# MOSAR

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| **Deliverable Reference** | : | D2.5 |
| **Title** | : | HOTDOCK Preliminary Design Definition File (DDF) |
| **Confidentiality Level** | : | PU |
| **Lead Partner** | : | Space Applications Services |
| **Abstract** | : | This document provides key design information on HOTDOCK. It corresponds to a Design Definition File, for the Generation 1 (G1) of HOTDOCK. It covers the key aspects of the design, and should be released as a Public deliverable. |
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# 1 Introduction

## 1.1 Purpose and Context

HOTDOCK is a standard robotic interface, developed by Space Applications Services, supporting mechanical, data, power and thermal transfer. Its final purpose is to be used as standard connector, in future space applications, between spacecraft and payloads, and as end effector of robotic manipulator for their manipulation and transfer.

HOTDOCK is to be used as a standard interface in H2020 MOSAR (PG9) project, as well as in H2020 PULSAR (OG8) and H2020 PRO-ACT (OG11).

Space Applications Services is currently developing the HOTDOCK technology, through successive design and prototyping iterations. The purpose of this document is to provide information about the design of HOTDOCK, with the aim of releasing that material publicly, for the community to be able to include HOTDOCK as a possible technology in H2020 Space Robotics Technologies SRC Call 3 proposals (and next such calls in the future).

## 1.2 Document Structure

In brief, the document is structured as follows:

**Section 1: Introduction**

This introductory section.

**Section 2: Review of HOTDOCK requirements**

Review the initial HOTDOCK requirements, also indicating where they are addressed in this document.

**Section 3: System Configuration.**

Gives an overview of HOTDOCK and its declinations (active, passive, etc.).

**Section 4: Operational Description**

Introduces HOTDOCK operational principles.

**Section 5: HOTDOCK Standard Interface Design**

Presents the overall design of HOTDOCK.

**Section 6: HOTDOCK Controller**

Provides specific information on the HOTDOCK controller.

**Section 7: Technical Budgets**

Summarizes the technical budgets (mass and power).

**Section 8: Interface Requirements (IRD)**

Provides a list of project specific requirements (MOSAR, PULSAR, PRO-ACT) influencing the design of HOTDOCK and the interfacing of HOTDOCK with project specific components.

## 1.3 Applicable Documents

AD1 SRC_Guidelines_Space_Robotics_Technologies (COMPET-4-2016)

AD2 PRSPR-ESA-T3.1-TN-D3.1-Compendium of SRC activities (for call 1)-v1.8_0

## 1.4 Reference Documents

RD1 PULSAR (OG8) Grant Agreement

RD2 MOSAR (OG9) Grant Agreement

RD3 PRO-ACT (OG11) Grant Agreement

~~RD3~~RD4 D2.6 - HOTDOCK Preliminary Design Justification File

## 1.5 Acronyms

| | |
|---|---|
| ADC | Analog to Digital Converter |
| APM | Active Payload Module |
| CAN | Controller Area Network |
| DDF | Design Definition File |
| DJF | Design Justification File |
| EGSE | Electrical Ground Support Equipment |
| ESA | European Space Agency |
| GPIO | General Purpose Input/Output |
| I/F | Interface |
| ICD | Interface Control Document |
| IRD | Interface Requirements Document |
| I2C | Inter-Integrated Circuit |
| LVDS | Low Voltage Differential Signaling |
| MAC | Media Access Control |
| Mbps | Megabits per second |
| MGSE | Mechanical Ground Support Equipment |
| MOSFET | Metal–Oxide–Semiconductor Field-Effect Transistor |
| NTC | Negative Temperature Coefficient |
| OG | Operational Grant |
| ORU | Orbital Replacement Unit |
| PCB | Printed Circuit Board |

| | |
|---|---|
| PWM | Pulse Width Modulation |
| ROD | Review Of Design |
| rpm | rotations per minute |
| SpW | SpaceWire |
| SPI | Serial Peripheral Interface |
| SRC | Strategic Research Cluster |
| TBC | To Be Confirmed |
| TBD | To Be Defined |
| TC | TeleCommand |
| TM | TeleMetry |
| TRL | Technology Readiness Level |
| UART | Universal Asynchronous Receiver/Transmitter |
| USART | Universal Synchronous/Asynchronous Receiver/Transmitter |

# 2 Review of HOTDOCK Requirements

This section gathers the whole set of initial requirements having served as a driver for the design and development of the HOTDOCK interface.

Note that Call 2 projects specific requirements, as further elaborated during the execution of these projects, are not reviewed here. However, we consider that the Call projects' requirements form the baseline for an Interface Requirements Document (IRD), which is provided in the Section 8 of this document.

## 2.1 Functional Requirements

| | | | |
|---|---|---|---|
| **FuncR_001** | The standard interface shall provide a mechanical interface to couple spacecraft (active) modules with each other or to the spacecraft platform and bus respectively | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R01.1 |
| **COMMENT** | / | | |
| **COVERED IN SECTION** | 3,4,5,6 | | |

| | | | |
|---|---|---|---|
| **FuncR_002** | The standard interface shall provide an electrical interface to transfer electrical energy (power) | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R02.2 |
| **COMMENT** | / | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_003** | The standard interface shall provide a data interface to allow exchange of data between individual modules | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R02.3 |
| **COMMENT** | Modules can be payload, spacecraft or robotic manipulator | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_004** | The standard interface shall provide a thermal interface to allow active transfer of thermal flow | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R02.4<br>Call 1 SRC Comp, R07.3 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.3 | | |

| | | | |
|---|---|---|---|
| **FuncR_005** | The standard interface shall allow the mechanical, power, data and thermal coupling with another interface that cannot provide actuation | | M |
| **VERIFICATION** | ROD / Testing | **SOURCE** | HOTDOCK-TN-001 |
| **COMMENT** | To support faulty device and reduced interface functions (e.g. for cost reduction) | | |
| **COVERED IN SECTION** | 4, 5 | | |

| | | | |
|---|---|---|---|
| **FuncR_006** | The standard interface shall allow the mechanical, power, data and thermal de-coupling with another interface that cannot provide actuation | | D |
| **VERIFICATION** | ROD / Testing | **SOURCE** | HOTDOCK-TN-001 |
| **COMMENT** | To support faulty device | | |
| **COVERED IN SECTION** | 3,4,5 | | |

| | | | |
|---|---|---|---|
| **FuncR_007** | The standard interface shall be compliant with launch loads | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R04.2 |
| **COMMENT** | Compatible launch loads and conditions to be further analyzed. | | |
| **COVERED IN SECTION** | 3, 5 | | |

| | | | |
|---|---|---|---|
| **FuncR_008** | The mechanical interface shall withstand all mechanical loads brought by external sources to the interface during operations.<br><br>The standard interface shall support the transfer of the following mechanical loads in connected configuration:<br>• Axial Force: 400N<br>• Radial Force: 400N<br>• Bending Moment: 250Nm<br>• Torsion: TBD Nm | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R02.1<br>Call 1 SRC Comp, R04.1<br>HOTDOCK-TN-001-4.5.2 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **FuncR_009** | The mechanical interface shall minimize force/torque for mating and de-mating | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R04.3 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 4, 5.1 | | |

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|---|---|---|---|
| **FuncR_010** | The mechanical interface shall maximize positioning tolerance for mating, with a minimum of 5mm | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R04.8 |
| **COMMENT** | / | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **FuncR_011** | The standard interface shall be unlockable | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R03.1 |
| **COMMENT** | The term unlockable is interpreted by the capability for two attached interfaces to unlock by the mean of a secondary mechanism, different from | | |

| | |
|---|---|
| | the standard actuation approach/ |
| **COVERED IN SECTION** | 5.1.7 of RD4 |

| | | | |
|---|---|---|---|
| **FuncR_012** | The standard interface shall be provide dust protection | | M |
| **VERIFICATION** | ROD / Testing | **SOURCE** | HOTDOCK-TN-001-4.5.2 |
| **COMMENT** | To support planetary applications | | |
| **COVERED IN SECTION** | 5.4 | | |

| | | | |
|---|---|---|---|
| **FuncR_013** | The power distribution unit shall provide low-level voltage power rails to supply the internals of the HOTDOCK interface – controller, sensors and motor drive. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Architecture Analysis |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_014** | The electrical interface unit shall be capable of supporting TBC W of power transfer between two standard interfaces. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R02.2 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_015** | The electrical interface shall incorporate an overcurrent, overvoltage and thermal protection. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R05.1<br>Call 1 SRC Comp, R05.2<br>Internal expertise |
| **COMMENT** | Overcurrent includes protection against surge | | |
| **COVERED IN** | 5.2 | | |

| | |
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| **SECTION** | |

| | | | |
|---|---|---|---|
| **FuncR_016** | The electrical interface shall not cause electro-magnetic interference in the modules being coupled which affects their functionality. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R05.3 |
| **COMMENT** | The electrical interface shall provide electro-magnetic compatibility against couple modules | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_017** | The electrical interface shall incorporate a bidirectional power switch to control current flow at the interface. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R05.4<br>Call 1 SRC Comp, R05.9 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

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|---|---|---|---|
| **FuncR_018** | The electrical interface shall provide temperature, and power (voltage and current) telemetry from local (TBC) and global power buses | | M |
| **VERIFICATION** | Testing | **SOURCE** | Internal Expertise |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
|---|---|---|---|
| **FuncR_019** | Electrical system in passive state shall draw less than TBC mW of quiescent power. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Internal Expertise |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2, 7.2 | | |

| | | | |
| --- | --- | --- | --- |
| **FuncR_020** | The data interface shall allow a data rate of minimum 100Mbit/s | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | To support the recording and processing of large amounts of data between modules | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
| --- | --- | --- | --- |
| **FuncR_021** | The data interface shall provide duplex communication abilities | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, R06.4 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

| | | | |
| --- | --- | --- | --- |
| **FuncR_022** | The data interface shall support Ethernet or EtherCAT bus | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R06.5 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

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| --- | --- | --- | --- |
| **FuncR_023** | The data interface shall support SpaceWire bus | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOCK-TN-001-4.5.2 (OG9-MOSAR)<br>OG5 expertise |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2 | | |

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| --- | --- | --- | --- |
| **FuncR_024** | The data interface shall support at least one technology with capabilities of dynamic data bus re-configuration and routing | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOCK-TN-001-4.5.2 (OG9- |

| | | | |
|---|---|---|---|
| | | | MOSAR) |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.2, 6 | | |

| | | | |
|---|---|---|---|
| **FuncR_025** | The thermal interface shall allow a thermal flow rating of: TBD W. | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.3 | | |

| | | | |
|---|---|---|---|
| **FuncR_026** | The thermal interface shall provide active regulation of thermal flow | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.3 | | |

| | | | |
|---|---|---|---|
| **FuncR_027** | The interface controller shall be able to control the actuator and process the associated sensors | | M |
| **VERIFICATION** | Testing | **SOURCE** | System architecture |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 6 | | |

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|---|---|---|---|
| **FuncR_028** | The microcontroller shall convert required analog sensor signals to digital values and store them in internal memory. | | M |
| **VERIFICATION** | Testing | **SOURCE** | System Architecture |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 6 | | |

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|---|---|---|---|
| **FuncR_029** | The microcontroller shall define and store the status of the HOTDOCK interface based on sensor data:<br>• Alignment / proximity status<br>• Temperature<br>• Controller supply voltage<br>• Controller current consumption<br>• Connection status<br>• Motor position<br>• SI orientation (c.f. design symmetry) | | M |
| **VERIFICATION** | Testing | **SOURCE** | System architecture |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 6 | | |

| | | | |
|---|---|---|---|
| **FuncR_030** | The interface controller shall be to send and receive TM/TC from the module/spacecraft/EGSE OBC | | M |
| **VERIFICATION** | Testing | **SOURCE** | System Architecture |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 6 | | |

| | | | |
|---|---|---|---|
| **FuncR_031** | The interface controller shall be able to monitor the status of connection of the interface | | M |
| **VERIFICATION** | Testing | **SOURCE** | Previous SIROM expertise |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 6 | | |

## 2.2 Design Requirements

| | | | |
|---|---|---|---|
| **DesR_001** | The standard interface shall have an androgynous design | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>HOTDOCK-TN-001 |
| **COMMENT** | | | |

| | | | |
|---|---|---|---|
| **COVERED IN SECTION** | 3, 5.1 | | |
| **DesR_002** | The standard interface shall have a scalable design | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **DesR_003** | The standard interface design shall feature one-failure-tolerance redundancy<br><br>The mechanism should not have single point of failure components | | M |
| **VERIFICATION** | Review of Design / Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.5<br>Call 1 SRC Comp, R04.9 (mech)<br>Call 1 SRC Comp, R06.5 (data)<br>ECSS-E-ST-33-01 |
| **COMMENT** | This is applicable to the different sub-interfaces. Includes sensors, motors and electronic boards. If additional parts can't be included, then a proof of high design margins shall apply. | | |
| **COVERED IN SECTION** | | | |

| | | | |
|---|---|---|---|
| **DesR_004** | The standard interface design shall present a low complexity with minimization of moving parts | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.8 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **DesR_005** | The standard interface shall have a robust design | | M |
| **VERIFICATION** | Analysis / Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>ECSS-E-ST-33-01 |

| | |
|---|---|
| **COMMENT** | Mechanism design shall take into account worst-case combinations (including uncertainties) of:<br>• Extreme operational and survival steady state<br>• Transient temperature<br>• Mechanism heat dissipation<br>Temperature gradients across the assembly (differential expansion) |
| **COVERED IN SECTION** | 5 |

| | | | |
|---|---|---|---|
| **DesR_006** | The standard interface shall present a 90deg. rotational symmetry | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.6<br>HOTDOCK-TN-001-4.5.2 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **DesR_007** | The standard interface shall allow diagonal engagement up to 65 deg | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOC-TN-001-4.5.2 |
| **COMMENT** | 60 deg. Corresponds to the worst case provided by the PULSAR application, and considering 5 deg of margin | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **DesR_008** | The standard interface shall provide guidance form-fit features | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOC-TN-001-4.5.2 |
| **COMMENT** | To support the alignment process between two interfaces, specifically when multiple connections are considered. | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | |
|---|---|---|
| **DesR_009** | The standard interface shall be designed from dissimilar materials in case metallic materials are used | D(S) |

| | | | |
|---|---|---|---|
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, R03.10 |
| **COMMENT** | The implementation of this requirement in the context of this activity (non-space compatible device) needs to be confirmed, in regards to the additional costs. If not compliant, the design adaptation and material selection to reach a flight compatible design shall be described. | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **DesR_010** | The standard interface controller shall be integrated within the mechanical housing | | M |
| **VERIFICATION** | Review of Design / Inspection | **SOURCE** | Internal Expertise |
| **COMMENT** | In some circumstance with multiple standard interfaces connected to the same module, it could be interesting to centralize the controller functions and remove it from the individual interfaces (architecture TBD) | | |
| **COVERED IN SECTION** | 5, 6 | | |

| | | | |
|---|---|---|---|
| **DesR_011** | The electrical interface shall be integrated within the mechanical housing | | M |
| **VERIFICATION** | Review of Design / Inspection | **SOURCE** | Internal Expertise |
| **COMMENT** | In some circumstance with multiple standard interfaces connected to the same module, it could be interesting to centralize the electrical interface functions and remove them from the individual interfaces (architecture TBD)<br>The possibility to integrate the electrical interface electronics would be function of the required power rate transfer and list of functionalities. | | |
| **COVERED IN SECTION** | 5 | | |

| | | | |
|---|---|---|---|
| **DesR_012** | Mechanism shall be designed with a lubrication function (dry or liquid) at the contact surfaces which are in relative motion | | M(S) |
| **VERIFICATION** | Inspection (Part count)<br>Analysis | **SOURCE** | ECSS-E-ST-33-01 |
| **COMMENT** | The sliding surface should have lubrication (liquid or solid) to prevent wear and particle contamination. Only space grade lubricants must be used. | | |
| **COVERED IN SECTION** | 5.1 | | |

| **DesR_013** | The motorization assembly shall provide the minimum required torque for the worst lifetime conditions | | M |
|---|---|---|---|
| **VERIFICATION** | Analysis/Test<br>Inspection | **SOURCE** | ECSS-E-ST-33-01 |
| **COMMENT** | The final motorization torque shall incorporate the uncertainty factors | | |
| **COVERED IN SECTION** | 5.1 | | |

| **DesR_014** | The interface shall incorporate the minimum design safety factors | | M(S) |
|---|---|---|---|
| **VERIFICATION** | Analysis<br>Test | **SOURCE** | ECSS-E-ST-33-01<br>ECSS-E-ST-32-10 |
| **COMMENT** | Model uncertainty, fatigue life, buckling safety factors against yield must be demonstrated | | |
| **COVERED IN SECTION** | 5.1 | | |

| **DesR_015** | Peak hertzian contact stress shall below 93% of yield | | M |
|---|---|---|---|
| **VERIFICATION** | Analysis | **SOURCE** | ECSS-E-ST-33-01<br>ECSS-E-ST-32-10 |
| **COMMENT** | The model shall exhibit stress values smaller than 93% of the weakest material during operation | | |
| **COVERED IN SECTION** | 5.1 | | |

| **DesR_016** | Dissimilar metals shall have galvanic compatibility | | M |
|---|---|---|---|
| **VERIFICATION** | Analysis | **SOURCE** | ECSS-E-ST-33-01<br>ECSS-Q-ST-70 |
| **COMMENT** | Metal contact should prevent galvanic corrosion | | |
| **COVERED IN SECTION** | 5.1 | | |

| **DesR_017** | Selected materials shall be cracked resistant | | | M |
|---|---|---|---|---|
| **VERIFICATION** | Analysis | **SOURCE** | ECSS-E-ST-33-01<br>ECSS-Q-ST-70 | |
| **COMMENT** | The material of the interface shall have a high resistance to corrosion cracking | | | |
| **COVERED IN SECTION** | 5.1 | | | |

| **DesR_018** | Materials shall be flame retardant | | | M(S) |
|---|---|---|---|---|
| **VERIFICATION** | Analysis | **SOURCE** | ECSS-Q-ST-70-71 | |
| **COMMENT** | Low flammability materials for all components (harness, electronics, lubricants) | | | |
| **COVERED IN SECTION** | 5 | | | |

| **DesR_019** | Materials shall have low outgassing and toxicity | | | M(S) |
|---|---|---|---|---|
| **VERIFICATION** | Analysis | **SOURCE** | ECSS-Q-ST-70-71<br>ECSS-E-ST-33-01 | |
| **COMMENT** | All components (harness, electronics, lubricants) | | | |
| **COVERED IN SECTION** | 5 | | | |

## 2.3 Physical Requirements

| | | | | |
|---|---|---|---|---|
| **PhysR_001** | The standard interface shall be optimized regarding the mass | | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.7<br>Call 1 SRC Comp, R04.10 | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 5, 7 | | | |

| | | | | |
|---|---|---|---|---|
| **PhysR_002** | The standard interface shall be optimized regarding size and volume | | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.7 | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 5 | | | |

## 2.4 Interface Requirements

| | | | | |
|---|---|---|---|---|
| **IntR_001** | The standard interface shall provide a mechanical connection to the module, spacecraft bus or robotic end-effector manipulator, compatible with the mechanical loads transferred through the interface. | | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, R01.2<br>Call 1 SRC Comp, R04.6 | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 5 | | | |

| | | | | |
|---|---|---|---|---|
| **IntR_002** | The standard interface shall provide internal harnessing to connect power and data buses from the module, spacecraft or robotic end-effector manipulator | | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | Internal expertise | |
| **COMMENT** | | | | |

| | |
|---|---|
| **COVERED IN SECTION** | 5.2 |

| | | | | |
|---|---|---|---|---|
| **IntR_003 (TBC)** | The standard interface shall implement required RCOS software components | | | M (TBC) |
| **VERIFICATION** | Review of Design | **SOURCE** | Call 1 SRC Comp, R11 | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | | | | |

| | | | | |
|---|---|---|---|---|
| **IntR_004 (TBC)** | The standard interface shall allow data and commands transfer to/from other RCOS components through standardized RCOS data types | | | M (TBC) |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R11.1, R11.2 | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 5.2, 6 | | | |

| | | | | |
|---|---|---|---|---|
| **IntR_005** | The microcontroller shall provide command and telemetry of HOTDOCK interface to the APM/ASM computing unit. | | | |
| **VERIFICATION** | Testing | **SOURCE** | System Architecture | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 6 | | | |

| | | | | |
|---|---|---|---|---|
| **IntR_006** | The thermal interface shall enable thermal connection to the module structure | | | M |
| **VERIFICATION** | Review of Design | **SOURCE** | | |
| **COMMENT** | | | | |
| **COVERED IN SECTION** | 5.3 | | | |

## 2.5 Operational Requirements

| | | | |
|---|---|---|---|
| **OpR_001** | The standard interface shall be compatible with robotic servicing operations | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 3, 4 | | |

| | | | |
|---|---|---|---|
| **OpR_002** | The standard interface shall be reusable | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R03.2 |
| **COMMENT** | Our current assumption is that the number of required cycles should range between 100 and 1000 cycles (TBC) | | |
| **COVERED IN SECTION** | 3, 4, 5 | | |

| | | | |
|---|---|---|---|
| **OpR_003** | The standard interface shall allow module connections without restriction on relative module orientation | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, 8.6.1 |
| **COMMENT** | Related to androgynous and symmetry characteristics | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **OpR_004** | The open/locked state shall be detectable | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R03.3 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1, 5.2 | | |

| | | |
|---|---|---|
| **OpR_005** | Relative module orientation of the standard interface shall be detectable | M |

| | | | |
|---|---|---|---|
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R03.4 |
| **COMMENT** | / | | |
| **COVERED IN SECTION** | 5.1, 5.2 | | |

| | | | |
|---|---|---|---|
| **OpR_006** | The standard interface shall be able to open and close multiple times (including data, power thermal connectors mating/demating)<br><br>The standard interface shall allow TBD mating/demating cycles | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R04.4 (mech)<br>Call 1 SRC Comp, R05.5 (elec)<br>Call 1 SRC Comp, R06.2 (data)<br>Call 1 SRC Comp, R07.2 (therm) |
| **COMMENT** | Our current assumption is that the number of required cycles should range between 100 and 1000 cycles (TBC) | | |
| **COVERED IN SECTION** | 5.1, 5.2 | | |

| | | | |
|---|---|---|---|
| **OpR_007** | The temperature of the interface shall be monitored | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOCK-TN-001-4.5.2 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | | |
|---|---|---|---|
| **OpR_008** | The good alignment before starting the mating process shall be detectable. | | M |
| **VERIFICATION** | Testing | **SOURCE** | HOTDOCK-TN-001-4.5.2 |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 5.1 | | |

| | | |
|---|---|---|
| **OpR_009** | The standard interface controller shall be able to be switched on/off | D |

| | | | |
|---|---|---|---|
| **VERIFICATION** | Testing | **SOURCE** | Internal expertise |
| **COMMENT** | In regards to the total mission time, the operation time of the standard interface controller is very small. For energy optimization, it could be interesting to be able to switch off this component (and be able to revive it later). | | |
| **COVERED IN SECTION** | 5.1, 6 | | |

| | | | |
|---|---|---|---|
| **OpR_010** | The power consumption of the standard interface shall be minimized with a maximum of :<br>• 0.5W in passive mode (controller switched off)<br>• 2W in idle mode (controller switched on / motor off)<br>• 10W in active mode (controller switched on / motor on) | | M |
| **VERIFICATION** | Testing | **SOURCE** | SIROM expertise |
| **COMMENT** | Values TBC. | | |
| **COVERED IN SECTION** | 7.2 | | |

| | | | |
|---|---|---|---|
| **OpR_011** | The coupling time between two standard interfaces shall be minimized | | M |
| **VERIFICATION** | Testing | **SOURCE** | SIROM expertise |
| **COMMENT** | | | |
| **COVERED IN SECTION** | 4, 5 | | |

| | | | |
|---|---|---|---|
| **OpR_012** | The mechanism shall be maintenance free during storage and ground operation | | M |
| **VERIFICATION** | Inspection | **SOURCE** | ECSS-E-ST-33-01 |
| **COMMENT** | No maintenance or human intervention should be made during ground tests and operations | | |
| **COVERED IN SECTION** | | | |

## 2.6 Environmental Requirements

| | | | |
|---|---|---|---|
| **EnvR_001** | The standard interface shall withstand space environment conditions | | M / D (S) |
| **VERIFICATION** | / | **SOURCE** | Call 1 SRC Comp, 8.6.1<br>Call 1 SRC Comp, R04.5 (mech)<br>Call 1 SRC Comp, R05.6 (elec)<br>Call 1 SRC Comp, R06.3 (data)<br>Call 1 SRC Comp, R07.2 (thermal) |
| **COMMENT** | No testing in the current activity under space conditions. | | |
| **COVERED IN SECTION** | Not addressed in this document. | | |

| | | | |
|---|---|---|---|
| **EnvR_002** | The standard interface shall withstand operational environmental conditions | | M |
| **VERIFICATION** | Testing | **SOURCE** | Call 1 SRC Comp, R03.9 |
| **COMMENT** | No testing in the current activity under space conditions. | | |
| **COVERED IN SECTION** | Not addressed in this document. | | |

| | | | |
|---|---|---|---|
| **EnvR_003** | The standard interface shall withstand temperature range between -55 and 85 C. | | M |
| **VERIFICATION** | Analysis | **SOURCE** | Internal expertise |
| **COMMENT** | As a first step towards space compatible design, this is the selected range of temperature to be supported by the interface for the current developments.<br><br>The current activity doesn't foreseen verification by testing for this requirement. | | |
| **COVERED IN SECTION** | Not addressed in this document. | | |

## 2.7 Configuration Requirements

| | | |
|---|---|---|
| **ConfR_001** | The standard interface shall be declined in different configurations that are:<br>• Active<br>• Passive (not active behavior but can be couple and transmit data and power)<br>• Mechanical (not active and can only be coupled) | D |

| | | | |
|---|---|---|---|
| **VERIFICATION** | Review of Design / Testing | **SOURCE** | OGs costs and physical characteristics constraints |
| **COMMENT** | This is mainly to support costs and volume/weight reduction in the ground demonstrators. This could also be applicable in future mission depending on specific mission characteristics.<br><br>See section 3.2 for added explanation | | |
| **COVERED IN SECTION** | 3, 5 | | |

## 2.8 Human Factors Requirements

| | | | |
|---|---|---|---|
| **HumR_001** | If used in manned area then mechanism shall be compliant with Human Factor requirements | | M(S) |
| **VERIFICATION** | Inspection | **SOURCE** | SSP 57000R |
| **COMMENT** | Sharp edges, corners, uncovered holes bigger than 10 mm, uncovered slots shall not be present | | |
| **COVERED IN SECTION** | 5.1 | | |

# 3 System Configuration

## 3.1 Proposed design

HOTDOCK is a standard robotic mating interface supporting mechanical, data, power and thermal transfer. Its main application is to allow assembly and reconfiguration of spacecraft and payloads on-orbit and on planetary surfaces. It makes it straightforward to replace failed modules, or to swap payloads and provide chainable data interfaces for multiple module configurations.

HOTDOCK provides the following interfaces:

- The mechanical interface that provides the alignment, connection and load transfer capabilities. It is composed of fixed element and movable locking elements.
- The power interface, for the transfer of electrical power, through a central connector plate and POGO connectors
- The data interface, for the transfer of CAN and/or SpW data, through the central connector plate and POGO connectors

HOTDOCK includes also an internal PCB controller for local management (actuators, sensors, TM/TC communication) and external harnessing to access the power/data interface pins and the internal controller/powering of the device.

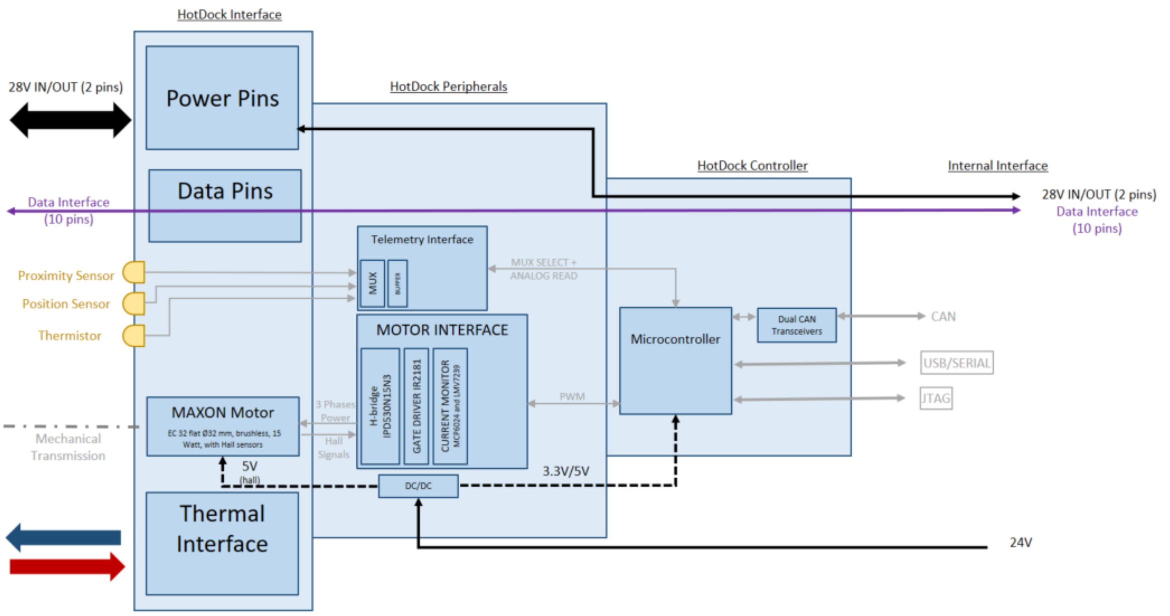


**Figure 3-1: HOTDOCK functional architecture**

The HOTDOCK mechanical interface provides the following main features:

- **Androgynous design**: both on the mechanical and electrical connections, such that one HOTDOCK can mate any other ones, with similar design.
- **90-degree symmetry:** on the mechanical and electrical side, that provides additional redundancy and increases the range of possible position/orientation for mating, for easier robotic manipulation or compatibility with parallelepiped spacecraft modules

- **Form-fit guidance:** tooth like geometries on the circumference enable self-guidance positioning during the final approach process and compensation for a range of transversal and orientation misalignments. The form-fit is also designed to support straight and diagonal engagement. The form fit has also a main role in the mechanical load transfer capabilities of the interface.
- **Locking mechanism:** is implementing peripheral locking elements equipped with steel balls that acts on the form-fit geometry of the other mated HOTDOCK. This simple solution offers high transversal and bending load transfer capabilities with good tolerance for misalignment and thermal gradient.

## 3.2 Declinations

In order to respond to different type of applications and constraints (for both the current OGs and future exploitation), different declinations of HOTDOCKs are currently considered, as illustrated in Table 3-1:

- **Active**: full features interface with active locking mechanism, supporting mechanical, data and power transmission.
- **Active Thermal**: active version including thermal interface for fluid transfer (under development)
- **Passive**: interface without actuation but providing capabilities to transfer mechanical, data and power. An Active interface is required to lock to a passive one.
- **Mechanical**: interface without actuation and without data/power transfer (connector plate). It supports only mechanical transmission. An active interface is required to lock to a mechanical one
- **Dummy/Visual**: visual representation of an HOTDOCK (e.g. 3D printed of the external mechanical structure), not supporting mechanical transmission.

The mating between two HOTDOCK requires always at least one Active (thermal) version that can connect to another Active, a Passive or Mechanical one. In the last case, the interface supports only the mechanical load transmission (not power and data).

**Table 3-1: Features of the different declinations of HOTDOCK**

| | Name | Visual | Mating | Mechanical Transmission | Data Transmission | Power Transmission | Thermal Transmission |
|---|---|---|---|---|---|---|---|
| ● (green) | Active | ✓ | ✓ | ✓ | ✓ | ✓ | |
| ● (blue) | Active Thermal | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| ● (yellow) | Passive | ✓ | | ✓ | ✓ | ✓ | |
| ● (orange) | Mechanical | ✓ | | ✓ | | | |
| ● (grey) | Dummy/Visual | ✓ | | | | | |

An Active HOTDOCK is a full featured HOTODCK (with possibly the thermal interface). The passive version is a more simple version, that removes the actuation and control sub-system. It remains the mechanical structure and the central connector plate to allow mechanical, data and power transmission with an active HOTDOCK. In a passive version, there is no moving part. The active one is able to mechanically attach to it, as well drive the central connector plate to reach the passive one.

In our exploitation analysis, it appeared that the passive version has a good potential to be used, especially when talking about payload operations:

- The passive is smaller in height and lighter
- It has no active components (actuator, electronics) and is more simple
- It is less expensive
- A passive version can be installed on a spacecraft/satellite with less integration constraints, waiting for an active one to connect to it (e.g. as part of a next mission). We think that this can be a great advantage for the early exploitation and diffusion of the technology (very low impact on spacecraft design)
- We can more easily envisage the installation of several interface point due to the limited integration constraints.
- We can also envisage a mechanical version (without the central connector plate for data and power), when we need only to manipulate items (e.g. beam structures)

## 3.3 Product tree

Figure 3-2 presents the top level HOTDOCK product tree, highlighting the main components of the product. The preliminary design description of these components is provided in the following sections.

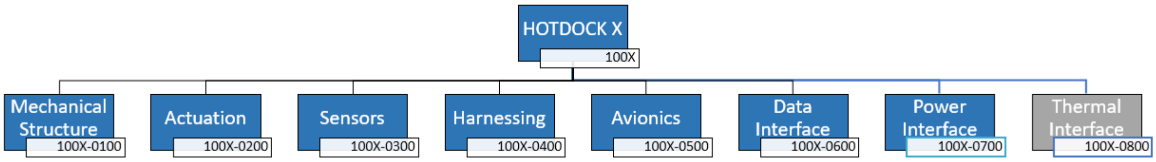


**Figure 3-2: HOTDOCK Product Tree**

# 4 Operational Description

## 4.1 Mating and de-mating sequences

Figure 4-1 illustrates the nominal sequence of operation of HOTDOCK and the associated states of the powering, latching and connector plate:

- **Offline**: the device is neither powered, latched or connected for data and power transfer (e.g. when the HOTDOCK is not used).
- **Idle**: the device is powered, able to exchange CAN TM/TC but not latched nor connected for data and power transfer.
- **Latched**: the device is powered and mechanically latched to another HOTDOCK (active, passive or mechanical). The connector plate is not deployed.
- **Connected**: the device is powered, latched and connected for data and power transfer (the connector plate is deployed to get contact with the other HOTDOCK connector plate.
- **Locked**: the device is powered off, while in connected mode (e.g. when the full connection operation is finished) (state TBC for OG demos).

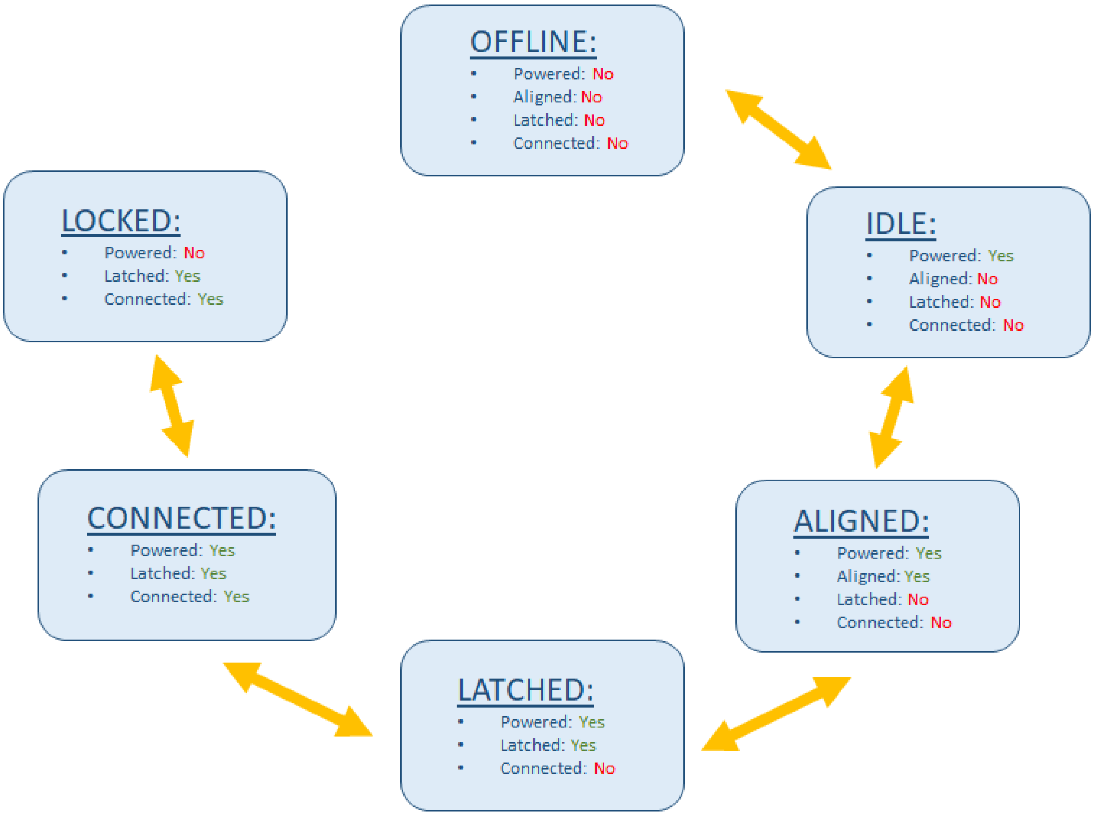


**Figure 4-1: Nominal sequence of operation of HOTDOCK**

## 4.2 State Machine

The HOTDOCK control electronics run a simple state machine (shown in Figure 4-2).This state machine is comprised of the 3 explicit states (Idle, Moving, Fault) and one implicit state (Power On).

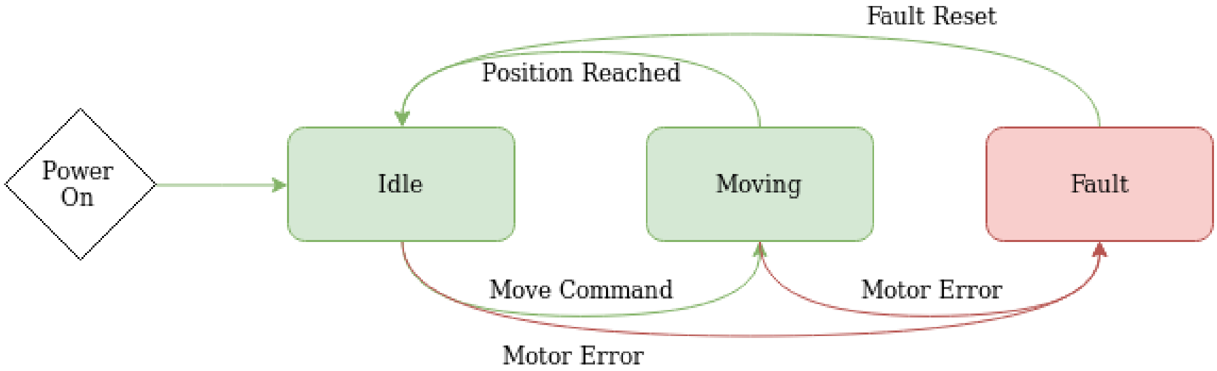


**Figure 4-2: State machine implemented in the HOTDOCK electronics.**

When power is applied to the HOTDOCK the controller boots up and enters the “Power On” state. In this state initial set-up tasks such as setting up sensors and initialising the communications module are performed. After completing these the device enters the “Idle” state and awaits commands from the CAN module. When a CAN command is received the device enters the “Moving” state; the motor is commanded to actuate the device in the “Open” or “Close” directions. When the target position is reached the device transitions back into the “Idle” state and waits for further commands. At any time, a “Stop” command can be sent to halt the operation of the device.

During operation, the firmware continuously monitors the state of the system to detect anomalies such as the motor position exceeding the allowed range or the cycle time of the main loop exceeding the required threshold. Errors are signalled by transitioning the device to the “Fault” state in which all motor operation is stopped. To recover from this error, the system must send a “Fault Recovery” command which may trigger automatic error recovery mechanisms to bring the system back into a known state. All other commands are rejected.

## 4.3 Telemetries and Telecommands (TM/TC)

Following tables provide a preliminary list of telecommands and telemetry to interface HOTDOCK through the CAN control interface. This list is currently informative and subject to evolutions.

**Table 4-1: HOTDOCK TC list**

| TMC Type | Packet ID | Field Name | Field Offset | Field Size | Description |
|---|---|---|---|---|---|
| TC – Control Cmd | TC_1 | GOTO_1 | 0x00 | 1B+CRC | State Machine :: Set Requested State |
| TC – Control Cmd | TC_2 | STOP_1 | 0x00 | 1B+CRC | Motor :: Emergency Stop |
| TC – Control Cmd | TC_3 | RSET_1 | 0x00 | 1B+CRC | Reset Controller |
| TC – Control Cmd | TC_4 | LED | 0x00 | 2B+CRC | LED :: control + pattern |
| TC – Control Cmd | TC_5 | Power Bus On/OFF | 0x00 | 1B+CRC | Power Bus switching (N+R) (TBC if managed by HOTDOCK) |

**Table 4-2: HOTDOCK telemetry list**

| TMC Type | Packet ID | Field Name | Field Size | Description |
|---|---|---|---|---|
| TM - House Keeping | HK_1 | THM_1 | 1B | Thermistor 1 (Motor) |
| TM - House Keeping | HK_1 | THM_2 | 1B | Thermistor 2 (MCU) |

| | | | | |
|---|---|---|---|---|
| TM - House Keeping | HK_1 | THM_3 | 1B | Thermistor 3 (Pogo PCB) |
| TM - House Keeping | HK_1 | HALL_1 | 1B | Proximity Hall effect Sensor 1 |
| TM - House Keeping | HK_1 | HALL_2 | 1B | Proximity Hall effect Sensor 2 |
| TM - House Keeping | HK_1 | HALL_3 | 1B | Proximity Hall effect Sensor 3 |
| TM - House Keeping | HK_1 | HALL_4 | 1B | Proximity Hall effect Sensor 4 |
| TM - House Keeping | HK_1 | CRC_1 | 1B | HK_1 Packet CRC |
| | | | | |
| TM - House Keeping | HK_2 | LOCK_1 | 1B | Locking ring position |
| TM - House Keeping | HK_2 | POSI_2 | 2B | Absolute position sensor |
| TM - House Keeping | HK_2 | MTI_1 | 2B | Motor Current [A] |
| TM - House Keeping | HK_2 | MTS_1 | 2B | Motor Speed [rpm] |
| TM - House Keeping | HK_2 | CRC_1 | 1B | HK_2 Packet CRC |
| | | | | |
| TM - House Keeping | HK_3 | PNV_1 | 2B | Power Bus N Voltage |
| TM - House Keeping | HK_3 | PNI_1 | 2B | Power Bus N Current |
| TM - House Keeping | HK_3 | PRV_1 | 2B | Power Bus R Voltage |
| TM - House Keeping | HK_3 | PRI_1 | 2B | Power Bus R Current |
| | | | | |
| TM - House Keeping | HK_4 | STAT_1 | 1B | State Machine :: Current State / Request |
| TM - House Keeping | HK_4 | SWV_1 | 1B | FSW Version |
| TM - House Keeping | HK_4 | ERR_1 | 1B | Current Error Code |
| TM - House Keeping | HK_4 | CRC_2 | 1B | HK_2 Packet CRC |
| | | | | |
| TM - Acknowledge | AK_1 | ACK_1 | 7B+CRC | TC has been properly received/parsed |
| TM - Acknowledge | AK_2 | ACK_2 | 7B+CRC | TC has been properly Processed |
| TM - Acknowledge | ER_1 | ERR_1 | 7B+CRC | Spontaneous Error Code |

# 5 HOTDOCK Standard Interface Design

## 5.1 Mechanical interface and actuation

This section provides a general description of the HOTDOCK mating interface. Figure 5-1 represents the current state of the HOTDOCK prototype. It provides the following interfaces:

- The mechanical interface that provides the alignment, connection and load transfer capabilities. It is composed of fixed element and a movable locking ring.
- The power interface, for the transfer of electrical power, through the central connector plate and POGO connectors
- The data interface, for the transfer of CAN and/or SpW data, through the central connector plate and POGO connectors

The interface features also an internal PCB controller for local management (actuators, sensors, TM/TC communication) and external harnessing to access the power/data interface pins and the internal controller/powering of the device.

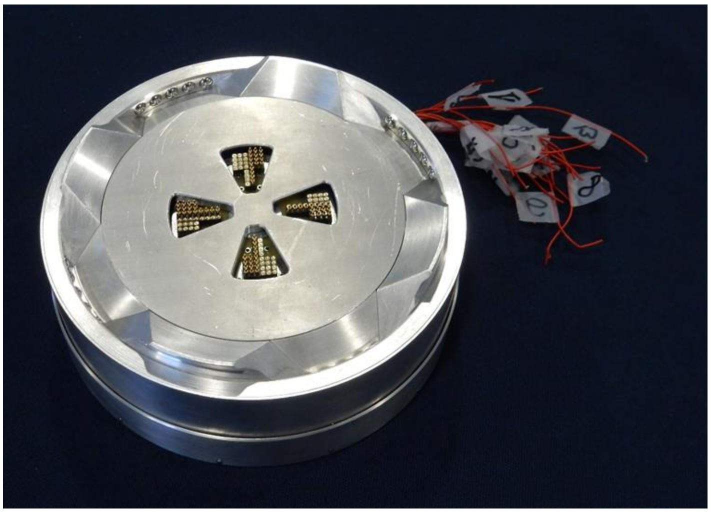

**Figure 5-1: HOTDOCK prototype**

### 5.1.1 Coordinate system

The coordinate system selected for the HOTDOCK envelope is shown in Figure 5-2. The coordinate center, denoted O, is on the center point of the HOTDOCK diameter of HOTDOCK bottom plate.

The coordinate axis of HOTDOCK are defined such that:

- Axis X goes from the coordinate center towards the androgyny plane of the first quarter of HOTDOCK connector plate (Q1).
- Axis Y is perpendicular to axis X, such that the direction of axis Z goes outside of HOTDOCK.
- Axis Z goes through the coordinate center O and is perpendicular to the bottom plate

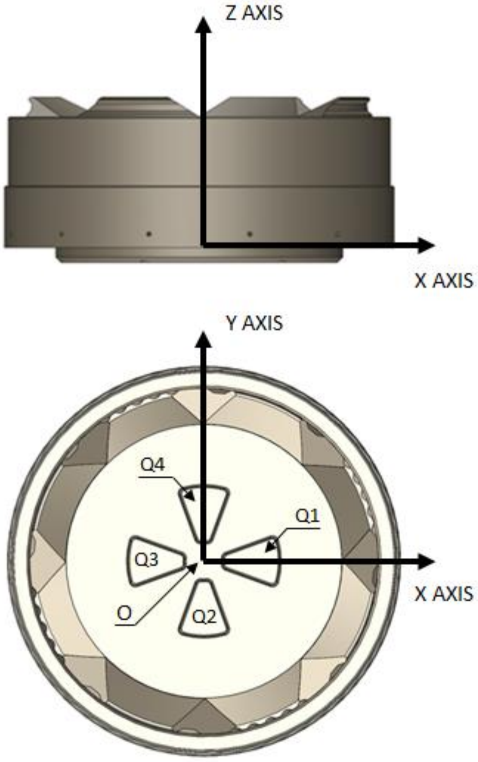


**Figure 5-2: HOTDOCK coordinate system. *Top*: Front view. *Bottom*: Top view.**

### 5.1.2 Mechanical Specification

The axial motion of the locking system is achieved by the transmission of a barrel-cam mechanism driven by a brushless DC motor connected to a gearing system. The gearing system is also driving a sensor shaft equipped with an absolute sensor, used to detect the motion and position of the locking ring.

The HOTDOCK interface outer geometry follows an entirely round shape. The body is machined in high strain aluminium alloy with surface coating. Figure 5-3 shows the external dimensions of the active declination of the interface. The passive and mechanical versions have the same outer diameter but present a reduced thickness, guided as function of the required mounting interface.

The HOTDOCK interface shall be mounted on the back side as shown in Figure 5-4 using M3 bolts. The ring of mounting points is close to the outer diameter which leads to a reduced stress of the mounting elements. The number of mounting points as well as the diameter of the bolt fixation ring will be consolidated following the PDR phase.

The back-side features openings to let through control, data and power harnessing, with connectors facing out.

The form-fit is designed to support straight and diagonal coupling trajectories up to 65 degrees (up to an aperture angle of 130 degrees).

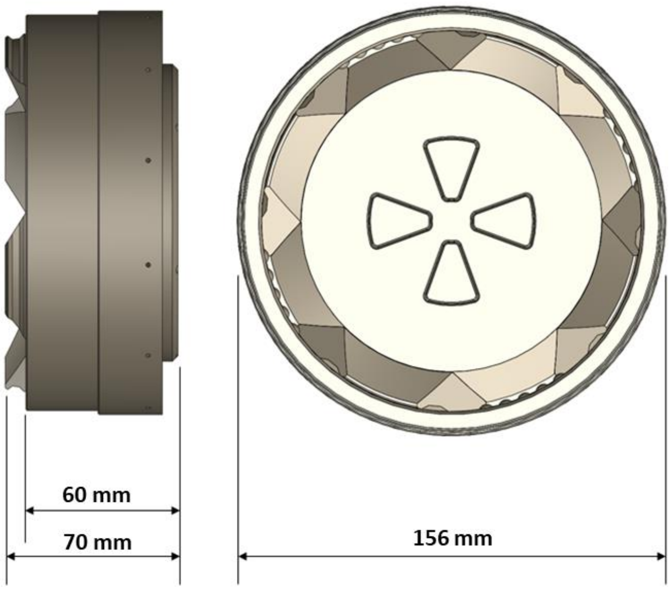


**Figure 5-3 HOTDOCK - Side and Top view with basic dimensions**

### 5.1.3 Fixation Layout

The HOTDOCK interface shall be mounted on the back side as shown in Figure 5-4 using M3 bolts. The ring of mounting points is close to the outer diameter which leads to a reduced stress of the mounting elements. The number of mounting points as well as the diameter of the bolt fixation ring will be presented at PDR-Meeting.

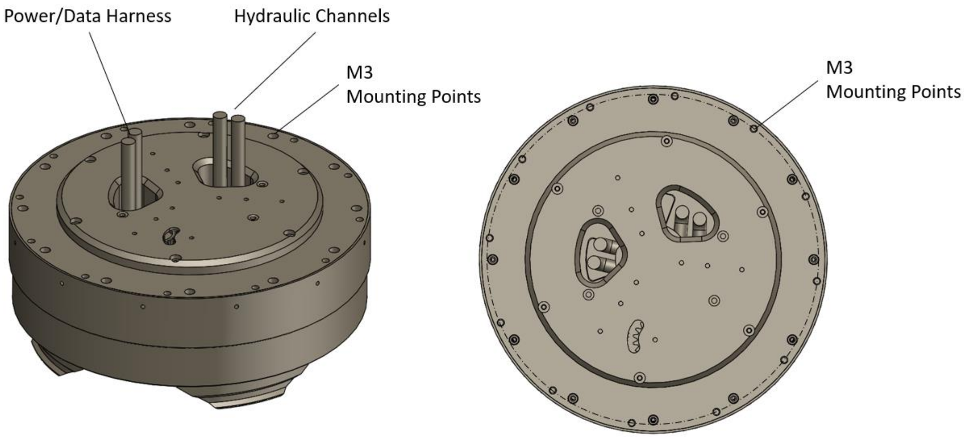


**Figure 5-4 HOTDOCK - back side with mounting points.**

The back-side features openings to let pass control, data and power harnessing, with connectors facing out.

### 5.1.4 Misalignment Tolerances and Approach Angle

HOTDOCK's form-fits are designed to support straight and diagonal coupling trajectory up to 65 degrees (up to an aperture angle of 130 degrees) compatible with three simultaneous approaches in hexagonal structure shape – which is considered a "worse case", typically as required in PULSAR.

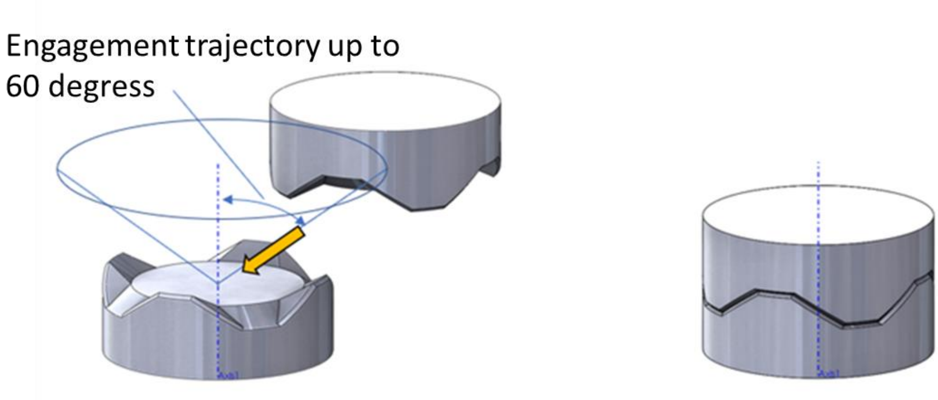


**Figure 5-5: Diagonal Engagement Trajectory**

Misalignment tolerances are covered according to two scenarios:

1) Misalignment tolerance when two sides are approaching by external guidance (e.g. robotic system).
2) Misalignment tolerance acceptable when starting coupling procedure.

Figure 5-6 shows the maximum misalignment tolerances of the Form-Fit geometry when two interfaces are approaching (scenario 1). The presented figures are based on preliminary motions studies performed by DLR, using a compliant robotic manipulator.

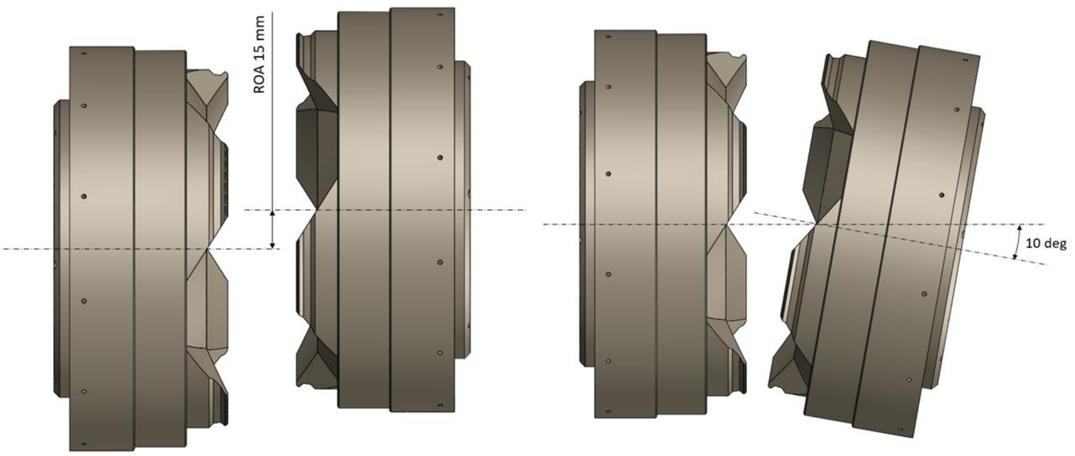


**Figure 5-6 HOTDOCK – Range of attraction (ROA) supported by Form-Fit geometry.**

Figure 5-7 shows the acceptable, remaining distance before the coupling procedure can be initiated. While coupling, both HOTDOCK interfaces will force each other into their final coupling position, that remains without gap.


**Figure 5-7 HOTDOCK – Max gap before locking.**

### 5.1.5 Mechanical Performances

We provide below key values about the mechanical performances achieved so far with the HOTDOCK interface.

Provided values are quite conservative, in the sense that they correspond to actual test results, performed with non-optimized prototype versions of HOTDOCKs, built from aluminium only.

| | |
|---|---|
| Axial load transfer performance with 2 active HOTDOCKs coupled | 500N (could not go higher with test setup) |
| Bending moment performance with 2 active HOTDOCK coupled | 100Nm (maximum) |
| Bending moment performance with 1 active HOTDOCK coupled to 1 passive HOTDOCK | 65Nm (maximum) |

## 5.2 Power and data interfaces

The HOTDOCK power and data interface are integrated in the inner section of the interface, through a connector plate (Figure 5-8). Both electrical power and data are transferred via a set of spring-loaded connectors also known as “Pogo” connectors. They are particularly tolerant to misalignment and prevent accumulation of dirt or dust. This keeps the power and data transfer interface simple and subsequently improves its reliability.

The connector plate is a PCB board split in four sections, equipped with a set of pogo pins and pads. They are arranged in mirror to ensure the androgynous and symmetric characteristic of the interface. The current version includes 128 connections that can be freely configured for data (CAN and/or SpW) and power transmission, including signal redundancy.

The connector plate is translated through the same drive mechanism than the locking system. The barrel cam is configured to ensure the timing sequence of the deployment. The range of motion allows an active interface to connect to a passive one (see below for active/passive definition).

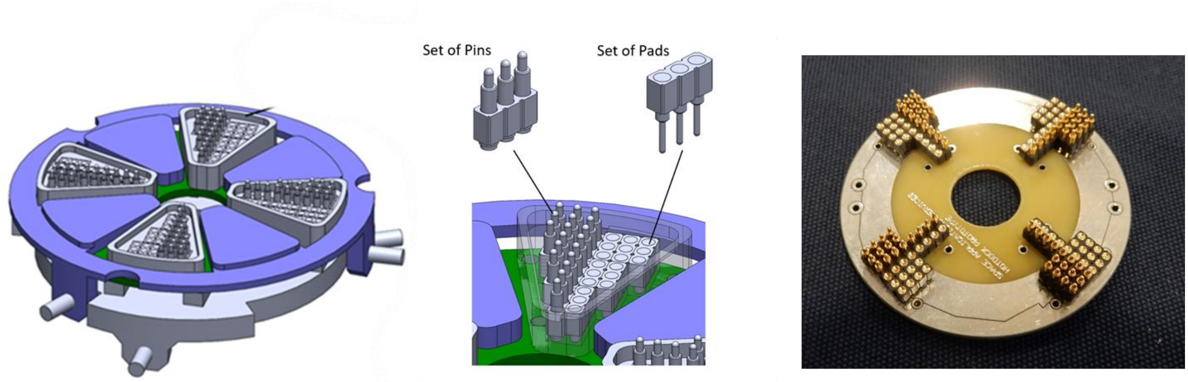


**Figure 5-8: HOTDOCK connector plate**

The data and electrical power transmission is performed through a bespoke connector PCB. This subsystem of the interface has three main functions: transfer, rerouting and sense.

### 5.2.1 Transfer

Power and data can be transferred to a mated HOTDOCK through a set of spring-loaded POGO pins. Each pin can transfer up to 3A of peak current. Dielectric separation distance between the POGO pins allows to transfer power with voltage >100V. The flexibility of connector layout makes it easy to integrate the POGOs in various patterns. Example shown below:

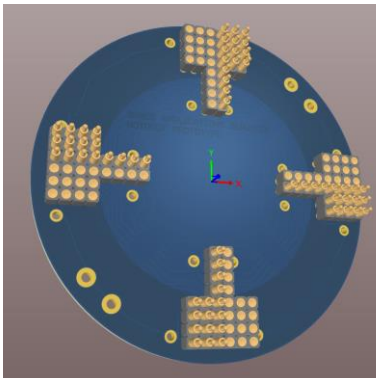

**Figure 5-9: HOTDOCK prototype connector pattern**

The prototype connector PCB is designed to withstand up to 8400W power transfer over 28 pins. Depending on the interface requirements (speed, number of signals), various data protocols can be implemented with the connector plate. Prototype design allows SpaceWire transfer of 100Mbps over 5.5m. Higher data rates can be accommodated with custom PCBs with correct track impedance.

### 5.2.2 Rerouting

In order to allow 90-degree androgynous design, data transfer implementation requires rerouting capability. For HOTDOCK with LVDS data interface (e.g. SpaceWire) this is achieved with an LVDS Crosspoint Switch.

The orientation of the HOTDOCK with respect to its mate is detected by reading a voltage on dedicated orientation pins of the mated HOTDOCK.

The controller then commands the crosspoint switch to route the signal pairs to their corresponding positions. In order to have this androgynous capability it is required to keep the crosspoint switch powered during data transmission. Some crosspoint switches offer buffering of the select state which means that the HOTDOCK controller does not have to be active once the switch is configured.

### 5.2.3 Sense

The connector PCB will provide telemetry for current and voltage passed though the HOTDOCK interface.

Manufacturing process of the connector plate requires custom made stencils to maintain the correct position and height of the POGO pins.

### 5.2.4 Electrical power and data characteristics

Preliminary characteristics of the data and power interface are summarized in table Table 5-1.

**Table 5-1: Power and Data characteristics of HOTDOCK**

| POWER TRANSFER INTERFACE – single channel | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Notes** | **Min** | **Typ** | **Max** | **Unit** |
| DC Resistance | | 0.3 | | 0.5 | Ohms |
| Current | Per power pin | | | | Amps |
| Voltage | | | | 130 | Volts |
| **DATA TRANSFER INTERFACE - SPACEWIRE (LVDS)** | | | | | |
| **Parameter** | **Notes** | **Min** | **Typ** | **Max** | **Unit** |
| Impedance | Characteristic impedance of transmission line | | 100 | | Ohms |

## 5.3 Thermal interface

The thermal interface previously developed in OG5 remains the baseline for thermal transfer in HOTDOCK.

The thermal interface is based on a double-quick connecting system for fluid circulation and heat exchange between a heat source and a heat sink up to 1400 W (cold side).

Although the connectors were formerly integrated in the SIROM demonstrators for validation of the connection/disconnection forces, the actual thermal transfer testing was performed on separate setup.

Different aspects have been successfully tested including heat exchange capabilities, leakage (with connection/disconnection), pressure drop or type of fluids.


**Figure 5-10: Thermal interface fluid connectors to be used in HOTDOCK**

In HOTDOCK, the thermal interface consists in 4 pairs of hydraulic connectors (one male and one female) integrated in a structural part. Two flexible metallic bellows are used to accommodate the required stroke for connection of the whole HOTDOCK. Additionally, two redundant NTC temperature sensors are integrated in HOTDOCK in order to measure the temperature before connection.

## 5.4 Dust protection

The purpose of the dust protection is to avoid internal contamination of the system (control electronics,...) and ensure the correct mechanical and data/power connection, despite the external conditions.

An initial concept of dust protection with HOTDOCK, based on retractable shutters, has been proposed in the initial phase of the project. This concept is illustrated below.

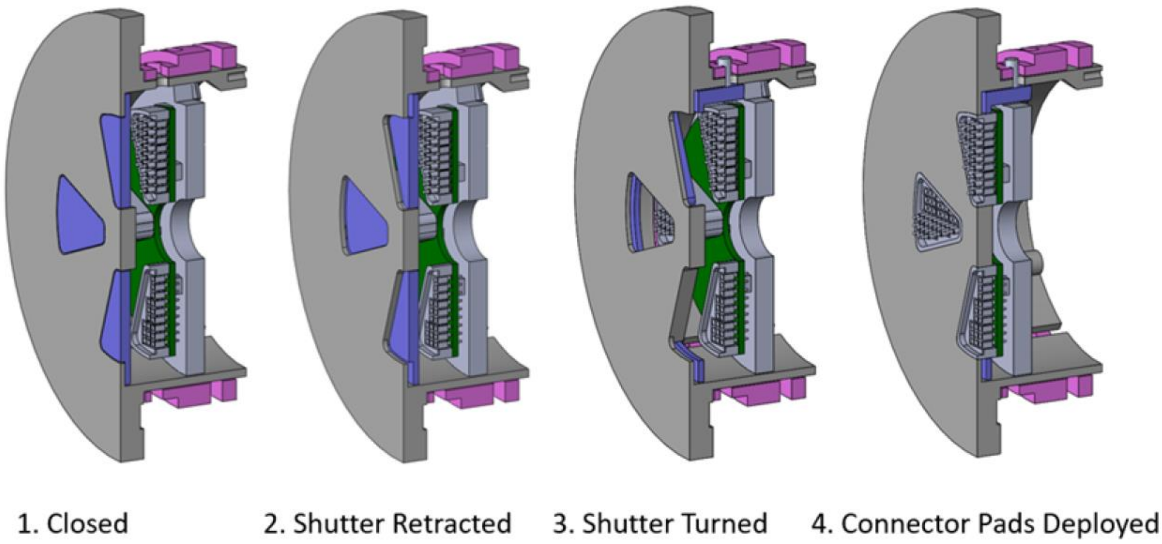


**Figure 5-11: Initial dust mitigation concept**

During the deployment procedure, the mechanism drives a double motion of shutters, with a successive translation and rotation, to free the path for the connector plate.

Based on the latest status of the design, and targeting a simplification of the internal mechanism, a trade-off analysis has been performed in order to analyse different solutions that could be considered, including actions on the interface design, but also actions at mission level, in order to propose alternative dust mitigations strategies.

**Table 2: Comparison of main dust mitigation strategies**

| **Mitigation Measure** | **Pros** | **Cons** |
|---|---|---|
| **Cover Lid** | • Full protection of HOTDOCK. The area of protection could also be increased.<br>• Long duration protection (low aging of the protection)<br>• Simple mechanical approach without additional mechanism on HOTDOCK<br>• Full accessible area for the connector plate | • Requires additional operation with the robotic manipulator<br>• Exposure of the elements during the transition phase between cover removal and HOTDOCK connection. |
| **Environmental Sealing** | • Static approach without additional mechanism on HOTDOCK<br>• Good protection of the internal components<br>• Full accessible area for the connector plate | • Remaining exposure of mechanical and connector components<br>• Efficiency and aging of the elements protecting movable components |
| **Rotative Cover** | • Protection of the connector plate<br>• Opening of the protection when HOTDOCK are mechanically connected ( no<br>• exposure during operations)<br>• Driven directly by HOTDOCK drive system (no external intervention) | • Remaining exposure of mechanical components<br>• Reduce by half the usable connector plate surface<br>• Additional mechanism and motion transmission inside HOTDOCK, and with passive interface<br>• Pushing of existing dust on the surface during the motion of the plate |
| **Grid / Membrane** | • Static approach without additional mechanism on HOTDOCK<br>• Good protection of the internal components<br>• Full accessible area for the connector plate | • Remaining exposure of mechanical and connector components<br>• Aging of the used material |

The topic of dust protection is very complex and highly demanding in terms of technologies, especially for the targeted applications on the Moon or Mars. By nature, the HOTDOCK design offers good initial protection against dust, especially once matted (closed system). Some weaknesses however remain, that need to be addressed for future missions. In practice we expect that an effective dust protection strategy should implement several of these concepts in order to offer the best possible protection.

# 6 HOTDOCK Controller

## 6.1 Functional Description

The HOTDOCK controller requires the following functionalities:

- Motor control – field oriented control of a brushless motor with hall sensor feedback (required for the latching process of the interface).
- Sensor interface – reading and processing signals about temperature, power consumption, docking proximity and internal mechanical state.
- Telemetry and tele-command – allow command and telemetry exchange between HOTDOCK and the host system over a standard bus (e.g. CAN).
- Connector plate control – command the connector PCB to reroute LVDS signals according to orientation.
- Power conversion – local low-level bus generation from the supplied 24V for supplying the microcontroller and supporting circuitry, including sensors.
- Power switching – in some HOTDOCK applications it is desirable to have the ability to control the electrical power flow through the interface. This requires an interface to either a solid state switch (bi-directional MOSFETs) or a relay.

## 6.2 HOTDOCK Controller Electrical Architecture and Interfaces

The electrical architecture is presented below. Important to note is that the controller is implemented as a round-shaped custom PCB to seamlessly fit around the HOTDOCK mechanism. The main functional blocks of the controller are shown in the architecture.

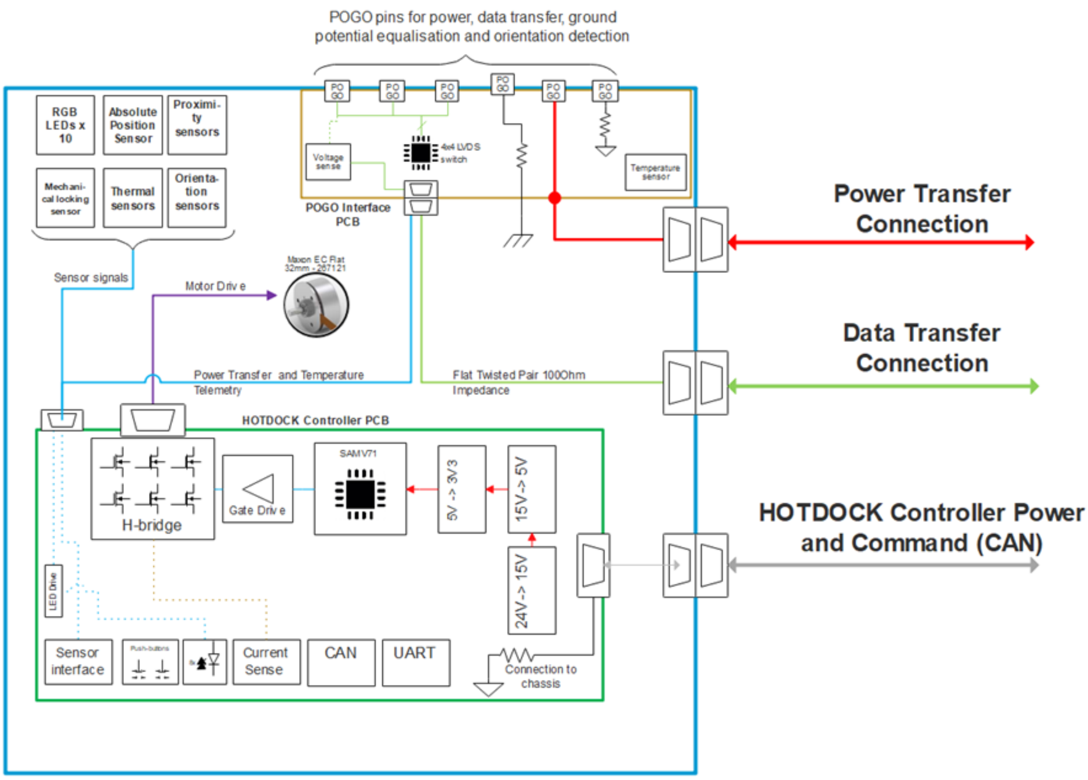


**Figure 6-1: HOTDOCK Electrical Architecture**

The HOTDOCK controller has the following functionalities:

- 114 GPIOs with external interrupt capability – Connector plate control, motor control and sensor interface
- 2048 KBytes of flash – programming and logging system's state
- Temperature sensor
- Low-power sleep and wait modes – lowering power consumption
- USB 2.0, Ethernet MAC, UART, USART, I2C, SPI, CAN – communication (telemetry and tele-command)
- PWM – motor control
- 24 ADC inputs – sensor interface

The brushless motor requires three phase control that is achieved through a proper front end chain (H-bridge, gate drive and buffer) that receives a PWM signal from the microcontroller.

All analog signals are passed through a set of buffers to remove the sensor impedance effect on the readings.

CAN bus is chosen as the main tele-command and telemetry interface due to its robustness, increasing space applications and ease of use.

A set of linear voltage regulators are used to convert the external supply (24V) to 3.3V, 5V and 15V to supply the microcontroller, sensors, CAN transceiver, motor control gate drive and other circuits.

If the HOTDOCK requires power switching capability integrated at the interface, additional circuitry will be added to allow MOSFET switch or relay control.

## 6.3 HOTDOCK Controller Electrical Specifications

A preliminary overview of electrical specifications is listed in Table 6-1.

**Table 6-1: Electrical characteristic of HOTDOCK controller**

| HOTDOCK CONTROLLER | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Notes** | **Min** | **Typ** | **Max** | **Unit** |
| **Power** | | | | | |
| Input Voltage | Regulated 24V bus | 23.5 | 24.00 | 24.5 | V |
| Input Current | Idle | | 50 | | mA |
| | During latching | | 150 | | mA |
| | Sleep mode | | 20 | | mA |
| | | | | | |
| **CAN** | | | | | |
| CAN baud-rate | | 125 | | 1000 | kbps |

# 7 Technical Budgets

## 7.1 Mass Budget

Mass budget for the HOTDOCK assembly and related subcomponents is detailed in the Table below. Mass margin is 10%. Thermal connectors and related circuitry is not included in that mass budget.

| Body | Module | Part | Unit mass (kg) | Quantity | Mass (kg) | SF | Mass with margin (kg) | SubAssy mass with margin (kg) |
|---|---|---|---|---|---|---|---|---|
| HOTDOCK | | | | | | | | |
| | Housing | | | | | | | 0.5951 |
| | | Main Housing and cover | 0.311 | 1 | 0.311 | 1.1 | 0.3421 | |
| | | Form Fit | 0.183 | 1 | 0.183 | 1.1 | 0.2013 | |
| | | Front plate | 0.047 | 1 | 0.047 | 1.1 | 0.0517 | |
| | Moto-reducer | | | | | | | 0.1749 |
| | | Motor | 0.057 | 1 | 0.057 | 1.1 | 0.0627 | |
| | | Gears | 0.093 | 1 | 0.093 | 1.1 | 0.1023 | |
| | | Sensor | 0.009 | 1 | 0.009 | 1.1 | 0.0099 | |
| | Guiding elements | | | | | | | 0.0176 |
| | | Bearing | 0.008 | 2 | 0.016 | 1.1 | 0.0176 | |
| | Barrel Cam | | | | | | | 0.1177 |
| | | Barrel Structure | 0.056 | 1 | 0.056 | 1.1 | 0.0616 | |
| | | Internal gear | 0.051 | 1 | 0.051 | 1.1 | 0.0561 | |
| | Docking Ring | | | | | | | 0.321662 |
| | | Ring Structure | 0.152 | 1 | 0.152 | 1.1 | 0.1672 | |
| | | Actuated internal ring | 0.123 | 1 | 0.123 | 1.1 | 0.1353 | |
| | | Balls | 0.000871 | 20 | 0.01742 | 1.1 | 0.019162 | |
| | Connector plate | | | | | | | 0.0627 |
| | | PCB | 0.032 | 1 | 0.032 | 1.1 | 0.0352 | |
| | | PCB support | 0.025 | 1 | 0.025 | 1.1 | 0.0275 | |
| | Cables | | | | | | | 0.11 |
| | | Data, power lines | 0.1 | 1 | 0.1 | 1.1 | 0.11 | |
| | HOTDOCK Controller | | | | | | | 0.165 |
| | | Controller board | 0.15 | 1 | 0.15 | 1.1 | 0.165 | |
| | TOTAL HOTDOCK | | | | 1.42242 | | | 1.564662 |

**Table 7-1: Mass budget of HOTDOCK**

## 7.2 Power Budget

An estimate of the power consumption for the main HOTDOCK components are provided in the Table below.

| Body | State | Components | Unit power (W) | Quantity | Power (W) |
|---|---|---|---|---|---|
| HOTDOCK Controller | | | | | |
| | Operation | | | | |
| | | Motor | 1.5 | 1 | 1.5 |
| | | Controller | 1.2 | 1 | 1.2 |
| | | | Total Operation | | 2.7 |

**Table 7-2: Power budget of HOTDOCK**

# 8 Interface Requirement Document (IRD)

This section covers HOTDOCK interface requirements as driven by the Call 2 projects OG8 PULSAR, OG9 MOSAR and OG11 PRO-ACT, and corresponds to the content one may expect in a standalone “Interface Requirements Document” (aka. IRD).

## 8.1 Common to OG8, OG9 and OG11

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0010 | SI androgynous design | Mandatory |
| **STATEMENT** | The SI shall have an androgynous design, including mechanical, data and power interfaces | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0020 | Form-Fit Guidance | Mandatory |
| **STATEMENT** | The standard interface shall provide guidance form-fit features | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0030 | SI Symmetry | Mandatory |
| **STATEMENT** | The standard interface shall present a 90deg. rotational symmetry, including mechanical, data, power and thermal interface | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0040 | SI alignment | Mandatory |
| **STATEMENT** | The two SI shall be correctly aligned before starting their mating process and the information shall be confirmed to the OBC | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0050 | SI connection monitoring and confirmation | Mandatory |
| **STATEMENT** | The connection process shall be monitored and the good connection of the SI shall be confirmed to the OBC. | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0060 | SI design configuration | Mandatory |
| **STATEMENT** | The SI design shall allow active, passive and mechanical configuration | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0070 | SI cost | Mandatory |
| **STATEMENT** | The design of the SI shall take into account optimization of the manufacturing and integration costs | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0080 | SI Mass | Mandatory |
| **STATEMENT** | The standard interface shall be optimized regarding its mass | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0090 | SI Volume | Mandatory |
| **STATEMENT** | The standard interface shall be optimized regarding size and volume | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0100 | SI power consumption | Mandatory |
| **STATEMENT** | The power consumption of the standard interface shall be minimized | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0110 | Mechanical, Data and Electrical Interface | Mandatory |
| **STATEMENT** | The SI shall provide<br>• a mechanical interface to mechanically couple two system components<br>• an electrical interface to transfer electrical energy (power) between two system components<br>• a data interface to allow exchange of data between two system components | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON -0120 | Passive coupling and decoupling | Mandatory |
| **STATEMENT** | The SI shall allow the coupling and decoupling with another interface that cannot provide actuation | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON-0130 | Electrical Interface Switch | Mandatory |
| **STATEMENT** | The electrical interface shall incorporate a bidirectional power switch to control current flow at the | |

| | |
|---|---|
| | interface. |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON-0140 | SI Telemetry | Mandatory |
| **STATEMENT** | The SI shall measure and store the following local SI parameters:<br>• Temperature (Power electronics if local, structure)<br>• Alignment / proximity status<br>• Locking status<br>• SI orientation (in relation with design symmetry)<br>• Data/Power interface status<br>• Thermal interface status<br>• Motor position (incremental or absolute) / Mechanism position (absolute)<br>• Motor current<br>• Controller supply voltage | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON-0150 | SI current protection | Mandatory |
| **STATEMENT** | Each SI power transmission shall be protected against short-circuit and surge | |

| | | |
|---|---|---|
| HOTDOCK-IRD-COMMON-0160 | SI redundant Data/Power/Control interfaces | Mandatory |
| **STATEMENT** | The SI shall feature redundant data, power and control interface | |

## 8.2 OG8 PULSAR specific

| HOTDOCK-IRD-PULSAR-0010 | SI connected to RAS |
|---|---|
| **Requirement** | **The RAS end-effector shall provide a mechanical connection to the SI and support mechanical loads of the application** |
| **Compliance** | Mandatory. |

| HOTDOCK-IRD-PULSAR-0020 | SI connected to SMT |
|---|---|
| **Requirement** | **The SMT shall provide several mechanical connections to the SI and support mechanical loads of the application** |
| **Compliance** | Mandatory. |

| HOTDOCK-IRD-PULSAR-0030 | SI approach angle |
|---|---|
| **Requirement** | **The SI shall allow an approach angle of minimum 65 degrees** |
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0040 | SI mechanical load capacity |
|---|---|
| **Requirement** | **The SI mechanical interface shall support the mechanical loads applied during PULSAR demonstration operations** |
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0050 | SI tile powering |
|---|---|
| **Requirement** | **The SI power interface shall support powering of its own controller and the payload of the SMT** |

| | |
|---|---|
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0060 | SI power transfer |
|---|---|
| **Requirement** | **The SI power interface shall support the electrical power rating transfer between tiles as required by the application** |
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0070 | SI power switching |
|---|---|
| **Requirement** | **We shall be able to switch the power transmission for each individual SI of the SMT.** |
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0080 | SI data bus |
|---|---|
| **Requirement** | **The SI data interface shall allow data transmission between the OBC and the SMT controller for TM/TC of the SMT payload** |
| **Compliance** | Mandatory |

| HOTDOCK-IRD-PULSAR-0090 | SI CAN interface |
|---|---|
| **Requirement** | **The SMT controller shall interface the SI CAN bus controller to transfer SI TM/TC received from the OBC** |
| **Compliance** | Mandatory |

## 8.3 OG9 MOSAR specific

| **HOTDOCK-IRD-MOSAR-0010** | **Thermal Interface** | Mandatory |
|---|---|---|
| **STATEMENT** | The standard interface shall provide a thermal interface to allow active transfer of thermal flow between two Spacecraft Modules | |

| **HOTDOCK-IRD-MOSAR-0020** | **Data Interface Support** | Mandatory |
|---|---|---|
| **STATEMENT** | The data interface shall support at least one technology with capabilities of dynamic data bus re-configuration and routing | |

| **HOTDOCK-IRD-MOSAR-0030** | **Mechanical Loads** | Mandatory |
|---|---|---|
| **STATEMENT** | The mechanical interface shall withstand, in connected mode, all mechanical loads induced by the demonstration operations:<br>• Axial Force: 250 / 160 N<br>• Radial Force: 250 / 160 N<br>• Bending Moment: 204 / 84 Nm<br>• Torsion: TBD Nm<br>As function of the gravity compensation of the SM (TBC). | |

| **HOTDOCK-IRD-MOSAR-0040** | **Power Transfer Rating** | Mandatory |
|---|---|---|
| **STATEMENT** | The electrical interface shall be capable of supporting [1-2kW] (TBC) of power transfer, as required by the MOSAR demonstration<br><br>The power interface of the SM shall support [1-2kW] [TBC] of power transfer | |

| **HOTDOCK-IRD-MOSAR-0050** | **Data Interface Rating** | Mandatory |
|---|---|---|
| **STATEMENT** | The data interface shall allow a data rate of minimum 50Mbit/s | |

| **HOTDOCK-IRD-MOSAR-0060** | **Thermal Interface Rating** | Mandatory |
|---|---|---|
| **STATEMENT** | The thermal interface shall allow a thermal flow rating of: TBD W | |

| **HOTDOCK-IRD-MOSAR-0070** | **Mechanical Interface to Components** | Mandatory |
|---|---|---|
| **STATEMENT** | The standard interface shall provide a mechanical connection to the modules, spacecraft bus or robotic base/end-effector manipulator, compatible with the mechanical loads transferred through the interface. | |

| **HOTDOCK-IRD-MOSAR-0080** | **Harnessing to Components** | Mandatory |
|---|---|---|
| **STATEMENT** | The standard interface shall provide internal harnessing to connect power, data and control buses from the module, spacecraft or robotic base/end-effector manipulator | |

| **HOTDOCK-IRD-MOSAR-0090** | **Interface to Module Thermal System** | Mandatory |
|---|---|---|
| **STATEMENT** | The thermal interface shall enable thermal connection to the thermal module sub-system | |

| **HOTDOCK-IRD-MOSAR-0100** | **Power Distribution Unit** | Mandatory |
|---|---|---|
| **STATEMENT** | The SI shall be interfaced with a Power Distribution Unit (PDU) to provide low-level voltage power rails to supply the internal components of the SI (controller, sensors and motor drives) | |

| **HOTDOCK-IRD-MOSAR-0110** | **Standard Interface TM/TC** | Mandatory |
|---|---|---|
| **STATEMENT** | The SI shall be able to send/receive local TM/TC to/from the module or spacecraft OBC<br>TM: See FuncR_D109 list<br>TC:<br>• Coupling / de-coupling (TBC for intermediate states)<br>• Electrical power transfer on/off<br>• Low-level control (TBC) | |

| **HOTDOCK-IRD-MOSAR-0120** | **Diagonal Engagement** | Mandatory |
|---|---|---|
| **STATEMENT** | The standard interface shall allow diagonal engagement up to 55 deg | |

| **HOTDOCK-IRD-MOSAR-0130** | **Standard Interface ShutDown** | Desirable |
|---|---|---|
| **STATEMENT** | The standard interface (or a part of it) shall be able to be switched off/on (behave as a passive plug), while ensuring data and power transfer. | |

| **HOTDOCK-IRD-MOSAR-0140** | **Coupling Time** | Mandatory |
|---|---|---|
| **STATEMENT** | The coupling time between two standard interfaces shall be minimized | |

| **HOTDOCK-IRD-MOSAR-0150** | **SI Safe Manipulation** | Mandatory |
|---|---|---|
| **STATEMENT** | The SI shall be safe to be manipulated during integration within SM, WM or Spacecraft Buses. If there exist potential risks, they shall be well documented | |

| **HOTDOCK-IRD-MOSAR-0160** | **SI Design Configurations** | Mandatory |
|---|---|---|
| **STATEMENT** | The standard interface shall be declined in different configurations that are:<br>• Active<br>• Passive (not active behavior but can be couple and transmit data and power)<br>• Mechanical (not active and can only be coupled)<br>• Thermal (including thermal interface connectors, either active or passive) | |

## 8.4 OG11 PRO-ACT specific

| **HOTDOCK-IRD-PRO-ACT-0010** | **RWA HOTDOCK alignment** |
|---|---|
| **STATEMENT** | The RWA (IBIS or Gantry) shall ensure HOTDOCK alignment before starting the connection process.<br>Note: The associated technical capabilities of the RWA (and potentially annexes systems as visual servoing) will be function of the selected HOTDOCK electro-mechanical technology (position accuracy, compliant control).<br>The tolerance translation error to initiate the connection process from 10 to 15mm (with then an initial phase of form fit guidance). |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0020** | **RWA compliant control** |
|---|---|
| **STATEMENT** | The RWA (IBIS or Gantry) shall provide compliant control during the HOTDOCK approach or connection process (as function of the selected technology) |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0030** | **Dust Protection** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall provide dust protection in connected mode |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0040** | **Gripper data interface** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall support the transfer of TM/TC between the IBIS and the gripper (through the data interface). |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0050** | **Gripper power interface** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall support power transfer to operate the gripper (through the power interface). |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0060** | **3D head data interface** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall support the transfer of TM/TC between the gantry OBC and the 3D printed head. |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0070** | **3D head power interface** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall support power transfer to operate the 3D printed head |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0080** | **Automatic HOTDOCK status confirmation** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall provide automatic confirmation of the connection status to support autonomous operations, as tool exchange |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0090** | **HOTDOCK power transfer switch and monitoring** |
|---|---|
| **STATEMENT** | The HOTDOCK power interface could provide switching and monitoring capabilities |

| | |
|---|---|
| **LEVEL** | Optional (not mandatory for the application. With the simple power architecture of the system, the functionallinity could be provided by external components) |

| **HOTDOCK-IRD-PRO-ACT-0100** | **HOTDOCK mechanical loads** |
|---|---|
| **STATEMENT** | Connected HOTDOCK interfaces shall support mechanical loading during PRO-ACT demonstrations scenarios:<br>• Bucket granding: bucket weight, debris and ground reaction forces (initial estimation: 400N in longitudinal and transversal force, 120Nm, for 40kg pressure and 0.3m lever arm)<br>• IBIS Gripper: gripper weight, lifted object and mechanical interaction forces<br>• Payload: weight of the payload and interaction forces (with IBIS or gantry application) (initial estimation: 200N in longitudinal and transversal force, 100Nm in bending torque, for a box of 20kg, COG 0.5m)<br>• Gantry 3D Head: weight of the 3D printing head in operating mode |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0110** | **HOTDOCK interface to IBIS** |
|---|---|
| **STATEMENT** | The IBIS manipulator end-effector (end of the mechanical chain) shall be equipped with an active HOTDOCK interface |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0120** | **HOTDOCK interface to bucket** |
|---|---|
| **STATEMENT** | The bucket tool shall be equipped with a mechanical HOTDOCK interface |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0130** | **HOTDOCK interface to gantry** |
|---|---|

| | |
|---|---|
| **STATEMENT** | The gantry end-effector (end of the mechanical chain) shall be equipped with an active HOTDOCK interface |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0140** | **HOTDOCK interface to gripper** |
|---|---|
| **STATEMENT** | The gripper shall be equipped with a passive HOTDOCK interface |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0150** | **HOTDOCK interface to 3D printed head** |
|---|---|
| **STATEMENT** | The 3D printed head shall be equipped with a passive HOTDOCK interface |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0160** | **HOTDOCK Power and Control EGSE** |
|---|---|
| **STATEMENT** | The RWA (IBIS or gantry) shall provide power and TM/TC interface (CAN communication) to operate the active HOTDOCK. |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0170** | **HOTDOCK configurations** |
|---|---|
| **STATEMENT** | To cover the PRO-ACT scenarios, the following number of HOTDOCK interfaces (per configuration) shall be delivered:<br>• Active: 1<br>• Passive: 1<br>• Mechanical: 2<br>This is taking into account the re-use of HOTDOCK interfaces between demonstration scenarios |

| | |
|---|---|
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0180** | **HOTDOCK symmetry** |
|---|---|
| **STATEMENT** | The HOTDOCK interface should provide connection symmetry (mechanical and data interface) to simplify robotic operations |
| **LEVEL** | Desirable |

| **HOTDOCK-IRD-PRO-ACT-0190** | **HOTDOCK Diagonal Engagement** |
|---|---|
| **STATEMENT** | The HOTDOCK interface should allow diagonal engagement to relax constraint of RWA trajectory planning and precision requirements |
| **LEVEL** | Desirable |

| **HOTDOCK-IRD-PRO-ACT-0200** | **HOTDOCK operation monitoring** |
|---|---|
| **STATEMENT** | The HOTDOCK operations and TM shall be monitored and displayed to the operator. |
| **LEVEL** | Desirable |

| **HOTDOCK-IRD-PRO-ACT-0210** | **HOTDOCK mechanical robustness** |
|---|---|
| **STATEMENT** | The HOTDOCK interface shall be robust to mechanical interaction in disconnected mode |
| **LEVEL** | Mandatory |

| **HOTDOCK-IRD-PRO-ACT-0220** | **HOTDOCK interaction force monitoring** |
|---|---|

| | |
|---|---|
| **STATEMENT** | The RWA could provide force feedback information to stop/reduce operation if HOTDOCK maximum load are exceeded (to avoid to break HOTDOCK interface in case of off-nominal operation) |
| **LEVEL** | Desirable |

******************************** End of Document ********************************