Strategies for Distinguishing between Indigenous Life and Earth Contamination

Laboratory Contamination Control and Containment

Judy Allton
Exploring

Difference between Contamination Control and Containment

Difference between Life Detection and Biohazard

- LIFE DETECTION related to CONTAMINATION CONTROL
- BIOHAZARD related to CONTAINMENT
Based on experience

Astromaterials Curation

• Moon rocks and fines
• Meteorites
• Cosmic dust
• Genesis Solar Wind atoms
• Stardust comet Wild-2
• Haybusa asteroid Itokawa
• Micro-impact craters
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1965</td>
<td>LRL 1964-1968</td>
</tr>
<tr>
<td>1969-1972</td>
<td>B. 31 Lunar Curation</td>
</tr>
<tr>
<td>1977-1979</td>
<td>B. 31N Lunar Curation, 1979+</td>
</tr>
<tr>
<td>1981+</td>
<td>Cosmic Dust Curation</td>
</tr>
<tr>
<td>1985+</td>
<td>Microparticle Impact Curation</td>
</tr>
<tr>
<td>1998-2000</td>
<td>Genesis Payload Assy</td>
</tr>
<tr>
<td>2000</td>
<td>Genesis Curation 2001+</td>
</tr>
<tr>
<td>2001+</td>
<td>(samples arrived 2004)</td>
</tr>
<tr>
<td>2006+</td>
<td>Stardust Curation</td>
</tr>
<tr>
<td>2012+</td>
<td>Hayabusa Curation</td>
</tr>
<tr>
<td>2015+</td>
<td>O-REx Reference Curation</td>
</tr>
<tr>
<td>1967-1970</td>
<td>Vacuum Glovebox</td>
</tr>
<tr>
<td>1970+</td>
<td>Positive Pressure Dynamic Nitrogen Glovebox</td>
</tr>
<tr>
<td>1970+</td>
<td>Positive Pressure Static Nitrogen Long-Term Storage</td>
</tr>
<tr>
<td>1981+</td>
<td>ISO Class 5 (Class 100) Laminar Flow Room</td>
</tr>
<tr>
<td>1998+</td>
<td>ISO Class 4 (Class 10) Laminar Flow Room</td>
</tr>
<tr>
<td>2012+</td>
<td>N2 glovebox in ISO Class 5 Laminar Flow Room</td>
</tr>
<tr>
<td>1968-1984</td>
<td>Freon 113 Final Cleaning for Containers &amp; Tools</td>
</tr>
<tr>
<td>1994+</td>
<td>Ultrapure Water Final Cleaning for Containers &amp; Tools</td>
</tr>
</tbody>
</table>
Issues

• TECHNICAL TENSION
• REQUIRED DOCUMENTATION ACCESS
• IDENTIFICATION OF CONTAMINATION
• DEDUCING SPECIMEN CHANGES SINCE COLLECTION
Issues

- TECHNICAL TENSION
- Organic vs inorganic (molecular vs particle)
- Clean vs contained (positive vs negative $\Delta P$)

**Particle-clean vs Organic-clean ... Technical Challenges**

**PARTICLE CLEAN**
Typically achieved by sweeping away particles using filtered air (HEPA, ULPA).

**ORGANIC CLEAN**
Typically handled in a glovebox, a non-particle-sweeping environment.
Issues

- TECHNICAL TENSION
- Clean vs contained (positive vs negative $\Delta P$)

**Positive vs Negative $\Delta P...$ Technical Challenges**

**CLEAN**
Typically achieved by pressure gradients – highest pressure is cleanest environment.

**CONTAINED**
Sealed container or handled in a negative pressure glovebox.
Issues

• REQUIRED DOCUMENTATION ACCESS
• Many institutions
• Electronic models – engineering drawings: can they be read in the future
• IDENTIFICATION OF CONTAMINATION
• Natural biological vs industrial
  • Species, isotopes, chirality
• Natural biological Mars vs natural biological Earth
  • Blanks, mineral context/morphology
  • Hardware and process reference materials
• Natural biological Mars vs natural biological meteorite Mars infall
  • Species, Mars meteorite reference, Mars in situ reference, meteorite reference, experiments
• DEDUCING SPECIMEN CHANGES SINCE COLLECTION
  • During collection
    • Analog experiments
    • Reference sample material
    • Reference hardware material
  • During storage and transport (Mars wait time, cruise, Earth entry)
    • Thermal and pressure histories
  • Chemical reactions (redox, biological)
    • With container
    • Among sample components
  • Changes of state (thermal cycling)
    • Volatile loss, isotope fractionation,
Basic Contamination Control for Sample Return

• START CLEAN – STAY CLEAN
• LAB DESIGN & CONTROLS
• DOCUMENTATION
• REFERENCE MATERIALS

EXAMPLE: Genesis solar wind
Basic Contamination Control for Sample Return

Start Clean – Stay Clean: Defined by those who will analyze samples

• **Cleanliness level of collectors set by science team:** C, N, O <10E15 atoms/cm², remainder not to exceed solar wind fluence
• Science team responsible for identifying methods for measuring pre-flight cleanliness levels on collectors and for verifying adequate contamination control performance and surface cleanliness of flight materials
• JSC responsible for overall mission contamination control, with specific responsibilities for providing cleanroom facilities for Science Canister cleaning, assembly and function testing. Further, for design and set-up of facility for receiving post-flight the Science Canister and curating collectors.
• JSC continues to work closely with the Science Team analyzing collectors.

Genesis
Collector Materials are “containers” which will capture and hold solar wind.

- Must be pure enough
  - Solar wind fluence is low
  - Design goal is signal to noise ratio >100, critical requirement SNR >10

- Must be clean enough
  - Surface contamination < 2 year SW fluence for any element
  - If some surface contamination does occur, there must be methods for removing it
Basic Contamination Control for Sample Return

Start Clean – Stay Clean: cleaning and assembly

- ISO Class 4 for cleaning and assembly
- New cleaning techniques – megasonic energized UPW
- Verification methods: particle count rinse water, optical inspection, witness coupon measurement (XPS) to validate process
- Measurement of airborne molecular contamination (semi-annually), particle counts (weekly)
- Continual monitoring of UPW quality: resistivity 18.2 MW, TOC, 5 ppb. UPW chemical & biological analyses (semi-annually or as needed). Ion concentration low parts/trillion
- Material and personnel access controlled
Basic Contamination Control for Sample Return

Start Clean – Stay Clean: mission lifetime

Mission Design

- Collector material purity, cleanliness and variety
- Canister sealed in cleanroom until arrival at L1
- Sealed canister on nitrogen purge from JSC cleanroom until launch
- Thruster plume not in line-of-sight of exposed collectors
- Re-entry filtration/sorbent during re-pressurization
Basic Contamination Control for Sample Return

• LAB DESIGN
  • Pressure control, HEPA filtered
  • Acceptable materials

• LAB CONTROLS
  • Procedures
    • Access, sample handling, tool and container cleaning
  • Monitoring & witness plates
    • Airborne molecular, particulate chemistries
    • Airborne particle sizing
    • UPW resistivity, TOC, cation-anion composition
    • Purge gas composition monitoring (water, O2)
    • Witness plates
  • Reference environmental materials
Basic Contamination Control for Sample Return Lab Design

- Pressure control, HEPA filtered
- Acceptable materials
Basic Contamination Control for Sample Return Lab Design

- Pressure control, HEPA filtered
- Acceptable materials

All materials used in constructing and equipping the building (including floor coverings, walls, plumbing, light fixtures, and paint) were carefully screened to exclude chemical elements that would pose unacceptable contamination threats to the lunar samples.

Materials allowed into the laboratory and into the gloveboxes are constrained to a few, simple composition of acceptable chemical elements, non-shedding and easily cleanable with UPW.

Scientific oversight committee carefully reviewed details throughout construction.
Basic Contamination Control for Sample Return
Lab Controls

- Procedures
- Monitoring & witness plates
- Reference environmental materials

149 procedures detail work, for all collections, in these categories:
- Sample handling, characterization, packaging, storage
- Tool and container cleaning
- Laboratory operation (N2, UPW, air handling), housekeeping
- Documentation, database requirements
- Entry/exit, access, security, sample inventory, hurricane shutdown
Basic Contamination Control for Sample Return
Lab Controls

• Procedures
  Monitoring & witness plates
  Airborne molecular, particulate chemistries
  Airborne particle sizing
  UPW resistivity, TOC, cation-anion composition
  Purge gas composition monitoring (water, O2)
  Witness plates

• Reference environmental materials
  Samples flooring, wall paint, etc.

Example: Genesis laboratory, with 54 ULPA and HEPA fan filter units supplied by a HEPA filtered air handler, deposits 10 ng/cm² on a 24-hour witness wafer. The composition is mostly siloxanes from the RTV and plasticizers. This technique captures the higher molecular weight species, likely to “stick” to sample surfaces.
Basic Contamination Control for Sample Return Documentation needed in the future

Pre-flight hardware assembly
- Lab construction material composition
- Lab cleanliness monitoring
- **Flight hardware drawings**, material usage lists
- Flight hardware cleanliness and assembly records (procedures)

Flight data
- Basic – launch, entry, ascent, landing
- Surface operations – timeline, environmental conditions, spacecraft anomalies
- Instrument operations

Recovery data
- Activity logs, field procedures
- Imagery of recovery operations
- Cleanliness monitoring at site

Curation data – ongoing for life of collection
- DETAILED sample handling records (when, where and what for each move), audit trail – needed for control
- Facility operation & cleanliness monitoring logs & data
- Procedures – samples, security & housekeeping, container & tool cleaning
- Sample characterization, including imagery
- Allocation records, correspondence with oversight committees
Basic Contamination Control for Sample Return

- REFERENCE MATERIALS
- Essential for low level measurements
- High fidelity for material and processing

Wentworth 2007

Genesis capturing the sun: Solar wind irradiation at Lagrange 1
Michael J. Calaway a,*, Eileen K. Stansbery b, Lindsay P. Keller c
a Jacobs (IESDC) at NASA Johnson Space Center, Mail Code KT, 2101 NASA Parkway, Houston, TX 77058, United States
b NASA at NASA Johnson Space Center, Houston, TX 77058, United States
c NASA at NASA Johnson Space Center, Houston, TX 77058, United States

>600 Genesis-flown
>300 reference pieces
List of sample laboratories within the LRL (behind the bio barrier):

- Vacuum system
- Gas Analysis Lab
- Physical-Chemical Test Lab
- Spectrographic lab
- Radiation Counting Lab
- Bio-prep Lab
- Bio-analysis Lab
- Holding lab for germ-free mice
- Holding lab for conventional mice
- Lunar Microbiology Lab
- Bird, fish, invertebrate lab
- Microbiology lab
- Egg and tissue culture lab
- Plant lab for germ-free algae, spores, seeds

Other labs behind the LRL bio-barrier:
- Crew virology lab
- Bio-safety lab
- Bio-medical lab
Containment

Apollo Lunar Receiving Laboratory Vacuum Glovebox
Debate between biohazard detection and planetary science - portion of samples required for biohazard testing:

Portions of some samples, including samples from core tubes to obtain subsurface material shielded from radiation, were allocated for quarantine testing. A total of 2.259 kg from all missions, less than 1%, was allocated for quarantine testing and the follow-up biological measurements for Apollo 15, 16 and 17 samples.
Conclusion

Difference between Contamination Control and Containment

Difference between Life Detection and Biohazard

• LIFE DETECTION related to CONTAMINATION CONTROL
• BIOHAZARD related to CONTAINMENT

Team building helps manage the conflicts.
PARTICULATE VS ORGANIC CLEANLINESS: Technical tension

Room air particulate cleanliness achieved by continual filtration using HEPA, ULPA filters. Clean air sweeps away airborne particles. These devices are typically constructed using RTV sealant, which offgases siloxanes and other airborne molecular species.

Cleanest air is achieved with controlled unidirectional flow.

Organic cleanliness for small work areas, like gloveboxes or robotic enclosures, may be achieved by use of clean cover gas, e.g., point-of-use purification and filtration of nitrogen.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>30 Elements on 200mm or smaller Bare Wafers by VPD</th>
<th>COLD GLOVE BOX</th>
<th>CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units: 1e10 atoms/cm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>0.05</td>
<td>81</td>
<td>*</td>
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<tr>
<td>Antimony (Sb)</td>
<td>0.005</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Barium (Ba)</td>
<td>0.001</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>0.3</td>
<td>0.5</td>
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<tr>
<td>Cadmium (Cd)</td>
<td>0.003</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>0.1</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Cerium (Ce)</td>
<td>0.001</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>0.01</td>
<td>1.3</td>
<td></td>
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<tr>
<td>Cobalt (Co)</td>
<td>0.005</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.01</td>
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<td>*</td>
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<tr>
<td>Gallium (Ga)</td>
<td>0.005</td>
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<td>*</td>
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<tr>
<td>Indium (In)</td>
<td>0.001</td>
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<td>*</td>
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<tr>
<td>Iron (Fe)</td>
<td>0.05</td>
<td>5.3</td>
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<td>Lithium (Li)</td>
<td>0.05</td>
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<td>*</td>
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<tr>
<td>Magnesium (Mg)</td>
<td>0.05</td>
<td>2.7</td>
<td>0.59</td>
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<tr>
<td>Manganese (Mn)</td>
<td>0.01</td>
<td>0.16</td>
<td>0.01</td>
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<tr>
<td>Molybdenum (Mo)</td>
<td>0.005</td>
<td>0.005</td>
<td>*</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.05</td>
<td>0.97</td>
<td></td>
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<tr>
<td>Potassium (K)</td>
<td>0.05</td>
<td>0.41</td>
<td>0.50</td>
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<tr>
<td>Rubidium (Rb)</td>
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<tr>
<td>Sodium (Na)</td>
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<td>Strontium (Sr)</td>
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<td>Thorium (Th)</td>
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<td>Tin (Sn)</td>
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<td>Titanium (Ti)</td>
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<td>Uranium (U)</td>
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<tr>
<td>Vanadium (V)</td>
<td>0.01</td>
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<td>*</td>
</tr>
<tr>
<td>Yttrium (Y)</td>
<td>0.002</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.05</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Zirconium (Zr)</td>
<td>0.005</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* = Analysis revealed that the analyte was not found at or above the reporting limit.  RL = Reporting Limit.

Report Notes: Witness wafer exposed for 24 hours, 5/13-14:08.