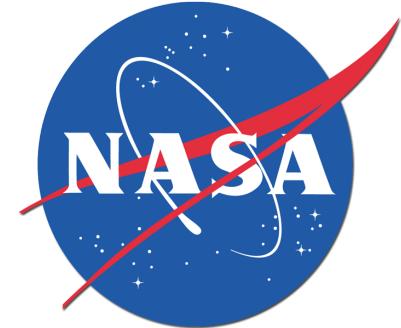


# NASA - BETTII

Goddard Space Flight Center

By: Joe Gibson

# National Aeronautics and Space Administration

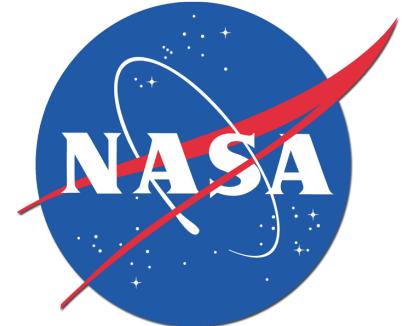


- Founded in 1958 by President Eisenhower
- Big missions (past, present and future)
  - Apollo
  - International Space Station
  - Hubble
  - COBE
  - WMAP
  - Space Shuttle
  - Kepler
  - Mars Science Laboratory (Curiosity)
  - James Webb Space Telescope



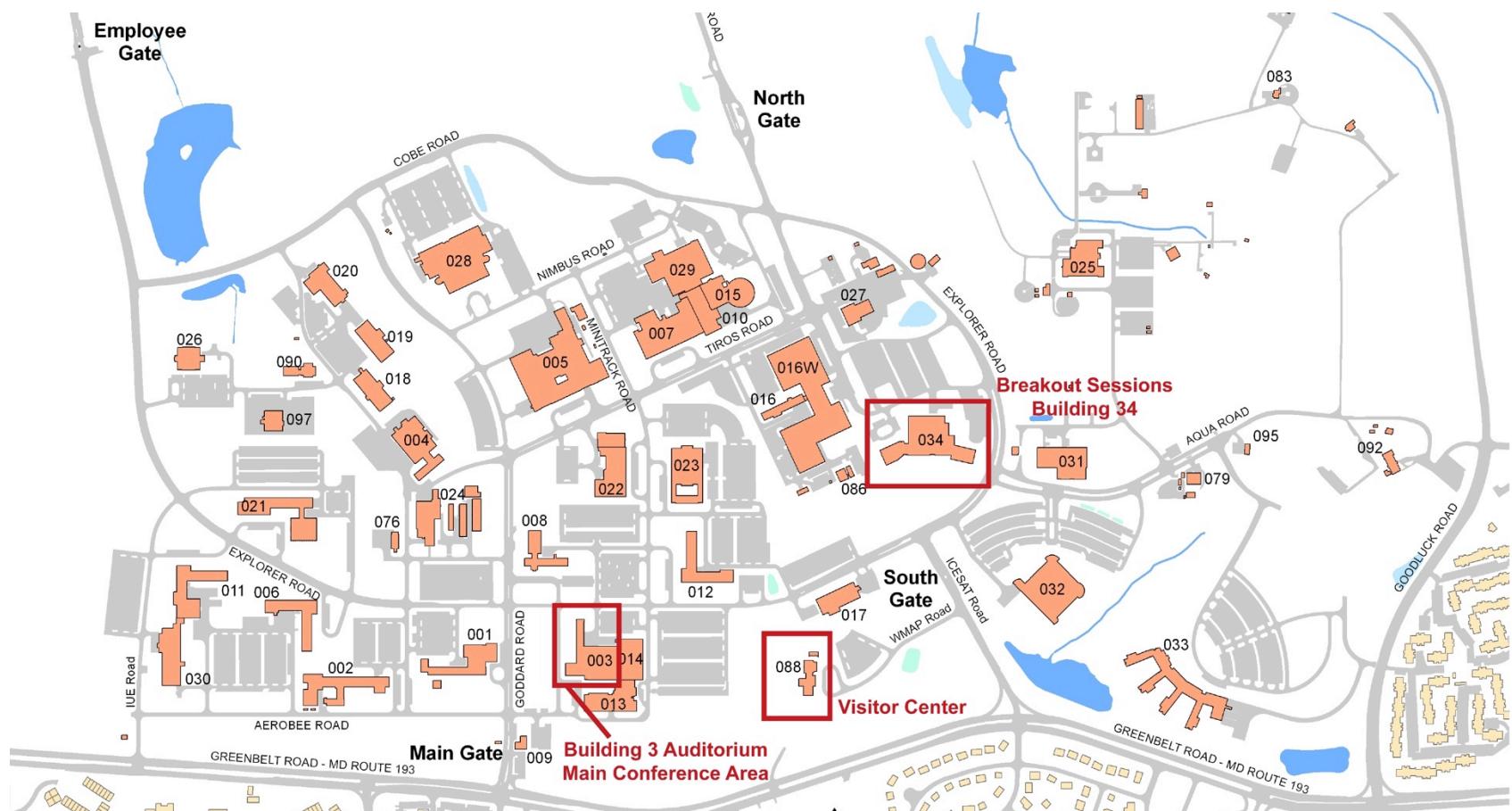
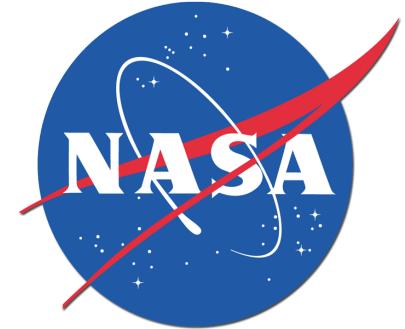
Spiral Galaxy M74  HUBBLESITE.org

# Goddard Space Flight Center

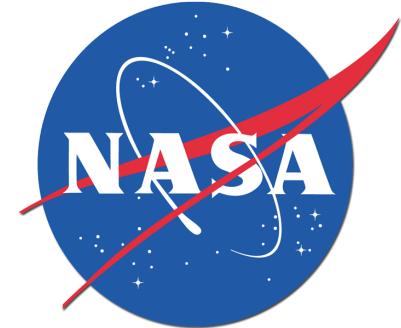


- Located 6.5 miles north of Washington D.C.
- 9800 Employees
  - Largest space research center
  - First and largest NASA center
  - 3400 civil servants
  - 6400 contractors
- Largest ISO-7 cleanroom in the world (Hubble/JWST)
- Focus on space science and research
  - Astrophysics (665)
  - Heliophysics
  - Earth science
  - Cosmology
  - Astrobiology
  - Astrochemistry
  - Engineering

# Goddard Space Flight Center



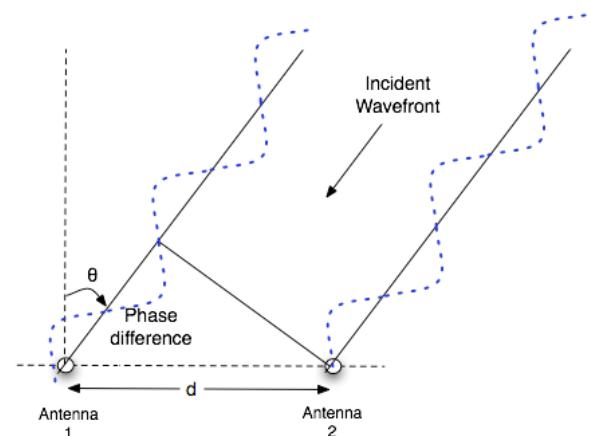
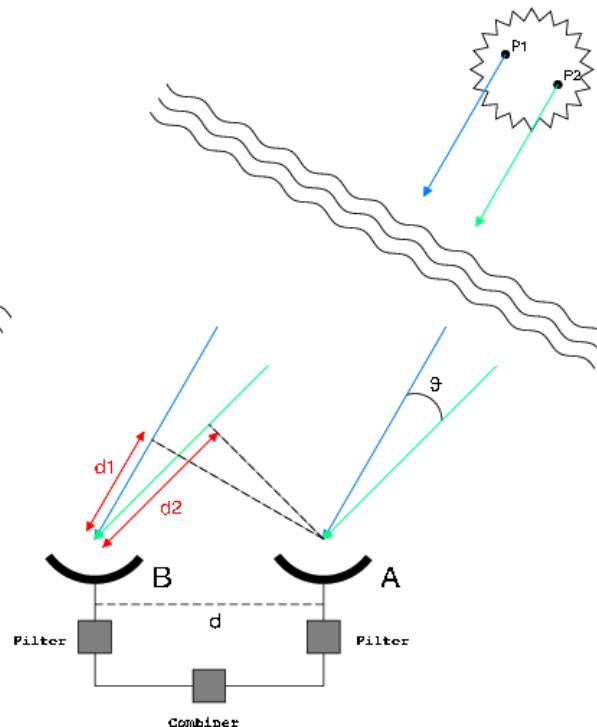
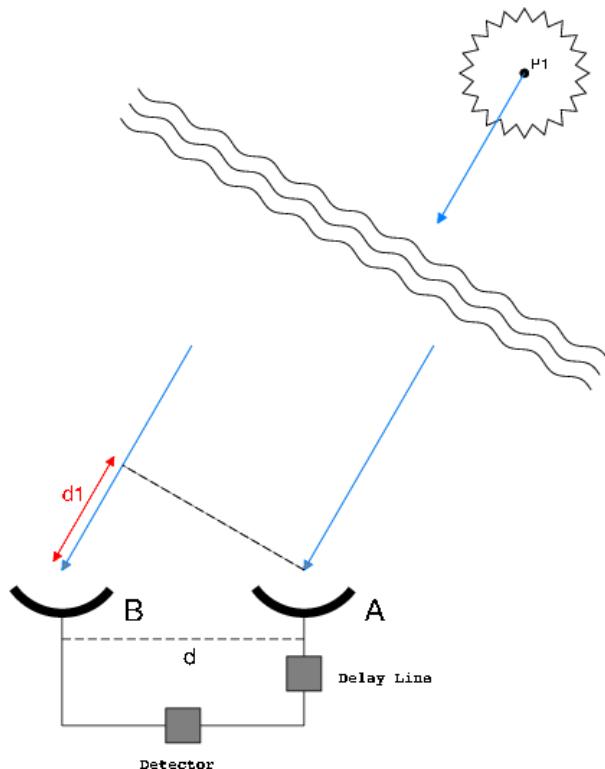
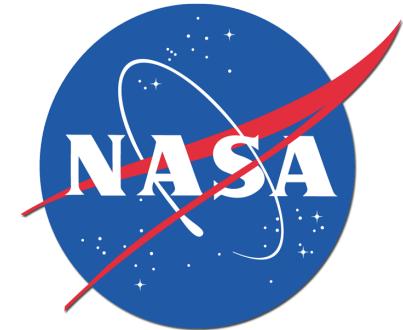
# BETTII



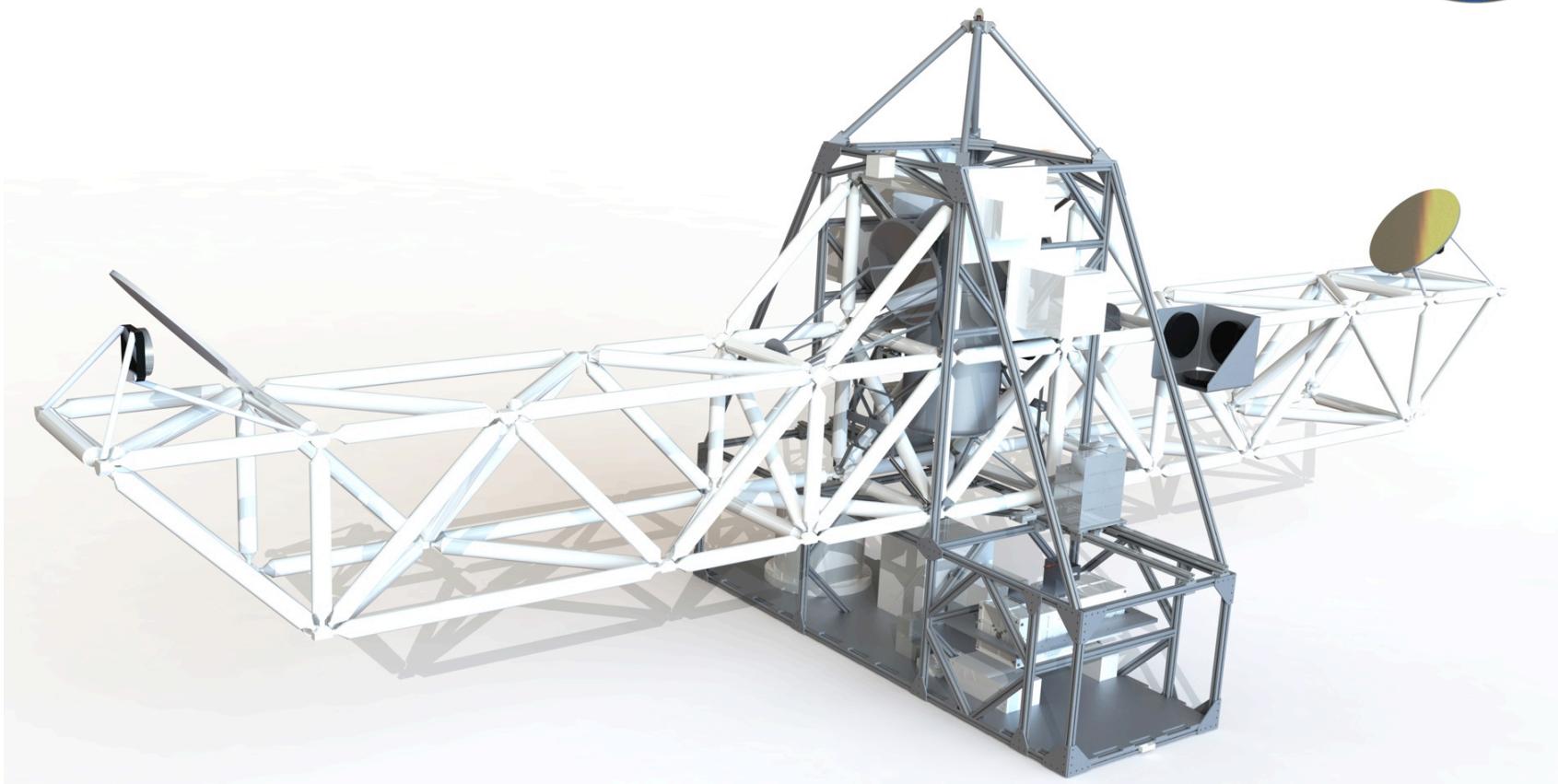
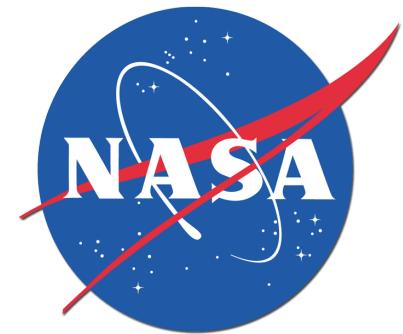
- Balloon Experimental Twin Telescope for Infrared Interferometry
- Star formation
  - Individual star formation never observed
- Active galactic nuclei
- Interferometry: *a family of techniques in which waves are superimposed to extract information about the waves*<sup>1</sup>
- Far Infrared (FIR):  $15\mu\text{m}$  to  $1\text{mm}$ 
  - Visible light:  $400\text{nm}$  to  $700\text{nm}$
- Fly at 40,000 meters (130,000 feet)... In SPACE!
  - No air, atmosphere, etc.
  - Vacuum
  - Cold!
- Balloon the size of a football field ( $\sim 11,000,000 \text{ ft}^3$ )
- Launch out of New Mexico desert in Fall 2015

<sup>1</sup>Wikipedia

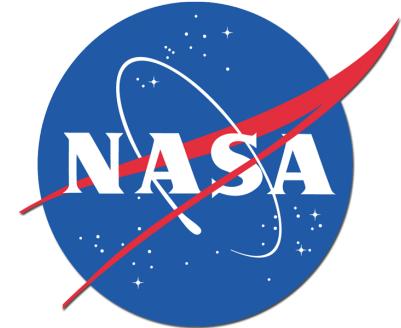
# Interferometry



- Much higher angular resolution
  - Distinguish between two close points of light

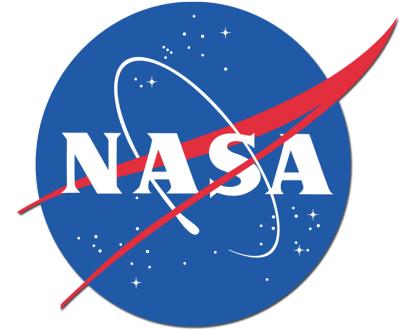


# BETTII Personnel



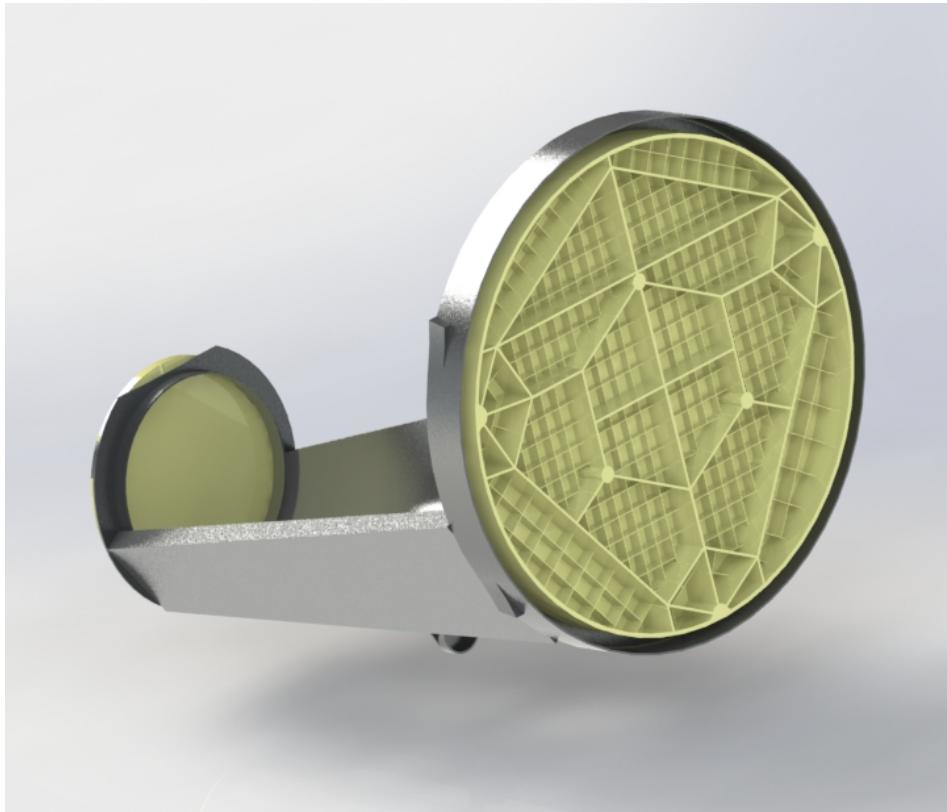
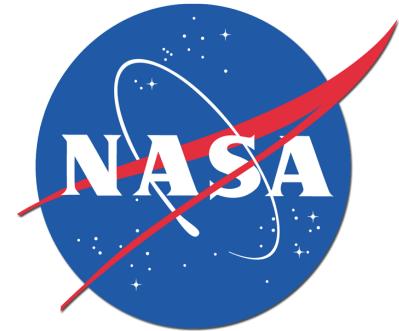
- Dr. Stephen Rinehart, Ph.D. Astrophysics, MIT, Cornell, BETTII PI
- Dr. Dominic Benford, Ph.D. Physics, CalTech
- Dr. Dale Fixsen (Contributions to COBE, 2006 Nobel Prize in Physics)
- Dr. Todd Veach
- Steve Maher, M.S. Computer Science
- Maxime Rizzo, M.S. Astronomy, Univ. of Maryland
- Arnab Dhabal, M.S. Astronomy, Univ. of Maryland
- Yamil Huertas, B.S. Electrical Engineering, Univ. of Puerto Rico

# BETTII Sub-systems

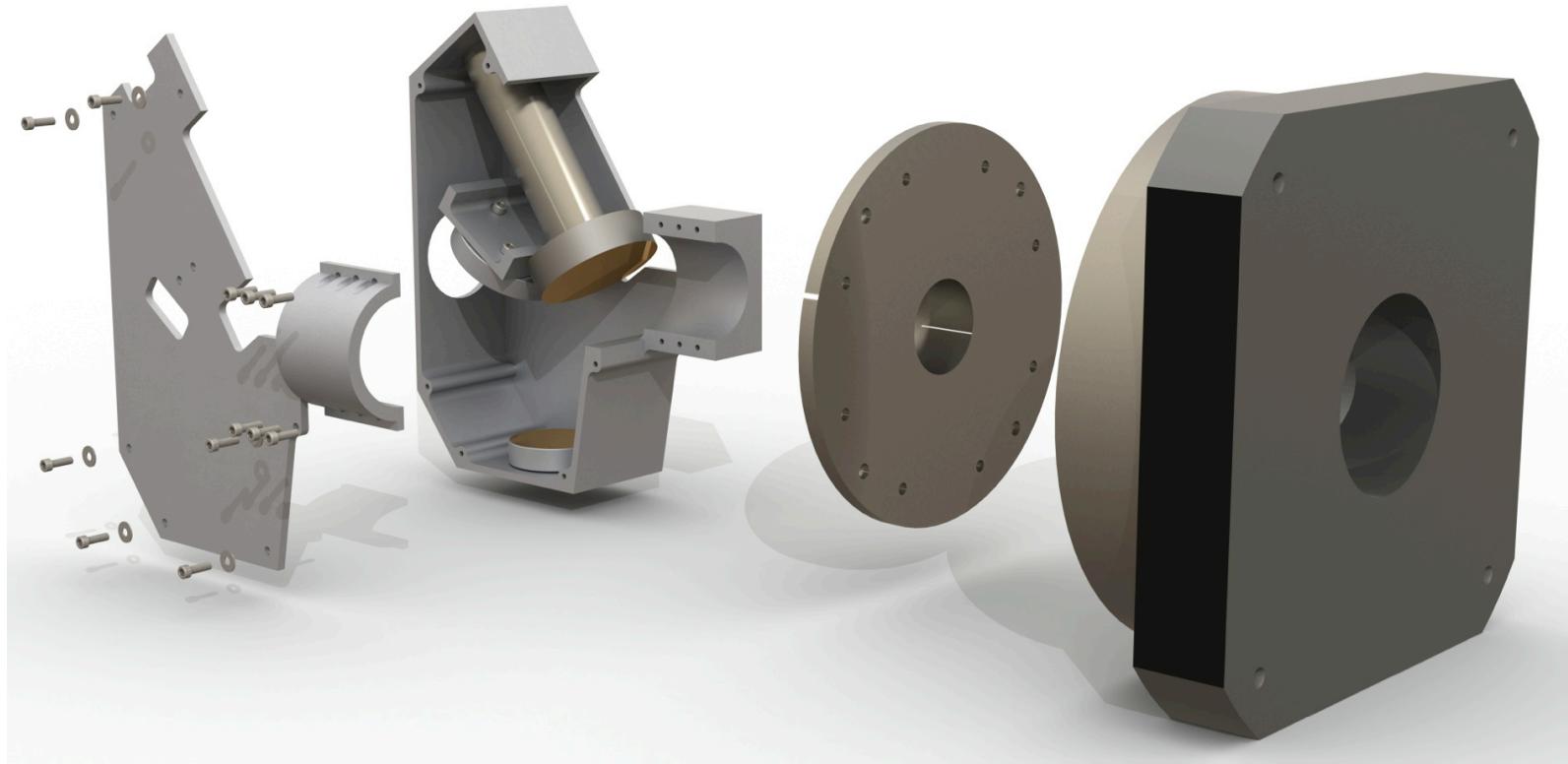
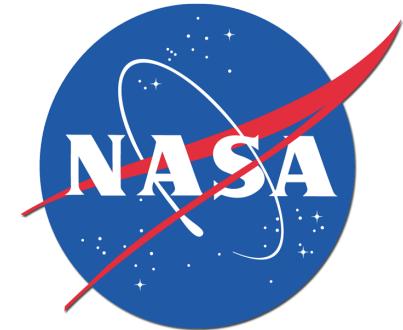


- Main mirrors (telescope)
- K-Mirror
- CCMGs
- Momentum Dump
- Gyroscopes
- Star Camera
- Flight Computers
- Dewar

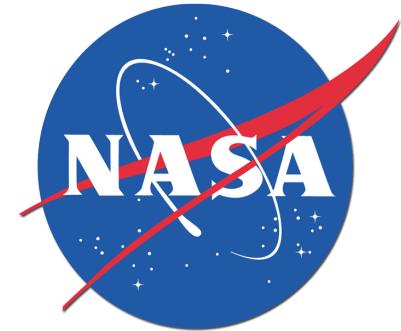
# Telescope



# K-Mirror



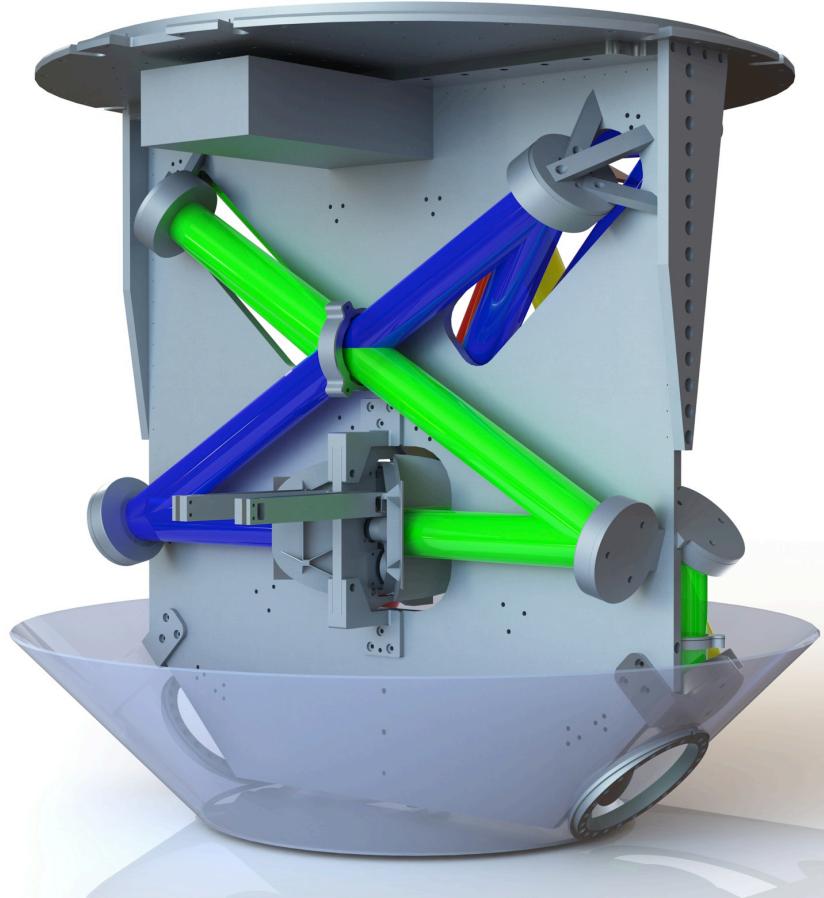
# Optics Bench



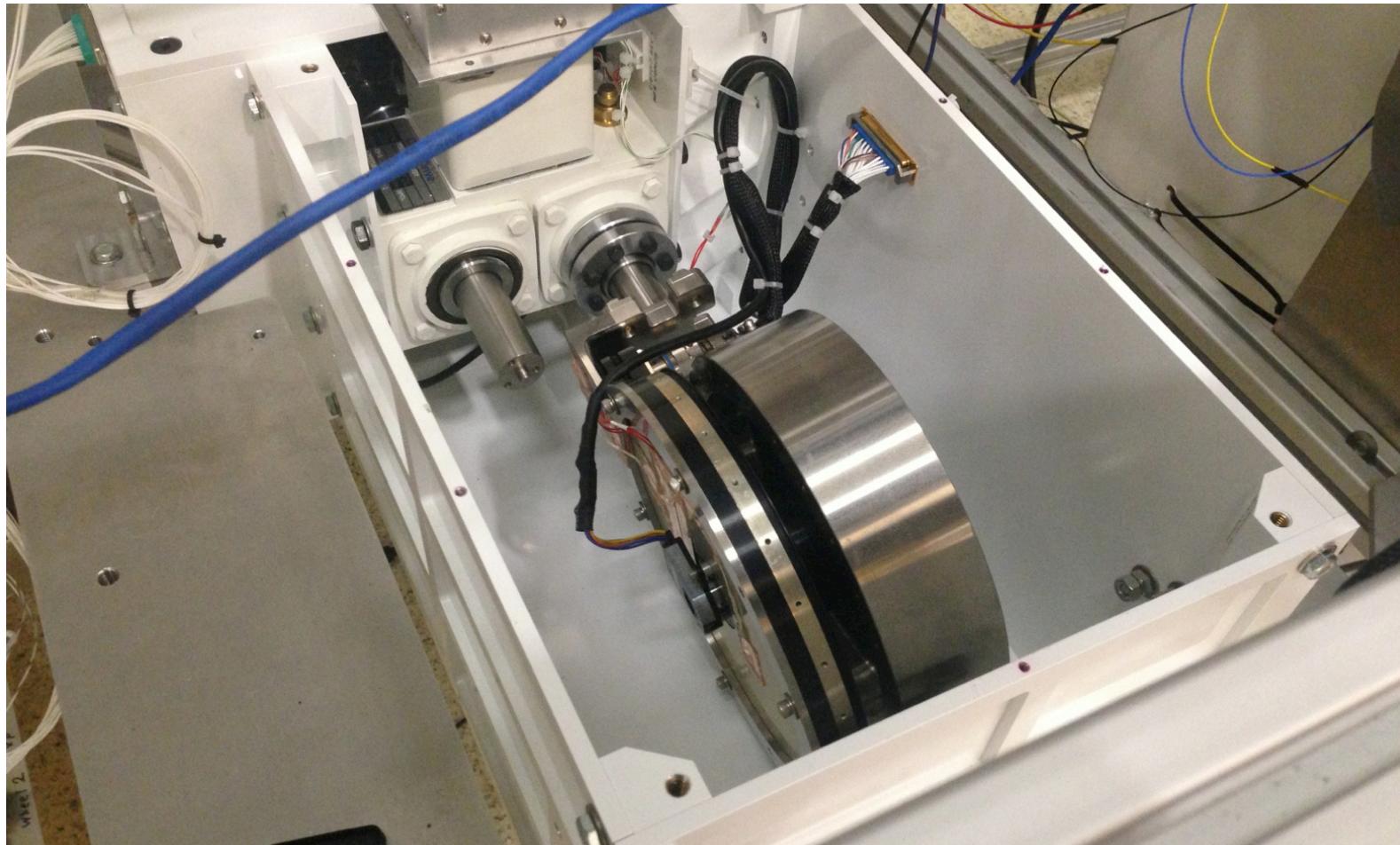
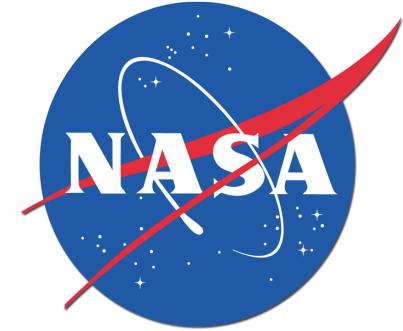
Front



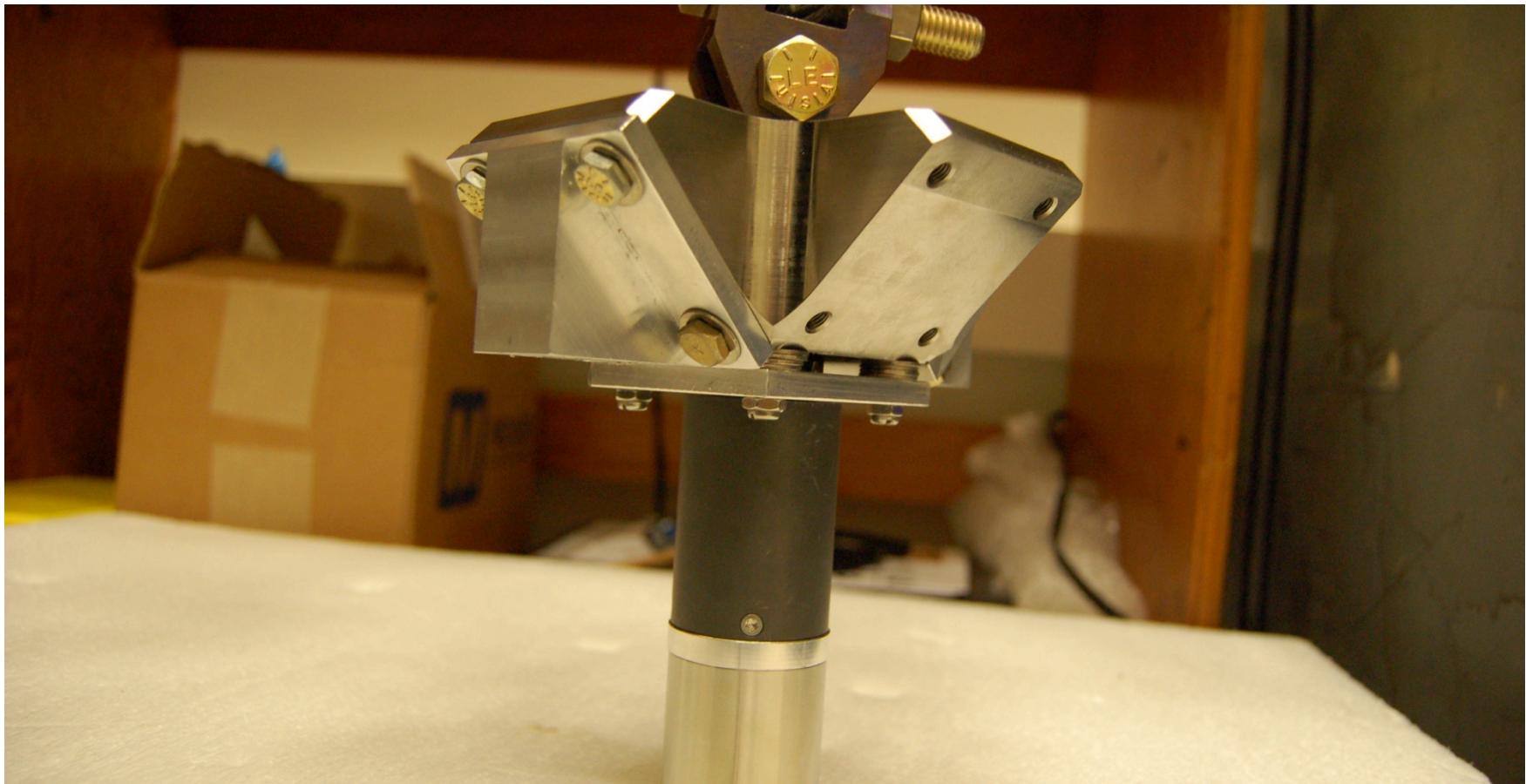
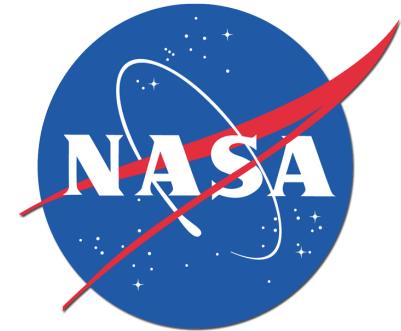
Rear



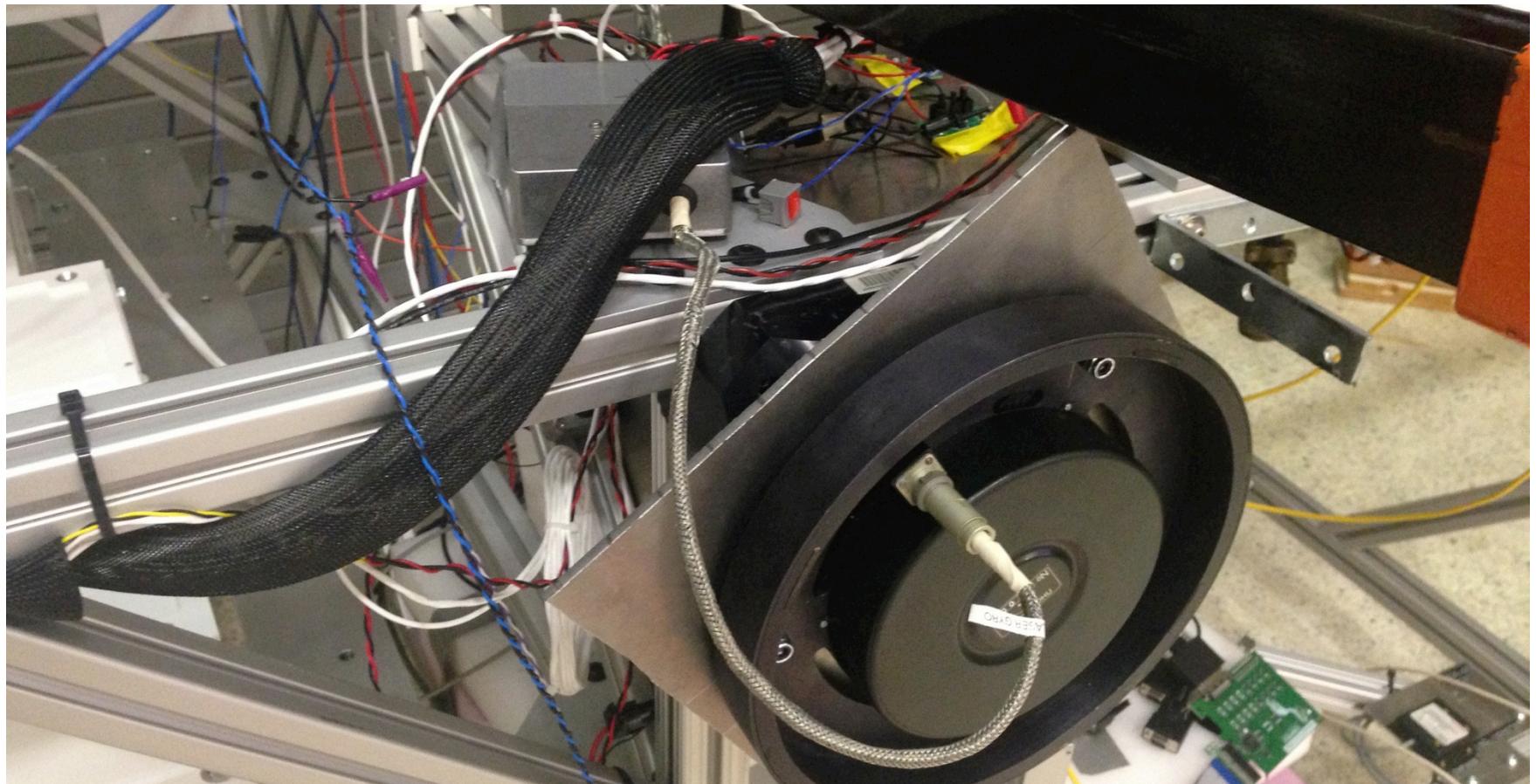
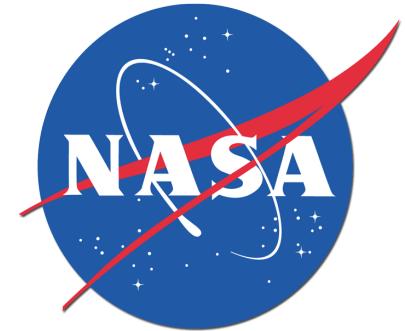
# CCMG Momentum Wheels



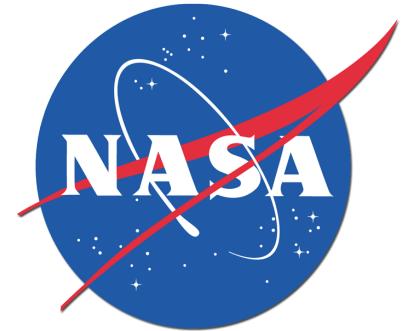
# Momentum Dump



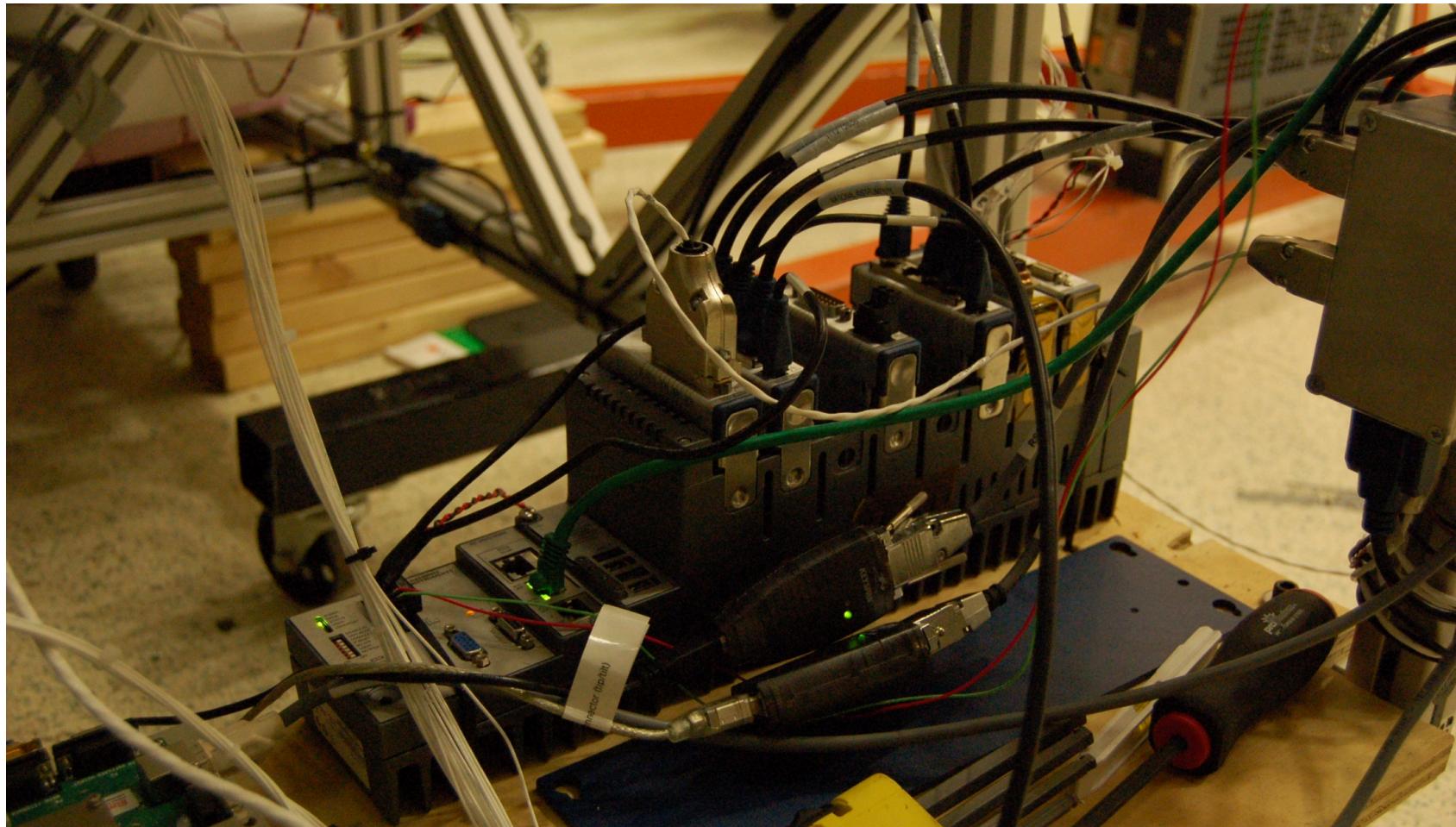
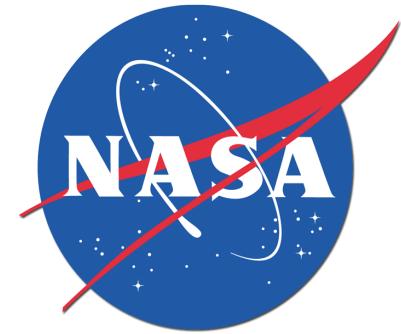
# Gyroscopes



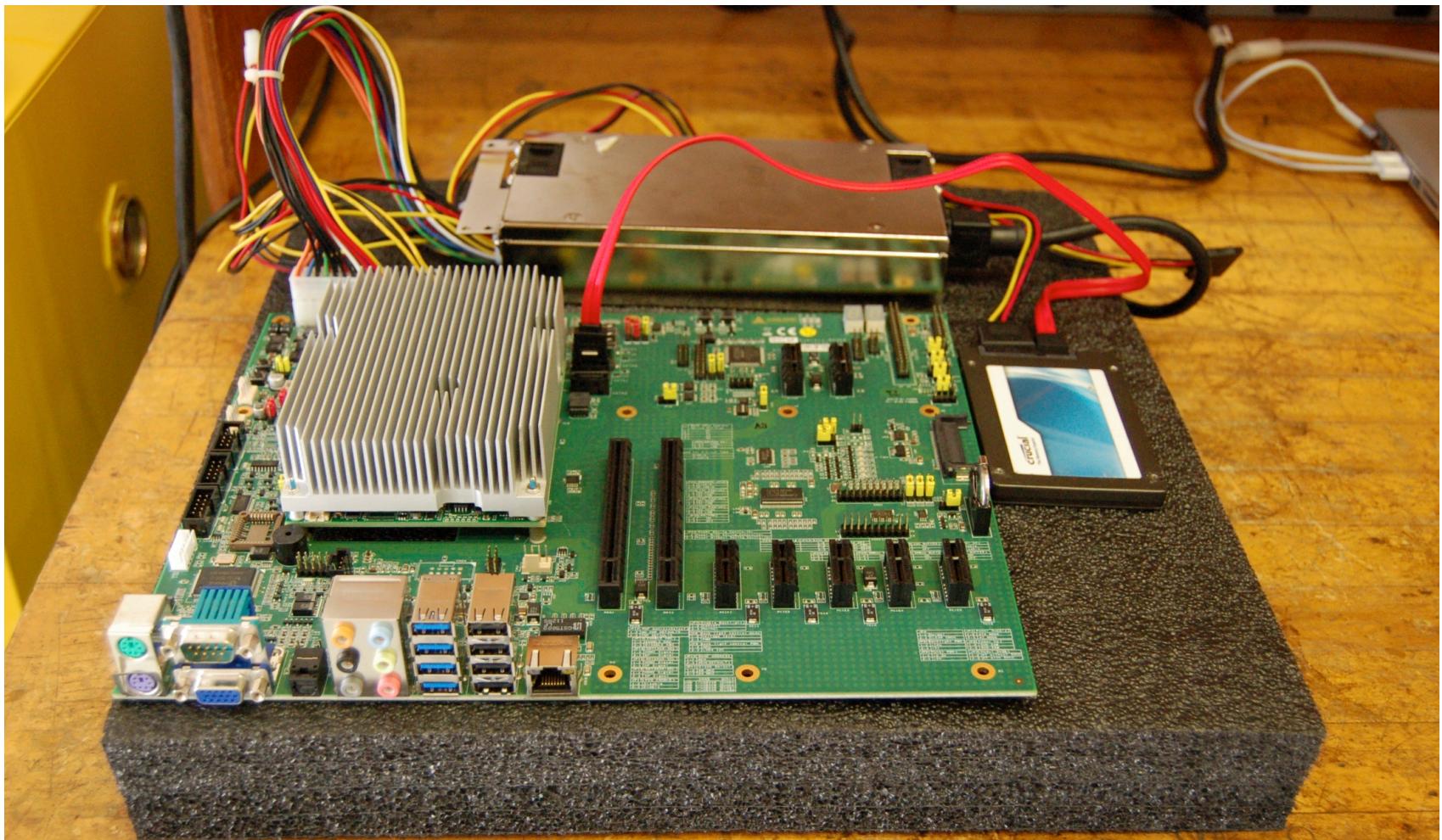
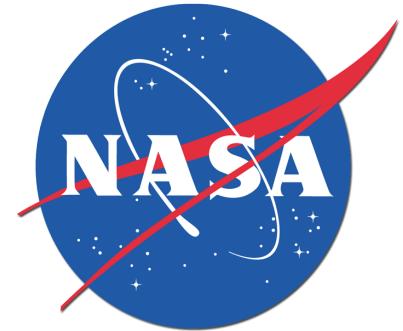
# Star Camera



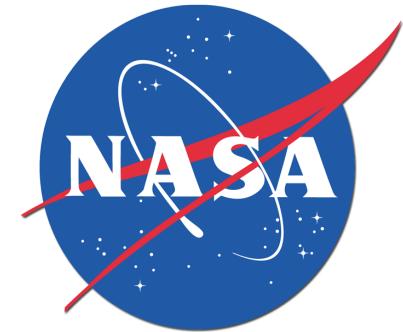
cRIO



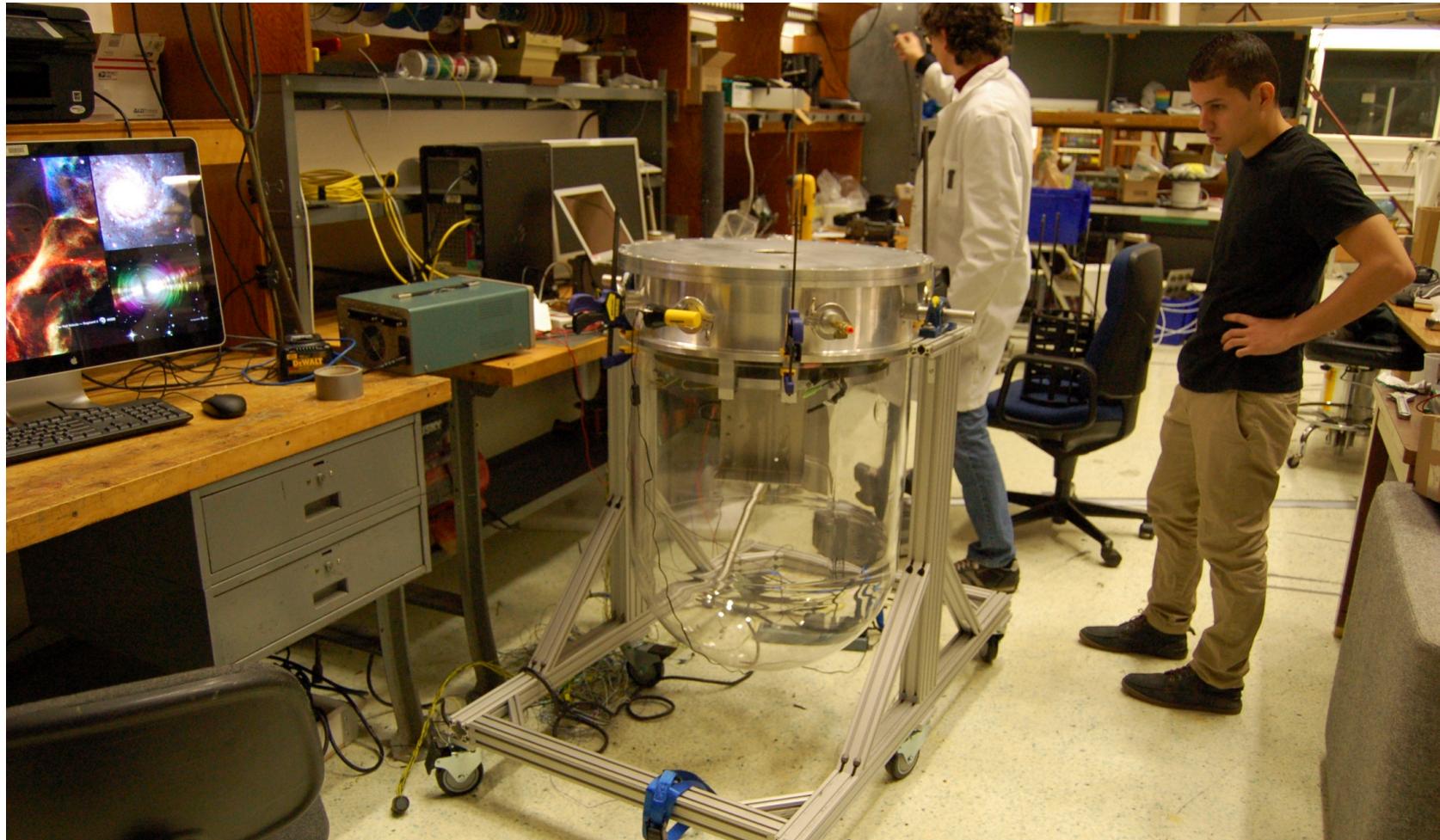
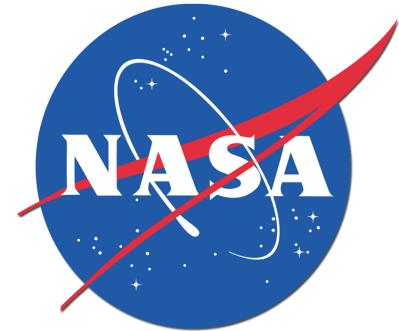
Ford



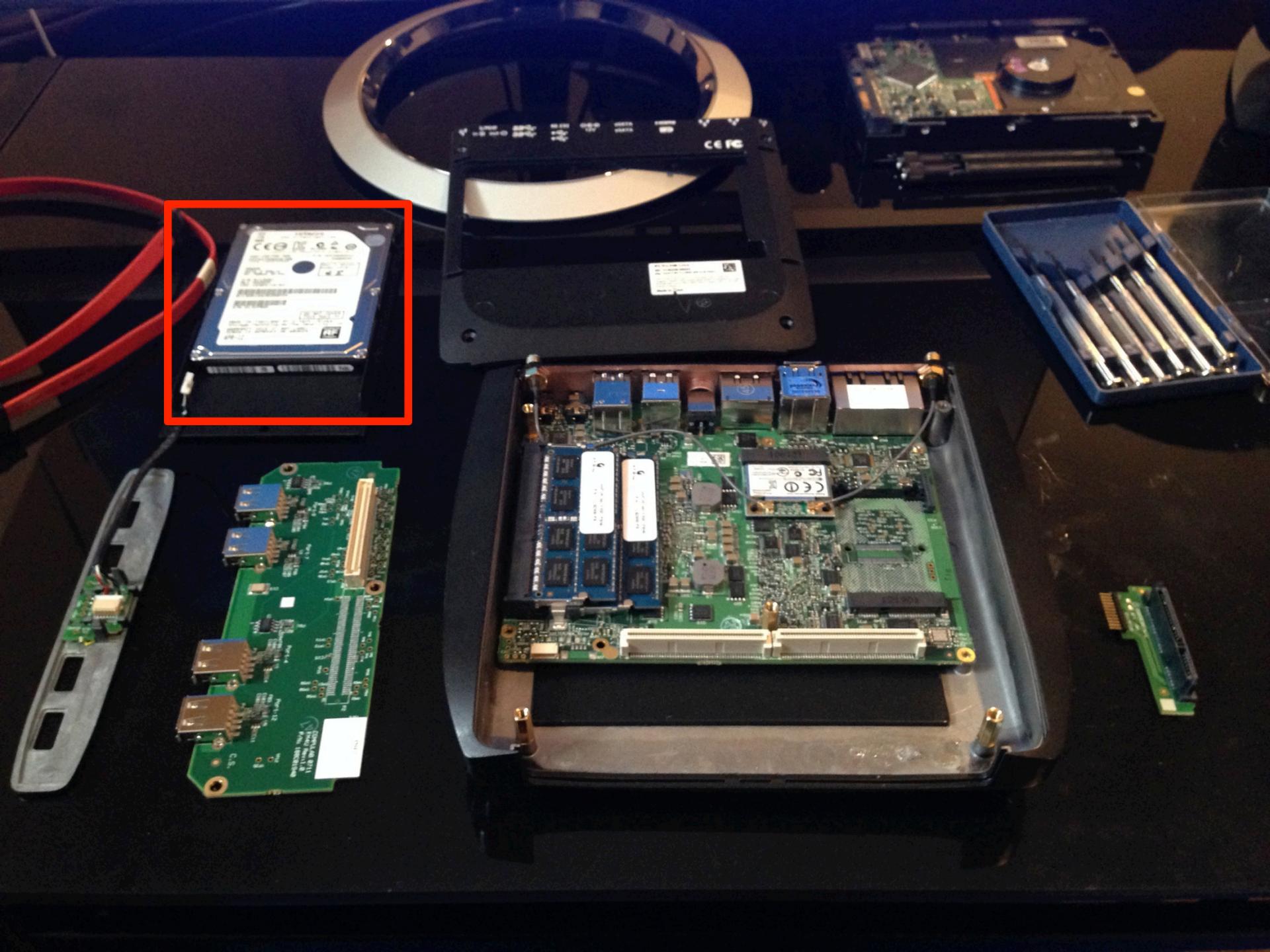
# PHAST



# Bubble Chamber



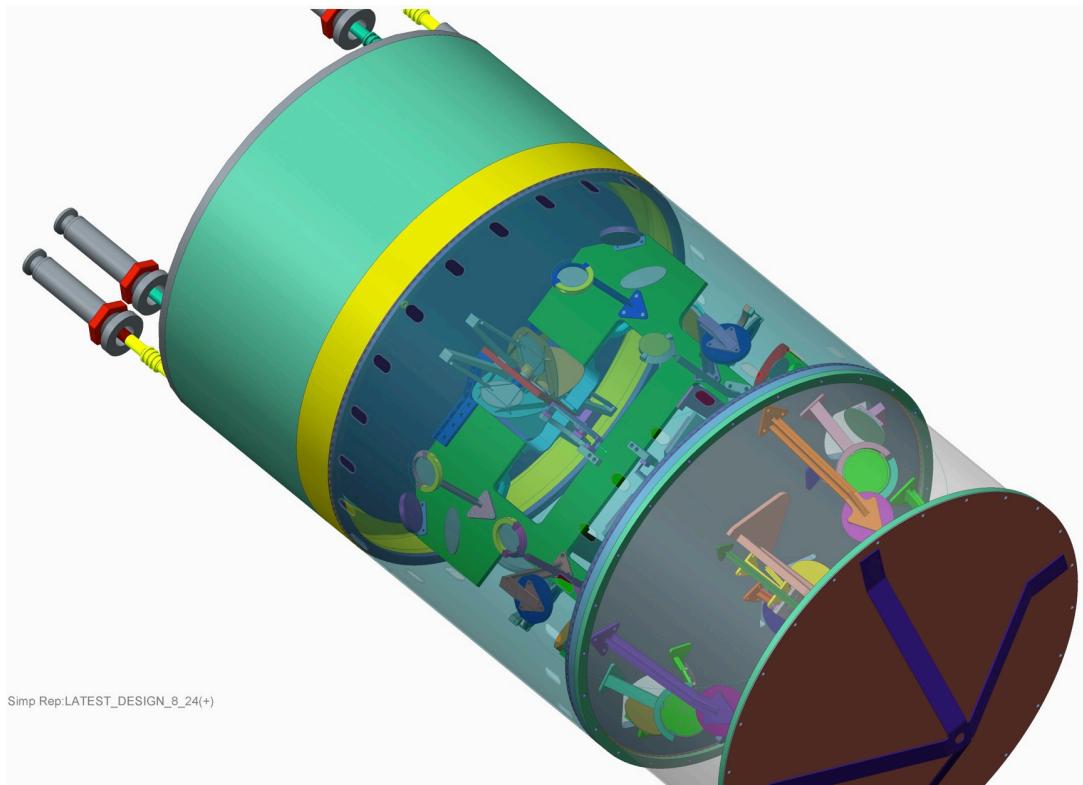
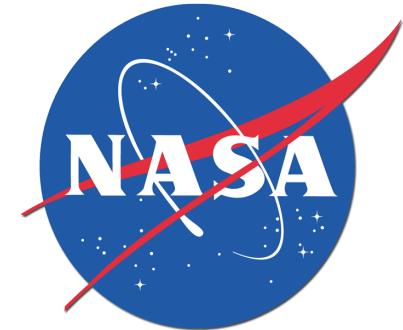




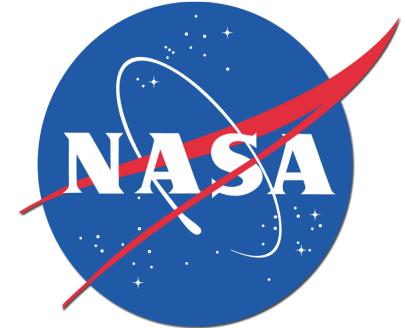
# Dewar

Coldest thing in the **universe**: 0.300K (-459.1°F)

'Empty' space is about 2.75K (-454.2°F)

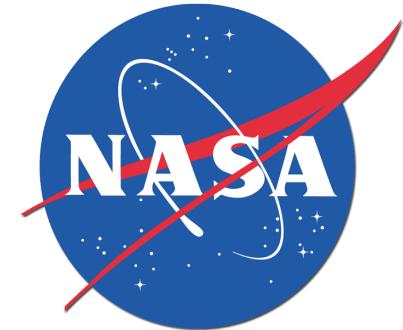


# My Tasks

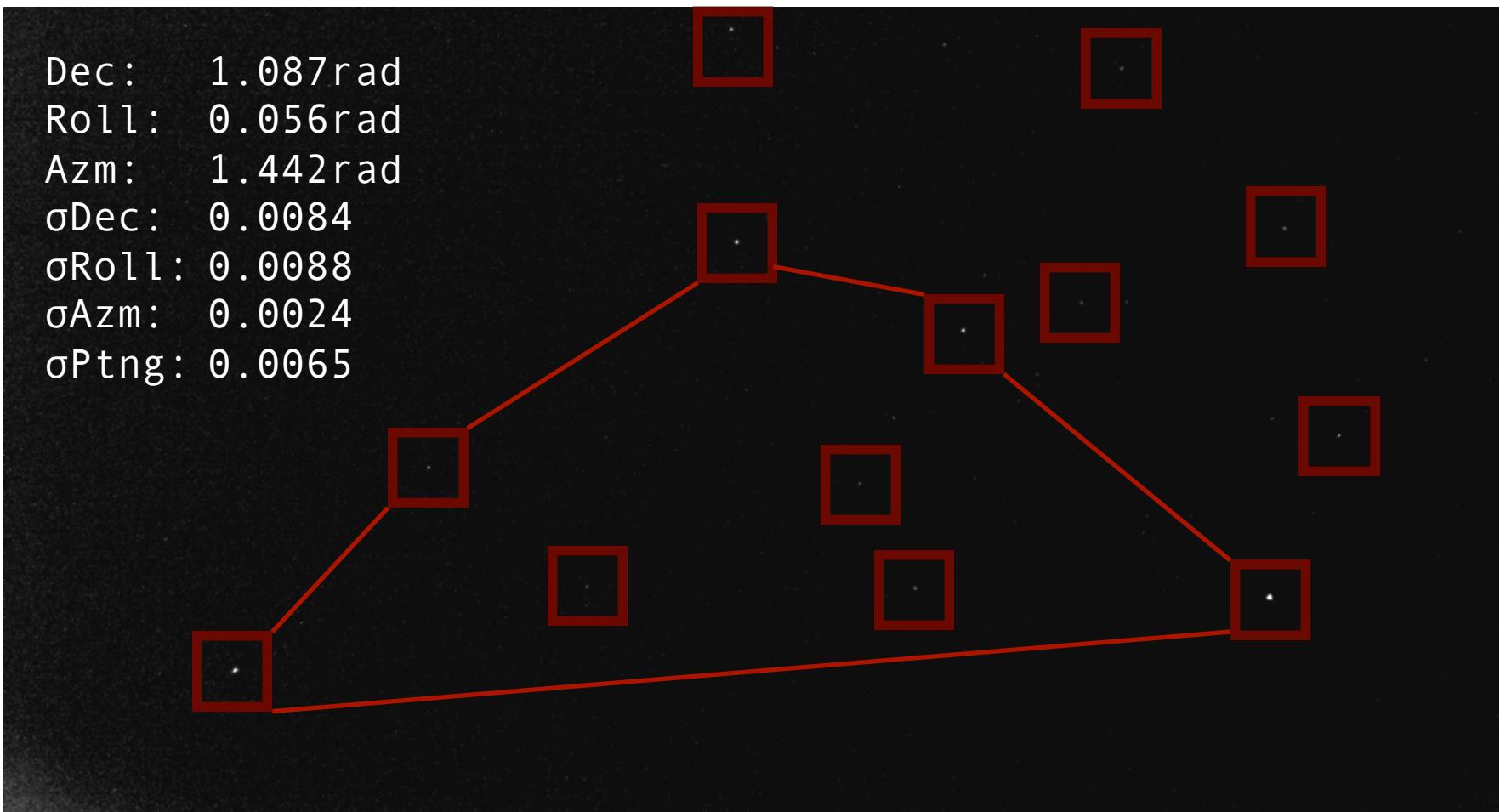


- Create Star Tracker Software
  - Determine BETTII's position in the sky by looking at the stars
    - Take images with PCO.Edge and/or PGR Flea3 camera
    - Save image to FITS
    - Analyze image with Star Finder (Cardiff University)
    - Perform mathematical analysis (simple trig, quaternion rotations)
    - Send necessary data to cRIO
      - cRIO interprets data and moves truss with CCMGs
  - Multi-processed (fork)
- Design communication system between instruments and FPGA
  - Full-blocking (r/w via semaphores) shared ring buffer to store data from multiple instruments – multiple readers/writers simultaneously
- Create RS-422 receiver code for FPGA in LabVIEW
- Lots of small control/sensor programs (CCMGs, 422 serial transmitter, etc.)

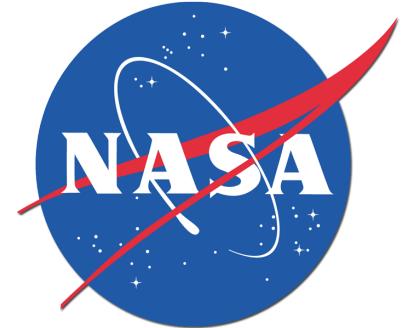
# Star Camera Image



Dec: 1.087 rad  
Roll: 0.056 rad  
Azm: 1.442 rad  
 $\sigma$ Dec: 0.0084  
 $\sigma$ Roll: 0.0088  
 $\sigma$ Azm: 0.0024  
 $\sigma$ Ptng: 0.0065

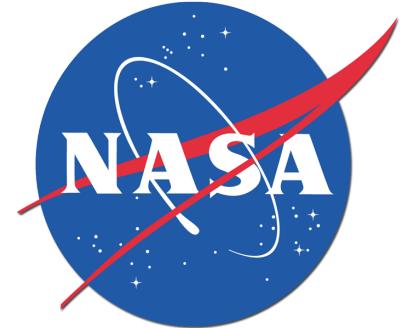


# Star Camera Image Cont.



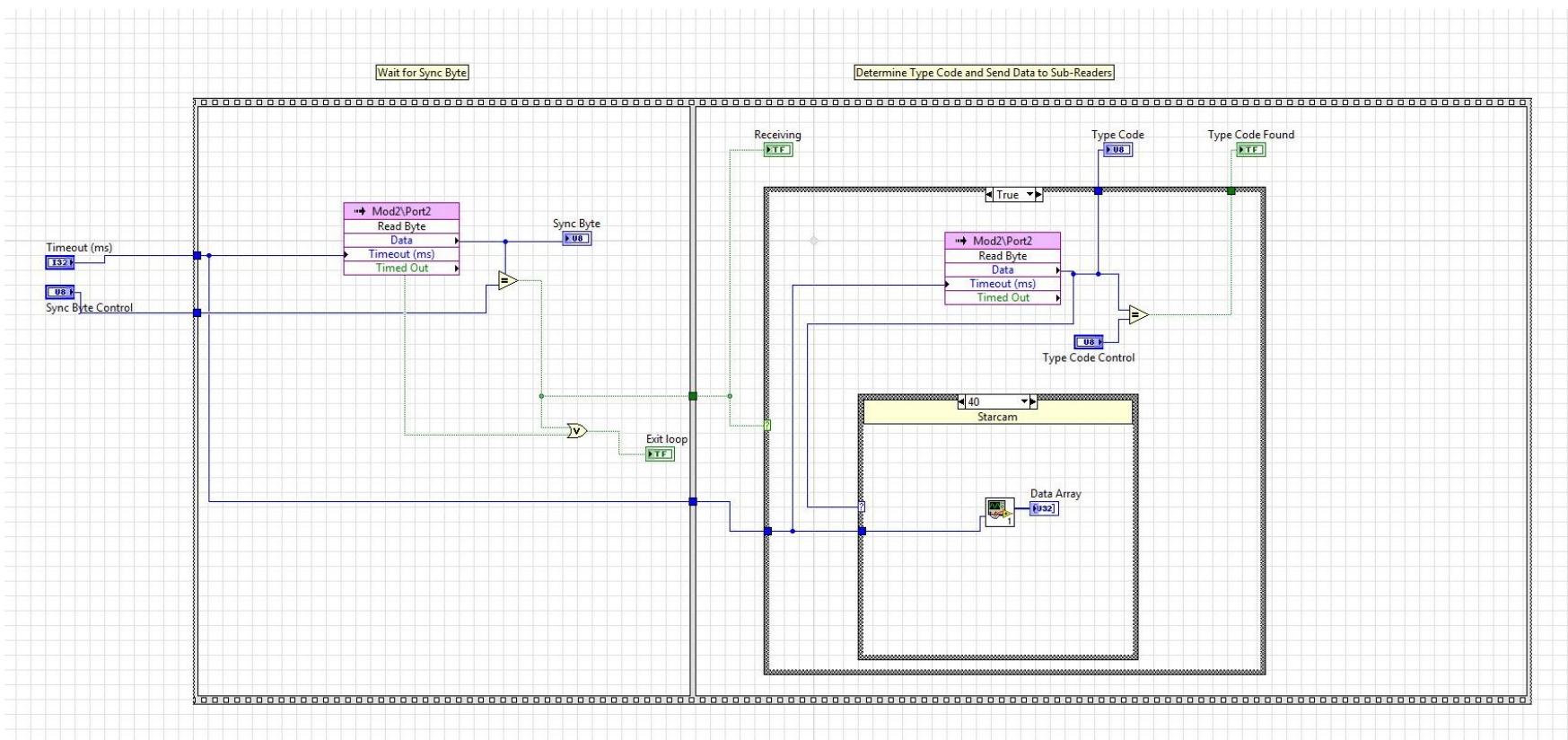
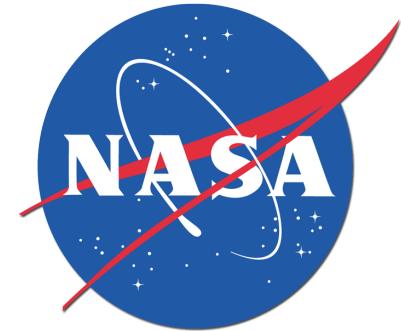
- Need to know:
  - GPS coordinates (from GPS unit)
  - Time of year, month, day, etc.
- One of the oldest forms of determining location
  - The Egyptians did it...
- Cameras
  - PCO.Edge
  - Point Grey Research Flea3

# What Now?

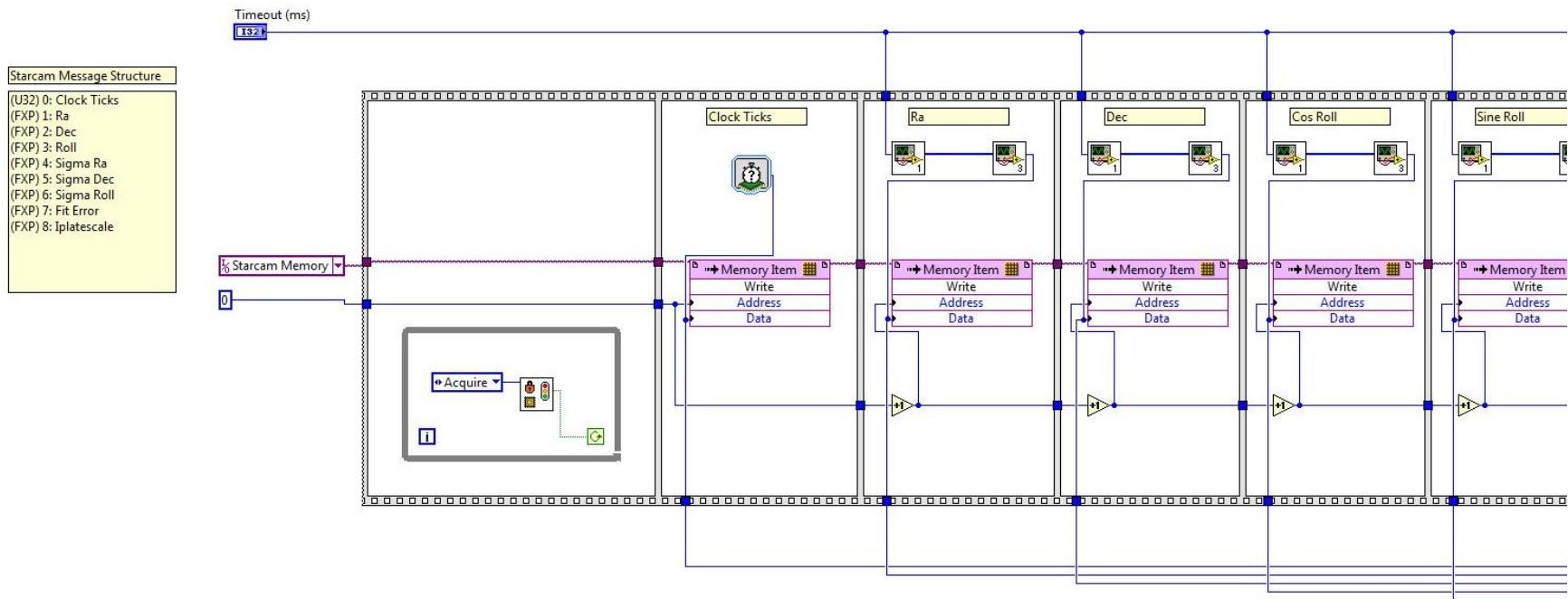
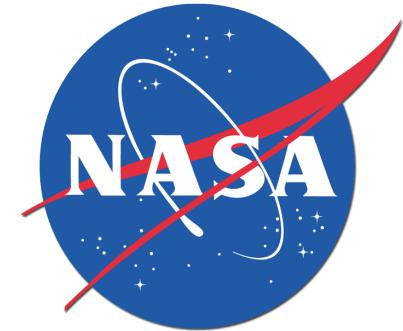


- Next, the solution is sent to FPGA (Boop)
  - declination (dec)
  - azimuth (azm/ra)
  - $\sin(\text{roll})$ ,  $\cos(\text{roll})$
  - sigma dec, roll, azm, pointing
  - Quaternion (matrix + vector / vector quotient) rotations
- Solution stored as 32 bit fixed point data structure in shared ring buffer on flight computer (Ford)
- Ring buffer data sent to FPGA via RS-422 transceiver
- Fixed point decoder FPGA block on Boop interprets solution
- Algorithm determines delta and controls gimbals and gallils to move spacecraft

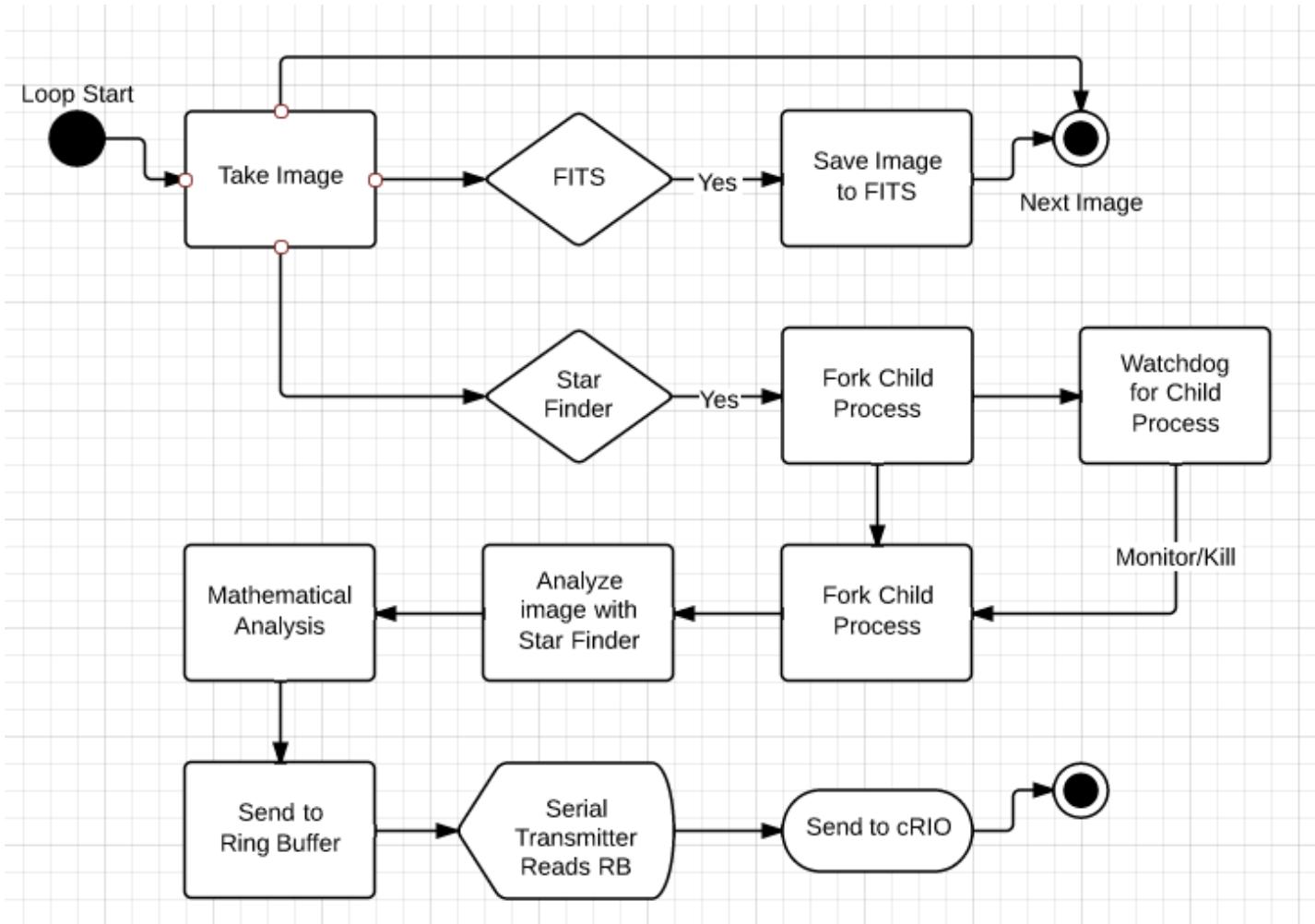
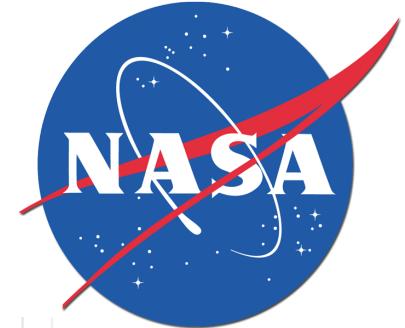
# High-Level Receiver Block



# StarCam FP Decoder



# Star Tracker



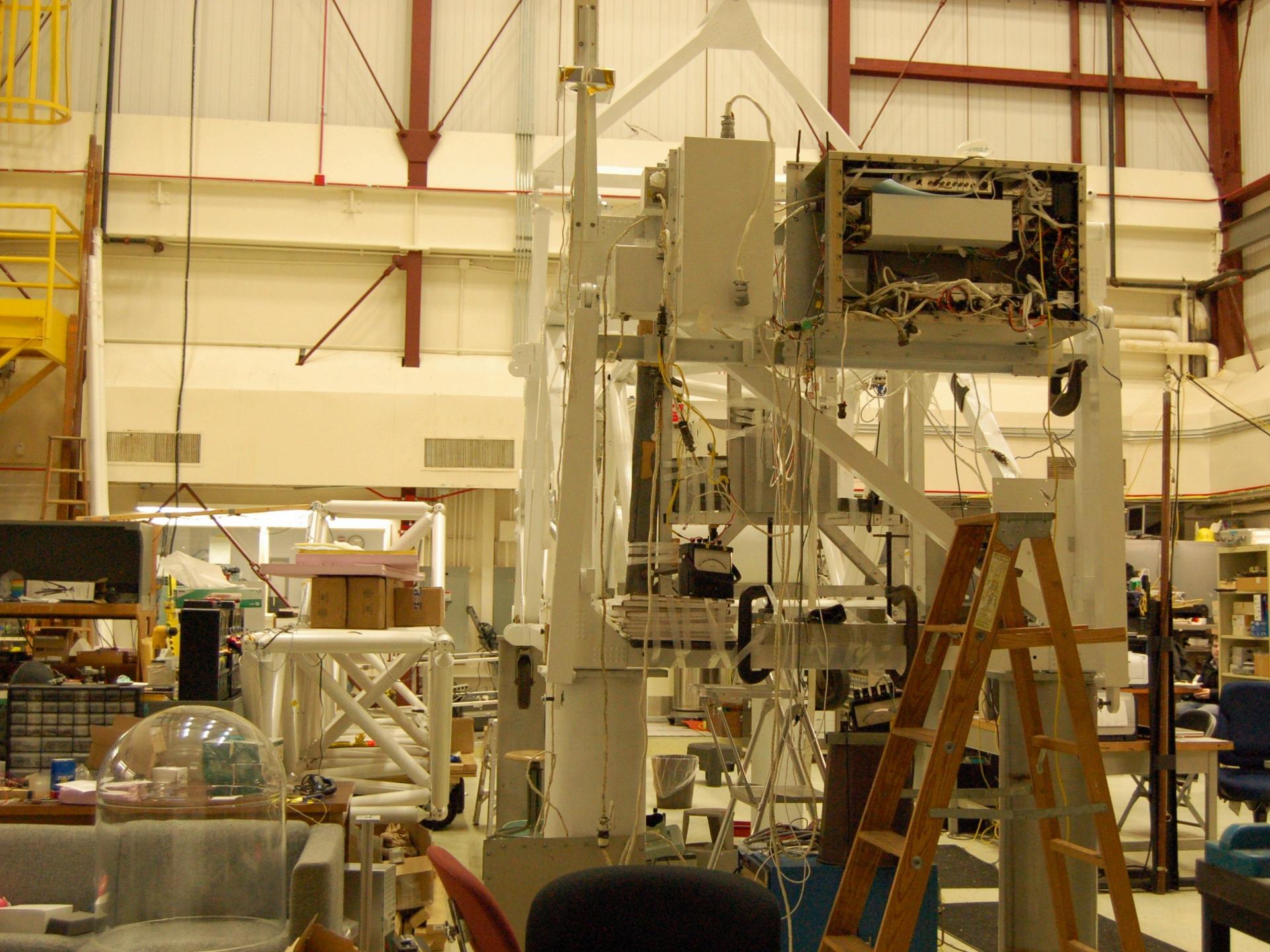
```
/*=====
 * Description: Starcam API for the Mint software package. Calling
 * stcam() and passing an image buffer (uint_16) allows
 * for the image to be processed as if it were a FITS
 * image being processed by the normal Starcam software.
 * Creation: Created 01/28/2014 by Joe Gibson, NASA GSFC
 =====*/
/*
Notes:
- Memory use rose from about 5% to 25% after taking a few hundred photos
- Should stay between 5-10% over 1000+ photos
*/
#include <boost/date_time posix_time.hpp>
#include <CCfits>
#include <cmath>
#include <iostream>
#include "./logging/logger.h"
#include "./shared/shared_list.h"
#include "./shared/image/status.h"
#include "./solving/finding/finder.h"
#include "./solving/logger.h"
#include "./solving/solver.h"
#include "./parameters/manager.h"
#include "stcamAPI.h"
#include "logger_main.h"
using namespace std;
using namespace Solving;
using namespace Solving::Finding;
using namespace Parameters;
using namespace CCfits;
#ifndef _MSC_VER
#include <signal.h>
#endif
#define shared_shutdown (Shared::General::shutdown_for_main())
#define CBuf CircularBuffer
#define CBufP CircularBufferPass
Logging::Logger Solving::logger("solving", true);
Logging::Logger Main::logger("main", true);
std::string stars_absolute_dir = "/home/bettii/stcam/";
///Global Image Dimensions
int width = 2560;
int height = 2160;
int depth = 65536;
Image::Status shared_status;
Image::Status shared_image;
Image::Status solvers_working_image;
```

```
#include <boost/date_time posix_time.hpp>
#include <CCfits>
#include <cmath>
#include <iostream>
#include "./logging/logger.h"
#include "./shared/shared_list.h"
#include "./shared/image/status.h"
#include "./solving/finding/finder.h"
#include "./solving/logger.h"
#include "./solving/solver.h"
#include "./parameters/manager.h"
#include "stcamAPI.h"
#include "logger_main.h"
using namespace std;
using namespace Solving;
using namespace Solving::Finding;
using namespace Parameters;
using namespace CCfits;
#ifndef _MSC_VER
#include <signal.h>
#endif
#define shared_shutdown (Shared::General::shutdown_for_main())
#define CBuf CircularBuffer
#define CBufP CircularBufferPass
Logging::Logger Solving::logger("solving", true);
Logging::Logger Main::logger("main", true);
std::string stars_absolute_dir = "/home/bettii/stcam/";
///Global Image Dimensions
int width = 2560;
int height = 2160;
int depth = 65536;
Image::Status shared_status;
Image::Status shared_image;
Image::Status solvers_working_image;
```

**beTTii**

Balloon Experimental  
Twin Telescope for  
Infrared Interferometry

**GO FOR LAUNCH!! 2015**









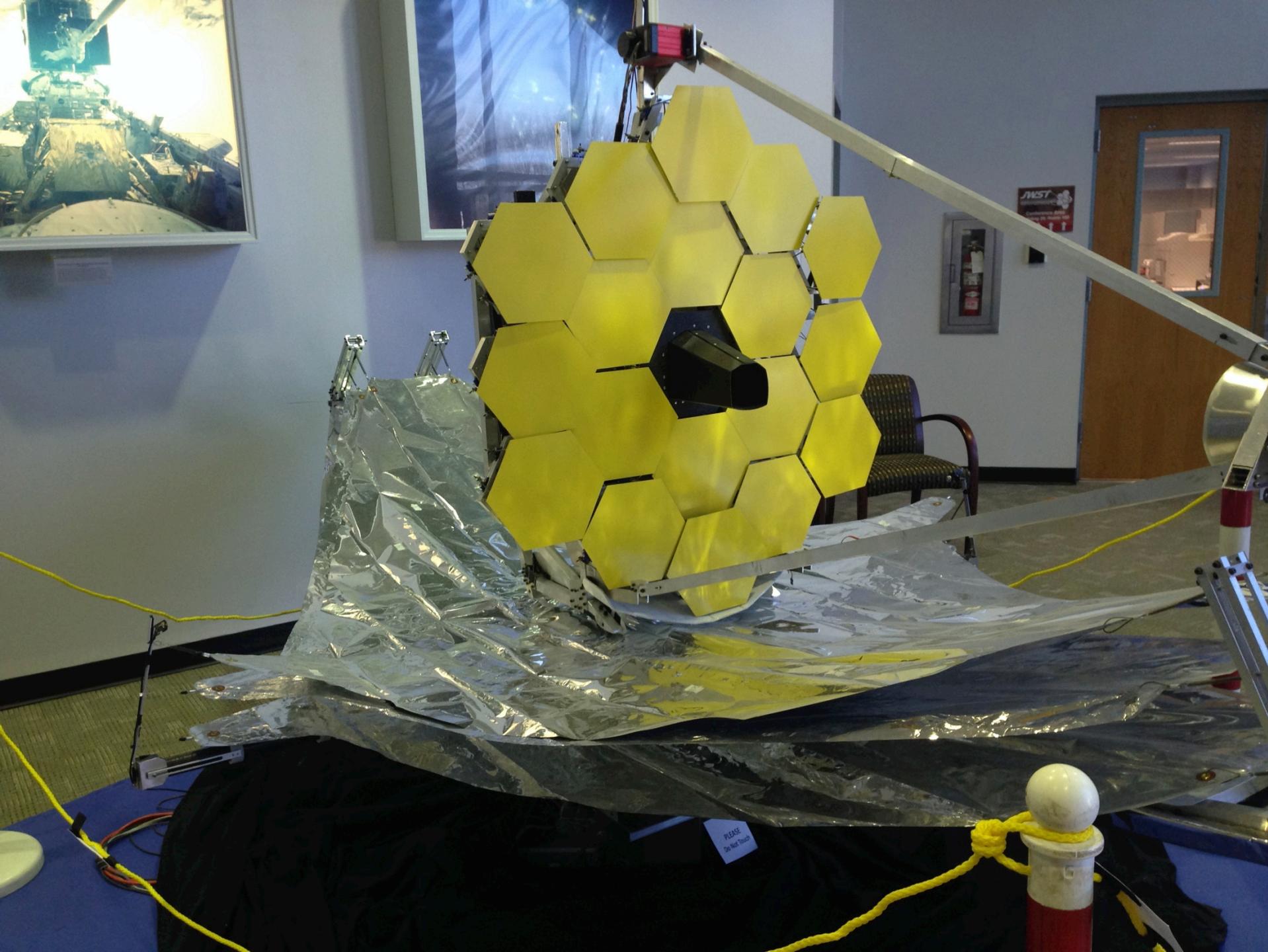
DO NOT  
CLAMP

THIS SIDE OF  
SHIPPING STACK

CLAMP

FORKLIFT

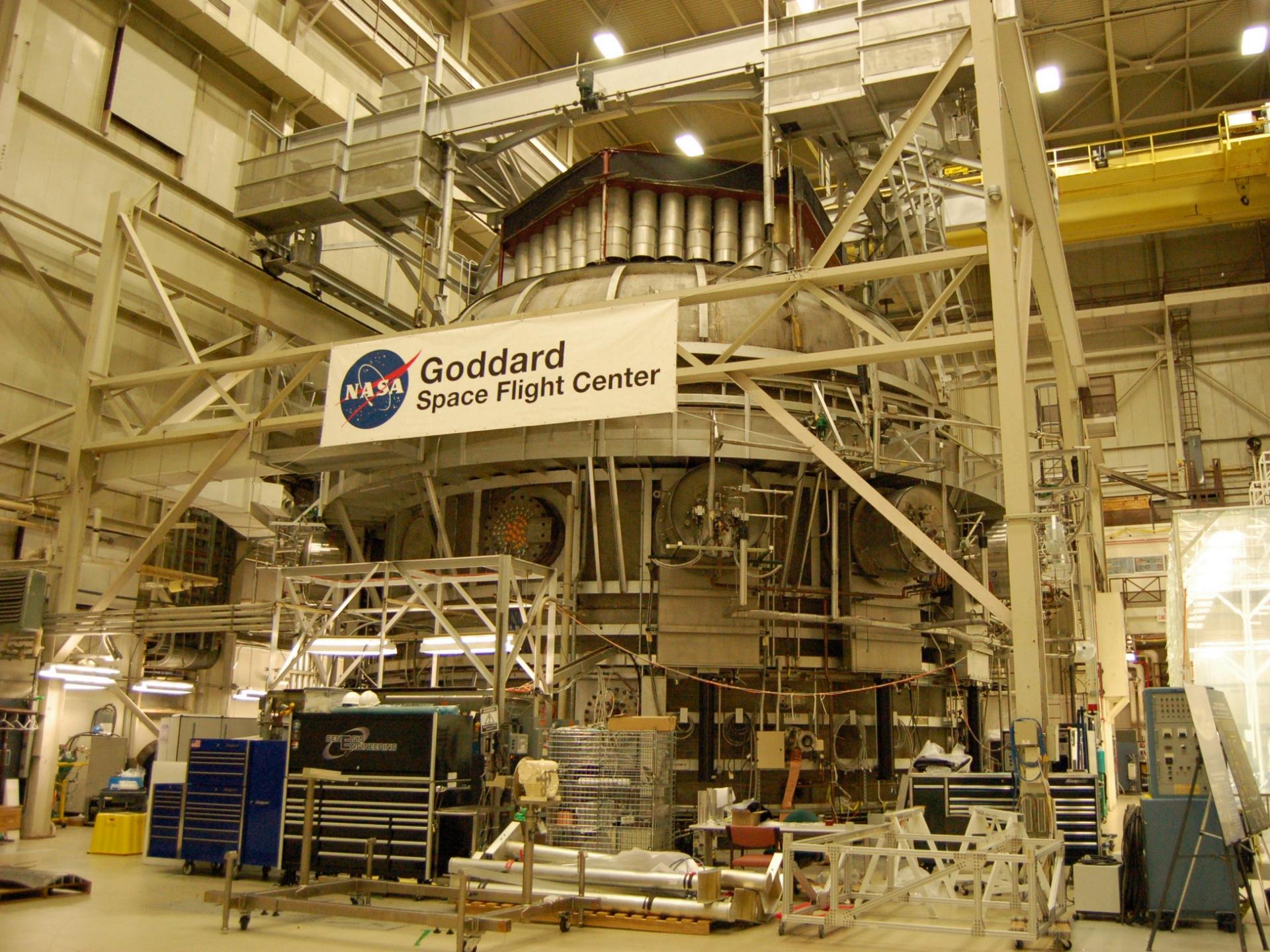
DO NOT  
CLAMP



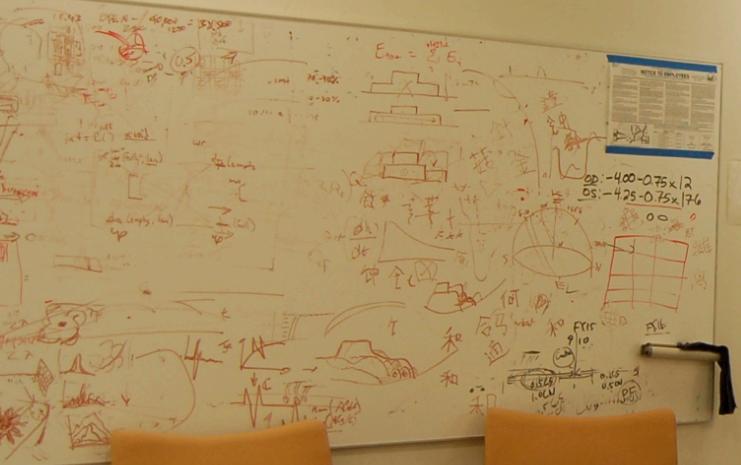
PLEASE  
Do Not Touch



Goddard  
Space Flight Center







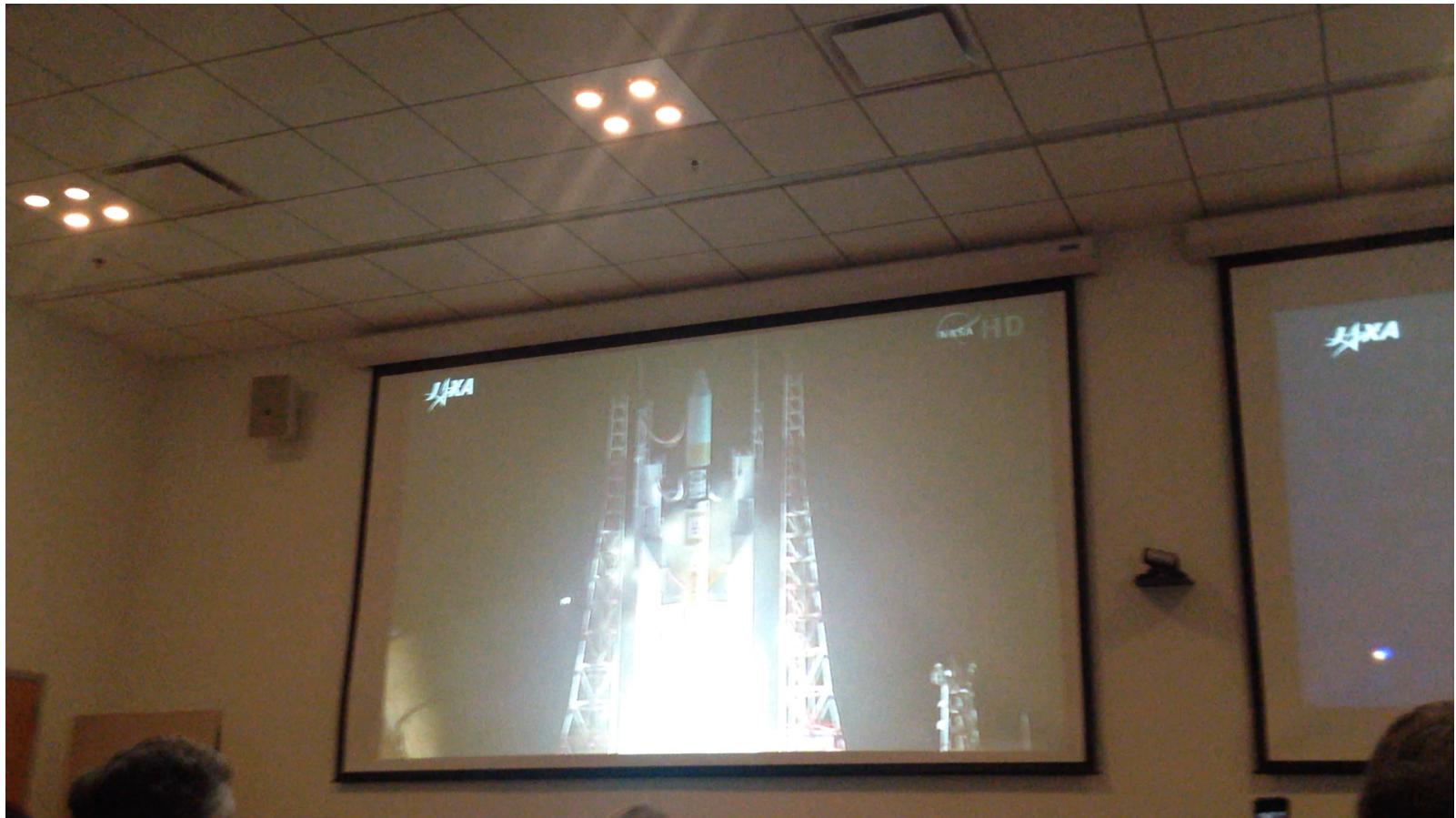
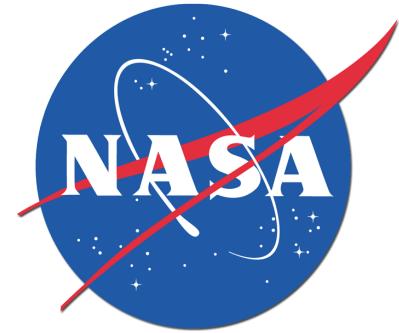
Fire alarm  
Please do not smoke  
Please do not smoke  
Please do not smoke







# GPM Launch





衛星フェアリング分離  
Payload fairing jettison

U.S.-39-NOAA-U.S. Navy/NASA-GEMINI  
Space Launch

CGイメージ  
Google ea



NASA's Earth Observing  
Fleet 2013





12:08



6-1  
6-1

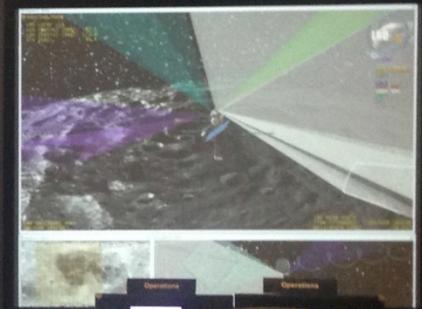
OUT

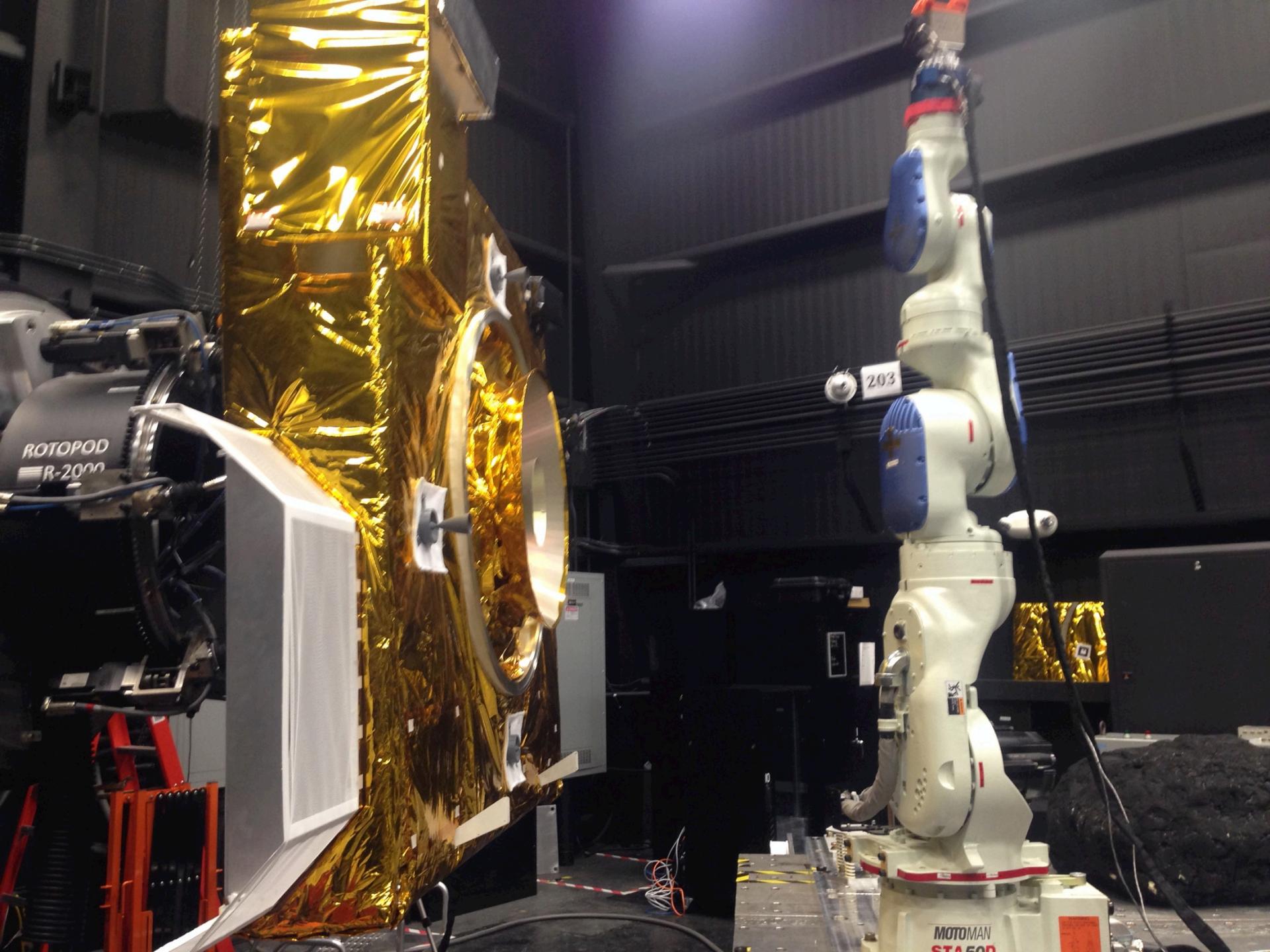




2014 SEP 18 09:30  
LAT: 105 17.7000  
LONG: 105 16.1200  
TIME: 10:10  
ODOMETER: 00000000

Flight Controller	Flight Control	Flight Control	Flight Control
Flight Controller	Flight Control	Flight Control	Flight Control
Flight Controller	Flight Control	Flight Control	Flight Control
Flight Controller	Flight Control	Flight Control	Flight Control
Flight Controller	Flight Control	Flight Control	Flight Control

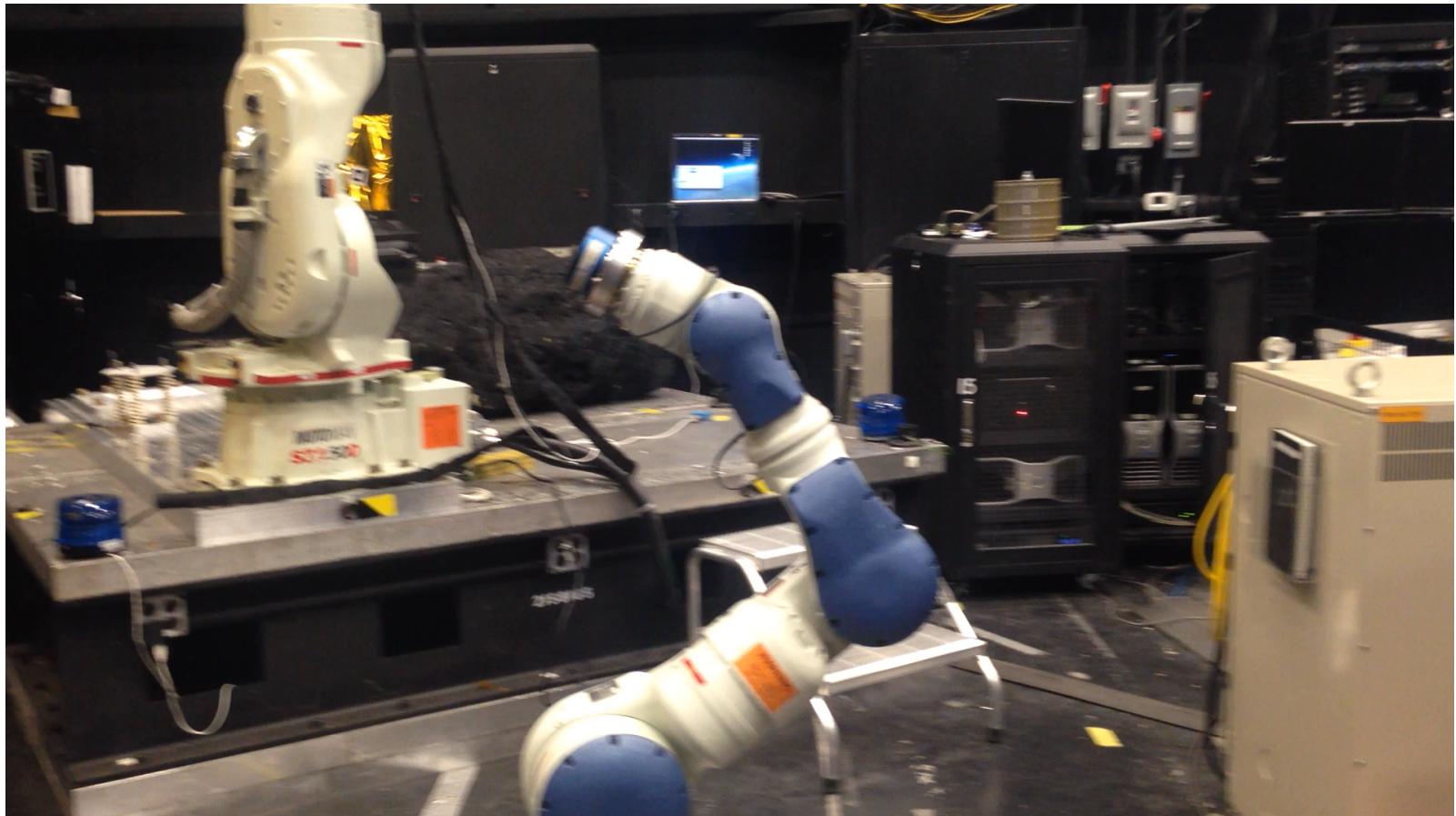
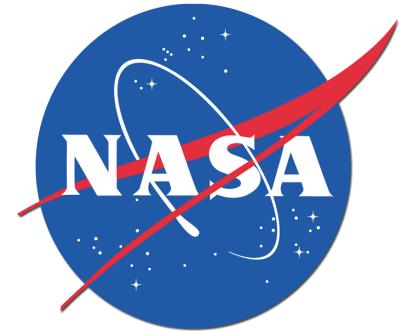


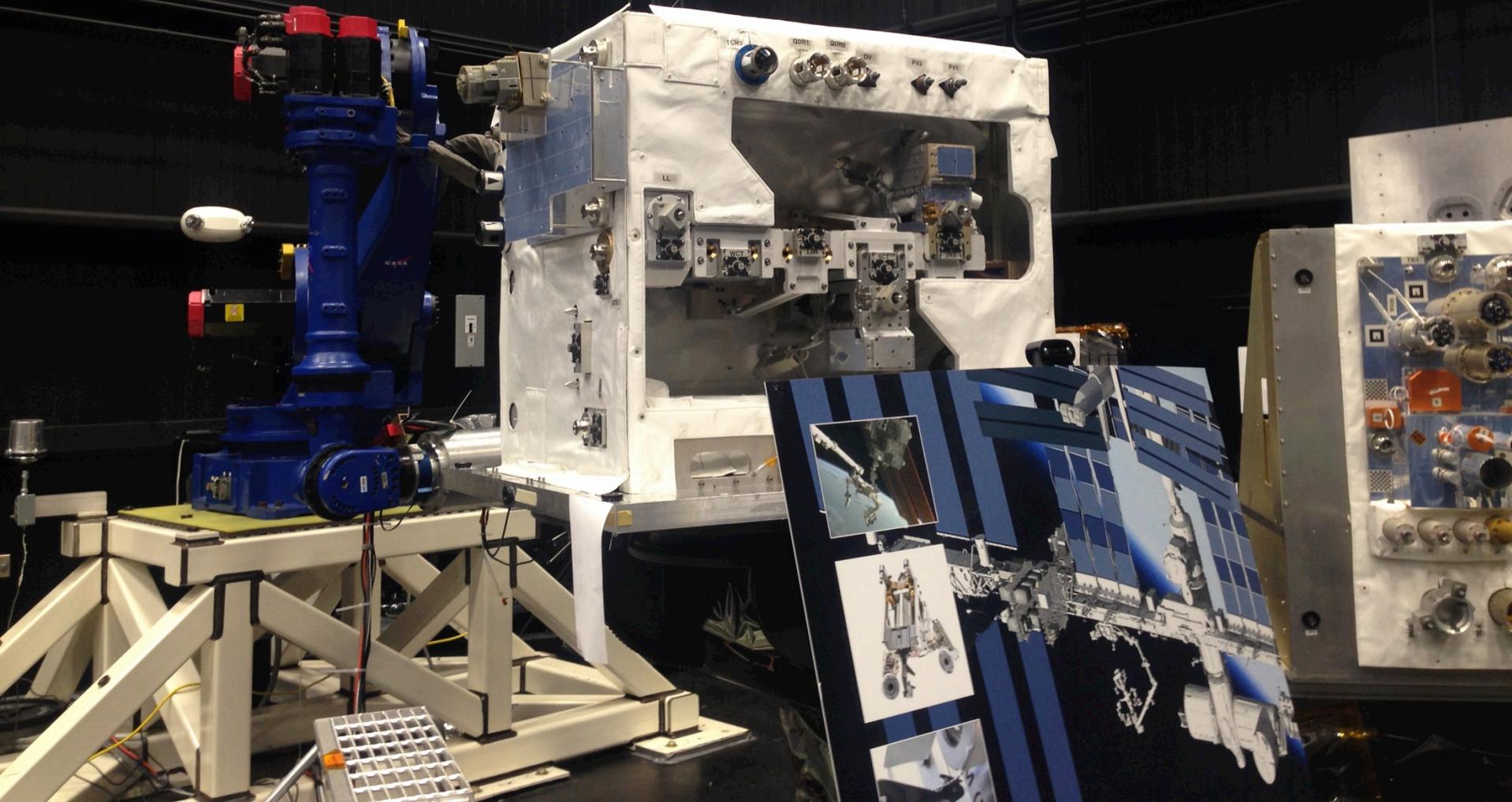


203

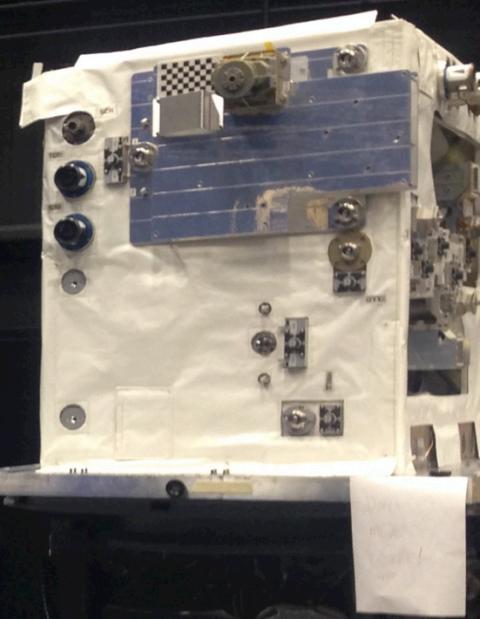
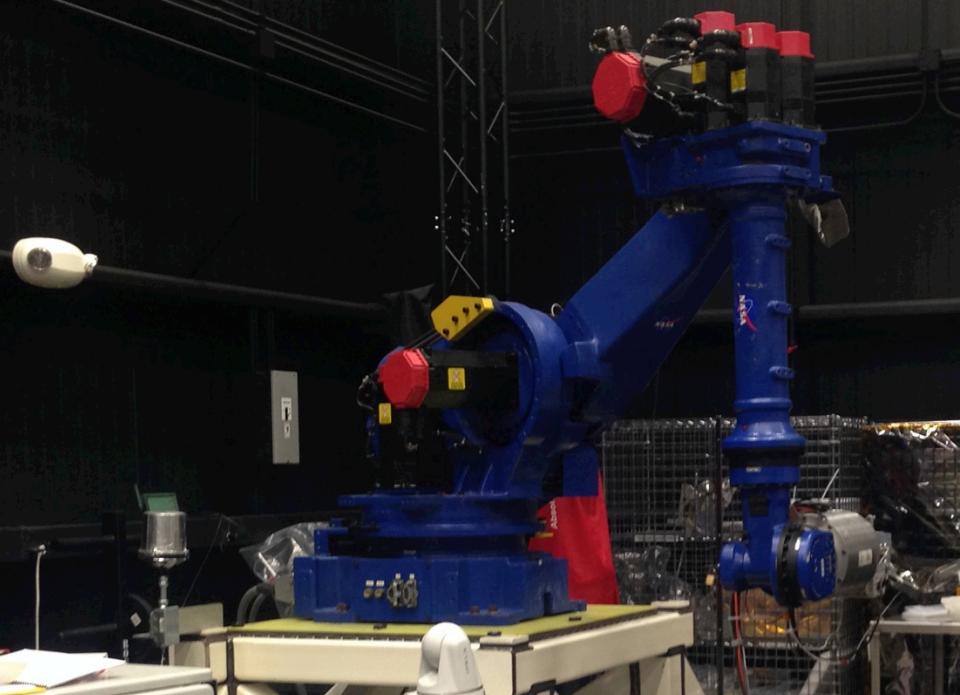
MOTOMAN  
STA 50D

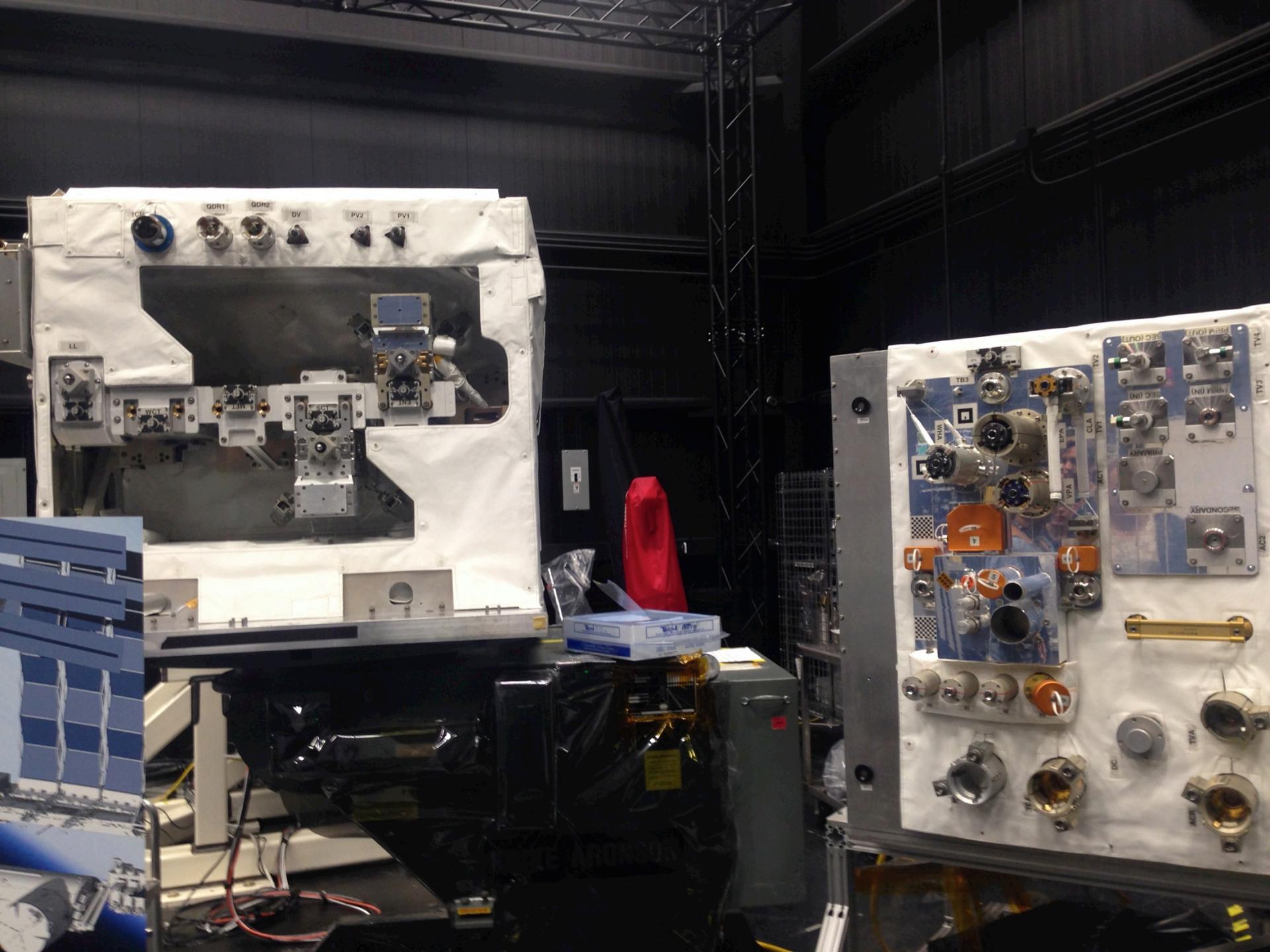
# Robotic Refueling Mission

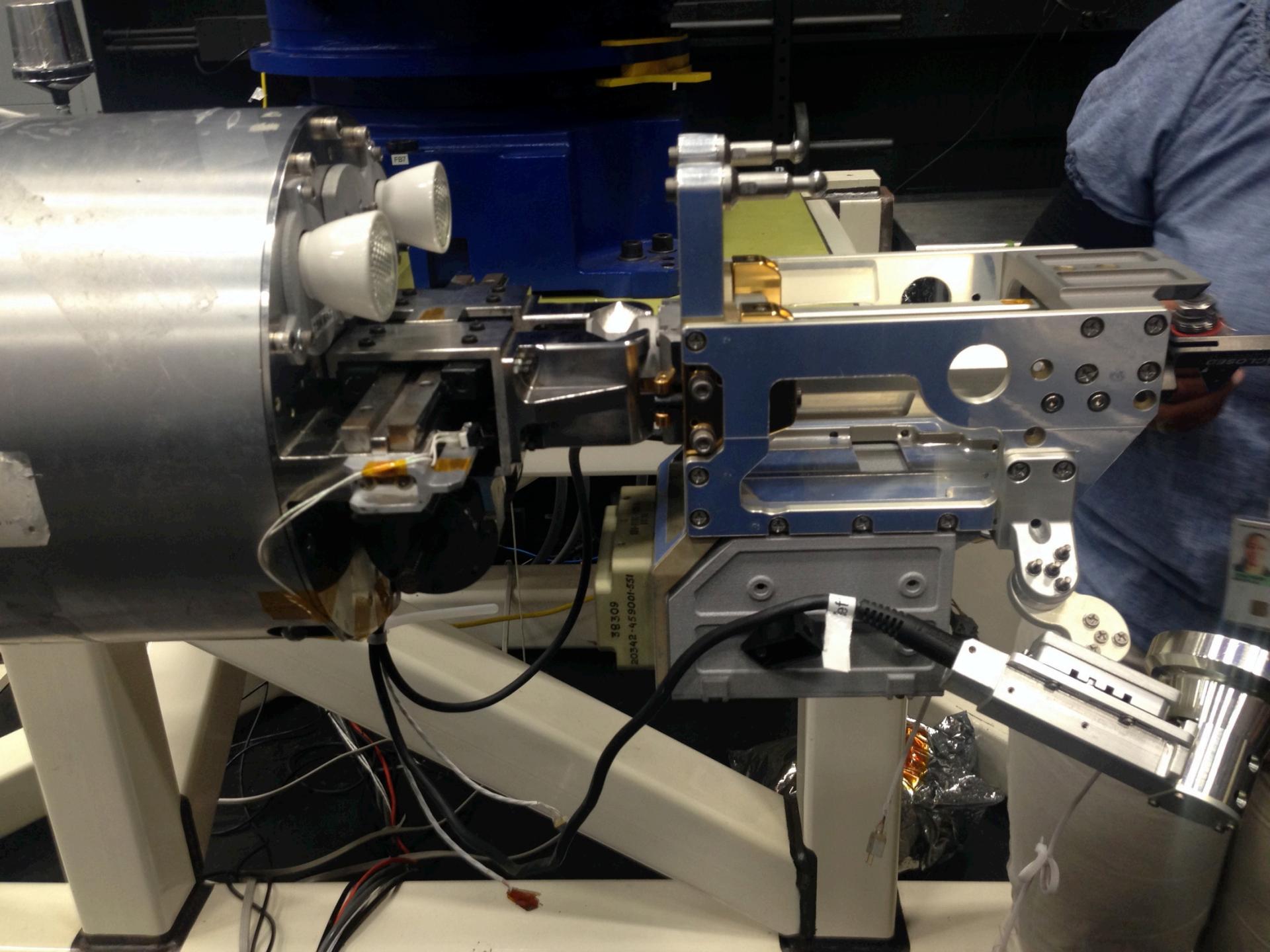




**NASA GSFC**  
NASA GODDARD SPACE FLIGHT CENTER

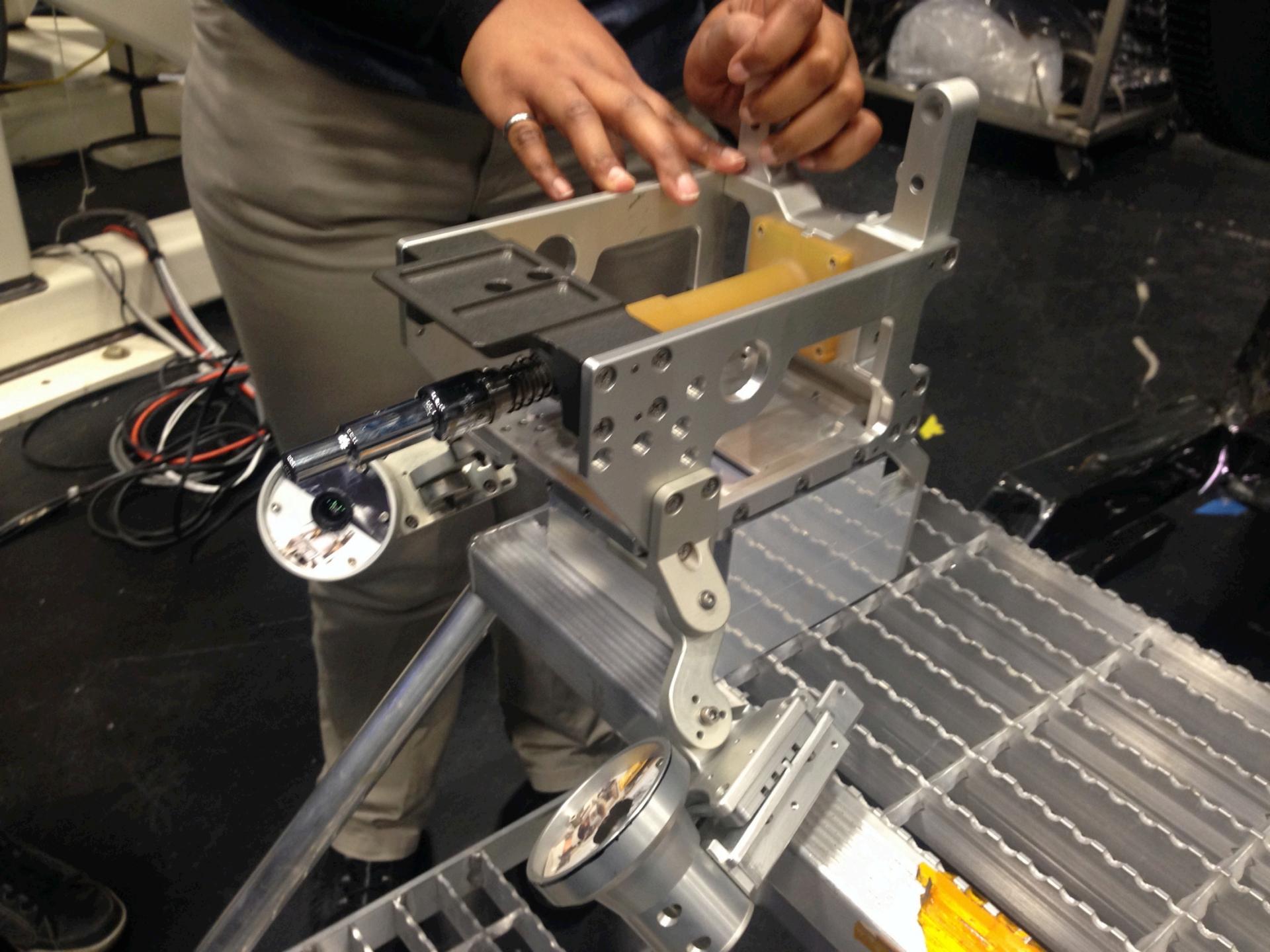


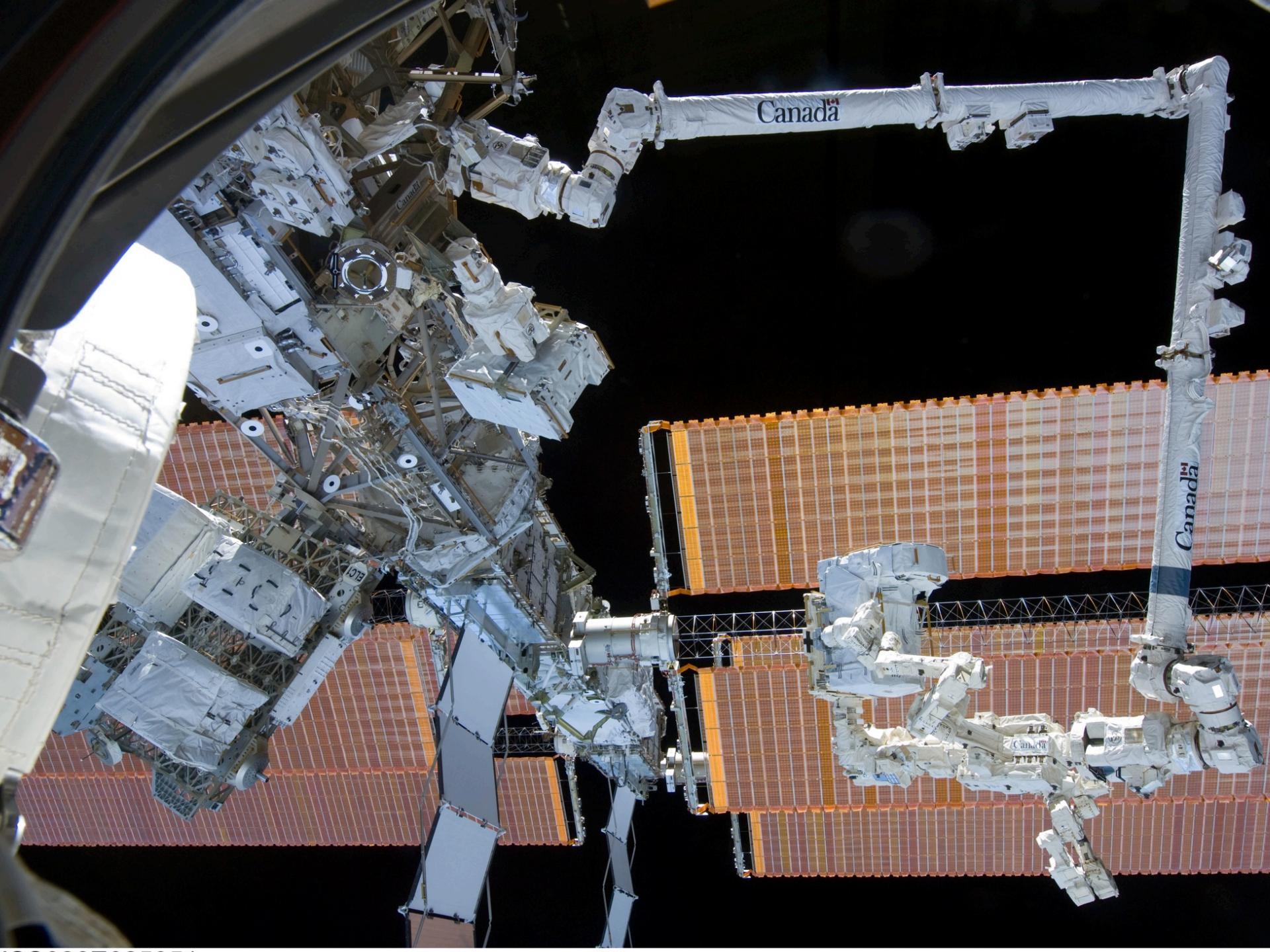














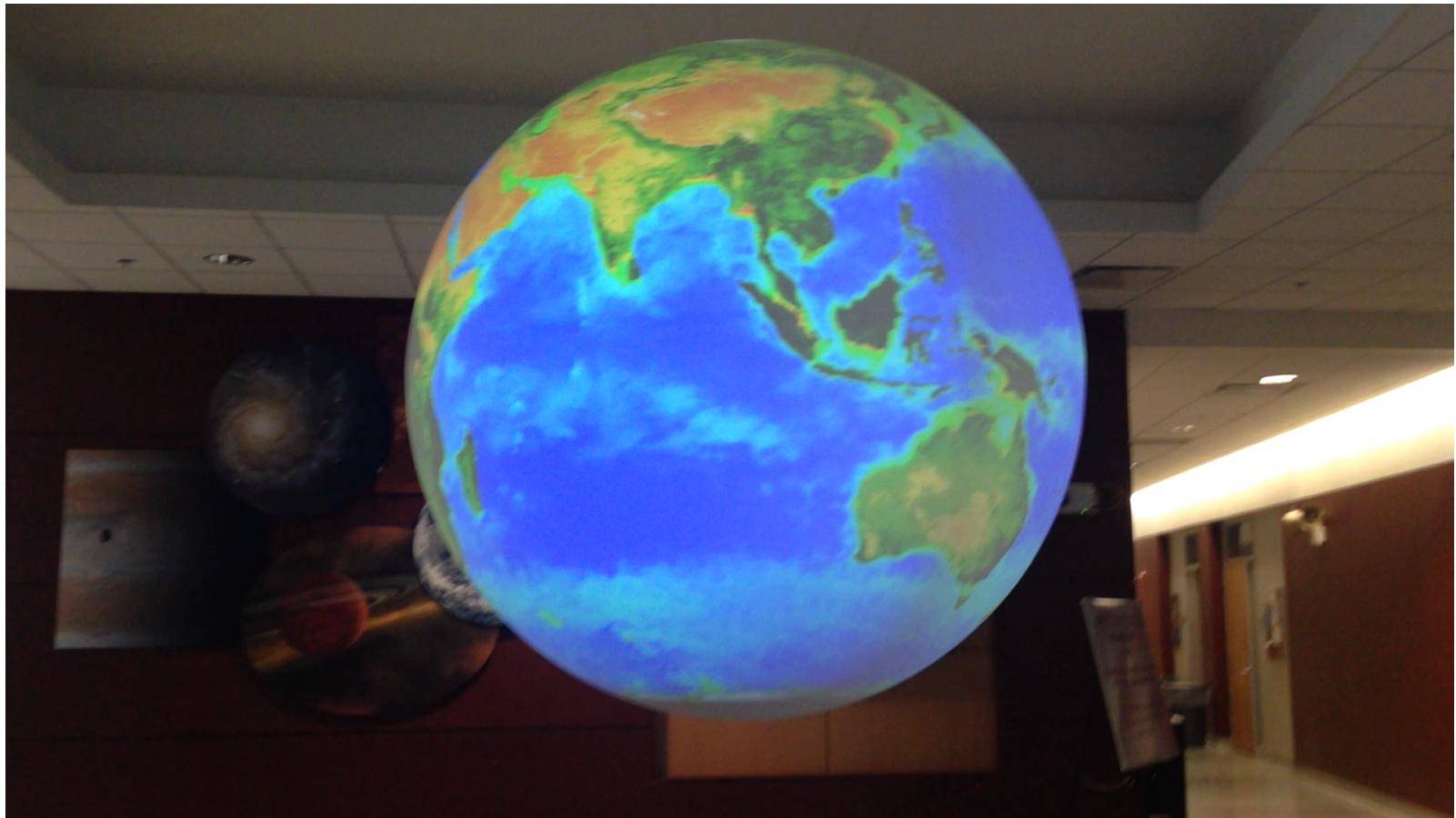
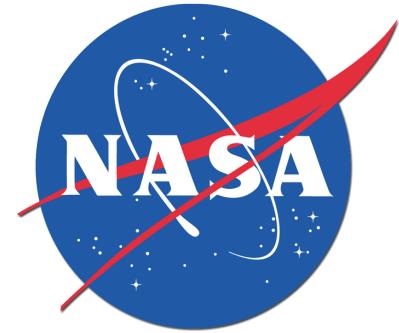
RED  
WORKCELL







# NOAA Globe

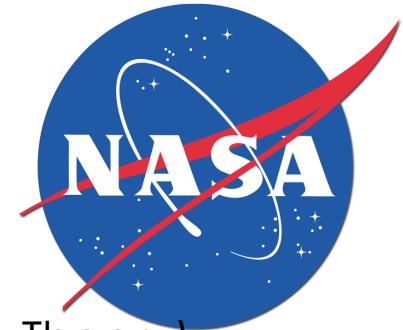


# Famous People at NASA

2006 Nobel Prize Winner John Mather

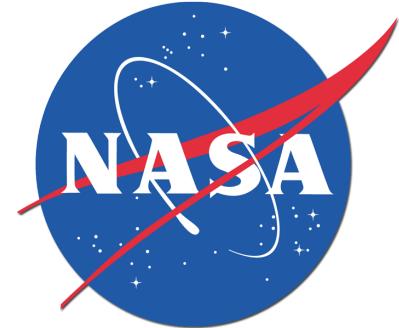


Brian Greene (String Theory)



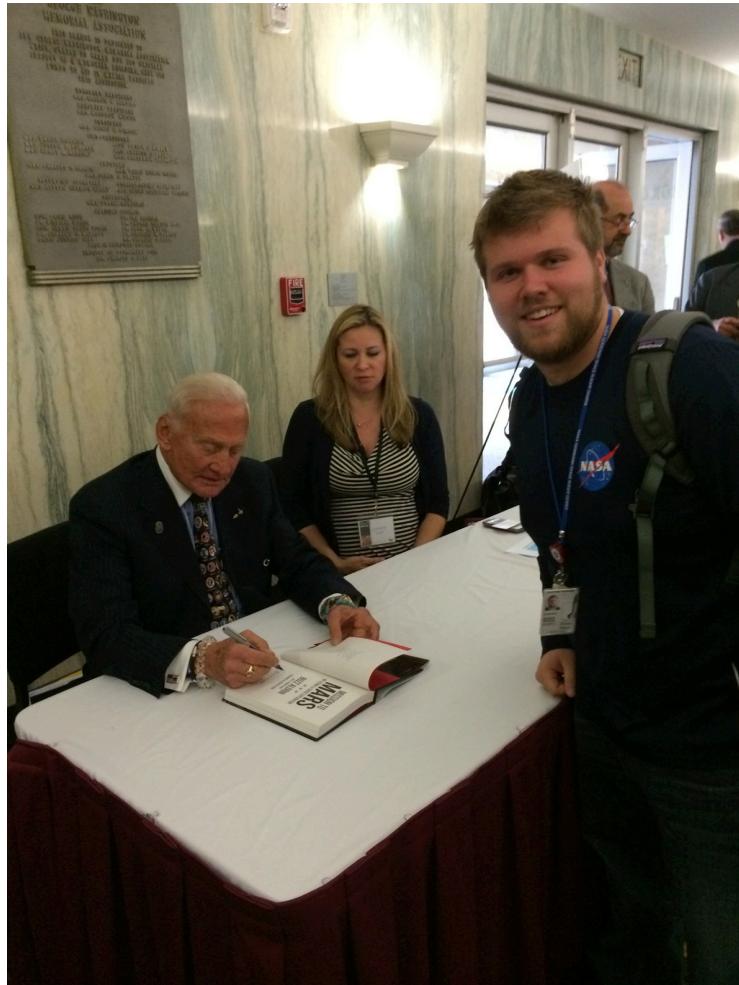
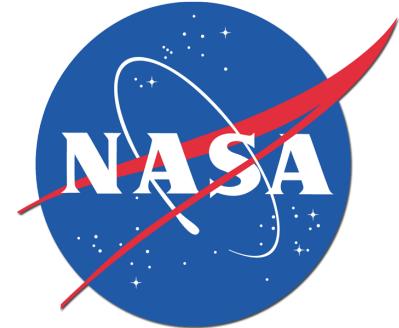
# Famous People at NASA

Michelle Thaller



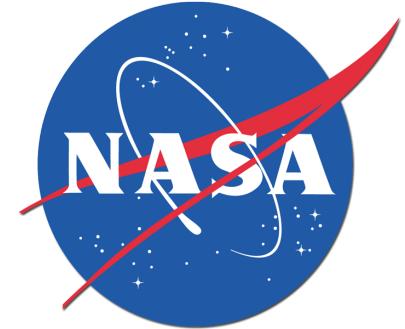
# Famous People at NASA

Buzz Aldrin





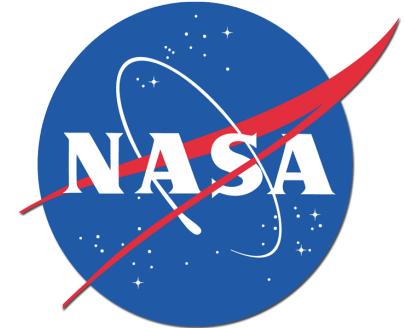
# BETTII Article



- <http://www.nasa.gov/content/goddard/new-players-for-the-bettii-puzzle/>

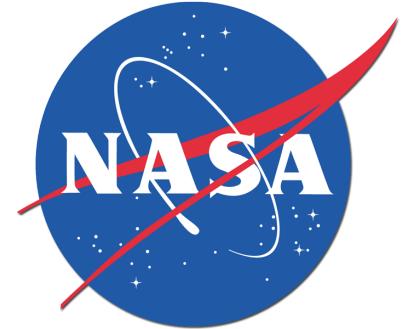


# Brewing Beer in Space



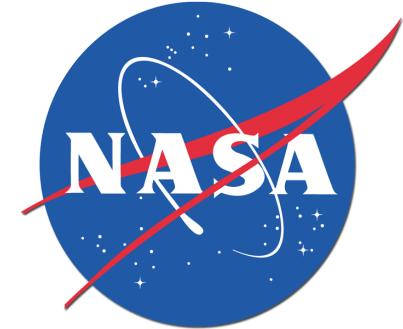
- GVSU Brewing Club
  - Myself
  - Jesse Millwood
  - Dr. Richard Lord
- NASA Zymernauts Club
  - Scott Glubke
  - Jim Busch (Victory Brewing – PA)
- ISS Experiments for cell growth, crystal growth, bacteria, mice, etc...  
Why not beer?
- Brewing is a real science!
  - Many different engineering disciplines involved
  - Need for self-contained, autonomous experiment

# Brewing Beer in Space



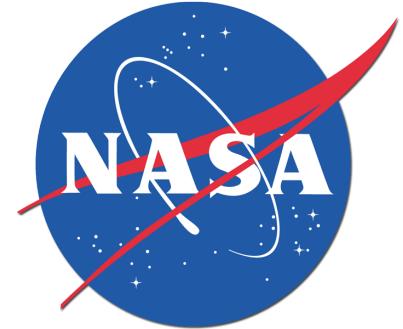
- Becks on Columbia (1993): Yeast performance
- Japanese flew malted barley
- Challenges:
  - Pressure
  - Gravity
  - Filtration
  - Osmotic pressure
  - Radiation
  - Equilibrium of gases through membrane (Carbonation)
- Learn about cell dynamics, fluid dynamics, fermentation science

# Applying at NASA



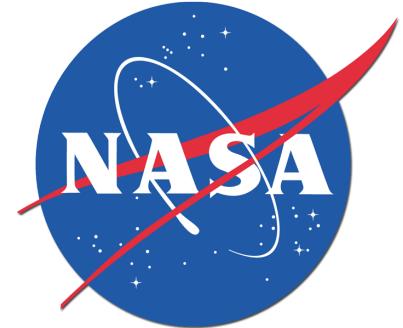
- Apply through NASA One Stop Shop Initiative (OSSI)
- <https://intern.nasa.gov/ossi/web/students/>
- Can apply for up to 15 positions at all NASA centers
  - Requires letters of recommendation
  - Location, dates, project description listed for each opportunity
  - One single 'resume' to apply for all positions
- Tips:
  - Apply for Fall and Winter semesters
  - Summer semesters are **very** competitive (500+ students)
  - Apply for all 15 positions
  - Express a deep interest in space technology in your statements ("Why do you want to work for NASA?")

# Working at NASA



- Very challenging projects
  - 'Selective mentorship' – very effective
  - Experimentation encouraged
- Extremely high-caliber co-workers
  - Nobel prize winners
  - Worlds leading astrophysicists, astronomers, engineers
  - Talk about reliable co-workers...
- Experience of a lifetime
- Interns get 'special access'

# More info on BETTII



- <https://www.facebook.com/bettiiballoon>
- <http://asd.gsfc.nasa.gov/bettii/>
- <https://twitter.com/NASAGoddard/status/466995684563251201/photo/1>
- [http://instagram.com/p/oBpnJTt\\_G6/](http://instagram.com/p/oBpnJTt_G6/)

# Questions?

