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November 2010

# **NASA DOCKING SYSTEM (NDS) USERS GUIDE**

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**INTERNATIONAL SPACE STATION PROGRAM  
NASA DOCKING SYSTEM (NDS)  
USERS GUIDE**

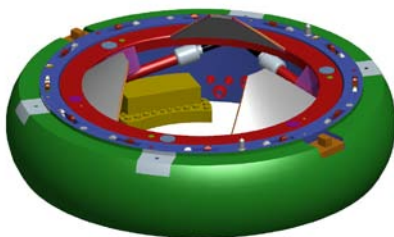
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**PREFACE**

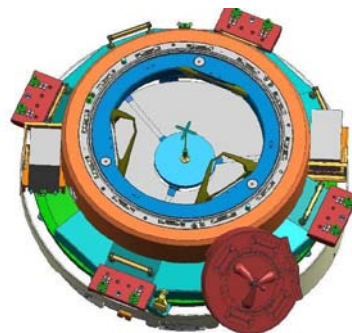
The NASA Docking System (NDS) Users Guide provides an overview of the basic information needed to integrate the NDS onto a Host Vehicle (HV). This Users Guide is intended to provide a vehicle developer with a fundamental understanding of the NDS technical and operations information to support their program and engineering integration planning. The Users Guide identifies the NDS Specification, Interface Definition or Requirement Documents that contain the complete technical details and requirements that a vehicle developer must use to design, develop and verify their systems will interface with NDS.

***This Guide is an initial reference and must not be used as a design document. In the event of conflict between this Users Guide and other applicable interface definition or requirements documents; the applicable document will take precedence.***

The NDS is the NASA implementation of an androgynous peripheral docking system, which can operate in either the active (chaser) or passive (target) vehicle role. The NDS is compliant with the International Docking System Standard (IDSS). The NDS can be installed on any two Host Vehicles to enable docking mission applications such as: International Space Station (ISS) cargo/crew transport, technology flight demonstration, on-orbit assembly and rescue operations.



NDS Conceptual Design



CDA Conceptual Design

The ISS Common Docking Adapter (CDA) element will be the first “host vehicle” that will be equipped with a NDS. The CDA will allow spacecraft properly equipped with the NDS to dock to the ISS and receive available station resources. The term Visiting Vehicle (VV) is used by the ISS Program for cargo/crew transport vehicles that typically berth/dock to the station for periods up to 210 days. The Users Guide may also use the term VV to describe a Host Vehicle, since ISS VVs are expected to be the initial users of the NDS.

***This Users Guide draft release is being written concurrently with NDS development. The information in this draft is subject to change as the NDS designs are finalized, certified and delivered.***

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**INTERNATIONAL SPACE STATION PROGRAM  
NASA DOCKING SYSTEM (NDS)  
USERS GUIDE**

**CONCURRENCE**

**NOVEMBER 2010**

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**INTERNATIONAL SPACE STATION PROGRAM  
NASA DOCKING SYSTEM (NDS)  
USERS GUIDE**

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## 1.0 INTRODUCTION

### 1.1 PURPOSE AND SCOPE

The NASA Docking System (NDS) Users Guide provides an overview of the basic information needed to integrate the NDS onto a Host Vehicle (HV) and dock to the Common Docking Adapter (CDA) on the International Space Station (ISS) or another NDS equipped spacecraft. This Users Guide is intended to provide a vehicle developer with a fundamental understanding of the NDS technical and operations information to support their program and engineering integration planning. The Users Guide defines the NDS Specification, Interface Definition or Requirement Documents that contain the complete technical details and requirements that a vehicle developer must use to design, develop and verify their systems will interface with NDS.

**This Guide is an initial reference and must not be used as a design document. In the event of conflict between this Users Guide and other applicable interface definition or requirements documents; the applicable document will take precedence.**

This Users Guide is organized in three main sections. Chapter 1 provides an overview of the NDS and CDA hardware and the operations concepts for the NDS. Chapter 2 provides information for Host Vehicle Program integration with the NDS Project Office. Chapter 2 describes the NDS Project organization, integration and verification processes, user responsibilities, and specification and interface requirement documents. Chapter 3 provides a summary of basic technical information for the NDS design. Chapter 3 includes NDS hardware component descriptions, physical size and weight characteristics, and summary of the capabilities and constraints for the various NDS sub-systems.

### 1.2 NDS OVERVIEW

The NDS is the NASA implementation of an androgynous peripheral docking system that complies with the new International Docking System Standard (IDSS). The NDS can function as either an active docking system (active mode) when it is on the “chaser” vehicle, or a passive docking system (passive mode) when it is on the “target” vehicle.

The NDS Project is presently developing several configuration variants of the NDS assembly. The NDS product structure and potential applications are shown in Table 1.2-1. The NDS -301 is the core configuration, with 120 VDC avionic boxes installed inside the pressure tunnel section. The NDS -302 variant has same functionality as the NDS -301 configuration, but has a shorter tunnel section that needs the avionic boxes to be installed inside the host vehicle. The NDS-302 configuration is optimized for the CDA element application. While the NDS-302 assembly is capable of active-mode operation, it will initially be certified only for passive-mode operations. The NDS -303 variant is identical to the NDS -301 configuration, but with 28 VDC avionics boxes. The NDS -304 variant is also similar to the NDS -301 configuration, but with less docking functionality and the associated components removed to minimize the assembly weight. Additional details on the differences between the NDS configurations is provided in Section 3 and summarized in Table 3.13-1.



The NDS -301 and -303 configurations are the fully androgynous: the NDS -301 can dock with another -301; the NDS -303 can dock with another -303; and the NDS -301 and -302 configurations can dock with each other. The NDS -301, -303 and -304 in active-mode can also dock to the NDS -302 in passive-mode. However, there are several NDS configuration variants and modes that are not compatible for docking operations, as shown in Table 3.1.1-1.

The NDS Block 0 development includes the -301, -302, -303 and -304 configurations, which only have power and data external pass-thru umbilical connections. The NDS -301 and -302 versions are the standard configurations that are fully flight certified and routinely produced. The NDS -303 and -304 versions are optional configurations that are Available On Request (AOR) by a host vehicle project. Future NDS block upgrades may incorporate fluid (water & propellants) external pass-thru umbilical connections and may certify the NDS for berthing operations.

**TABLE 1.2-1 NDS PRODUCT STRUCTURE**

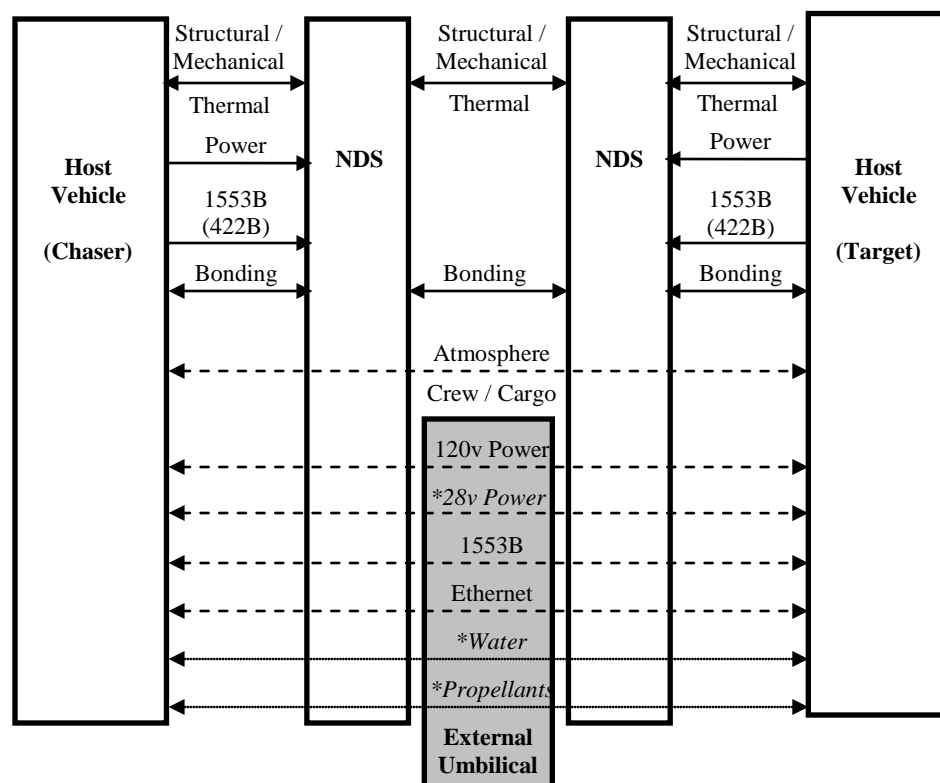
<b>NDS Product Structure</b>					
<b>NDS Project</b>					
<b>Development Phase</b>	<b>Block 0</b>				<b>Future Blocks</b>
Configuration	-301	-302	-303	-304	-TBD
<b>Host Vehicle Applications</b>					
ISS Docking Elements – CDA	-	X	-	-	-
ISS Visiting Vehicles (VV)	X	-	AOR	AOR	-
Space Exploration / Technology Demo Projects	X	X	AOR	AOR	Future

The NASA Docking System is designed to support a wide variety of space vehicle applications. The vehicle, on which the NDS assembly is installed, is called the “Host Vehicle.” The initial Host Vehicle applications of the NDS are expected to be on the CDA element and on the ISS Visiting Vehicles (VVs) to allow them to dock to the station at the CDA. So this Users Guide may occasionally use the terms “host vehicle” and “visiting vehicle” interchangeably.

Figure 1.2-1 shows the generic end-to-end functional interfaces that are provided by the mated NDS assembly. These end-to-end functional interface capabilities include:

- Structural / Mechanical
  - Soft Capture System (SCS)
  - Hard Capture System (HCS)
  - Resettable separation “push-off” spring mechanism
  - Mounting Flange and Pressure Seals
  - Pyrotechnic Bolt (Contingency Hook Release on NDS -301/303)
- Power Supply Connections to Host Vehicle Electrical Power System (EPS)
- MIL-STD-1553B (or TIA-422B) Connections to Host Vehicle Computer and Data Handling (C&DH) System
- System Status and Health Indications

- Active and Passive Thermal Conditioning
- Docking and Undocking Status Sensing
- Electrical Bonding
- Atmosphere Pressurization and Inter-module/vehicle Circulation
- Crew and Cargo Inter-Vehicular Activity (IVA) Translation Path
- External Umbilicals / Mated Vehicle Resource Exchange
  - EPS 120 VDC Power (2 independent channels/circuits)
  - *\*EPS 28 VDC Power (ISS/CDA future capability)*
  - C&DH MIL-STD-1553B system (2 independent buses)
  - C&DH 10/100 Base TX Ethernet system (2 independent buses)
  - *\*Water Supply and Return (Future Block capability)*
  - *\*Propellant, Oxidizer, and Pressurant (Future Block capability)*
- Ground Support Equipment (GSE) Interfaces (Structural, Mechanical, EPS and C&DH)



**FIGURE 1.2-1 MATED NDS END-TO-END FUNCTIONAL INTERFACES**

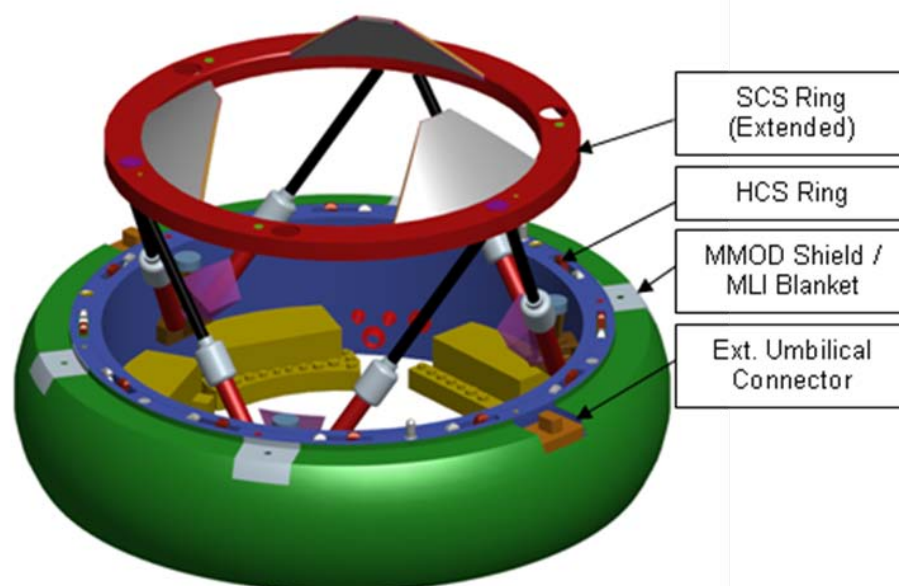
In Figure 1.2-1, the solid lines represent the functional interfaces between NDS and the Host Vehicle; while the dashed lines represent the functional interfaces for the “pass-through” utilities (resources) that can be exchanged between the mated vehicles. Additional information on the capability and constraints of the NDS sub-system interfaces and functions is provided in later sections of the Users Guide.

**NDS Assembly Summary.** The NDS assembly is comprised of six main components:

- Soft Capture System (SCS)
- Hard Capture System (HCS)
- Pressure tunnel and mounting flange structures
- Avionic controller and power supply boxes
- External umbilical connectors
- Passive Multi-layer Insulation (MLI) blanket and active heater thermal control system
- Micrometeoroid/Orbital Debris (MMOD) shield

The SCS and HCS comprise the docking interfaces on the mating plane of the NDS assembly. The mounting flange is opposite of the mating plane of the NDS assembly and provides the structural interface and pressure seal with the host vehicle pressure tunnel.

Figure 1.2-3 illustrates the SCS and HCS docking interfaces for the NDS assembly. SCS inner capture ring in the extended position is illustrated in the center (red shaded) area. The SCS is comprised of the soft capture ring, docking petals, capture magnets and striker plates, soft docking status sensors and electro-mechanical actuators. The soft capture ring on the chaser vehicle is extended above the hard capture interface plane by the electro-mechanical actuators that also provide the “low-impact” capability to reduce the interface loads during initial contact and capture events with the NDS on the “target” vehicle. The HCS outer mating ring and pressure seal area is illustrated in the middle (blue shaded) area. The HCS components include: the hard capture ring structural mating surface and pressure seals, alignment pins, 12 tangential engagement hook pairs, the hook engagement drive mechanisms, separation springs and hard docking status sensors. The outer (green shaded) area contains the external “pass-thru” umbilical connectors, the MMOD shield and passive thermal MLI blankets.



**FIGURE 1.2-3 NDS WITH SCS RING EXTENDED (CONCEPTUAL DESIGN)**

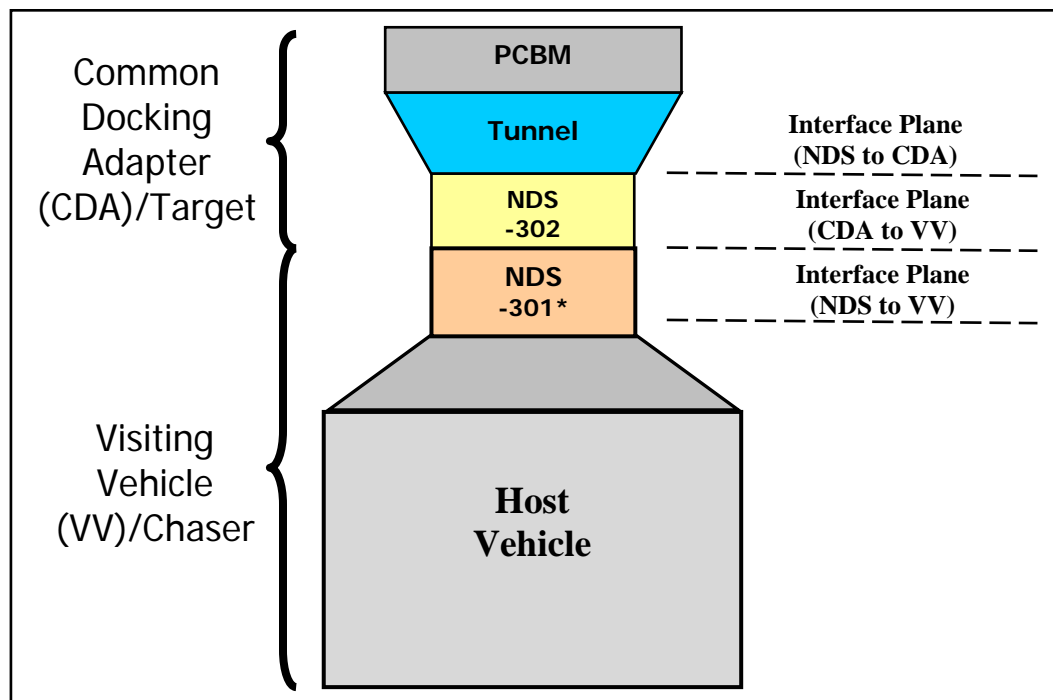
The fully androgynous NDS (-301 and -303) assembly may be installed on any two spacecraft to allow them to dock together. The fully androgynous NDS configurations can be designated as either the “active” or the “passive” interface for docking operations. When the NDS is in the passive-mode on the target vehicle, the SCS and HCS interfaces remain passive. When the NDS is in the active-mode on the maneuvering chaser vehicle, the SCS is deployed and performs the soft capture functions. Likewise, the active-hooks on the NDS that operates in the active-mode, will engage the passive-hooks on the opposing target vehicle.

The fully androgynous NDS in passive-mode also has a functional HCS, which can provide a contingency capability to complete hard capture in the event the active-hooks in the active-mode NDS on the chaser vehicle fail to engage the passive-hooks in the target vehicle. When desired, the HCS functionality in the passive-NDS assembly can also provide additional structural capability. Nominally, only the 12 active hooks in the active-mode NDS are engaged on the 12 passive hooks on the opposing passive-NDS to provide structural integrity for mated operations. However when enabled, the 12 active hooks on the opposing passive-mode NDS can also engage the 12 passive-hooks in the active-mode NDS on the docking chaser vehicle -- to provide increased structural integrity from a total of 24 engaged hooks. (Note, the -302 configuration is not certified for active-mode functionality, which is necessary for the contingency hook-engagement capability).

For additional technical information on the NDS subsystems and interface design, please refer to Chapter 3.

**CDA Element NDS -302 Application.** The CDA element is being developed by the NDS Project Office within the ISS Program. The CDA element is equipped with the NDS -302 assembly and mates to the ISS with the Passive Common Berthing Mechanism (PCBM). The NDS should achieve Initial Operational Capability in the year 2014, when the first CDA flight article will replace one of the Pressurized Mating Adapter (PMA) docking ports that are currently on the ISS. Visiting vehicles that are properly equipped with a NDS assembly (or another IDSS-compatible docking system) will then be able to dock to the ISS and receive available power and data resources.

Figure1.2-2 shows the basic NDS and CDA configuration architecture and interface plane with an ISS Visiting Vehicle. The soft and hard capture interfaces between the NDS -302 installed on CDA element (target) and the NDS -301\* assembly installed on the visiting vehicle (chaser) comply with JSC 65795, NDS Interface Definition Document (IDD). When NDS hard capture is complete, the docking system is in the “hard mate” configuration. (\*Note: a host/visiting vehicle equipped with a NDS -303 or -304 assembly can also dock to the CDA/NDS -302 interface).



**FIGURE 1.2-2 NDS TO VV AND CDA INTERFACE CONFIGURATION**

For additional technical information on CDA element and ISS integration please refer to SSP 50808, ISS to COTS IRD.

### 1.3 OPERATIONS CONCEPT

The NASA Docking Systems operations concept for Rendezvous, Proximity Operations, Docking and Undocking (RPODU) activities are very similar to the requirements, procedures and flight rules that are currently established for the Space Shuttle docking to the ISS with the Androgynous Peripheral Attachment System (APAS) interface that is currently installed on the PMA. The NDS low-impact docking systems capability will enhance the current ISS RPODU operations concept by reducing the docking interface loads generated by the VV during the initial contact and capture phase.

The operations concept for the NDS assembly is for multi-mission use. The NDS is designed to re-usable, within the constraints of the supplied environmental parameters. Post mission refurbishment and Acceptance Testing will be required in order to assure integrity for mission success. Optionally, the NDS assembly can be jettisoned from a recoverable vehicle prior to re-entry to improve clearance for parachute deployment and reduce landing weight – or for an expendable vehicle is destroyed during vehicle re-entry. A recoverable vehicle that plans to land with the NDS still attached will require vehicle specific aero, stability, loads and thermal analyses to verify the re-entry/landing loads and thermal environment do not exceed the NDS capabilities.

Appendix D provides an outline summary of the NDS operations concept scenarios.

## 2.0 NDS INTEGRATION

Section 2 provides an overview of the NDS Project (NDSP) Office organization, NDS standard products and services, and the generic NDS integration analysis, test responsibilities, and associated integration cycle timeline for host/visiting vehicle integration with the NDS docking system assembly. The NDS Project integration process with the specific Host Vehicle (HV) Project will be described in the appropriate Memorandum of Understanding (MOU), Space Act Agreements (SAA) or Protocol, with further detail in an NDS Integration Agreement (NIA). A typical NDS MOU example and the NIA template will be provided (TBS -when available) for reference in the NDS Project Library.

## 2.1 NDS PROJECT ORGANIZATION

The NDSP Office is housed within the NASA ISS Program Organization as shown in Figure 2.1-1.

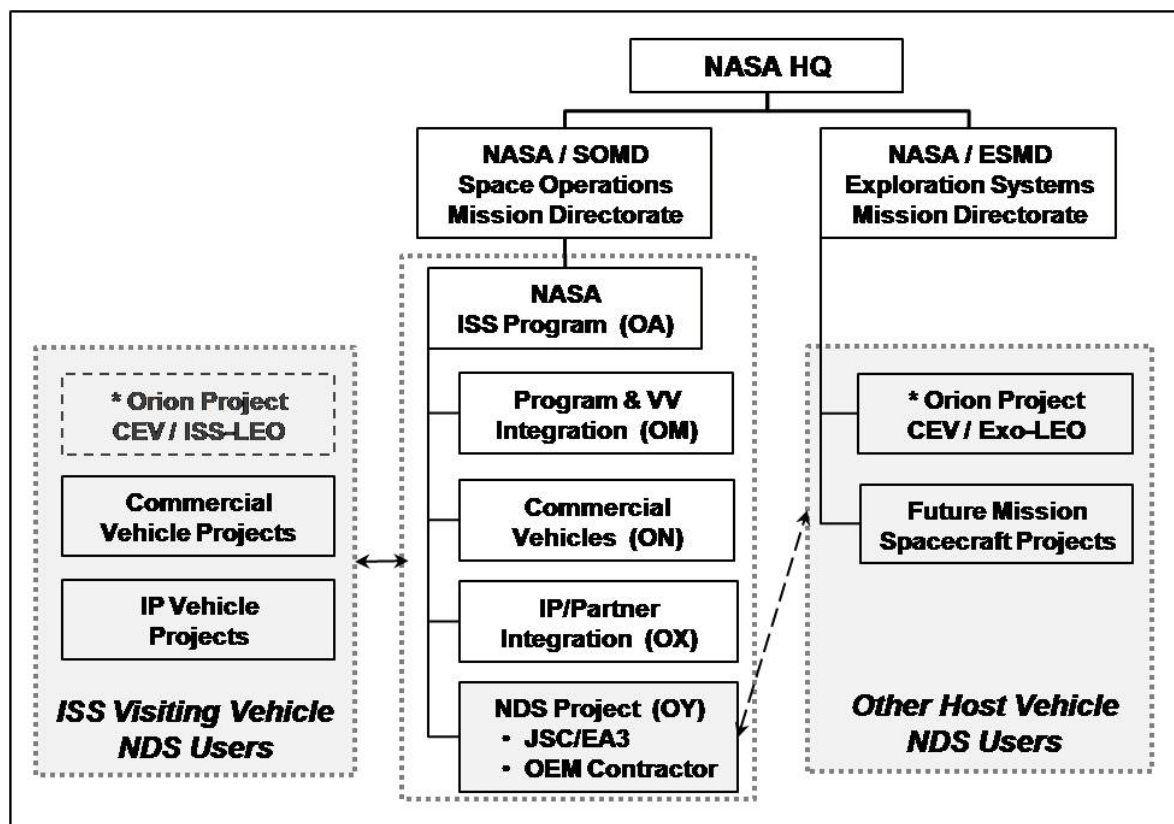


FIGURE 2.1-1 NDS PROJECT ORGANIZATION CHART

The NDSP Office is responsible for system management, engineering, development, manufacturing and sustainment for all of the NASA Docking System hardware and software end-item products. The NDSP Office is directly supported by the JSC Engineering Directorate (JSC/EA3) and the Original Equipment Manufacturer (OEM) contractor. JSC/EA3 Systems Architecture & Integration Office is the engineering authority for the NDS assembly hardware



and software components. The OEM contractor is responsible for recurring production, acceptance test, delivery and logistics support for the NDS end-items.

The NDS Project has the leadership of all technical integration tasks that involve NDS installation, qualification and certification with the host/visiting vehicle. Potential NDS Users should establish contact with the Space Operations Mission Directorate (SOMD), who will assign an appropriate point of contact based on the stated mission. The NDSP will support SOMD in the development of agreements on support services related to the NDS. The NDSP facilitates coordination on the MOU, SAA or Protocol with the Host/Visiting Vehicle Project that defines the top-level NDS use agreements, in partnership with the assigned SOMD lead. After the MOU is completed, the NDSP Office leads the development of the detailed NIA for host vehicle.

### **NDS Project Key Positions**

The NDSP Office provides both project and technical integration support to the NDS User. The NDSP Office typically assigns a dedicated Point of Contact (POC) to support a new Host Vehicle Project through the entire NDS integration cycle for their first Flight Vehicle, and to handle routine questions and requests. The NDS Project Manager or Representative resolves project/non-technical issues (integrated schedule, budget, resource conflict, etc.) that may arise with the host vehicle project. The NDS SE&I Manager resolves technical issues (interface problems, technical expert support, etc) that may arise with the host vehicle project during design, integration or testing.

## **2.2 NDS STANDARD PRODUCTS AND SERVICES**

The NDS Project offers a range of standard products and services to the Host/Visiting Vehicle Project. The NIA will define the specific product and services with corresponding integration milestone date commitments that are to be provided to and from the Host Vehicle Project. For Host Vehicles that are International Projects (not a United State Project), Export Control restrictions and procedures will apply as defined in the appropriate MOU, or Agreement/Protocol and approved by the regulating US Government Agency.

**NDS Provisioning.** The current means to obtain NDS products is by Government Furnished Equipment (GFE) transfer to the Host Vehicle Project organization. Funding transfer requirements are normally specified in the specific Host Vehicle agreement/protocol. As design availability matures, Host Vehicle Projects will have the option to contract with the OEM, as well as to build to print from the NASA supplied fabrication documents.

**NDS Product Catalog.** The standard NDS end-items products are shown in Table 2.2-1. The NDS Project does not plan to support custom modification of the standard NDS product configurations that are listed in Table 2.2-1. The different capabilities in the various standard NDS configurations are described in Section 3 and summarized in Table 3-13-1.

TABLE 2.2-1 CATALOG OF NDS STANDARD PRODUCTS

Product Use	Product Name / Part Number	Comments
<b>Flight Equipment (FE) NDS Block 0</b>		
	P/N: SEZ29101800-301	Core configuration
	P/N: SEZ29101800-302	Optimized for CDA element application
	P/N: SEZ29101800-303	28 VDC Avionics - Available On Request (AOR)
	P/N: SEZ29101800-304	Reduced Functionality/Weight - AOR
<b>Ground Support Equipment (GSE)</b>		
	TBD – GSE Item (P/N: TBD)	<i>GSE items are TBD. Following are examples.</i>
	TBD – Ground Handling Fixture (P/N: TBD)	<i>TBD. (Supports Host Vehicle integration/assembly support?)</i>
	TBD – Alignment Tool (P/N: TBD)	<i>TBD. (Supports Installed NDS alignment/calibration?)</i>
	TBD – Shipping Container(s) (P/N: TBD)	<i>TBD. (Supports Flight H/W shipping to Host Vehicle facility?)</i>
	TBD – Other GSE Item (P/N: TBD)	<i>TBD</i>
<b>Test Support Equipment (TSE)</b>		
	TBD – TSE Item (P/N: TBD)	<i>TSE items are TBD. Following are examples.</i>
	TBD – NDS S/W Test Tool(s) (P/N: TBD)	<i>TBD (NDS emulator, Flt S/W interface test device, etc?)</i>
	TBD – Form-Fit-Function Mock-up (P/N: TBD)	<i>TBD (Support Host Vehicle developmental testing?)</i>
	TBD – Master Verification Tool (P/N: TBD)	<i>TBD (NDS interface certified for C/O test with other NDS/IDSS compliant flt H/W?)</i>
	TBD – Other TSE (P/N: TBD)	<i>TBD</i>

**NDS Facilities.** The NDSP Office does not directly manage any NASA integration or test facilities, but does coordinate the use of NASA facilities as documented in the NIA. The Host/Visiting Vehicle Project normally provides the facilities needed for NDS integration and testing with the host vehicle. The NIA defines all the NASA facilities that are scheduled to be used by the NDS User during host vehicle integration and test activities.

NDS avionics are delivered to the Host vehicle Project pre-tested and in a flight-ready configuration. However, the Host Vehicle Project master integration schedules should allow for updates to critical NDS software/firmware configuration items.

**NDS Technical Document Library.** The primary technical documents that define the NDS interface requirements and technical specifications are shown in Figure 2.2-1. These primary NDS technical documents include:

- JSC 65795, NDS Interface Definition Document (IDD)
- JSC 63868, NDS Project Technical Requirements Specification

These NDS technical documents form the basis for the specific Interface Control Documents for Host/Visiting Vehicle to NDS interface requirements. These technical documents -- along with



all the applicable documents that they specify -- are available in the NDS Technical Document Library. The NDS Technical Document Library is described in Appendix C, which also contains the URL/Hyperlinks (TBS) to the database where electronic copies of these documents are maintained. (Note, the NDS Project web-page (TBS – when eventually implemented) will also include the Technical Document List with URL links).

The NDS Technical Documents are stored on the ISS Program Electronic Data Management System (EDMS). EDMS is restricted access and requires a password. The NDS User is provided with an EDMS access after the MOU or other appropriate document is signed.

Additional documents will be applicable for specific Host Vehicle missions, such as docking to the ISS.

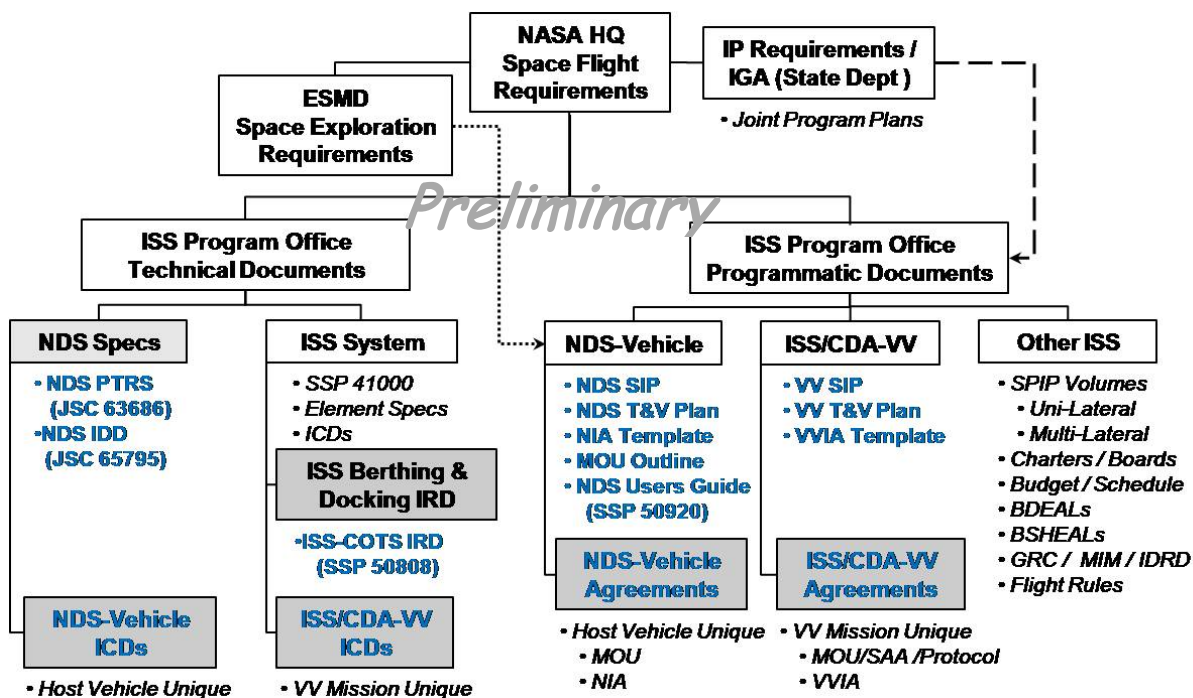


FIGURE 2.2-1 NDS DOCUMENT TREE

**NDS Technical Data and Models.** The NDS User is provided with the technical data and analytical models that are needed for their host vehicle design, analysis, integration, and verification efforts. The NDS technical data and format is shown in Table 2.2-2.

TABLE 2.2-2 CATALOG OF NDS STANDARD PRODUCTS

Technical Data Item	Format	Notes
Assembly Drawings • -301 & -302	TBD	Available NET CDR
CAD Model • -301 & -302	PTC Pro-ENGINEER (Pro-E) Wildfire 4.0	Simplified volumetric models currently available. Final model NET CDR

Finite Element Models • -301 & -302	TBD (NASTRAN & CB?)	<i>Initially available NET CDR</i>
Thermal Model • -301 & -302	TBD	<i>Initially available NET CDR</i>
Verification Analysis and Qualification Test Reports • -301 & -302	PDF Document	<i>Available NET TBD</i>
Acceptance Data Package	PDF Docs / CD Disk	<i>Provided with the delivered flight end-item / serial#</i>
Standard Procedures • -301 & -302	PDF Document	<i>Installation and check-out test procedures</i>

These technical data items are under configuration/data management, with most of the baseline released versions stored on EDMS (TBC). Table 2.2-2 provides the URL/Hyperlinks to the technical data files stored on EDMS. The Acceptance Data Packages for the delivered flight article/serial number is not stored on EDMS, but can be provided on a CD disk when requested.

**NDS Technical Expert Support.** Technical Experts are available to support questions or resolution of technical issues that may arise during the NDS User host vehicle design, analysis, integration, and verification efforts. The NDS User can request technical expert support through the NDS SE&I manager or the NDS POC (when assigned).

## 2.3 NDS INTEGRATION ANALYSES AND TESTS

NDS analytical integration with a new host/visiting vehicle involves a nominal set of design and verification analysis and tests to ensure all NDS interface requirements are properly satisfied for mission success and safety. The Host Vehicle Project is typically responsible for most of the generic NDS analysis and test tasks that are described in the following paragraphs and summary tables. The NDS Project is responsible for certain analyses and supports the NDS User in their NDS analysis and test tasks. The specific NDS integration analysis and testing plans with the associated milestone dates and responsibilities are defined in the NIA.

The complete set of NDS analyses and tests are needed for qualification/design certification with the host/visiting vehicle first flight article. Only a sub-set of these NDS integration analyses and tests is needed for acceptance and flight readiness certification on subsequent vehicle flights. Additional information on the standard NDS analyses and test is contained in the TBD, NDS-Host Vehicle System Integration Plan.

**NDS Integration Analyses.** The generic NDS integration analyses and task responsibility are shown in Tables 2.3-1. These generic NDS integration analyses are representative and should be considered as preliminary until finalized in the NIA. (Note, these analysis tasks do not include the initial verification analyses accomplished by the NDS Project to certify the NDS designs satisfy their respective interface, functional and performance requirements).

A synopsis of the significant NDS Integration Analysis follows:

- **Docking Capture and Loads Analysis.** The NDSP Office performs a capture analysis to verify the host vehicle final approach and initial contact conditions will provide the capture performance required by the mating vehicles. This analysis also recovers the resultant attenuation loads and vehicle motion to verify the docking/capture loads are within the structural load limits and physical constraints of both the NDS and host

vehicle. The host vehicle project supports this analysis by providing the FEM for docking vehicle configuration, mass properties for the Design Reference Missions (DRMs), and G&NC initial contact conditions with statistical deviations.

- NDS Integration Analysis. TBS...to be provided in later draft User Guide revision.
- Other NDS Integration Analyses. TBS...to be provided in later User Guide revision.

**NDS Integration Testing.** The generic NDS integration tests and task responsibility are shown in Table 2.3-2, NDS Integration Testing. These generic NDS Integration Tests are representative and should be considered as preliminary until finalized in the NIA. (Note, these test tasks do not include the initial verification analyses accomplished by the NDS Project to certify the NDS designs satisfy their respective interface, functional and performance requirements).

A synopsis of the significant NDS Integration Tests follows:

- NDS Integration Test. TBS...to be provided in later draft User Guide revision.
- Other NDS Integration Tests. TBS...to be provided in later User Guide revision.

**Master Verification Plan.** The Host/Visiting Vehicle Project is responsible for developing a Master Verification Plan (MVP) and coordinating vehicle-NDS verification plan with the NDSP Office. The NDS Project Office supports the development of the MVP and can provide a MVP template (TBC) to assist the NDS User in MVP preparation. The MVP document content is TBD.

**TABLE 2.3-1 GENERIC NDS INTEGRATION ANALYSES**

Analysis Task	Responsibility	Notes
Vehicle-NDS Thermal <ul style="list-style-type: none"> <li>• Ground</li> <li>• Ascent &amp; On-Orbit</li> <li>• RPODU</li> </ul>	NDS User	Verify host/launch vehicle with planned on-orbit trajectory/beta angles meet NDS temperature limits
Vehicle-NDS Loads <ul style="list-style-type: none"> <li>• Ground / LV Operations</li> <li>• Lift-off &amp; Ascent</li> <li>• Landing Recovery (As Needed)</li> </ul>	NDS User	Verify host/launch vehicle meet the NDS structural load limits
Vehicle-NDS Docking Capture Performance and Loads	NDS Project	Verify host vehicle approach/contact parameters meet NDS structural load limits
Vehicle-NDS Environments <ul style="list-style-type: none"> <li>• Ground / LV Operations</li> <li>• Lift-off &amp; Ascent</li> <li>• Landing Recovery (As Needed)</li> <li>• Abort (As Needed)</li> </ul>	NDS User	Verify host/launch vehicle meet the NDS vibro-acoustic limits
Vehicle-NDS mounting fastener	NDS User	Verify NDS fastened to host vehicle

torque assessment		mounting flange with required bolt torque
Vehicle Stress, Fracture and Fatigue Analysis	NDS User	Verify host vehicle structures has adequate margin of safety for worst case loads, fracture and fatigue spectrum
Vehicle-NDS EPS I/F Compatibility Assessment	NDS User	Verify host vehicle EPS complies with NDS electrical power interface rqmts
Vehicle-NDS C&DH I/F Compatibility Assessment	NDS User	Verify host vehicle C&DH complies with NDS C&DH I/F rqmts
Vehicle-NDS ACS I/F Compatibility Assessment	NDS User	Verify host vehicle atmospheric pres/depress rates within the NDS limits
Vehicle-NDS MMOD Analysis • Free-flight	NDS Project	Verify host vehicle mission parameters satisfy NDS MMOD safety limits
Vehicle-NDS Other Analyses -- TBD	NDS User / NDS Project	TBD (MMOD free-flight & docked analyses, etc.)

Note, the ISS VV analyses that are needed to verify the VV systems comply with the ISS docked/mated interface requirements are defined in SSP 50808, ISS to COTS IRD.

**TABLE 2.3-2 GENERIC NDS INTEGRATION TESTING**

Test Task	Responsibility	Notes
TBS Test • TBS	NDS User	Verify host/launch vehicle ..tbs
TBS Test • TBS	NDS User	Verify host/launch vehicle ..tbs
TBS Test • TBS	NDS User	Verify host/launch vehicle ..tbs
TBS Test • TBS	NDS User	Verify host/launch vehicle ..tbs
TBS Test • TBS	NDS User / NDS Project	Verify host/launch vehicle ..tbs

Note, the ISS VV tests that are needed to verify the VV systems comply with the ISS docked/mated interface requirements are defined in SSP 50808, ISS to COTS IRD.

## 2.4 NDS INTEGRATION CYCLE TIMELINE

The template for NDS integration cycle timeline with key milestones and associated integration event products is shown in Table 2.4-1, NDS Integration Cycle Timeline Template.

**TABLE 2.4-1 NDS INTEGRATION CYCLE TIMELINE TEMPLATE**

Typical Time	Event Timeline		
	Project Integration	Analytical Integration	Physical Integration
L-36+ Months	Initial NDS User Contact		
L-36 Months	Kickoff • MOU Signed • Integration POC Assigned	• NDS IDD – Basic • Vehicle Preliminary Design	
L-24 Months	Vehicle Baseline Review • NDS Integration Agreement – Preliminary • Board Approval / Actions	• ICD – Preliminary • NDS Models • NDS Technical Data	

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L-18 Months	Mission Integration Review <ul style="list-style-type: none"> <li>NDS Integration Agreement – B/L</li> <li>Board Approval / Actions</li> </ul>	<ul style="list-style-type: none"> <li>ICD – Baseline</li> <li>HV Loads &amp; Environments Analysis / Validation</li> </ul>	
L-12 Months	System Readiness Review <ul style="list-style-type: none"> <li>Board Approval / Actions</li> </ul>	<ul style="list-style-type: none"> <li>Master Verification Plan</li> <li>HV Analysis Data – Prelim</li> <li>HV Software Design Data</li> <li>HV Models &amp; Data– Prelim</li> </ul>	<ul style="list-style-type: none"> <li>NDS Standard Procedures</li> <li>NDS S/W Emulator Ship</li> </ul>
	NDS Integration Support <ul style="list-style-type: none"> <li>Technical Expert Support</li> <li>Issue Resolution</li> </ul>		HV Software Dev Test Start <ul style="list-style-type: none"> <li>Engineering Test S/W</li> </ul>
L-6 Months		Integration Analysis Complete <ul style="list-style-type: none"> <li>HV-NDS Analyses – Final</li> </ul>	HV Assembly Start <ul style="list-style-type: none"> <li>HV Assembly Procedure</li> <li>Flight H/W &amp; GSE Ship</li> <li>Acceptance Data Package</li> </ul>
L-5 Months	Test Readiness Review <ul style="list-style-type: none"> <li>Board Approval / Actions</li> <li>Test Issue Resolution</li> </ul>		HV-NDS Assembly Complete HV Test & Checkout Start <ul style="list-style-type: none"> <li>HV Test Procedures</li> <li>Mass Properties</li> </ul>
L-4 Months		Flight/Verification Loads Cycle <ul style="list-style-type: none"> <li>HV Models – Final</li> </ul>	HV S/W Verification Test Start <ul style="list-style-type: none"> <li>HV Flight Software Ship</li> </ul>
L-2 Months		Verification Complete <ul style="list-style-type: none"> <li>Verification Closure Notice / Certification</li> <li>Qualification Data</li> </ul>	HV Ground Processing / Launch Site Operations Start
L-2 Weeks	Flight Readiness Review <ul style="list-style-type: none"> <li>Board Approval</li> </ul>	<ul style="list-style-type: none"> <li>HV Flt Certifications</li> <li>NDS Flt Certs</li> </ul>	
L-2 Days	Launch Readiness Review <ul style="list-style-type: none"> <li>Board Approval</li> </ul>		HV Launch Preparation Complete <ul style="list-style-type: none"> <li>Launch Commit Status</li> </ul>
L-0			Launch

This template represents the “typical” integration cycle time for the host vehicle’s first flight article. The initial NDS-Vehicle integration cycle starts about 36 months prior to vehicle launch (L-36), as needed to support the host vehicle design activity. The NDS integration cycle can start closer to L-24 months, for Host Vehicle Projects with a mature design or shorter development schedules. The integration cycle timeline may be reduced to less than twelve months for subsequent vehicle flights. The integration master schedule milestones are tailored for the specific Host/Visiting Vehicle Project and documented in the NIA.

### 3.0 NDS TO HOST VEHICLE (HV) INTEGRATION

#### 3.1 OVERVIEW

Section 3 provides a summary of technical information on the NDS design to support host vehicle developers with initial integration planning activities. **The technical values in this section may be approximate and must be confirmed against the applicable specification and interface documents before use in host vehicle engineering design activity.** Detailed technical data on the NDS interface definition and requirements for systems integration with the host vehicle are contained in JSC 65795, NDS Interface Definitions Document (IDD) and JSC-63686, Project Technical Requirements Specification for the NDS Government Furnished Equipment (GFE). The NDS assembly, when properly installed on a Host Vehicle, provides the needed capabilities to satisfy the interface requirements in SSP 50808, ISS to COTS IRD, for docking to ISS at the CDA/NDS equipped docking ports.

The NDS is being developed in block configurations. The NDS Block 0 configuration is the current baseline that is intended to primarily support the CDA element and ISS Visiting Vehicles applications. Future NDS block upgrades are intended to provide system enhancements that are described in later paragraphs in Section 3.

#### 3.1.1 NDS ASSEMBLY DESCRIPTION

The NDS assembly, shown in Figure 1.2-3, is the NASA Docking System implementation of an androgynous peripheral docking system. The NDS facilitates low approach velocity docking via a reconfigurable, active, closed-loop, and force-feedback controlled mating system using modern technologies. The NDS supports both crewed and autonomous vehicles during mating and assembly operations. Future NDS configurations will be certified to allow docking at positive, zero, and negative approach velocities, as well as berthing. The NDS is an androgynous system that can be commanded via NDS electronics interface from the host vehicle in either an “active” or “passive” mode. Active-mode is when the NDS controls the soft capture function and all sequences of docking. Passive-mode is when the NDS on the target vehicle yields control and allows the NDS on the chaser vehicle, in active-mode, to mate to it.

The NDS is modular and reconfigurable to support a variety of space mission applications. The NDS Block 0 has four configuration variants. The NDS -301 is the core configuration, which has 120 VDC avionic boxes that are installed in the pressurized tunnel section. The NDS -303 is identical to the -301, but with 28 VDC avionics boxes. The NDS -301 and -303 configurations are fully androgynous and can dock with themselves or the other NDS configuration.

The NDS-302 configuration is optimized for the CDA element application and has most of the functionality of the -301 assembly. However the -302 has a shorter pressurized tunnel section, and the 120 VDC avionics boxes must be installed elsewhere inside the host vehicle. The -302 configuration also must rely on the host vehicle for MMOD and passive thermal MLI protection. Additionally, the -302 does not have seals on the HCS



capture interface and cannot dock with another NDS -302 unit. The NDS -302 configuration will initially be certified only for passive-mode operations.

The NDS -304 configuration is also similar to the -301 configuration, but is not fully androgynous. The -304 configuration has reduced capture functionality to minimize the assembly weight and can only operate in the active-mode.

The NDS configuration variant differences are further described in the following paragraphs and then summarized in a configuration comparison table in Paragraph 3.13. The docking compatibility of the various NDS configurations and modes is summarized in Table 3.1.1-1.

**TABLE 3.1.1-1 NDS CONFIGURATION DOCKING COMPATIBILITY**

		Active-mode NDS			
		-301	-302	-303	-304
Passive-mode NDS	-301	<input type="checkbox"/>	N/A <sup>(1)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
	-302	<input type="checkbox"/>	None <sup>(2)</sup>	<input type="checkbox"/>	<input type="checkbox"/> <sup>(3)</sup>
	-303	<input type="checkbox"/>	N/A <sup>(1)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
	-304	None <sup>(4)</sup>	None <sup>(4)</sup>	None <sup>(4)</sup>	None <sup>(4)</sup>
		<b>Legend</b>			
		<input type="checkbox"/>	Compatible for hard capture/mate.		

Notes:

- (1) The -302 is only certified for passive-mode operations.
- (2) The -302 does not have HCS seals and cannot support pressurization after docking with another -302 unit.
- (3) Neither the -304 nor the -302 units contain pyrotechnic bolts to support contingency undocking in event of a hook disengagement failure.
- (4) The -304 does not contain HCS passive hooks and cannot function in passive-mode for docking with any active-mode NDS.

**Functional Capability.** The NDS end-to-end functional interfaces and capabilities are described in Section 1.2. These functional capabilities are allocated to major NDS components that are described in the next paragraphs.

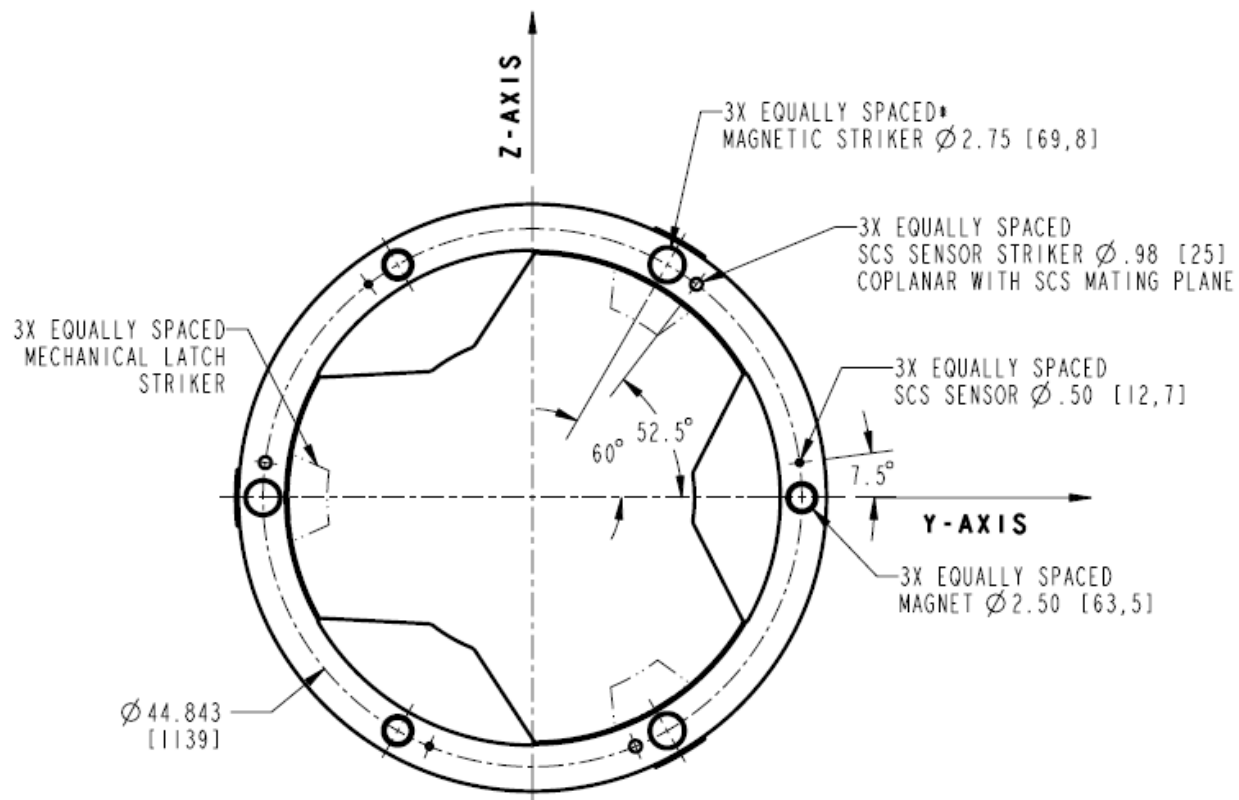
**NDS Major Components.** The NDS is comprised of six main components:

- Soft Capture System (SCS)
- Hard Capture System (HCS)
- Pressure tunnel and mounting flange structures
- Avionic controller and power supply boxes
- External umbilical connectors
- Passive and active thermal control system
- Micrometeoroid/Orbital Debris (MMOD) shield

A short description follows on these major components, along with a brief discussion of the differences between the NDS-301, -302, -303 and -304 configuration variants.

- **Soft Capture System (SCS) Components**

The NDS SCS is a deployable ring interface that provides the “low impact docking” soft capture capability. Figure 3.1-1 illustrates the conceptual design for the main components that are part of the SCS Soft Capture Ring: the guide petals, the soft capture sensor, and the capture magnets and striker plates. Figure 3.1-2 illustrates the SCS capture ring components.



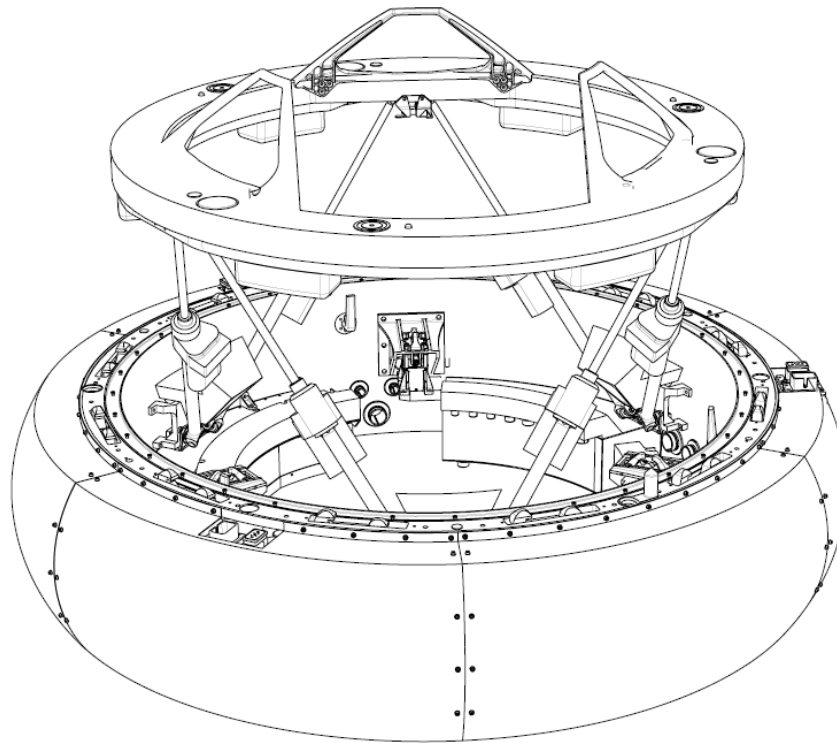
**FIGURE 3.1-1 SOFT CAPTURE RING COMPONENTS (CONCEPTUAL DESIGN)**

The SCS has three docking petals that are equally spaced at 120 degree intervals and inwardly incline at 45 degree angles. After first contact, the petals guide and align the docking vehicle with the soft capture ring mating plane. (Note, the SCS guide petals can be manually removed after docking to increase the passageway clearance. Section 3.11.1 provides more information on petal removal capability).

The Soft Capture Sensors detects when the SCS rings on the docking and target vehicle are flush, and then activates the contact magnets to initiate the soft capture sequence. The SCS magnets connect with the striker plates on the opposing SCS ring to hold the soft capture rings on the two mating vehicles together during the soft capture sequence. (Note, the NDS -304 does not have the magnetic striker components installed in the SCS ring to reduce assembly weight). The Block 0 NDS is scarred for future implementation of SCS mechanical latch strikers that will allow other IDSS-compatible docking systems with mechanical latches to soft capture with the NDS.



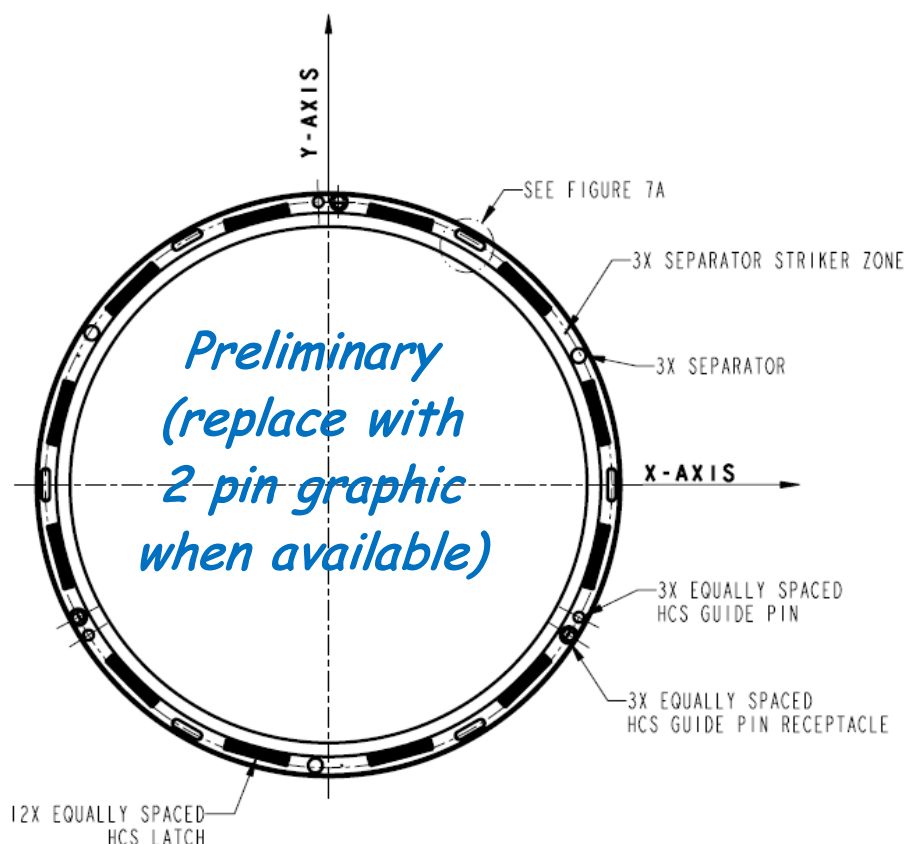
Prior to docking operations, the SCS (on the NDS in active-mode) unlatches the soft capture ring and the electro-mechanical actuators extend it about 14-inches above the HCS mating interface plane. The SCS mechanism provides docking motion and load attenuation during the soft capture sequence. The mechanism has load cells that furnish force feedback to the avionics that control the load attenuation function and enables the “low impact” docking capability. After the SCS mechanism positions the soft capture ring into the null position, the deployment mechanism is retracted back down to bring the HCS on docking vehicle together with HCS on the target vehicle.



**FIGURE 3.1-2 NDS WITH SCS RING EXTENDED (CONCEPTUAL DESIGN)**

- **Hard Capture System (HCS) Components**

The NDS HCS is the docking ring interface that provides the hard mate capability for VV docked operations at the CDA element. Figure 3.1-3 shows the conceptual design for the main components that are part of the HCS ring: the alignment pins and receptacles, the pairs of passive and active hooks, and the push-off springs. The NDS HCS ring sub-assembly is designed to the NDS capture interface specifications.



**FIGURE 3.1-3 HCS RING COMPONENTS (CONCEPTUAL DESIGN)**

The HCS has two fine alignment pins and receptacles, which provide fine alignment of the docking and the target vehicle HCS rings as the SCS ring is retracted. The two docking NDS units can only mate in a unique relative clocking orientation that is determined by the pair of alignment pins and receptacles. The “ready-to-hook” sensors indicate when HCS rings are flush and the active VV can engage the docking hooks. The HCS contains 12 pairs of docking hooks that provides the structural integrity while the two vehicles are hard mated. Each hook pair has both an active and a passive hook. The 12 active hooks on the active-NDS engage with the passive hooks on the opposing passive-NDS interface to perform the hard capture function.

The 12 unused passive hooks in the NDS assembly in the active mode provide a fault tolerance capability in a contingency event when the “active” hook on the docking vehicle fails to properly engage. In this contingency, the active hook in the opposing NDS interface can be used to engage the passive hook on the docking vehicle. The

NDS -302 configuration has the capability for its active-hooks to engage the passive-hooks on the docking vehicle; however, this capability is will not be initially certified for docking operations. The NDS -304 configuration does not include passive hooks to reduce assembly weight and can only function in the passive-mode. The -304 configuration, without passive-hooks, also cannot support contingency hook engagement by an opposing NDS.

When hard docked, the NDS hard capture ring interface provides redundant concentric seals that allow pressurization of the shared vestibule volume between the docked vehicles. The NDS design supports both seal-on-seal and seal-on-metal hard capture interface mating. The NDS -302 configuration does not have concentric seals on the HCS ring, but instead has a corresponding flat sealing surface to provide a pressure seal with the other NDS configurations and support recurring VV dockings at the CDA over multiple years of service. (Note, the -302 configuration cannot form a pressure seal with another NDS -302 unit). The HCS “pressure seal compressed” and hook position sensors indicate when hard capture has been fully achieved and the redundant concentric seals have been compressed and pressurization of the vestibule volume can begin.

The NDS HCS ring provides three resettable push-off springs to separate the VV from the CDA element for undocking after the active hooks are disengaged. The NDS HCS interface also includes “undocked” sensors to indicate when separation of the two elements has been achieved. The three separation sensors indicate NDS approximate clearance of guide pins after the mated vehicles have been pushed apart (??TBC). The NDS active and passive hooks include pyrotechnic bolts that can be fired through the host vehicle controls as a last-resort in a contingency when a hook hangs-up and does not properly disengage for undocking. The NDS -302 and -304 configurations have the pyrotechnic bolt removed and replaced with inert bolts. (See Section 3.7.3 for additional information on the NDS pyrotechnic bolt interface)

- **Pressure Tunnel and Mounting Flange Structures.**

The NDS assembly includes a pressure tunnel with a flange interface on the bottom of the assembly for mounting onto the pressure tunnel section of the host vehicle. When hard docked, the NDS pressure tunnel forms the shared vestibule volume between the docked vehicles. This shared volume allows for open-hatch operations and air circulation between the docked vehicles. The tunnel section provides the passageway for Inter-vehicular Activity (IVA) crew and cargo transfer operations. For docking at the ISS, this shared volume is between the interior passageways inside the CDA and the NDS tunnel on the VV. During closed-hatched docked operations, either mated vehicle can pressurize or depressurize the shared vestibule volume using the pressure equalization valves in their respective vehicle. The previous figures 1.2.3 and 3.1-2 show the NDS pressure tunnel, which is the interior volume inside and beneath the HCS ring. The height of the NDS -302 tunnel section is shorter than the other NDS configuration variants.

The NDS mounting flange provides a circular bolt pattern to fasten to the corresponding host vehicle mounting flange. (Section 3.3.2 has additional information on the mounting flange interface). The NDS mounting flange includes redundant concentric seals that provide the pressure seal when the NDS assembly is properly installed on the host vehicle. The NDS mounting flange does not include a jettison capability. (Note: If NDS assembly jettison is required to support a recoverable vehicle mission profile, the host vehicle must provide the jettison capability -- including docking system electrical and data cable/connector separation).

- **Avionics Controller and Power Supply Boxes.**

The NDS assembly includes a redundant set of avionics control and power supply boxes. These twin sets of avionics boxes support integration with the host vehicle electrical power and Computer Data and Handling (C&DH) Systems on independent channels. The avionics boxes are installed inside the pressure tunnel in the NDS (except -302). For the NDS -302 configuration, the avionics boxes must be accommodated inside the host vehicle due to the shorter height of the pressure tunnel.

The avionics boxes on the NDS -301, -302 and -304 configurations need 120 VDC power supplied by the host vehicle to function; while the avionic boxes for the NDS -303 function with 28 VDC power. The avionics boxes can communicate with the Host Vehicle C&DH system through either a MIL-STD-1553B or a TIA-422B format serial interface. The Host Vehicle selects the desired serial communication format by installing a jumper on the host communication connector during NDS integration and check-out.

- **External Umbilical Connectors.**

The NDS Block 0 assembly has external umbilical interface points to enable the “pass-thru” exchange of redundant power and data resources between the vehicles during mated operations. The NDS Block 0 design provides two power/data electrical connectors; and reserves volume for the additional water and propellant fluid interface connectors that may be implemented in future NDS block upgrades.

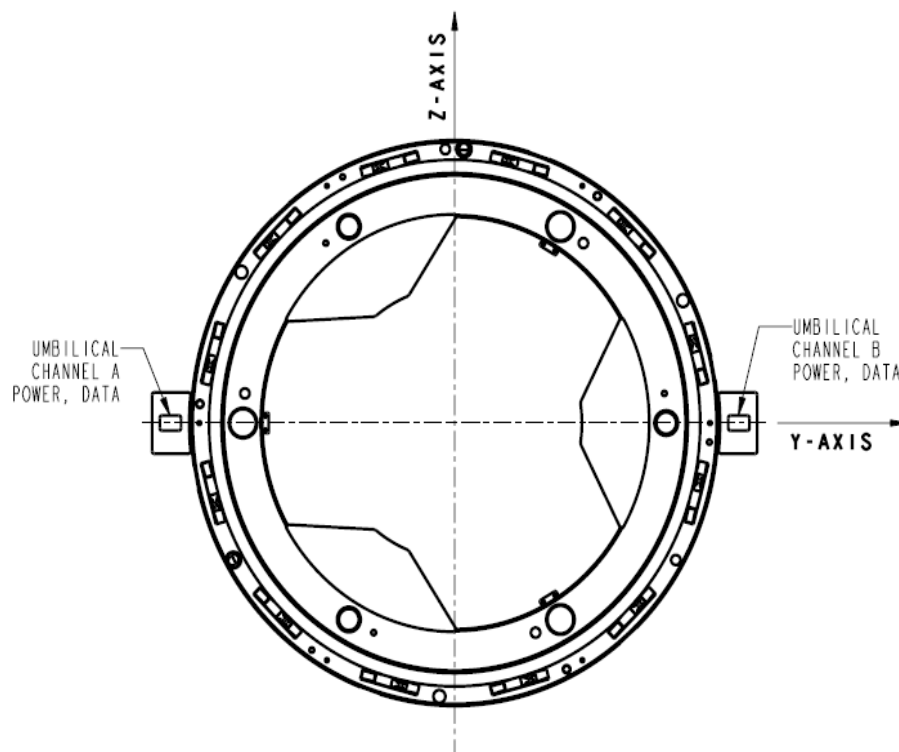
Figure 3.1-4 illustrates the conceptual design for the external power and data umbilical connectors. There are two umbilical connectors (one male and one female) that both provide for power and data transfer in a single SSQ22680 FRAM-type connector. Separate power and data umbilical cables are routed to the external connector and then combined in the connector backshell. The NDS (except -302) external power and data umbilicals route to hermitically sealed feed-thru connectors to provide interfaces with the host vehicle cables inside the pressure tunnel. The NDS -302 configuration does not have feed-through connections; and its umbilical connections with the host vehicle remain exterior to the NDS pressure tunnel.

Each external umbilical connector has two circuits of 8AWG wiring for 120 VDC or 28 VDC electrical power transfer. In addition, each connector provides independent MIL-STD-1553 and 10/100 Base T Ethernet computer data buses. The two external power

and data umbilical connectors and cables are fully implemented on the NDS -302 installed on the CDA.

The umbilical connectors are automatically driven to mate and demate during docking operations, without crew intervention. After the HCS tangential hooks are fully engaged, the umbilical connectors are mechanically mated by separate motorized extension/retraction mechanisms. These same mechanisms load the push-off springs that are later used to separate the mated NDS interfaces apart at undocking. The umbilical connectors provide an indication when the connectors are seated with the pins engaged and ready for power and data resource transfer.

For undocking, these connectors are nominally driven to the demated state prior to unlatching the hooks. However, the NDS umbilical connectors can also be separated passively by the energized push-off springs, should the automated mechanism fail to demate the umbilical.



**FIGURE 3.1-4 EXTERNAL UMBILICAL CONNECTORS (CONCEPTUAL DESIGN)**

- **Active and Passive Thermal Control System.**

The NDS -301, -303 and -304 configurations include heaters for active thermal conditioning of the NDS docking surfaces and components. However, the NDS-302 assembly does not contain heater strips and depends on the host vehicle to provide thermal conditioning to keep the NDS components within the acceptable temperature ranges (TBR).

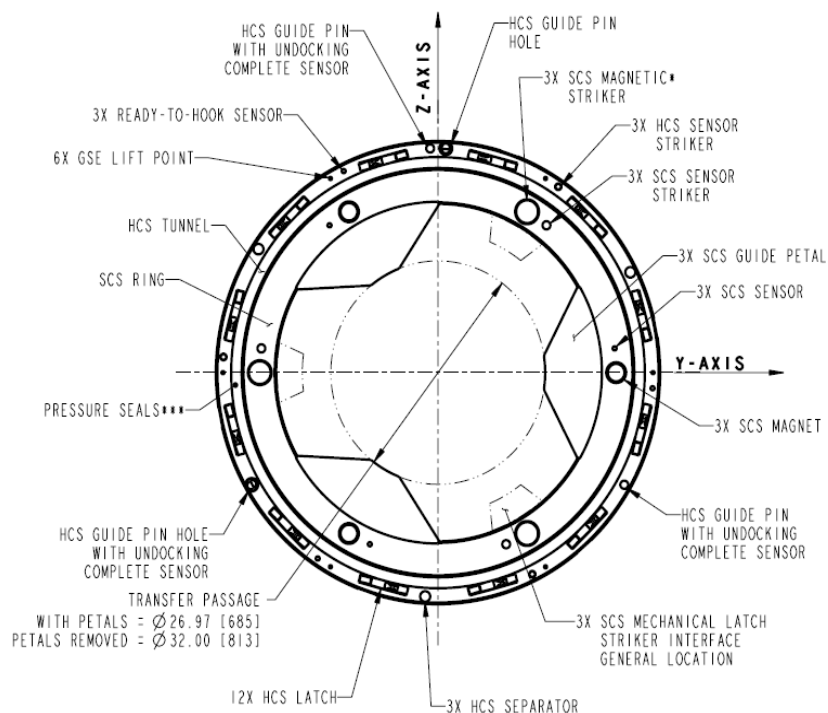
The NDS (except -302) also includes passive thermal control systems. Multi-layer Insulation (MLI) blankets and the MMOD shield with optical coating are attached to the exterior side (non-docking) surface of the NDS structure to provide passive thermal control, as well as Micro Meteorite Orbital Debris (MMOD) protection. The -302 configuration does not have MLI blankets or a MMOD shield for a passive thermal system and depends on the Host Vehicle to provide it with suitable passive thermal protection for the unique mission application.

- **Micrometeoroid/Orbital Debris (MMOD) Shield.**

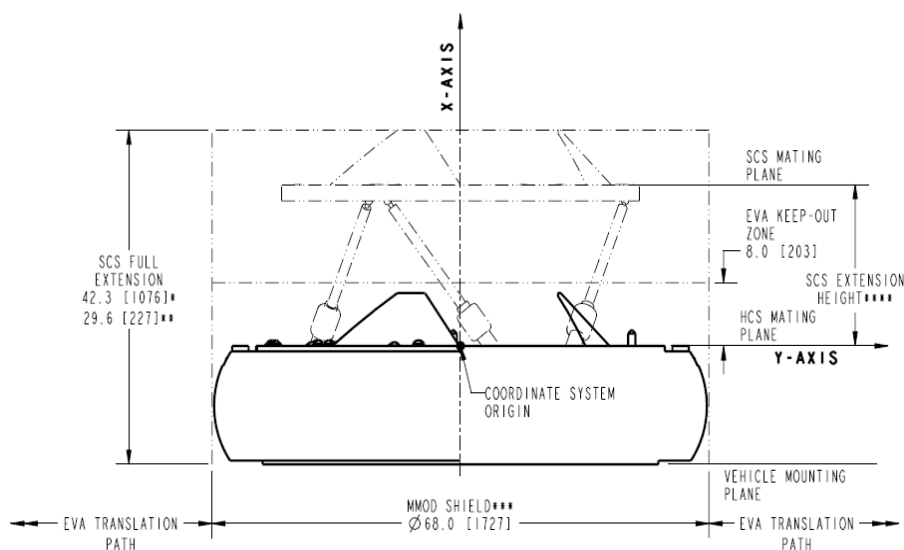
The NDS -301, -303 and -304 configurations have a MMOD shield that is an integral part of the Passive Thermal/MLI blanket design. The MMOD shield is attached to the exterior of the NDS structural surfaces (except the capture interfaces) to protect the NDS from MMOD damage, as shown on the exterior of Figure 3.1-2. During ground processing/integration activity with the host vehicle, the MMOD shield is attached to the NDS assembly after the unit has been properly fastened to the host vehicle mounting flanges. The NDS -302 configuration does not have a MMOD shield and depends on the host vehicle to provide adequate MMOD protection.

## 3.2 COORDINATE SYSTEM AND UNITS

**Coordinate System Description.** The NDS coordinate system is defined in Section 3.6 of JSC 65795, NDS IDD. The NDS design uses a right-hand orthogonal body coordinate system; with the origin at intersection of the NDS cylindrical axis and the hard capture interface plane. A representative view of the coordinate system is shown below in Figure 3.2-1.







**FIGURE 3.2-1 NDS COORDINATE SYSTEM (LOOKING AT CAPTURE INTERFACE)**

**Units.** The NDS unit system and tolerances are defined in JSC 65795, NDS IDD. The NDS design uses the English unit system; except for the NDS interface control dimensions that are defined in the System International (SI) units (metric units). The NDS documentation will typically show metric unit conversions in parenthesis along side of the English unit definition.

### 3.3 PHYSICAL CHARACTERISTICS

#### 3.3.1 MASS PROPERTIES

The NDS assembly mass properties are defined in JSC 65795. The NDS assembly Not To Exceed (NTE) control weight is:

- 750 pounds (lbs) <TBR> NDS -301 and -303 configurations
- 704 lbs <TBR> NDS -302 configuration\*
- 711 lbs <TBR> NDS -304 configuration

(Note, the -302 configuration mass includes the weight of the avionics boxes that are installed inside the Host Vehicle. The additional hardware needed to integrate the -302 with the Host Vehicle are not included in the NTE mass above and estimated to be approximately ~65 lbs).

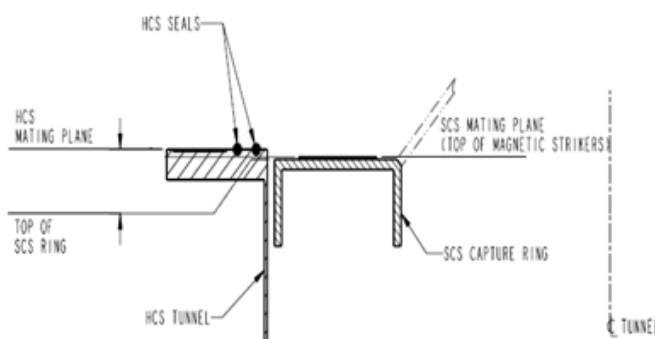
#### 3.3.2 DIMENSIONS

The NDS assembly dimensions are fully defined in JSC 65795, NDS IDD. A summary of the key interface dimensions are provided in the following paragraphs.

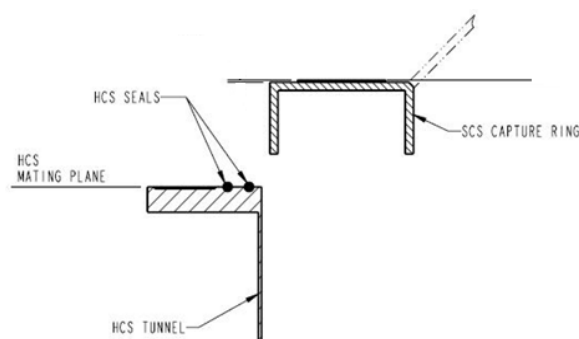
**Outer Envelope.** The NDS assembly outer envelope has the following approximate dimensions.

- Total Height (except -302): ~22 inches (*retracted SCS ring*)  
~36 inches (*ready-to-dock SCS ring extension*)  
~42 inches (*maximum SCS ring extension*)
- Diameter (except -302): ~68 inches (*with MMOD shield*)
- Total Height (-302): ~16 inches (*retracted SCS ring*)  
~30 inches (*ready-to-dock SCS ring extension*)  
~37 inches (*maximum SCS ring extension*)
- Diameter (-302): ~50 inches (*without MMOD shield*)

**Docking Plane Interface.** The NDS assembly docking plane top interface detailed dimensions are defined in JSC 65795, NDS IDD and comply with the NDS control parameters. The NDS docking interface is illustrated in Figures 3.3.2-1 and 3.3.2-2.



**FIGURE 3.3.2-1 NDS DOCKING PLANE - SCS RING RETRACTED (SIDE VIEW)**



**Figure 3.3.2-2: NDS Docking Plane - SCS RING EXTENDED (SIDE VIEW)**

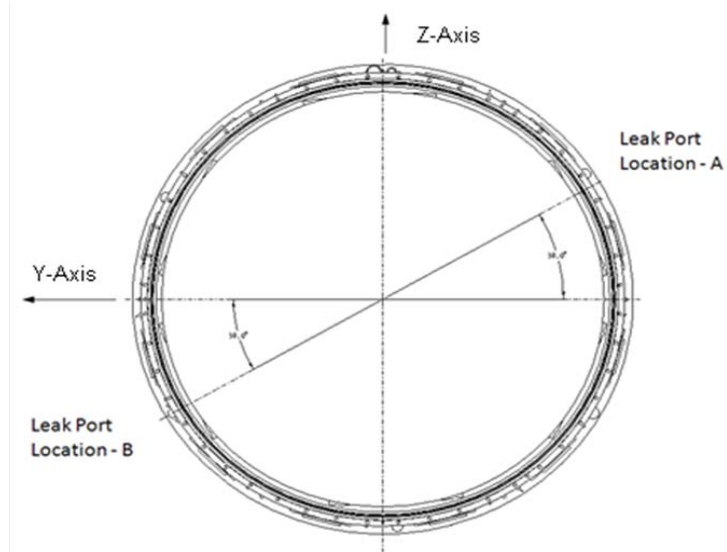
**Profile.** The NDS assembly profile dimensions details are contained in JSC 65795, NDS IDD. The NDS assembly profile is illustrated in Figures 3.2-1. Some of the key NDS profile dimensions are as follows.

- Guide Petal Height (Docking Deployed Position): ~ 6.9 inches
- Pressure Tunnel Height (except -302): ~15.0 inches
- Pressure Tunnel Height (-302): ~9.3 inches



- Pressure Tunnel Inner Diameter: ~49.4 inches
- Transfer Passage Diameter (Petals Deployed) ~27.0 inches
- Transfer Passage Diameter (Petals Removed) ~32.0 inches
- Maximum Volume (except -302) ~16.6 ft<sup>3</sup>
- Maximum Volume (-302) ~10.3 ft<sup>3</sup>

**Pressure Tunnel Flange Interface.** The NDS pressure tunnel flange bottom interface dimensions details are contained in the JSC 65795, NDS IDD. The NDS pressure tunnel flange is illustrated in Figure 3.3.2-3. The NDS assembly attaches to the host vehicle docking tunnel with forty-eight 10 mm bolts on a bolt ring diameter of 1350 mm. The NDS Project provides the bolts required to fasten the NDS assembly onto the host vehicle in accordance with the NDS-TBD installation procedure. The pressure tunnel flange interface includes alignment pins to support NDS assembly installation and alignment with the host vehicle. The host vehicle must provide the corresponding bolt hole interface specified by the NDS IDD on its mounting flange.

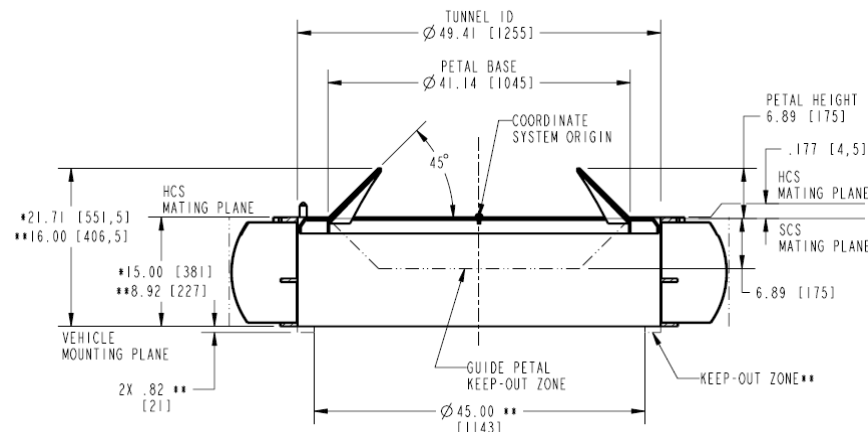


**FIGURE 3.3.2-3 NDS MOUNTING FLANGE INTERFACE (BOTTOM VIEW)**

**Keep-out Zones.** The detailed keep-out zones for integration with the NDS assembly onto the host vehicle are defined in JSC 65795, NDS IDD. These keep-out zones are:

- The host vehicle exterior structures and mechanisms, which are located above the docking tunnel interface plane, must remain outside of the NDS outer envelope dimensions. This exterior keep-out zone avoids interference with the capture interfaces on the target vehicle during docking operations.
- The host interior structures and mechanisms, which are located inside the docking tunnel area (i.e., VV docking hatch), must remain out of the space that is ~7 inches below the capture interface plane, as shown in Figure 3.3.2-4. This interior keep-out zone avoids interference with the docking petals on the target vehicle during capture operations.

- Note, additional keep-out zones for VV docking to the ISS/CDA are defined in SSP 50808, ISS to COTS IRD.



**FIGURE 3.3.2-4 NDS GUIDE PETAL KEEP-OUT ZONE**

### 3.3.3 MATERIALS AND FINISHES

The host vehicle docking tunnel flange materials and finish constraints to interface with the NDS mounting flange and ensure the pressure seal are defined in the JSC 65795, NDS IDD.

## 3.4 STRUCTURES AND LOADS

The NDS assembly structures and capture mechanisms are certified to the interface loads and environments capabilities defined in JSC 65795, NDS IDD and in JSC-63686, Project Technical Requirements for the NDS Government Furnished Equipment (GFE).

### 3.4.1 INSTALLATION AND ALIGNMENT SUPPORT

The NDS assembly has provisions to support installation, adjustment and alignment with the host docking tunnel. The outer MMOD shield must be removed in order to install the NDS on the host. These installation and alignment provisions include the alignment pins on the mounting flange interface. The NDS assembly also includes the capability to perform a ground leak check between the redundant pressure seals without pressurization of the adjacent pressure volumes.

### 3.4.2 DOCKING SOFT CAPTURE ENVELOPE LIMITS

NDS soft capture mechanisms can perform the capture functions within the following envelope of "nominal" docking vehicle initial contact conditions show in Table 3.4.2-1, as defined in the JSC 65975, NDS IDD. Additional analysis is necessary to validate NDS soft capture capability for other docking initial contact conditions.

**TABLE 3.4.2-1 NDS INITIAL CONTACT “DESIGN-TO” LIMITS**

<b>Initial Conditions</b>	<b>Limiting Value</b>
Closing (axial) rate	0.05 to 0.15 ft/sec
Lateral (radial) rate	0.15 ft/sec <sup>(4)</sup>
Angular rate	0.15 des/sec about NDS X axis, Vector sum of 0.15 des/sec about NDS Y and Z axes
Lateral (radial) misalignment	4.2 ± 0.125 inches
Angular misalignment	4.0 ± 0.25 deg about NDS X axis, Vector sum of 4.0 ± 0.25 deg about NDS Y and Z axes

**Notes:**

- (1) Initial conditions to be applied simultaneously. (Initial conditions applicable for a chaser vehicle with mass range of 1000 slugs (15000 kg) to 1700 slugs (25000 kg) and no lateral CG offset; docking to a target vehicle with a mass of at least 24000 slugs (350000 kg).
- (2) The NDS uses a right-hand orthogonal body coordinate system, per paragraph 3.2.
- (3) Lateral (radial) rate limit includes combined lateral and rotational rates of both vehicles.
- (4) Chaser vehicle Post Contact Thrust (PCT) firing with TBD properties may be necessary to achieve NDS capture with these initial conditions.

**3.4.3 BERTHING SOFT CAPTURE ENVELOPE LIMITS**

RESERVED. (The NDS will be certified for berthing operations in a future block upgrade).

**3.4.4 LOADS CAPABILITY**

**Soft Capture Interface Loads.** The NDS soft capture interface loads capability is defined in JSC 65795, NDS IDD.

**Hard Capture Interface Loads.** The NDS assembly is certified to the mated load limits specified in JSC 65795, NDS IDD and to the mated loads spectra are specified in TBD.

**Lift-off and Ascent Interface Loads.** The NDS liftoff and ascent interface loads capability is fully defined in JSC 65795, NDS IDD.

**Descent and Landing Loads.** The NDS assembly is not certified for vehicle descent and landing loads. The NDS operations concept is for the host vehicle to jettison the NDS assembly prior to re-entry operations. The host vehicle may also retain the NDS assembly for “destructive” re-entry operation (i.e., vehicle does not land for crew/cargo recovery), since the NDS assembly does not have to survive the re-entry / descent loads. The host vehicle developer is responsible for performing landing loads analysis

with the NDS still attached to verify with NDS Project concurrence that interface loads do not exceed structural capability.

**Thermally Induced Loads.** The NDS assembly is certified for the thermally induced loads that occur during docking with the maximum thermal differential that is allowed between the docking and the target capture interface surfaces at initial contact as defined in paragraph 3.5.1.

**Pressure Loads.** The NDS pressure loads capability is fully defined in JSC-63686, NDS PTRS. The NDS assembly is certified for a Maximum Design Pressure (MDP) of ~15.5 psid (TBC) and to function after exposure to a rapid decompression of the spacecraft. The NDS is certified for a repressurization and depressurization rate of ~6.7 psia/sec, over the operational pressure range of 0.0 to 15.5 psia.

**Fracture Control and Fatigue.** The NDS structures and mechanisms are designed for fracture control in accordance with SSP 30558 Fracture Control Requirements for Space Station. The NDS structures and mechanisms are certified to function and meet performance requirements after exposure to the docked loads spectra defined in JSC 65795, NDS IDD.

### **3.4.5 VIBRATION ACOUSTIC AND SHOCK ENVIRONMENTS CAPABILITY**

The NDS assembly components are certified for the vibro-acoustic and shock environments defined in JSC 63686, NDS PTRS. These qualification environments were established as a bound for the known induced environments for current and anticipated ISS VVs and their respective launch systems. The NDS vibro-acoustic environments are determined by the host vehicle lift-off and ascent conditions, which dominate the on-orbit docked “quiescent” conditions.

The NDS shock environment is for contingency firing of the pyrotechnic bolts installed in the hook pairs in the event the docking hooks fail to disengage by normal system undock operation. The host vehicle components, which are critical for safe undocking, return and landing and located in the vicinity of the NDS tunnel flange interface, must be able to tolerate this shock environment.

## **3.5 THERMAL CONTROL SYSTEMS (TCS)**

The detailed data on the NDS assembly TCS capabilities and constraints is defined in the JSC 65795, NDS IDD. The NDS assembly includes both passive and active thermal control systems, which provide temperature control and support the interface thermal requirements for vehicle docking operations. Multi-layer Insulation (MLI) blankets are attached to the exterior side (non-docking) surface of the NDS structure. These MLI blankets contain thermal insulation and surface optical coating to furnish the passive thermal control capability. The blankets attach to the sheet metal closeouts that also serve as Micro Meteorite Orbital Debris (MMOD) protection.

The NDS (except -302) include heater strips for active thermal conditioning of the NDS docking surfaces and components. The heater strips are controlled by NDS avionics. The NDS -302 assembly does not contain heater strips; and relies on the host vehicle to maintain the docking interfaces and components within the temperature ranges defined in the JSC 65795, NDS IDD.

### 3.5.1 THERMAL INTERFACE

The thermal contact conductance across the NDS to NDS docking interface is defined as ranging from 15 Btu/hr-ft<sup>2</sup>-°F to 50 Btu/hr-ft<sup>2</sup>-°F for the metal to metal contact area.

The NDS utilizes heaters to condition/maintain temperatures above the minimum limits for each operating mode. The NDS heater control has automated on/off control sensors with programmable set-points for the desired temperature range for various docked and undocked conditions.

The NDS maximum temperature limit may be exceeded whenever the host vehicle flight attitude points the NDS towards the sun for extended time periods. The host vehicle developer is responsible for analysis that the NDS TCS can maintain the component and capture interfaces within the various temperature constraints across the entire range of "planned" flight attitudes and solar beta angles.

The allowable NDS interface temperature ranges for each operating condition are defined in the JSC 65795, and discussed in the following paragraphs. The additional thermal constraints on the NDS for VV docking and mating to the ISS are discussed in SSP 50808, ISS to COTS IRD.

#### 3.5.1.1 NON-OPERATIONAL – SURVIVAL TEMPERATURE LIMITS

The following applies to NDS components when the system is unmated in passive mode with heaters active.

Limits: -65°F to +192°F (-54°C to +89°C)

*Minimum – The minimum survival temperature is defined by the minimum non-operational temperature for NDS component acceptance/certification.*

*Maximum – The maximum survival temperature is defined by the maximum non-operational temperature for NDS component acceptance/certification.*

#### 3.5.1.2 OPERATIONAL – DOCKING AND UNPRESSURIZED TEMPERATURE LIMITS

**Soft Capture Mating Interface.** The following applies to soft capture components when the system is preparing to dock up through hard mate but prior to pressurization.

Limits: -65°F to +165°F (-54°C to +74°C)

*Minimum – The minimum interface temperature is defined by the minimum acceptance level limit switch operational temperature limit.*

*Maximum – The maximum interface temperature is defined by the maximum acceptance level load cell operational temperature limit.*

**Tunnel and Seal Mating Interface.** The following applies to the docking system (excluding the soft capture system) when the system is preparing to dock up through hard mate but prior to hard capture.

Limits: -38°F to +122°F (-39°C to +50°C)

*Minimum – The minimum interface temperature is defined by the minimum acceptance level seal operational temperature limit.*

*Maximum – The maximum interface temperature is defined by the maximum acceptance level seal operational temperature limit.*

(Note, the NDS -302 configuration does not contain the hard capture mating seals and has expanded interface temperature limits that are defined in JSC 65795 (TBR)).

During hard capture operations, the allowable temperature differential between the NDS sealing interfaces on the mating target and chaser vehicles may be further restricted. JSC 65795, NDS IDD Figure 4-5, NDS Mating Interface Allowable Thermal Differential for Hard Capture, defines the acceptable temperature regions for hard capture of the two mating interfaces. If the temperatures are not within these defined boundaries, a thermal hold is required prior to hard latching until the temperature requirements are satisfied.

### **3.5.1.3 OPERATIONAL – MATED AND PRESSURIZED TEMPERATURE LIMITS**

The following applies to the NDS interior surfaces and components when mated and pressurized.

Limits: Dew Point < Min°F to +113°F (Min °C to +45°C)

*Minimum – The minimum NDS interior temperature is defined by the mated vehicles dew point temperature to avoid condensation during pressurized operations.*

*Maximum – The maximum NDS interior temperature is defined by the crew bare handed surface touch temperature limit.*

The NDS passive and active thermal control system is designed to help maintain the interior IVA passage-way temperatures within the atmospheric dew-point and the NASA crew exposed surface touch temperature limits for a wide range of docked vehicle flight attitudes and solar beta angles.

The NDS heaters may take up to 8-hours when starting at the minimum operating temperature to warm the NDS assembly above the minimum dew-point temperature. This warm-up time can be shortened by adjusting the heater control set-points and pre-heating the NDS assembly prior to docking. Specific host thermal analysis for the planned mission profile is necessary to verify the NDS interior surface temperatures do not exceed the allowable dew point and crew touch temperature limits.



## **3.6 ELECTRICAL SYSTEMS**

The technical details for the NDS electrical systems, grounding and bonding interface capability are defined in JSC 65795, NDS IDD and in JSC 64599, NDS Electrical Power Quality Description Document. The NDS (except -303) are designed to operate on 120 VDC power supplied by the host vehicle electrical system. The -303 configuration provides the option to operate the NDS on 28 VDC power supply from the host vehicle. The NDS assembly includes two external umbilical electrical connections that enable the “pass-thru” transfer between the mated vehicles of two independent channels of either 120 or 28 VDC power, along with the associated grounding lines.

### **3.6.1 POWER DEMAND**

The NDS assembly has two independent power channels (System A and B) that provide docking system redundancy. To make the NDS fully redundant, the System A and B channels each require separate, independent power feeds from the host vehicle via two separate connectors. Each separate power feed also requires several individual Remote Power Control (RPC) circuits from the host vehicle. JSC 64599, NDS Electrical Power Quality Description Document, details the power circuits configuration required from the host vehicle.

The two independent channels (System A and B) operate in active-passive mode for nominal docking operations. Along with the NDS power demand on the Host Vehicle EPS during docking operations, power is needed to operate the heater elements during mission operations. JSC 64599 contains the detailed power demand timeline for various phases of NDS operation, including the power required on each individual RPC feed into the NDS.

### **3.6.2 POWER CABLES AND CONNECTOR INTEGRATION**

The NDS EPS connection interfaces are located inside the pressure tunnel. The host vehicle EPS is responsible for providing current over-protection for the electrical power that is supplied to NDS electrical components. The host vehicle EPS is also responsible for providing the electrical power cables to connect the NDS avionics and power supply box interfaces with their EPS power channels.

The detailed data on the NDS EPS wire rating, connectors, and pin-outs are fully defined in JSC 65795, NDS IDD. The NDS Power Quality Characteristics are defined in JSC 64599, Electric Power Quality Description Document.

### **3.6.3 ENVIRONMENT LIMITATIONS**

The NDS avionics are not environmentally sealed and are not certified to tolerate condensation moisture conditions. During mated operations, the host and target vehicle systems must prevent condensation from occurring inside the NDS pressure tunnel by controlling the cabin air dew point and the NDS tunnel/avionics box temperature.

### 3.6.4 ELECTRICAL GROUNDING AND BONDING

The details on the NDS grounding and bonding capabilities and constraints are defined in JSC 65975, NDS IDD.

**Grounding.** The NDS electrical umbilical system provide ground lines for pass-thru power transfer, as well as grounding that support integration with the host vehicle electrical system ground.

**Bonding.** NDS establishes bond paths to mitigate electrical hazards on the integrated subsystem interfaces. The electrical bond meets the requirements established in NASA-STD-4003 Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads and Flight Equipment.

- **Electrical Bonding at Soft Capture: Class-S**

*NDS protects against static discharge by maintaining a Class-S bond on the soft capture ring while performing initial contact during docking operations. The bond path is from the electromagnet on the NDS in the active mode and the striker plate on the NDS in the passive mode.*

- **Electrical Bonding at Hard Capture: Class-R**

*NDS protects against RF emissions by maintaining a Class-R bond at the "hard-capture" interface between the NDS docking interface. There are three Class R bond paths between the mated NSA systems: the first path is through the metal to metal contact on the seal interface; the second path is through the electrical umbilical connector backshell for the plug connector; and the third path is through the electrical umbilical connector backshell for the receptacle connector.*

- **Electrical Bonding at Hard Capture: Class-H**

*The NDS provides an electrical path for currents to flow in the structure between mated vehicles. There are three Class H bond paths between the mated NDS systems: the first bond path is through the metal to metal contact on the seal interface; the second bond path is a #8 wire carried through the electrical umbilical plug connector; and the third path is a #8 wire carried through the electrical receptacle connector. These wires are provided as a resource between the mated vehicles. Termination of these lines should be negotiated between the two mating vehicles*

### 3.6.5 ELECTROMAGNETIC INTERFERENCE / ELECTROMAGNETIC CAPABILITY

The details on the NDS Electromagnetic Interference (EMI) and Electromagnetic Capabilities (EMC) are fully defined in the JSC 63686, NDS PTRS.

### 3.6.6 POWER PASS-THROUGH UMBILICAL CAPABILITY

The NDS assembly includes two external umbilical electrical connections that enable redundant circuits for 28 or 120 VDC electrical power transfer with associated grounding between the mated vehicles on independent power channels. (See the External



Umbilical Connector description in Section 3.1.1). The pin-outs for the external 28 and 120 VDC electrical power and data umbilical connectors are defined in the JSC 65975, NDS IDD, Table 4-6. For the NDS configurations (except -302), the connector interface with the host vehicle electrical power cables is located inside the pressure tunnel. The host vehicle developer is responsible for providing the power cables needed to integrate the NDS pass-thru power umbilical channels with their vehicle EPS.

### **3.7 COMMAND & DATA HANDLING (C&DH) SYSTEM**

The technical details for the NDS C&DH systems are defined in JSC 65795, NDS IDD and in JSC 64096, Software Requirements Specification for the ILIDS Control System. The core of the NDS C&DH system is redundant avionics controller boxes that receive commands from the host vehicle C&DH system to control the NDS soft and hard capture systems. These avionics boxes also provide NDS health and status data back to the host vehicle C&DH. The NDS design is designed to work with either MIL-STD-1553B or TIA-422B protocols to communicate with the host vehicle C&DH system.

The NDS assembly also includes external umbilical connectors that enable the “pass-thru” transfer of both MIL-STD-1553B and 10/100 Base-TX Ethernet communications between the mated vehicles.

#### **3.7.1 COMMAND AND STATUS DATA DESCRIPTION**

The NDS receives C&DH commands (e.g. docking, undocking, docking termination) from and provides data and status to the host vehicle through a serial interface. All communications with the NDS are sent with this serial interface; for operating both the NDS docking systems and heater elements. There are two serial formats available: MIL-STD-1553B and TIA-422B. The host vehicle selects the desired serial protocol, by installing a jumper in the host communications connector during vehicle integration and check-out.

The host vehicle C&DH system must be able to send valid commands to and receive data from the NDS avionics using the selected serial communication protocol. Two independent serial interfaces are required: one for NDS System A and one for NDS System B. See JSC 65795, NDS IDD for details on the 1553B and 422B serial interfaces, pin-outs and installation of the jumpers.

The host vehicle C&DH system may send either auto-sequence control commands or individual manual commands to NDS system that is initiated at a crew computer display, crew control panel or flight control team ground station. The NDS communications consist of two application level packet structures that include a command packet and a health and status packet. The command packet will be used by the host vehicle to command the NDS operations. The command packet has a size of 58 Bytes. The command packet size and rate can be found in JSC 65795, NDS IDD.

The health and status packet will be used to send periodic health and status data to host vehicle. This data will include command responses and measurements. The health and status packet can be used for different types of data transfer. The configuration parameter packet will be sent to the host vehicle when the NDS software is in Safe mode and the Configuration state. The configuration packet will replace the final health and status packet in a major frame. The packet type identifier will be created using a minimum hamming distance of 3, which will ensure that more than two bit flips would be required to misrepresent a packet type. Command responses are transmitted using the command response and response type data fields of the health and status packet. The command response is transmitted once per command received. Command response history can be obtained in the health and status payload data. The NDS uses a transfer frame format that includes a sync marker and a 16 bit CRC for TX and RX messages. The maximum size of the packet including the payload and transfer frame overhead is 1024 (TBC) Bytes. The NDS software data packet parameters are defined in JSC 65795, NDS IDD.

Table 3.7.1-1 provides a partial example list of the type of NDS commands and state data items that the host vehicle C&DH system must support, consistent with the NDS operations concept. The detailed definitions of all the NDS software commands and data items are contained in JSC 65975, NDS IDD. The command/response protocol or “handshake” between the NDS and the Host Vehicle C&DH/avionics is also defined in the JSC 65975, NDS IDD.

The NDS power and pyrotechnic commands are not supported by the NDS avionics and must be handled directly by the host vehicle C&DH. Similarly, some of the NDS FDIR functions must be performed by the Host Vehicle – in particular, switching between redundant springs (System A to System B) is handled by the Host Vehicle.

**TABLE 3.7.1-1 PARTIAL EXAMPLE LIST OF NDS COMMANDS**

<b>Command</b>	<b>Valid Modes</b>	<b>Valid States</b>
LIDS_CMD_SCS_EXTEND	Checkout, Dock, Undock	Checkout(Unlock), Dock(Unlock), Undock(Unlatch)
LIDS_CMD_SCS_HOLD	Dock	Extend
LIDS_CMD_LOADCELL_CAL	Dock, Engineering	Dock(Hold), Engineering(All)
LIDS_CMD_SCS_CAPTURE	Dock	Hold
LIDS_CMD_SCS_ATTENUATE	Dock	Capture
LIDS_CMD_SCS_ALIGN	Dock	Attenuate
LIDS_CMD_SCS_RETRACT	Dock	Align
LIDS_CMD_HCS_LATCH	Dock	Retract
LIDS_CMD_SCS_STOW	Checkout, Dock, Undock	Checkout(Motion Check), Dock(Rigidize), Undock(Stow)
LIDS_CMD_SCS_HOME	Checkout, Dock, Undock, Engineering	Dock(Stow), Engineering(All)

### **3.7.2 HARD CAPTURE PASS-THOUGH UMBILICAL CAPABILITY**

The NDS assembly includes two pass-thru umbilical computer data connections that enable the redundant transfer of both MIL-STD-1553B and 10/100 Base-TX Ethernet data communications between the mated vehicles C&DH systems on independent computer buses. (See the External Umbilical Connectors description in Section 3.1.1). The pin-outs for the external electrical power and 1553B and the Ethernet data umbilical connectors are defined in the JSC 65975, NDS IDD. The NDS external umbilical connector interface includes a switch to terminate with MIL-STD-1553B bus when the connectors are demated.

### **3.7.3 NDS PYROTECHNIC INTERFACE AND CONTROL**

The NDS -301 and -303 configuration hooks contain pyrotechnic bolts that can be fired by the host vehicle for contingency undocking when the active hooks do not disengage normally. In the NDS -302 and -304 configurations, the pyrotechnic bolts are replaced with inert bolts. The NDS assembly provides wire harness and connectors for the pyrotechnic bolts in the hook pairs. The NDS also contains 24 NASA Standard Initiators (NSI) (one per hook). The NDS pyrotechnic bolt interface requirements and pin-outs are defined in JSC 65795, NDS IDD.

The host vehicle is responsible for providing the control panel and triple safety inhibits for commanding the pyrotechnic bolt firing. The Host Vehicle must provide a pyrotechnic controller channel (e.g. Pyrotechnic Event Controller (PEC) or Pyrotechnic Initiator Controller (PIC)) for each NSI. Since the pyrotechnic bolts are only used in contingency event after two failures to undock, no redundancy is required in the pyrotechnic NSI or the controller channel.

## **3.8 GUIDANCE, NAVIGATION AND CONTROL (GNC) SYSTEM**

### **3.8.1 APPROACH AND DOCKING AIDS**

The NDS assembly does not directly provide GNC system approach or docking aids for Rendezvous, Proximity Operations, Docking and Undocking (RPODU) operations. The NDS soft capture system can safely capture a docking vehicle that is within the initial contact condition envelope described in paragraph 3.4.2.

The host vehicle developer is responsible for integration of the necessary approach and docking aids equipment with their vehicle GNC systems that are needed for accurate guidance and navigation during RPODU operations with the target vehicle.

### **3.8.2 UNDOCKING SEPARATION CAPABILITY**

The NDS outer HCS ring contains three resettable push-off springs that provide non-propulsive separation of the docked vehicle after the tangential hooks are released for

undocking. The push-off springs are designed to give the undocking vehicle sufficient separation velocity to achieve a safe distance to initiate thrusters firing for departure maneuvers without causing plume damage to the other vehicle (i.e., VV plume damage the ISS/CDA element). The separation system provides a initial separation force of between 551 and 595 lbs (270 Kgf), which can give undocking vehicles with a maximum mass of 25 metric tons a separation velocity of approximately 0.04 m/s. The NDS separation system also overcomes any seal stiction and provides a contingency capability to unmate of the external umbilicals.

### **3.9 ATMOSPHERIC PRESSURIZATION SUPPORT**

When hard docked, the NDS assembly pressure tunnel and seal create a “pressure-tight” shared vestibule volume between the mated vehicles that indirectly supports pressurized operations. The NDS pressure-tight passageway supports pressurized operations and crew cabin air exchange with between the docked vehicles during open-hatch operations.

#### **3.9.1 ATMOSPHERIC PRESSURE AND LEAKAGE RATE CAPABILITY**

The NDS pressure tunnel is certified for atmospheric pressures between 0 and ~15.5 psia, with repressurization and depressurization rates up to ~6.7 psia/sec per JSC 63686, NDS PTRS.

The NDS HCS ring provides two concentric pressure seal interfaces that are certified for seal-on-seal docking operations with another qualified NDS docking system. The NDS redundant pressure seals are also certified for the metallic sealing surface on the passive-NDS assembly, which accommodates the concentric seal diameters of the A-NDS assembly.

When mated to another NDS equipped vehicle, the NDS -301, -303 and -304 configurations are designed for a maximum atmospheric leak rate of 0.0040 lbm/day (dry air) at 14.7 psia. The NDS -302 assembly is designed for a maximum atmospheric leak rate of 0.0030 lbm/day (dry air) at 14.7 psia. The maximum leakage rate is the total from the NDS to NDS seal interface (with 12 hooks engaged), the docking tunnel host flange seal interface, and the external umbilical connector penetrations in the NDS tunnel. When a NDS -301 assembly is mated to a NDS -302 assembly on the CDA element, they will have a maximum leak rate of 0.0053 lbm/day from one host interface to the mated host interface.

#### **3.9.2 ATMOSPHERIC PRESSURE CONTROL CAPABILITY**

The NDS assembly does not include valves or vents to perform pressurization and depressurization of the shared vestibule volume between the mated vehicles. The pressurize equalization of the NDS pressure tunnel must be performed by either one of

the docked vehicles using pressure equalization valves that are provided within their vehicles.

### **3.9.3 INTER-VEHICLE ATMOSPHERIC INTERFACE**

The NDS assembly provides the pressure-tight passageway that supports crew cabin air exchange with between the docked vehicles during open-hatch operations, but does not include ventilation fans or ducting to facilitate atmospheric circulation. The host vehicle is responsible for the additional Atmospheric Control System (ACS) capability, which may be needed for cabin air exchange, temperature and dew-point control during docked mission operations.

### **3.10 OTHER FLUID SYSTEMS**

The NDS assembly for Block 0 reserves volume for the external umbilical connectors that will provide capability to exchange water, propellant, oxidizer and pressurant fluids between the docked vehicles. The capability to exchange fluids through external umbilicals will be part of the future NDS block upgrades.

### **3.11 CREW AND GROUND CONTROL INTERFACES**

#### **3.11.1 IVA TRANSFER CORRIDOR AND AIDS**

The Block 0 NDS design has SCS docking alignment petals that are fixed and cannot fold back into a stowage position for mated operations. With the SCS petals fixed in the deployed position, the NDS assembly provides an IVA transfer corridor diameter of ~27 inches as shown in Figure 3.3.2-1. The deployed petal clearance of ~27 inches (685 mm) has been evaluated as suitable for IVA Crew and Cargo Transfer Bag/Locker transfer. After the NDS is hard mated and pressurized, the SCS petals can be manually removed by an IVA crewmember to enlarge the transfer corridor diameter up to ~32 inches. However, the SCS alignment petals must be re-installed prior to vehicle undocking.

The translation path through the NDS pressure tunnel section is less than 15 inches, and does not need additional crew mobility aids. The host vehicle provider is responsible for providing crew mobility aids at the appropriate locations near their docking hatch to support IVA crew/cargo transfer activity.

### 3.11.2 EVA SUPPORT

The NDS assembly is designed and certified to be compatible with EVA operations. The NDS exterior surfaces, materials and fasteners comply with the applicable NASA safety requirements to avoid catastrophic leak hazards to the EVA suit during EVA operations around the NDS hardware. While undocked, the interior portion of NDS is considered as an EVA Keep Out Zone. The NDS assembly does not directly support EVA operations; and so it does not include attachment points for either EVA mobility aids or EVA equipment.

### 3.11.3 CREW DISPLAYS AND CONTROLS

The NDS assembly does not include stand-alone crew displays or control panels. The host vehicle developer is responsible for developing the NDS docking displays and controls for the crew and integrating them into their specific vehicle C&DH, control panel and electrical systems design architecture.

### 3.11.4 GROUND CONTROL SUPPORT

The NDS assembly indirectly supports remote ground operations by the flight controllers at the host vehicle mission/flight control center. The NDS health and status data can be routed by host vehicle C&DH system to their Communications and Tracking (C&T) system for down-link to the mission control center for monitoring by the vehicle flight control team. Likewise, NDS can receive software commands that originate at the vehicle mission control center, and are up-linked to the host vehicle C&T system and sent to the C&DH system for routing to the NDS avionics for execution.

The host vehicle developer is responsible for development and integration of the ground systems needed for their flight control team to remotely monitor and command NDS during vehicle docking and undocking operations.

## 3.12 RELIABILITY, MAINTENANCE AND LOGISTICS

The technical details for the NDS assembly Service Life, Reliability, Maintenance and Logistics capability are defined in JSC-63686, PTRD for NDS

**Reliability.** The NDS assembly is designed to support multi-mission use, within the constraints of the supplied environmental parameters. Post mission refurbishment and acceptance testing will be required in order to assure integrity for follow-on mission success. The NDS -301 is certified for a nominal On-orbit Service Life of 231 days. To support the CDA Element application, the NDS -302 is certified for a nominal On-orbit Service Life of 15 years.

The NDS assembly provides the high reliability needed for mission assurance for the specified on-orbit service life. The NDS -301 capture mechanisms are certified for 2 active and 50 passive docking cycles per vehicle mission. The NDS capture functionality is single-fault tolerant. The NDS design provides redundant avionics, HCS



hooks and drive mechanisms, and power and computer circuits that allow integration with independent power and computer system channels on the host vehicle.

**Maintenance.** The NDS -301 assembly will not need any Preventative Maintenance during the 231 day on-orbit service life. The NDS Project will ensure all PM actions that may become due in scheduled mission period are completed prior to the initial shipment of an NDS unit to the Host Vehicle developer. The Preventative Maintenance requirements for the Passive NDS assembly are TBD.

NDS configurations are not designed for on-orbit Corrective Maintenance. So the NDS assembly currently does not contain components that are designated as on-orbit replacement units. However, the -302 avionics boxes installation in the Host Vehicle should enable on-orbit IVA remove & replace maintenance if needed for a 15-yr mission life.

**Logistics Support.** The NDS hardware is assembled and cleaned to at least the Visibly Clean (VC) level. The NDS pressure seals may have a higher cleanliness level. After cleaning, the NDS components are protected in heat-sealed double bagging for storage and shipping; items that are too large for heat-sealed double bagging are pre-packaged to cover all critical surfaces. The NDS assembly is shipped in a special shipping container to the VV developer. After acceptance testing is complete, the NDS assembly is typically shipped with the MMOD shield removed. (Note, the MMOD shield must be removed to fasten the NDS assembly onto the host vehicle mounting flange). After delivery of the NDS assembly, the host vehicle developer is responsible for routine post-shipping inspections, handling and storage in appropriate environmentally controlled conditions.

### 3.13 ASSEMBLY INTEGRATION AND TEST SUPPORT

The NDS assembly has a dedicated GSE connector on the NDS control box that can interface with a standard laptop computer. The NDS Project provides the GSE software that runs on a standard laptop. This GSE software includes a Graphical User's Interface (GUI) that allows User personnel to command the NDS flight unit and to monitor its health & status data when the laptop computer is connected at the GSE connector port for engineering evaluation and check-out test activities.

The NDS Project can provide Host Vehicle Projects with GSE and other Test Support Equipment (TSE) items to support NDS flight unit integration with the host vehicle and the associated qualification and acceptance/checkout test procedures. See Section 2.3 for additional information on the NDS GSE and TSE assets that can be made available to NDS Users.



### 3.14 SUMMARY OF THE NDS CONFIGURATION DIFFERENCES

Table 3.13-1 is a summary recap of the key configuration differences between the various NDS configurations that were identified in the previous paragraphs.

**TABLE 3.13-1 NDS CONFIGURATION SUMMARY**

Dash Number	NDS (-301)	NDS (-302)	NDS (-303)	NDS (-304)
<b>Configuration Differences</b>				
Status <sup>(1)</sup>	In Development	<input type="checkbox"/>	Available on Request	Available on Request
Specification Max Weight (lbs)	750	704 <sup>(2)</sup>	<input type="checkbox"/>	711
Host Power	120 VDC	<input type="checkbox"/>	<b>28 VDC</b>	<input type="checkbox"/>
NDS Tunnel Height (in.)	15	TBD <sup>(3)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic Seal or Seal Surface	Seal	<b>Seal Surface</b>	<input type="checkbox"/>	<input type="checkbox"/>
Host Leak Check Port	NDS Tunnel	<b>Host Tunnel</b>	<input type="checkbox"/>	<input type="checkbox"/>
Separator Striker Interface	Integral to NDS	TBD	<input type="checkbox"/>	<input type="checkbox"/>
Power & Data Umbilical Interface	Integral to NDS	<b>On Host</b>	<input type="checkbox"/>	<input type="checkbox"/>
SCS Magnet Striker	Yes	<input type="checkbox"/>	<input type="checkbox"/>	<b>No</b> <sup>(4)</sup>
Active/Passive Hooks	12 Pairs	<input type="checkbox"/>	<input type="checkbox"/>	<b>12 Active</b> <sup>(5)</sup>
Pyrotechnic Hook Release	Yes	<b>No</b> <sup>(6)</sup>	<input type="checkbox"/>	<b>No</b> <sup>(6)</sup>
Electrical Boxes Mounting	Integral to NDS	<b>On Host</b> <sup>(3)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
Electrical Cable Length / Routing	Integral to NDS	<b>Host Specific Routing</b>	<input type="checkbox"/>	<input type="checkbox"/>
Hermetic Pass Thru for NDS Control	Integral to NDS	<b>In Host Structure</b>	<input type="checkbox"/>	<input type="checkbox"/>
MMOD Shield	Integral to NDS	<b>Host Provided</b> <sup>(7)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
Passage Way Closeout	Integral to NDS	<b>Host Provided</b>	<input type="checkbox"/>	<input type="checkbox"/>
Life	231 Days	<b>15 Years</b>	<input type="checkbox"/>	<input type="checkbox"/>
Active Docking Cycles	2	<b>Future</b> <sup>(8)</sup>	<input type="checkbox"/>	<input type="checkbox"/>
Passive Docking Cycles	50	<input type="checkbox"/>	<input type="checkbox"/>	None
<b>Other Key Interfaces</b>				
S/W Interface to Host	TIA422 or MIL-STD-1553	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comm Channels to Host (NDS capture & heater control)	1 each channel for System A & B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Motorized External "Pass-Thru" Umbilicals Connectors	Power / Data <sup>(9)</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Motorized Separation System	Yes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Legend</b>				
	<input type="checkbox"/>	Indicates configuration is same as -301		

**NOTES:**

- (1) NDS -302 developed for initial application on the CDA Element. NDS -303 & -304 configurations will not be produced until requested.
- (2) NDS -302 mass includes weight of avionics boxes, but does not include host provided components (e.g. MMOD shield, Passive TCS)

- (3) NDS -302 pressure tunnel section is shorter than the standard NDS configuration. The -302 configuration does not accommodate avionics boxes, which must be installed inside the host.
- (4) NDS -304 does not include magnetic striker plates to reduce weight.
- (5) NDS -304 configuration only contains active hooks, and does not support contingency hook latching by the opposing target vehicle. The passive hooks are removed to save weight.
- (6) NDS -302 and 304 configurations have the pyrotechnic bolts moved and have inert bolts installed in the hook pairs.
- (7) NDS -302 configuration does not include MMOD shield or MLI blanket. The host vehicle must provide the necessary MMOD and passive thermal protection for the NDS.
- (8) The NDS -302 configuration is initially certified only for passive-mode operations on the CDA Element, but has partial soft and hard capture functionality.
- (9) The Block 0 NDS only has power/data external umbilical connectors, but is scarred to support fluid water or propellant umbilical connectors in future block upgrades.

**APPENDIX A - ACRONYMS AND ABBREVIATIONS**

ACS	Attitude Control System
	Atmospheric Control System
Amp (or A)	Ampere(s)
ANSI	American National Standards Institute
AOR	Available On Request
APAS	Androgynous Peripheral Attachment System
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
CBM	Common Berthing Mechanism
CDA	Common Docking Adapter
CN	Change Notice
C&DH	Command and Data Handling
C&T	Communication and Tracking
DC	Direct Current
deg	Degree
DQA	Document Quality Assurance
DRM	Design Reference Mission
ECLSS	Environmental Control & Life Support System
EDMS	Electronic Document Management System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Electrical Power System
ESMD	Exploration Systems Mission Directorate
°F	Degrees Fahrenheit

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g	Acceleration due to gravity
GN&C	Guidance, Navigation and Control
GFE	Government Furnished Equipment
HCS	Hard Capture System
hr	Hour
HV	Host Vehicle
Hz	Hertz
ICD	Interface Control Document
IDD	Interface Definition Document
IDSS	International Docking System Standard
IEEE	Institute of Electrical and Electronic Engineers
iLIDS	International Low Impact Docking System
IMV	Inter-Module Ventilation
in	Inch(es)
IRD	Interface Requirements Document
ISS	International Space Station (Program)
IVA	Intra-vehicular Activity
JSL	Joint Station LAN
JSC/EA	JSC Engineering Directorate
kg	Kilogram(s)
LAN	Local Area Network
lb(s)	Pound(s)
lbm	pounds mass
LIDS	Low Impacts Docking System
MCC	Mission Control Center
MIL	Military
MDM	Multiplexer /Demultiplexer

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MDP	Maximum Design Pressure
MLI	Multi-layer Insulation
MMOD	Micro Meteorite Orbital Debris
mm	Millimeter(s)
MOU	Memorandum of Understanding
MVP	Master Verification Plan
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NC	Noise Criteria
NDS	NASA Docking System
NDSP	NDS Project
NIA	NDS Integration Agreement
NSI	NASA Standard Initiator
NTE	Not To Exceed
OEM	Original Equipment Manufacturer
ORG	Organization
ORU	Orbital Replaceable Unit
PCBM	Passive Common Berthing Mechanism
PEC	Pyrotechnic Event Controller
PIC	Pyrotechnic Initiator Controller
PMA	Pressurized Mating Adapter
POC	Point of Contact
psia	pounds per square inch absolute
psid	pounds per square inch (differential)
Rad.	Radial
ref	Reference
Rev.	Revision

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RPCM	Remote Power Control Module
RPODU	Rendezvous, Proximity Operations, Docking and Undocking
RF	Radio Frequency
RT	Remote Terminal
sccs	Standard Cubic Centimeters per Second
SCS	Soft Capture System
SI	System Internationale
SOMD	Space Operations Mission Directorate
SSP	Space Station Program (documents)
SSQ	Space Station Quality
SSRMS	Space Station Remote Manipulator System
STD	Standard
TBC	To Be Confirmed
TBD	To Be Determined
TBS	To Be Scheduled
TCS	Thermal Control System
UART	Universal Asynchronous Receiver/Transmitter
USOS	United States On-orbit Segment
V	Volts
VC	Visibly Clean
VDC	Volts Direct Current
Vrms	Volts Root-mean-square
VV	Visiting Vehicle
W	Watts

**APPENDIX B - GLOSSARY OF TERMS**

Abort	Specific action or sequence of actions taken by crew or ground control that terminates a flight process. Same as "emergency termination".
Active-NDS	NDS on chaser vehicle that is in the "active" mode.
Approach	Action of the chaser vehicle as it nears the target vehicle. "Final Approach" is usually the straight-line approach along the vector directly to the target mating mechanism or robotic arm grapple position.
Attached	Visiting Vehicle is in hard capture / mated configuration with the CDA.
Automated	An apparatus, process, or system manufactured to operate without human observation, effort, or decision.
Autonomous	Having the right or the power of self government; undertaken or carried on without outside control. This term addresses operational usage.
Capture	State when the mating mechanisms of approaching vehicle and ISS achieve physical connection. Many mating mechanisms first achieve "soft docking" state in which the two vehicles are captured at an extendible interface, then a "hard docking" when the extendible mechanism is retracted and relative motion is fully constrained.
CDA Element	ISS element that is equipped with NDS -302 to allow VV that are equipped with the NDS or IDSS compliant docking system to dock to the ISS.
Chaser Vehicle	Vehicle with the active-NDS that maneuvers to capture the passive NDS on the target vehicle. Same as the vehicle conducting "Proximity Ops."
Corridor	Physical touching of two space objects.
Contact	During final approach; a cone-shaped region extending from a desired approach end point, within which an approaching vehicle must stay due to plume constraints. It is formed by allowing an angular error from the center line vector which extends out from the desired end point. This may also apply to separation, if separating vehicle must fire its maneuvering jets. The allowable angular deviation from the center line may also be range dependent, resulting in a series of 'steps' in the conical corridor.
Critical Commands	All the commands that can modify the trajectory of the chaser vehicle; modify the limits placed on the vehicle, which are monitored by the target vehicle crew or the Ground; and change the fault tolerance of the vehicle.
Departure	The mission phase which includes reconfiguration, undocking, and separation of target and chaser vehicles.
Deploy	Deliberate release of a mechanism or appendage from a stowed or retracted configuration
Dock	Mating of chaser vehicle, under its own flight control, to target vehicle.



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Hard Capture	The configuration of the chaser and target hard mate seals and the capture latches are locked. Same as "Hard Dock or Hard Mate."
Host Vehicle	A vehicle (or element) onto which the NDS assembly is attached.
International Docking System Standard (IDSS):	New international docking interface standards, which are currently being developed. The NDS design is consistent with the preliminary interface standards that have been developed for the IDSS.
International Low Impact Docking System (iLIDS)	Initial name for the NASA Docking System (NDS) as follow-on to previous NASA Low Impact Docking System that was redesigned to comply with new IDSS docking interface standards.
Mate	To bring two pieces of hardware together so that they mechanically attach to each other.
NASA Docking System (NDS)	The NASA implementation of an androgynous peripheral docking system, which is consistent with the preliminary IDSS interfaces that are currently being developed.
Passive-NDS	NDS on target vehicle that is in the "passive" mode.
Proximity Operations	Activities of a space vehicle within close range (< ~1 km) and with small relative velocity (< tenths of m/sec) with respect to a target vehicle. Includes final approach, station-keeping, fly-around and initial separation.
Rendezvous	Activities to bring a space vehicle ("chaser") close to another ("target") at low or zero relative velocity. This involves guidance (both from the ground and from on board the vehicle), navigation and control.
Separation	Motion of one space object away from another. It may be initiated by propulsive forces, by spring forces, or even by orbital mechanics effects.
Soft Capture	The configuration of the VV making the first contact with the CDA petals while the extension ring is extended through VV capture by the magnets or mechanical latches. Same as "Soft Dock."
Target Vehicle	The vehicle with the passive-NDS that will be captured by the Chaser Vehicle with the active-NDS. Includes the "CDA element."
Undock	Open the mechanical latches connecting two mated space objects. Same as "release."
Visiting Vehicle	Vehicle that berths/docks to the ISS for crew/cargo transportation mission.

**SSP 50920****November 2010****APPENDIX C – REFERENCE DOCUMENTS**

The following reference documents include specifications, models, standards, guidelines, handbooks, and other special publications. The current issue of the following documents is available in the NASA Electronic Document Management System (EDMS) at the following link.

<http://iss-www.jsc.nasa.gov/ss/issapt/edms/>

The EDMS is restricted and requires a password. VV programs are provided access to EDMS after the appropriate Memorandum of Agreement has been signed.

<b>Document</b>	<b>Title</b>
SSP 50808 Revision C November 2010	International Space Station (ISS) To Commercial Orbital Transportation Services (COTS) Interface Requirements Document (IRD)
JSC 65795 Basic May 20, 2010	NASA Docking System (NDS) Interface Definition Document (IDD)
JSC-64599	NDS Electrical Power Quality Description Document
ASME Y14.5M-1982 1 January 1982	Dimensioning and Tolerancing
IEEE/ASTM SI10      2002	American National Standard for Use of the International System of Units (SI): The Modern Metric System
MIL-STD-1553B      Notice 4, January 15, 1996	Interface Standard for Digital Time Division Command/Response Multiplex Data Bus
SSP 30219 Revision J 1 May 2008	Space Station Reference Coordinate Systems
SSP 30240 Revision G May 30, 2006	Space Station Grounding Requirements
SSP 30242 Revision J September 29, 2006	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility
SSP 30243 Revision M February 28, 2007	Space Station Requirements for Electromagnetic Compatibility

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<b>Document</b>	<b>Title</b>
SSP 30245 Revision N February 28, 2007	Space Station Electrical Bonding Requirements
SSP 30482 Revision C July 7, 1997	Electric Power Specifications and Standards Volume 1: EPS Electrical Performance Specifications
SSP 41162 Revision BA 30 December 2008	Segment Specification for the United States On-Orbit
SSP 50005 Revision E June 30, 2006	International Space Station Flight Crew Standard (NASA-STD-3000/T)
SSP 50892 Baseline June 2009	Ethernet Requirements for Interoperability with the Joint Station LAN (JSL)
SSP 52051 Revision A September 1, 2005	User Electric Power Specifications and Standards Volume 1: 120 Volt DC Loads
SSQ 21635 Revision L August 14, 2006	Connectors and Accessories, Electrical, Circular, Miniature, IVA/EVA Compatible, Space Quality, General Specification For
SSQ 21652 Revision G February 15, 2005	Wire, Electric, Silicone-Insulated, Nickel-Coated Copper, Space Quality, General Specification For
SSQ 21656 Revision E January 27, 2004	Wire and Cable, Electric, Fluoropolymer-Insulated, Nickel Coated Copper or Copper Alloy, General Specification For

## APPENDIX D – OPERATIONS CONCEPT SCENARIOS

The following scenarios provide a summary of the concept of typical operations for the active-NDS docking and undocking event sequence and for the overall Visiting Vehicle (chaser) to CDA (target) operations. Some of these scenario steps may be altered or refined in actual mission planning.

### **NDS Specific Docking and Undocking Operations Performed by VV Crew or Ground-ops**

- **VV/NDS Approach & Docking Event Sequence**
  - VV at ISS control zone initial point and ready to start approach
  - Configure active-mode NDS on VV (Chaser) for docking
    - Power-up docking systems
      - Main bus power to avionics boxes
      - Activate system heaters
    - Perform system checkout
    - Monitor temperatures within limits
    - Release Soft Capture System (SCS) lockdown
    - Extend SCS load/docking ring
    - Initiate SCS -- waiting for contact
  - Contact with the CDA (target vehicle)/passive-mode NDS interface
    - Guide petals mesh
    - SCS minimized contact forces as SCS ring come together
    - SCS “soft-capture” sensor indicates soft capture attainable
    - SCS energized magnets for soft capture
    - SCS magnet captures striker plate on CDA passive inner ring
    - SCS attenuates vehicle motions
  - Zero/null SCS misalignment
    - SCS reach null position
    - SCS ring retract to Hard Capture System (HCS) ready to hook position
    - HCS guide pins engaged
    - HCS “ready-to-hook” sensor indicates ready to hook position achieved
  - Close Active-hook latching system
    - HCS motor drives hook mechanisms
    - HCS 12 tangential hooks engage with 12 passive-hooks in CDA (target)
    - HCS seals compressed
    - HCS “interface sealed” sensor indicates seal achieved
  - Engage SCS Lock-down
    - SCS magnets de-energize
    - SCS load ring returns to home position
    - SCS lock-down engaged
    - SCS lock-down switch indicates lock-down achieved
  - Drive external pass-through power/data umbilicals and compress push-off springs
    - Umbilicals engaged and undocking push-off spring compressed
    - Activate ISS power and data interface
    - Confirm power and data transfer
  - Power-down active-NDS for VV mated ops

- **VV/NDS Berthing Event Sequence**
  - Reserved. This feature to be implemented in future block/version capability  
(*Note these events should be similar to the docking event sequence; except that the Station robotic arm is used to maneuver VV from station keeping to NDS petal engage/soft capture ready position and the NDS load attenuation system is not needed*).
- **VV/NDS Undocking and Departure Event Sequence**
  - Configure active-NDS on VV for undocking
    - Power-up docking systems
    - Perform system checkout
  - Initiate Undock
    - HCS active hooks disengage from passive hooks in CDA
    - HCS “undocking complete” sensors indicate hook release
  - Performs contingency hook release (if nominal release not achieved)
    - Manually recycle hook release command
    - If unable to disengage hooks by other means:
      - Power and command pyrotechnical bolt fire
    - (Note: the passive hooks in CDA/NDS-302 do not have pyrotechnic bolts installed for contingency hook release).
  - Undocking and initial separation from CDA/ISS (target)
    - HCS push-off springs stroke 1 inch
    - HCS push-off springs provide initial separation velocity
    - (Note: passive-NDS on CDA also has push-off springs that provide redundant capability)
  - When safe separation distance achieved:
    - VV fires thrusters for departure maneuvers
  - Power-down active-NDS for VV re-entry ops.

### **VV to CDA Generic Integration Operations**

- **VV Program Integration and Ground Processing**
  - VV informs ISS/NDS program of interest
  - NDS program assigns a integration manager to assist VV project
  - VV and ISS sign Integration Agreement
  - NDS provides VV with NDS engineering documents
  - VV performs engineering analysis and verification data
  - NDS provides NDS flight hardware
  - VV receives and inspects NDS flight hardware and test equipment
  - VV installs and tests NDS flight hardware
    - Initial installation and verification testing supported by NDS
  - VV provides verification data package to ISS/NDS Program for review
    - Interface requirement compliance data package and certifications
  - VV integrates with launch vehicle
    - Perform functional checkout of NDS prior to launch
  - VV and ISS perform Flight Operations Readiness Review
- **VV Launch and Rendezvous Ops**
  - VV/Launch Vehicle Launch operations
  - VV insertion into orbit
  - VV rendezvous with ISS

- VV perform post-launch check-out of NDS functionality
- VV arrive at ISS control zone / initial approach point
- **VV Approach and Docking Ops to ISS/CDA**
  - ISS configures CDA and confirms thermal preconditioning achieved
  - VV approved to start approach
  - VV power-up and check NDS readiness
  - VV and ISS confirm docking interface temperature within limits
  - VV deploy/ready NDS SDS
  - ISS confirm flight attitude hold parameters
  - VV acquire ISS/CDA approach and navigation aids
    - CDA laser reflectors
  - VV maneuver to ISS docking port final approach course
  - VV maneuver within docking approach corridor/cone to docking port
  - VV acquires CDA docking target and fine-align to SCS petal engagement point
  - VV confirm ISS ACS mode status by radio call (or by MCC ground communications)
  - VV NDS SCS petals engages CDA petals to soft capture point
  - VV NDS SCS performs soft capture and load ring retraction
  - ISS modes to free drift
  - VV NDS SCS attenuates/nulls motion and retracts load ring
  - VV NDS HCS perform hard capture
  - VV and ISS confirm hard capture and interface seal integrity
  - ISS resumes active attitude control mode
  - VV engage NDS external pass-through power/data umbilicals
  - ISS confirm power and data interface integrity
  - VV power-down NDS
- **ISS Mated Operations with ISS/CDA**
  - VV pressurizes CDA-NDS shared vestibule volume and conducts leak check
    - CDA-NDS vestibule may be pressurized by ISS when necessary
  - ISS tests CDA/VV air (for VV unmanned cargo mission)
  - ISS equalizes CDA and ISS cabin pressure and opens/stows the Node Hatch
  - ISS removes/stows the CDA docking target
  - ISS removes NDS SCS docking petals as necessary for 32 inch passageway clearance
  - CDA IMV air flex duct positioned in VV docking system
  - VV opens/stows VV hatch (may be done by ISS for unmanned VV)
  - ISS activates Node IMV fan for intermodule air flow/circulation with VV
    - VV circulates intermodule air inside VV cabin and returns back through the VV docking tunnel/NDS passageway to the CDA passageway to the ISS node hatch.
  - ISS provides VV with electrical system power resources per integration agreement and mission timeline
  - ISS provides VV C&DH systems resources per integration agreement
    - VV ground control commands can be routed though ISS Mission Ops Center at JSC and up-linked on the S-band to the ISS C&C computer and routed through 1553 bus to VV computer system
    - VV provides critical health and safety status on ISS 1553 bus to inform ISS crew and to downlink to ISS Mission Control Room
    - VV can provides system status telemetry on Ethernet bus to downlink on KU-band to ISS mission control room and route to VV mission ops center

- ISS & VV conduct crew and cargo transfer as appropriate
- VV configured for quiescent/low-power ops mode
- VV performs periodic power-up checks as needed
- **ISS Undocking and Landing Operations**
  - Prior to scheduled undock date: VV power-up and check NDS functionality
  - VV return cargo complete / crew ingress mated vehicle
  - ISS crew re-installs SCS docking petals in deployed position, if necessary
  - VV crew close VV hatch (*done by ISS crew for unmanned cargo vehicle*)
  - ISS crew remove IMV duct, reposition CDA alignment petals and re-install CDA docking target
  - ISS crew close ISS/NODE hatch
  - VV power-up and configure for undocking. Active-NDS power-up and checks.
  - ISS discontinue station power and data utility resource transfer
  - ISS or VV crew depressurize the CDA-NDS shared vestibule volume
  - VV approved for undocking and departure flight
  - ISS and VV mode to free drift
  - VV command active-NDS hook disengagement
  - ISS and VV confirm undocking complete sensor status
    - VV perform contingency hook release procedures if necessary
  - VV NDS push-off spring initiates VV separation from ISS
    - CDA passive-NDS provides redundant push-off springs
  - When safe separation distance achieved:
    - ISS resumes active attitude control/hold
    - VV fires thrusters for departure maneuvers
  - VV power-down active-NDS
  - VV initiate re-entry burn
  - VV jettison NDS from docking tunnel (*as applicable*)
    - NDS nominal jettison at docking tunnel flange with VV pyrotechnic device
    - NDS jettison provides additional clearance for drogue/parachute deployment  
(*Note: Additional analysis/testing would be needed to certify NDS for landing loads on specific VV application*)
  - VV re-entry, landing and recovery -- mission complete!!



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**APPENDIX E – (RESERVED)**