Evolution of the Lunar Receiving Laboratory to Astromaterial Sample Curation Facility: Technical Tensions Between Containment and Cleanliness, Between Particulate and Organic Cleanliness

Judy Allton
Genesis Solar Wind Sample Curator
(and collector of Apollo rock lab stories)
NASA Johnson Space Center
Houston, Texas USA

OVERVIEW

- Setting the scene and timeline
- General comparison of purpose, “customers”, and who defined requirements
- Lunar Receiving Laboratory (LRL)
  - Description and lab operation
  - Debates over technical aspects of containment vs cleanliness
- Lunar Curatorial Facility
  - Description and lab operation
  - Focus on control of materials of construction and equipment
- Added astromaterial collection laboratories
  - Retrofitting lab spaces
  - Approaches to particulate and organic cleanliness

Setting the scene and timeline

The Lunar Receiving Laboratory and the Lunar Curation Facility both were:

- Major facilities
- Defined purpose
- Extended planning and oversight/advisory committees

LUNAR RECEIVING LABORATORY

PURPOSE: Distribution of samples to the scientific community, perform time-critical sample measurements, permanently store under vacuum a portion of each sample, and quarantine testing of samples, spacecraft and astronauts

CUSTOMERS: in-house biohazard testers, planetary science researchers

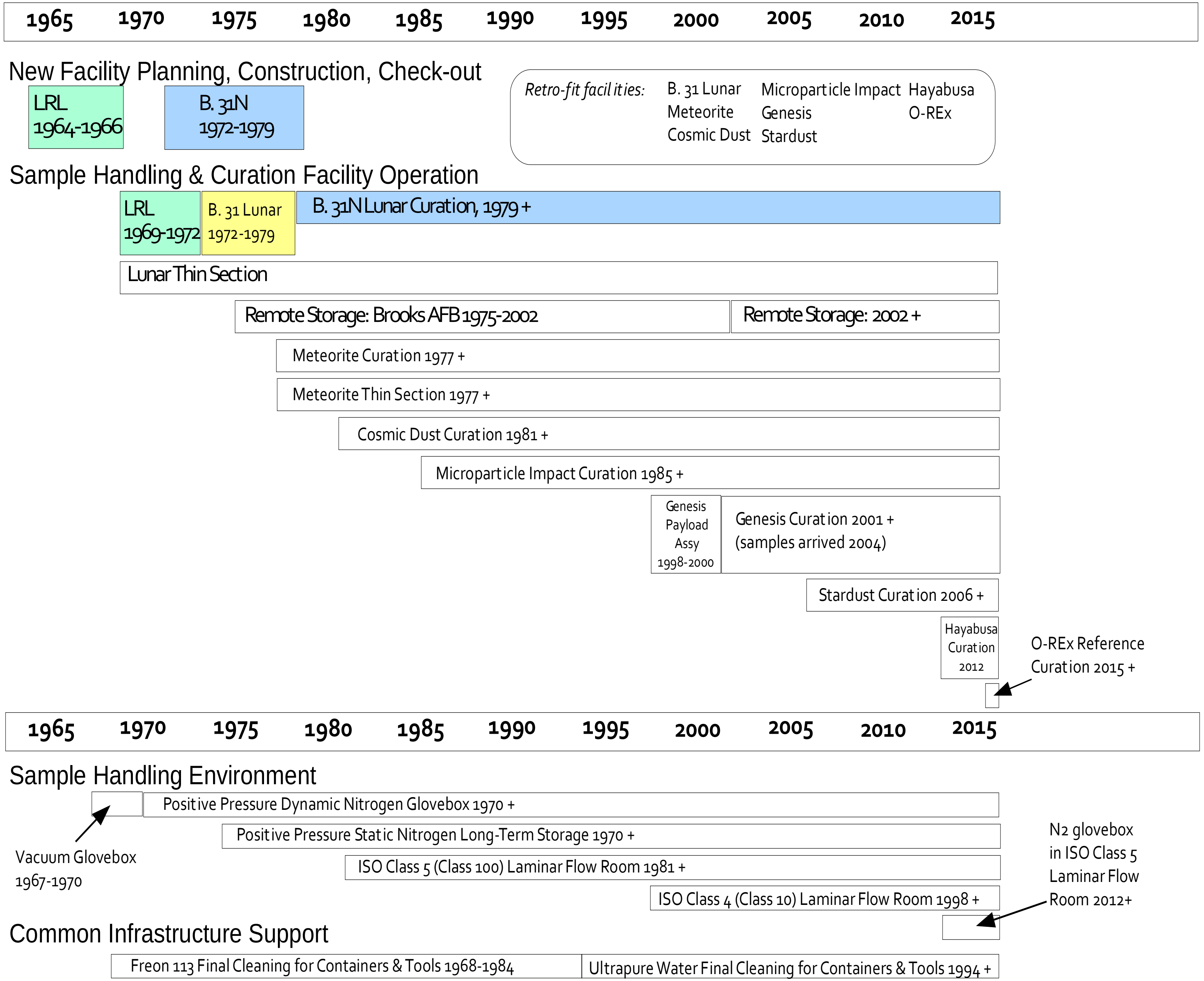
WHO DEFINED REQUIREMENTS FOR FACILITY: US Public Health Service (plus others, making up the Interagency Committee on Back Contamination), Manned Spacecraft Center management (with input from geoscience)

LUNAR CURATION FACILITY

PURPOSE: Keep the samples pure, preserve accurate historical information about the samples, examine and classify samples, publish information about newly-available samples, and prepare and distribute samples for research and education

CUSTOMERS: Planetary science researchers, educators

WHO DEFINED REQUIREMENTS FOR FACILITY: Planetary science researchers

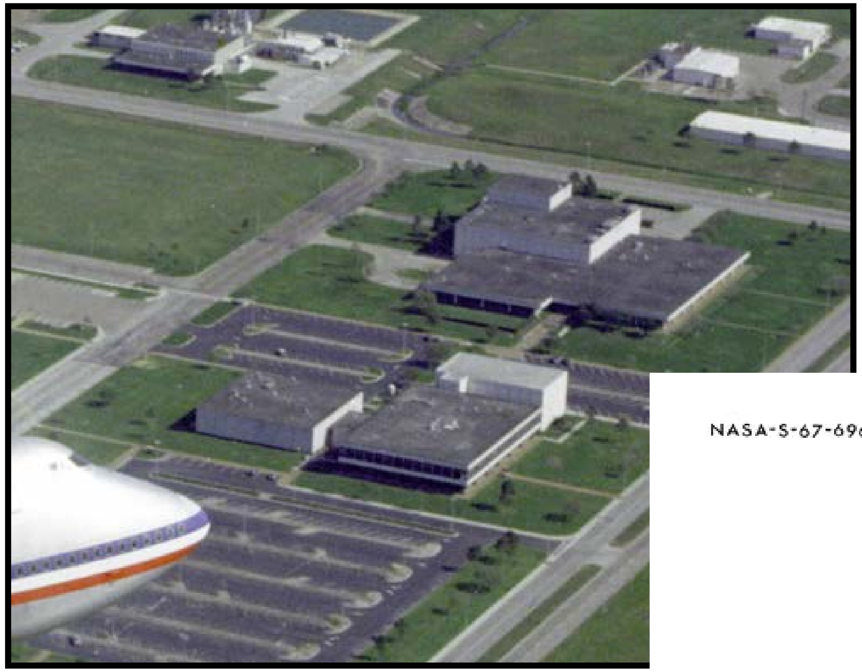

1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
New Facility Planning, Construction, Check-out
LRL 1964-1966
B. 31N 1972-1979
Retro-fit facilities: B. 31 Lunar Meteorite Cosmic Dust Microparticle Impact Genesis Stardust Hayabusa O-REx
Sample Handling & Curation Facility Operation
LRL 1969-1972
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
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 +

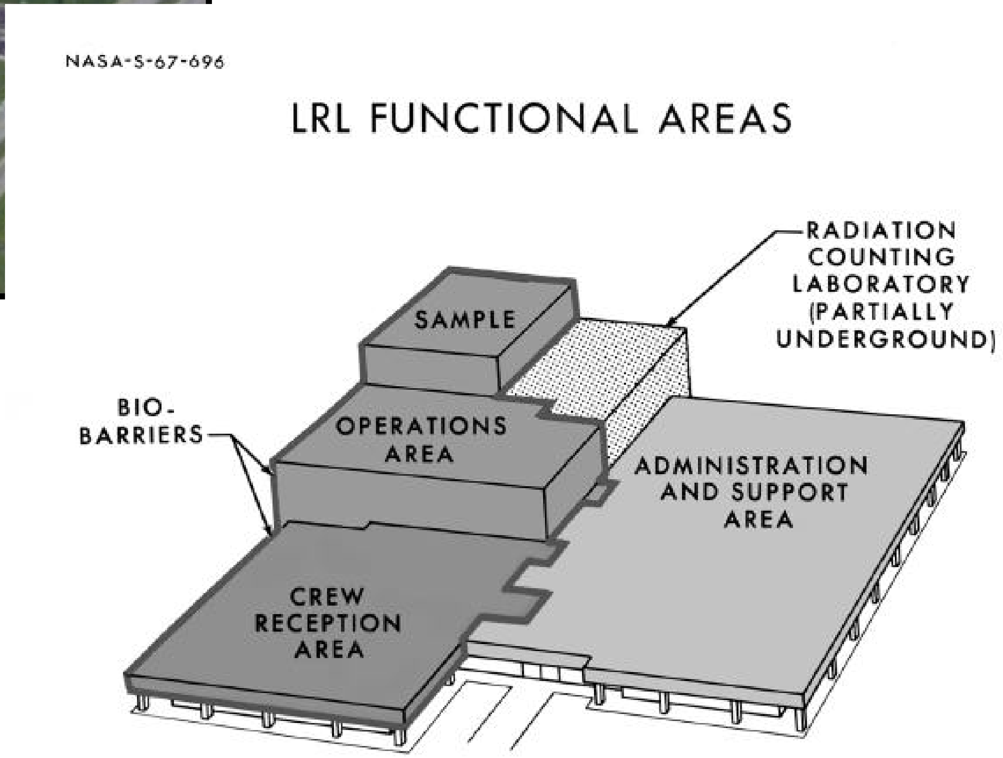
LRL DESCRIPTION

8000 m^2, $24M (most expensive vacuum system, low level radiation counting)

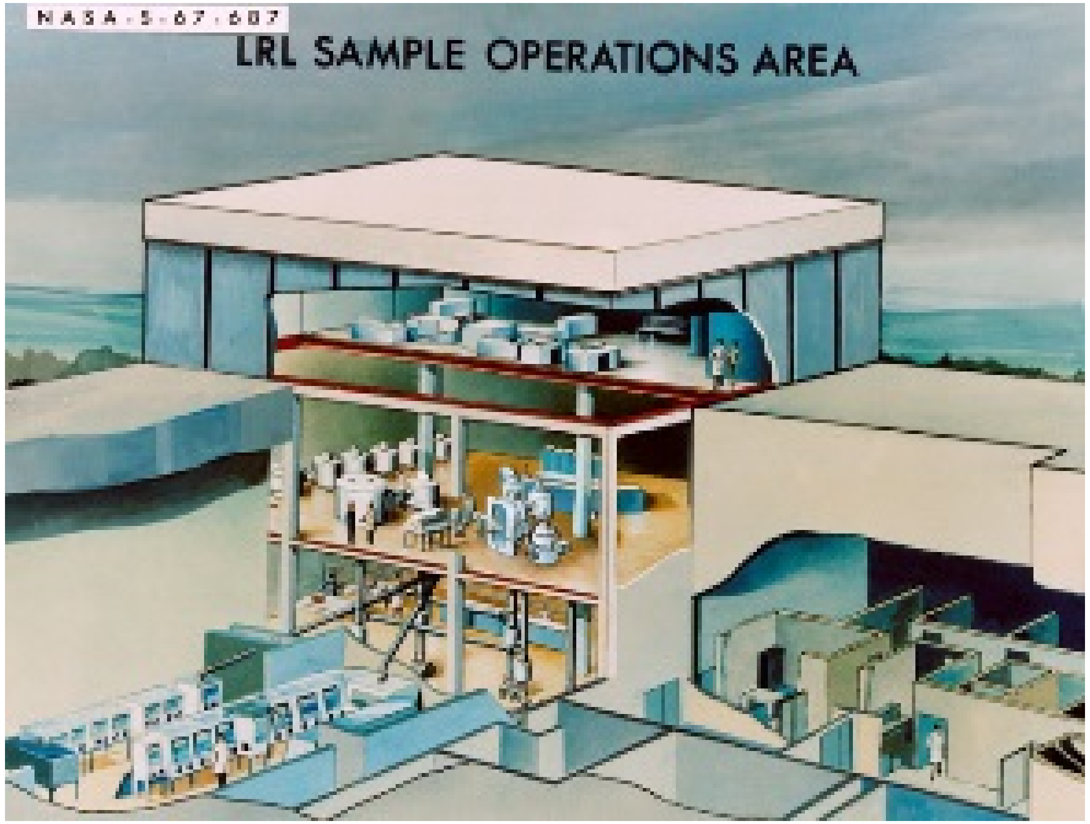
100 NASA civil servants and visiting scientists, 200 technicians working 3 shifts

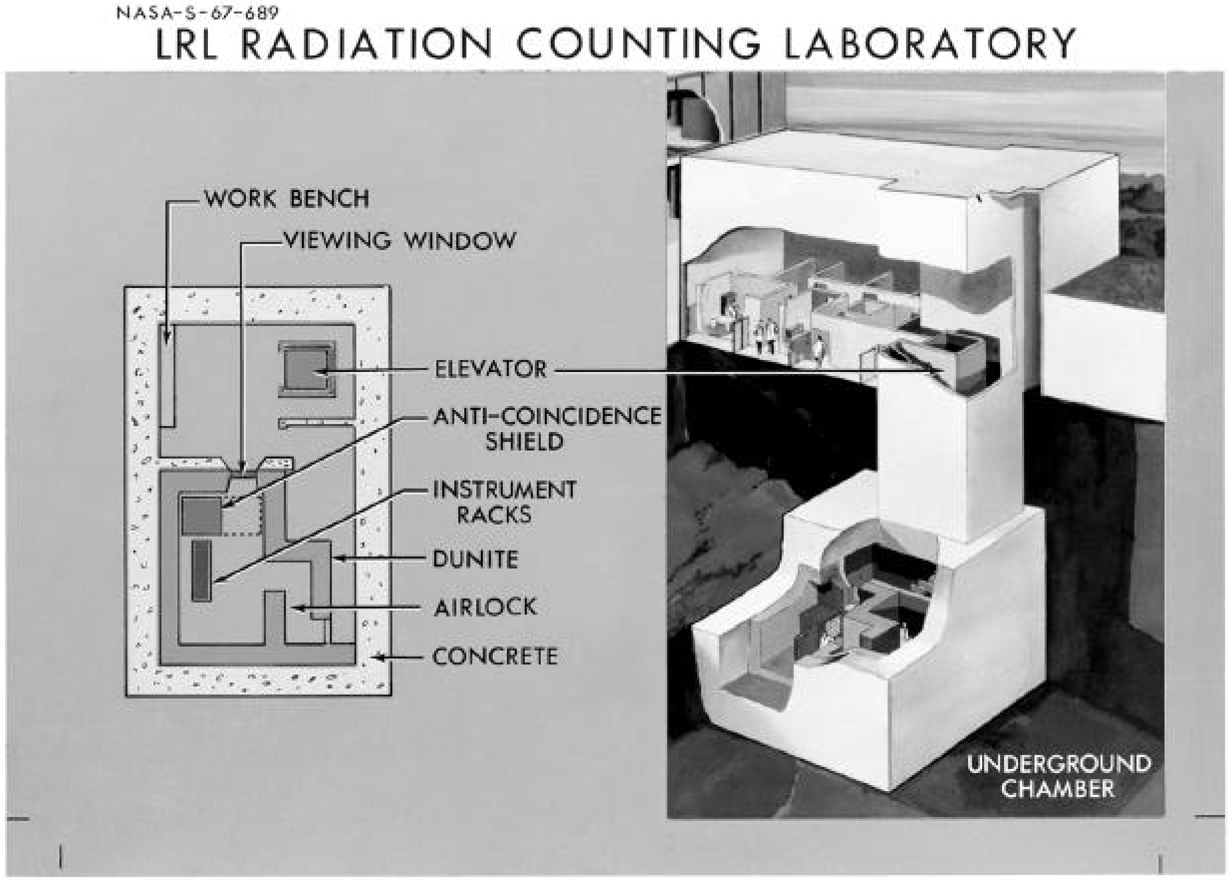
Outside science community recruited to participate in 1) scientific oversight of sample curation and allocation (Lunar Sample analysis Planning Team, LSAPT), and 2) Preliminary Examination Team (PET)





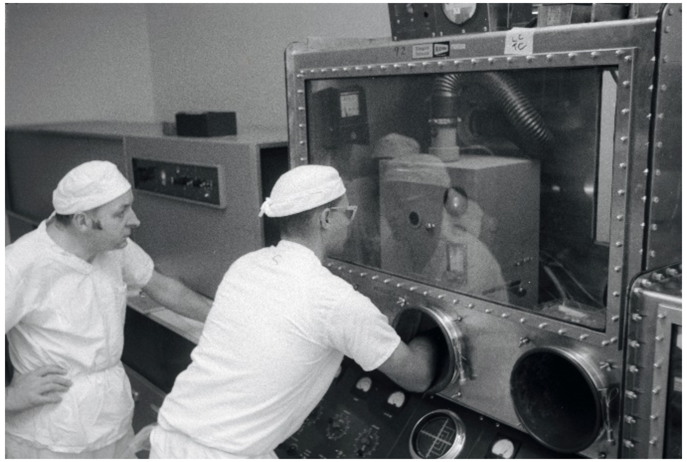
LRL DESCRIPTION

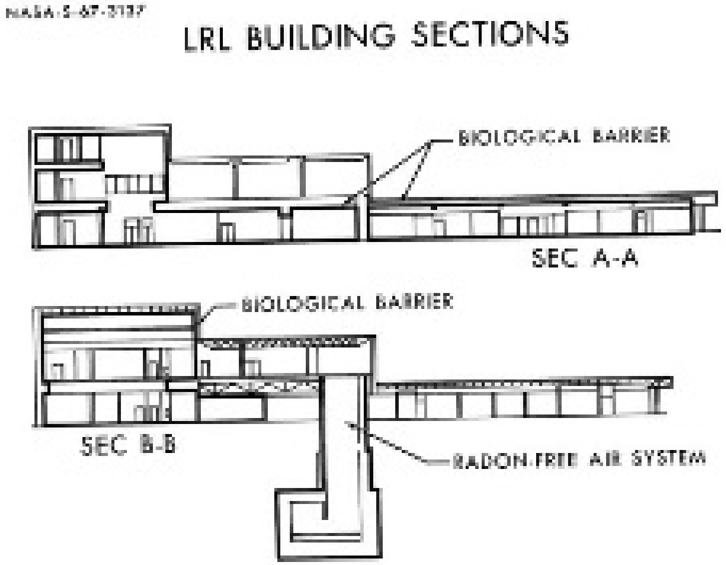




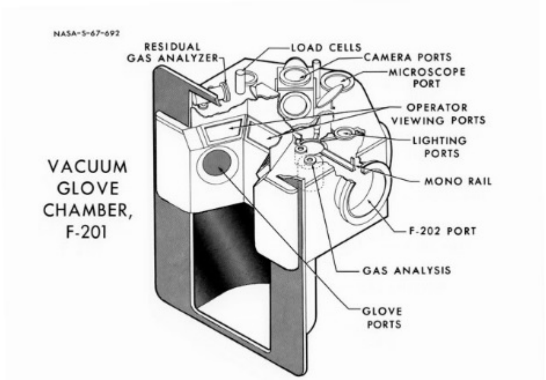
LRL DESCRIPTION

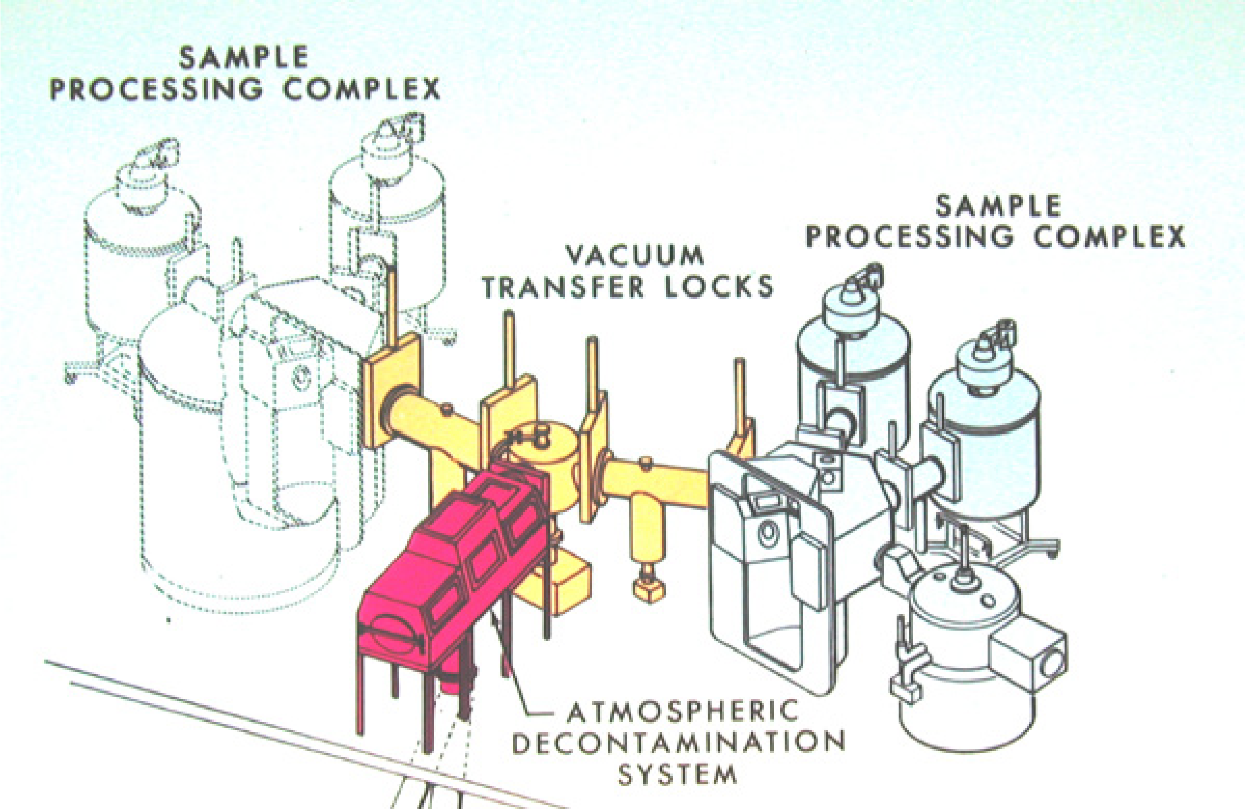
Physically, the main divisions of the LRL behind the biological barrier were the samples operations areas and the Crew Reception Area, consisting of crew living areas and medical examination facilities. The sample operations areas included the vacuum sample handling system, laboratories for quarantine testing, laboratories for analysis of samples and the subsurface facility for counting low levels of radiation. Complex plumbing spanning 3 floors was required to operate the sophisticated vacuum system constructed for lunar sample handling



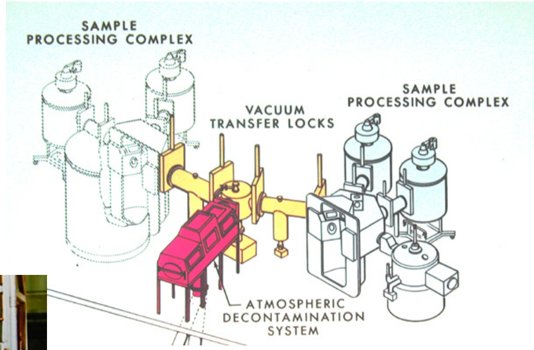


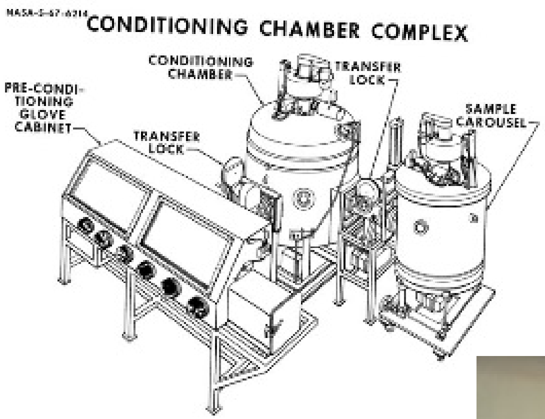
LRL DESCRIPTION: vacuum glovebox

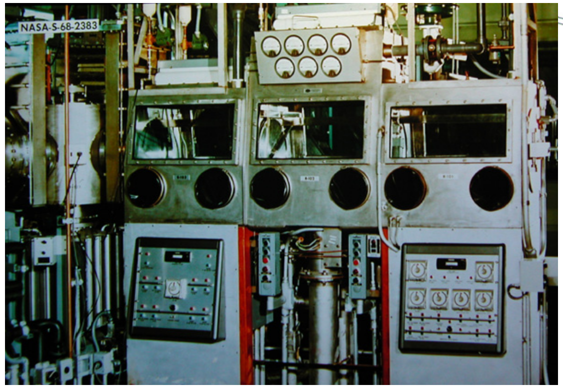


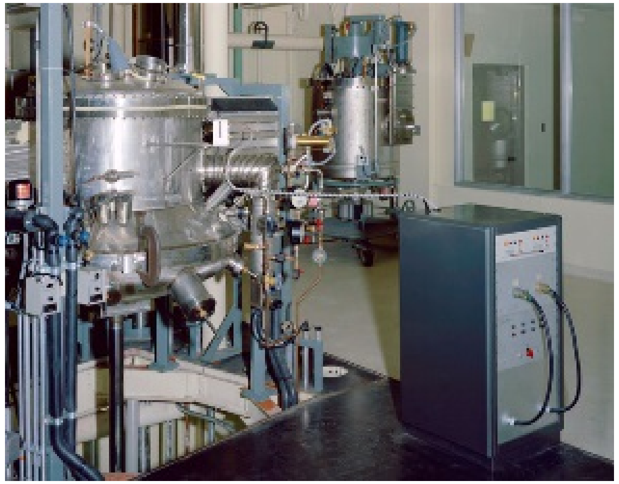


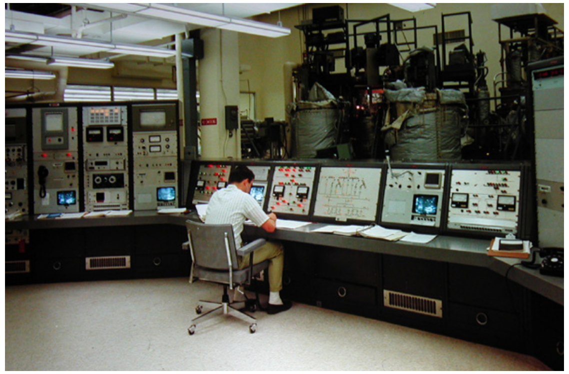
LRL DESCRIPTION: vacuum glovebox







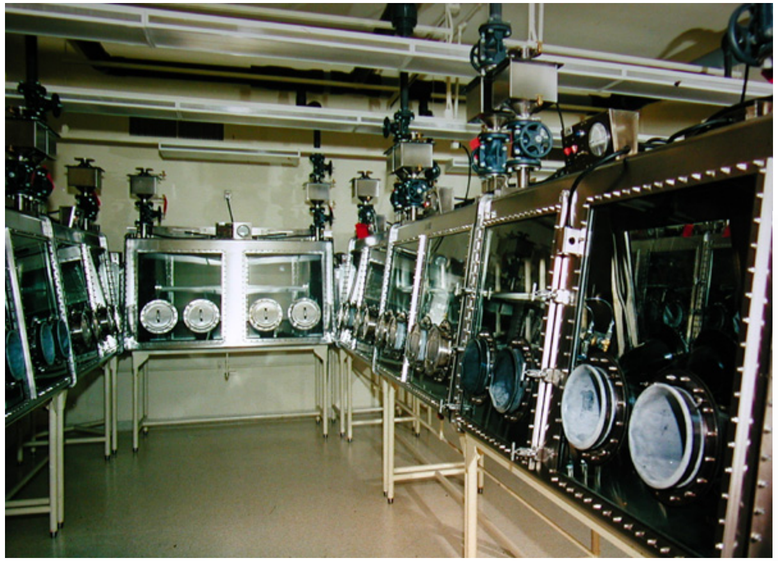


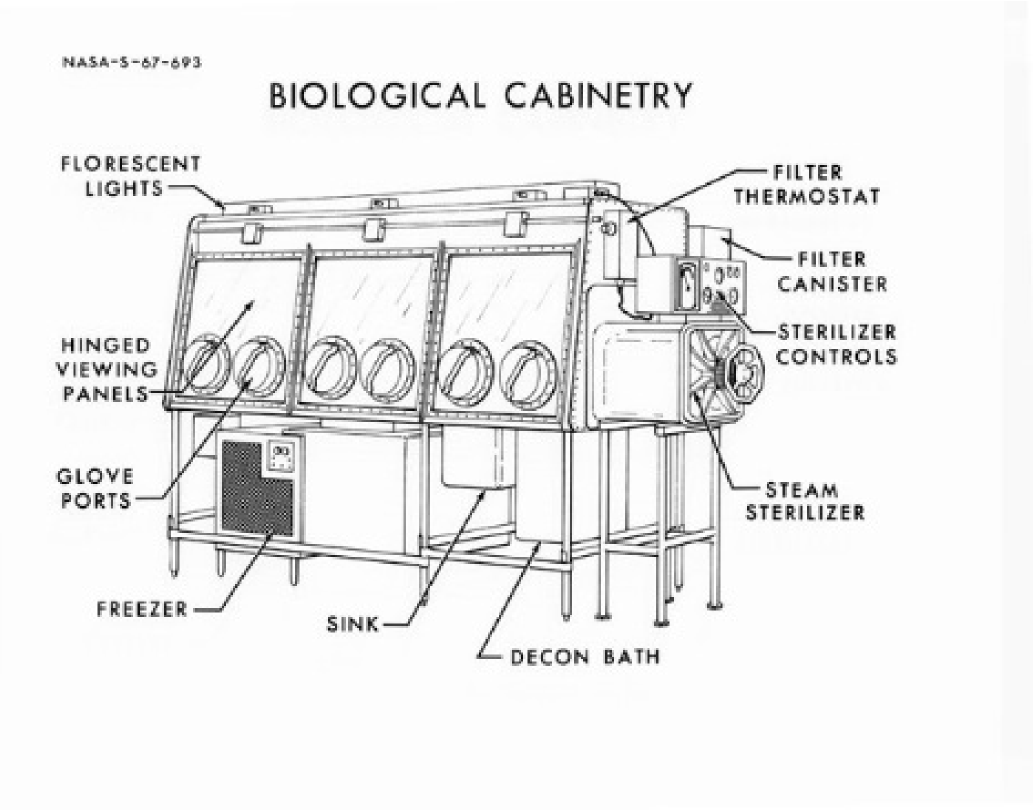


LRL DESCRIPTION: vacuum glovebox

Underfloor support for vacuum glovebox: sterilant tanks, vacuum pumps

LRL DESCRIPTION: biological gloveboxes

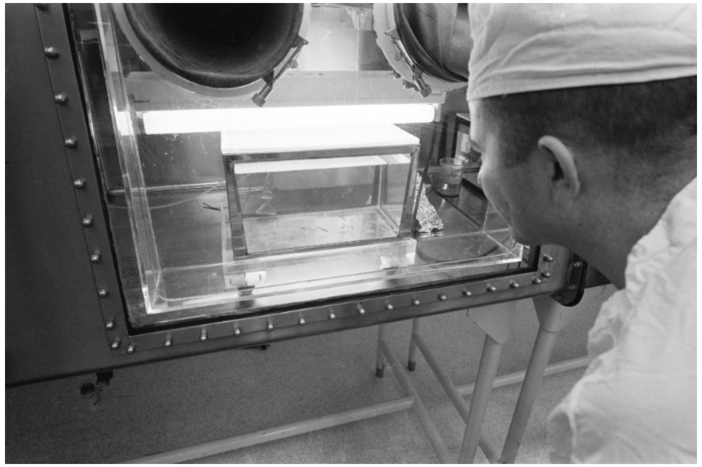




DEBATES: Technical tension between containment & cleanliness

Negative pressure containment did not protect sample purity from terrestrial contaminants
Abundance of biological sterilants in the laboratory environment threatened sample pristinity
Vacuum glovebox system leakage introduced laboratory contaminants (vacuum glovebox was made more reliable after a few years, but by then positive pressure nitrogen gloveboxes were preferred)

OTHER DEBATES – how samples are used



- 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.

OTHER DEBATES – how samples are used

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

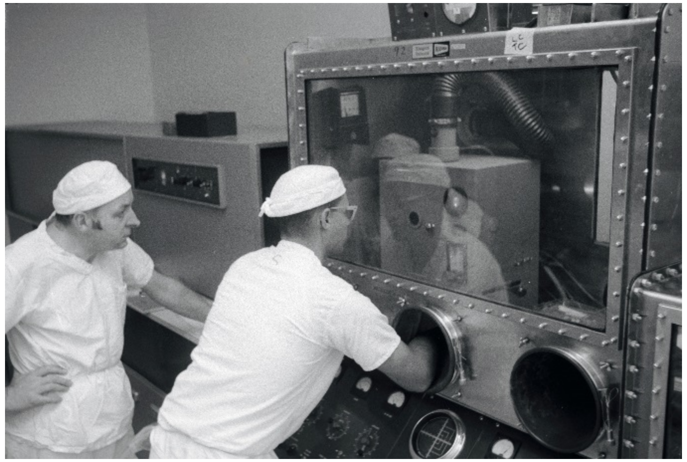
Vacuum system
Gas Analysis Lab
Physical-Chemical Test Lab
Spectrographic lab
Radiation Counting Lab
Bio-prep Lab
Bio-analysis Lab
Holding lab for germ-free mice
Holding lab for conventional mice
Lunar Microbiology Lab
Bird, fish, invertebrate lab
Microbiology lab
Egg and tissue culture lab
Plant lab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

Other labs behind the LRL bio-barrier:

Crew virology lab
Bio-safety lab
Bio-medical lab

The rules have changed! Planetary Protection now includes both hazard detection and life detection at the molecular level. Different facilities and protocols are required – probably cleaner ones requiring less sample.

OTHER DEBATES – how samples are used

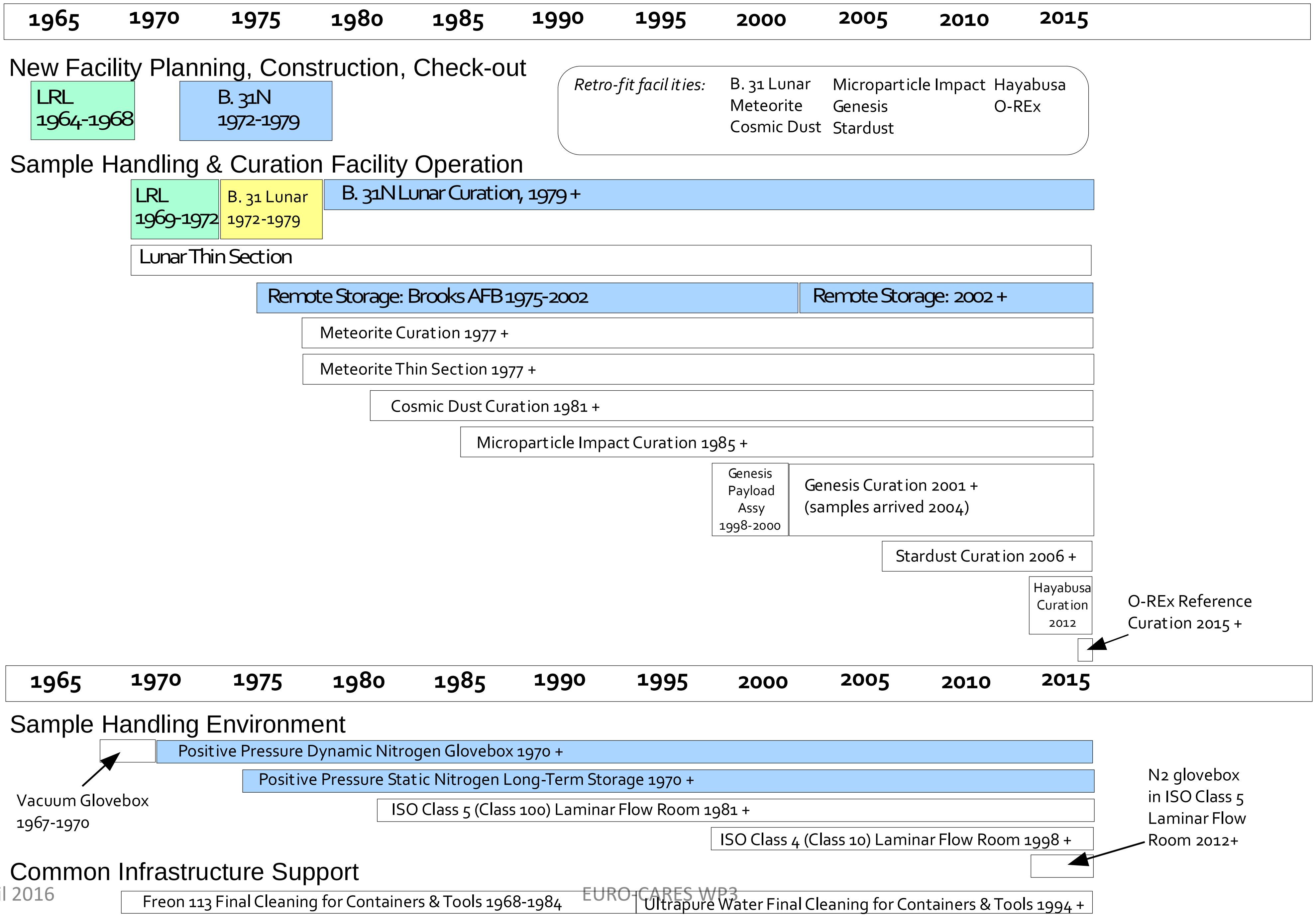


What is the appropriate depth of preliminary examination of samples?

For the Apollo samples, the Preliminary Examination Team (PET) was charged with describing the samples so they could be appropriately allocated for research. They worked inside the LRL, viewing specimens in gloveboxes. Instruments provided inside the bio-barrier included an emission spectrograph for elemental composition, gas mass spectrometer for noble gases, radiation counting lab for short-lived species, and optical microscopes for basic characterization.

The Lunar Sample Analysis Planning Team (LSAPT) was charged with responding to sample requests from outside investigators by determining appropriate sample and making allocation recommendations. LSAPT worked outside the LRL, meeting frequently with the PET to gather information about the samples.

ISSUE: Maintain fair access to the science rewards resulting from sample study. PET was not allowed to scoop the best science because of access to the samples.


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 +

LUNAR CURATORIAL FACILITY DESCRIPTION

1100 m^2, two floors, $2-3M

About 8 NASA civil servants and 20 contractors (1980 estimate-not current actual) working one shift

Outside science community recruited to participate in scientific oversight of sample curation/allocation and planning for other astromaterials curation (Lunar and Planetary Sample Team, LAPST, 1978-1993)

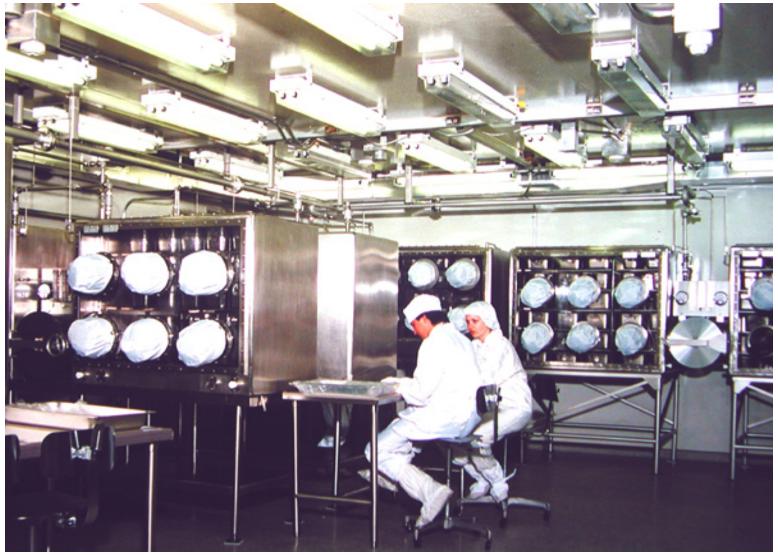
Facility focus on

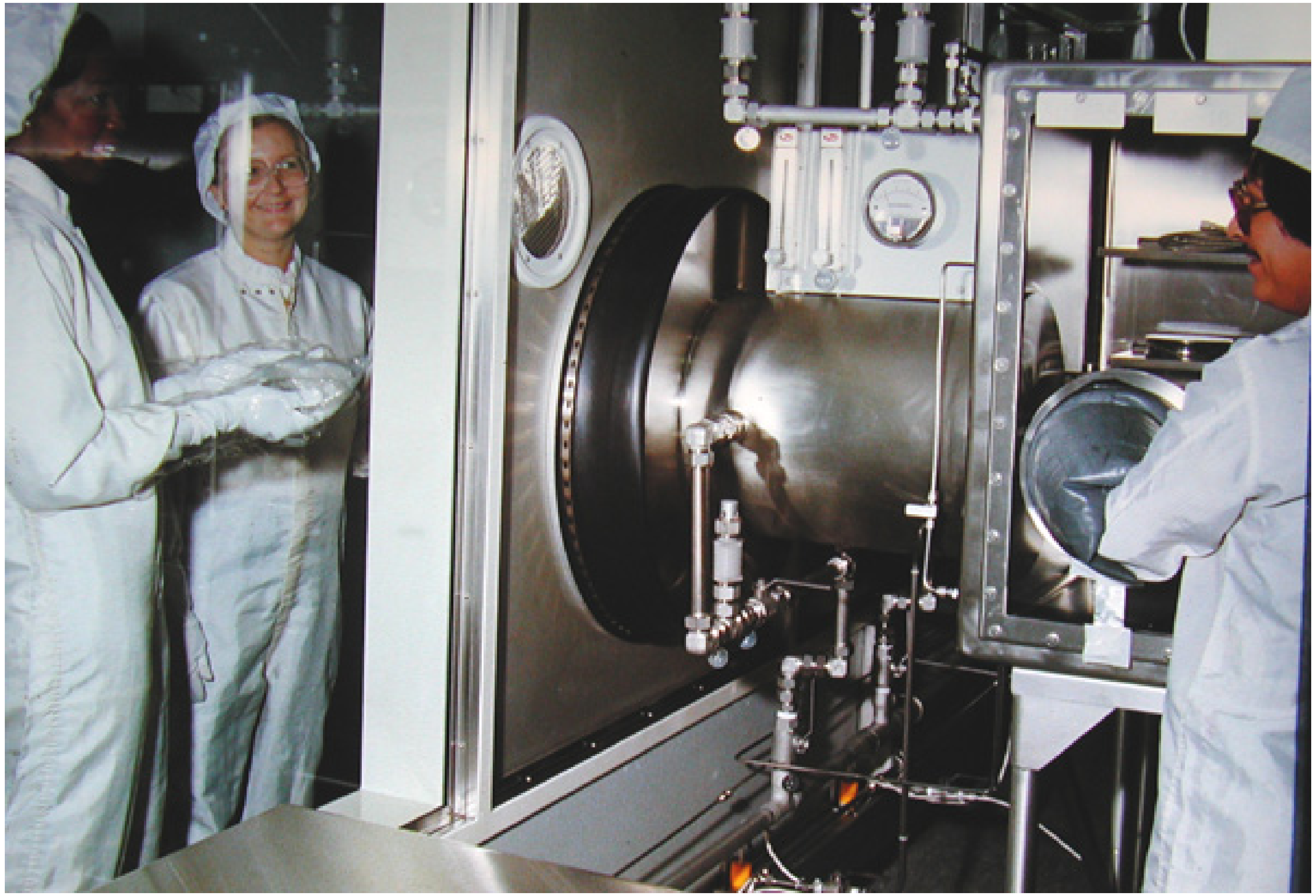
- Physical security
- Protection from natural hazards
- Core location for ultilities – air handlers, nitrogen gas
- Rigorous screening of construction and equipment material composition

LUNAR CURATORIAL FACILITY DESCRIPTION

http://curator.jsc.nasa.gov/lunar/laboratory_tour.cfm

PRISTINE CORRIDOR & VAULT
PRISTINE SAMPLE LAB
RETURNED SAMPLE VAULT
EXPERIMENT LAB
CORE & SAW ROOM





LUNAR CURATORIAL FACILITY DESCRIPTION

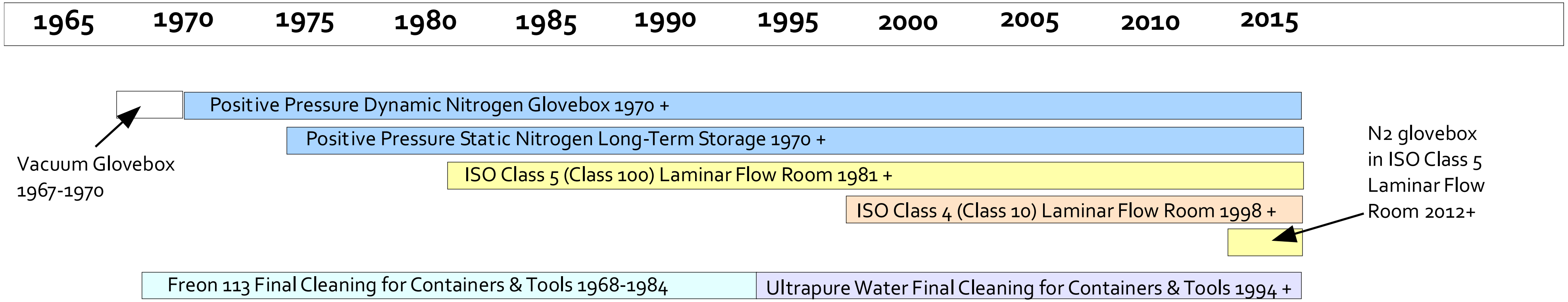
http://curator.jsc.nasa.gov/lunar/laboratory_tour.cfm

PRISTINE CORRIDOR & VAULT
PRISTINE SAMPLE LAB
RETURNED SAMPLE VAULT
EXPERIMENT LAB
CORE & SAW ROOM

LUNAR CURATORIAL FACILITY: Material screening

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.

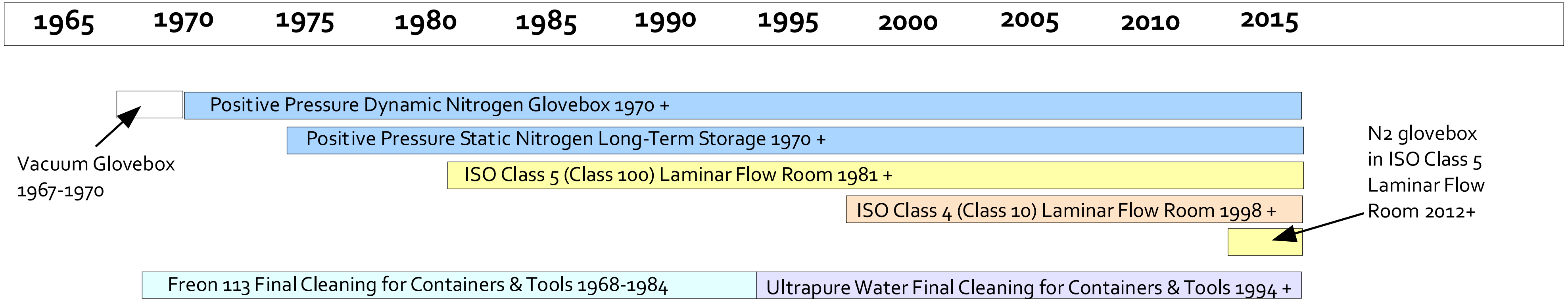
Materials allowed into the laboratory and into the gloveboxes are constrained to a few, simple composition of acceptable chemical elements, non-shedding and easily cleanable with UPW.

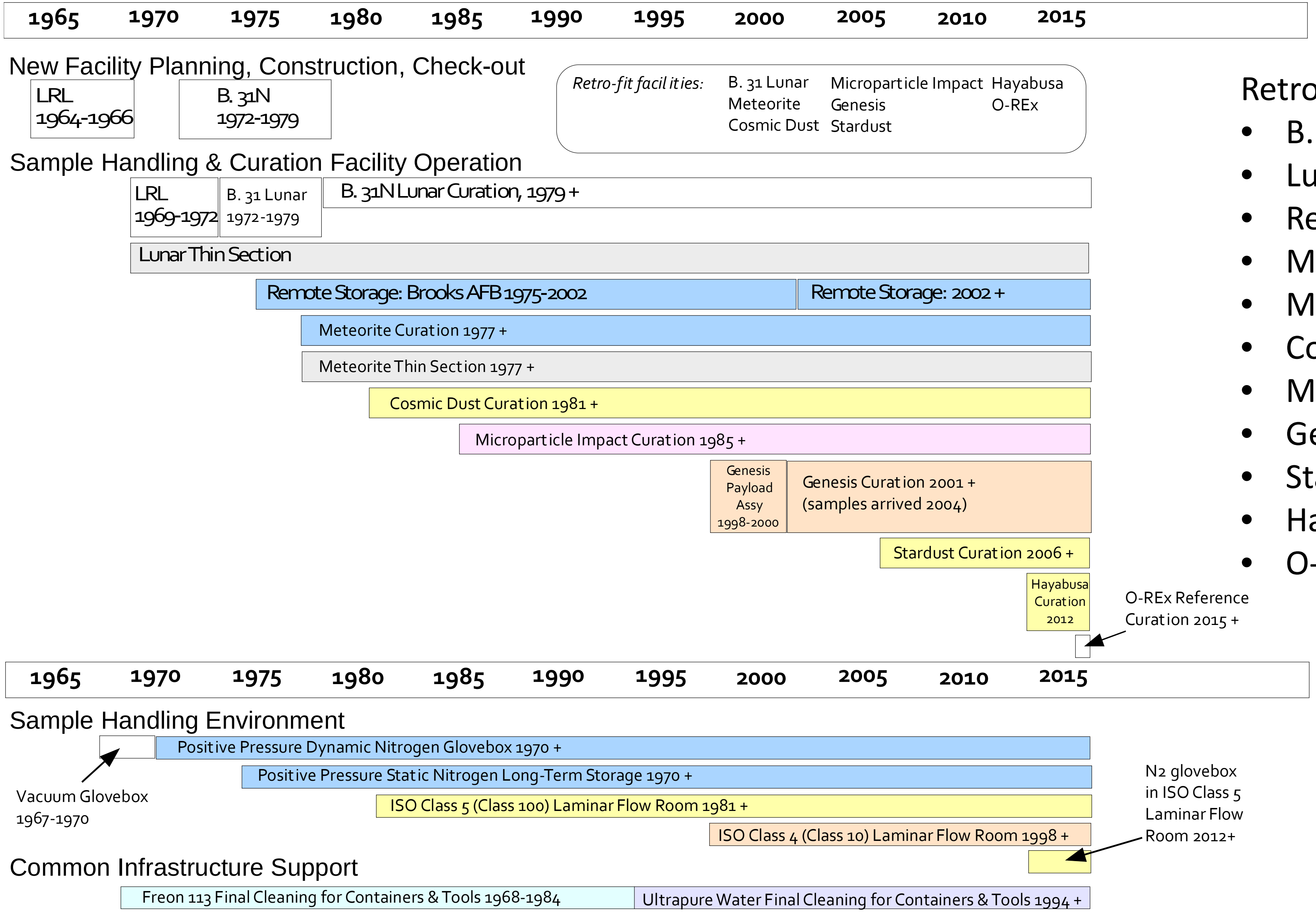


ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space

- **Faster**
  - Eliminates lengthy review period
  - Restricted focus
  - Modification is faster than whole construction
- **Less expensive**
  - Less formal review process
  - Takes advantage of existing structure
  - Takes advantage of existing utilities, shared resources
  - Multiple, smaller contracts for construction, certification

- **May not achieve optimum layout for long-term curation**
  - Equipment maintenance and upgrade may be more costly or difficult





Retrofitted lab spaces:

- B. 31 Lunar Curation temporary
- Lunar thin section
- Remote storage
- Meteorite curation
- Meteorite thin section
- Cosmic Dust Curation
- Microparticle Impact Curation
- Genesis Curation
- Stardust Curation
- Hayabusa I Curation
- O-Rex Reference Materials

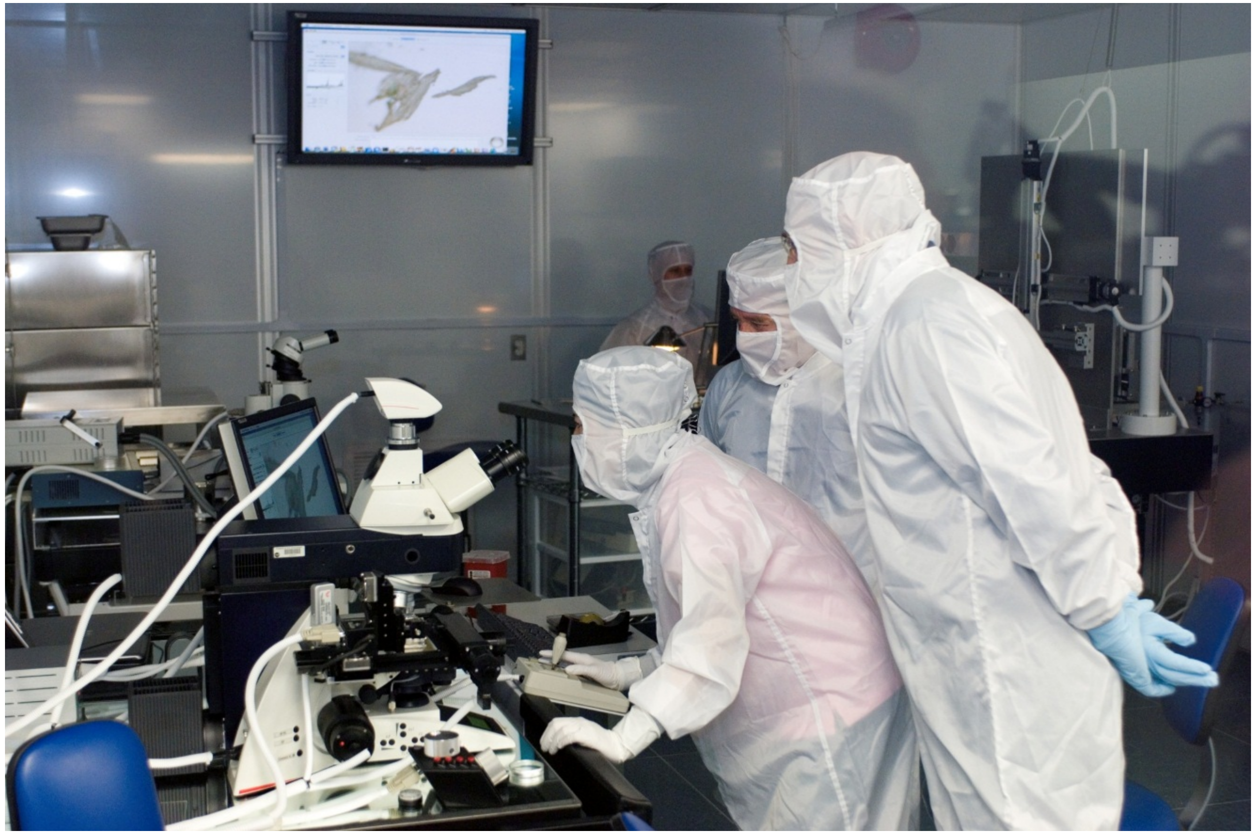
ADDING ASTROMATERIAL CURATION LABORATORIES:
Retrofitting lab space

ROCKS - METEORITES

ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space

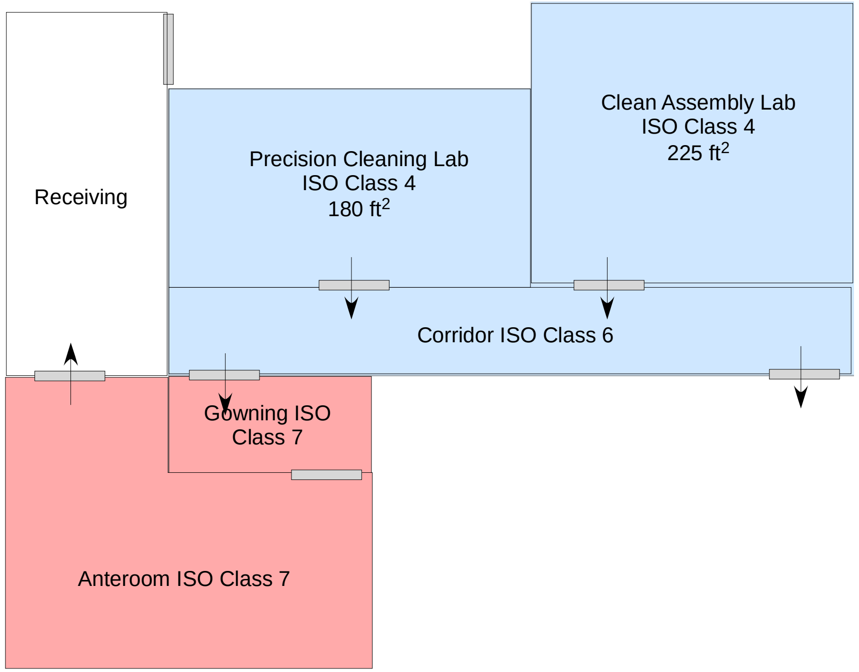
Cosmic Dust particles removed from silicone oil

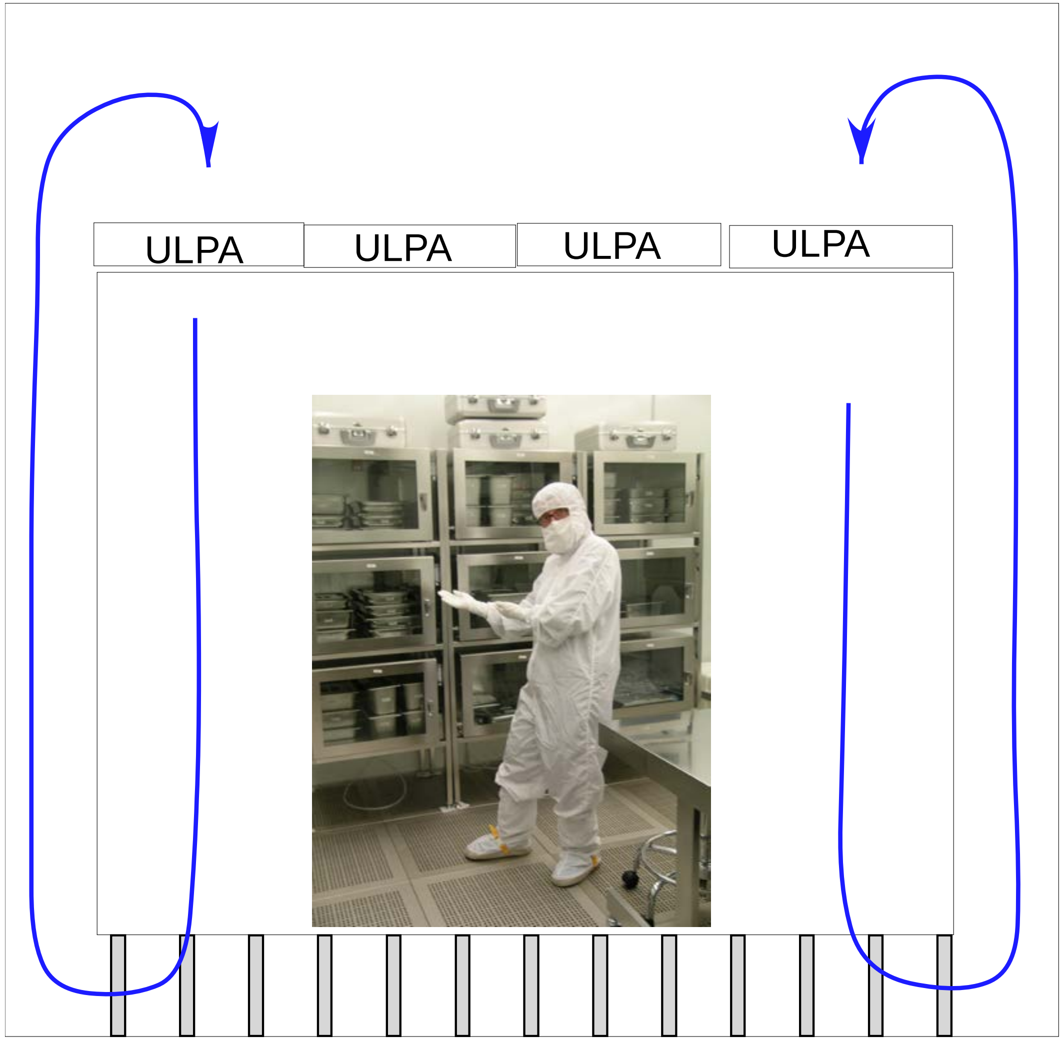
Stardust particles in aerogel



SMALL PARTICLES

FACILITY FOCUS: ISO Class 4, a drop-in room





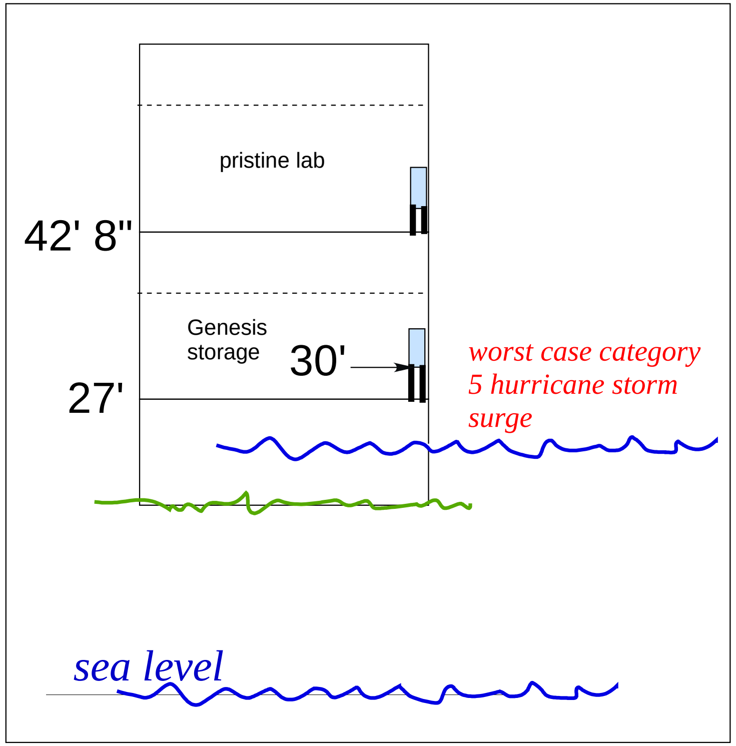
SHOWN IN BLUE
Vertical laminar flow
100 fpm ULPA (<0.12 μ)
Fed by HEPA air handler (<0.3 μ)
Total ULPA coverage ceiling
Total floor air flow holes

ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space

Genesis
Clean Assembly for flight
Characterize and clean fragments

ATOMS – SOLAR WIND

FACILITY FOCUS: Hurricane readiness storage



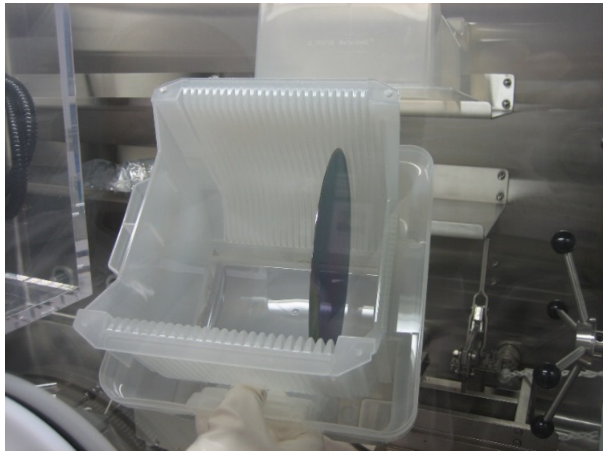
Samples not currently being worked are stored in upstairs vault during hurricane season. Kept in rolling desiccators purged with nitrogen. Moving process practiced annually.

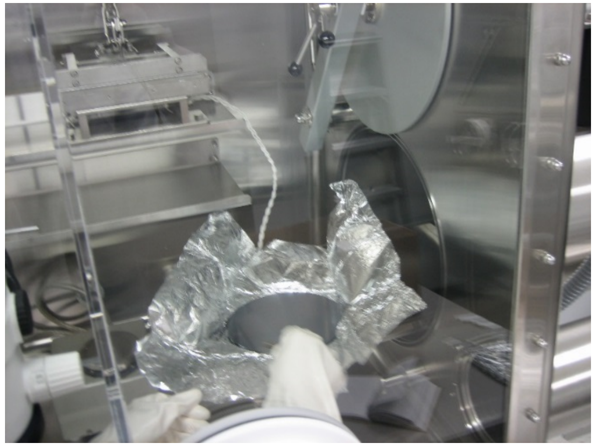
PARTICULATE VS ORGANIC CLEANLINESS: Technical tension

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.

LUNAR CURATION FACILITY: is almost 40 years old!

And looks like new!

It was well planned for Apollo sample curation requirements!

Carefully executed!

Can accept upgrades and served Apollo collection well!