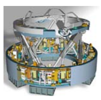
ADVANCED DOCKING/BERTHING SYSTEM

Brandan Robertson
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

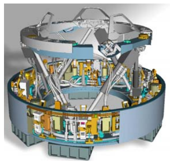


Advanced Docking/Berthing System
NASA Seal Workshop
GRC

November 9-10, 2004

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

NASA/CP—2005-213655/VOL1



Outline

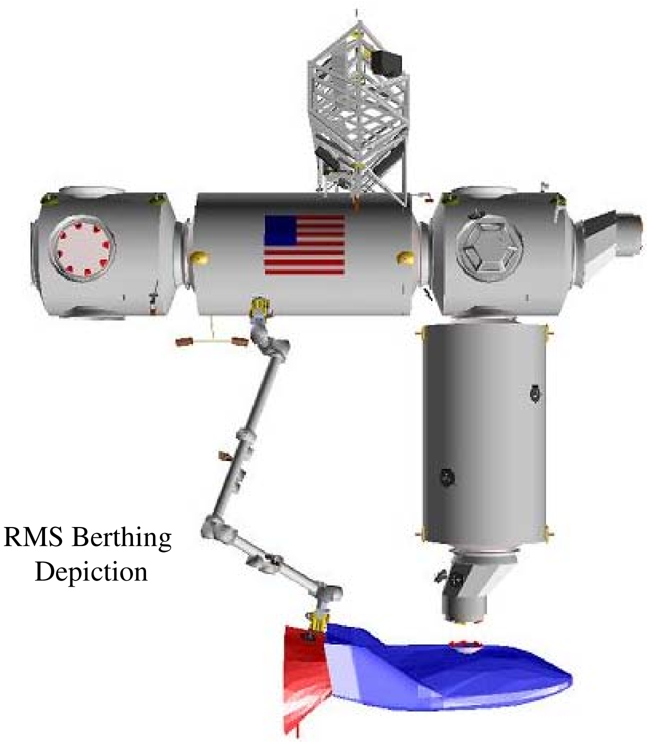
- Background
- Future Program Needs
- Existing Systems
- Status
- Advanced Docking/Berthing System (ADBS) Overview
- Key Seal Requirements
- Early Seal Development Work

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

Background

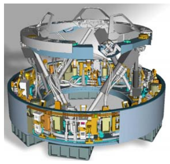
Berthing refers to mating operations where an inactive module/vehicle is placed into the mating interface using a Remote Manipulator System-RMS.

Docking refers to mating operations where an active vehicle flies into the mating interface under its own power.



RMS Berthing Depiction

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

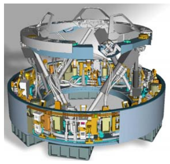


Future Needs

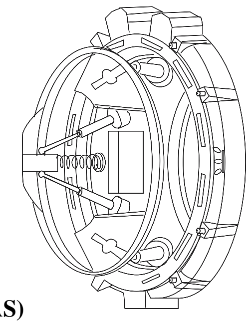
Future Mating System Capability Requirements:

- A system able to support a variety of missions: CTV/CEV/CRV, lunar gateway, Moon, and Mars
- Lightweight, fault tolerant system that blends well into vehicle OML (aero)
- Capable of autonomous rendezvous & docking
- Berthing capable for modular assembly and vehicle swap-out
- Software reconfigurable for a range of vehicles and operations
- Fast separation for rapid release
- Modular for maintenance and servicing
- Constellation safety & reliability goals
- Adaptable to ISS
- Crew and large cargo transfer
- Power, data, and fluid transfer
- Vehicle to vehicle mating (CRV-CTV-others) requires androgynous interface

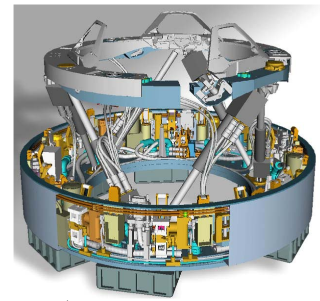
Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX



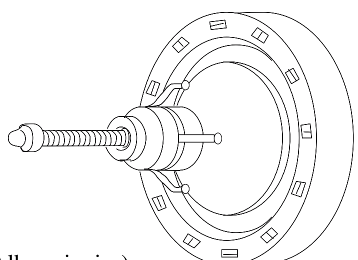
Existing Systems



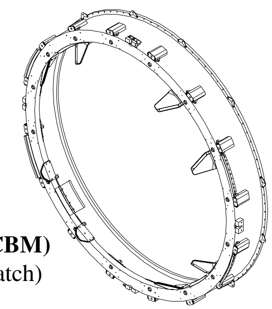
Androgynous Peripheral Docking System (APAS)
Weight: ~950 lbs (660 lbs APDA-6001 + 276 lbs avionics) (hatch not incl.)
Max OD: 69” dia
Hatch Pass Through: 31.38” dia
Source: JSC-26938, “Procurement Specification for the Androgynous Peripheral Docking System for the ISS Missions



Advanced Docking/Berthing System (ADBS)[1]
Weight: est. 750 lbs (includes electronics & hatch)
Max OD: 54” dia
Hatch Pass Through: 31” dia
Source: X-38 Program Group



Russian Probe
Weight: 700 lbs (550 lbs cone + 150 lbs avionics)
Max OD: 61” dia
Hatch Pass Through: 31.5” dia (approximate)
Source: Energia

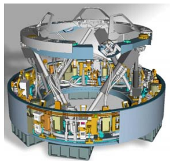


Passive Common Berthing Mechanism (PCBM)
Weight: 680 lbs[2] (440 lbs PCBM + 240 lbs hatch)
Hatch Pass Through: 50” square
Max OD: 86.3” dia
Source: SSP 41004, Part 1, “Common Berthing Mechanism to Pressurized Elements ICD” & SSP 41015, Part 1, Common Hatch & Mechanisms To Pressurized Elements ICD

[1]ADBS currently under development
[2]Bulkhead hatch ring structure not included

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

NASA/CP—2005-213655/VOL1

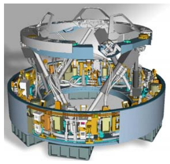


Existing Systems

Limitations of existing systems:

- Do not meet 2-fault tolerant, time-critical release requirement for crewed vehicles
  - APAS for Shuttle relies on 96 bolt EVA to meet 2nd fault tolerance
  - CBM powered bolts in nominal ops are not time critical and are single fault tolerant
- Unique active & passive halves: precludes vehicle-to-vehicle mating
- Do not support autonomous operations
  - No automatic mating of fluid, power (APAS does have a single power/data connector) and forced air umbilicals
  - CBM cannot mate to unmanned vehicles
- Standard ISS racks cannot pass through existing docking ports
- Significant velocities required to provide alignment & capture forces
- Crit-1 operations supported by intensive training & analysis
- High part count / mechanical complexity with single point failures (reliability and failure tolerance problems)
- Berthing mechanisms do not dock and docking mechanisms do not berth
- Russian systems are supplied by a foreign vendor with substantial economic concerns
  - Purchase of additional units banned by Iran Missile Proliferation Sanctions Act of 1997
  - Very limited access to engineering data
- Systems designed and/or certified for very few cycles and short exposure life

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

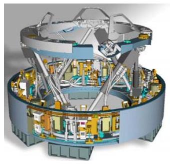


Current Status

Advanced Mating System Development Activities

- Exploration Systems Technology Maturation Program has selected advanced mating systems for continuation during the recent ICP activity.
- JSC has been developing an advanced mating system (ADBS) since 1996.
  - Originally intended for use on the X-38 project
  - Designed to support both berthing and docking operations and to provide future mission architecture flexibility (cross-cutting technology)
  - The current design baseline is a X-38-sized risk reduction unit (RRU)
    - Fully androgynous interface
    - Uses electromagnets and closed-loop force-feedback for soft-capture
    - Minimally sized for crew transfer
    - Fully integrated ground based system to show TRL 4 maturity
  - Work on Constellation scale system to begin as RRU matures
- Long-duration seal technology (seal-on-seal) has been identified as a current design gap.

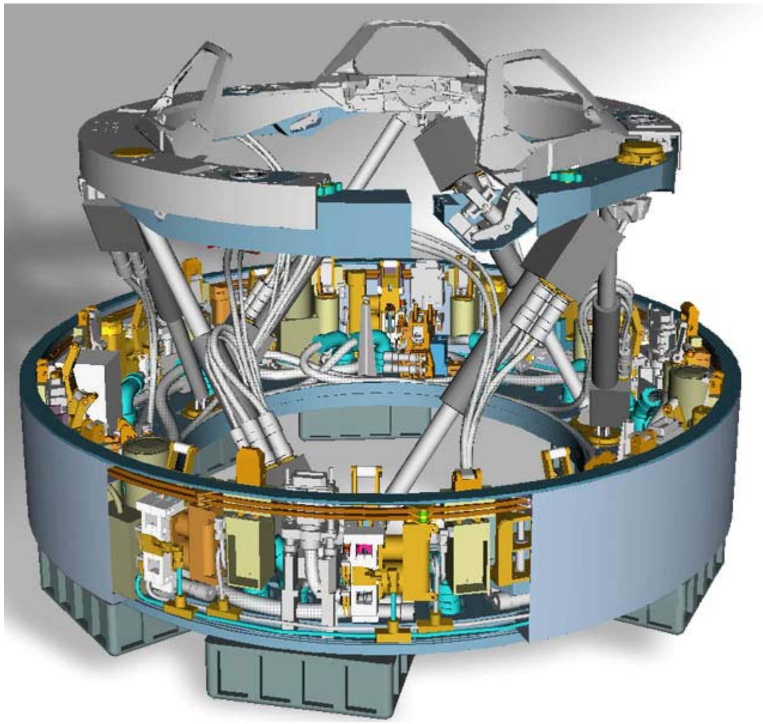
Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX



ADBS Overview

A Next-Generation Mating Mechanism

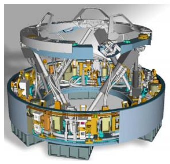
- Designed specifically to take advantage of modern electromechanical technology
- Incorporates the lessons learned and experiences from previous/current mating mechanism development and use
- Desensitizes mating mechanism operations and performance from other vehicle systems requirements
- Supports both docking and berthing operations
- Supports autonomous rendezvous & mating
- Aligned with NASA Strategic Plan



CAD Image

Interactive Overview

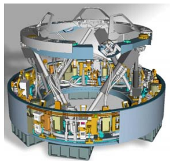
Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX



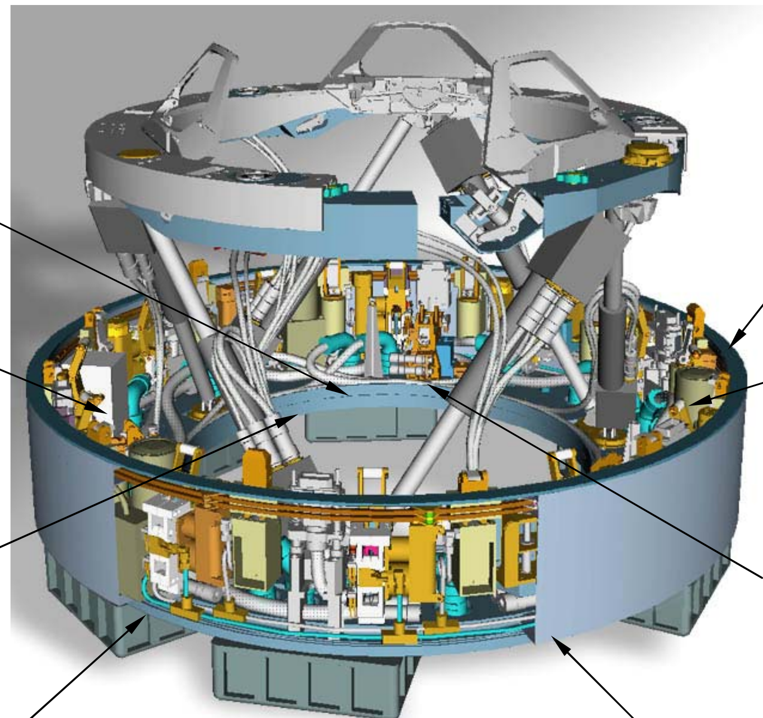
Key Seal Requirements

- Seal-on-seal interface
- Very low leak rate
- Long life
  - Long-duration exposed periods
  - Long-duration mated periods
  - Deep-space environments
  - May also be a potential for high mate/demate cycle life
- Redundancy

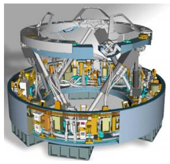
Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX



ADBS Seal Locations



Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX



Early ADBS Seal Development

To preserve the fully androgynous design concept the seal design approach baselined was a seal-on-seal implementation similar to the Apollo Soyuz (ASTP) seals.

Subscale seal-on-seal elastomeric development with Parker Inc.

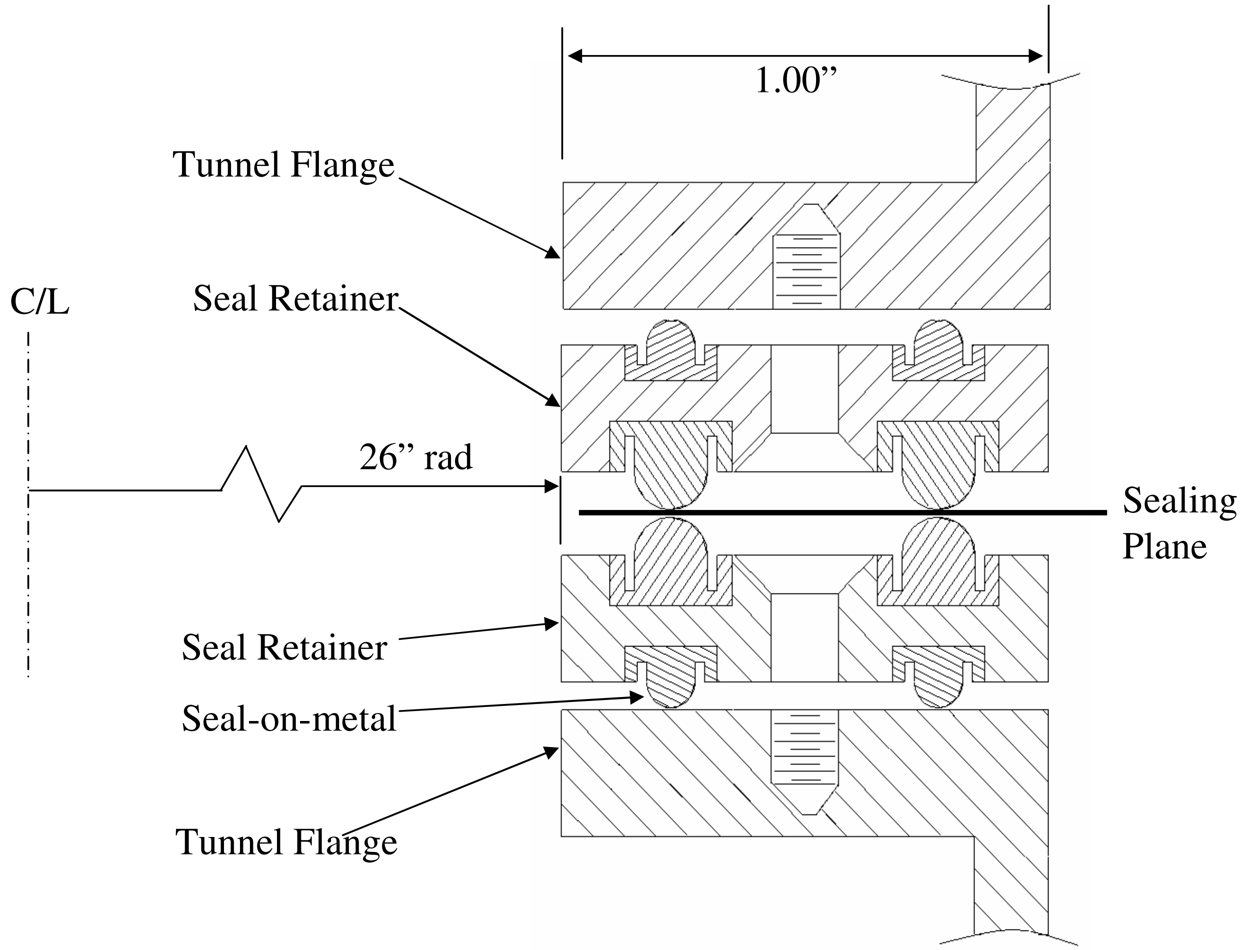
- Quick development and testing to evaluate seal-on-seal potential
- 2 cross-sections (flat top and elliptical) and 2 different durometer silicon materials
- Helium leak testing and seal load force testing completed in July 2001
- Adhesion testing is ongoing

Test results

- Leak rates comparable to ISS CBM seals with offset of 0.050 inches and no gapping (~20 configurations tested)
- Compression force testing showed that “flat top” slightly higher than “elliptical” for the 70 durometer at (96 & 87 lb/in) and for the 50 durometer at (46 & 42 lb/in). Results indicated that seal-on-seal in the “acceptable” range for use.
- Adhesion test results pending; series of “buttons” molded from each material are currently mated and compressed for eventual separation and inspection at TBD regular intervals of time.

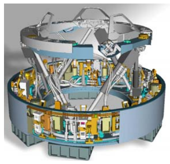
Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

RRU Interface Seal Concept



Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

NASA/CP—2005-213655/VOL1



Early ADBS Seal Development

Conclusions

- No elastomeric seal-on-seal show stoppers yet

Forward work

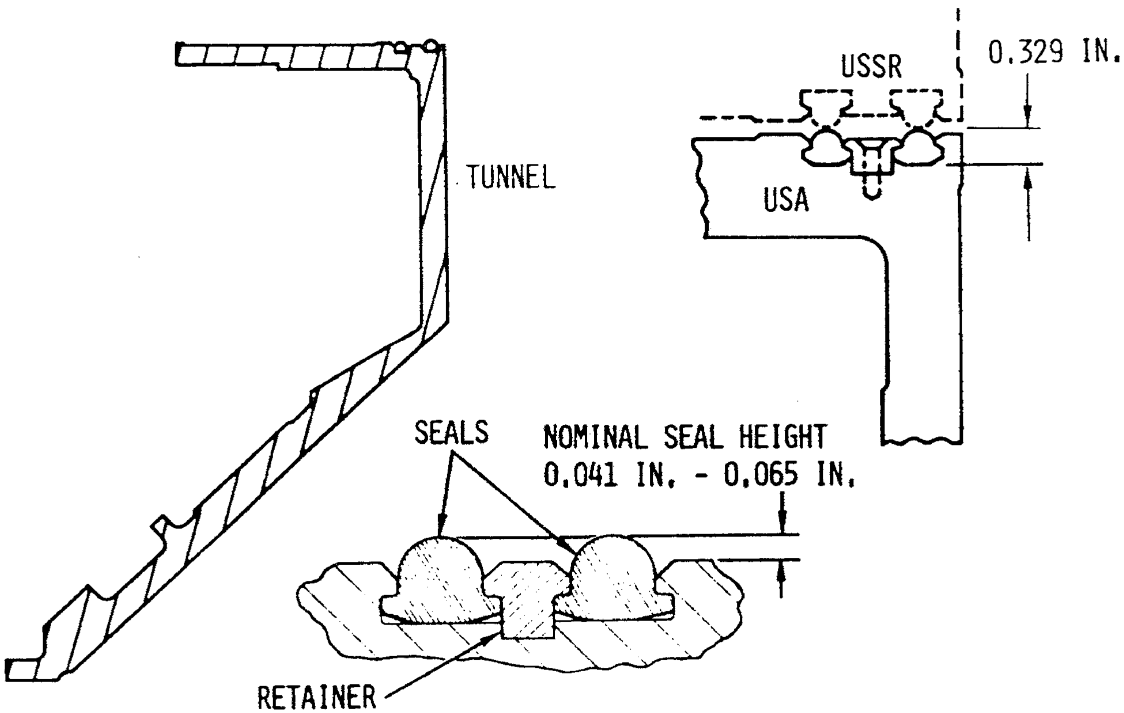
- As soon as funding picture clears up, move forward with a full development seal purchase for the RRU
- Need to establish “the” baseline seal cross-section
  - Optimize seal to guarantee optimal sealing: percent of fill, squeeze, crown profile and height, if elastomeric
  - Establish total potential seal mismatch: misalignment, thermal expansion, flange deflection
  - Establish acceptable seal force and leak rate
- Determine if a single piece ~54” seal/retainer construction possible. Parker has indicated they do this now in a newly acquired facility.
- Evaluate concepts and results for full-scale Constellation implementation
  - Evaluate RRU design upward scaling
  - Are metallic seals a better solution?

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

Backup Slides

Brandan Robertson, NASA-JSC/ES5 281-483-3732, Houston, TX

Existing System Seals



Apollo Soyuz Test Program
Docking System Interface Seal Diagram