Printed Electronic Devices in Human Spaceflight

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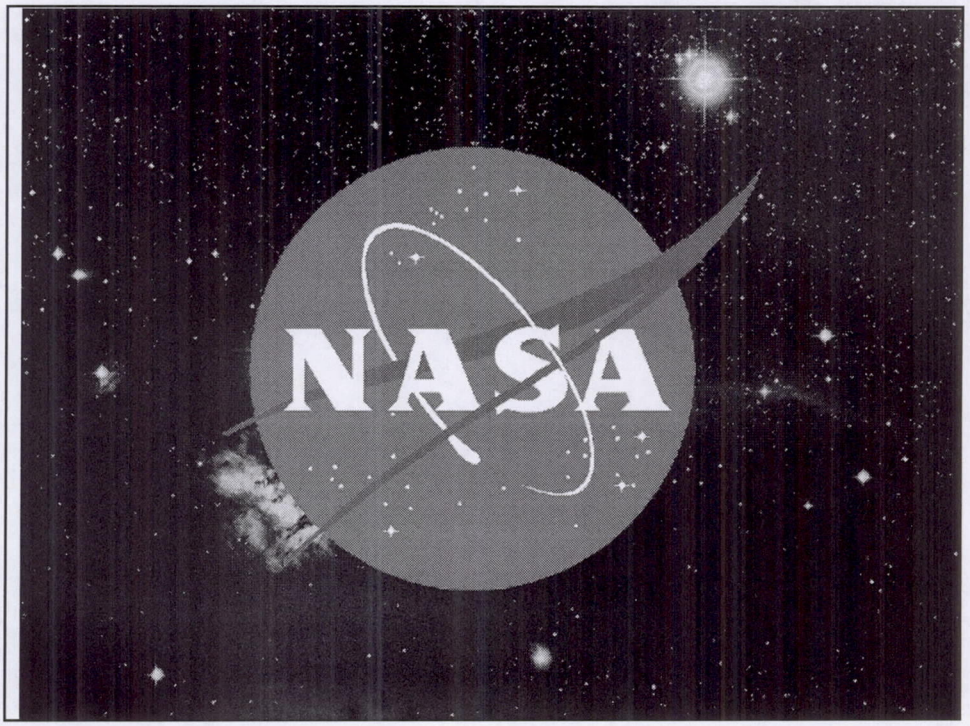
(Presentation to IDTech EX Printed Electronics 2004 Industry Conference,
Ritz Carlton Hotel, New Orleans)
Dec 6-8 2004

The space environment requires robust sensing, control, and automation, whether in support of human spaceflight or of robotic exploration. Spaceflight embodies the known extremes of temperature, radiation, shock, vibration, and static loads, and demands high reliability at the lowest possible mass. Because printed electronic circuits fulfill all these requirements, printed circuit technology and the exploration of space have been closely coupled throughout their short histories. In this presentation, we will explore the space (and space launch) environments as drivers of printed circuit design, a brief history of NASA's use of printed electronic circuits, and we will examine future requirements for such circuits in our continued exploration of space.



Printed Electronic Devices in Human Space Flight

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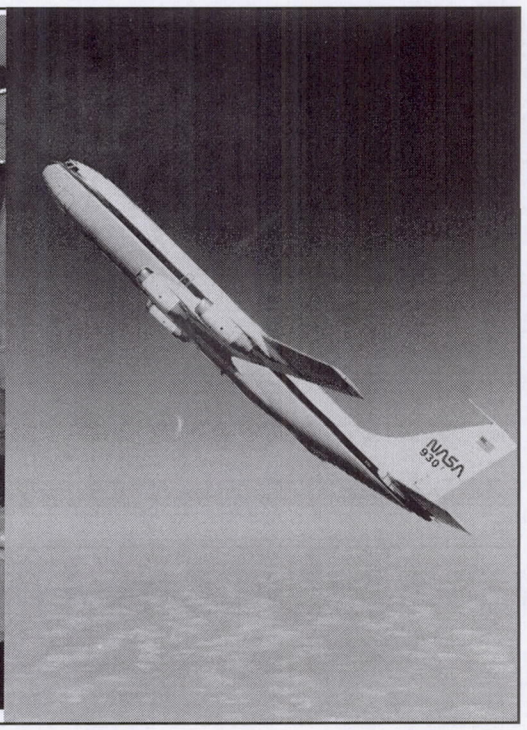
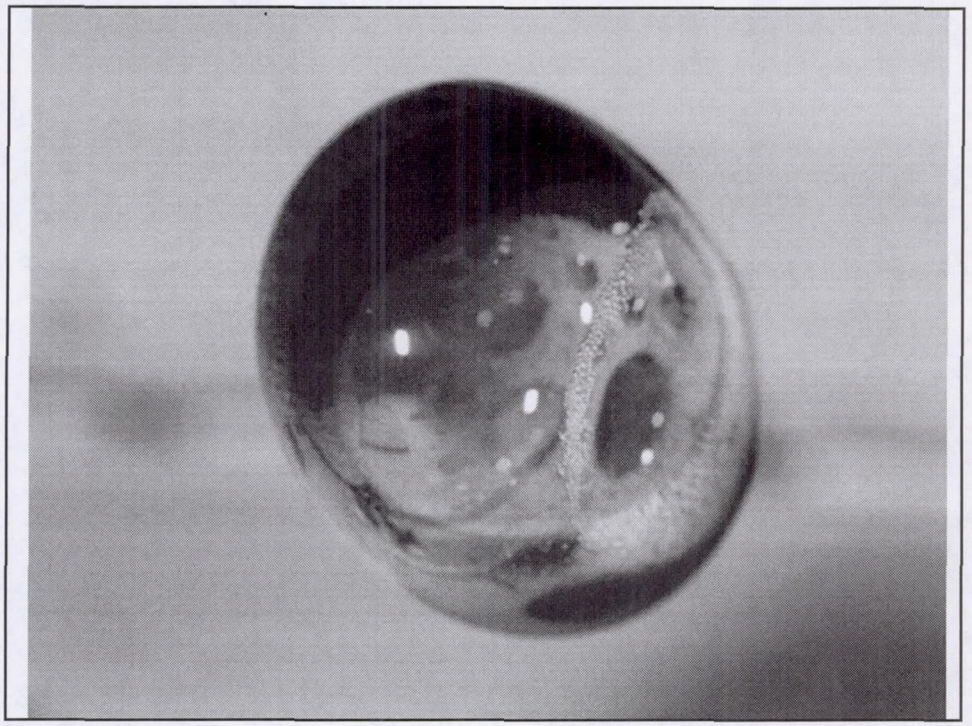
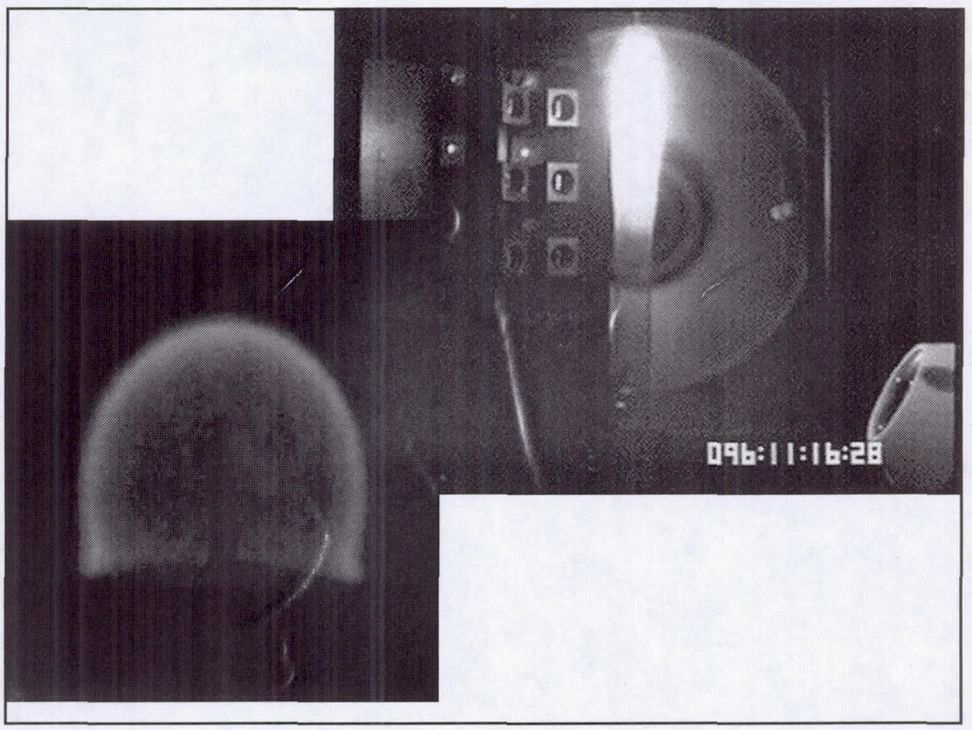
Agenda

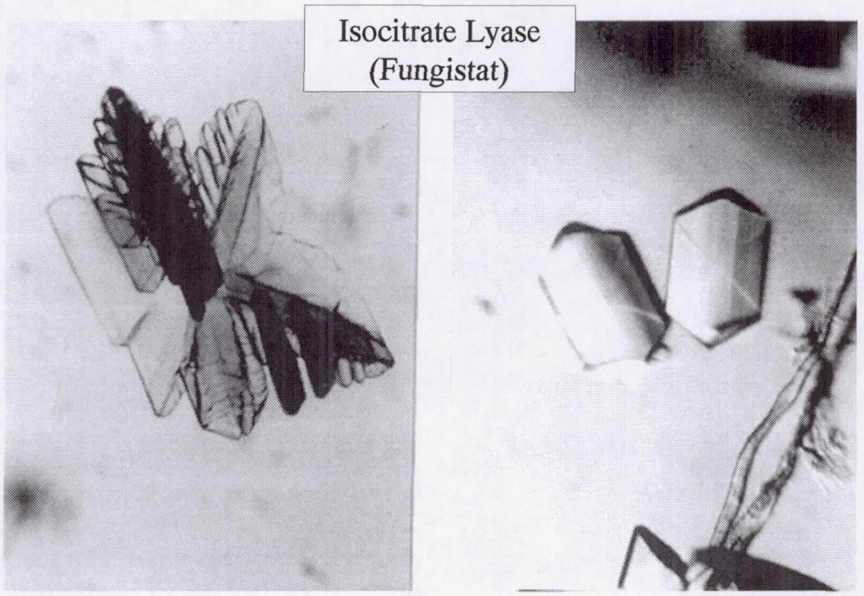
- Part 1:
  - Why and how people go to space
- Part 2:
  - Challenges of the space environment
- Part 3:
  - Status, Challenges and Opportunities for Printed Electronics in Human Spaceflight



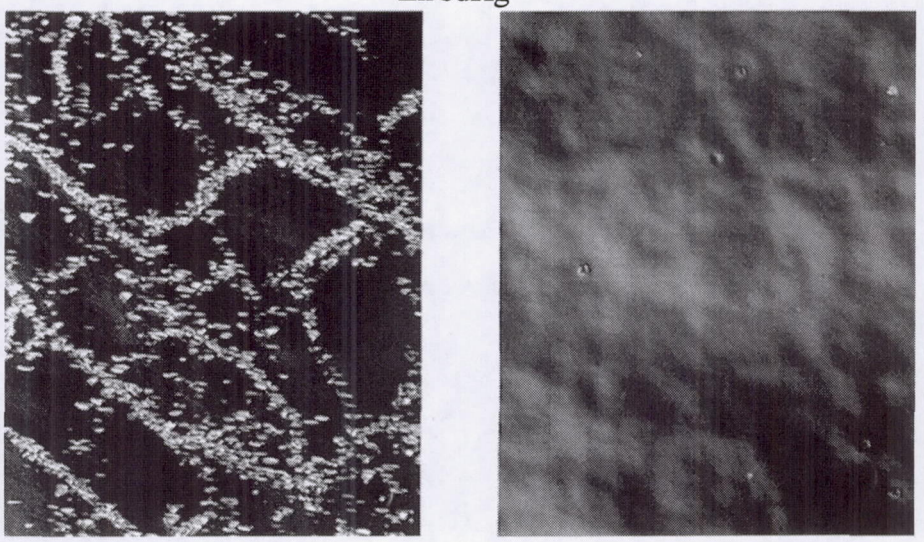


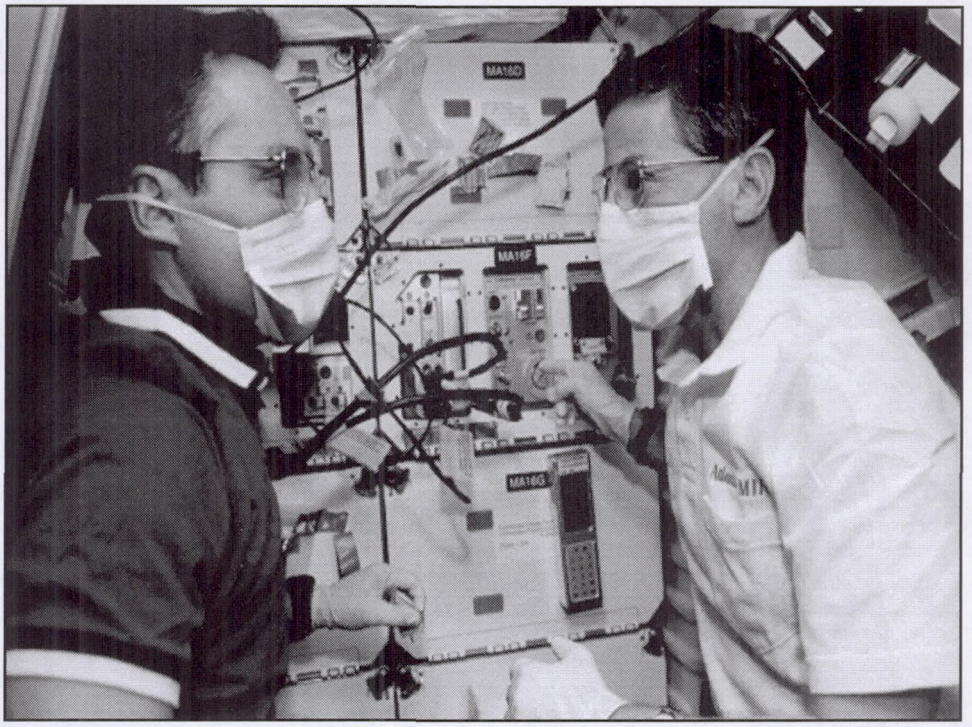

096:11:16:28

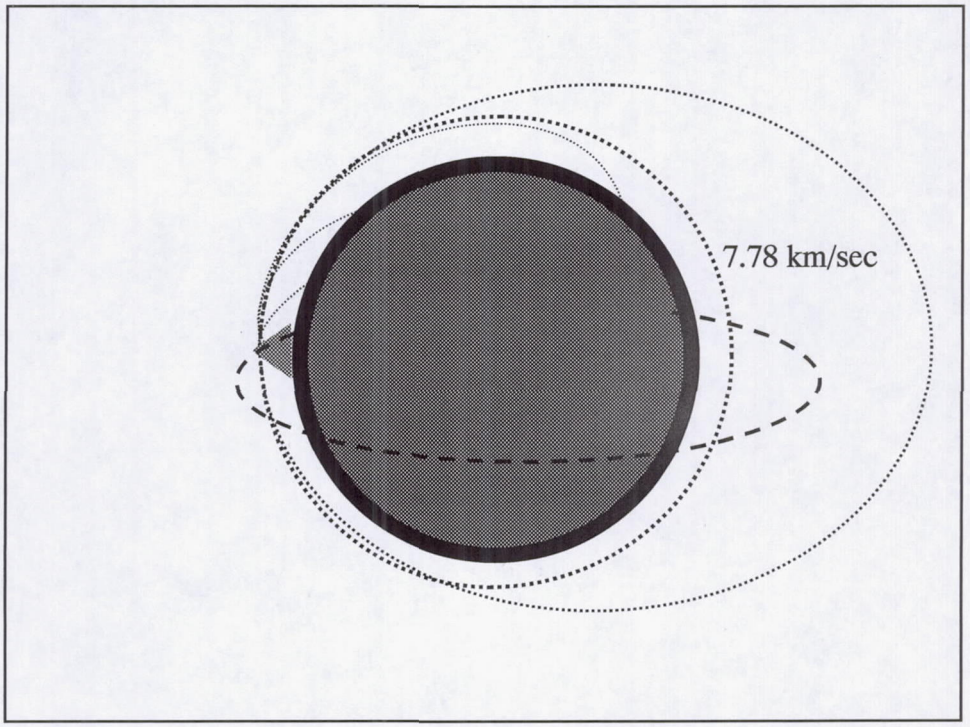
Isocitrate Lyase
(Fungistat)

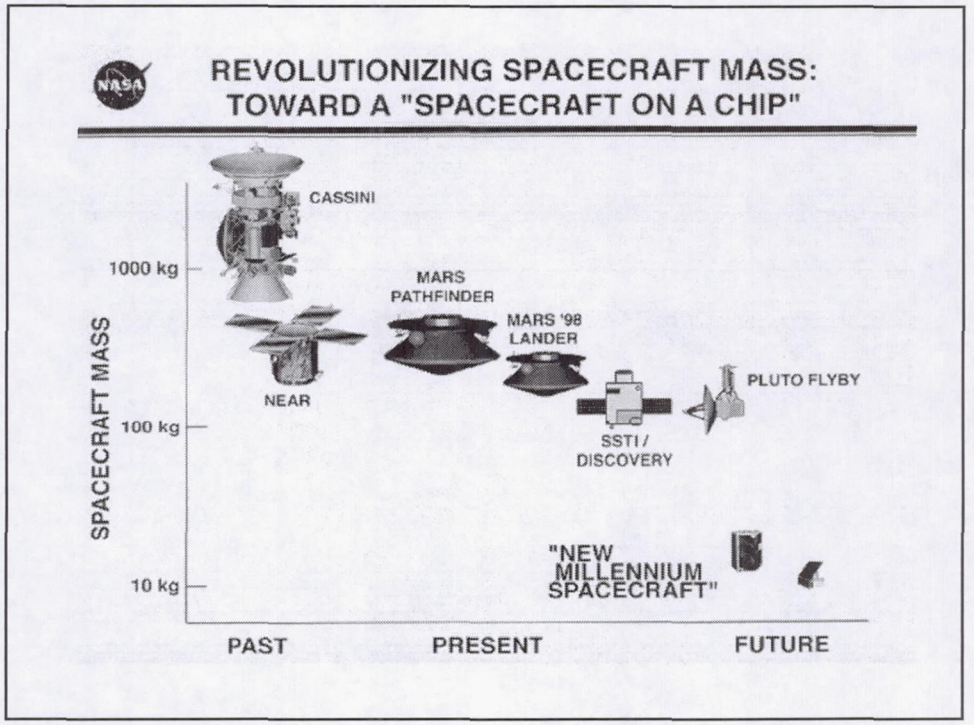


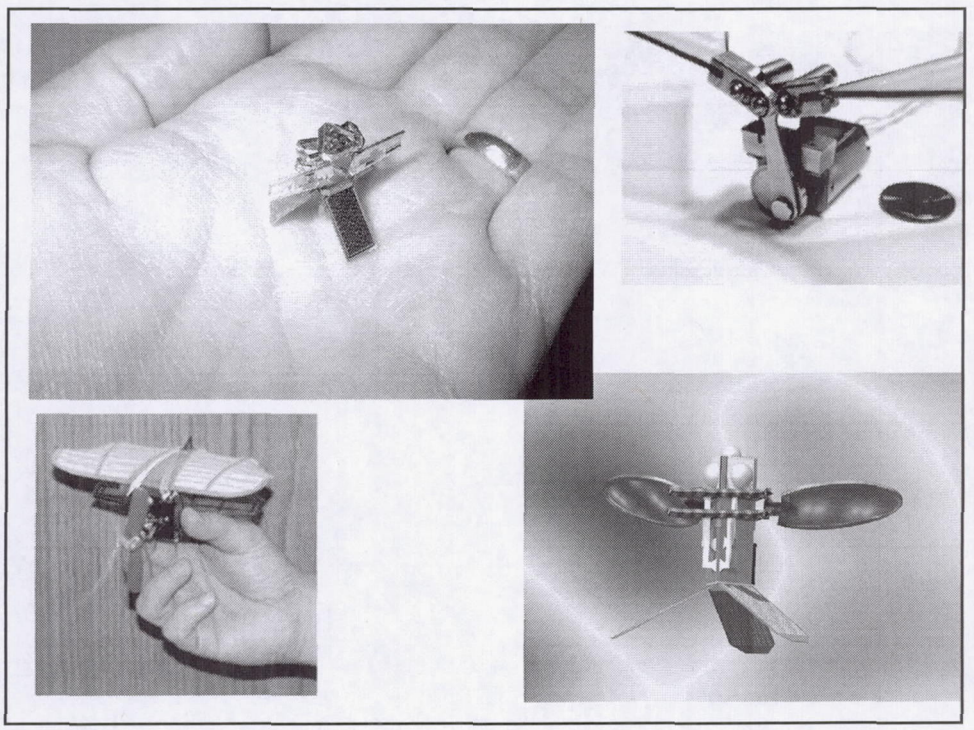
ZnCdHg

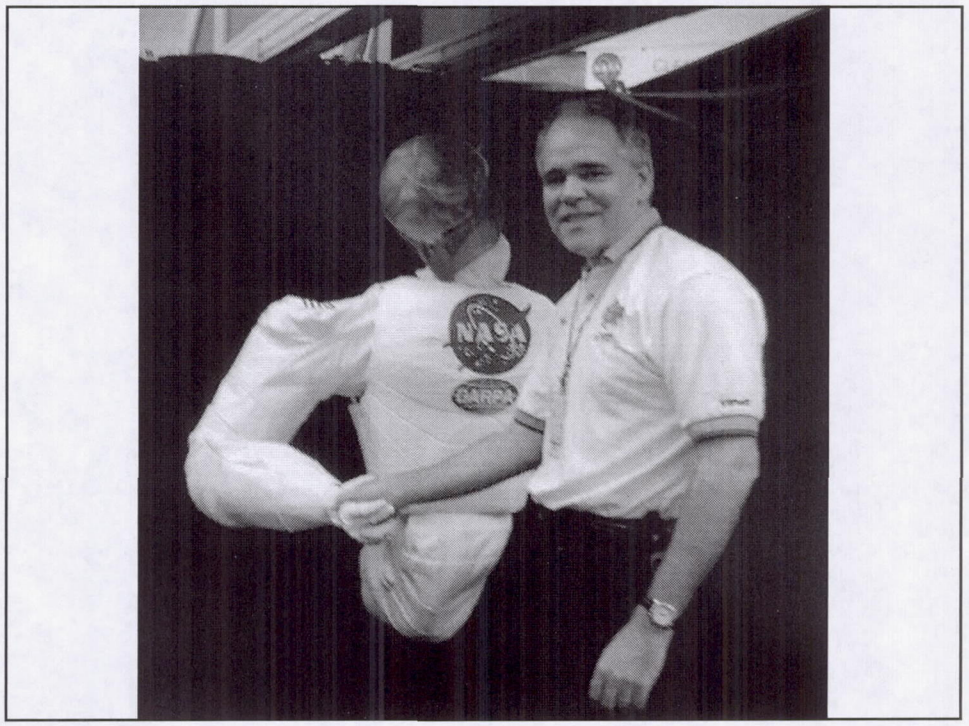


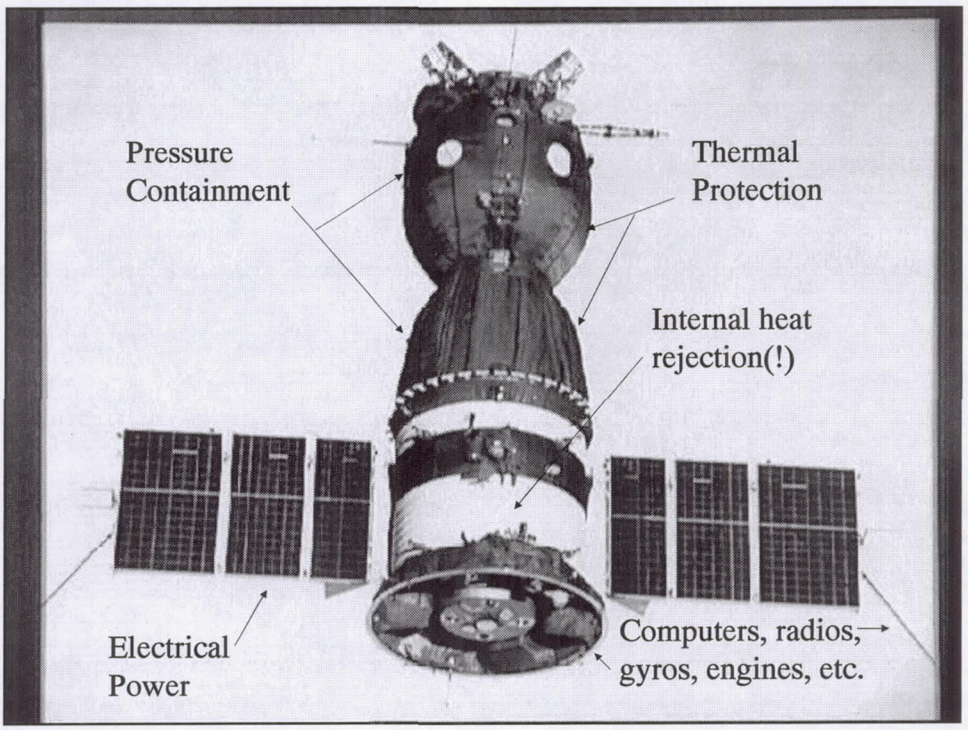

MA16C
MA16F
MA16G

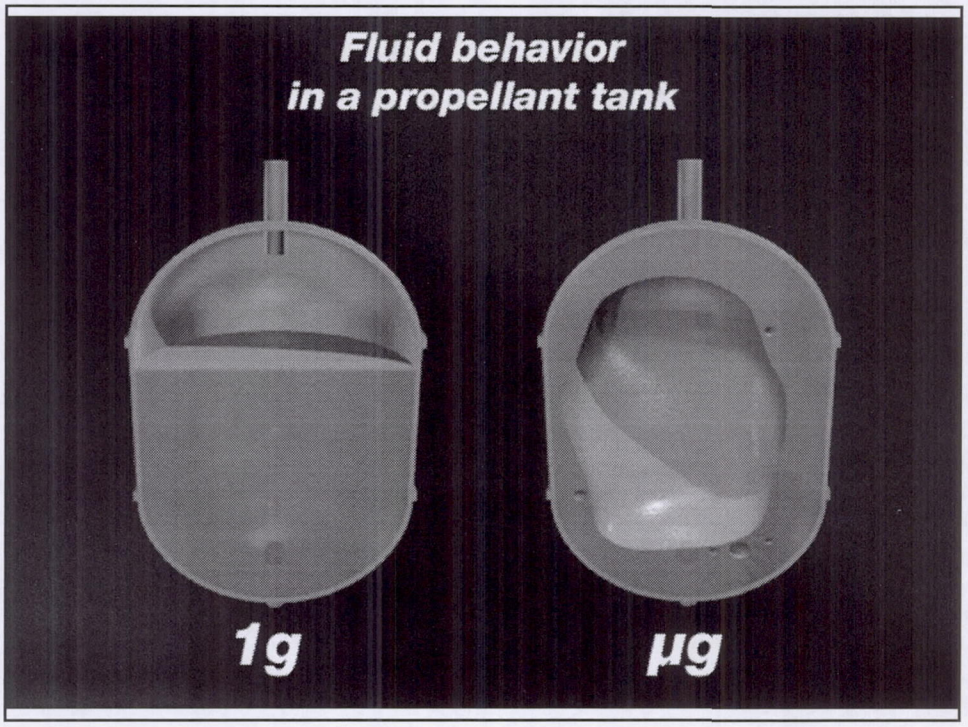

7.78 km/sec

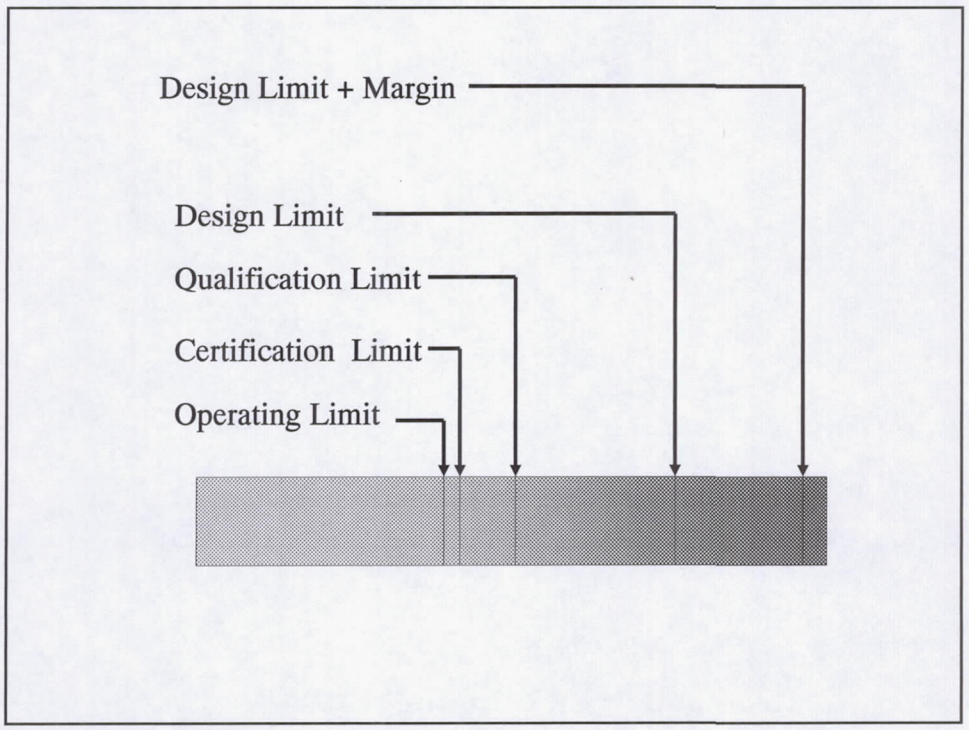

REVOLUTIONIZING SPACECRAFT MASS:
TOWARD A "SPACECRAFT ON A CHIP"
SPACECRAFT MASS
1000 kg
100 kg
10 kg
CASSINI
NEAR
MARS
PATHFINDER
MARS '98
LANDER
SSTI /
DISCOVERY
PLUTO FLYBY
"NEW
MILLENNIUM
SPACECRAFT"
PAST
PRESENT
FUTURE

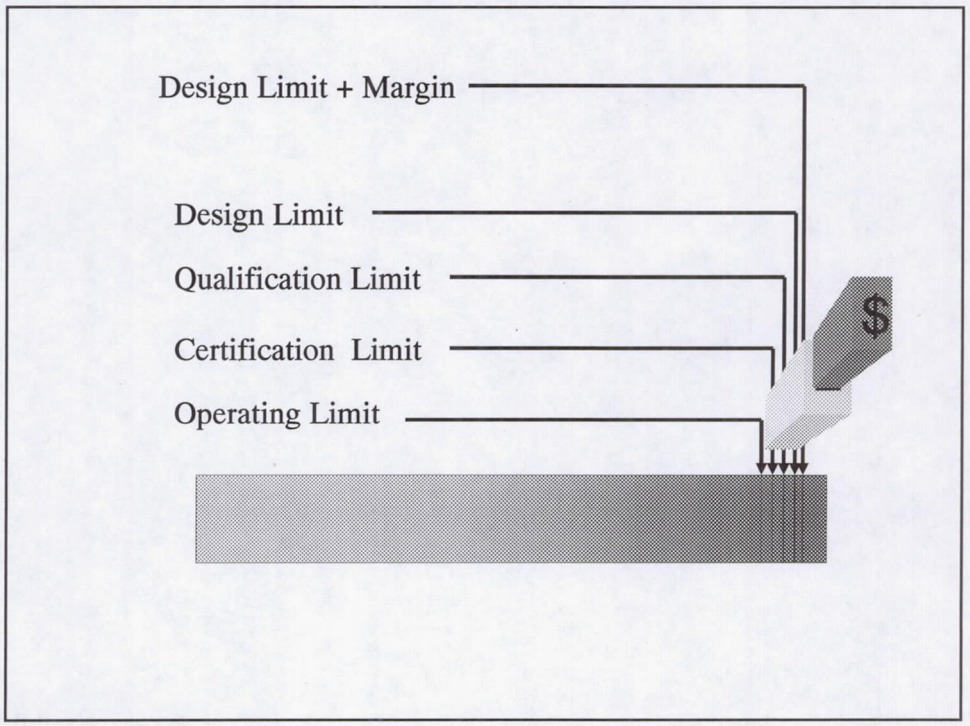


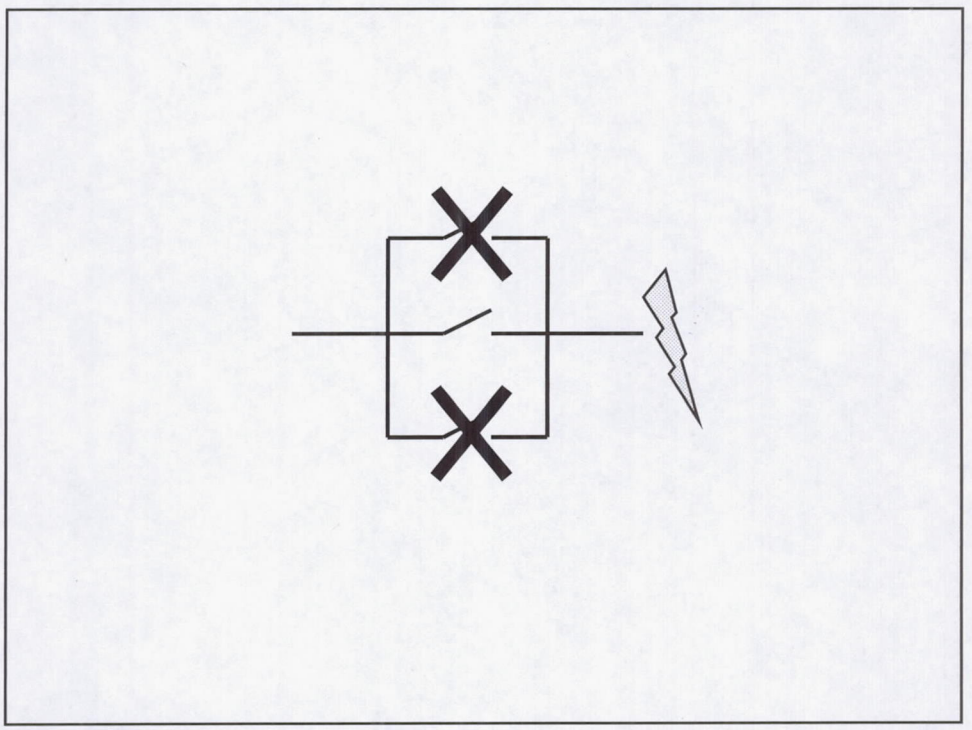


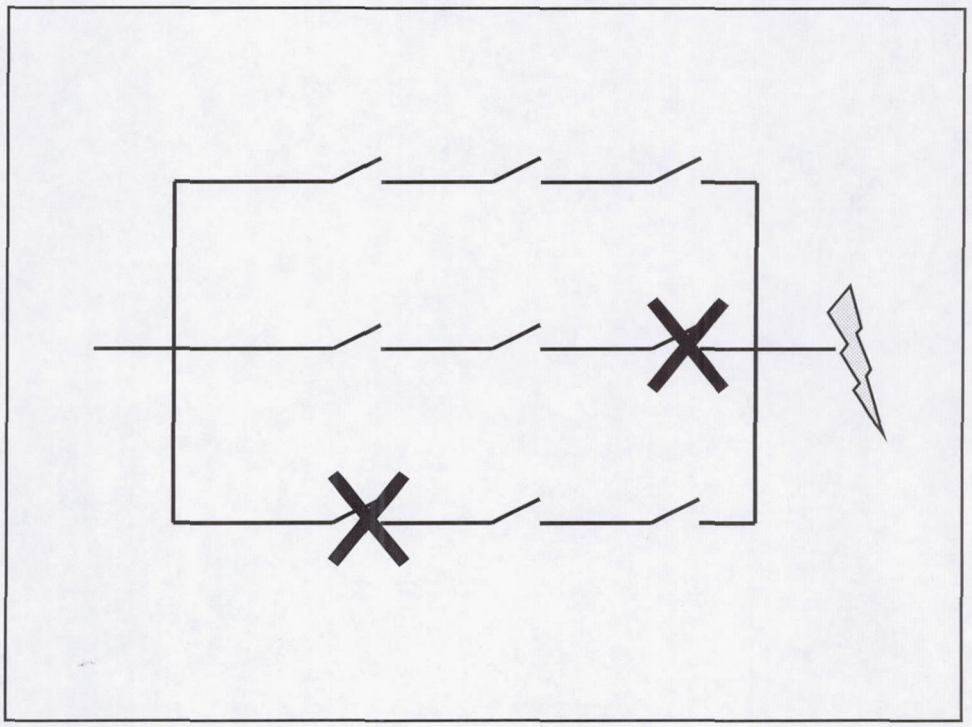

Pressure
Containment
Thermal
Protection
Internal heat
rejection(!)
Electrical
Power
Computers, radios,
gyros, engines, etc.

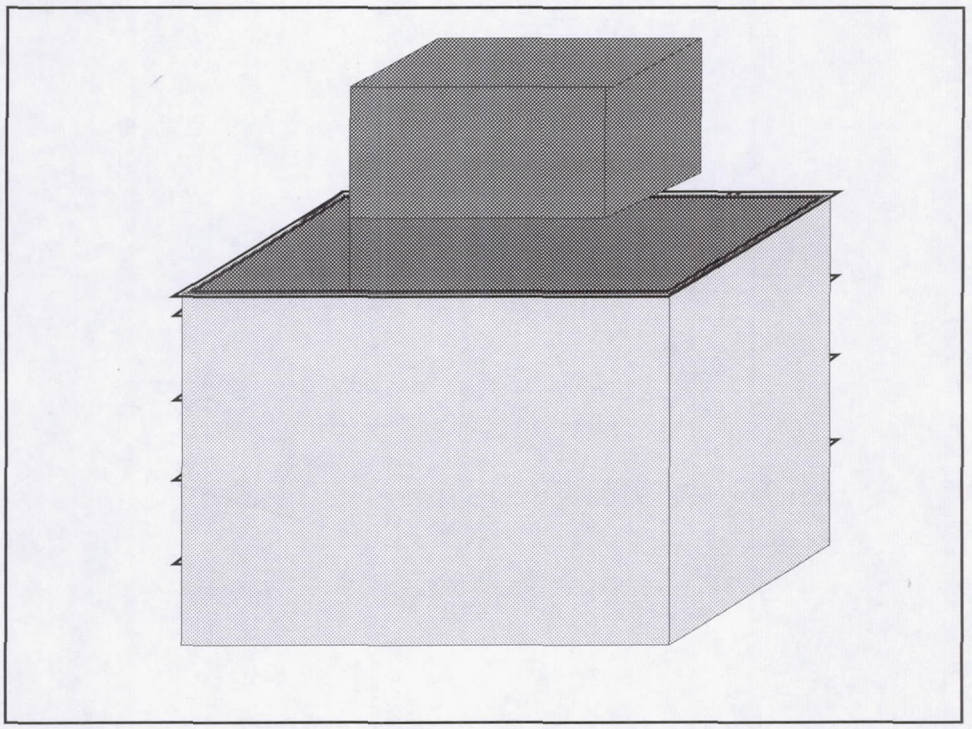

Fluid behavior
in a propellant tank
1g
µg

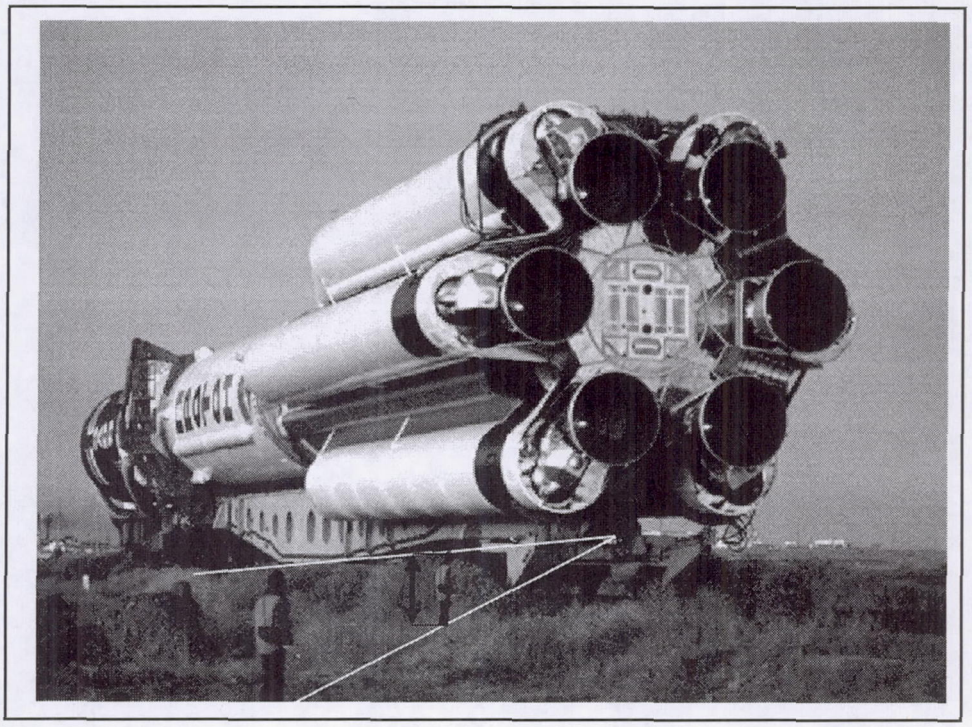

Design Limit + Margin
Design Limit
Qualification Limit
Certification Limit
Operating Limit

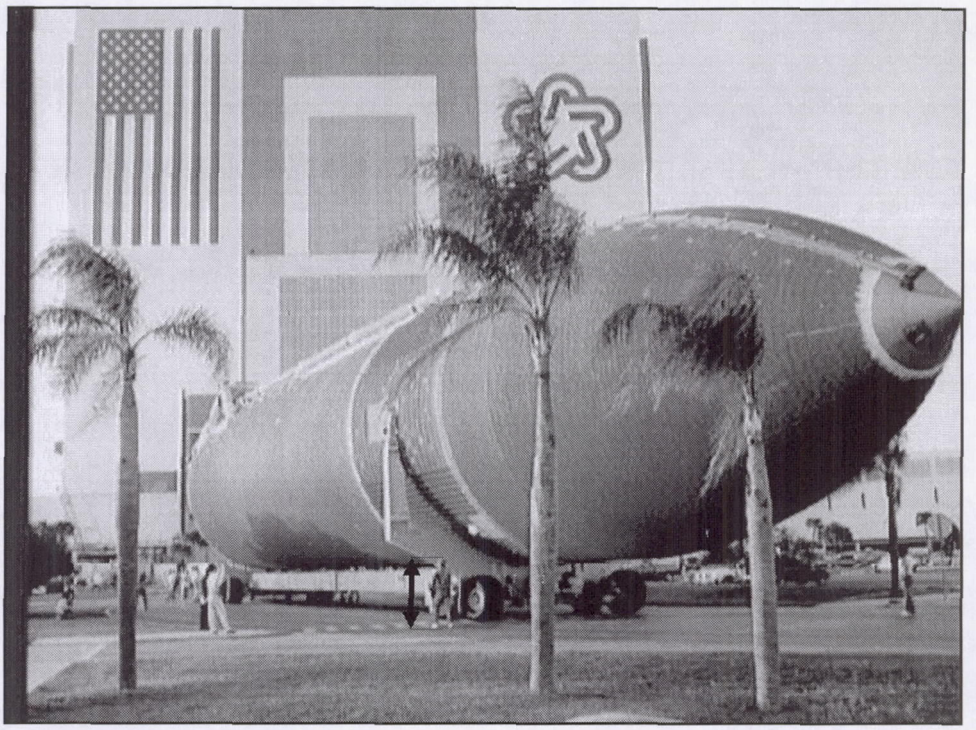

Design Limit + Margin
Design Limit
Qualification Limit
Certification Limit
Operating Limit
$

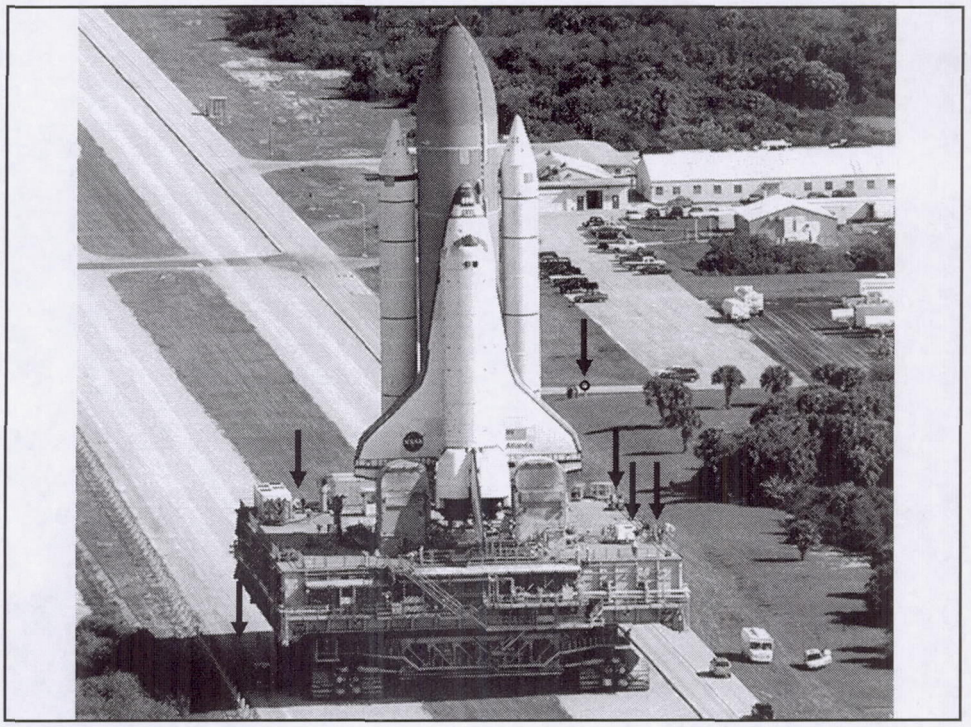


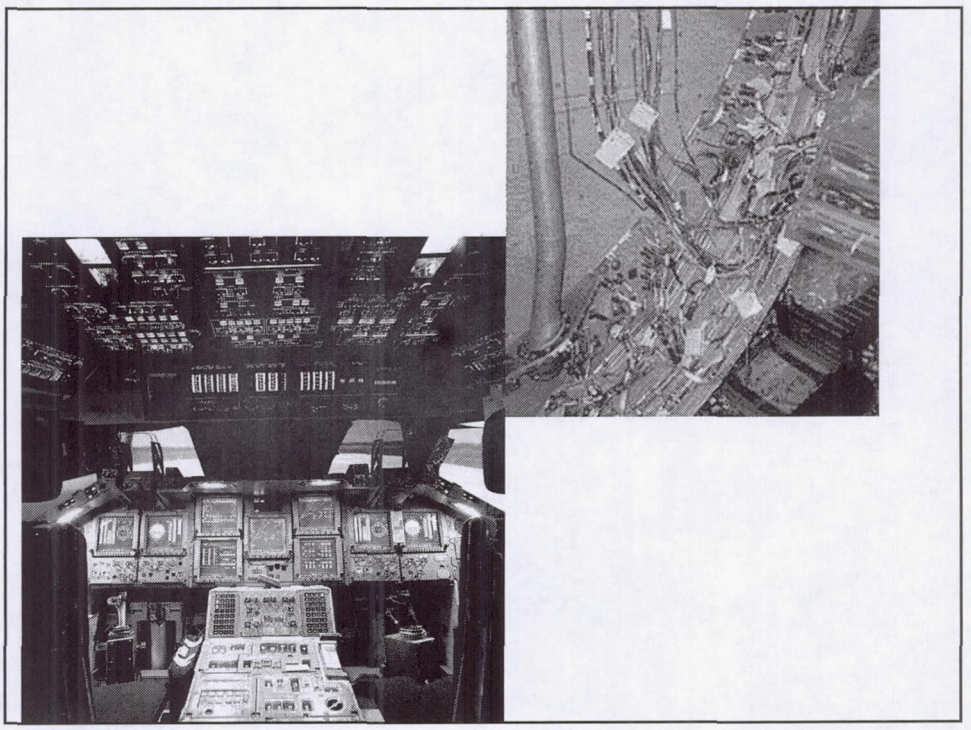


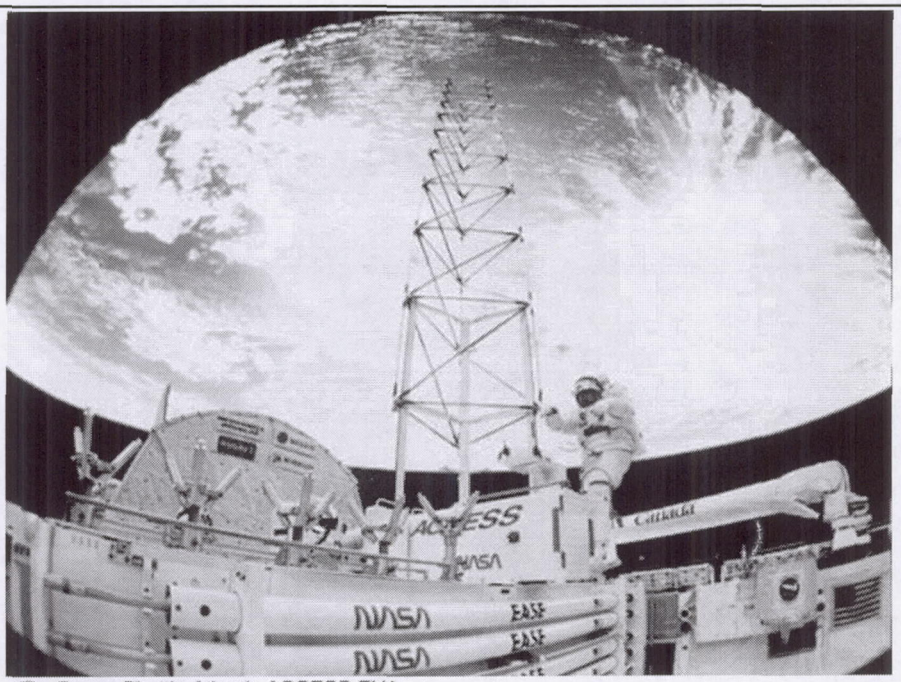




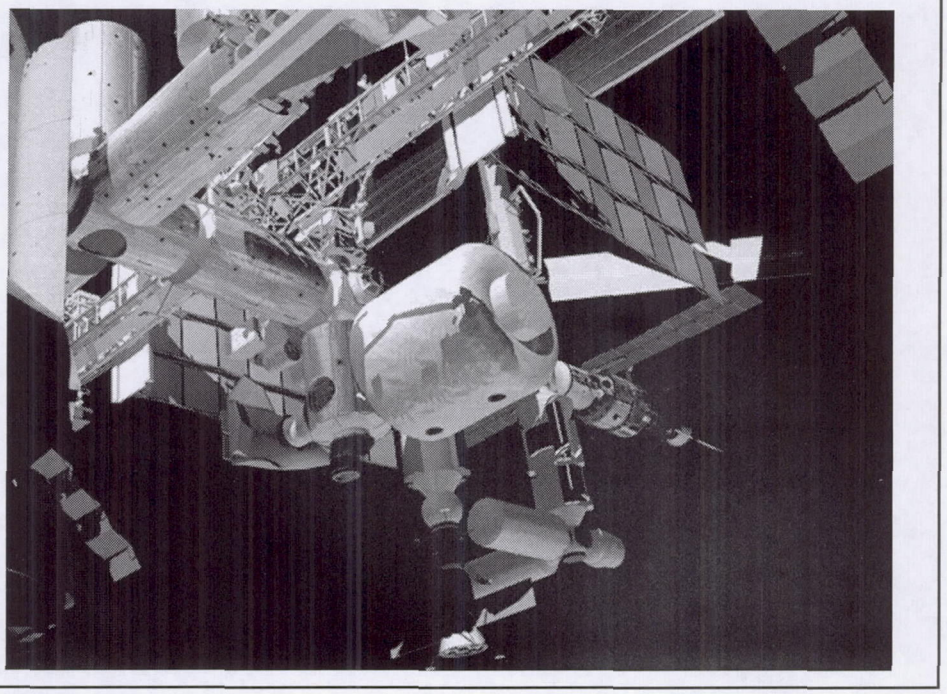




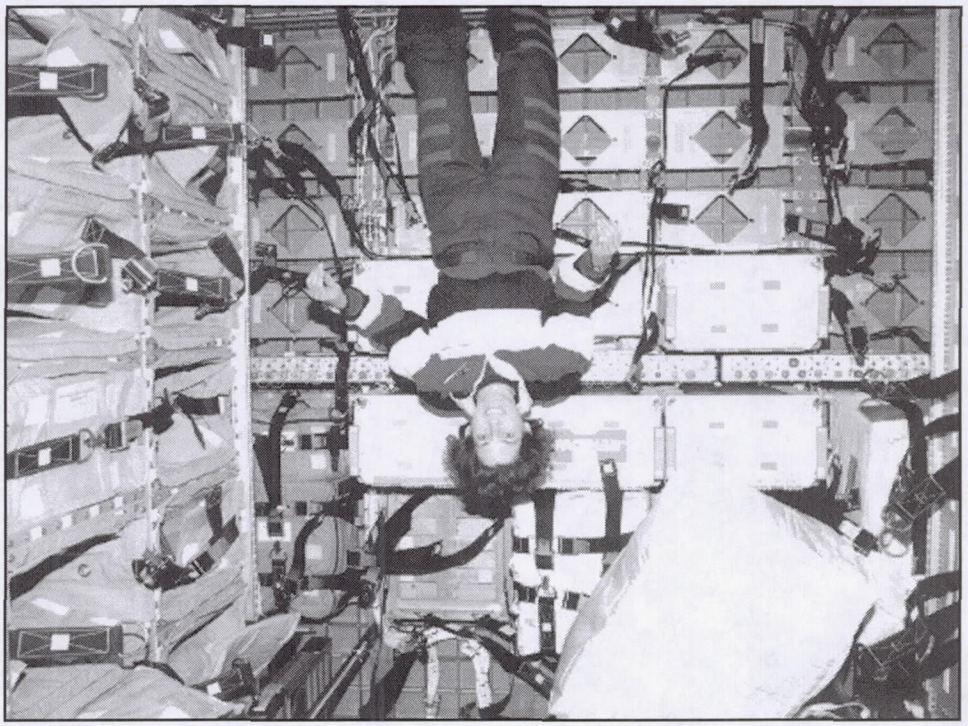


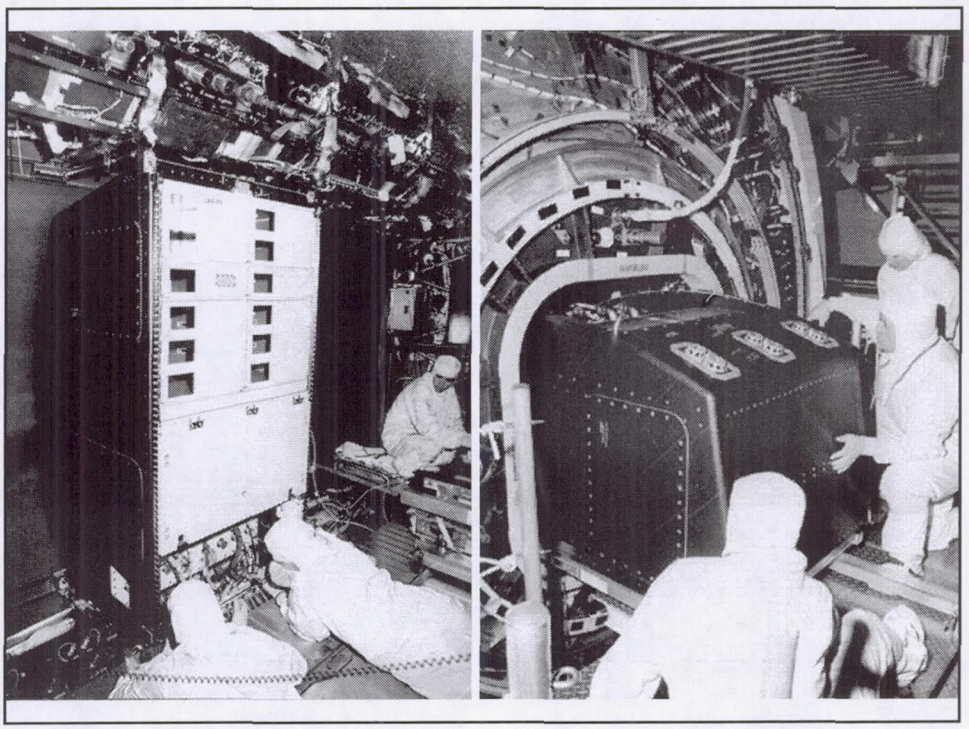


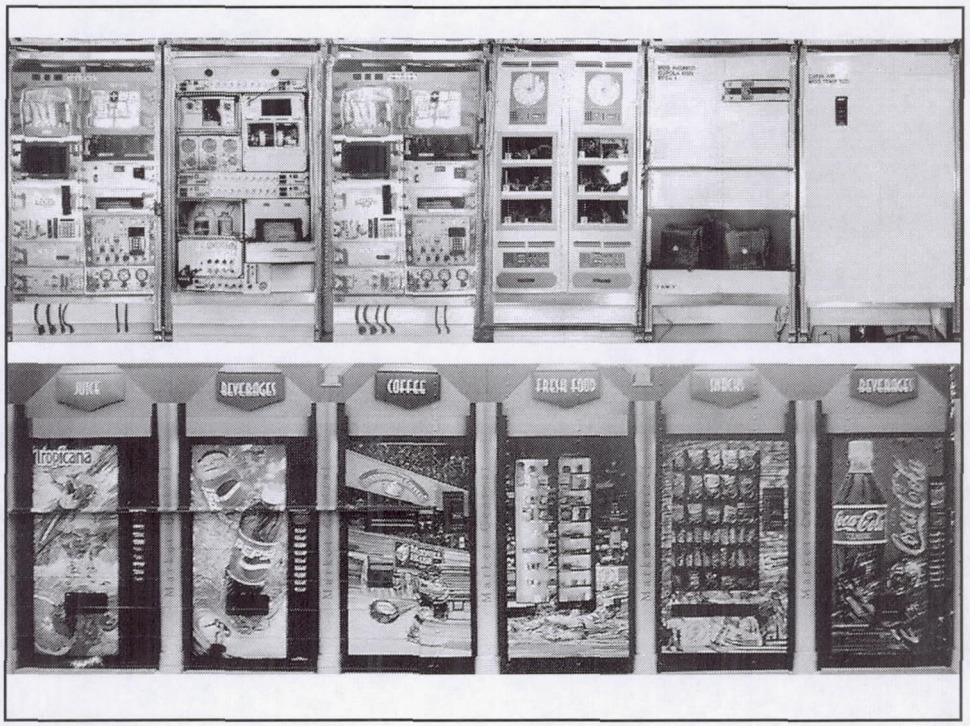
Space Shuttle Atlantis ACCESS EVA
NASA Langley Research Center 2/26/1986 Image # EL-1996-00066

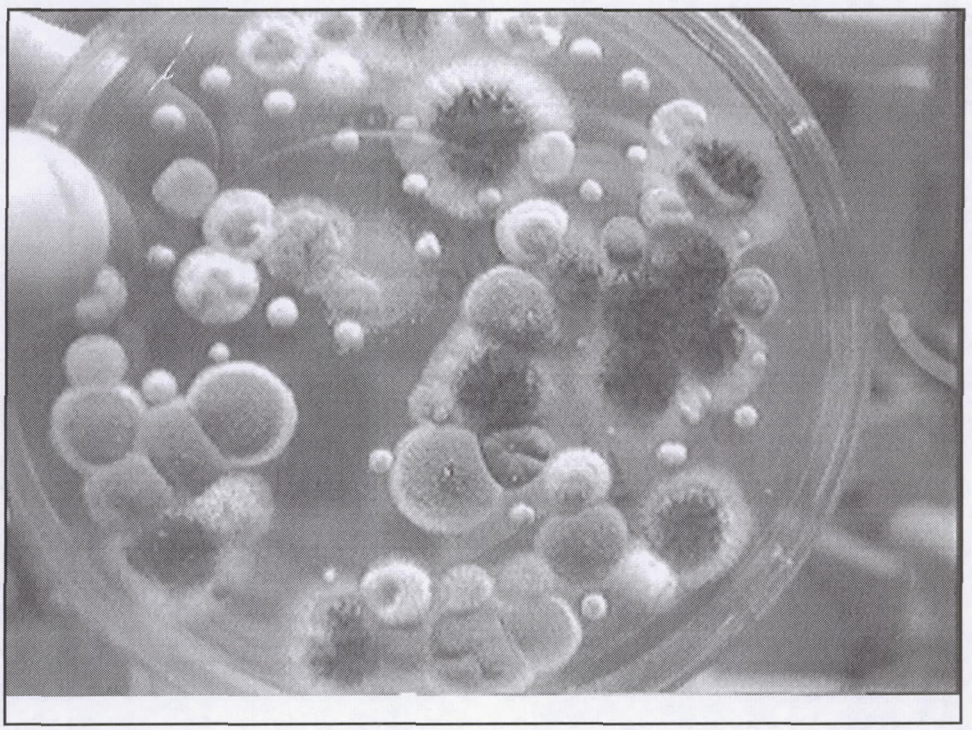


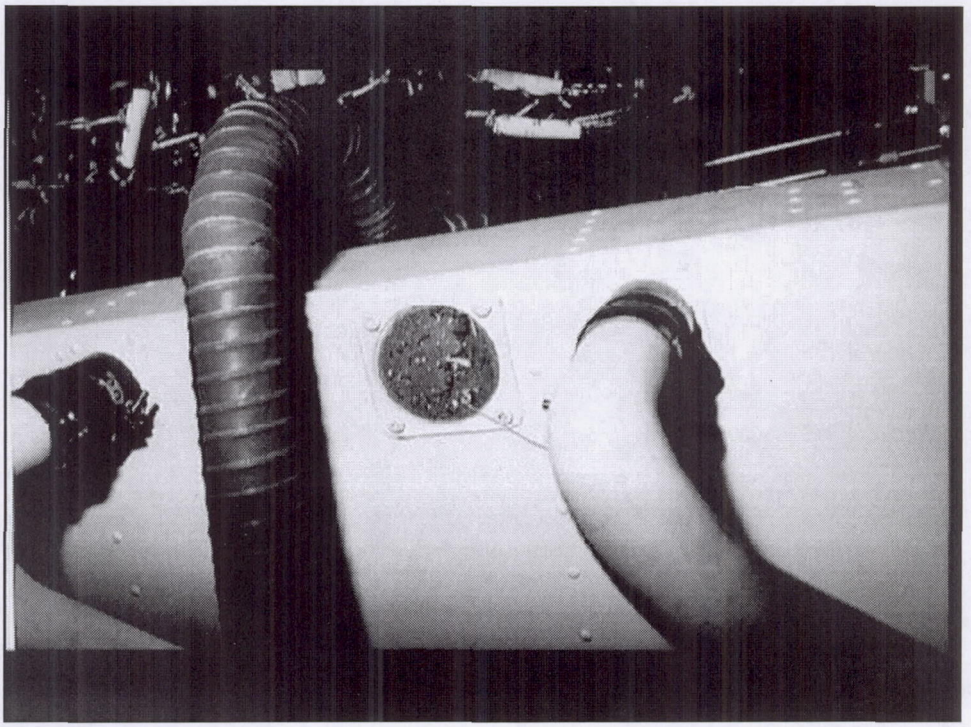

INTERNATIONAL
SPACE STATION
A New Star On the Horizon!
Science Power Platform
Service Module
Life Support Module
Docking Compartment
Control Module (Zarya/Sunrise)
Universal Docking Module
Pressurized Mating Adaptor 1
Research Module
Soyuz
Research Module
FGB Derived Module
Soyuz
Thermal Control Panels
S0 Truss Segment
Mobile Transporter
S3 Truss Segment
P3 Truss Segment
Solar Alpha Rotary Joint
P6 Truss Segment
P5 Truss Segment
Port Photovoltaic Arrays
S6 Truss Segment
P1 Truss Segment
CSA Remote Manipulator System
P4 Truss Segment
S1 Truss Segment
Node 1 (Unity)
Z1 Truss Segment
Centrifuge Accommodations Module
S5 Truss Segment
Cupola
JEM Experiment Logistics Module
Starboard Photovoltaic Arrays
Airlock
JEM Remote Manipulator System
S4 Truss Segment
Solar Alpha Rotary Joint
Node 3
U.S. Lab
JEM Exposed Facility
Japanese Experimental Module (JEM)
ESA Lab
Crew Return Vehicle
Habitation Module
Node 2
Pressurized Mating Adaptor 2
Pressurized Mating Adaptor 3
BOEING
United States
Russia
Japan
Europe
Canada
Brazil

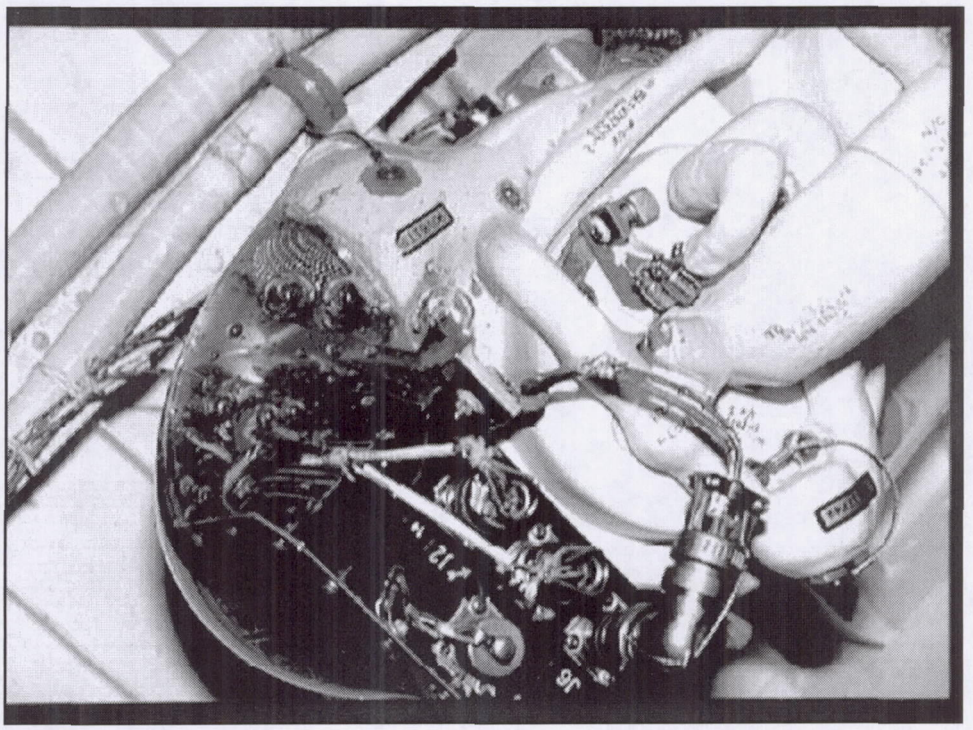


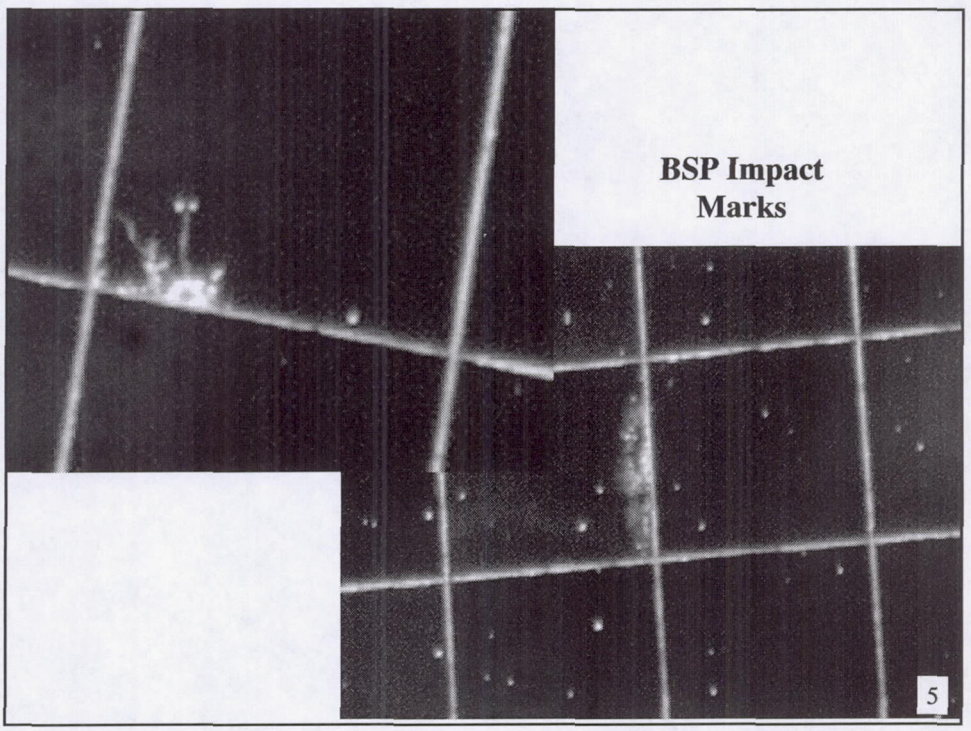



JUICE
BEVERAGES
COFFEE
FRESH FOOD
SNACKS
BEVERAGES
Tropicana
Coca-Cola



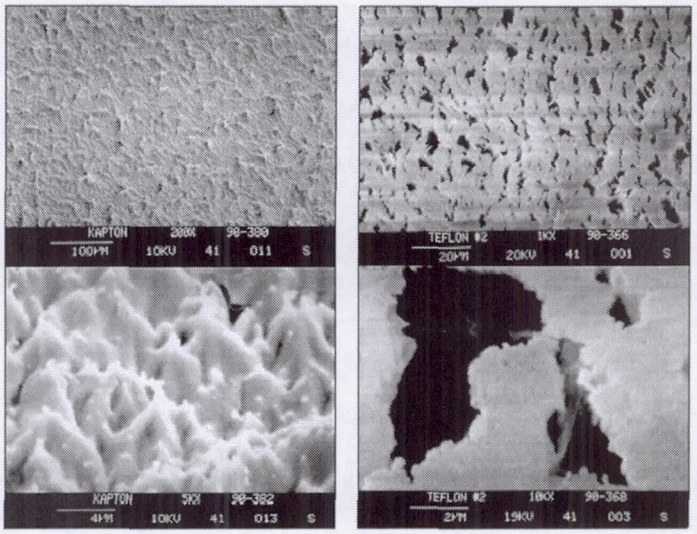


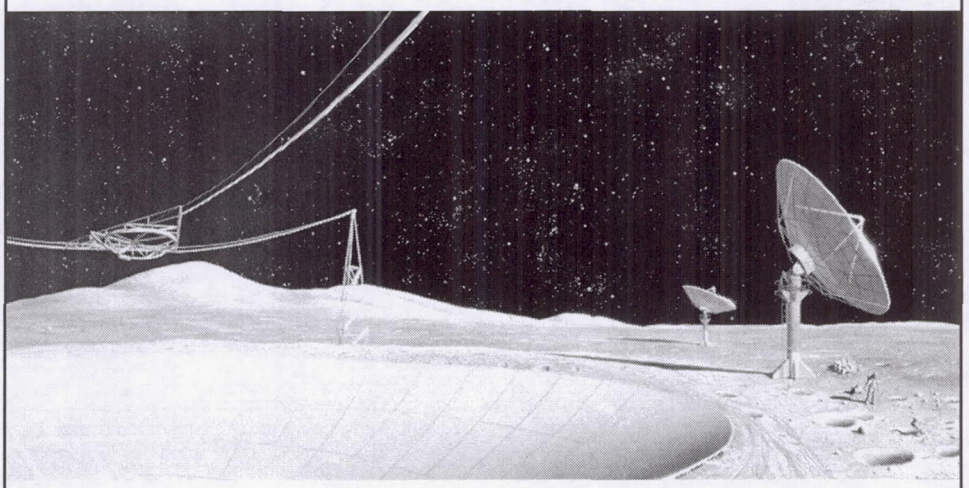


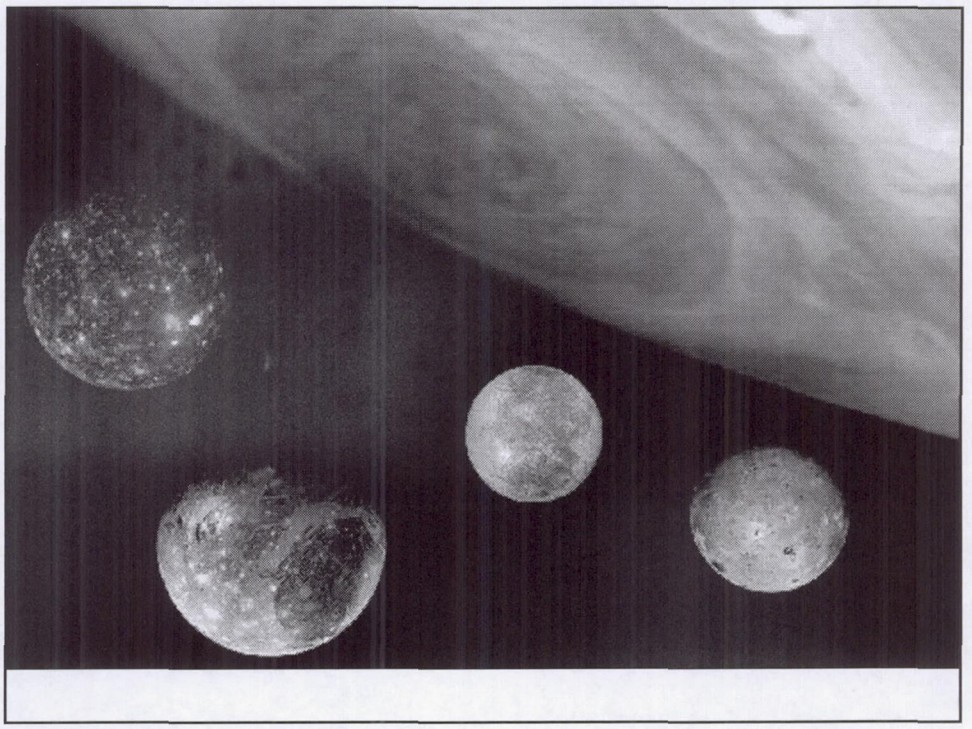

BSP Impact
Marks
5

Source: NASA Reference Publication 1390
Failures and Anomalies Attributed to the
Natural Space Environment

AO Erosion

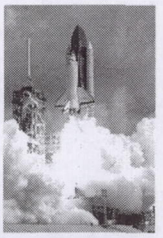


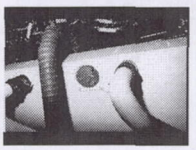




Factors Affecting Space Systems

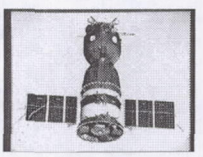
- High accelerations
  - Static/oscillating ~3 G's
  - Shock ~ 0.05G²/Hz, up to 1000 G's peak load
- Highly competitive RF environment
  - Spacecraft in view of 98% of world population
    - **Every** manmade source is line-of-sight
    - EMI field high: especially outside
    - IVA environment in a Faraday cage with hundreds of sensitive systems- including **people**
- 3-phase medium (gas, solids, liquids)

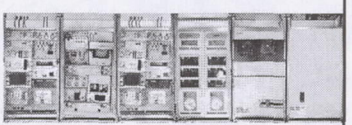


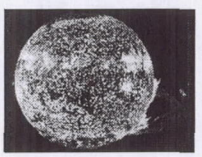


Factors Affecting Space Systems

- Severe materials limits
  - Flammability
  - Offgassing
  - Outgassing
  - Toxicity
- Dense packing
- Multi-layer assemblies & systems
- High radiation environment
- Large thermal extremes

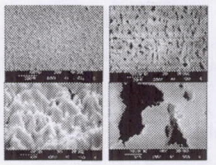






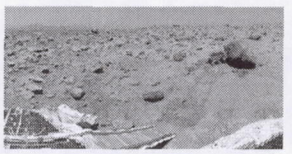
Factors Affecting Space Systems

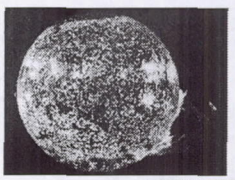
- Atomic Oxygen corrosion (LEO)
- Particulate erosion/puncture
- Vacuum
- Oscillating Temperatures

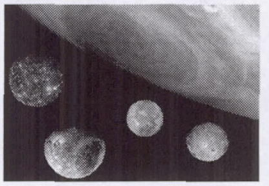


Future Issues

- Lunar and Martian Dust
  - Gums up any works...
- Higher radiation
- Longer durability
  - (years/decades)
- The Unknown....

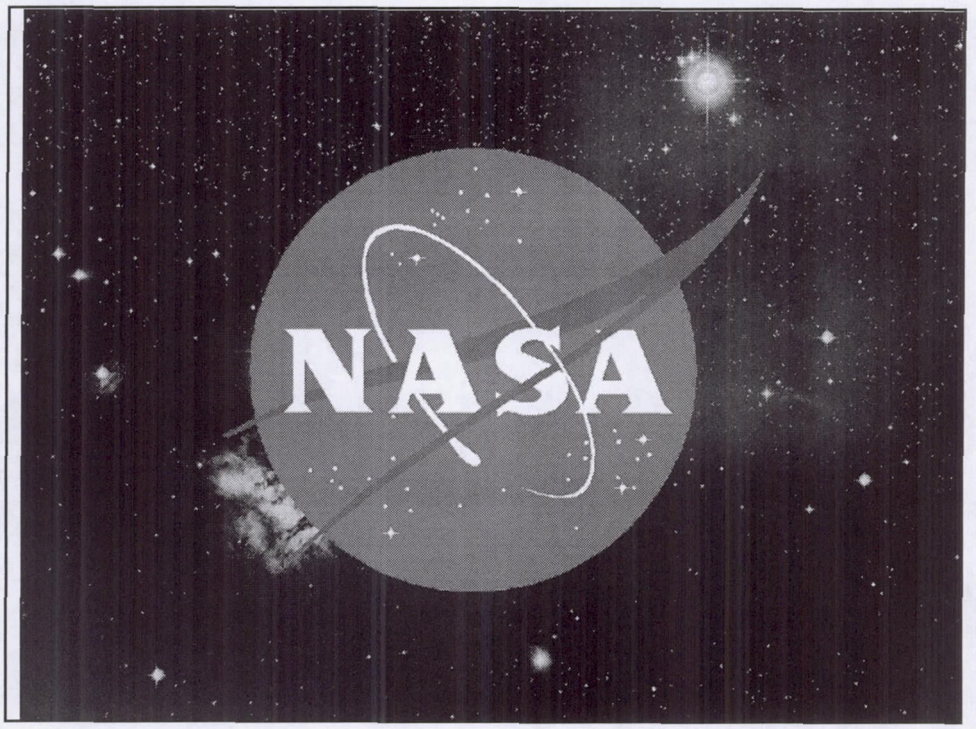






Opportunities:

- Inventory is critical
  - **Finding it** can be a problem
- Weight and performance are drivers
  - Sensors
  - Effectors
  - Connectivity
- Reliability and Durability
  - If it moves, it can break
  - If it moves a lot, it can break faster
    - ...and it must not break....


NASA