Johnson Space Center Overview

Johnson Space Center is more than Mission Control

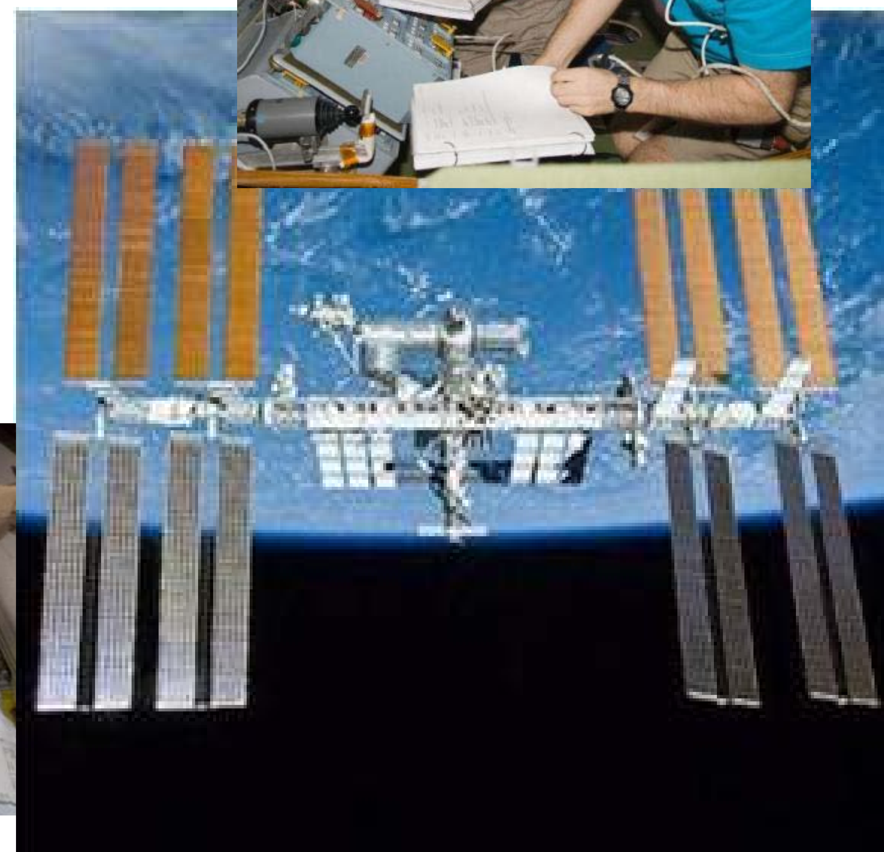
Main Site: Houston, TX
Civil Servants ~3300
On/near site ~13,000

Additional Facilities:
White Sands, NM
Neutral Buoyancy Lab
Ellington Field, TX

We Achieve the Impossible with Bold Explorers and Incredible Machines!

International Space Station: Challenges met every day

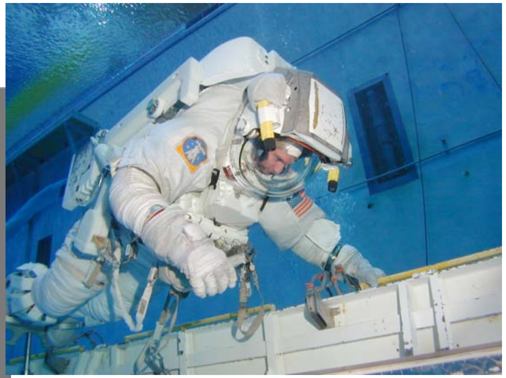
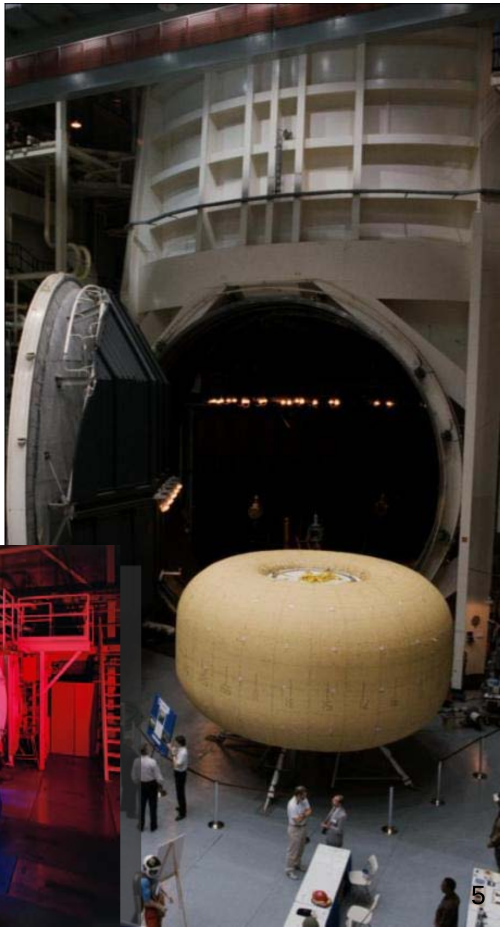
- Remote hazardous environment
- Complex systems engineering and integration
- Continuous operations with six member crew
- Focus on sustainability with limited resupply

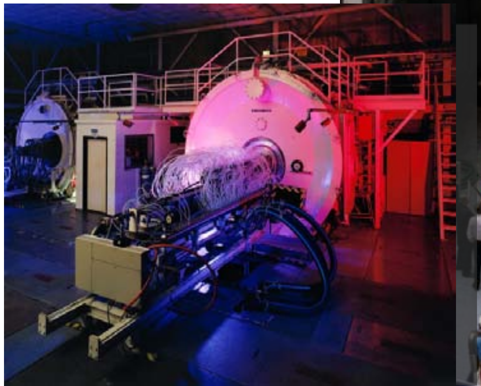


NASA Johnson Space Center Space Flight Services

- Integrated Human Space Vehicle Systems
- Life Support Systems & Environmental Control
- Flight Design
- Integrated Environments Testing and Analysis
- Mission Operations

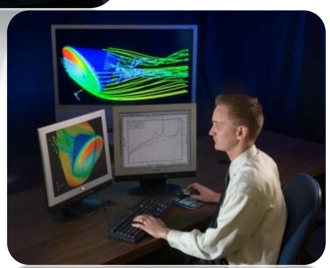


Program Partnerships

We engage our Program partners by providing



Technical Expertise

Analysis & Test Support

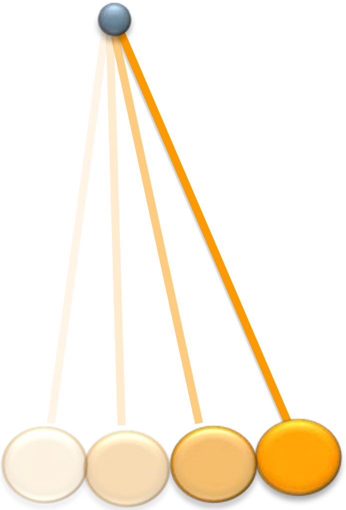
High Fidelity Simulation & Modeling

In-house Development

Technology Maturation

The outcome we strive to achieve is that partners embrace us as an integral partner who fulfills our commitments and proactively brings credible solutions forward while maintaining a work environment that emphasizes continual learning and development

Changing Policy Environment



Priorities

1. Retire the Space Shuttle no later than 2010
2. Complete the International Space Station
3. Develop and fly the Crew Exploration Vehicle by2014
4. Return to the Moon no later than 2020
5. Extend human presence across the solar system and beyond

Policy Focus:

Advance U.S. Scientific, Security, Economic interests

Priorities

1. Protect the Earth's Environment
2. Enhance Relevance to Earth Science
3. Green Aeronautics
4. Human Spaceflight Technology Development

Policy Focus:

Tech., Environment, Commercial, Int'l

ESMD

SOMD

SMD

ARMD/Tech

Trend is increasing commercial, multinational collaboration

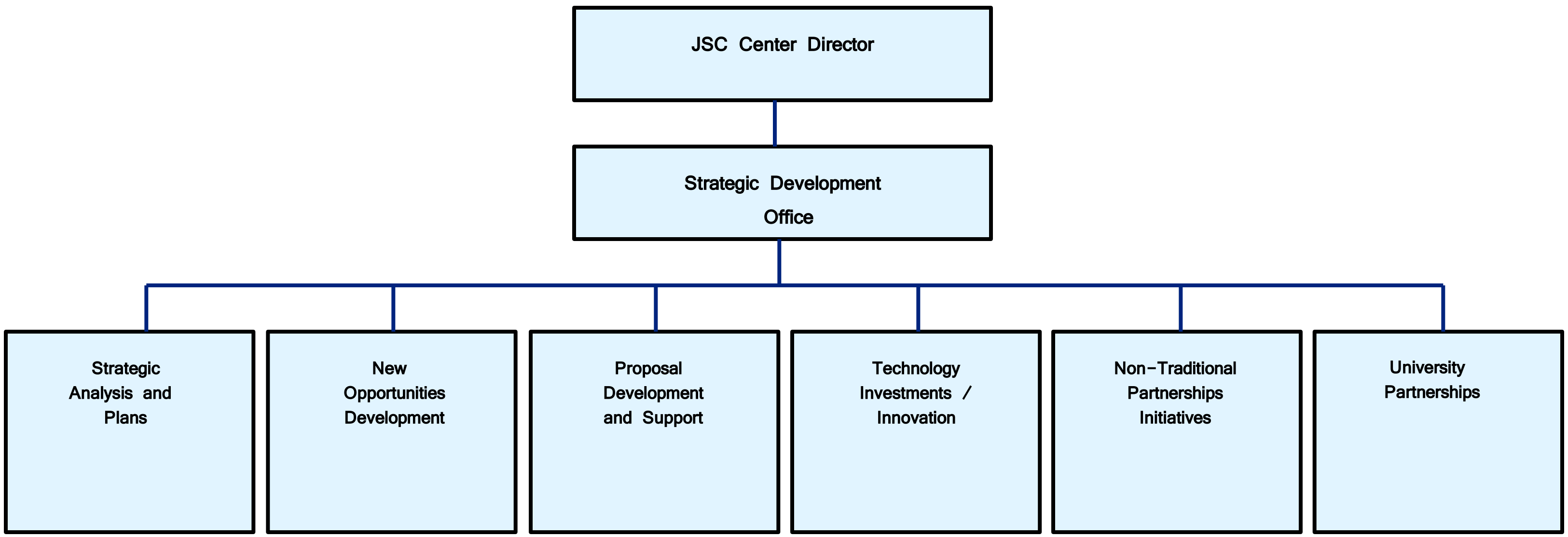
- Complex Integration, Systems Engineering, Partnership

- ISS Program is Prototypical Example of Success

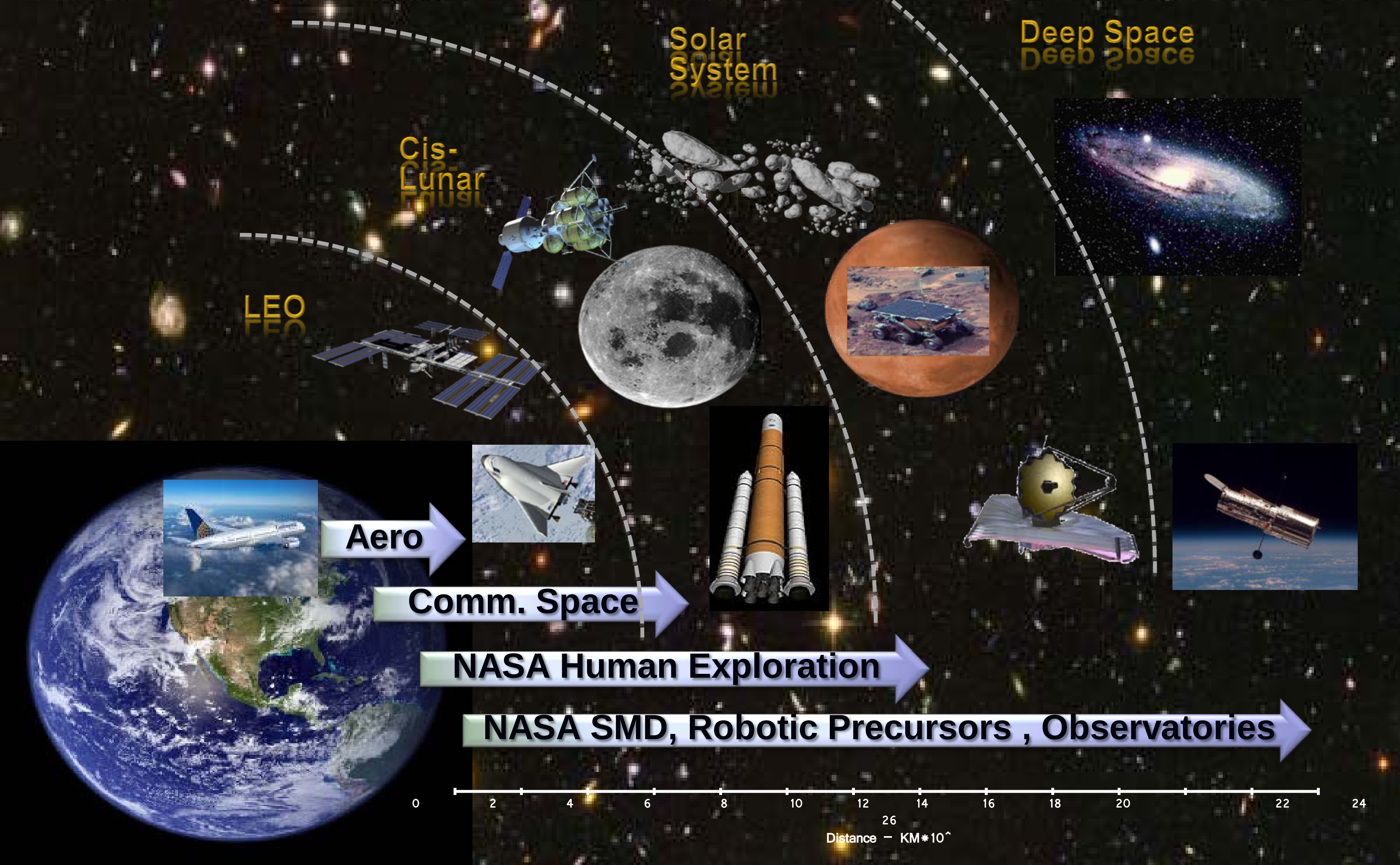
NASA,
International,
Commercial,
Technology

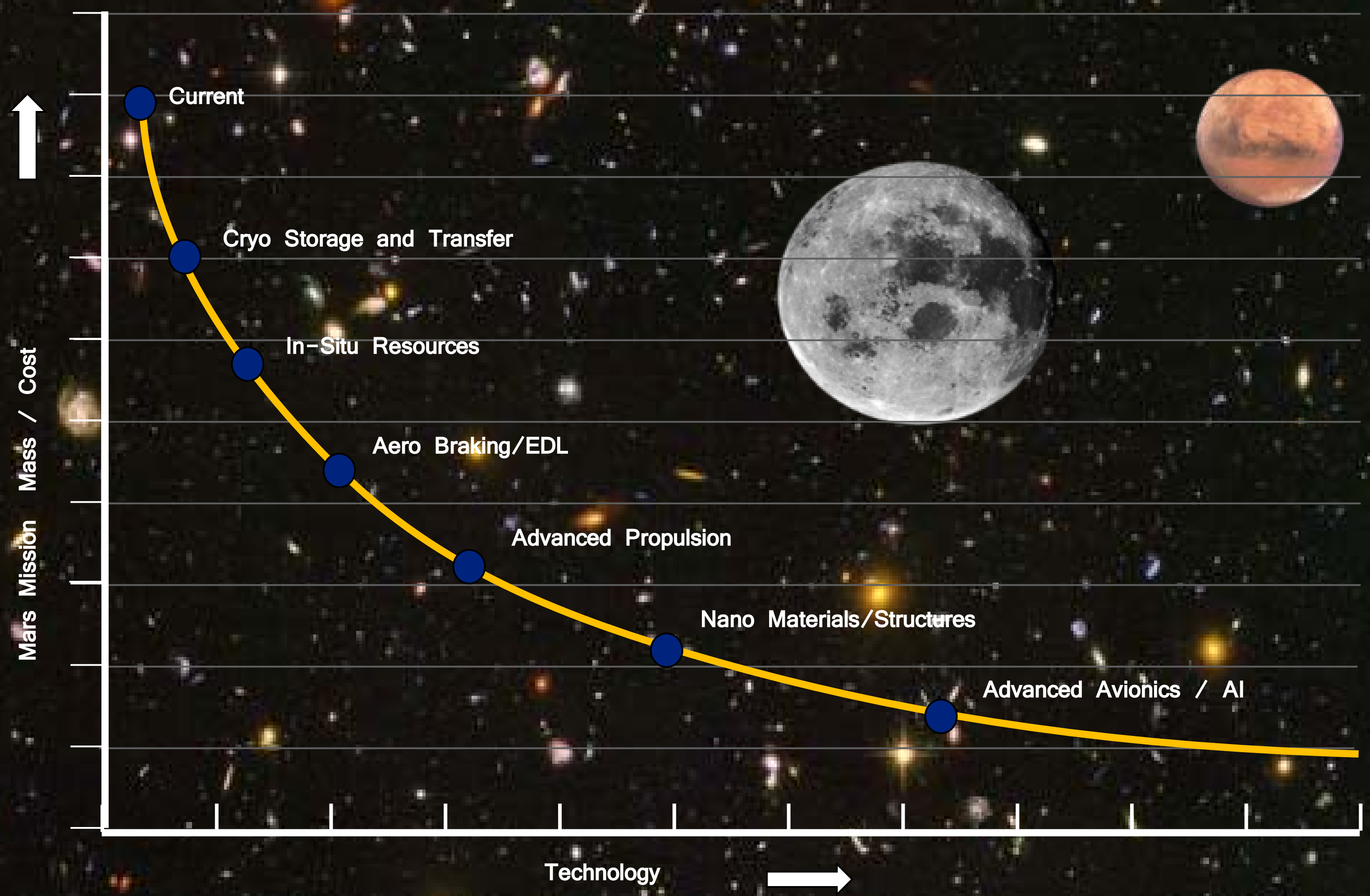
Competition → *Collaboration*

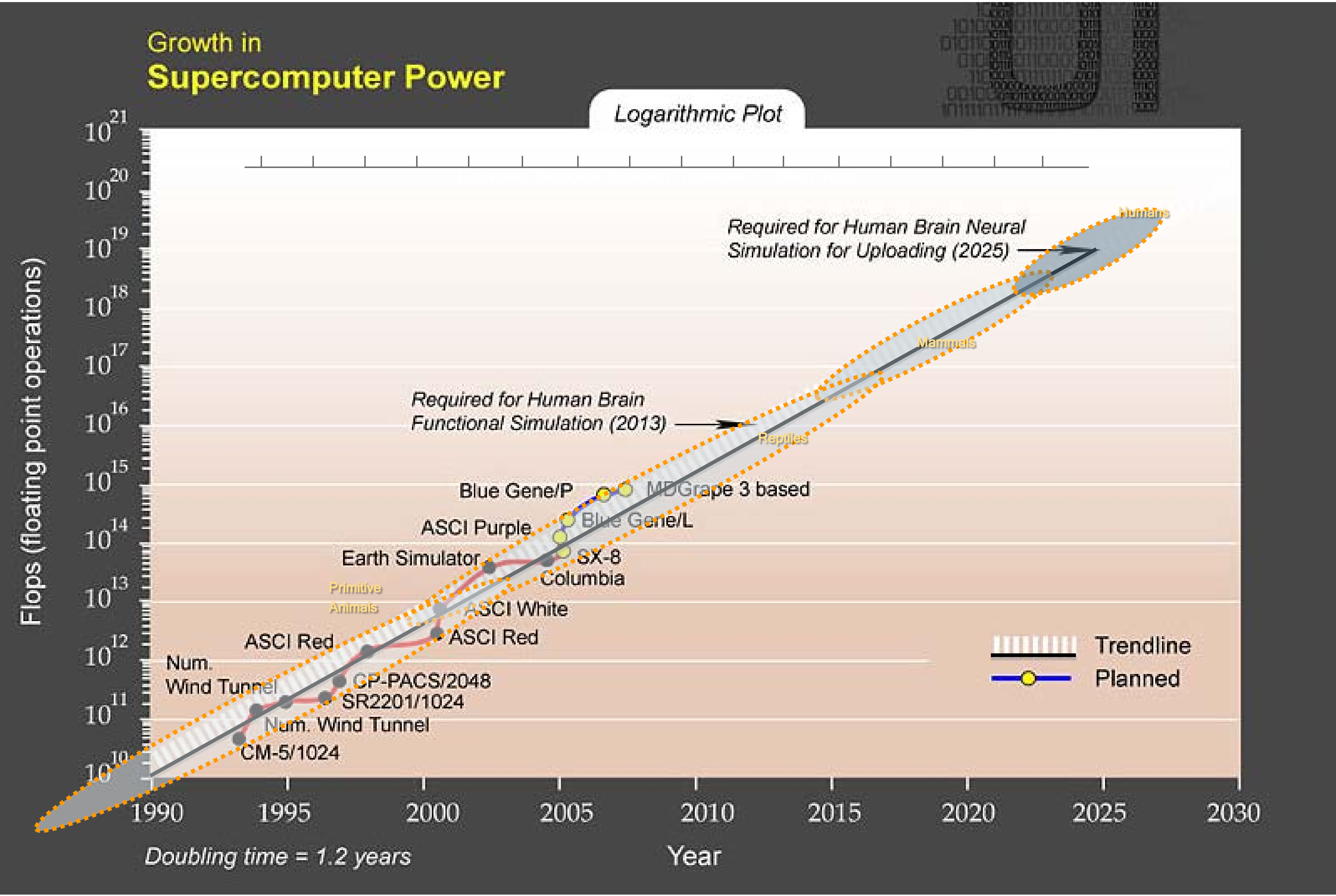
Strategic Development Office



Exploration Domain Evolution



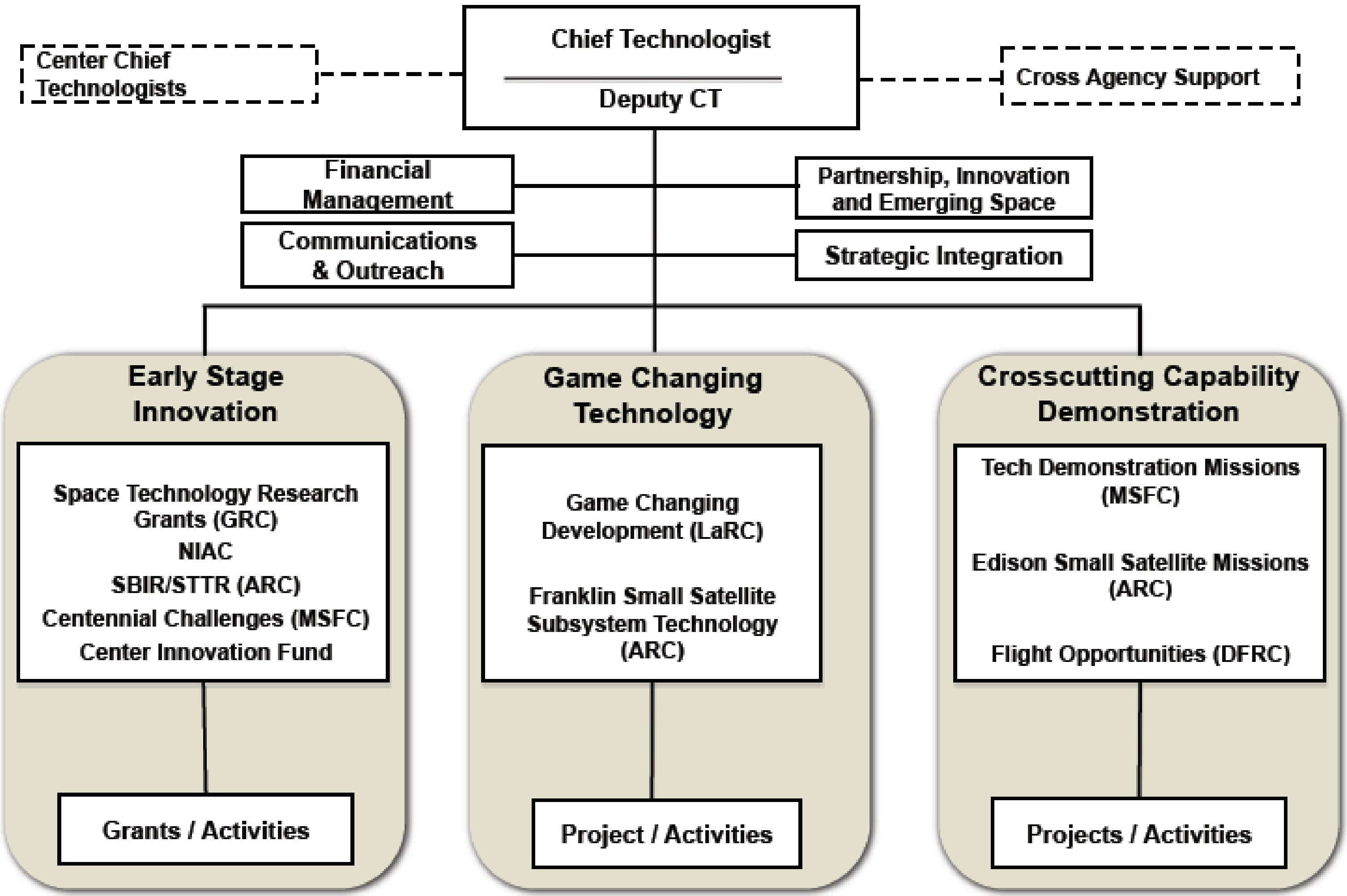

Current
Cryo Storage and Transfer
In-Situ Resources
Aero Braking/EDL
Advanced Propulsion
Nano Materials/Structures
Advanced Avionics / AI
Mars Mission Mass / Cost
Technology



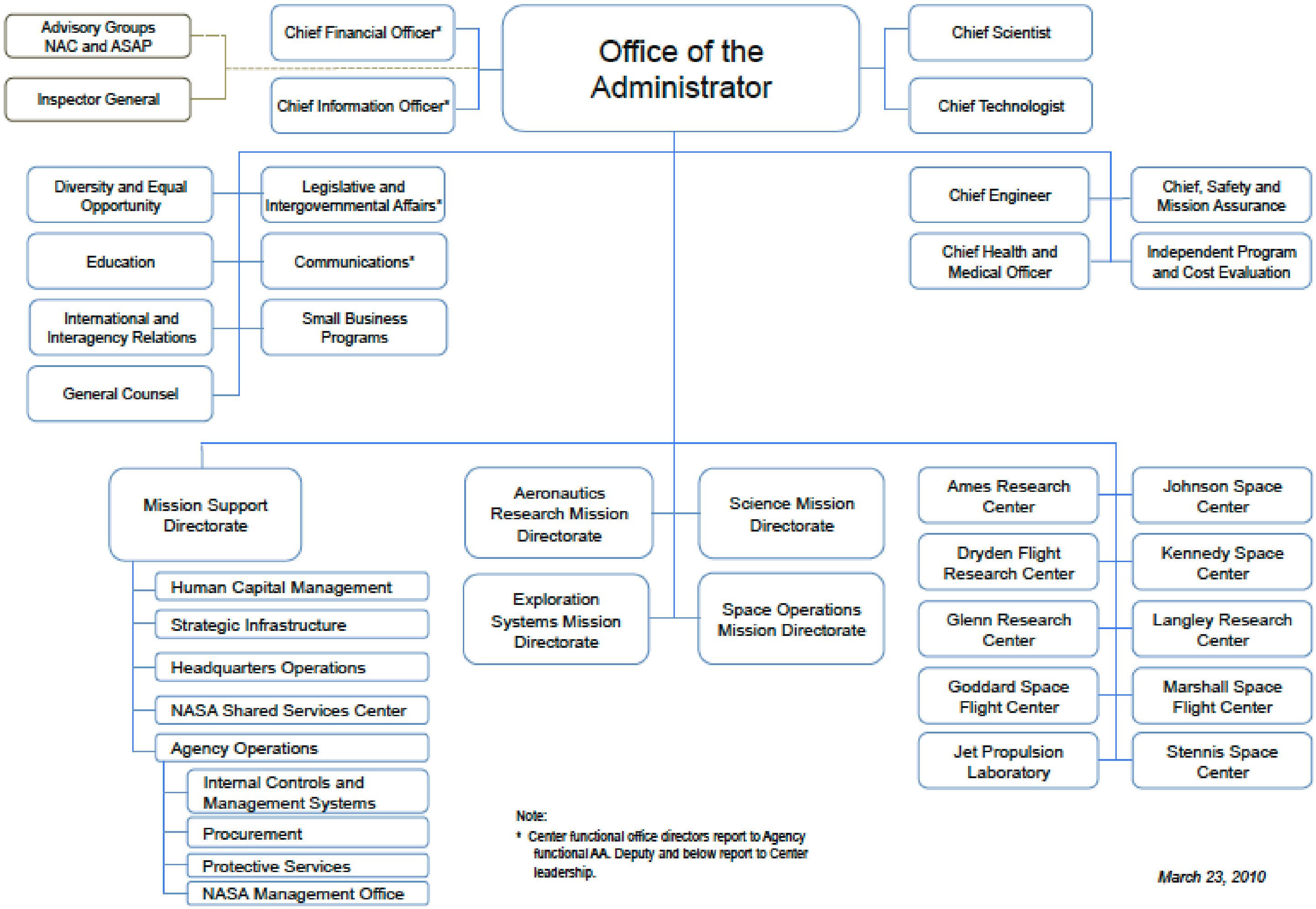
Growth in
Supercomputer Power
Logarithmic Plot
Flops (floating point operations)
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Required for Human Brain Neural Simulation for Uploading (2025)
Humans
Mammals
Required for Human Brain Functional Simulation (2013)
Reptiles
Blue Gene/P
MDGrape 3 based
Blue Gene/L
ASCI Purple
Earth Simulator
SX-8
Columbia
Primitive Animals
ASCI White
ASCI Red
ASCI Red
Num. Wind Tunnel
CP-PACS/2048
SR2201/1024
Num. Wind Tunnel
CM-5/1024
Trendline
Planned
1990
1995
2000
2005
2010
2015
2020
2025
2030
Doubling time = 1.2 years
Year

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center


Chief Technologist
Deputy CT
Center Chief Technologists
Cross Agency Support
Financial Management
Communications & Outreach
Partnership, Innovation and Emerging Space
Strategic Integration
Early Stage Innovation
Space Technology Research Grants (GRC)
NIAC
SBIR/STTR (ARC)
Centennial Challenges (MSFC)
Center Innovation Fund
Grants / Activities
Game Changing Technology
Game Changing Development (LaRC)
Franklin Small Satellite Subsystem Technology (ARC)
Project / Activities
Crosscutting Capability Demonstration
Tech Demonstration Missions (MSFC)
Edison Small Satellite Missions (ARC)
Flight Opportunities (DFRC)
Projects / Activities

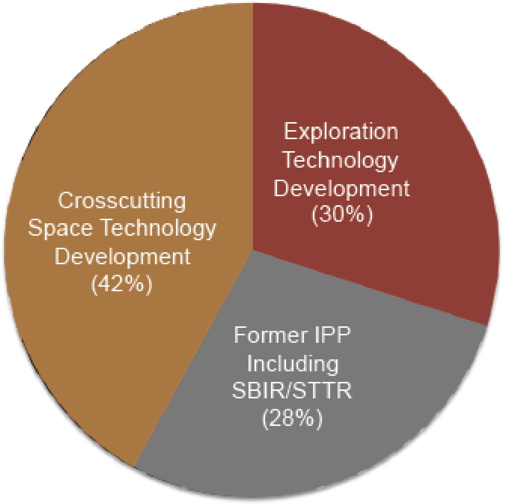
National Aeronautics and Space Administration



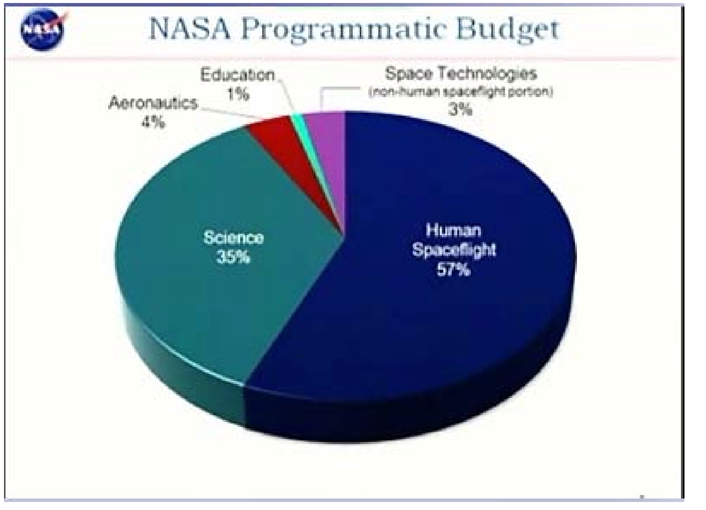
Note:
* Center functional office directors report to Agency functional AA. Deputy and below report to Center leadership.

March 23, 2010

Budget



NASA FY2012 Proposed Space Technology Budget ($1024M)



RV $ in Millions Full Cost	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
SPACE TECHNOLOGY Guideline Controls	**1,024.2**	**1,024.2**	**1,024.2**	**1,024.2**	**1,024.2**	**1,024.2**
Partnership Development and Strategic Integration PRA	33	33	33	33	33	33
SBIR/STTR PRA	184.1	184.1	184.1	184.1	184.1	184.1
Crosscutting Space Technology Development PRA	497.1	497.1	497.1	497.1	497.1	497.1
Space Technology Research (STRG)	45	55	60	60	60	60
NASA Innovative Advanced Concepts (NIAC)	6	9	9	12	12	12
Center Innovations Fund (CIF)	40	40	40	40	40	40
Centennial Challenges	10	10	10	10	10	10
Game Changing Development (GCD)	133	134	151	153.1	143.1	143.1
Franklin Small Satellite Subsystem Technologies	13	15	15	15	15	15
Technology Demonstration Missions (TDM)	211.1	192.1	165.1	160	170	170
Edison Small Satellite Demonstration Missions	22	25	30	30	30	30
Flight Opportunities	17	17	17	17	17	17
Exploration Technology Development PRA	310	310	310	310	310	310
Exploration specific Game Changing Development	191	167	140	145	185	185
Exploration specific Technology Demonstration Missions	119	143	170	165	125	125

Technology Development Areas

Tammy Gafka, James Smith, Omar Hatamleh
NASA/Johnson Space Center
Houston, Texas

Collaborations with Airbus (Toulouse, France / Hamburg, Germany)
April 2011

Composite Structures – Technology Needs

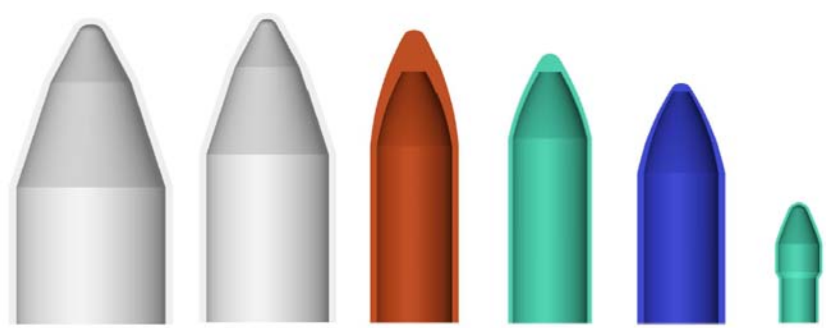
Technology Needs

- Large Composite Manufacturing
- Composite Damage Tolerance/Detection
- Light-weight Composite Joining
- COPVs/Composite Cryotanks
- Elevated Temperature Designs
- Multi-Functional Designs/Human Habitation (Certification Methods)

Composite Crew Module

Goals

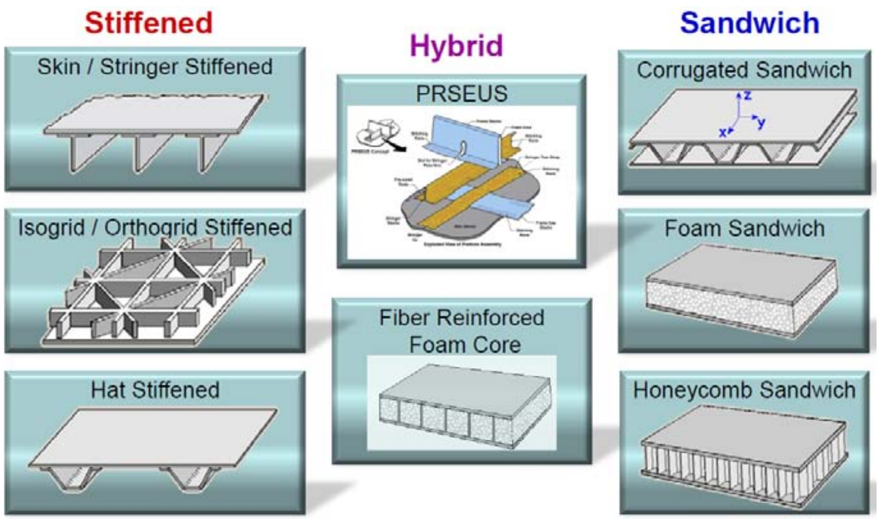
- 25-30% structural weight savings compared to metallics
- 20-25% cost savings compared to metallics
- Technical Maturity: consistent, predictable response



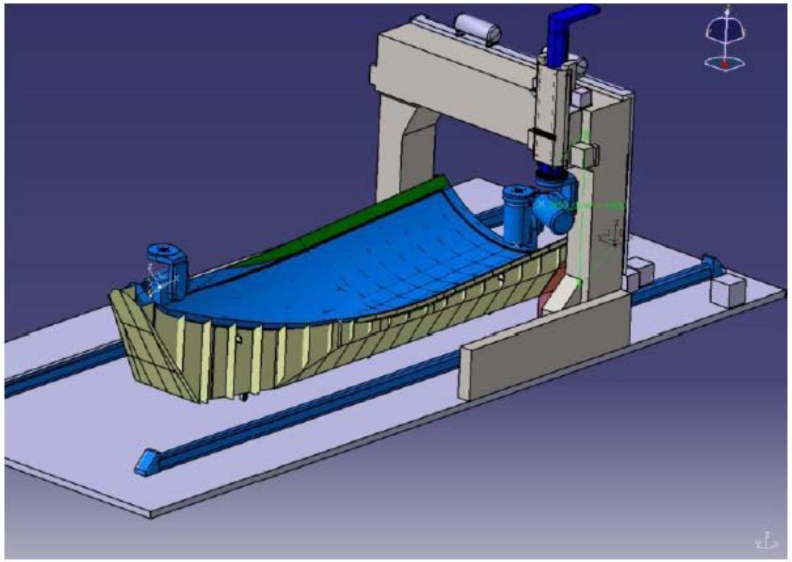
Vehicle	Ares V	Ares V	Atlas V	Delta IV	Ariane	Delta II
Dia	10 m	8.4 m	5.4 m	5.1 m	5.4 m	3 m
Area	~561 m²	~493 m²	~311 m²	~277 m²	~254 m²	~63 m²

Composite Structures – Large Structure Manufacturing

Structural Concepts



Automated Fabrication

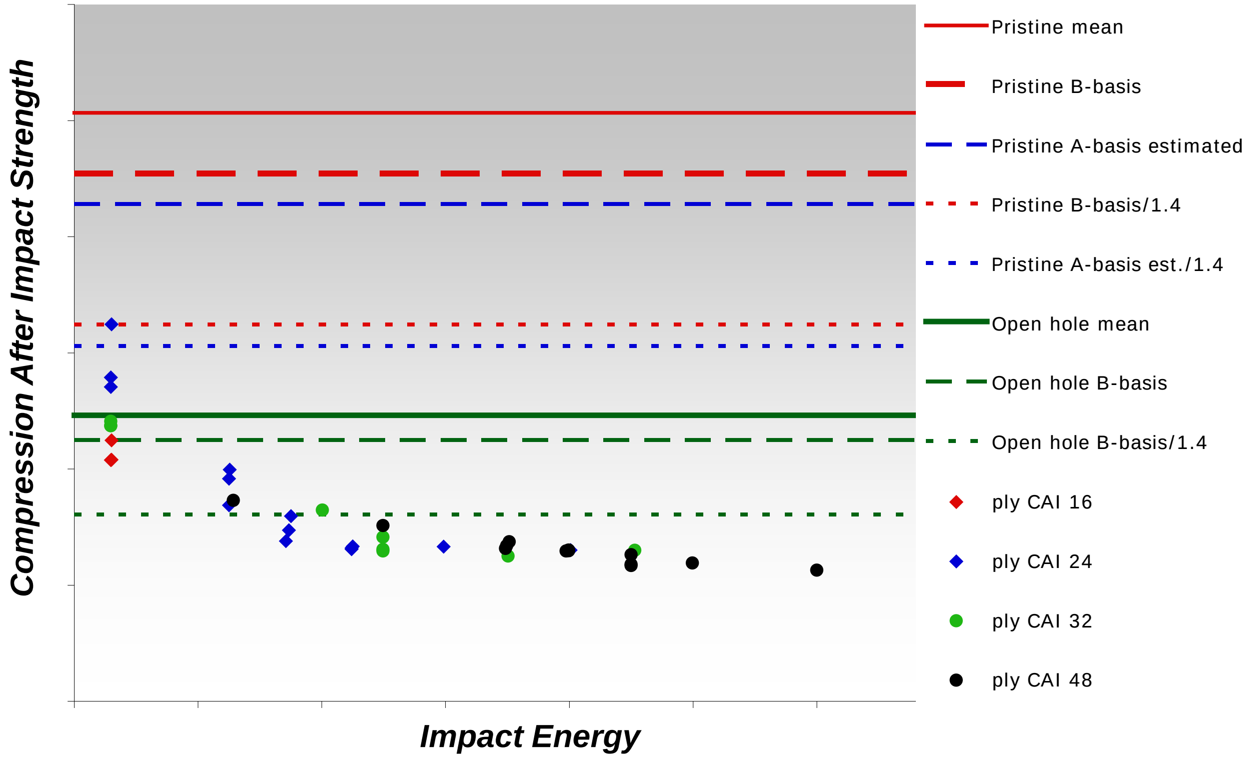


Out-of-Autoclave/ Out-Time Studies

Concept Out-Time					
Sandwich		Skin-Stringer		Fluted	
Process Step	Time (days)	Process Step	Time (days)	Process Step	Time (days)
Inner skin	12	Skin	12	Inner skin	12
Film adhesive	12	Film adhesive	12	Film adhesive	12
Debulk	4	Debulk	4	Debulk	4
Core	10	stringer charge	5	flute charge	7
Core splicing	5				
Core rework	2				
Film adhesive	3				
Outer skin	12			Outer skin	12
Final bag	8	Final bag	8	Final bag	8
Total	68	Total	41	Total	55
Allowable	40	Allowable	40	Allowable	40
Margin	-28	Margin	-1	Margin	-15

Composite Structures - Damage Tolerance

The Issue…



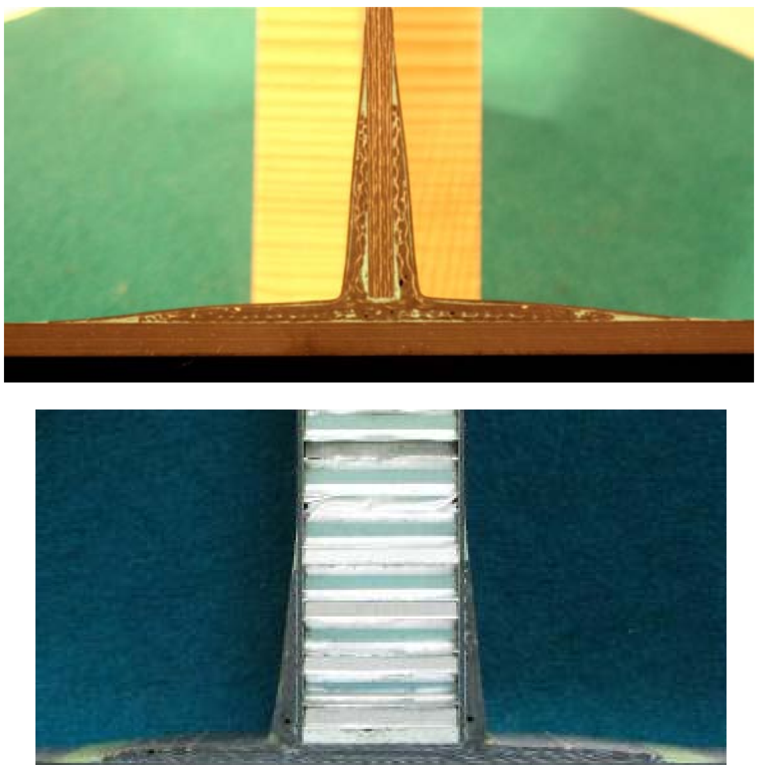
Mitigations Through Technology Development:

- Damage tolerant material systems
- Late-in-flow production NDE / IVHM to reduce “design-to” damage thresholds
- Novel ground-based protection mechanisms (e.g. shielding, impact-indication coatings…)
- Late-in-flow repair materials and techniques

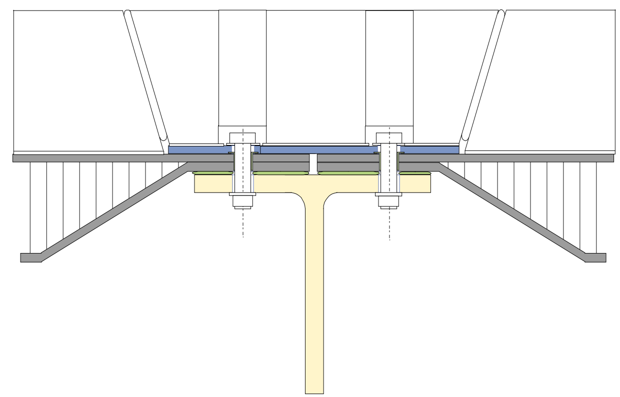
Composite Structures – Lightweight Composite Joining

Advanced joints that

- **efficiently transfer load**
- **limit permeabilty (for tanks and habs)**
- **are compatible with space environments**



Bonded Fabric Pre-Forms



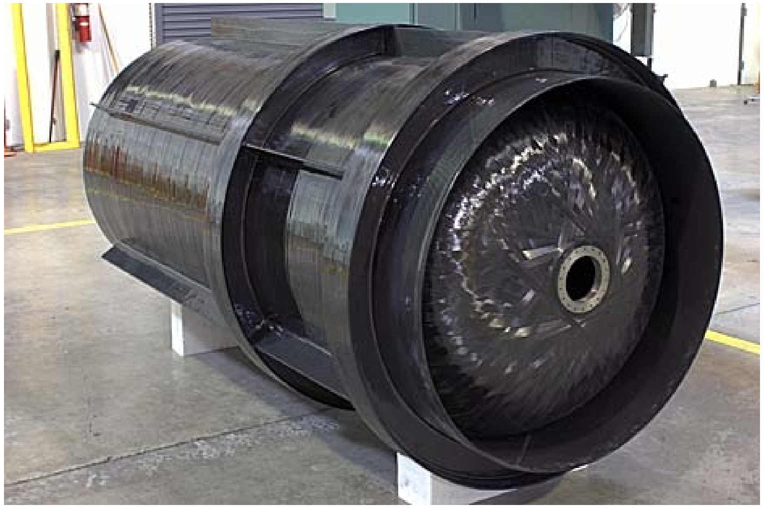
Fastening Systems

Composite Structures – Cryotanks

Technical Challenges

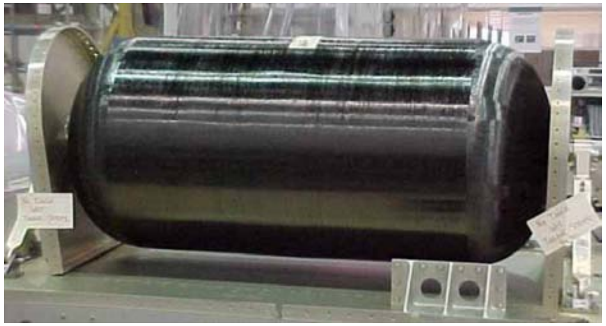
- Hydrogen Permeability
- Immature Out-of-Autoclave Material Systems
- Manufacturing and NDE Scale-Up
- Damage Tolerance
- Design Allowables at Representative Environments
- Integrated w/ Structural Elements
- Verification/Certification

X-34 Tank



Microcosm Tank

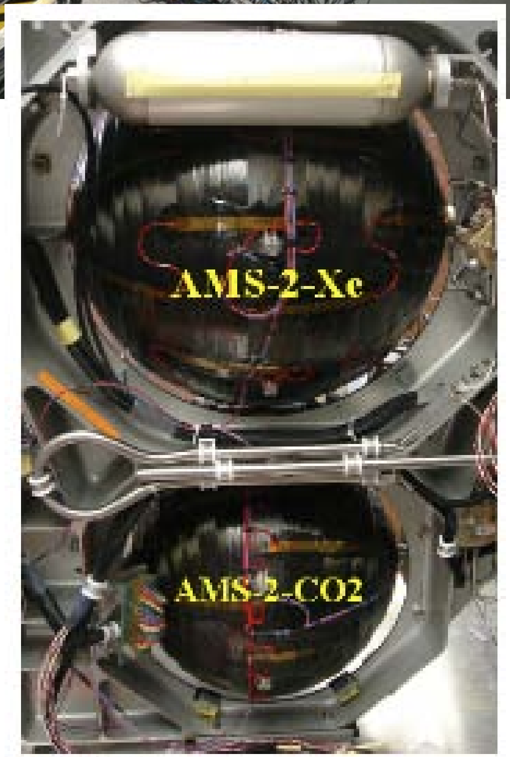
Composite Structures - COPV



ISS N2 Tank

SAFER Tank

Subscale Vessel Test Program



NASA photos

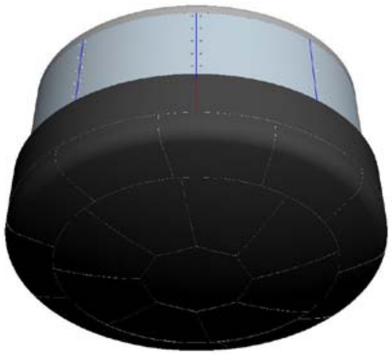
AMSTank

Composite Failure Concerns

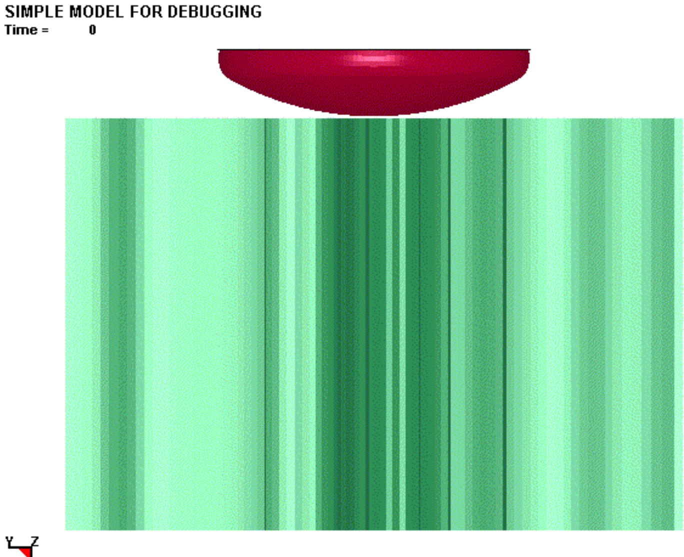
- Damage propagation from impacts
  Mitigated by Damage Control Plan
- Manufacturing variability
  Mitigated by qualification tests which include burst tests after thermal and pressure cycle tests
- Stress rupture (creep-like) failure
  Catastrophic failure after a given time at stress levels
  Mitigated by this proposed phased test approach

Composite Structures – High Temperature Systems

High temperature (500+ deg F) material systems (composites, core, adhesives) with controlled impact energy absorption needed for re-entry/landing vehicle heat shields



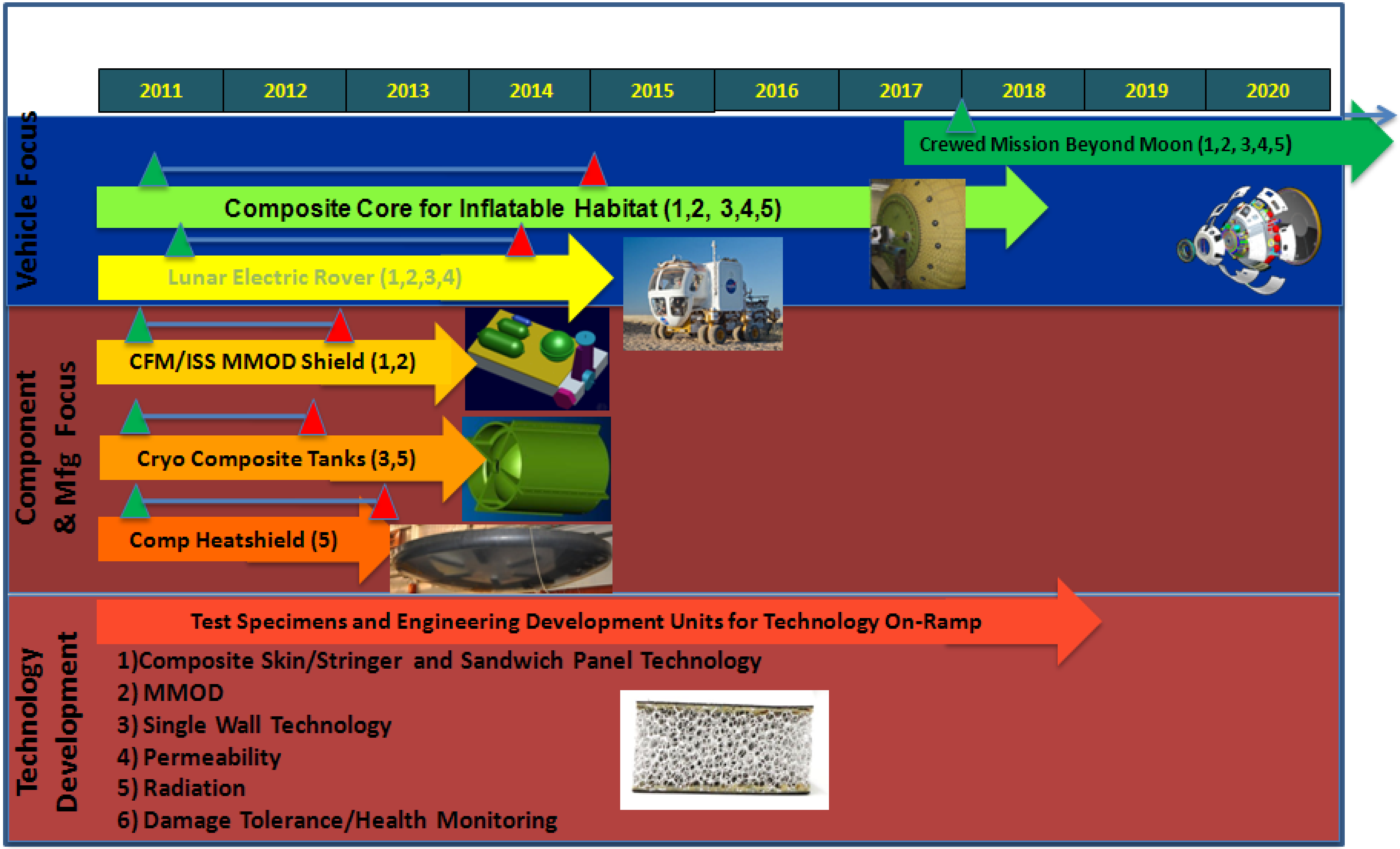
ISS Downmass Capsule



Orion Heatshield

Composite Structures - Multi-Functional Designs

JSC Composite Structure Roadmap

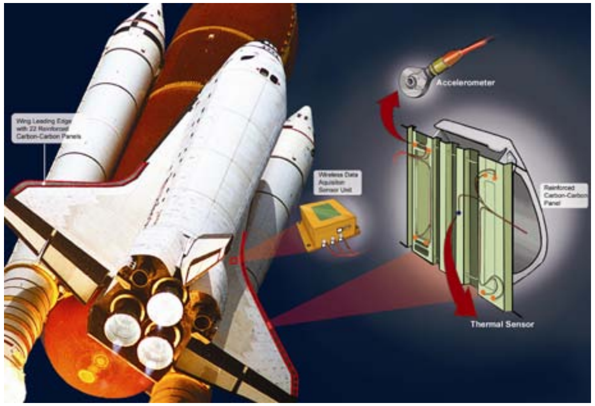


Non-Destructive Evaluation/Structural Health Monitoring

To enable long duration space flight, vehicle risk mitigation requires on-orbit ability to first, protect, then…

- **detect**
- **inspect**
- **repair**

…an anomalous structure/mechanism



Candidate technologies needed for on-orbit inspection of manned systems:

1. Visual Cameras with Illuminators
2. Laser-Based Systems: next generation of the systems used on Orbiter including 3D borescopes
3. Micro-Wave SAF Video Imagers
4. Time-Domain Terahertz Computed Axial Tomography Line Scanner
5. X-ray Back-Scatter
   - Backshell TPS and structure inspection at suspect MMOD impact sites
6. Hit Grid Imbedded in the RTV Bond Layer
   - Damage to this layer recorded mechanically
7. Acoustic Emission Detection from Back Side of Substrate.
   - Impact sensing to the panel level
   - Damage sensing: impact to face sheet(s) or not
8. Charge Time of Arrival
   - Impact and location based on conducted emission

Some of these NDE technologies are also applicable to ground processing

Applied Nanotechnology

Advanced Life Support
- Regenerable CO_2 Removal
- Water recovery

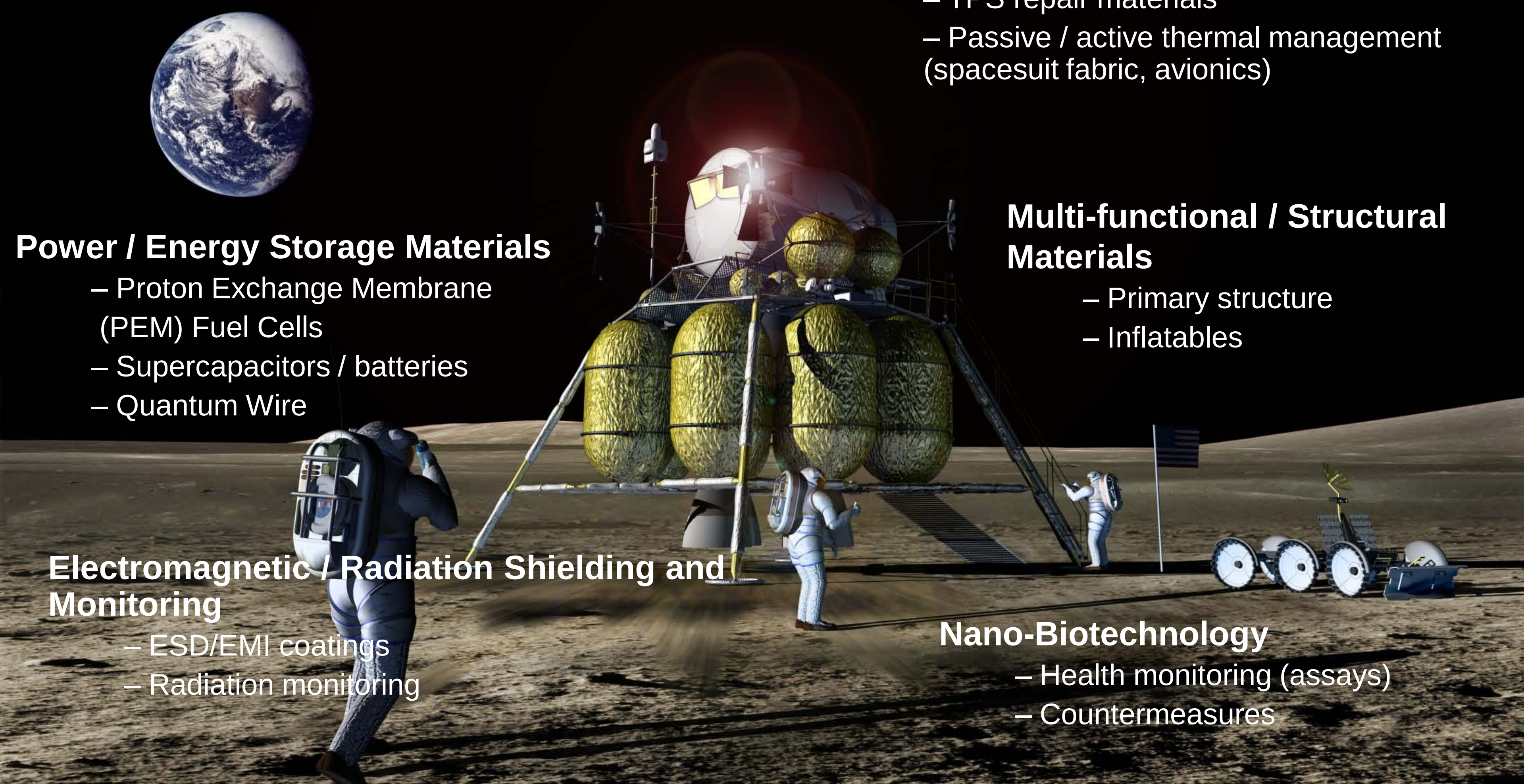
Thermal Protection and Management
- Ablators and ceramic nanofibers
- TPS repair materials
- Passive / active thermal management (spacesuit fabric, avionics)

Power / Energy Storage Materials
- Proton Exchange Membrane (PEM) Fuel Cells
- Supercapacitors / batteries
- Quantum Wire

Multi-functional / Structural Materials
- Primary structure
- Inflatables

Electromagnetic / Radiation Shielding and Monitoring
- ESD/EMI coatings
- Radiation monitoring

Nano-Biotechnology
- Health monitoring (assays)
- Countermeasures



Nanotechnology

The Nanotechnology Group's Current Projects:

- Self healing multifunctional Composites
- Gas Absorption: MOF Nanomaterials
- Solar Cells – Band Gap Engineered High Efficiency Solar Cells
- Aluminum/Nanocomposite Materials – Aluminum having the strength of steel yet the weight of aluminum.

Our Main Focus Areas:

Energy: this area includes energy storage, energy generation, and energy systems

Environmental Control and Life Support Systems: This area is primarily the systems required to ensure the astronauts health and survivability. It includes air systems, temperature control, food, waste, humidity control, space suites, life support systems, radiation protection, etc.

Nanomaterials: This includes nanocomposites, Improved damage tolerance, structural health monitoring, self repair materials, multifunctional materials, lightning strike protection, coatings, and textiles/fabrics, seals, thermal materials

Life Sciences (nano-biotechnology): crew health, nanomedicine

Possible Areas of Collaboration:

Nanocomposites: Nanotechnology offers self healing capabilities, lightning strike protection (multifunctional capabilities), and high structural strength.

Gas/Energy Storage: We have interest in hydrogen, carbon dioxide, methane, and oxygen gas storage. This has applications for fuel storage for long duration space missions and terrestrial applications for sustainability efforts.

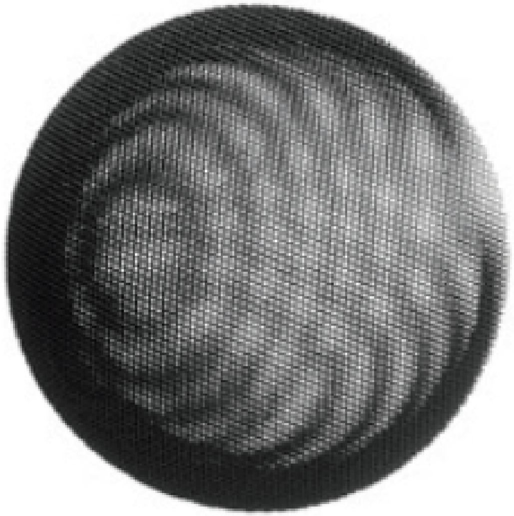
Other Energy Storage: We also have interest in ultra capacitors, fly wheels and batteries.

Energy Generation: Our interests include solar cells, fuel cells, piezoelectrics, and thermoelectric.

Gas Separation: We are interested in areas to more efficiently separate gases for applications such as bioreactors.

Additive Manufacturing

- Definition
  - ASTM F42: "process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies"
  - Born out of rapid prototyping
  - "Add instead of subtract"
- Why?
  - Put material where you want it
  - Waste less material on chips
  - Make complex geometry
  - Reduce part count
  - Gradient materials
  - "On-demand" from model



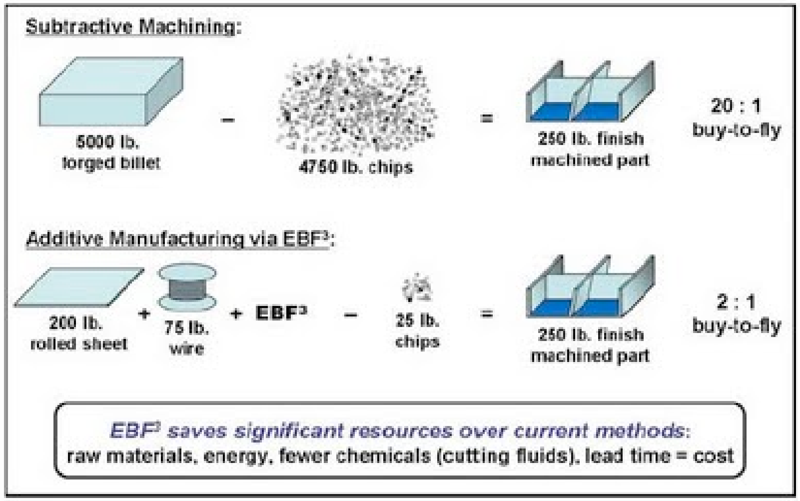
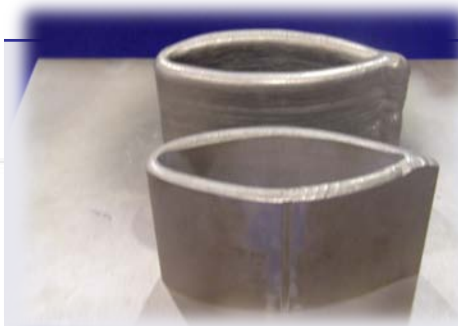


Figure 1. Comparison of traditional machining versus additive manufacturing.

Selected NASA Additive Systems

Laser Engineered Net Shaping (LENS)	Electron Beam Free Form Fabrication (EBF3)	Selective Laser Melting (SLM)	Electron Beam Melting (EBM)
JSC	LaRC	LaRC	MSFC
-Laser -Gas-delivered powder -0.010” -Ti, Steel, Inconel	-Electron Beam -Wire -0.125” -Al, Ti, Steel, Inconel	- Laser -Power bed -0.005” -Al, Ti, Steel, etc.	-Electron beam -Powder bed -0.005” -Al, Ti, Steel, Inconel, etc.


Novel structures created by LENS



14

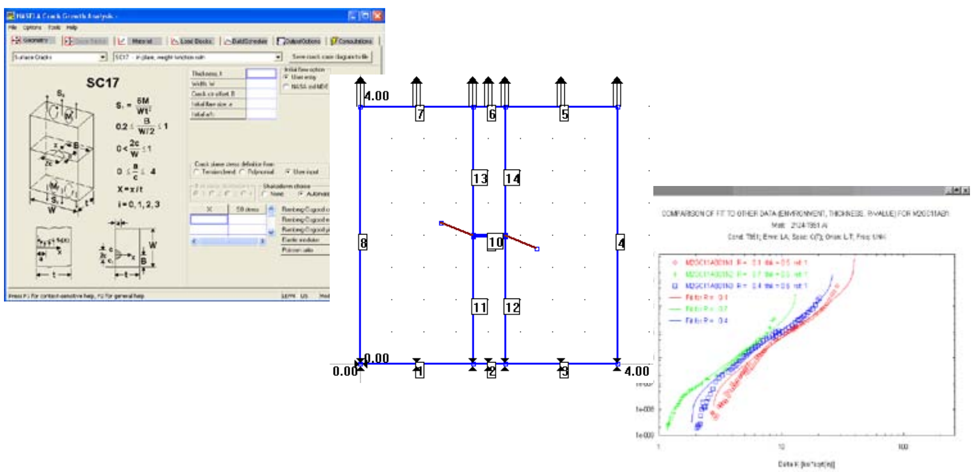
Fracture/Fatigue Analytical Methods

Fracture Mechanics & Fatigue Crack Growth Analysis Software

www.nasgro.swri.org

Integrated modules with user-friendly graphical interfaces:

- Calculate FCG life, critical crack size, or stress intensity factors
- Store, retrieve, and curve-fit FCG and fracture toughness data
- 2-D boundary element program to calculate SIFs and stresses



Consortium Partners

Airbus
Hamilton Sundstrand
Siemens Power Generation
AgustaWestland
Honeywell
Sikorsky
Boeing
Israel Aerospace Industries
Spirit AeroSystems
Bombardier Aerospace
Lockheed Martin
Volvo Aero
Embraer
Mitsubishi Heavy Industries

New Development Focuses

- Include Mode II and III fracture modes (currently only Mode I)
- Fracture/fatigue models in support of damage tolerance for composites

Structural Analysis Capabilities Within NASA/JSC

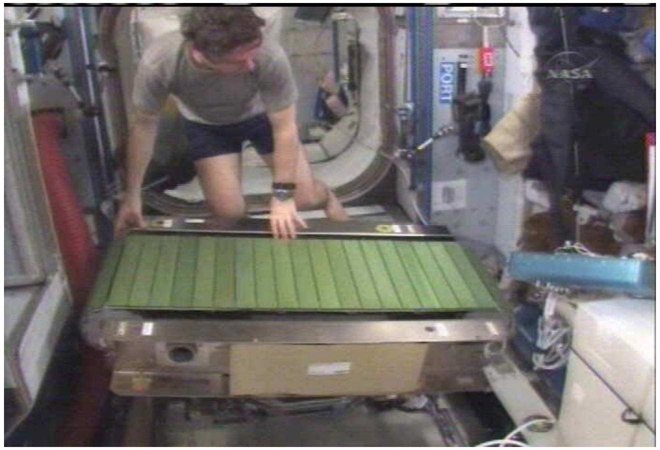
James P. Smith, Ph.D.
NASA/JSC/ES2
James.P.Smith@nasa.gov

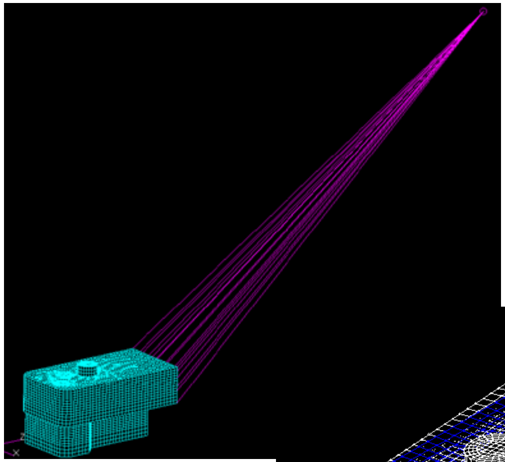
Software Programs

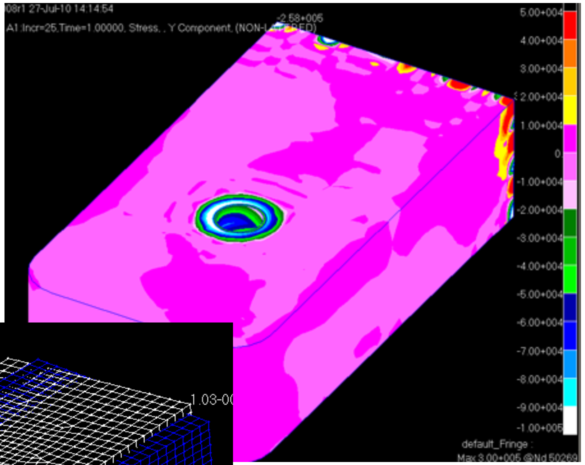
- NASA/JSC has access to a number of analysis programs for a wide area of analysis
  - Structural design (Pro/Engineer)
  - Pre/post-processors (MSC/PATRAN, I-DEAS)
  - Structural dynamics (MSC/NASTRAN, LS-Dyna, ADAMS, in-house codes for multi-body contact dynamics (flex and/or rigid), in-house codes for coupled loads analysis and modal characterization from service data, AutoSEA)
    - Coupled loads analysis
    - Berthing contact analysis
    - Aeroelastic analysis
    - Random vibration
  - Structural analysis (MSC/NASTRAN, Abaqus, Ansys, I-DEAS, StressCheck)
    - Material yielding
    - Stability analysis
    - Hardware verification
    - Optimization

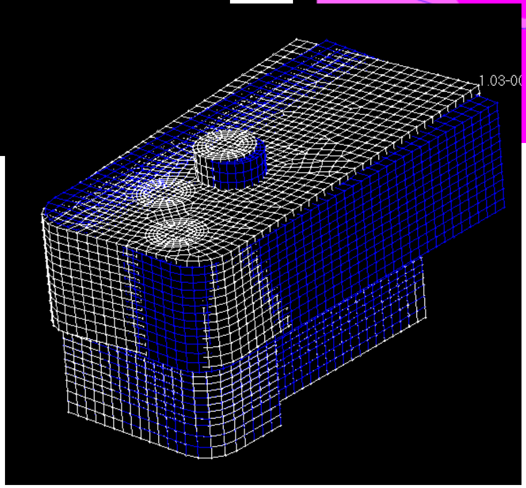
Treadmill-2/COLBERT Anomaly

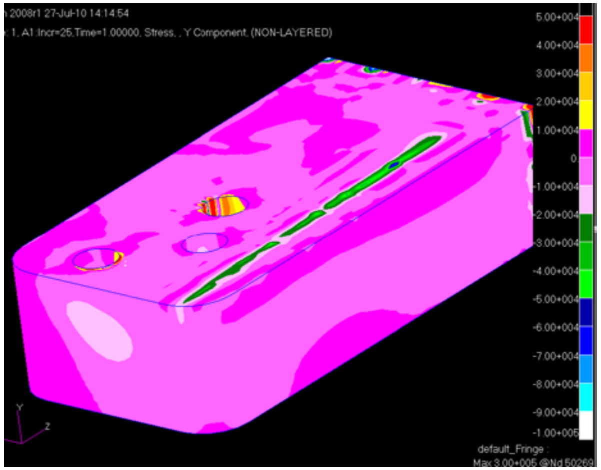
- Mis-use by the ISS crew of the COLBERT system caused a suspect condition of the structural integrity of the downstream joint
- Nonlinear material, geometric, and contact analysis performed to assess if there was reserve capacity in the bracket attach hardware





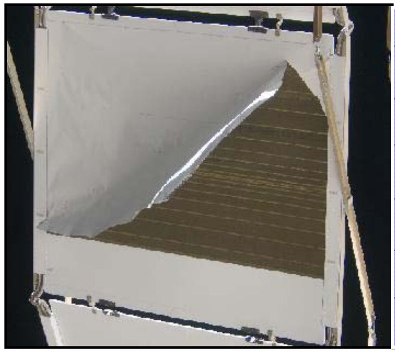


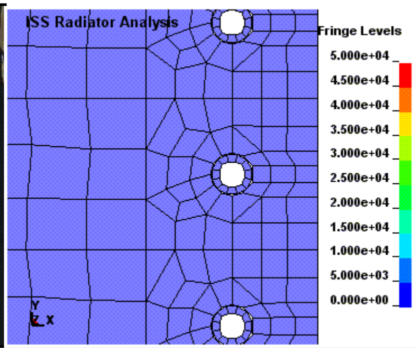


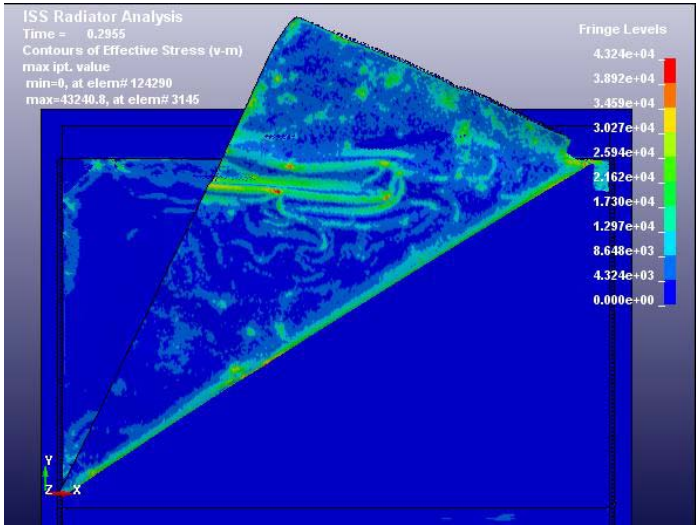


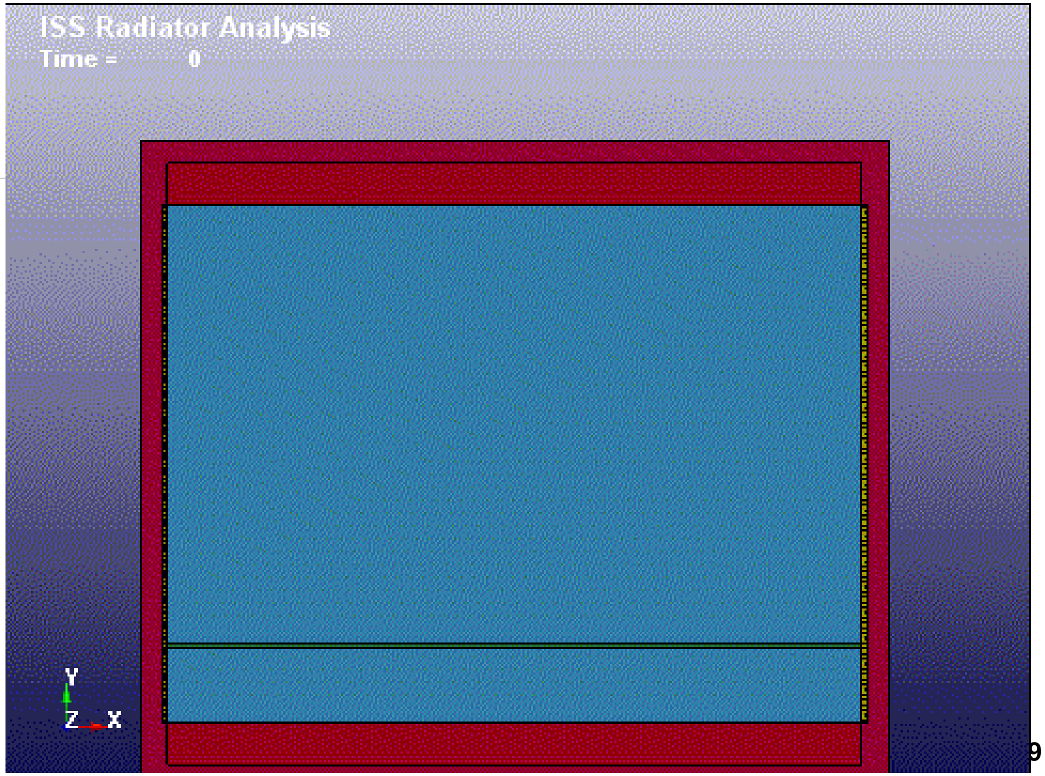
ISS Radiator Anomaly

- An anomaly occurred on ISS where a radiator panel sheet separated from the support structure
- The root-cause analysis utilized LS-Dyna to recreate the problem using fully nonlinear behavior, including tearing



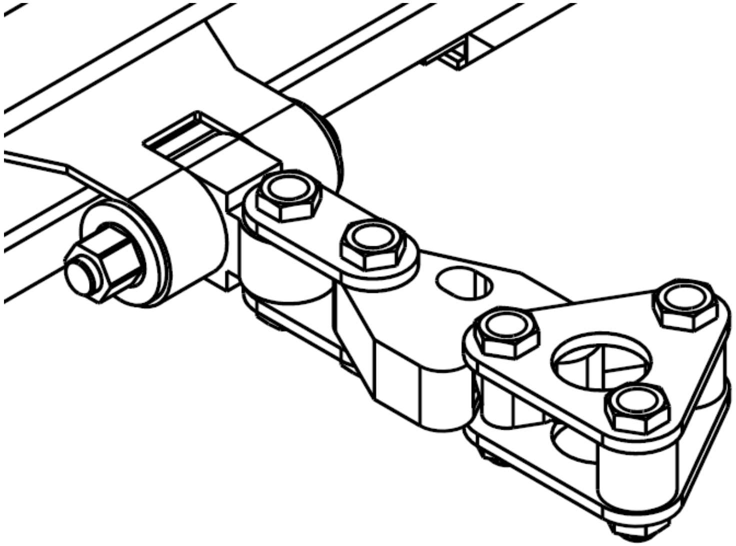






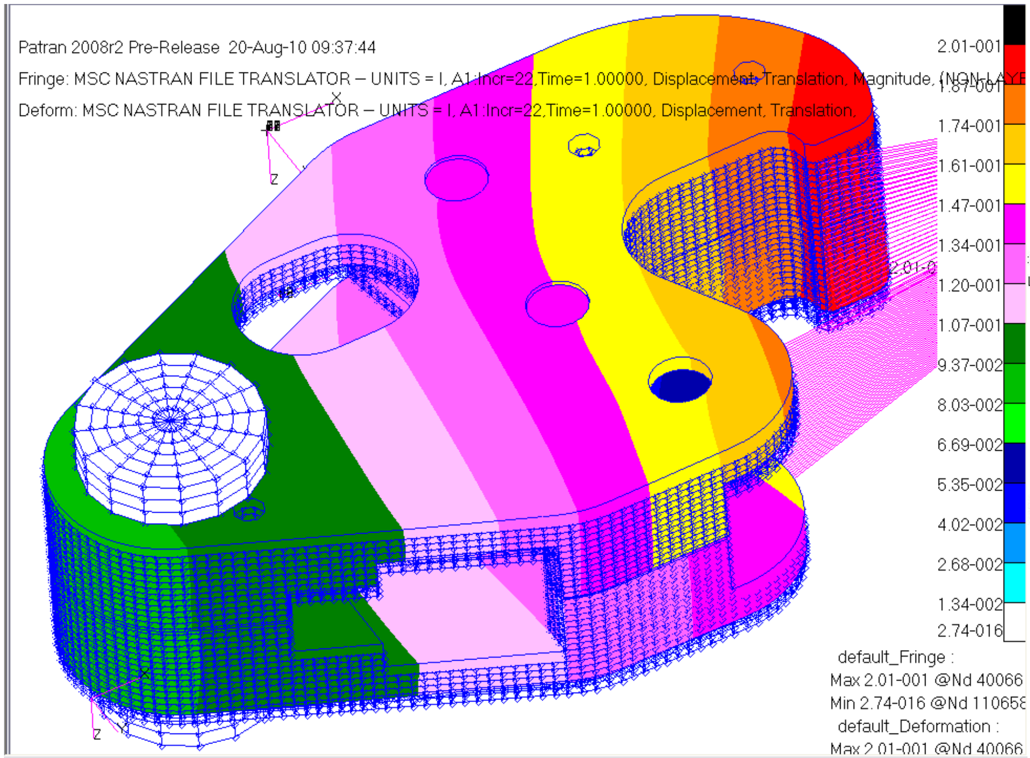
Extraction Force Transfer Coupling Failure

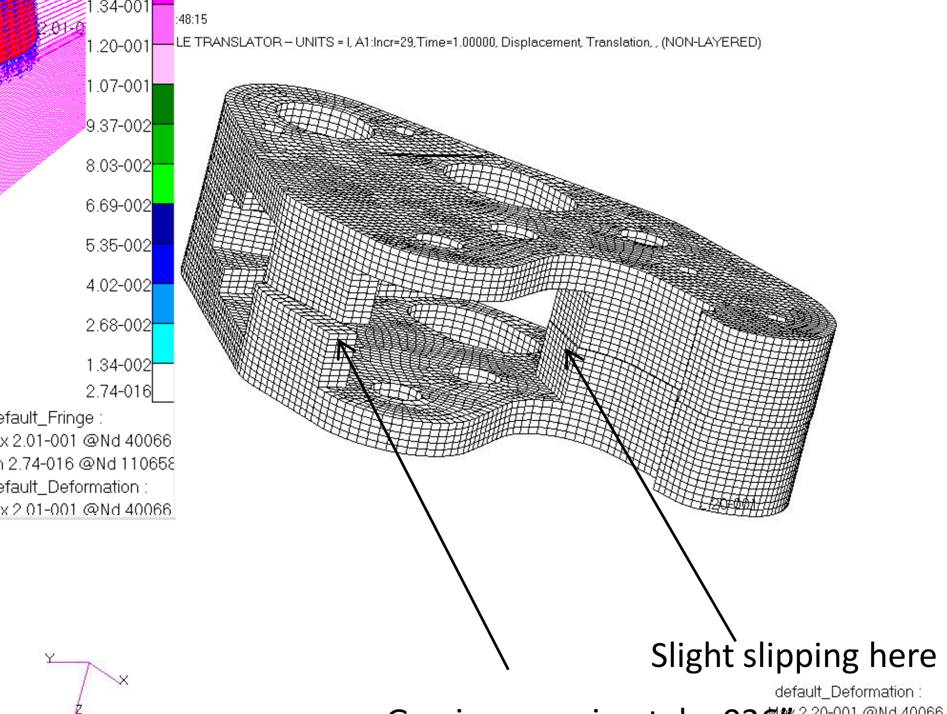
- In support of the Orion program, a drop test was performed. During the test, a coupling system intended to pull a chute did not separate. A combination of analysis and testing was performed to determine the root cause.
- Contact analysis performed to determine the loads going through bolts holding the halves together and to determine if excessive displacements are a source of binding.
- Flight failure shows evidence of plastic deformation in one of the fasteners



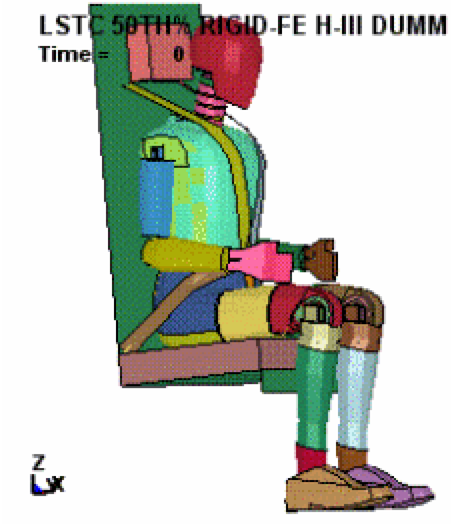
Extraction Force Transfer Coupling Failure

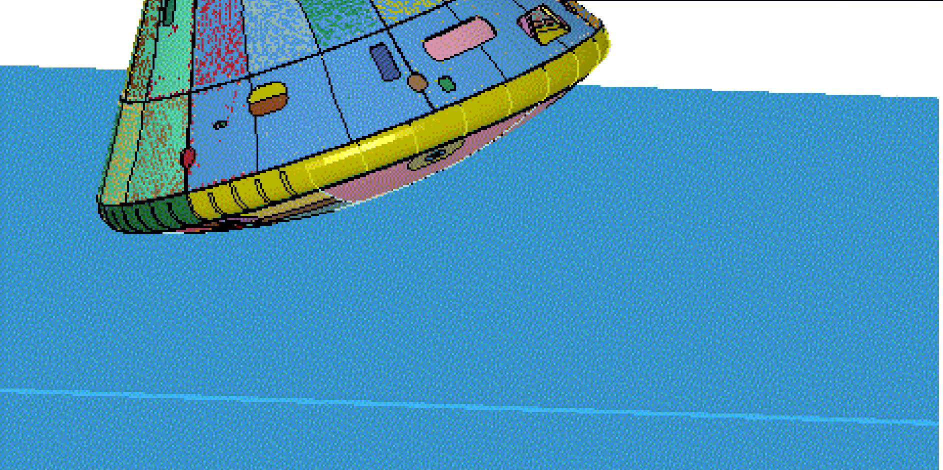
- Externally applied loads with multi-body contact between finite element models



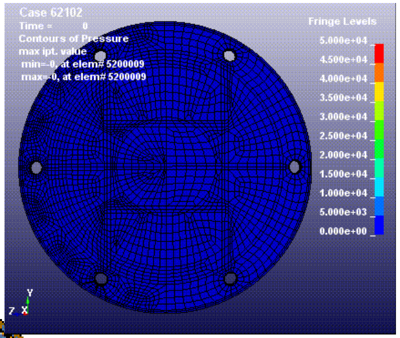


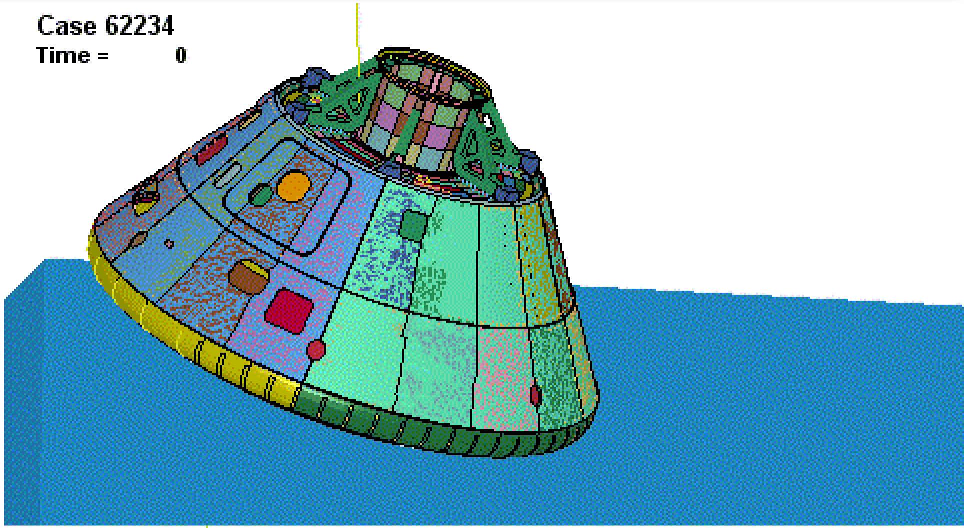
Orion Support - CM Splashdowns

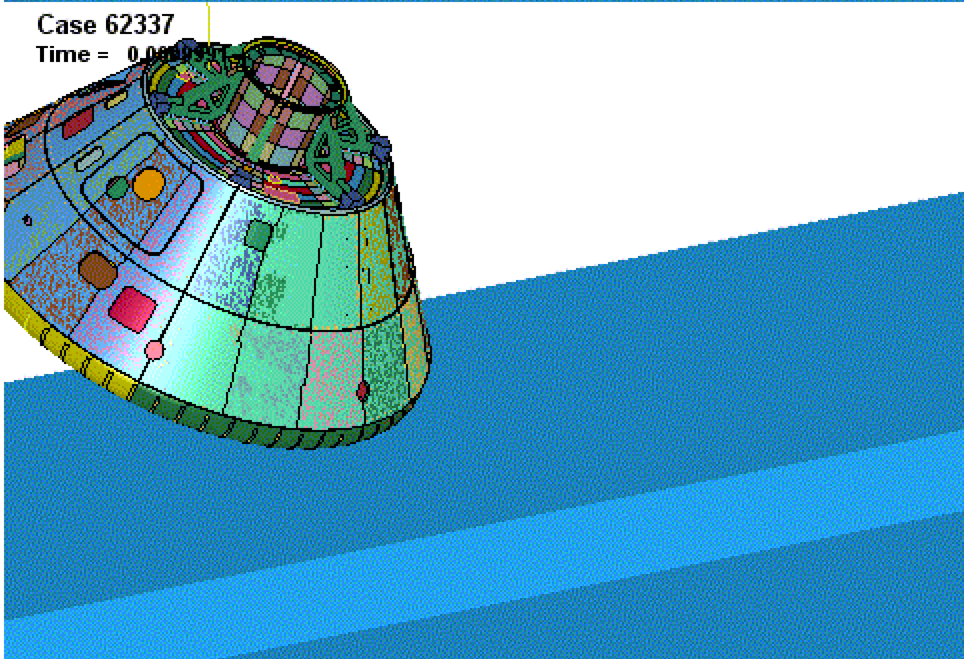




HS Stress







TO VIEW ANIMATIONS, POWERPOINT MUST BE IN FULL SCREEN "SLIDE SHOW" MODE

Friction Stir Welding and Laser Peening

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Friction Stir Welding

- Friction Stir Welding (FSW) is a solid-state metal joining process producing high-strength, defect-free joints in metallic materials. The process employs a pin tool with a low rotational speed and applied pressure that "mechanically stirs" two parent materials together to produce a uniform weld.
- The process employs a pin tool with a low rotational speed and applied pressure that "mechanically stirs" two parent materials together to produce a uniform weld.

National Center for Advanced Manufacturing

- Partnership between NASA, the State of Louisiana, and the University of New Orleans
- NCAM combines education, research, and manufacturing to provide leadership in technology.
- Located in New Orleans, Louisiana at NASA's Michoud Assembly Facility (MAF), which is managed by Marshall Space Flight Center in Huntsville, Alabama
- NCAM has three machines for FSW called the Universal Weld Systems or UWS 1-3, in the order in which they were installed.

Source: http://www.ncamlp.org/about/about.html

FSW at JSC

- JSC equipment includes an MTS FSW Process Development System (PDS)
- The PDS is a fully instrumented research system that is capable of simultaneous force-controlled operation of three independent axes (X, Z, Pin)
- The PDS can do research work and process development for the larger MTS systems at the Michoud Assembly Facility which use the same weld head

Source: http://www.mts.com/en/TechnologyShowcase/FSW/Intelligent/index.asp

NCAM UWS#1 & UWS #2

Capacity

- 16 ft. x 21.5 ft. x 10 ft. of linear motion
- 2 axis of gimbal motion of the weld head
- 30 ft. rotary table with one rotational degree of freedom

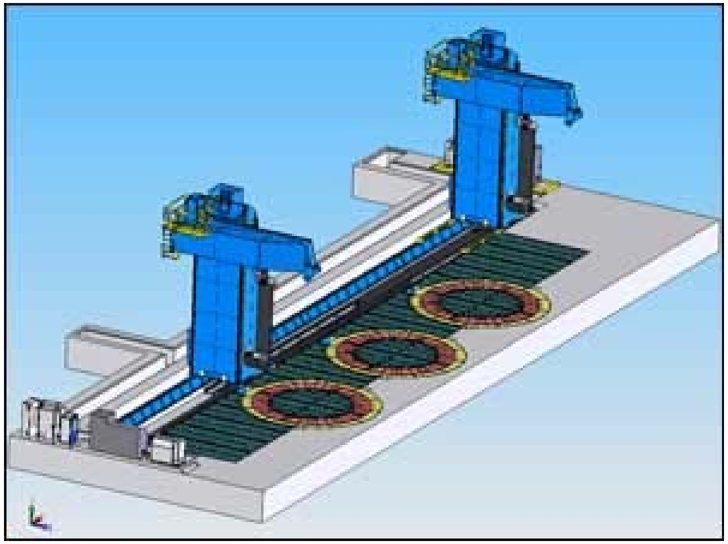
http://www.ncamlp.org/technology/fsw-UWS1.html

Capacity

- 40 ft. 10 in. X-Axis x 22 ft. 8 in. Y-Axis x 12 ft. 2 in. Z-Axis of linear motion
- 2 axis of gimbal motion of the weld head
- 22 ft. rotary table with one rotational degree of freedom
- 40 ft. x 20 ft. flat weld area with T-slots

http://www.ncamlp.org/technology/fsw-UWS2.html

NCAM UWS #3



- MTS Robotic Weld Tool (RWT)
- 6-axis integrated weld system
- Capable of fixed pin / retractable pin / self reacting Friction Stir Welds
- Combined axis of motion allows for complex curvature welding
- Control system provides coordinated motion for all 7 axes of the UWS3One of the largest, most advanced FSW machines in the world
- Floor level turntables

Source: http://www.ncamlp.org/technology/fsw-UWS3.html

NCAM UWS#3

Capacity

- **2 axis of gimbal motion of the weld head; pitch: +5° to -95°, roll: ±15°**
- **Three 20 ft. annular ring rotary tables, each with one rotational degree of freedom**
- **20 ft. outer diameter, 15 ft. inner diameter annular turntables with unlimited rotary motion and locking capability**
- **Two columns, each with an independently operated weld head**
- **7 degrees-of-freedom (DOF) delivered through 5 physical axes**
-

X-axis	Y-axis	Z-axis
93 ft. Each weld machine	22 ft. 5 in. Each weld machine	12 ft. Each weld machine
Note: UWS3 has 2 weld machines that share a common X-rail. Each weld head can access any of the 3 turntables.		

Source: http://www.ncamlp.org/technology/fsw-UWS3.html