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# Handle to Spacecraft Interface Control Document

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Public release is authorized.

# Contents

# 1. Overview

Handle is a compact, radiation-tolerant Ethernet-over-Serial (EoS) interface system which can connect up to 20 EoS payloads to a common network (Pat. No. US 11,055,254). On behalf of connected payloads, Handle provides serial digital communications for up to 4 high-speed (gigabit data rates) and 16 low-speed (up to 20 Mbps data rates) payloads to connect to each other and to the host spacecraft bus. Handle also provides switched, regulated, and current limited power to payloads; powers and reads a temperature sensor within each payload; and provides 4 bilevel controls and 4 bilevel statuses from the payload infrastructure. Figure 1 shows a picture of the Handle configuration as incorporated into the Slingshot 1 spacecraft.


Figure 1: Handle as configured for Slingshot 1 Mission

The Handle system is designed to serve as the power and data interface between the payloads and the host spacecraft. Its design uses common power and data interfaces to the host spacecraft bus in an effort to maximize the number of host busses which could directly connect without modification or tailoring. The spacecraft power bus assumes unregulated power (nominally 12V) but allowed to range from 9 – 14V and 20Mbps SpaceWire for data and command interfaces. Figure 2 provides a block diagram for the Handle system.

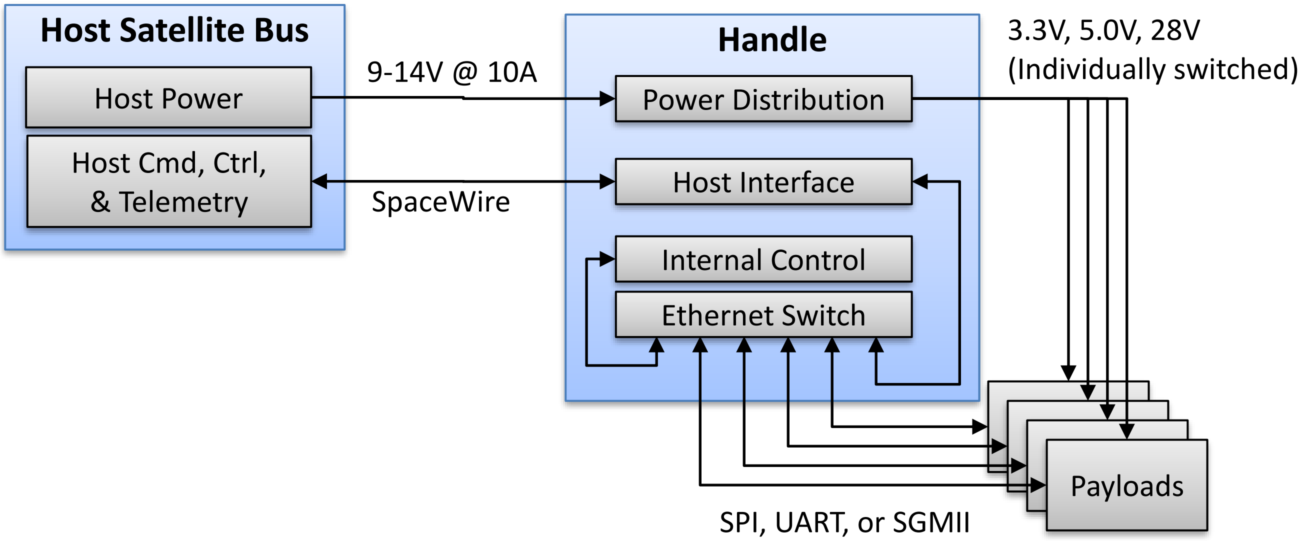


Figure 2: Handle and Supported Systems Block Diagram

| **Handle Scale** |  |  |  |  |
|---|---|---|---|---|
| **Size** | 3.3 x 3.6 x 1.95 inches (0.39U) | 3.3 x 3.6 x 2.6 inches (0.52U) | 3.3 x 3.6 x 3.25 inches (0.62U) | 3.3 x 3.6 x 3.9 inches (0.78U) |
| **Mass** | 383 grams | 487 grams | 591 grams | 694 grams |
| **Data Ports** | 4 Gigabit Ethernet<br>4 SPI/UART | 4 Gigabit Ethernet<br>8 SPI/UART | 4 Gigabit Ethernet<br>12 SPI/UART | 4 Gigabit Ethernet<br>16 SPI/UART |

Table 1: Handle Configuration Options

The Handle mechanical and electrical design provides for scalability using a slice-based architecture and stacking Glenair HD-Stacker backplane for interfacing between boards. The stacking backplane is for internal use only and does not connect to the host bus or to payloads.

All Handle configurations require a Power Board at the base of the stack and an Ethernet switch at the top of the stack – the number of included Low-Speed Boards depends on the number of low-speed ports needed for the specific mission being supported. Table 1 shows how the system scales in size, mass and number of serial digital ports provided for each configuration.

In addition to the serial digital interfaces, Handle also passes the GPS time fiducial to payloads and provides a cross-bar switch for 4 each bilevel status and 4 bilevel controls for all connected payloads. These signals are implemented as 3.3V logic signals, and their routing is configurable via ground commands.

## 2. Electrical Interfaces

The Handle system has 2 interface cables to the host spacecraft. The power connector is a 15-pin micro-D and expects to receive unregulated 9V – 14V power with up to current draws of 10 amps; connector pins are grouped in multiples to cover the total maximum power consumption for downstream payloads.

The communications connector is a 37-pin nano-D and includes SpaceWire transmit/receive signals, 4 bilevel status lines, 4 bilevel control lines, and the GPS 1pps signal to be broadcast to payloads.

Figure 4 shows Handle with power and communications cable locations identified.


Figure 4. Handle to Spacecraft Interface Connector Locations

### 2.1 Power Interface

#### 2.1.1 Power Connector Specification

The Handle power connector is a 15-pin micro-D connector. The connector part number is M83513/13-B01CP.

#### 2.1.2 Power Connector Pinout

| Pin Number(s) | Signal | Comment |
|---|---|---|
| 1, 2, 3, 4, 5, 6, 7, 8 | VBUS | Power Input to Handle; 9V – 14V expected at up to 10A |
| 9, 10, 11, 12, 13, 14, 15 | VRET | Power Input Return |

Table 2: Power Connector Specification

#### 2.1.3 Power Connector Signal Definition – 12V Unregulated Power

The VBUS signal is the unregulated power input to Handle. The voltage range accepted is 9V – 14V. The large number of pins provided allows for up to 10 amps of input current to Handle to supply regulated power for downstream payloads connected on Handle outputs.

### 2.1.4 Power Connector Signal Definition – 12V Unregulated Power Return

The VRET signals are the return path for the power supplied on VBUS. These signals are connected to power return for payloads.

## 2.2 Communications Interface

### 2.2.1 Communications Connector Specification

The communications interface connector on Handle is a 37-pin nano-D connector. The connector part number is A28410-137.

### 2.2.2 Communications Connector Pinout

| Pin Number(s) | Signal | Comment |
|---|---|---|
| 1 | BL_CTRL_1 | Bilevel control #1 to Handle and payloads from Bus |
| 2, 4, 6, 8, 10, 12, 14, 16, 17, 18, 19, 28, 29, 34, 35, 37 | GND | Signal return for digital signals |
| 3 | BL_CTRL_2 | Bilevel control #2 to Handle and payloads from Bus |
| 5 | BL_CTRL_3 | Bilevel control #3 to Handle and payloads from Bus |
| 7 | BL_CTRL_4 | Bilevel control #4 to Handle and payloads from Bus |
| 9 | BL_STAT_1 | Bilevel status #1 from Handle and payloads to Bus |
| 11 | BL_STAT_2 | Bilevel status #2 from Handle and payloads to Bus |
| 13 | BL_STAT_3 | Bilevel status #3 from Handle and payloads to Bus |
| 15 | BL_STAT_4 | Bilevel status #4 from Handle and payloads to Bus |
| 20 | DAT_SH_OUT_P | SpaceWire data, Handle to Bus, + side |
| 21 | DAT_SH_OUT_N | SpaceWire data, Handle to Bus, - side |
| 22 | CLK_SH_OUT_P | SpaceWire strobe, Handle to Bus, + side |
| 23 | CLK_SH_OUT_N | SpaceWire strobe, Handle to Bus, - side |
| 24 | CLK_SH_IN_P | SpaceWire strobe, Bus to Handle, + side |
| 25 | CLK_SH_IN_N | SpaceWire strobe, Bus to Handle, - side |
| 26 | DAT_SH_IN_P | SpaceWire data, Bus to Handle, + side |

| Pin Number(s) | Signal | Comment |
|---|---|---|
| 27 | DAT_SH_IN_N | SpaceWire data, Bus to Handle, - side |
| 30, 31, 32, 33 | NO_CONNECT | Leave these signals floating in the interface |
| 36 | GPS_PPS_TO_SH | GPS 1 pulse per second signal |

Table 3: Communications Connector Pinout

### 2.2.3 Communications Connector Signal Definition – BL_CTRL_[1 – 4]

The 4 bilevel control pins (BL_CTRL_1 – BL_CTRL_4) are sourced by the Spacecraft Bus and provide logic level controls for Handle and the downstream connected payloads. BL_CTRL_1 and BL_CTRL_2 have special meanings (see below) however BL_CTRL_3 and BL_CTRL_4 can be configured (by commands to Handle) to route to the BL_CTRL pin input to any of the payloads. These signals are all 3.3V CMOS signals where a logic ‘1’ goes from 1.65V to 3.3V. Logic ‘0’ is anything below 1.65V. The Bus should not drive these signals below -0.3V or above 3.6V at any time.

BL_CTRL_1 and BL_CTRL_2 are used by Handle to allow the Spacecraft Bus to configure which boot images inside Handle are to be used. The signals are defined as follows:

BL_CTRL_1: If held low (logic ‘0’) at power application to Handle, then Handle will boot its PolarFire FPGA normally and move to normal operations. If the signal is instead held high (logic ‘1’) at power application to Handle, then Handle will enter its bootloader mode to allow for code patches to be installed to flash memory.

BL_CTRL_2: If held low (logic ‘0’) and BL_CTRL_1 is also low, then Handle’s PolarFire FPGA will load its code from the golden image. If instead this signal is high (logic ‘1’) when BL_CTRL_1 is low, then the latest code image will be loaded from patch flash memory.

The normal configuration for operation is BL_CTRL_1 = ‘0’ and BL_CTRL_2 = ‘1’.

### 2.2.4 Communications Connector Signal Definition – BL_STAT_[1 – 4]

The 4 bilevel status pins (BL_STAT_1 – BL_STAT_4) are sourced by Handle and provide logic level status via Handle from the downstream connected payloads. Routing to payload by status bit are configurable by Handle command. These signals are all 3.3V CMOS signals where a logic ‘1’ goes from 1.65V to 3.3V. Logic ‘0’ is anything below 1.65V.

### 2.2.5 Communications Connector Signal Definition – DAT_SH_OUT_[P / N]

Signals DAT_SH_OUT_P (+ side) and DAT_SH_OUT_N (- side) form an LVDS pair which is sourced by Handle to communicates data between Handle and the Spacecraft Bus using SpaceWire protocols. This LVDS pair is used in concert with the CLK_SH_OUT_P and CLK_SH_OUT_N LVDS pair which provide the strobe needed to synchronize the data. These signals are sourced by Handle and comply with LVDS standard signaling at up to 20 Mbps. The LVDS signal pair should be terminated in the Spacecraft Bus with a 100 ohm resistor (between + side and – side).

### 2.2.6 Communications Connector Signal Definition – CLK_SH_OUT_[P / N]

Signals CLK_SH_OUT_P (+ side) and CLK_SH_OUT_N (- side) form an LVDS pair which are sourced by Handle and is the strobe for data receipt (by the SpaceCraft Bus). These signals are sourced by Handle and comply with LVDS standard signaling at up to 20 Mbps. The LVDS signal pair should be terminated in the Spacecraft Bus with a 100 ohm resistor (between + side and – side).

### 2.2.7 Communications Connector Signal Definition – CLK_SH_IN_[P / N]

Signals CLK_SH_IN_P (+ side) and CLK_SH_IN_N (- side) form an LVDS pair which is sourced by the Spacecraft Bus and is the strobe for data receipt (by Handle). These signals are sourced by the Spacecraft Bus and comply with LVDS standard signaling at up to 20 Mbps. The LVDS signal pair is terminated inside Handle with a 100 ohm resistor (between + side and – side).

### 2.2.8 Communications Connector Signal Definition – DAT_SH_IN_[P / N]

Signals DAT_SH_IN_P (+ side) and DAT_SH_IN_N (- side) form an LVDS pair to communicates data between the Spacecraft Bus and Handle using SpaceWire protocols. This LVDS pair is used in concert with the CLK_SH_IN_P and CLK_SH_IN_N LVDS pair which provide the strobe needed to synchronize the data. These signals are sourced by the Spacecraft Bus and comply with LVDS standard signaling at up to 20 Mbps. The LVDS signal pair is terminated internal to Handle with a 100 ohm resistor (between + side and – side).

### 2.2.9 Communications Connector Signal Definition – NO_CONNECTs

The communications connector pins 30, 31, 32, and 33 are for Handle testing only. These signals should be left floating in normal operations.

### 2.2.10 Communications Connector Signal Definition – GPS_PPS_TO_SH

The GPS_PPS_TO_SH is the 1 pulse-per-second pulse from the Spacecraft Bus to Handle to tell the time-at-tone for the separately received GPS time message. The signal shall be a 3.3V signal with the active edge being the rising edge. The pulse shall be at least 1 msec wide (positive pulse). The signal shall always be in the range from -0.3V to 3.6V.

### 2.2.11 Communications Connector Signal Definition – GNDs

The GND pins are used as reference for all digital signals on the communications cable.

## 2.3 Communications Packet Formats

Command and data packets transmitted between the Spacecraft Bus and Handle are formatted per CCSDS Space Packet Protocol per CCSDS 133.0-B-1 standards, and only primary headers are included. Handle contains a single ApId (0x200) for Bus to Handle frames and a second ApId (0x201) for Handle to Bus packets.

Within the Handle to payloads network, packets with these ApId values are formatted as Ethernet frames. i.e., The contents of each such CCSDS packet must be an Ethernet frame complete with header, data, and frame-check sequence (FCS). On the receiving side (bus to payloads) Handle receives the CCSDS packet, then extracts the embedded Ethernet packet from within and sends it to the payload network. In the opposite direction, Handle receives Ethernet packets from payloads, and then wraps those packets with the CCSDS primary/secondary headers before delivering the data to the bus.

A special time-at-the-tone packet (ApId = 0x1FF) is transmitted from the Host Spacecraft to Handle every second, and this packet includes the time that will be injected on the next 1 pulse-per-second rising edge.

### 2.3.1 Command Packet Format (Spacecraft Bus to Handle)

Command packets communicated from the Spacecraft Bus to Handle are formatted as shown in Table 4. The ApId for command packets is 0x200.

| **Byte(s)** | **Contents** |
|---|---|
| 0 – 1 | Bits 15:13 = CCSDS version (ignored) |
| | Bit 14 = Packet type (ignored) |
| | Bit 13 = Secondary header flag (must be zero) |
| | Bits 12:0 = ApId (must be 0x200) |
| 2 – 3 | Ignored |
| 4 – 5 | Packet length (bytes) |
| 6+ | Packet contents = the embedded Ethernet-formatted frame for use by Handle and for forwarding to payloads. Must include Ethernet header, data, and frame checksum (FCS). |

Table 4: Generic Command Messages (Host Spacecraft to Handle)

### 2.3.2 Telemetry Packet Format (Handle to Spacecraft Bus)

Telemetry packets communicated from Handle to the Spacecraft Bus are formatted as shown in Table 5. The ApId for data packets is 0x201.

| **Byte(s)** | **Contents** |
|---|---|
| 0 – 1 | Bits 15:13 = CCSDS version (ignored) |
| | Bit 14 = Packet type (ignored) |
| | Bit 13 = Secondary header flag (must be zero) |
| | Bits 12:0 = ApId (must be 0x201) |
| 2 – 3 | Ignored |

| Byte(s) | Contents |
|---|---|
| 4 – 5 | Packet length (bytes) |
| 6+ | Packet contents = the embedded Ethernet-formatted frame from Handle and the payload subsystem. Must include Ethernet header, data, and frame checksum (FCS). |

Table 5: Generic Data Messages (Handle to Host Spacecraft)

### 2.3.3 Time-at-the-Tone Packet Format (Spacecraft Bus to Handle)

Time-at-the-Tone packets communicated from the Spacecraft Bus to Handle are formatted as shown in Table 6. The ApId for Time-at-the-Tone packets is 0x1FF. Time-at-the-Tone messages should be sent from the Host Spacecraft approximately half way between 1 pulse-per-second (1pps) pulses to insure that the messages are fully received prior to receipt of the 1pps.

| Byte(s) | Contents |
|---|---|
| 0 – 1 | Bits 15:13 = CCSDS version (ignored) |
| | Bit 14 = Packet type (must be zero) |
| | Bit 13 = Secondary header flag (must be one) |
| | Bits 12:0 = ApId (must be 0x1FF) |
| 2 – 3 | Ignored |
| 4 – 5 | Packet length (bytes) |
| 6 - 9 | 32-bit second counter since Jan 1, 2000 at 00:00:00. This is the valid time at the next 1 pulse-per-second pulse. |

Table 6: Time-at-the-Tone Messages (Host Spacecraft to Handle)

## 3. Mechanical Outline & Mounting

As described in Section 1, the Handle system is based upon a slice architecture where the system can be tailored for the number of low-speed ports needed for a particular mission. The sections which follow show the mechanical drawings for the various configurations. The drawings (in order) are the 4 low-speed port version, 8 port version, 12 port version, and 16 port version. All configurations shown include 4 each gigabit Ethernet ports.

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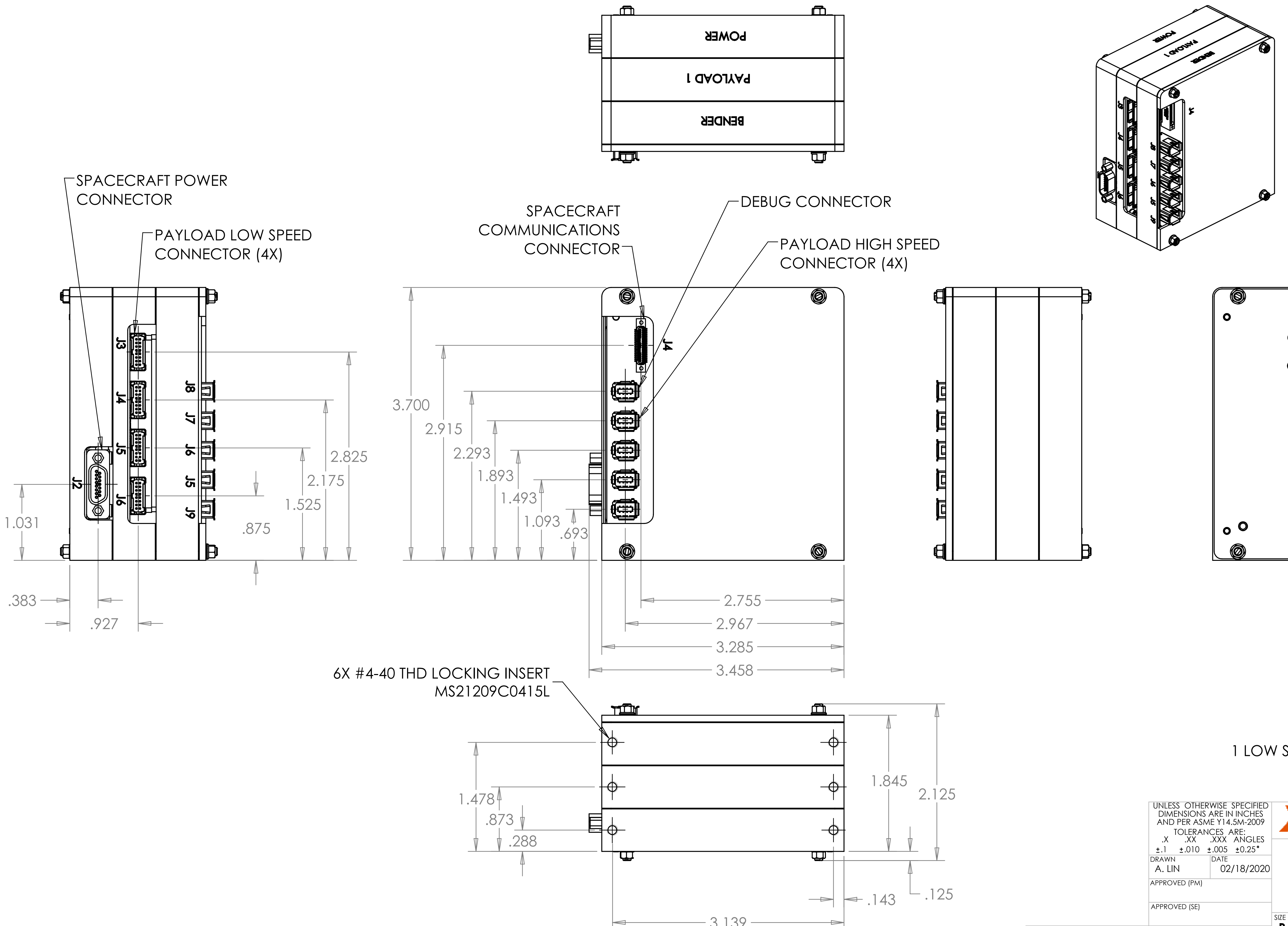



1 LOW SPEED PAYLOAD SLICE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER ASME Y14.5M-2009
TOLERANCES ARE:

| .X | .XX | .XXX | ANGLES |
|---|---|---|---|
| ±.1 | ±.010 | ±.005 | ±0.25° |

DRAWN: A. LIN — DATE: 02/18/2020
APPROVED (PM)
APPROVED (SE)
APPROVED (QA)
USED ON: SLINGSHOT

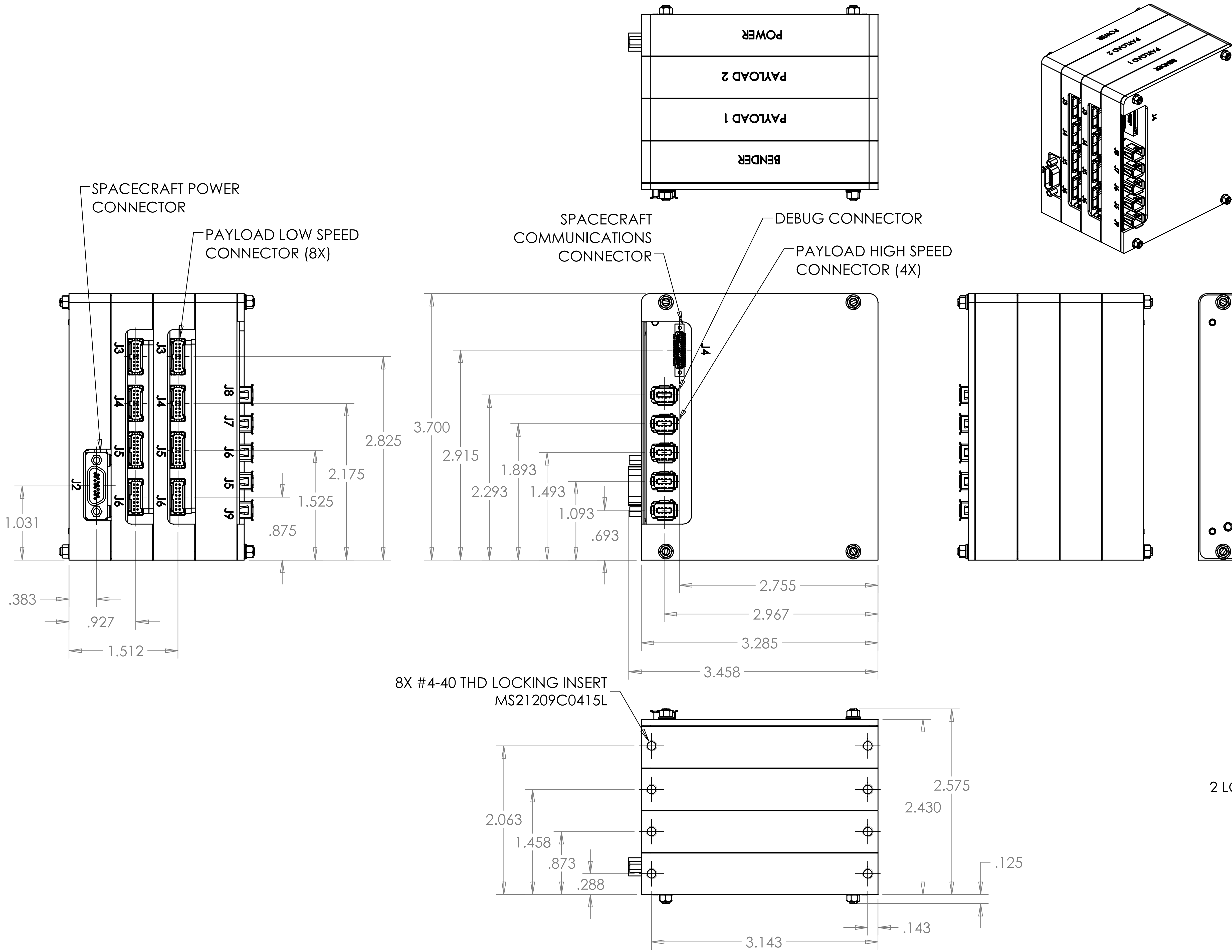
XLab AEROSPACE

SPOON HANDLE, BOARD STACK

SIZE: B — DWG. NO.: 35621 — REV.:

DO NOT SCALE DRAWING

SHEET 1 OF 4



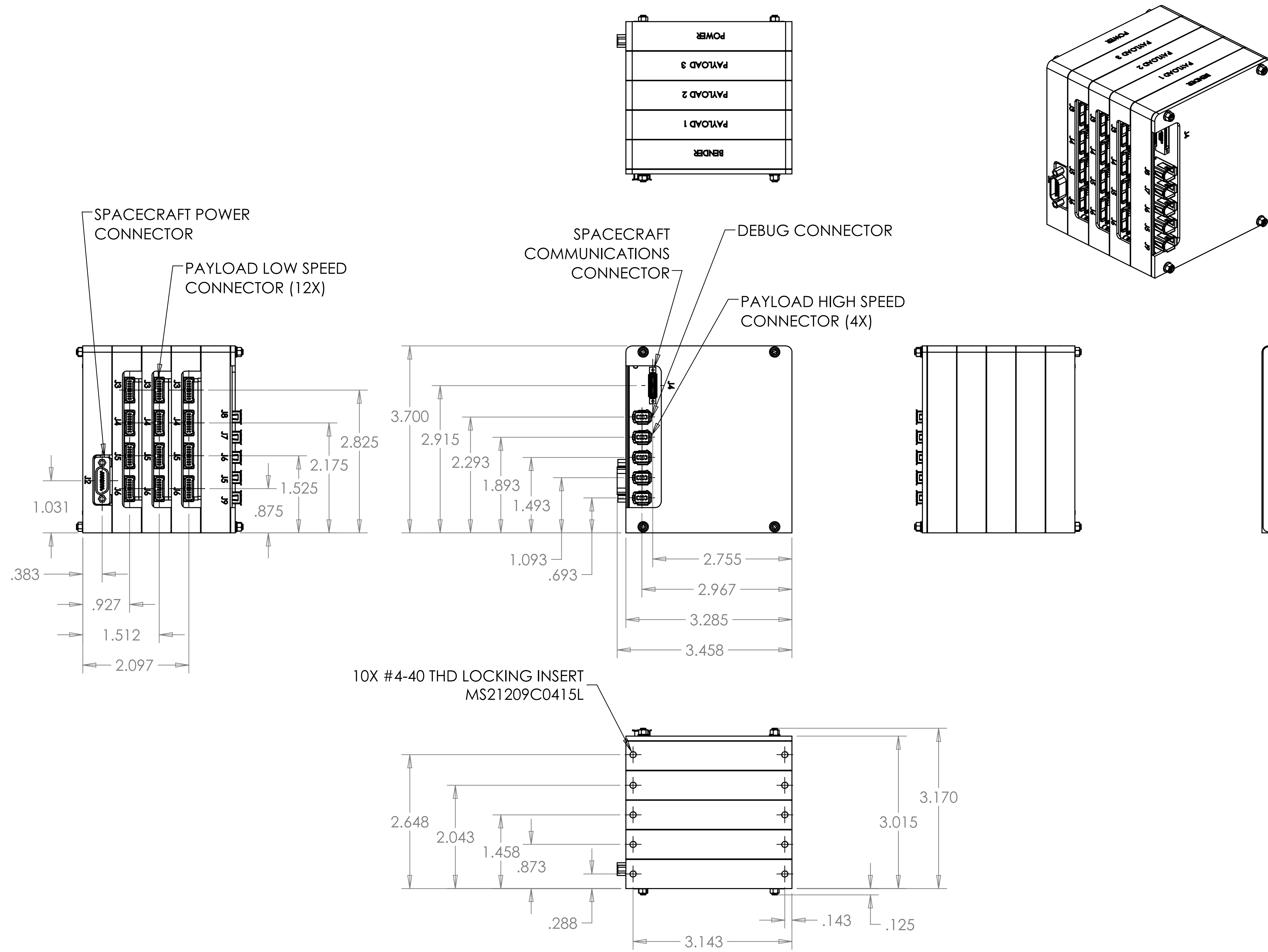

2 LOW SPEED PAYLOAD SLICES

SPOON HANDLE, BOARD STACK

| SIZE | DWG. NO. | REV. |
|---|---|---|
| B | 35621 | |

DO NOT SCALE DRAWING

SHEET 2 OF 4



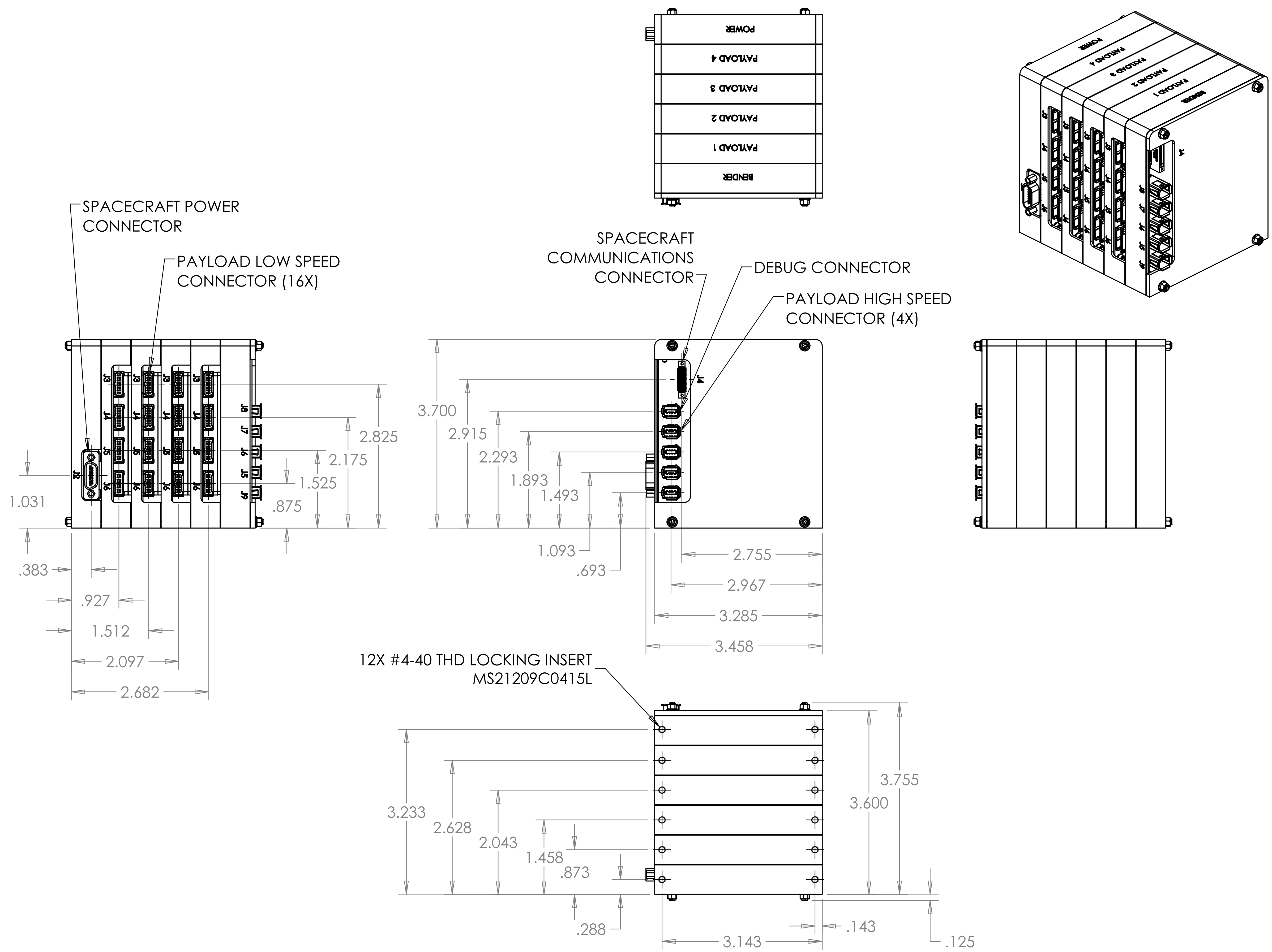

3 LOW SPEED PAYLOAD SLICES

SPOON HANDLE, BOARD STACK

| SIZE | DWG. NO. | REV. |
| --- | --- | --- |
| B | 35621 | |

DO NOT SCALE DRAWING

SHEET 3 OF 4




4 LOW SPEED PAYLOAD SLICES

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SPOON HANDLE, BOARD STACK

SIZE B | DWG. NO. 35621 | REV.

DO NOT SCALE DRAWING

SHEET 4 OF 4

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