International Space Station External Contamination Status
[4096-101]

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Effects, Measurements, and Control

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External Contamination Requirements

Requirements

- Contaminant Releases:

  - At the ISS system level, molecular deposition onto ISS sensitive surfaces, from all contamination sources, is limited to 130 Å/year.

  - For active vacuum vents, the design and operation shall meet the requirement that the molecular column density shall be less than $10^{14}$ molecules/cm$^2$ when viewed from selected ISS locations.
Requirements (continued)

- **Contaminant Releases (at the ISS system level):**
  - Total molecular deposition: 130 Å/year
  - Quiescent molecular deposition: 30 Å/year
    - Materials outgassing
    - Venting
    - Leakage
  - Non-quiescent molecular deposition: 100 Å/year
    - Proximity Operations
    - Mated Operations
    - Reboost and Attitude Control

- **Molecular Column Density:**
  - Quiescent periods: $10^{14}$ molecules/cm$^2$ (along line-of-sight)
  - No requirement during non-quiescent periods
Requirements (concluded)

- "Design-To" Requirement:
  - All vehicle hardware suppliers and all users must design to the external contamination environment stated in the previous chart; e.g.,
    - Solar arrays
    - Radiators (active and passive)
    - Sensors
    - Payloads ("design-to" requirement not imposed on Attached Payloads)
External Contamination Requirements

"Design-to" Level 130 Å/year
(solar arrays, radiators, payloads, etc. designed to this level)

- Materials outgassing
- Active vacuum vents
- Leakage

Space Shuttle prox ops
Space Shuttle mated ops
Russian Segment reboost and attitude control
Progress
Soyuz
ESA ATV
NASDA HTV
U.S. Propulsion Module
ICM

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ISS External Contamination Sources

- Materials outgassing (vacuum exposed materials)
- Vacuum venting
- Leakage
- Propellant purging
- ISS reboost and attitude control:
  - Russian thrusters on Service Module and SPP
  - ESA Automated Transfer Vehicle (ATV) as part of the Russian Segment
  - U.S. Propulsion Module
  - U.S. Interim Control Module (ICM)
- Proximity operations:
  - Space Shuttle
  - ESA ATV
  - NASA H-2 Transfer Vehicle (HTV)
  - Russian Progress
  - Russian Soyuz
- Space Shuttle mated operations:
  - Fuel cell and waste water dumping
- Attached and pressurized payloads
ISS External Contamination
Sensitive Surfaces

- Debris shields
- Solar arrays
- Radiators (active and passive)
- Viewing ports/windows
- Vehicle optical sensors, cameras, etc.
- Transmitters
- Payload locations:
  - S3 Truss
  - JEM EF and ELM
  - Columbus external payload facility
  - Service Module and SPP
  - Lab window
ISS External Contamination
Sensitive Surfaces

Solar Arrays
Active Radiators
Passive Radiators

Windows
Payloads
Pressurized Modules

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ISS External Contamination Control

Pre-Launch Verification
- Analyses for Verification
- Laboratory testing
  - Materials outgassing
  - Water venting
  - Optical degradation due to induced external contamination and environmental exposure
  - Plume measurements
- Flight Experiments and observations
  - Space Shuttle flight experiments
  - Mir flight experiments
  - Shuttle-Mir (Phase 1) Risk Mitigation Experiments

On-Orbit
- Inspection of hardware
- Flight imaging (flight-by-flight)
- ISS flight data:
  - Vehicle performance
  - Payloads environmental data

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ISS External Contamination Control for Pre-launch Verification

ISS Configuration Assembly Sequence Traffic Model

Outgassing Testing

Identification Usage Operating Temperatures

Materials Post-Processing (If Necessary)

Vacuum Exposed Materials

Proximity Operations

Reboost and Attitude Control

Mated Configuration
- Operations (Water Dumping)
- Materials Outgassing

Plume Models Jet Firing Histories

Flight Experiments PIC/SPIFEX

Laboratory Tests

External Contamination Analyses

Flight/Laboratory Test Data

Verification

Master Database
- Source-by Source
- Stage-by-Stage
- Sensitive Surfaces
- Induced Optical Properties Degradation

Operational Constraints

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Flight Experiments and Observations

- **Mir**
  - Docking Collar Camera Bracket (U.S.)
  - ICA (ESA Euro-Mir '95)
  - Astra-II (Russian)
  - Comes-Aragatz (French)
  - Mir Imaging (U.S.)
  - TREK (U.S.)
  - Phase 1 Risk Mitigation Experiments (U.S.):
    - Mir Environmental Effects Payload (MEEP)
    - Optical Properties Monitor (OPM)
    - Space Portable SpectroReflectometer (SPSR)
    - Mir Solar Array Return Experiment (SARE)

- **Space Shuttle**
  - SPIFEX (STS-64)
  - PIC (STS-74)
  - Water Dump (STS-29)
  - IECM (STS-2, STS-3, STS-4)
  - IOCM (STS-34, STS-44)
  - HST SM2 (STS-82)
  - EOIM-III (STS-46)
  - AMS (STS-91)

- Long Duration Exposure Facility (LDEF)
- Hubble Space Telescope (HST)
Example Flight Observation:
Space Shuttle Orbiter Waste Water Dump
Materials Outgassing

- All materials which are possible sources of contamination undergo outgassing rate testing.

- Condensable materials outgassing rates are obtained by long duration ASTM E 1559 testing.

  - Material sample (emitter) is tested over the on-orbit operational temperature range identified by the ISS system level thermal model.

  - Temperature-Controlled Quartz Crystal Microbalances (TQCMs), or receivers, are held at different temperatures covering the typical range of operational temperatures of ISS contamination sensitive hardware, such as the Active Thermal Control System (ATCS) and passive radiators.

  - Testing is of long duration, typically 144 hours.

- ASTM E 595 testing is used as an initial screen.
Active Vacuum Vents

- The current ISS vent database identifies 33 active vacuum vents on the International Space Station.
- Vacuum venting must comply with molecular column density and molecular deposition requirements.
  - ISS vents are considered quiescent sources (with exception of the U.S. Lab condensate water vent which is considered non-quiescent until assembly complete).
  - Most ISS vents do not produce molecular deposits on ISS surfaces. Typical exhaust composition for these vents include air, carbon dioxide and hydrogen.
  - Molecular column density (MCD) requirements limit mass flow rates for ISS vents. Scheduling of venting events may be required for vacuum exhaust systems on U.S. Lab, ESA Columbus module and JEM Pressurized Module due to their high flow rate capacities to accommodate internal payloads.
Example of Molecular Column Density Profile

View from Starboard Upper Payload Position Looking in the Wake Direction

SUW View  - log10(#/cm^2)
Location : 0.75,-10
Direction : -1,0,0
LAB1 VES "T"
Combustion Facility

- >15.5
- >15.35
- >15.2
- >15.05
- >14.9
- >14.75
- >14.6
- >14.45
- >14.3
- >14.15
- >14
The NASAN program is used to model external contamination for the ISS program.

- Evolved from the MOLFLUX program, previously used during the Space Station Freedom program.

- NASAN can model up to 100,000 surface elements, with variable geometry and multi-spacecraft interactions. MOLFLUX was limited to about 3,000 to 4,000 surfaces, with fixed geometry.

- NASAN produces output in graphical format, condensing hundreds of pages of information in a single color plot.

- Direct Simulation Monte Carlo (DSMC) methods have been employed to model return flux and small features of specific problems encountered during ISS design activities.

- A Smooth Particle Hydrodynamics (SPH) code is being used to examine particle impacts to ensure no damage to ISS structures.
Sources of Outgassing Induced Contamination Analyzed To Date

Note: Elements analyzed shown in color.
Example of Outgassing Induced Contamination Analysis

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S0 Truss Element Outgassing

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ISS External Contamination: Quiescent Sources

Sources: FGB, Node 1, PMA1, PMA2, Service Module, Progress, Z-1 Truss, Ku & S-band Antennas, PMA3, Soyuz 1, P6 IEA, P6 Long Spacer, S6 IEA (PH), S6 Long Spacer (PH), S4 IEA (PH), P4 IEA (PH), Soyuz 2, US Lab, Airlock, S0 Hab (PH), PDGF, Orbiter

Assembly Complete Total Yearly Deposition (Å/year)

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Ron Mikatarian
John Alred  February 4, 2000

ISS External Contamination : Non-Quiescent Sources

Sources : Progress, Soyuz, Russian Segment Reboost & Attitude Control, HTV, Orbiter

Assembly Complete Total Yearly Deposition (Å/year)

- Progress
- Soyuz
- RS Reboost & AC (w/ updated Plume Model)
- HTV Prox. Ops. (Preliminary)
- Orbiter Prox. Ops.
Observations on Optical Degradation due to Induced External Contamination in LEO

- Organic silicones typically convert to silicates (SiO$_x$) on-orbit due to AO/VUV exposure.

- Hydrocarbon contaminants usually erode on-orbit due to AO exposure.

- On orbit, silicone contaminants deposit on surface. In the laboratory, silicone and hydrocarbon contaminants diffuse into the porous structure of the substrates.

- Optical degradation on samples pre-contaminated with hydrocarbons observed to recover on-orbit.

- On-orbit induced contamination optical degradation depends on contaminant flux, AO flux, and VUV exposure.
Example of Typical Contaminant Profile

Sample AZC027: Pre-contaminated Z93 White Ceramic Paint - Ground Control

Sample AZC028: Pre-contaminated Z93 White Ceramic Paint - Flight Exposed

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Examples of Contaminant Depth Profile

Clad Aluminum Substrate

Sulfuric Acid Anodized Aluminum Substrate
ISS System
○ System Level Requirements will be met.

Material Outgassing
○ Process in place working effectively with US and IP hardware producers to control external contamination.

Thruster Plumes
○ New activity in place for developing updated plume contamination model.
  ➤ Laboratory tests being conducted.
  ➤ Space Shuttle flight test in 2001 (STS-108).

Optical Degradation
○ Activity in place for developing updated LEO external contamination optical degradation model.
○ Laboratory tests being conducted.