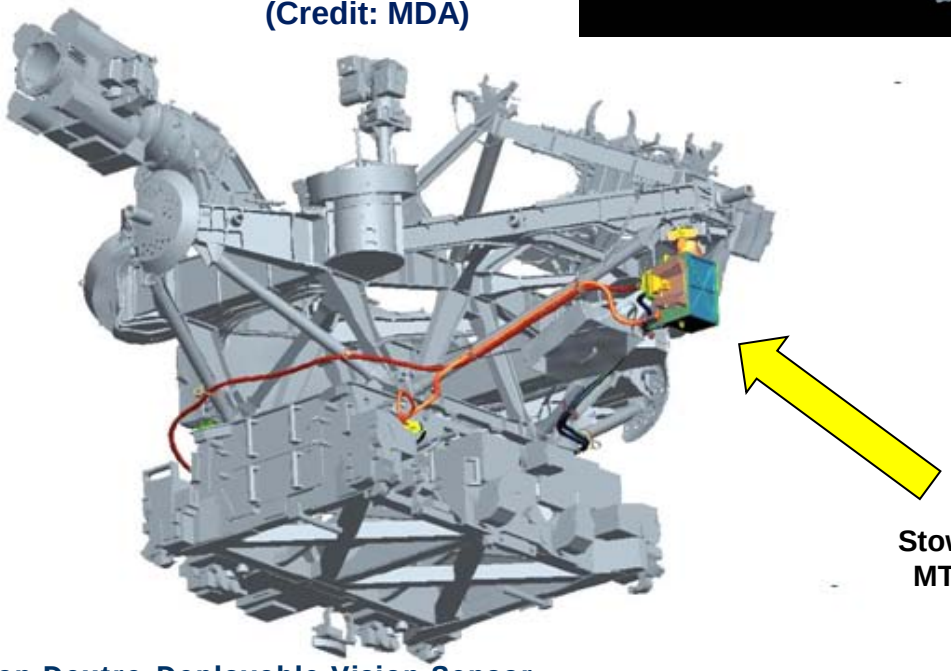


Concept of Operation

- **Goal: cover the spectrum of damage detection from coarse inspection up to focused inspection (surface)**
- **Concept:**
  1. Detection*: detect potential damage
  2. Coarse inspection phase: from a distance, perform a localized inspection on the potential damage.
  3. Focused inspection phase: if deemed necessary, perform a focused surface inspection, at sub-millimeter resolution.
- **Operation:**
  - Commanding through the 1553
  - Data is transmitted via WiFi to ground support station, with on-board buffering

***Detection is performed while the operator is moving Dextre with the sensor (on OTCM) acquiring images. Detection would be performed using a combination of HD, IR cameras and/or long range LiDAR, with automated damage detection.**

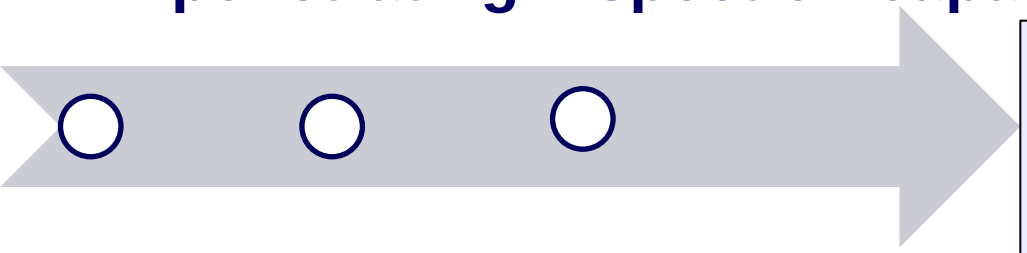
Benefits to the ISS

- **Enhanced robotic inspection capability will reduce risk, address challenges and increase efficiency:**
  - Introduce new capability and new technology combinations
  - Address “Blind” Spots
    - Address external ISS surveys, including unexpected damage (handrails)
    - Reach areas not accessible from windows
  - Reduce Crew Time – transfer tasks to robotics
  - Reduce Operations Time
    - Automatically detect damage, followed by coarse or focused inspection
    - Less motion – detection at a greater standoff distance
  - Detect early, potentially reduce wear and tear on hardware
  - Improved response time to issues, easier than current ops
  - Visiting Vehicles
  - New Crew Vehicles
  - Unknowns

Forward Plan

- **May 2014:** Complete concept work and options analysis
- **July 2014:** Seek CSA Executive Committee approval to proceed to Phase 0

- **Longer Term Goal: Technology development to target penetrating inspection capability and tools**



- Boroscope Tool
- Backscatter X-Ray Technology (penetrating) Tool
- Terahertz Imaging (penetrating) Tool

Address via CSA Development Activities
- Concept /Phase 0 Studies
- STDP (Space Technology Development Program)