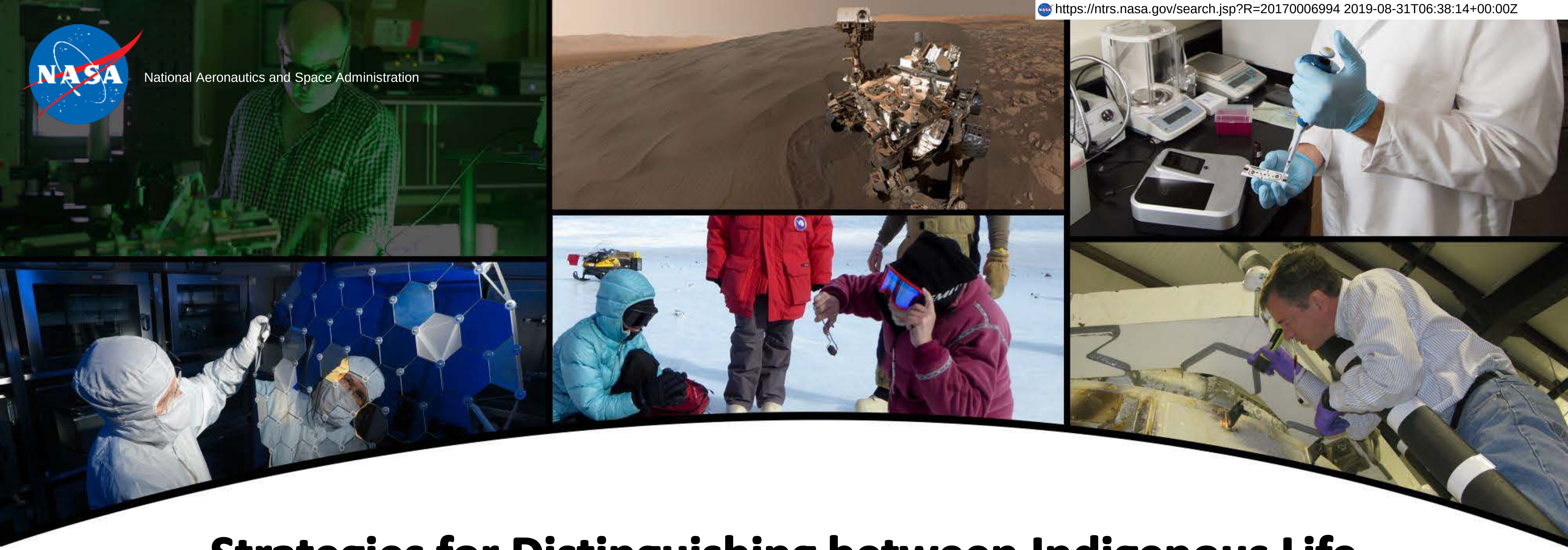
National Aeronautics and Space Administration



Strategies for Distinguishing between Indigenous Life and Earth Contamination

Laboratory Contamination Control and Containment

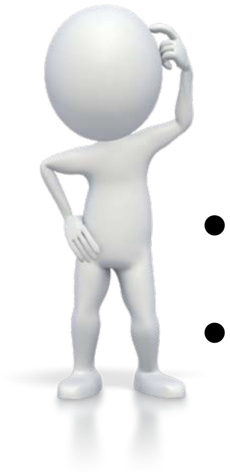
Judy Allton

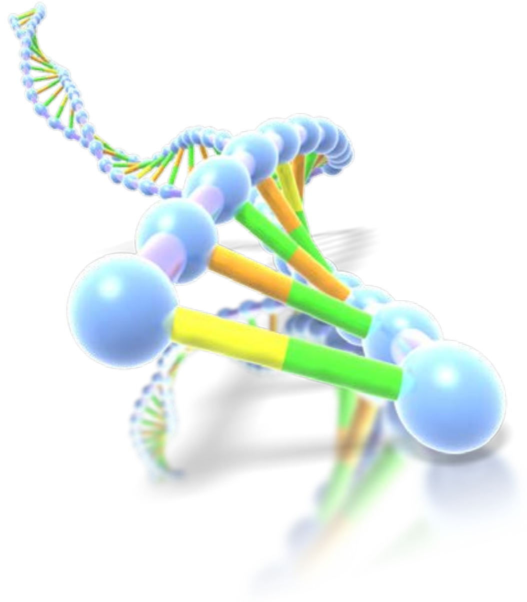
EXPLORATION INTEGRATION AND SCIENCE DIRECTORATE

Exploring

Difference between Contamination Control and Containment

Difference between Life Detection and Biohazard



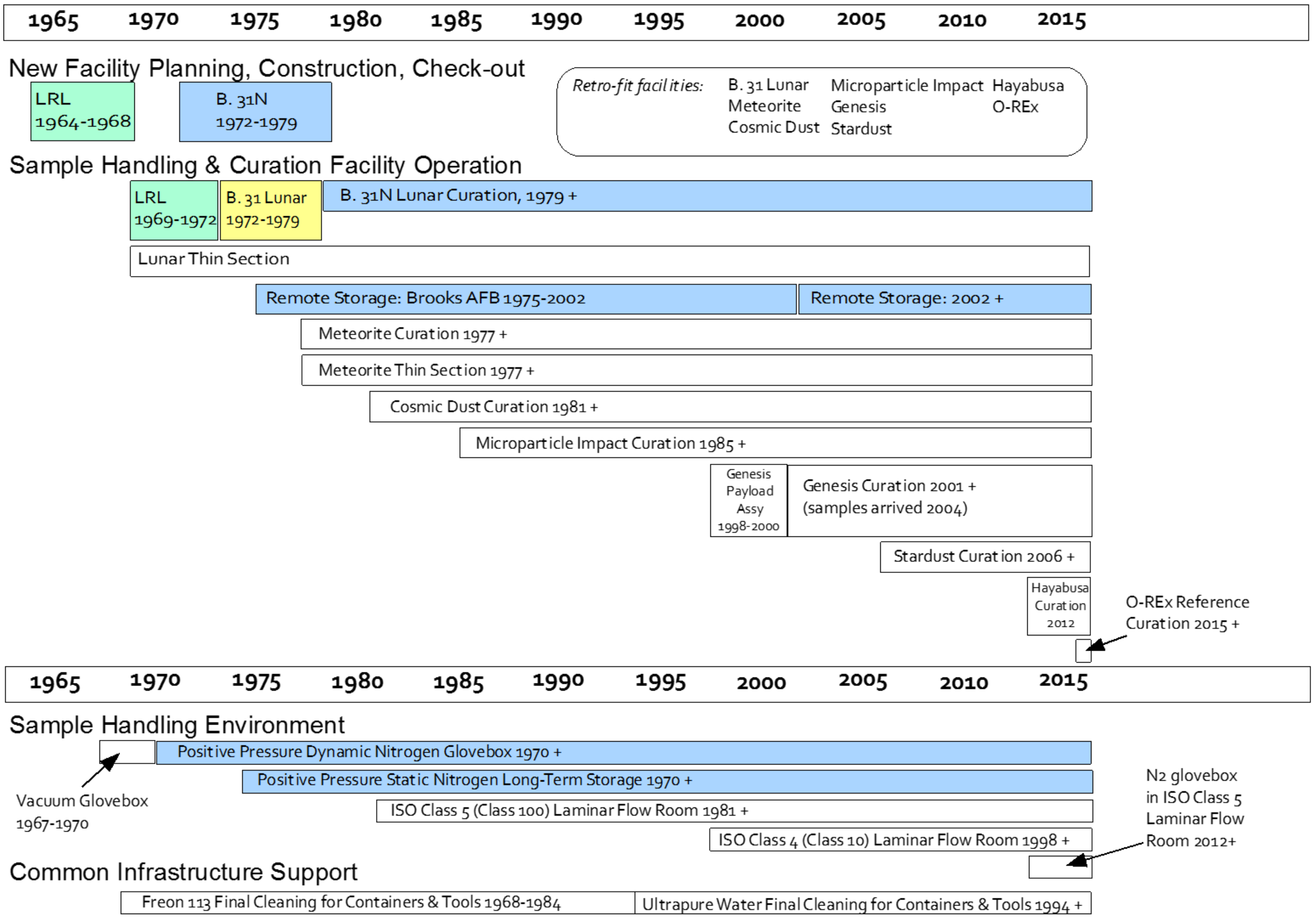


- LIFE DETECTION related to CONTAMINATION CONTROL
- BIOHAZARD related to CONTAINMENT

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



1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
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 +
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Sample Handling Environment
Positive Pressure Dynamic Nitrogen Glovebox 1970 +
Vacuum Glovebox 1967-1970
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 +

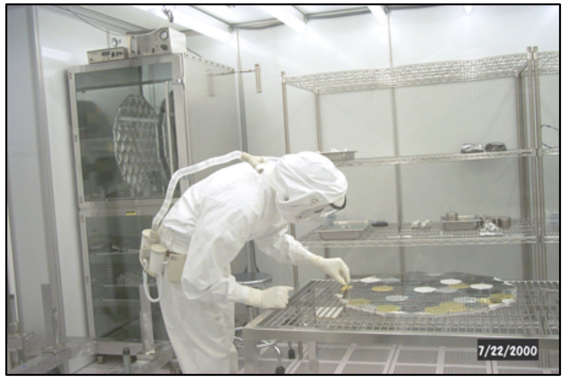
Issues

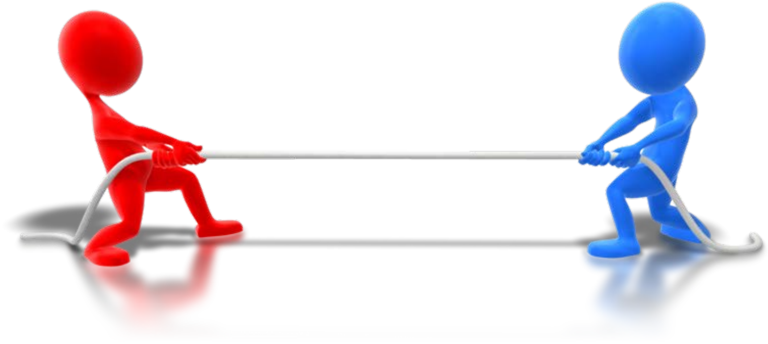
- TECHNICAL TENSION
- REQUIRED DOCUMENTATION ACCESS
- IDENTIFICATION OF CONTAMINATION
- DEDUCING SPECIMEN CHANGES SINCE COLLECTION

Issues

- TECHNICAL TENSION
- Organic vs inorganic (molecular vs particle)
- Clean vs contained (positive vs negative ΔP)

Particle-clean vs Organic-clean … Technical Challenges





PARTICLE CLEAN

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

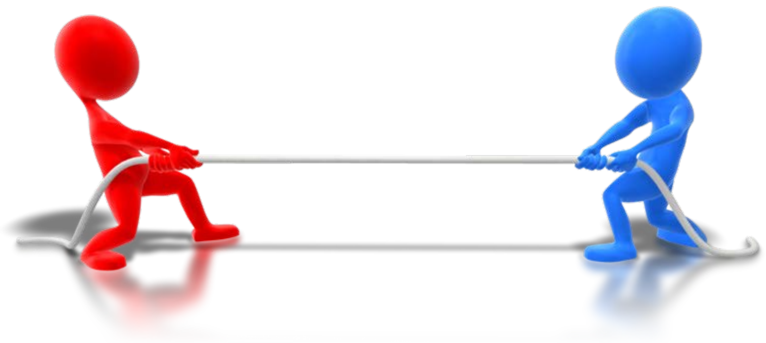
ORGANIC CLEAN

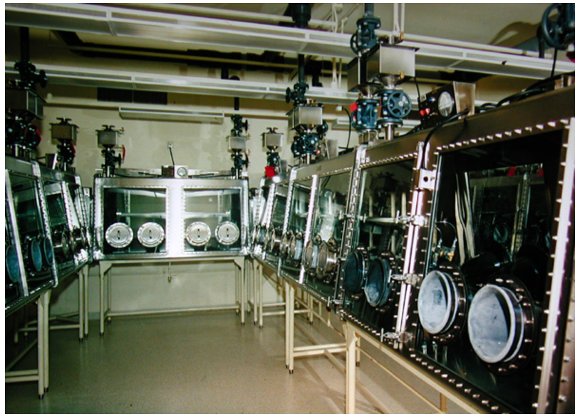
Typically handled in a glovebox, a non-particle-sweeping environment.

Issues

- TECHNICAL TENSION
- Clean vs contained (positive vs negative ΔP)

Positive vs Negative ΔP… Technical Challenges





CLEAN

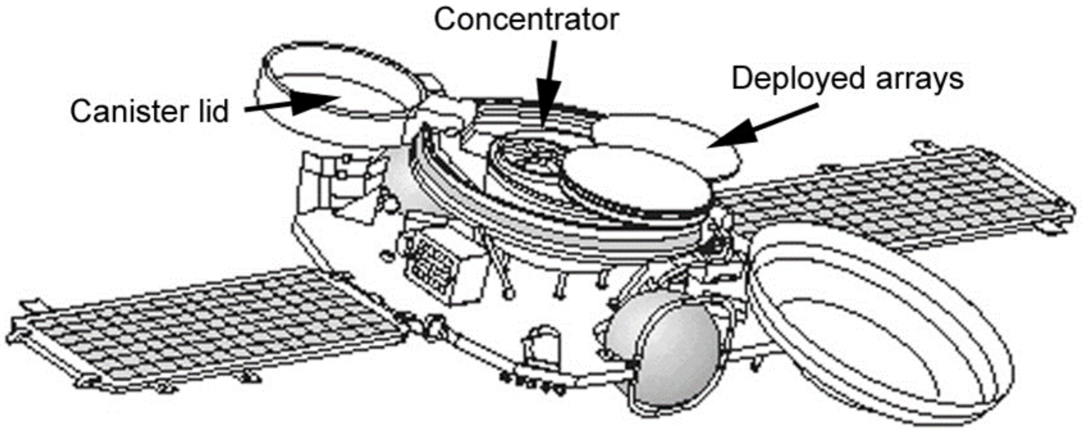
Typically achieved by pressure gradients – highest pressure is cleanest environment.

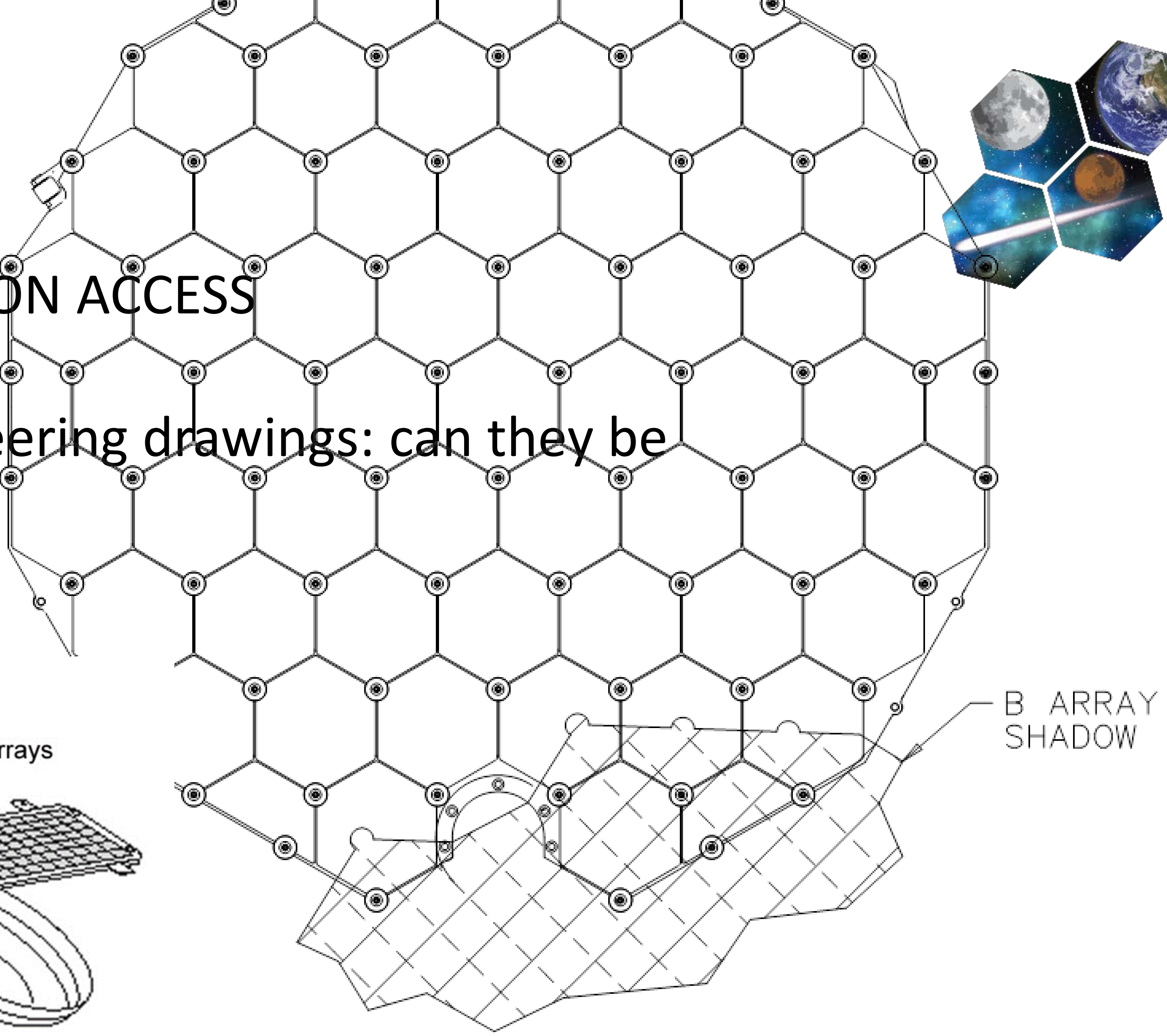
CONTAINED

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

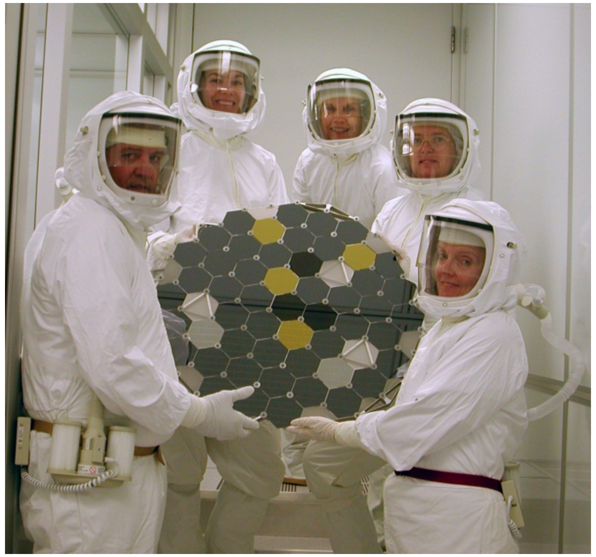
- IDENTIFICATION OF CONTAMINATION
- Natural biological vs industrial
  - Species, isotopes, chirality
- Natural biological Mars vs natural biological Earth
  - Blanks, mineral context/morphology
  - Hardware and process reference materials
- Natural biological Mars vs natural biological meteorite Mars 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

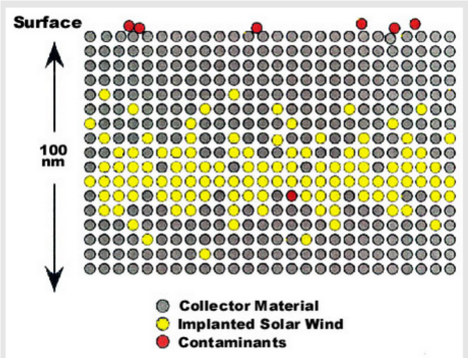
- **Cleanliness level of collectors set by science team**: C, N, O <10E15 atoms/cm^2, remainder not to exceed solar wind fluence
- Science team responsible for identifying methods for measuring pre-flight cleanliness levels on collectors and for verifying adequate contamination control performance and 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.

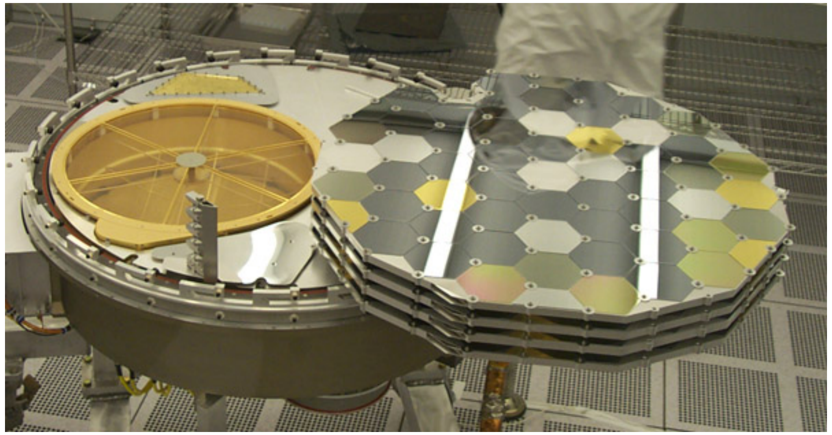
Genesis

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

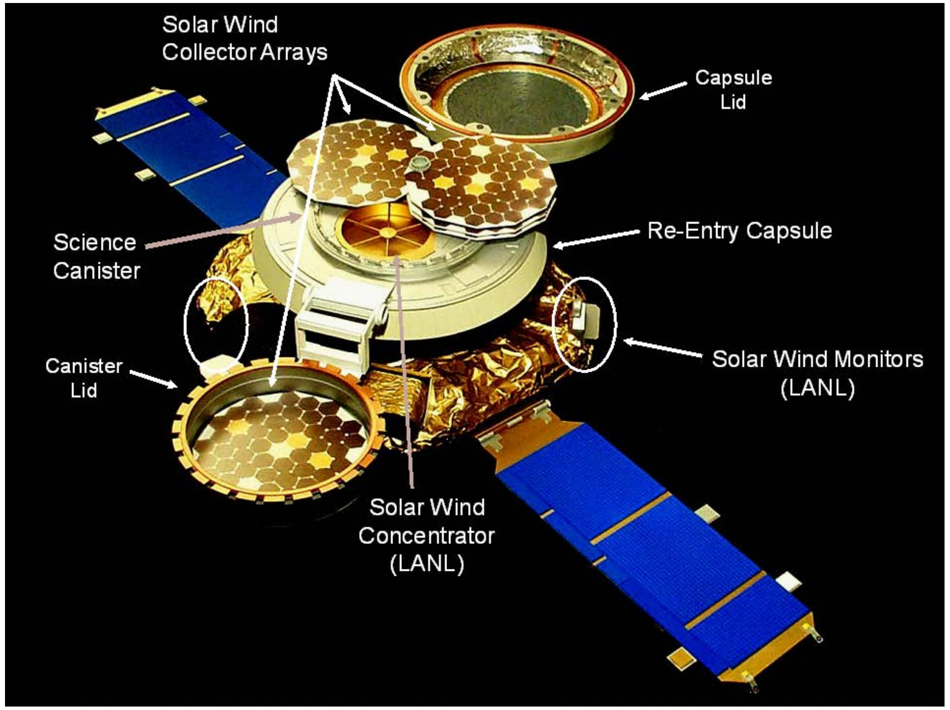
- ISO Class 4 for cleaning and assembly
- New cleaning techniques – megasonic energized UPW
- Verification methods: particle count rinse water, optical inspection, witness coupon measurement (XPS) to validate process
- Measurement of airborne molecular contamination (semi-annually), particle counts (weekly)
- 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

Genesis

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

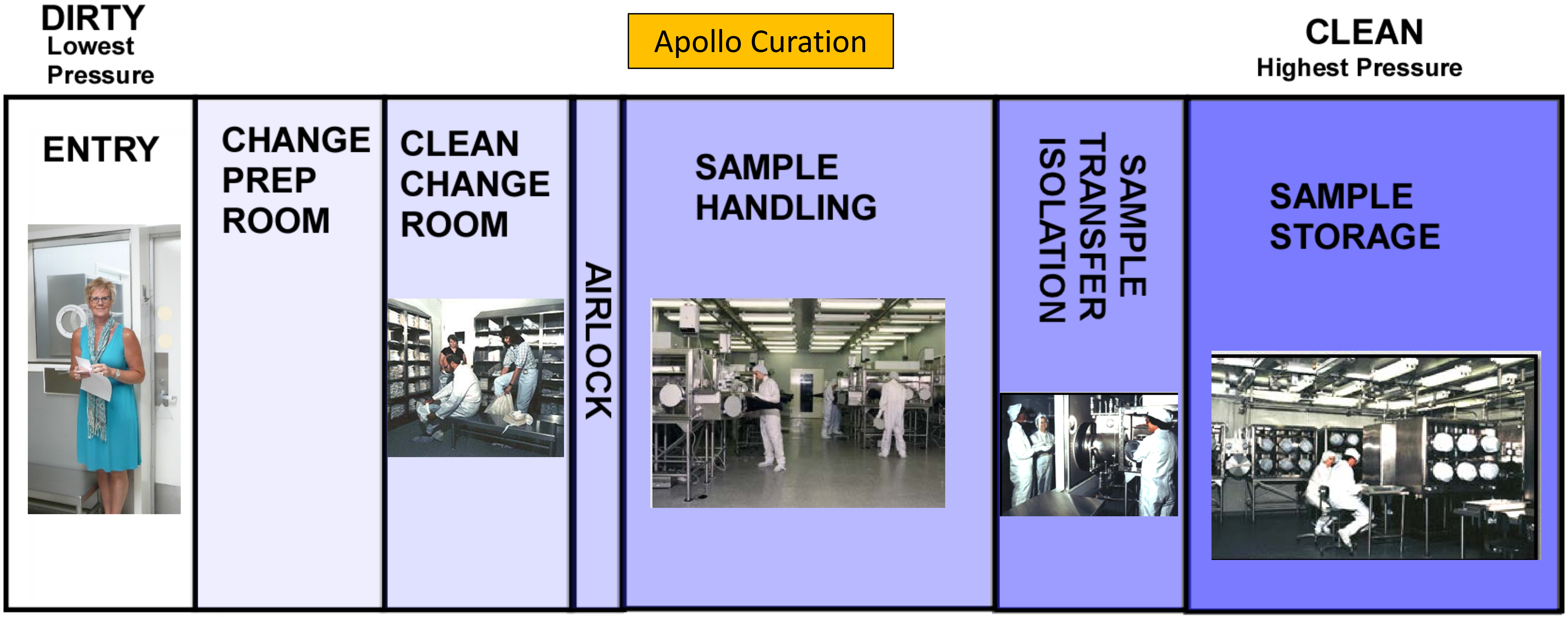
Basic Contamination Control for Sample Return

- **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, 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

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 (N2, UPW, air handling), housekeeping**
- **Documentation, database requirements**
- **Entry/exit, access, security, sample inventory, hurricane shutdown**

Basic Contamination Control for Sample Return
Lab Controls

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.

- 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.

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

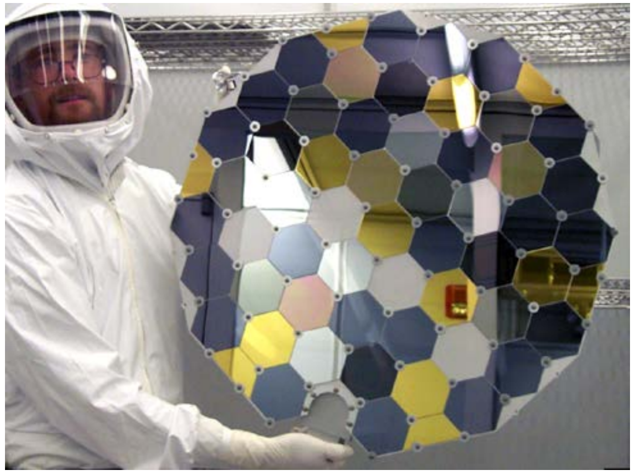
Recovery data
- Activity logs, field procedures
- Imagery of recovery operations
- Cleanliness monitoring at site

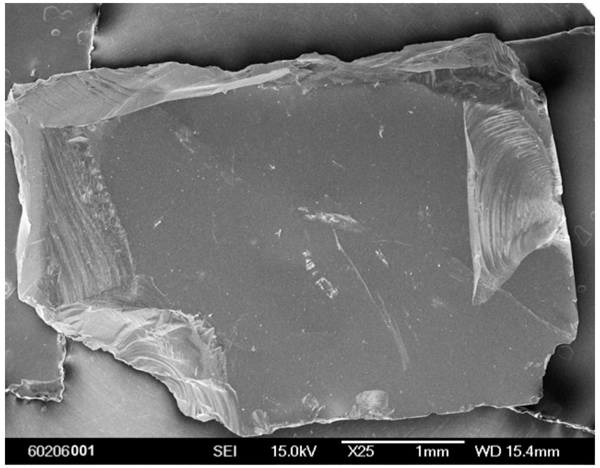
Curation data – ongoing for life of collection
- DETAILED sample handling records (when, where and what for each move), audit trail – needed for control
- Facility operation & cleanliness monitoring logs & data
- Procedures – samples, security & housekeeping, container & tool cleaning
- Sample characterization,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

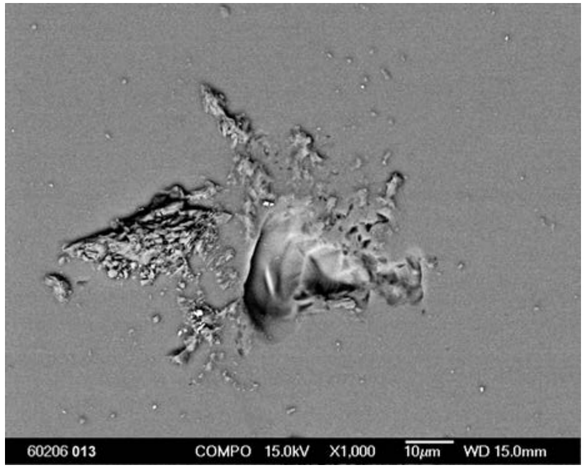
Basic Contamination Control for Sample Return

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

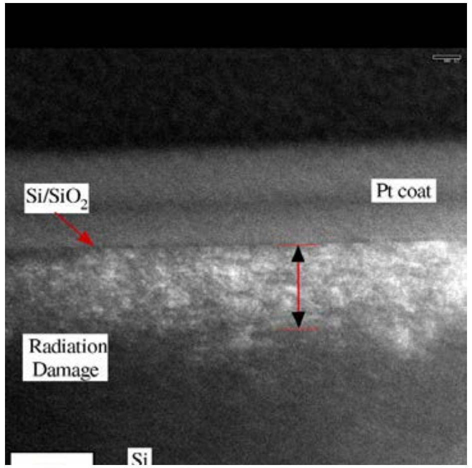
>600 Genesis-flown
>300 reference pieces







Wentworth 2007



Genesis capturing the sun: Solar wind irradiation at Lagrange 1

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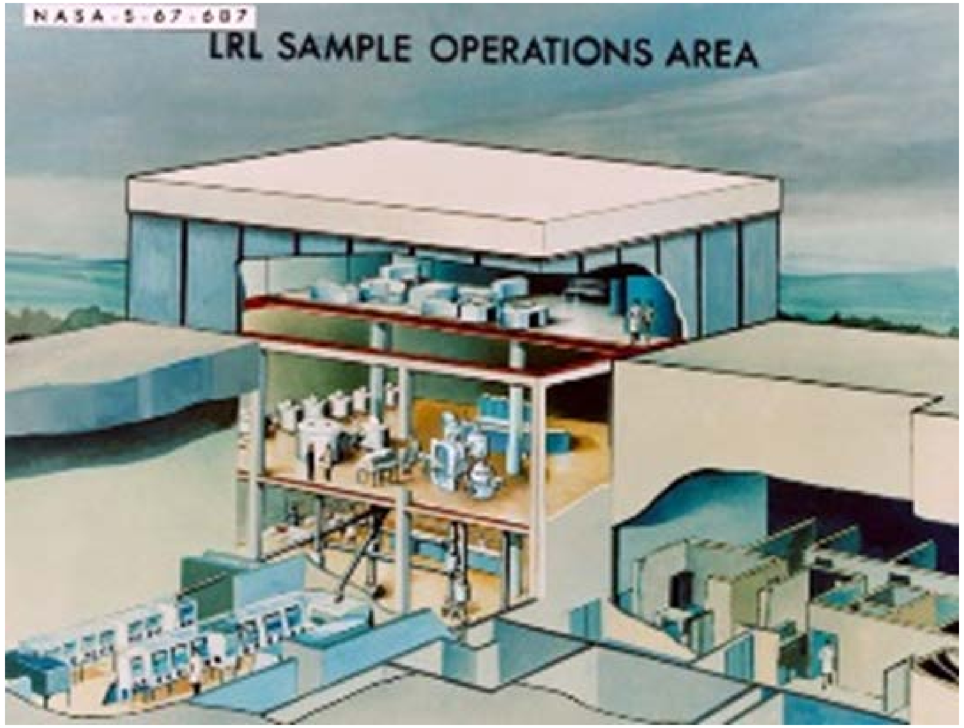
b NASA at NASA Johnson Space Center, Houston, TX 77058, United States

Containment

Apollo Lunar Receiving Laboratory



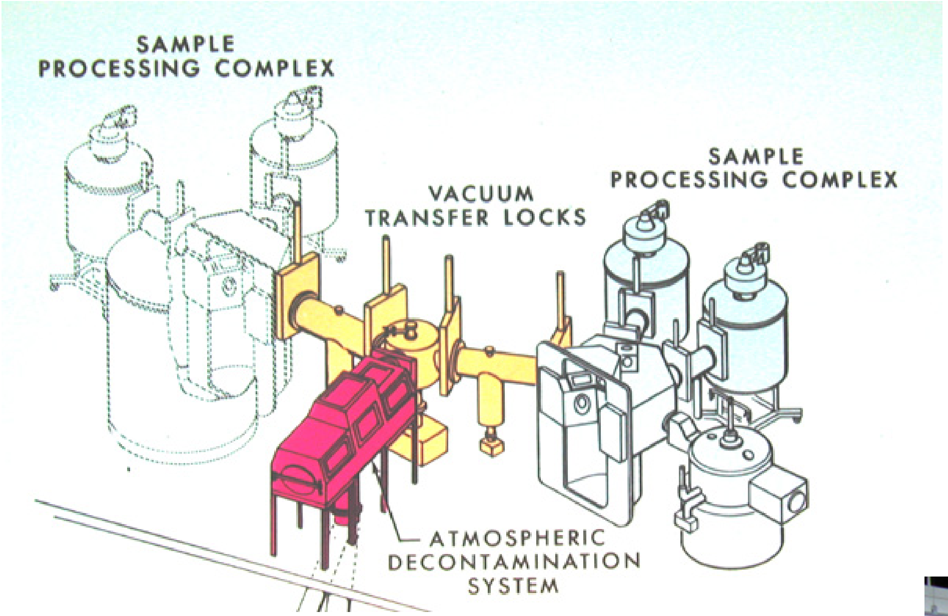
Other labs behind the LRL bio-barrier:
Crew virology lab
Bio-safety lab
Bio-medical lab

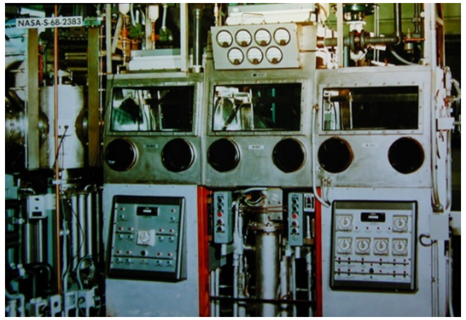
List of sample laboratories within the LRL (behind the bio barrier):

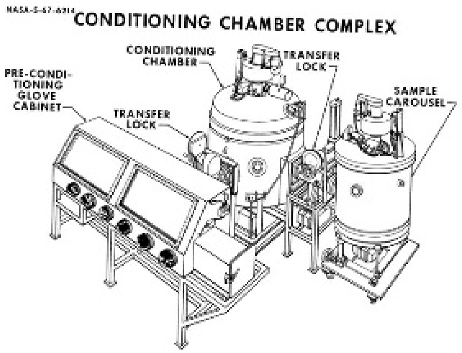
Vacuum system
Gas Analysis Lab
Physical-Chemical Test Lab
Spectrographic lab
Radiation Counting Lab
Bio-prep Lab
Bio-analysis Lab
Holding lab for germ-free mice
Holding lab for conventional mice
Lunar Microbiology Lab
Bird, fish, invertebrate lab
Microbiology lab
Egg and tissue culture lab
Plant lab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

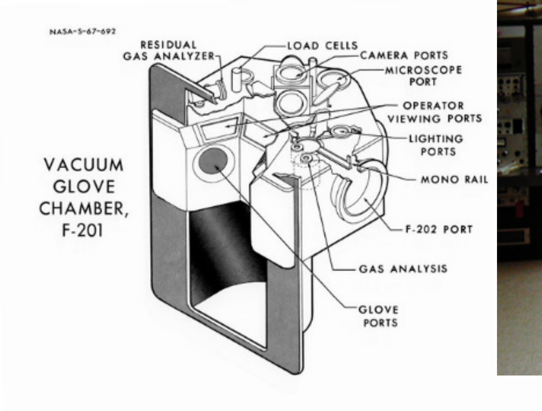
Containment

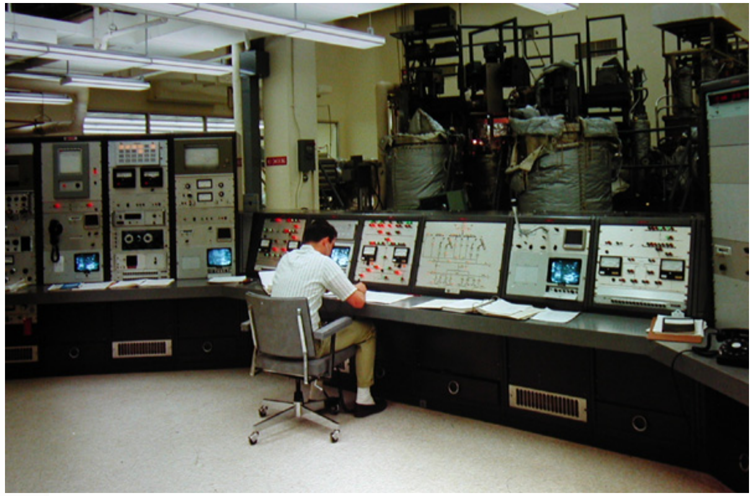
Apollo Lunar Receiving Laboratory Vacuum Glovebox





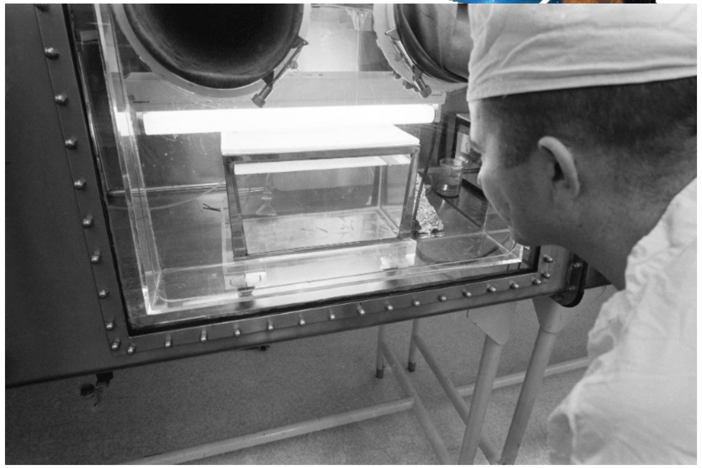






Containment

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

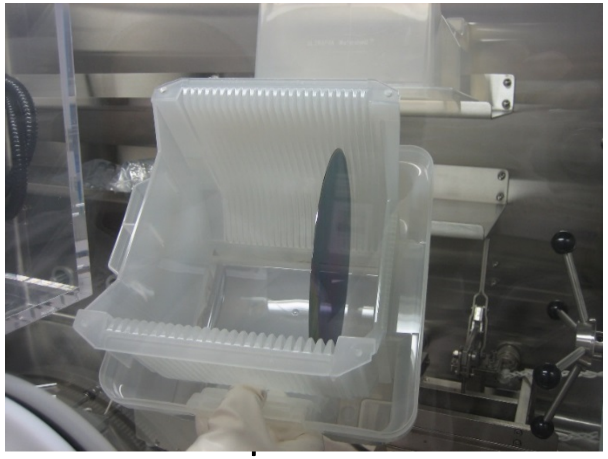
Team building helps manage the conflicts.

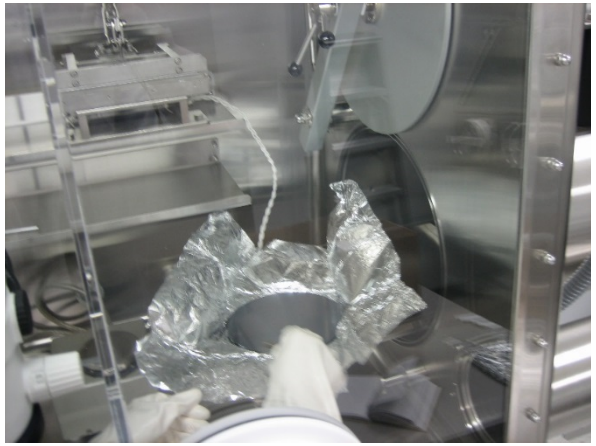
PARTICULATE VS ORGANIC CLEANLINESS: Technical tension

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	
30 Elements on 200mm or smaller Bare Wafers by VPD			
Wafer Size: 200mm		COLD GLOVE BOX	CONTROL
Units: 1E10 atoms/cm2			
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.