Kaber Small Satellite Deployment System

NanoRacks ISS Workshop
George Washington University
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Introduction

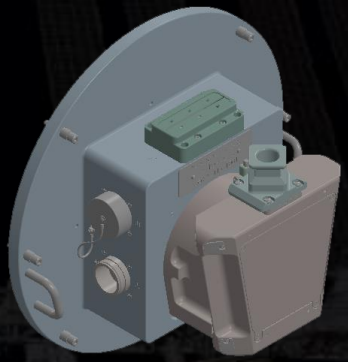
- NanoRacks Microsatellite Deployer System for the ISS called “Kaber”
- Payloads transported via ISS Visiting Vehicles
- Kaber uses JEM airlock and ISS robotic infrastructure as deployment platform SPDM for microsatellite-class payloads
- Kaber IOC
  - Microsatellite manifested on SpaceX-7 (2Q2015)
- Kaber FOC
  - 2 Microsatellites planned (4Q2015)

Kaber System Status

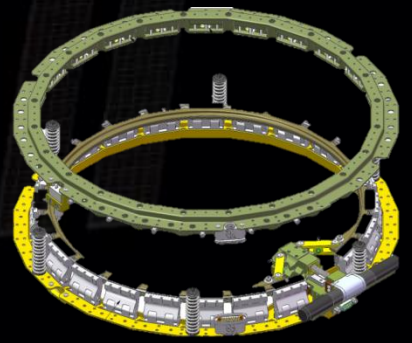
- Flight model in Assembly
- Hardware Delivery April 14, 2015
- NASA Phase I and Phase II Safety Reviews Complete- Phase III

Kaber Small Satellite Deployer System

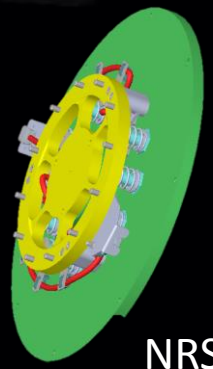
- Kaber Deployer
- JCAP
  - JEM slide table interface
- Satellite Separation System
  - Motorized Lightband (MLB)
  - NanoRacks Separation System (NRSS)



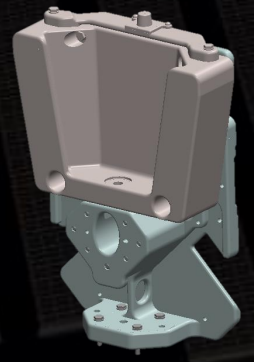
Kaber



MLB



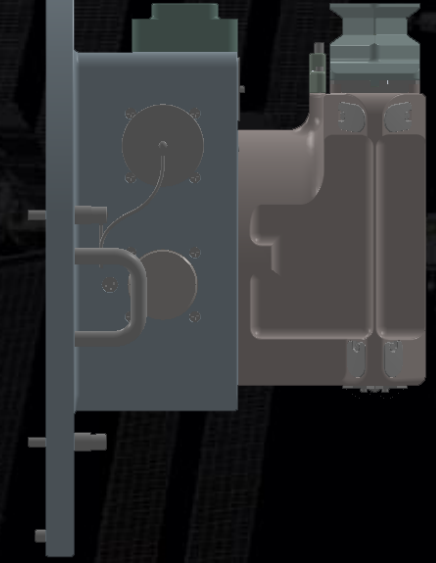
NRSS



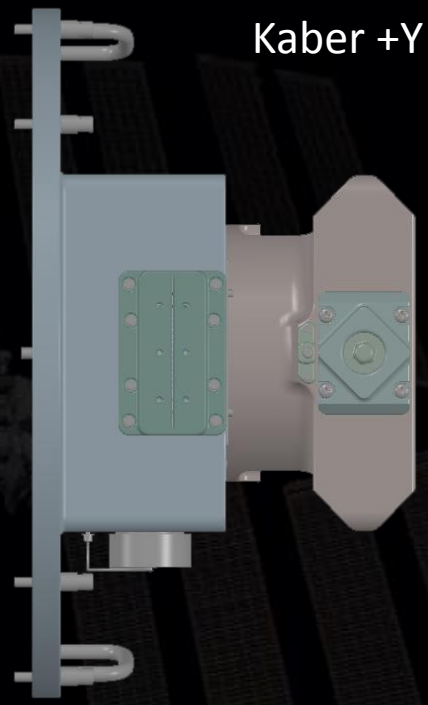
JCAP

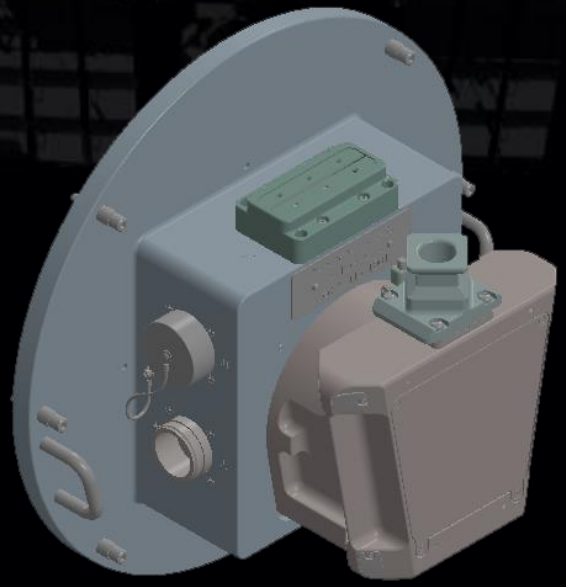
Kaber Lateral View Study

Kaber +X



Kaber +Y





Kaber perspective view

JEM CLPA Adapter Plate “JCAP”

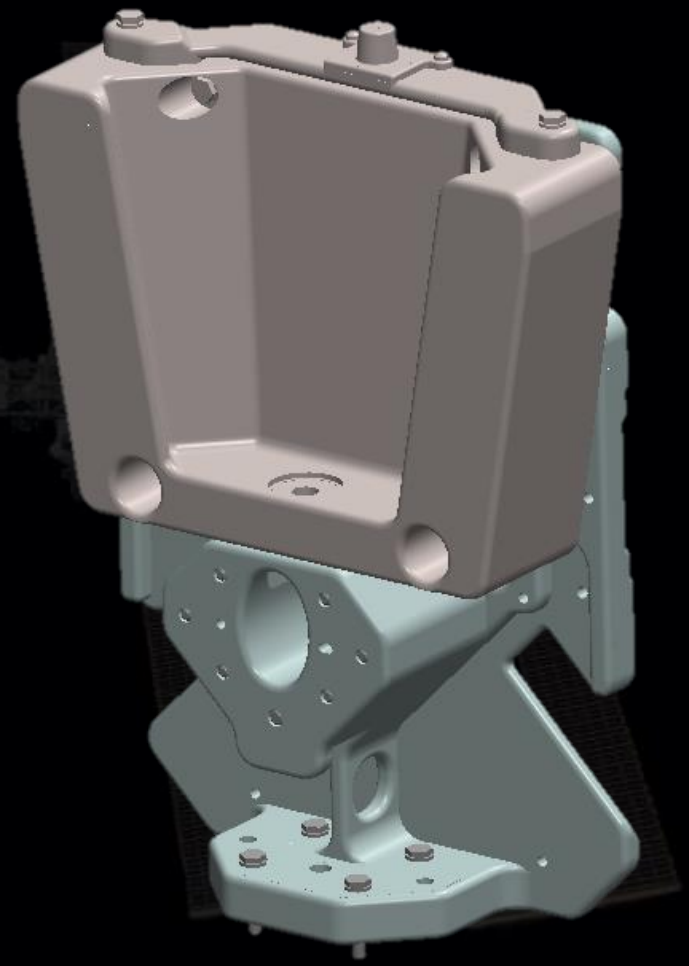
Purpose

- Mechanical interface to JEM airlock slide table

Flight Heritage

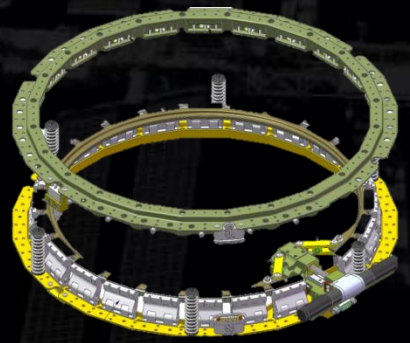
- Original intent for CLPA (Camera, Light Pan and tilt Assembly)
- Currently utilized in support of ISS robotic operations

JCAP Bracket

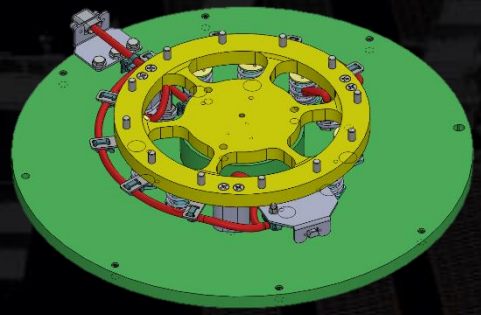


JCAP Plate

Kaber Separation System Options



Customer Choice

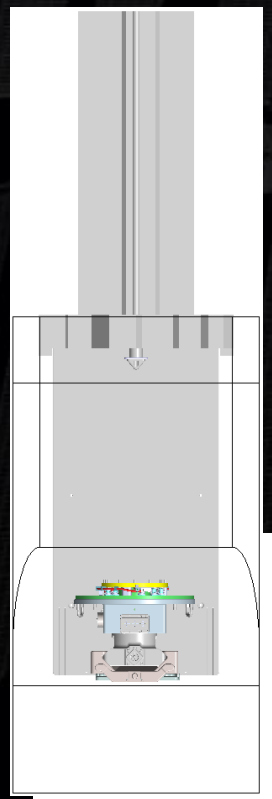


Planetary Systems Corp. “LightBand” Separation System, Mk1 & Mk2

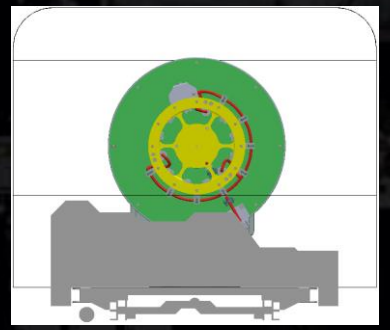
NanoRacks Separation System

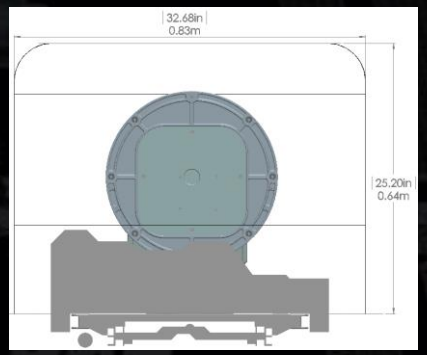
NanoRacks Kaber Deployment Service- JEM Air Lock Payload Envelope

- Note: Standard payload envelope is for a rectangular form factor. Additional envelope is available to accommodate other form factors.

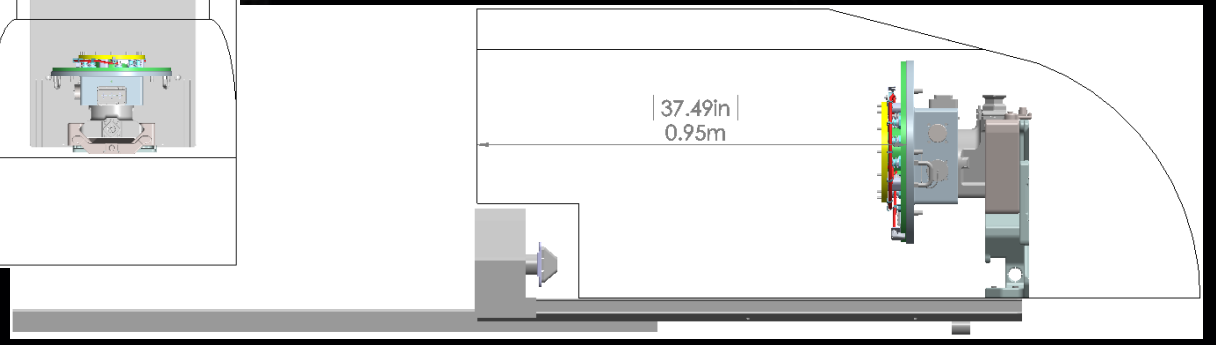


JEM Interior





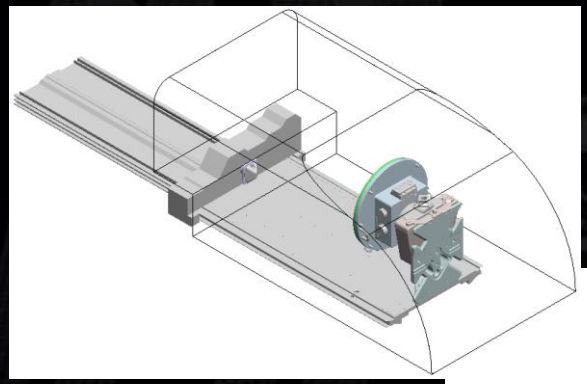
Payload Mass: up to 100Kg



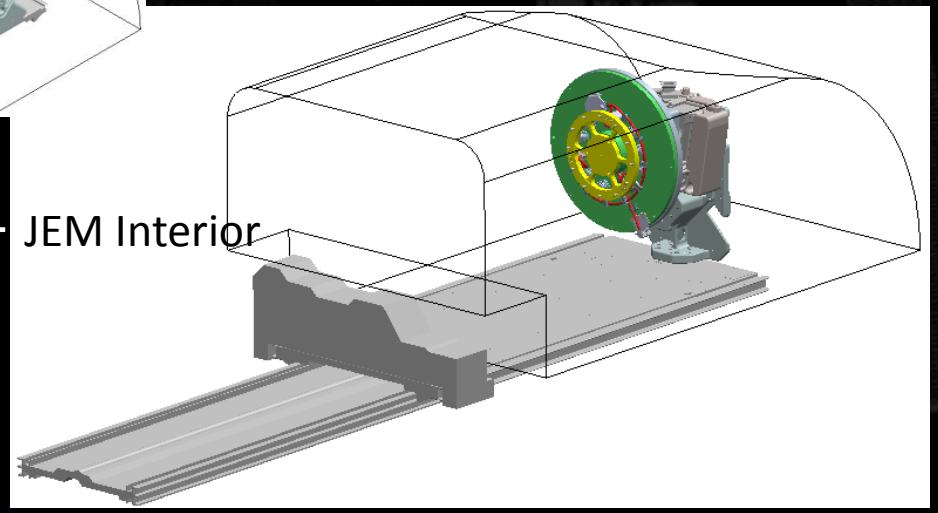
JEM Airlock Hatch

NanoRacks Kaber Deployment Service- JEM Air Lock Payload Envelope

- Note: Standard payload envelope is for a rectangular form factor. Additional envelope is available to accommodate other form factors.

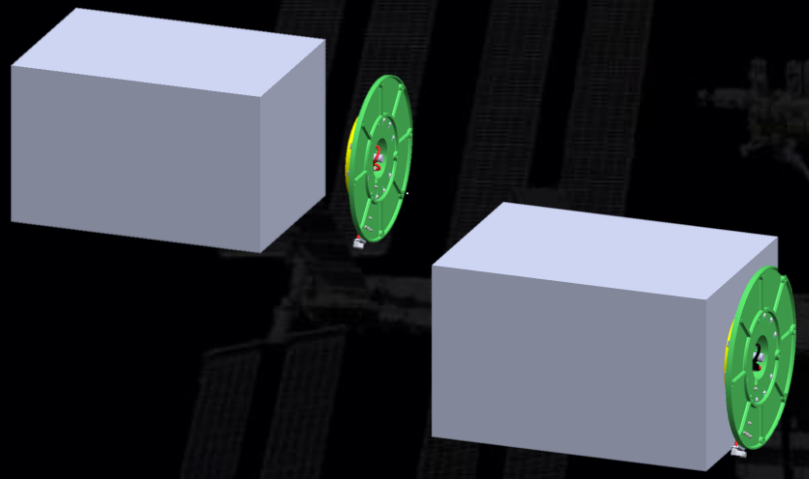


JEM Airlock Hatch →



← JEM Interior

Kaber Deployment Service- Flight Integration and Payload Delivery



1. Payload integrated to separation system at Customer Site
2. Delivery to NanoRacks, Houston facility
3. NanoRacks, NASA Close out processing and HFIT Inspection
4. Delivery to NASA JSC Cargo Mission Contract facility
5. CMC Processes Hardware & Preps for Ship to Launch Site

Flight Hardware Hard Foam Encased

Kaber Deployment Service – On Orbit Pre-Deployment

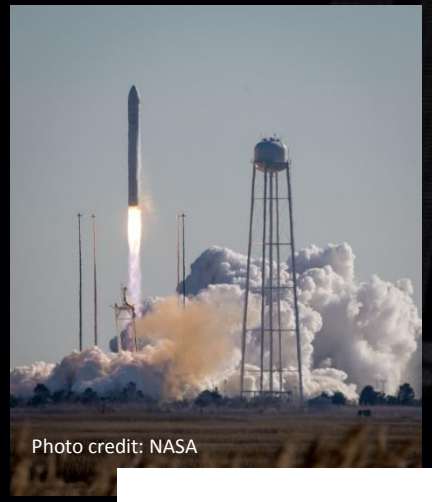
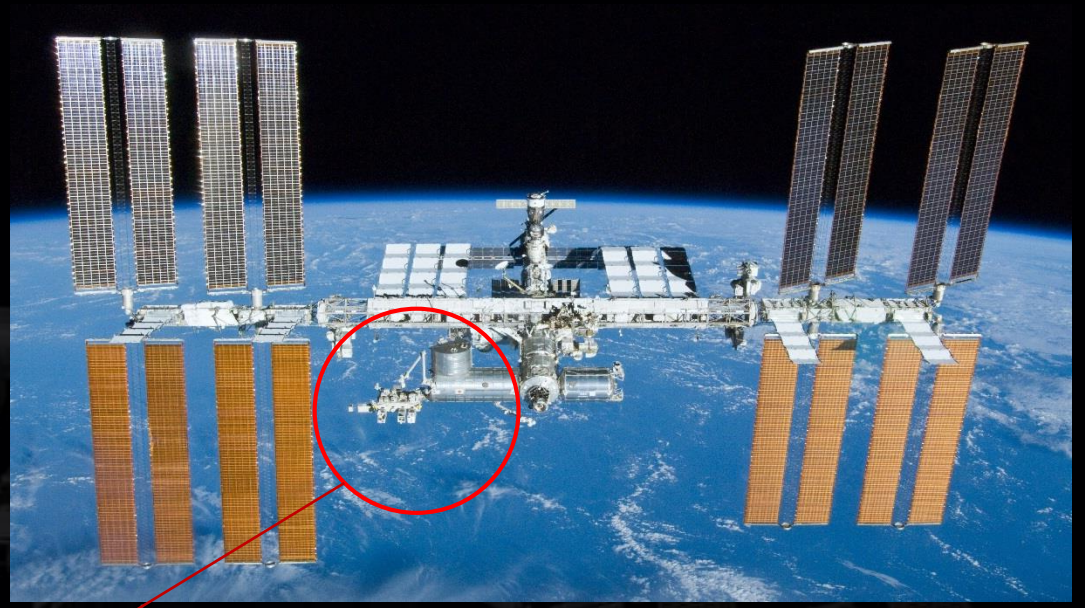
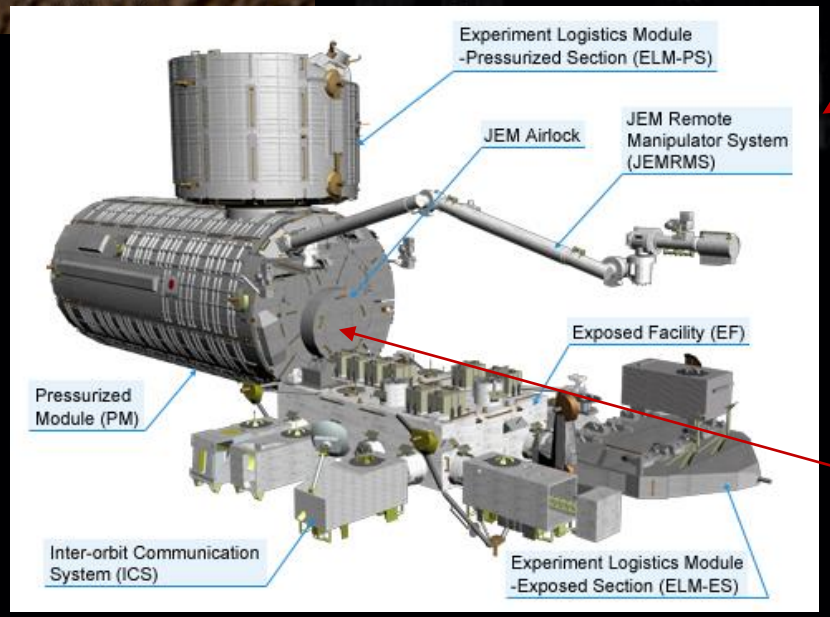
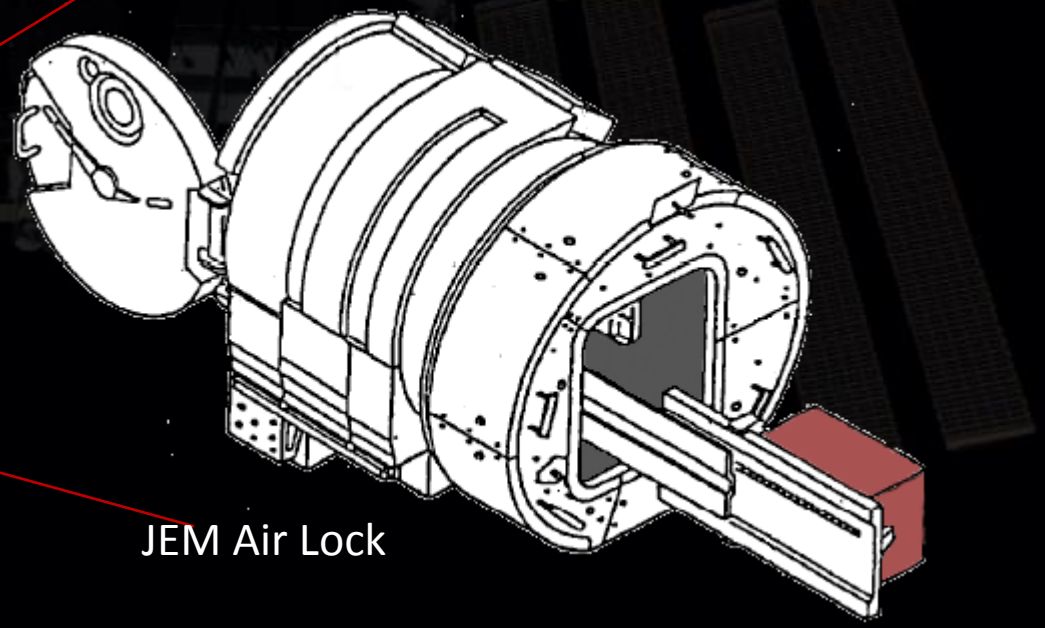


Photo credit: NASA

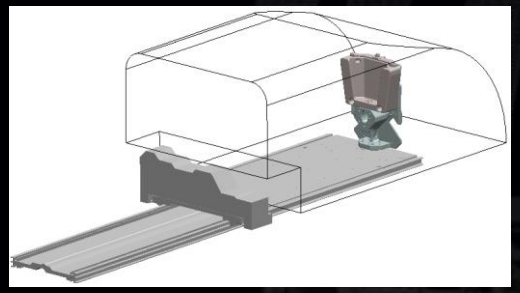





JEM Air Lock

Kaber Deployment Service – On Orbit Pre-Deployment Operations

1



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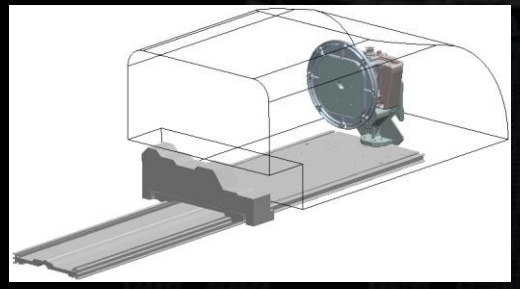

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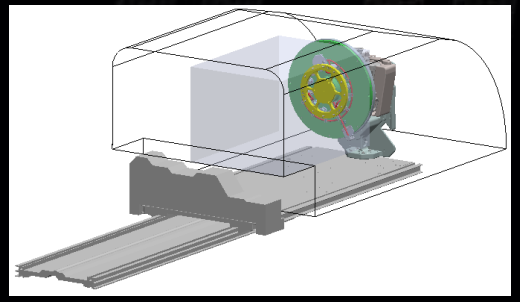
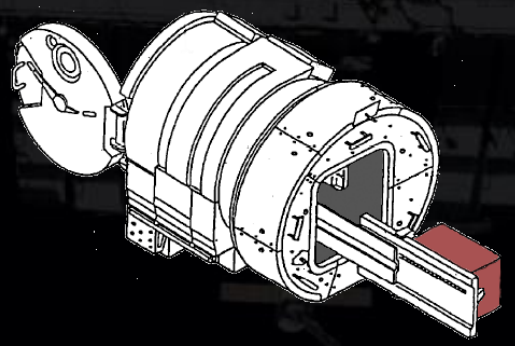


3,4,5



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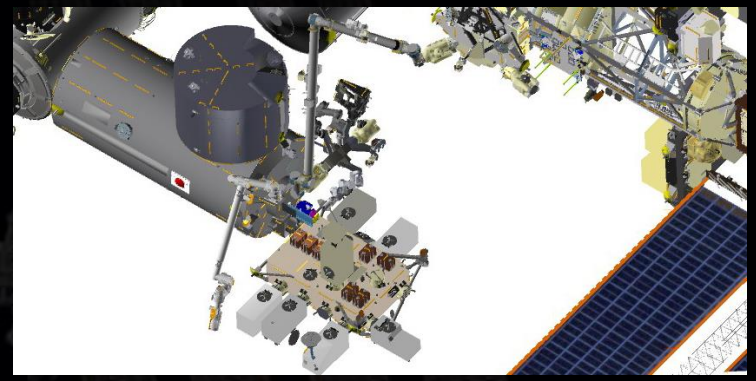

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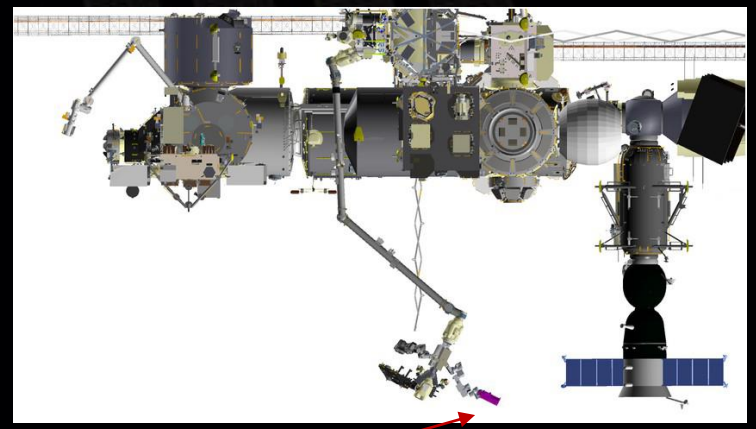
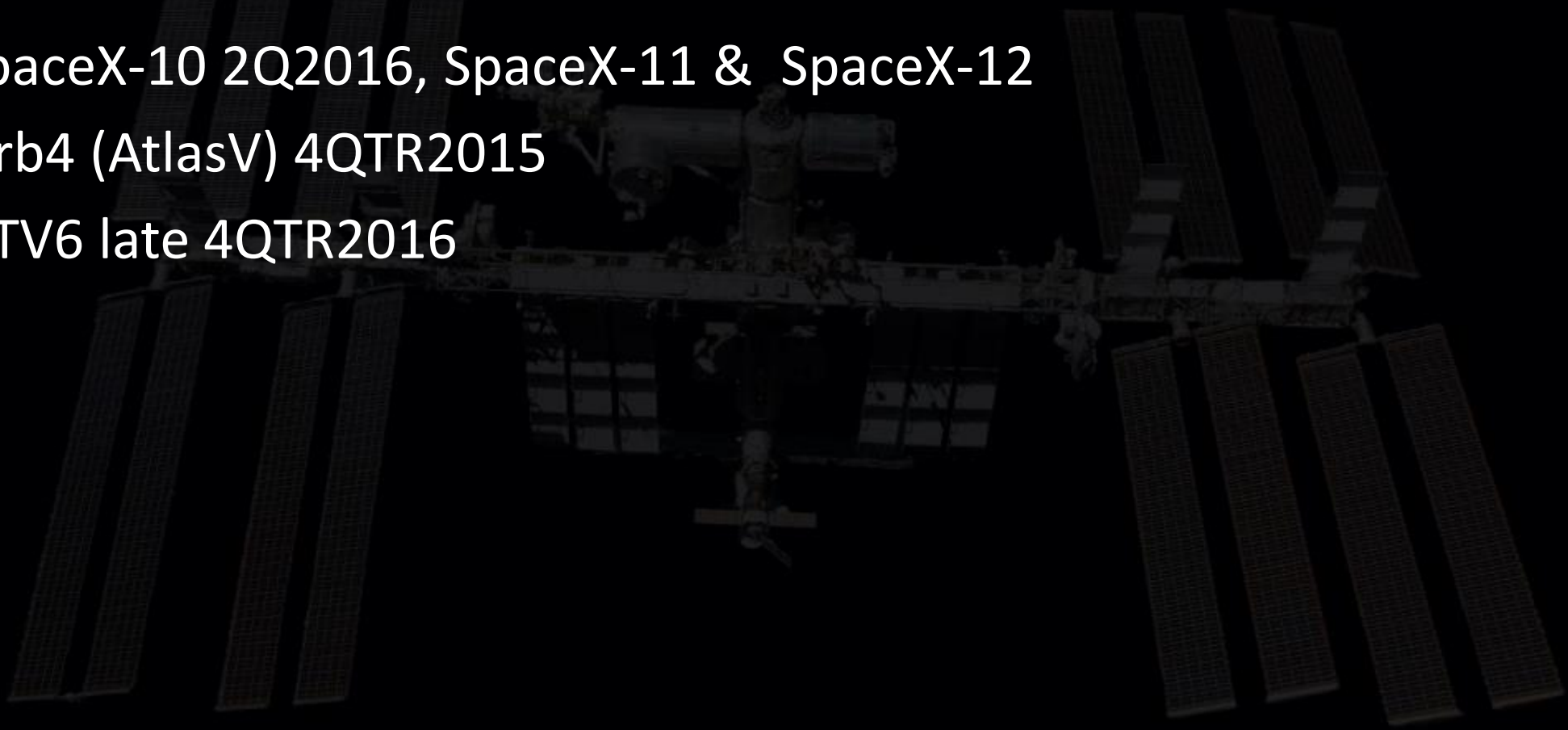


Kaber-Payload Assembly

Availability of Flight Opportunities

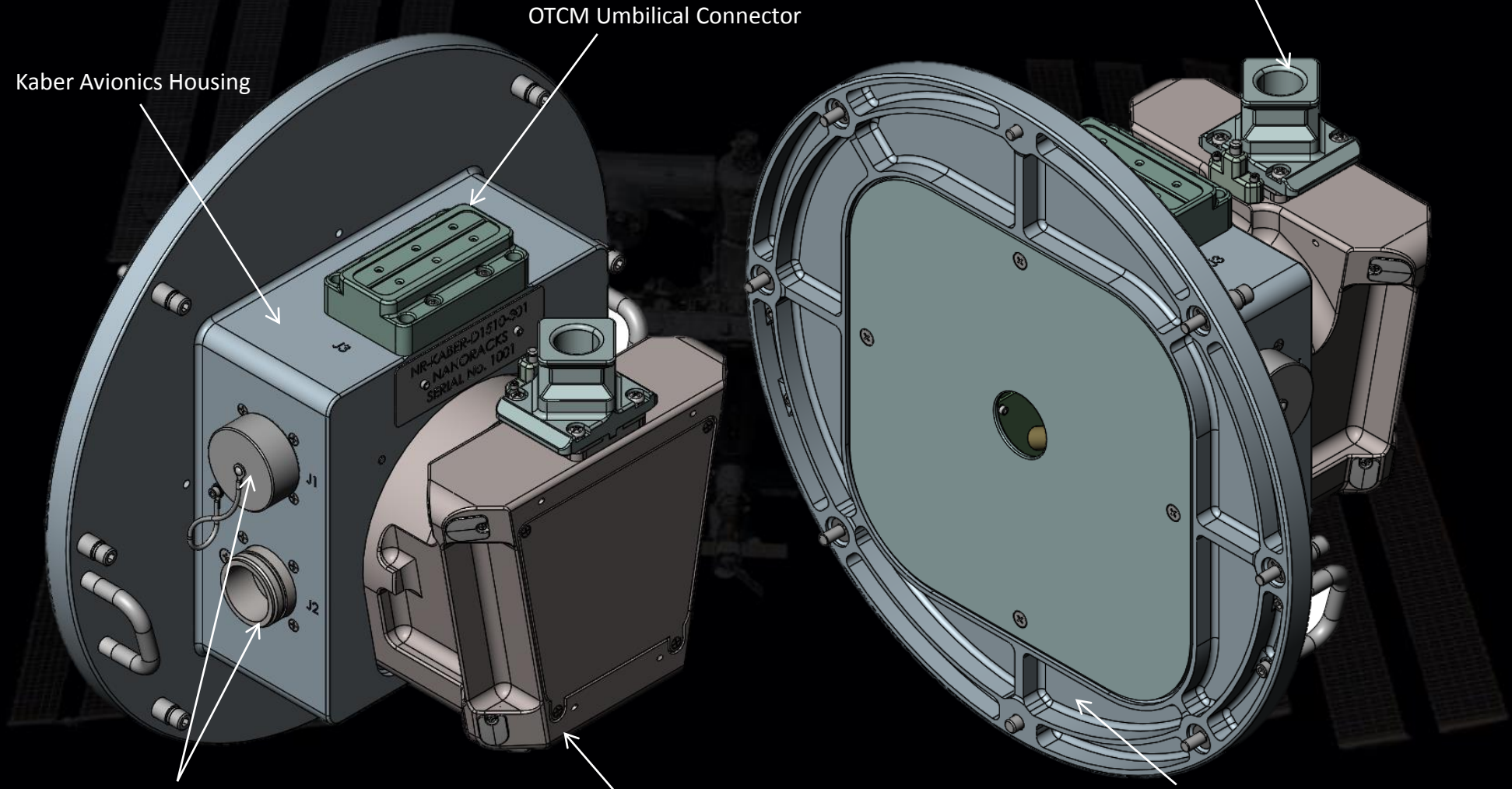


- SpaceX-10 2Q2016, SpaceX-11 & SpaceX-12
- Orb4 (AtlasV) 4QTR2015
- HTV6 late 4QTR2016

Backup Slides

NanoRacks Kaber Microsatellite Deployment Service from the ISS

Kaber Deployer

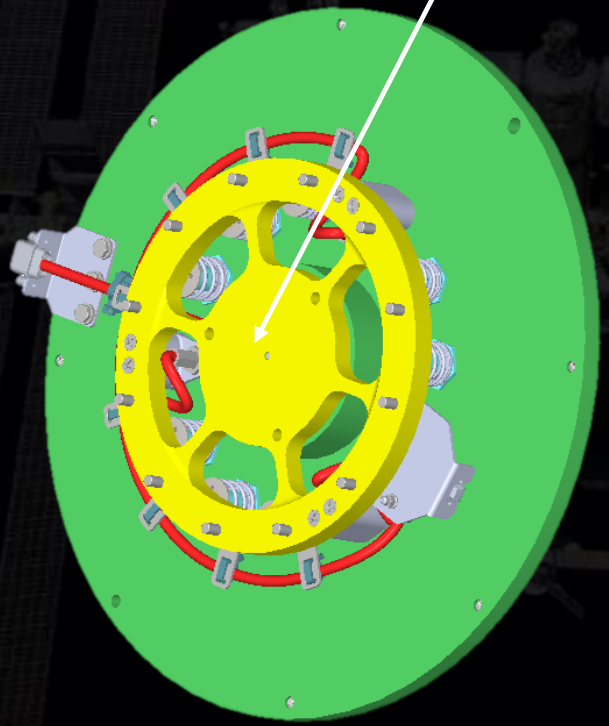


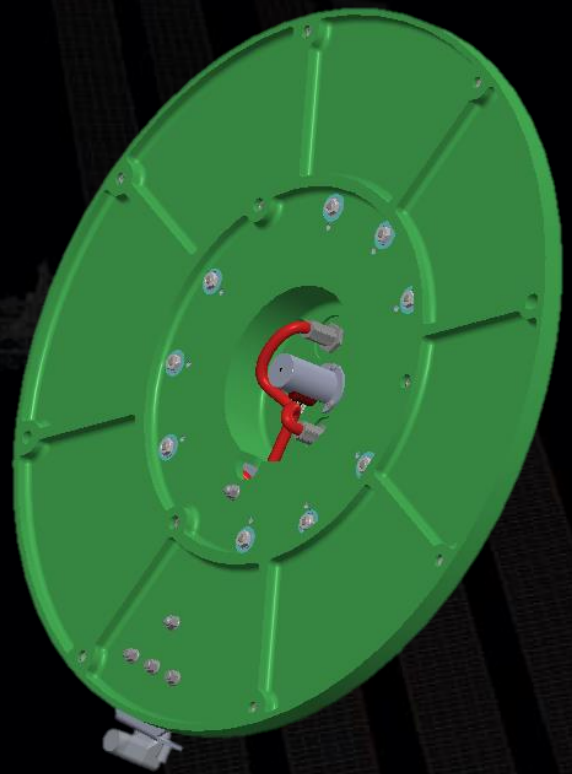
NanoRacks Separation System (NRSS)

- Satellite separation system for use with Kaber
  - Alternative to Lightband Separation System
  - Compatible with LightBand Satellite Bolt Pattern (8”, 11.47”, 13”,15”,18.2”)
  - Compatible with Lightband electrical interface
- NRSS fabricated specific to mission requirements
- (3 point), ultra low-shock separation system
- (Variable number) of separation springs for fine thruster vector tuning
- Unitary release mechanism
  - Release actuated by a frangibolt - COTS by TiNi Aerospace (high reliability, flight heritage)
- Tip-Off target performance ~1 deg/sec

NRSS

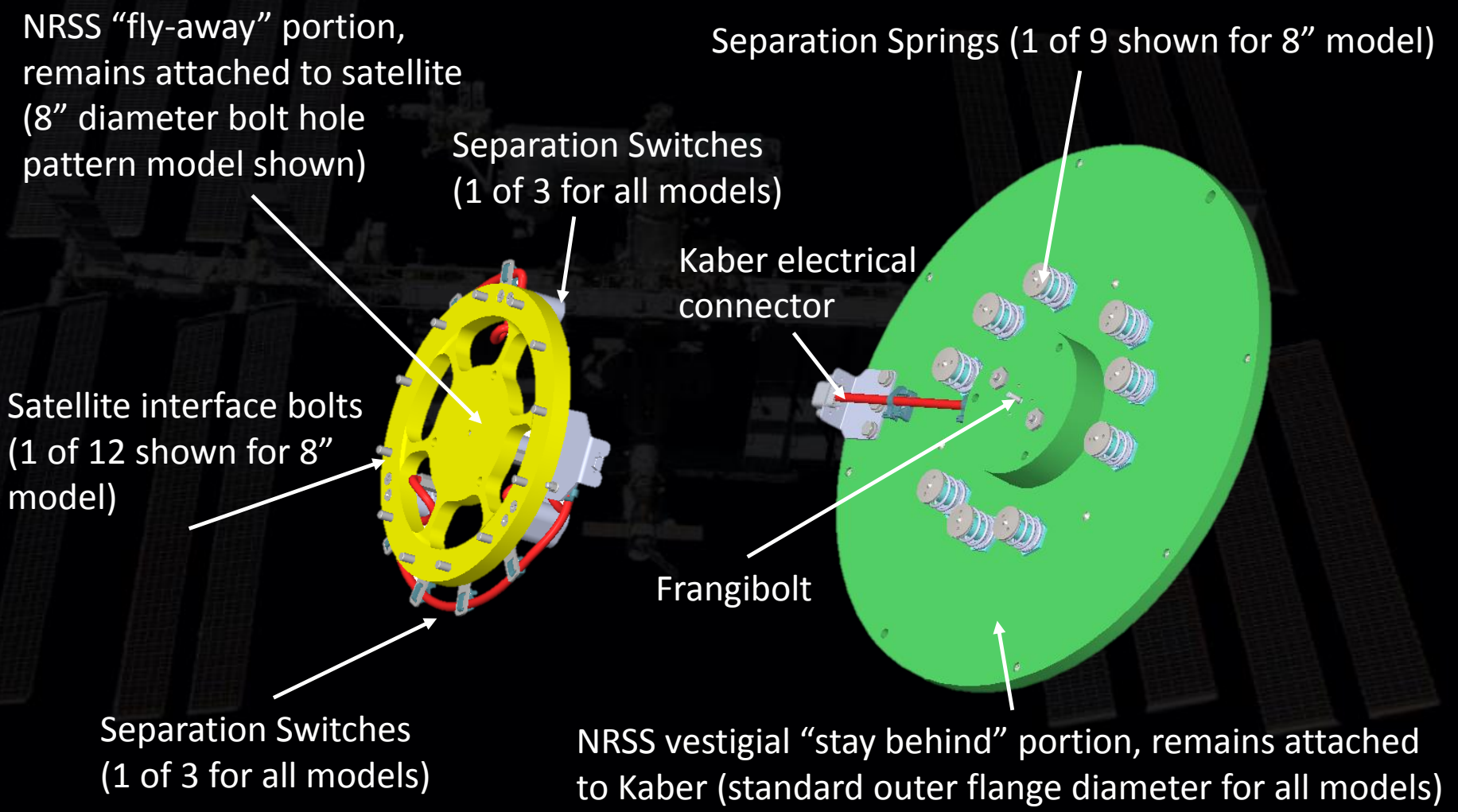
NRSS “fly-away” portion, remains attached to satellite
(8” diameter bolt hole pattern model shown)





NRSS vestigial “stay behind” portion, remains attached to Kaber (standard outer flange diameter for all models)

NRSS Functional Elements



Kaber System Conops (1)

- Satellite and Separation System Flight Integration On-site
- Integrated Satellite/NRSS shipped direct to NASA JSC for cargo acceptance; forward ship to launch site
- Satellite/NRSS packed into large Crew Transfer Bag (CTB) and integrated into ISS visiting vehicle (currently Orbital Sciences Cygnus)
- Launched on ISS Visiting Vehicles to ISS
- Post Visiting Vehicle berthing, CTB transferred to ISS and stored

Kaber System CONOPS (2)

- NASA schedules deployment window
  - Subject to constraints e.g. ISS visiting vehicles, availability of ground support operations staff, etc.
- On-orbit installation
  - JCAP installed to JEM air lock slide table
  - Kaber/Wedge assembly installed to JCAP
  - Satellite/NRSS assembly installed to Kaber
- JEM Airlock Depressurization Ops
  - Operations managed by JAXA controllers
  - Air lock slide retracts into JEM airlock
  - Inner door closed, and airlock depressurized
  - JEM air lock outer door opened

Kaber System CONOPS (3)

- Robotic Operations
  - SPDM grapples Kaber System by micro-square fixture
  - SPDM translates Kaber System to NASA-JAXA pre-approved deployment position (pointed retrograde to ISS)
- Deployment Operations
  - NASA controllers send deployment command to Kaber via ISS CD&H backbone
  - NRSS deploys satellite with ~ 0.25-0.5m/sec velocity
  - Satellite cannot operate RF systems for 30 minutes or perform maneuvers (if propulsion capable)

Flight Safety Requirements

- NanoRacks represents the Customer at NASA Safety Reviews (three reviews supported by iterative data from the Customer)
- NanoRacks provides consolidated safety data call template and procedures for required tests
- General principle of two fault redundancy for electrical and propulsion system
- Minimum of (3) electrical inhibits (deployment switches set inhibit state)
- Bill of Materials analysis combined with possible component level off-gas testing sufficient to comply with NASA hazardous materials/toxicity requirements
- Flight batteries require acceptance testing
- Deployment retention mechanisms, typically required to be redundant
- Vibration testing for workmanship and frangible materials is required; not included in safety certification services
- Certification for ISS crew handling- Satellites briefly exposed to ISS crew, require human rating for external surfaces (sharp edges, burrs, etc.)
- RF systems evaluated for human exposure and ISS communications interference
- Propulsion systems typically require redundant propellant feed valves

Battery Flight Acceptance Testing

- Main Flight Battery Testing
- NanoRacks provided test procedure
  - Physical properties recorded (mass, dimensions)
  - Initial charge/discharge
  - Battery protection circuit required and must be tested
  - Thermal cycling
  - Vacuum cycling
  - Vibration test
- “Coin/button” batteries exempt if capacity < 80 WHr/Kg

Random Vibration Flight Acceptance

- Required for ISS Flight Safety Certification
- Flight acceptance testing requires the Satellite be subjected to random vibration along each axis. The test period for each axis shall be 60 seconds. [1]
- Random vibration testing shall use the profile shown in Table 1.

Table 1.

Frequency (Hz)	Maximum Flight Envelope (g2/Hz)
20	0.057 (g^2/Hz)
20-153	0 (dB/oct)
153	0.057 (g^2/Hz)
153-190	+7.67 (dB/oct)
190	0.099 (g^2/Hz)
190-250	0 (dB/oct)
250	0.099 (g^2/Hz)
250-750	-1.61 (dB/oct)
750	0.055 (g^2/Hz)
750-2000	-3.43 (dB/oct)
2000	0.018 (g^2/Hz)
OA (grms)	9.47
Table 1 Random Vibration Test Profile	

[1] NASA SSP 50835, Rev C, TABLE 4.3.1.1.2.1.2.3.1-1 SUMMARY OF THE TEST CONDITIONS FOR FOAM PACKED ITEMS FOR QUALIFICATION, PROTOFLIGHT, AND ACCEPTANCE TESTING

Payload Environments

- Integration Cleanliness, Humidity and Temperature
  - Visually Clean (limited by ISS ambient cabin air)
  - 30% - 70% relative humidity (RH) environments during ground processing.
  - Nitrogen purge available
  - stored and processed with air temperatures between 4 – 32°C
- Deployment Thermal Environment
  - Nominal temperatures while positioned on SPDM
  - 10 – 57°C

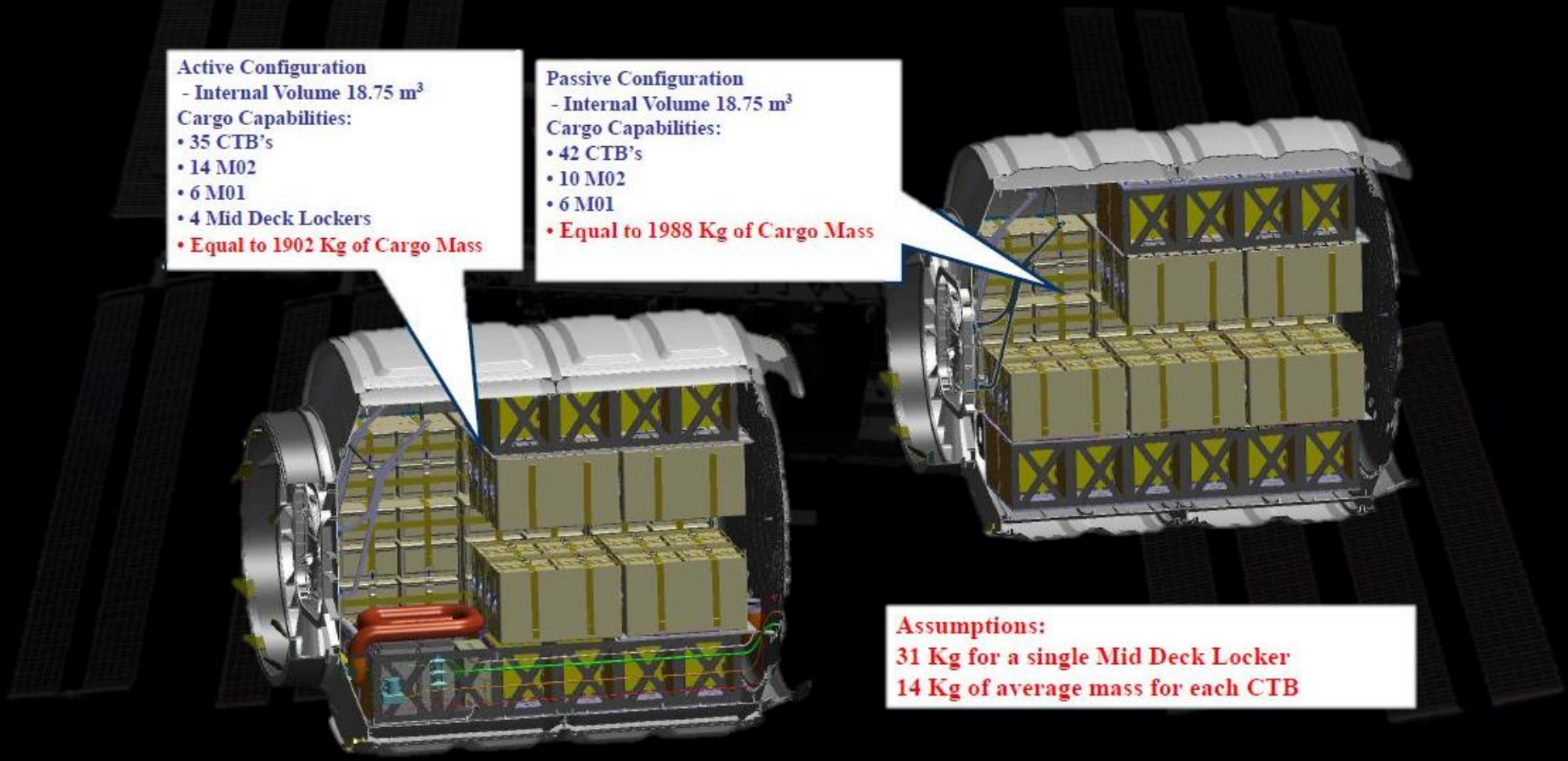
Project Management

- Contract Signing/Authority to Proceed
- NanoRacks Account Manager Assigned
- NanoRacks Web-based Project Collaboration Services
  - Customer.nanoracks.com
  - Issues tracking during major phases through deployment
- Standard Documents Issued
  - Interface Control Document (ICD)
  - Vibration test supplement
  - Battery Test Procedures
  - NanoRacks Flight Safety Data Template
  - Secondary locking guidance

Payload Developer Timeline

Milestone/Activity	Launch minus Months
Authority to Proceed	L-12
Technical Interchange Meeting (TIM) Data Submittal	L-11
TIM	L-10.5
Phase 1 Safety Data Package Submittal / Phase 1 Safety Review	L-7 / L-6
Phase 2 Safety Data Package Submittal / Phase 2 Safety Review	L-5 / L-4
Hazardous Materials/Toxicity Testing	L-5
Flight Batteries Acceptance Testing	L-5
Satellite-Separation System Fit Check	L-5
Phase 3 Safety Data Package Submittal /Phase 3 Safety Review	L-3/L-2
Environmental Testing (vibration, thermal, etc.)	L-2
Customer Delivery to NanoRacks	L-1.5
NanoRacks Delivery to NASA	L-1

Cygnus Pressurized Cargo Module (PCM)



Cygnus (PCM) CTB Loading and Stowage