

Lecture 4: Spaceflight Environment

Space Environment and Effects

1. Gravity (see Lecture 3):

[Microgravity](#), Microgravity Simulation

Launch / Landing Acceleration

Launch / On-orbit Vibration and Microgravity Perturbation

2. Other Space Environment

Radiation Environment:

[Radiation, Plasma, Meteoroids and Space Debris, Atomic Oxygen, Geomagnetic Effects, Contamination](#)

[Radiation Fundamentals](#)

Space is full of ionized radiation and solar radiation such as gamma rays, x-rays, and ultraviolet rays. The space radiation environment is composed of various types of particles. These include a radiation belt consisting of particles captured by the Earth's magnetic field and surrounding the Earth like a donut; protons with energies ranging from 10 through 10¹⁶ Mev; galactic radiation composed of many types of nuclei such as helium, carbon, oxygen, and iron; and high levels of particles generated by solar flares. Utilizing such an environment, various types of research can be conducted in the fields of life science, medicine and so on. For instance, research on the adaptability and ecology of living things in the space environments and research on physical effects of radiation on living things and mankind can be performed.

Vacuum Environment:

Space provides a large-scale high-level vacuum environment which can never be obtained on the ground. The level of space vacuum depends on the altitude above the Earth. At the ISS altitude about 400km (250mi), the pressure of the environment is about one 100,000th of 1Pa, which is about one 100 millionth of the pressure on the ground. Utilizing the features of this high-level vacuum and microgravity, pure materials can be produced from the

melted state with a purity which can never be realized on the ground. High-quality semiconductors are also expected to be produced utilizing the high-level vacuum.

Human Exposure to Space Vacuum: <http://www.sff.net/people/Geoffrey.Landis/vacuum.html>

Also: residual atmosphere (spacecraft offgassing / discharges / thrusters - contamination)

<http://www.corrosion-doctors.org/Space/Frames.htm>

Space debris / micro-meteorites

UV and ionizing radiation (photochemical degradation), atomic oxygen (erosion),

thermal gradients between sunlight and shadow

charged and neutral particles.

3. Spaceflight Environment

Pressurized Carriers (NSTS, ISS):

Atmosphere: Temperature, Humidity, Pressure, Partial Pressure (Atmosphere Composition), Trace Contaminants

Other: Radiation, EMI/EMC, Services: power, thermal, data/communication/video

Unpressurized Carriers (Satellites):

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For additional details, refer to the appropriate Interface Definition Documents (IDD) for the carrier of interest:

Middeck IDD: <http://shuttlepayloads.jsc.nasa.gov/data/PayloadDocs/PayloadDocs.htm>

Spacehab IDD: http://www.boeing.com/nosearch/sh_verification/

From NSTS-21000-IDD-MDK, REV B 6-1 17-Jul-02 / Section 6.1 Environmental Conditions:

- Dew Point +61oF to +39oF
- Cabin Pressure
 - 14.7 + 0.2 PSIA (Normal Operation)
 - 8.0 + 0.2 PSIA (Abort Operations – To be considered for Structural Design Purposes. Payload required to be powered off.)
 - 16.0 PSIA Maximum On-Orbit (Relief Valve Operation)

- 18.1 PSIA maximum (Ground Pressurization Test)
 - Reduced cabin pressure EVA procedure: 10.2 ± 0.5 psia (+ 0.2 PSIA dynamic operating range, ± 0.3 PSIA sensor bias error)
- Cabin Rate of Pressure Change
 - Nominal Ops 2.0 psi/min Repressurization/Depressurization
 - Contingency (other than Bailout) 9.0 psi/min Depressurization/Repressurization
 - 6.1.1 Emergency Bailout Requirements: Payloads located within the crew compartment area shall be designed to meet the following depressurization requirements in order to insure they will not present a hazard to the crew or to the Orbiter which could jeopardize crew survivability or impede crew egress during emergency bailout procedures:
 - Initial (Max) 15.2 PSIA / Final (Min) 3.95 PSIA / Max Depressurization Rate 24.0 PSI/Minute
- Cabin O2 Concentration
 - 25.9 percent at $14.7 + 0.2$ PSIA 30.0 percent maximum at 10.2 PSIA
 - 32.0 percent at 8 psia
- Temperature (Cabin Air)
 - 65 - 80 °F Nominal on-orbit operations
 - 80 °F Peak launch/ascent
 - 75 °F Peak entry/landing
 - 95 °F Peak contingency operations
 - 32 - 120 °F Ferry flight

Pressure and Atmosphere Composition (Partial Pressure)

Structural Loads proportional to pressure - reduce mass with reduced pressure.

Minimum pressure limited by partial pressure oxygen - [physiological limits](#).

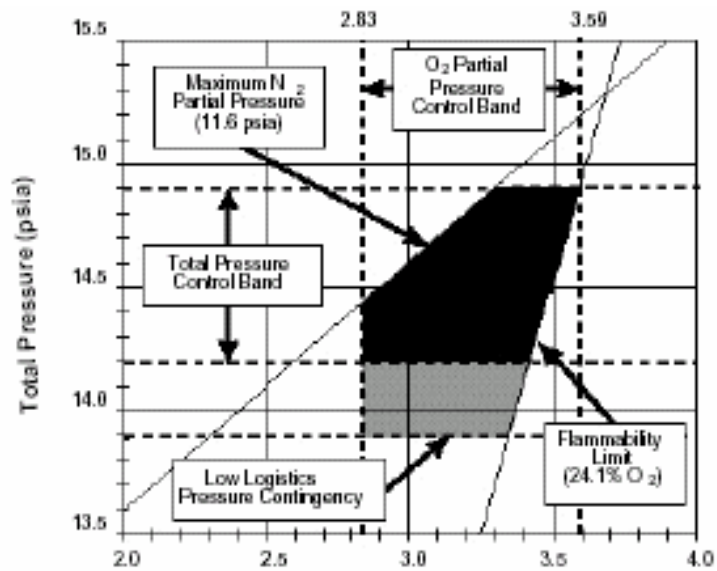
Reduced pressure limits convective heat transfer.

Partial Pressure Oxygen (O2)

Typically keep at 21-30%; Earth: 21%

Flammability (keep at less than 30%): [study of oxygen effects](#)

[Physiological](#) Requirements



Partial Pressure Carbon Dioxide (CO₂)

[Physiological Limits](#): keep below 1% = 10,000 ppm; Earth: 350 ppm

Typical levels depending on crew activity: 2,000 - 7,000 ppm (0.2 - 0.7%)

Pressure Effects: Decompression, Extra-Vehicular Activity

Reduce pressure prior to EVA to aid in reduction of dissolved N₂ in blood

Emergency depressurization rates: 9 psi/min: ==> adequate venting of sealed containers

Trace Contaminants

[offgassing of solvents](#): limited material choices / prefer metals

allowable trace contaminants listed in SMAC (Shuttle Maximum Allowable Concentrations)

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each payload needs offgas test or analysis ([NASA-STD-6001](#)) (72 hrs. @120F @ambient pressure +/- 0.5 psi)

trace contaminants may be harmful to other systems but not humans (ethylene = plant hormone)

Temperature

Comfort / Crew Safety

4°C < T < 45°C for crew safety;

no exposed surfaces below dew point temperature (controlled to 63°F), otherwise condensation

Humidity

Two-Phase Fluid Handling - gas - liquid separation

Dew Point - Condensation - minimum allowable surface temperature > dew point

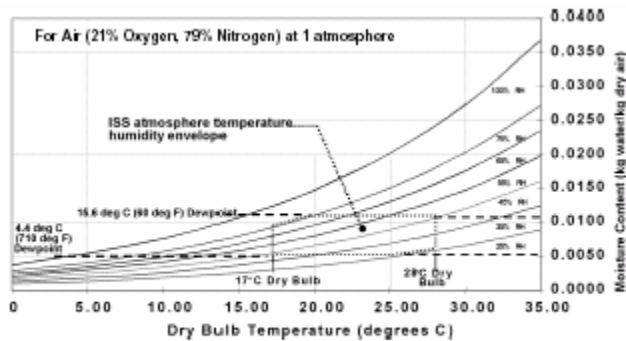


FIGURE 5-1A ISS TEMPERATURE/HUMIDITY ENVELOPE

Airflow / Circulation

- limited exhaust velocity - discomfort / noise

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- limited convective cooling: The ISS design value for the convective heat transfer coefficient from the payload enclosure to the cabin environment is 0.20 Btu/hr °F ft² for 14.7 psia or 0.17 Btu/hr °F ft² for 10.2-psia cabin pressure. These values shall be used in thermal analysis/testing.
- requires cleaning of air inlet / outlet filters

Heat Rejection

- Avionics air cooling (acoustics, crew comfort, air recirculation, maximum allowable exhaust velocity)
- Water cooling (rack payloads only)

Electric Power

- typically 28 VDC, some 110 VAC / 400 Hz available; 5, 10 and 20 Amp typical. Limited number of powered payloads - heat !
- typical middeck locker experiment limited to 130 Watt: heat rejection limit
- Voltage drop across lines
- Conducted EMI: protection against 'noisy' environment needed
- Requires over-current protection devices (fuse, breaker) and adequate wire sizing

Communication

- Even with TDRS, expect LOS (loss of signal) for typically 5-30% of time (during 90 minute orbit)
- Shuttle limited to 'simple' RS232 serial data system for limited number of users
- Space Station: Ethernet communication

Video

- Analog and, more recently digital video downlink available (limited)

Electro-Magnetic Interference EMI

- conducted and radiated EMI - both emissions from payload and susceptibility to EMI from others
- typical sources: DC-DC converters, switches, Ac inverters, computers, display screens, solenoids, motors, valves

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