Portable Cleanroom for NASA OSIRIS-REx Mission Deintegration

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Agenda

- Background
- Cleanroom Operations
- Cleanroom Construction
- Questions

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Background – Mission

OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

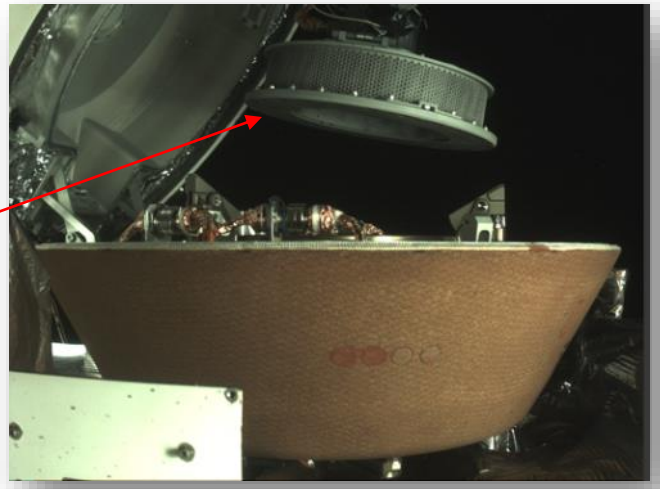
Launch 2016
Arrival 2018
Samples 2020
Depart 2021
Return 2023

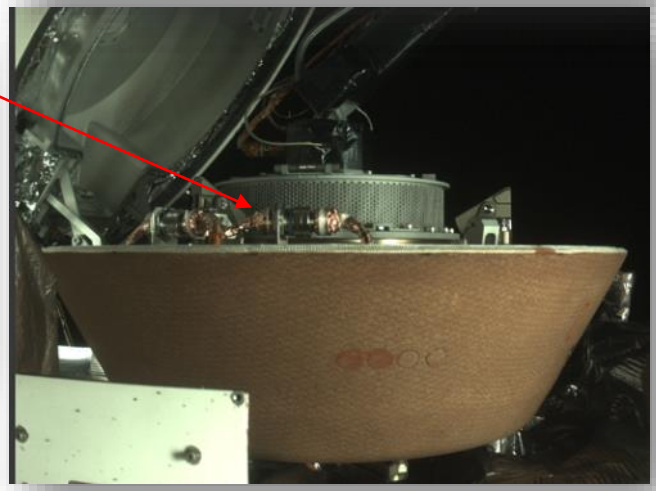
Background – Sample Gathering

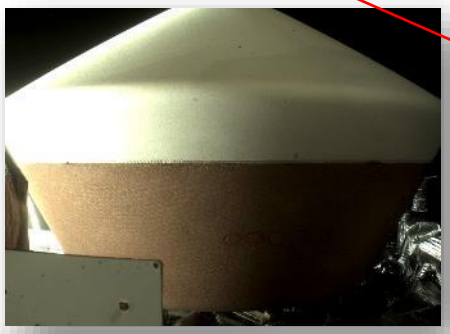
The OSIRIS-REx spacecraft, which launched Sept. 8, 2016, collected rocks and dust – an estimated 8.8 ounces, or 250 grams – from the surface of asteroid Bennu on Oct. 20, 2020.

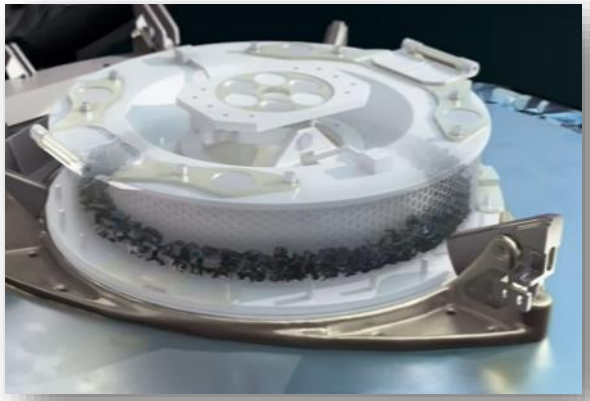
Background – Sample Containment

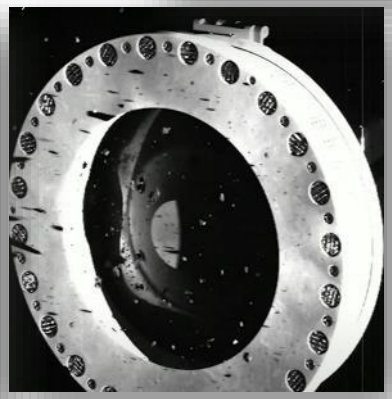
- NASA's OSIRIS-REx mission successfully placed the spacecraft's sample collector head into its Sample Return Capsule (SRC).
- The first image shows the collector head hovering over the SRC after the Touch-And-Go Sample Acquisition Mechanism (TAGSAM) arm moved it into the proper position for capture.
- The second image shows the collector head secured onto the capture ring in the SRC.











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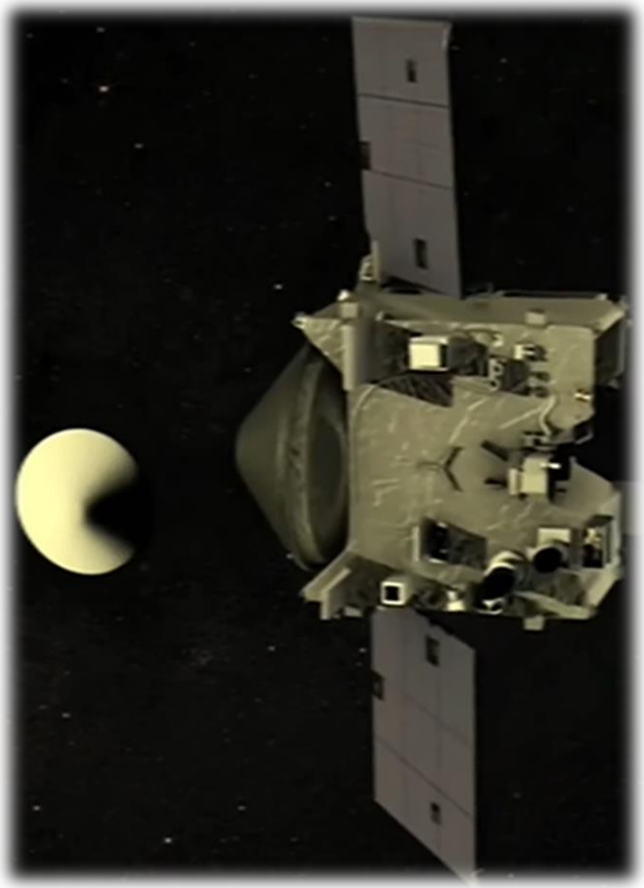
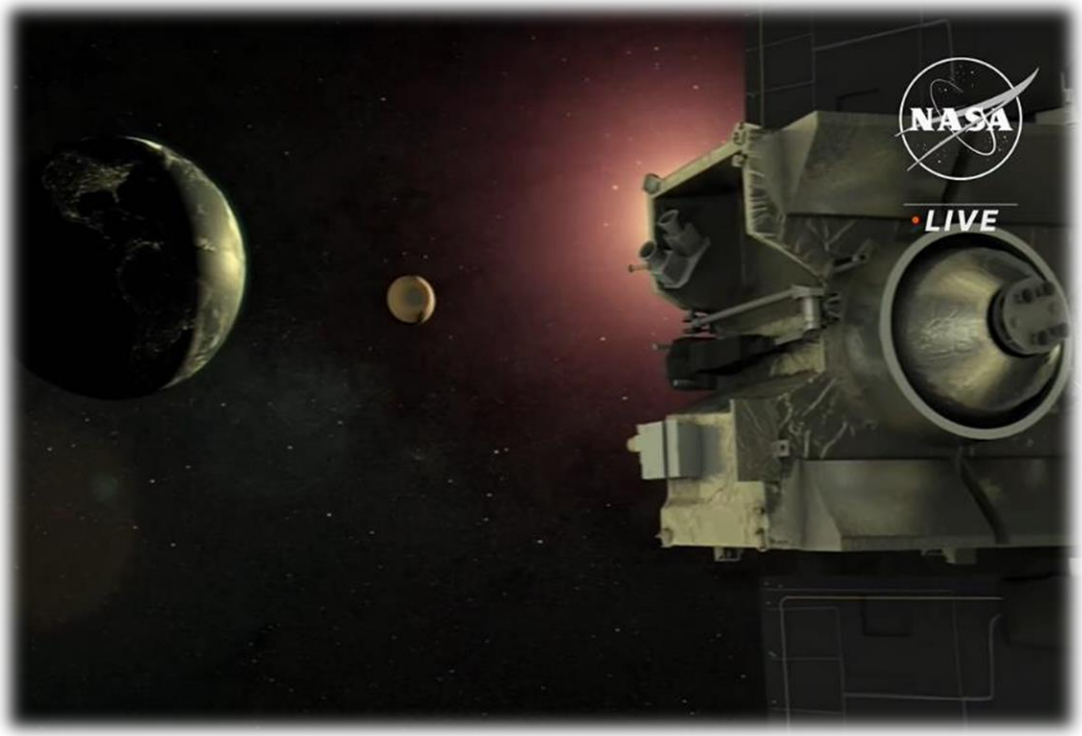
Background – Sample Departure

- After traveling billions of miles to Bennu and back, the OSIRIS-REx spacecraft released its sample capsule toward Earth's atmosphere at 6:42 a.m. EDT (4:42 a.m. MDT).
- The spacecraft was 63,000 miles (102,000 kilometers) from Earth's surface at the time – about one-third the distance from Earth to the Moon.





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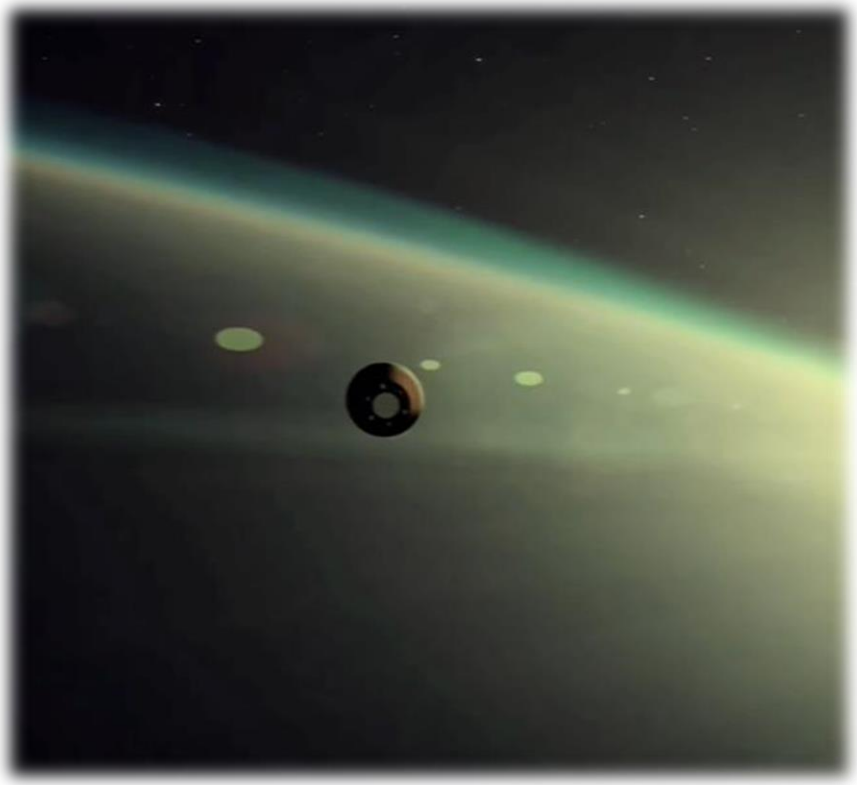
Background – Sample Arrival to Earth

- Traveling at 27,650 mph (44,500 kph), the capsule pierced the atmosphere at 10:42 a.m. EDT (8:42 a.m. MDT), 9/24/23 off the coast of California at an altitude of about 83 miles (133 kilometers).



Background – Sample Landing

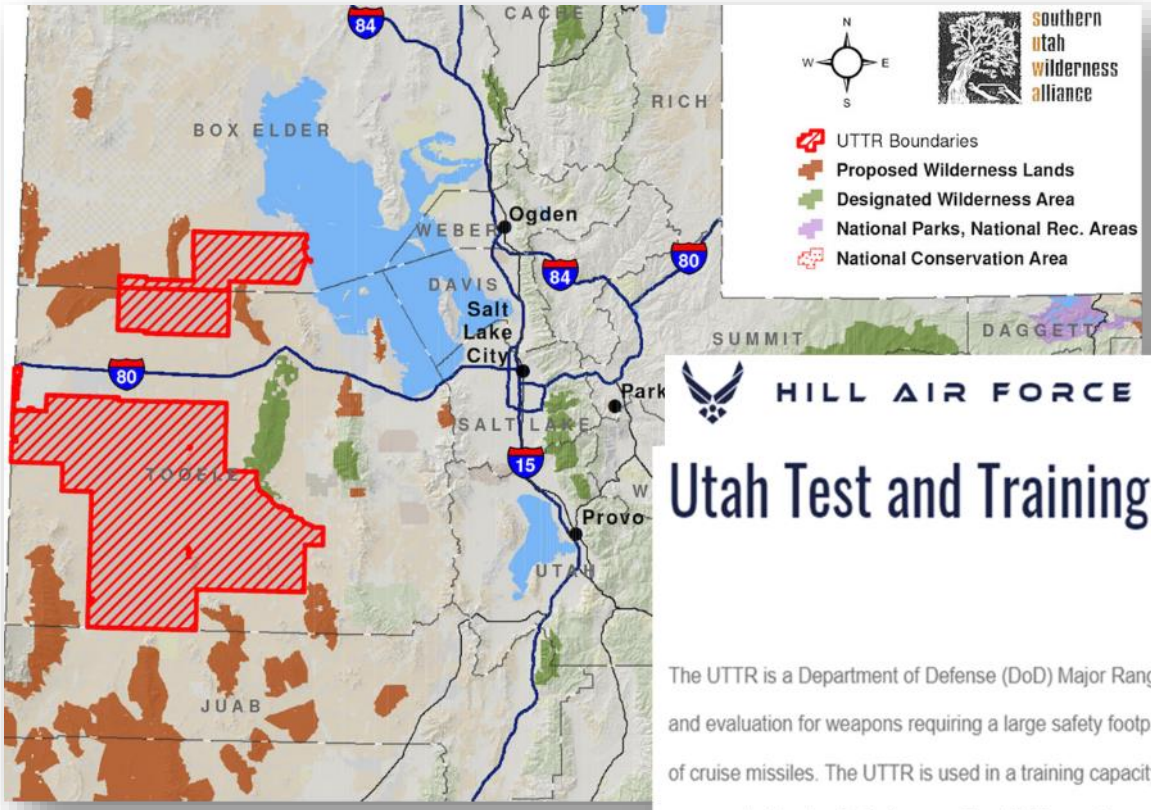
- Within 10 minutes, it landed on the military range. A parachute successfully deployed to stabilize and slow the capsule down to a gentle 11 mph (18 kph) at touchdown.

Background – Sample Landing

- Touchdown!

Background – Sample Landing

- Landing Site Information



HILL AIR FORCE BASE

Utah Test and Training Range

Mission

The UTTR is a Department of Defense (DoD) Major Range and Test Facility Base and provides an ideal location for operational test and evaluation for weapons requiring a large safety footprint. The UTTR is also the only location capable of supporting overland testing of cruise missiles. The UTTR is used in a training capacity for air-to-air-combat, air-to-ground inert and live practice bombing and gunnery training by DoD aircrews. The UTTR provides a vast area of realistic terrain for world-class test and training scenarios to ensure the war fighter is prepared to deploy at a moments' notice to win any conflict with decisive air and space power.

Background – Sample Transport

- Radar, infrared, and optical instruments in the air and on the ground tracked the capsule to its landing coordinates inside a 36-mile by 8.5-mile (58-kilometer by 14-kilometer) area on the range.
- Within several minutes, the recovery team was dispatched to the capsule's location to inspect and retrieve it.
- The team found the capsule in good shape at 9:07 a.m. MDT (11:07 a.m. EDT) and then determined it was safe to approach.
- Within 70 minutes, they wrapped it up for safe transport to a **temporary clean room** on the range, where it remain under continuous supervision and a nitrogen purge.

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Background – Sample Transport

- It was then prepared and hooked up for helicopter transport

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Background – Sample Transport

- Transported by helicopter directly to building with cleanroom in it.

Background – Sample Transport

- Successful dropped off at building with cleanroom in it.

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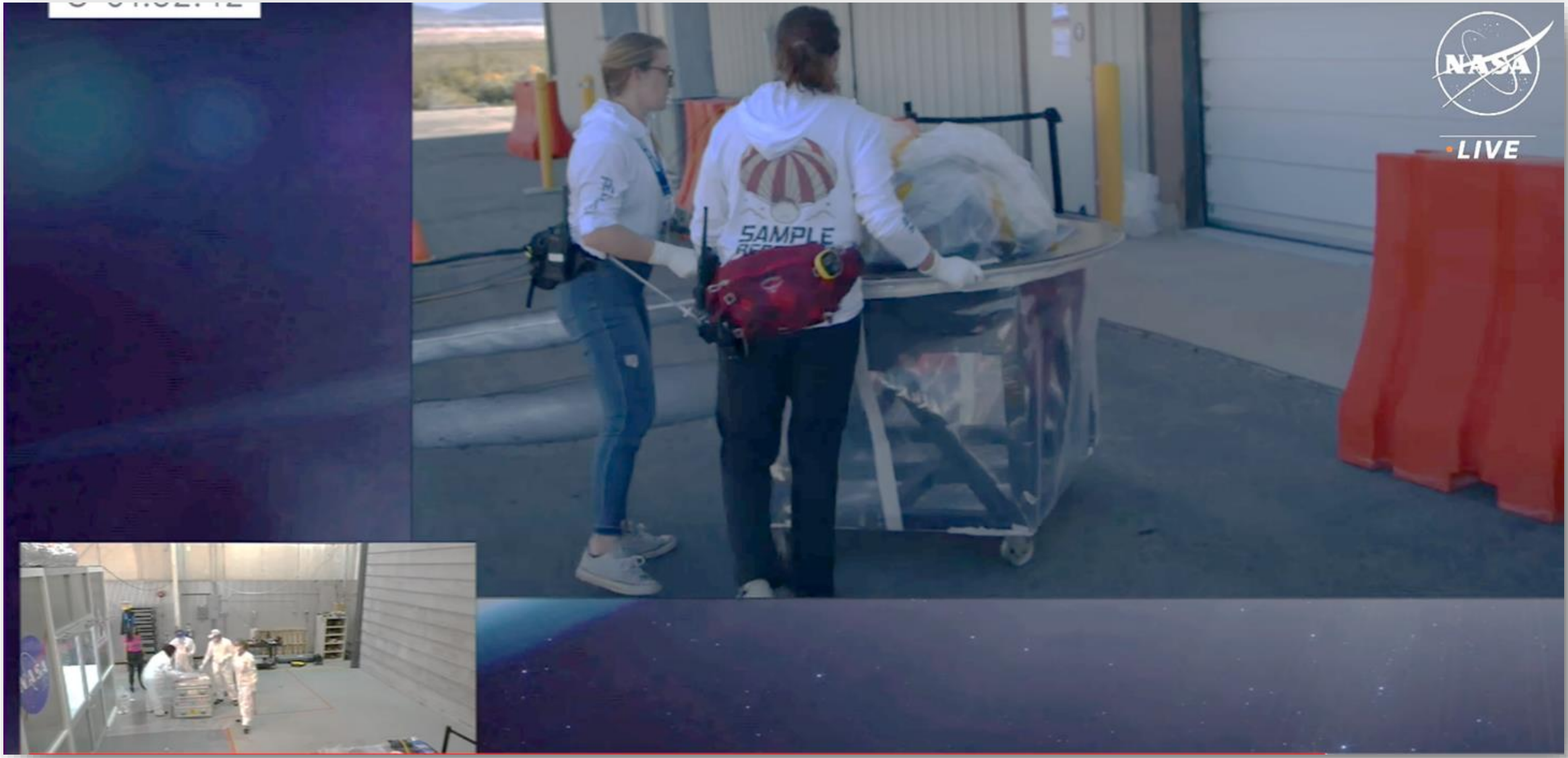
Background – Cleanroom Preparations

- Cleanroom personnel are gowned up getting ready to receive sample return capsule.

Background – Sample Transfer

- Sample return capsule was lifted onto cart for safe transport to cleanroom.



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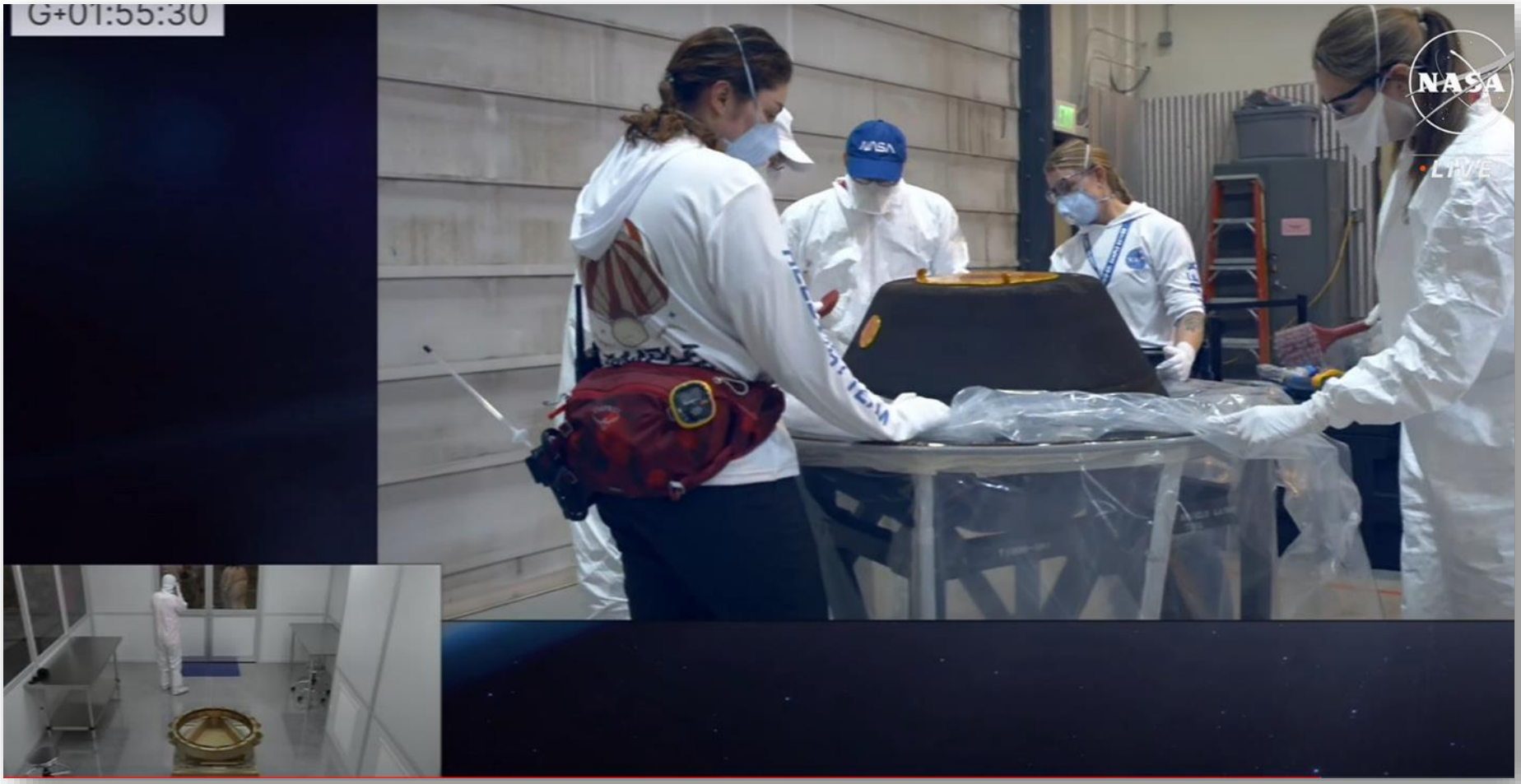
Background – Sample Transfer

- Sample return capsule was brought into building via a roll up door.

Background – Sample Transfer

- Sample return capsule was uncovered.



Background – Sample Transfer

- Sample return capsule cart was wiped down with isopropyl alcohol wipes before entering cleanroom.

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Background – Sample Transfer

- Sample return capsule was pushed up the floor ramp into the cleanroom.

Background – Sample Transfer

- Sample return capsule entered cleanroom via double doors.

Background – Sample Transfer

- Sample return capsule was lifted onto a clean stand in the cleanroom.

Background – Sample Transfer

- Sample return capsule was successfully transferred into the cleanroom.

Background – Sample Transfer

- Cleanroom doors were closed.

Background – Sample Transfer

- Lockheed Martin had "control" of the Sample Return Capsule the whole time it was at UTTR. After some glovebox steps in the JSC OREX cleanroom it was NASA Curation's.

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Background – Sample Transfer Complete

- OSIRIS-Rex with rocks and dust from asteroid Bennu landed at 8:52 a.m. MDT (10:52 a.m. EDT) on Sunday, at the Department of Defense's Utah Test and Training Range near Salt Lake City.
- Within an hour and a half, the capsule was transported by helicopter to a **temporary clean room** set up in a hangar on the training range, where it now is connected to a continuous flow of nitrogen.

Sep 24, 2023
RELEASE 23-109

NASA's First Asteroid Sample Has Landed, Now Secure in Clean Room

Cleanroom Operations

- Scientists and engineers needed the clean room to safely open the capsule and extracted the sample canister in a clean environment.

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Cleanroom Operations

- Getting the sample under an Ultra-high Purity (UHP) nitrogen purge was one of the OSIRIS-REx team's most critical tasks. Nitrogen is a gas that doesn't interact with most other chemicals, and a continuous flow of it into the sample container inside the capsule will keep out terrestrial contaminants to leave the sample pure for scientific analyses.

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Cleanroom Operations

Operations completed in the cleanroom:

- Rehearsal and disassembly of OREX sample return canister.
- Heat shield and backshell were removed inside the cleanroom.
- Sample return canister was prepped (hardware removed) to allow a nitrogen purge to be installed (via a cart).

The next day, on Sept. 25, 2023, the mission team transported the sample to NASA's Johnson Space Center in Houston, where it is documented, cared for, and stored.

- Here the sample return capsule is opened.

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Cleanroom Construction

Cleanroom was a Long-lead time item, 6-8 months *after:*

- Curation technical staff in-person examination of current condition of the UTTR Building 1012 space (happened September 2022). Delay in deciding the floor system. Science team didn't want vinyl flooring due to organic outgassing.
- Defining requirements with input from mission contamination control
- Iterating with vendors and contamination control to identify acceptable options
- Ultimately settled on diamond aluminum 6061 flooring rather than vinyl flooring used for Stardust and Genesis. This took about 2-3 months
  - ➢ Lesson learned for next mission - Recommend budgeting more time

This was tight in recovery timeline, which made this a particularly stressful procurement

- Pro: no organic off-gassing
- Cons: particle generation onto cleaning cloths, uneven mating with cleanroom walls, no anodization, and no time to properly clean potential oil/grease.

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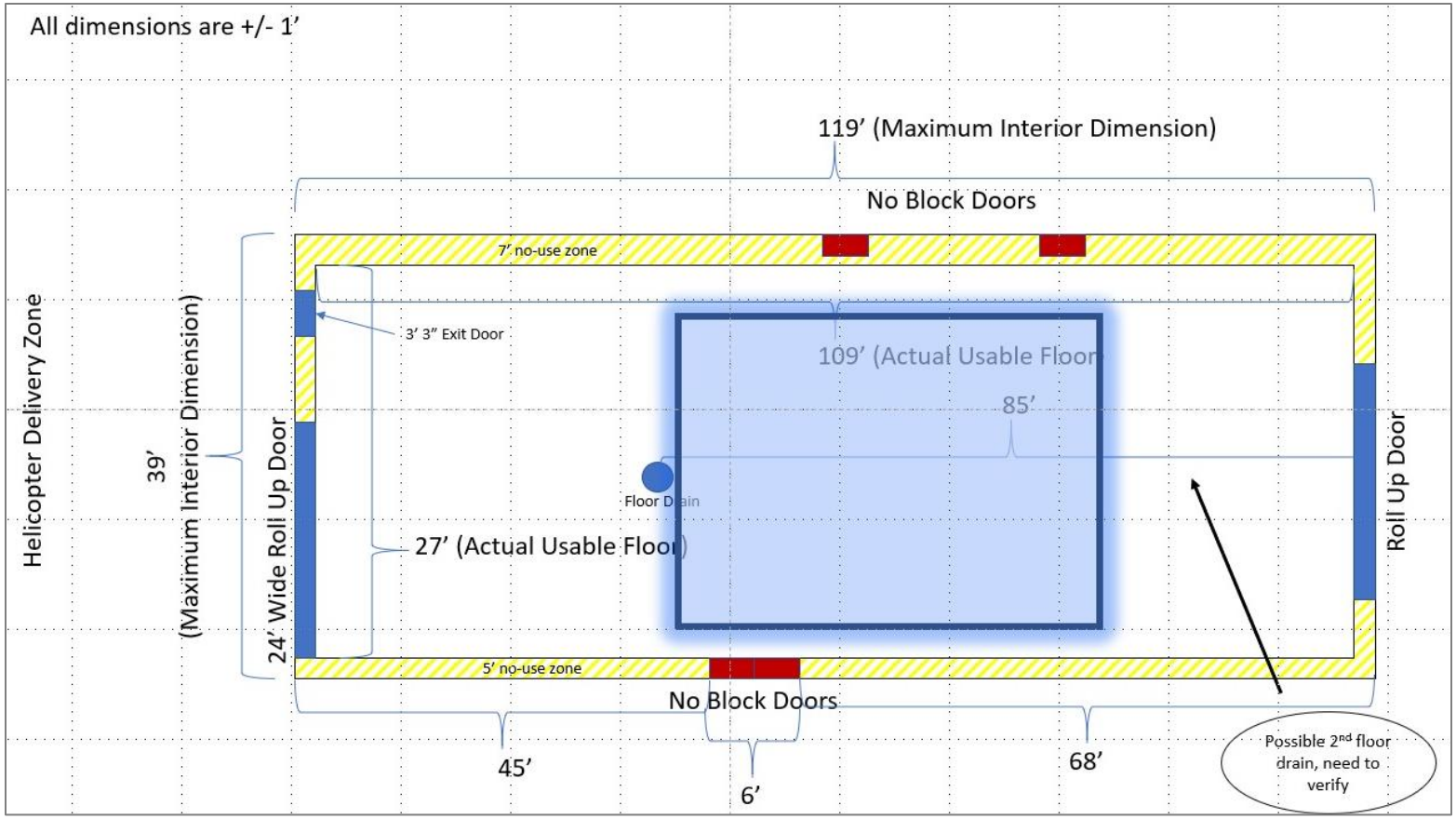
Cleanroom Construction

- Location onsite inside existing highbay building so verified size of cleanroom that could fit and meet mission requirements.

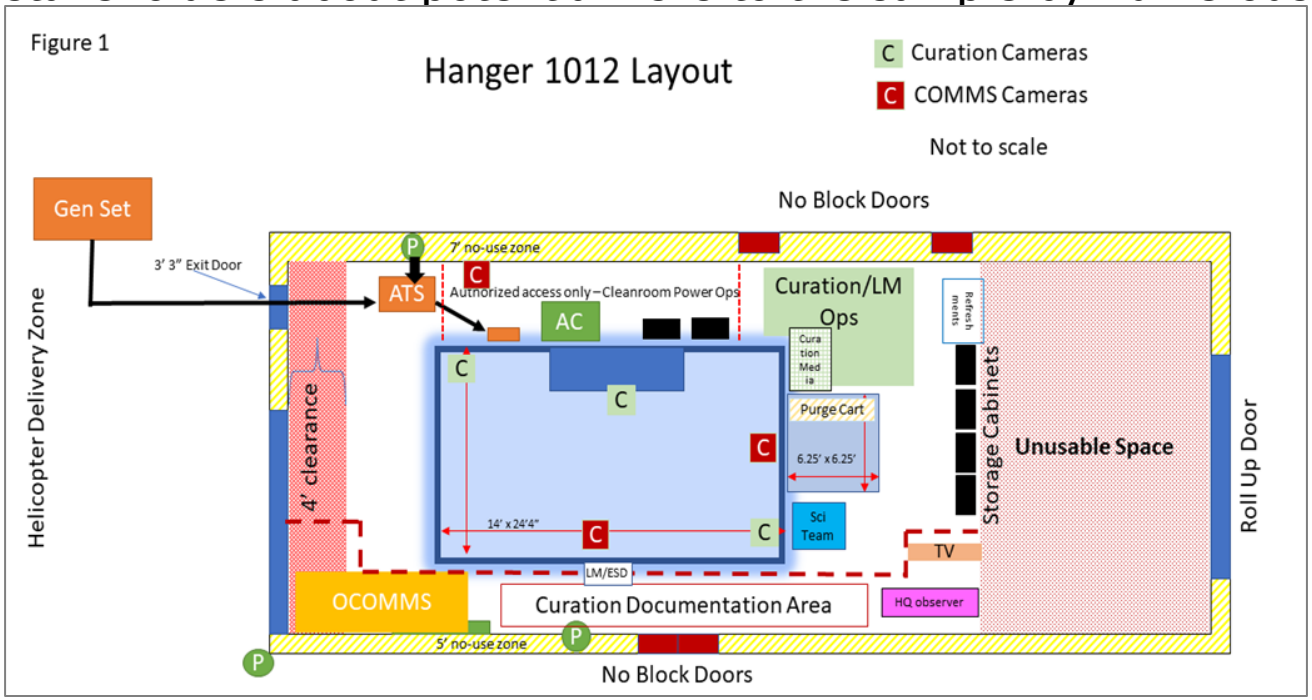


Cleanroom Construction

- Then planned for space around cleanroom because all returned flight hardware are collection items that need to be secured and tracked so need to limit access to essential personnel only
- Designated "cleanroom cops" to maintain limits on access
- Defined list of personnel and very small list of approved visitors
- Communication to all stakeholders about potential risks to the sample by numerous visitors

- Locations for personnel ended up being more flexible on actual landing day, but it wasn't a problem because the approved personnel list was mostly respected

Figure 1



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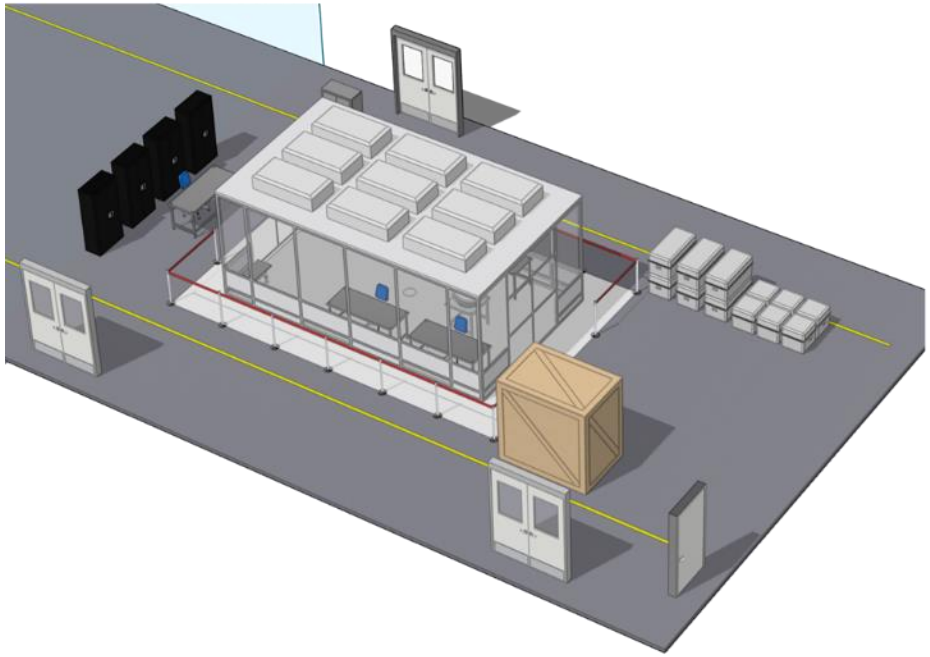
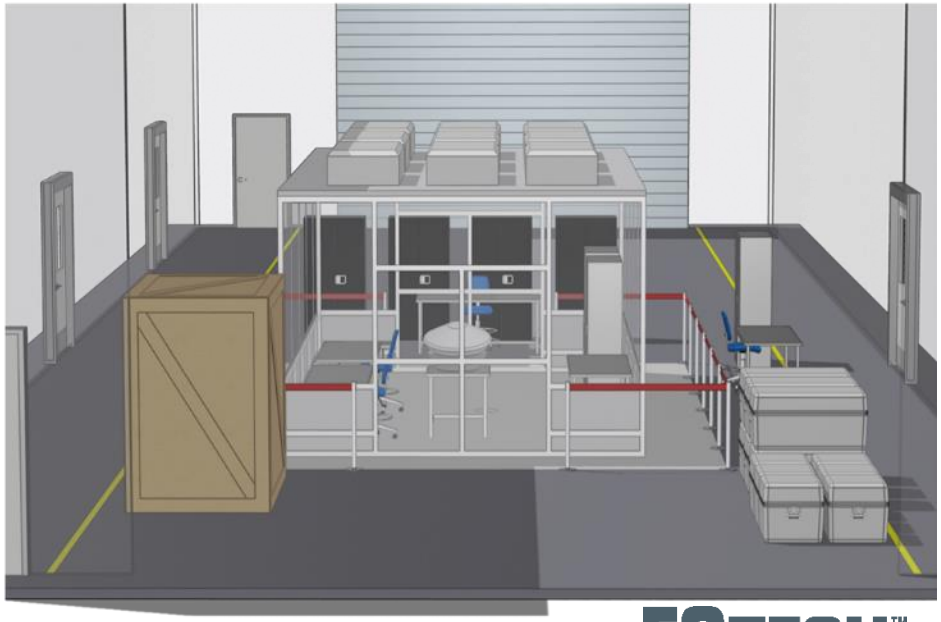
Cleanroom Construction

- Renderings of the cleanroom in the highbay were completed to verify everything would fit and function:
  - Planned for locations of personnel during operations
  - Like the rest of the recovery team, there was very limited space for curation personnel at UTTR between duties
  - In downtime, most curation personnel worked at tables in the hangar part of building 1012, which even with AC could be a hot unpleasant space





Cleanroom Construction

- After Purchase Order awarded to Lasco Services, they began full construction at their facility to flush out any issues before installation in the field at UTTR.
- Created Master drawing – fabricated and labeled according to drawing.
- Onsite floor was sloped so accounted for it in the shop to accommodate field install

Room #	Clean Classification	Wall Height	Length	Width	Ceiling Height
Cleanroom	ISO 7	10’	24’	14’	10’

Scope of Work:

Furnish & Install Cleanroom at Building 1012 of the Dugway Proving Grounds.
6/12/2023 Start Cleanroom Installation
07/10/2023 Cleanroom Installation complete (NLT)
11/06/2023 Cleanroom Removal
11/13/2023 Removal complete (NLT)

Cleanroom

Lasco 1751 Modular Cleanroom Wall System

- Trims are clear anodized
- White PVC Snap Cover
- Solid Panels are ¼” aluminum composite panels
- Clear Panels are ¼” clear acrylic
- Framing Tubes are Powder Coat White
- Includes return air grills

Lasco 2” Smooth Face Cleanroom Ceiling Grid

- Santoprene gasket
- Finish is Clear Anodized
- Self-supported
- Ceiling Tiles are Vinyl faced

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Cleanroom Construction

- In shop – one module was backward (quality issue) so it was swapped out in shop versus in the field
- They hooked up the air conditioner, lights, FFUs and electrical power to test everything in the shop before being deployed to the field. Commissioned FFUs and took particle counts.

Cleanroom Construction

- Once it was built and tested in the shop meeting all requirements. It was taken down, all pieces were labeled and packaged together for easy reinstallation reducing install time, then shipped to UTTR.
- Lasco used same people to build in shop and then in the field – made it very smooth operation

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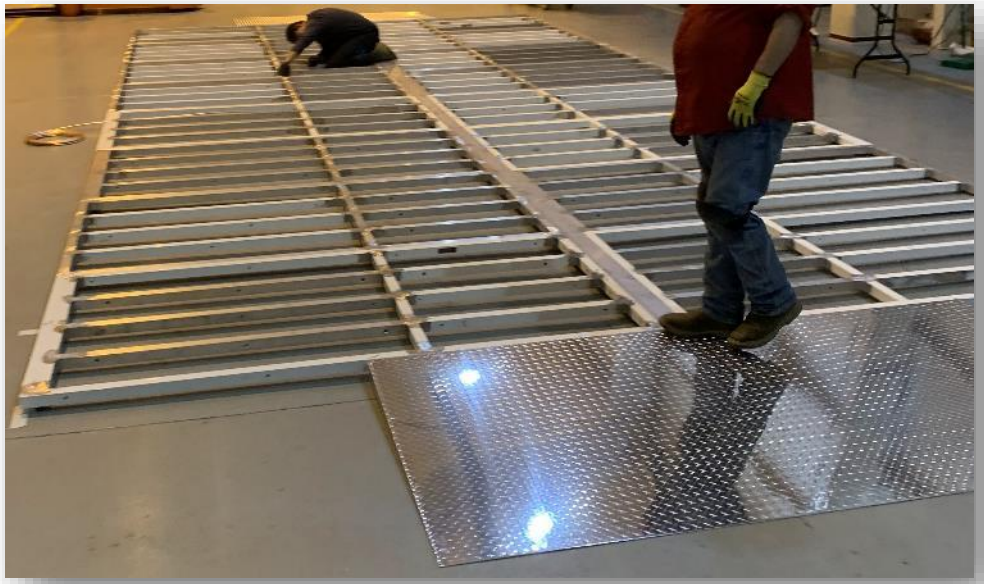
Cleanroom Construction

- Location in the field was inside another building (warehouse style).
- Conducted site visit to verify that location would work and noted some issues with garage roll-up doors being very contaminated and there was also contamination from the lights. Mitigations implemented later.

Cleanroom Construction

Flooring:

- Layout to be 32’x16’
- .250 6061 Aluminum Tread Brite Plate fastened to Aluminum Tube Framing
- Tube platform to be 1.75”x1.75” welded tube frames, mill finish. Platform to be prefabricated into bolt together modules and leveled onsite.
- Includes (2) 2”Hx72”Wx14”D Ramps



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Cleanroom Construction

- Usually just sit cleanroom frame directly on floor. Took some engineering to make metal floor work with 1/8” diamond plate so not too heavy but didn’t want it to deflect. Thousands of screws to attach floor to frame.
- Added cleanroom tape to any open seam to better seal up cleanroom on the outside of the wall floor system. The 6061-diamond aluminum flooring did not mate seamlessly with the temporary cleanroom because that flooring type is inherently not flat, so we ended up taping the exterior of the cleanroom to the floor with cleanroom tape to mitigate dust, etc., getting in through the gap.

Cleanroom Construction

- Onsite location was remote and no local hardware stores available – spare materials were brought just in case (4-hour trip to get parts).

- 5 installers in the field (landing to ready in 3 days and then powered up when temp power was available. 1 guy left to commission in the field to verify all working)

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Cleanroom Construction

- Only had access to one side of building so changed orientation of cleanroom so original curtain door did not face the outside roll up door.

Doors:

(1) 6'0 x 7'0 Double Cleanroom Doors:

- Aluminum Framing
- ¼" Clear Acrylic in top and bottom panels
- Push/Pull hardware
- Closer included

(1) 6'0 x 10'0 Clear Strip Curtain Door:

- .040 Clear PVC Strips
- 8" Strips with 2" overlap
- Aluminum Mounting Bar

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Cleanroom Construction

- Building didn't have a/c just heat so had to provide a/c as part of cleanroom

HVAC:

- Furnish and Install wall mount HVAC Unit
- Add one 24" x 96" RA Chase within Cleanroom
- Supply and recirculating ducting to Plenum boxes on each FFU
- Return air ducting
- Thermostat and wiring
- Condensate piping to within 10'

- Air conditioning that does not require exterior doors are needed next time (Swamp coolers offered by UTTR required a large door being partially open).
  - LM provide localized AC units with exhaust diverted out thru an intermediate side room.

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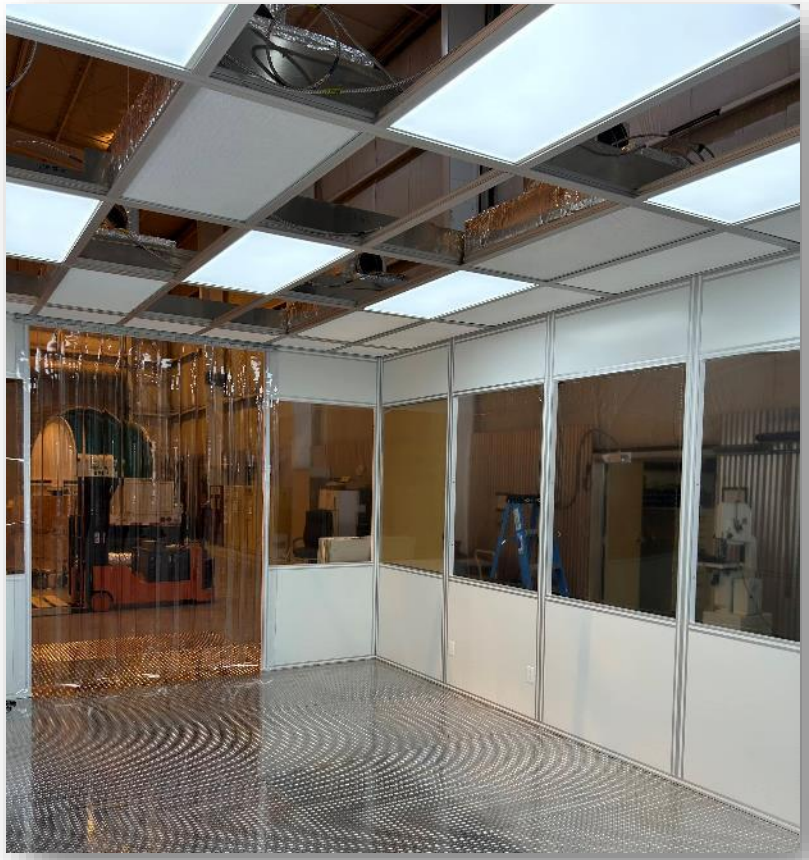
Cleanroom Construction

Electrical:

- Provide 1 120/240 100AMP single phase panel
- Panel to mount to surface mount to outside side of cleanroom wall
- Breaker and circuits J boxes for four outlets in Cleanroom
- Breaker and circuit for six Fan filter units
- Breaker and circuit for lights
- Breakers and circuits to HVAC equipment
- Provide and install new raceway and wiring for (4) duplex/data receptacles. Receptacle are flush mounted in wall, wired to J-box on top of wall module



Lights:

- Provide 2' x 4' LED Cleanroom lights

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Cleanroom Construction

- HEPA FFUs directly ducted and wrapped.
- Lasco commissioned particle counts and FFU setpoints and ARES verified particle counts and FFU settings for ISO-7.

HEPA FFUS

- Variable Speed or 3-speed control
- 23 5/8”’ x 47 5/8”’ x 12” Nominal dimensions
- Voltage is 120V or 277V
- Filter efficiency is 99.9% at 0.3 micron
- Aluminum housing
- White face-screen

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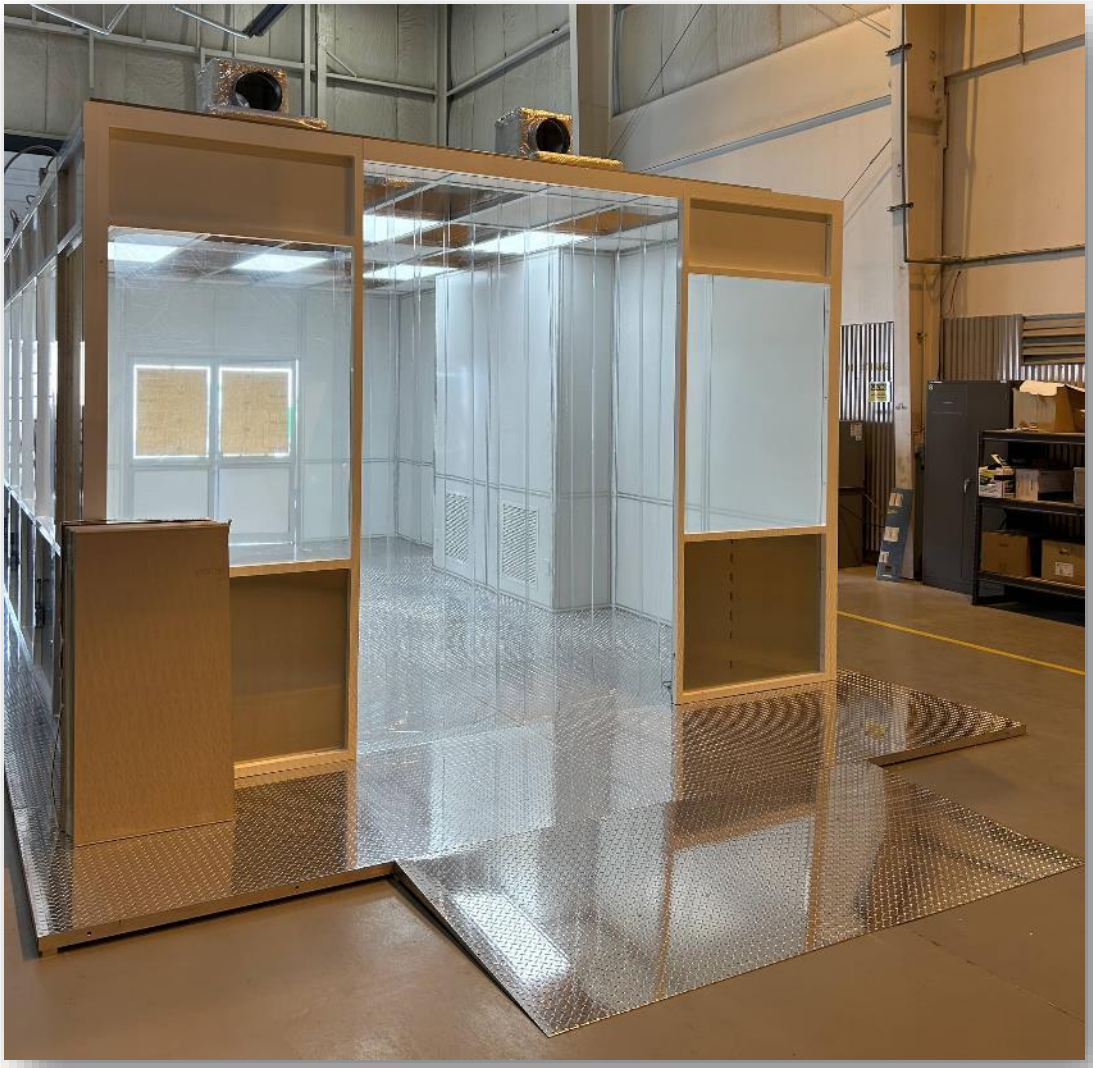
Cleanroom Construction

- Lots of integration for power from facility to generator for a/c, FFUs and lights.
- Vendor left some ceiling panels and one FFU along with some elec breakers plus a ladder at site in case it was needed later.



Cleanroom Construction

- No issues with actual Lasco construction/tear down (3 people 1 day)
- Lasco deconstructed the cleanroom and transported it back to their facility where they were able to utilize it for another customer – who built it themselves from the master drawings. They will also use the flooring for the permanent installatio, but right now it is at a temporary location.

Cleanroom Construction

- Cleanliness Challenges
  - Debris of black flaky material "raining" down from ceiling heating elements
  - Particles in cleanroom increased when any of the exterior doors to the hangar were open
  - Flies were disconcertingly abundant inside hangar part of the building in June and July
- Mitigation for Cleanliness Challenges
  - The readiness review findings that we add an anteroom came much too late to include in the procurement so we were lucky that we could borrow an anteroom that curation already had in storage at JSC.

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Cleanroom Construction

- Cleanroom installed by Lasco in June 2023 – Anteroom added by ARES Curation in July 2023
- Lesson learned – recommend that the mission review that includes the UTTR temporary cleanroom happen with enough lead time for feedback to be incorporated into purchase order

- Mitigation for Cleanliness Challenges
  - Coordinated with rest of the Recovery team and ultimately UTTR to minimize the time and extent that exterior hangar doors would be open

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Cleanroom Construction

- Wrapped cleanroom doors with additional layer of plastic sheeting and taped the sheeting down with cleanroom tape when not in use
- Archived and analyzed debris from ceiling heating elements

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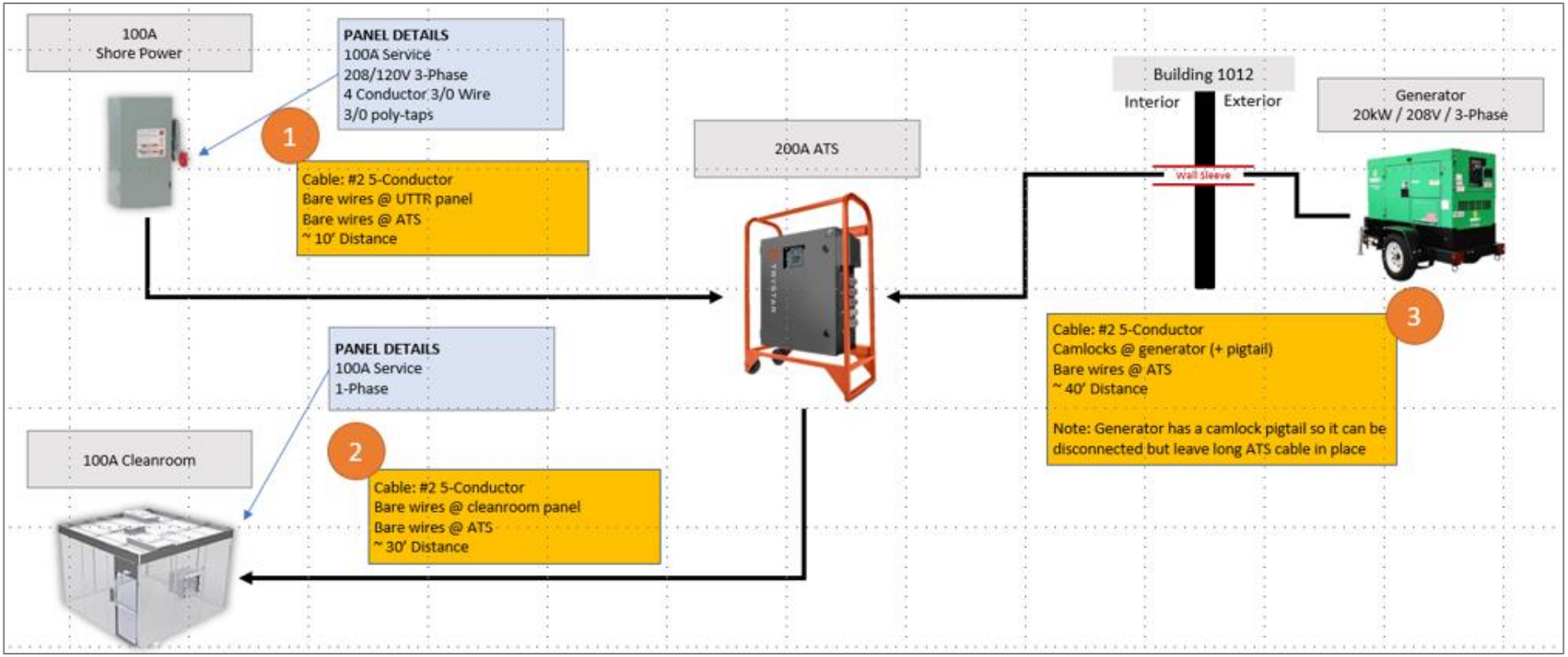
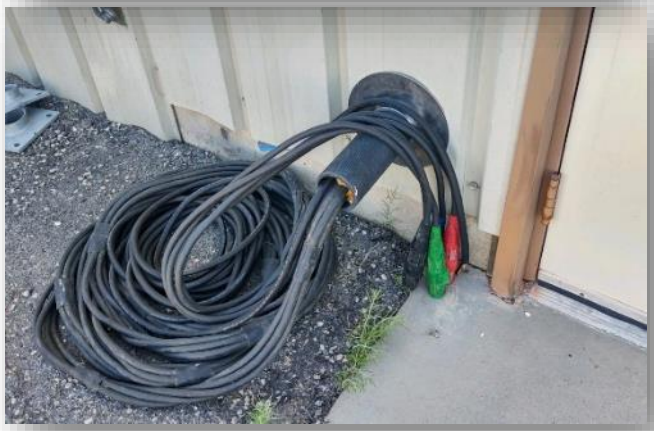
Cleanroom Construction

- Power supply design coordinated with onsite facility support and cleanroom vendor.



Cleanroom Construction

- Power panel connection to backup generator (20KW, 208V, 3 phase) outside installed by vendor.



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Cleanroom Construction

- Conducted a full wipe down with 70% isopropyl alcohol wet wipes and Ammonia free Windex with our ARES Cleaning Techs. Mopped floor a lot to keep clean. Cleaned to ISO 5 levels.

OSIRIS-Rex CLEAN CHECKLIST ISO CLASS 5

POC: RACHEL FUNK

GOWNING:BOOTIES HAIR NET FACE MASK HOOD BUNNY SUIT BOOTS SINGLE GLOVES (NO JEWELRY ALLOWED)

SUPPLIES: VALUTEK-IPA NON-AMMONIA WINDEX

MOP ALL FLOORS WITH CONTEC WIPES AND WATER

(ONLY USE VALUTEK-IPA OR NON-AMMONIA WINDEX ON STAINED FLOORS. WIPE AGAIN WITH WATER.)

DAILY	Monday		Tuesday		Wednesday		Thursday		Friday	
RM 216	Date	Initials	Date	Initials	Date	Initials	Date	Initials	Date	Initials
Remove trash										
Clean SS surfaces										
Wipe down all surfaces										
Mop floor with contec floor & water										
Clean all glass and pass thru										

MONTHLY	Monday		Tuesday		Wednesday		Thursday		Friday	
RM 216	Date	Initials	Date	Initials	Date	Initials	Date	Initials	Date	Initials
Ceiling to floor cleaning										
Remove trash										
Clean SS surfaces										
Wipe down all surfaces/walls										
Mop floor with contec floor & water										
Clean all glass and pass thru										

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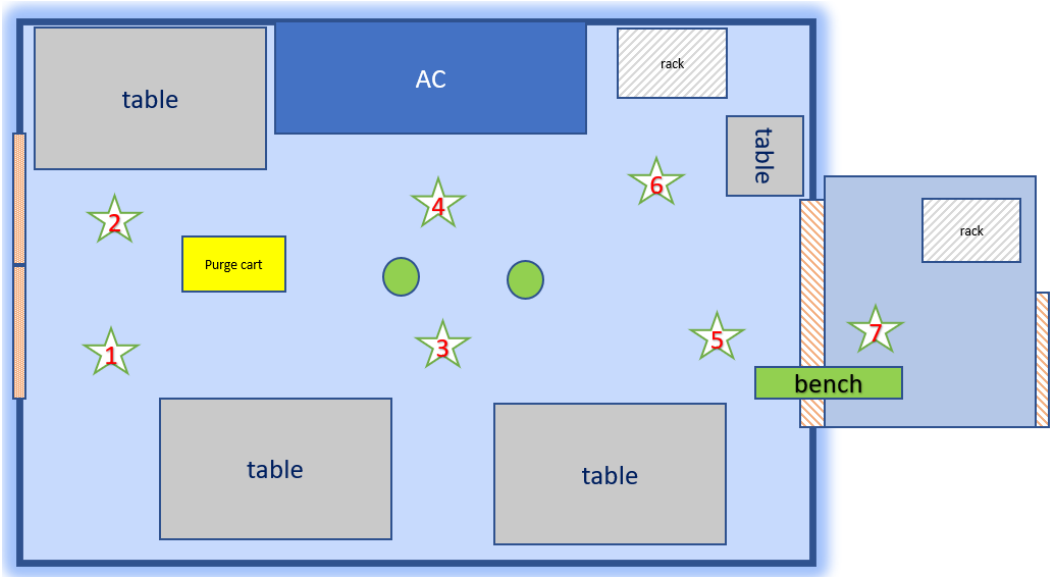
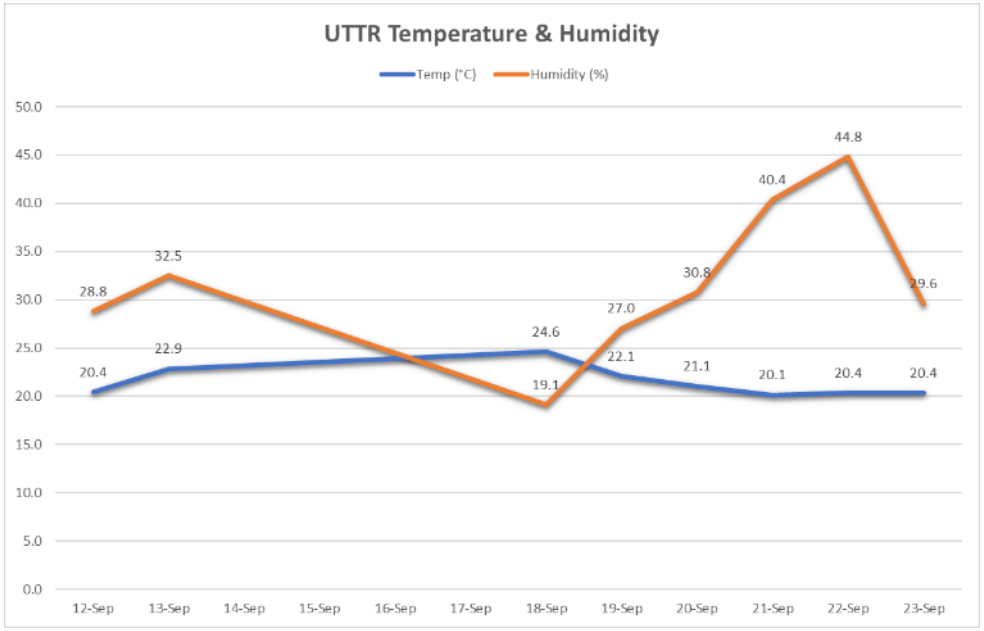
Cleanroom Construction

- Particle Counts were taken with ARES Technicians using TSI Handheld particle counter with Sample rate: 2.83 L/min at the following marked locations.
- Nominal Environmental Conditions *(except spike when roll-up doors to the outside were opened)*





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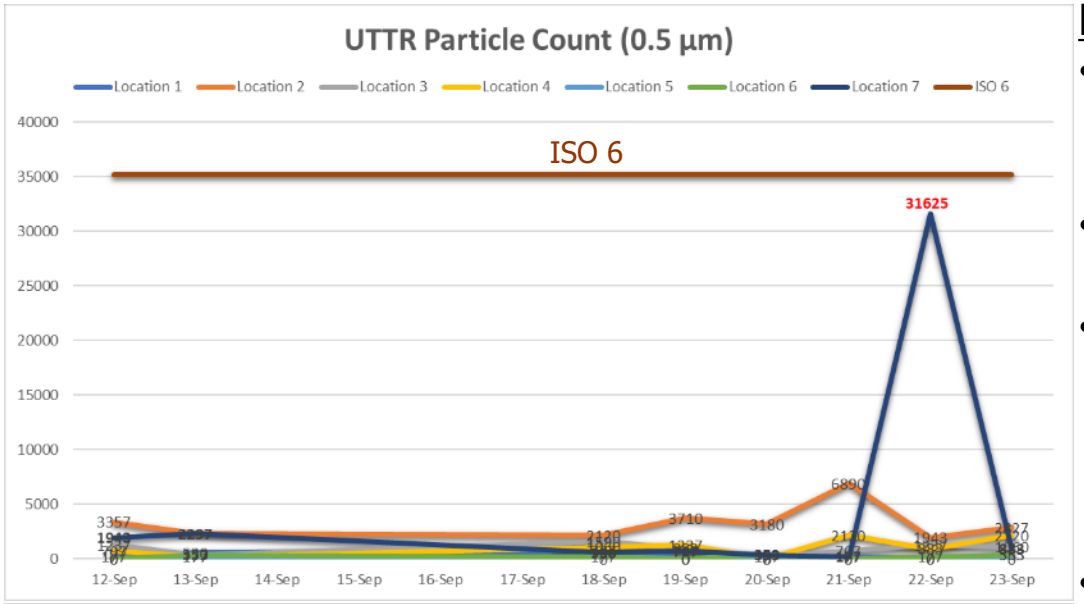
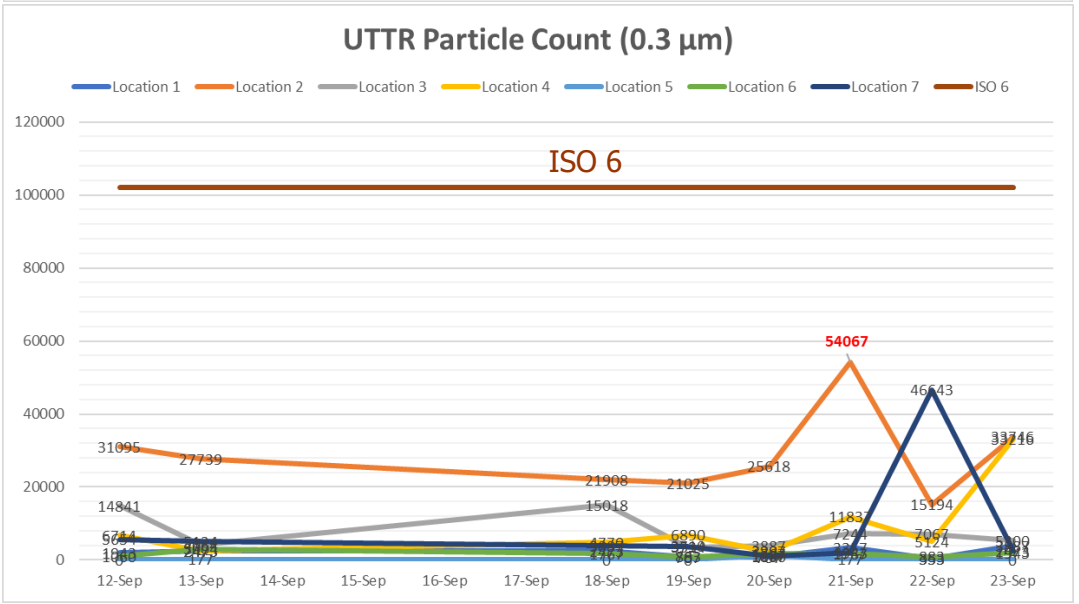
Cleanroom Construction

Particle Counts:

- The data covers from 12 days before landing to 1 day before landing. The cleanroom was built to ISO7 and the particle data indicates better than ISO6.
- The a/c was left off when not in use (until Sep 21st). It was turned on for return and then left on all the time.





Particle Spike:

- Heavier traffic inside of the cleanroom
- Rollup door was opened
- All the tools were being transported into the cleanroom
- Camaras were being set up in the cleanroom
- Particle count back to normal on the 23rd

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Cleanroom Construction

- Very clean for inorganic contamination with possible contamination sources

Balazs Inorganic	Detection Limit	OSIRIS-REx UTTR July 2023	OSIRIS-REx UTTR Sept. 2023	
35 Elements	$1x10^{10}$ atoms/cm²	$1x10^{10}$ atoms/cm² (* = Below Detection Limit)		
Aluminum (Al)	0.05	9.3	0.17	Hardware Cross-Contamination
Antimony (Sb)	0.005	*	*	
Arsenic (As)	0.05	*	*	
Barium (Ba)	0.001	0.015	*	
Beryllium (Be)	0.3	*	*	
Boron (B)	0.5	210	130	FFU Boron
Cadmium (Cd)	0.003	*	*	
Calcium (Ca)	0.1	7.1	0.4	Human Cross-Contamination
Cerium (Ce)	0.001	*	*	
Chromium (Cr)	0.01	*	*	
Cobalt (Co)	0.005	*	*	
Copper (Cu)	0.01	0.01	0.02	
Gallium (Ga)	0.005	*	*	
Germanium (Ge)	0.05	*	*	
Hafnium (Hf)	0.05	*	*	
Indium (In)	0.001	*	*	
Iron (Fe)	0.05	0.74	*	
Lanthanum (La)	0.04	*	*	
Lead (Pb)	0.01	*	*	
Lithium (Li)	0.05	*	*	
Magnesium (Mg)	0.05	1.6	0.23	Human Cross-Contamination
Manganese (Mn)	0.01	0.02	*	
Molybdenum (Mo)	0.005	*	*	
Nickel (Ni)	0.05	*	*	
Potassium (K)	0.05	1.1	0.09	Human Cross-Contamination
Sodium (Na)	0.05	24	0.78	Human Cross-Contamination
Strontium (Sr)	0.002	0.018	*	
Tantalum (Ta)	0.05	*	*	
Tin (Sn)	0.005	0.091	*	
Titanium (Ti)	0.05	0.09	*	
Tungsten (W)	0.05	*	*	
Vanadium (V)	0.01	*	*	
Yttrium (Y)	0.07	*	*	
Zinc (Zn)	0.05	0.08	*	
Zirconium (Zr)	0.005	*	0.009	

- Possible cross-contamination sources in July
- At-rest results were all good in Sep

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Cleanroom Construction

- Ok cleanliness for organic particulates (organic wafer results) for this type of cleanroom

Balazs Organics on Wafer	OSIRIS-REx UTTR July 2023	OSIRIS-REx UTTR Sept. 2023
	ng/cm² (* = Below Detection Limit: < 0.1 ng/cm²)	
Low Boilers C7-C10	0.5	0.8
Medium Boilers >C10-C20	4.5	15.2
High Boilers >C20	1.4	6.8
Sum >=C7	6.4	22.8
2-Ethyl-5-methylfuran	*	0.1
2-Ethylhexyl methyl isophthalate	*	0.2
Alkyl benzene + 3-(4-Isopropylphenyl)-2-methylpropionaldehyde	0.1	*
Bis(2-chloroethyl) vinylphosphonate	*	1
Bis-2-chloroethyl-2-chloroethylphosphonate	*	0.4
C10-C15 Hydrocarbons	*	2.2
C16-C24 Hydrocarbons	*	6.3
C16-C28 Hydrocarbons	0.1	*
C6-C9 Hydrocarbons	*	0.3
Caprolactam	0.1	0.3
Cyclo(Me2SiO)10	*	0.1
Cyclo(Me2SiO)9	*	0.1
Dehydroabietic aldehyde	*	0.2
Dibutyl isophthalate	0.2	*
Dibutyl phthalate	*	0.2
Dicumyl peroxide	*	0.1
Diisobutyl phthalate	0.2	0.4
Di-tert-butyloxaspiro decadienedione	*	0.1
Hexadecamethylheptasiloxane	*	0.2
Isopropyl palmitate	*	0.2
n-Butyl stearate	*	0.1
n-Propyl benzoate	*	0.1
Phosphonic acid, ethenyl-, bis(2-chloroethyl) ester	0.5	*
Siloxanes	0.2	0.2
Tetramethyldecyndiol	*	0.8
Texanol	*	0.1
Tributyl aconitate	*	0.1
Triethyl citrate	0.2	*
Trimethylspirodeca-dienone	*	0.2
TXIB	0.2	*
TXIB + Diethyl Pthalate	*	0.3
Unknown (m/z: 55,83,99,115,157,173)	*	0.4
Unknown(m/z:43,59,67,81,93,109,151,165,193)	0.1	*

- Increase hydrocarbon load could possibly be from generators and vehicles operating with fumes entering the building in Sep

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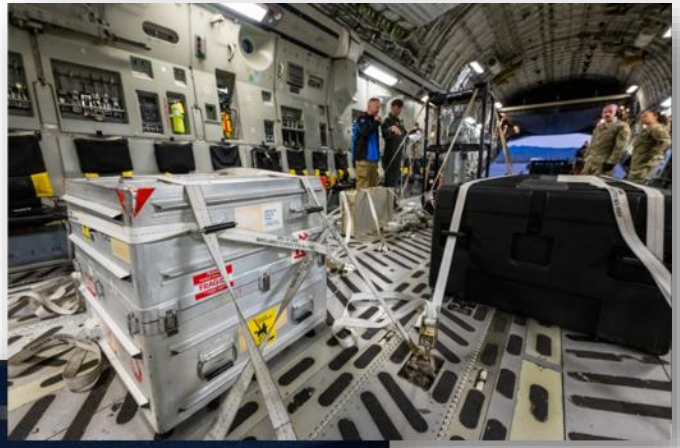
Background – Final Transport

- The Bennu sample – an estimated 8.8 ounces, or 250 grams, was transported under nitrogen purge onto the aircraft for a flight to Houston, Tx.



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Background – Final Transport

- The Bennu sample was transported in its unopened canister by aircraft to NASA's Johnson Space Center in Houston on Monday, Sept. 25, 2023.
- Curation scientists there disassembled the canister, extracted and weighed the sample.
- They are in the process of creating an inventory of the rocks and dust and will, over time, distribute pieces of Bennu to scientists worldwide.

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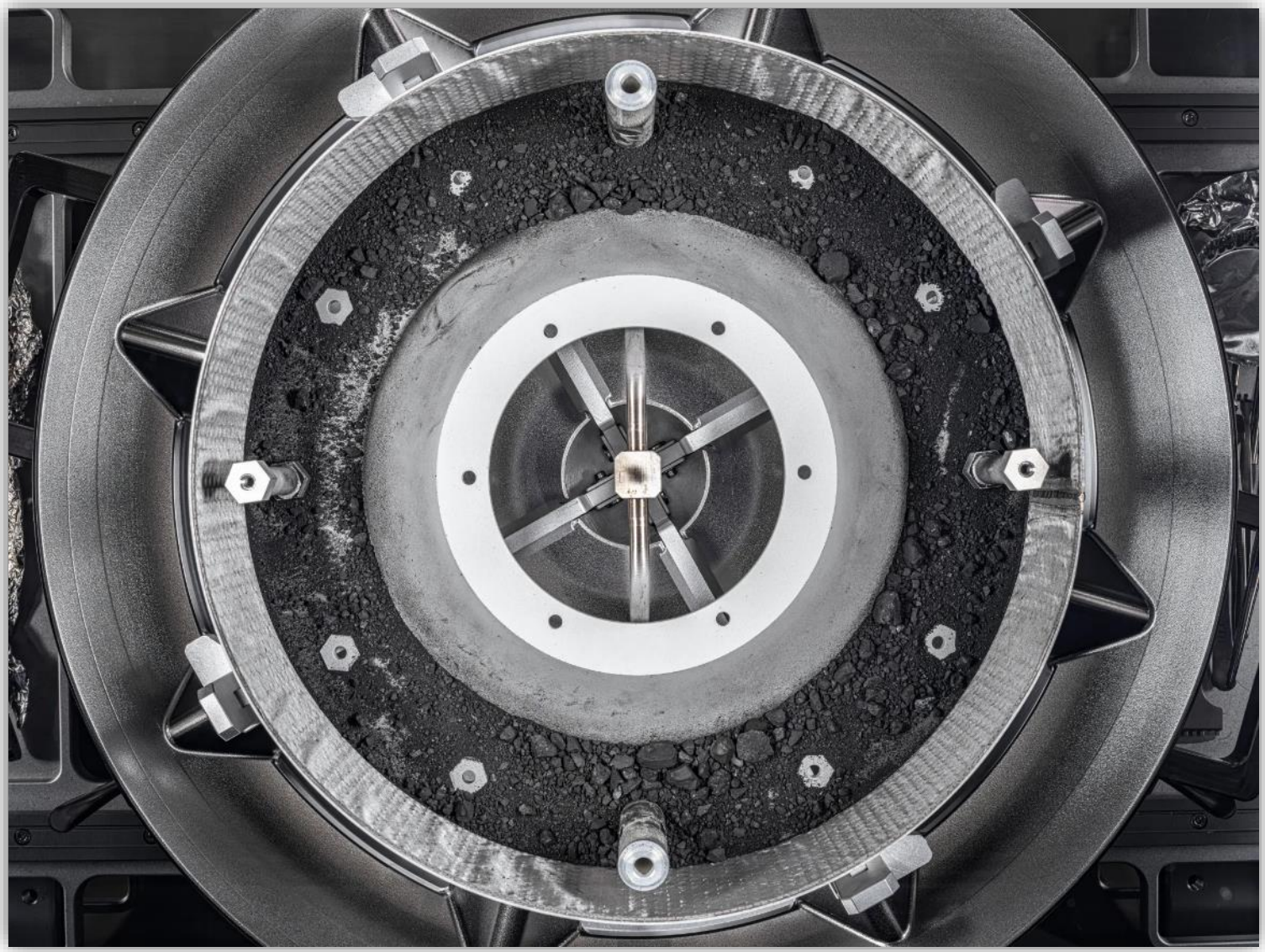
Background – Sample Delivery Complete

- The Bennu samples were opened in the cleanroom at the Johnson Space Center where preliminary analysis is being completed to categorize the sample set.



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Thank you. Questions?

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