



National Aeronautics and Space Administration



# Strategies for Distinguishing between Indigenous Life and Earth Contamination

Laboratory Contamination Control and Containment

Judy Allton



EXPLORATION INTEGRATION AND  
SCIENCE DIRECTORATE

# Exploring

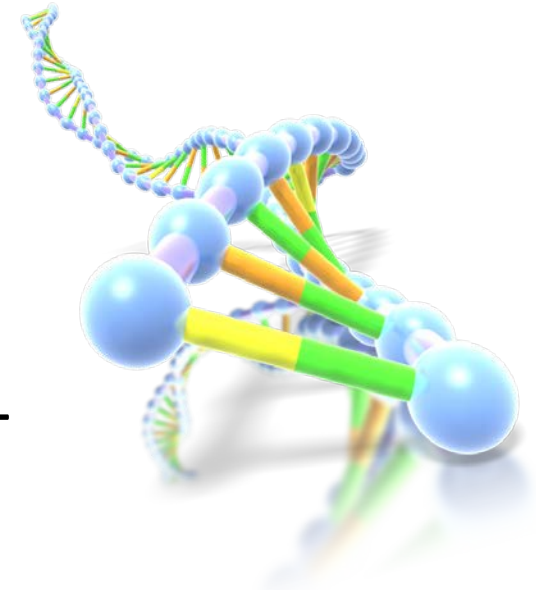


## Difference between Contamination Control and Containment

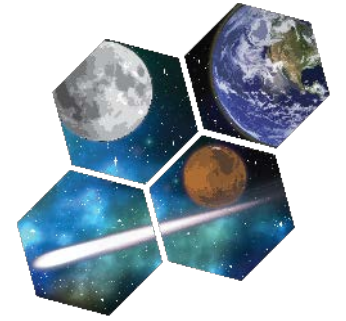
## Difference between Life Detection and Biohazard



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

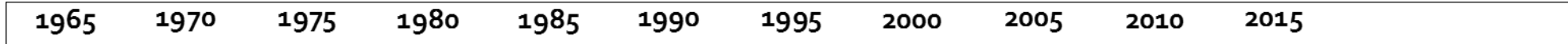


# Based on experience



## Astromaterials Curation

- Moon rocks and fines
- Meteorites
- Cosmic dust
- Genesis Solar Wind atoms
- Stardust comet Wild-2
- Haybusa asteroid Itokawa
- Micro-impact craters



### New Facility Planning, Construction, Check-out

LRL  
1964-1968

B. 31N  
1972-1979

*Retro-fit facilities:* B. 31 Lunar Meteorite Cosmic Dust    Microparticle Impact Genesis Stardust    Hayabusa O-REx

### Sample Handling & Curation Facility Operation

LRL  
1969-1972

B. 31 Lunar  
1972-1979

B. 31N Lunar Curation, 1979 +

Lunar Thin Section

Remote Storage: Brooks AFB 1975-2002

Remote Storage: 2002 +

Meteorite Curation 1977 +

Meteorite Thin Section 1977 +

Cosmic Dust Curation 1981 +

Microparticle Impact Curation 1985 +

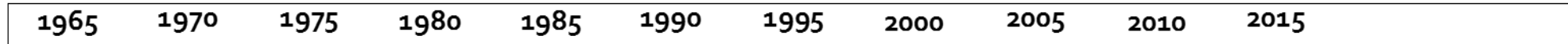
Genesis Payload Assy 1998-2000

Genesis Curation 2001 + (samples arrived 2004)

Stardust Curation 2006 +

Hayabusa Curation 2012

O-REx Reference Curation 2015 +



### Sample Handling Environment

Vacuum Glovebox  
1967-1970

Positive Pressure Dynamic Nitrogen Glovebox 1970 +

Positive Pressure Static Nitrogen Long-Term Storage 1970 +

ISO Class 5 (Class 100) Laminar Flow Room 1981 +

ISO Class 4 (Class 10) Laminar Flow Room 1998 +

N2 glovebox in ISO Class 5 Laminar Flow Room 2012+

### Common Infrastructure Support

Freon 113 Final Cleaning for Containers & Tools 1968-1984

Ultrapure Water Final Cleaning for Containers & Tools 1994 +

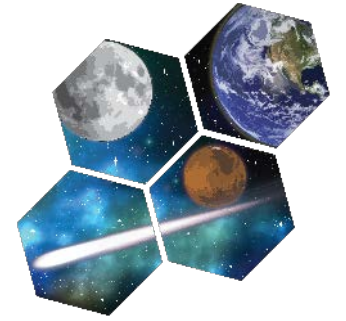
# Issues



- 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  $\Delta P$ )

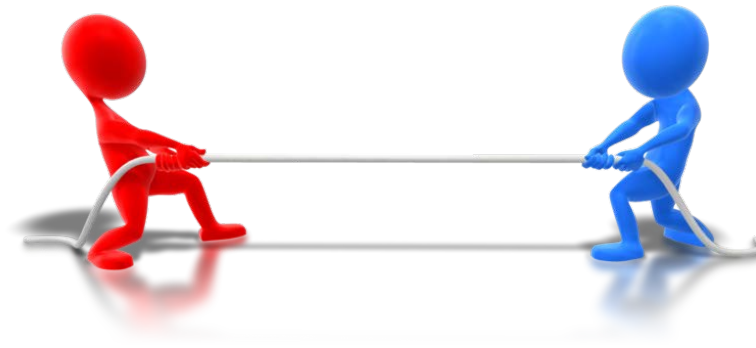


## Particle-clean vs Organic-clean ... Technical Challenges



### 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



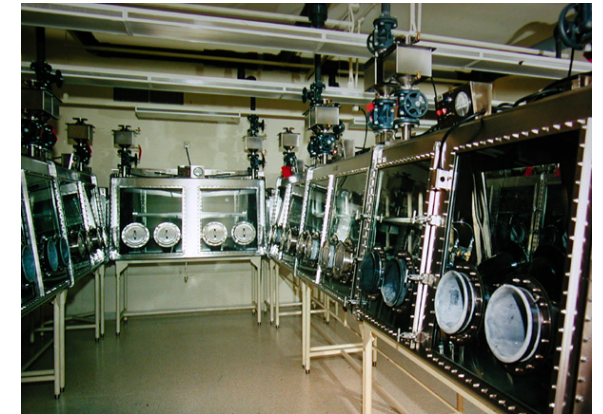
### CLEAN

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



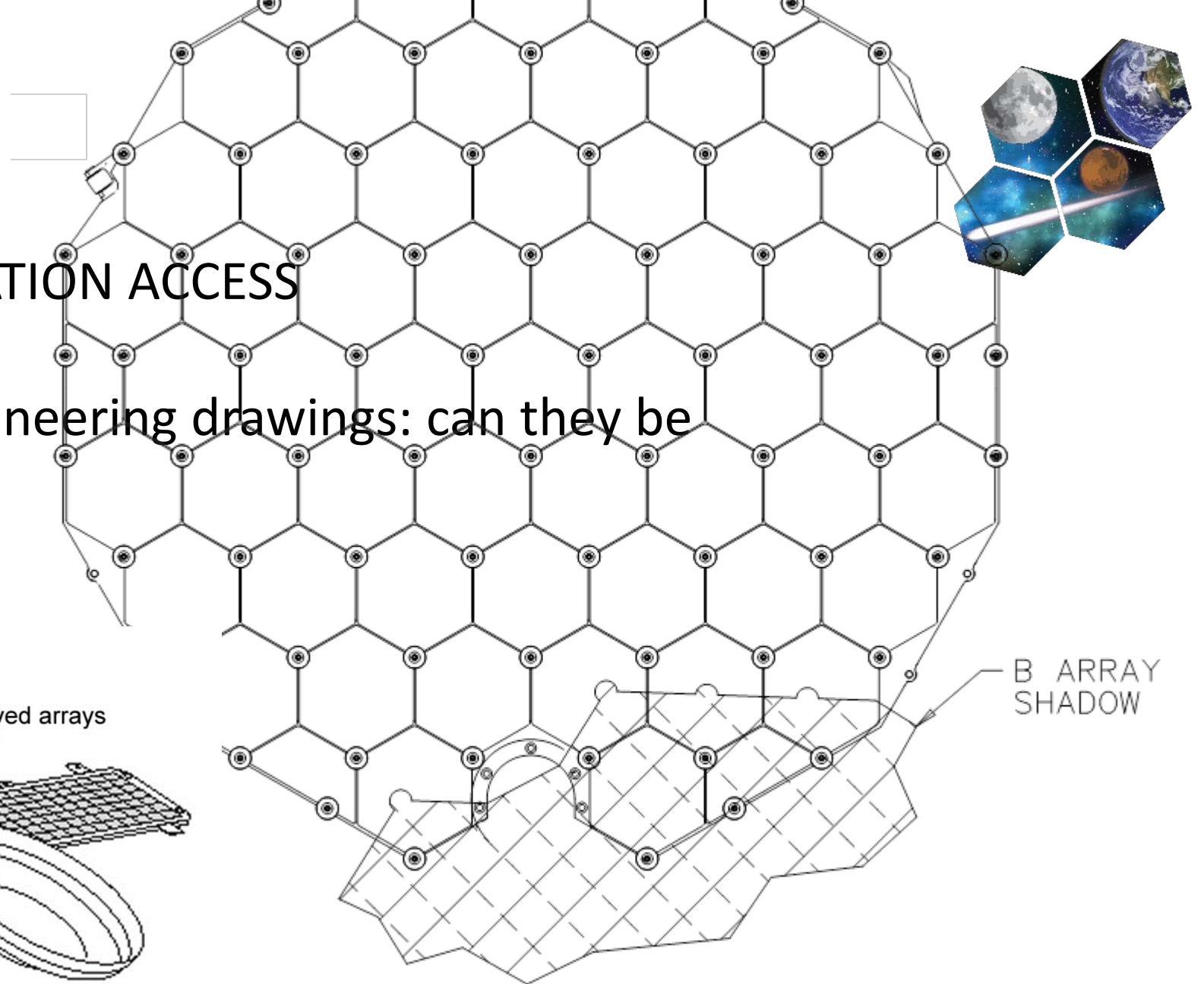
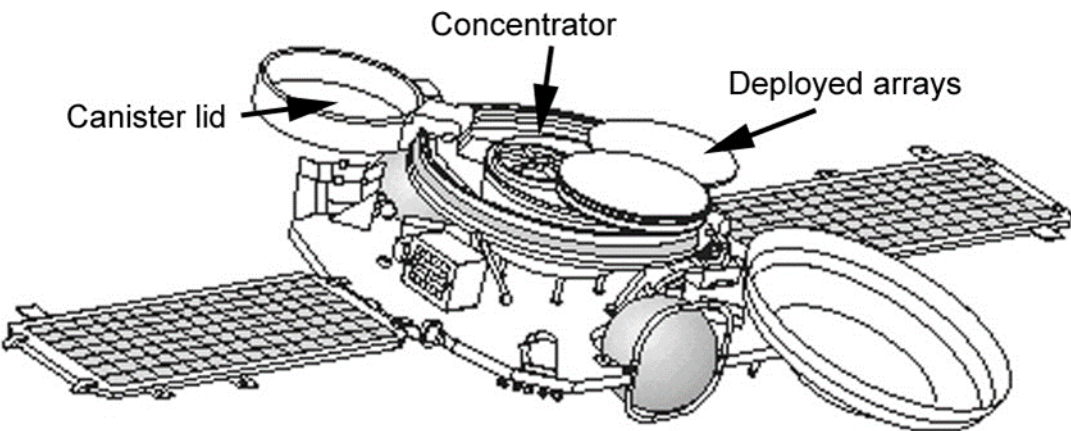
### CONTAINED

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



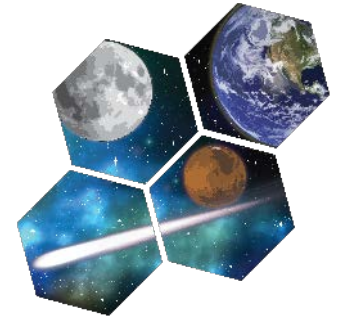


# Issues



- 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

# Issues

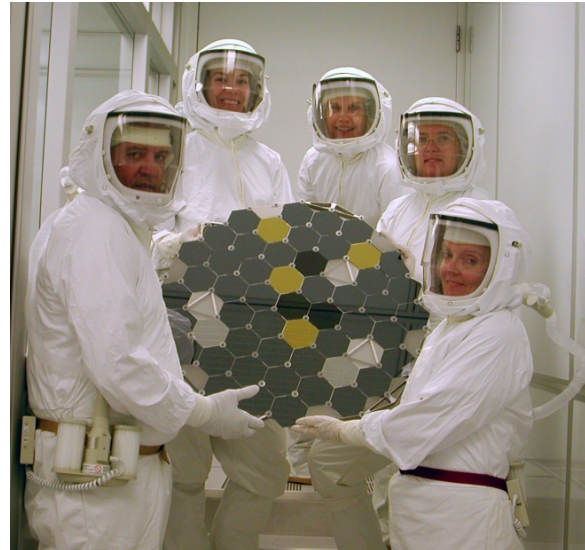


- DEDUCING SPECIMEN CHANGES SINCE COLLECTION
  - During collection
    - Analog experiments
    - Reference sample material
    - Reference hardware material
  - During storage and transport (Mars wait time, cruise, Earth entry)
    - Thermal and pressure histories
  - Chemical reactions (redox, biological)
    - With container
    - Among sample components
  - Changes of state (thermal cycling)
    - Volatile loss, isotope fractionation,

# Basic Contamination Control for Sample Return

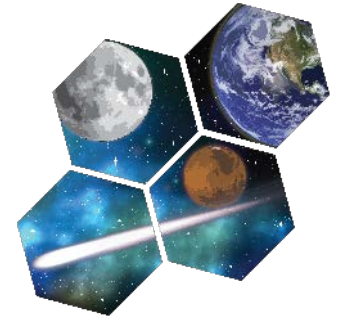


- START CLEAN – STAY CLEAN
- LAB DESIGN & CONTROLS
- DOCUMENTATION
- REFERENCE MATERIALS



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/cm<sup>2</sup>, 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.

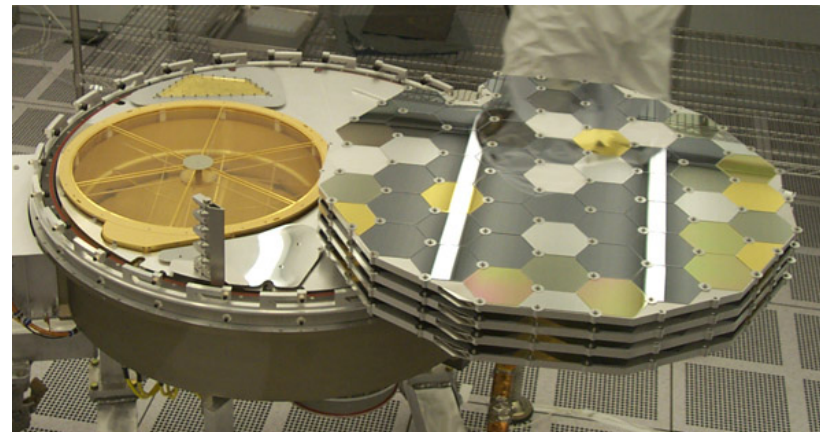
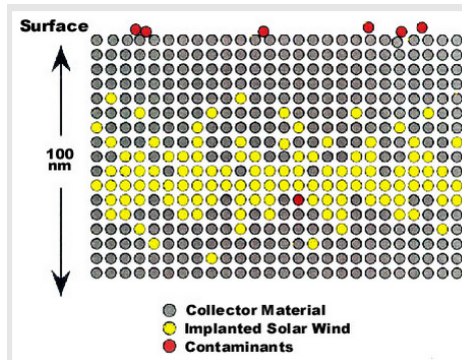
Genesis

# Basic Contamination Control for Sample Return



## Start Clean – Stay Clean: pure, clean hardware

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

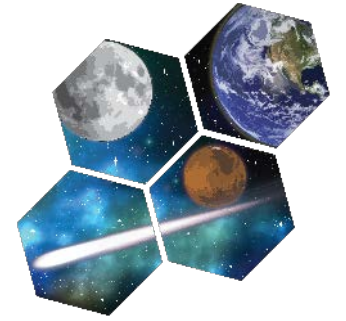


- Must be pure enough
  - Solar wind fluence is low
  - Design goal is signal to noise ratio >100, critical requirement SNR >10
- Must be clean enough
  - Surface contamination < 2 year SW fluence for any element
  - If some surface contamination does occur, there must be methods for removing it

Genesis

# Basic Contamination Control for Sample Return

## Start Clean – Stay Clean: cleaning and assembly



### Genesis

- 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

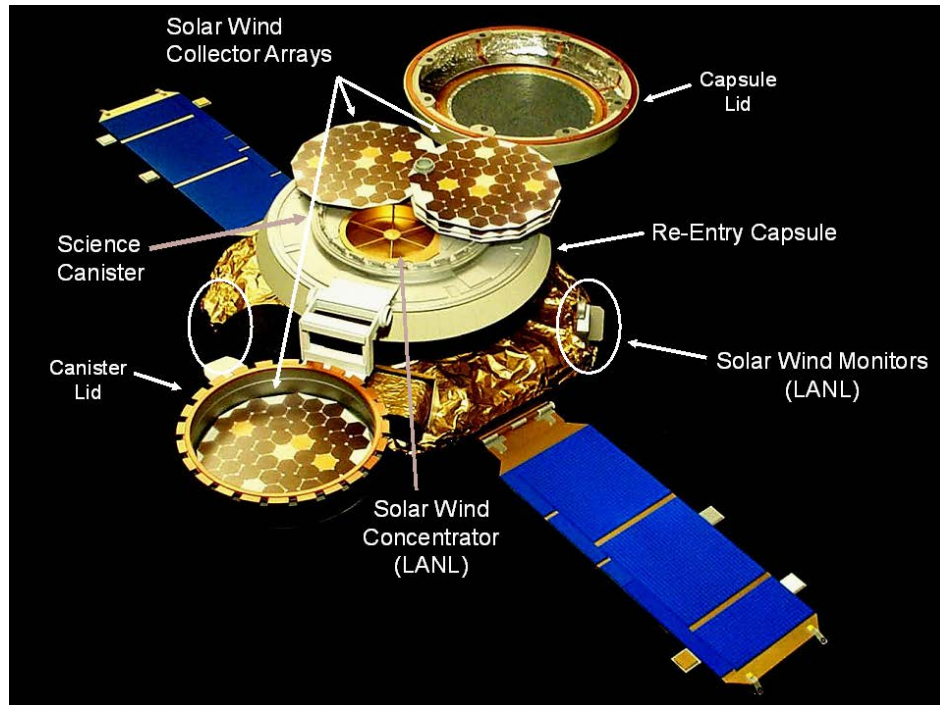


# Basic Contamination Control for Sample Return

## Start Clean – Stay Clean: mission lifetime



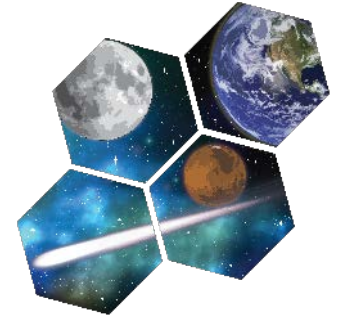
Genesis



### 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, O<sub>2</sub>)
  - Witness plates
- Reference environmental materials



# Basic Contamination Control for Sample Return Lab Design

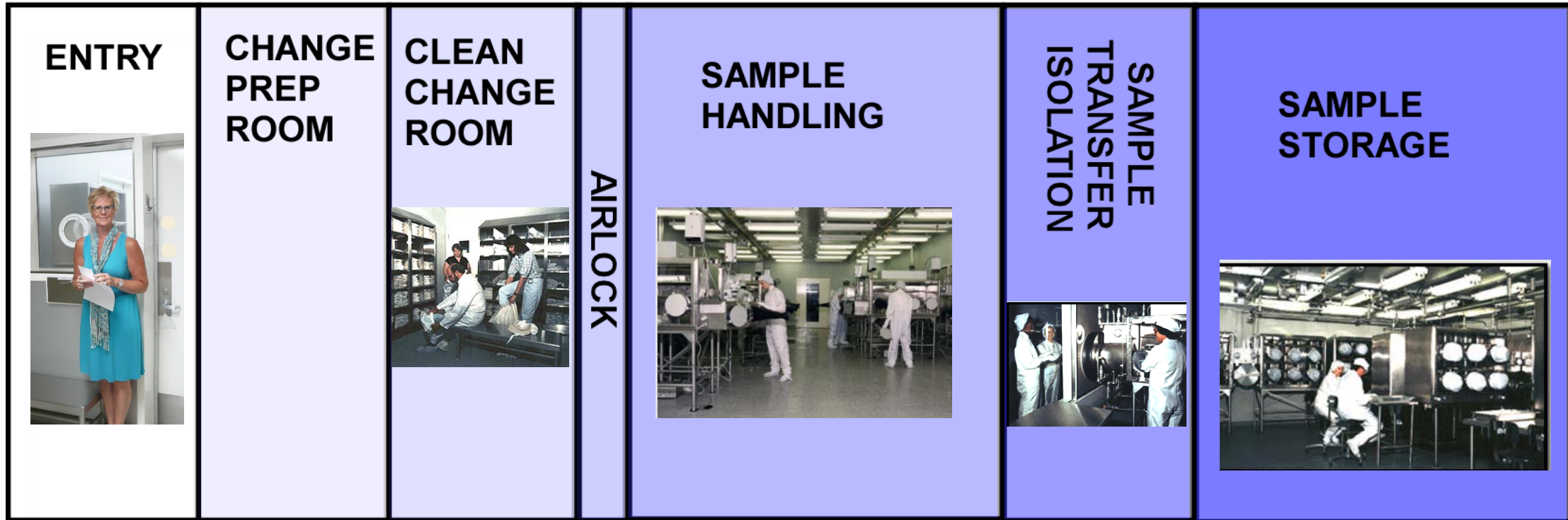


- Pressure control, HEPA filtered
- Acceptable materials

**DIRTY**  
Lowest  
Pressure

Apollo Curation

**CLEAN**  
Highest Pressure



# Basic Contamination Control for Sample Return Lab Design

- Pressure control, HEPA filtered
- **Acceptable materials**

Apollo Curation



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

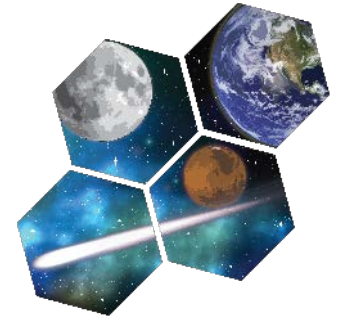
- **Procedures**
- Monitoring & witness plates
- Reference environmental materials



**149 procedures detail work, for all collections, in these categories:**

- **Sample handling, characterization, packaging, storage**
- **Tool and container cleaning**
- **Laboratory operation (N<sub>2</sub>, 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, O<sub>2</sub>)

    - 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/cm<sup>2</sup> 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

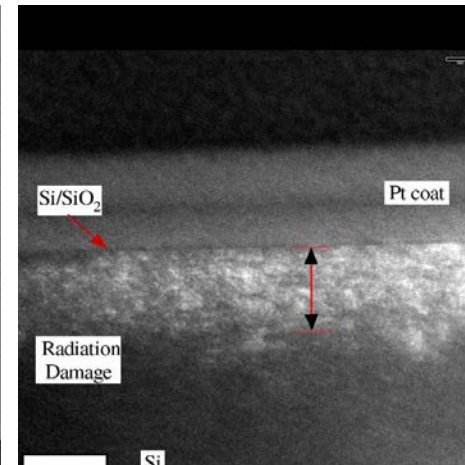
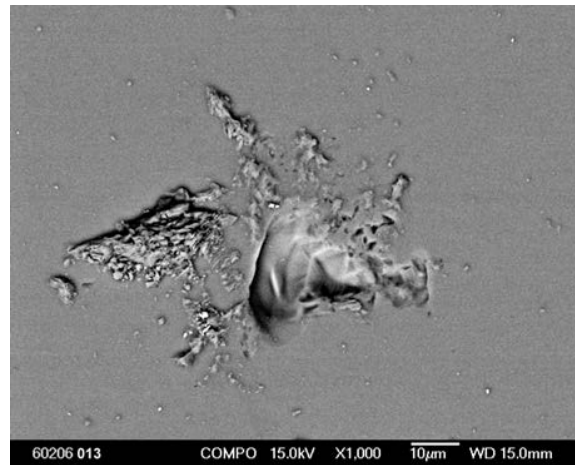
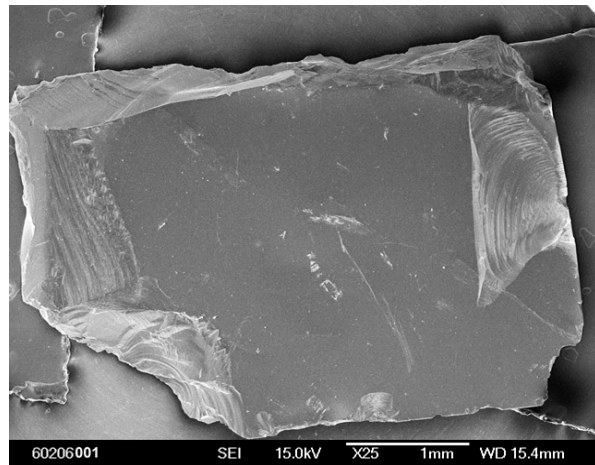
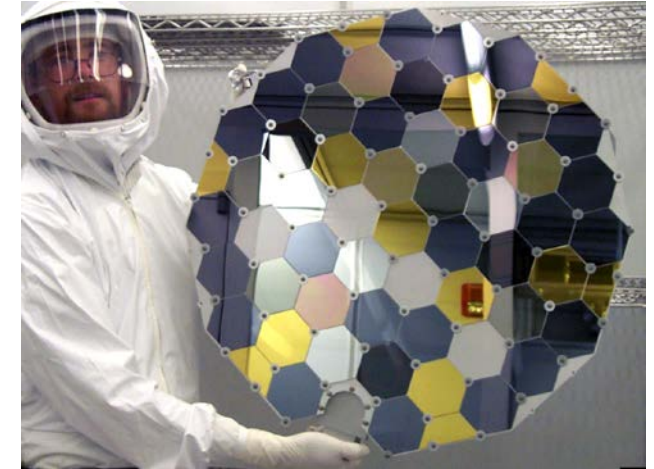
- DETAILED sample handling records (when, where and what for each move), audit trail – needed for control
- Facility operation & cleanliness monitoring logs & data
- Procedures – samples, security & housekeeping, container & tool cleaning
- Sample characterization, including imagery
- Allocation records,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



# Basic Contamination Control for Sample Return

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

>600 Genesis-flown  
>300 reference pieces



Wentworth 2007

Genesis capturing the sun: Solar wind irradiation at Lagrange 1

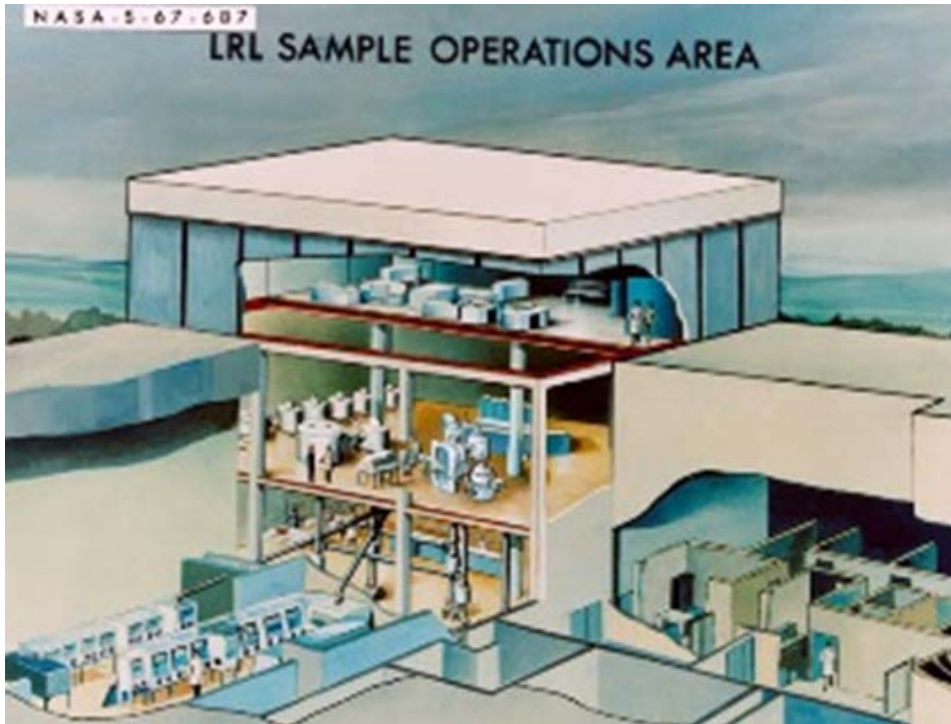
Michael J. Calaway <sup>a,\*</sup>, Eileen K. Stansbery <sup>b</sup>, Lindsay P. Keller <sup>b</sup>

<sup>a</sup>Jacobs (ESCG) at NASA Johnson Space Center, Mail Code KT, 2101 NASA Parkway, Houston, TX 77058, United States

<sup>b</sup>NASA at NASA Johnson Space Center, Houston, TX 77058, United States

# Containment

## Apollo Lunar Receiving Laboratory



### List of sample laboratories within the LRL (behind the bio barrier):

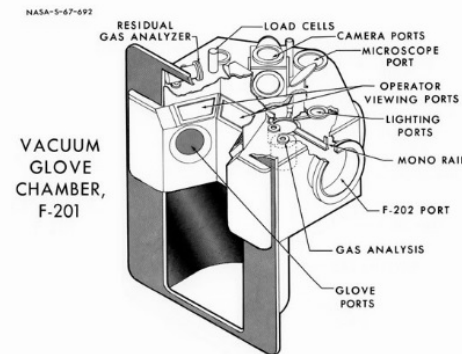
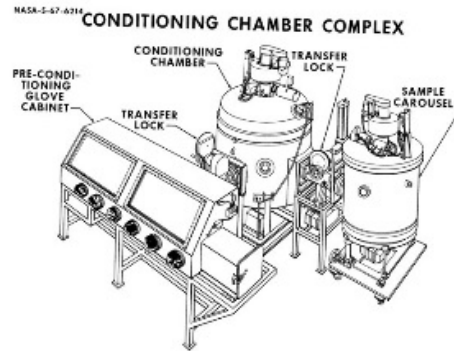
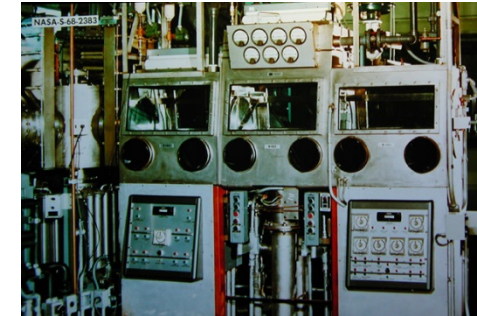
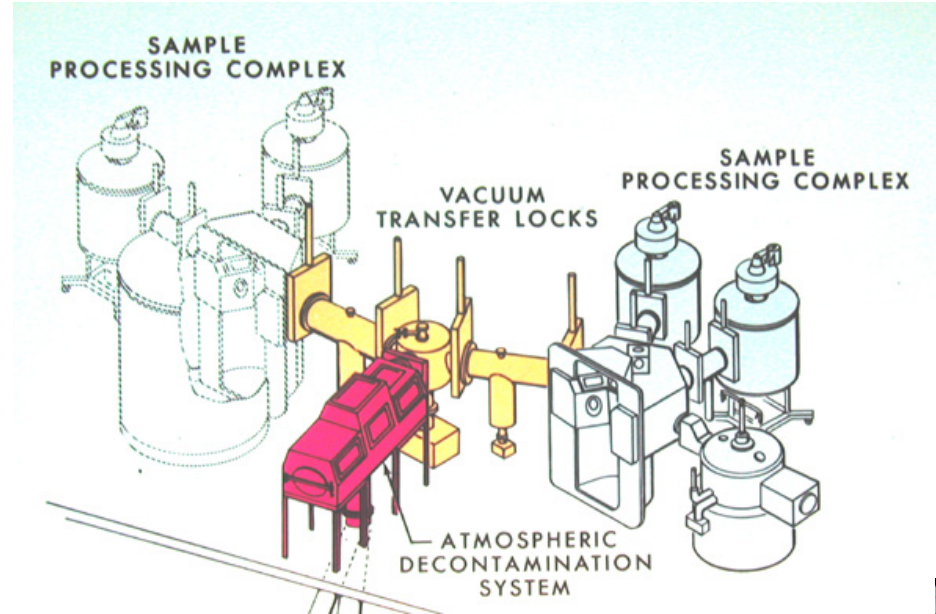
- Vacuum system
- Gas Analysis Lab
- Physical-Chemical Test Lab
- Spectrographic lab
- Radiation Counting Lab
- Bio-prep Lab
- Bio-analysis Lab
- Holding lab for germ-free mice
- Holding lab for conventional mice
- Lunar Microbiology Lab
- Bird, fish, invertebrate lab
- Microbiology lab
- Egg and tissue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



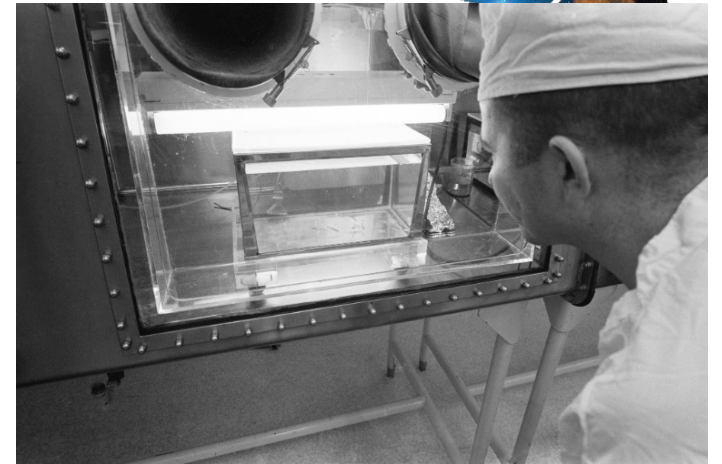


# Containment

## Samples for bio-hazard testing

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.

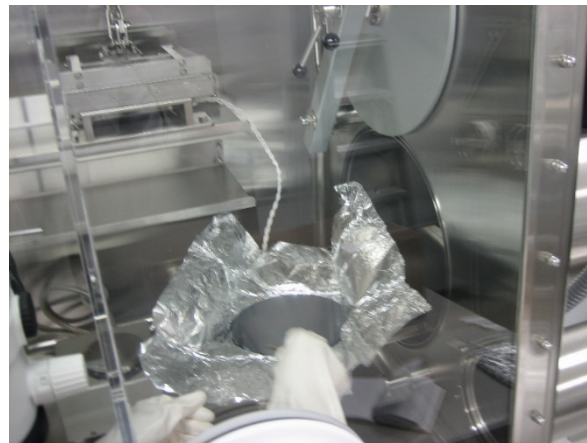
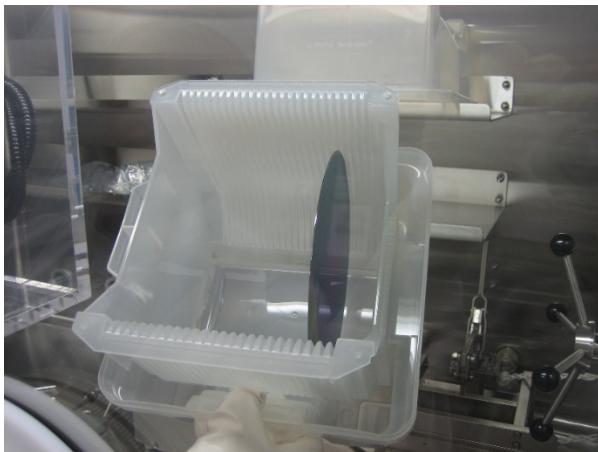


# PARTICULATE VS ORGANIC CLEANLINESS: Technical tension

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.



Parameter	RL	Sample Identification / Site	
		COLD GLOVE BOX	CONTROL
<b>30 Elements on 200mm or smaller Bare Wafers by VPD</b>			
Wafer Size: 200mm			
<i>Units: 1E10 atoms/cm2</i>			
Aluminum (Al)	0.05	81	*
Antimony (Sb)	0.005	*	*
Barium (Ba)	0.001	*	*
Beryllium (Be)	0.3	0.5	*
Cadmium (Cd)	0.003	*	*
Calcium (Ca)	0.1	0.6	0.4
Cerium (Ce)	0.001	*	*
Chromium (Cr)	0.01	1.3	*
Cobalt (Co)	0.005	*	*
Copper (Cu)	0.01	*	*
Gallium (Ga)	0.005	*	*
Indium (In)	0.001	*	*
Iron (Fe)	0.05	5.3	0.74
Lithium (Li)	0.05	*	*
Magnesium (Mg)	0.05	2.7	0.59
Manganese (Mn)	0.01	0.16	0.01
Molybdenum (Mo)	0.005	0.085	*
Nickel (Ni)	0.05	0.97	*
Potassium (K)	0.05	0.41	0.50
Rubidium (Rb)	0.05	*	*
Sodium (Na)	0.05	2.1	0.15
Strontium (Sr)	0.002	*	*
Thorium (Th)	0.001	*	*
Tin (Sn)	0.005	0.042	0.007
Titanium (Ti)	0.05	0.15	0.06
Uranium (U)	0.001	*	*
Vanadium (V)	0.01	*	*
Yttrium (Y)	0.002	*	*
Zinc (Zn)	0.05	*	*
Zirconium (Zr)	0.005	*	*

\* = 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.