NASA Goddard Space Flight Center Cleanroom Filtration and HVAC Designs

Innovations and Challenges for Space Flight Cleanrooms

GSFC Cleanrooms Through the Years

- First cleanroom built in late 1960s.
  - Still in operation today
- Very different requirements
  - Cleanliness standards barely established
- Very different size/mass
  - TIROS-1(pictured right)
    - Weather satellite
    - Mass: 122.5 kg

Photo Credit: NASA Archive

GSFC Cleanrooms Through the Years

- First cleanrooms are still in operation
  - Older-style bag filters
  - Shared plenum with 3 different spaces
  - Upgraded most motors from belt driven to variable frequency drives (VFD)

Photo Credit: NASA Archive

GSFC Cleanrooms Now

- Large, hard-walled cleanrooms with dedicated HVAC
- Modular tents, filter banks, cleanrooms that can be deployed and taken down quickly

Photo Credit: NASA/ Sydney Rohde

NASA Builds Largest ISO 7 Cleanroom in the World

- Spacecraft System Design and Integration Facility (SSDIF)
- NASA's largest cleanroom
- Built in 1989
- 36,000 m^3
- Certified ISO 7 cleanroom
- Horizontal laminar flow
- Originally designed to support 2 simultaneous shuttle missions

Photo Credit: NASA Archive

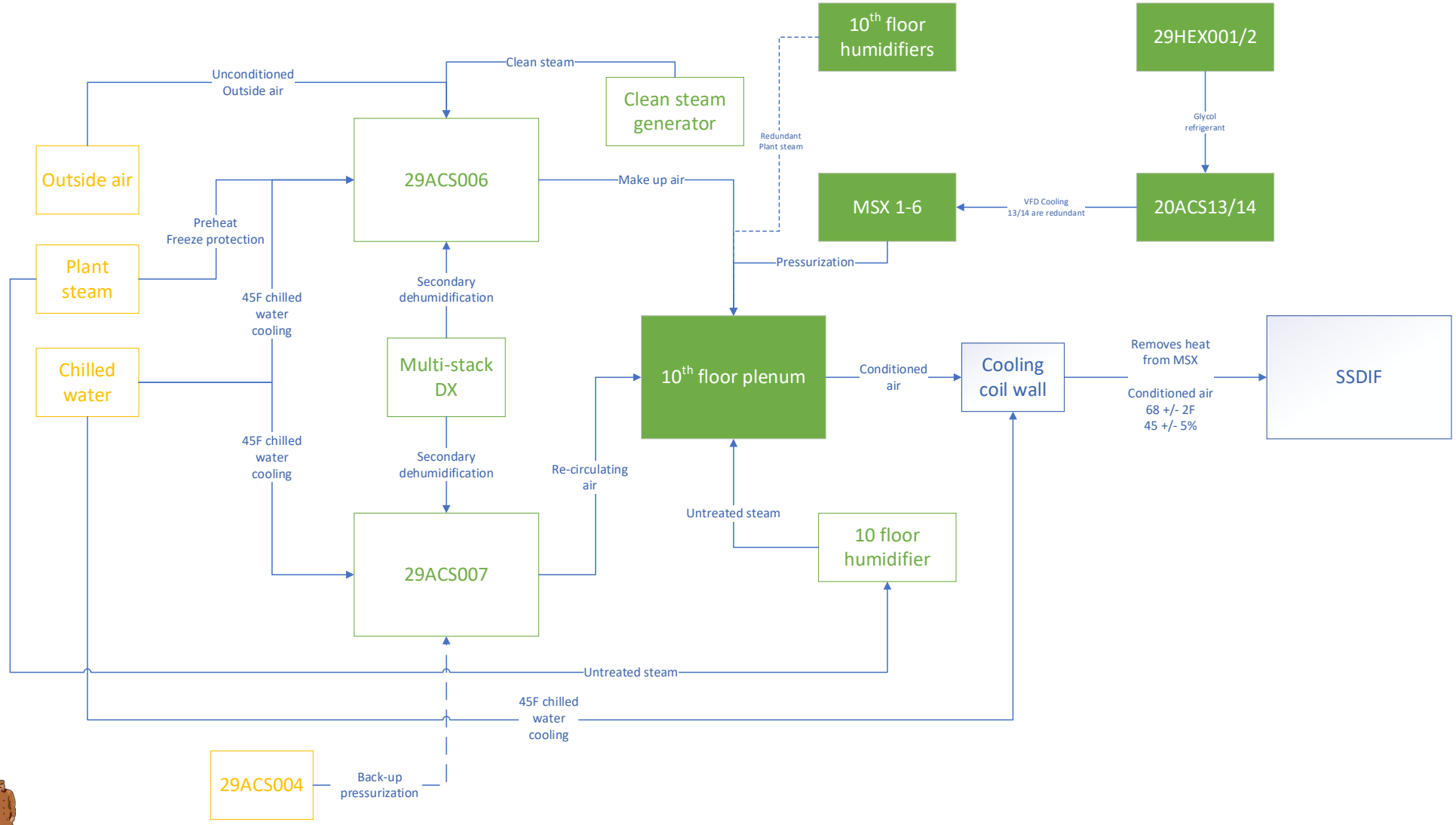
SSDIF Projects – James Webb Space Telescope

Photo Credit: NASA/Chris Gunn

SSDIF Projects – Roman Space Telescope

Photo Credit: NASA/Jolearra Tshiteya/Chris Gunn

SSDIF Design



SSDIF Design

- ISO Class 7 cleanroom
- Live particulate monitoring
- Temperature: 68 +/- 2F
- %RH: 45 +/- 5%
- 1 Pa room pressurization
- 690 kPa compressed air
- Ultra pure gaseous nitrogen (GN2) ports

Photo Credit: NASA/Jolearra Tshiteya/Chris Gunn

SSDIF Design

- 2 air handlers providing 6.4 m^3/sec and 5.2 m^3/sec
- Cooling provided by 6C center chilled water
- 103kPa steam provides pre-heat
- 6x150kW belt driven pressurization fans heat the room
- Secondary cooling wall removes heat from pressurization fan as needed
- 6 stages of HEPA filtration
  - 1x Carbon filter
  - 3x MERV 16 pre-filter
  - 2x MERV 18 HEPA filtration
- Controls by originally Honeywell EBI
- Cosmetic upgrades completed in 2018
- Hardware upgrades started in 2019
- Software upgrades started in 2022

SSDIF Cosmetic Upgrades 2018

- In 2018, the SSDIF shut down for the first time since 1989
- Cosmetic upgrades were completed, including:
  - New floors
  - Maintenance on roll up doors
  - Oil change for 2x 20T cranes
  - Upgrade to LED lighting

Photo Credit: NASA/Zao Huang

SSDIF Hardware Upgrades – Makeup Air Unit

Photo Credit: NASA/Zao Huang

- Provides 6.4 m^3/sec of outside air
- 1x MERV 16 1x MERV 19 filtration
- Upgraded to direct drive fans.
- Automated outside air damper to open/close
- Updated pre-heat operations for freeze protection
- Easier serviceability
- Updated to 2019 standards for HVAC, electrical, and fire safety

SSDIF Hardware Upgrades – Recirculating Air Unit

Photo Credit: NASA/Zao Huang

- Provides 5.2 m^3/sec of recirculated air
- 1xMERV 16 filtration
- Upgraded to direct drive fans
- Allows for additional humidification tie-in
- Easier serviceability
- Updated to 2019 standards for HVAC, electrical, and fire safety

SSDIF Hardware Upgrades – Pressurization

Photo Credit: NASA/Zao Huang

Photo Credit: NASA/Zao Huang

- Belt driven to direct drive
- 149 kW motor powers a 2.4m fan
- Allows for more consistent pressurization
- Allows for ramp up/ramp down due to room changes
- Allows for easier maintenance
- Variable frequency drives (VFD) required independent glycol cooling units

SSDIF Controls Hardware Upgrades

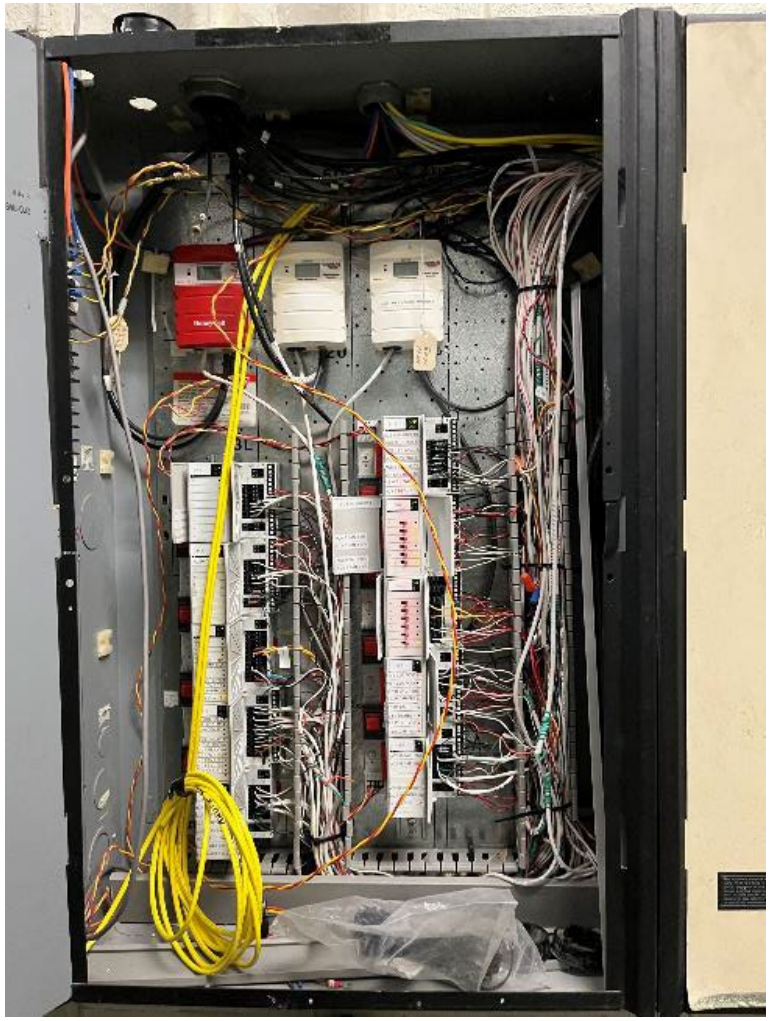


Photo Credit: NASA/Nafeez Talukder

- Proprietary Honeywell EBI® system
- Relied on RS485 serial comms
- Data averaging every 6 seconds
- No back up power on the controllers
- Lack of configuration management and constant patch work

SSDIF Controls Hardware Upgrades

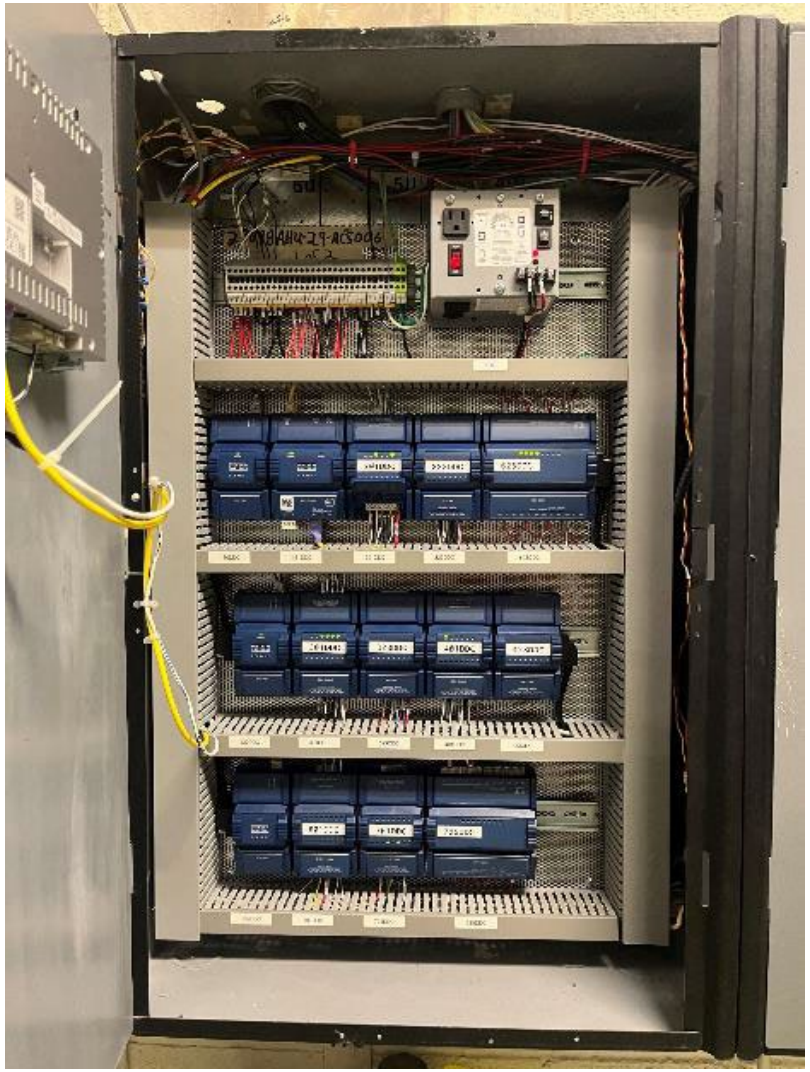
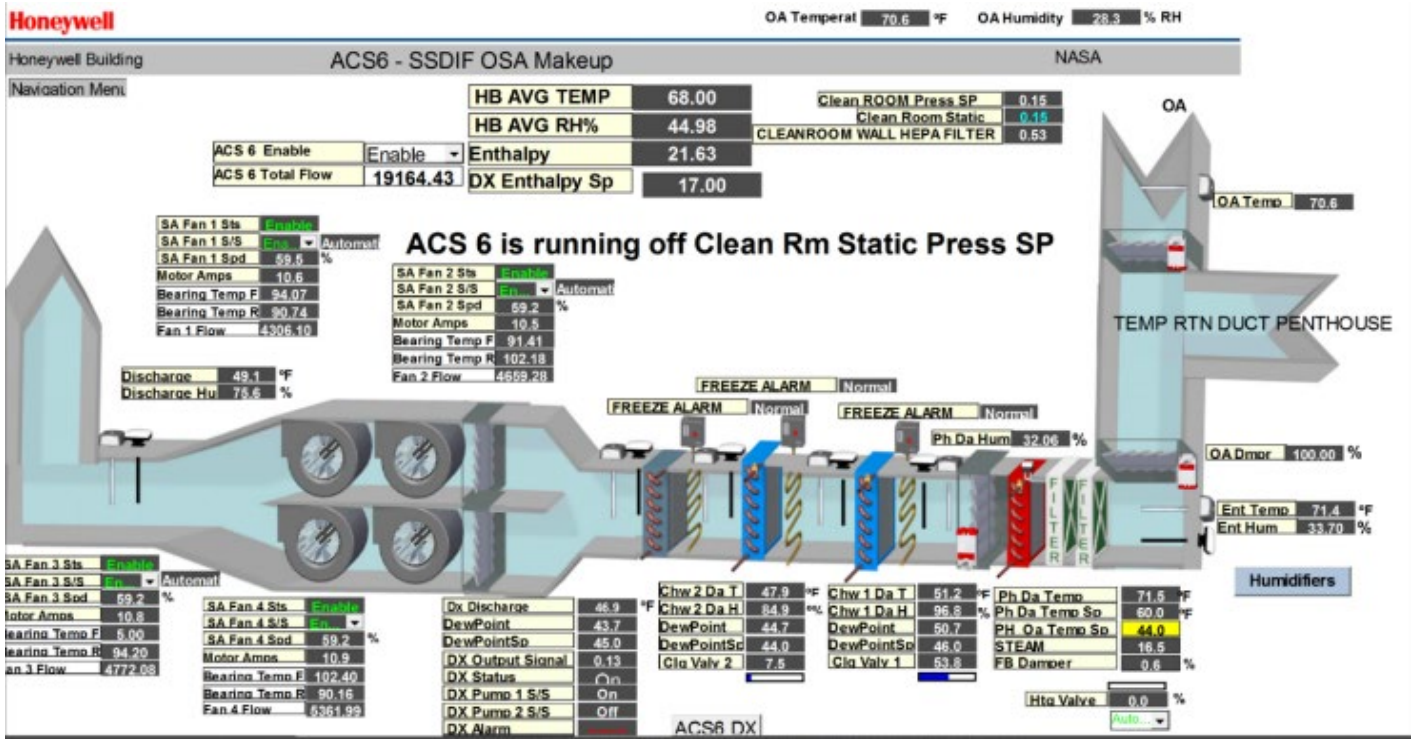


Photo Credit: NASA/Nafeez Talukder

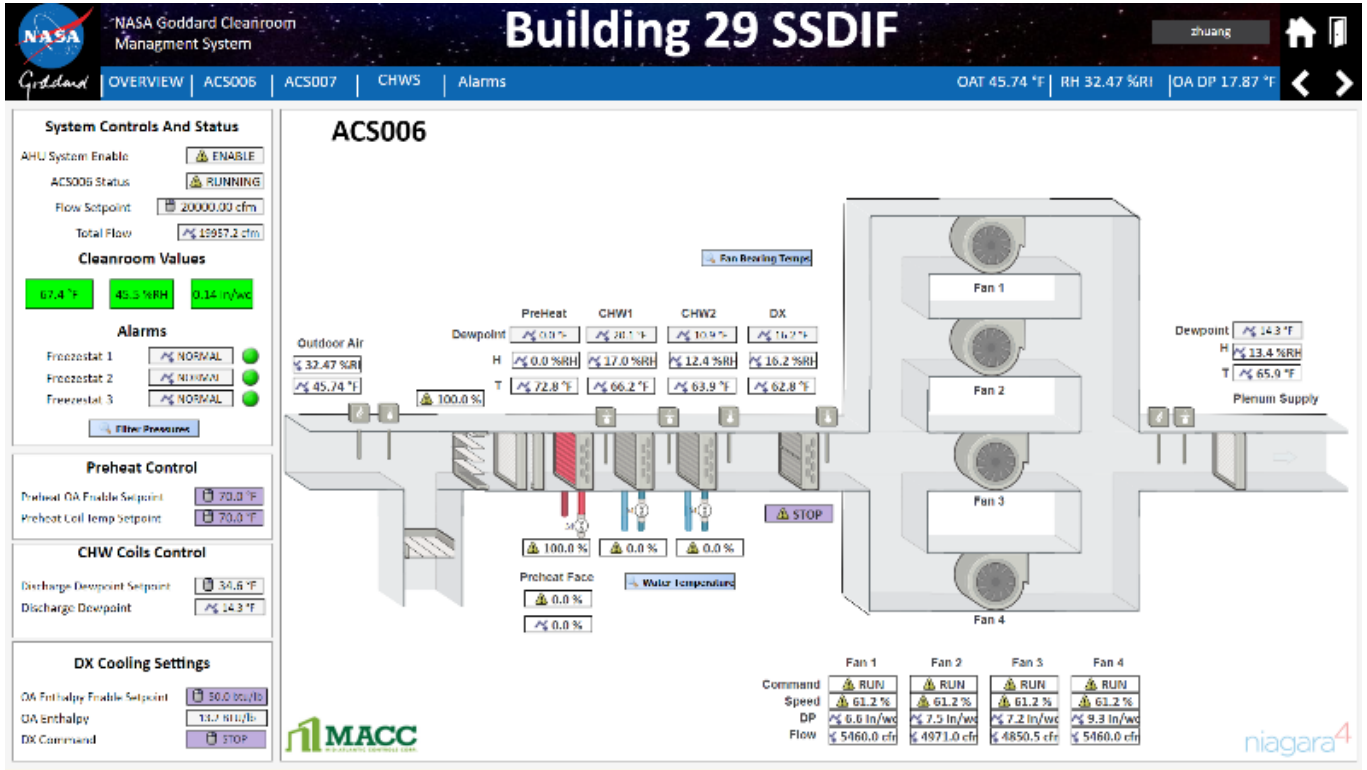
- Open-source Tridium® system
- Ethernet comms with constant data stream
- Greater data redundancy
- Improved alarming to 24/7 on call team

SSDIF Controls Software Upgrade



- Moved to cloud-based UI from virtual machine access
- Moved to Niagara® framework
- Improved UI interface and data layout

SSDIF Controls Software Upgrade

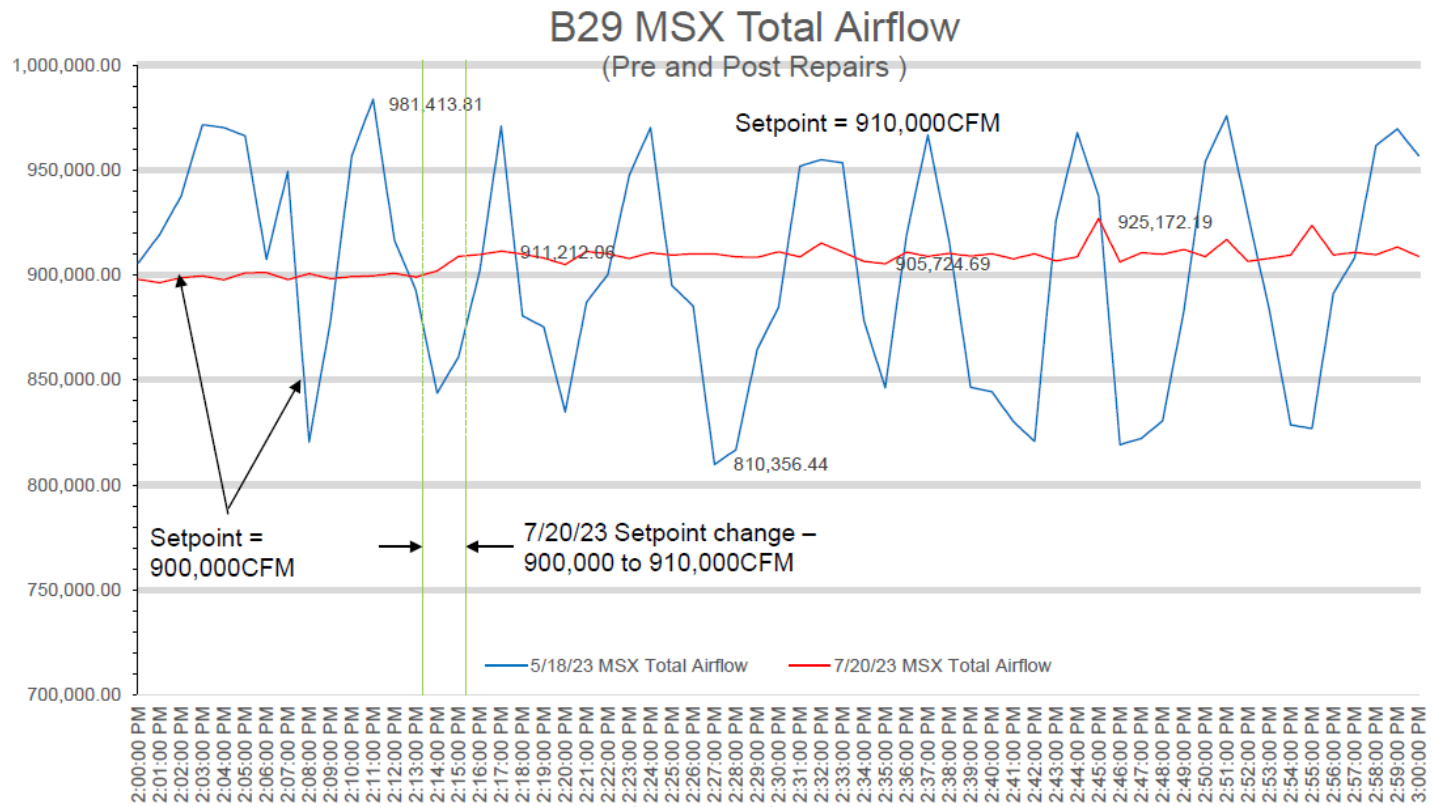


- Federal Information Security Modernization Act (FISMA) compliant
- Automated reporting and data reduction
- Future scalability
- Resolved Proportional-Integral-Derivative (PID) loop hunting for pressurization

Proportional-integral-derivative (PID) Resolution

Mission Support Directorate

E1405 MSX Fan Repairs



PID tuning chart pre and post repairs
Credit: NASA/Todd Sanders

- Tuned PID loop paraments using Ziegler-Nichol tuning method
- Allowed for more consistent air flow in the cleanroom
- Lowered oscillations on individual VFD

Rapidly Deployed Filtration

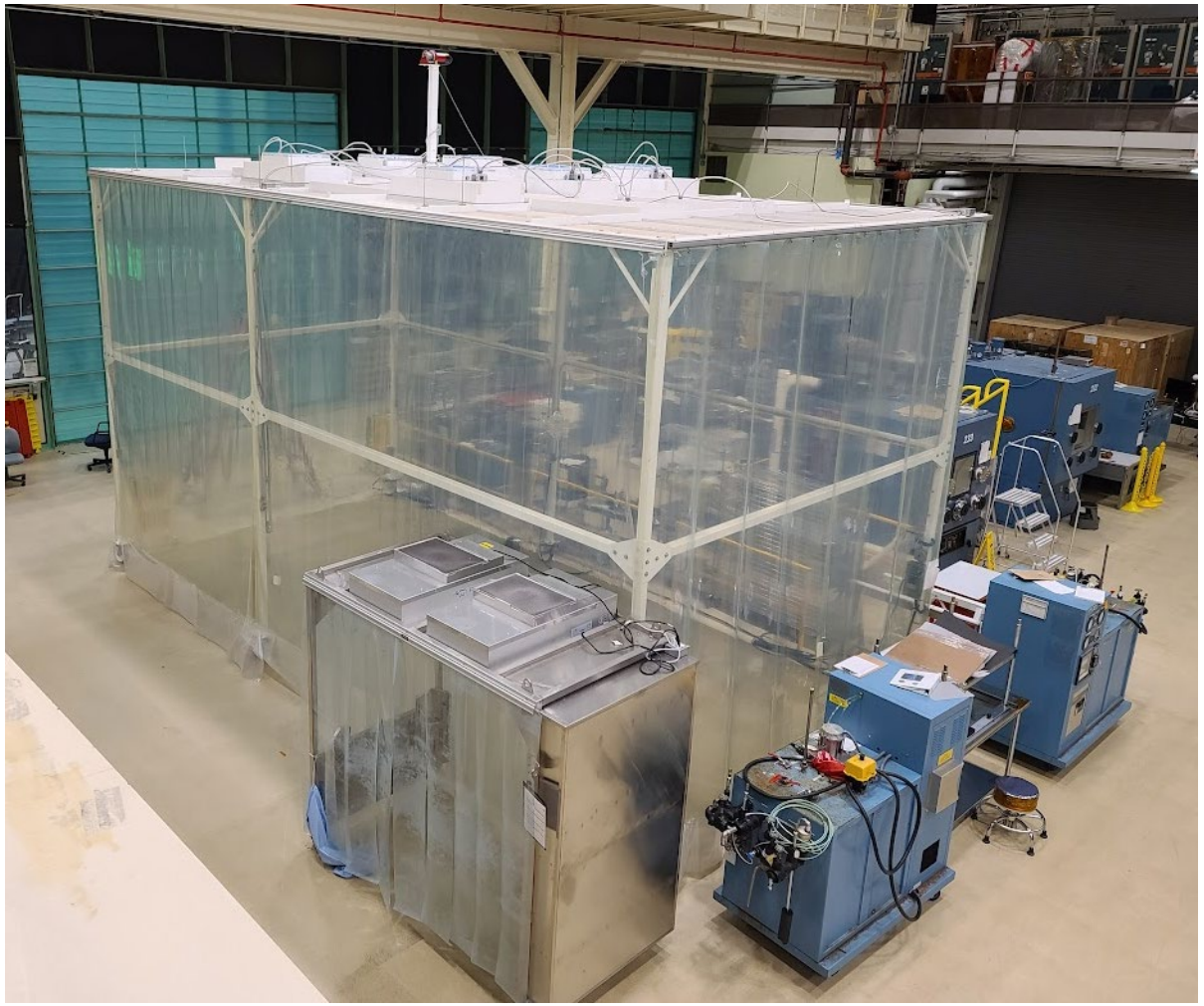


Photo Credit: NASA/Zao Huang

- Modular cleantents:
  - Polyurethane curtains
  - 1x MERV 13 pre-filter
  - 1x MERV 19 HEPA filter
  - Fan motor provides air flow
  - 208V/30A/3P

- Modular filter banks
  - 2 or more large filter banks
  - 1x MERV13 pre-filter
  - 1x MERV 19 HEPA filter
  - Fan motor provides air flow
  - 208V/30A/3P or
  - 440V/60A/3P

Rapidly Deployed Filtration

Photo Credit: NASA/Zao Huang

Rapidly Deployed Filtration

Photo Credit: ESA/M. Pedoussaut

Rapidly Deployed Filtration

- Advantages
  - Quick setup
  - Modular components
  - Good for subsystem/instrument development
  - Can move with the project
  - Much more cost effective

- Disadvantages
  - No dedicated HVAC
  - Less environmental control
  - Size limitations
  - Not much utilities
  - Loud (60+ dBs)

Support Services

- Pre-clean room for hardware processing
- Rapid chemistry lab for materials testing
  - NASA GSFC is a silicone-free complex
- Non-volatile residue (NVR) monitoring per IEST-STD-CC1246
- Continuous particle monitoring per ISO 14644
- On-call technicians and contamination control engineer 24/7

Photo Credit: NASA/ Sydney Rohde

Future Challenges

- NASA flight projects have increasingly stringent temperature and humidity control requirements
- Air flow restrictions due to hardware placement
- Material property and selection challenges

Photo Credit: NASA/Chris Gunn

Future Challenges

- Lack of shutdown time prevents full system maintenance
  - We run 24/7/365
- Construction within the cleanroom must happen while flight projects continue work
- Building maintenance moving towards predictive vs preventative time-based maintenance
  - Monthly vibration analysis
  - Differential pressure monitoring