

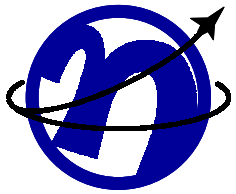
ETA
Flight Materials

Space Environments and Effects

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Space Environments and Effects

Environment

Logistics and Launch

Microgravity

Thermal/Vacuum

Neutral Atmosphere

5 eV atomic oxygen

Plasma Environment

1 to 25 keV protons

1 to 25 keV electrons

Radiation

Solar ultraviolet

Solar proton events

Trapped radiation belts

Cosmic "rays"

Micrometeoroids/Orbital Debris

Effects

Shock, dirt, pressure changes

Space sickness & fluid management

Outgassing & condensation

Atomic oxygen attack

Spacecraft glow

Surface charging

Electrostatic discharge

Enhanced sputtering

Scission of polymer chains

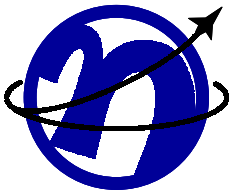
Single event upsets

Deep dielectric charging

Chemical changes

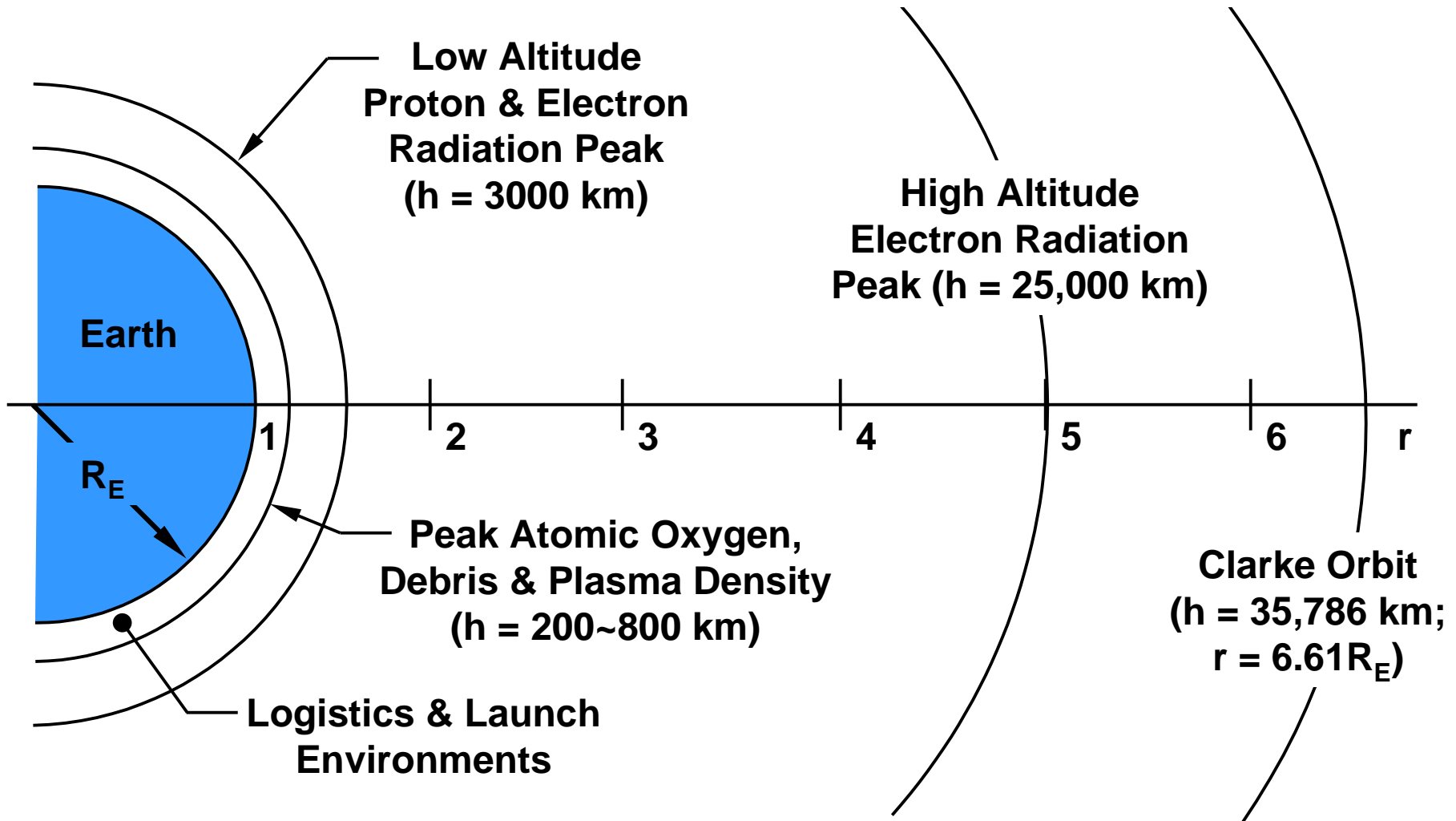
Degradation of electronics

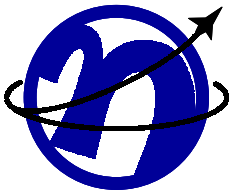
**Catastrophic impacts, optical decay,
End of Space Age**



Spatial Distribution of Environments at the Equator

← Thermal, Vacuum, Meteoroids, UV, Solar Proton & Cosmic Radiation →

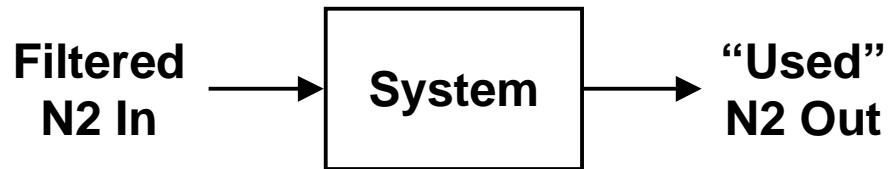




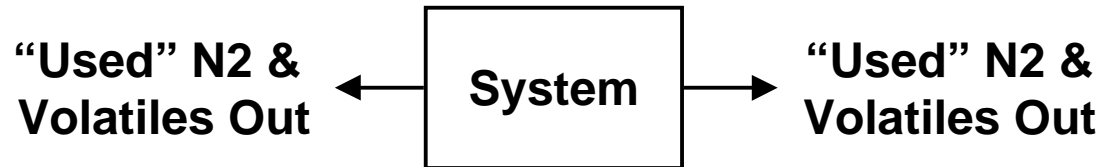
Logistics and Launch

- Drop shock / transport vibration mitigated by shipping container
- Aging and corrosion minimized thru materials and process control
- Contamination controlled via purge system
- Pressure changes during test & launch controlled via vent system:

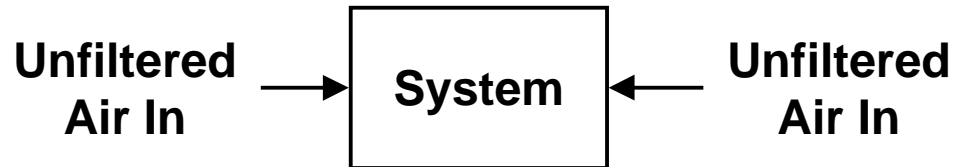
Purge Mode:

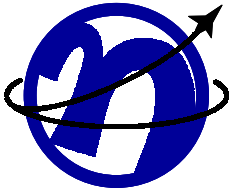


Vent Mode:



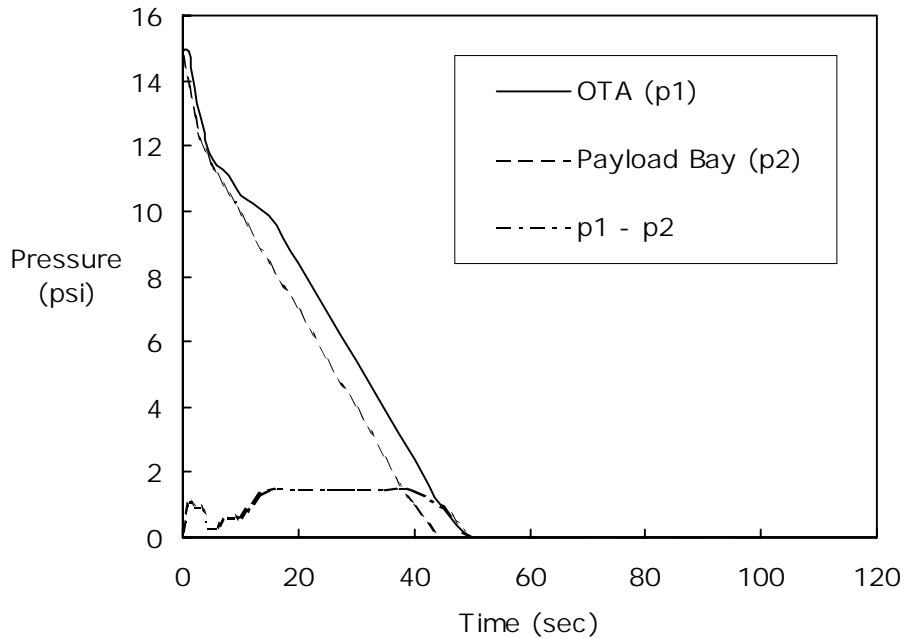
ERP Mode:



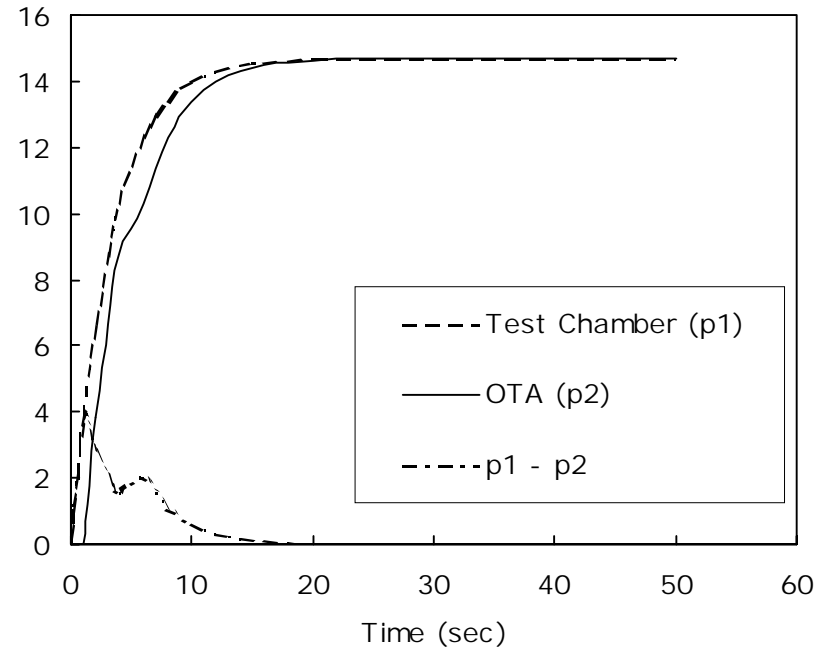


Typical Purge and Vent Profiles

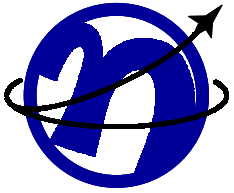
Ascent Depressurization



Explosive Repressurization

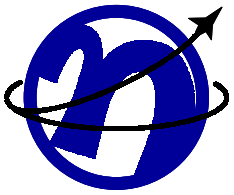


Max operational inside-outside pressure differential <2 psi
Min operational margin of safety +0.32 in flexure adhesive



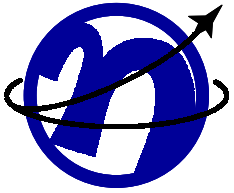
Thermal/Vacuum Environment

- **High local temperatures on sunlit surfaces and low ambient pressures encourage vaporization of high vapor-pressure materials such as polymers, cadmium and tin**
- **Low local temperatures on shaded or operationally cooled surfaces can induce condensation of volatiles lost from sunlit surfaces; this is a major source of on-orbit contamination**
- **In closed spaces such as unvented honeycomb cores, a phase change from liquid to gas can produce explosive forces**
- **Loss of relatively volatile plasticizers to space increases brittleness of plastics and elastomers, accelerating aging**
- **Low ambient and operational temperatures increase brittleness of most polymers and some metals, such as molybdenum:**
 - **polymers pass thru glass transition temperature**
 - **molybdenum passes thru ductile-brittle transition**



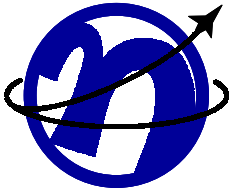
Atomic Oxygen

- **Atomic oxygen is a primary concern for LEO spacecraft, some concern for Molniya orbit spacecraft, and should not pose a problem for Clarke orbit (GEO) spacecraft -- unless they are parked in LEO more than 1 week prior to transfer**
- **Exposure levels vary with altitude and duration:**
 - **Surface materials aboard a typical 2-week Shuttle flight are exposed to a total atomic oxygen fluence of $\sim 1E20$ atom/cm²**
 - **Ram surfaces on the long-duration exposure facility (LDEF) saw up to $9E21$ atom/cm² over 5.8 years**
- **Surface materials should be checked for reactivity:**
 - **Ceramics are generally non-reactive, though ITO is questionable**
 - **Most metals besides silver have acceptably low rates of decay**
 - **Most polymers are attacked moderately to severely (evaporated!)**
- **Optical systems may be affected by spacecraft glow phenomena**

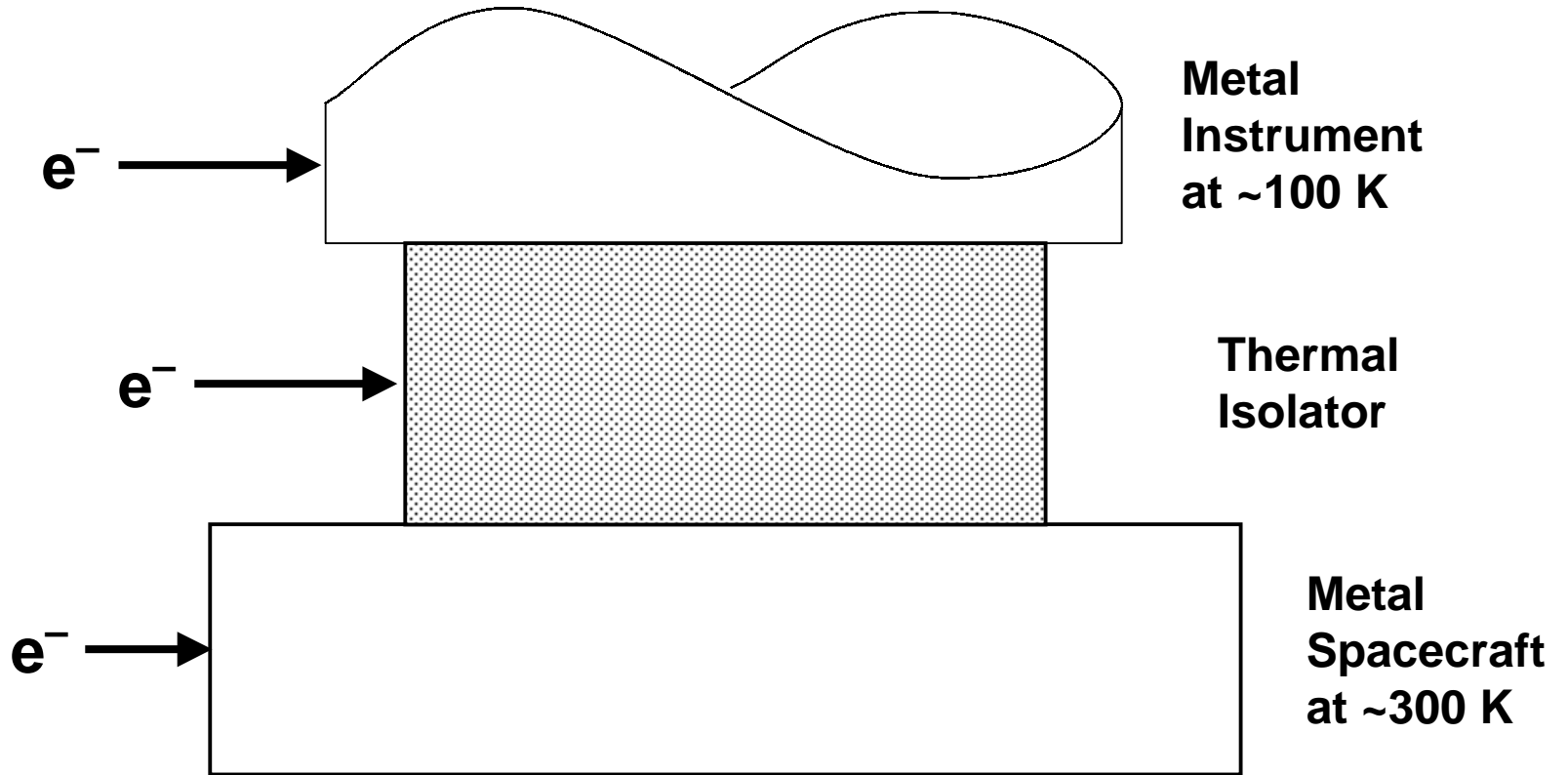


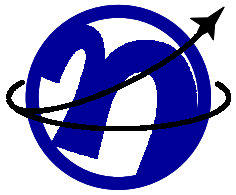
The Plasma Environment

- **Charged particles are everywhere:**
 - **Peak plasma density is at low altitudes and high latitudes**
 - **High altitude particles have higher energies**
 - **High altitude spacecraft are more susceptible to "substorms"**
- **Different surface temperatures and illumination (sunlit v. shaded) lead to differential charging (up to kilovolts)**
- **Differential charging leads to electrostatic discharge (ESD)**
- **ESD leads to surface damage, electromagnetic interference (EMI)**
- **Preventative measures:**
 - **Make all surface materials conductive (< 1 Megohm-cm)**
 - **Minimize composition differences if possible**
 - **Make sure all surface materials are electrically connected with sufficiently low resistance (milliohms to ohms)**
- **Problem areas include adhesively-bonded joints, chem-filmed surfaces, ITO, beryllium and composite structures (use BOSS)**

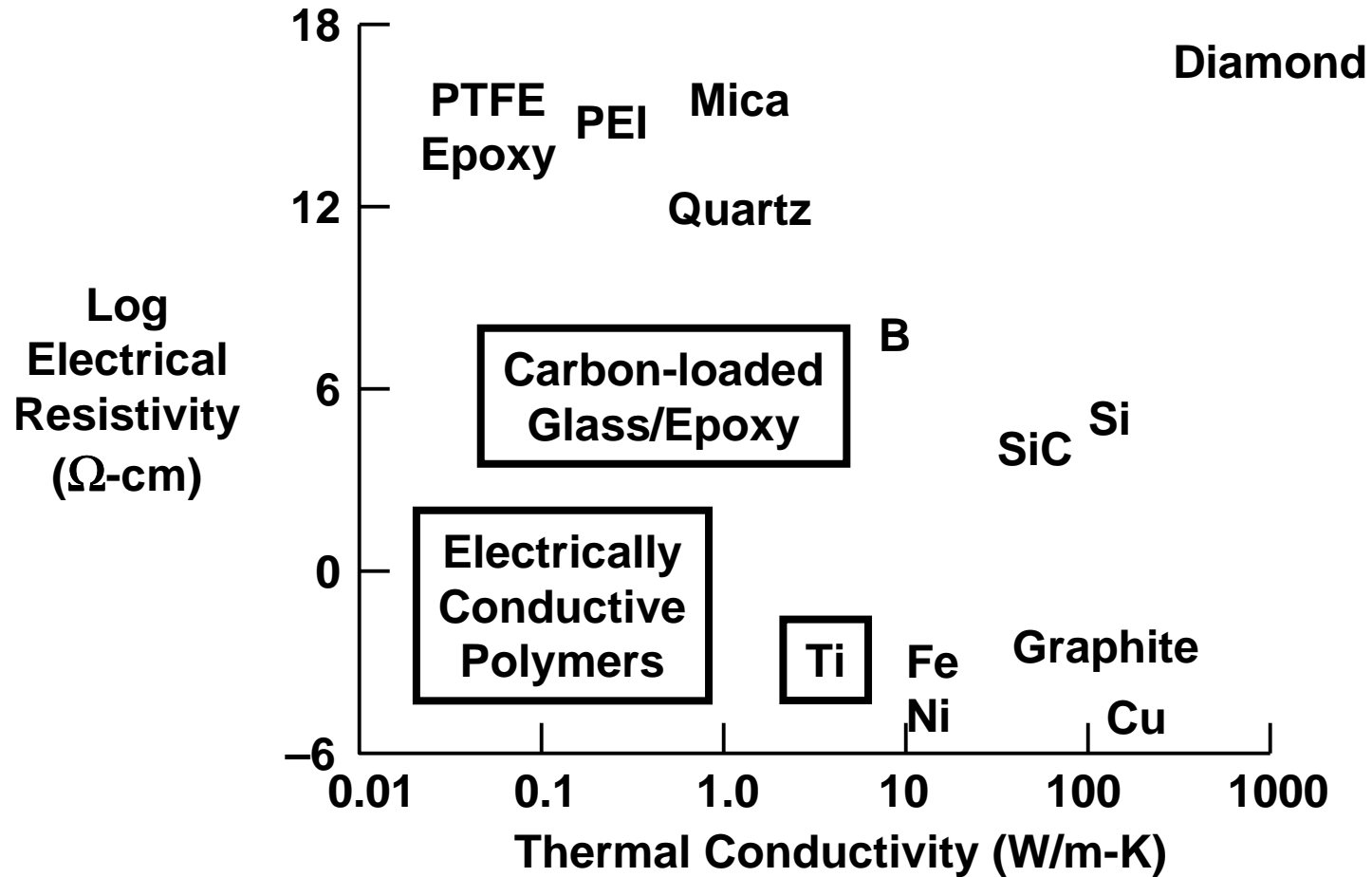


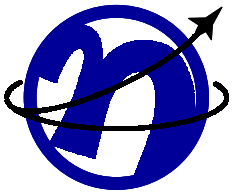
A Spacecraft Charging Problem



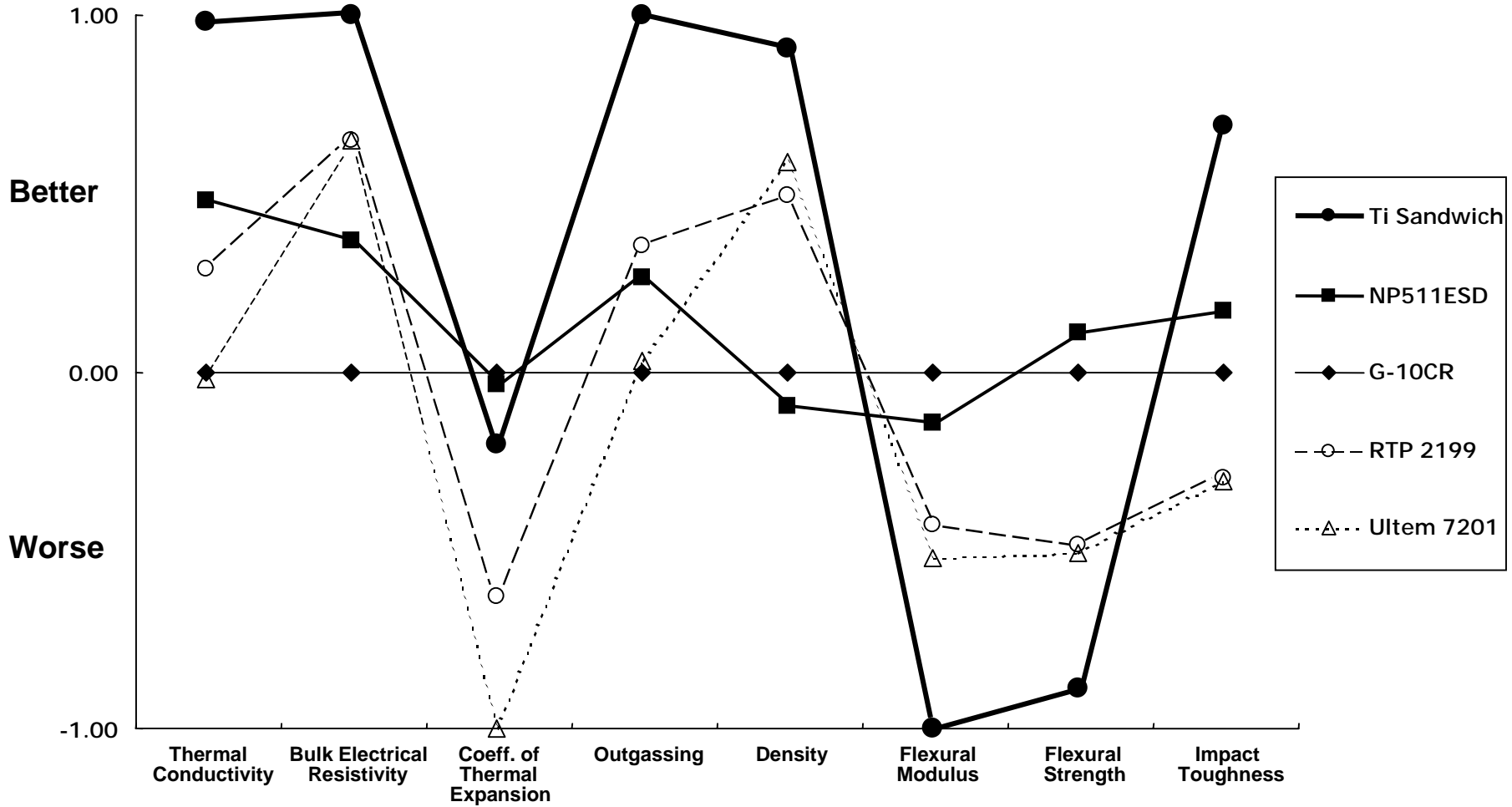


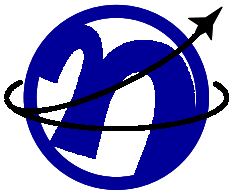
Comparison of Materials





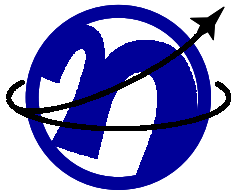
Material Profiles





Radiation Environments

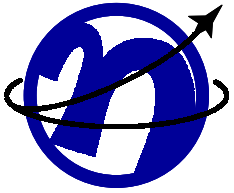
- **Cosmic "Rays"**
 - Actually heavy ions at extremely high energies (GeV and higher)
 - Low flux density has little effect on materials or humans
 - primary problem single event upsets (SEU's) in avionics
- **Solar ultraviolet**
 - Color changes and embrittlement of polymers and coatings
- **Coronal Mass Ejections (CME's); AKA Solar Proton Events (SPE's)**
 - Severe bursts of x-rays and ions during solar maximum
 - Small addition to high orbit trapped radiation total fluence
 - Potentially lethal flux densities of radiation for crews
- **Van Allen trapped radiation belts**
 - High cumulative surface doses in high orbits (~1E9 rad)
 - Many widely-used polymers degrade too quickly for GEO craft (e.g., Neoprene, Nylon, Mylar, Acrylic, most Teflons)
 - Crew exposure must be limited with current shielding technology
- **Hostile action**
 - X-ray bursts, system-generated electromagnetic pulse (SGEMP) produce potentially high currents & local temps in structure



Micrometeoroids & Orbital Debris

- **Micrometeoroids are fairly predictable**
 - **Some "streams" follow orbits of extinct comets, produce "showers"**
 - **Flux density is not growing**
- **Orbital debris**
 - **Spreads out to fill space around Earth**
 - **Flux density is growing year by year**
- **Between 8,500,000 and 10,000,000 lbs of stuff orbits below 2,000 km today**
- **26,000 objects over 10 cm (3.94 in) in diameter have been catalogued**
- **About 8,800 of these in orbit right now:**
 - **650 functional spacecraft**
 - **Thousands of derelicts**
 - **Millions of bits of debris**

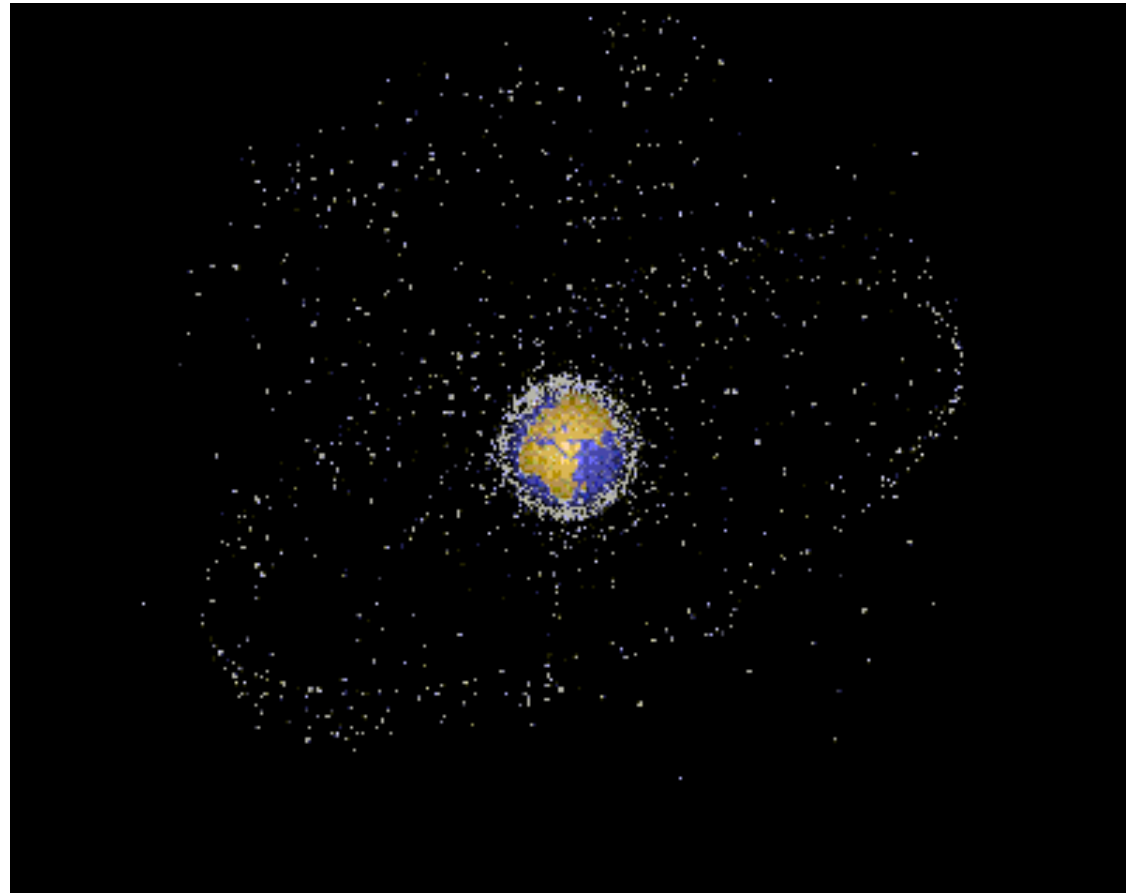
Snapshot of near-Earth space

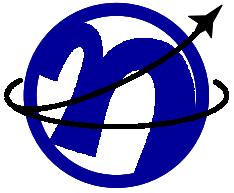


A Man-Made Asteroid Belt

Computer-generated deep-space snapshot of catalogued objects orbiting the Earth.

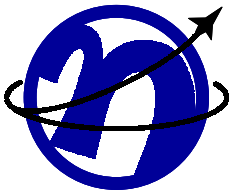
Note the ring at Clarke orbit and large number of objects in Navstar and Molniya orbits.





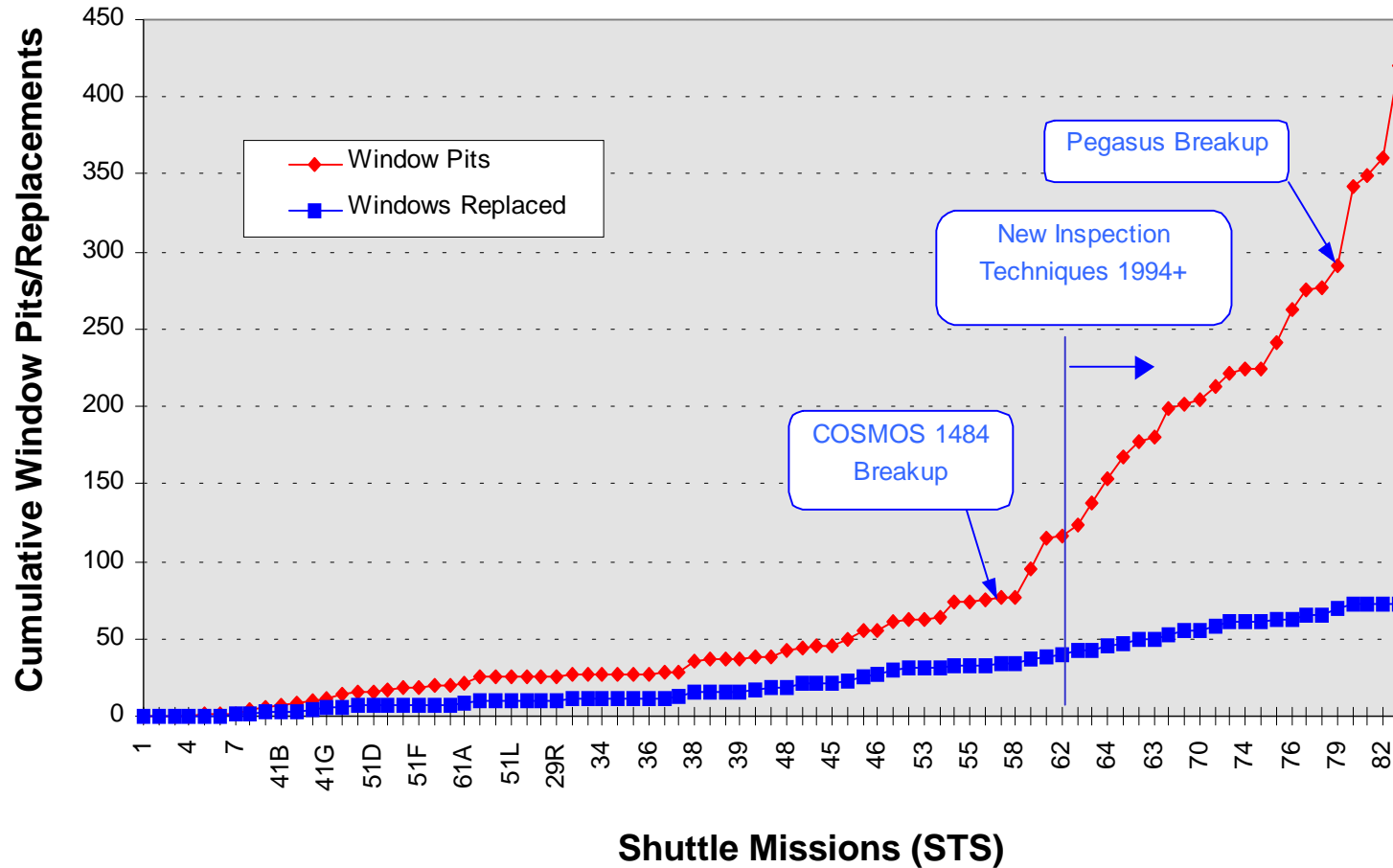
Micrometeoroid & Debris Effects

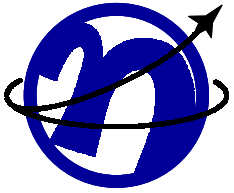
- **Catastrophic impacts**
 - Low probability with meteoroids
 - Growing probability with debris; some have already occurred (e.g., Cerise v. Ariane upper stage debris, Kosmos 1275)
 - Bona fide threat to astronauts on EVA
- **Mission-impairing impacts**
 - Damage to optics, antennas and sensors
 - Damage to propulsion tanks and thrusters
 - Damage to solar arrays, radiators and thermal blankets
- **Mission-shortening impacts**
 - Ram surfaces subject to steady bombardment by smaller debris
 - Optical and thermal control surfaces WILL degrade
 - Synergistic effects with atomic oxygen in low orbits
- **Legal and economic impacts**
 - Cerise and Ariane both ESA
 - Other collisions may involve rival countries or companies
 - Some Shuttle windows replaced every flight



Shuttle Window Replacement

(Currently, window replacements averaging 2-3 per mission)





SEE Summary

- **Microgravity, thermal extremes, vacuum, cosmic radiation, solar radiation and meteoroids are present at all altitudes & inclinations**
- **Trapped particle radiation, atomic oxygen, plasma and debris vary with altitude and orbital inclination**
- **We can do nothing to change the natural environments**
- **We CAN do something to change the debris environment:**
 - **De-orbit low altitude spacecraft at end-of-life**
 - **Consolidate assets at all altitudes onto "farms" to maintain better control over new derelict and debris generation**
- **We MUST do something to change the debris environment:**
 - **Continued growth of debris is creating a "shell" around the Earth of high-velocity projectiles**
 - **Sometime soon, orbital debris will reach **CRITICAL DENSITY** and become *self-propagating***
 - **This will End the Space Age for *at least* 1,000 years**