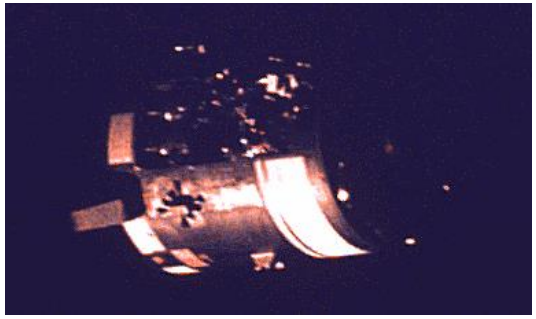
In-Space Inspection Technologies Vision and Workshop Summary

JSC/ES2/George Studor

Apr 25, 2012

Motivation

- Apollo 13 – couldn't see the damage
  "Houston, we've got a problem"
  after the SM was released…
  "There's one whole side of that spacecraft missing"



- MIR Spectre damaged by Progress – 24 minutes to find/plug leak before having to shut the hatch.
  http://www.youtube.com/watch?v=88XS2G7xRxg

- Columbia – suspected impact to Wing Leading Edge, no sensors or good inspection options.

Sorry,
No Photo Available

"AF ground cameras see damage 60 sec. before the vehicle broke up over Texas"

Today's Situation

- **ISS to maintain and extend life to 2025 or 2028?**
  - Existing Risks, Challenges and Inefficiencies
  - "Blind" Spots - Crew Time
  - IVA Access - EVA Resources
  - Visiting Vehicles - Unknowns

- **New breed of Commercial Crewed Vehicles.**
  - Efficiency and Safety
  - Experience with MMOD and Re-Entry Systems
  - Inspection Responsibilities/Capabilities

- **New Missions Being Defined**
  - Satellite Servicing
  - Human Exploration Destinations beyond low-Earth Orbit

- **Technology Demos supporting next gen manned space vehicles.**
  - Need for Autonomy - Robotic Inspections
  - Reduced Crew Time - No EVA required
  - Eliminate the Blind Spots - New Technologies

In-Space Inspection
What's the Problem?

Biggest Risks That Demand Inspections:

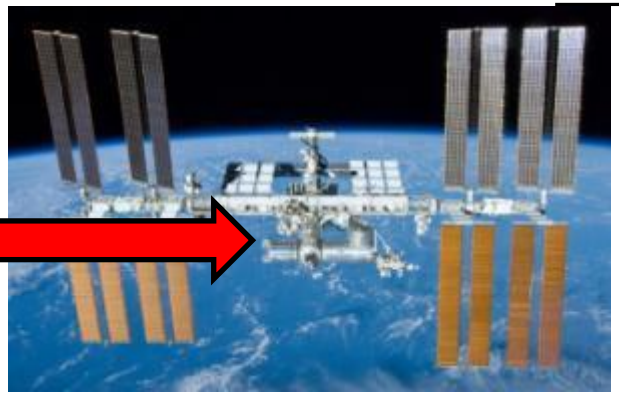
- Crew Time for Imagery Support for EVA and Robotic Planning and Operations
- MMOD Impact Damage Inspection
  - Pressurized Modules, Primary Systems, ORUs , Window, Re-entry TPS, etc.
- System Trouble-shooting, Mechanisms like BGA, Leaks and Corrosion

Challenges to Getting Inspections Done:

- Limited Requirements agreed to – we only buy/fly what we can prove we need ahead of time.
- Limited Inspection Tools ready for in-space use on ISS – None planned for stand-alone vehicles.
- Limited Budget to develop/fly new inspection tools
- Limited Crew Time to operate tools/manipulators – planned/emerg.
- Limited Access – internally and externally
- Limited Line-of-Sight Views - ISS cameras don't cover the entire vehicle, resolution limited
- Limited Resources for EVA – limited resupply of consumables
- Limited Vehicle Communications(IVA & EVA) and Down-link of inspection results
- Limited Life for ISS Components – inspections to understand remaining life
- Limited Crew Training Options – equipment can require too much interpretation
- Limited Ability to Interpret Results In-Space - Dependency on Ground Engineering Support
- Zero-G Limitations on use of both hands, securing/manipulating inspection equipment
- Limited MMOD Shielding in certain areas – configuration upgrades in work, require EVA time
- Increasing MMOD Debris in LEO (Low Earth Orbit)

In-space NDE Inspection System for MMOD Damage
The Problem

MMOD Impact Damage Threat

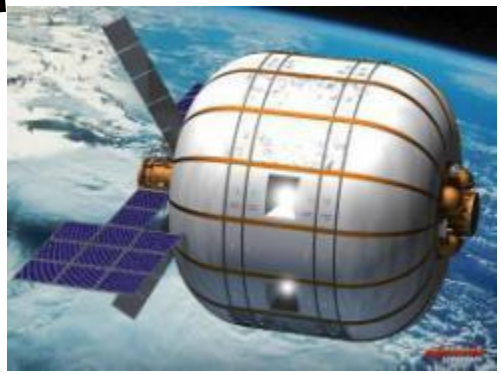


International Space Station

- Pressurized Modules
- External Systems
- Hi Priority Spares
- COPVS

New Commercial Crewed Spacecraft

- TPS/supporting structure
- Pressurized Module



Inflatable Module Technology

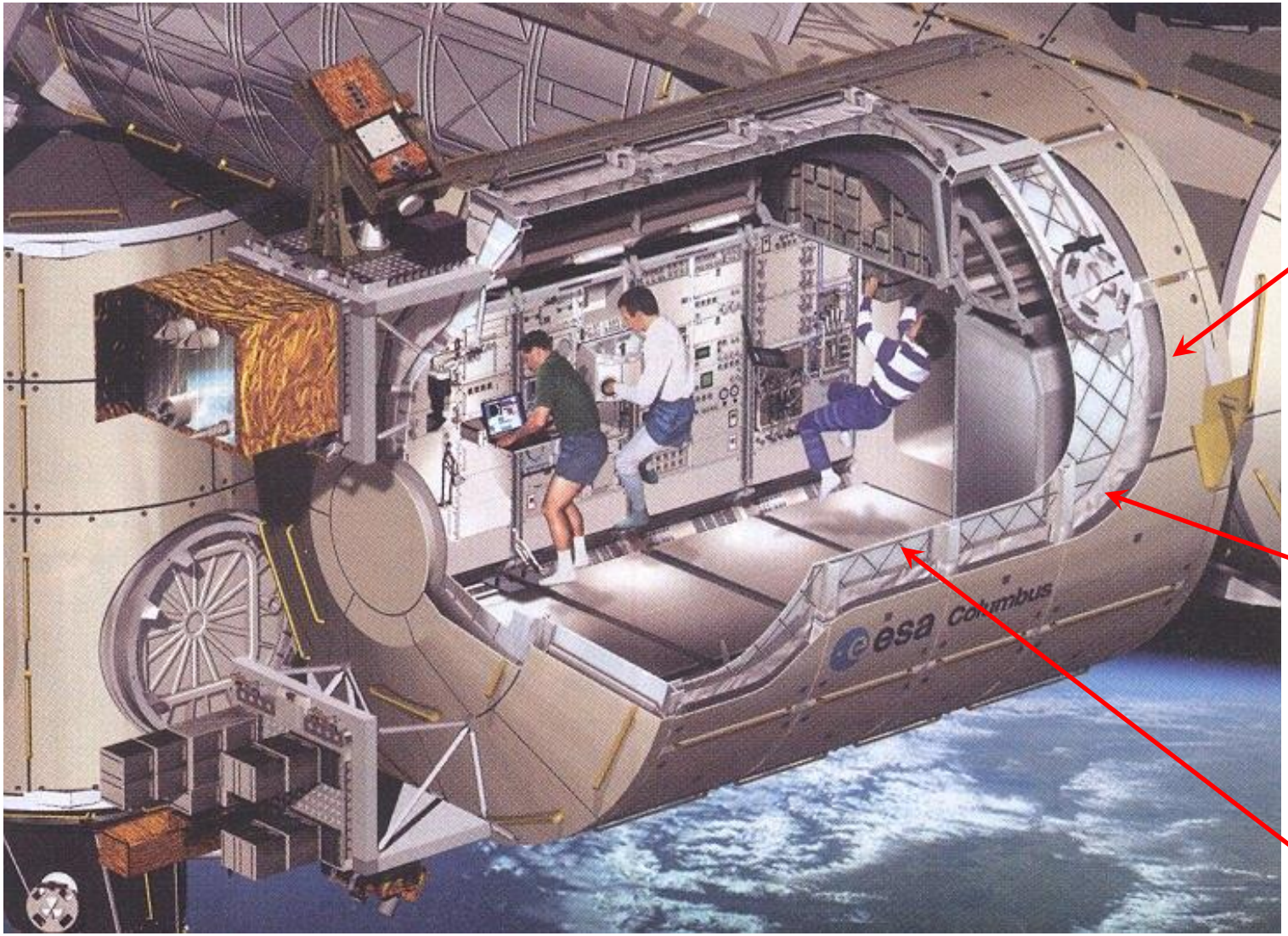
- Load-bearing Fabric Layer
- Leaks to Bladder

ISS Impact (IVA Inspection)
What is the damage to the Pressure Wall?

Aluminum Plate sample of MMOD-like damage to outer side of ISS pressurized module.

Nextel and Kevlar shield Layers

ISS Module



Whipple shield for MMOD

thermal blanket

Pressure vessel

International Space Station as a Proving Ground for Future Manned Spacecraft

		Current: LEO	Future: Exo-LEO
Autonomy-driven Inspection Priorities:	1	Mostly Crew	Autonomous Systems
	2	None	Robotic Auto, Dextrous, Mobile
	3	Robotic Manipulator	Insp Sys/Robotic - Remote Control
	4	Autonomous Systems	Crew Inspections
International Participation			
- Language/Culture		Unique	Unique, Real-time Translation
- Tools, Cert, Procedures, Trng		Unique/Intense	Common/Intl Sources
Interior Volume Inspection			
- Accessibility		US Module Racks Design	No ISS-like racks
		Russian Module Design	Highly packed, but modular
- IVA NDE		Aluminum wall damage/repair Location, Corrosion	Comp., Inflatable, Multi-func. SHM/IVHM events/indicators
			Req Prelaunch In-space Inspections
Exterior Inspection		Windows+EVA+Remote Cameras	Mobile platforms + Modular
		Accepted Risks	Req. Prelaunch In-Space Inspections

Technology Efforts

- **ISS IVA tools** – Videoscope, IR Camera, Russian BAR set
- **ISS Leak Detection & Repair Team** – Ultrasonic Hand-held Leak Locator.. Working on contact sensors for module wall inspections
- **NESC NDE TDT and NASA NDE Working Group** – Various Projects
- **NASA SBIR Subtopic:**

  X5.03 Spaceflight Structural Sensor Systems and NDE
  http://sbir.nasa.gov/SBIR/sbirsttr2010/solicitation/SBIR/TOPIC_X5.html
- **Penetrating Inspector Technology Quests:** "In-Space Inspection Sensors Look Through Conductive Material to Target Surface"
  - MMOD Impacted Test articles circulated to industry
  - DeVenci Challenge – June 2011
  - NASA@Work Challenge – July 2011
    https://nasa.innocentive.com/ici/challenge/show/1053
  - NASA Tech Needs: July 2011
    http://www.techbriefs.com/component/content/article/10507
- **National Research Council** assessment of priorities includes:

  Smart Habitats (Section 7.4.3), Nanoscale Sensors and Actuators(Section 10.4.1), Autonomous Inspection(Section 12.5.1), TPS Repair(Section 14)
- **Survey of ISS Risks, Challenges and Inefficiencies (not Requirements)**

Example ISS Needs, Risks, Challenges, and Inefficiencies

High MMOD Risks:

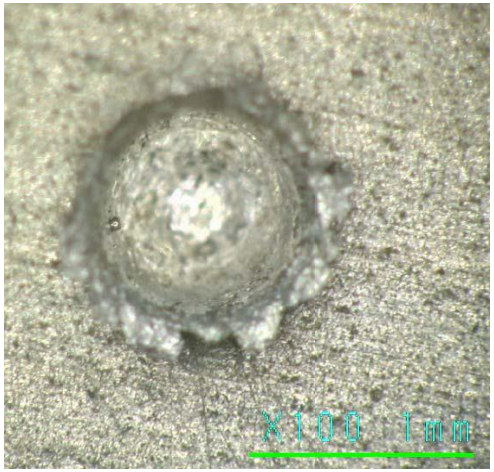
- **Highest risk operational components and External Spares(70)**
  - Holes in MLI (often with Alumuminized layers) are the only visual clues
- **Module Leak Location and Repair** – MMOD penetration of pressurized module
- **Thermal Protection Tile/Heatshields** to visiting vehicles
  - Damage could be deeper/more extensive than are visible with cameras
- **Windows** – especially the most vulnerable windows
  - Damage to the outer pane is difficult to quantify
- **Robotic Manipulators - SSRMS/MBS/SPDM**
  - composite boom, avionics, external spares
- **Solar Array Mast** – guide-wires, holes, tears
- **Radiators** - PV and TCS Active Thermal Control
- **Commercial Crew Vehicle Integrity**

MMOD Environments – Models

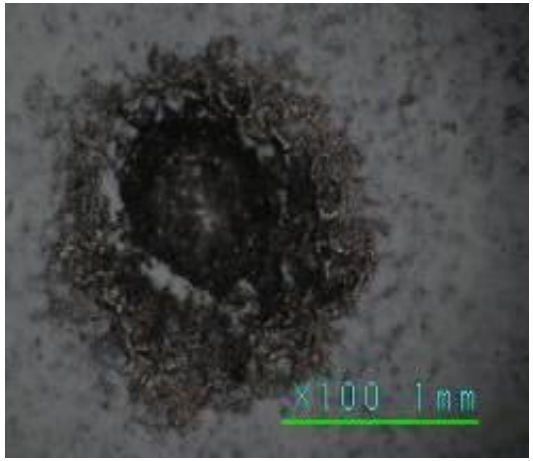
- **Inspections** to determine actual trends – size, density, direction

MMOD Impacts to ISS (Examples)

Trailing Umbilical System for Mobile Transporter - 11 Impacts

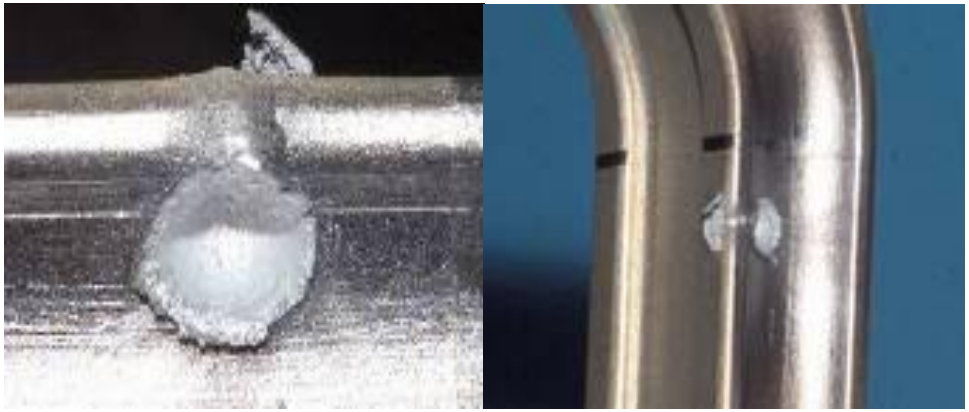


S-Band Antenna Support Assembly - 71 Impacts

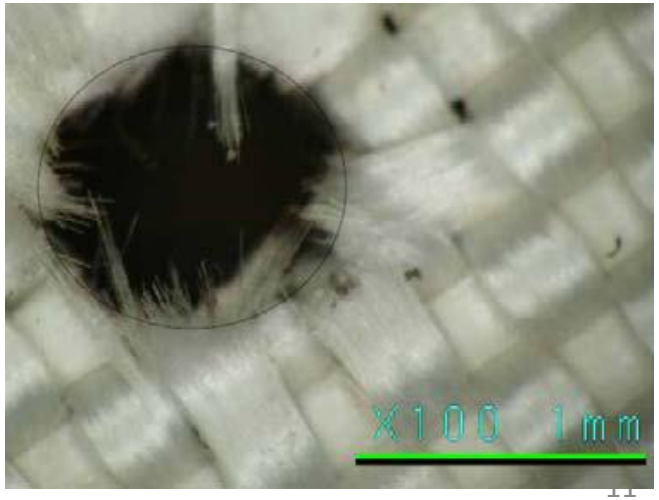


FGB Thermal Blanket

EVA Handrail Impacts - sharp edges

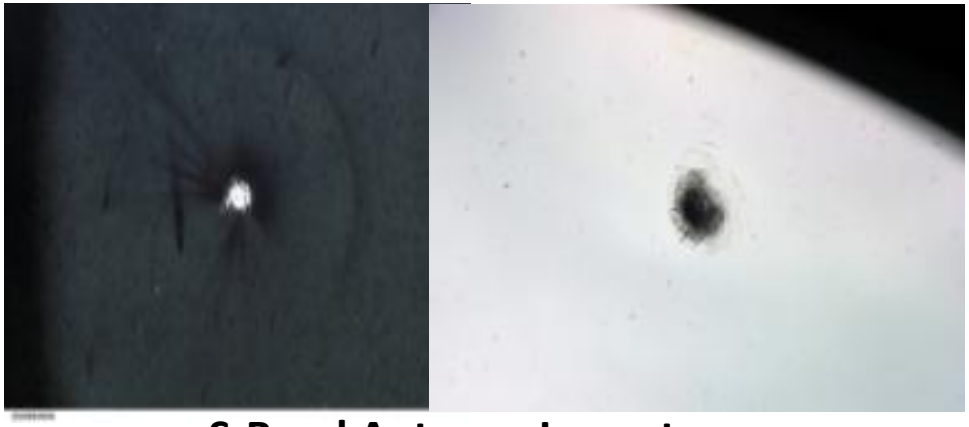


Node 1 Port Common Berthing Mechanism Cover

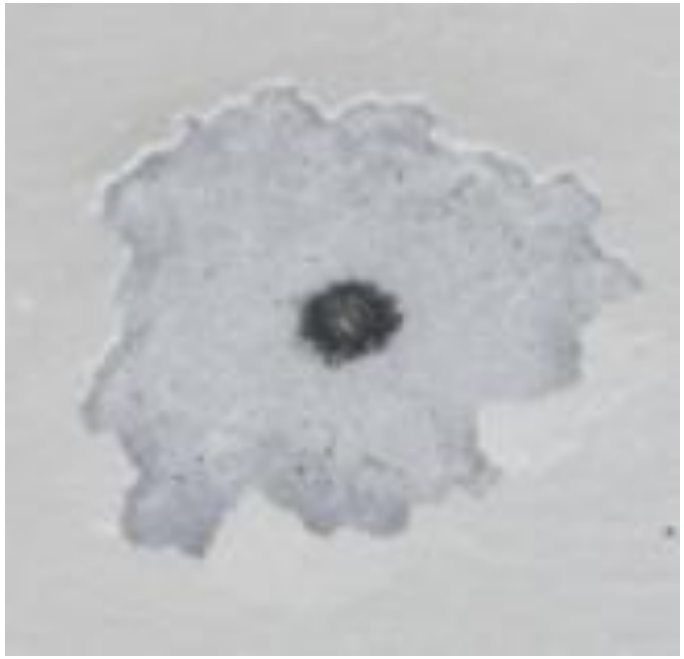


MMOD Impacts to ISS (Examples)

MMOD Damage to Windows



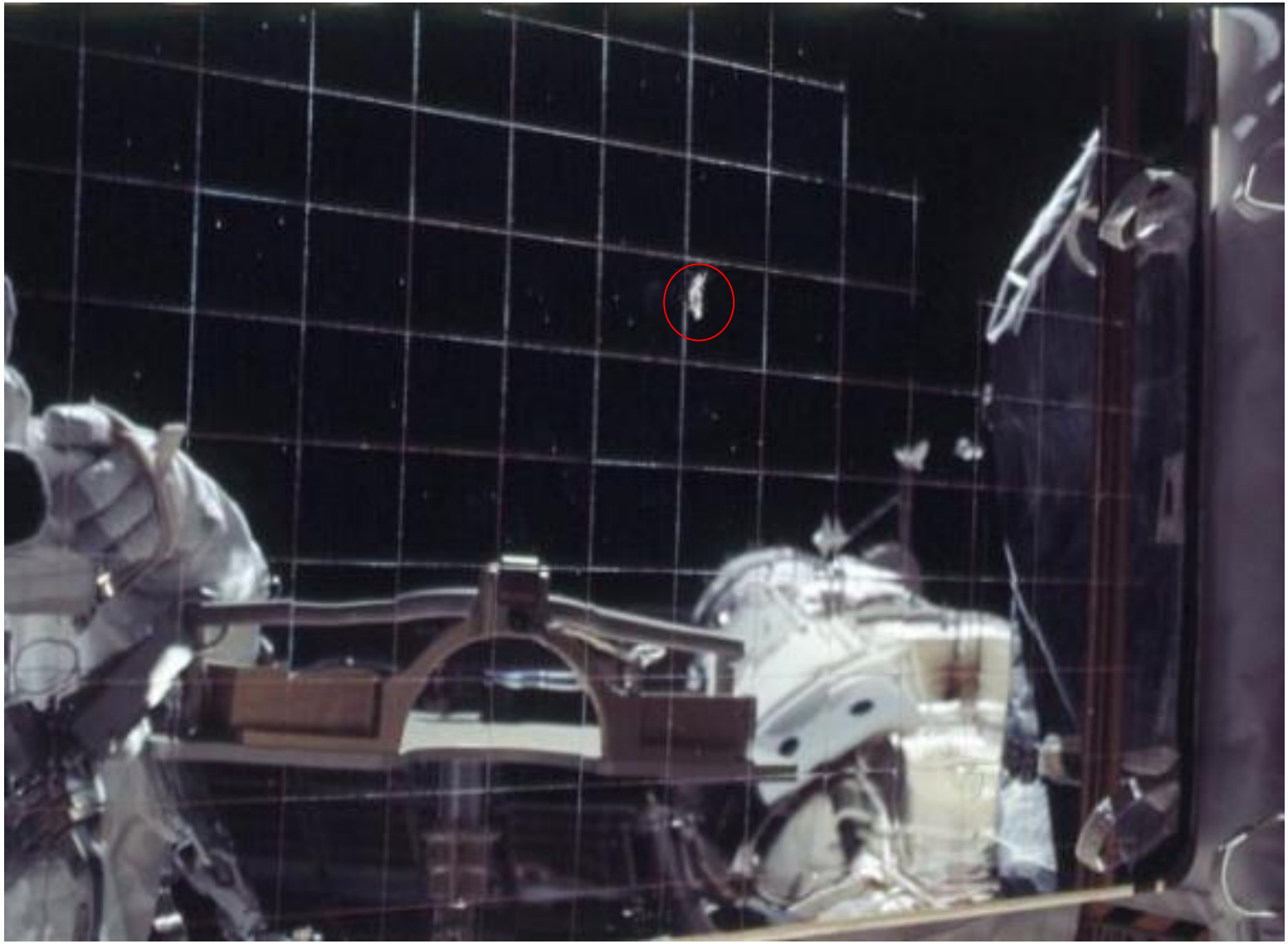
S-Band Antenna Impact



P6 Photo-Voltaic Radiator

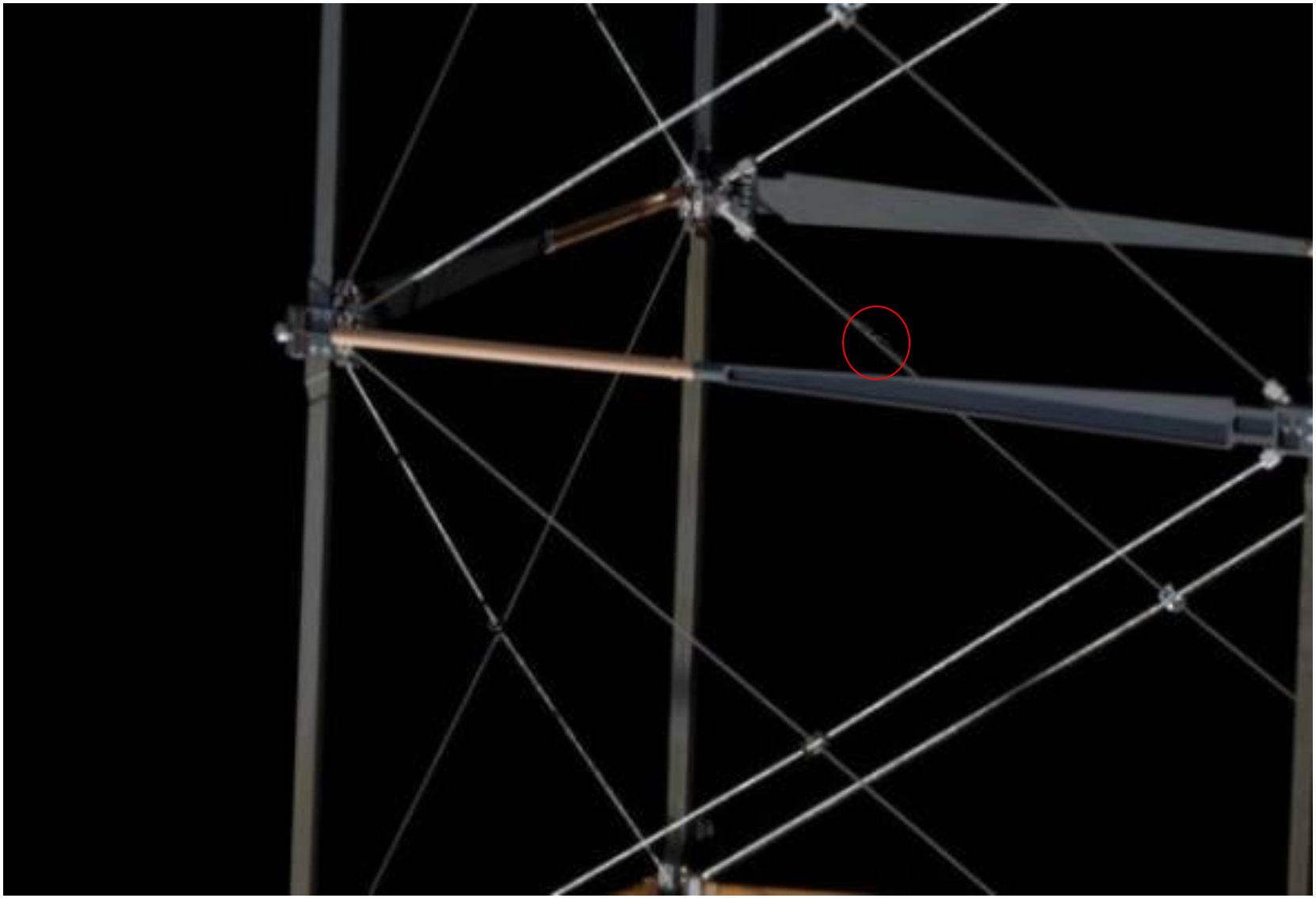
MMOD Impacts to ISS (Examples)

Radiator Damage from MMOD



MMOD Impacts to ISS (Examples)

Solar Array Mast Guide Wire Damage from MMOD:



Example ISS Needs, Risks, Challenges, and Inefficiencies

Operations - ISS-based External Inspection Optical Cameras:

- **Incomplete Viewing from Windows and Robotic Manipulators**
  - Fill in Blind-Spots and areas with Insufficient Resolution
- **Replace Shuttle fly-around**
  - General ISS periodic inspection
  - Public Awareness/Interest for PAO use
- **EVA Translation Path Planning** to avoid cut gloves from sharp edges
  - Determine which of the 90 potential damage sites to avoid during EVA are actually sharp-edge damage?
  - Determine if more damage has happened prior to each EVA.
- **ISS Camera Upgrade Capability:**
  - Better resolution, Stereo vision/depth
  - Camera capability and maintainability until end-of-program
- **Reduce Robotics tasks for docking/berthing surface Inspections:**
  - Inspection of surfaces prior to mating

Example ISS Needs, Risks, Challenges, and Inefficiencies

Structural Dynamic Measurements - General assistance with photogrammetry

Suspected Damage: Loaded Array Power Generation Degradation-why?
TARJ, Solar Array mast degradation

Previous Damage: P1/S1 Radiator Face Sheet damage bulges (related to MMOD?)
SARJ Grease - port side has cover off - 10'dia rotates in 90 min
Solar Array Blanket Damage P6 SA Radiator Deploy 2B/4B
2B initial deploy lost one string - where? Why?
SSRMS composite boom - MMOD impact to MLI

Thermal Imagery: Heat pipe anomalies - S0, Z1 ORUs, MDMs on PMA1
Avoiding EVAs to obtain good images for troubleshooting

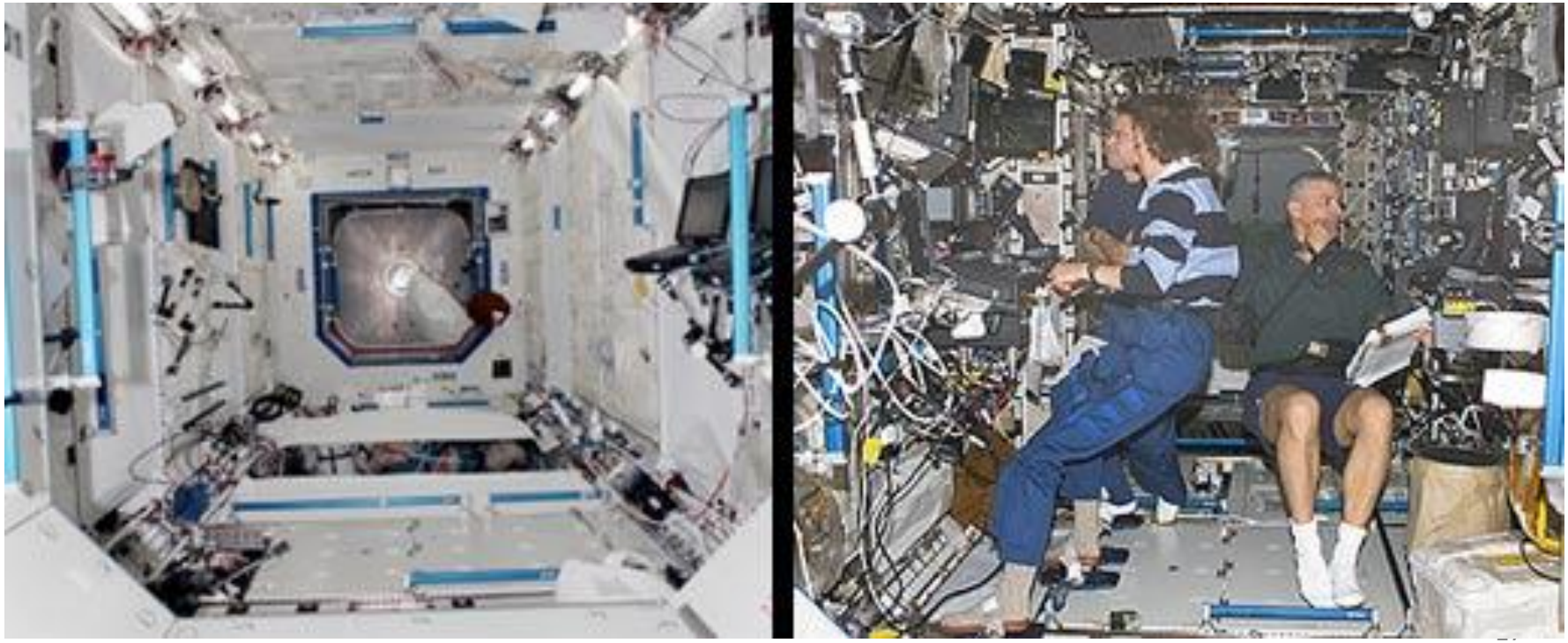
Quick Response: Module Leak Location and Repair
SARJ not working – contamination
FGB Blanket MMOD Impact near Compressor Pump Module
MMOD impact/High Risk ORUs(Batteries, various elect boxes)
Avionics: External Antennas, Communication & Power lines
External Experiments and Payloads: AMS,

Example ISS Needs, Risks, Challenges, and Inefficiencies

Reality May Not Agree with our Perception
US Laboratory

"Just Rotate the Rack and get Easy Access"

Initial Configuration **Typical Operations**



http://www.nasa.gov/mission_pages/station/structure/elements/destiny.html

Current Inspection Tools(US)

IR Camera

Fiberscope

Ultrasonic Leak Detector - Locator

Example ISS Needs, Risks, Challenges, and Inefficiencies

<u>Internal Issues for Inspections</u>:

US Module design – because of rack design, generally good access(70%) except

- Stowage can be in the way
- Crew time to rotate racks can be 2 hours
- Standoff-areas and end cones
- Some issues (e.g. module leak) could reduce risk(time) with better IVA tools:
    - Improve Ultrasonic Leak Detector adapters
    - Full-length Controllable Stereo View Endoscopes
        - see desired technology functionality chart
    - Access NDE inspection after leak plug has been installed
    - Many system people trouble-shoot without knowing that the on-board inspection tools we do have may be able to help them…

Russian Modules – divided responsibility

- Limited Access (70%) panels to remove,
- Module susceptibility to condensation
- Some IVA tools already, but limited access/understanding on US side

Example ISS Needs, Risks, Challenges, and Inefficiencies

ISS External Inspection Challenges

- EVA/Robotics – no time for dedicated surveys
- ISS Fixed Cameras + Windows – limited line-of-sight, resolution issues
- ISS Robotics – Planning joint angles/operations, Moving the manipulator to inspection location, Viewing and resolution still may not be sufficient
- Hole in Thermal Blanket not really indicative of damage underneath… Boeing not worried about holes smaller that 1/8th inch dia.

In-Space Non Destructive Inspection Technology Workshop

Purpose:

- Assess In-Space NDE technologies and needs - current & future spacecraft.
- Discover & build on needs, R&D & NDE products in other industries and agencies.
- Stimulate partnerships in & outside NASA to move technologies forward cooperatively.
- Facilitate group discussion on challenges and opportunities of mutual benefit.

Focus Areas:

- Miniaturized 3D Penetrating Imagers
- Controllable Snake-arm Inspection systems
- Miniature Free-flying Micro-satellite Inspectors

Agenda:

- Session 1: Vision/Background
- Session 2 & Lunch – End-User Needs
- Session 3 & 4 - Technology Developers(3 Tracks)
- Session 5 & 6 & Lunch – End-User Needs
- Session 7 – One-on-One Sessions with End-User at Individual Tables
  - Sign-up Sheets at Reception Desk
- Session 8 – Forward Planning Sessions - Discussion Groups – Leaders to be assigned

In-Space Non Destructive Inspection Workshop
3 Primary Focus Areas

- **Penetrating 3D Sensors:**
  - ISS Pressure Wall (IVA - look from inside – out)
  - TPS tile & backshell substructure(EVA)
  - Metalized MLI blankets that protect numerous systems
  - Composite Pressure Vessels

- **Serpentine Inspection Robots:**
  - Zero-G Derivative of 1-G systems
  - Internal Inspections in poor access situations – behind racks and panels and utility areas
  - External Inspections – MMOD damage holes, exterior Surveys, Satellite Servicing/Phoenix Missions
  - Apply Biomemetics to understand design goals
  - Stimulate other Agency/Industry – Developer – University relationships

- **Free-Flyer Inspection:**
  - Planned(after deployments and prior to starting back to Earth) and Unplanned(Anomalies)
  - Aerospace Aerocube4 Capability + SPHERES Testbed + Mini-Aercam lessons learned
  - Autonomous Inspection Functionality
  - Active "Doghouse" provides cubesat inspector with power, comm, nav, deploy-retrieve
  - Upgradable Camera for use as Robotic manipulator Inspection (Aerocube better than current)
  - Deploy-return in free-flyer mode along line-of-sight path from doghouse
  - On ISS demo - Return to IVA servicing through JEM airlock

In-Space Inspection Sensors Look Through Conductive Material to Target Surface

By George Studor and Ajay Koshti, Johnson Space Center, Houston, TX

Friday, July 01 2011

http://www.techbriefs.com/component/content/article/10507

NASA needs a sensor system to characterize damage from Micro-meteoroid and Orbital Debris (MMOD), corrosion, or to perform configuration verification when there is a conductive surface in between the sensor and the site. The in-space system(s) will need to look from the inside (IVA) out or from the outside (EVA) in for both existing and future to-be-designed vehicles. The ground versions will be very useful for ground inspection purposes in areas of vehicles that are "closed out," or areas with limited access behind conductive structures. The damage includes, but is not limited to, deformations, penetrations, fractures, cracks, corrosion, and disbonds.

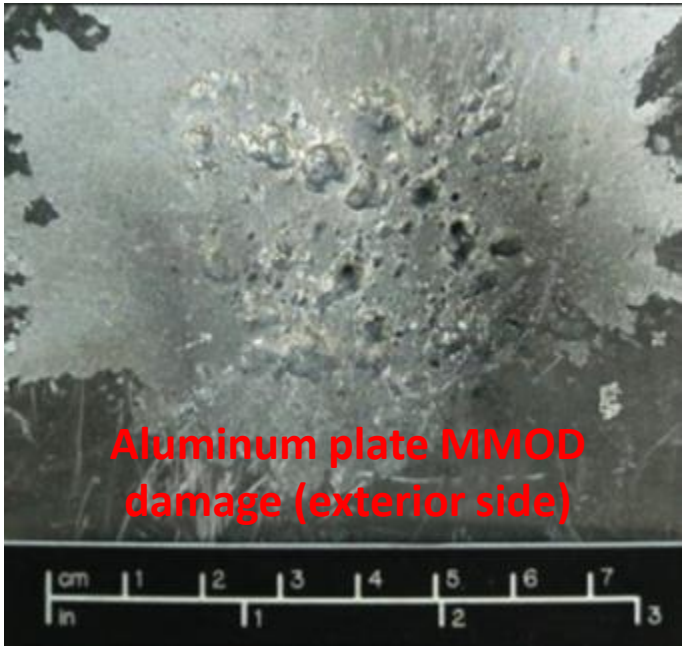
Requirements and Goals:

- Product: 3D image/data after minutes of on-board post-processing, with no down-link required.
- Scan area of 5 × 5".
- Resolution of 1 mm in any dimension, with no practical limit on the time to obtain the image.
- Depth of field must be adjustable based on the need.
- The distance to the object must be adjustable from 1 m to 1 cm.
- Must meet or exceed ANSI/OSHA standards.
- Near real-time feedback of video image and depth of penetration.
- Calibration: must be able to have certified resolution and accuracy via NDE standards.
- Motion compensation is as needed based on handheld or robotic manipulator motion when attempting to provide a still platform in order to obtain the required resolution.

3D Penetrating Imager – July '11 NASA Tech Need

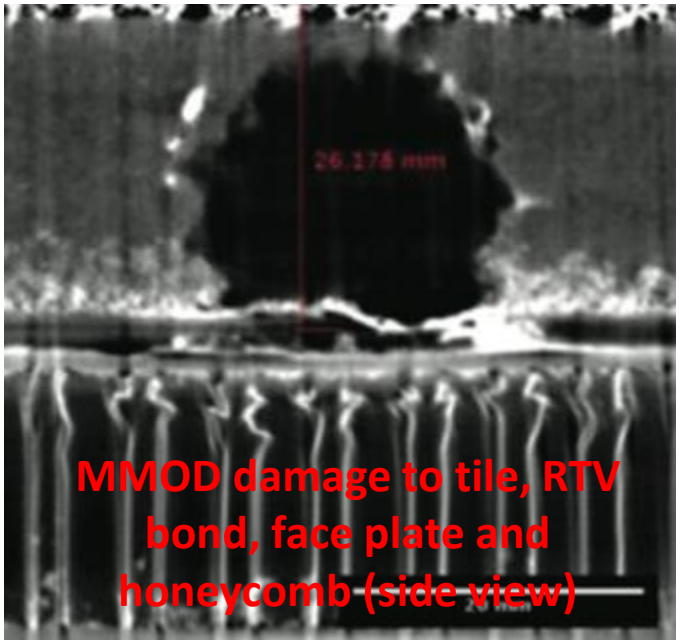
MMOD damage to the ISS pressurized module exterior wall

- Sensor needs to look from inside out.
- Time to acquire high res image – up to 20 minutes
- Single-sided, illumination source & sensor on the same side.
- Interior or exterior operations could be two different systems.
- Range - 1 m to 1 cm (goal), physical contact may be allowed.
- Single unit, with few internal or no moving parts (goal).
- The size, weight, and power would be less than
  1 cubic foot, 40 pounds, and 10W (goal)
- It should be portable or handheld
- Min interfaces: power, data processing, displays, controls human operator complexity and comm (less wires/wireless).

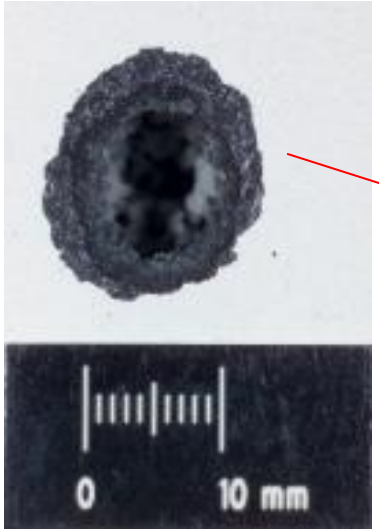


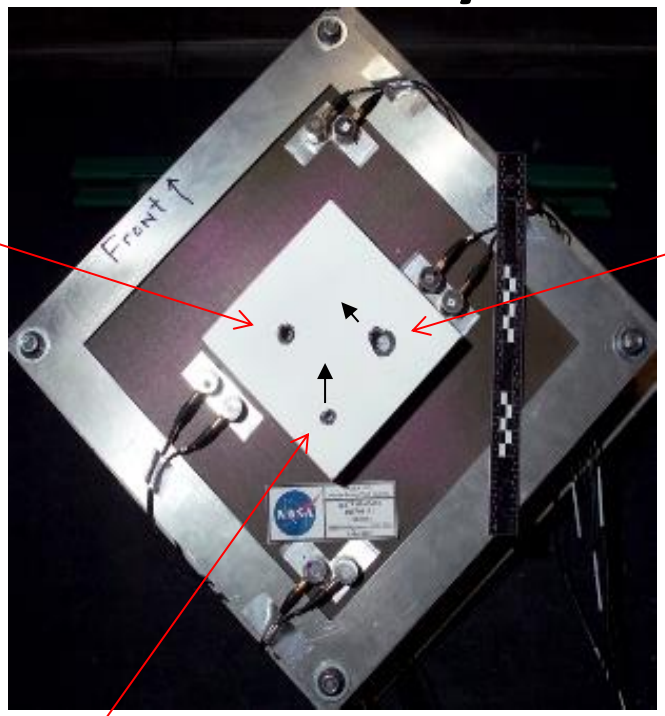
MMOD damage to re-entry tile and substructure

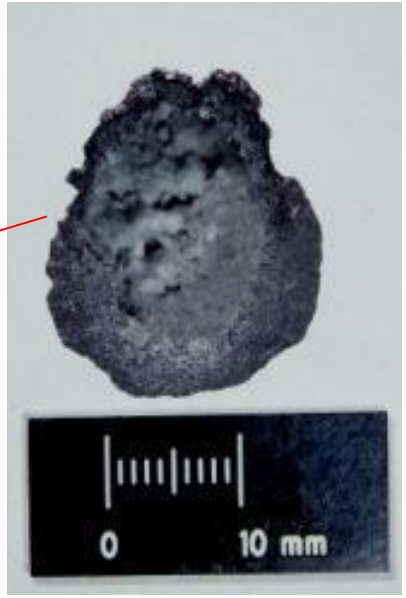
- Sensor needs to look from outside in.
- Low maintenance and costs with minimal or no servicing.
- The materials to see through, and materials containing the feature of interest include see-through aluminum, composite, thermal protection materials such as low-density silica tile, and rubber (RTV to the material and multi-layer insulation).
- Materials are consistent in each layer, but
  different materials may be present in each layer.
- Damage is usually in low- or medium-density material.
- Material doping may be allowed to enhance (NDE) results for future vehicles only.

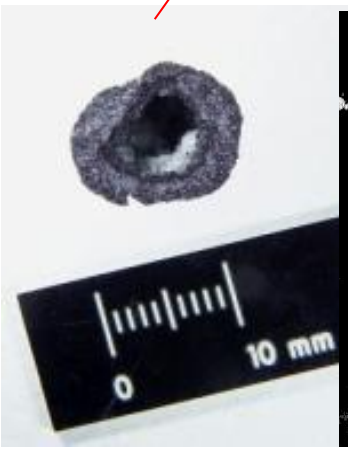


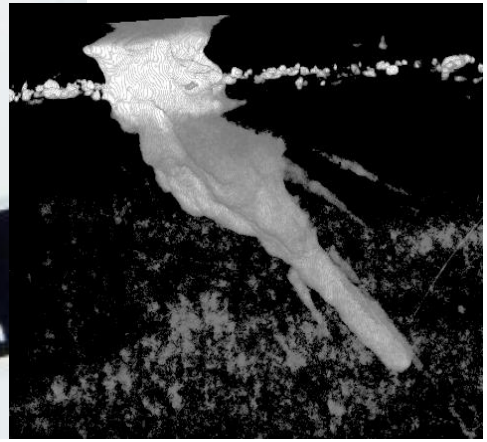
Hypervelocity Impacts to Sample Re-entry Tile Entry Holes and X-ray CT Images

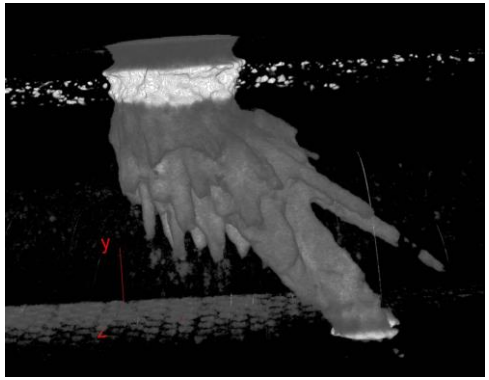












Why Snake-arm Robot?

Internal Inspections:

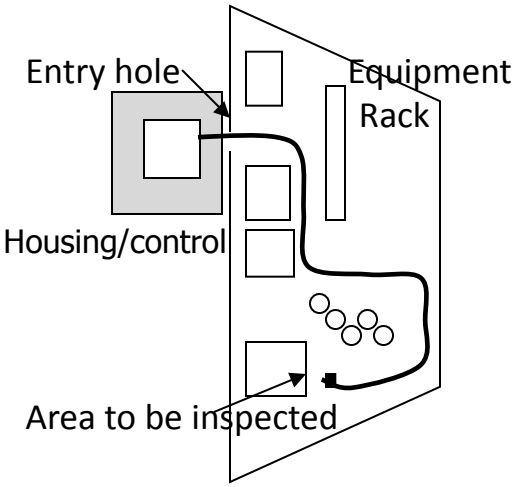
- Access for inspection can be limited, sometimes not possible.
- Access takes crew time and/or EVA and robotics time.
- Zero-g helps controllable snakes get where we need them to.
- Avoid Hazards – needs to be practical & verifiable before start.
- Coiled snake can have less volume.

External Inspections:

- Holes in MMOD Shields and Thermal blankets
- Getting under shields and blankets from the side
- Spacecraft surveys – uncoil/coil
- Additional Viewing angles for robotic operations(servicing)

What do we need Snake Inspector to do? Internal Functionality

Snake Inspector



1. **Stereo vision and articulating head** with lighting, designed in stiffness at various sections along the length
2. **SLAM - Simultaneous Location and Modeling Software** - builds the 3d model as it goes in and subsequently determines position and orientation of all parts very accurately.
3. **Articulating snake robot** - mechanical or piezo-control of the entire snake length- not just the tip as in a typical endoscope. Sensors that sense contact and feed controls to alleviate it.
4. **Snake real-time location** - know/display the location of the entire snake - plot against accurate 3D model built in #1.
5. **Self-following Software** - each segment of the snake knows where and how to turn as it follows the head or backs out of a complex physical path.
6. **Very small size, weight and power and works well Zero-g** (assumed)
7. **Length of at least 2 meters and diameter 3/8" or less –** go through existing penetrations such as the holes for sending fire extinguishing
8. **Minimum crew involvement/training** - easy to use, hands-free, possibly remotely operated from ground.
9. **Ability to change imagers at the end, and/or add sensors/wireless sensors at the tip.**
10. Ability to **grab items at the tip.**

Role of Biomemetics: "Snake-arm" like

Monkey's tail, Elephant's trunk, Octopus tenacle, Snail's eye

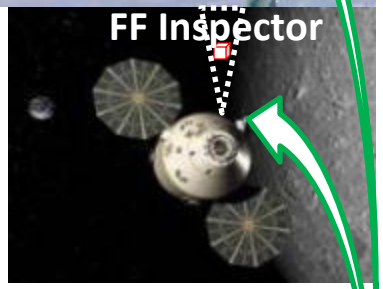
- Continuous backbone structure with flexibility and control.
  - Joints are coupled – causing complexities.
- Conform around objects without required to touch them.
- Grasp an object with the body.
- Control for balance purposes.
- Exact tip position, orientation and control.
- Full body position, orientation and control.
- Skin with sense of touch/pressure along the entire body.
- Tip with stereo eyes for depth and redundancy.
- Must account for gravity or neutral buoyancy when in water.

Studor Free-flying Inspector Vision…

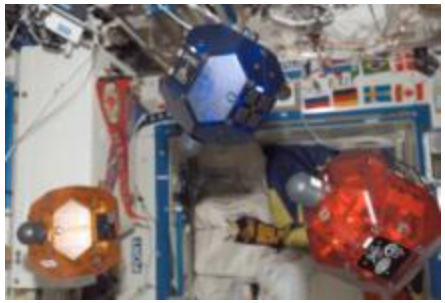
NASA
Mini-Aercam
Prototype

Lessons Learned from Mini-Aercam

Proto-types include Auto Inspect & Doghouse



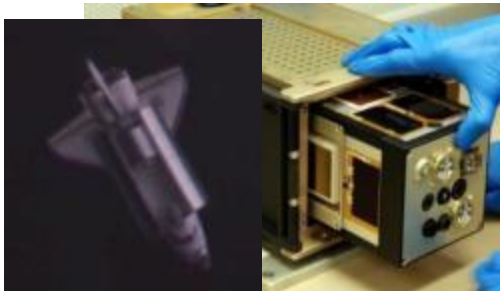
SPHERES Test Bed
Magnetic Field Control



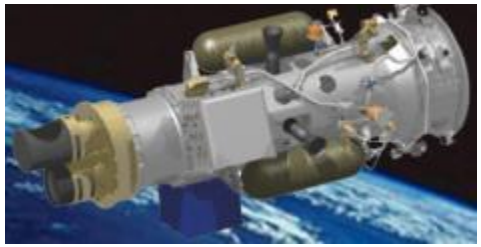
Autonomous Inspection Demo

- Survey to identify Potential Damage Sites
- Identify sites that are real damage
- Identify sites for Focused Inspection
- Obtain/Report Focused Inspection results
- Determine remaining uncertainties

PSSC2 STS-134



AFRL XSS-10 (28Kg)
Survey Delta Upper Stage



AeroCube 4 - Jun '12
10cm cube < 1 kg

Cube Sat Active "Doghouse"
(A Single Cube Active "PeaPod")

- Power, Comm, Nav, Thermal
- Sensors Active while mated
- Active Deploy and Retrieve
- Powered Grapple Interface or Installed at OML

Cube Sat Flight Demo
Commanded Survey
Of Upper Stage

Cube Sat Flight Demo
Autonomous Survey
Of Upper Stage

Cube Sat Flight Demo
Autonomous Survey
- Active "Doghouse"
- Retrieve/Download

Temporary Adhesion Technology

- **Electro-Static Adhesion**
  - Outside on Spacecraft Surface
  - Inside on “safe” areas
  - Thin metallic layer is enough to shield the generated field
- **Gecko-foot Bio-memetic materials**
  - EVA or IVA
  - Passive Temporary Attachment without Velcro
  - Active “Velcro” Attach/Detach

<u>Benefits to In-Space Inspection</u>:
Attach sensors/scanners in difficult to access areas
Free up Astronaut hands in Zero-G for inspection
- provide Attachment on-demand, anywhere
- better use of crew time!
Allows Robot Inspectors to Crawl on surfaces
Reduce Velcro in future spacecraft – Integ. costs, fibers contaminate

In-Space Non-Destructive Inspection Technology Workshop
Feb 29 - Mar 1 at JSC Gilruth Center Alamo Ballroom

http://www.nasa.gov/offices/nesc/workshops/in_space_non_destructive.html

Chair: JSC/ES2/George Studor

Sponsor: NESC - NDE/TDT - Bill Prosser

Support Team (NESC provided): 3 On-site, 3 at LaRC - all part time…

Workshop Team: JSC/Ajay Koshti, LaRC/Eric Burke, BP/Dave Lafferty

Purpose: Long Term Technology Development through Multi-agency and Industry mutual interests.

Focus Areas:
- Fully controllable endoscopic snake inspectors
- 3D Penetrating Imagers - moving toward hand-held
- Free-Flying Autonomous Inspectors
- Adhesion through Electro-Statics and new Gecko-feet technologies

Outcomes:
- Informal relationships - in and outside NASA and NESC; Presentations on Website
- Partnerships for future proposals/projects - no particular targets
- Groups that meet in the future to keep discussing mutual interests - plug in elsewhere
- Better understanding of common inspection needs and opportunities for collaboration
- Workshop Summary Presentation at NESC Face-to-Face (April) & ISA Conference(June)

Outcome

Presenters: **Vision/Background – 4**
Technologies - 30 (including Universities);
3 Tracks of 2 sessions each with 5 presentations and Webex/telecon avail
End Users - 16 (Including numerous NDE leads in major organizations)

Attendees: **Feb 29 = 165, Mar 1 = 164; Total 175 (86 Gov, 74 Ind, 15 Univ)**
"Work from Anywhere" Credit: 10 attended via Webex/Telecon

Display/Demo Tables: 25

One-on-One Tables: 20 - 1pm - 3pm Mar 1, scheduled 15 min blocks of time for private meetings

Future Planning Discussion Sessions: 5 3:15 to 4:30pm, Then leaders gave verbal summary

Food - orders (snacks/beverages, lunches) had to go in 1 week ahead of time Gilruth restrictions

Brochure and Presentations are Publicly Releasable - on Website
http://www.nasa.gov/offices/nesc/workshops/in_space_non_destructive.html

InSpace NDE/Inspection Workshop Agenda

Feb 29th: **7:00-8:00am** **Check-in**

Session 1: Alamo Ballroom

Welcome/Logistics: NASA/NESC/JSC Chief Engineer/Scott West
"NESC NDE TDT & Future Human Spaceflight Missions" - NASA/NDE TDT/Bill Prosser
"In-Space Inspection Technology Needs/Vision" - NASA/JSC/George Studor
"SBIR/STTR Relevant Subtopics and Award Summaries" - NASA/LaRC Eric Burke
"MMOD Risk/Ext Inspection Needs for Re-entry TPS" - NASA/JSC/Rollins/Christiansen

Break: 10:00-10:15am

Session 2: Alamo Ballroom - End User Needs Presentations

"NDE Inspection Needs at BP" - BP Technology/NDE - David Lafferty
"Asset Integrity Monitoring: the Needs and Challenges" - Shell/NDE-Sergio Kapusta
"Robotic Flexibility Considerations for Phoenix" - DARPA/Peter Will
"Defense Threat Reduction Agency Security Inspection Needs" - DTRA/Robert Woods
"Flexible Display Center Overview" - Arizona State Univ/Doug Loy
"DHS TSA Inspection Requirements" - DHS/TSA/Nicholas Santoro

Lunch:

"Modular Snake Robot - Robotics Institute at CMU" - Carnegie Mellon/Howie Choset

Feb 29

InSpace NDE/Inspection Workshop
Agenda

Session 3:

3A Alamo Ballroom East end Miniature 3D Penetrating Imagers	3B San Jacinto Room Misc Inspection Technologies	3C Alamo Ballroom West end Technologies for Flexible, Controllable Inspection
3D mm&Microwave Imag. MO S&T/Reza Zoughi	Direct Stress of Windows Stress Photonics/Lesniak	Novel Ultra-mini Videoscope Xigen/Jason Geng
Hand-held MMwave Camera Walleye/Dave Hollbrook	Sensing w/Magnetic Waves Gen Magnetic Sci/John Menner	Lightweight CNT Cables Mn-Wire/Tom Kukowski
Hand-held T-Hz Imaging Picometrix/Dave Zimdars	M-Wave Imaging w/Dual Coils Exel Orbital/Kevin McGushion	IPMC Artificial Mechatronics Future Prospectus UMaine/Moshen Shahinpoor
3D Backscatter Xray Aribex/Arturo Reyes	Gecko-like Adhesive Orbital Applications NASA/JPL/Aaron Parness	Biologically Inspired Trunk & Tentacle Robots Clemson/ Ian Walker
Image Processing of Digital X-ray Images VJ Tech/ N. Shashishekhar	Micro-Robotic Inspectors with Electro-Adhesive SRI/Ron Pelrine	Real Time Fiber Optic Strain and Shape Sensing NASA/DFRC/Patrick Chan

InSpace NDE/Inspection Workshop
Agenda

Feb 29:

Session 4:

4A	4B	4C
Alamo Ballroom East end	**San Jacinto Room**	**Alamo Ballroom West end**
Miniature 3D Penetrating Imagers	**Mini Free-Flying Inspection Satellites**	**Controllable Snake-arm Inspection Systems**
3 Approaches to Bx Imaging AS&E/Lou Wainwright	Mini-AERCam JSC/ER/Steven Fredrickson	Snake-robots/following S/W OCRobotics/Rob Buckingham
X-Ray Backscatter Systems Nucsafe/Dan Shedlock	SPHERES ARC/Mark Micire	3D Videoscope - next steps Olympus/Frank LeFleur
Compton IT for 3D NDI POC/Victor Grubsky	Pico and Nano Sats Aerospace Corp/Dave Hinkley	Snake Robot Inspection Tech SRI/Ron Pelrine
3D BX-ray & Adv DR GE/Rebecca Rudolph	ISS/Spacecraft Insp F.Flyer JSC/ES/George Studor	Remote Visual Inspection GE/M&C/Joshua Scott

InSpace NDE/Inspection Workshop
Agenda

March 1:

Session 5: Alamo Ball Room	**End-User Needs Presentations**
"Assembly and Automation Technology"	- Boeing MFG R & T/Jim Buttrick
"BXray for Aerospace Applications & Snakes on a Plane"	- Boe/NDE/Gary Georgeson
"Overview of USAF NDE R&D Activities"	- AFRL/ WPAFB /NDE/Stephan Russ
"Inflatable Module Inspection Needs"	- JSC/Inflatable Tech/Gerard Valle

Break: 10:00-10:15am

Session 6: Alamo Ball Room	**End-User Needs Presentations**
"Comp Pressure Vessel/Rocket Propulsion Inspections"	-WSTF/ Regor Saulsberry
"Subsea Inspection and Sensing Technology"	- Astro Technology/Dave Brower
"Spacecraft Pre-launch/Turnaround NDE Needs at KSC"	- KSC/NDE - Rick Russell
"Satellite Servicing Capabilities Office"	- GSFC/SSCO -Ben Reed

Lunch: "New Areas of Automotive NDE: Li-ion Batteries and Composite Materials" - USCAR/NDE - Leo Lev

InSpace NDE/Inspection Workshop
Agenda

Session 7:
Scheduled One-On-Ones with End Users at their tables - sign up during workshop
(approximately 15 minutes per session)

Session 8:
Forward Planning Discussion Groups:
- miniature backscatter X-ray – Bence Bartha
- free-flying inspection satellites - George Studor
- temporary adhesion technologies and applications – Aaron Parness
- university NDE programs – Iowa State/Lisa Brashe
- future workshop and follow-up activities – BP/Dave Lafferty
- controllable robotic snake inspectors – not enough participants remained

Reports from Forward Planning Groups by designated lead

Closing Remarks - Comments from Participants

What's happened Since?
- Upside -

- Boeing Aircraft Inspection Technology meeting
- Franklin-Edison Small Satellite Submittals
- DARPA Phoenix Submittals
- Developed JSC/ES In-Space NDE/Inspection Roadmap
  - IVA Ops Con, Driven mainly by Pressurized Module Damage
- Proposals for Gecko and Electro-Adhesive Technology
- Several "match-ups" of attendees(most I wouldn't know)
- Additional info from Backscatter X-ray developers
  - VJ Tech results to be briefed
  - POC system for AF deliver this summer/SBIR Ph1
- NESC Robotics TDT white paper on Bio-Inspiration
- DOT-BP-NASA – planning… Astrotech, Raytheon…

Autonomous Underwater & In-Space Inspection Workshop

What's happened Since?
- Downside -

- SBIR Subtopics reduced – In-Space NDE did NOT survive.
- No responsibility assigned for visiting vehicle TPS inspection.
- Limited Time to follow-up…

Conclusions

- Need Near Term ISS and Re-entry Vehicle Inspection/NDE

- More Autonomy means more In-Space NDE/Inspection
  – may need robotic or human operated options

- Need to work more closely with other Industries and Agencies to move forward on the technologies