Real Time Nitrogen Monitoring and Quality Control System for NASA Astromaterials Collection

Presented by:

LeSong Yan (presenter) & Jeff McQuillan

Amentum at NASA Johnson Space Center, Houston, TX

lesong.yan@nasa.gov & Jeffrey.mcquillan@nasa.gov

Agenda

- Overview of NASA ARES (Astromaterials Research and Exploration Science)
- Background on the NASA ARES Nitrogen (N_2) System
- Cleanroom Facilities at NASA ARES
- Nitrogen (N_2) Quality Requirements and Control Standards
- Development of the N_2 Quality Monitoring System
- Capabilities of the N_2 Quality Monitoring System
- Operational Workflow of the N_2 Quality Monitoring System



Background – NASA Astromaterials

- NASA - Johnson Space Center at Houston
- ARES - Astromaterials Research and Exploration Science Division
  - performs the physical science research at the Johnson Space Center
  - Serves as the curator for all NASA-held extraterrestrial samples
- Houses 9 unique Astromaterial collections
- Supports key missions including Artemis, Mars 2020, Mars Exploration Rover…



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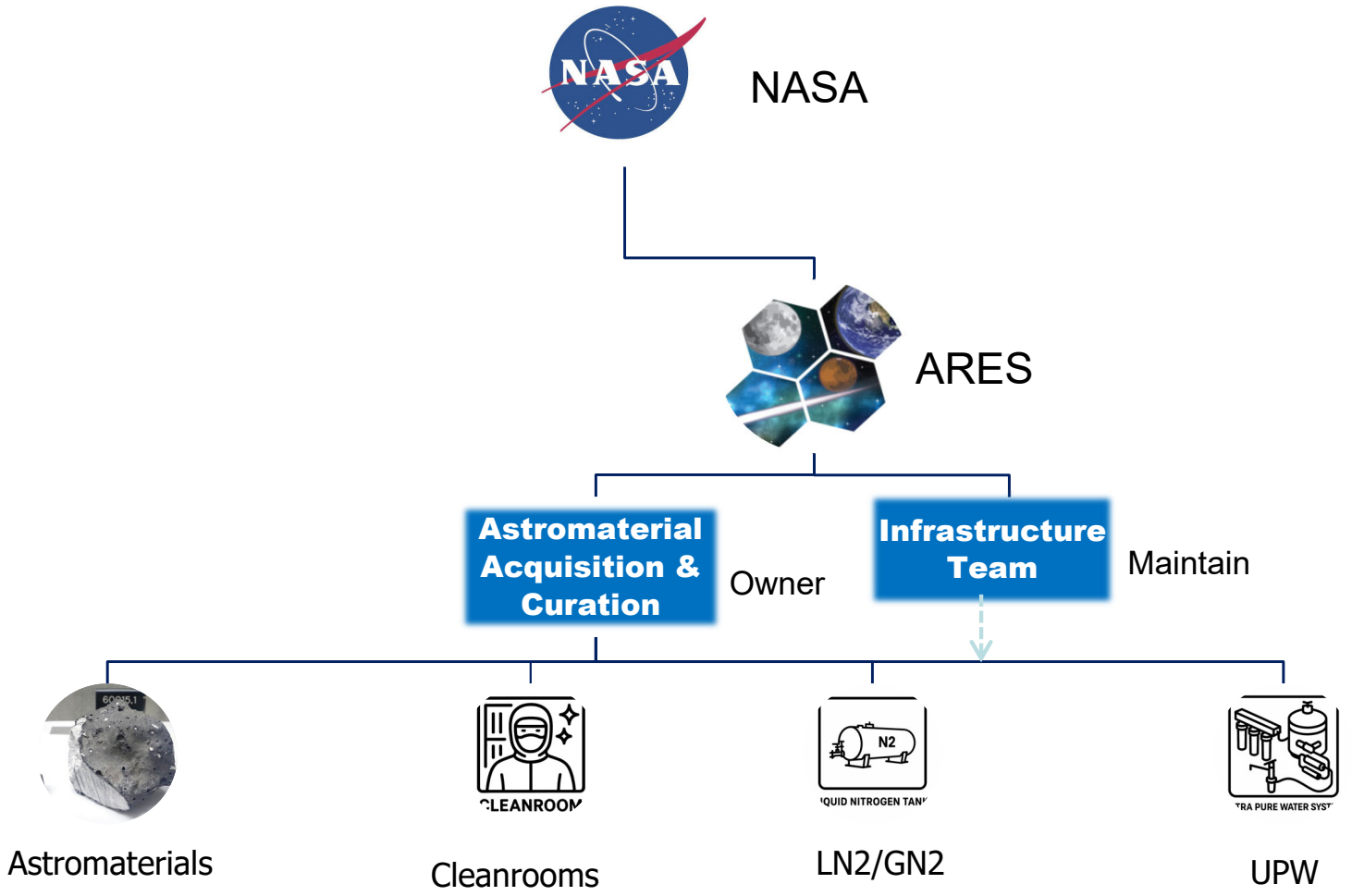
Background – NASA Astromaterials



- Astromaterial Acquisition & Curation : Curation of extraterrestrial samples from NASA's past and future sample return missions
- Infrastructure Team: maintain and improve the infrastructure and critical systems

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Background – ARES Cleanroom

Number	Lab Name	ISO Class	Number of ISO Class Rooms (Cleanrooms)
1	Meteorite	7	6
2	Cosmic Dust	5	2
3	Lunar	6/7	12
4	Genesis	4	5
5	Raman	7	1
6	Stardust	5	2
7	Mars Research	5	2
8	Hayabusa	5	2
9	Small Particle Research	5	2
10	CICG (research lab)	6/7	10
11	MIC	7	2
12	PreClean/Final Clean	5/6	4
13	Adv. Cleaning	6	1
14	Adv. Curation	7	1
15	OSIRIS-REx	5	5
16	Hayabusa2	5	2
17	Cold Curation*	6/7	3
18	Mars CK*	5/6/7	6
19	MMX*	6	1
20	Clean Sample Prep	7	2
Total	**20 Lab Suites**		**71**

ARES Cleanrooms

- 20 dedicated lab suites for mission sample collection and scientific research
- Projected to exceed 70 cleanrooms post-2025 (including ante and gowning)
- ISO-certified cleanroom classifications ranging from Class 4 to Class 7

*Labs numbered 17–19 are currently under construction and are scheduled for completion by 2025

Background – ARES Cleanroom Monitoring

ARES Cleanrooms Monitoring

- Airborne cleanliness and ISO classification
- Differential pressures
- FFU velocity and Air change rate
- Temperature and Humidity
- Organics and trace metals analysis in cleanroom air
- Ultra pure water (UPW) cleanliness
- **Compressed Gas (LN2/GN2) cleanliness**



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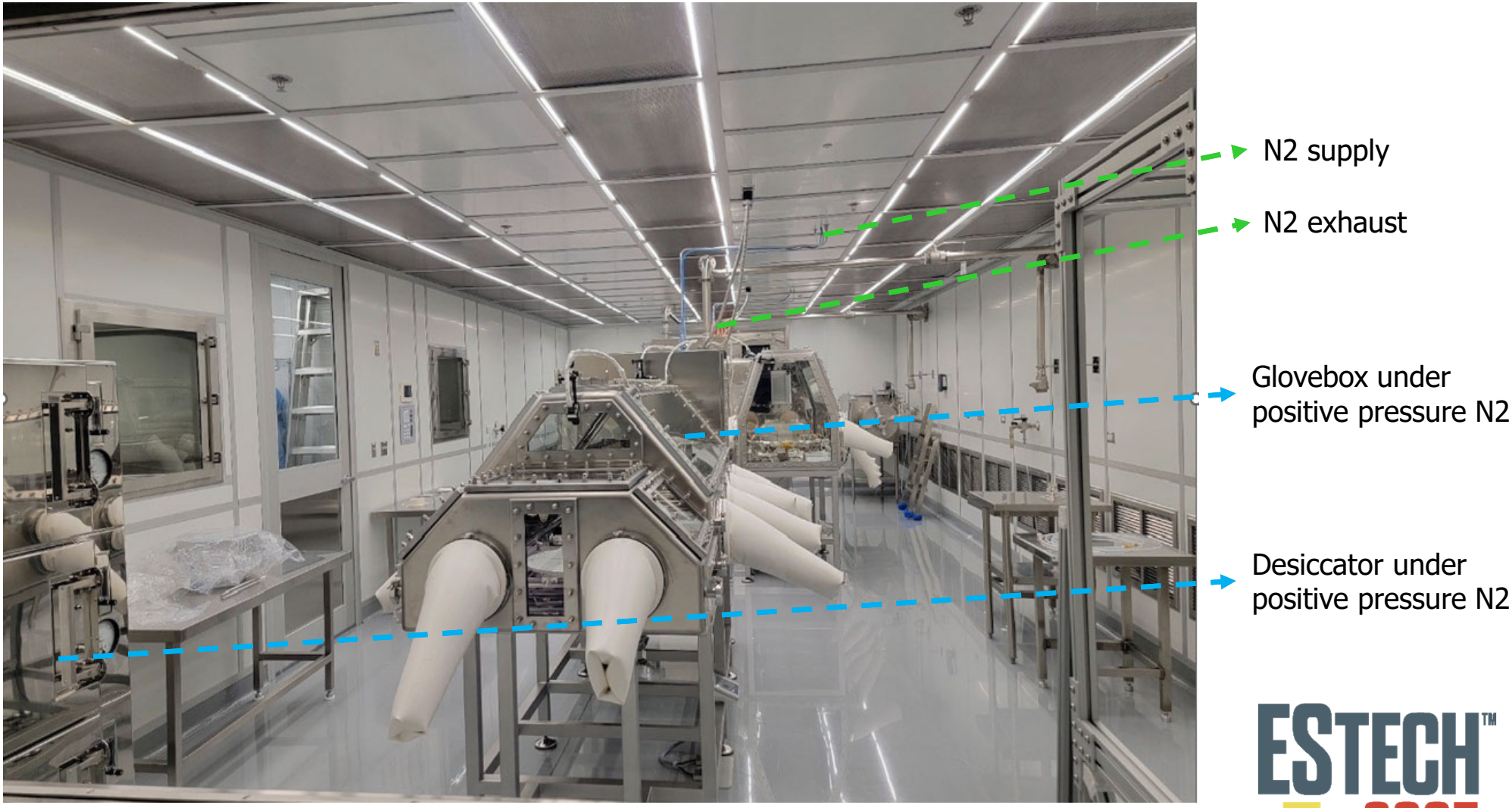
Background – ARES Cleanroom

ISO 5 Cleanroom - OSIRIS-REx Mission (Asteroid Samples)



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Background – N2 as Inert Gas

Inert Gas	Abundance	Cost	Reactivity	Common Use Cases	Advantages
Nitrogen (N_2)	**Very high (78% of air)**	**Low**	**Inert under normal conditions**	**Astromaterials, electronics, food packaging**	**✅ Widely available, low-cost, safe, effective barrier. ✅ Preferred even when cost is not a factor due to lower risk of scientific contamination. ✅ Enables use of low-argon N_2 for critical applications like cabinet purging.**
Argon (Ar)	Moderate (0.93% of air)	Moderate to high	Extremely inert	Welding, scientific instruments	More inert than N_2, but more expensive and can pose contamination concerns in sensitive environments.
Helium (He)	Very low	High	Extremely inert	Cryogenics, leak detection	Very light and non-reactive, but costly, scarce, and has high scientific value—better preserved for critical uses.
Neon (Ne)	Very low	Very high	Inert	Specialty lighting	Inert, but rarely used due to very high cost and high scientific demand.
Krypton (Kr)	Very low	Very high	Inert	High-end lighting, insulation	Heavier than Ar, very inert, used only in niche applications due to rarity and scientific importance.
Xenon (Xe)	Extremely low	Extremely high	Highly inert	Ion propulsion, anesthesia	Very dense and inert, but prohibitively expensive and of significant scientific interest—impractical for routine use.

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Background - NASA ARES Nitrogen System

- Safeguarding NASA’s Astromaterials Since 1969
  - Continuous protection of Apollo samples since their return
- The Nitrogen system is a vital utility supporting NASA's ARES Division
  - Essential for preserving the integrity of NASA’s astromaterial collections
  - Enables a contamination-free, controlled environment for pristine sample curation and cutting-edge research

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Background – NASA ARES Nitrogen System



- Liquid nitrogen tank is located at NASA JSC, adjacent to the ARES facility
- An average of 3,500 SCFH of gaseous nitrogen (GN2) is supplied to JSC Curation laboratories
- High-purity, modified Grade C liquid nitrogen (LN2) is delivered on a weekly basis

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Background – NASA ARES Nitrogen System



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Background – GN2 Glovebox & Samples





luna

- Lunar Glovebox
- Apollo mission returned samples: six Apollo missions brought back 382 kilograms (842 pounds) of lunar rocks, core samples, and regolith (i.e., soil) from the lunar surface

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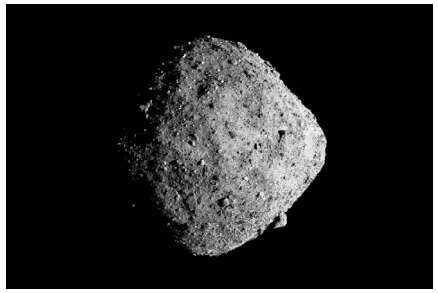
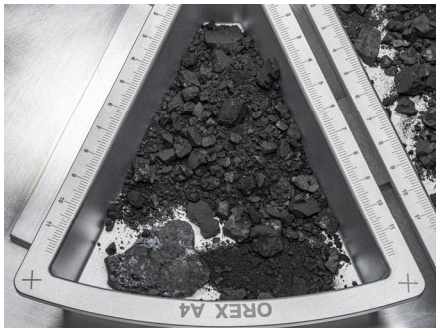
Background – GN2 Glovebox & Samples





Asteroid Bennu



- OSIRIS-REX Gloveboxes
- Asteroid Bennu samples: The OSIRIS-REx spacecraft returned over 120 grams of sample from asteroid Bennu

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Nitrogen Quality Control - Requirements

- NASA-ARES specifies strict purity and impurity limits for delivered liquid nitrogen (LN2)
- Industrial gas suppliers must comply with NASA-ARES Modified Grade C nitrogen specifications
  - Ultra-High Purity (UHP) Gaseous Nitrogen (GN2) is widely used across various industries
  - Argon levels are controlled under Modified Grade C, but are typically not regulated in standard UHP

	LN2 Delivery Requirment Mil-PRF-27401G Std.
	Modified Grade C
Purity %	N/A
Impurities	N/A
H2O	< 10 ppm
THC as CH4	< 1.0 ppm
O2	< 10 ppm
H2	< 10 ppm
Ar	< 30 ppm
CO2	< 10 ppm
CO2	< 10 ppm
Particulate	< 1.0mg/L

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Off Nominal Nitrogen Quality Control - Process

- All LN2 deliveries are required to have a CoA for all elements or compounds of interest, or the delivery is rejected.
- However, if circumstances require the acceptance of an untested (or incompletely tested) truck in order to keep the samples safe, then previously ARES lacked the capability to perform real-time LN_2 purity testing on a delivery prior to filling the 15,000-gallon tank.

Old process (verification):

- LN_2 samples collected during delivery after being added to the storage tank
- Samples sent to a third-party analytical lab for testing
- Result turnaround: **4-6 days**

Improved process (real-time QC):

– Real-time LN_2 purity analysis during delivery

– Result turnaround: **20 minutes**

The new testing system also provides 24/7 real-time GN_2 monitoring of the nitrogen interacting with our samples.

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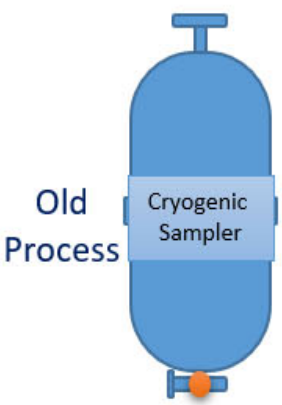
Off Nominal Nitrogen Quality Control - Process



LN2 Sampling



HazMat Transportation



Analytical Laboratory

4-6 days



20 Minutes



Test Results

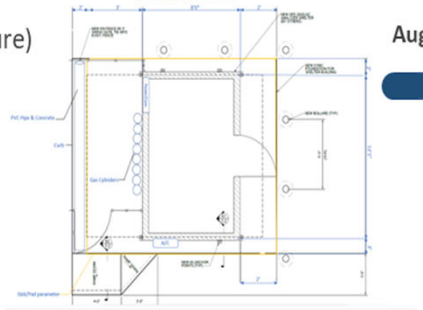
Currently, deliveries that have a valid CoA are tested on a quarterly basis

AGS Lab – Project Timeline

Subcontractors identified
Sep. 2022

1 Project started (ARES Infrastructure)
Feb. 2023

PAE
Plan & Quotation

2

Aug. 2023
Design

2 ASTG
Oct. 2023

Assembly


Concrete Pad & power

4 Jan. 2024

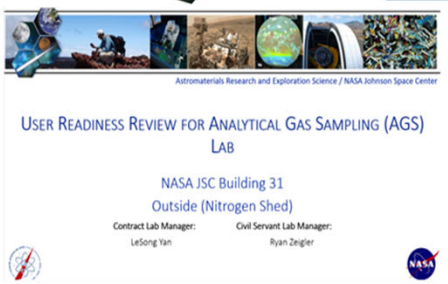
Delivery & Anchor

5 Feb. 2024

Commissioning

6 Mar-Jun. 2024

HA inspection and corrective actions

7 Jul. 2024


HA signed; URR scheduled

- Implementation of Improved Process: Establishment of an Analytical/QC Shed adjacent to the LN_2 Tank
- Facility Name: **Analytical Gas Sampling (AGS) Lab**

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AGS Lab Project - Design and Layout

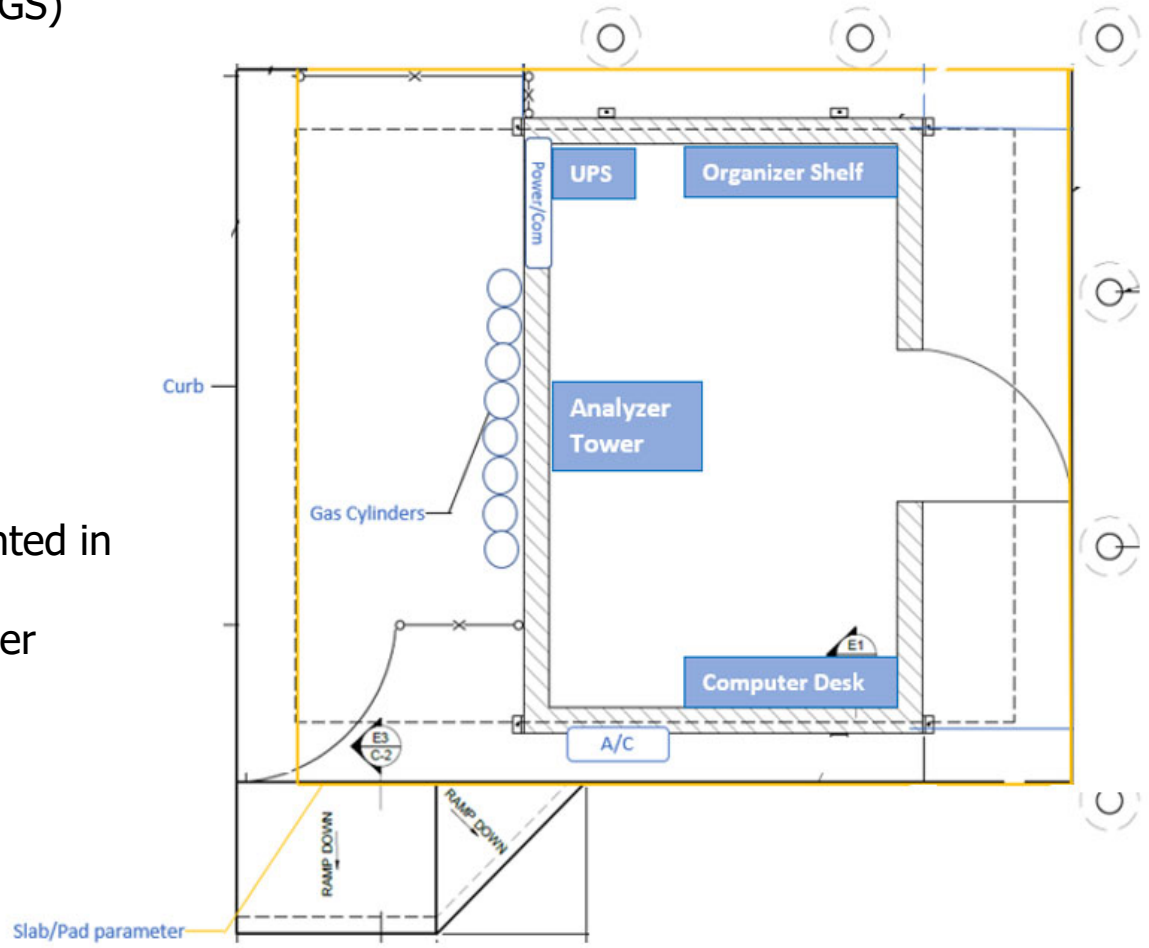
Facility Name: Analytical Gas Sampling (AGS) Lab

Size: 100 ft2

Primary Applications:
- Nitrogen quality verification
- Nitrogen continuous monitoring

Interior Features:
- Dedicated space for 4 gas analyzers (mounted in analyzer rack)
- IT equipment: desktop computer and printer
- Uninterruptible Power Supply (UPS)
- Organizer shelf for lab accessories

Exterior Features:
- 8 compressed gas cylinders:
  - 4 carrier gases
  - 2 pneumatic gases
  - 2 span gas
- Secured with 6 protective bollards
- Integrated with 15,000-ton LN_2 tank for continuous analyzer monitoring



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AGS Lab Project – Concrete Foundation Construction





Concrete Slab

- Positioned adjacent to the LN_2 tank for connection to the GN_2 supply
- Includes a 24” trench for electrical routing
- Reinforced with rebar spaced 12” in both directions

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AGS Lab Project - Foundation, Power, & Comm





Concrete Slab and Conduits

- compressive strength of 3,000 psi to ensure durability and long-term performance
- Includes 1½” conduit to accommodate both electrical power and communication wiring

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AGS Lab Project – Foundation Construction





Concrete pad foundation

- 6” thick concrete slab designed for structural stability and load-bearing support
- Integrated ramp with a gentle slope to facilitate safe and efficient transport of gas cylinders

AGS Lab Project - Shed and Analyzers Assembly







AGS Lab Assembly at Vendor facility

- Integration of the analyzer into the lab system tower
- Routing of gas tubing gas tubing to ensure proper flow and connectivity
- Installation of switch-over system and pressure regulators for safe and continuous gas supply management

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AGS Lab Project - Delivery and Installing





AGS Lab delivery and anchoring

- Fully assembled lab transported to NASA – JSC in Houston for final installation
- Anchoring of the facility performed by NASA's rigging team

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AGS Lab Project - Bollards and Fence





Safety precautions

- Six 6” diameter steel bollards installed to protect the facility from potential vehicle impact and ensure structural safety
- A 6-foot perimeter fence with a swing gate installed to restrict access to chemical storage areas, specifically gas cylinders

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Analytical Gas Sampling Lab







Completed AGS Lab

- Commissioned and calibrated by the vendor to ensure proper functionality and performance of all systems
- Successfully inspected and approved by NASA's safety and hazard analysis team, compliance with all safety standards

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Analytical Gas Sampling Lab - Analyzers



Delta F 310 – O2 Analyzer

- Coulometric oxygen sensor/cell
  - Detect trace O2
- Fast response time and low detection limits
  - T95 ≈ 30 seconds
  - DL ≈ 0.01 ppm or 10 ppb



Chroma GCs (Gas Chromatography)

- Dual GC System: Argon carrier and Helium carrier Channel
  - Detect trace H2, Ar, He, CO, CO2, and CH4
- DL ≈ 0.1 ppm or 100 ppb
- Point to point calibration with calibration gases



Tiger Optics SPARK – H2O Analyzer

- Laser-based: pulses a laser through the flowing N2
  - Detect trace H2O
- Fast response time and low detection limits
  - T95 < 1 minute
  - DL ≈ 0.01 ppm or 10 ppb



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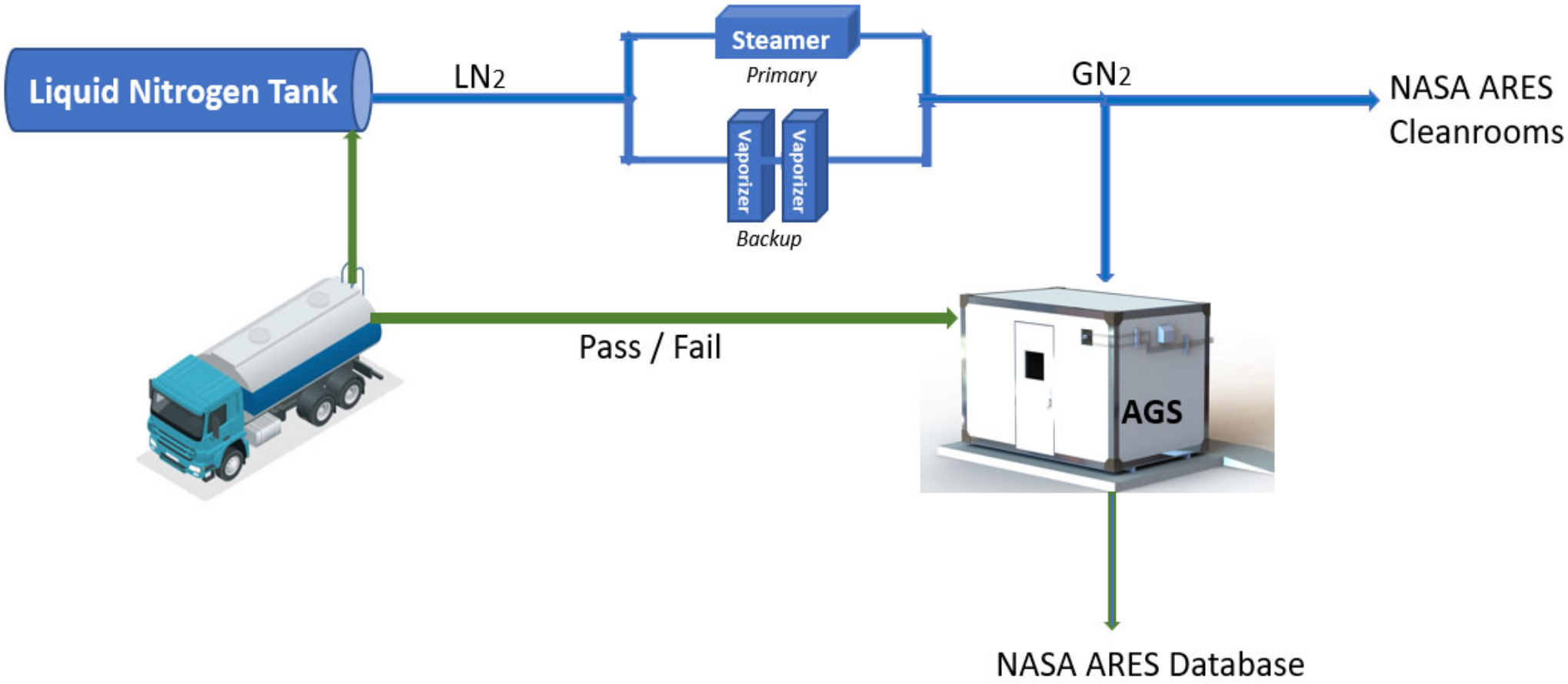
AGS Lab – Capabilities & Modes



- GN2 Monitoring (QA)
- LN2 Verification (QC)

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AGS Lab – Capabilities & Modes

2 AGS Operation Modes

- **LN2 Quality Verification (Q**uality **C**ontrol**)**
  During LN_2 deliveries, a cryogenic vaporizer converts liquid nitrogen (LN_2) into gaseous nitrogen (GN_2). The GN_2 is then analyzed for impurities including H_2, Ar, O_2, CO, CO_2, H_2O, THC, and nitrogen assay.

- **GN2 Quality Monitoring (Q**uality **A**ssurance**)**
  The AGS analytical system automatically samples nitrogen from the NASA ARES GN2 system every 15 minutes to ensure continuous quality monitoring.

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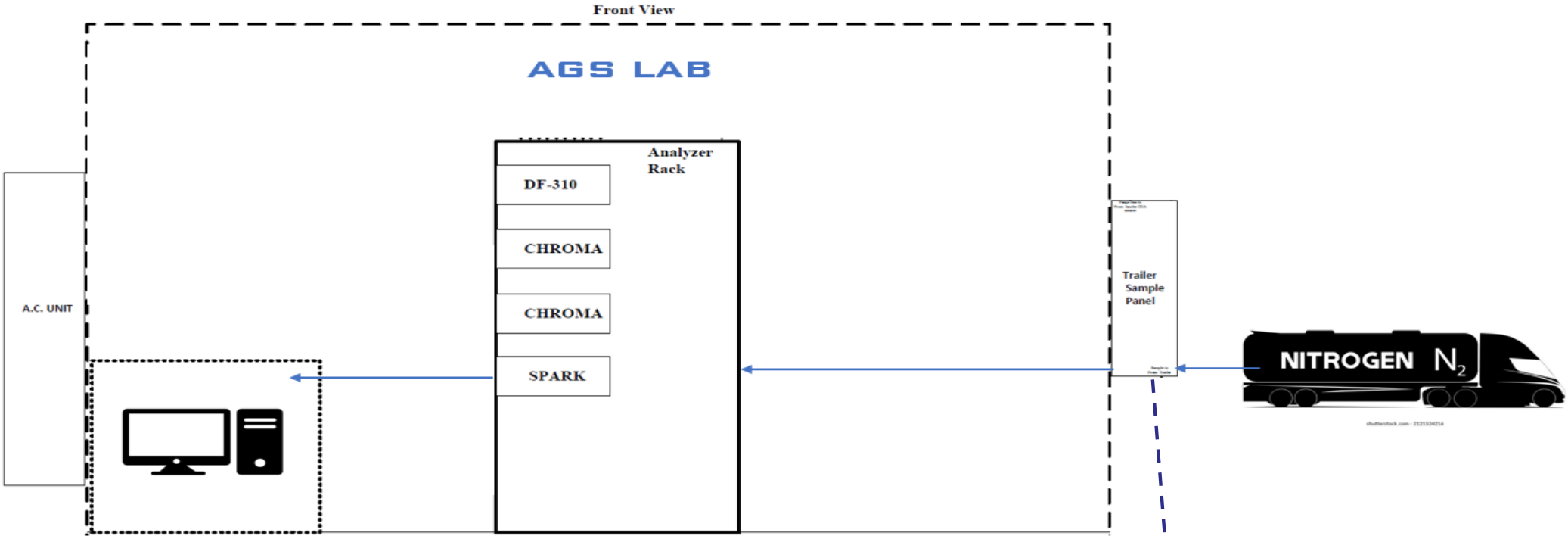
Nitrogen Quality Control – LN2 Verification



Cryogenic Liquid Trailer Sampler

- Converts cryogenic liquid to gas for analytical testing
- Reduces pressure to a safe operating level
- Utilized by government agencies and major industrial gas suppliers



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Nitrogen Quality Control – LN2 verification

Sample Analysis Report



Lab	AGS (B31)
Sampled Date	15-Jan-25
Test Date	15-Jan-25
Sample Product	Liquid Nitrogen
Serial number	seal# 7241360 lot#1637

Component (Chemical Formula, Units)	Method	Specification	LDL	Result	Pass/Fail
Nitrogen Purity (N2, %)	by Difference	100.00%	0.01	100.00%	pass
Hydrogen (H2, ppm)	GC-DID	< 10.0 ppm	0.1 ppm	0.12 ppm	pass
Argon (Ar, ppm)	GC-DID	< 30.0 ppm	0.1 ppm	5.34 ppm	pass
Carbon Dioxide (CO2, ppm)	GC-DID	< 10.0 ppm	0.1 ppm	0.01 ppm	pass
Carbon Monoxide (CO, ppm)	GC-DID	< 10.0 ppm	0.1 ppm	0.06 ppm	pass
Oxygen (O2, ppm)	Coulometric	< 10.0 ppm	0.01 ppm	1.15 ppm	pass
Water (H2O, ppm)	CRDS	< 10.0 ppm	0.01 ppm	0.23 ppm	pass
Total Hydrocarbons (ppm)	GC-DID	< 1.0 ppm	0.1 ppm	< 0.1 ppm	pass
non-Methane Total Hydrocarbons (ppm)	GC-DID	N/A	0.1 ppm	< 0.1 ppm	pass
Commets:					

LN2 Test Result

- Includes detailed sample information
- Analytical methods used
- Detection limits (LDL) for each component
- Specifications for pass/fail assessment

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Nitrogen Quality Assurance – GN2 Monitoring

Date/Time	Analysis D	NA0045	NA0032	NA0056	NA0056	NA0056	NA0056	NA0056	NA0056	NA0056
		H2O (PPM)	O2 (PPM)	H2 (PPM)	CO (PPM)	CO2 (PPM)	Ar (PPM)	CH4 (PPM)	NMHC (PPM)	THC (PPM)
8/4/2024 0:00	TAP A	0.02	0.24	0	0.15	0.08	16.62	0.07	0	0.07
8/4/2024 0:00	TAP A	0.02	0.24	0	0.15	0.08	16.62	0.07	0	0.07
8/4/2024 0:01	TAP A	0.02	0.24	0	0.15	0.08	16.62	0.07	0	0.07
8/4/2024 0:01	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:02	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:02	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:03	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:03	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:04	TAP A	0.02	0.24	0	0.15	0.08	16.62	0	0	0
8/4/2024 0:04	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:05	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:05	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:06	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:06	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
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8/4/2024 0:07	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:08	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:08	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:09	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:09	TAP A	0.02	0.24	0	0.15	0.09	16.62	0	0	0
8/4/2024 0:10	TAP A	0.02	0.24	0.1	0.15	0.09	16.62	0	0	0
8/4/2024 0:10	TAP A	0.02	0.24	0.1	0.15	0.09	16.62	0	0	0

GN2 Monitoring Data

- Data collected from analyzers at 30-second intervals
- Automatically grouped by date for easy navigation
- Export functionality available for advanced trend analysis

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Nitrogen Quality – Additional Quality Assurance Measures

SEQ	READING	LOCATION	NOMINAL VALUE	NOTIFY VALUE	OBSERVED VALUE
1	Tank Level (%)	tank	> 30%	< 25	77.2
2	Tank Pressure (psig)	tank	65 psig	< 50 & > 80	60.7
3	Is White Light Flashing? (Y/N)	tank piping	No	Yes	No
3a	If Y: North or South vaporizer?	tank piping	N/A	N/A	
3b	If Y: GN2 temp on ambient side	tank piping	outside air temp	N/A	
3c	If N: GN2 temp on steam side	tank piping	70 - 90 F	N/A	85
4	GN2 pressure	tank piping	25 - 35%	< 25 & > 35	32.237
5	GN2 flow	tank piping	1500 - 4000 scfh	< 1500 & > 4000	3,699
6	GN2 temp	tank piping	60 -100 F	N/A	86.46
7	3/4" black steam line	tank piping	Yes (slow drip)	No	Yes
8	1 1/2" black pump return line	tank piping	No (liquid flowing)	Yes	No
9	31 GN2 temp	1MIT	60-90 F	< 60 & > 90	
10	Temp	1108	60-80 F	< 60 & > 80	73
11	Pressure	1108	40 - 50 psi	< 40	47
12	Flow	1108	1.5 - 3.5	< 1.5 & > 3.5	2.9
13	Temp	2M3	65 - 75 F	< 65 & > 75	75
14	Pressure	2M3	40 - 50 psi	< 40 & > 50	46
15	Power head HZ A/H 13	1109 A/H 13	37 Hz	N/A	46.2
16	Power head HZ A/H 14	1109 A/H 14	34 Hz	N/A	42.2
17	Power head HZ A/H 12	1109 A/H 12	35 Hz	N/A	39.5

GN2 System critical parameters

- Monitoring temperature, pressure, flow rate, and tank level
- Recording readings and performing daily check

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Nitrogen Quality – Additional Quality Assurance Measures



Lunar Gloveboxes Monitoring System

- Monitoring 25+ gloveboxes housing lunar samples
- Cycling each glovebox every 15 minutes
- Analyzing for trace levels of H_2O and O_2

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Thank You Questions?

Special thanks to contributors and reviewers:

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