Overview of the NASA Docking System and the International Docking System Standard

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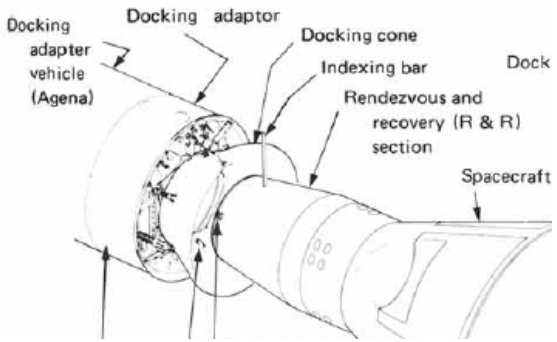
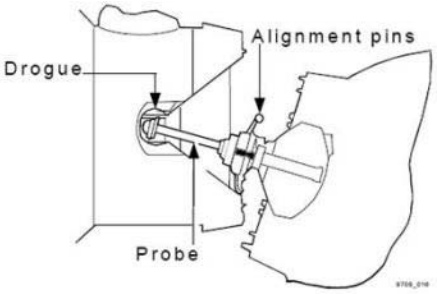
Agenda

- Docking Systems Background
- Evolution of the International Docking System Standard
- NASA Docking System Overview
- ISS Implementation

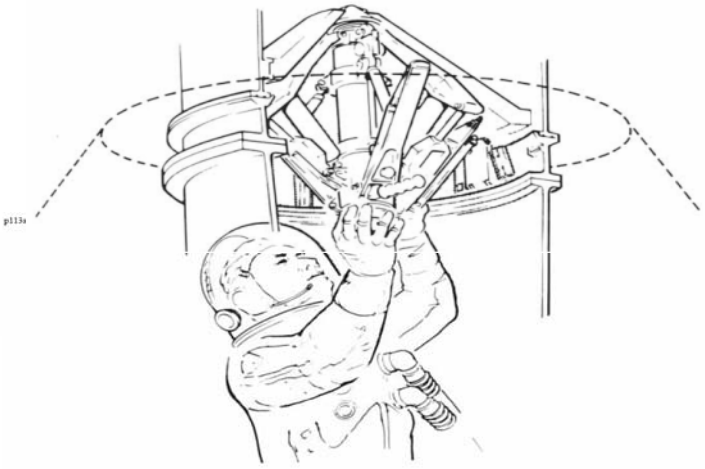
Docking Overview – Heritage Systems



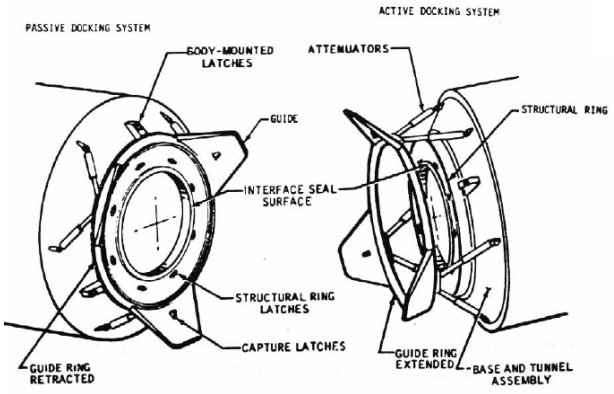
Agena/Gemini



Russian Probe Cone

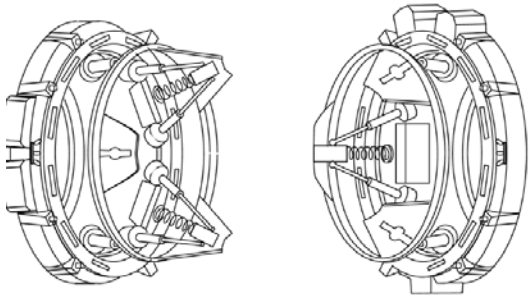


Apollo Probe Cone



Apollo Soyuz

(No scale is implied between figures)



Androgynous Peripheral Assembly System (APAS)

Low Impact Docking System (LIDS) - Background

- NASA began developing Low Impact Docking System (LIDS) technology in the 1980's
- The purpose of low impact docking technology is to greatly reduce or eliminate the use of impacts to achieve alignment and capture
  - All previous docking mechanisms have required the use of impacts (i.e. velocity or post-contact thrusting) to create the energy required to force the passive soft capture mechanism interfaces into alignment, then capture the mating docking interface
  - Low Impact technology can be used to greatly reduce and even eliminate the need for impact energy and provide flexibility for future mission planners
- LIDS utilizes force-sensing, active control technology with S/W driven characteristics "tunable" to meet performance of a broader range of unique operations
  - offers capture with minimal contact forces, I.e. "low impact"
  - offers requirements relief to other vehicle systems and critical vehicle operations
  - provides both docking and berthing capability
  - real-time performance adjustment and configurability
- LIDS was chosen as the baseline system for the Constellation Program

Low Impact Docking Key Requirements

- *Perform soft-capture* between two spacecraft
  - Vehicle movement/thrusting and/or a compliant mechanism is needed to overcome gross interface misalignments to achieve initial capture
- *Energy absorption/dampening* of residual motion/dynamics
- *Precision retraction and fine alignment* onto sealing/shear interface (I/F)
- *Structural mating* of latching mechanism
  - Provide seal compression, interface preload
  - React coupled dynamic loads (ISS reboost, TLI Burns)
- *Internal pressurization and passage for crew and cargo transfer*
- *Utilities transfer*
  - Power, data, and commands
  - Consumables: air, water (future), fuel (future)
- Impart *separation* force/velocity

LIDS Active Mode Animation

Docking Sequence

LIDS Active Mode Prototype Video

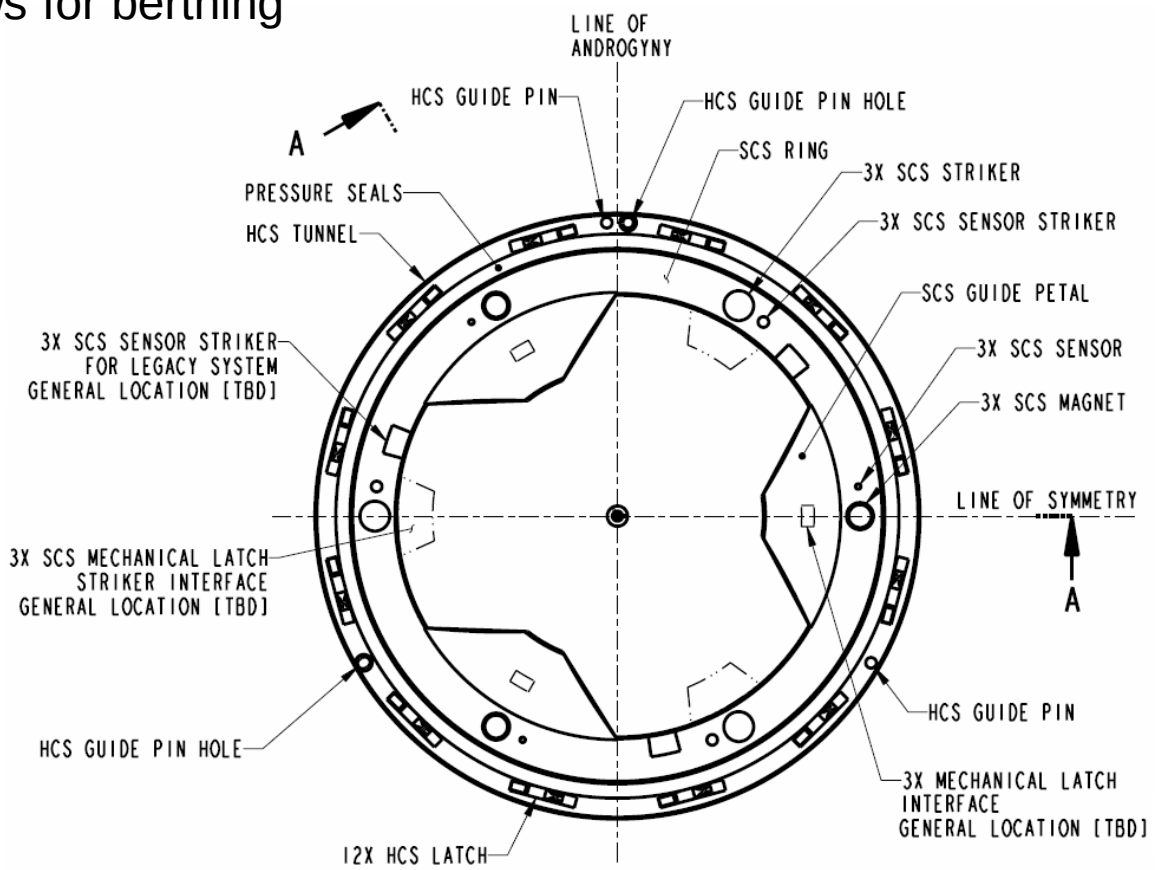
Hand-Push Demo

NASA Changes to the IDSS

- In 2009, the International Space Station (ISS) Multilateral Control Board (MCB) began an initiative to develop an International Docking System Standard (IDSS) to enable
  - Greater international cooperation in space
  - International crew rescue capability
- In February 2010, NASA made a policy decision to redesign the LIDS to the newly evolving IDSS, and to demonstrate its use by converting the docking ports on the ISS USOS into IDSS docking ports.
  - The LIDS project was transferred from the Constellation Program to the ISS, and became the International LIDS, or iLIDS
  - iLIDS was later renamed the NASA Docking System (NDS), and will be NASA's implementation of an IDSS compatible docking system for all future US vehicles
  - NDS will be compliant with the IDSS Interface Definition Document (IDD) http://www.internationaldockingstandard.com/

Overview of Features in the IDSS IDD Rev. A (1 of 2)

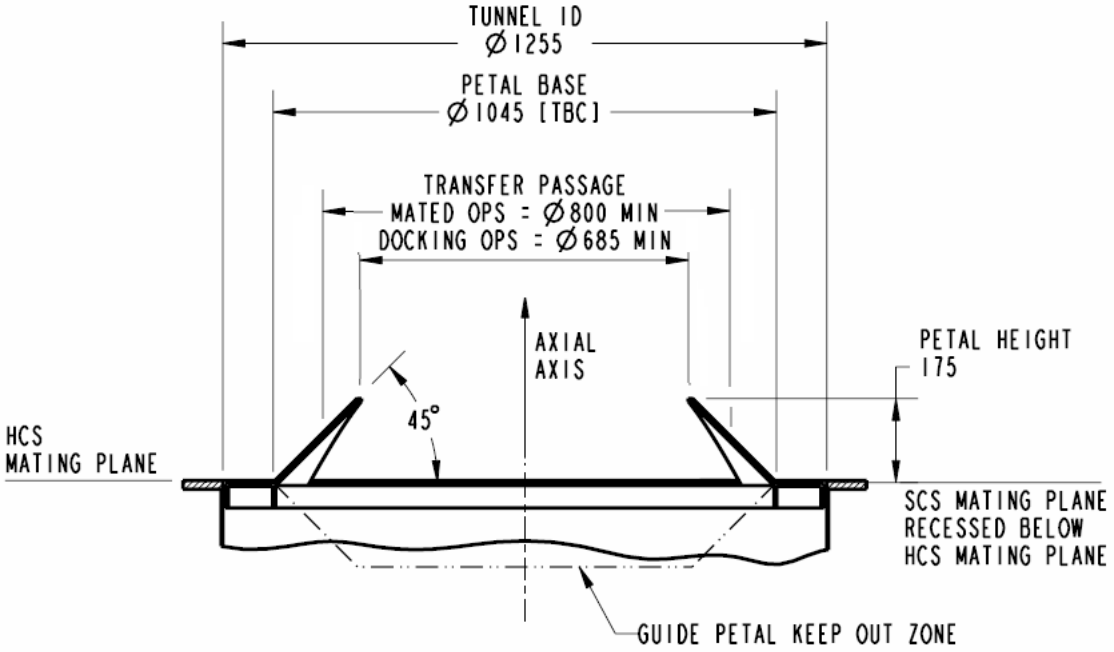
- The IDSS interface
  - Is androgynous (it can dock to duplicates of itself)
  - Is limited to interface geometry and loads only
  - Allows for berthing



View looking down at the Docking Interface (IDSS IDD Figure 3-1)

Overview of Features in the IDSS IDD Rev. A (2 of 2)

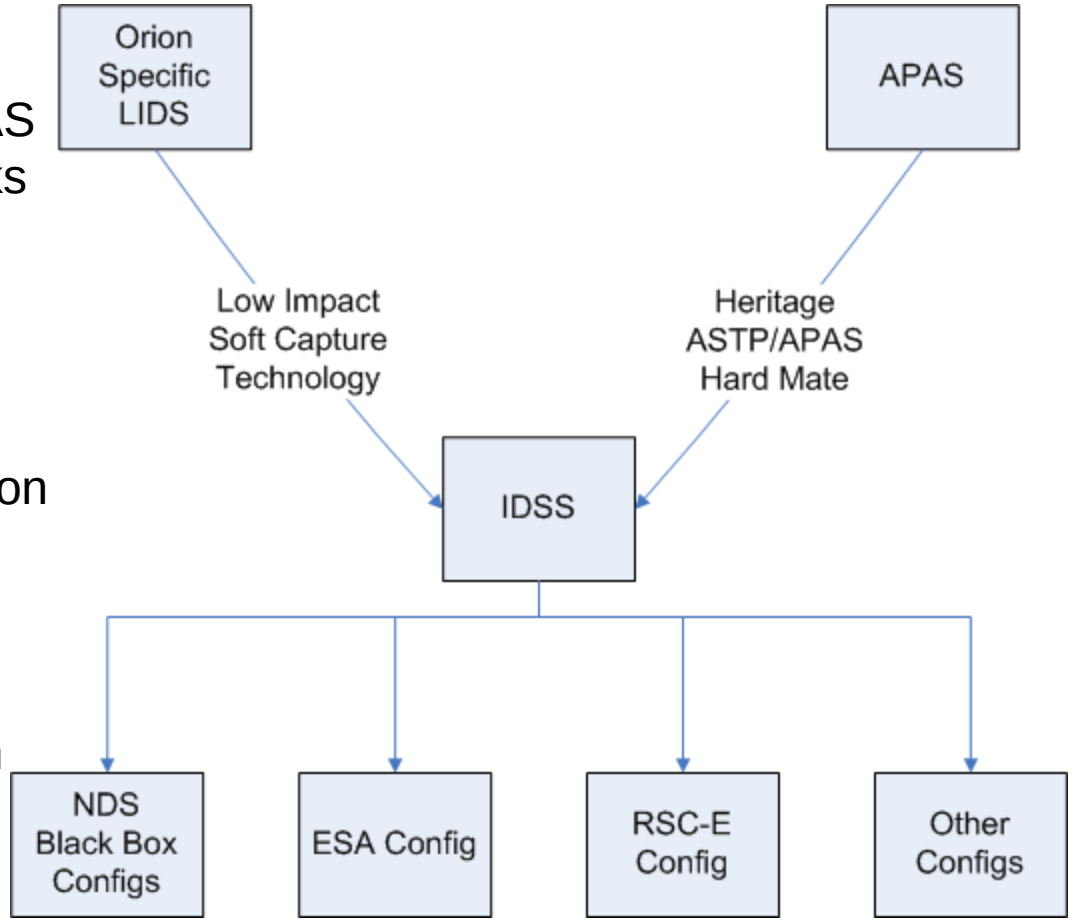
- The IDSS Soft Capture System (SCS)
  - Ring is wider than APAS; petals are removable for larger crew passageway
  - Must accommodate both magnetic and mechanical soft capture latches
- The IDSS Hard Capture System
  - Is nearly identical to the Russian APAS HCS
  - Requires that the push-off springs retract out of the way for docking
- Docking umbilicals are not yet defined in the standard.



Section A-A (IDSS IDD Figure 3-2)

Evolution from Constellation LIDS to NDS Black Box Configuration

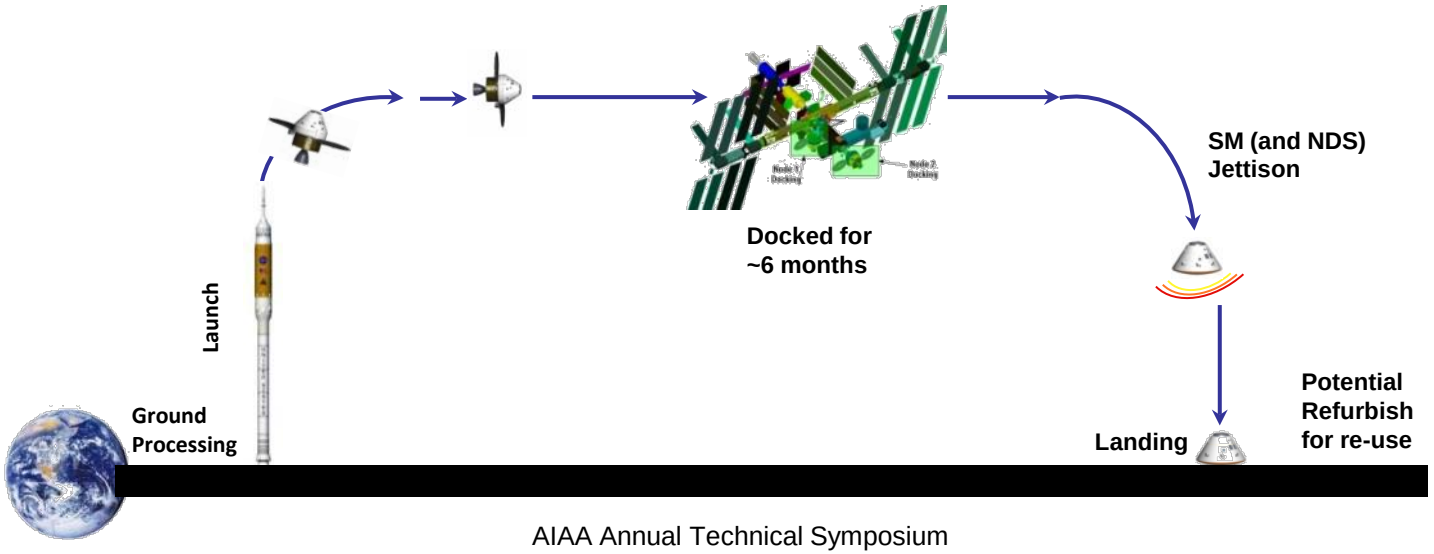
- Hard Capture System
  - From radial latches to APAS compatible tangential hooks
  - From internal custom fixed power/data connectors to external retractable FRAM type connectors
  - Added retractable separation system
- Soft Capture System
  - Diameter increased to fit in APAS compatible tunnel
  - Added scarring for mechanical latch striker



NDS Overview - Key Assumptions & Capabilities (1 of 2)

- Designed to handle jettison during ascent – Host Vehicle must provide severance and launch abort systems
- Host Vehicle responsible for all GN&C & relative navigation sensors
- Supports 210 day docked mission, 21 day free-flying mission
- If host provides environmental protection during re-entry and landing, system could be refurbished and re-used multiple times; host vehicles may also choose to jettison the NDS prior to re-entry

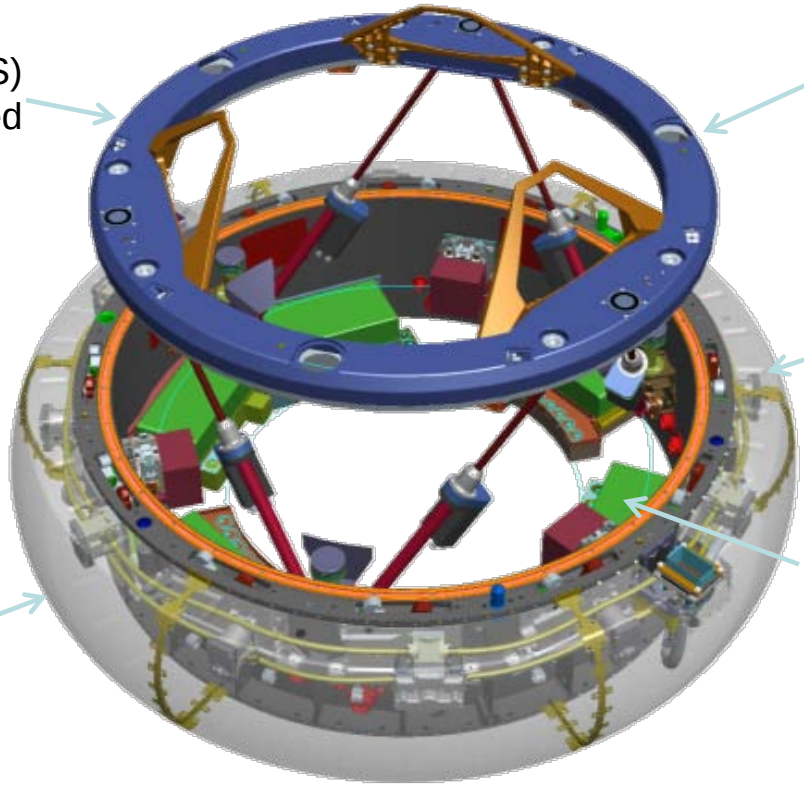
Typical ISS-type Low Earth Orbit Mission Profile



NDS Overview - Key Assumptions & Capabilities (2 of 2)

- NDS Functional Capabilities (Block 0)
  - Transfer Crew/cargo through 32” (813 mm) diameter with petals removed
    - 27” (685 mm) diameter with petals installed
  - Power and Data pass-through from ISS to Host Vehicle
    - Mechanized umbilicals engage connectors during docking sequence
  - Supports 2 Fault Tolerance (FT) through redundancy (meets ISS requirements)
    - Fault tolerance controls are shared with the host vehicle
  - Autonomous Internal Heater Control
  - Mechanized push off separation system
  - Micro-meteoroid/Orbital Debris (MMOD) Protection
  - IDSS compatible, accommodates APAS-like hard mate
  - Sensors indicating soft capture, ready-to-hook, hook position, and undocking complete
  - FDIR (Fault Detection Isolation and Recovery)
    - NDS controllers detect fault and notify vehicle
    - Vehicle performs switching function between systems

Systems Description – NDS Primary Sub-Systems



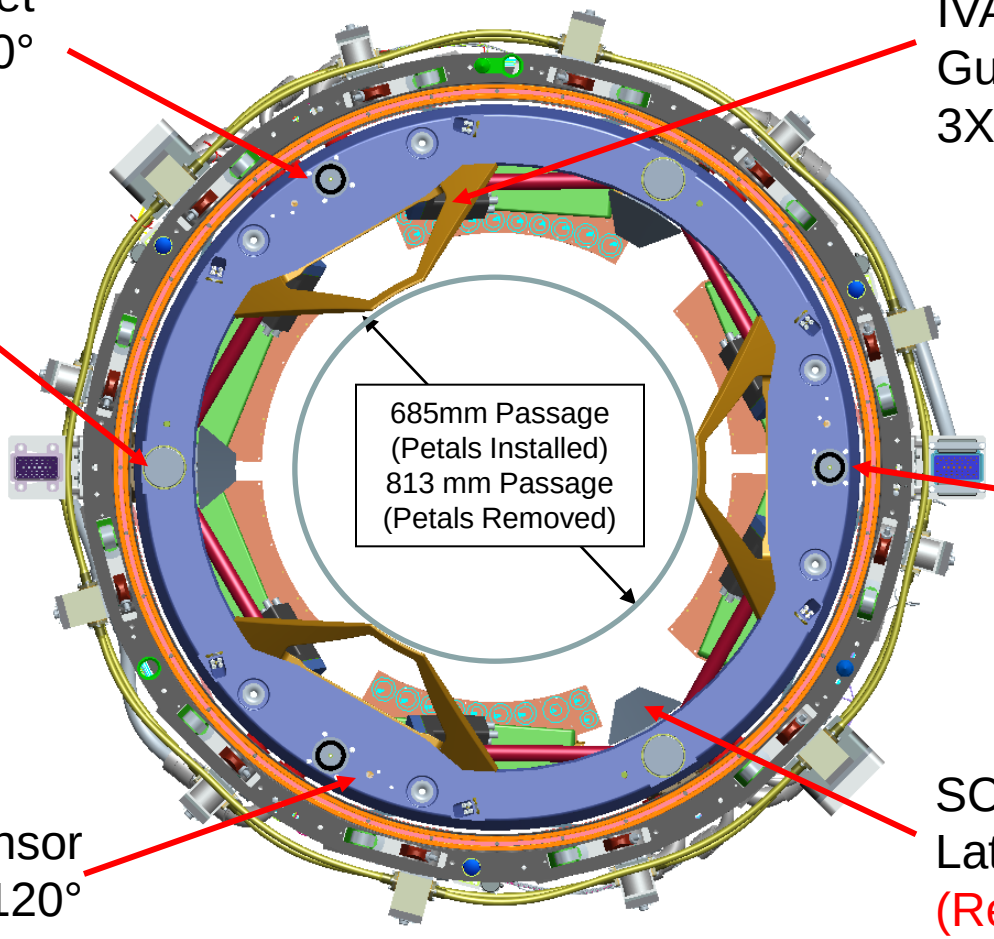
- Soft Capture System (SCS)
- Hard Capture System (HCS) including MMOD
- Electronics Boxes
- Communications via either TIA-422-B or MIL-STD-1553B
- Software

Hardware Overview – SCS Components

Magnet
3X @ 120°

IVA Removable
Guide Petals
3X @ 120°

Magnet Striker
3X @ 120°
(excluding -304)



SCS Lockdown
Located under
Magnet
3X @ 120°

SCS Capture Sensor
3X @ 120°

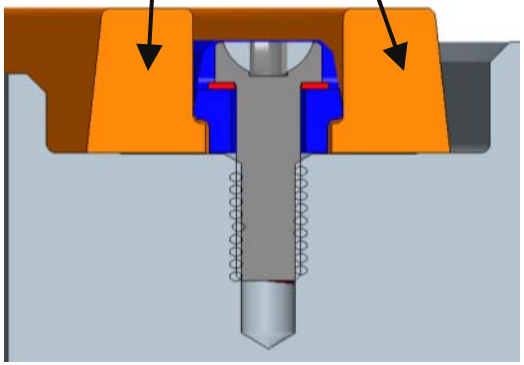
SCS Mechanical
Latch Striker
(Reserved volume
for future implementation)
3X @ 120°

Note: MMOD Shielding not shown for clarity

Hardware Overview – HCS Components

Guide Pin / Receptacle Pair

Redundant elastomer seal bulbs

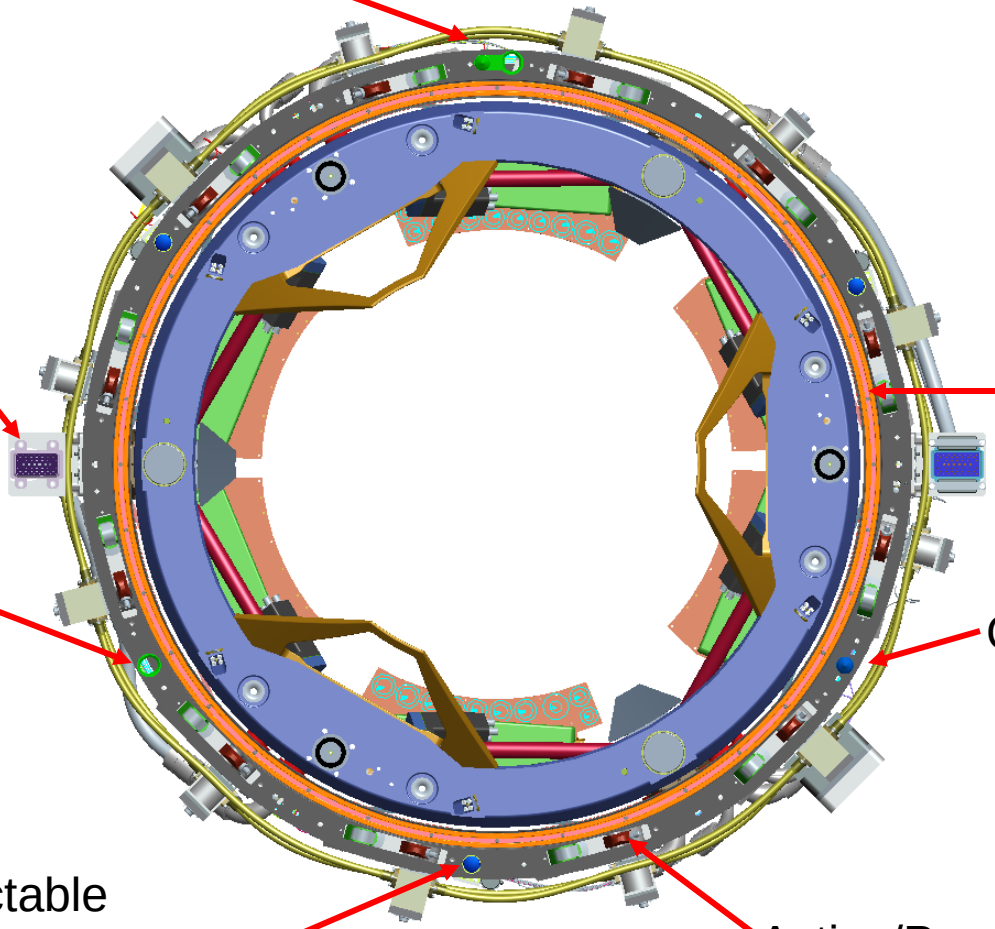


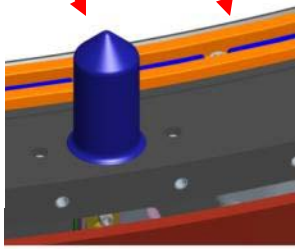
Retractable
Power/Data
Umbilical
2X @ 180°

Docking Seals

Guide Pin
Receptacle

Guide Pin





Retractable
Separator System
3X @ 120°

Active/Passive
Hook Pairs
12X @ 30°

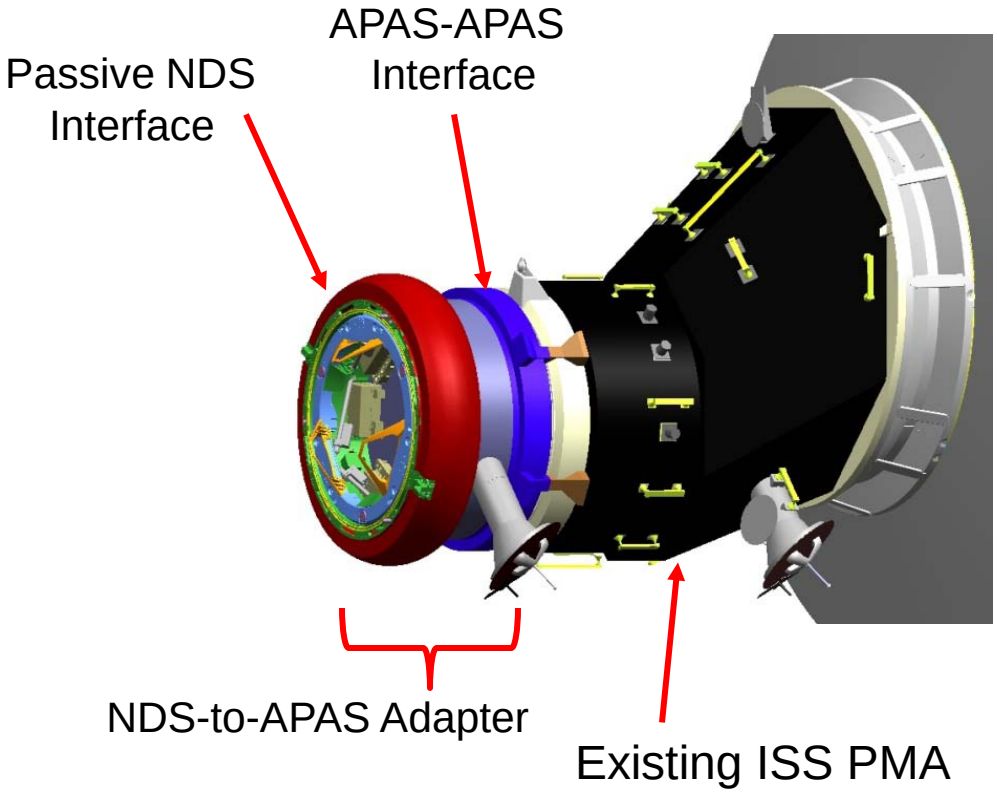
Note: MMOD shielding not shown for clarity

Docking Sequence

- Docking Sequence
  - Extend SCS
  - Host vehicle rendezvous
  - Guide petals make contact
    - Transfer contact/load inputs into the load sensing cells
  - Electromechanical actuators driven to correct lateral and angular misalignment to trip soft capture sensors
  - Energize magnets to complete soft capture
  - SCS attenuates the relative motion between the two vehicles
  - SCS then aligns the two mating vehicles
  - SCS retracts onto guide pins into hard capture range
  - 12 active hooks are driven closed
  - Spring-loaded separation system is energized (compressed)
  - Mechanized resource transfer umbilicals are extended and engaged
- Undocking Sequence
  - Power/Data Umbilicals are retracted
  - Active hooks are driven to release structural connection
  - Spring-loaded separation system pushes vehicles apart

ISS Implementation Plan

- For ISS missions, the Visiting Vehicle (VV) will carry an active NDS, and will dock to a passive NDS interface on ISS.
- ISS will create an IDSS-compatible docking interface adapter for the current Pressurized Mating Adapters (PMA's) Shuttle/APAS interface
  - Current planned locations:
    - Node 2 Forward
    - Node 2 Zenith
- Tentative Delivery/Integration Schedule
  - 1st adapter – late 2014
  - 2nd adapter – mid 2016



Next Steps for the IDSS and NDS

- IDSS IDD Rev A just approved by the ISS MCB
  - The IDD will be revised and matured as developers gain experience with their designs
  - Companion publications will be developed (e.g., docking system design best practices, IDSS-compliance certification process, etc.)

- NDS
  - Critical Design Review (CDR) just completed
    - Dynamics Simulation Results
  - First full Engineering Development Unit complete July 2012
  - NDS “black-box” (-301) configuration will be certified initially
    - Other configuration variants may be certified if needed
  - First certified flight unit delivered February 2014
  - Design will be made available to US companies through arrangements still being worked out by NASA HQ