United States Naval Academy Standard Bus CubeSat
Version 2.0

Payload Subsystem Interface Control Document

November 2023

Revision History

Date	Version	Description, Author
18OCT23	1.0	Initial Draft, Saroka
08NOV23	2.0	Update and add Figures, Update of all sections

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1. Introduction

The Naval Academy Standard Bus (NASB) is a standard 1U CubeSat bus that attaches to a payload module. The payload module will be 2U and will carry two payloads and a dummy weight. The standardization of the NASB will allow for the United States Naval Academy (USNA) to consistently launch spacecraft with a reliable and tested payload bus making space more accessible for students at a low cost. USNA-16 is the first mission of the NASB. For USNA-16, the NASB and payload module will support two customer payloads, the FalconRAD designed by cadets from the United States Air Force Academy (USAFA) Space Physics and Atmospheric Research Center (SPARC) and one from University of Maryland (UMD) and the Students for the Exploration and Development of Space (SEDS). The USNA NASB payload team is responsible for the design of the payload module structure, and therefore this ICD contains requirements for both the interface between the payload module and the customer payloads, as well as the interface between the payload module and the NASB.

1.2. Purpose

The purpose of this Interface Control Document (ICD) is to define requirements for the customer payload boards to ensure proper integration with the payload module. Upon formal approval for each customer payload, this ICD shall be incorporated into the requirements baseline for each system.

1.3. Scope

The specific requirements that this ICD defines are physical, electrical, and software requirements. This ICD defines the interfaces between the NASB, the payload module, the payload interface board, and the customer payloads. For mechanical requirements, this ICD describes the concept of operations for interfaces, sets physical standards for the payload module, and identifies mounting hardware requirements. For electrical requirements, this ICD describes the concept of operations for the interfaces, establishes power allotments to the customer payloads, and sets connection standards. For software requirements, this ICD describes the concept of operations for the interfaces, defines message structures and protocols which govern the interchange of data, and identifies the hardware requirements for communication paths along which data are expected to flow.

1.4. System Identification

Descriptions of key systems for USNA-16 are provided in this section.

1.4.1. Orientation

A CAD rendering of the complete 3U USNA-16 spacecraft is shown in Figure 1.1 below. The axis-system included in the figure will be referred to for the remainder of the ICD.

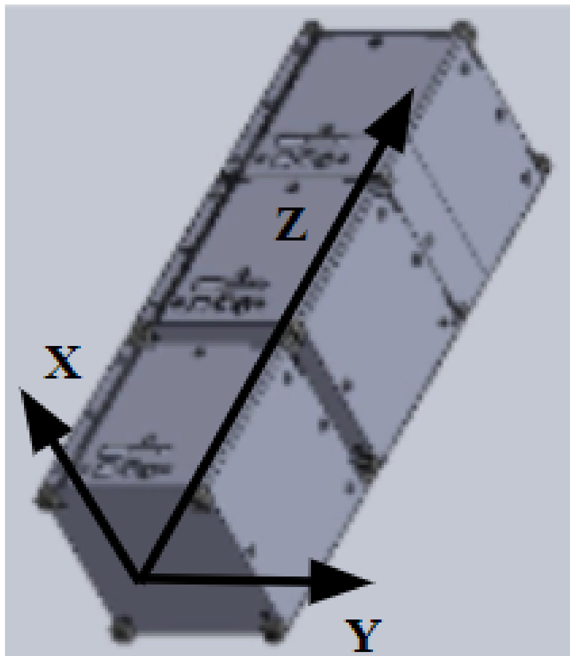

Figure 1.1. CAD Rendering of Complete 3U USNA-16 CubeSat

1.4.2. Naval Academy Standard Bus (NASB)

The NASB is the 1U bus that provides critical subsystems to the payload module. Relevant parameters of the capabilities of the NASB are listed below in Table 1.1.

Table 1.1. NASB Details

System	Details
Total space	1U
S-band patch antenna	2.4 GHz
UHF dipole antenna	400 MHz
L-band GPS patch antenna	1575 MHz
Maximum data downlink	76.2 kbps
Maximum data uplink	1.56 kbps

3U SA Config. Power to payload module (at EOL)	3.5 W +/- 0.15W

1.4.3. 2U Payload Module

The 2U payload module is the largest size payload module the NASB can connect to. The payload module for USNA-16 will be 1U, of which 0.4U will be occupied by the payload interface board. Table 1.2 includes power, volume, and mass properties of the 2U payload module.

Table 1.2 2U Payload Module Details

System	**Details**
Total space	2U
Space used by payload interface board	0.4U
Available space	1.6U
Maximum mass	2 kg
Total power	3.5 W +/- 0.1W
Power used by payload interface board	0.1W
Available power	3.4 W +/-0.1W

1.5. Operational Agreement

This ICD provides the specifications for an interface between the NASB, the payload module, the payload interface board, and the customer payloads regarding mechanical, electrical, and software requirements. Modifications to this ICD shall be documented in the Revision History and communicated to the customers.

2. Mission Overview

The mission of the NASB is to integrate the standardized NASB with a customer designed payload module in order to facilitate the design of customer missions. The NASB shall have all of the systems required to support the two customer payloads from USAFA and UMD.

2.1. System Overview

The NASB is a 1U self-sufficient CubeSat bus. The 2U payload module shall attach to the NASB mechanically and the customer payloads shall connect electrically to the payload interface board. Power and data transmission shall be provided to customer payloads by the NASB via the payload interface board. The customer shall be responsible for designing and constructing the customer payloads IAW this ICD. Midshipmen at USNA shall build the NASB, the payload module, and the payload interface board, and assemble, integrate, and test the combined CubeSat in preparation for launch and mission operations. Figure 2.1 shows the overview of the system as described above.

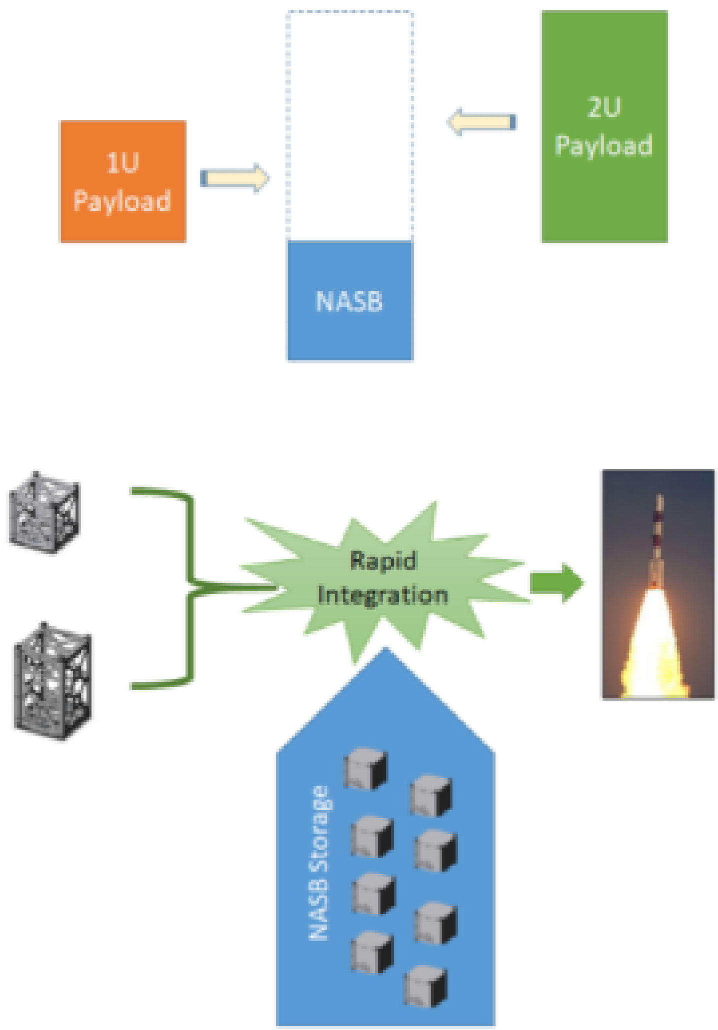

Figure 2.1. USNA-16 OV-1
(adapted from USNA-2101 presentation, Kang)

2.2. Interface Overview

All customer payloads shall interface with the payload module and the payload interface board. The payload module will provide the structure to which the customer payloads shall be connected. The payload interface board (PIB) will be provided with continuous bus power. Customer payloads shall communicate using the UART protocol. Software interfacing will be standardized by the software lead on the payload team in conjunction with members of the USAFA team who created a “simulation” PIB to test with inorder to ensure their payload is operational . An Adafruit FeatherBoard with a micro-SD card on the payload interface board will provide data storage and shall route commands from the NASB to the customer payloads.

2.3. Operations

During standard operations, the payload interface board will alternate between payload data collection and checking for commands from the NASB. Upon receiving a command from the NASB, the payload interface board will determine where it is addressed, and either execute the command at the payload module level or forward it to the designated customer payload within the payload module. Once all commands have been executed, the payload interface board will return to its default mode.

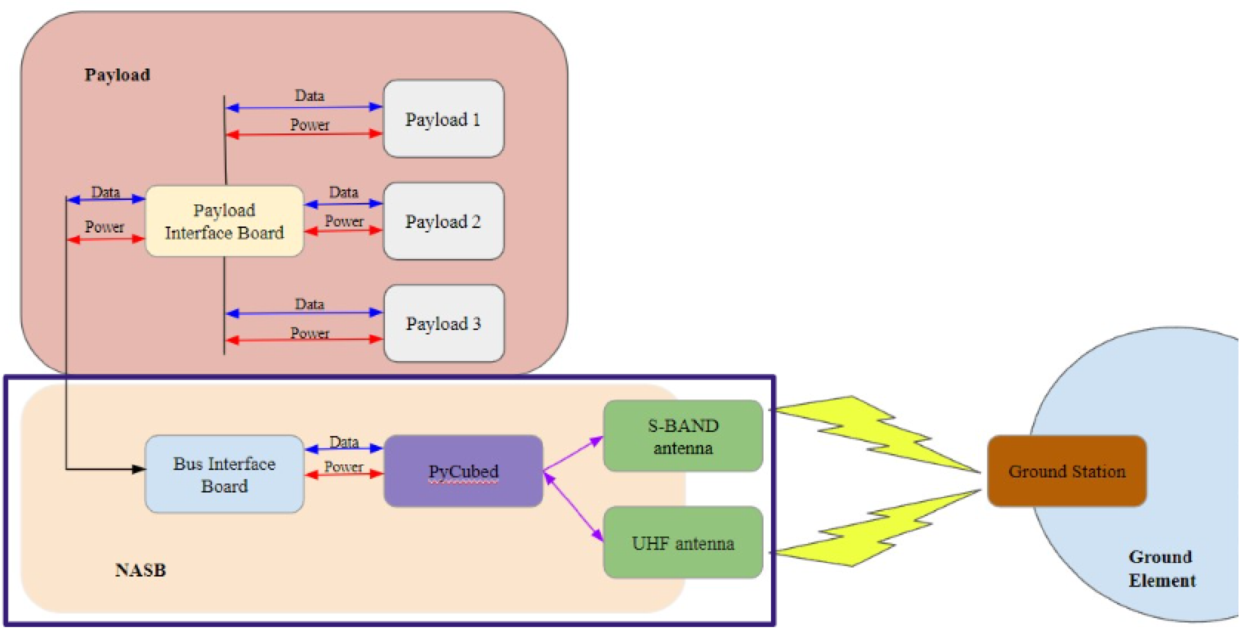

Figure 2.2 Payload Interface Board Standard Operations

3. NASB Interface Requirements

This section details how the NASB will interface with the payload module and the payload interface board. There are three critical interfaces between the NASB and the payload module. The mechanical interface will secure the structure of the payload module to the NASB. The electrical interface will provide connections for data transfer and power transmission from the NASB to the payload interface board. The software interface will allow for data transmission between the NASB and payloads via the payload interface board.

3.1. Mechanical Interface Requirements

3.1.1. Physical Requirements

The system will mechanically connect the 2U payload module to the 1U NASB. The system will also successfully integrate the customer payloads from USAFA and UMD. The mass of each individual payload shall not exceed 500 grams. The center of gravity for both the 2U payload module shall fall within the ranges specified in Table 3.1 in accordance with CubeSat Design Specification Rev. 14.1. The locations specified in Table 3.1 are measured from the geometric center on each major axis.

Table 3.1 Acceptable Ranges for Center of Gravity Locations

	Payload Module Center of Gravity
X Direction	±2 cm
Y Direction	±2 cm
Z Direction	±7 cm

3.1.2. Structural Connection

The payload module will be connected to the NASB using an aluminum plate as shown in Figure 3.1 below. The male end of the connector is placed on the -Z face of the payload module while the female end is placed on the +Z face of the NASB, Figure 3.2. The connector plate on the NASB also serves to house the UHF antenna deployment mechanism.

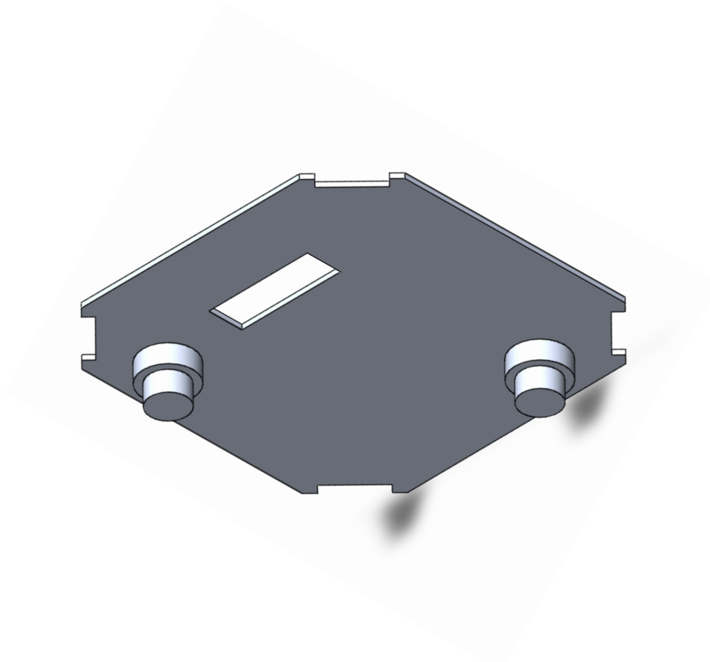

Figure 3.1. Connector Plate on -Z Face

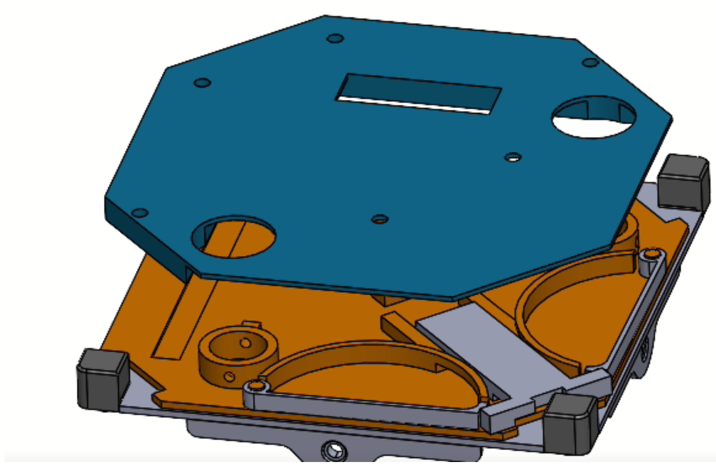

Figure 3.2. Connector Plate on -Z Face

3.2. Bus to Payload Interface Requirements

The NASB will connect to the payload module via a 10-wire, 24 AWG ribbon running between the bus interface board and payload interface board. The ribbon from the payload interface board will be connected to a Molex 151100010 male connector which will be plugged into a Molex 1510980010 female connector from the bus interface board during assembly of the 3U spacecraft. A diagram of the connector can be found in Figure 3.3, and a description of each connection can be found in Table 3.2. for the two connectors can be found in appendices A and

B, respectively.

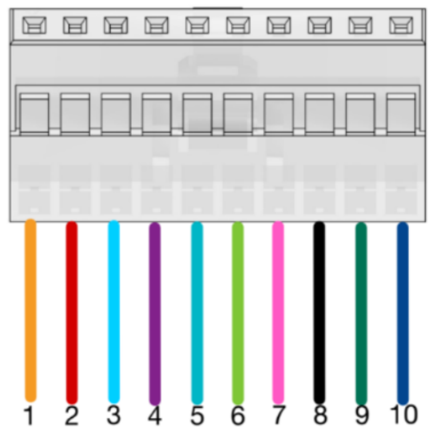

Figure 3.3 NASB to Payload Interface Board Electrical Connector Diagram

Table 3.2 NASB to Payload Module Electrical Connector Reference

Connection #	Label
Connection 1	3.3V
Connection 2	5V
Connection 3	Vbatt 7.4V
Connection 4	Rx (b)
Connection 5	Tx (b)
Connection 6	Rx (c)
Connection 7	Tx (c)
Connection 8	Ground
Connection 9	Flag
Connection 10	Spare

3.3. Software Interface Requirements

The software on both the NASB and the payload interface board will be written in CircuitPython. The payload interface board will receive commands from the NASB, and either

execute them or forward them
to a customer payload. The payload interface board and the NASB will understand a common list of commands, which will be formatted as a string. All commands and data will be sent over UART protocol.

Table 3.3 NASB to Payload Interface Board Command List

Type:	String: English
Diagnostic	“dia1” ADCS payload respond with diagnostic message
Diagnostic	“dia2” USAFA payload respond with diagnostic message
Diagnostic	“dia3” UMD payload respond with diagnostic message
Data	“sf#ns#ne#” payload interface board send Payload # file(s) from number start # to number end #
Data	“df#nf#” payload interface board delete # files of Payload # file(s) from oldest file on SD
Mode switch	“safe” Payload module enter safe mode
Mode switch	“nmnl” Payload module enter nominal operations mode
Mode switch	“dtbl” Payload module enter detumble mode
Mode switch	“stby” Payload module enter standby mode

3.4. Payload Interface Board Design

The payload interface board distributes power to each individual payload and acts as the communications hub between the payloads and the NASB. The board conforms to PC/104 form factor specifications and is the first payload from the bottom Z-axis base plate in the payload module. An Adafruit Feather M0 serves
as the microcontroller for managing power distribution and data flow between the payloads and NASB. Three Linear Technology LTC1478CS solid state switches and three Mouser TX2-LT-5V latching relays are used to control the three switched power outputs to the payloads (3.3V, 5V, and Vbatt). The datasheets for the switches and relays are enclosed in appendices C and D, respectively. There are three surface-mounted 10-pin Mouser TE connectivity headers on the +Z face of the payload interface board to connect to each payload and one 10-pin connector on the -Z face to connect with the NASB bus interface board. Figures 3.4 and 3.5 show the PIB schematic and in progress PCB.

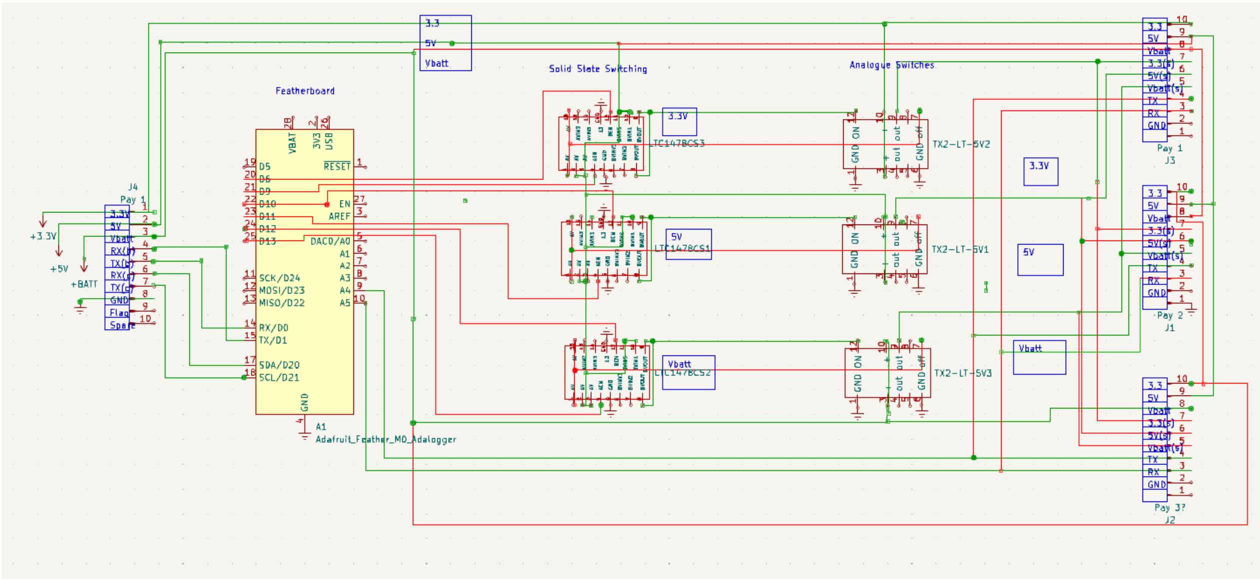

Figure 3.4. USNA-16 PIB Schematic

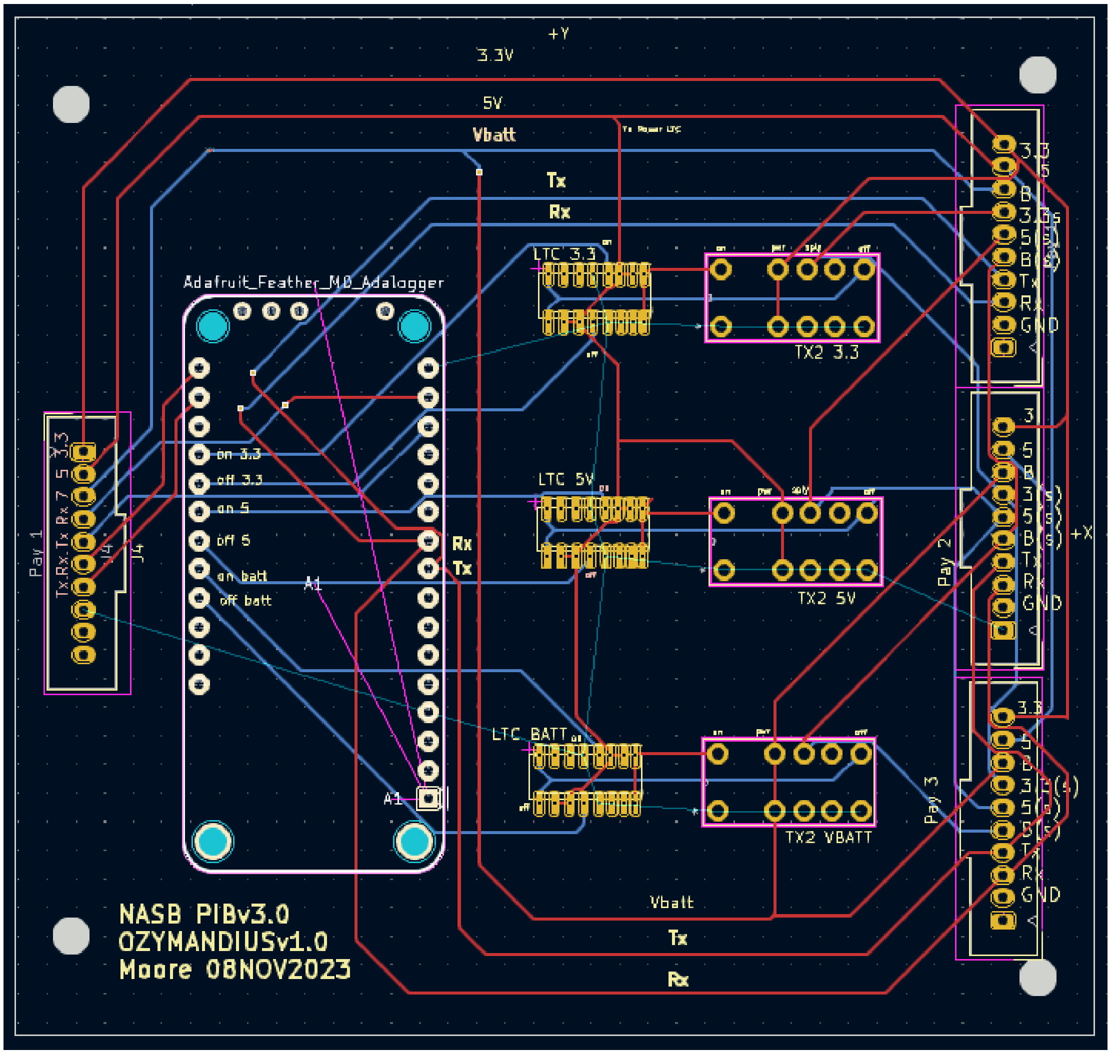

Figure 3.5 USNA-16 PIB Schematic

4. Payload Interface Requirements

This section defines how the customer payloads will interface with the payload module and with the payload interface board. There are three critical interfaces detailed in this section. The mechanical interface secures the customer payloads to the structure of the payload module. The electrical interface provides connections for power transmission from the payload interface board to customer payloads. The software interface supports data transfer between the payload interface board and the customer payloads.

4.1. Mechanical Interface Requirements

The customer payload boards must follow the modified PC/104 form factor as shown below in Figure 4.1 in order to interface with the payload module's rod-and-spacer mechanism. Four threaded M3 rods are affixed to the base plate of the payload module according to the hole positions prescribed by the PC/104 specification. The pad diameter on each customer payload shall be 6.35mm with a hole diameter of 3.30 mm. Coaxial aluminum through-hole spacers with an external diameter of 6.0mm will be used to space the payloads apart. The M3 rod will be secured to the chassis walls at the +Z end plate of the payload module to retain the entire module stack. Figure 4.2 is an example of the customer payload boards. The cut out seen on the +X face is in order to ensure there is enough room for the wires to run from each board to the PIB without coming into contact with the structure of the payload module and potentially damaging the connection.

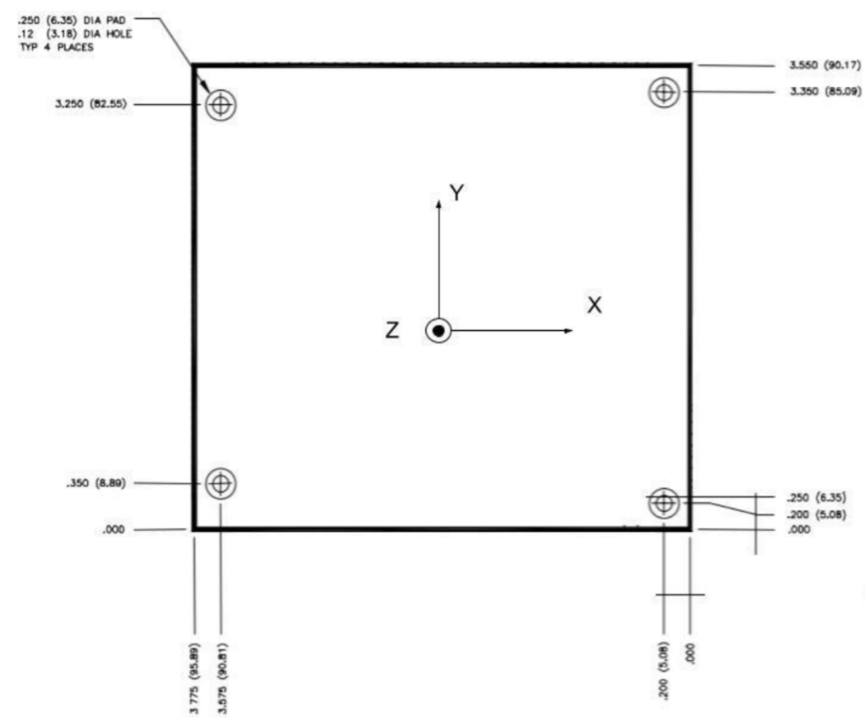

Figure 4.1. Modified PC/104 Form Factor as viewed from the +Z orientation

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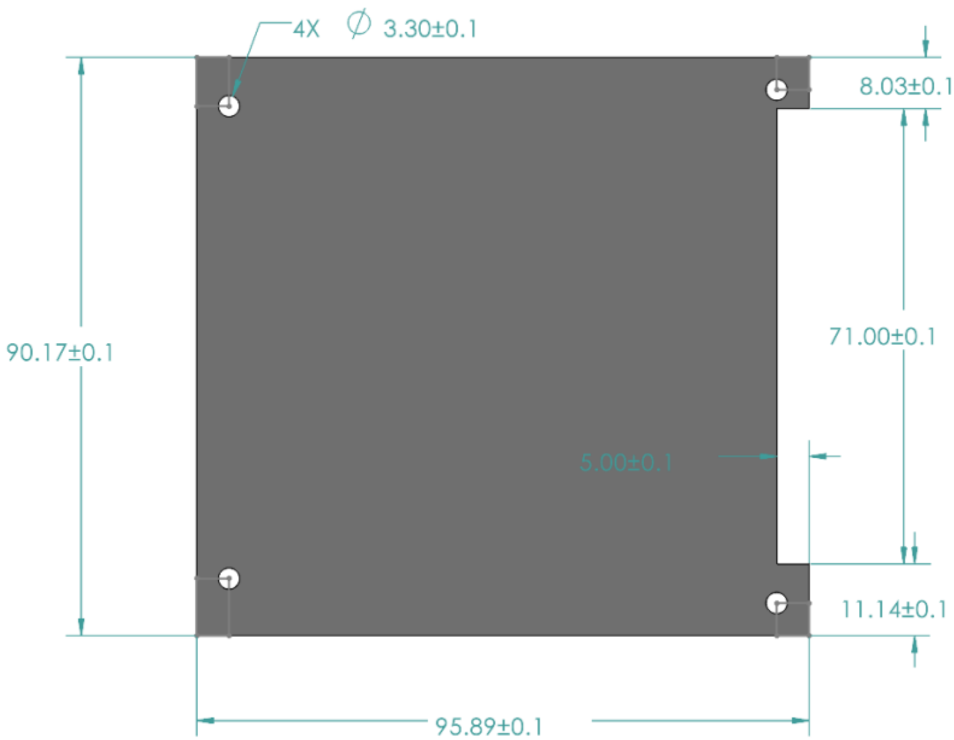

Figure 4.2 Example of Customer Payload Board Dimensions from +Z Perspective

4.2. Electrical Interface Requirements

The payload interface board will connect to the customer payloads via ribbon wires terminating in single-row electrical connectors. The electrical connectors will have ten pins total, with nine pins being used, and with one undesignated pin available for potential payload customer utilization. Pin assignments are listed in Table 4.5 below. The ribbon length will vary depending on the number of payloads being flown and the position of the individual payload within the 2U payload module.

Three TE Connectivity surface-mounted single-row, 10-pin, 2.54mm pitch headers (Mfr. # 3-644861-0) are on the +Z surface of the payload interface board. The connection between the surface-mounted headers, on both the payload interface board and the payload board, will be spanned by a ribbon with a TE Connectivity receptacle housing (Mfr. # 4-644540-0) on either end. Datasheets for the headers and receptacle housings can be found in appendices E and F, respectively. The TE Connectivity surface-mounted pitch headers will be mounted to each payload on the -Z surface on the edge it is assigned to in table 4.1. The pin order for the customer payloads, as viewed from the -Z face, shall be in accordance with table 4.2 and figure 4.2. USNA will be responsible for mounting the housings onto each customer payload as well as routing the ribbon connectors following payload delivery.

Table 4.1. Ribbon Connector Position for each Payload on USNA-16

Payload	Order from -Z baseplate Position of connector to PIB
Payload Interface Board	1 N/A
Dummy Weight	2 N/A
Falcon-RAD	3 +X edge
UMD	4 +X edge

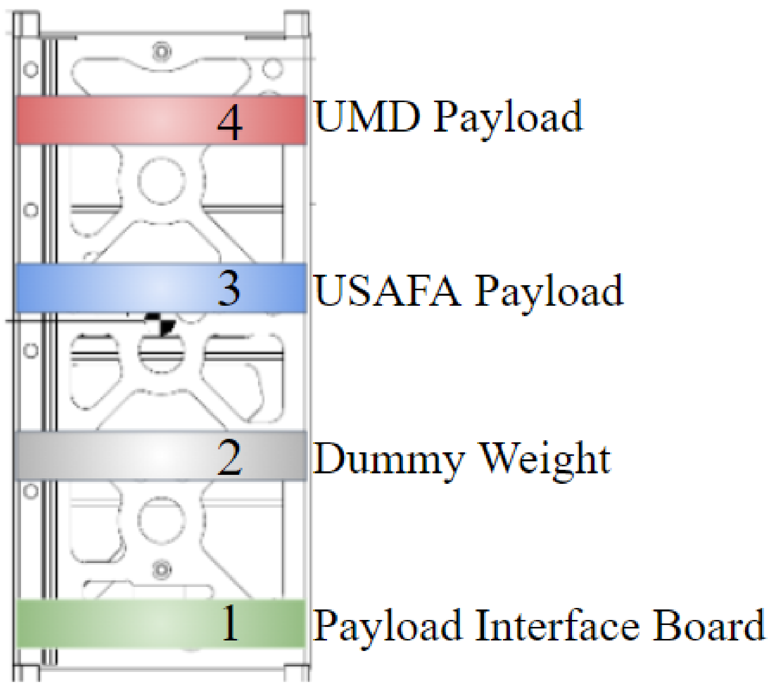

Figure 4.3 Payload Module Order

Payloads shall not use the hardwired power (Pin 8, 9, 10) for the USNA-16 mission. Payloads will receive different levels of wattage depending on the operational mode of USNA-16. In nominal, standard operating conditions, payloads will not exceed 1±0.1W of power consumption. During safe modes and detumble, payloads will receive power not to exceed 0.5W of power.

Table 4.2 Payload Interface Board to Customer Payload Electrical Connector Reference

Connection #	Label Target Value	Tolerance
Connection 1	SPARE	N/A
Connection 2	GROUND	N/A
Connection 3	UART TX	N/A
Connection 4	UART RX	N/A
Connection 5	Switch Vbatt 7.4V	6.5V-8.4V
Connection 6	Switch 5V	+/-0.2V
Connection 7	Switch 3.3V	+/-0.2V
Connection 8	Hardwire Vbatt 7.4V	6.5V-8.4V
Connection 9	Hardwire 5V	+/-0.2V
Connection 10	Hardwire 3.3V	+/-0.2V

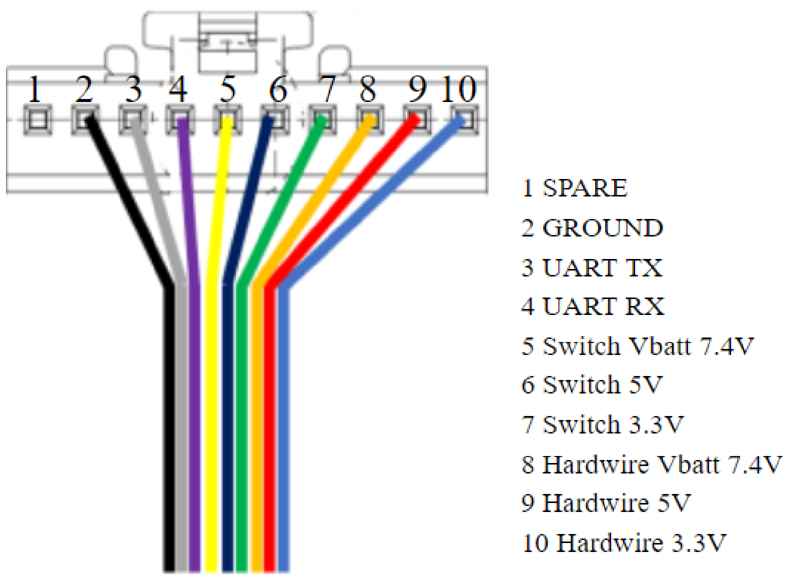

Figure 4.4 10-Pin Harness Diagram

4.3. Software Interface Requirements

UART is single ended (RS232), 115200 baud, at 3.3V logic voltage. Falcon-RAD will communicate at 3.3V. The USNA-16 payload interface board communicates with payloads via Feather M0 Adalogger. If data storage is required for the payload, the payload interface board will offer storage on the payload interface board SD card not to exceed 1GB. All files stored on the SD card can be retrieved only by the NASB via ground station command.

4.3.1. Message/File Requirements

Commands will be formatted based on payload requirements, and a command list must be provided to the USNA team by third party developers.

4.3.2. List of Commands

The following commands apply to all payloads:

Table 4.3 Payload Commands

Type:	String: English:
Diagnostic	"dia" Payload transmits payload specific diagnostic message
Diagnostic/Data	Payload determined Payloads may request commands specific to their payload to achieve their payload objectives
Mode switch	"safe" Payload module enter safe mode
Mode switch	"nmnl" Payload module enter nominal operations mode
Mode switch	"dtbl" Payload module enter detumble mode
Mode switch	"stby" Payload module enter standby mode

5. Interface Verification

5.1 Customer Documentation

Each customer payload developer is expected to deliver the payload with the following documentation:

- Master equipment list
- Materials list
- Support equipment necessary
- Handling/assembly procedures
- Software

5.2 Testing

Prior to the Mission Readiness Review, the payload module with all of the customer payload modules integrated will undergo command and day-in-the-life testing. Upon successful completion of these tests, the payload module will be integrated with the NASB to complete the full 3U spacecraft and undergo additional testing to include thermal-vacuum chamber, vibration table, charge cycle, simulated communications, and full function tests.

6. Appendices

Appendix A. Molex 151100010 Datasheet
Appendix B. Molex 1510980010 Datasheet
Appendix C. LTC1478CS Switch Datasheet
Appendix D. TX2-LT-5V Relay Datasheet
Appendix E. TE 3-644861-0 Datasheet
Appendix F. TE 4-644540-0 Datasheet

Parts List