Lessons Learned in the Flight Qualification of the S-NPP and NOAA-20 Solar Array Mechanisms

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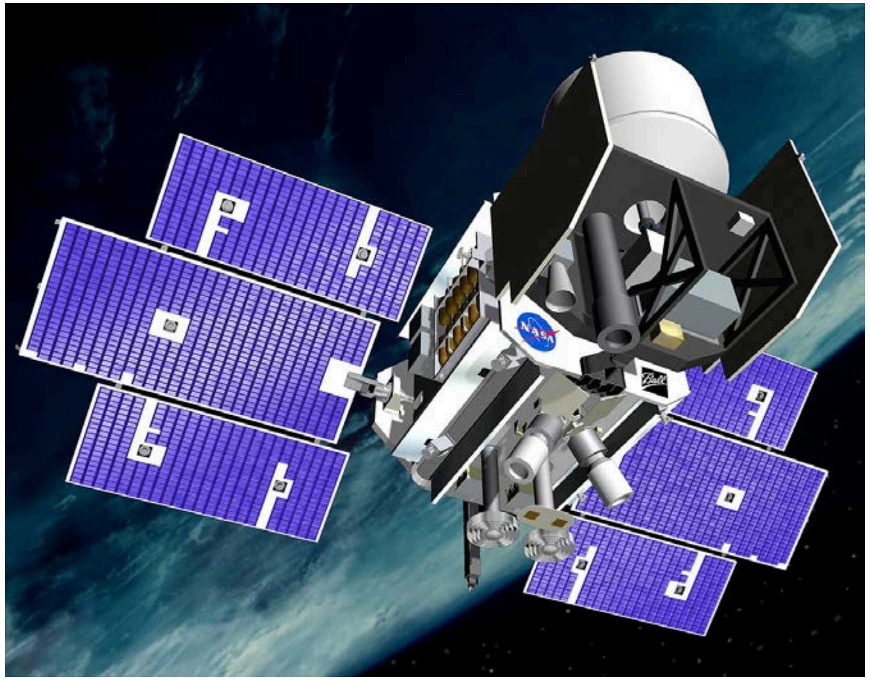
Evolution of Ball Aerospace Solar Array Design

QuikScat

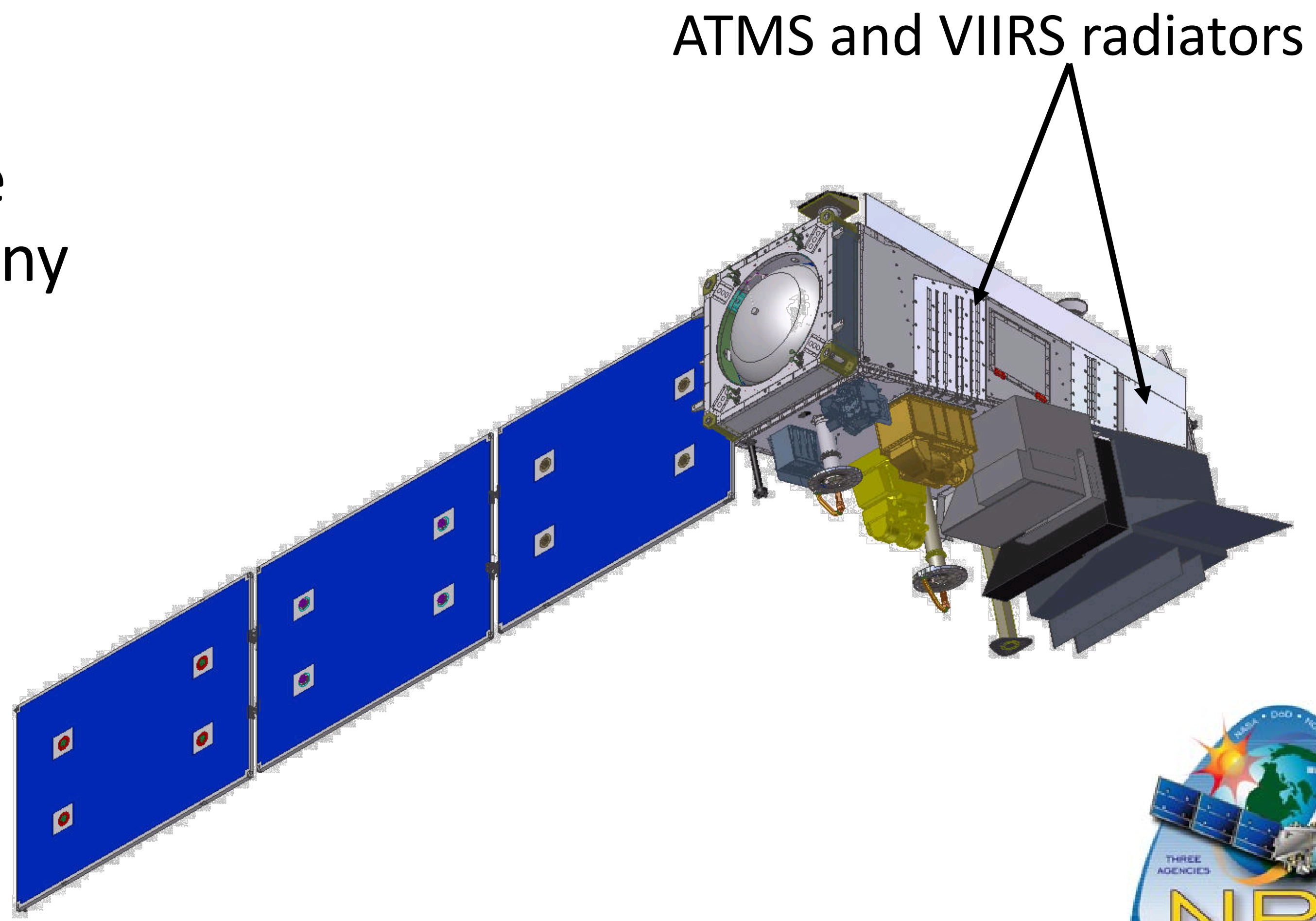


Icesat

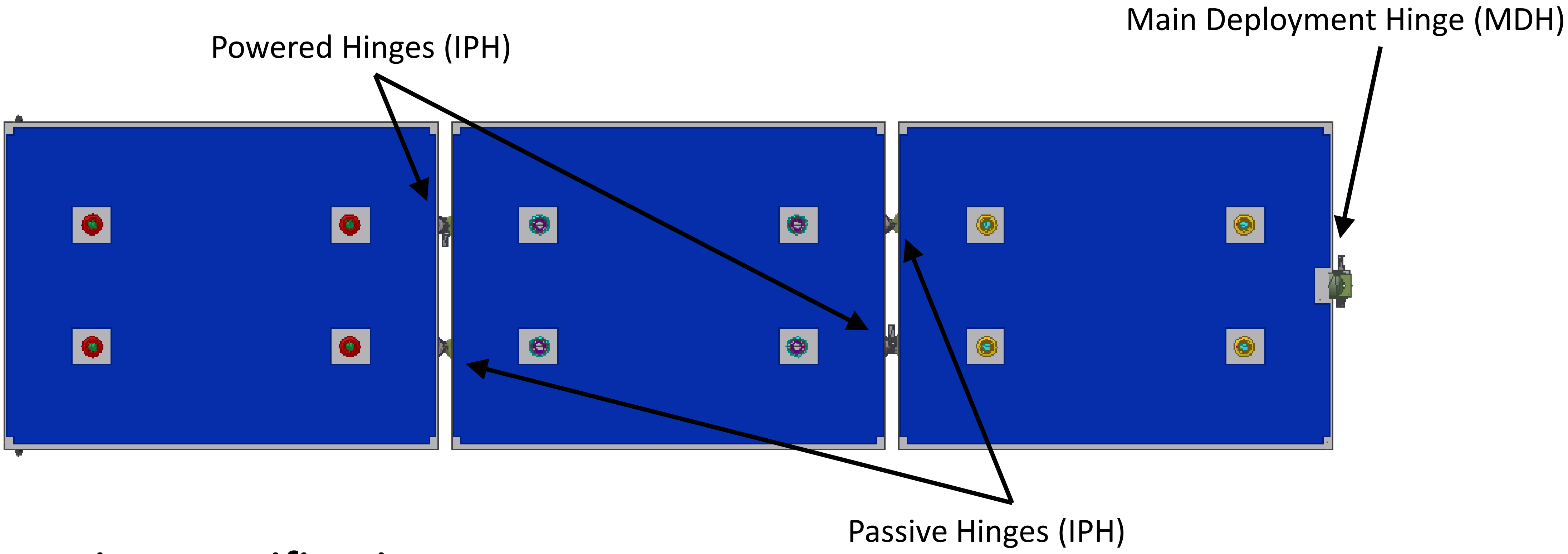
- Heritage Ball programs had utilized smaller wrap around style arrays
- QuikScat, QuickBird 1 and 2, Icesat and Cloudsat all used this architecture

NPP Instrument Requirements Drove Change

- VIIRS, CrIS, and ATMS had requirements for their instrument radiators to face cold space and be clear of any other hardware
- Prevented wrap around heritage solar array design
- Power budget required multipanel array



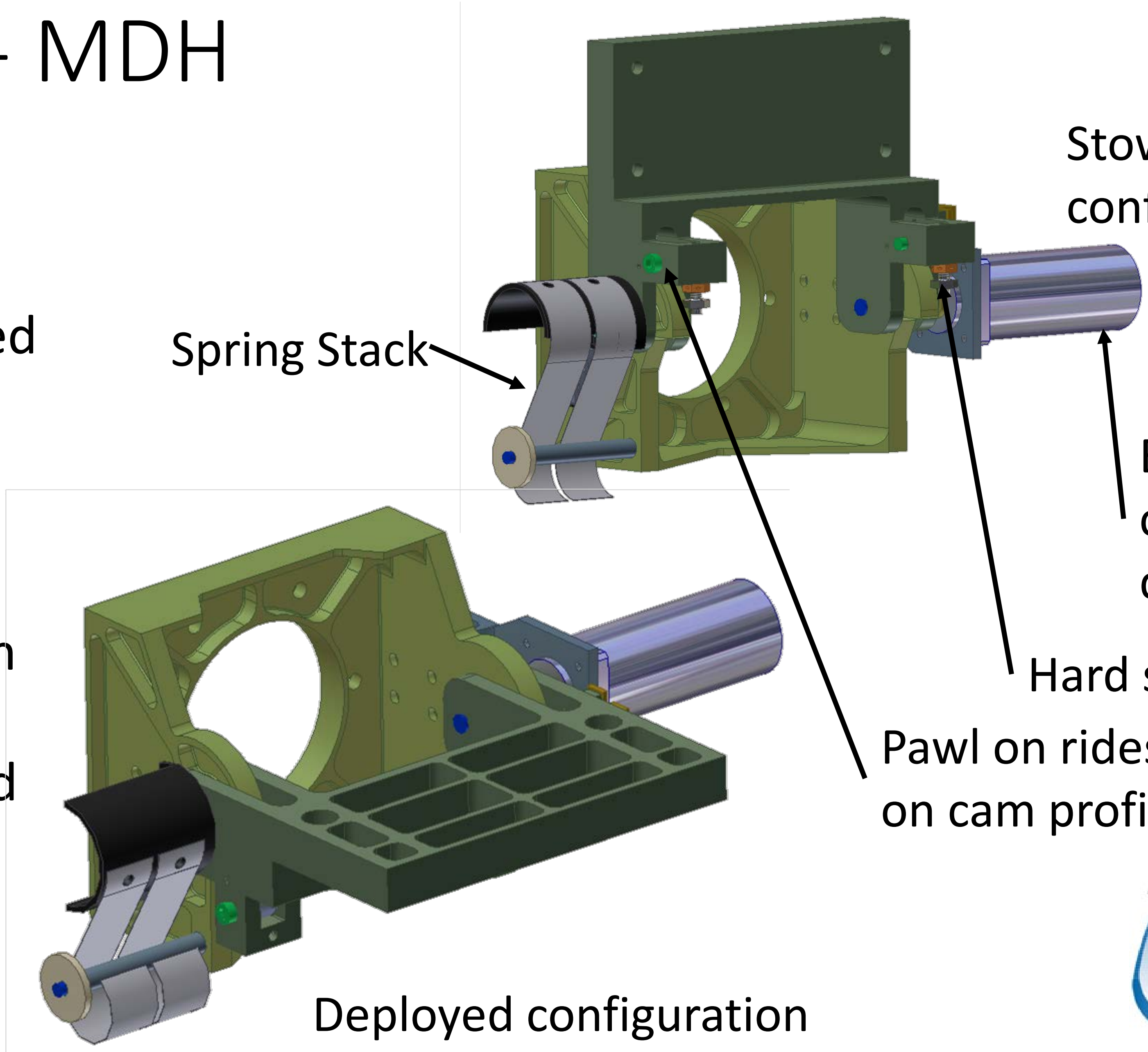
Solar Array Configuration S-NPP and JPSS-1



- Governing specifications
  - Moving Mechanism Assembly (MIL-B-83577)
  - Goddard Environmental Verification Specification (GEVS)

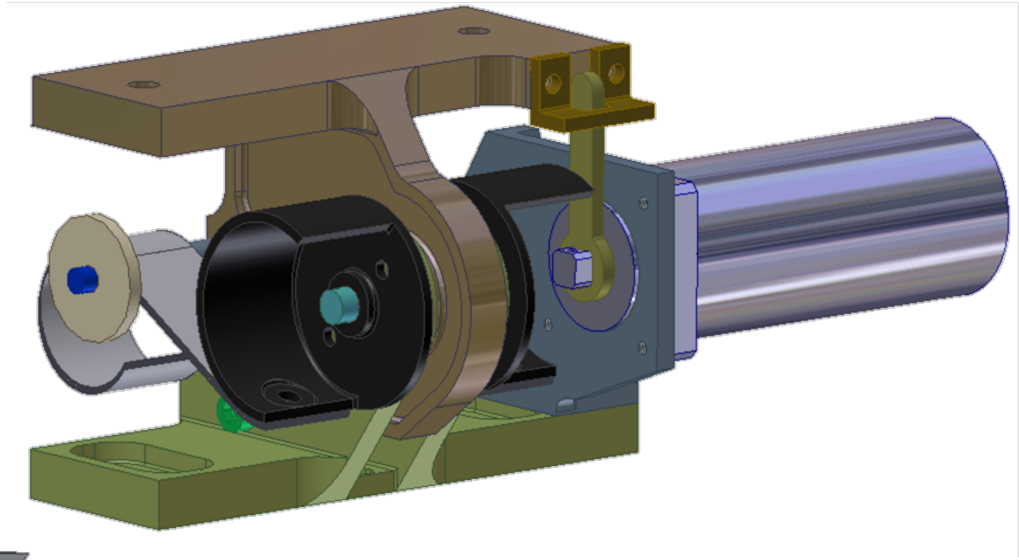
Hinge Design - MDH

- Driven by constant torque Negator springs
- Deployment rate controlled through an eddy current damper
- Titanium structural components
- Deployed position set with adjustable hard stop
- Pawl eliminates dead band

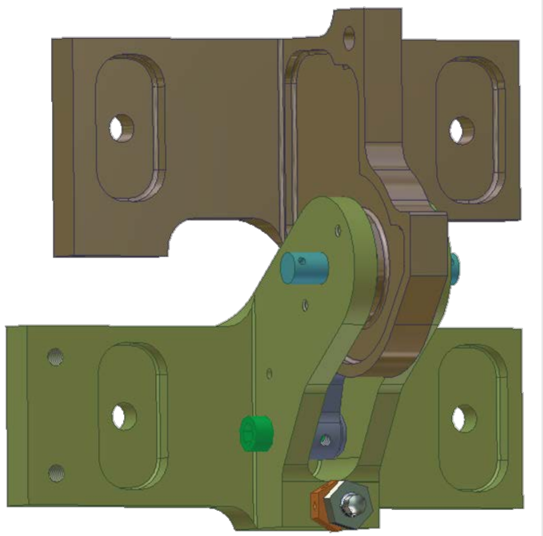


Hinge Design – IPH

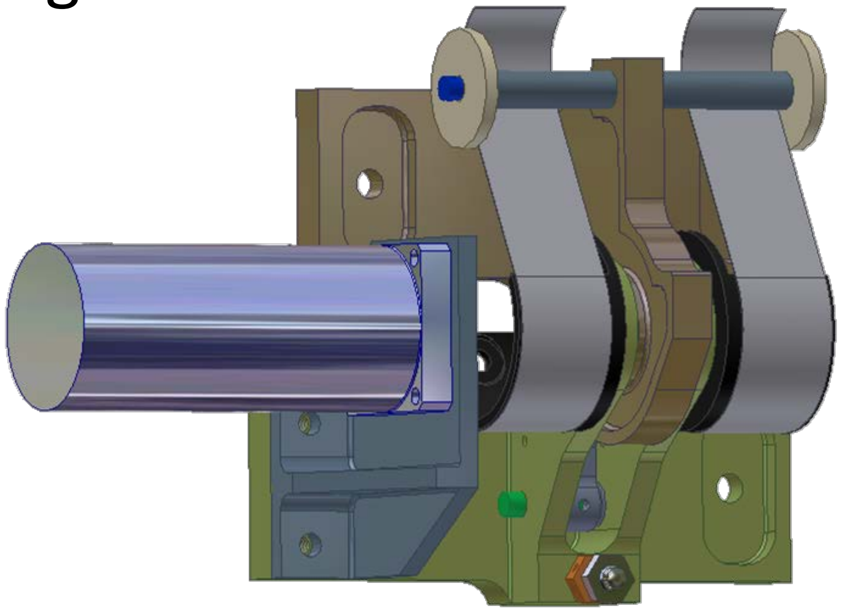
- Inter panel hinge lines consist of a passive and powered hinge
- Components are consistent between the IPH and MDH designs



IPH Powered - Deployed



IPH Passive - Stowed



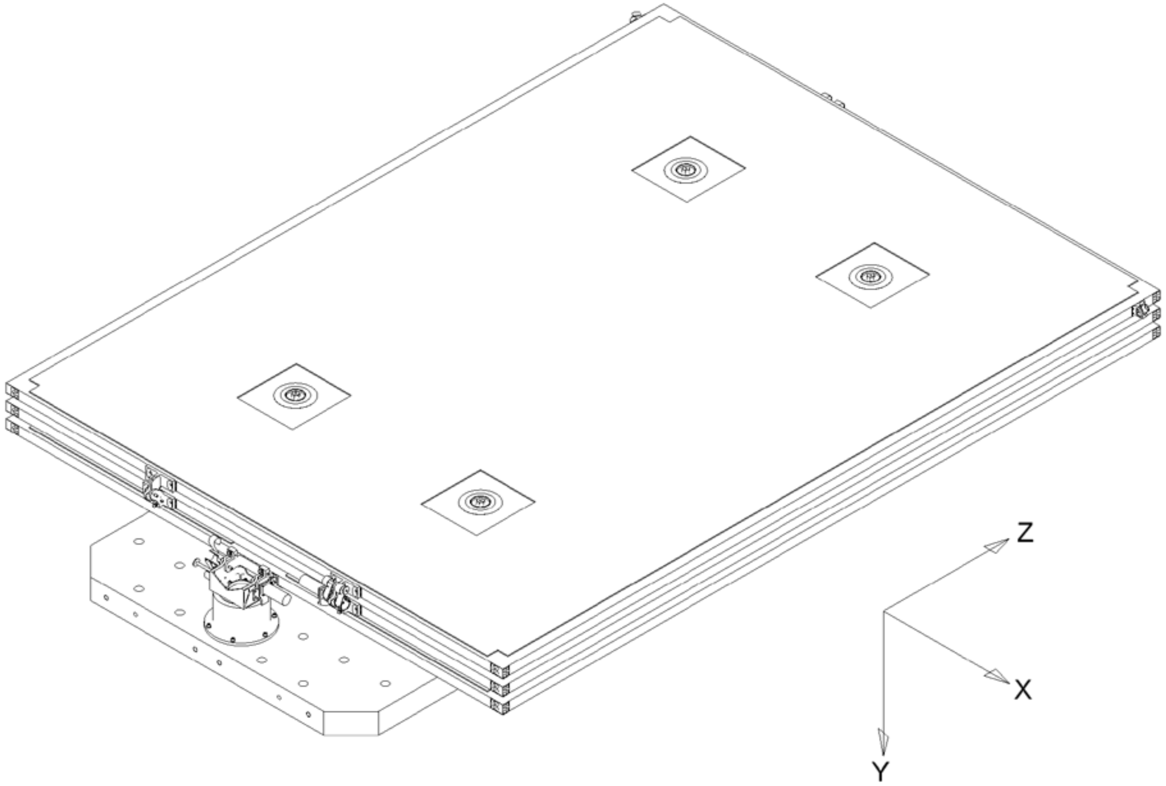
IPH Powered - Stowed

Hinge Level Testing

- Static loads and thermal cycling completed to characterize stiffness and performance of hinge.
- Torque outputs characterized with a torque wrench – limited characterization

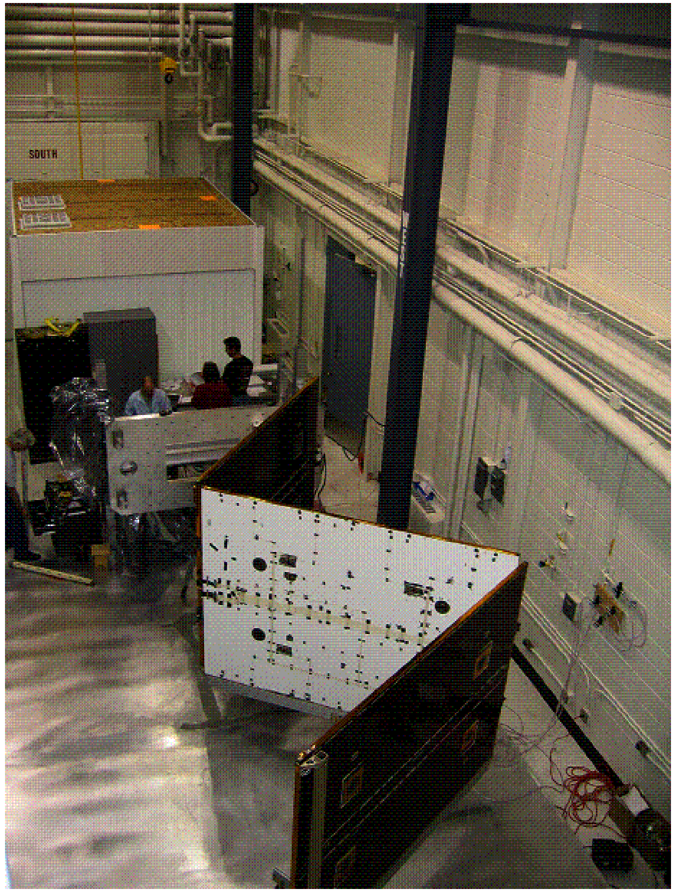
Solar Array Subsystem Environmental Testing

- Vibration and Thermal testing was performed in configuration shown
- Vibration fixture flexibility issues prevented testing at full level
  - Qualification had to be deferred to the bus level vibration test
- Thermal testing did not encounter any issues
- 4 cycles to meet GEVS requirements



Solar Array Subsystem Deployment Testing

- MGSE consisted of 5 inch thick connected aluminum honeycomb panels to create deployment surface
- Gravity offloaded by using air bearings
- First deployments were held up at panel edges
- Surface covered with sheet of polymeric roofing material



First test set up configuration

Final test set up configuration

System Level Test Deployment Testing

- “Pop and Catch” testing was performed at Observatory Level testing
- Smaller deployment table utilizing same air bearing offloader system

Evolution of Margin Requirements

Initial set of factors

Program Phase	Known Torque Factor of Safety (FS_K)	Variable Torque Factor of Safety (FS_V)
Preliminary Design Review	2.00	4.0
Critical Design Review	1.5	3.0
Acceptance/Qualification Test	1.25	3.0

Final set of factors

Program Phase	Known Torque Factor of Safety (FS_K)	Variable Torque Factor of Safety (FS_V)
Preliminary Design Review	2.00	4.0
Critical Design Review	1.5	3.0
Acceptance/Qualification Test	1.5	2.0

- Factors of safety changed during program

Torque Margin Trending - MDH

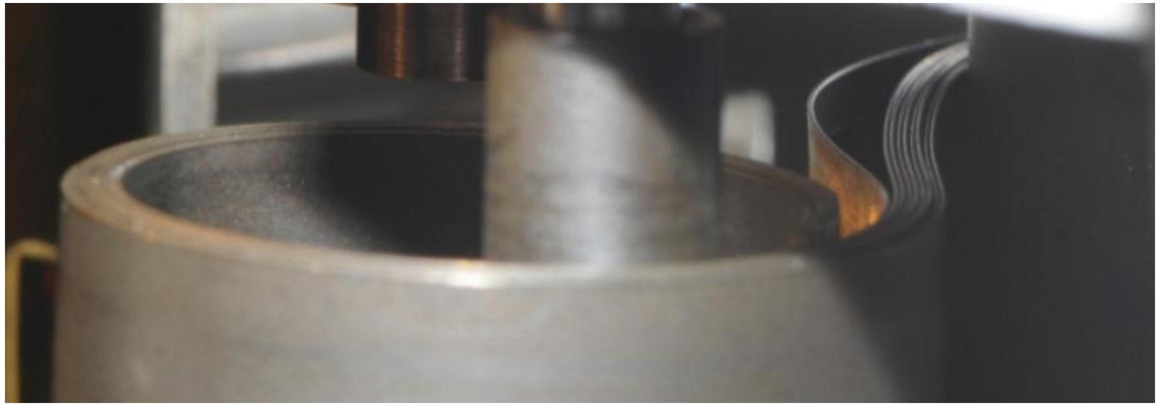
Hinge Type	Rev -	Rev A	Rev B	Rev C	Pre S/C Integration	Pre-Ship Torque Margin	Pre-Ship Torque Ratio
MDH	0.306	0.780	0.439	0.780	0.09	-0.22	1.48
MDH Torque – known (in-lbs)	12.33	11.37	11.37	11.37	7.87	7.85	
MDH Torque – variable (in-lbs)	7.62	13.1	13.1	13.1	16.60	33.1	
MDH Available torque (in-lbs)	54	77	77	77	49	60.5	
FS known	1.5	1.5	1.25	1.5	1.5	1.5	
FS unknown	3.0	3.0/2.0	3.0	2.0	2.0	2.0	

Evolution of Available/Resistive Torques

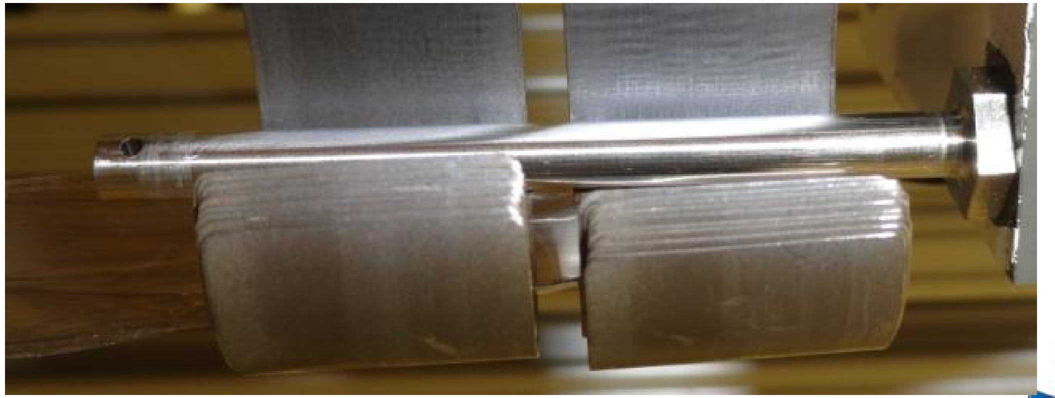
- Initial hinge characterization was done using torque watches and did not have refined torque versus angle characterization
- In-situ measurements of the hinge lines found that the torque versus angle generated a minimum available torque that was different than characterized during hinge level testing and led to a lower level of available torque
- NASA requested that a “Zero-Neutral” harness characterization test be performed
- This resulted in a summing of the resistive torque in both the deploying and stowing direction
- This lead to a significant increase in the variable torques the hinges had to overcome.

Post-Storage Hinge Inspection

- S-NPP required storage of the bus and solar array while awaiting final delivery of the observatory instruments
- Take up roller axle found to be missing dry lube
- Leaf springs were seen to be gapping
- 601EF was applied to both the axle and the spring to minimize resistive torque



Gapping leaf spring

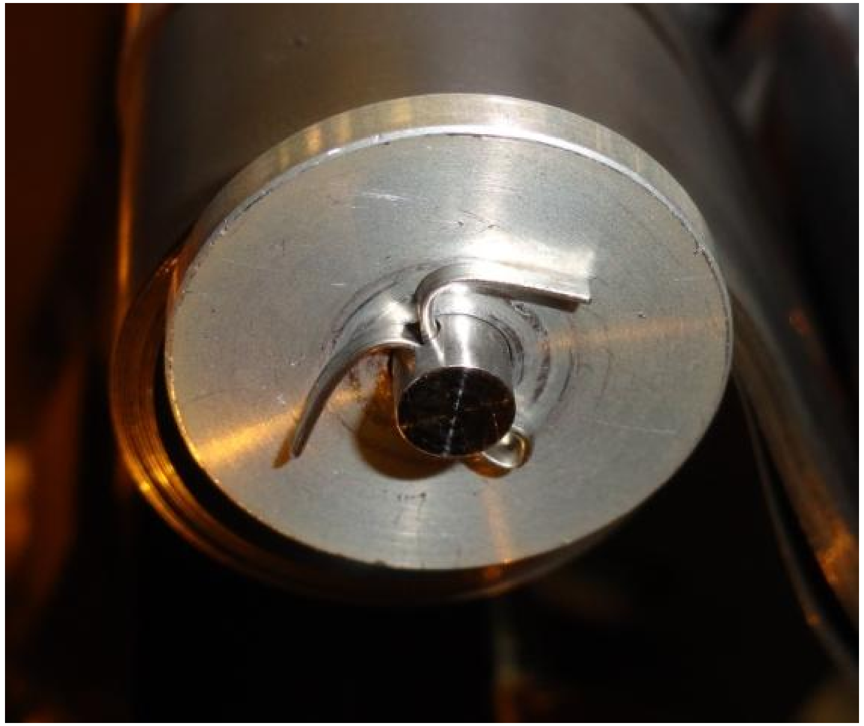


Missing Lubricant

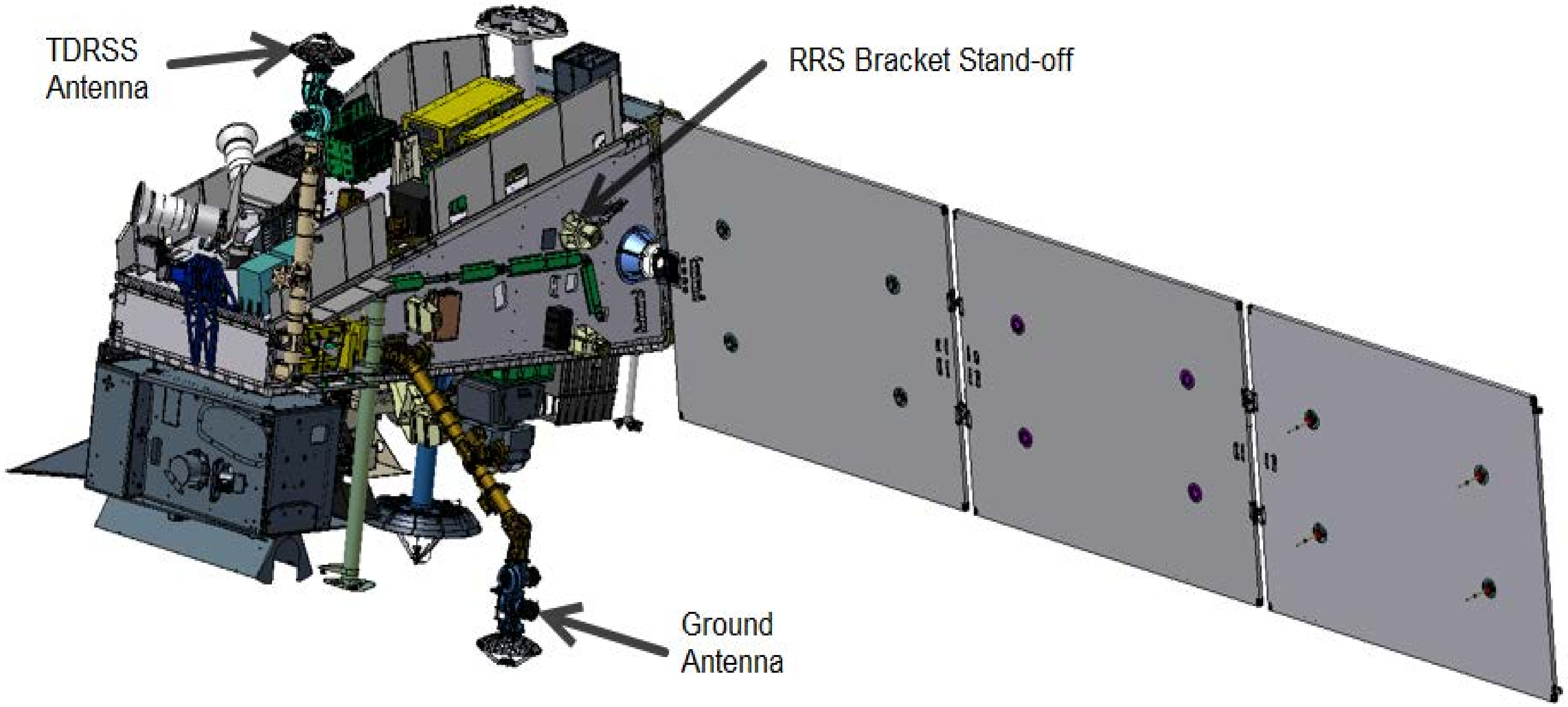
THREE AGENCIES ONE MISSION NPP NPOESS PREPARATORY PROJECT

Post-Storage Hinge Inspection

- Wear marks found between washer and cotter pin suggested unplanned source of drag torque
- Additional washer included to prevent unwanted drag



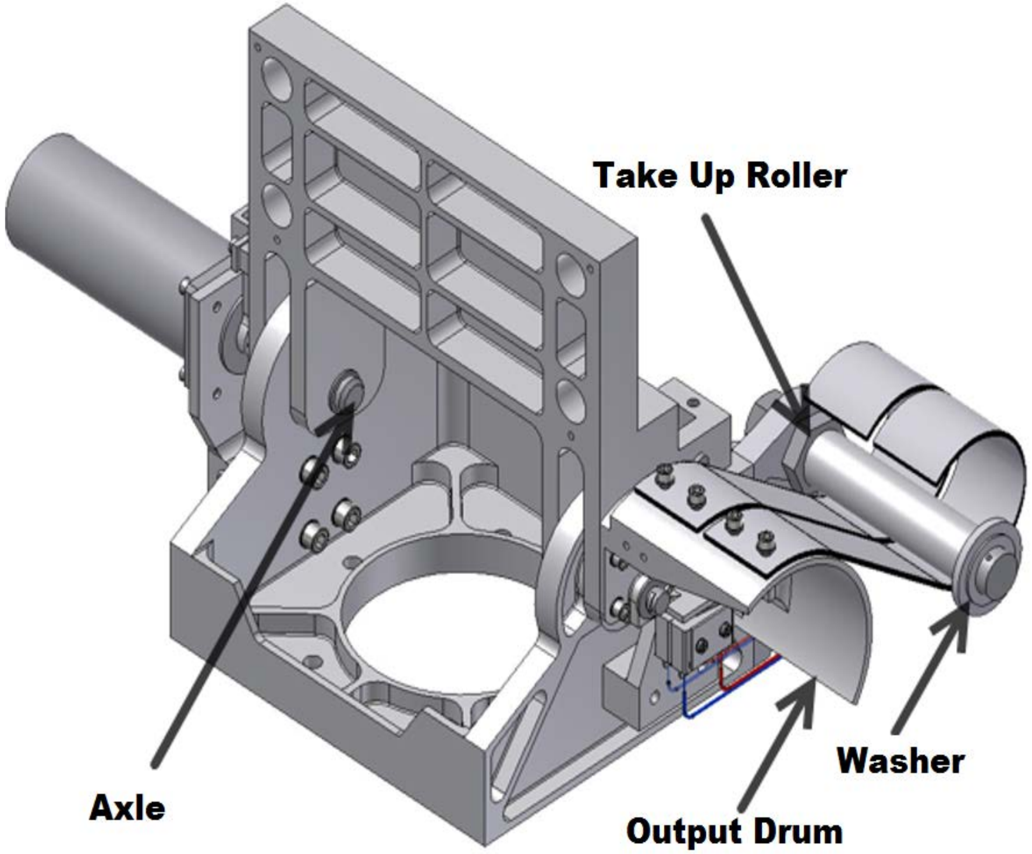
JPSS-1 Requirements Drive Change



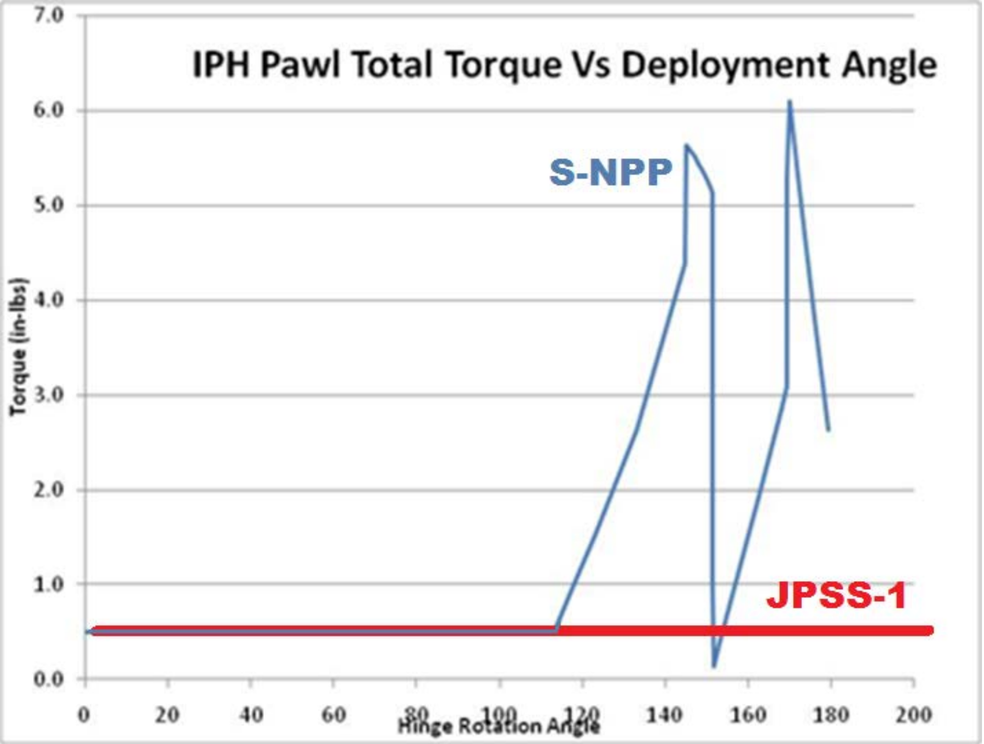
- Inclusion of TDRSS antennas drove change to interface between solar array and bus – pushing array away from bus
- New cell technology increases current being passed and increases wire count

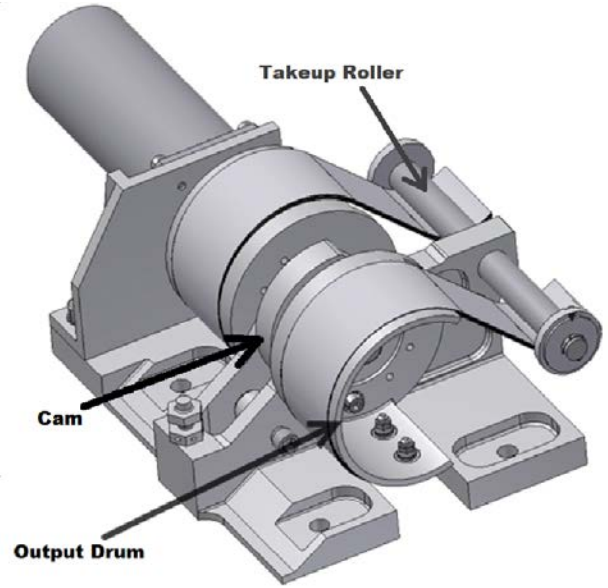
Incorporation of NPP Lessons Learned - MDH

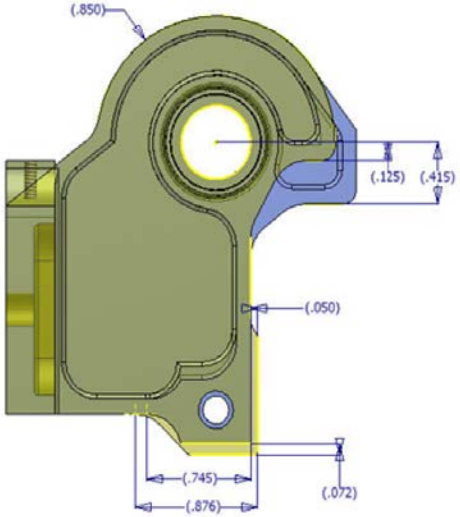
- Components redesigned to prevent repeat of spring issues found on NPP and reduce chance of harness damage
  - Take Up roller diameter increased
  - Modified design of take up drum
  - Redesign of Negator spring to limit number springs per stack
  - Removed cotter pins from interior portion of hinge



Incorporation of NPP Lessons Learned - IPH

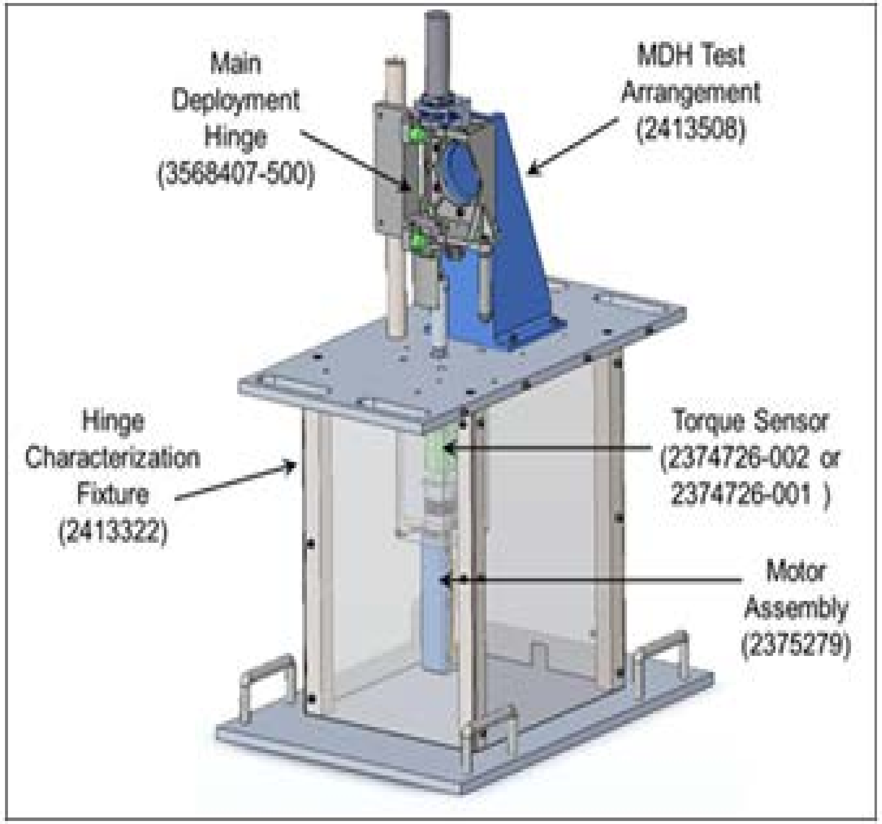


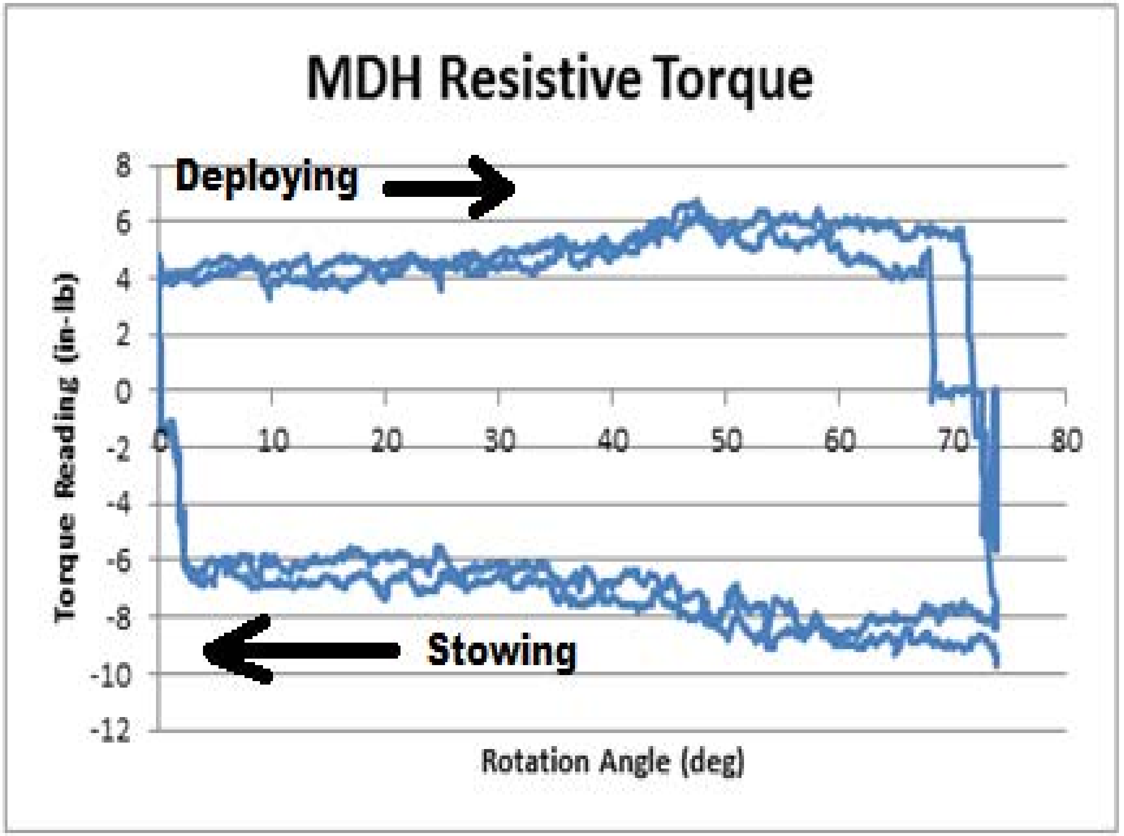




- Similar changes to IPH design as MDH
- Major change was in profile of cam
- Eliminated variation in drag torque over range of motion of hinge

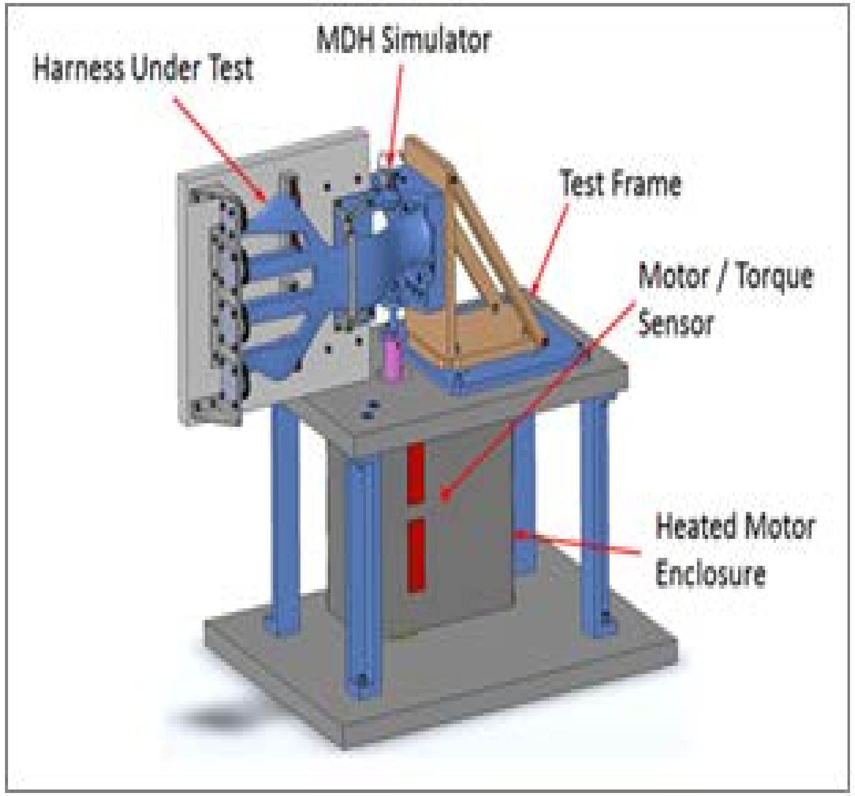
Drag Torque Characterization

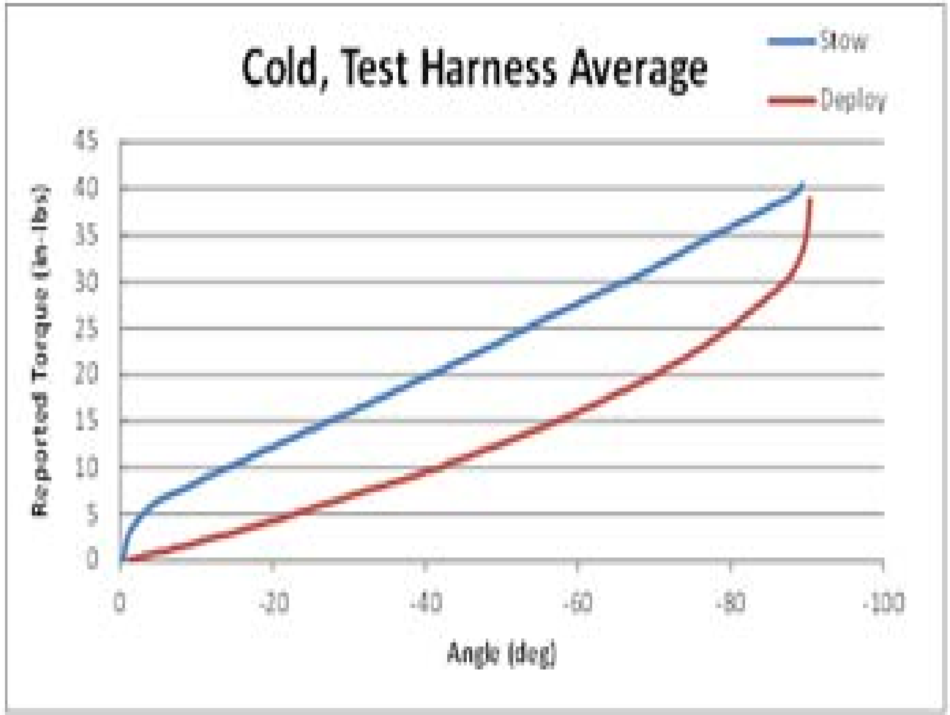




- Change in testing approach to allow torque versus angle characterization of each hinge over temperature

Harness Drag Torque characterization

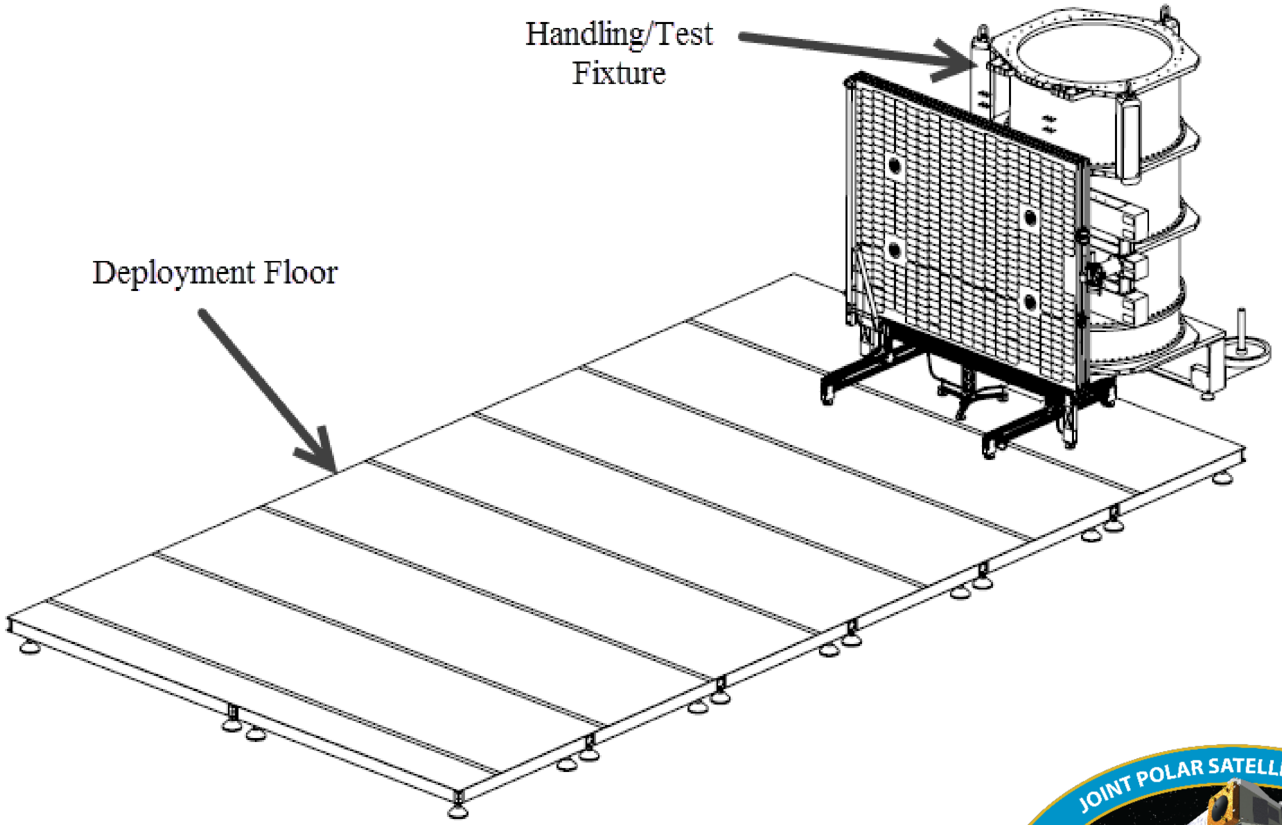




- More accurate characterization of harness resistive torque utilizing “Zero-Neutral” approach

Subsystem Level MGSE Changes

- S-NPP test fixture issues motivated changes to fixture that could easily transition from deployment testing, to thermal testing and vibe testing



Incorporation of GPM Lessons Learned

- Polyolefin membrane used on S-NPP would not lay flat during JPSS-1 installation
- Worked with Goddard to implement Mellinex/Poron Pad approach to covering deployment floor based on work done on the GPM (Global Precipitation Measurement) program

Vibration/Thermal Testing

- Redesign of the MGSE support structure allowed for easy transition from deployment testing to thermal and vibe testing

JPSS-1 Subsystem Level Deployment Testing

- Existing air bearing MGSE did not provide compliance relative to deployment floor other than Poron pad under Mellinex
- MGSE alignment did not prove as repeatable as planned when returning from environmental testing
- Transition from Observatory Pop and Catch to subsystem testing was challenging in reconfiguring MGSE
- Issues resulted in repeating deployment testing to demonstrate that mechanisms were not demonstrating degraded performance
  - No issues found with mechanism all issues related to test setup

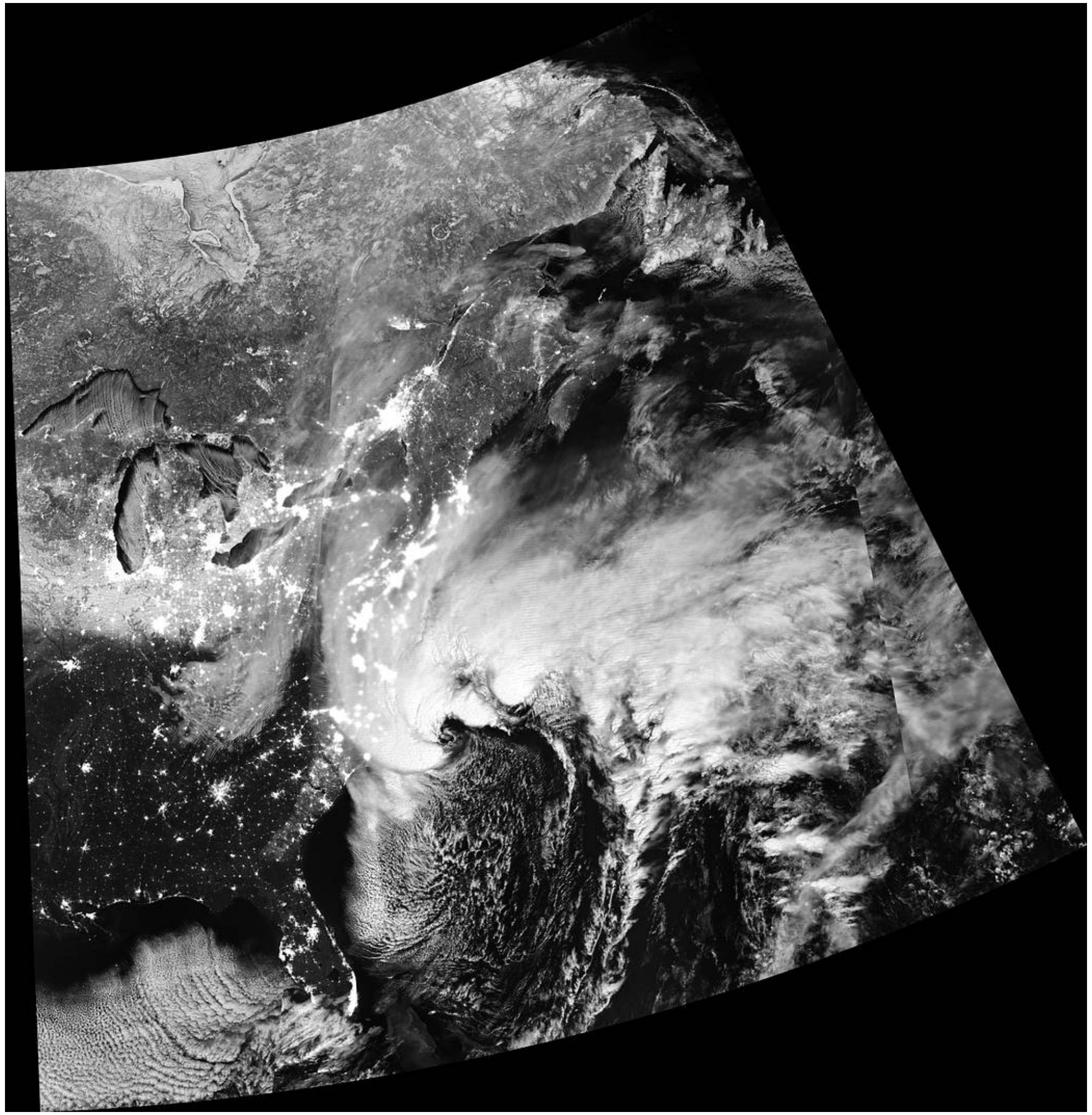
Lessons Learned – NPP

- Number of leaf springs used within each drive stack to limit inter-spring friction
- Inspection of parts and verification of part processing
- Cam profile of hinge surfaces to provide constant resistive torque
- Inadequate resistive torque characterization
- Inadequate output torque characterization
- Agreed upon requirements for resistive torque characterization
- Design of vibe fixtures to achieve required test spectrum
- Deployment fixturing design and verification

Lessons Learned – JPSS-1

- Deployment floor material changes from polyolefin membrane to Poron™ and Melinix
- Repeatability of MGSE alignment
- Maintaining configurations of air bearing MGSE between different test set up usage
- Difficulty repeating air bearing alignments and determining proper offloading
- IRAD effort at Ball to enhance capability of offload MGSE

S-NPP and NOAA-20 performing on orbit



- S-NPP image from VIIRS showing first Nor’easter of 2018
- NOAA-20 has finished commissioning activity and is supporting weather forecasting activities

Lessons Learned in the Flight Qualification of the S-NPP and NOAA-20 Solar Array Mechanisms

Q and A

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