MOD PAYLOAD

A Modular Payload Design Standard for UAS, Manned Aircraft and Small Maritime Vessels

Revision 5.1

May 25, 2021

DISTRIBUTION STATEMENT A: Approved for public release: distribution unlimited.

FOREWORD

This standard contains requirements for the form factor, weight, design, and environmental tolerance for EW/SIGINT/Communications systems for Group 1-3 UAS (detailed in Volume I) and manned aircraft and small maritime vessels (detailed in Volume II). These requirements are designed and developed under government contracts to define the Modular Payload standard. The requirements of this standard are specifically developed to improve the packaging efficiency, increase the reliability, enhance the interchangeability and maintainability, promote the rapid removal and replacement by flight maintenance personnel, and reduce the life cycle cost of EW/SIGINT/Communications systems.

This standard provides guidance to payload vendors on how to build a compliant payload and to platform vendors on how to bring a platform into compliance. The standard also provides example integrations to provide a more comprehensive look at the variations in implementation supported by the standard.

While initially launched by USSOCOM for EW/SIGINT systems on UAS, the standard has been expanded to other payload types, e.g., communication payloads and radars, and other platforms, e.g., manned aircraft and maritime vessels. Further expansion to other payload types (e.g., radars) and platforms (e.g., USVs) is ongoing.

RECORD OF CHANGES

Revision	Date	Description of Changes
1.0	06-15-2017	Initial release.
1.1	01-19-2018	Added as-built configurations.
2.0	05-31-2018	Included better interface definitions.
2.1	06-07-2018	Major re-formatting. Improved descriptions.
2.2	06-27-2018	Further re-formatting. Improved interface details.
3.0	07-03-2019	Further re-formatting and clarifications. Added Jump-20 and Stalker appendices.
4.0	10-30-2019	Updated dimensioning of modules to address compatibility issue from tolerance stack up. Updated dimensioning of antenna mounts and brackets to address compatibility issue.
5.0	04-30-2021	Expanded and split into separate volumes: Volume I for UAS and Volume II for extended applications of manned aircraft and small maritime vessels. Added Appendix for SkyRaider.
5.1	05-25-2021	Changed to unlimited distribution, added clarifications in Appendix B.

Updated Sections

The following table lists all sections in the document that were significantly revised in this update.

Revision	Sections Revised	Importance	Description of Changes
4.0	3.1.4.5	Minor	Corrected reference for LVDS 1PPS signal.
	3.1.4.6	Minor	Corrected reference for LVDS Zeroize signal.
	3.3.3.2	Minor	New section, adding explicit module compatibility requirements for Primary Mount.
	4.2.1	Major	Updated 1U, 2U, and 3U module definition and mechanical drawings.
	4.2.3.1	Major	Better defined wedge lock requirements.
	4.4.3	Minor	Clarified allowable connectors on payload antennas.
	5.1	Major	Updated antenna mechanical interface definition and mechanical drawings.
5.0	Whole	Major	Separated the Index, Volume I, and Volume II sections into three documents
	V1: 2.1	Major	Better specified power in-rush requirement Clarified higher power payload requirement Clarified IP network responsibility and requirements
	V1: 2.2	Major	Added subsections on installation, configuration and calibration of the INS
	V1: 2.3	Minor	Better specified primary mount interfaces Clarified primary mount thermal requirements
	V1: 2.4	Major	Moved from antenna section to platform section Better defined all antenna mount interfaces
	V1: 2.5	Major	Added subsections on MAIM and RF cabling Clarified RF cable and connector requirements Updated platform grounding requirements
	V1: 3.1	Major	Better specified power in-rush requirement Updated payload grounding requirements
	V1: 3.2	Major	Better specified payload mechanical volumes Added subsections on mechanical variations
	V1: 3.3	Minor	Clarified payload thermal requirements
	V1: 3.4	Major	Moved from antenna section to payload section Better defined all antenna adaptor interfaces
	V1: App A	Minor	Corrected error in SKY message example
	V1: App B-E	Minor	Updated overall appendix structure Add Compliance Summary table Removed unnecessary information
	V1: App F	Major	New – SkyRaider appendix
	VII	Major	New – draft MPx volume
5.1	Whole	Major	Removed distribution restrictions
	VI: App B	Minor	Added descriptive clarifications

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ORDER OF PRECEDENCE

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations, unless a specific exemption has been obtained. A list of applicable government documents can be found in each Volume.

Table of Contents:

Table of Contents, Volume I:

Table of Contents, Volume II:

1. BACKGROUND

The Modular Payload, a.k.a. "Mod Payload" (MP) Program was developed to promote modularity in the DoD arsenal of Group 2 Unmanned Aerial Systems (UAS). It has since been expanded to support Groups 1 and 3 UAS. The Modular Payload Expanded Capability (MPx), developed under the Joint Threat Warning System (JTWS) program, further expanded the MP Standard to support both manned aircraft and maritime platforms. This standard aims to define the common interfaces and attributes for both EW / SIGINT / Communications payloads and also the platforms into which such payloads will be integrated. Specifically, the primary objectives of the MP Program are as follows:

(1) To reduce Government cost for new payload integrations.

(2) To reduce time and complexity for crew to swap capabilities down range.

Figure 1-1. MP Overview Briefing

If not already completed, it is highly recommended that the reader first review the Mod Payload overview briefing. This briefing is available over DTIC as well as through POCs listed in this document. It provides an explanation at a top level, which will make absorbing this more complex document much easier.

The program office maintains a repository of reference designs that are available as government furnished information (GFI) which is available to platform developers to accelerate development. Contact Mac McAlister, JHU/APL, for more information (see Page iv).

2. SCOPE

The Modular Payload Standard is split into an introduction (this document) and multiple volumes based on the platform class. This introduction document covers the overarching description of the standard. Volume I defines the MP Standard for payloads for Group 1-3 UAS, detailing the requirements for the development of modular payloads and the architectural modifications levied upon the host UAS platform to accommodate modular payloads. Volume II defines the MPx Standard for payloads for manned aircraft and small maritime vessels. These larger platforms allow for more flexibility in payload size, weight and power (SWAP) and expanded capability in payload performance. However, backwards compatibility to the UAS MP Standard was also maintained, meaning an MP-compliant UAS payload can also be flown on an MPx-compliant platform

2.1 Volume I, Modular Payload Design Standard for Small UAS

Volume I details the UAS specific requirements for compatible platforms and compliant payloads. Aircraft-specific MP implementations are then detailed in the Appendices. To achieve modularity, the MP Standard:

- Mandates a common platform-payload architecture to interface to payloads, and
- Specifies the form factor, mechanical/electrical/RF interfaces, and environmental requirements for payloads.

The common infrastructural features of the MP concept include the definition of the Modular Aircraft Interface Module (MAIM), the Primary Mount, payload modules, and Antenna Mounts, as highlighted in Figure 2-1, the top-level block diagram of the MP architecture.

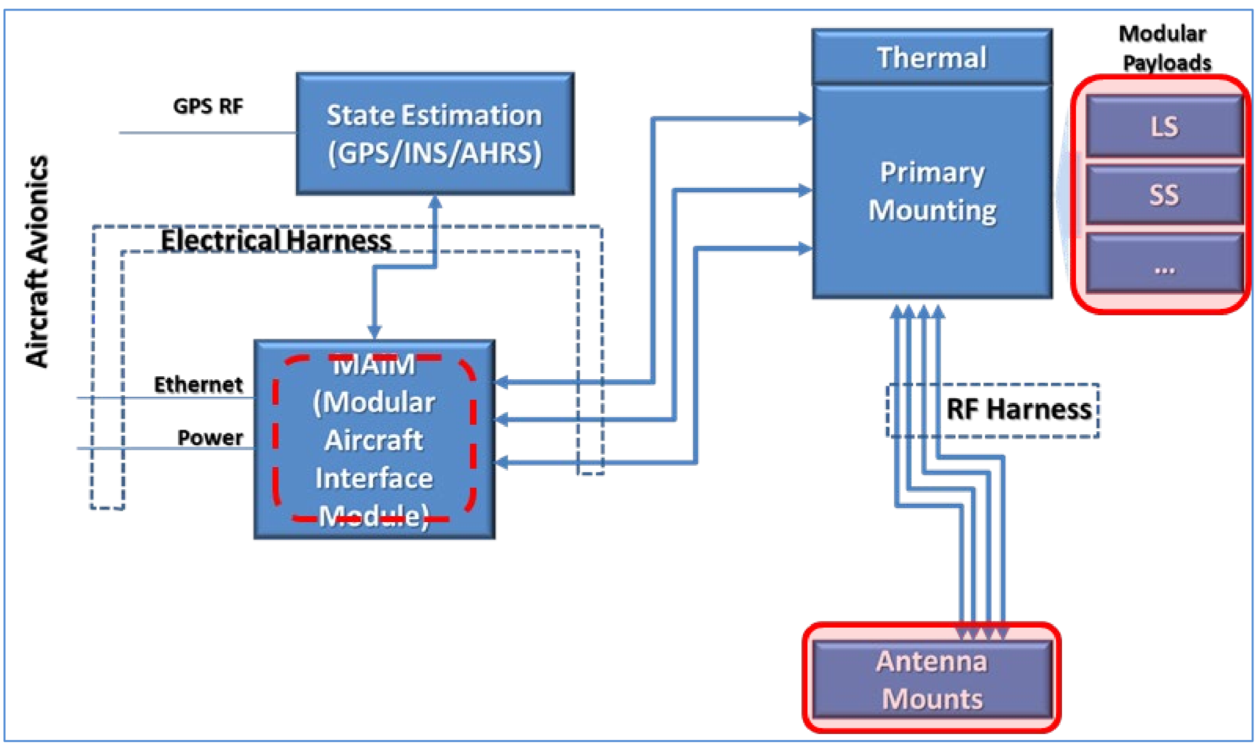

Figure 2-1. MP Block Diagram

UAS platform-specific MP implementations are then detailed in the Appendices.

2.2 Volume II, Modular Payload Expanded Capability Set (MPx)

Volume II defines the MPx Standard for SIGINT and EW payloads for airborne and maritime platforms. This Standard details the requirements for the development of modular payloads and the architectural modifications levied upon the host platform to accommodate modular payloads. To achieve modularity, the MPx Standard:

- Mandates a common platform-payload architecture to interface to payloads, and
- Specifies the form factor, mechanical/electrical/RF interfaces, and environmental requirements for payloads.

The core of this document covers the information required for all common infrastructural features of the MP concept. This includes definition of the Platform Integration Module (PIM), the Primary Mount, payload modules, and Antenna Mounts, as highlighted in Figure 2-2, the top-level block diagram of the MP architecture.

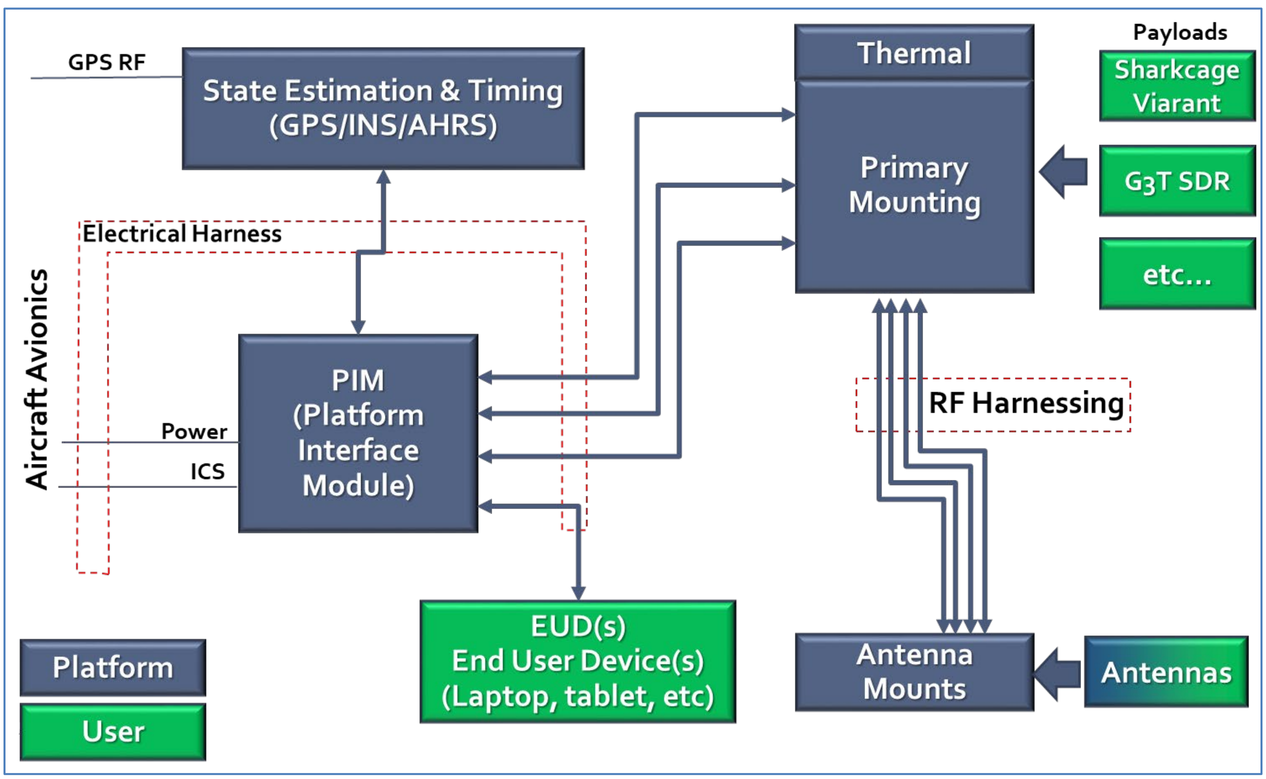

Figure 2-2 MPx Block diagram

Extended platform-specific MP implementations are then detailed in the Appendices.

Mod Payload, Volume I:

Modular Payload Design Standard for Small UAS

Revision 5.1

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Table of Contents:

1. Overview

Volume I of the Modular Payload (MP), or "Mod Payload," Standard defines the modular payload requirements for Group 1-3 UAS. Section 2 details the attributes and interfaces required of a UAS platform for MP-compliance. Section 3 details the attributes and interfaces required of a payload for MP-compliance. MP implementations on specific platforms are provided in the appendices as an aid to both UAS integrators and payload vendors.

2. REQUIREMENTS FOR UAS PLATFORMS

A number of requirements are levied on the UAS to support modular payloads. For existing UAS, MP-compliance will likely require modifications to the aircraft. These modifications will add some weight and complexity to the platform but will provide common mechanical, power, data, and RF interfaces to simplify payload integrations. These modifications include the development and installation of a MAIM and a Primary Mount, the integration of a specific inertial navigation system (INS), provisions for payload antennas and the installation of RF cabling to support the payload antennas. For new UAS, the same payload accommodations must be made, but MP-compliance is much less intrusive and can be readily and more efficiently incorporated as part of the initial platform design.

2.1 MAIM

The MAIM provides the interface between the non-compliant host UAS and the payload modules. The MAIM is a scalable design ***customized for each platform*** to provide the electrical interfaces required for modular payloads.

2.1.1 Applicability

A MAIM is only required to bring an existing UAS into MP-compliance. A newly developed UAS may be able to support all MAIM functionality and requirements with its native avionics suite.

2.1.2 Description

The MAIM is a circuit board or enclosed module, customized to the host UAS to provide the required platform and payload interfaces and the required data ingestion, processing and dissemination capabilities to support payload integration and operation. The MAIM should be considered an additional avionics component, not a payload itself. As such, the size, weight, and payload capacity of the MAIM are not strictly defined, but should be commensurate to the UAS capacity. As a result, the MAIM may vary substantially for different UAS platforms.

Figure 2-1 depicts an example MAIM circuit board, capable of supporting up to four payloads.

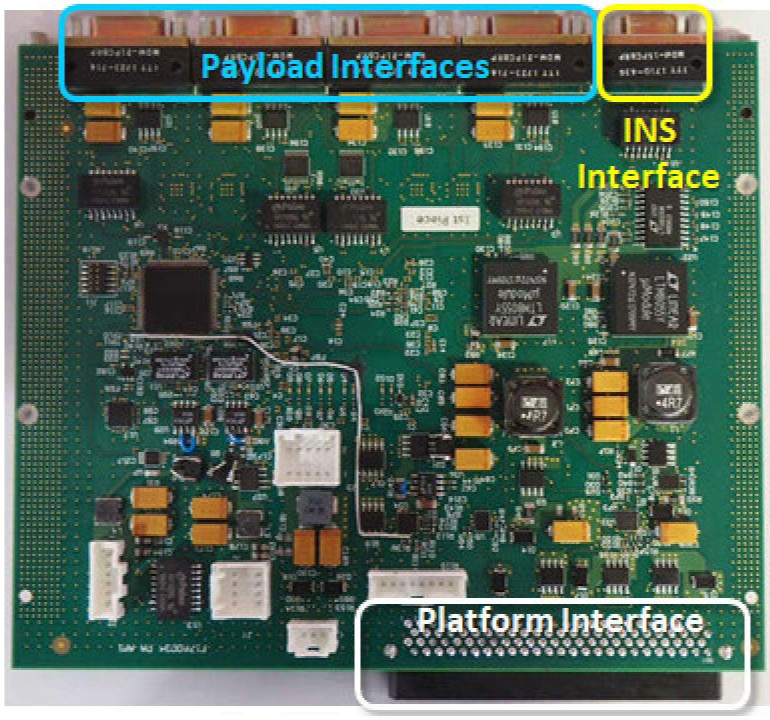


Figure 2-1. Example MAIM

2.1.3 Interfaces

The MAIM shall provide each payload the following interfaces:

- Power (as described in Section 2.1.4.1)
- Serial – state (as described in Section 2.1.4.2)
- Serial – console (as described in Section 2.1.4.4)
- Ethernet (as described in Section 2.1.4.3)
- 1PPS (as described in Section 2.1.4.5)
- Zeroize (as described in Section 2.1.4.6)

No specific connector or pinout is mandated for the MAIM itself. The interface connector is only specified on the payload itself (Section 3.1.4). In some cases, a separate, dedicated connection for each payload is feasible, providing some benefits. In others, it may be preferred to have all payload lines coming from a single physical connector on the MAIM. The flexibility to choose is left to the UAS integrator.

No specific mechanical interface is dictate for the MAIM. This is left to the UAS integrator to decide how best to implement based on the specific UAS platform.

2.1.4 Required Functionality

As the platform-payload interface, the MAIM must provide power, power switching and monitoring, state distribution, network connectivity, serial console, serial to Ethernet conversion, time synchronization and a zeroize capability for payloads. The requirements for each are detailed in the subsequent sections.

Figure 2-2 illustrates the functionality, major components, and interfaces for an example MAIM. In addition to the required functionality, each MAIMs is expected to require customization to address platform-specific needs.

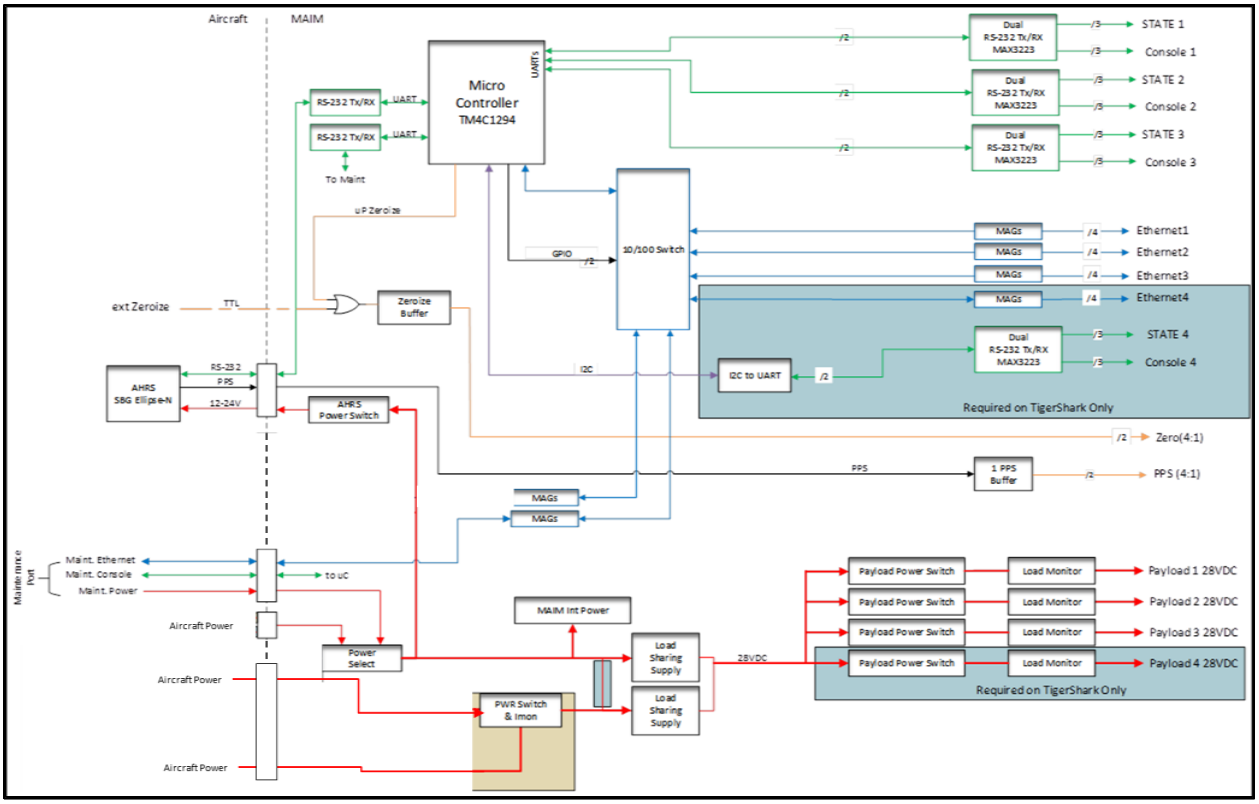


Figure 2-2. Example MAIM Block Diagram

2.1.4.1 Power

The MAIM shall interface to the available platform power and supply up to 56W at 28VDC ±2% to each payload interface (provided at the payload). The MAIM shall monitor the power draw of each payload separately and generate an alert if a payload is exceeding the allowable power draw. The MAIM shall provide the ability to secure power to the payload manually, commanded by the platform operator. It is also recommended that the MAIM provide the ability to automatically secure power to the payload, when the payload is 50% in excess of its allowable power draw for greater than 5s. The MAIM should be able to handle a 4A, 5ms in-rush current and be protected with a minimum 4A circuit protection for each payload.

For platforms supporting more than one payload connection, the MAIM shall support higher power payloads. To support payloads requiring greater than 56W (see Section 3.1.1), the MAIM shall also support the ability to power a single payload from multiple payload interfaces. The MAIM should be able to load share up to the number of payload interfaces available. For example, a two-channel MAIM should be able to load share to provide up to 112W to a single payload. For this functionality, the MAIM shall support even the case where the multiple payload channels are effectively shorted together inside the payload.

2.1.4.2 State Distribution

The MAIM shall interface to the MP-approved INS* to receive and distribute state data to each payload to which it interfaces. State data shall be provided to each payload over both Ethernet and serial interfaces. Once received from the INS, state data should be transmitted across each interface at the rates detailed in Appendix A with minimal latency. The state data provided shall include:

- From GPS: Status, Week, Time of Week, GPS UTC, Latitude, Longitude, Altitude, Velocity, Course, Roll, Pitch, Yaw, Speed Over Ground
- From GYRO: Velocity (North, East, Down), Latitude, Longitude, Altitude

NOTE: Only INS devices approved in this standard (see Section 2.2) are allowed to be used.

2.1.4.2.1 Ethernet Interface

The MAIM shall distribute state data to payloads over the internal Ethernet network using UDP/IP multicast. The recommended IP address of the multicast group is 239.255.1.1, however, alternate multicast addresses are permissible at the discretion of the UAS integrator. To utilize this communications mechanism, the UAS network must have implemented an IP stack supporting multicast groups via IGMP.

The MAIM shall re-package the state data from the MP-compliant INS into a JavaScript Object Notation (JSON) message structure to distribute the data over Ethernet. The MAIM shall transmit these JSON messages at the prescribed rates, either 1Hz or 10Hz, depending on message. The size of the messages sent over the Ethernet connection shall not exceed the maximum transmission unit (MTU) of 1500 bytes.

The JSON messages are fully detailed in Appendix A, Section A.2.

2.1.4.2.2 Serial Interface

The MAIM shall distribute state data to payloads using a serial interface in accordance with TIA/EIA-232-F. The operating parameters of this RS-232 interface are 115,200 bps, 8 Data bits, 1 Stop bit, No Parity, and No Flow Control. The direction of data flow shall be from the MAIM to the payloads. There shall be no data flow from the payloads to the MAIM over this interface. The following signals shall not be connected at the MAIM: DTR, DCD, DSR, RI, RTS, RTR, CTS.

The MAIM shall re-transmit the state data from the MP-compliant INS using the sbgECom binary and NMEA protocols natively output by the MP-compliant INS. The MAIM shall transmit the binary messages at the prescribe rates, either 1Hz, 5Hz, or 20Hz, depending on message and shall transmit the NMEA message at 1Hz.

The sbgECom binary messages are detailed in Appendix A, Section A.3.

2.1.4.3 Network Connectivity

The MAIM shall create an IP payload network connected to the UAS IP backhaul to provide connectivity to the ground station to allow for the remote command, control, configuration, and monitoring of the payload and payload data. While no specific bandwidth requirement is imposed herein, the IP backhaul is expected to support data transfer rates at mission-relevant ranges commensurate with MP-compliant payload command, control and data collection needs. The MAIM shall provide an Ethernet interface to each payload, to the IP backhaul, and for itself. The MAIM shall provide full Layer 2 switch functionality, support 100BASE-T connections, and allow IGMPv1/v2/v3 snooping for multicast packet filtering. The requisite IP address scheme is determined by the UAS integrator; the payload system shall conform to the determined scheme. Figure 2-3 below depicts an example Ethernet network for a MP-compliant UAS.

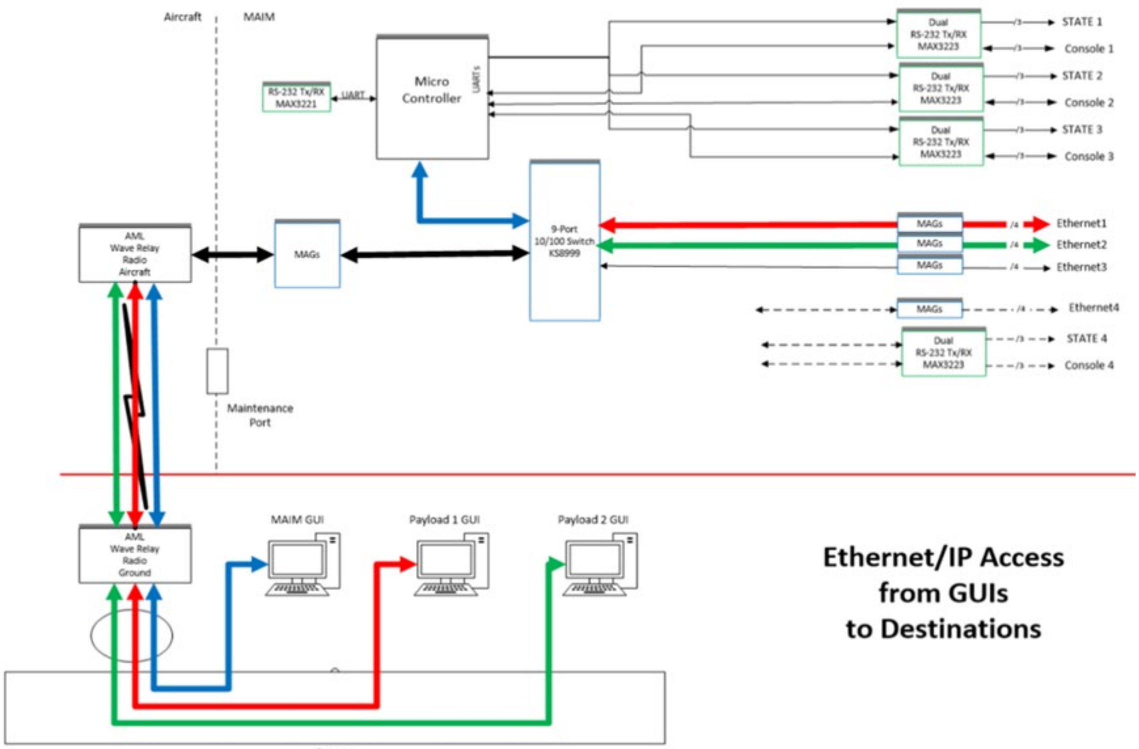


Figure 2-3. Example MAIM-Payload Network Connections

2.1.4.4 Serial Console and Ethernet Conversion

The MAIM shall provide a serial interface in accordance with TIA/EIA-232-F for each payload to serve as a data / console / maintenance connection. The operating parameters of this RS-232 interface are 115,200 bps, 8 Data bits, 1 Stop bit, No Parity, and No Flow Control. The data flow shall be bi-directional between the MAIM and the payloads. The following signals shall not be connected at the MAIM: DTR, DCD, DSR, RI, RTS, RTR, CTS.

To provide remote access to this serial console port on the ground, the MAIM shall create a virtual serial port over UDP for each payload console connection. Requisite IP addresses and ports for the virtual serial ports over UDP are determined by the UAS integrator; a payload ground system requiring this connection shall conform to the determined scheme. Figure 2-4 below depicts an example serial console network for a MP-compliant UAS.

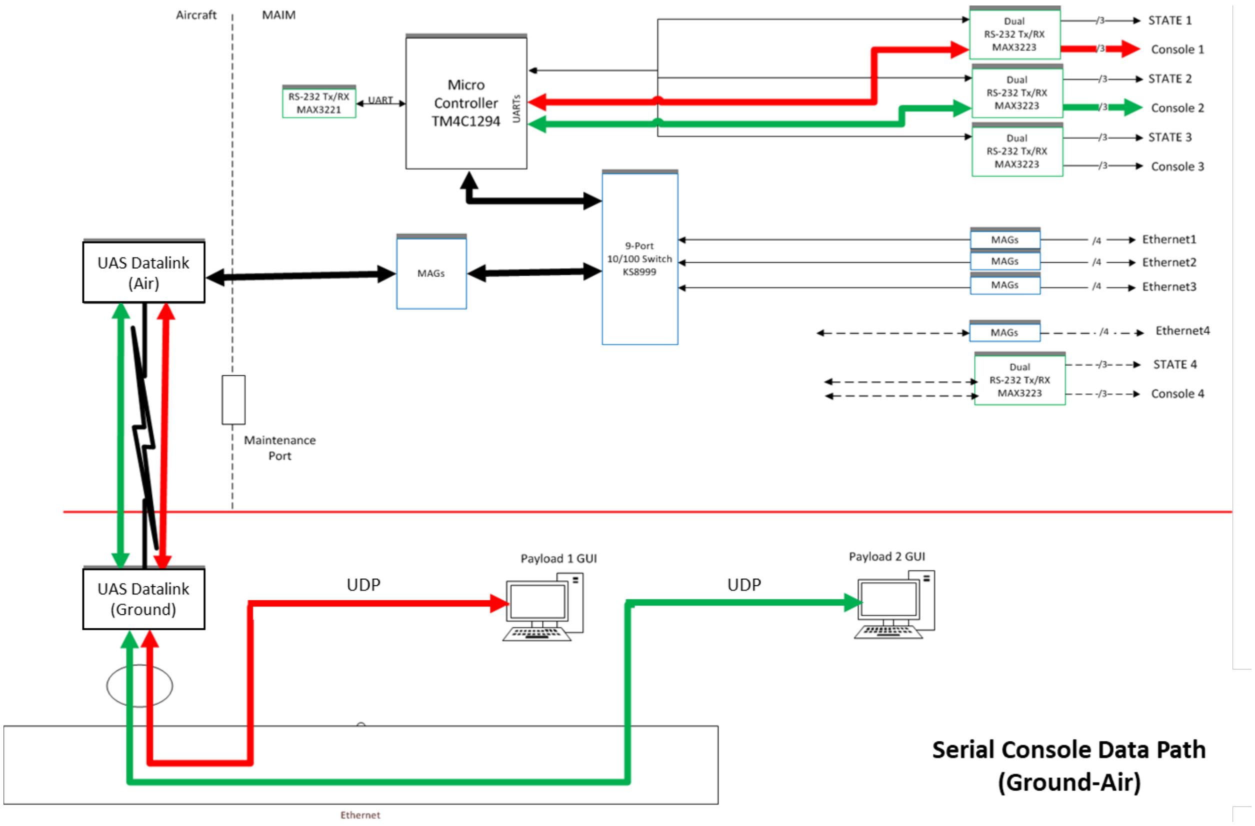


Figure 2-4. Notional Air-Ground Payload Console Connections

2.1.4.5 Time Synchronization

The MAIM shall receive and re-transmit the 1PPS signal from the INS (or an equivalent 1PPS source native to the aircraft) to each payload. The 1PPS signal provided by the MAIM shall be low voltage differential signal (LVDS) in accordance with the TIA/EIA-644 standard – 1.0V logic low, 1.4V logic high.

2.1.4.6 Zeroize

The MAIM is required to provide a zeroize signal to all payloads. This can be activated by one of two reasons:

- Aircraft autonomously signals the MAIM to zeroize (e.g. loss of link and crashing)
- Operator manually commands the MAIM to zeroize

An active low signal shall be used as the zeroize signal. The zeroize signal provided by the MAIM shall be an LVDS in accordance with the TIA/EIA-644 standard – 1.0V logic low, 1.4V logic high.

Note: the notion of a zeroizing standard for the UAS community has been discussed for many years but has not yet implemented. The MP requirement of a zeroize capability should prepare platforms and payloads to support this standard functionality when finally enacted.

2.1.5 Software / Firmware

The MAIM requires both airborne firmware and ground station software. The airborne component will reside onboard the MAIM itself in an embedded processor or a microcontroller. The ground station component will be the operator's user interface to communicate with the airborne component.

2.1.5.1 Embedded

The MAIM embedded firmware shall provide the following functions:

- Collection and distribution of INS-state data
- Network configuration and management
- Power control and monitoring
- Platform status monitoring

This firmware should be developed to run on a small microprocessor or microcontroller.

2.1.5.2 User Interface

The MAIM shall also interface to a ground software application for remote control, monitoring, and maintenance. This software application can be incorporated into the native UAS ground station software, be a standalone custom application, or be a combination of the two. This software application(s) shall serve as the graphical user interface (GUI) for the UAS operator.

2.1.5.2.1 GUI Requirements

The MAIM GUI shall provide the following capabilities to the operator:

- Monitor status of MAIM – connectivity, temperature, faults
- Energize and secure power to individual payloads
- Monitor connectivity to individual payloads
- Monitor power consumption of individual payloads
- Monitor status of INS – connectivity, temperature, faults, normalization
- Monitor current INS data – position, attitude, time
- Zeroize payloads
- View the MAIM network configuration settings
- Calibrate the INS (optional, can also be done by a stand-alone application)
- Set the MAIM network configuration (optional, if settings are configurable)
- Console access to the MAIM for debug activity (restrict to a super user)

For reference, screenshots from an existing MAIM GUI are shown in Figure 2-5, Figure 2-6 and Figure 2-7 below.

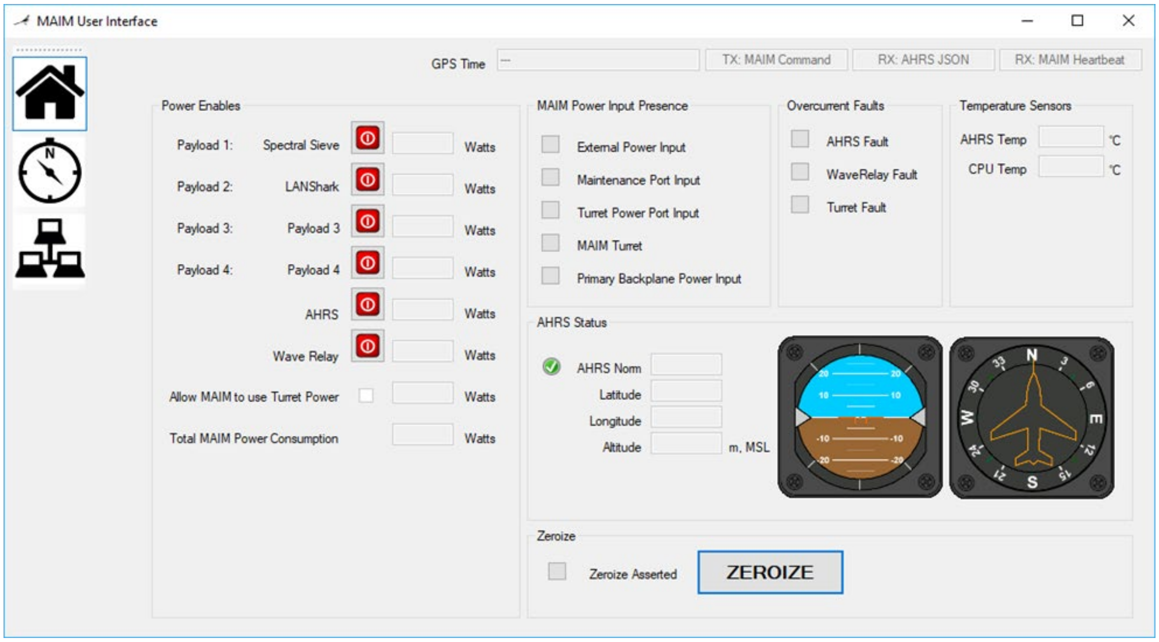


Figure 2-5. Example MAIM GUI Home Page

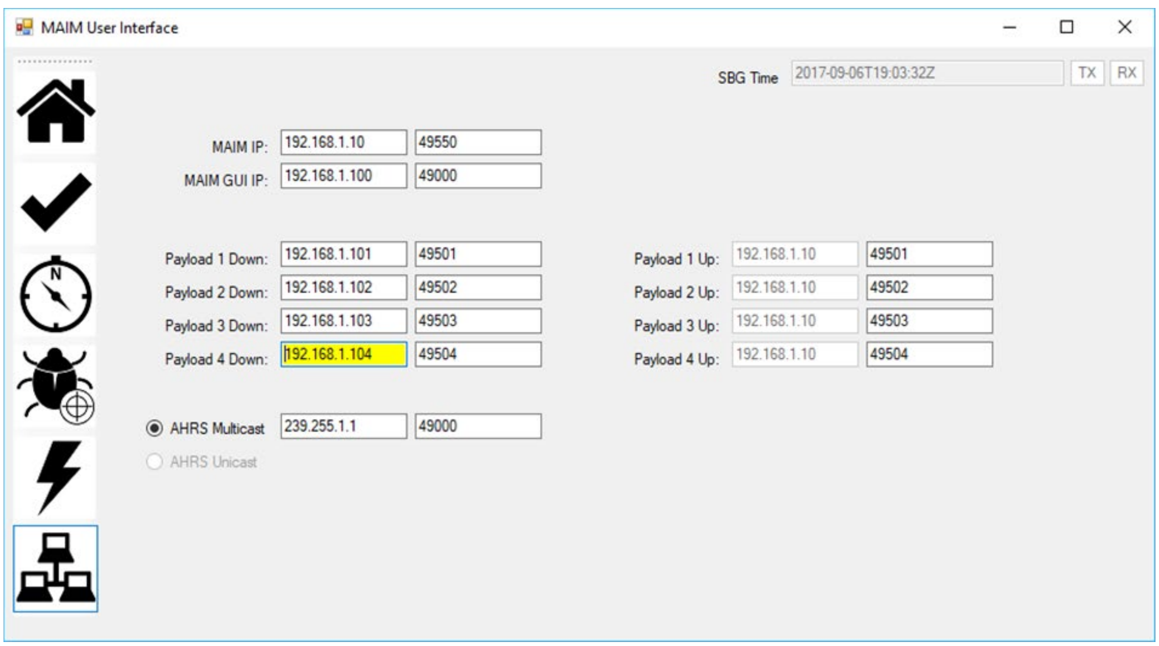


Figure 2-6. Example MAIM GUI Networking Page

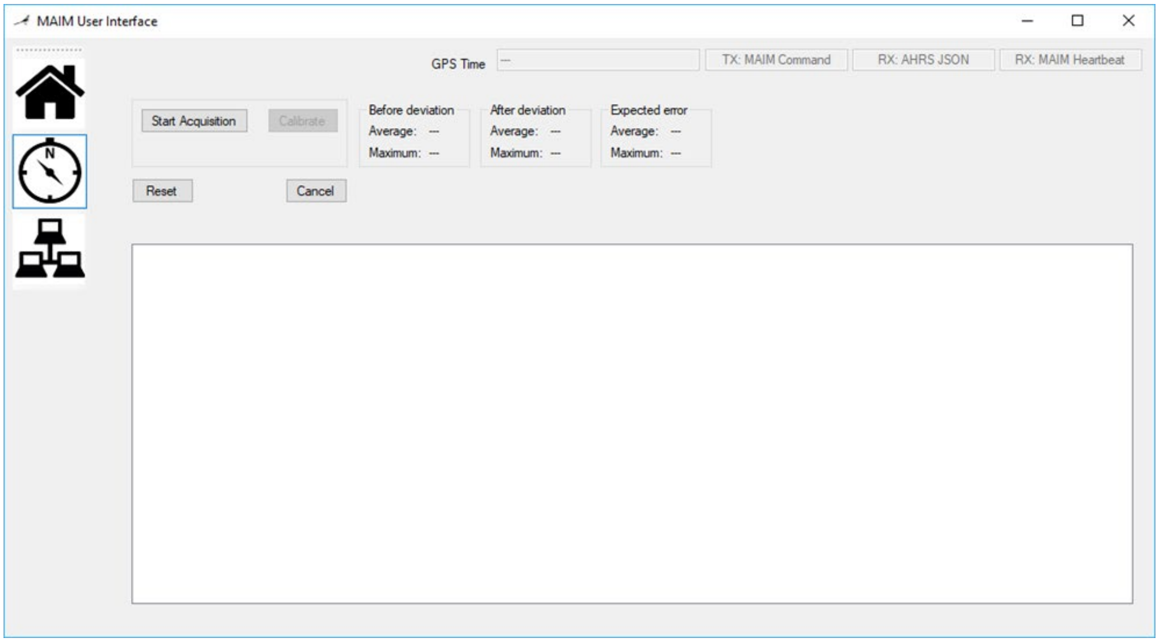


Figure 2-7. Example MAIM GUI INS Calibration Page

2.1.6 Maintenance

The MAIM should support a maintenance connection, supporting external power and both serial and Ethernet communications, for ground testing of both the MAIM as well as the payloads. This maintenance connection should provide sufficient power to allow the MAIM to power itself, the INS and at least one 56W payload, simultaneously.

2.2 INS

Some MP-compliant payloads require a higher accuracy INS than those native to a UAS. To meet the requirements of these payloads, a dedicated, high accuracy INS shall be installed on the UAS as part of the MP architecture. Position, velocity, attitude and timing information from the MP-compliant INS shall be transmitted to the MAIM for distribution to the payloads. Because of its light weight, exceptional orientation and navigation performance, and commonality with existing payloads, the only current MP-approved INS is the SBG Systems Ellipse2-N-G4A3-B1.

The list of MP-approved INS will be expanded in the next revision as other INS are vetted and confirmed to meet known payload requirements.

Ellipse2-N Specifications
Size: 26.8x18.8x9.5 mm
Weight: 10 g
Input Voltage: 4-17 V
Power consumption: 400 mW
Accuracy: Roll and Pitch 0.1° Heading 0.8° Heave 5 cm
2m GNSS Position (GPS, GALILEO, GLONASS, BEIDOU)
Output Rate: 200Hz
1PPS synchronization output

Figure 2-8. Ellipse2-N INS

Note: The INS is also referred to as the attitude heading reference system (AHRS) in some MP and reference documentation.

2.2.1 INS Installation

To assure the required level of performance from the INS, the following sections provide guidance for the installation of the INS onto a UAS.

2.2.1.1 Physical Orientation

The INS should be mounted in a position that fixes its orientation and position on the aircraft. The INS coordinate frame should be aligned with the aircraft cardinal points. Any deviation in the INS orientation in relation to the aircraft cardinal points will degrade performance. It is preferable to have the INS x-axis in alignment with the platform's forward direction. However, misalignments can be addressed using appropriate Euler angles. The sensor lever arm, the distance from the INS to the aircraft's center of gravity (CG), as well as GPS lever arm, the distance from the INS to the GPS antenna, should be measured. The INS placement, orientation, and lever arms should all be documented for reference.

2.2.1.2 Vibration Considerations

Good mechanical isolation from shock and vibration is required to avoid bias in the accelerometer reading. High amplitude vibrations cause the sensor to saturate resulting in large errors in orientation. When possible, the INS should be installed in an area of low vibration. When not possible, to mitigate the negative effect, vibration isolating mounts should be utilized.

2.2.1.3 Magnetic Distortions Considerations

Care should be taken to place the INS away from any magnetic distortions that can introduce hard or soft iron interference. Example sources of interference include, but are not limited to, large ferromagnetic materials, magnets, high current power supplies, high current carrying wires, or permanently magnetized hardware. The presence of these inferences in close proximity to the INS can cause the calibration to fail and, even when calibrated, result in heading inaccuracies. The following guidelines are recommended to avoid disturbing the magnetic field around the INS:

- Avoid the placement of the INS near items such as camera gimbals, motors, engines, servos, power supplies, and power cables.
- Any high current carrying wires near the INS should include twisted pairs and shielding.
- Cables should be routed as far away from the INS as possible and retained in a way that prevents them from being moved independently from the INS.
- Ferrous hardware or hardware that can be easily magnetized should be avoided when designing mounts for the INS.

2.2.1.4 Temperature Consideration

The INS should be installed in a location that can reliably keep the INS within its accepted temperature range: between -40°C and 85°C.

2.2.1.5 Installation Testing

After an INS position is selected and all the guidelines are met, INS placement testing should be conducted as part of the UAS integration / compliance effort; this includes both a ground test and a flight test. Additionally, INS placement testing should be repeated should any major changes be introduced to the aircraft configuration or architecture. It is recommended that a ground test is conducted to evaluate potential INS location options. The INS performance should be assessed by rotating the platform, about its CG, to measure heading and INS behavior while powering platform services (engine, camera, servos, strobes, etc.) to see if there are any changes / impacts to INS monitored data.

2.2.2 INS Configuration

The SBG Ellipse INS is designed to be able to operate in a number of dynamic vehicle environments. The UAS environment poses many unique challenges when trying to achieve optimum INS performance. Table 2-1 provides the configuration settings required to achieve this performance. Refer to the SBG documentation for the exact description of each setting.

Table 2-1. INS Configuration Summary

SBG Ellipse Firmware	V.1.3.178-stable (dated October 2017)
SBG Ellipse Configuration Settings	**Value**

sbgEComCmdGnss1SetLeverArmAlignment	(platform-dependent)
sbgEComCmdSensorSetAlignmentAndLeverArm	(platform-dependent)
sbgEComCmdSensorSetMotionProfileId	SBG_ECOM_MOTION_PROFILE_AIRPLANE
sbgEComCmdMagSetRejection	SBG_ECOM_AUTOMATIC_MODE
sbgEComCmdMagSetModelId	SBG_ECOM_MAG_MODEL_NORMAL
sbgEComCmdGnss1SetRejection	SBG_ECOM_ALWAYS_ACCEPT_MODE, SBG_ECOM_ALWAYS_ACCEPT_MODE, SBG_ECOM_NEVER_ACCEPT_MODE, SBG_ECOM_AUTOMATIC_MODE
sbgEComCmdGnssSetModelId	SBG_ECOM_GNSS_MODEL_UBLOX_GPS_GLONASS
sbgEComCmdSyncOutSetConf	SBG_ECOM_SYNC_OUT_A, SBG_ECOM_SYNC_OUT_MODE_DIRECT_PPS

The SBG Ellipse has internal memory that stores its configuration across power cycles. The parameters in the table above could potentially be configured once via SBG Center before installation, or they could be configured dynamically after installation via the MAIM firmware.

2.2.3 INS Magnetometer Calibration

In order for the INS to measure a valid magnetic heading, the magnetometer needs to be periodically calibrated. This is achieved by putting the INS into magnetometer calibration mode and flying an acceptable flight pattern. A successful airborne magnetometer calibration typically has these basic requirements:

- Set the INS into magnetometer calibration mode via the sbgEComCmdMagStartCalib command.
- Minimize large, time-varying magnetic field activity on the platform as possible. If the INS is installed in close proximity to a gimbaled payload, this means minimizing gimbal movement for the duration of the magnetometer calibration.
- Fly an appropriate pattern so that the INS can take measurements across a range of azimuth and roll angles. A "double figure-8" pattern is the recommended calibration flight pattern. On a typical group 2 UAS, the "double figure-8" pattern consists of one large figure-8 (nominally, with 1000m diameter orbits) followed by one small figure-8 (nominally, with 500m diameter orbits).
- Once the full pattern has been flown, take the SBG Ellipse out of magnetometer calibration mode via the sbgEComCmdMagComputeCalib command.

The magnetometer does not need to be calibrated on every single flight. A real-time indication of the quality of the magnetic calibration, referred to as the AHRS normalization (AHRS-norm), can be computed in the MAIM or the MAIM GUI. The AHRS-norm is calculated using the following normalization equation:

$$AHRSnorm = \sqrt{x_{mag}^2 + y_{mag}^2 + z_{mag}^2}$$

If the AHRS-norm is within limits, 1.00 ± 0.02, a magnetometer calibration need not be performed. If a change to the platform or a change to the location of the platform is significant enough to degrade the quality of the magnetometer calibration, the norm should reflect this. A previously-computed magnetic calibration can be saved to the MAIM or MAIMGUI, and programmed back into the SBG Ellipse via the sbgEComCmdMagSetCalibData command.

2.3 Primary Mount

The Primary Mount is the physical structure that houses the payload modules in the MP architecture.

2.3.1 Applicability

A Primary Mount is required for all MP-compliant UAS. While existing UAS being brought into MP-compliance require an add-on Primary Mount, a newly developed UAS may incorporate the Primary Mount interface into its native platform design to fulfill this requirement.

2.3.2 Description

The Primary Mount is a ***platform-specific*** mechanical assembly, customized to accommodate the physical characteristics of the UAS, while providing a standard, simple payload interface to promote rapid installation and removal of payload modules. The Primary Mount shall be designed to provide a standard payload interface, minimize weight, provide sufficient thermal dissipation for payloads, and endure platform loading.

The Primary Mount shall support a number of payloads commensurate with the UAS capacity. There is NO direct association between the number of 'U's a Primary Mount can support, and the number of payloads that platform's MAIM supports. For example, a platform may have room for 4U of space/weight, but only have enough electrical power to support 150W, thus it would be limited to two payload connections from the MAIM (each supporting 56W).

It is strongly recommended that the Primary Mount accommodate ***a minimum of at least 2U*** of payload space, as there are a number of 1.5 and 2U MP-compliant payloads.

Example Primary Mounts are illustrated in Figure 2-9 below.

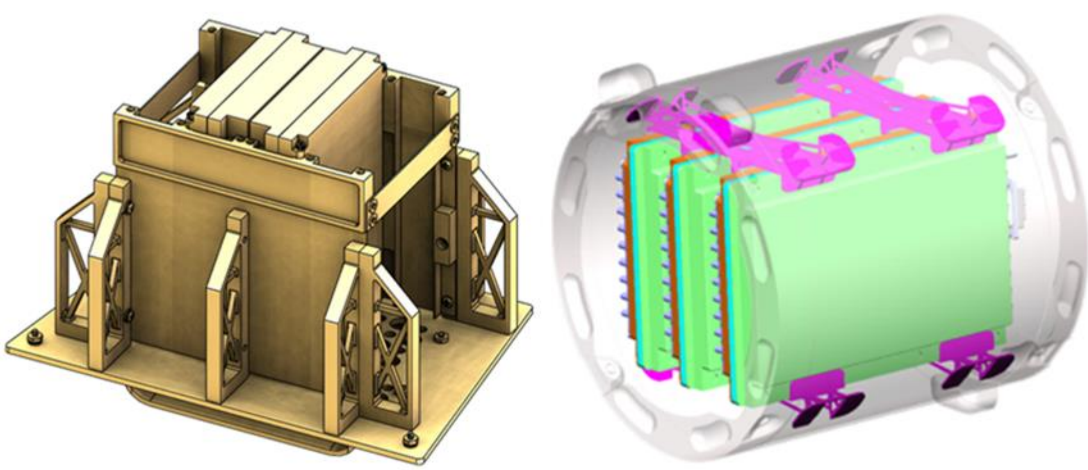


Figure 2-9. TigerShark 4U Primary Mount (left) and ScanEagle 3U Primary Mount (right)

2.3.3 Interfaces

The Primary Mount shall provide one of two interfaces, at the discretion of the platform, to support the mounting of payloads. The two Primary Mount interface options are:

- Rack, leveraging the wedge lock requirement for payloads
- Plate, leveraging the cold-plate requirement for payloads

As the Primary Mount must support MP-compliant payloads, the mechanical interface for the Primary Mount is actually defined by the payload module requirements in Section 3.2. However, to assure the Primary Mount accommodates MP-compliant payloads and reduce the design efforts of the UAS integrator, Figure 2-10 provides a fully MP-compliant rack interface and Figure 2-11 provides a fully MP-compliant plate interface.

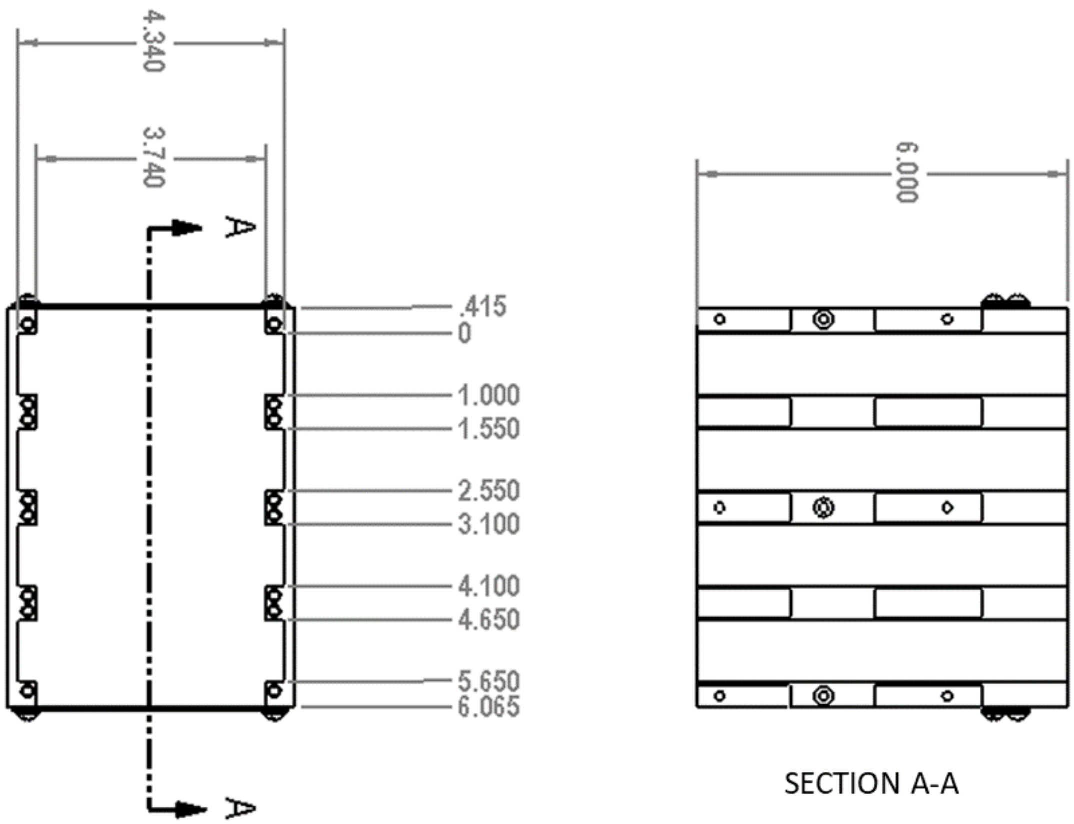


Figure 2-10. MP-compliant Rack Primary Mount Interface

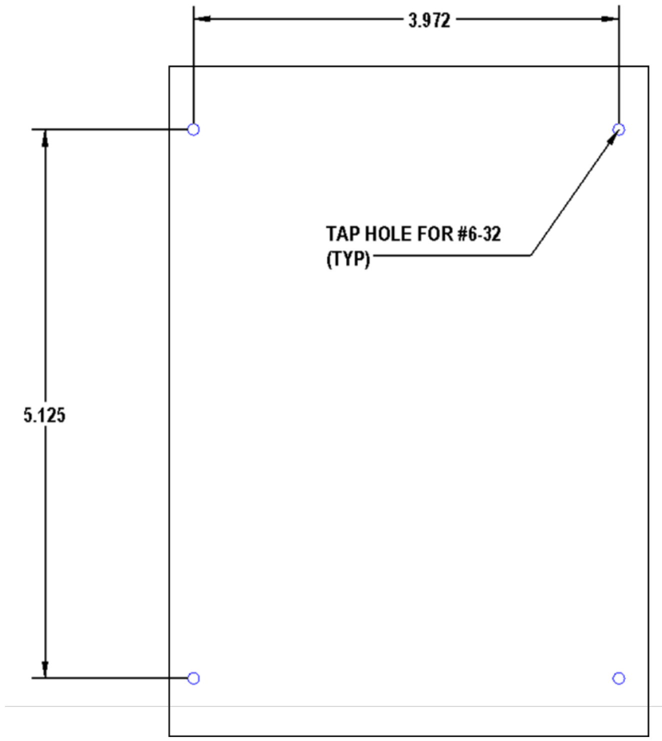


Figure 2-11. MP-compliant Plate Primary Mount Interface

2.3.4 Module Compatibility

The Primary Mount shall be designed to accommodate all sizes of modules, up to the maximum size supported by the UAS. For example, a 4U Primary Mount shall be able to accommodate modules of all sizes – 1U, 2U, or 3U; while a 2U Primary Mount shall be able to accommodate modules of 1U or 2U.

A rack Primary Mount shall be designed to support module installation into any module position (slot) in the Primary Mount. For example, a 1U module should be able to install in any of the four 1U positions in a 4U Primary Mount (slots 1, 2, 3, or 4); a 2U module should be able to install in any of three 2U positions in a 4U Primary Mount (slots 1-2, 2-3, or 3-4); a 3U module should be able to install in any of two 3U positions in a 4U Primary Mount (slots 1-3 or 2-4).

A plate Primary Mount should be designed to support at least one payload module of any size.

2.3.5 Thermal Dissipation

The Primary Mount shall assure the MP payloads are cooled via one of two approaches.

- Convective cooling
- Conductive cooling

For convective cooling, a minimum air flow of 175 LFM (at any point over the heatsink surface) at no greater than 45°C must be provided over the heatsink surface of the payload.

Note: the above air flow requirement is under review and is expected to be revised into more *accurate and potentially increased volumetric flow rate in the next standard.*

For conductive cooling, a cold plate must be provided for each module. The cold plate design must assure the surface temperature of the cold plate shall not exceed 65°C in a 45°C ambient environment under the maximum thermal load condition. The maximum thermal load condition is platform-specific and should be commensurate to the maximum payload power available for modular payloads.

2.3.6 Additional Requirements

The Primary Mount shall survive loading, shock, and vibration commensurate with all phases of operation of the specific UAS – launch, recovery, and flight. Additionally, Section 3.5 defines the requirements for MP-compliant payloads, the UAS integrator should reference these requirements for further guidance.

2.4 Antenna Mounts

As part of the MP architecture, platforms shall be equipped with antenna mounts at various locations along the UAS to accommodate payload antennas. Antenna mounts are the platform side of the MP antenna interface, while antenna adaptors (defined in Section 3.4.3.2) are the payload side of the MP antenna interface. Figure 2-12 illustrates a number of *potential* antenna mount locations on a notional UAS.

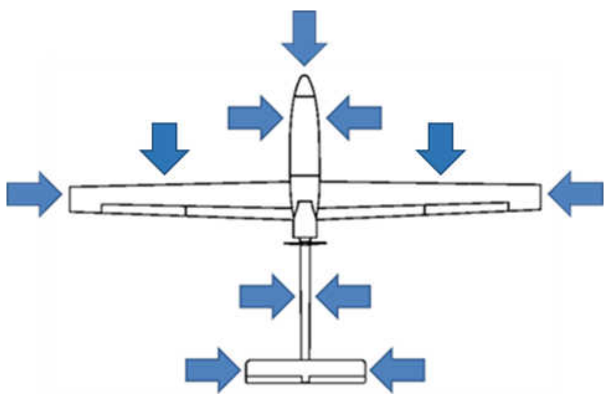


Figure 2-12. Possible MP Antenna Placements

2.4.1 Antenna Mount Requirements

Three types of antenna mounts are supported by the MP architecture: two-point (2-pt) mounts for smaller antennas, four-point (4-pt) mounts for larger antennas, and an array mount for multi-antenna arrays. Antenna mounts will have to be customized for each UAS, but a common mechanical interface is mandated for any antenna mount.

2.4.1.1 Configurations

At a minimum, a MP-compliant UAS must have sufficient antenna mounts to support the following antenna configurations:

- 1 side look or 45° mount (2-pt or 4-pt)

- 1 up look mount and 1 down look mount, concurrently (2-pt or 4-pt)
- 1 array mount

These configurations are driven by the antenna requirements of the various MP-compliant payloads. Additional mounts are recommended for UAS capable of carrying multiple payloads concurrently.

2.4.1.2 Two-Point Mount

2-pt mounts, as shown in Figure 2-13, are the simplest and most common MP antenna mount. 2-pt mounts should be used to support the smallest antennas.

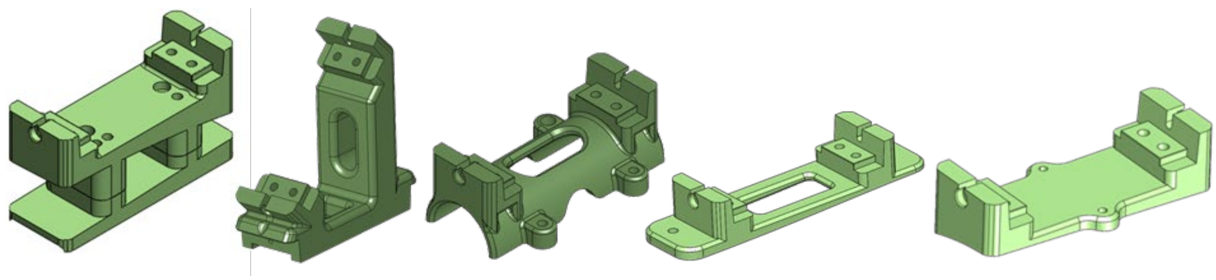


Figure 2-13. Example MP-compliant 2-pt Mounts

The 2-pt antenna mount interface is defined in Figure 2-14. Platforms employing a 2-pt antenna mount shall adhere to this interface. As illustrated below, 2-pt antenna mounts support two methods for attaching antenna adaptors:

- Top down via the pair of #6-32 holes on each side of the mount, or
- Through the side via the Ø0.144 hole on each side of the mount.

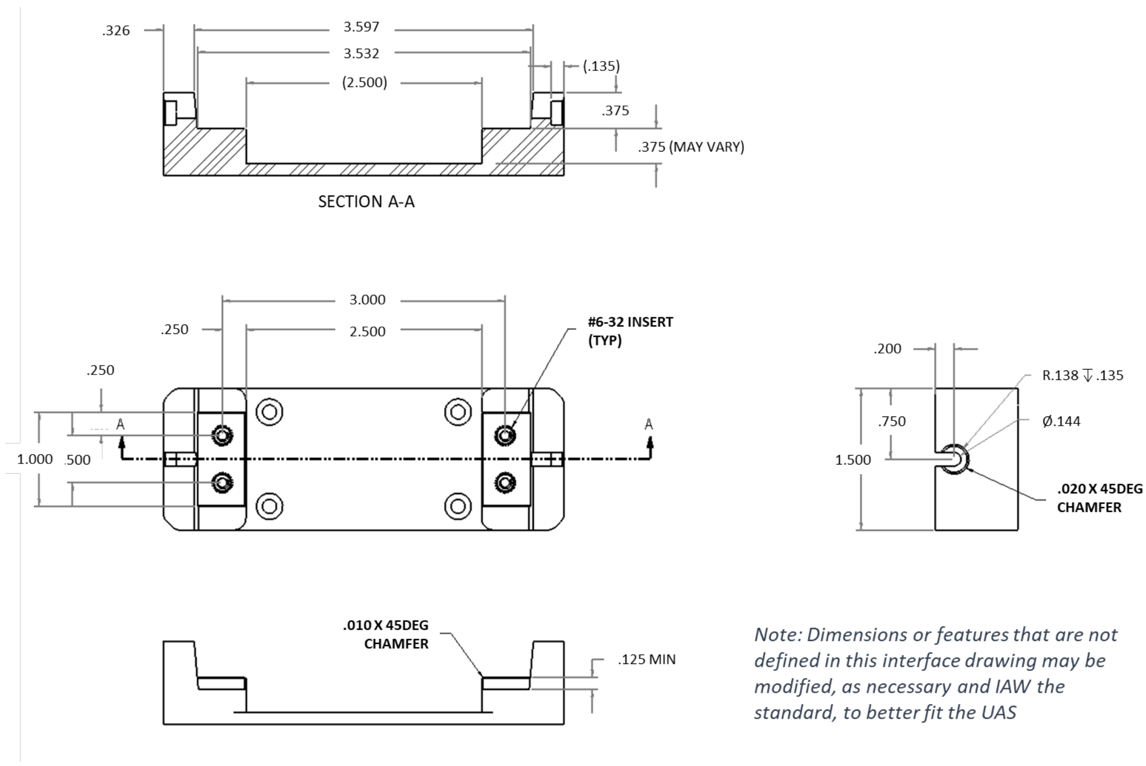


Figure 2-14. MP-compliant 2-pt Antenna Mount Interface

Though shown with a flat base in Figure 2-14, the antenna mount interface is only defined by the opposing facets and the separation between them. As evidenced in Figure 2-13 above, the requisite 2-pt mount interface should be incorporated into a platform-specific mount to best conform to the aircraft design. Whenever possible, a 2-pt mount should be oriented with its two facets along the fore-aft axis of the UAS, as shown in Figure 2-15.

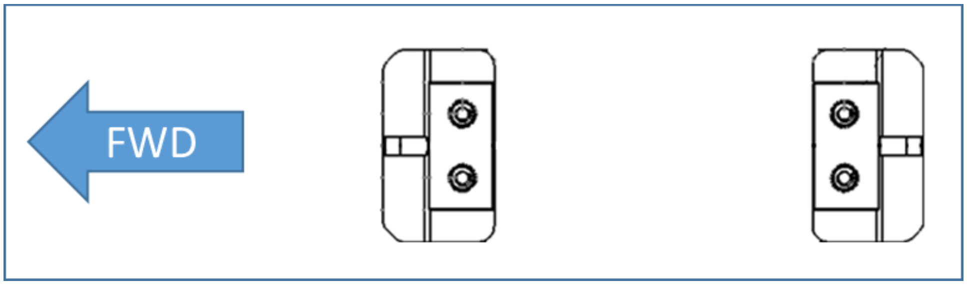


Figure 2-15. MP-compliant 2-pt Mount Preferred Orientation

2.4.1.3 Four-Point Mount

A 4-pt mount, as shown in Figure 2-16, is simply a pair of 2-pt mounts. 4-pt mounts should be used to support larger antennas on larger UAS.

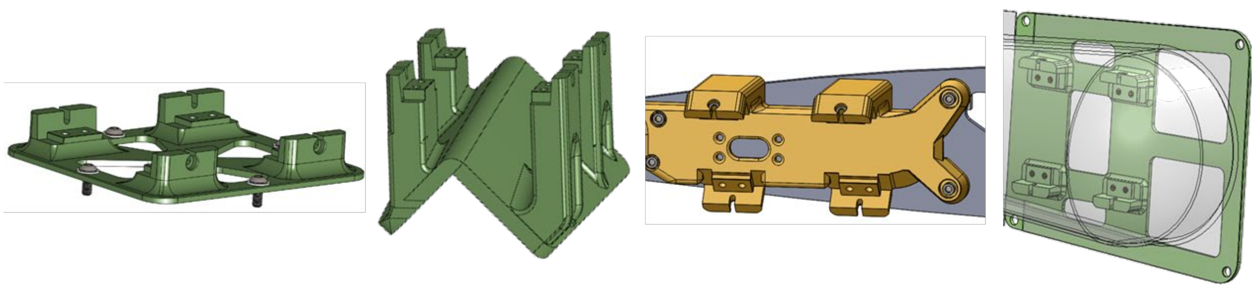


Figure 2-16. Example MP-compliant 4-pt Mounts

The 4-pt antenna mount interface is defined in Figure 2-17. Platforms employing a 4-pt antenna mount shall adhere to this interface. As illustrated below, 4-pt antenna mounts support two methods for attaching antenna adaptors:

- Top down via two pair of #6-32 holes on each side of the mount, or
- Through the side via a pair of Ø0.144 hole on each side of the mount.

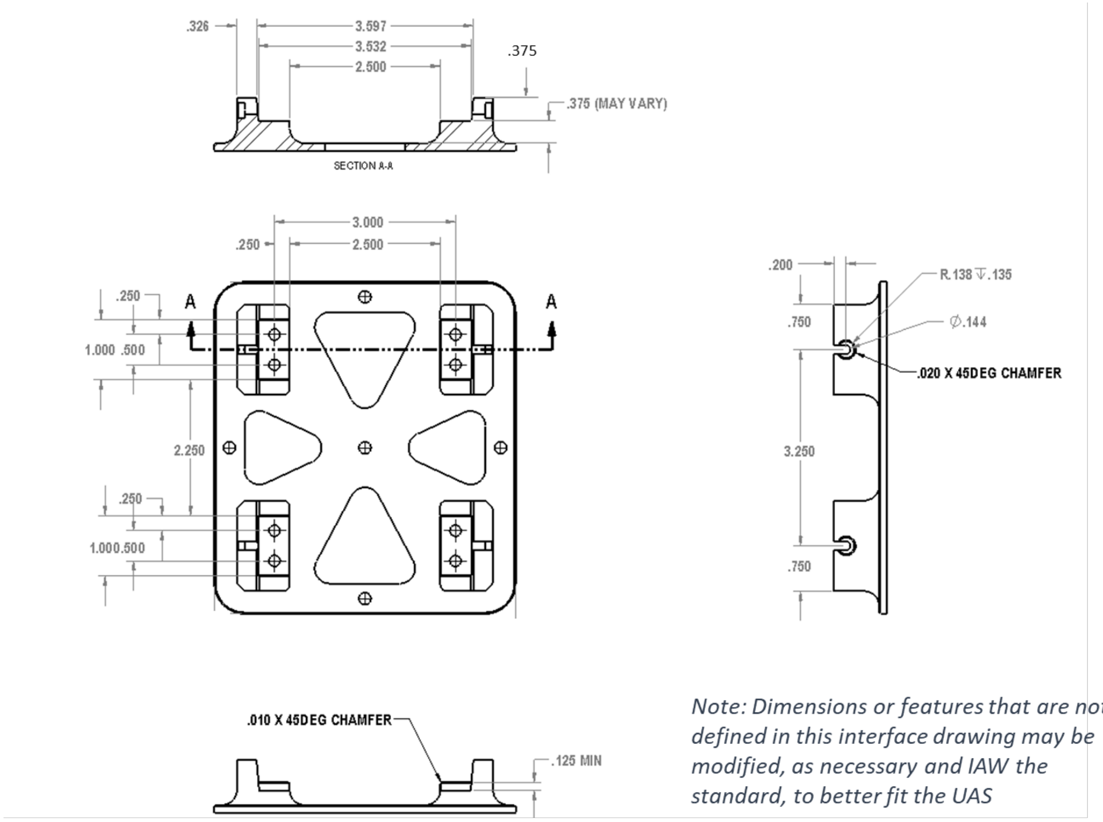


Figure 2-17. MP-compliant 4-pt Mount Interface

Though shown with a flat base in Figure 2-17, the antenna mount interface is only defined by the facets and the separation between them. As evidenced in Figure 2-16 above, the requisite 4-pt mount interface should be incorporated into a platform-specific mount to best conform to the aircraft design. Unlike a 2-pt mount, a 4-pt mount is typically oriented with the two 2-pt pairs positioned side-by-side, along the fore-aft axis of the UAS, as shown in Figure 2-18.

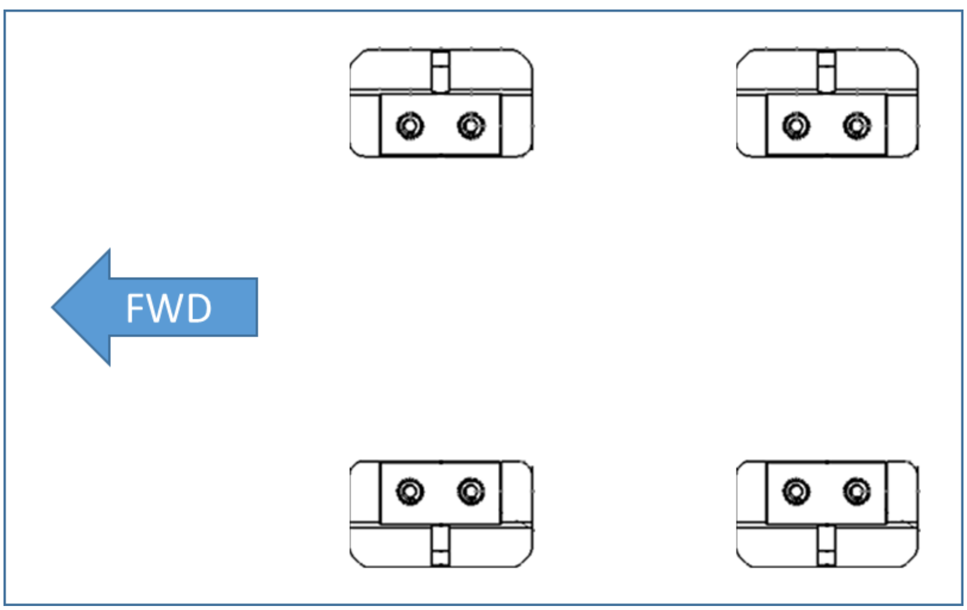


Figure 2-18. MP-compliant 4-pt Mount Preferred Orientation

2.4.1.4 Array Mount

As an electro-mechanical interface, the array mount is the most complicated MP antenna mount. An array mount should be used to support payloads requiring a multiple antenna array. The array interface consists of three SMPM-male connectors precisely positioned in a custom connector block, which is housed, slightly recessed, in a larger custom mechanical assembly. The array mount interface is defined in Figure 2-19. The requisite array mount interface should be incorporated into a platform-specific mount to best conform to the aircraft design. The array mount is typically oriented with the array mount interface facing either forward or aft on the UAS, whichever is determined more favorable by the UAS integrator. The position of the array mount interface should be such that it provides sufficient space, as is reasonable for the specific UAS, for a wide variety of mating payload antenna arrays.

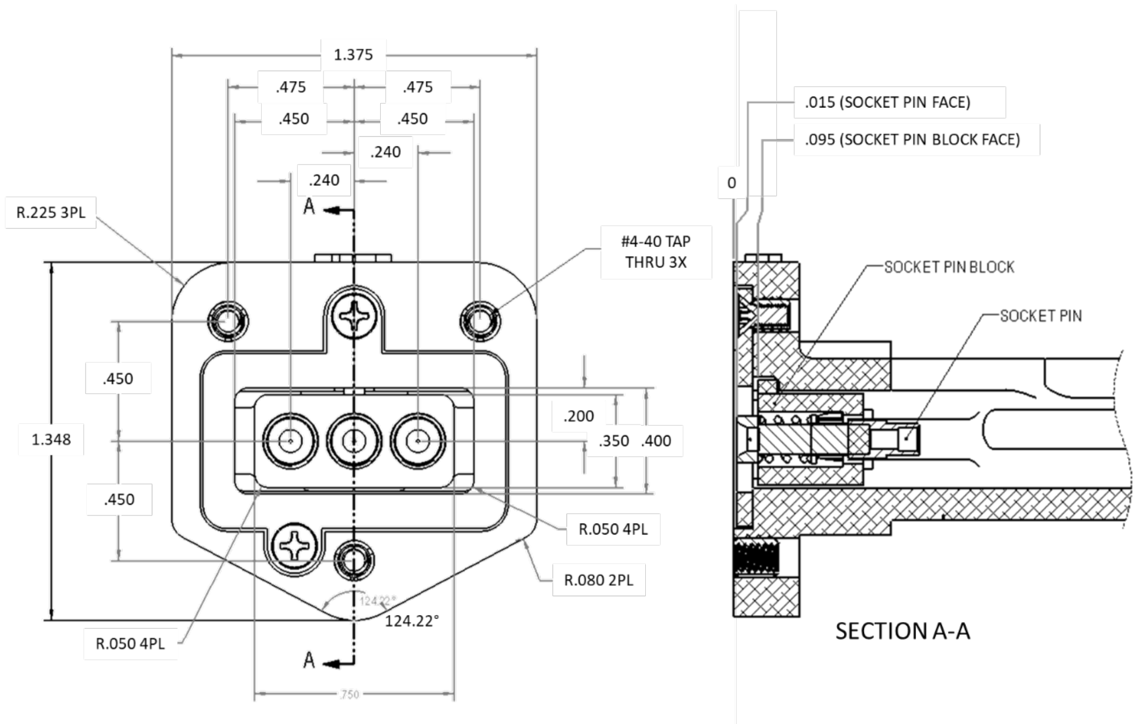


Figure 2-19. MP Array Antenna Mechanical Interface

2.5 Cabling and Grounding

2.5.1 MAIM Cabling

A number of cables will need to run to/from the MAIM. These cables include the interfaces between the MAIM and the UAS, the INS, and payloads. The MAIM-UAS cable(s) shall provide power to the MAIM and Ethernet connectivity to the UAS backhaul. The MAIM-INS cable(s) shall provide power to and bi-directional communications to/from the INS. The MAIM-payload cable(s) shall provide all interfaces to the payload as identified in Section 2.1.3. All MAIM cables should be permanently installed into the UAS at appropriate locations as determined by the UAS integrator. A MAIM-payload cable should be run for each payload the MAIM can support and be positioned such that connection to the payload can be achieved rapidly.

The specific connector(s) and pinout(s) for the MAIM-UAS cable(s) are at the discretion of the UAS integrator, as are the MAIM sides of the MAIM-INS and MAIM-payload cable(s). The connector and pinout for the INS-side of the MAIM-INS cable is defined by the INS specification. The MAIM-payload cable shall terminate at the payload in a 21-pin Micro-D connector, part number MDM-21PSB, or equivalent, using the pinout defined in Table 2-2. While the recommended connectors do not include jack screws, male jack screws using #2-56 threads are required. The UAS integrator may select jack screws compatible with the selected connector that best fit the UAS design and do not violate any other requirements of the MP standard.

Table 2-2. MAIM-Payload Connector Pinout (Payload Side)

Pin	Signal Name	Direction	Voltage/Type	Purpose & Definition
1	+28V	IN	28V	Source power to payload. 2.5 amps per pin (3.0 Max)
2	+28V	IN	28V	Source power to payload. 2.5 amps per pin (3.0 Max)
3	Signal Ground	---	GND	State ground return
4	State RX	IN	RS232	RX data (from MAIM). State information, relayed through MAIM microcontroller from the INS.
5	Console TX	OUT	RS232	TX data (to MAIM); provide console from ground to payload console through MAIM
6	Zeroize -	IN	LVDS-Diff	Active low signal to cause payload to zeroize (if payload requires that functionality).
7	Ethernet RX +	IN	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
8	Sensor PPS +	IN	LVDS-Diff	One pulse-per-second signal from the INS. Rising edge provides 1PPS reference. Positive pulse train
9	Ethernet TX +	OUT	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link
10	Reserved	---	---	Spare discrete wire(s) from MAIM to payload for future use. Possible sense line.
11	Shield	---	---	Terminate to ground through an EMI filter (optional)
12	Ground	---	GND	28 VDC ground return
13	Ground	---	GND	28 VDC ground return
14	Signal Ground	---	GND	Console ground return
15	State TX	OUT	RS232	TX data (to MAIM). State information, relayed through MAIM microcontroller from the INS.
16	Console RX	IN	RS232	RX data (from MAIM); provides console from ground to payload console through MAIM
17	Zeroize +	IN	LVDS-Diff	Active low signal to cause payload to zeroize (if payload requires that functionality).
18	Ethernet RX -	IN	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
19	Sensor PPS -	IN	LVDS-Diff	One pulse-per-second signal from the INS. Rising edge provides 1PPS reference. Negative pulse train
20	Ethernet TX -	OUT	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
21	Reserved	---	---	Spare discrete wire(s) from MAIM to payload for future use. Possible sense line.

2.5.2 RF Cabling

A minimum of one RF cable shall be run from the Primary Mount location to each of the 2-pt or 4-pt antenna mount locations. A minimum of three RF cables shall be run from the Primary Mount location to each array mount location. Any cable runs that are difficult / time-consuming to install, e.g., through the wings, should be permanently installed. Inline connections should be considered where convenient to support platform or payload maintenance operations.

RF cabling should be lightweight to minimize impact on platform. RF cabling should be low loss; it is highly recommended the RF cabling has less than 1.5 dB attenuation up to 1 GHz and less than 3.0 dB up to 6 GHz. Based on UAS capacity, lower loss RF cables can be considered to improve payload performance.

For 2-pt and 4-pt antenna cable runs, RF cables shall terminate in SSMB-female at the payload and in SMA-male connectors at the antenna mount. 2-pt / 4-pt antenna cables shall be run with sufficient length to attach to the antenna connector. A 2-pt / 4-pt cable run cannot simply end in a bulkhead SMA; an additional RF cable shall be provided by the UAS integrator to connect the bulkhead connection to the antenna.

For array antenna cable runs, RF cables shall terminate in SSMB-female at the payload and in a custom array connection (defined in Section 2.4.1.4) using three SMPM-male connectors. Additionally, the three cables run to the array interface should be phase-matched to within 1.0° up to 6GHz. The actual phase-match shall be measured and documented by the UAS integrator to be provided to payload vendors, as needed.

2.5.3 Grounding

The aircraft and Modular Payload grounding scheme must be carefully designed to eliminate ground loops. Payloads should maintain isolation between the chassis/shield and all other ground returns (power, state serial, and console serial grounds) (refer to Section 3.1.5). The platform/MAIM is therefore responsible for tying these grounds together. As the state serial, console serial, and power grounds are all collocated within the MAIM, this is the logical point to make these grounds common. If possible, it is highly recommended that the aircraft ground/shield should also be connected at this common point as in Figure 2-20. If this is not feasible, the aircraft ground should be tied to the power/state/console ground at a single point which is located elsewhere as in Figure 2-21. This alternative may be necessary when the power supply is providing power to multiple units of which the MAIM is only one unit.

Cable shielding is an area of particular concern in order to minimize EMI. All shielded signal cables should have the shield referenced to aircraft ground. To the best ability of the design, the cable shield should act as a Faraday cage for the signals within the cable. There shall be no current flow in the shield. For RF cables, shielding will typically be tied to signal ground. Care should be taken to minimize the number of potential ground loops.

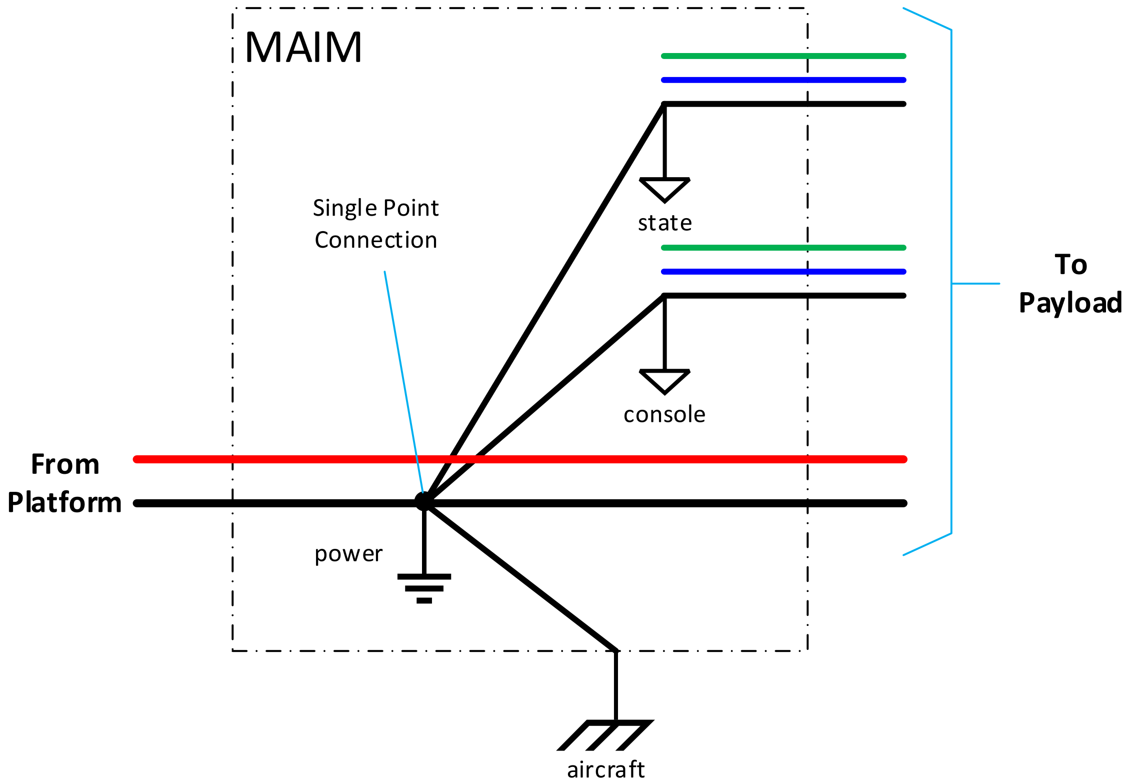


Figure 2-20. Grounding Scheme - Option A

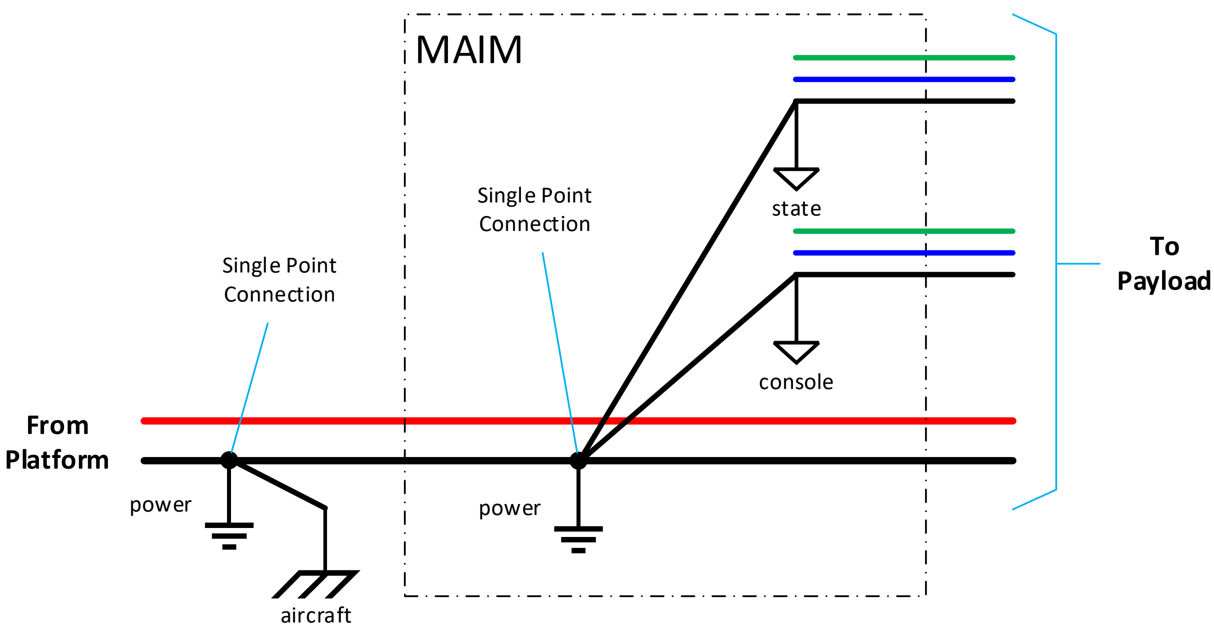


Figure 2-21. Grounding Scheme - Option B

3. REQUIREMENTS FOR PAYLOADS

The following sections specify the electrical, mechanical, thermal, environmental, and RF requirements for a payload to be MP-compliant.

3.1 Electrical Design

The MP standard imposes a common electrical interface on payload modules.

3.1.1 Power

A payload module should draw no more than 56W at 28VDC. This is the power provided by the MAIM to each payload interface. If additional power is needed, it must be sourced from a separate MAIM payload interface and input though an auxiliary payload module connector. Further, the increased power draw may limit platform compatibility (some platforms will only be capable of providing 56W).

A payload module shall be able to accommodate voltage fluctuations of ±2% from the nominal 28VDC. A payload module shall manage its in-rush, such that it does not exceed 4A per payload interface and does not span more than 5ms.

3.1.2 Communications

A payload module will have access to two serial and one Ethernet interfaces provided by the MAIM, as described in Section 2.1.4., to transmit and receive communications. A payload module may use any or all of the provided interfaces.

3.1.2.1 Serial

The serial connections can be used to (1) receive state data from the MAIM and (2) access the payload for command, control, data or debugging. The state serial communications interface is detailed in Section 2.1.4.2.2. The console serial communications interface is detailed in Section 2.1.4.4. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

3.1.2.2 Ethernet

The Ethernet connection can be used to (1) command and control the payload and transmit payload data and (2) provide state data to the payload. The Ethernet communications interface is detailed in Section 2.1.4.3. The state Ethernet communications interface is detailed in Section 2.1.4.2.1. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

3.1.3 Other Signals

A payload module can also require a 1PPS timing signal and a zeroize signal from the MAIM. The 1PPS signal is detailed in Section 2.1.4.5. The zeroize signal is detailed in Section 2.1.4.6. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

3.1.4 Main Connector

A payload module shall use a single MicroD-21 connector (part numbers below) as its main power and signal connector.

- Connector, Board Mount: MDM-21SCBR, or equivalent
- Connector, Panel Mount with Pigtail: M83513/04-C11N, or equivalent

While the recommended connectors do not include jack posts, female jack posts using #2-56 threads are required. The payload provider may select jack posts compatible with the selected connector that best fit the payload module design and do not violate any other requirements of the MP standard.

When necessary, additional connectors can be utilized, provided they can be supported by the host UAS and do not violate any other requirements of the MP standard. Any additional connectors must be clearly identified as deviations, and any required interfacing cables shall be provided by the payload vendor.

3.1.4.1 Main Connector Pin Out

The required pin out for the payload module main connector is listed in Table 3-1.

Table 3-1. Payload Module Main Connector Pin Out

Pin	Signal Name	Direction	Voltage/Type	Purpose & Definition
1	+28V	IN	28V	Source power to payload. 2.5 amps per pin (3.0 Max)
2	+28V	IN	28V	Source power to payload. 2.5 amps per pin (3.0 Max)
3	Signal Ground	---	GND	State ground return
4	State RX	IN	RS232	RX data (from MAIM). State information, relayed through MAIM microcontroller from the INS.
5	Console TX	OUT	RS232	TX data (to MAIM); provide console from ground to payload console through MAIM
6	Zeroize -	IN	LVDS-Diff	Active low signal to cause payload to zeroize (if payload requires that functionality).
7	Ethernet RX +	IN	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
8	Sensor PPS +	IN	LVDS-Diff	One pulse-per-second signal from the INS. Rising edge provides 1PPS reference. Positive pulse train
9	Ethernet TX +	OUT	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link
10	Reserved	---	---	Spare discrete wire(s) from MAIM to payload for future use.
11	Shield	---	---	Terminate to ground through an EMI filter (optional)
12	Ground	---	GND	28 VDC ground return
13	Ground	---	GND	28 VDC ground return
14	Signal Ground	---	GND	Console ground return
15	State TX	OUT	RS232	TX data (to MAIM). State information, relayed through MAIM microcontroller from the INS.
16	Console RX	IN	RS232	RX data (from MAIM); provides console from ground to payload console through MAIM
17	Zeroize +	IN	LVDS-Diff	Active low signal to cause payload to zeroize (if payload requires that functionality).
18	Ethernet RX -	IN	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
19	Sensor PPS -	IN	LVDS-Diff	One pulse-per-second signal from the INS. Rising edge provides 1PPS reference. Negative pulse train
20	Ethernet TX -	OUT	ENET-Diff	Ethernet link through switch on MAIM routes to other payloads, or to ground station via RF link.
21	Reserved	---	---	Spare discrete wire(s) from MAIM to payload for future use.

3.1.5 Grounding

The payload shall maintain isolation of the aircraft ground, power ground, console serial ground, and state serial ground from each other. If any one of these connections cannot be 100% isolated, a minimum of a low-Q (non-resonant) ferrite bead isolator is required. Care must be taken to assure the ferrite bead is effective over the entire temperature range for which the payload is rated. In addition, to reduce the effects of core saturation, the bead's rated current must be at least 50% (preferably 100%) higher than the expected maximum current.

The overarching grounding scheme for the MP architecture is detailed in Section 2.5.3.

3.2 Mechanical Design

The MP standard imposes a common, relatively strict mechanical interface on payload modules to assure cross-platform compatibility.

3.2.1 Enclosure

Payload modules shall be lightweight enclosures in sizes ranging between 1U and 3U. Variations in payload sizes shall generally be accounted for by these discrete increments in module height. No module may exceed 3U. The maximum volumes of the different U modules are defined in Table 3-2 below.

Table 3-2. Maximum Module Dimensions

Module Size	Height (in)	Width (in)	Depth (in)
1U	1.500[1]	4.290	6.250, 7.250[2]
2U	3.050[1]	4.290	6.250, 7.250[2]
3U	4.600[1]	4.290	6.250, 7.250[2]

[1] Maximum dimension. See Section 3.2.1.1.1

[2] Deeper modules can be accommodated if certain conditions are met. See Section 3.2.1.1.2.

Figure 3-1 illustrates the conceptual designs of 1U, 2U and 3U modules. Figure 3-2, Figure 3-3, Figure 3-4 and Figure 3-5 provide the detailed dimensions of 1U, 2U, and 3U modules. These enclosure definitions constitute the standard volumes a module can be. However, some variability in the module design, as detailed in Section 3.2.1.1, is permitted.

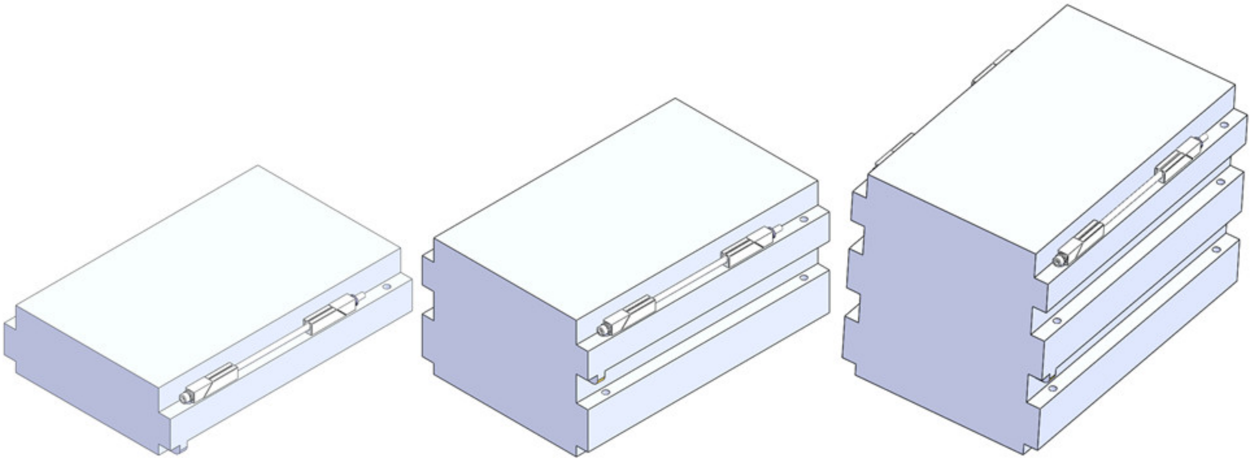


Figure 3-1. 1U, 2U, 3U Module Concepts

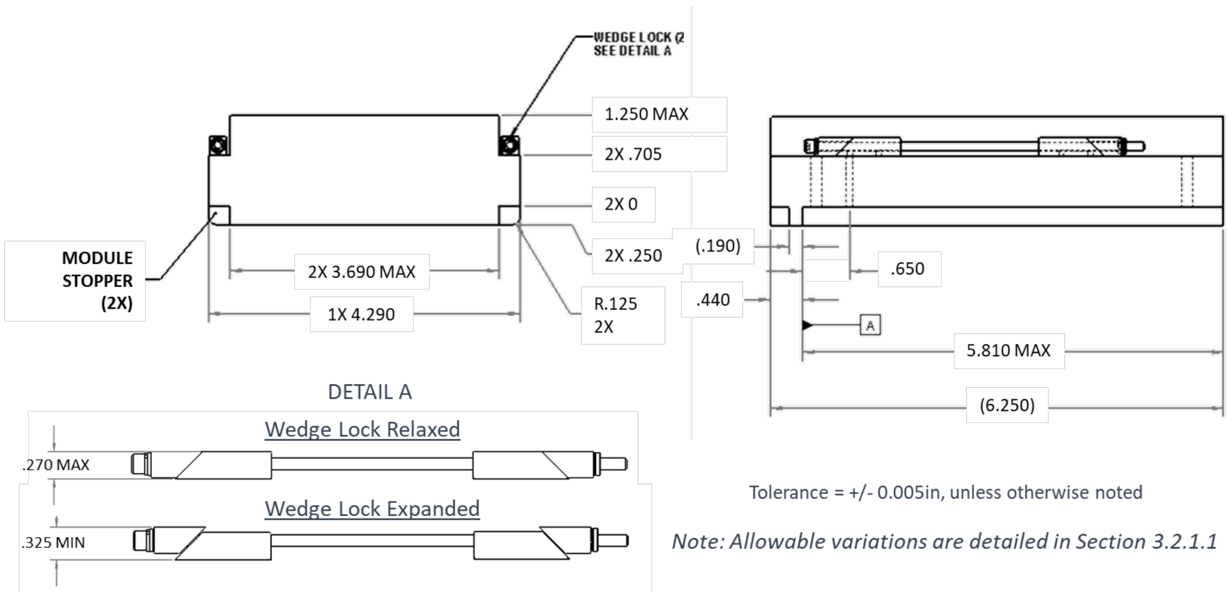


Figure 3-2. Detailed Dimensions of 1U Module

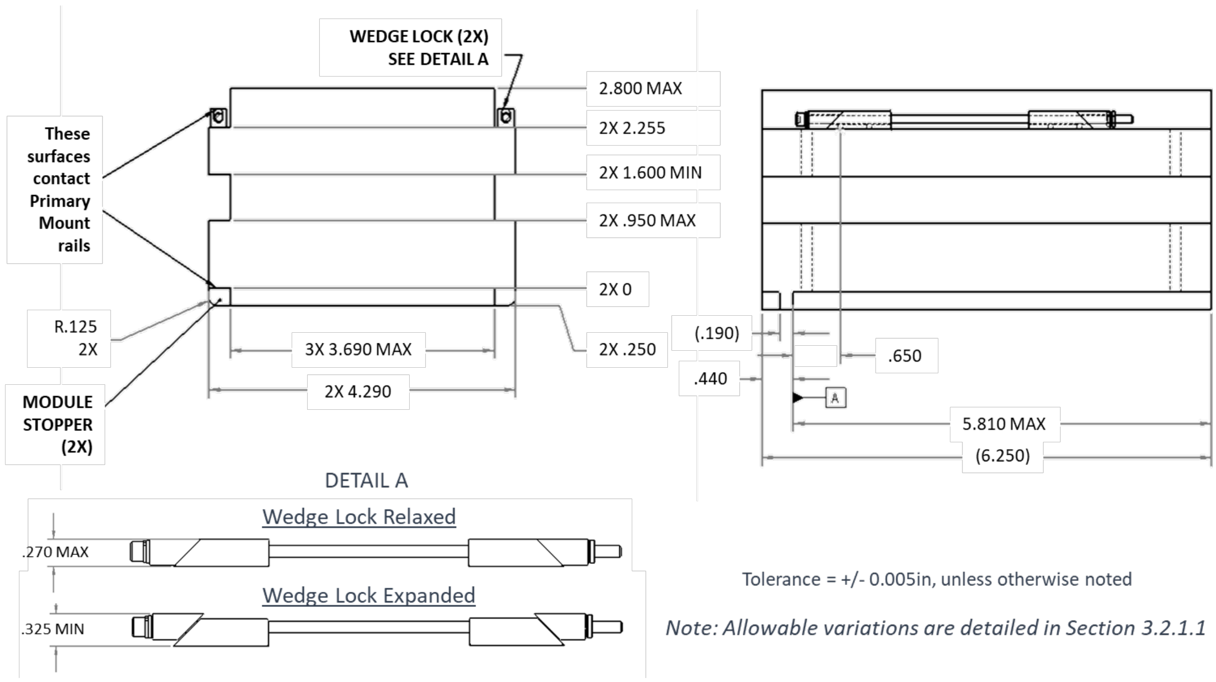


Figure 3-3. Detailed Dimensions of 2U Module

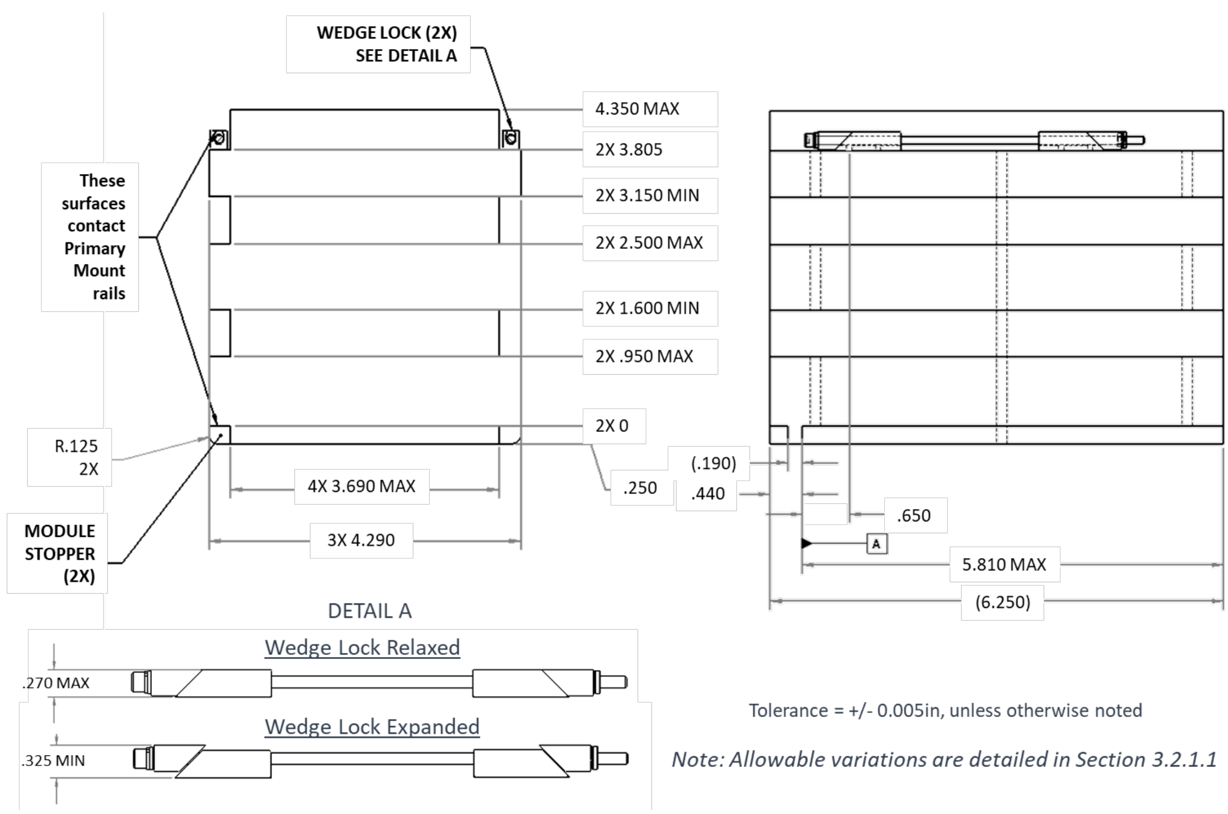


Figure 3-4. Detailed Dimensions of 3U Module

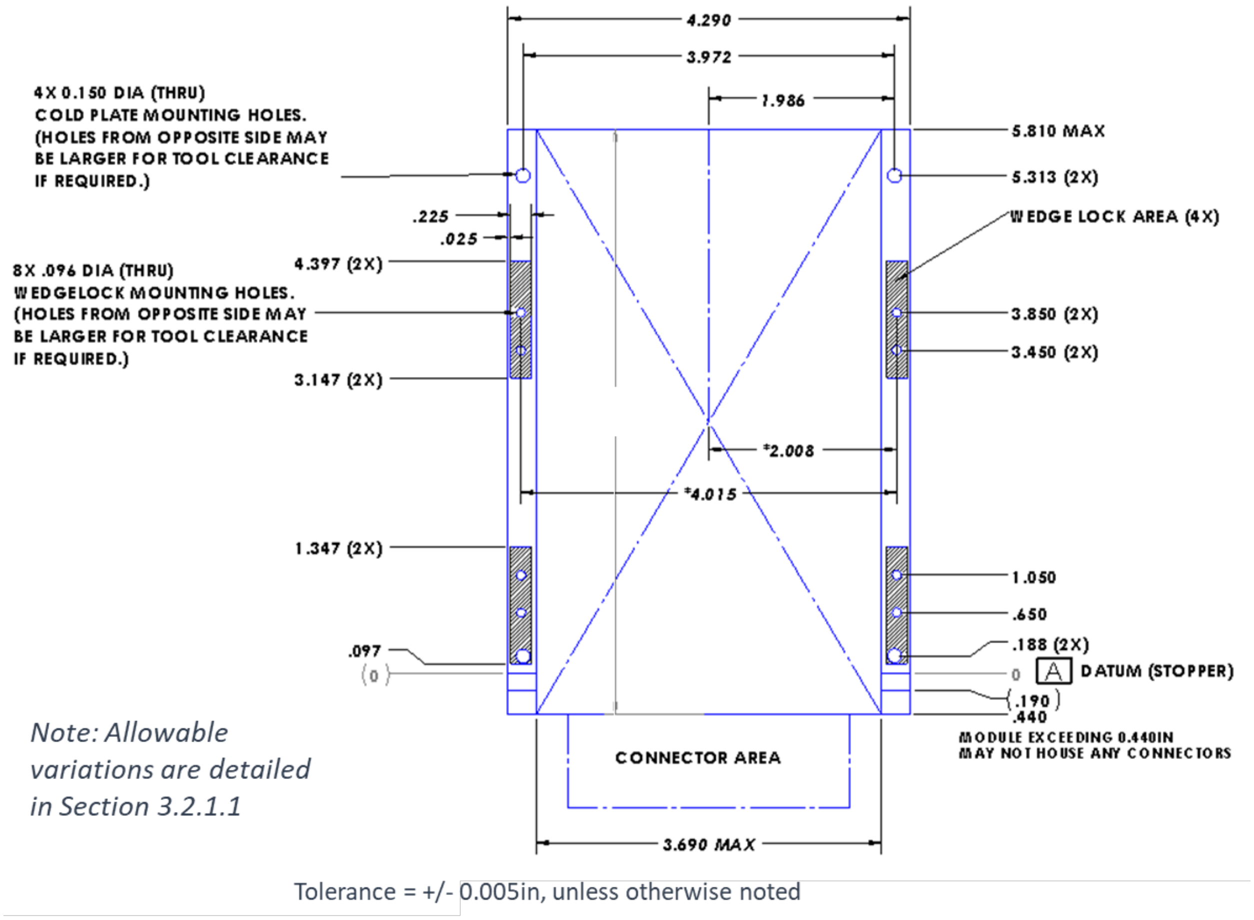


Figure 3-5. Detailed Dimensions of Module (Plan View)

3.2.1.1 Enclosure Variability

To allow payload flexibility and minimize weight, a number of variations are allowed to the enclosure form factor. The following subsections discuss the allowable variations. Any variations not listed should be considered non-compliant and must be identified as deviations.

3.2.1.1.1 Half U Modules

The height dimension of a payload module is defined as a maximum height. Non-maximum height modules, referred to as partial or half U modules (e.g., 0.5U, 1.5U or 2.5U) are permitted. This partial U allowance helps reduce the overall weight of the payload.

Note: Half U module heights are not strictly defined; they simply denote a height that is less than 1U, between that of a 1U and 2U module or between that of a 2U and 3U module.

3.2.1.1.2 Extended Length Modules

A payload module may extend past an overall 6.25in length, if no connector is on the surface orthogonal to the extended direction. Further, a payload module may only be extended towards the front of the module (in the direction of the connector face), i.e., the 0.440 dimension in Figure

3-5 may be extended by 1in up to 1.440, but the 5.810 dimension cannot be exceeded. Rails should not be extended for extended length modules. An example extended length module is shown in Figure 3-6.

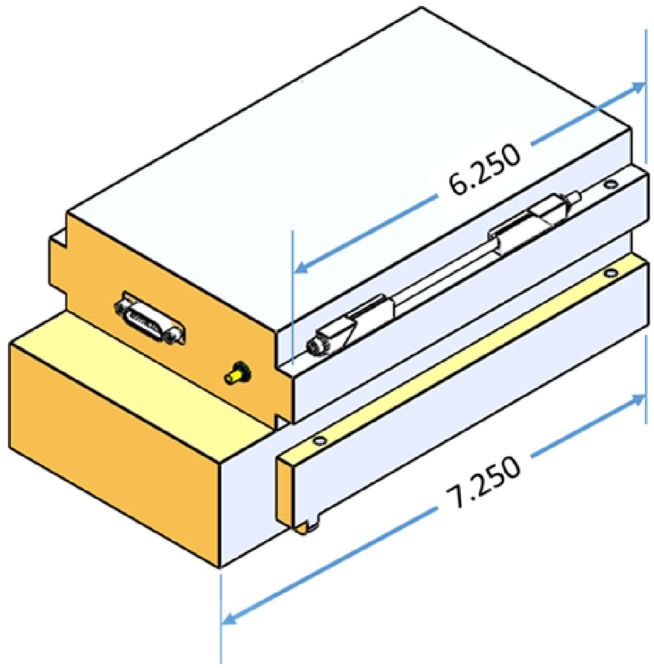


Figure 3-6. Example Extended Length Module

3.2.1.1.3 Reduced Length Modules

To minimize weight, a payload module may be shorter than an overall 6.25in length. A payload module may only be reduced from the back of the module (in the direction opposite the connector face), i.e., the 5.810 dimension in Figure 3-5 may be reduced as desired, but the 0.440 dimension cannot be decreased. However, a reduced length payload module must maintain its cold plate mount interface, even if the payload module body no longer extends to the rear cold plate mounting holes (the 5.313 dimension in Figure 3-5). In this case, the payload module shall either maintain the length of its rails to accommodate the holes or provide an adaptor plate that can be attached when needed to secure the module to a cold plate. Examples of each are shown in Figure 3-7.

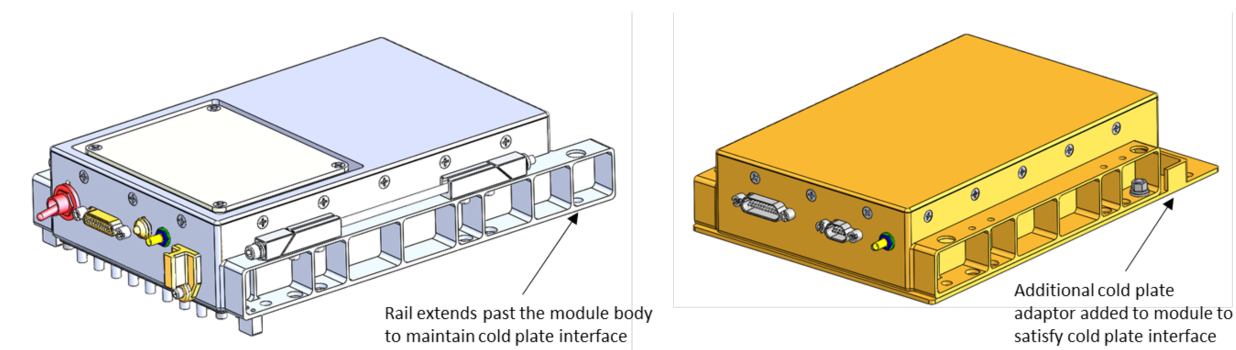


Figure 3-7. Example Reduced Length Modules

3.2.1.1.4 Rail Thickness

For 2U and 3U payload modules, the top surface of the top rail and bottom surface of the bottom rail are the critical dimensions for supporting the rack mount configuration. As such, all inner rail surfaces are defined with minimum or maximum dimensions. This allows the thickness of the rails, and, therefore, module weight to be significantly reduced.

3.2.1.1.5 Stopper location

The stopper should be incorporated into the lowest rail of the payload module. Alternatively, if required, the stopper can be incorporated into one of the other rails; however, when incorporated into an alternate, the alternate rail shall be full thickness, i.e., the lower edge dimension of the alternate rail (the 1.600 or 3.150 dimensions in Figure 3-3 and Figure 3-4) shall no longer be considered a minimum dimension.

3.2.1.1.6 Heatsink Location

To assure thermal performance, a payload module will likely require a heatsink, as discussed in Section 3.3.2. The size/volume of the heatsink is not defined; however, the heatsink may not extend outside the payload volumes identified in Section 3.2.1. Additionally, the heatsink may be installed on the either the top or bottom surface of the payload module.

3.2.1.2 Connector Locations

All connectors shall be located and accessible on the front side of the payload module, preferably, located centrally on the module. To prevent interference and clearance issues, specific keep out areas for connectors shall be followed. Figure 3-8 illustrates the keep out zones on a 1U module. All other size modules shall have the same keep out areas: a 0.750in x 0.580in (from the top and side surface), a 0.750in x 0.880in (from the bottom and side surface).

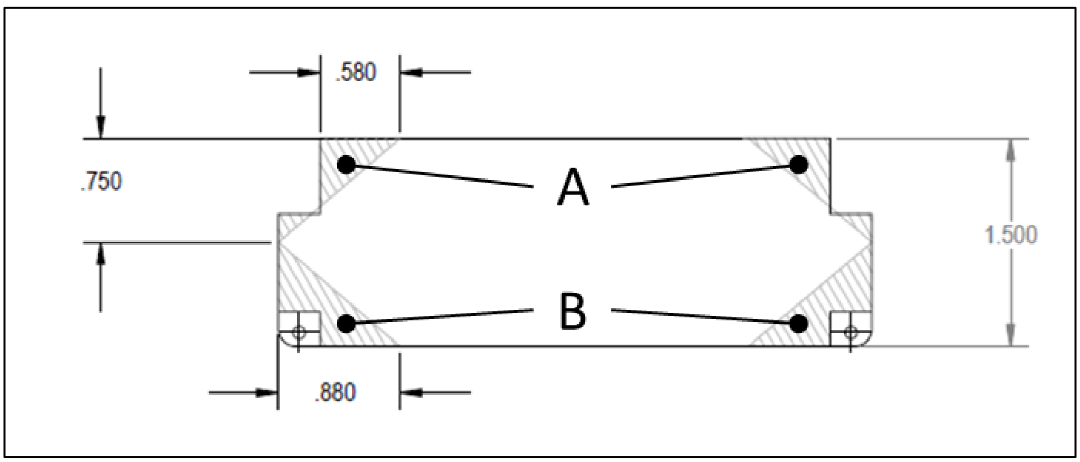


Figure 3-8. Connector Keep Out Zones

Modules with connectors that exceed the envelope limit provided by Table 3-2 or the keep out zones may not be compatible with all MP-compliant UAS. Any use of such payload modules must be approved by the host UAS.

3.2.2 Module Weight

Module weight should be minimized. It is expected that the payload vendor invest time into optimizing the structural weight of the module assemblies. For reference, a reasonable estimate of fuel consumption for a Group 2-3 UAS is ~300g fuel per hour. Any added weight from payloads can reduce fuel carried, and, thus endurance, making non-optimized payloads less desirable.

Example reasonable weight estimates (based on and extrapolated from modules that exist today) are as follows: 700g for a 1U module, 900g for a 2U module, 1.1kg for 3U module. Again, these are not limits, they are merely for reference.

3.2.3 Mounting Configurations

The module design shall be flexible to allow for multiple mounting configurations. The primary method shall be a small rack mount configuration where mechanical capture is achieved by lightweight wedge locks. An alternate mounting method shall also be supported (**and is required**) by the payload module to accommodate installation on UAS using a conductive cold plate for thermal management. The selection of which of the two mounting methods used for a payload module is determined by the UAS integrator, not the payload vendor.

3.2.3.1 Rack Mounting Option

Each module shall have integrated wedge locks that provide the mechanical support to secure the module into a rack-style Primary Mount. Figure 3-9 illustrates the wedge lock concept on a 1U module. A single pair of wedge locks is sufficient for modules of all sizes. Wedge locks shall be installed on the top rail of the payload module.

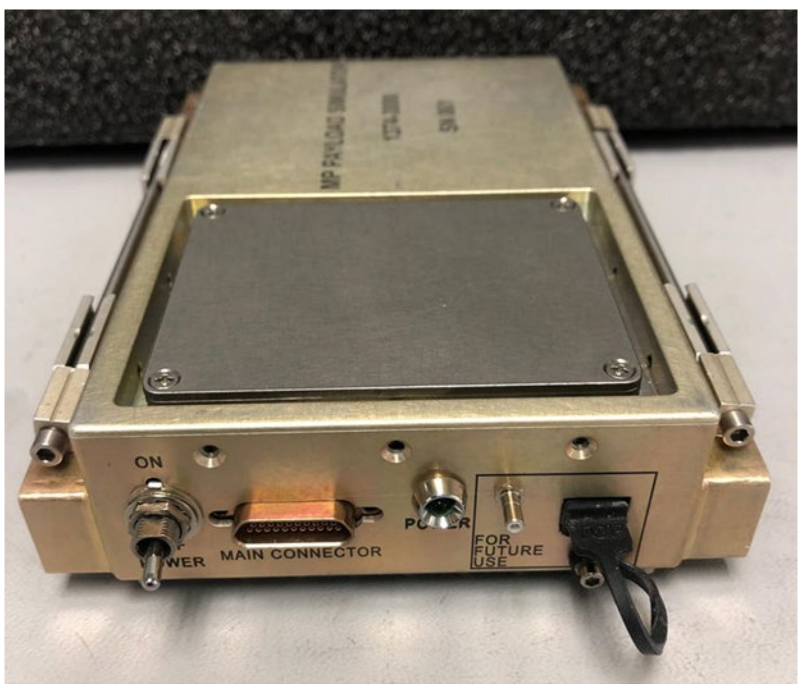


Figure 3-9. Example Payload Module Configured for Rack Mounting

Wedge locks shall have a maximum relaxed height of 0.270in and a minimum expanded height of

0.320in, providing a total travel of no less than 0.055in to span the gap between the top rail of the payload module and the corresponding slot surface in the Primary Mount. Figure 3-10 provides the detailed wedge lock design.

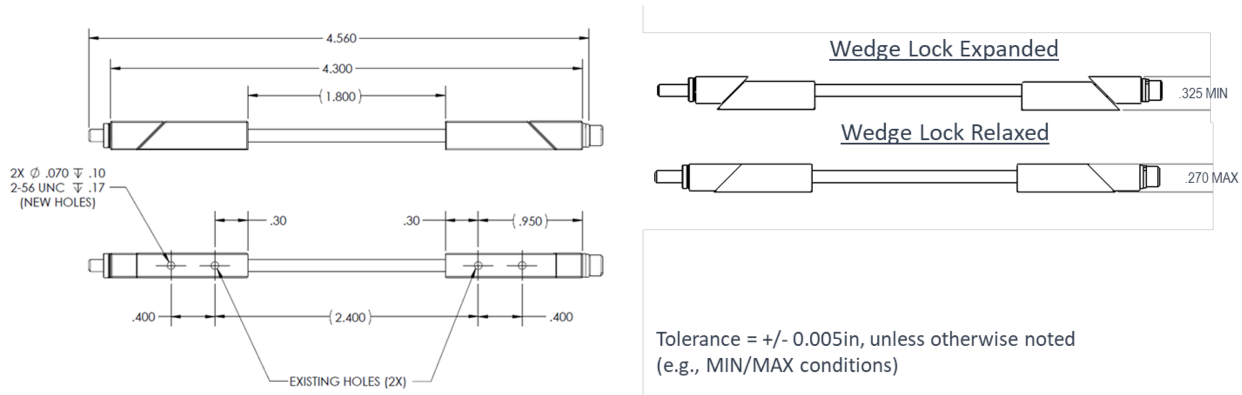


Figure 3-10. Wedge Lock Detailed Design

The following wedge locks have been demonstrated as MP-compliant:

- Wakefield 426B-430SSG-W
- Birtcher 40-5-12-T, modified to be equivalent to above

Alternate wedge locks are permitted, if functionally and dimensionally equivalent.

3.2.3.2 Cold Plate Mounting Option

Each module shall also be capable of mounting to a cold-plate-style Primary Mount. To support this requirement, the heatsink (if equipped) shall be removed from the module (along with wedge locks, if necessary), allowing the module to be bolted directly to the cold plate structure through the mounting holes identified in Figure 3-5. Figure 3-11 illustrates a payload module with its heatsink removed to allow for mounting to a cold plate.

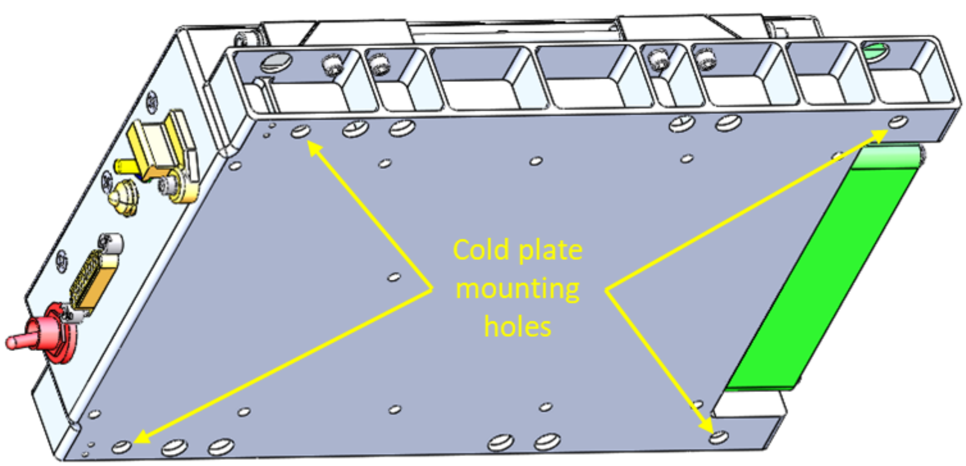


Figure 3-11. Payload Configured for Cold Plate Mounting

3.2.4 Tools for Integration and Removal

No custom tools should be required for module integration or removal. The prescribed wedge locks require a 3/32 inch hex nut driver. The Micro-D connector requires an 8mm hex nut driver.

3.2.5 Accessibility

Each module shall be provided with means for removal without affecting other adjacent systems, i.e., removal of an individual module shall not require removal of an adjacent module.

3.3 Thermal Design

Thermal design of the payload module shall be flexible to support various host UAS. Both convective and conductive cooling must be supported by the payload design. The payload vendor is responsible for the payload thermal design and verification to ensure that it is operating within the allowable limits.

3.3.1 UAS Thermal Environment

Payloads shall be able to operate in an ambient environment of up to 45°C with a minimum of 175 LFM airflow at any point over the heatsink. Payload shall be able to operate without airflow with a single side attached to a cold plate at up to 65°C.

3.3.2 Heatsink

A removable round-pin heatsink (Figure 3-12) can be added to the module for thermal convection enhancement, if required. The size and weight of the heatsink shall be included in the overall size (as defined in Section 3.2.1) and weight of the module (as defined in Section 3.2.2). Since module orientation may differ between UAS, only round-pin heatsinks shall be permitted. Because of the cold plate requirement, only one side of the payload shall have a heatsink. The payload shall be designed to transfer the majority of its heats across this surface.

Note: If a payload cannot meet the above heatsink requirement, the payload vendor shall identify the deviation, request a concession, and, if granted, clearly indicate that it is only partially MP-compliant and not compatible with platforms using a cold plate for cooling.

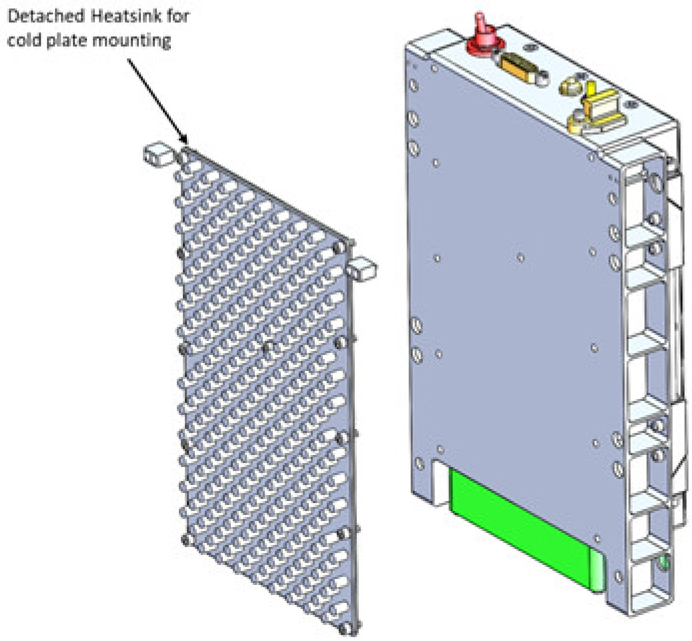


Figure 3-12. Heatsink Detached from the Bottom Surface of a Payload

3.3.3 Additional Ground Cooling

The payload vendor shall clearly identify to the UAS integrator a payload module that requires forced convection to support bench testing, ground integration testing or pre-flight checks. The payload vendor should provide a benchtop cooling kit (appropriate size fan), if one is required.

Note: The platform vendor is responsible for maintaining operational temperatures of the payload once it is installed.

3.4 RF Design

3.4.1 RF Cabling

In general, a payload module shall use the RF cabling integrated into the platform as part of the MP effort. Platform RF cabling is specified in Section 2.5.2.

When necessary, additional RF cabling can be utilized, provided it can be supported by the host UAS and does not violate any other requirements of the MP standard. Any additional cables must be clearly identified as deviations, and shall be provided by the payload vendor.

3.4.2 RF Connectors

Payload modules shall use SSMB-male connectors for RF connections to the payload antennas.

When necessary, additional RF connectors can be utilized, provided they can be supported by the host UAS and do not violate any other requirements of the MP standard. Any additional connectors must be clearly identified as deviations, and any required interfacing cables shall be provided by the payload vendor.

3.4.3 Antennas

Payload modules may utilize a variety of antennas. Thus, the MP standard is flexible and does not define specific antennas – omni antennas, patch antennas, dipoles and dipole arrays are all supported. However, the MP standard does specify the electrical and mechanical interfaces that the antennas must support.

The standard does not dictate the antenna locations on a UAS. Antenna locations and orientations are determined by the UAS integrator, so will vary across MP-compliant UAS. However, a minimum number and orientation of antenna mounts that a MP-compliant UAS must support is defined in Section 2.4.1. Specific UAS antenna mount implementations are documented in the appendices.

3.4.3.1 Antenna Connectors

As RF cabling to antennas will terminate in either an SMA-male connector or an array connection (defined in Section 0), payload antennas shall either be able to directly accept these connections or be provided with the requisite RF adaptors / cabling to do so.

3.4.3.2 Antenna Adaptors

To interface to the UAS antenna mounts, as defined in see Section 2.4.1, a payload's antenna shall be housed into an antenna-specific mechanical adaptor. This antenna adaptor shall provide the appropriate mechanical interface to secure the antenna to any MP-compliant UAS (with sufficient SWAP capacity to fly it). While each antenna adaptor is specific to the particular antenna, there are only three adaptor types supported by the standard – 2-pt adaptor, 4-pt adaptor, and array adaptor – analogous to the three types of antenna mounts to which the adaptors interface. The standardized mechanical interfaces between the UAS-provided antenna mounts and the payload-provided antenna adaptor allow for rapid installation and removal and compatibility across UAS.

3.4.3.2.1 2-pt Adaptor

2-pt adaptors, as shown in Figure 3-13, are the simplest and most common (supported on all MP-complaint UAS) MP antenna adaptors. They should be used to support the smallest antennas.

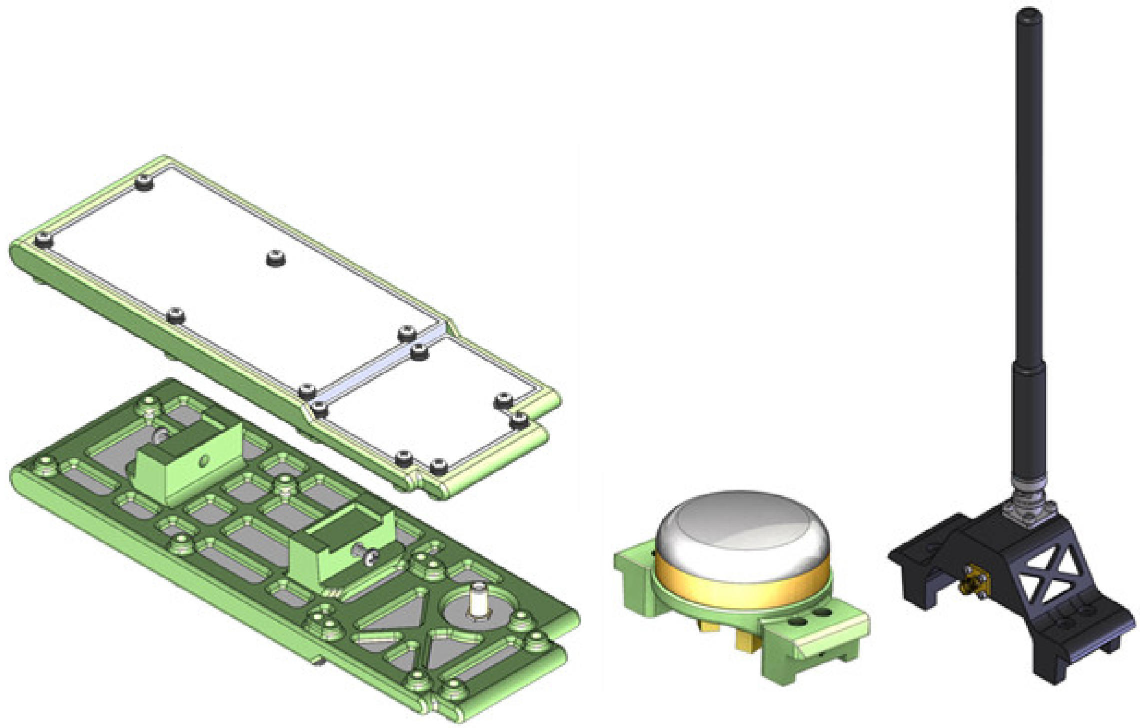


Figure 3-13. Example MP-compliant 2-pt Antenna Adaptor Assemblies

The 2-pt antenna adaptor interface is defined in Figure 3-14. Payload antennas employing a 2-pt antenna adaptor shall adhere to this interface. 2-pt adaptors shall be secured to 2-pt mounts using 6-32 bolts via one of two methods:

- Through the top of the adaptor and into the mount via the pair of holes on each side of the adaptor / mount, or
- Through the side of the mount and into adaptor via the single hole on each side of the mount / adaptor.

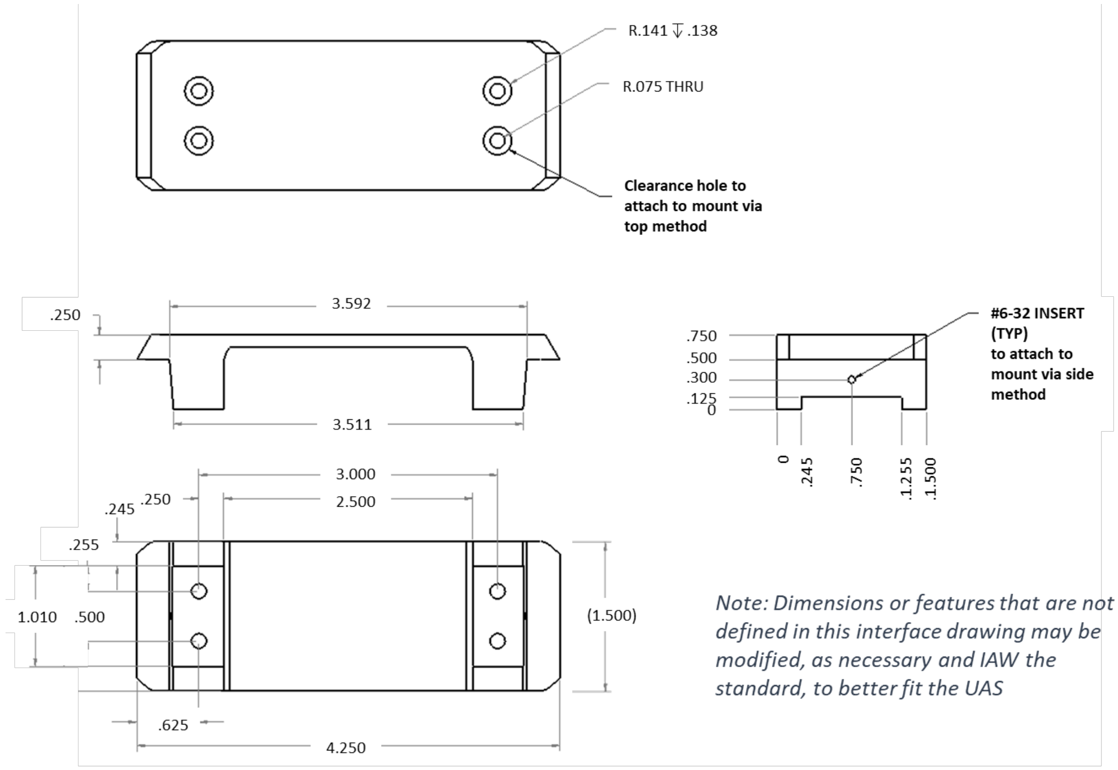


Figure 3-14. 2-pt Antenna Adaptor Interface

As evidenced in Figure 3-13 above, the requisite 2-pt adaptor interface should be incorporated into an antenna-specific adaptor to conform to the antenna design, while also considering potential impact to the UAS.

Note: To limit drag on the aircraft, 2-pt mounts are generally oriented such that the major axis of the antenna adaptor will align with fore-aft axis of the UAS.

3.4.3.2.2 4-pt Adaptor

A 4-pt adaptor, as shown in Figure 3-15, is an assembly consisting of two 2-pt adaptors. 4-pt adaptors should be used to support larger antennas on larger UAS.

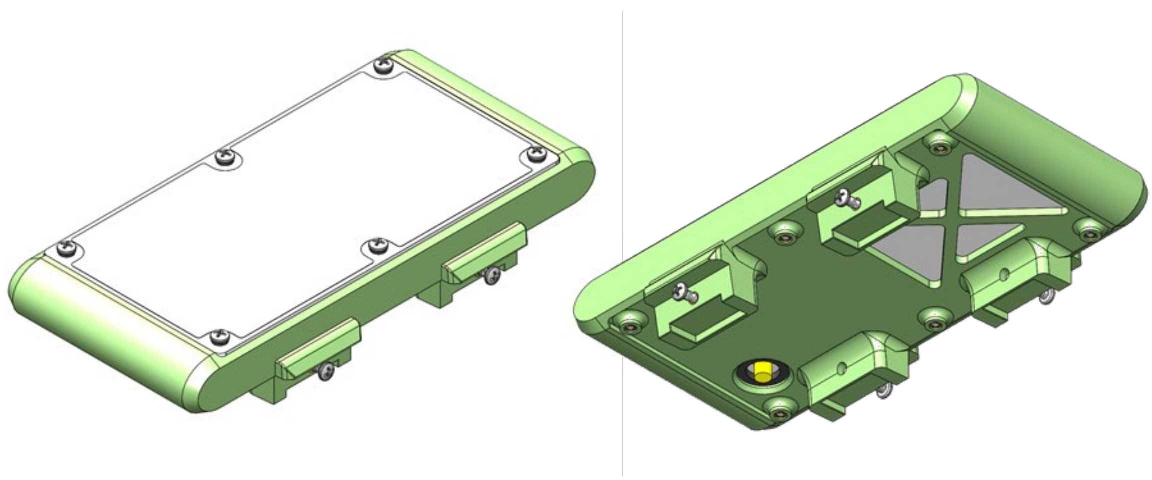


Figure 3-15. Example MP-compliant 4-pt Antenna Adaptor Assembly

The 4-pt antenna adaptor interface is defined in Figure 3-16. Payload antennas employing a 4-pt antenna adaptor shall adhere to this interface. 4-pt adaptors shall be mounted using one of the two methods described in Section 3.4.3.2.1.

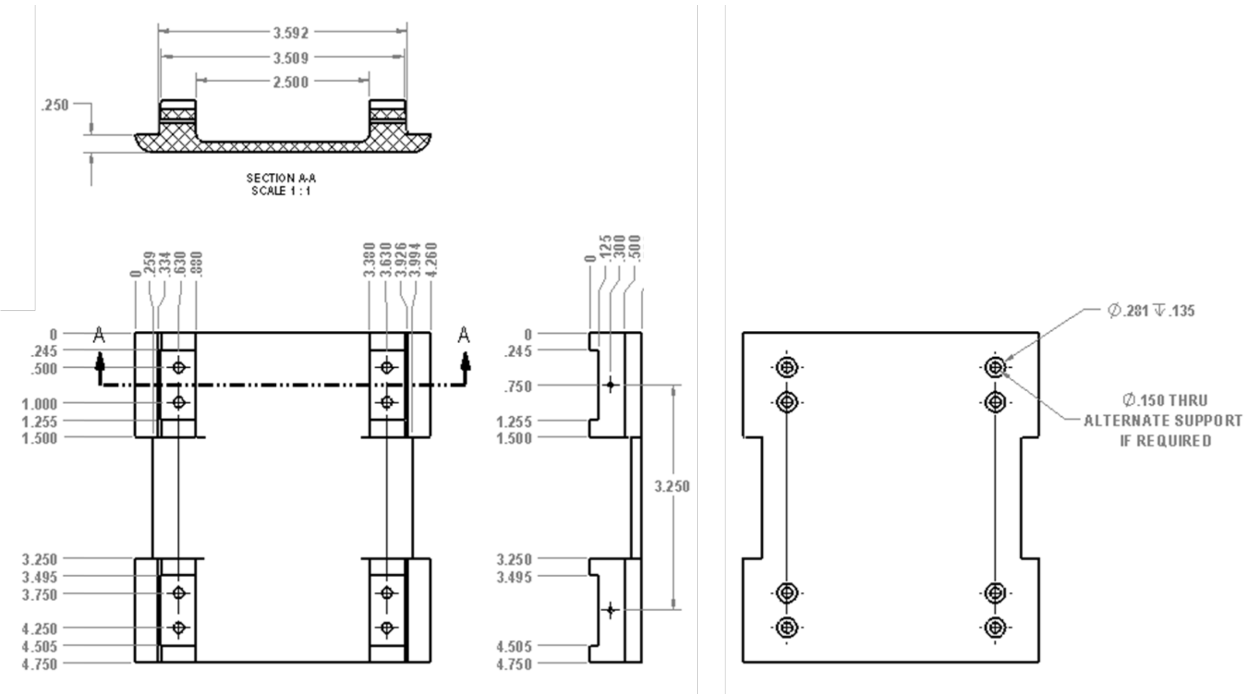


Figure 3-16. 4-pt Antenna Adaptor Interface

As evidenced in Figure 3-15 above, the requisite 4-pt adaptor interface should be incorporated into an antenna-specific adaptor to conform to the antenna design, while also considering potential impact to the UAS.

Note: To limit drag on the aircraft, 4-pt mounts are generally oriented such that the two 2-pt interfaces are positioned adjacently along the fore-aft axis of the UAS.

3.4.3.2.3 Array Adaptor

As a breakaway, electro-mechanical interface, the array adaptor is the most complicated MP antenna adaptor. An array adaptor should be used to support payloads requiring multiple phase-matched antennas or an antenna array. The array adaptor interface consists of three SMPM-female connectors precisely positioned in a custom connector block and housed in a larger custom mechanical assembly. The array adaptor interface is defined in Figure 3-17.

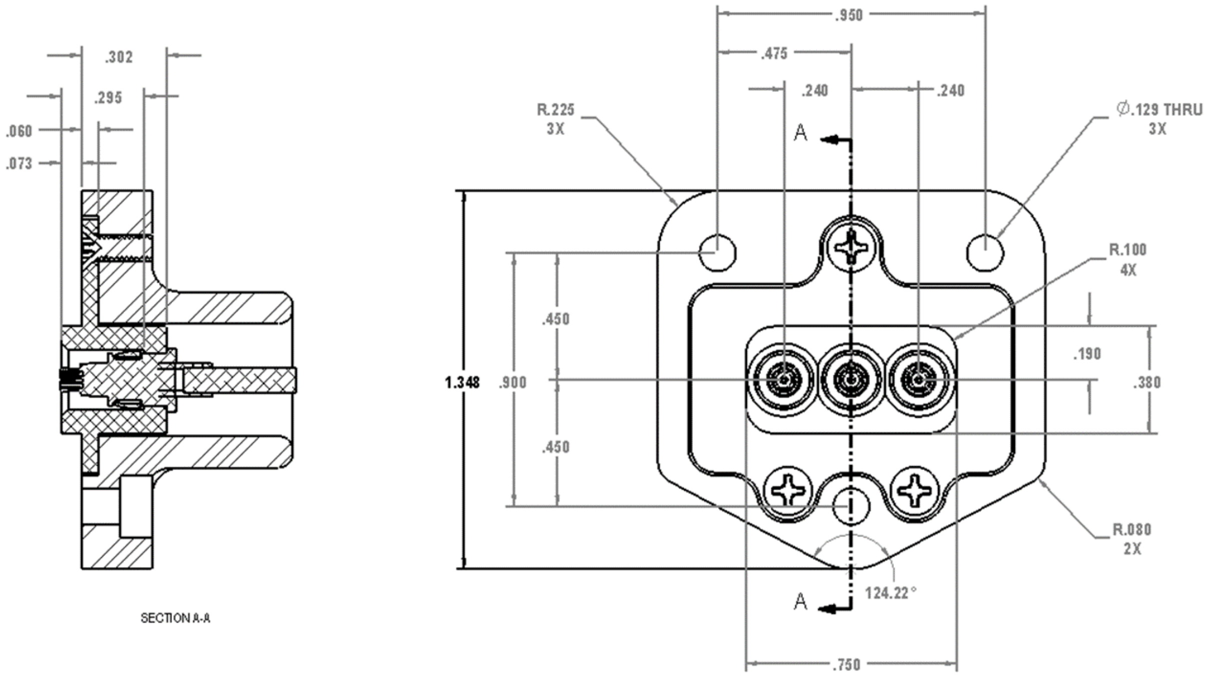


Figure 3-17. Array Adaptor Interface

The requisite array adaptor interface should be incorporated into an antenna-specific adaptor to conform to the antenna design, while also considering potential impact to the UAS. While an array interface is supported on all MP-compliant UAS, the volume available for the array adaptor will vary. Larger arrays may not be able to be installed on smaller MP-compliant UAS. The antenna array interface is also typically designed to breakaway at landing, so array adaptors should be designed for this use case.

Note: the array mount is typically oriented with the array mount interface facing either forward or aft on the UAS, whichever is determined more favorable by the UAS integrator.

3.4.4 EMI

The system shall not have unintentional emissions that interfere with operations of major onboard UAS systems. Harmonics, except the second and third, and all other spurious emissions should be at least 80 dB down from the level at the fundamental frequency. Per MIL-STD-461 for RE103 for the 10kHz to 40GHz range, the second and third harmonics should be suppressed to a level of -20 dBm or 80 dB below the fundamental, whichever requires less suppression. The MP contractor will provide information on the RF behavior of their system (particularly notating any deviations to the above guidance) to support frequency masking, if required.

3.5 Environmental

MP-compliant payloads shall adhere to the environmental requirements defined in the subsequent section.

3.5.1 Shock

Per MIL-STD-810, the payload shall be able to withstand a shock level of 20g peak with the cross over frequency of 45Hz for a duration of 15-23ms.

3.5.2 Vibration

The payload shall be able to withstand the random vibration as listed in Figure 3-18.

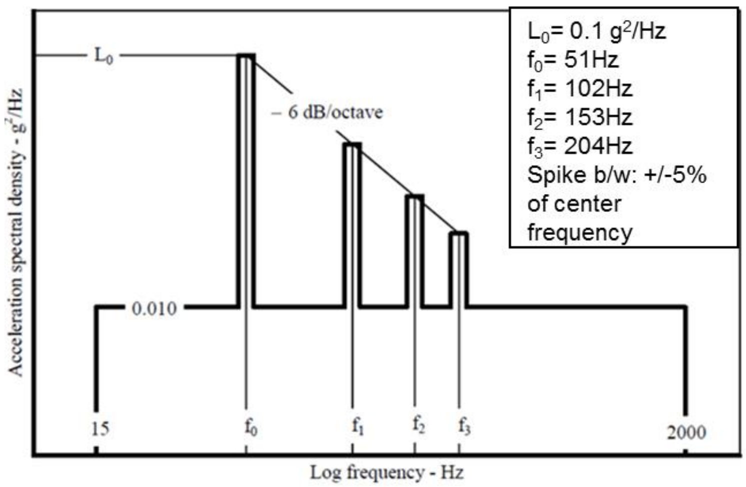


Figure 3-18. Vibration Requirement Pattern

3.5.3 Ambient Temperature

Ambient temperature requirements are detailed in Section 3.3.1.

3.5.4 Storage Temperature

The payload shall be able to survive in an off state in external ambient environments ranging from -20°C to 70°C.

3.5.5 Sand and Dust

The payload shall be able to survive blowing dust and sand as would be experienced in a desert environment.

3.5.6 Salt Atmosphere

The payload shall be able to endure marine conditions as would be experienced in a shipboard or littoral environment.

3.5.7 Humidity

The payload shall be able to endure high humidity conditions as would be experienced in a shipboard or littoral environment.

3.5.8 Altitude

As a goal, the payload should be capable of operation up to 15,000ft Density Altitude (DA). However, if this altitude is not achievable for a payload, the payload capability should be documented clearly.

3.5.9 Handling

The payload shall be able to be simply installed by a flight team in a tactical environment, (e.g., no ESD straps or other specialized requirements).

Appendix A. **State Distribution Messages**

A.1 Overview

The MAIM distributes state data over two interfaces – serial and Ethernet – to provide flexibility for payloads. The Ethernet interface uses a JSON message format for distribution, while the serial interface uses both the sbgEcom binary and NMEA message formats. This appendix details these message formats.

A.2 State over Ethernet: JSON Messages

JSON is a human-readable text format normally used to exchange data between servers and browsers. It is intended to simplify the interpretation of the communicated data and remove the complexity of interpreting binary quantities due to Endianness, size, and packing differences between hosts.

The MAIM distributes state data over Ethernet utilizing the JSON classes:

- MAIM_VER
- STATUS
- IMUNAV
- PRESSURE
- TPV
- ATT
- SKY
- ADDL

The subsequent sections define each class.

A.2.1 MAIM _VER

The MAIM_VER message contains the hardware / software version information for the MAIM. The MAIM_VER message is distributed by the MAIM at 1Hz.

Measurement/Definition	**JSON Field Name**	**Type**	**Units / Notes**
Name of this group	class	string	MAIM_VER
Version of the JSON classes	sw	string	string - Major.Minor dot notation
Name of the Sensor	dev	string	string - human readable product code
Sensor Hardware version	devhw	string	string - Major.Minor dot notation
Sensor Firmware version	devsw	string	string - Major.Minor dot notation

Example:

{"class":"MAIM_VER","sw":"1.0","dev":"SBG ELLIPSE-N","devhw":"2.4","devsw":"6.5"}

A.2.2 STATUS

The STATUS message contains the various status fields for the INS. The STATUS message is distributed by the MAIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	STATUS
General status with enums	general	string	Hex characters
Communications status	com	string	Hex characters
Aiding Equipment status	aiding	string	Hex characters
UTC time and clock sync	utc	string	Hex characters
IMU status	imu	string	Hex characters
Magnetometer status	mag	string	Hex characters
Global Solution status	sol	string	Hex characters
GPS velocity fix and status	vel	string	Hex characters
GPS position fix and status	pos	string	Hex characters
Altimeter status	alt	string	Hex characters

Example:

{"class":"STATUS","general":"7F","com":"17FFFFFF","aiding":"3FFF","utc":"64", "imu":"17E","mag":"0C5","sol":"1234CC7","vel":"C3","pos":"FFABC","alt":"3"}

The tables presented below provide information on the bitmasks and enumerations coded into the fields of the STATUS class. The information is taken directly from the corresponding SBG Ellipse sbgECom Binary Protocol LOG message.

A.2.2.1 STATUS – General

Description: General status bitmask and enumerations

Bit	Name	Description
0	SBG_ECOM_GENERAL_MAIN_POWER_OK	Set to 1 when main power supply is OK.
1	SBG_ECOM_GENERAL_IMU_POWER_OK	Set to 1 when IMU power supply is OK.
2	SBG_ECOM_GENERAL_GPS_POWER_OK	Set to 1 when GPS power supply is OK.
3	SBG_ECOM_GENERAL_SETTINGS_OK	Set to 1 if settings were correctly loaded.
4	SBG_ECOM_GENERAL_TEMPERATURE_OK	Set to 1 when temperature is within limits.
5	SBG_ECOM_GENERAL_DATALOGGER_OK	Set to 1 the data-logger is working correctly
6	SBG_ECOM_GENERAL_CPU_OK	Set to 1 if the CPU headroom is correct

A.2.2.2 STATUS – Com

Description: Communication status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_PORTA_VALID	Set to 0 in case of low level communication error.
1	SBG_ECOM_PORTB_VALID	Set to 0 in case of low level communication error.
2	SBG_ECOM_PORTC_VALID	Set to 0 in case of low level communication error.
3	SBG_ECOM_PORTD_VALID	Set to 0 in case of low level communication error.
4	SBG_ECOM_PORTE_VALID	Set to 0 in case of low level communication error.
5	SBG_ECOM_PORTA_RX_OK	Set to 0 in case of saturation on PORT A input
6	SBG_ECOM_PORTA_TX_OK	Set to 0 in case of saturation on PORT A output
7	SBG_ECOM_PORTB_RX_OK	Set to 0 in case of saturation on PORT B input
8	SBG_ECOM_PORTB_TX_OK	Set to 0 in case of saturation on PORT B output
9	SBG_ECOM_PORTC_RX_OK	Set to 0 in case of saturation on PORT C input

10	SBG_ECOM_PORTC_TX_OK	Set to 0 in case of saturation on PORT C output
11	SBG_ECOM_PORTD_RX_OK	Set to 0 in case of saturation on PORT D input
12	SBG_ECOM_PORTD_TX_OK	Set to 0 in case of saturation on PORT D output
13	SBG_ECOM_PORTE_RX_OK	Set to 0 in case of saturation on PORT E input
14	SBG_ECOM_PORTE_TX_OK	Set to 0 in case of saturation on PORT E output
15	SBG_ECOM_ETH0_RX_OK	Set to 0 in case of saturation on PORT ETH0 input
16	SBG_ECOM_ETH0_TX_OK	Set to 0 in case of saturation on PORT ETH0 output
17	SBG_ECOM_ETH1_RX_OK	Set to 0 in case of saturation on PORT ETH1 input
18	SBG_ECOM_ETH1_TX_OK	Set to 0 in case of saturation on PORT ETH1 output
19	SBG_ECOM_ETH2_RX_OK	Set to 0 in case of saturation on PORT ETH2 input
20	SBG_ECOM_ETH2_TX_OK	Set to 0 in case of saturation on PORT ETH2 output
21	SBG_ECOM_ETH3_RX_OK	Set to 0 in case of saturation on PORT ETH3 input
20	SBG_ECOM_ETH3_TX_OK	Set to 0 in case of saturation on PORT ETH3 output
23	SBG_ECOM_ETH4_RX_OK	Set to 0 in case of saturation on PORT ETH4 input
24	SBG_ECOM_ETH4_TX_OK	Set to 0 in case of saturation on PORT ETH4 output
25	SBG_ECOM_CAN_RX_OK	Set to 0 in case of saturation on CAN Bus output buffer
26	SBG_ECOM_CAN_TX_OK	Set to 0 in case of saturation on CAN Bus input buffer
27-29	SBG_ECOM_CAN_BUS	Enum Define the CAN Bus status (see below)

A.2.2.2.1 CAN BUS Status Enumeration Values

Value	Name	Description
0x0	SBG_ECOM_CAN_BUS_OFF	Bus OFF operation due to too much errors
0x1	SBG_ECOM_CAN_BUS_TX_RX_ERR	Transmit or received error
0x2	SBG_ECOM_CAN_BUS_OK	The CAN bus is working correctly.
0x3	SBG_ECOM_CAN_BUS_ERRORA	General error has occurred on the CAN bus

A.2.2.3 STATUS – aiding

Description: Aiding equipment status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_AIDING_GPS1_POS_RECV	Set to 1 valid GPS 1 position data is received
1	SBG_ECOM_AIDING_GPS1_VEL_RECV	Set to 1 valid GPS 1 velocity data is received
2	SBG_ECOM_AIDING_GPS1_HDT_RECV	Set to 1 valid GPS 1 true heading data is received
3	SBG_ECOM_AIDING_GPS1_UTC_RECV	Set to 1 valid GPS 1 UTC time data is received
4	SBG_ECOM_AIDING_GPS2_POS_RECV	Set to 1 valid GPS 2 position data is received
5	SBG_ECOM_AIDING_GPS2_VEL_RECV	Set to 1 valid GPS 2 velocity data is received
6	SBG_ECOM_AIDING_GPS2_HDT_RECV	Set to 1 valid GPS 2 true heading data is received
7	SBG_ECOM_AIDING_GPS2_UTC_RECV	Set to 1 valid GPS 2 UTC time data is received
8	SBG_ECOM_AIDING_MAG_RECV	Set to 1 valid Magnetometer data is received
9	SBG_ECOM_AIDING_ODO_RECV	Set to 1 Odometer pulse is received
10	SBG_ECOM_AIDING_DVL_RECV	Set to 1 valid DVL data is received
11	SBG_ECOM_AIDING_USBL_RECV	Set to 1 valid USBL data is received
12	SBG_ECOM_AIDING_EM_LOG_RECV	Set to 1 valid EM Log data is received
13	SBG_ECOM_AIDING_PRESSURE_RECV	Set to 1 valid Pressure sensor data is received

A.2.2.4 STATUS – utc

Description: Time and clock sync status

Bit	Name	Description
0	SBG_ECOM_CLOCK_STABLE_INPUT	Set to 1 when a clock input can be used to synchronize the internal clock.
1-4	SBG_ECOM_CLOCK_STATUS	Define the internal clock estimation status (see below)
5	SBG_ECOM_CLOCK_UTC_SYNC	Set to 1 if UTC time is synchronized with a PPS
6-9	SBG_ECOM_CLOCK_UTC_STATUS	Define the UTC validity status (see below).

A.2.2.4.1 Clock Status Enumeration

Value	Name	Description

0x0	SBG_ECOM_CLOCK_ERROR	An error has occurred on the clock estimation
0x1	SBG_ECOM_CLOCK_FREE_RUNNING	The clock is only based on the internal crystal
0x2	SBG_ECOM_CLOCK_STEERING	A PPS has been detected and the clock is converging to it
0x3	SBG_ECOM_CLOCK_VALID	The clock has converged to the PPS and is within 500s

A.2.2.4.2 UTC Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_UTC_INVALID	The UTC time is not known, we are just propagating the UTC time internally
0x1	SBG_ECOM_UTC_NO_LEAP_SEC	We have received valid UTC time information but we don't have the leap seconds information
0x2	SBG_ECOM_UTC_VALID	We have received valid UTC time data with valid leap seconds.

A.2.2.5 STATUS - imu

Description: IMU Status bitmask

Bit	Name	Description
0	SBG_ECOM_IMU_COM_OK	Set to 1 the communication with the IMU is ok.the internal clock.
1	SBG_ECOM_IMU_STATUS_BIT	Set to 1 if internal IMU passes Built In Test (Calibration, CPU)
2	SBG_ECOM_IMU_ACCEL_X_BIT	Set to 1 accelerometer X passes Built In Test
3	SBG_ECOM_IMU_ACCEL_Y_BIT	Set to 1 accelerometer Y passes Built In Test
4	SBG_ECOM_IMU_ACCEL_Z_BIT	Set to 1 accelerometer Z passes Built In Test
5	SBG_ECOM_IMU_GYRO_X_BIT	Set to 1 gyroscope X passes Built In Test
6	SBG_ECOM_IMU_GYRO_Y_BIT	Set to 1 gyroscope Y passes Built In Test
7	SBG_ECOM_IMU_GYRO_Z_BIT	Set to 1 gyroscope Z passes Built In Test
8	SBG_ECOM_IMU_ACCELS_IN_RANGE	Set to 1 accelerometers within operating range
9	SBG_ECOM_IMU_GYROS_IN_RANGE	Set to 1 gyroscopes are within operating range

A.2.2.6 STATUS – mag

Description: Magnetometer status bitmask

Bit	Name	Description
0	SBG_ECOM_MAG_MAG_X_BIT	Set to 1 magnetometer X passed the self test.
1	SBG_ECOM_MAG_MAG_Y_BIT	Set to 1 magnetometer Y passed the self test.
2	SBG_ECOM_MAG_MAG_Z_BIT	Set to 1 magnetometer Z passed the self test.
3	SBG_ECOM_MAG_ACCEL_X_BIT	Set to 1 accelerometer X passed the self test.
4	SBG_ECOM_MAG_ACCEL_Y_BIT	Set to 1 accelerometer Y passed the self test.
5	SBG_ECOM_MAG_ACCEL_Z_BIT	Set to 1 accelerometer Z passed the self test.
6	SBG_ECOM_MAG_MAGS_IN_RANGE	Set to 1 magnetometer is not saturated
7	SBG_ECOM_MAG_ACCELS_IN_RANGE	Set to 1 accelerometer is not saturated
8	SBG_ECOM_MAG_CALIBRATION_OK	Set to 1 magnetometer seems to be calibrated

A.2.2.7 STATUS – sol

Description: Global solution status.

Bit	Name	Description
0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)

12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)
25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.2.2.7.1 SOLUTION MODE Enumeration

Value	Name	Description
0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.2.2.8 STATUS – vel

Description: GPS velocity fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_VEL_STATUS	The raw GPS velocity status (see the 5 below)
6-11	SBG_ECOM_GPS_VEL_TYPE	The raw GPS velocity type (see the 6 below)

A.2.2.8.1 Velocity Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_VEL_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_VEL_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_VEL_LIMIT	Velocity limit exceeded

A.2.2.8.2 Velocity Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_NO_SOLUTION	No valid velocity solution available
0x1	SBG_ECOM_VEL_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_VEL_DOPPLER	A Doppler velocity has been computed
0x3	SBG_ECOM_VEL_DIFFERENTIAL	A velocity has been computed between two positions

A.2.2.9 STATUS – pos

Description: GPS position fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_POS_STATUS	The raw GPS position status (see the 7 below)

6-11	SBG_ECOM_GPS_POS_TYPE	The raw GPS position type (see the 8 below)
12	SBG_ECOM_GPS_POS_GPS_L1_USED	Set to 1 if GPS L1 is used in the solution
13	SBG_ECOM_GPS_POS_GPS_L2_USED	Set to 1 if GPS L2 is used in the solution
14	SBG_ECOM_GPS_POS_GPS_L5_USED	Set to 1 if GPS L5 is used in the solution
15	SBG_ECOM_GPS_POS_GLO_L1_USED	Set to 1 if GLONASS L1 is used in the solution
16	SBG_ECOM_GPS_POS_GLO_L2_USED	Set to 1 if GLONASS L2 is used in the solution

A.2.2.9.1 POS Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_POS_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_POS_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_POS_HEIGHT_LIMIT	The height limit has been exceeded

A.2.2.9.2 POS Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_NO_SOLUTION	No valid solution available
0x1	SBG_ECOM_POS_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_POS_SINGLE	Single point solution position
0x3	SBG_ECOM_POS_PSRDIFF	Standard Pseudorange Differential Solution (DGPS)
0x4	SBG_ECOM_POS_SBAS	SBAS satellite used for differential corrections
0x5	SBG_ECOM_POS_OMNISTAR	Omnistar VBS Position (L1 sub-meter)
0x6	SBG_ECOM_POS_RTK_FLOAT	Floating RTK ambiguity solution (20 cms RTK)
0x7	SBG_ECOM_POS_RTK_INT	Integer RTK ambiguity solution (2 cms RTK)
0x8	SBG_ECOM_POS_PPP_FLOAT	Precise Point Positioning with float ambiguities
0x9	SBG_ECOM_POS_PPP_INT	Precise Point Positioning with fixed ambiguities
0x10	SBG_ECOM_POS_FIXED	Fixed location solution position

A.2.2.10 STATUS – alt

Description: Pressure status bitmask

Bit	Name	Description
0	SBG_ECOM_PRESSURE_VALID	Set to 1 altimeter was correctly initialized
1	SBG_ECOM_ALTITUDE_VALID	Set to 1 if the altitude output is valid

A.2.3 IMUNAV

The IMUNAV message contains the north, east, down velocity data from the INS. The IMUNAV message is distributed by the MAIM at 10Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Velocity in North Direction	veln	numeric	meters per second - North positive
Velocity in East Direction	vele	numeric	meters per second - East positive
Velocity in Down Direction	veld	numeric	meters per second - Down positive

Example:

{"class":"IMUNAV","veln":-175.135,"vele":-22.0,"veld":-4.234}

A.2.4 PRESSURE

The PRESSURE message contains the barometric pressure data from the INS. The PRESSURE message is distributed by the MAIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	PRESSURE
Measured Sensor Pressure	pressure	numeric	Pascals
Altitude from Barometer	alt	numeric	meters

Example:

{"class":"PRESSURE","pressure":101325.0,"alt":0.0}

A.2.5 TPV

The TPV message contains the time, position and course data and their error estimates from the INS. The TPV message is distributed by the MAIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class		TPV
Time	time	string	ISO8601 Format UTC
Estimated Timestamp Error	ept	numeric	nanoseconds
Course over ground	track	numeric	Degrees from true north (0 to 360)
Latitude	lat	numeric	Degrees - North Positive (-90 to +90)
Longitude	lon	numeric	Degrees - East Positive (-180 to +180)
Altitude	alt	numeric	Meters above mean sea level
Status	status	numeric	2 if DGPS used; absent otherwise
Type of Position Fix	mode	numeric	0=Not Available; 1=nofix; 2=2D; 3=3D
Latitude Error Estimate	epx	numeric	meters
Longitude Error Estimate	epy	numeric	meters
Altitude Error Estimate	epv	numeric	meters
Speed of ascent	climb	numeric	meters per second (Down - Positive)
Direction Error Estimate	epd	numeric	Degrees (0 - 360)
Climb/Sink Error Estimate	epc	numeric	meters per second (Down - Positive)

Example:

*{"class":"TPV","time":"2017-05-15T10:30:43.123Z","ept":500,
"track":123.45,"lat":12.12345,"lon":-12.12345,"alt":12345.12,
"mode":3,"epx":12.12,"epy":12.12,"epv":12.12,"climb":-4.234, "epd":12.345,"epc":12.345}*

Additional information regarding the stability, error, and synchronization of the clock is provided in the STATUS class. Additional information regarding the GPS position status and type is provided in the STATUS class. Estimated Timestamp Error (ept) shall only be included when the clock has converged to the PPS.

A.2.6 ATT

The ATT message contains the acceleration, attitude, and heading data from the INS. The ATT message is distributed by the MAIM at 10Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	ATT

X component of Acceleration	acc_x	numeric	meters per second squared
Y component of Acceleration	acc_y	numeric	meters per second squared
Z component of Acceleration	acc_z	numeric	meters per second squared
X component of Gyroscope	gyro_x	numeric	radians per second
Y component of Gyroscope	gyro_y	numeric	radians per second
Z component of Gyroscope	gyro_z	numeric	radians per second
Temperature at Sensor	temp	numeric	degrees centigrade
X component of Magnetic Field Strength	mag_x	numeric	Atomic Units (a.u)
Y component of Magnetic Field Strength	mag_y	numeric	Atomic Units (a.u)
Z component of Magnetic Field Strength	mag_z	numeric	Atomic Units (a.u)
Roll	roll	numeric	Radians (-3.142 to +3.142)
Pitch	pitch	numeric	Radians (-1.571 to +1.571)
Yaw	yaw	numeric	Radians (-3.142 to +3.142)
Heading	heading	numeric	Degrees from True North (0 to 360)

Example:

{"class":"ATT","acc_x":3.123,"acc_y":2.123,"acc_z":-1.456,"gyro_x":1.456, "gyro_y":2.789,"gyro_z":3.567,"temp":12.12,"mag_x":123.456,"mag_y":234.789, "mag_z":24.223,"roll":3.001,"pitch":-0.345,"yaw":-2.789,"heading":123.45}

Additional information regarding the status of the Accelerometer, Gyroscope, Magnetometer, and Internal Kalman Filter is provided in the STATUS class.

A.2.7 SKY

The SKY message contains the uncertainty estimate from the INS. The SKY message is distributed by the MAIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	SKY
Time	time	string	ISO8601 Format UTC
Horizontal Dilution of Precision	hdop	numeric	Dimensionless

Example:

{"class":"SKY","time":"2017-05-15T10:30:43.123Z","hdop":6.3}

A.2.8 ADDL

The ADDL message contains the GPS-based north, east, and down velocities and their error estimates from the INS. The ADDL message is distributed by the MAIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	ADDL
Device UP Time	up	numeric	microseconds
GPS Time of Week	tow	numeric	milliseconds
Undulation - Altitude difference between the geoid and the Ellipsoid	und	numeric	Meters (WGS-84 Altitude - MSL Altitude)
GPS North Velocity	gveln	numeric	meters per second (North Positive)
GPS East Velocity	gvele	numeric	meters per second (East Positive)
GPS Down Velocity	gveld	numeric	meters per second (Down Positive)

North Velocity Error Estimate	epn	numeric	meters per second
East Velocity Error Estimate	epe	numeric	meters per second
Down Velocity Error Estimate	epd	numeric	meters per second
Number of space vehicles	nsv	numeric	satellites

Example:

*{"class":"ADDL","up":1345786201,"tow":375218453,"und":3.7,"gveln":-175.135,
"gvele":-22.0,"gveld":-4.234,"epn":4.75,"epe":1.66,"epd":0.37,"nsv":7}*

A.3 State over Serial: sbgECom Binary Protocol Messages

The sbgECom Binary protocol is the native format emitted by the SBG Ellipse-N INS. The MAIM distributes state data over serial utilizing the sbgECom messages:

- SBG_ECOM_CMD_INFO (04),
- SBG_ECOM_LOG_STATUS (01)
- SBG_ECOM_LOG_UTC_TIME (02)
- SBG_ECOM_LOG_IMU_DATA (03)
- SBG_ECOM_LOG_MAG (04),
- SBG_ECOM_LOG_EKF_EULER (06)
- SBG_ECOM_LOG_EKF_NAV (08)
- SBG_ECOM_LOG_GPS1_VEL (13)
- SBG_ECOM_LOG_GPS1_POS (14)
- SBG_ECOM_LOG_PRESSURE (36)

Sections A.3.3 - A.3.12 define the messages listed in the message IDs above.

A.3.1 Type Definitions

The following table defines the variable types use by the sbgECom Binary protocol.

Type	Description
Mask	This type defines an unsigned integer variable used to store a set of bit-masks. This type has no pre-defined size and user should refer to each occurrence for corresponding size.
Enum	This type defines a group of several bits defining a list of possible states. Each value corresponds to a state. This type has no pre-defined size and user.
bool	8 bits boolean, 0x00 is FALSE, 0x01 is TRUE uint8 8 bits unsigned integer
int8	8 bits signed integer
uint16	16 bits unsigned integer
int16	16 bits signed integer
uint32	32 bits unsigned integer
int32	32 bits signed integer
uint64	64 bits unsigned integer
int64	64 bits signed integer
float	32 bits single floating point, standard IEEE 754 format
double	64 bits double floating point, standard IEEE 754 format

void[]	Data buffer, with variable length
string	Standard, null terminated ASCII string. String max size is defined in the message

A.3.2 Frame Definition

All frames sent through the sbgECom protocol have a common format. The following table defines the format.

Field	SYNC 1	SYNC 2	MSG	CLASS	LEN	DATA	CRC	ETX
Size (bytes)	1	1	1	1	2	0 to 4086	2	1
Description	Sync. word	Sync. word	Message ID	Message class	Length of DATA section	Payload data	16 bit CRC	End of frame
Value	0xFF	0x5A	-	-	-	-	-	0x33

The LEN field contains the DATA section size in bytes. A 0 LEN field implies that no DATA section is present. Maximum length value is 4086. The whole protocol is defined in LITTLE endian, so LEN and CRC fields are written directly in little endian

Sections A.3.3 through A.3.12 define the various payload data messages. The CRC is defined in Section A.3.13.

A.3.3 SBG_ECOM_CMD_INFO (04)

The SBG_ECOM_CMD_INFO (04) message provides information regarding the attached SBG device, including name, software and hardware versions, and date of the last calibration. The SBG_ECOM_CMD_INFO (04) message is distributed by the MAIM only when issued to test for INS presence.

Field	Description	Unit	Format	Size	Offset
productCode	Human readable Product Code	-	string	32	0
serialNumber	Device serial number	-	uint32	4	32
calibationRev	Calibration data revision	-	uint32	4	36
calibrationYear	Device Calibration Year	-	uint16	2	40
calibrationMonth	Device Calibration Month	-	uint8	1	42
calibrationDay	Device Calibration Day	-	uint8	1	43
hardwareRev	Device hardware revision	-	uint32	4	44
firmwareRev	Firmware revision	-	uint32	4	48
				Total size	52

A.3.4 SBG_ECOM_LOG_STATUS (01)

The SBG_ECOM_LOG_STATUS (01) message provides the general, communications, and aiding status information for the attached SBG device. The SBG_ECOM_LOG_STATUS (01) message is distributed by the MAIM at 1Hz.

Message name (ID)	SBG_ECOM_LOG_STATUS (01)				
Field	Description	Unit	Format	Size	Offset
TIME STAMP	Time since sensor is powered up	µs	uint32	4	0
GENERAL STATUS	General status bitmask and enums	-	uint16	2	4
RESERVED 1	Reserved status field for future use	-	uint16	2	6
COM STATUS	Communication status bitmask and enums.	-	uint32	4	8
AIDING STATUS	Aiding equipment status bitmask and enums.	-	uint32	4	12
RESERVED 2	Reserved status field for future use	-	uint32	4	16
RESERVED 3	Reserved field for future use	-	uint16	2	20
UP TIME	System up time since the power on.	s	uint32	4	22
				Total size	26

A.3.4.1 GENERAL_STATUS

Description: General status bitmask and enumerations

Bit	Name	Description
0	SBG_ECOM_GENERAL_MAIN_POWER_OK	Set to 1 when main power supply is OK.
1	SBG_ECOM_GENERAL_IMU_POWER_OK	Set to 1 when IMU power supply is OK.
2	SBG_ECOM_GENERAL_GPS_POWER_OK	Set to 1 when GPS power supply is OK.
3	SBG_ECOM_GENERAL_SETTINGS_OK	Set to 1 if settings were correctly loaded.
4	SBG_ECOM_GENERAL_TEMPERATURE_OK	Set to 1 when temperature is within limits.
5	SBG_ECOM_GENERAL_DATALOGGER_OK	Set to 1 the data-logger is working correctly
6	SBG_ECOM_GENERAL_CPU_OK	Set to 1 if the CPU headroom is correct

A.3.4.2 COM_STATUS

Description: Communication status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_PORTA_VALID	Set to 0 in case of low level communication error.
1	SBG_ECOM_PORTB_VALID	Set to 0 in case of low level communication error.
2	SBG_ECOM_PORTC_VALID	Set to 0 in case of low level communication error.
3	SBG_ECOM_PORTD_VALID	Set to 0 in case of low level communication error.
4	SBG_ECOM_PORTE_VALID	Set to 0 in case of low level communication error.
5	SBG_ECOM_PORTA_RX_OK	Set to 0 in case of saturation on PORT A input
6	SBG_ECOM_PORTA_TX_OK	Set to 0 in case of saturation on PORT A output
7	SBG_ECOM_PORTB_RX_OK	Set to 0 in case of saturation on PORT B input
8	SBG_ECOM_PORTB_TX_OK	Set to 0 in case of saturation on PORT B output
9	SBG_ECOM_PORTC_RX_OK	Set to 0 in case of saturation on PORT C input
10	SBG_ECOM_PORTC_TX_OK	Set to 0 in case of saturation on PORT C output
11	SBG_ECOM_PORTD_RX_OK	Set to 0 in case of saturation on PORT D input
12	SBG_ECOM_PORTD_TX_OK	Set to 0 in case of saturation on PORT D output
13	SBG_ECOM_PORTE_RX_OK	Set to 0 in case of saturation on PORT E input
14	SBG_ECOM_PORTE_TX_OK	Set to 0 in case of saturation on PORT E output
15	SBG_ECOM_ETH0_RX_OK	Set to 0 in case of saturation on PORT ETH0 input
16	SBG_ECOM_ETH0_TX_OK	Set to 0 in case of saturation on PORT ETH0 output
17	SBG_ECOM_ETH1_RX_OK	Set to 0 in case of saturation on PORT ETH1 input
18	SBG_ECOM_ETH1_TX_OK	Set to 0 in case of saturation on PORT ETH1 output
19	SBG_ECOM_ETH2_RX_OK	Set to 0 in case of saturation on PORT ETH2 input
20	SBG_ECOM_ETH2_TX_OK	Set to 0 in case of saturation on PORT ETH2 output
21	SBG_ECOM_ETH3_RX_OK	Set to 0 in case of saturation on PORT ETH3 input
20	SBG_ECOM_ETH3_TX_OK	Set to 0 in case of saturation on PORT ETH3 output
23	SBG_ECOM_ETH4_RX_OK	Set to 0 in case of saturation on PORT ETH4 input
24	SBG_ECOM_ETH4_TX_OK	Set to 0 in case of saturation on PORT ETH4 output
25	SBG_ECOM_CAN_RX_OK	Set to 0 in case of saturation on CAN Bus output buffer
26	SBG_ECOM_CAN_TX_OK	Set to 0 in case of saturation on CAN Bus input buffer

27-29	SBG_ECOM_CAN_BUS	Enum Define the CAN Bus status (see below)

A.3.4.2.1 CAN BUS Status Enumeration Values

Value	Name	Description
0x0	SBG_ECOM_CAN_BUS_OFF	Bus OFF operation due to too much errors
0x1	SBG_ECOM_CAN_BUS_TX_RX_ERR	Transmit or received error
0x2	SBG_ECOM_CAN_BUS_OK	The CAN bus is working correctly.
0x3	SBG_ECOM_CAN_BUS_ERRORA	General error has occurred on the CAN bus

A.3.4.3 AIDING_STATUS

Description: Aiding equipment status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_AIDING_GPS1_POS_RECV	Set to 1 valid GPS 1 position data is received
1	SBG_ECOM_AIDING_GPS1_VEL_RECV	Set to 1 valid GPS 1 velocity data is received
2	SBG_ECOM_AIDING_GPS1_HDT_RECV	Set to 1 valid GPS 1 true heading data is received
3	SBG_ECOM_AIDING_GPS1_UTC_RECV	Set to 1 valid GPS 1 UTC time data is received
4	SBG_ECOM_AIDING_GPS2_POS_RECV	Set to 1 valid GPS 2 position data is received
5	SBG_ECOM_AIDING_GPS2_VEL_RECV	Set to 1 valid GPS 2 velocity data is received
6	SBG_ECOM_AIDING_GPS2_HDT_RECV	Set to 1 valid GPS 2 true heading data is received
7	SBG_ECOM_AIDING_GPS2_UTC_RECV	Set to 1 valid GPS 2 UTC time data is received
8	SBG_ECOM_AIDING_MAG_RECV	Set to 1 valid Magnetometer data is received
9	SBG_ECOM_AIDING_ODO_RECV	Set to 1 Odometer pulse is received
10	SBG_ECOM_AIDING_DVL_RECV	Set to 1 valid DVL data is received
11	SBG_ECOM_AIDING_USBL_RECV	Set to 1 valid USBL data is received
12	SBG_ECOM_AIDING_EM_LOG_RECV	Set to 1 valid EM Log data is received
13	SBG_ECOM_AIDING_PRESSURE_RECV	Set to 1 valid Pressure sensor data is received

A.3.5 SBG_ECOM_LOG_UTC_TIME (02)

The SBG_ECOM_LOG_UTC_TIME (02) message provides UTC time reference. This frame also provides a time correspondence between the device TIME_STAMP value and the actual UTC Time. Thus, this frame can be used to timestamp all data to an absolute UTC or GPS time reference. The SBG_ECOM_LOG_UTC_TIME (02) message is distributed by the MAIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_UTC_TIME (02)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
CLOCK_STATUS	General UTC time and clock sync status	-	uint16	2	4
YEAR	Year	year	uint16	2	6
MONTH	Month in Year [1 ... 12]	month	uint8	1	8
DAY	Day in Month [1 ... 31]	d	uint8	1	9
HOUR	Hour in day [0 ... 23]	h	uint8	1	10
MIN	Minute in hour [0 ... 59]	min	uint8	1	11
SEC	Second in minute [0 ... 60] Note 60 is when a leap second is added.	s	uint8	1	12
NANOSEC	Nanosecond of second.	ns	uint32	4	13
GPS_TOW	GPS Time of week	ms	uint32	4	17
				Total size	21

A.3.5.1 CLOCK_STATUS

Description: General UTC time and clock sync status

Bit	Name	Description
0	SBG_ECOM_CLOCK_STABLE_INPUT	Set to 1 when a clock input can be used to synchronize the internal clock.
1-4	SBG_ECOM_CLOCK_STATUS	Define the internal clock estimation status (see below)
5	SBG_ECOM_CLOCK_UTC_SYNC	Set to 1 if UTC time is synchronized with a PPS
6-9	SBG_ECOM_CLOCK_UTC_STATUS	Define the UTC validity status (see below).

A.3.5.1.1 Clock Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_CLOCK_ERROR	An error has occurred on the clock estimation
0x1	SBG_ECOM_CLOCK_FREE_RUNNING	The clock is only based on the internal crystal
0x2	SBG_ECOM_CLOCK_STEERING	A PPS has been detected and the clock is converging to it
0x3	SBG_ECOM_CLOCK_VALID	The clock has converged to the PPS and is within 500ns

A.3.5.1.2 UTC Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_UTC_INVALID	The UTC time is not known, we are just propagating the UTC time internally
0x1	SBG_ECOM_UTC_NO_LEAP_SEC	We have received valid UTC time information but we don't have the leap seconds information
0x2	SBG_ECOM_UTC_VALID	We have received valid UTC time data with valid leap seconds.

A.3.6 SBG_ECOM_LOG_IMU_DATA (03)

The SBG_ECOM_LOG_IMU_DATA (03) message provides status, accelerations and velocities from the IMU. The SBG_ECOM_LOG_IMU_DATA (03) message is distributed by the MAIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_IMU_DATA (03)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
IMU_STATUS	IMU Status bitmask	-	uint16	2	4
ACCEL_X	Filtered Accelerometer – X axis	m/s²	float	4	6
ACCEL_Y	Filtered Accelerometer – Y axis	m/s²	float	4	10
ACCEL_Z	Filtered Accelerometer – Z axis	m/s²	float	4	14
GYRO_X	Filtered Gyroscope – X axis	rad/s	float	4	18
GYRO_Y	Filtered Gyroscope – Y axis	rad/s	float	4	22
GYRO_Z	Filtered Gyroscope – Z axis	rad/s	float	4	26
TEMP	Internal Temperature	°C	float	4	30
DELTA_VEL_X	Sculling output – X axis	m/s²	float	4	34
DELTA_VEL_Y	Sculling output – Y axis	m/s²	float	4	38
DELTA_VEL_Z	Sculling output – Z axis	m/s²	float	4	42
DELTA_ANGLE_X	Coning output – X axis	rad/s	float	4	46
DELTA_ANGLE_Y	Coning output – Y axis	rad/s	float	4	50
DELTA_ANGLE_Z	Coning output – Z axis	rad/s	float	4	54
				Total size	58

A.3.6.1 IMU_STATUS

Description: IMU Status bitmask

Bit	Name	Description
0	SBG_ECOM_IMU_COM_OK	Set to 1 the communication with the IMU is ok.the internal clock.
1	SBG_ECOM_IMU_STATUS_BIT	Set to 1 if internal IMU passes Built In Test (Calibration, CPU)
2	SBG_ECOM_IMU_ACCEL_X_BIT	Set to 1 accelerometer X passes Built In Test
3	SBG_ECOM_IMU_ACCEL_Y_BIT	Set to 1 accelerometer Y passes Built In Test
4	SBG_ECOM_IMU_ACCEL_Z_BIT	Set to 1 accelerometer Z passes Built In Test
5	SBG_ECOM_IMU_GYRO_X_BIT	Set to 1 gyroscope X passes Built In Test
6	SBG_ECOM_IMU_GYRO_Y_BIT	Set to 1 gyroscope Y passes Built In Test
7	SBG_ECOM_IMU_GYRO_Z_BIT	Set to 1 gyroscope Z passes Built In Test
8	SBG_ECOM_IMU_ACCELS_IN_RANGE	Set to 1 accelerometers within operating range
9	SBG_ECOM_IMU_GYROS_IN_RANGE	Set to 1 gyroscopes are within operating range

A.3.7 SBG_ECOM_LOG_MAG (04)

The SBG_ECOM_LOG_MAG (04) message provides magnetometer and associated accelerometer data. When an internal magnetometer is used, the internal accelerometer is also provided. The SBG_ECOM_LOG_MAG (04) message is distributed by the MAIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_MAG (04)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
MAG_STATUS	Magnetometer status bitmask	-	uint16	2	4
MAG_X	Magnetometer output – X axis	a.u	float	4	6
MAG_Y	Magnetometer output – Y axis	a.u	float	4	10
MAG_Z	Magnetometer output – Z axis	a.u	float	4	14
ACCEL_X	Accelerometer output – X axis	m/s²	float	4	18
ACCEL_Y	Accelerometer output – Y axis	m/s²	float	4	22
ACCEL_Z	Accelerometer output – Z axis	m/s²	float	4	26
				Total size	30

A.3.7.1 MAG_STATUS

Description: Magnetometer status bitmask

Bit	Name	Description
0	SBG_ECOM_MAG_MAG_X_BIT	Set to 1 magnetometer X passed the self test.
1	SBG_ECOM_MAG_MAG_Y_BIT	Set to 1 magnetometer Y passed the self test.
2	SBG_ECOM_MAG_MAG_Z_BIT	Set to 1 magnetometer Z passed the self test.
3	SBG_ECOM_MAG_ACCEL_X_BIT	Set to 1 accelerometer X passed the self test.
4	SBG_ECOM_MAG_ACCEL_Y_BIT	Set to 1 accelerometer Y passed the self test.
5	SBG_ECOM_MAG_ACCEL_Z_BIT	Set to 1 accelerometer Z passed the self test.
6	SBG_ECOM_MAG_MAGS_IN_RANGE	Set to 1 magnetometer is not saturated
7	SBG_ECOM_MAG_ACCELS_IN_RANGE	Set to 1 accelerometer is not saturated
8	SBG_ECOM_MAG_CALIBRATION_OK	Set to 1 magnetometer seems to be calibrated

A.3.8 SBG_ECOM_LOG_EKF_EULER (06)

The SBG_ECOM_LOG_EKF_EULER (06) message provides the computed orientation of the IMU in an Euler angles format. The SBG_ECOM_LOG_EKF_EULER (06) message is distributed by the MAIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_EKF_EULER (06)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
ROLL	Roll angle	rad	float	4	4
PITCH	Pitch angle	rad	float	4	8
YAW	Yaw angle (heading)	rad	float	4	12
ROLL_ACC	1σ Roll angle accuracy	rad	float	4	16
PITCH_ACC	1σ Pitch angle accuracy	rad	float	4	20
YAW_ACC	1σ Yaw angle accuracy	rad	float	4	24
SOLUTION_STATUS	Global solution status. See SOLUTION_STATUS definition for more details.	-	uint32	4	28
				Total size	32

A.3.8.1 SOLUTION_STATUS

Description: Global solution status.

Bit	Name	Description
0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)
12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)
25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.3.8.1.1 SOLUTION MODE Enumeration

Value	Name	Description
0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.3.9 SBG_ECOM_LOG_EKF_NAV (08)

The SBG_ECOM_LOG_EKF_NAV (08) message provides velocity in a NED coordinate system, position (Latitude, Longitude, Altitude), and associated accuracy parameters. The SBG_ECOM_LOG_EKF_NAV (08) message is distributed by the MAIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_EKF_NAV (08)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
VELOCITY_N	Velocity in North direction	m/s	float	4	4
VELOCITY_E	Velocity in East direction	m/s	float	4	8
VELOCITY_D	Velocity in Down direction	m/s	float	4	12
VELOCITY_N_ACC	1σ Velocity in North direction accuracy	m/s	float	4	16
VELOCITY_E_ACC	1σ Velocity in East direction accuracy	m/s	float	4	20
VELOCITY_D_ACC	1σ Velocity Down direction accuracy	m/s	float	4	24
LATITUDE	Latitude	°	double	8	28
LONGITUDE	Longitude	°	double	8	36
ALTITUDE	Altitude above Mean Sea Level	m	double	8	44
UNDULATION	Altitude difference between the geoid and the Ellipsoid. (WGS-84 Altitude = MSL Altitude + undulation)	m	float	4	52
LATITUDE_ACC	1σ Latitude accuracy	m	float	4	56
LONGITUDE_ACC	1σ Longitude accuracy	m	float	4	60
ALTITUDE_ACC	1σ Vertical Position accuracy	m	float	4	64
SOLUTION_STATUS	Global solution status. See SOLUTION_STATUS definition for more details.	-	uint32	4	68
				Total size	72

A.3.9.1 SOLUTION_STATUS

Description: Global solution status.

Bit	Name	Description
0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)
12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)

25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.3.9.1.1 SOLUTION MODE Enumeration

Value	Name	Description
0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.3.10 SBG_ECOM_LOG_GPS1_VEL (13)

The SBG_ECOM_LOG_GPS1_VEL (13) message provides velocity and course information from the primary or secondary GNSS receiver. The time stamp is not aligned on main loop but instead of that, it dates the actual GNSS velocity data. The SBG_ECOM_LOG_GPS1_VEL (13) message is distributed by the MAIM at 5Hz.

Message name (ID)	SBG_ECOM_LOG_GPS1_VEL (13)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
GPS_VEL_STATUS	GPS velocity fix and status bitmask	-	uint32	4	4
GPS_TOW	GPS Time of Week	ms	uint32	4	8
VEL_N	Velocity in North direction	m/s	float	4	12
VEL_E	Velocity in East direction	m/s	float	4	16
VEL_D	Velocity in Down direction	m/s	float	4	20
VEL_ACC_N	1σ Accuracy in North direction	m/s	float	4	24
VEL_ACC_E	1σ Accuracy in East direction	m/s	float	4	28
VEL_ACC_D	1σ Accuracy in Down direction	m/s	float	4	32
COURSE	True direction of motion over ground (0 to 360°)	°	float	4	36
COURSE_ACC	1σ course accuracy (0 to 360°).	°	float	4	40
				Total size	44

A.3.10.1 GPS_VEL_STATUS

Description: GPS velocity fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_VEL_STATUS	The raw GPS velocity status (see the 5 below)
6-11	SBG_ECOM_GPS_VEL_TYPE	The raw GPS velocity type (see the 6 below)

A.3.10.1.1 Velocity Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_VEL_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_VEL_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_VEL_LIMIT	Velocity limit exceeded

A.3.10.1.2 Velocity Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_NO_SOLUTION	No valid velocity solution available
0x1	SBG_ECOM_VEL_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_VEL_DOPPLER	A Doppler velocity has been computed
0x3	SBG_ECOM_VEL_DIFFERENTIAL	A velocity has been computed between two positions

A.3.11 SBG_ECOM_LOG_GPS1_POS (14)

The SBG_ECOM_LOG_GPS1_POS (14) message provides position information from the primary or secondary GNSS receiver. The time stamp is not aligned on main loop but instead of that, it dates the actual GPS position data. The SBG_ECOM_LOG_GPS1_POS (14) message is distributed by the MAIM at 5Hz.

Message name (ID)	SBG_ECOM_LOG_GPS1_POS (14)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
GPS_POS_STATUS	GPS position fix and status bitmask	-	uint32	4	4
GPS_TOW	GPS Time of Week	ms	uint32	4	8
LAT	Latitude, positive North	°	double	8	12
LONG	Longitude, positive East	°	double	8	20
ALT	Altitude Above Mean Sea Level	m	double	8	28
UNDULATION	Altitude difference between the geoid and the Ellipsoid (WGS-84 Altitude – MSL Altitude)	m	float	4	36
POS_ACC_LAT	1σ Latitude Accuracy	m	float	4	40
POS_ACC_LONG	1σ Longitude Accuracy	m	float	4	44
POS_ACC_ALT	1σ Altitude Accuracy	m	float	4	48
NUM_SV_USED	Number of space vehicles used in GNSS solution	-	uint8	1	52
BASE_STATION_ID	ID of the DGPS/ RTK base station in use	-	uint16	2	54
DIFF_AGE	Differential data age	0.01 s	uint16	2	56
				Total size	57

A.3.11.1 GPS_POS_STATUS

Description: GPS position fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_POS_STATUS	The raw GPS position status (see the 7 below)
6-11	SBG_ECOM_GPS_POS_TYPE	The raw GPS position type (see the 8 below)
12	SBG_ECOM_GPS_POS_GPS_L1_USED	Set to 1 if GPS L1 is used in the solution
13	SBG_ECOM_GPS_POS_GPS_L2_USED	Set to 1 if GPS L2 is used in the solution
14	SBG_ECOM_GPS_POS_GPS_L5_USED	Set to 1 if GPS L5 is used in the solution
15	SBG_ECOM_GPS_POS_GLO_L1_USED	Set to 1 if GLONASS L1 is used in the solution
16	SBG_ECOM_GPS_POS_GLO_L2_USED	Set to 1 if GLONASS L2 is used in the solution

A.3.11.1.1 POS Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_POS_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_POS_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_POS_HEIGHT_LIMIT	The height limit has been exceeded

A.3.11.1.2 POS Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_NO_SOLUTION	No valid solution available
0x1	SBG_ECOM_POS_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_POS_SINGLE	Single point solution position
0x3	SBG_ECOM_POS_PSRDIFF	Standard Pseudorange Differential Solution (DGPS)
0x4	SBG_ECOM_POS_SBAS	SBAS satellite used for differential corrections
0x5	SBG_ECOM_POS_OMNISTAR	Omnistar VBS Position (L1 sub-meter)
0x6	SBG_ECOM_POS_RTK_FLOAT	Floating RTK ambiguity solution (20 cms RTK)
0x7	SBG_ECOM_POS_RTK_INT	Integer RTK ambiguity solution (2 cms RTK)
0x8	SBG_ECOM_POS_PPP_FLOAT	Precise Point Positioning with float ambiguities
0x9	SBG_ECOM_POS_PPP_INT	Precise Point Positioning with fixed ambiguities
0x10	SBG_ECOM_POS_FIXED	Fixed location solution position

A.3.12 SBG_ECOM_LOG_PRESSURE (36)

The SBG_ECOM_LOG_PRESSURE (36) message provides the altitude above reference level and pressure. Altitude is referenced to a standard 1013 hPa zero level pressure. The SBG_ECOM_LOG_PRESSURE (36) message is distributed by the MAIM at 1Hz.

Message name (ID)	SBG_ECOM_LOG_PRESSURE (36)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	μs	uint32	4	0
PRESSURE_STATUS	Altimeter status	-	uint16	2	4
PRESSURE	Pressure measured by the sensor	Pa	float	4	6
ALTITUDE	Altitude computed from barometric almtimeter	m	float	4	10
				Total size	14

A.3.12.1 PRESSURE_STATUS

Description: Pressure status bitmask

Bit	Name	Description
0	SBG_ECOM_PRESSURE_VALID	Set to 1 altimeter was correctly initialized
1	SBG_ECOM_ALTITUDE_VALID	Set to 1 if the altitude output is valid

A.3.13 CRC Calculation

The CRC field is computed on [MSG, CLASS, LEN, DATA] fields. The sbgECom protocol uses a 16-bit CRC. This CRC uses a polynomial value of 0x8408.

SBG provides an SDK for use in developing applications to interface with their devices. In the SDK is the sbgECom library source code for computing the CRC. It is in the file misc/sbgCrc.c. The SDK implementation uses a lookup table to optimize the speed of the CRC computation.

A non-optimized, C source code algorithm for computing the CRC is provided below.

```
/*!
*	Compute a CRC for a specified buffer.
*	\param[in] pBuffer Read only buffer to compute the CRC on.
*	\param[in] bufferSize Buffer size in bytes.
```

```
*       \return The computed 16 bit CRC.
*/
uint16 calcCRC(const void *pBuffer, uint16 bufferSize)
{
const uint8 *pBytesArray = (const uint8*)pBuffer; uint16 poly = 0x8408;
uint16 crc = 0; uint8 carry; uint8 i_bits; uint16 j;

for (j =0; j < bufferSize; j++)
{
crc = crc ^ pBytesArray[j];
for (i_bits = 0; i_bits < 8; i_bits++)
{
carry = crc & 1; crc = crc / 2; if (carry)
{
crc = crc^poly;
}
}
}
return crc;
```

A.3.14 Additional Information

Further, complete information regarding the sbgECom Binary Protocol is provided in the Ellipse, Ekinox & Apogee, High performance Inertial Sensors, Firmware Manual available from SBG.

A.4 State over Serial: SBG NMEA Protocol Messages

The implemented NMEA sentences are based on NMEA 0183 Version 4.1 and will be contained in the payload section of the frame described in Section A.3.2. Each data field is comma separated. Sometimes, a field cannot be defined and can be left empty.

From MAIM developers, the NMEA frames are identified in the frame header by the message class SBG_ECOM_CLASS_LOG_NMEA_1 (0x03). As with the binary messages, any other messages received from the SBG can be dropped.

A.4.1.1 SBG_ECOM_LOG_NMEA_GGA (0x00)

The GGA log provides detailed Kalman filtered position, altitude and accuracy data. The SBG_ECOM_LOG_NMEA_GGA message is distributed by the MAIM at 1Hz.

Field	Name	Format	Description
0	$##GGA	string	Message ID – GGA frame
1	Time	hhmmss.ss	UTC Time, current time
2	Latitude	ddmm.mmmmm	Latitude: degree + minutes
3	N/S	char	North / South indicator
4	Longitude	dddmm.mmmmm	Longitude: degree + minutes
5	E/W	char	East / West indicator
6	Quality	i	Fix status (see definition in Quality indicators section)
7	SV used	ii	Number of satellites used in solution
8	Horizontal DOP	ff.f	Horizontal dilution of precision, 1 (ideal) to > 20 (poor)
9	Altitude MSL	ffff.fff	Altitude above Mean Sea Level in meters
10	M	M	Altitude unit (Meters) fixed field.
11	Undulation	fff.fff	Geoidal separation between WGS-84 and MSL in meters).
12	M	M	Units for geoidal separation (Meters) fixed field.
13	Diff. Age	-	Age of differential corrections. Not filled by the device, always empty.
14	Diff. station ID	-	Differential station id. Not filled by the device, always empty.
15	Check sum	*cs	Xor of all previous bytes except $
16	End of frame	<CR><LF>	Carriage return and line feed

Example:

*$GPGGA,000010.00,4852.10719,N,00209.42313,E,0,00,0.0,-44.7,M,0.0,M,,,*63<CR><LF>*

Integer numbers are represented using the char 'i'. The number of 'i' chars define the maximum number of digits that can be used to represent this integer. Decimal numbers are represented by the char 'f'. The char '.' is used to separate the integer part from the decimal one. The number of 'f' chars define the maximum number of digits that can be used to represent both the integer and decimal part.

Appendix B. **MP-ScanEagle Block D UAS**

This appendix details the MP implementation on the ScanEagle Block D UAS.

B.1 Overview

The MP-compliant ScanEagle UAS can support up to 3U of payloads in a custom aft slice. UAS power capacity restricts the number of concurrent payloads to a maximum of two. The MP-compliant ScanEagle UAS is equipped to support two wingtip array mounts, one wingtip down look 2-pt mount, one slice 45° right facing 4-pt mount, one slice up look 2-pt mount, and one slice down look 2-pt mount. A platform-specific MAIM and the MP-compliant INS are both required for this UAS.

B.1.1 MP Architecture

Figure B-1 depicts the architectural layout of the MP implementation on the ScanEagle UAS.

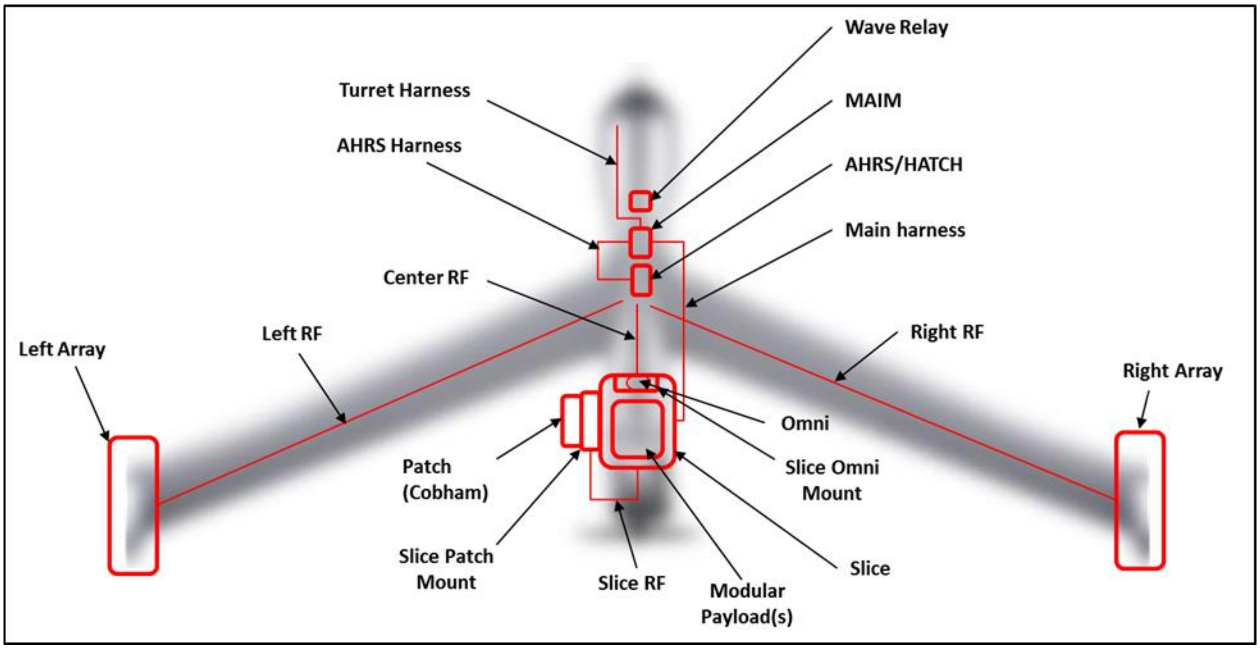


Figure B-1. Architectural Layout for MP-ScanEagle

B.1.2 Compliance / Capability Summary

Table B-1 provides a top-level summary of the MP compliance and capability on the ScanEagle UAS.

Table B-1. MP-ScanEagle Compliance and Capability

MP Components	Location
MAIM	Avionics Module – upper card slot
Primary Mount	Aft Slice
INS	Center Wing Hatch

Payload Capacity		Description	
Number of Payloads		2	
Available Payload Power		65.7W total* (requires disabling non-critical flight hardware)	
Available Payload Volume		3U	
Available Payload Weight		1400g	
Primary Mount			
Mounting Method		Rack	
Cooling Method		Convection	
Antenna Mounts	**Qty**	**Location**	**Orientation**
Two-point	2	Left Wingtip Aft Slice	Down Up, Side, Down and 45°
Four-points	1	Aft Slice	Side and 45°
Array	2	Left and Right Wingtips	Aft

*power shown is for ScanEagle Block D. Higher payload power available on ScanEagle Block E forward

B.1.3 System Diagram

Figure B-2 details the system diagram for the MP-ScanEagle UAS. MP-specific additions are highlighted in teal.

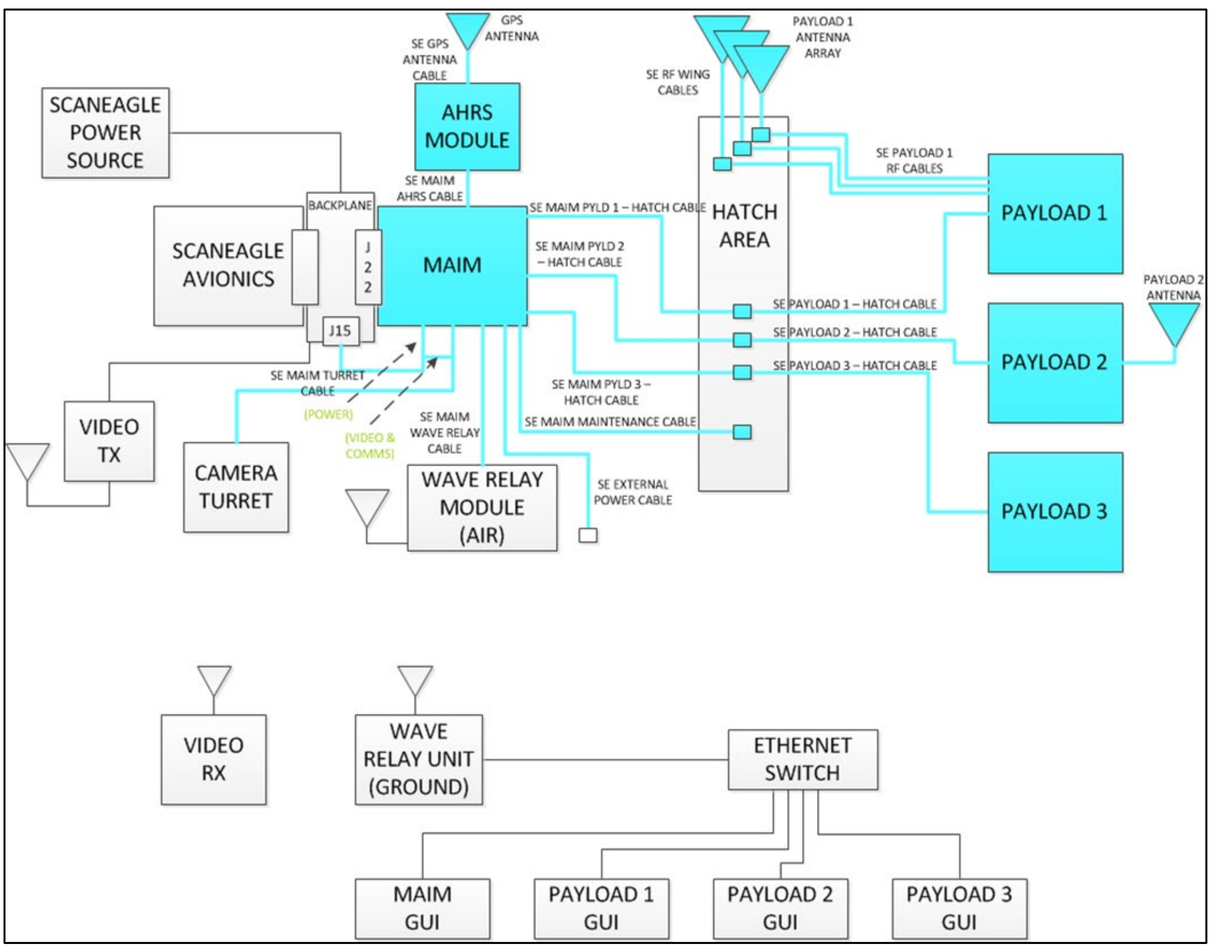


Figure B-2. System Diagram for MP-ScanEagle

B.2 Platform Weight and Power Budgets

The ScanEagle is a fairly SWAP-constrained Group 2 UAS. Moreover, the ScanEagle is constrained in each SWAP attribute.

B.2.1 Weight Budget

Discounting payloads (and corresponding antennas and antenna adaptors), the core MP architecture (of MAIM, Primary Mount assembly, INS, GPS antenna assembly, and wire harnesses) adds 1.7kg to the ScanEagle. This leaves an allowance of 1.4kg for MP-compliant payloads, while maintaining the platform's primary FMV turret.

B.2.2 Power Budget

The notional power available to support the MP architecture is 30.7W for ScanEagle Block D. The ScanEagle Block D is an early adapter of the MP standard, higher payload power is available on ScanEagle Block E forward. To allocate this much power, both the battery charger and landing/strobe lights need to be disabled. *Note: the battery charger can only be turned off once fully charged; typical charge time is 10-15 minutes.*

An additional 35W of power can be allocated to MP components by securing power to other non-critical flight hardware, specifically the transponder and the turret.

B.3 MAIM

The MAIM is a custom circuit board installed in the ScanEagle Avionics Module, filling the slot typically used by the Power Distribution Board, which it physically and functionally replaces.

B.3.1 Mechanical Description

The MAIM board is 6.25in x 5in x 0.73in and weighs 192g. Figure B-3 shows the MAIM.

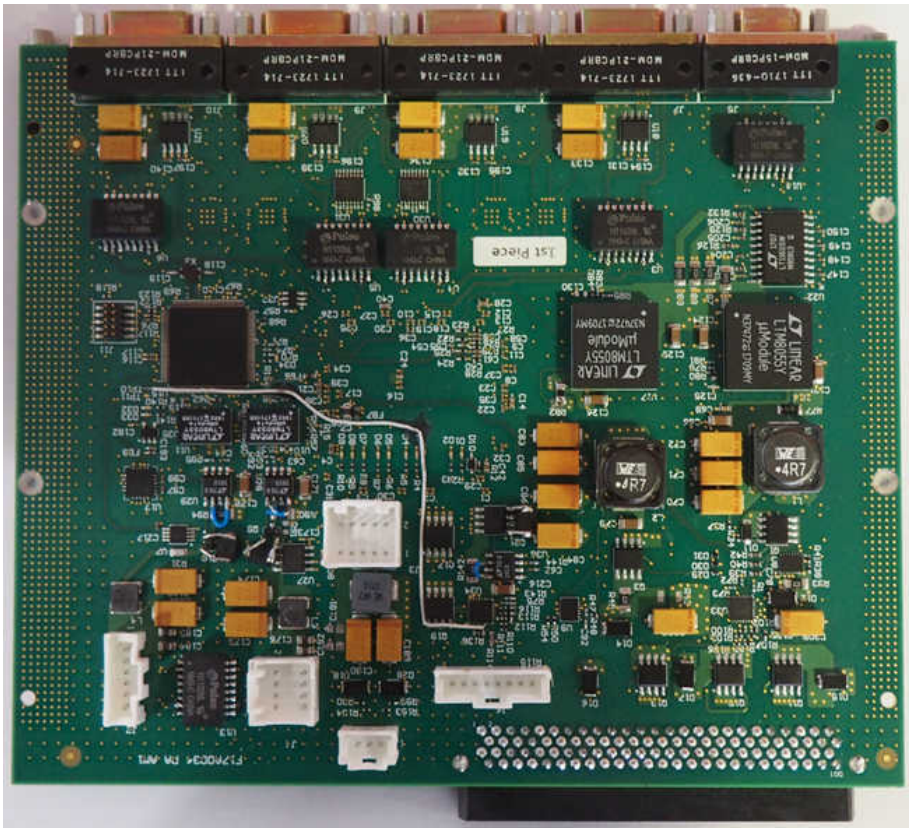


Figure B-3. MAIM for ScanEagle

B.3.2 Electrical Description

The MAIM is a custom, printed circuit board (PCB) designed specifically to interface to the ScanEagle UAS and support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure B-4, the microcontroller along with an Ethernet switch, serial transceivers, and power regulation and sense circuitry allow the MAIM to interface to both the platform and payloads. The MAIM itself draws ~4W.

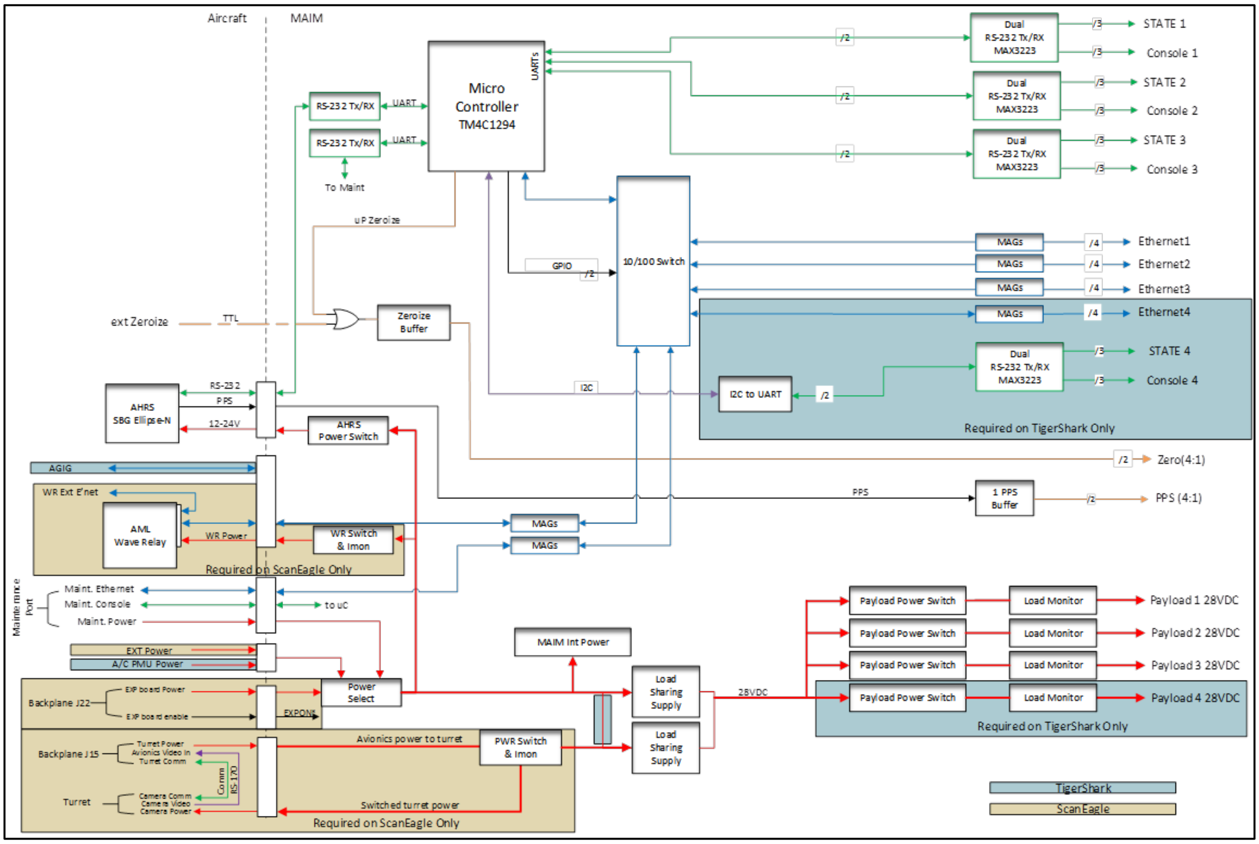


Figure B-4. MAIM Block Diagram for ScanEagle

B.3.2.1 Power Input

To maximize power available to the payloads, the MAIM draws power from two separate sources on the ScanEagle. The MAIM provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on all power inputs. The MAIM can also be powered externally though the maintenance port.

B.3.2.2 Payload Interfaces

The MAIM supports up to two payloads. As required by the standard, each payload interface provides power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides the 28VDC power (140mV load regulation, 25mV ripple) to each payload and limits the maximum current draw to 2A (continuous).

The MAIM uses the standard-defined, 21-pin Micro-D connector and pinout to interface to each payload.

B.3.2.3 Power Sharing and Monitoring

The power modules on the MAIM can current-share in unequal amounts. They can also be configured (via resistor) to limit how much current is pulled from a source. The microcontroller monitors current draw from each module as required by the standard. The block diagram for the MAIM power circuitry is given in Figure B-5.

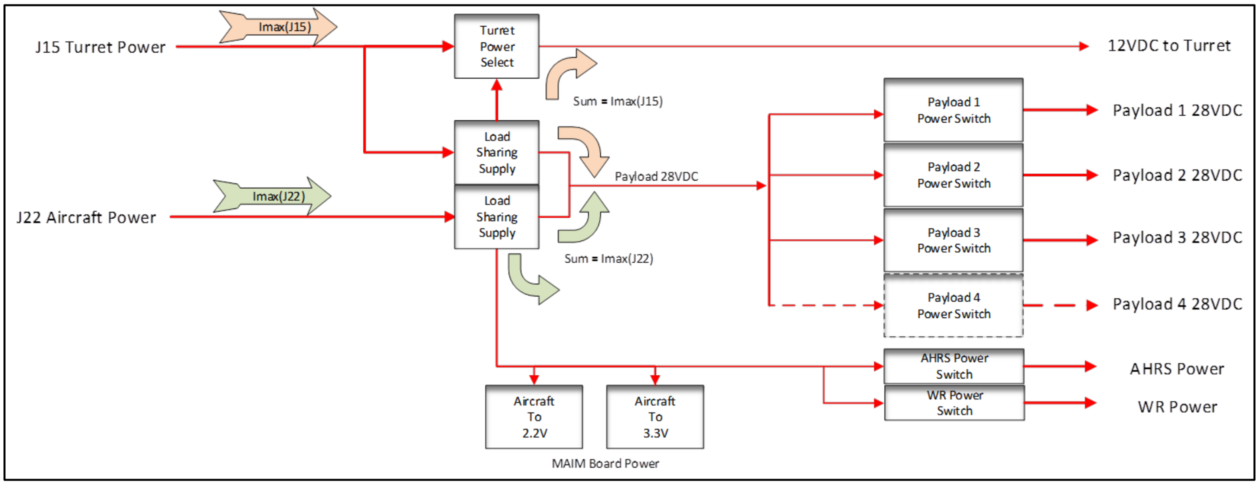


Figure B-5. MAIM Power Circuitry Block Diagram

B.3.2.4 INS Interface

The MAIM provides power and bi-directional serial communications to the MP-compliant INS. Power is provided at 12V. State data and the 1PPS signal are received from the INS, while commands are transmitted to the INS.

B.3.2.5 Maintenance Interface

The MAIM provides a dedicated maintenance port to support required debug efforts. The maintenance interface includes an external power hook up, an Ethernet and a serial interface. The maintenance port is a 15-pin Micro-D connector.

B.3.2.6 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the MAIM interfaces with the ScanEagle's Avionics Module Lower (AML) and the Wave Relay (WR4) radio. In addition to the expected Ethernet interface, the MAIM also provides power to the AML at 12VDC.

The secondary power input described in Section B.3.2.1 is typically used for turret power in the ScanEagle. As this additional power source is needed for the MP architecture, the MAIM powers the turret at 9.3 to 15V from the J22 connector.

B.3.3 MAIM Integration

The MAIM is installed in the upper card slot in the Avionics Module (Figure B-6). The entire Avionics Module must be removed to install the MAIM. A maintenance cable (Section B.7.9) is routed from the MAIM maintenance port to the top hatch area, directly above the Avionics Module, to provide direct communications to the MAIM without removing the Avionics Module.

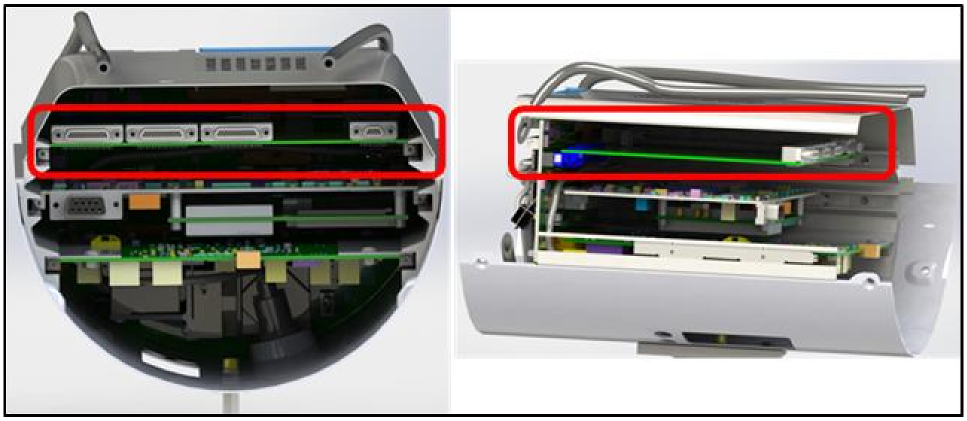


Figure B-6. MAIM Installed in ScanEagle

B.4 Primary Mount

A 7.25-inch aft slice modified with an integrated 3U MP-compliant mini-rack is the Primary Mount for the ScanEagle. Figure B-7 shows the Primary Mount with two payload configurations: one with three notional 1U modules installed and another with a notional 1U module and an actual 1.5U module installed.

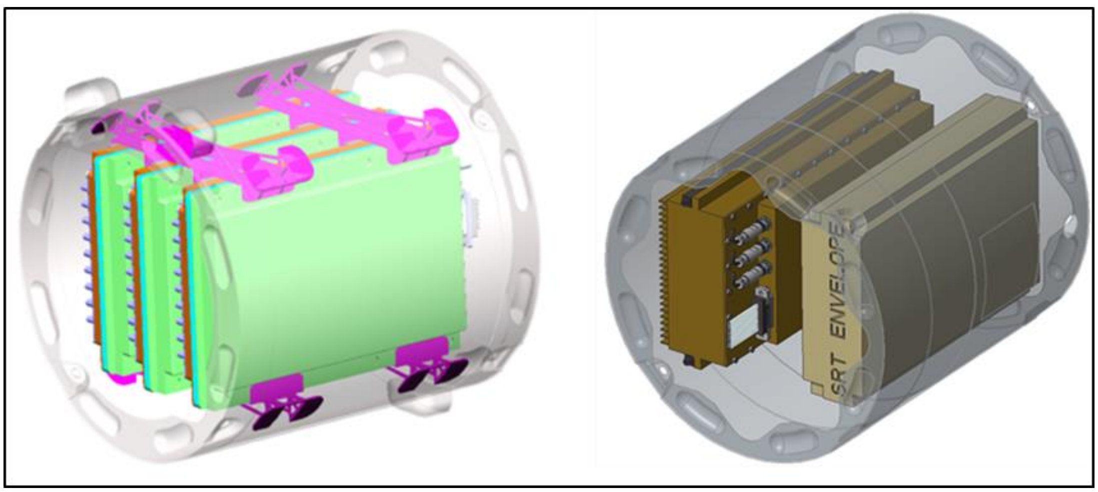


Figure B-7. Scan Eagle Primary Mount Aft Slice with Payloads

B.4.1 Mechanical Description

The Primary Mount is 7.0in (diameter) x 7.25in (length) and weighs 594g. The aft slice is carbon fiber shell with two sets of aluminum brackets that provide the required MP interface.

B.4.2 Installation

The Primary Mount is installed just as a normal aft slice on the Scan Eagle. The Primary Mount is oriented as shown in Figure B-8. Payload connectors and access for insertion and removal of payloads are toward the aft end of the slice. Payloads can be installed with the heatsink surface facing either left or right.

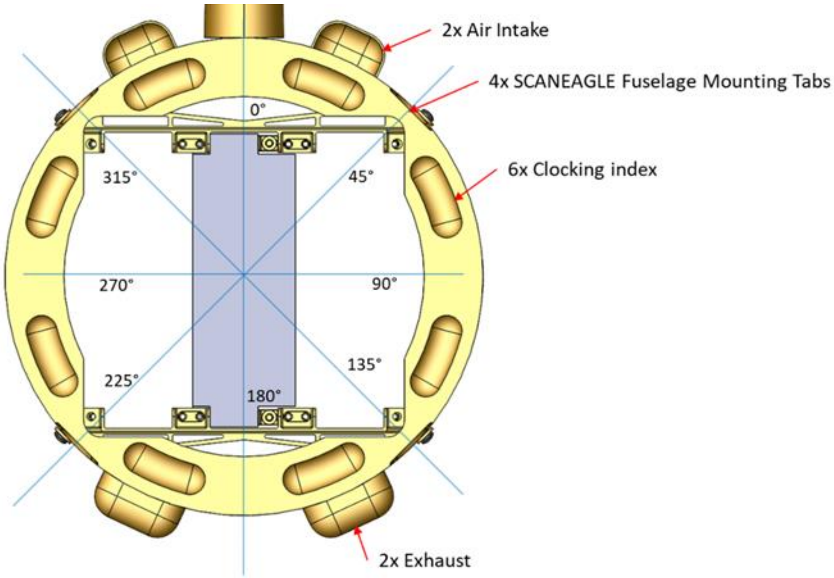


Figure B-8. ScanEagle Primary Mount Orientation

B.4.3 Thermal

Air ducts on the slice surface provide the requisite air flow for forced convection cooling of the payloads. Intakes on the upper half of the slice feed air between the modules across their heatsink surfaces to and out the exhausts on the lower half of the slice.

B.5 INS

The ScanEagle center wing hatch is replaced with a custom hatch accommodating the Ellipse2-N INS and a small GPS antenna (Figure B-9). The custom hatch (including the INS) weighs 245g (a 109g delta to the standard hatch).

Figure B-9. Custom Hatch for MP-ScanEagle

B.6 Antenna Mounts

The MP-compliant ScanEagle supports antenna mounts in three locations: around the aft slice primary mount and each wingtip.

B.6.1 Aft Slice Antenna Mounts

The ScanEagle has multiple options for aft slice antenna mounts:

- A 2-pt up look antenna mount
- A 2-pt down look antenna mount
- A 2-pt or 4-pt 45° antenna mount (right side only)

All configurations use the same customized aft slice, which allows for different antenna mounts to be installed. Two slice mount styles – feet and sleds – can be employed to accommodate a variety of antenna options. A slice mount is only installed when a payload requiring one is installed. Captured nuts internal to the aft slice allow the antenna mounts to be swapped without requiring the removal of the aft slice itself.

B.6.1.1 Feet

Feet are one ScanEagle adaptation of the 2-pt mount interface that match the curvature of the aft slice. Feet can be installed at multiple locations around the aft slice (Figure B-10) to allow efficient configuration for different antenna sizes and antenna orientations (0°, 180° and 225°). A pair of feet is required to mount an antenna. Two pairs of feet can be used to create a 4-pt mount. A single pair of feet weighs 42g.

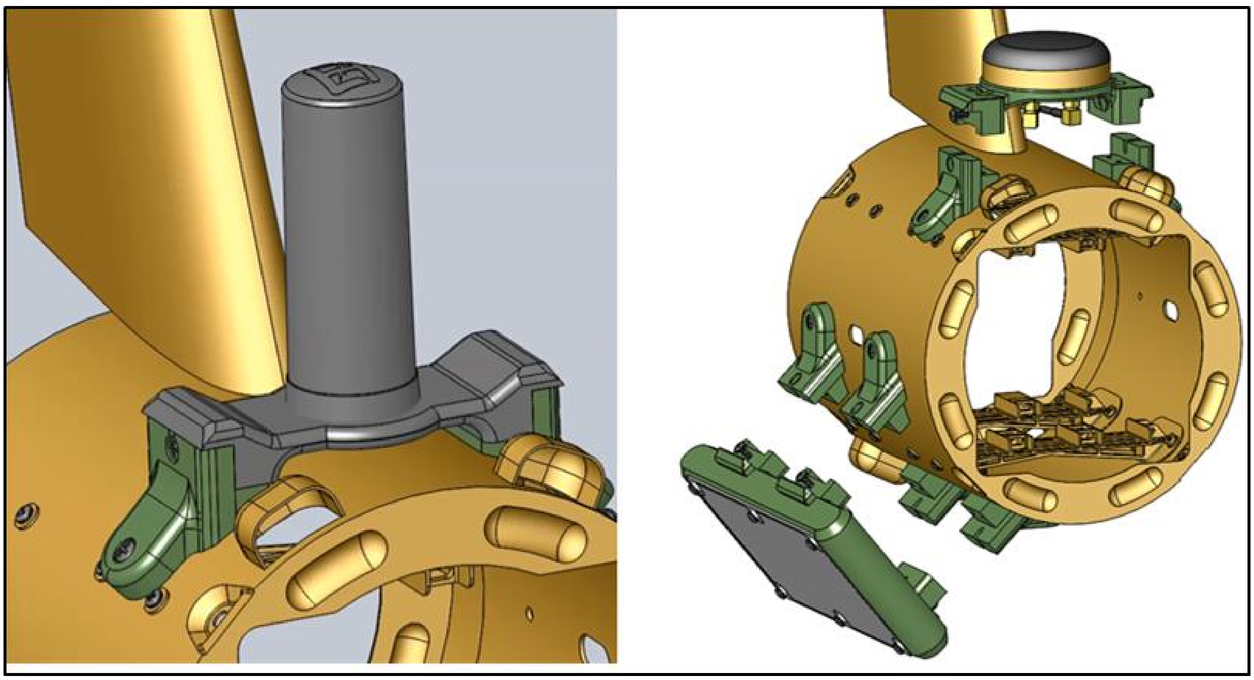


Figure B-10. Feet Antenna Mounts on the Aft Slice Primary Mount

B.6.1.2 Sled

A sled antenna mount (Figure B-11) is a second ScanEagle adaptation of the 2-pt mount interface to support antenna installations at 180° and 270° orientations.

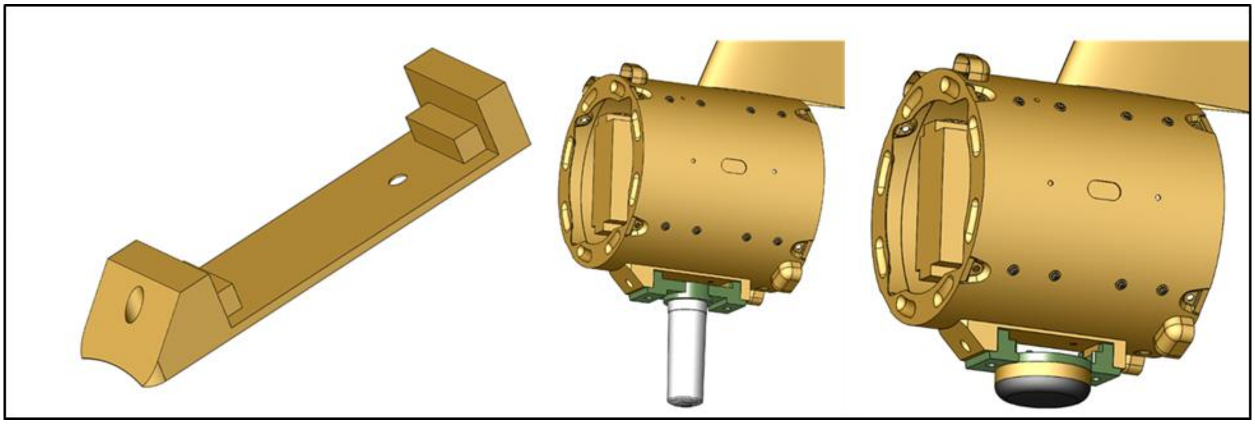


Figure B-11. Sled Antenna Mounts on the Aft Slice Primary Mount

A 2-pt sled weighs 33g. The aft slice antenna mount capacity is defined in Table B-2.

Table B-2. Aft Slice Antenna Mount Capacity

Max Weight	To Be Added in Rev 6	
Max Volume		

[1] CAD defining volume available upon request

B.6.2 Wingtip Mounts

An array mount (strut) is installed on each wingtip. The strut is installed using the two mounting holes for the winglet. The strut-array interface is designed to allow the array to break away from the wingtip if it gets caught on the skyhook line during capture. An array is attached using three frangible screws; during capture, if the array is subject to improper loading, the screws shear, allowing the antenna to break away and avoid damage the UAS.

An additional 2-pt, down look antenna mount is installed on the left wingtip only.

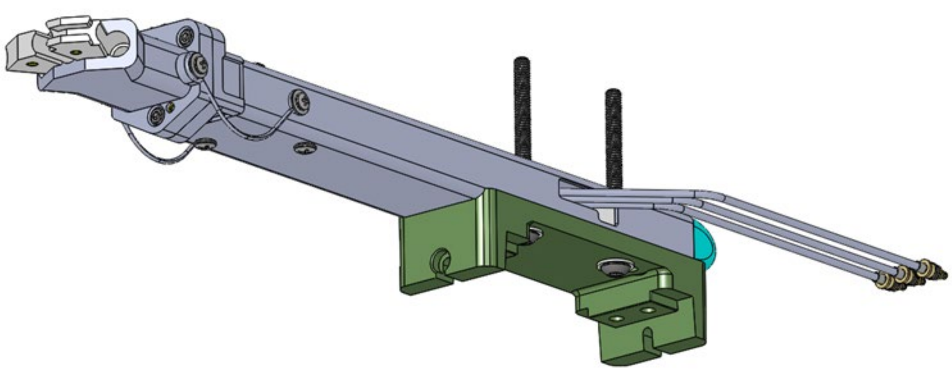


Figure B-12. Wingtip Antenna Mount

The strut weighs 100g and the 2-pt. down look mount weighs 45g. The wingtip antenna mount capacity is defined in Table B-3.

Table B-3. Wingtip Antenna Mount Capacity

Max Weight	To Be Added in Rev 6	
Max Volume		

[1] CAD defining volume available upon request

B.7 Cabling

Due to the complex design of the aircraft, cabling is the most difficult and invasive aspect of the MP architecture on ScanEagle. The complete cable laydown is illustrated in Figure B-13, while the MAIM cable diagram is detailed in Figure B-14. The following sections provide further detail on each cable installed. RF cables are detailed in Section B.7.8.

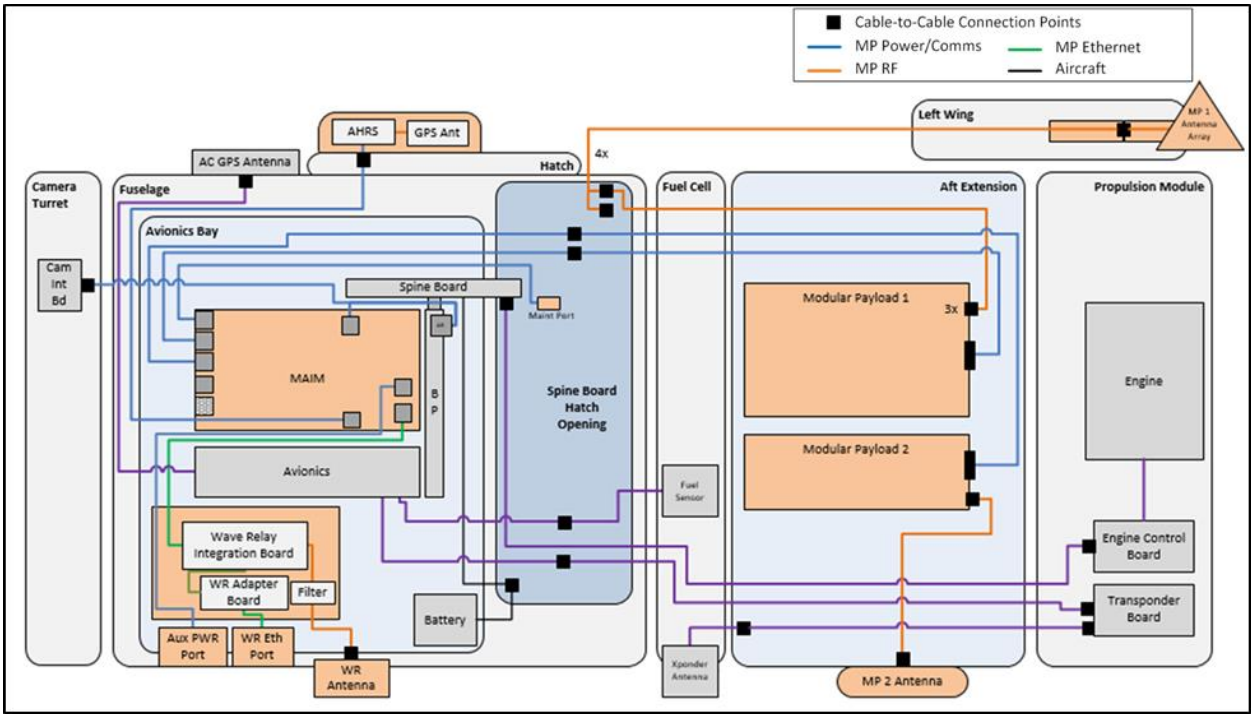


Figure B-13. MP Cables and Routing for Scan Eagle

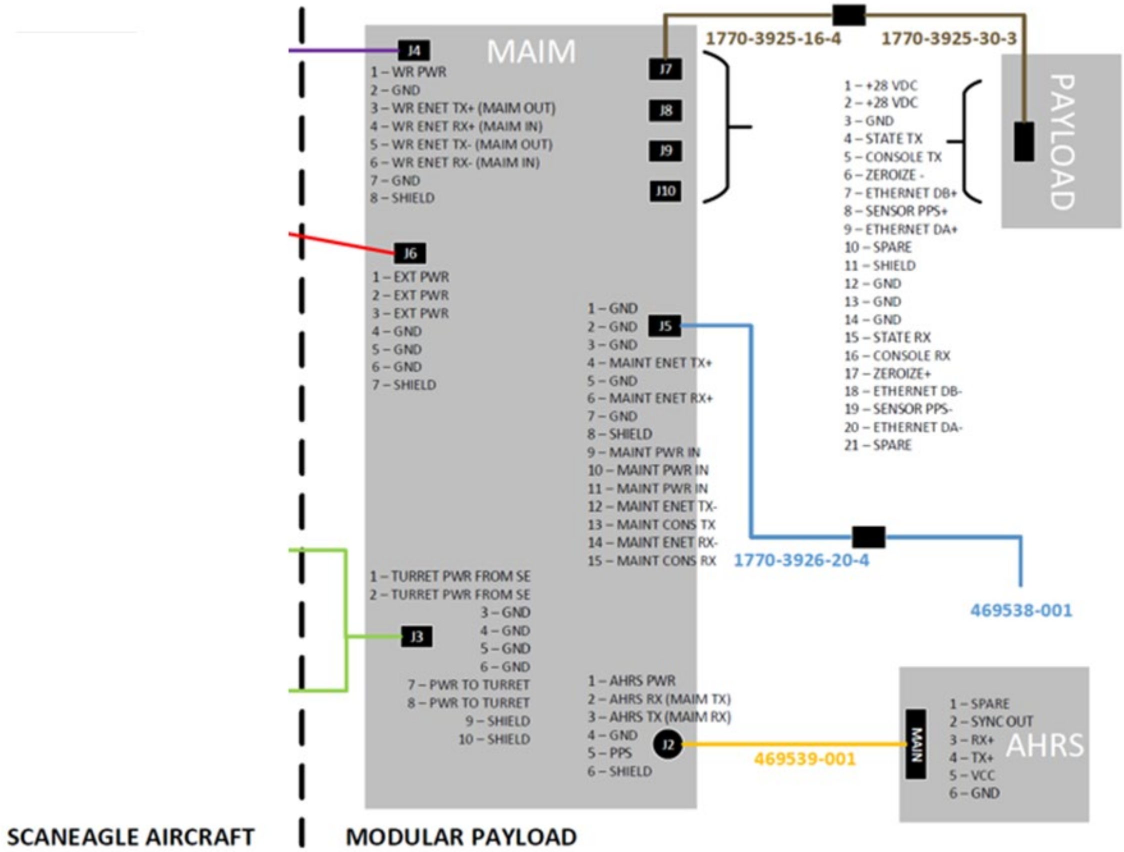


Figure B-14. ScanEagle MAIM Cable Diagram

B.7.1 UAS-MAIM Connections

The MAIM plugs directly into the ScanEagle's avionics backplane. An additional cable from the rear of the avionics module provides additional power to the MAIM.

B.7.2 MAIM-Payload Cables

The MAIM-payload cables are COTS Glenair cables with EMI shielding and 26 AWG UTP terminated straight thru at each end in the standard-defined 21-pin Micro-D connector. Two sets of MAIM-payload cables run out the front and over the top of the Avionics Module, under the center wing hatch, over the fuel tank, into and through to the rear of the aft slice. The aft slice portion of the cable run is illustrated in Figure B-15. A single MAIM-payload cable set consists of two MAIM-payload cables (Glenair p/n 1770-3925-16-4 and 1770-3925-30-3) with an inline connection at the center wing hatch opening. Each MAIM-payload cable set is 46-inches long and weighs 441g (combined the two sets add 882g to the aircraft weight).

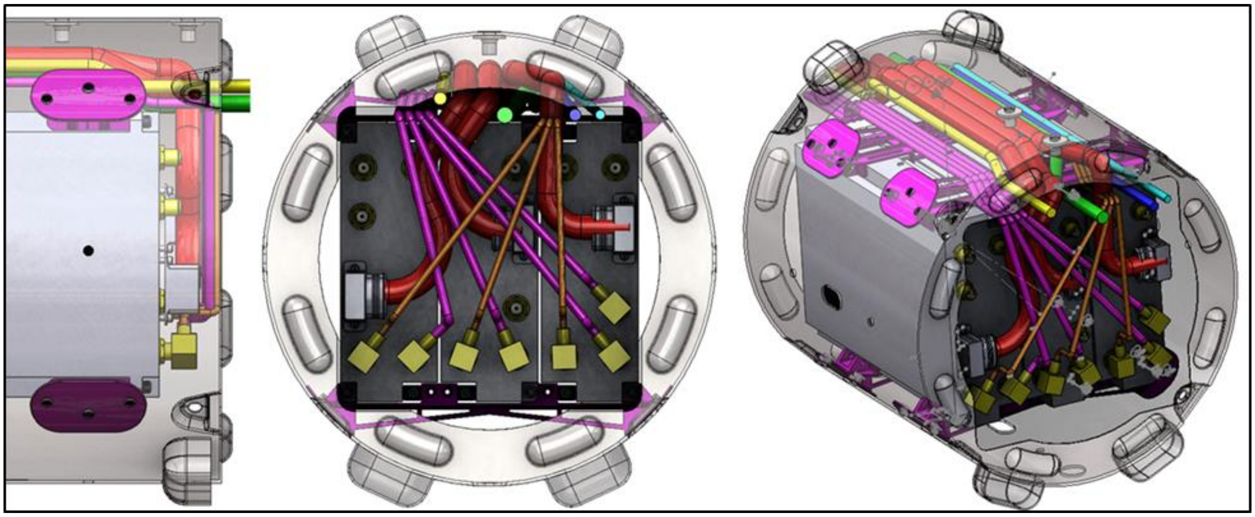


Figure B-15. Payload Cable Runs over the Primary Mount

B.7.3 MAIM-INS Cable

The MAIM-INS cable is a bundle of M22759/33 shielded twisted pair/triple/quad (26 AWG) with Expando sleeving and terminated as detailed in Figure B-16. The MAIM-INS cable runs out the front and over the top of the Avionics Module, into and out the top of the center wing hatch opening. The MAIM-INS cable is 22-inches long and weighs 21g.

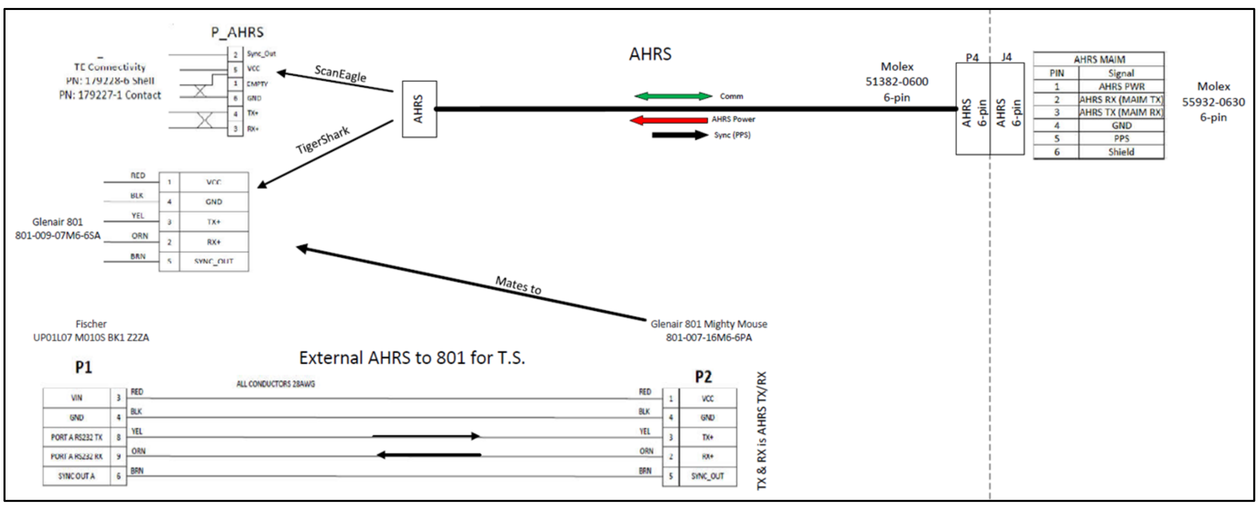


Figure B-16. MAIM to INS Cable

B.7.4 GPS Antenna Cable

The GPS is co-located with the INS in the center wing hatch and does not require a separate cable as shown in Section B.5

B.7.5 Network Cable

The MAIM network cable runs from the MAIM in the top of the Avionics Module to the AML at the bottom of the Avionics Module. The MAIM-network cable is 16-inches long and weighs 24g.

B.7.6 External Power Cable

The MAIM external power cable is a bundle of M22759/33 shielded twisted pair/triple/quad (22AWG) with Expando sleeving and terminated as detailed in Figure B-17. The MAIM external power cable runs from the MAIM in the top of the Avionics Module to the AML at the bottom of the Avionics Module. The MAIM external power cable is 13-inches long and weighs 13g.

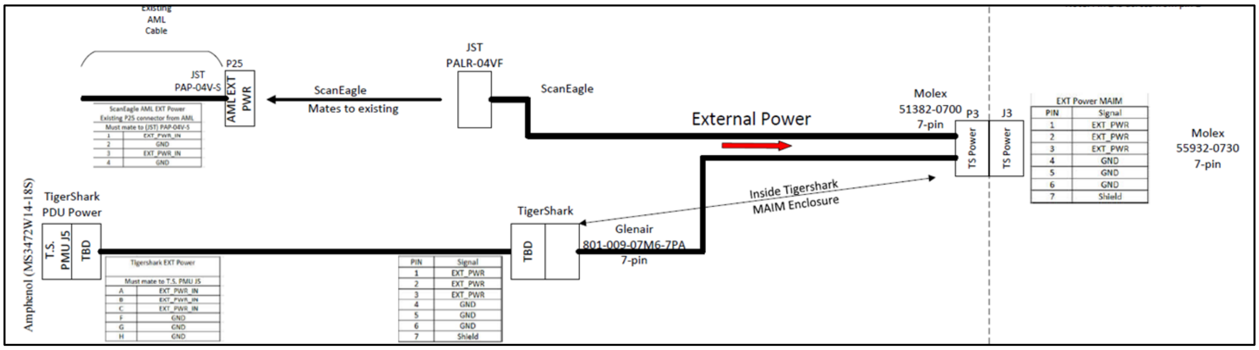


Figure B-17. MAIM External Power Cable

B.7.7 Turret Cable

The MAIM-Turret cable runs out the front of the Avionics Module through the forward bulkhead to the turret. The MAIM-turret cable is 28-inches long and weighs 46g.

B.7.8 RF Cables

Three sets of RF cables are installed to support the various payload antenna options. One set runs out to the left wingtip, one set runs out to the right wingtip, and a third simply runs through the surface of the aft slice. The RF cable runs and schematics are detailed in Figure B-18.

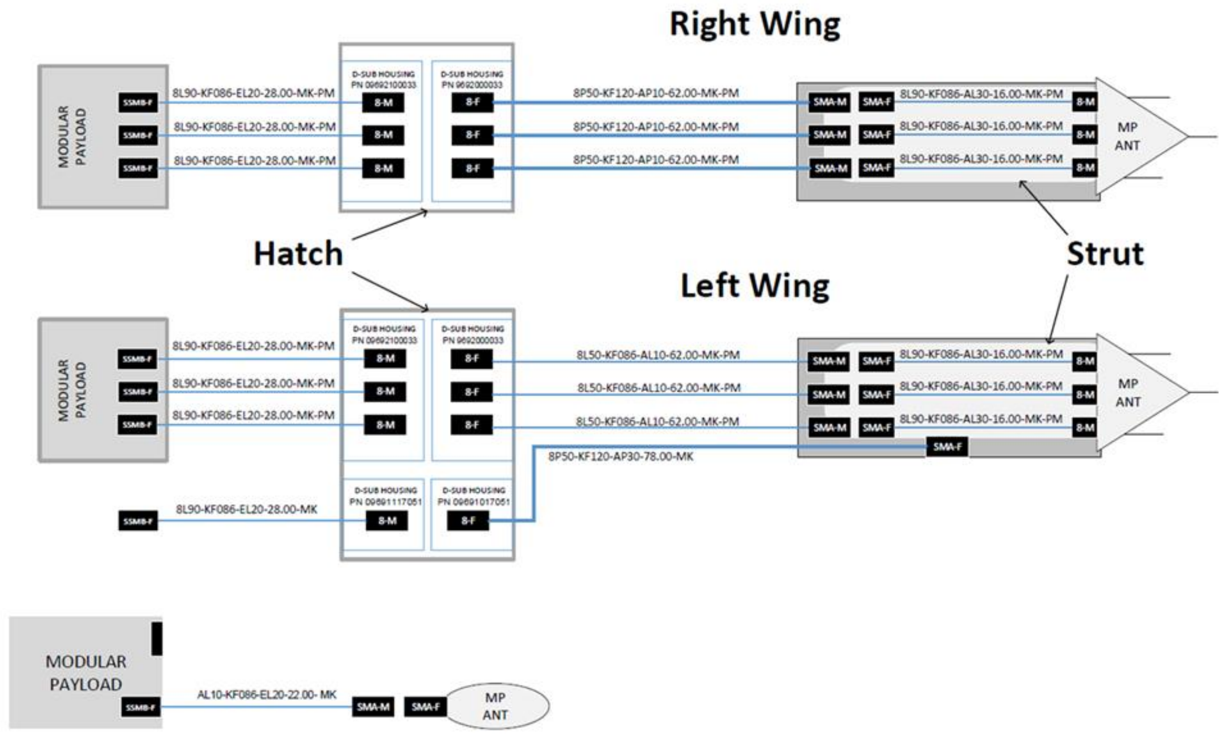


Figure B-18. MP-ScanEagle RF Schematic

B.7.8.1 RF Cable Summary Table

The following table provides useful characteristic and performance information for all RF cable runs.

Table B-4. ScanEagle RF Cable Summary

Cable Set	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Left Wingtip – Array	3	106	307	1.71
Left Wingtip – Down	1	106		1.23
Right Wingtip	3	106	284	1.32
Aft Slice *(nominal)*	1	16	12	0.26

Note 1: A nominal length has been used for an aft slice cable run. Actual cable length could vary by up to 100%
Note 2: Attenuation calculated for a 1GHz signal
Note 3: Weight and attenuation from connectors and inline couplers have been neglected

B.7.8.2 Left Wingtip Cables

The left wingtip cable set consists of four cable runs with multiple inline connections: three phase-matched cables to support a wingtip array and an additional fourth cable, with better RF characteristics at higher frequencies, to support an additional down look antenna. Figure B-18 details the cable types and terminations for each cable in each cable run. In total each cable run is 106-inches and passes from the rear of and through the aft slice, over the fuel tank, under the center wing hatch, into and through the left wing, and out the wingtip. The left wingtip cable runs are permanently installed.

B.7.8.3 Right Wingtip Cables

The right wingtip cable set consists of three phase-matched cable runs with multiple inline connections to support a wingtip array. The longest section of each run uses cable with better RF characteristics at higher frequencies to support higher band operations. Figure B-18 details the cable types and terminations for each cable in each cable run. In total each cable run is 122-inches and passes from the rear of and through the aft slice, over the fuel tank, under the center wing hatch, into and through the right wing, and out the wingtip. The right wingtip cable runs are permanently installed.

B.7.8.4 Aft Slice Cables

Aft slice cables are used to connect a payload to its aft slice antenna. Figure B-18 details the cable type and terminations for the aft slice cable. Aft slice cables simply run from the payload (in the aft slice) to its antenna (on the aft slice), so are installed only when a payload requiring them is installed.

B.7.9 Maintenance Cable

The MAIM maintenance cable is a COTS, prewired Glenair cable (177-740-2-21CS6J1-24SXG) with EMI shielding Expando sleeving and terminated as detailed in Figure B-19. The MAIM maintenance cable runs out the front and over the top of the Avionics Module, into the center wing hatch opening, where it is secured. The MAIM maintenance cable is 24-inches long and weighs 67g.

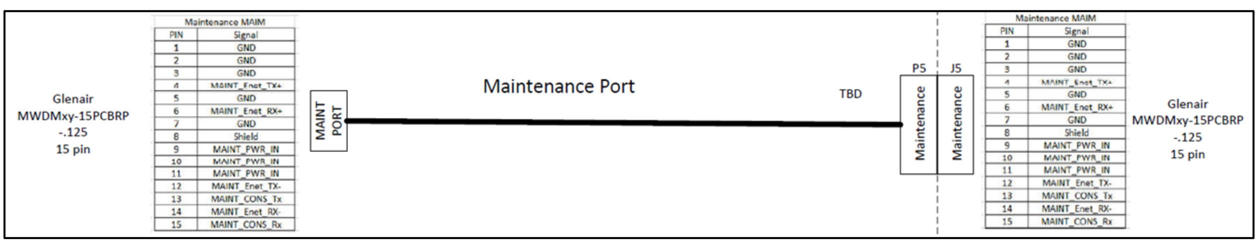


Figure B-19. MAIM Maintenance Cable

An additional user cable (not flown) mates to the maintenance cable to breakout the signals into more user friendly RJ45 and Molex connections.

B.8 Platform-Payload Concessions

As noted in Table B-1 and Section B.2.2, ScanEagle is constrained in available power and can only meet the 56W payload requirement by securing power to several pieces of non-critical flight hardware.

Appendix C. **MP-RQ23A TigerShark UAS**

The following details the MP implementation for the RQ-23A TigerShark.

C.1 Overview

The MP-compliant TigerShark UAS can support up to 4U of payloads in a custom nose-bay Primary Mount. Similarly, UAS power capacity can support up to four concurrent payloads. The MP-TigerShark UAS is equipped to support one wingtip array, one wingtip 2-pt up look antenna, one wingtip 2-pt down look antenna, one wingtip 4-pt 45° antenna, a fuselage 4-pt down look antenna and a fuselage 4-pt 45° antenna. A platform-specific MAIM and the MP-compliant INS are both required for this UAS.

C.1.1 MP Architecture

Figure C-1 illustrates the architectural layout of the MP implementation on the TigerShark UAS.

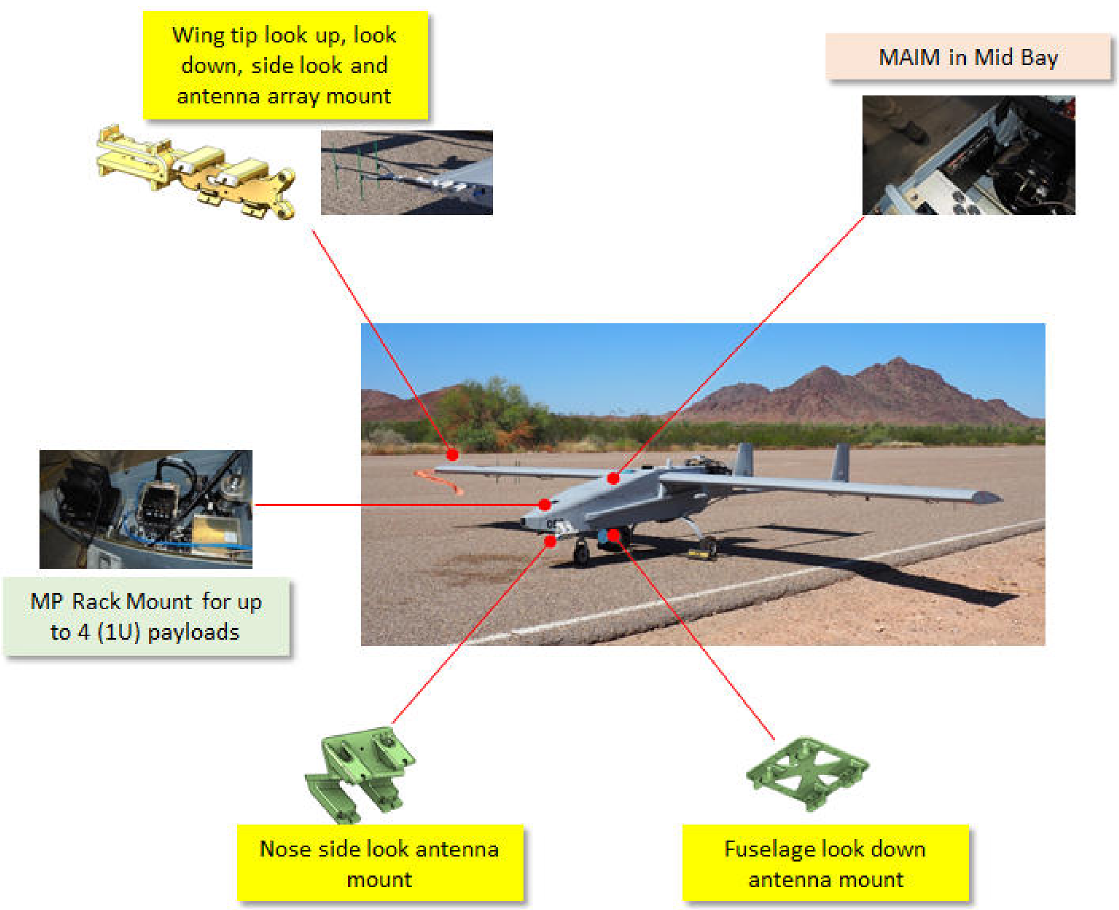


Figure C-1. Architectural Layout for MP-TigerShark

C.1.2 Compliance / Capability Summary

Table C-1 provides a top-level summary of the MP compliance and capability on the TigerShark UAS.

Table C-1. MP-TigerShark Compliance and Capability

<table>
<tr><th colspan="2">MP Components</th><th colspan="2">Location</th></tr>
<tr><td colspan="2">MAIM</td><td colspan="2">Main Payload Bay</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">Nose Bay</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Main Payload Bay</td></tr>
<tr><th colspan="2">Payload Capacity</th><th colspan="2">Description</th></tr>
<tr><td colspan="2">Number of Payloads</td><td colspan="2">4</td></tr>
<tr><td colspan="2">Available Payload Power</td><td colspan="2">224W</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">4U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">>10kg</td></tr>
<tr><th colspan="2">Primary Mount</th><th colspan="2"></th></tr>
<tr><td colspan="2">Mounting Method</td><td colspan="2">Rack</td></tr>
<tr><td colspan="2">Cooling Method</td><td colspan="2">Convection</td></tr>
<tr><th>Antenna Mounts</th><th>Qty</th><th>Location</th><th>Orientation</th></tr>
<tr><td rowspan="2">Two-point</td><td>1</td><td>Wingtip</td><td>Up</td></tr>
<tr><td>1</td><td>Wingtip</td><td>Down</td></tr>
<tr><td rowspan="3">Four-points</td><td>1</td><td>Wingtip</td><td>45°</td></tr>
<tr><td>1</td><td>Fuselage (Nose)</td><td>45°</td></tr>
<tr><td>1</td><td>Fuselage (Mid)</td><td>45° or Down</td></tr>
<tr><td>Array</td><td>1</td><td>Wingtip</td><td>Aft</td></tr>
</table>

C.1.3 System Diagram

Figure C-2 details the system diagram for the MP-TigerShark UAS. MP-specific additions are highlighted in teal.

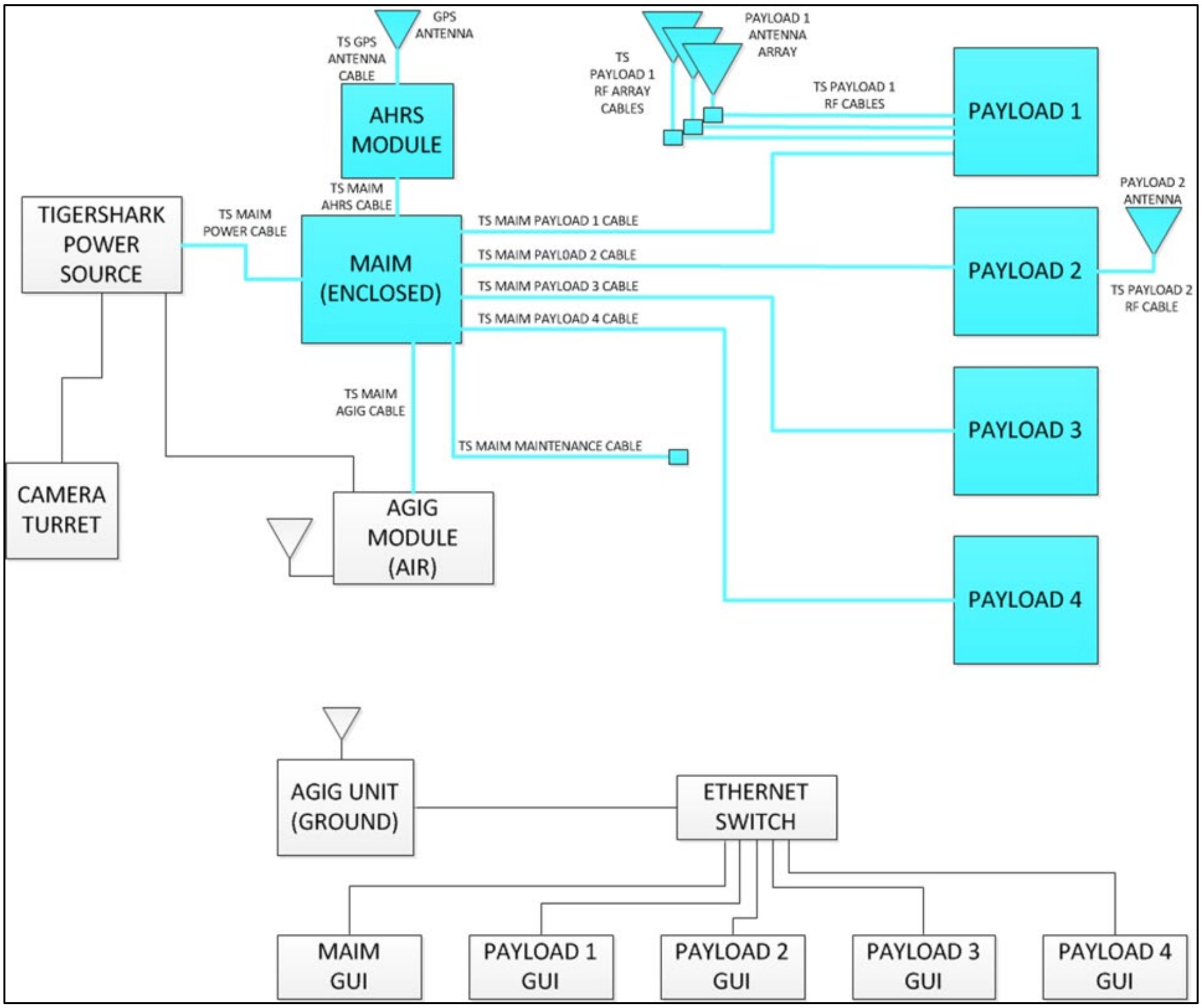


Figure C-2. System Diagram for MP-TigerShark

C.2 Platform Weight and Power Budgets

As a Group 3 UAS, the TigerShark is not SWAP-constrained. The TigerShark has ample volume, power and weight capacity for the MP architecture.

C.2.1 Weight Budget

Due to the relatively large payload capacity of the aircraft, there is no need to establish a maximum allowable total weight for the MP hardware. Thus, little effort was made to minimize the weight impact on the UAS. Discounting payloads (and corresponding antennas and antenna adaptors), the MP architecture adds 5.7kg to the TigerShark.

C.2.2 Power Budget

To support four payloads, MP requires 224W. After adding the power draws for the MAIM and INS and accounting for efficiencies, MP requires 239W. This power can be fully accommodated by the TigerShark Power Module Unit (PMU).

C.3 MAIM

The MAIM is a custom circuit board housed in custom enclosure. The MAIM enclosure is mounted to the right fuselage wall in the main payload bay.

C.3.1 Mechanical Description

The MAIM enclosure is 8.1in x 5.6in x 1.6in and weighs 1.44kg. Figure C-3 shows the MAIM enclosure (left) and the MAIM board (right).

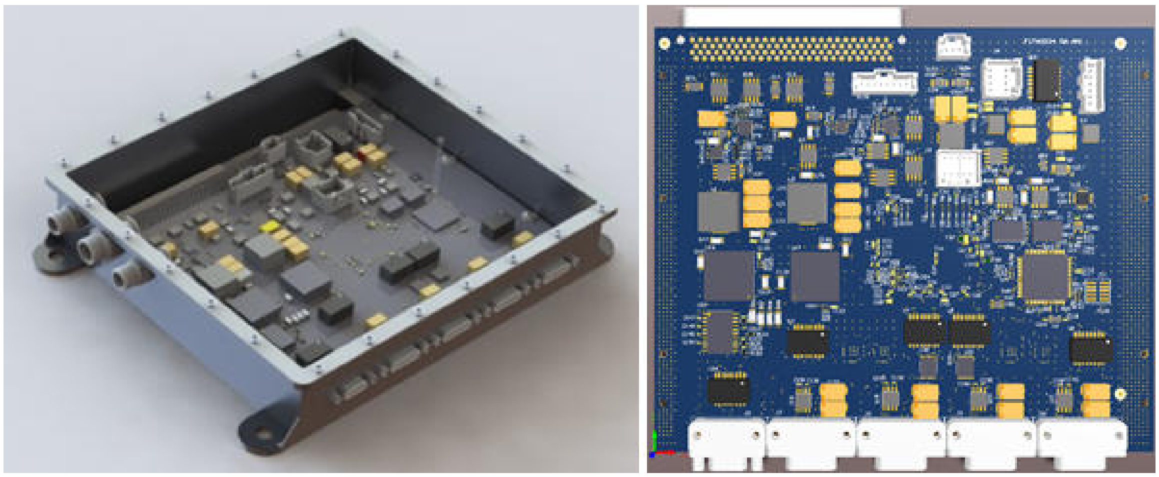


Figure C-3. MAIM for TigerShark

C.3.2 Electrical Description

The MAIM is a custom PCB designed specifically to interface to the TigerShark UAS and support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure D-4, the microcontroller along with an Ethernet switch, serial transceivers, and power regulation and sense circuitry allow the MAIM to interface to both the platform and payloads. The MAIM itself draws ~4W.

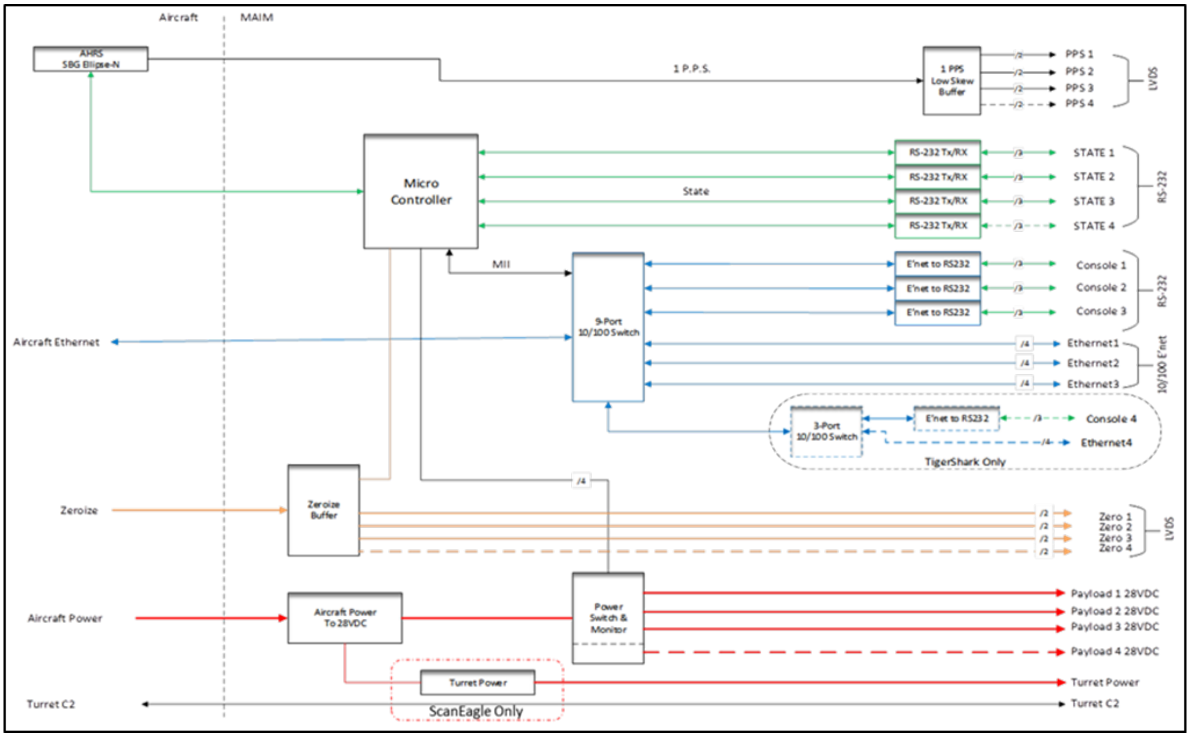


Figure C-4. MAIM Block Diagram for TigerShark

C.3.2.1 Power Input

The MAIM draws 28VDC power from the TigerShark PMU. The MAIM provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on all power inputs. The MAIM can also be powered externally though the maintenance port.

C.3.2.2 Payload Interfaces

The MAIM supports four payload interfaces. As required by the standard, each payload interface provides power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides the 28VDC power (140mV load regulation, 25mV ripple) to each payload and limits the maximum current draw to 2A (continuous).

The MAIM uses the standard-defined, 21-pin Micro-D connector and pinout for each payload interface.

C.3.2.3 Power Sharing and Monitoring

In addition to power regulation, the MAIM microcontroller monitors current draw to the INS and each payload. The block diagram for the MAIM power circuitry is given in Figure C-5.

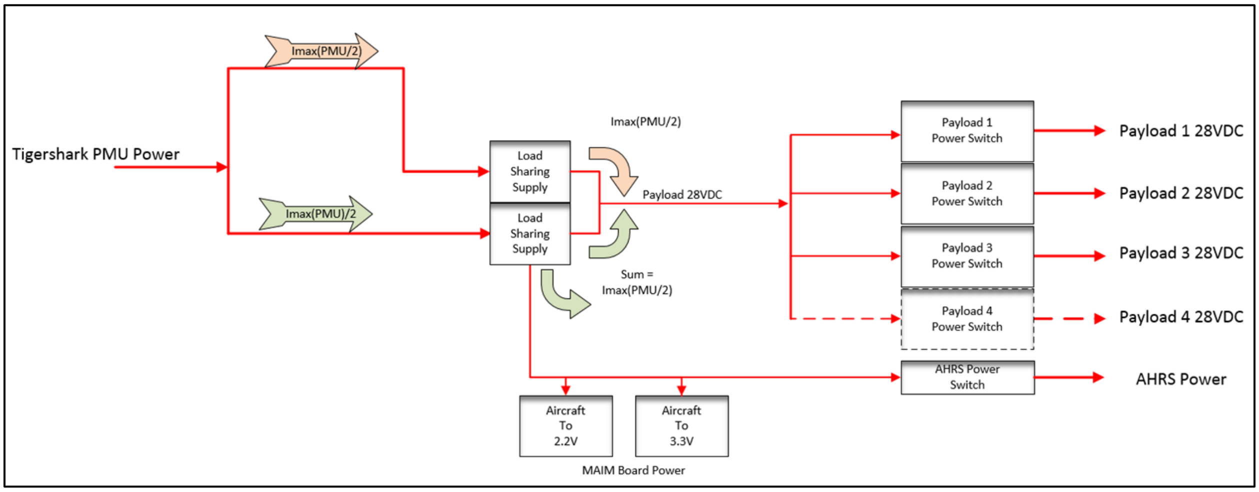


Figure C-5. MAIM Power Circuitry Block Diagram

C.3.2.4 INS Interface

The MAIM provides power and bi-directional serial communications to the MP-compliant INS. Power is provided at ~28V. State data and the 1PPS signal are received from the INS, while commands are transmitted to the INS.

C.3.2.5 Maintenance Interface

The MAIM provides a dedicated maintenance port to support required debug efforts. The maintenance interface includes an external power hook up, an Ethernet and a serial interface.

C.3.2.6 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the MAIM connects to an onboard Ethernet switch. An AGIG radio also tied to that network provides the UAS backhaul to the ground station.

C.3.3 MAIM Integration

The MAIM enclosure is installed to the right side of the fuselage in the primary payload bay (Figure C-6). The MAIM is directly bolted to the fuselage, adding mounting holes where necessary.

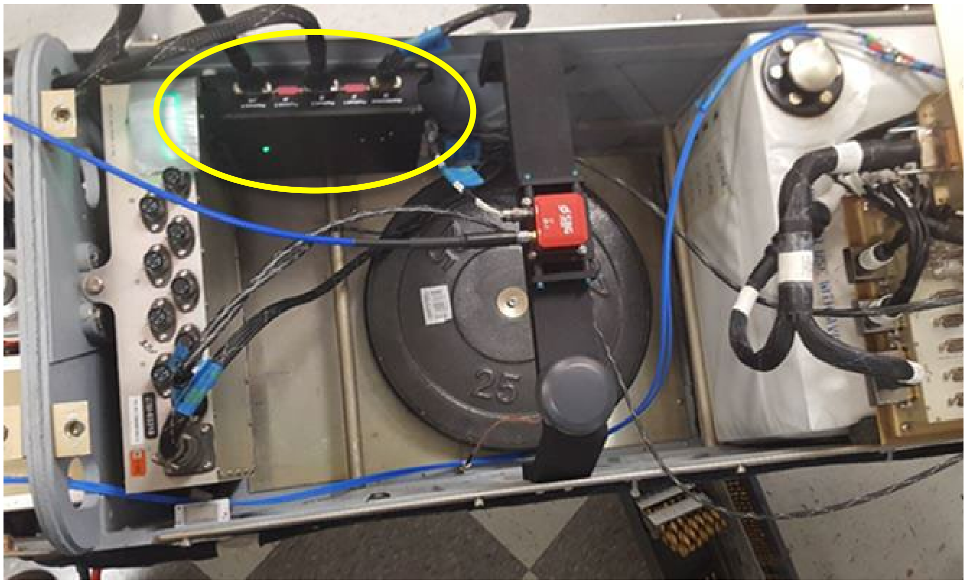


Figure C-6. MAIM Installed in TigerShark Payload Bay

C.4 Primary Mount

The Primary Mount for the TigerShark is a 4U rack installed in the nose payload bay. Figure C-7 shows the Primary Mount with a 1.5U and a 1U payload installed.

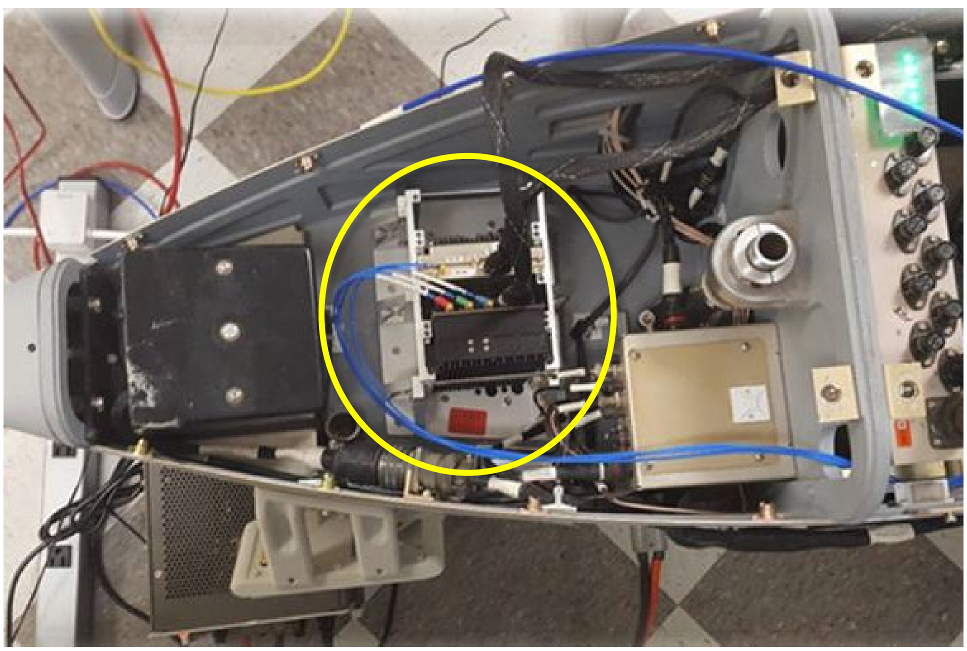


Figure C-7. TigerShark Primary Mount with Two Payloads

C.4.1 Mechanical Description

The Primary Mount as illustrated in Figure C-8 consists of the rack assembly, mounting plate and air exhaust. The rack is an aluminum assembly, 7.25 in (length) x 9.0 in (width) x 6.25 in (height). The mounting plate is an aluminum sheet, 7.25 in (length) x 10.9 in (width) x 0.25 in (thickness). Including the additional exhaust, the Primary Mount weighs 1.5kg.

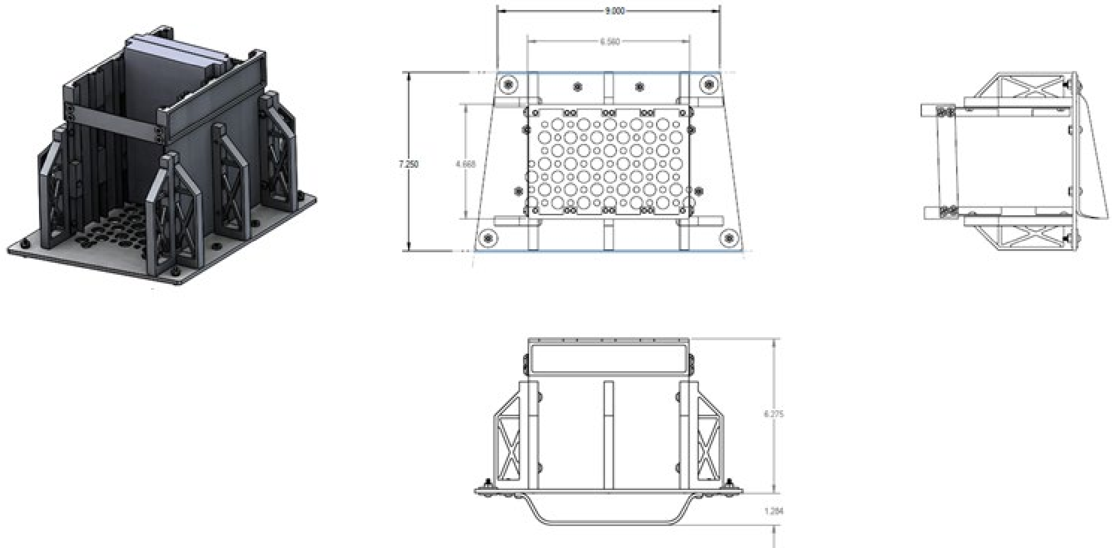


Figure C-8. TigerShark Primary Mount Assembly

C.4.2 Installation

The Primary Mount should be fully assembled, i.e., rack assembly and exhaust attached to the mounting plate, prior to installation into the UAS. As depicted in Figure C-9, the Primary Mount is installed in the center of the nose payload bay. Modules can either be installed at this time or installed later with the UAS top hatch removed.

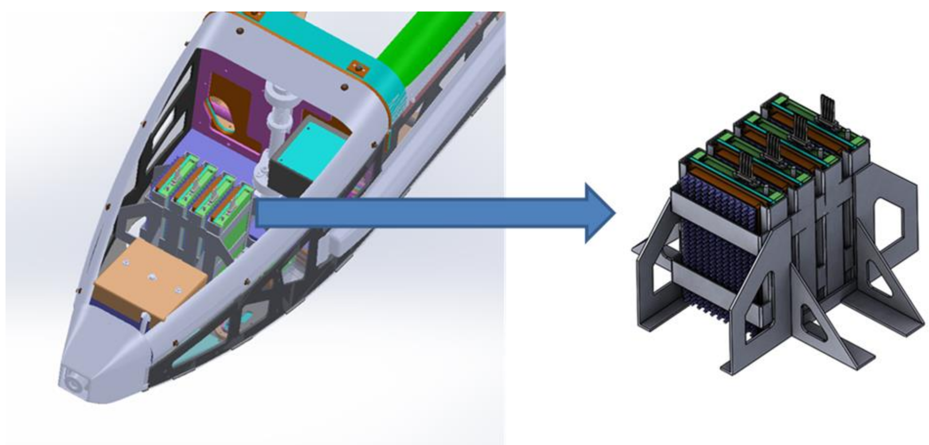


Figure C-9. TigerShark Primary Mount Installation

C.4.3 Thermal

Multiple considerations are made to and around the Primary Mount to provide the requisite air flow for forced convection cooling of the payloads. The air scoop (native to the TigerShark) on the top hatch of the fuselage collects air and directs it down between the modules across their heatsink surfaces through a collection of holes in the mounting plate and out the exhaust on the bottom surface of the Primary Mount. These details are depicted in Figure C-10.

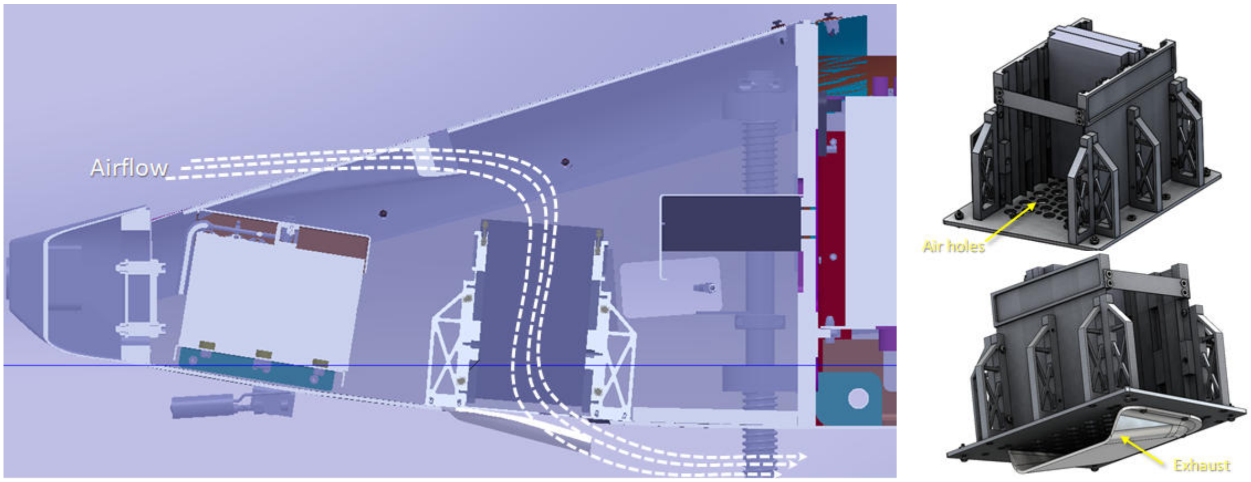


Figure C-10. TigerShark Thermal Considerations

C.5 INS

The Ellipse2-N INS is installed on a lightweight arm spanning the top of the main payload bay. A dedicated GPS antennas is also installed on the arm for use by the INS. Figure C-11 shows the INS installation.

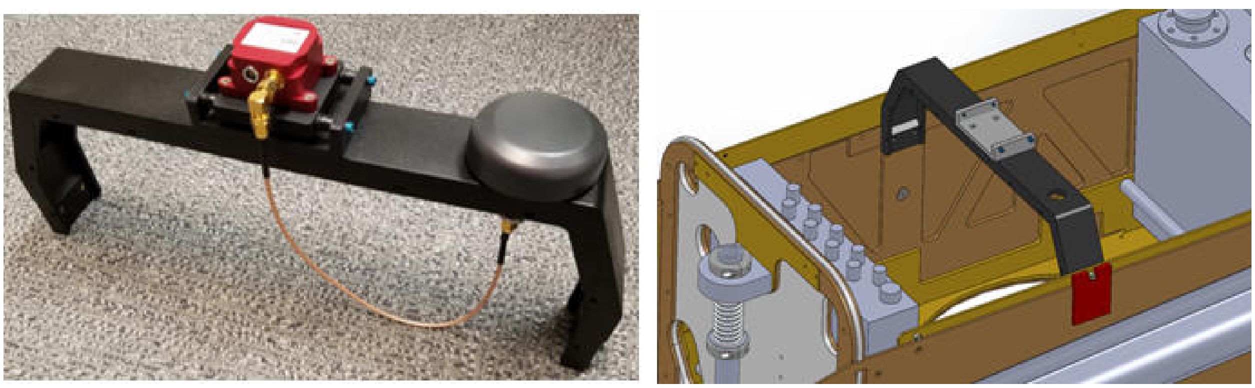


Figure C-11. TigerShark INS Installation

C.6 Antenna Mounts

The MP-TigerShark supports antenna mounts in three locations: on the right wingtip, off the left side of the main payload bay, and on the left side of the nose.

C.6.1 Wingtip Mount

The TigerShark has multiple options for wingtip antenna mounts:

- An array mount (strut)
- A 2-pt up look antenna mount
- A 2-pt down look antenna mount
- A 4-pt 45° antenna mount

All configurations use the same wingtip mount. The number of antennas installed is limited by the wingtip RF cabling (see Section C.7.5.2). The wingtip antenna mount allows for array, patch, and omni antennas. The antenna mount accommodates the MP mechanical interface in three orientations, utilizing two existing wingtip mounting holes and adding two additional mounting holes.

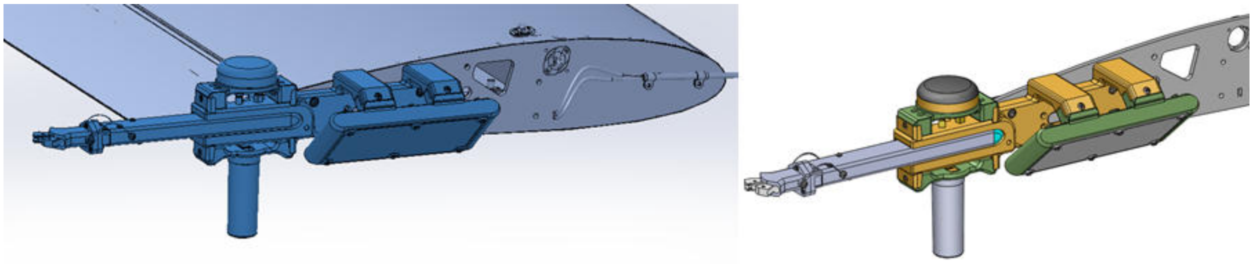


Figure C-12. TigerShark Wingtip Antenna Mount

The wingtip platform mount weighs 445g. The wingtip antenna mount capacity is defined in Table C-2.

Table C-2. Wingtip Antenna Mount Capacity

Max Weight	
Array Mount	To Be Added in Rev 6
2-pt Up Look	
2-pt Up Look Max Volume	
4-pt 45° Look Max Volume	

C.6.2 Main Payload Bay Mounts

The TigerShark has multiple options for antenna mounts external to the main payload bay:

- A 4-pt 45° antenna mount, or
- A 4-pt down look antenna mount

A different mount is used for each configuration, depending on the payload requirement. As such, the specific fuselage mount is installed only when needed.

Figure C-13 illustrates the 45° mount with a patch antenna installed.

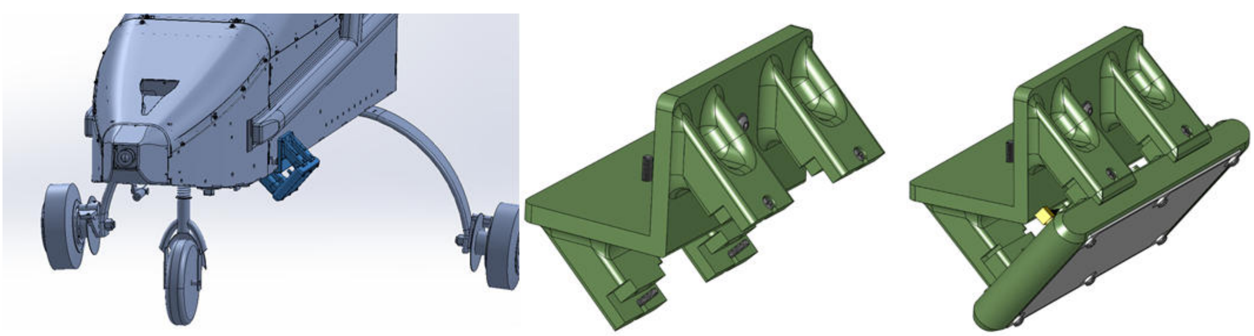


Figure C-13. TigerShark Main Payload Bay 45° Antenna Mount

Figure C-14 illustrates the down look mount with both a puck and omni antenna installed.

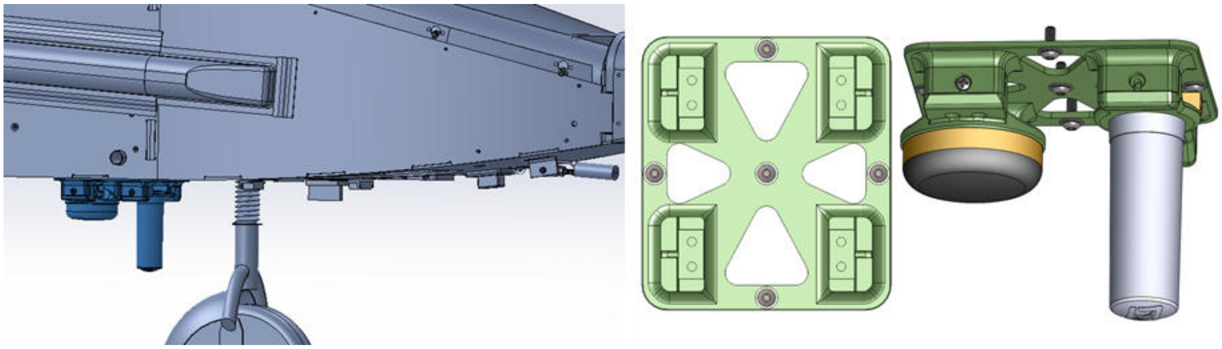


Figure C-14. TigerShark Main Payload Bay Down Look Antenna Mount

The main payload bay 45° antenna mount weighs 428g and the main payload bay down look antenna mount weighs 120g. The main payload bay antenna mount capacity is defined in Table C-3.

Table C-3. Main Payload Bay Antenna Mount Capacity

Max Weight	
45° Look Mount	
Down Look Mount Max Volume	

To Be Added in Rev 6

C.6.3 Nose Mount

To minimize cable runs for sensitive payloads, the TigerShark also supports a 4-pt 45° antenna mount on the nose. Figure C-15 illustrates the 45° mount with a patch antenna installed.

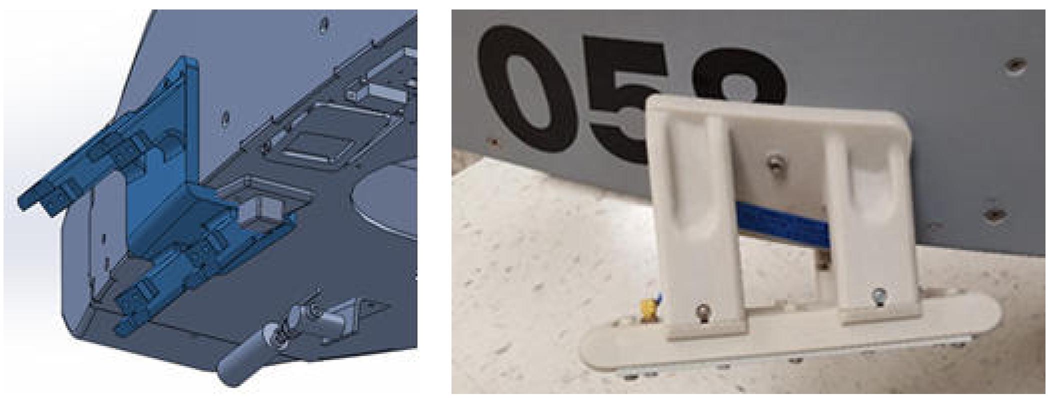


Figure C-15. TigerShark Nose Bay 45° Antenna Mount

The nose 45° antenna mount weighs 455g. The nose antenna mount capacity is defined in Table C-4.

Table C-4. Nose Antenna Mount Capacity

Max Weight	
45° Look Mo	

To Be Added in Rev 6

C.7 Cabling

The schematic for all MAIM cables is provided in Figure C-16. The following sections provide further detail on each of these cables. RF cables are covered in Section C.7.5.

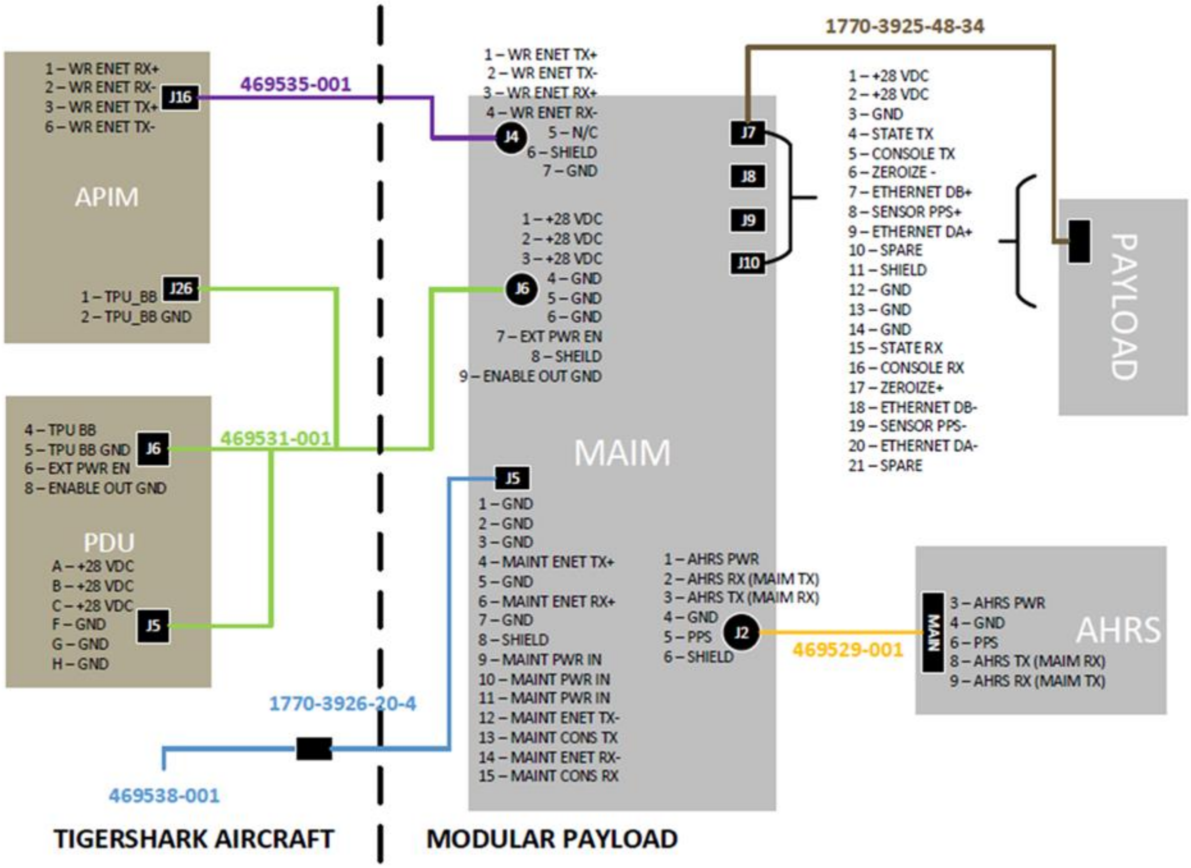


Figure C-16. TigerShark MAIM Cabling Schematic

C.7.1 UAS-MAIM Cables

The MAIM connects to the UAS using two cables, the MAIM Network Cable and the MAIM Power Cable.

C.7.1.1 MAIM Power Cable

The MAIM Power cable is a collection of 22AWG and 26AWG twisted shielded pairs with Expando sleeving and terminated as detailed in Figure C-17. The MAIM power cable runs from the PDU and AGIG Payload Interface Module (APIM) along the side of the fuselage to the top of the MAIM. The MAIM primary power cable is 34-inches long and weighs 177g.

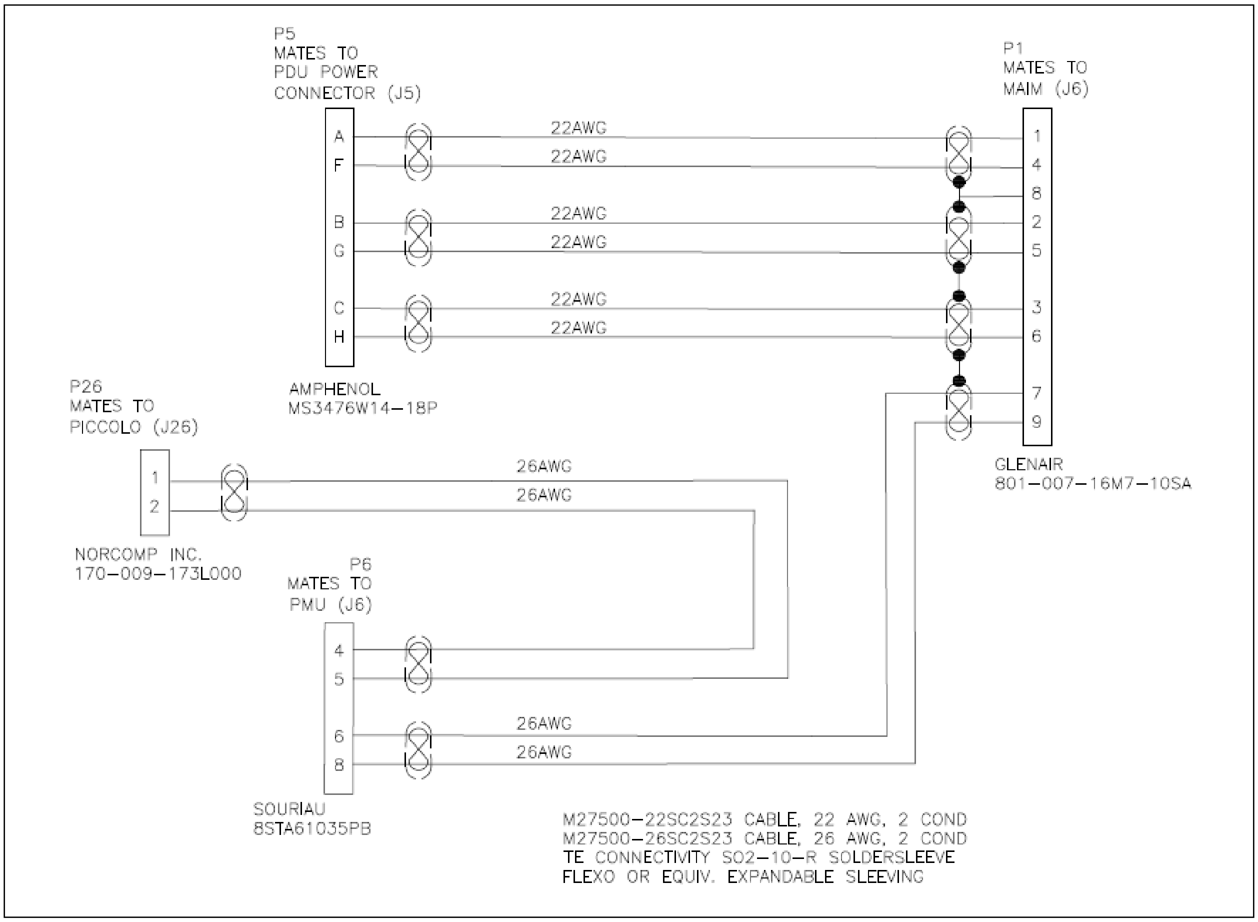


Figure C-17. MAIM Power Cable

C.7.1.2 MAIM Network Cable

The MAIM Network cable is two 28AWG twisted shielded pairs with Expando sleeving and terminated as detailed in Figure C-18. The MAIM network cable runs from the MAIM along the side of the fuselage to the APIM. The MAIM network cable is 28-inches long and weighs 71g.

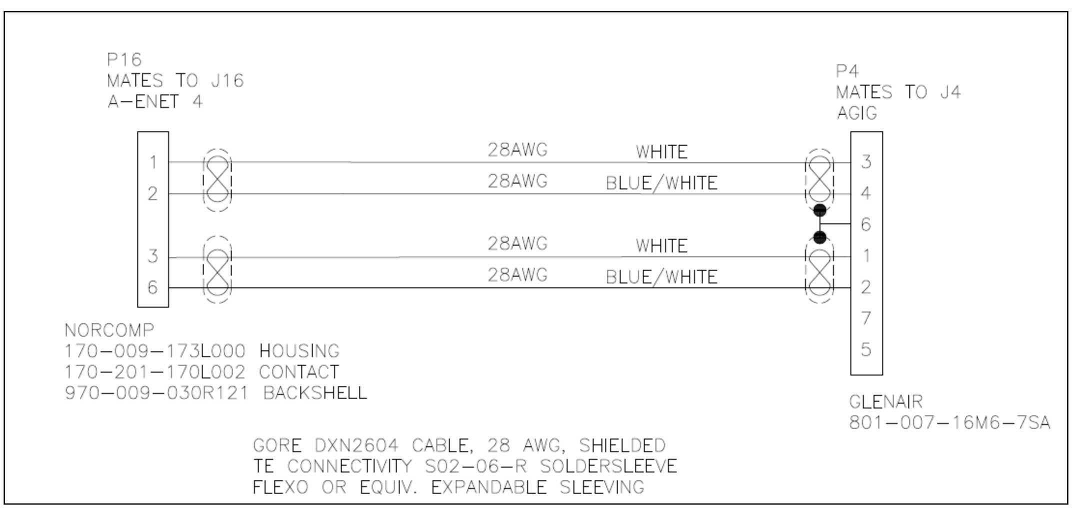


Figure C-18. MAIM Network Cable

C.7.2 MAIM-Payload Cables

The MAIM-payload cable is a COTS, prewired Glenair cable (177-3925-48-34) with EMI shielding and 26 AWG UTP terminated straight thru at each end in the standard-defined 21-pin, Micro-D connector. MAIM-payload cables run from the MAIM along the side of the fuselage forward to the nose payload bay to the Primary Mount. Each MAIM-payload cable is 48-inches long and weighs 128g.

C.7.3 MAIM-INS Cable

The MAIM-INS cable is a 26AWG twisted shielded pair and a 26AWG twisted shielded triple with Expando sleeving and terminated as detailed in Figure C-19. The MAIM-INS cable runs from the top of the MAIM to, along, and up the mounting arm for the INS. The MAIM-INS cable is 26-inches long and weighs 30g.

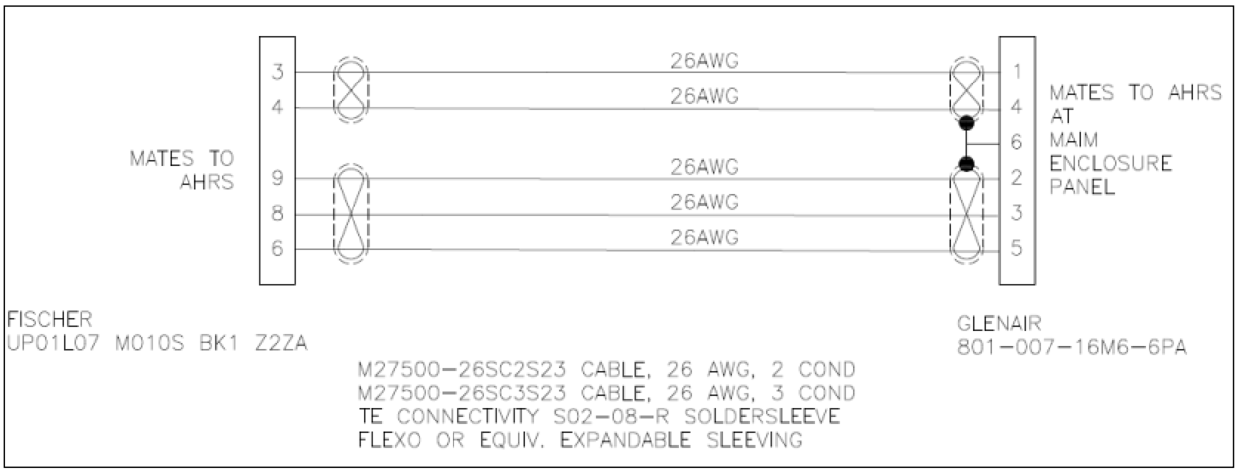


Figure C-19. MAIM to INS Cable

C.7.4 GPS Antenna Cable

The GPS antenna cable is part of the INS installation (see Section C.5) and is depicted in Figure C-11 in that section.

C.7.5 Payload RF Cables

Three sets of RF cables are installed to support the three antenna mount locations on the aircraft. The main set runs to the right wingtip and is permanently installed, while shorter runs to the main payload bay and nose are only installed as needed, depending on the payload. All three cable runs are depicted in Figure C-20 and are detailed further in the subsequent sections.

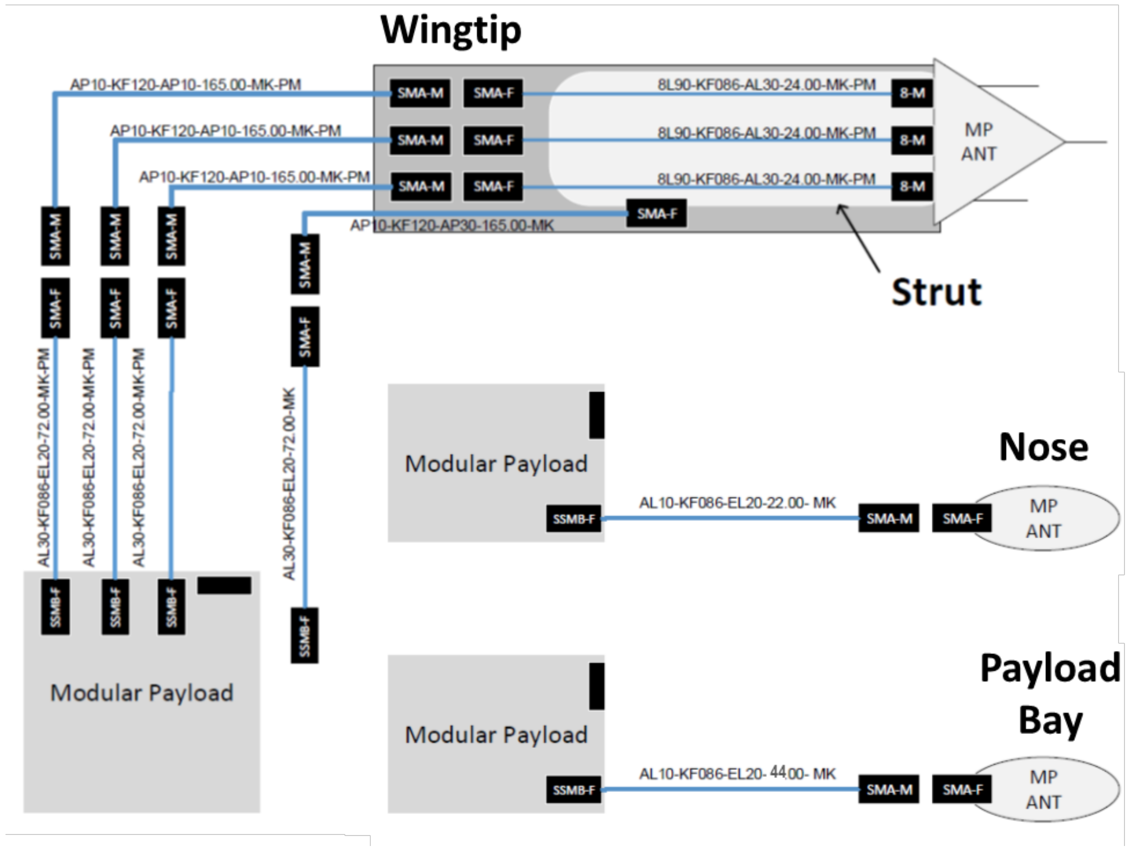


Figure C-20. TigerShark RF Cable Runs

C.7.5.1 RF Cable Summary Table

The following table provides useful characteristic and performance information for all RF cable runs.

Table C-5. TigerShark RF Cable Summary

Cable Set	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Right Wingtip – Array	3	261	583	3.11
Right Wingtip – Extra	1	237	182	2.74
Main Payload Bay	1	44	24	0.68
Nose	1	22	12	0.34

Note 1: Attenuation calculated for a 1GHz signal
Note 2: Weight and attenuation from connectors and inline couplers have been neglected

C.7.5.2 Wingtip Cables

The cables that make up the wingtip cable set are low-loss, lightweight coax. As detailed in Figure C-20, the wingtip cable set consists of four cable runs. Three cable runs are phase-matched cables to support an antenna array, while the other run is a single (fourth) cable to support an additional up look, down look, or 45° look antenna.

C.7.5.3 Main Payload Bay Cables

The main payload bay RF cable run, shown in Figure C-20, is an optional run from the Primary Mount aft to the main payload bay and out the left side of the fuselage to support a 2-pt or 4-pt, down look or 45° antenna.

C.7.5.4 Nose Cables

The nose RF cable run, shown in Figure C-20, is an optional run from the Primary Mount forward to the left side of the fuselage to support a 4-pt 45° antenna.

C.8 Platform-Payload Concessions

No concessions are required for the RQ-23A TigerShark.

Appendix D. **MP-Jump-20 UAS**

This appendix details the MP implementation on the Jump-20 UAS.

D.1 Overview

The MP-compliant Jump-20 UAS can support up to 4U of payloads on a custom Primary Mount aft payload tray. UAS power capacity restricts the number of concurrent payloads to a maximum of three. The MP-Jump-20 UAS is equipped to support two wingtip arrays, two wingtip 2-pt up look antennas, two mid-wing 2-pt down look antennas, and a side hatch 2-pt or 4-pt, 45° or side look antenna. A platform-specific MAIM and the MP-compliant INS are both required for this UAS.

D.1.1 MP Architecture

Figure D-1 depicts the architectural layout of the MP implementation on the Jump-20 UAS.

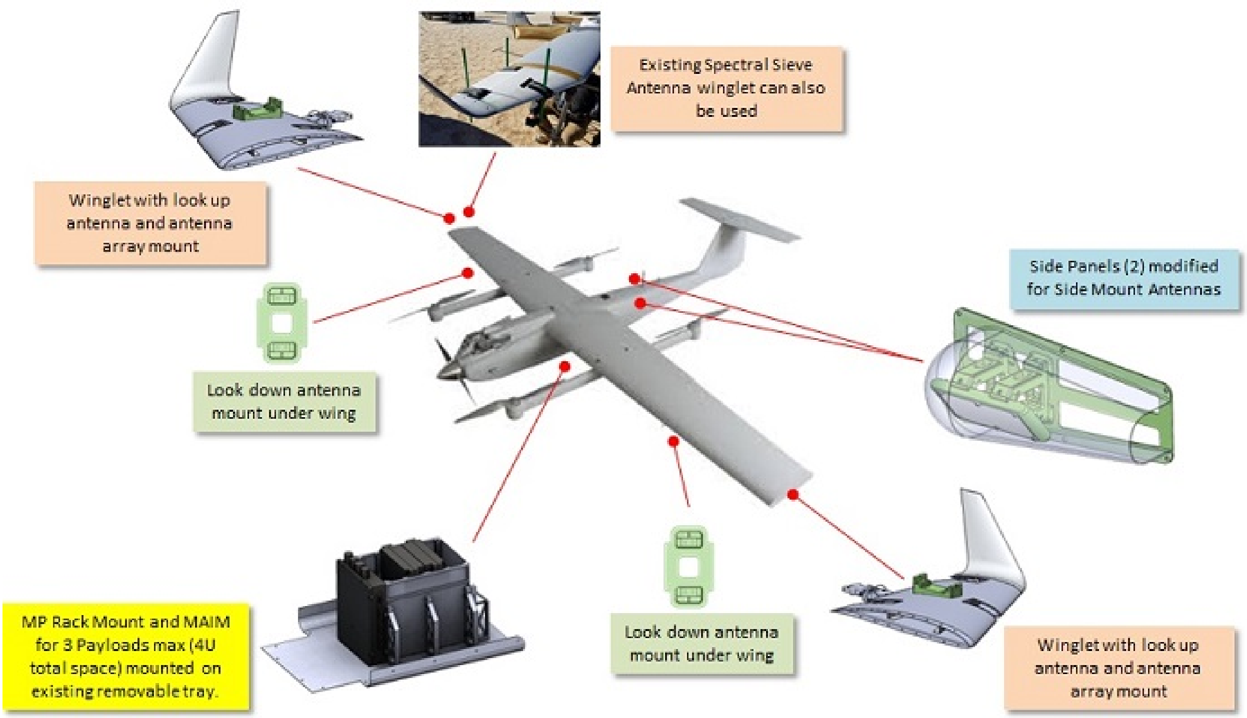


Figure D-1. Architectural Layout for MP-Jump-20

D.1.2 Compliance / Capability Summary

Table D-1 provides a top-level summary of the MP compliance and capability on the Jump-20 UAS.

Table D-1. MP-Jump20 Compliance and Capability

<table>
<tr><th colspan="2">MP Components</th><th colspan="2">Location</th></tr>
<tr><td colspan="2">MAIM</td><td colspan="2">Aft Payload Tray</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">Aft Payload Tray</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Fuselage Interior, Upper Surface</td></tr>
<tr><th colspan="2">Payload Capacity</th><th colspan="2">Description</th></tr>
<tr><td colspan="2">Number of Payloads</td><td colspan="2">3</td></tr>
<tr><td colspan="2">Available Payload Power</td><td colspan="2">168 W</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">4U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">5.7 kg</td></tr>
<tr><th colspan="2">Primary Mount</th><th colspan="2"></th></tr>
<tr><td colspan="2">Mounting Method</td><td colspan="2">Rack</td></tr>
<tr><td colspan="2">Cooling Method</td><td colspan="2">Convection</td></tr>
<tr><th>Antenna Mounts</th><th>Qty</th><th>Location</th><th>Orientation</th></tr>
<tr><td rowspan="3">Two-point</td><td>2</td><td>Wingtip</td><td>Up</td></tr>
<tr><td>2</td><td>Mid-wing</td><td>Down</td></tr>
<tr><td>2</td><td>Side Hatch</td><td>Side or 45°</td></tr>
<tr><td>Four-points</td><td>2</td><td>Side Hatch</td><td>Side or 45°</td></tr>
<tr><td>Array</td><td>2</td><td>Wingtip</td><td>Aft</td></tr>
</table>

D.1.3 System Diagram

Figure D-2 details the system diagram for the MP-Jump-20 UAS. MP-specific additions are highlighted in teal.

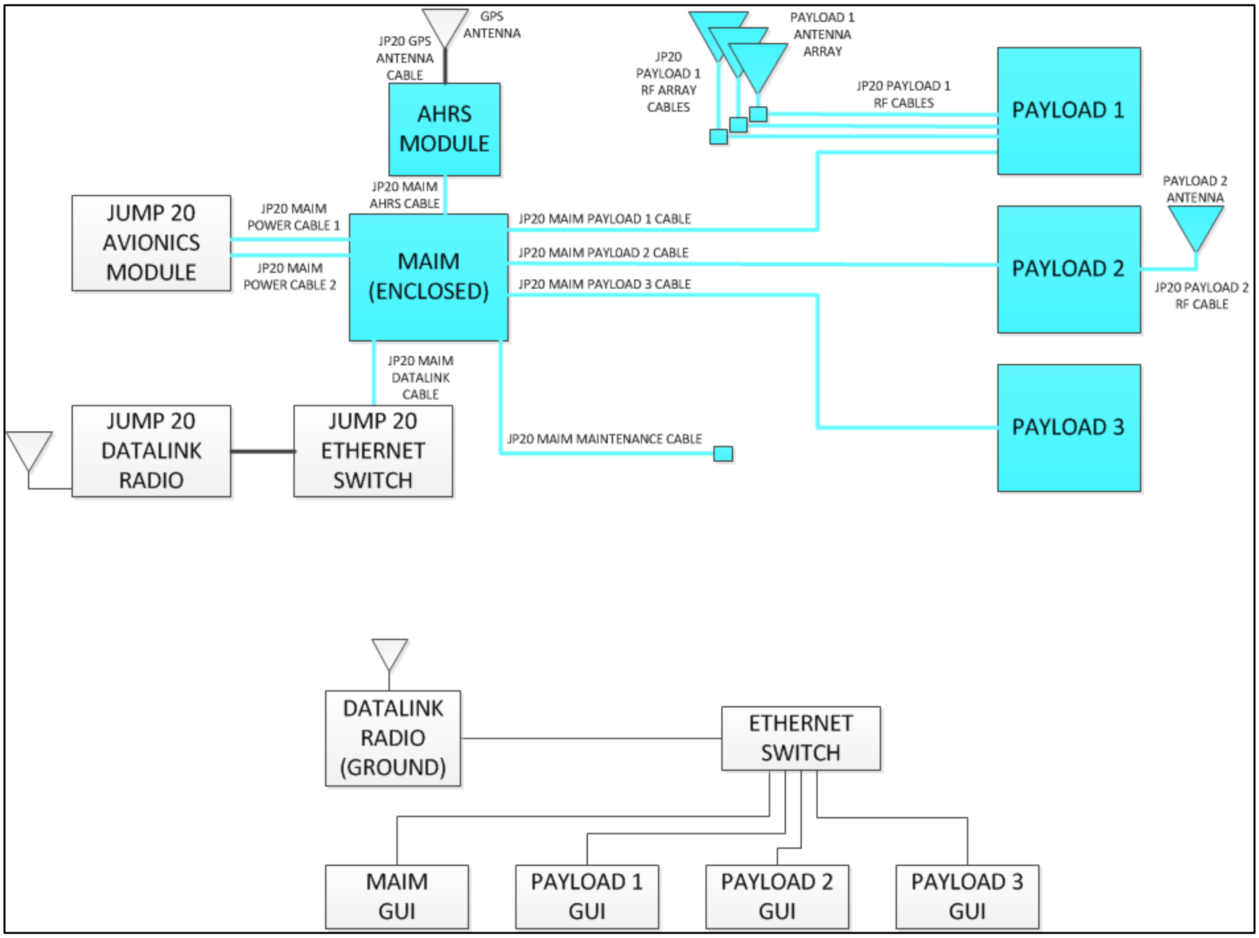


Figure D-2. System Diagram for MP-Jump-20

D.2 Platform Weight and Power Budgets

Even as a Group 3 UAS, the Jump-20 is still SWAP-constrained. The Jump-20 has ample volume, but limited power and weight capacity, as a result of the number of additional payloads desired on the UAS.

D.2.1 Weight Budget

Discounting payloads (and corresponding antennas and antenna adaptors), the MP architecture adds 3.1kg to the Jump-20. This leaves an allowance of 5.7kg for MP-compliant payloads, while maintaining the platform's primary FMV turret. Any weight added by MP hardware in excess of this results in the reduction of fuel and, thus, endurance of the UAS.

D.2.2 Power Budget

The platform power available to support the MP architecture is 179W (140W from the 26VDC bus and 39W from the 13VDC bus). To support three payloads, MP only requires 168W. After adding the power draws for the MAIM and INS and accounting for efficiencies, MP requires 184W. Even though this exceeds the platform power available above, the 184W total MP power draw will almost certainly never be reached as it would require three payloads all drawing the maximum 56W power allowed.

D.3 MAIM

The MAIM is a custom circuit board housed in custom enclosure. The MAIM enclosure is coupled to Primary Mount and installed on payload tray.

D.3.1 Mechanical Description

The MAIM enclosure is 6.6in x 5in x 1.7in and weighs 485g. Figure D-3 shows the MAIM enclosure (left) and the MAIM board (right).

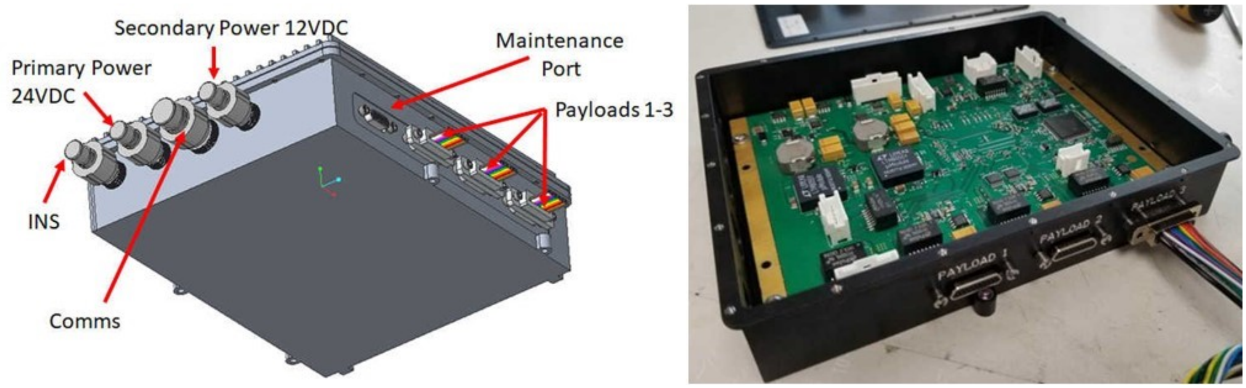


Figure D-3. MAIM for Jump-20

D.3.2 Electrical Description

The MAIM is a custom PCB designed specifically to interface to the Jump-20 UAS and support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure D-4, the microcontroller along with an Ethernet switch, serial transceivers, and power regulation and sense circuitry allow the MAIM to interface to both the platform and payloads. The MAIM itself draws ~4.8W.

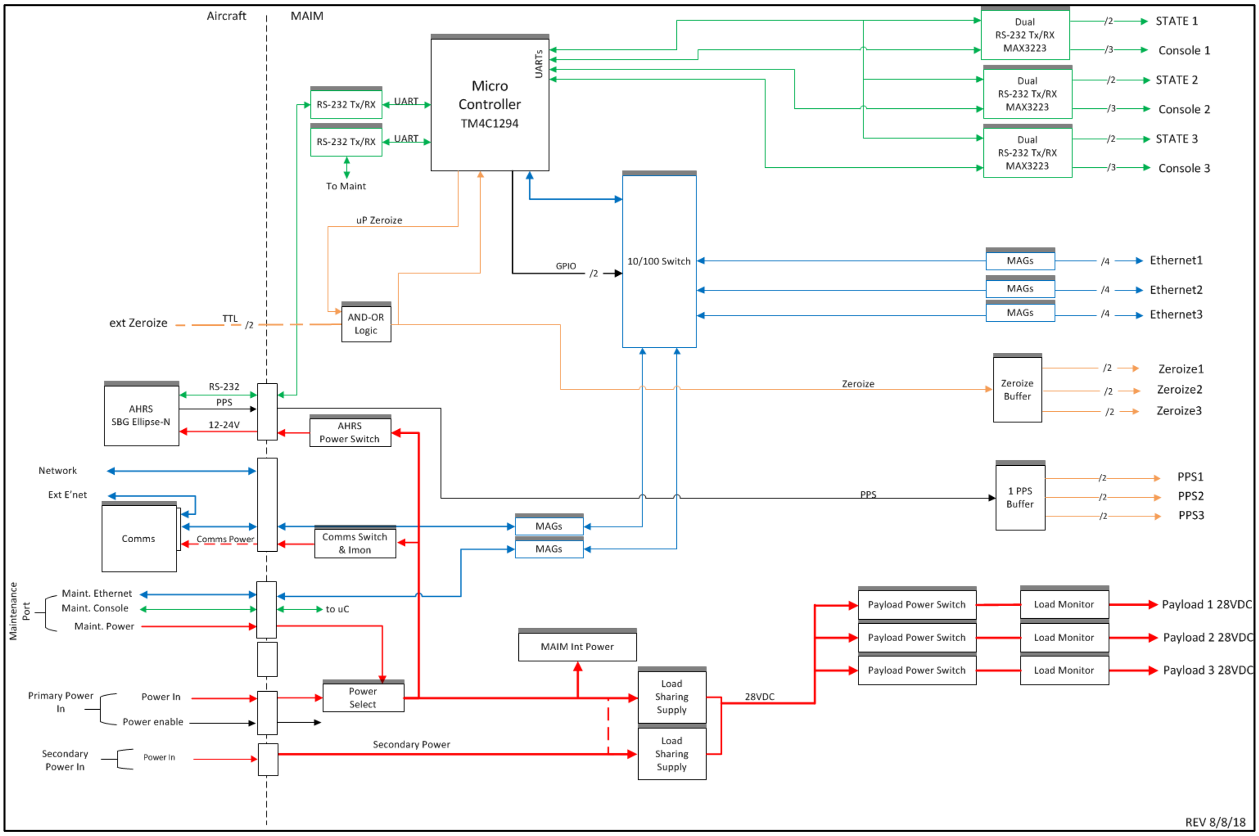


Figure D-4. MAIM Block Diagram for Jump-20

D.3.2.1 Power Input

To maximize power available to the payloads, the MAIM draws power from two separate sources on the Jump-20. The MAIM provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on all power inputs. The MAIM can also be powered externally though the maintenance port.

D.3.2.2 Payload Interfaces

The MAIM supports three payload interfaces. As required by the standard, each payload interface provides power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides the 28VDC power (140mV load regulation, 25mV ripple) to each payload and limits the maximum current draw to 2A (continuous).

The MAIM uses the standard-defined, 21-pin Micro-D connector and pinout to interface to each payload.

D.3.2.3 Power Sharing and Monitoring

The MAIM power circuitry manages load sharing between the primary and secondary power inputs. Additionally, the microcontroller monitors current draw from each module. The block diagram for the MAIM power circuitry is given in Figure D-5.

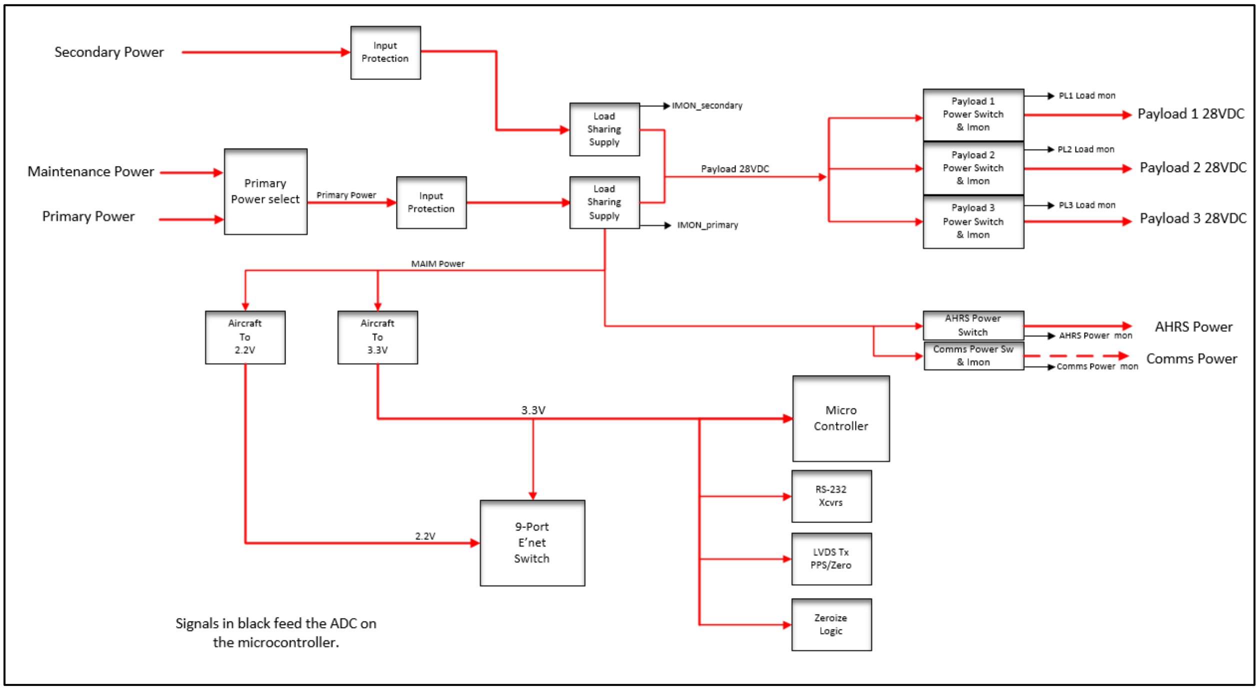


Figure D-5. MAIM Power Circuitry Block Diagram

D.3.2.4 INS Interface

The MAIM provides power and bi-directional serial communications to the MP-compliant INS. Power is provided at 26VDC. State data and the 1PPS signal are received from the INS, while commands are transmitted to the INS.

D.3.2.5 Maintenance Interface

The MAIM provides a dedicated maintenance port to support required debug efforts. The maintenance interface includes an external power hook up, an Ethernet and a serial interface.

D.3.2.6 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the MAIM connects to the Jump-20 network via an onboard Ethernet switch. A Silvus radio also tied to that network provides the UAS backhaul to the ground station.

D.3.3 MAIM Integration

The MAIM enclosure is installed to the forward face of the Primary Mount (Figure D-6). The entire MP payload tray must be removed to install/remove the MAIM. All three payload cables are installed on the MAIM and secured to the Primary Mount prior to payload tray installation.

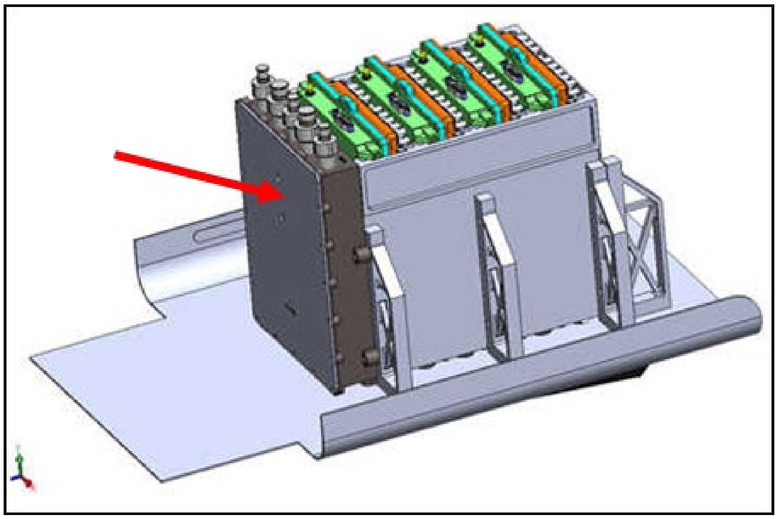


Figure D-6. MAIM Installed on Jump-20 MP Payload Tray

D.4 Primary Mount

The Primary Mount for the Jump-20 is a 4U rack installed on a modified aft payload tray. Figure D-7 shows the Primary Mount with the MAIM, a 1.5U and a 1U payload installed.

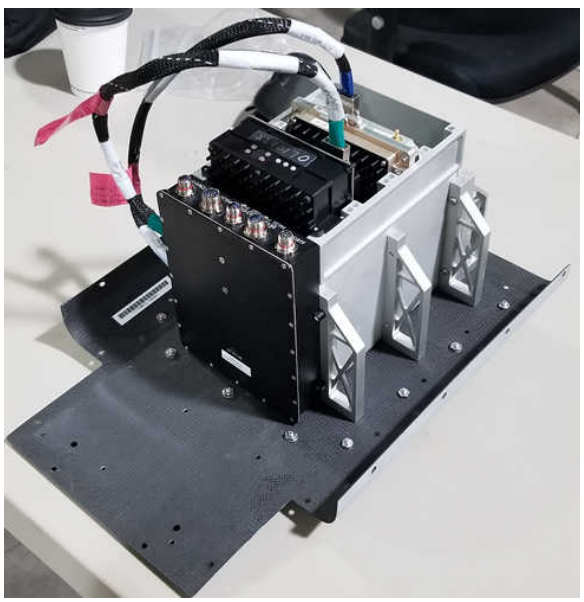


Figure D-7. Jump-20 Primary Mount with MAIM and Two Payloads

D.4.1 Mechanical Description

The Primary Mount consists of the rack assembly, exhaust and the payload tray. The rack is an aluminum assembly, 6.48 in (length) x 5.17 in (width) x 6.00 in (height). The payload tray is a carbon fiber sheet, 15.75 in (length) x 10.9 in (width) x 0.50 (thickness). Including the additional exhaust, the Primary Mount weighs 1027g. The Primary Mount assembly is detailed Figure D-8.

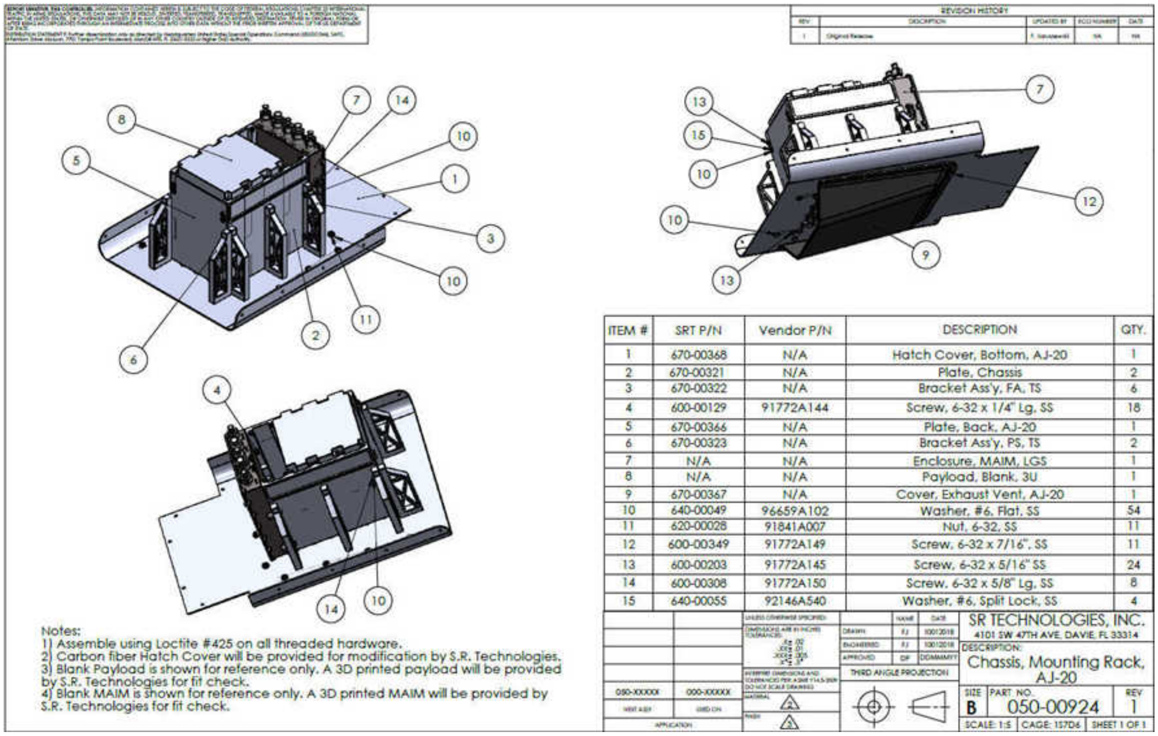


Figure D-8. Jump-20 Primary Mount Assembly Drawing

D.4.2 Installation

The Primary Mount should be fully assembled, i.e., rack assembly and exhaust mounted to the payload tray, prior to installation into the UAS. The MAIM should also be mounted to the Primary Mount, as described in Section D.3.3, prior to installation into the aircraft. As depicted in Figure D-9, the Primary Mount and MAIM are installed together in the aft half of the payload bay. Payloads can either be installed at this time or installed later through the top hatch opening.

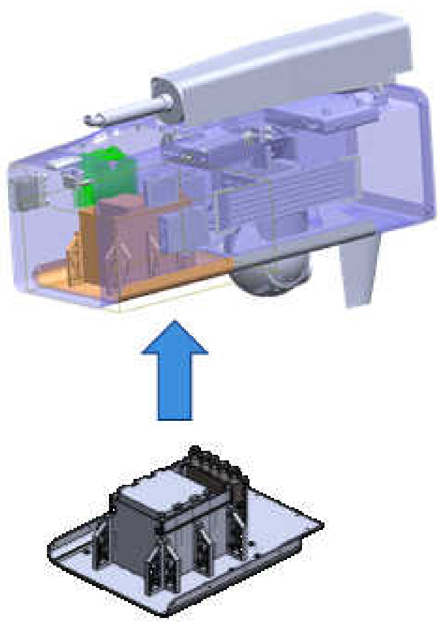


Figure D-9. Jump-20 Primary Mount Installation

D.4.3 Thermal

Multiple considerations are made to and around the Primary Mount to provide the requisite air flow for forced convection cooling of the payloads. Air intakes on a custom top hatch feed air between the modules across their heatsink surfaces through a collection of holes in the payload tray and out the exhaust attached to payload tray. These modifications are depicted in Figure D-10.

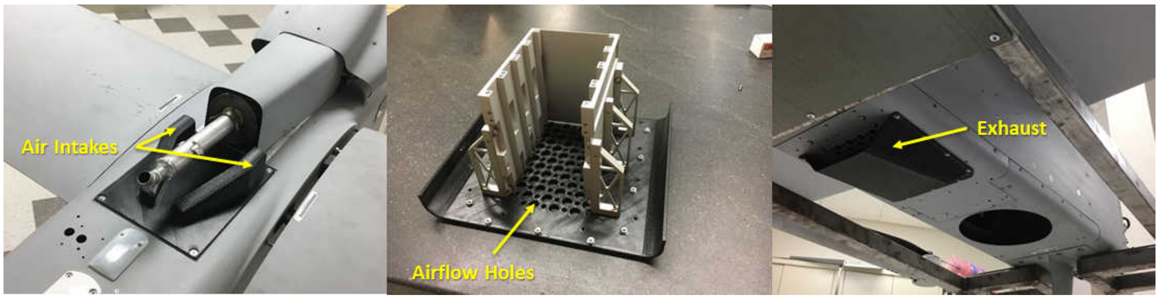


Figure D-10. Forced Convection Modifications

D.5 INS

The Ellipse2-N INS is installed inverted to the inside of the upper surface of the fuselage, aft of the payload access hatch. One of the existing payload GPS antennas is used by the INS. Figure D-11 shows the INS installation location and the platform payload antenna farm.

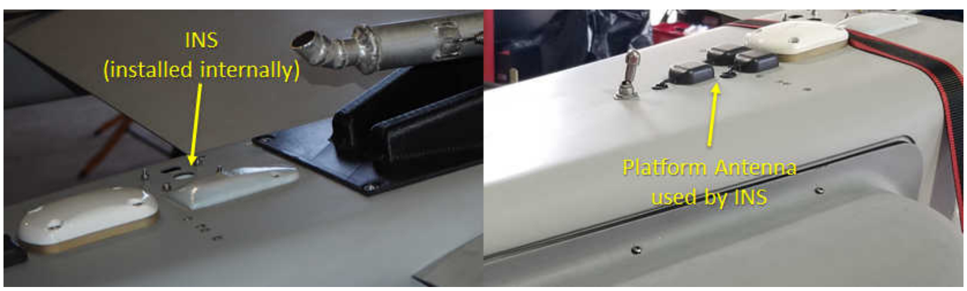


Figure D-11. Jump-20 INS Location and GPS Antenna

D.6 Antenna Mounts

The MP-Jump-20 supports antenna mounts in six locations: on the each wingtip, midway down each wing, and on each side hatch.

D.6.1 Wingtip Mounts

The Jump-20 has multiple options for wingtip antenna mounts:

- An array mount (strut)
- A 2-pt up look antenna mount
- A combination array and 2-pt up look mount

All configurations use the same customized wingtip. This wingtip allows for different antenna mounts to be installed through it to support the requisite antenna configuration. Figure D-12, Figure D-13 and Figure D-14 show each wingtip configuration.

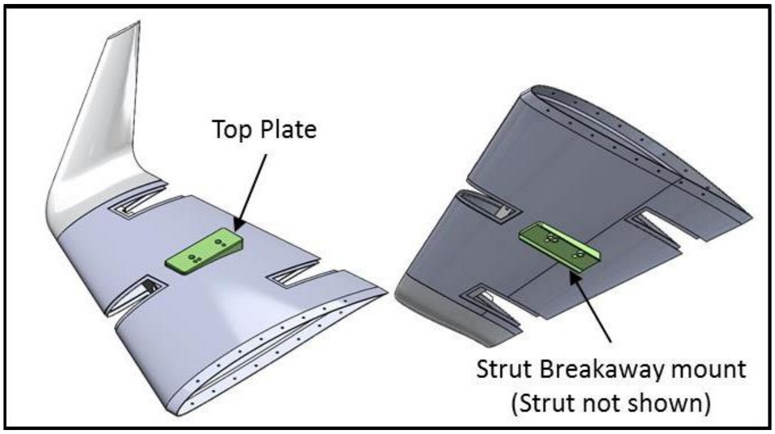


Figure D-12. Jump-20 Wingtip – Array Configuration

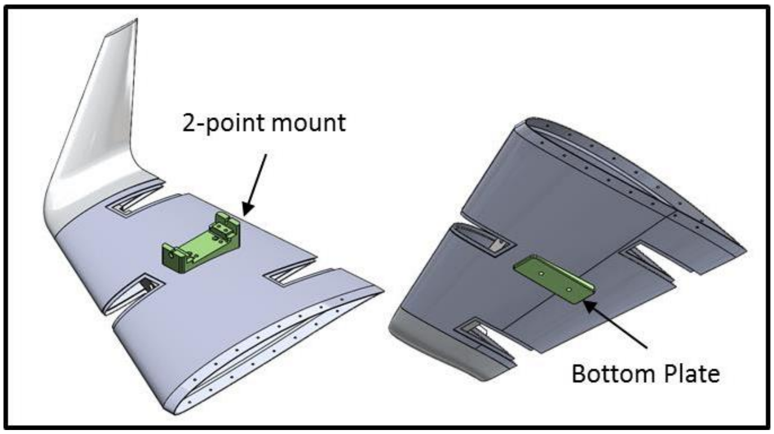


Figure D-13. Jump-20 Wingtip – 2-pt Up Look Configuration

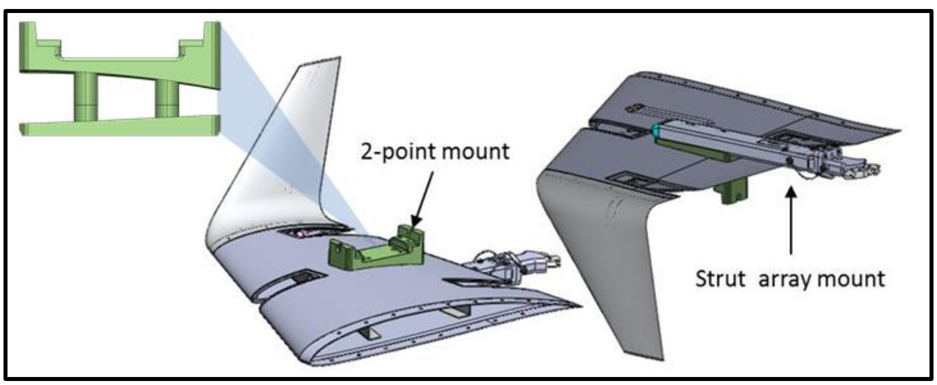


Figure D-14. Jump-20 Wingtip – Array and 2-pt Up Look Configuration

The strut and 2-pt up look mounts provide the standard-defined antenna array and 2-pt interfaces, respectively. The weights of the various antenna mount configurations are shown in Table D-2.

Table D-2. Jump-20 Wingtip Antenna Mount Weights

Configuration	Weight (g)
Array only	196
Up Look only	101
Array and Up Look	215

The capacities for the array and 2-pt up look antenna mounts is defined in Table D-3.

Table D-3. Antenna Array Mount Capacity

Antenna Array Mount	
Max Weight	
Max	To Be Added in Rev 6
2-pt Up Look Antenna Mount	
Max Weight	
Max Volume	

An additional non-MP-compliant wingtip is discussed in Section D.8.1.

D.6.2 Mid-Wing Mount

A 2-pt down look antenna mount is installed underneath each wing by replacing an existing wing access cover with a customized bracket, as shown in Figure D-15.

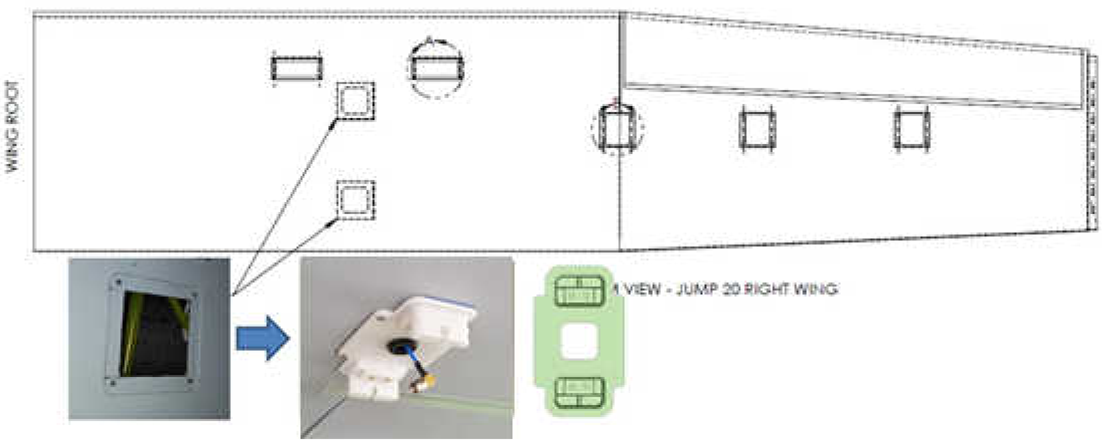


Figure D-15. Jump-20 Mid-wing 2-pt Down Look Mount

The 2-pt down look mount weighs 60g. The 2-pt down look antenna mount capacity is defined in Table D-4.

Table D-4. Down Look Antenna Mount Capacity

Max	To Be Added in Rev 6
Max	

D.6.3 Side Hatch Mounts

A custom antenna mount can be installed on either side hatch, replacing the standard side hatch cover. This mount can support 2-pt or 4-pt, side look or 45° antennas. Due to the relatively large size of such antennas, a radome is employed to decrease drag. Figure D-16 shows the antenna mount assembly both with and without the radome.

Figure D-16. Jump-20 Side Hatch Antenna Mount – With Radome (left), Without Radome (right)

The side hatch antenna mount assembly consists of three parts: an interface plate, the antenna mount, and the radome. While the interface plate and radome are meant to be universal, the antenna mount can vary depending on payload / antenna requirements. The interface plate and radome weigh 155g and 450g. The various antenna mount weights are listed in Table D-5.

Table D-5. Jump-20 Side Hatch Antenna Mounts

Antenna Mount	Weight (g)
2-pt Side Look	124
2-pt 45° Look	170
4-pt Side Look	165
4-pt 45° Look	261

The capacities for the array and 2-pt up look antenna mounts is defined in Table D-6.

Table D-6. Jump-20 Hatch Antenna Mount Capacity

2-pt Side Look Antenna Mount		4-pt Side Look Antenna Mount	
Max Weight		Max Weight	
Max Volume			
2-pt 45° Antenna Mount		4-pt 45° Antenna Mount	
Max Weight		Max Weight	
Max Volume		Max Volume	

To Be Added in Rev 6

D.7 Cabling

With well-defined interfaces, co-located MAIM and Primary Mount, and ample fuselage and internal wing volume, cabling is relatively straightforward. The schematic for all MAIM cables is provided in Figure D-17. The following sections provide further detail on each of these cables. RF cables are covered in Section D.7.6.

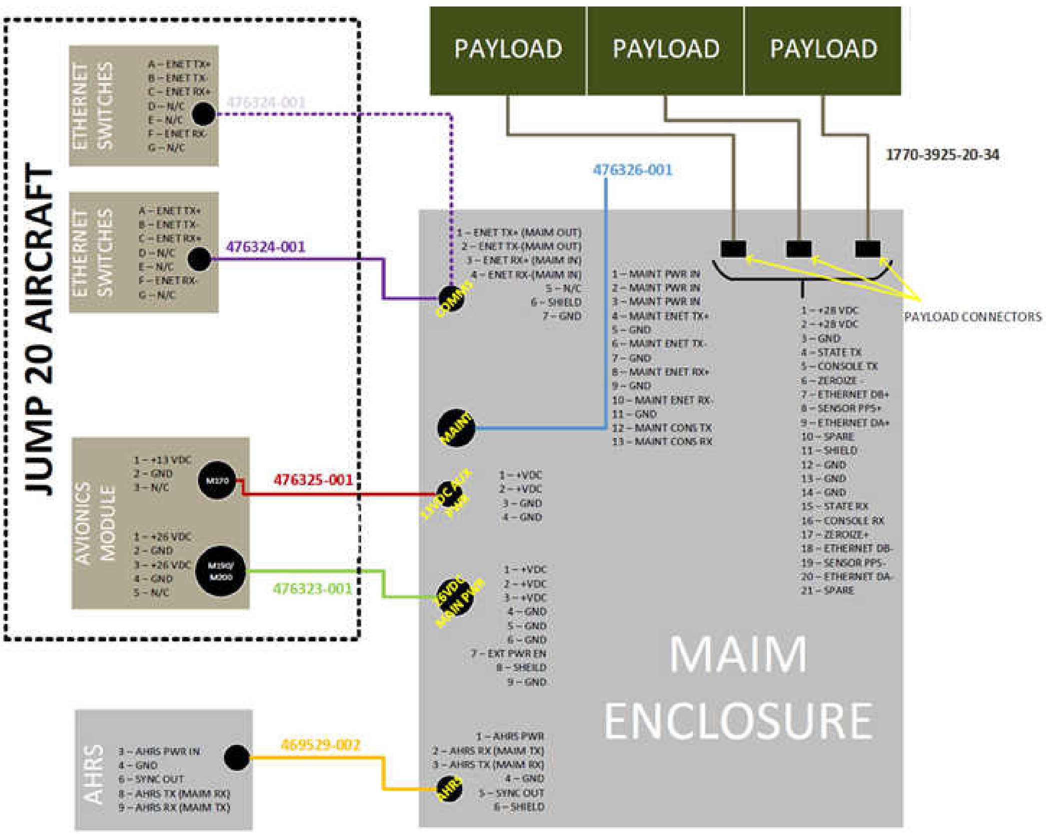


Figure D-17. Jump-20 MAIM Cabling Schematic

D.7.1 Primary Power Cable

The MAIM primary power cable is two 22AWG twisted shielded pairs with Expando sleeving terminated as detailed in Figure D-18. The MAIM primary power cable runs forward from the Avionics Module along and up the side of the fuselage, then across the top of the fuselage before dropping down to the top of the MAIM. The MAIM primary power cable is 25-inches long and weighs 42g.

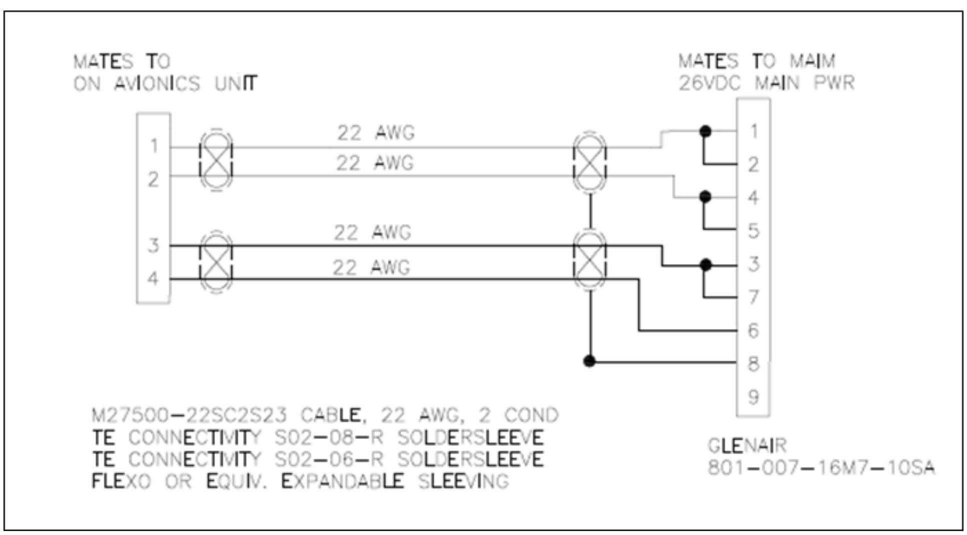


Figure D-18. MAIM Primary Power Cable Pinout

D.7.2 Secondary Power Cable

The MAIM secondary power cable is one 22AWG twisted shielded pair with Expando sleeving terminated as detailed in Figure D-19. The MAIM secondary power cable runs forward from the Avionics Module along and up the side of the fuselage, then across the top of the fuselage before dropping down to the top of the MAIM. The MAIM secondary power cable is 25-inches long and weighs 25g.

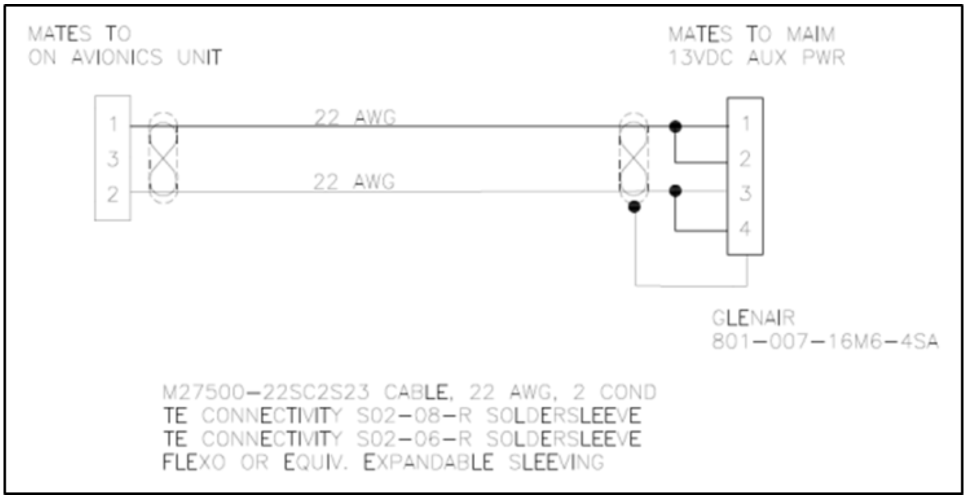


Figure D-19. MAIM Secondary Power Cable Pinout

D.7.3 MAIM-Payload Cables

The MAIM-payload cable is a COTS, prewired Glenair cable (177-3925-20-34) with EMI shielding and 26 AWG UTP terminated straight thru at each end in the standard-defined, 21-pin Micro-D connector. Three MAIM-payload cables run from the MAIM along the side of Primary Mount to the three furthest payload positions in the Primary Mount. Figure D-20 depicts this cable run, but with only two MAIM-payload cables. Each MAIM-payload cable is 20-inches long and weighs 47g.

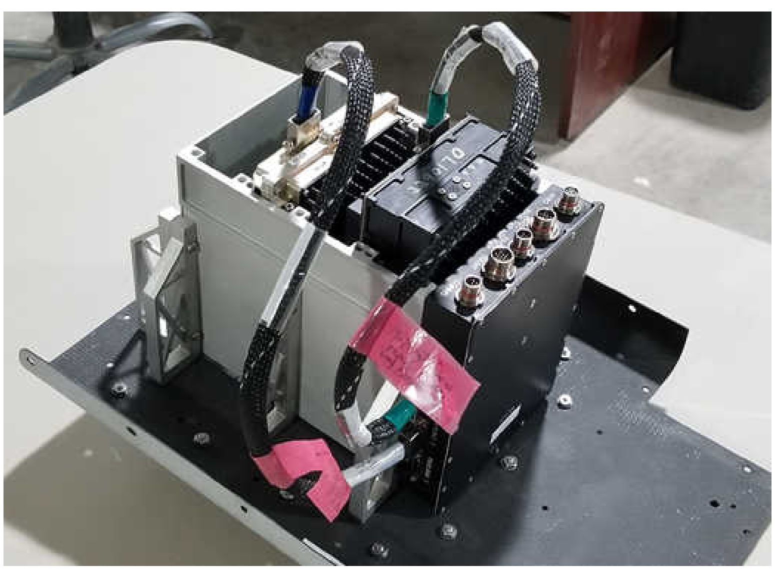


Figure D-20. MAIM-Payload Cable Runs

D.7.4 MAIM-INS Cable

The MAIM-INS cable is a 26AWG twisted shielded pair and a 26AWG twisted shielded triple with Expando sleeving and terminated as detailed in Figure D-21. The MAIM-INS cable runs from the top of the MAIM to, along, and up the side of the fuselage to the INS. The MAIM-INS cable is 26-inches long and weighs 25g.

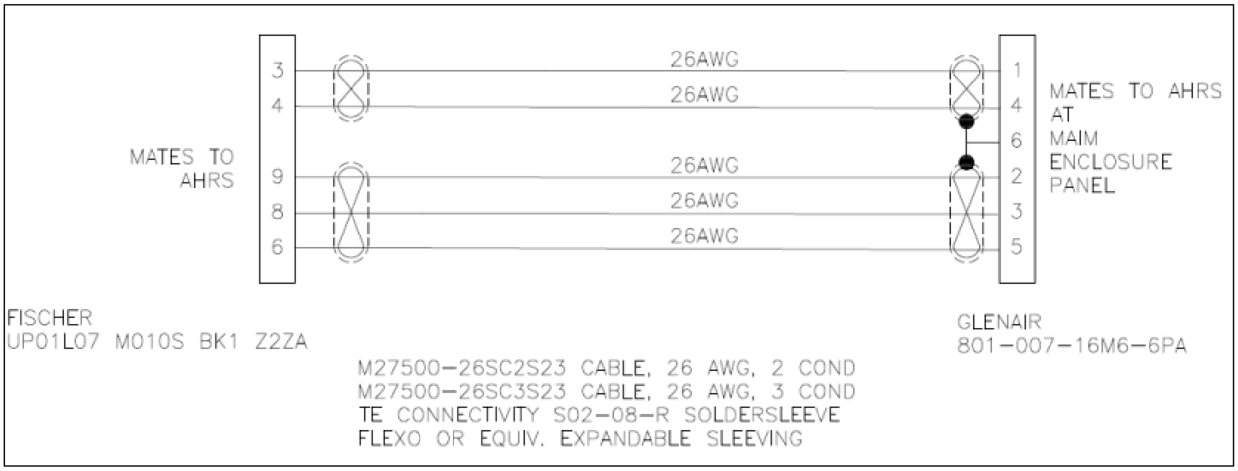


Figure D-21. MAIM to INS Cable

D.7.5 Network Cable

The MAIM network cable is two 28AWG twisted shielded pairs with Expando sleeving and terminated as detailed in Figure D-22. The MAIM network cable runs from the MAIM along the fuselage to the platform network switch. The MAIM network cable is 28-inches long and weighs 32g.

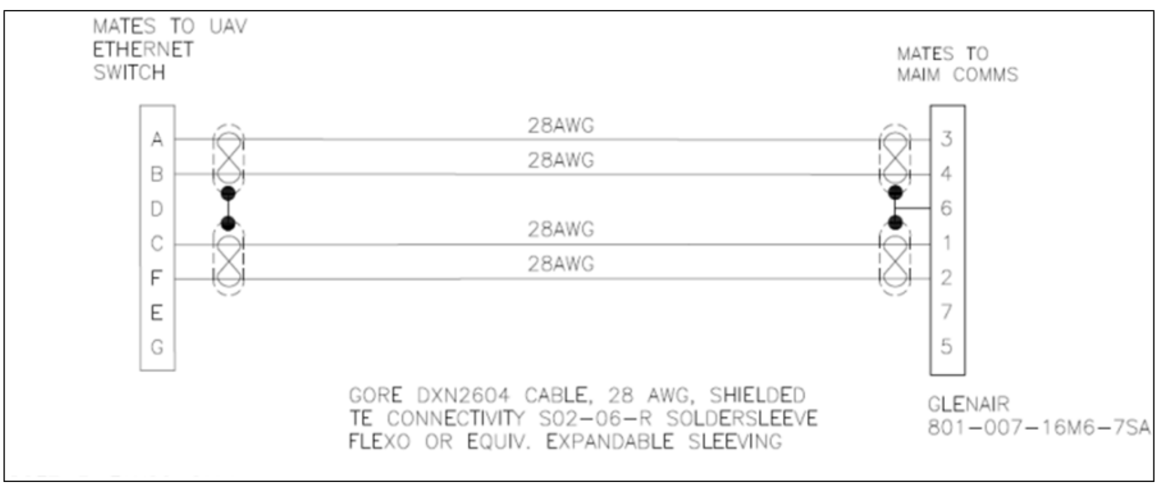


Figure D-22. MAIM Network Cable

D.7.6 RF Cables

Two sets of RF cables are installed to support the various payload antenna options. One set runs to the left side of the aircraft with endpoints at the side hatch, in the mid wing, and on the wingtip; the second set runs on the right side of the aircraft, mirroring the first set. Both left and right cable runs are detailed in the subsequent sections.

D.7.6.1 RF Cable Summary Table

The following table provides useful characteristic and performance information for all RF cable runs.

Table D-7. Jump-20 RF Cable Summary

Cable Set	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Left Wingtip – Array	3	128	225	2.21
Left Wingtip – Up	1	130	77	2.24
Left Mid Wing	1	60	41	1.06
Left Side Hatch	1	12	10	0.24
Right Wingtip – Array	3	128	333	1.56
Right Wingtip – Up	1	130	113	1.59
Right Mid Wing	1	60	62	0.72
Right Side Hatch	1	16	21	0.28

Note 1: Attenuation calculated for a 1GHz signal
Note 2: Weight and attenuation from connectors and inline couplers have been neglected

D.7.6.2 Left Side Cables

The cables that make up the left side cable set are low-loss, lightweight coax. As detailed in Figure D-23, the left cable set consists of four cable runs that terminate in four different antenna mount locations along the left side of the UAS.

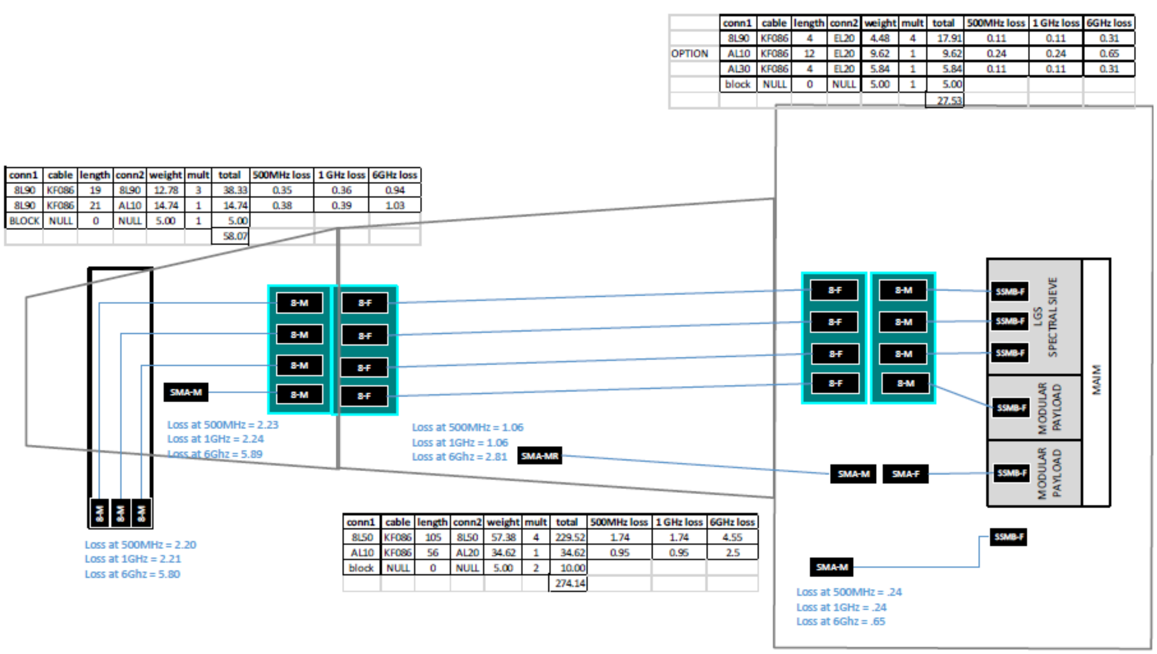
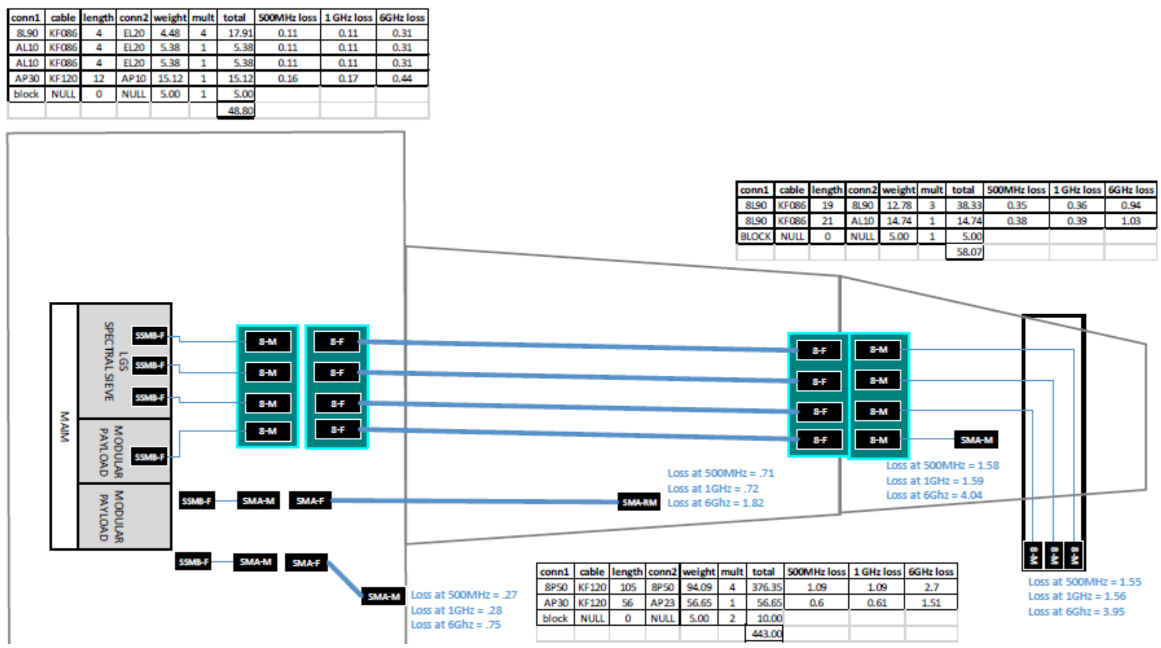


Figure D-23. Jump-20 Left RF Cables

The longest two cable runs pass from the payload bay through the left wing and into the wingtip. One run consists of three phase-matched cables to support an antenna array, while the other run is a single (fourth) cable to support an additional 2-pt up look antenna. A third cable run from the payload bay to the mid wing supports a 2-pt down look antenna. The last run is the shortest and is optional (unlike the other runs); it runs from the payload bay aft to the left side hatch to support a 2-pt or 4-pt, side look or 45° antenna. To simplify maintenance and installation, where applicable, cable runs include inline connections at the wing root and wing tip.

D.7.6.3 Right Side Cables

The cables that make up the right side cable set are lower-loss, heavier-weight coax. As detailed in Figure D-24, the right cable set consists of four cable runs that terminate in four different antenna mount locations along the right side of the UAS.



conn1	cable	length	conn2	weight	mult	total	500MHz loss	1 GHz loss	6GHz loss
8L90	KF086	4	EL20	4.48	4	17.91	0.11	0.11	0.31
AL10	KF086	4	EL20	5.38	1	5.38	0.11	0.11	0.31
AL10	KF086	4	EL20	5.38	1	5.38	0.11	0.11	0.31
AP30	KF120	12	AP10	15.12	1	15.12	0.16	0.17	0.44
block	NULL	0	NULL	5.00	1	5.00			
						48.80			

conn1	cable	length	conn2	weight	mult	total	500MHz loss	1 GHz loss	6GHz loss
8L90	KF086	19	8L90	12.78	3	38.33	0.35	0.36	0.94
8L90	KF086	21	AL10	14.74	1	14.74	0.38	0.39	1.03
BLOCK	NULL	0	NULL	5.00	1	5.00			
						58.07			

conn1	cable	length	conn2	weight	mult	total	500MHz loss	1 GHz loss	6GHz loss
8P50	KF120	105	8P50	94.09	4	376.35	1.09	1.09	2.7
AP30	KF120	56	AP23	56.65	1	56.65	0.6	0.61	1.51
block	NULL	0	NULL	5.00	2	10.00			
						443.00			

Figure D-24. Jump-20 Right RF Cables

The longest two cable runs pass from the payload bay through the right wing and into the wingtip. One run consists of three phase-matched cables to support an antenna array, while the other run is a single (fourth) cable to support an additional 2-pt up look antenna. A third cable run from the payload bay to the mid wing supports a 2-pt down look antenna. The last run is the shortest and is optional (unlike the other runs); it runs from the payload bay aft to the right side hatch to support a 2-pt or 4-pt, side look or 45° antenna. To simplify maintenance and installation, where applicable, cable runs include inline connections at the wing root and wing tip.

D.8 Platform-Payload Concessions

A single concession is documented for the MP-Jump-20, and it is payload-specific.

D.8.1 SURFR3B Antenna Array

In lieu of using the MP-compliant array interface, a custom wingtip (Figure D-25) is permitted to be used to support the SURFR3B paylaod. This wingtip has been previously assessed to meet the payload requirements. The MP architecture easily accommodates this deviation – rather than swapping antennas or antenna mounts when installing the SURFR3B, the entire wingtip is replaced. The custom wingtip attaches to the MP RF cabling at the wingtip breakpoint to connect the antennas back to the SURFR3B payload installed in the Primary Mount.

Figure D-25. Non-compliant SURFR-3B Wingtip Array

Appendix E. **MP-Stalker XE25 UAS**

This appendix details the MP implementation on the Stalker XE25 UAS.

E.1 Overview

The MP-compliant Stalker UAS can support up to 2U of payloads on a custom, external payload tray. UAS power capacity restricts the platform to a single payload. The MP-Stalker XE25 UAS is equipped to support one boom, 2-pt antenna mount and either an array or a 2-pt down look antenna mount at the center of the right wing. A platform-specific MAIM and the MP-compliant INS are both required for this UAS.

E.1.1 MP Architecture

Figure E-1 depicts the architectural layout of the MP implementation on the Stalker XE25 UAS.

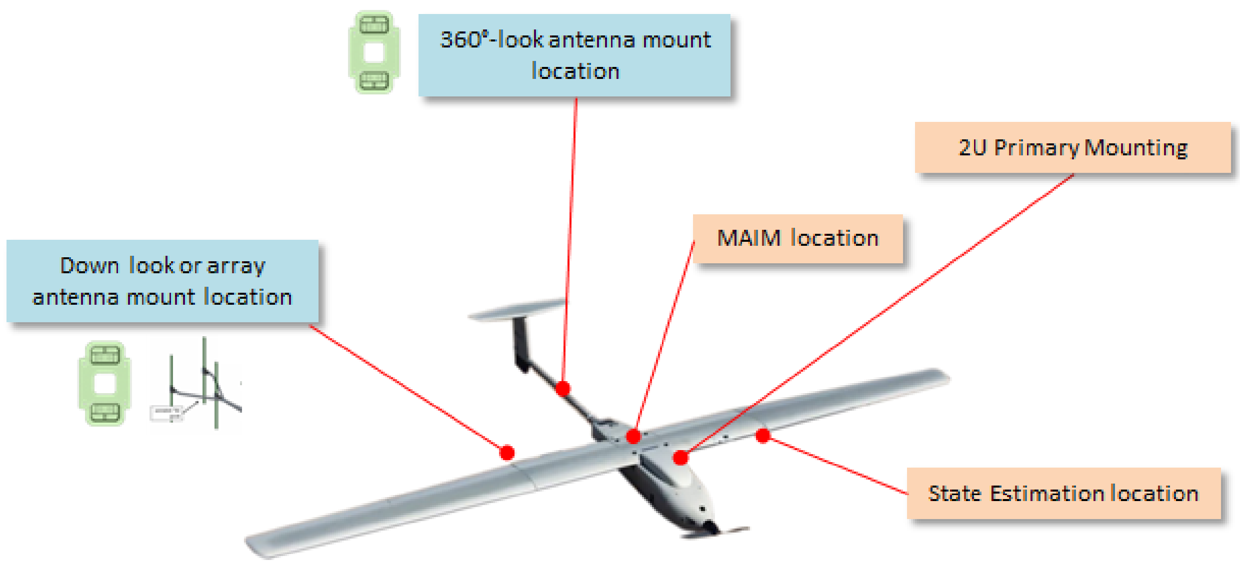


Figure E-1. Architectural Layout for MP-Stalker

E.1.2 Compliance / Capability Summary

Table E-1 provides a top-level summary of the MP compliance and capability on the Stalker XE25 UAS.

Table E-1. MP-Stalker Compliance and Capability

MP Components	Location
MAIM	Fuselage, Mid-bay
Primary Mount	Nose (External)
INS	Wing, Left Hard Point
Payload Capacity	**Description**
Number of Payloads	1
Available Payload Power	56W

Available Payload Volume		2U	
Available Payload Weight		Varies – 3.0 lbs (1.3 kg) minimum	
Primary Mount			
Mounting Method		Plate	
Cooling Method		Convection	
Antenna Mounts	**Qty**	**Location**	**Orientation**
Two-point	2	Boom Wing, Right Hard Point	360º Down
Four-points	0	N/A	N/A
Array	1	Wing, Right Hard Point	Forward

E.1.3 System Diagram

Figure E-2 details the system diagram for the MP-Stalker XE25 UAS. MP-specific additions are highlighted in teal.

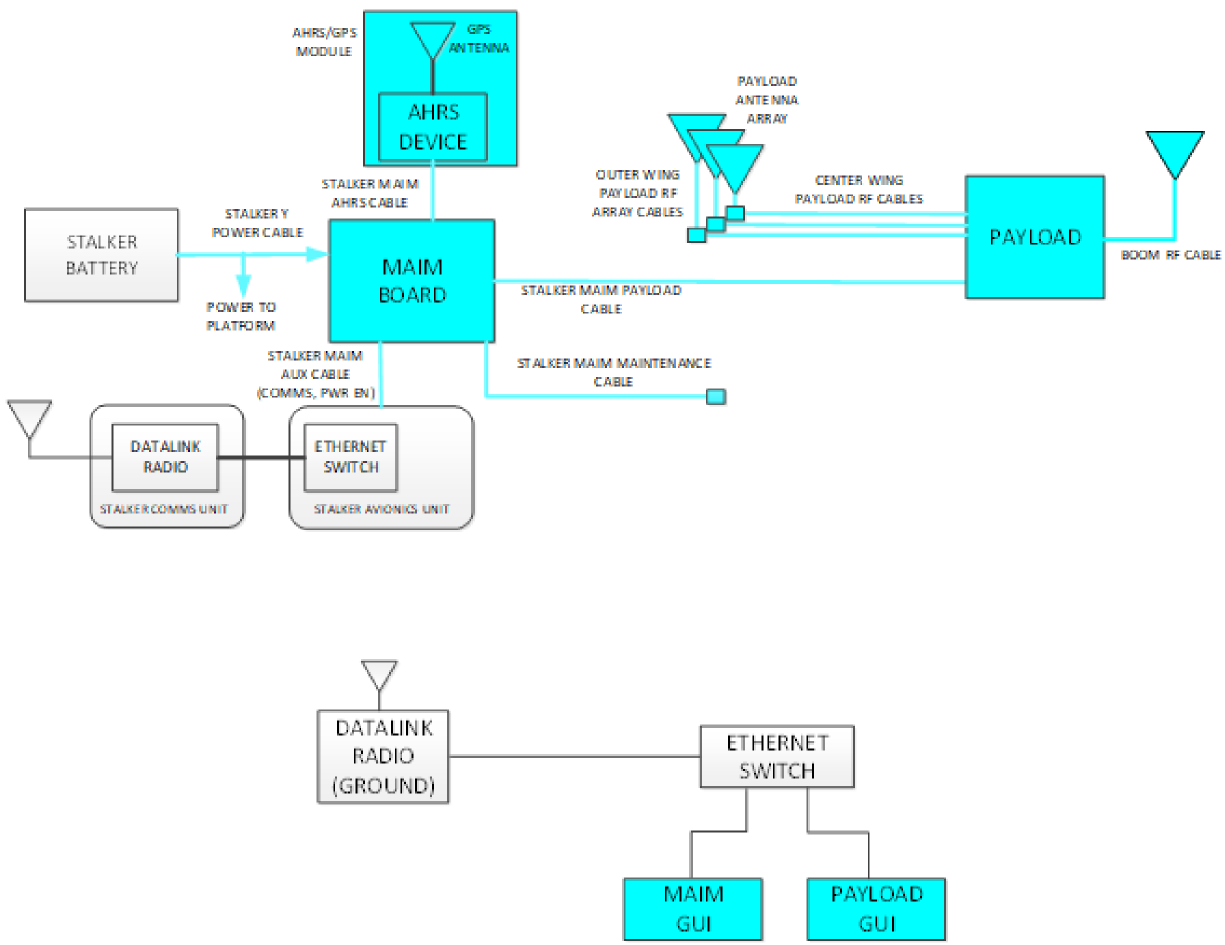


Figure E-2. System Diagram for MP-Stalker

E.2 Platform Weight and Power Budgets

As a small Group 2 UAS, the Stalker is considerably SWAP-constrained. Moreover, the Stalker is constrained in each SWAP attribute.

E.2.1 Weight Budget

Discounting payloads (and corresponding antennas, antenna adaptors and optional cabling), the core MP architecture (of MAIM, Primary Mount Assembly, INS, INS mount, GPS Antenna, antenna mounts, and Wire Harnesses) adds 708g to the Stalker. This leaves an allowance of 1.3kg for MP-compliant payloads, while maintaining the platform's primary FMV turret.

E.2.2 Power Budget

The platform power available to support the MP architecture is 65W (pulled from the main battery). After adding the power draws for the MAIM and INS to the 56W payload requirement and accounting for efficiencies, the MP architecture requires 62W.

E.3 MAIM

The MAIM is a custom circuit board installed inside the fuselage.

E.3.1 Mechanical Description

The MAIM board is 5.7in x 2.5in x 0.5in board and weighs 72g. Figure E-3 shows the MAIM.

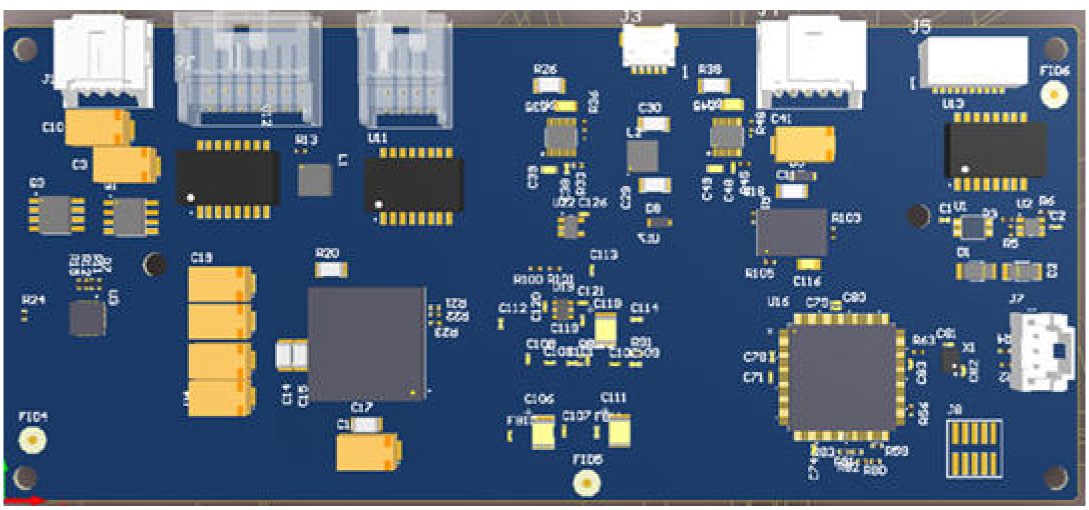


Figure E-3. MAIM for Stalker

E.3.2 Electrical Description

The MAIM is a custom PCB designed specifically to interface to the Stalker UAS and support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure E-4, the microcontroller along with an Ethernet switch, serial transceivers, and power regulation and sense circuitry allow the MAIM to interface to both the platform and payload. The MAIM itself draws ~3W.

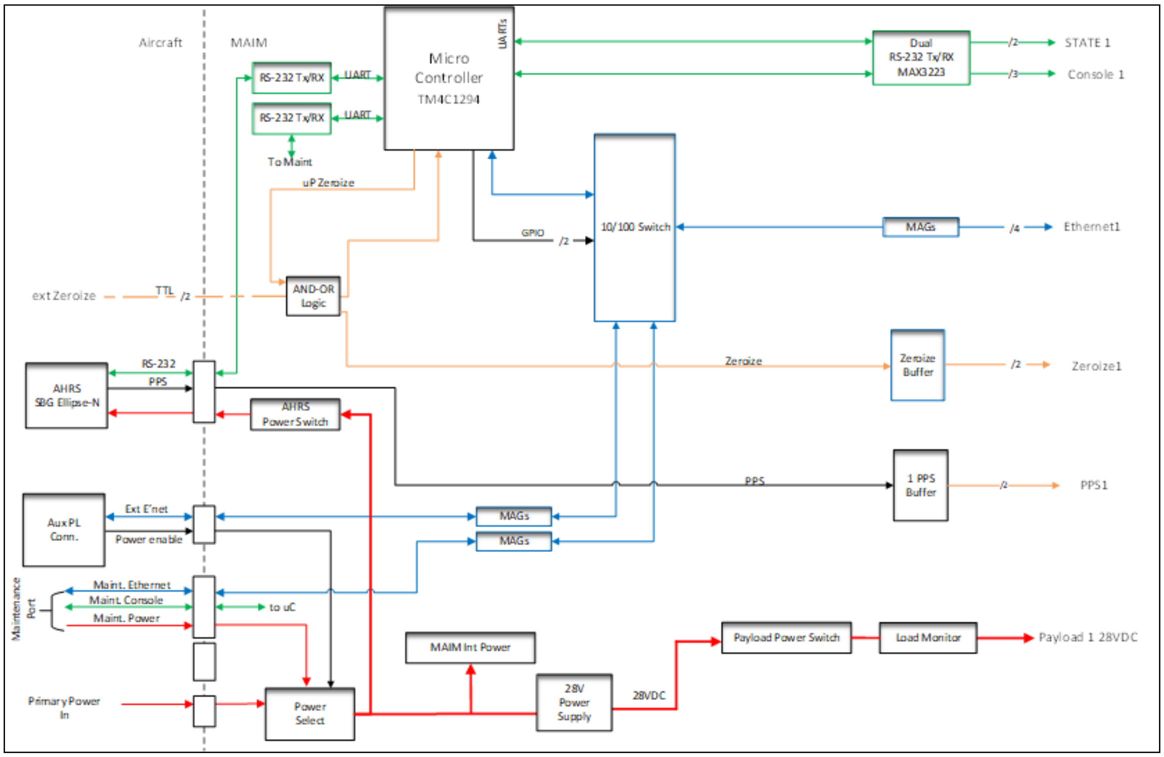


Figure E-4. MAIM Block Diagram for Stalker

E.3.2.1 Power Input

To maximize power available to the payloads, the MAIM draws power directly from the main battery via a custom Y-cable. The MAIM provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on the power input. The MAIM can also be powered externally though the maintenance port.

E.3.2.2 Payload Interfaces

The MAIM supports one payload interface. As required by the standard, the payload interface provides power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides the 28VDC power (140mV load regulation, 25mV ripple) to the payload and limits the maximum current draw to 2A (continuous).

The MAIM uses a 5-pin molex connector for payload power and a 20-pin molex connector for payload communications as its payload interface. *Note: the MAIM-payload cable (detailed in Section E.7.2), which mates to this interface presents the standard-defined, 21-pin Micro-D connector to the payload.*

E.3.2.3 Power Monitoring

In addition to power regulation, the MAIM microcontroller monitors and reports current draws from the INS and the payload.

E.3.2.4 INS Interface

The MAIM provides power and bi-directional serial communications to the MP-compliant INS. Power is provided at 28VDC. State data and the 1PPS signal are received from the INS, while commands are transmitted to the INS.

E.3.2.5 Maintenance Interface

The MAIM provides a dedicated maintenance port to support required debug efforts. The maintenance interface includes an external power hook up, an Ethernet and a serial interface.

E.3.2.6 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the MAIM connects to the Stalker network via an onboard Ethernet switch. A Silvus radio also tied to that network provides the UAS backhaul to the ground station.

The MAIM also includes a 12V power enable interface and an external zeroize interface, but neither of these signals are currently supported by the Stalker at this time.

E.3.3 MAIM Integration

The MAIM is installed in the mid bay to the side of the fuselage (Figure E-5), using existing holes in the airframe. The MAIM is oriented with connectors facing up to allow for the easy installation and removal of cables.

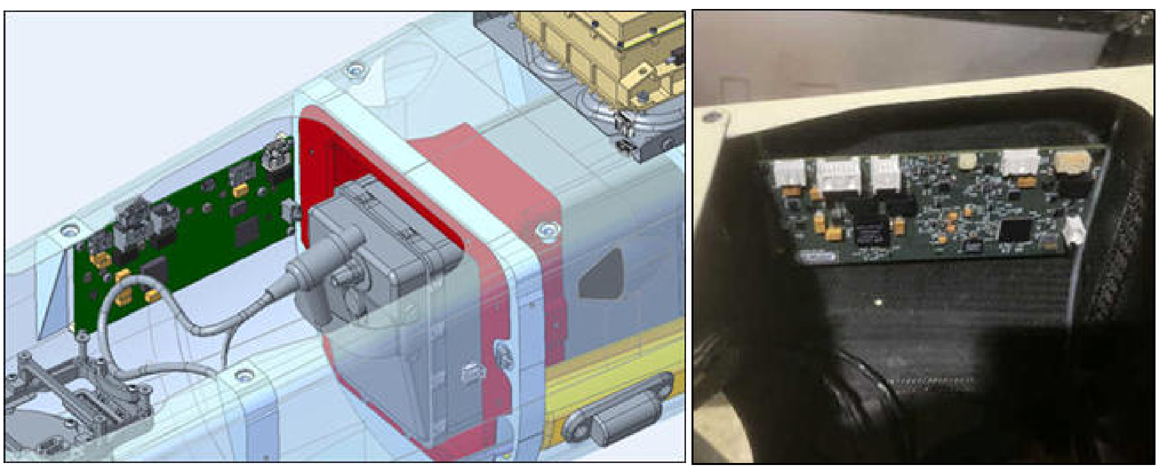


Figure E-5. MAIM Installed on Stalker

E.4 Primary Mount

The Primary Mount for the Stalker is a hybrid approach using convective cooling, but mounting using the cold plate option. This was done primarily due to the SWAP constraints of such a small platform.

A customized payload tray, installed atop the fuselage just forward of the wings, replaces the Stalker Expansion Bay. Unlike typical Primary Mounts, the size is dependent upon the size of the payload installed. Figure E-6 shows the Primary Mount with a 1U payload installed. Details on the various Primary Mount configurations are addressed in the subsequent sections.

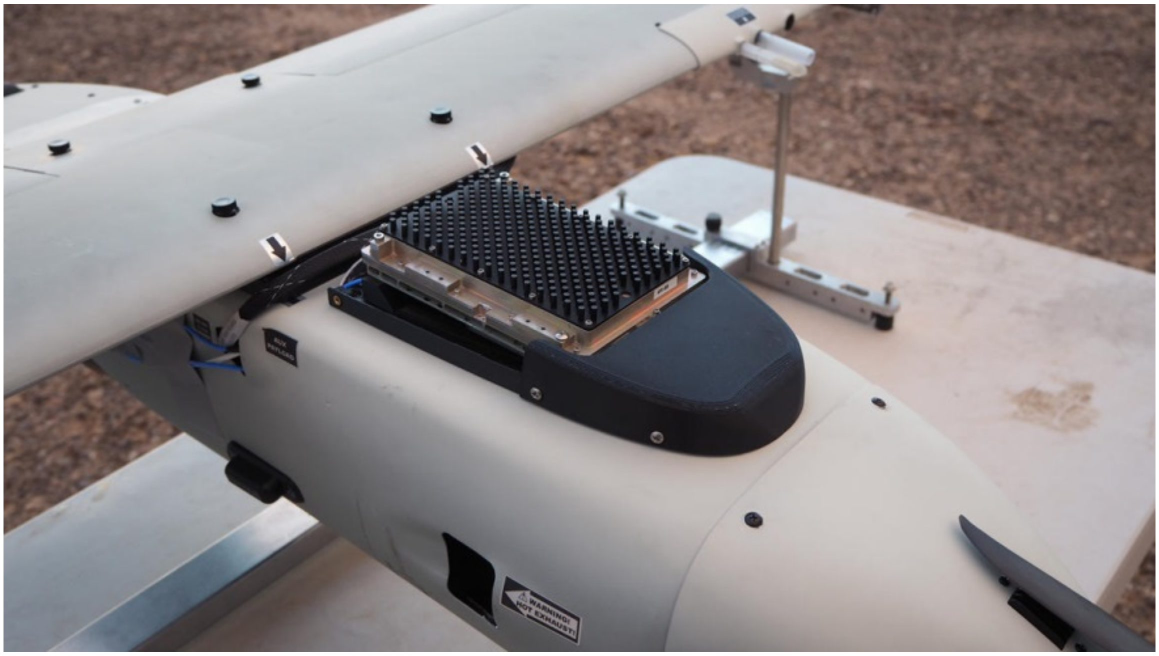


Figure E-6. Stalker Primary Mount with 1U Payload

E.4.1 Mechanical Description

The Primary Mount consists of a payload tray, a 1U, 1.5U, or 2U cowling, and spacer brackets, as necessary. The payload tray is a 3D-printed, FDM ABS part, 9.60 in (length) x 5.86 in (width-max) x 0.61 in (height). The cowlings are also 3D-printed, FDM ABS parts. The cowling size varies by payload height. Aluminum spacer brackets may be required to mount the payload to the tray, depending on payload size and heatsink surface. Table E-2 summarizes the height and weight of the Primary Mount in the current configuration options. The Primary Mount assembly is detailed in Figure E-7.

Table E-2. Stalker Primary Mount Weights

Payload Size	Height (in)	Weight (g)
1U	1.53	101
1.5U	2.59	181
2U	3.57	133

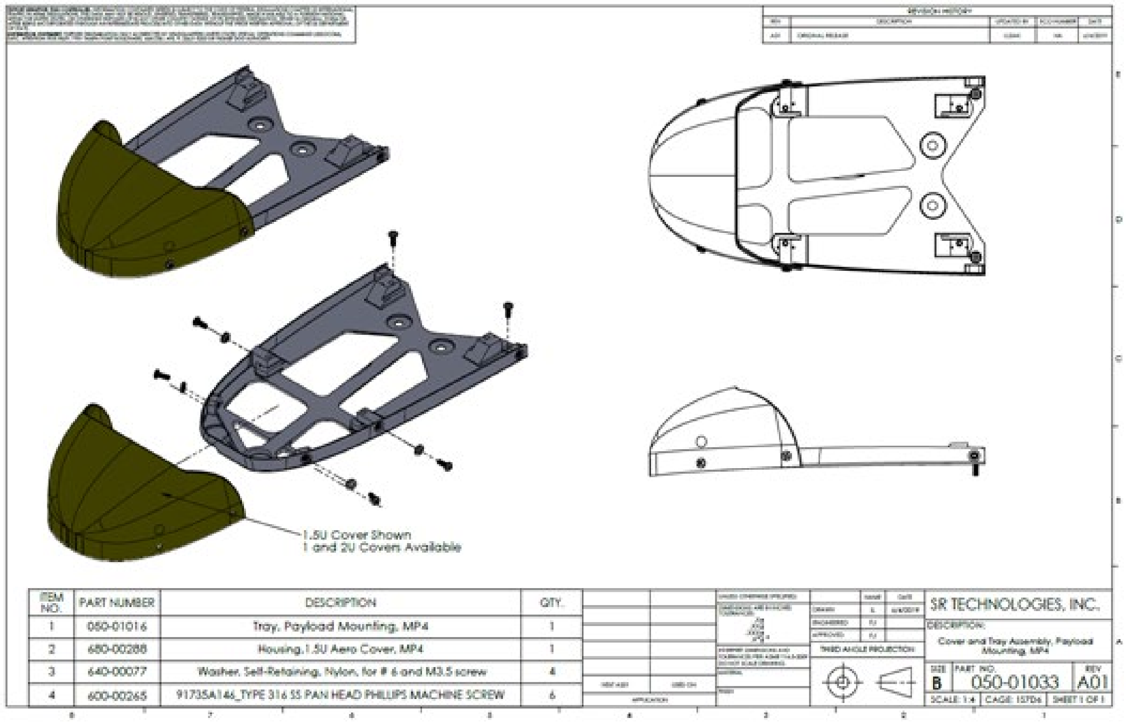


Figure E-7. Stalker Primary Mount Assembly Drawing

E.4.2 Installation

Using the MP cold plate mounting option, a payload is directly bolted to the Primary Mount. Accordingly, before installing the Primary Mount, the wedge locks are removed from the payload to expose two mounting holes on each rail to be used for this installation. Once the payload is prepared, the MP payload tray is installed atop the fuselage. The MP payload tray contains four t-nuts spaced to align with the unused cold plate mounting holes; the payload is bolted to the payload tray at these points. At this point all payload cables (see Section E.7.2 and Section E.7.3) are connected to the payload and positioned between the payload and payload tray, as shown in Figure E-8.

Figure E-8. Stalker Primary Mount – Payload Installation (1 of 3)

Depending on the rail location height relative to the non-heatsinked surface of the payload, a spacer bracket is installed between the payload rails and payload tray (Figure E-9). The spacer is mounted to the payload using the wedge locks mounting holes. Once the payload is installed, the appropriate fairing is installed to the front of the payload tray (Figure E-10).

Figure E-9. Stalker Primary Mount – Payload Installation (2 of 3)

Figure E-10 Stalker Primary Mount – Payload Installation (3 of 3)

E.4.3 Thermal

The Primary Mount is designed to expose the payload heatsink to direct air flow, as evident in Figure E-10 above.

E.5 INS

The Ellipse2-N INS is installed inverted on the bottom side of the left wing hard point at the junction to the left wing. Its GPS antenna is installed above it on the topside of the wing. Figure E-11 shows the INS and GPS installations.

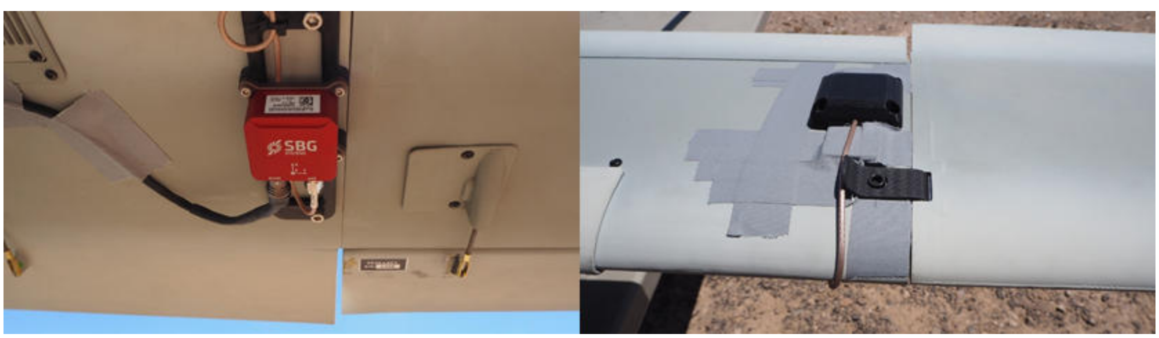


Figure E-11. Stalker INS and GPS Antenna

E.6 Antenna Mounts

The MP-Stalker supports antenna mounts in two locations: the underwing hard point at the right edge of the center wing and on the boom. The underwing mount allows for different antenna mounts to be installed through it to support the requisite antenna configuration.

E.6.1 Array Mount

The array mount (strut) is one of two antenna mounts that can be installed on the right underwing hard point. The array antenna mount is designed to be easily installed or removed, connecting to the wing using only two 10-32 screws. The strut provides the standard-defined antenna array interface. As shown in Figure E-12, unlike other MP implementations, the strut is oriented to place the array facing forward (in front of the wing).

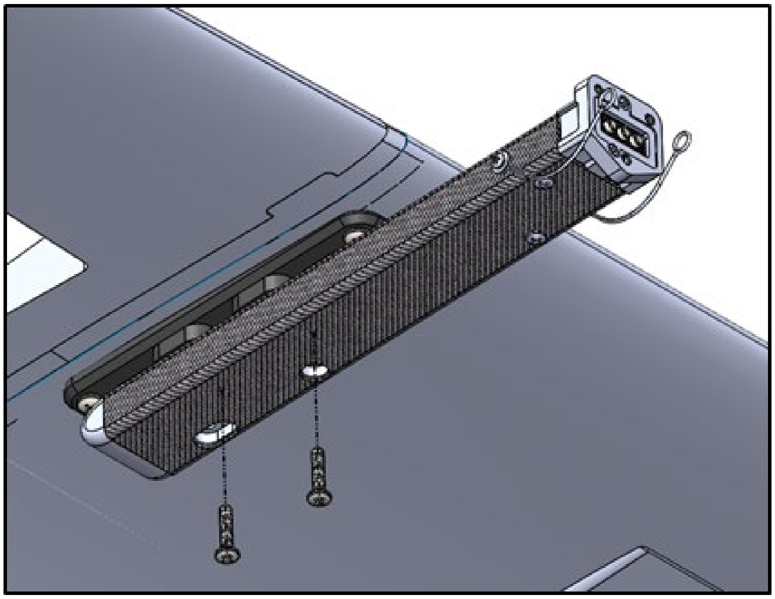


Figure E-12. Stalker Array (Strut) Mount

The weight of the array antenna mount is 130g. The array antenna mount capacity is defined in Table E-3.

Table E-3. Array Antenna Mount Capacity

Max	To Be Added in Rev 6	
Max		

E.6.2 2-pt Down Look Antenna Mount

The 2-pt down look mount is the second of two antenna mounts that can be installed on the right underwing hard point. The 2-pt antenna mount is designed to be easily installed or removed, connecting to the wing using only two 10-32 screws and provides the standard 2-pt antenna interface.

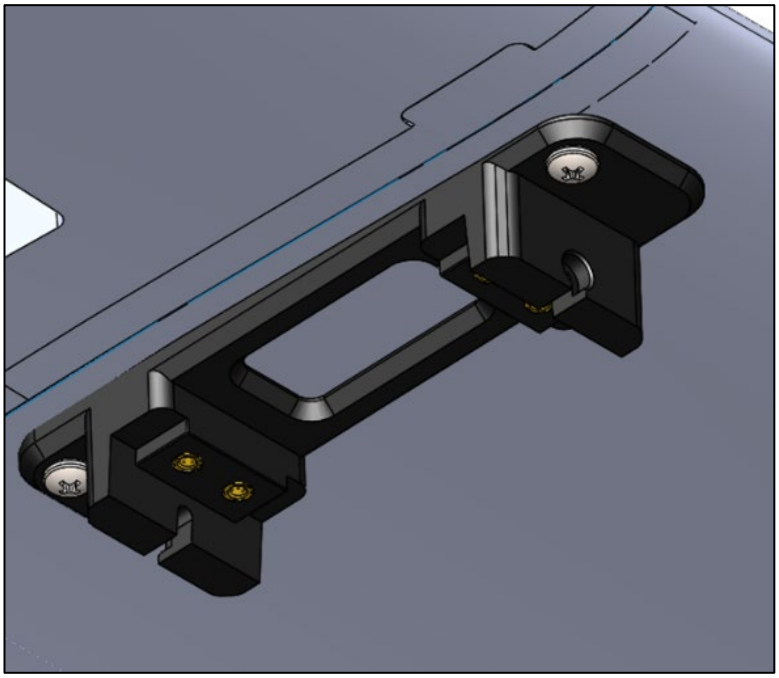


Figure E-13. Stalker 2-pt Down Look Mount

The weight of the 2-pt down look antenna mount is 38g. The 2-pt down look antenna mount capacity is defined in Table E-4.

Table E-4. 2-pt Hard Point Antenna Mount Capacity

Max W	To Be Added in Rev 6
Max V	

E.6.3 Boom Mount

The Stalker boom can be equipped with a 2-pt antenna mount, as shown in Figure E-14. The boom mount is a two-piece collar that fits around the boom and can be oriented in any direction (0-360°) to meet the payload requirement.

Figure E-14. Stalker Boom Mount

The weight of the boom mount assembly is 75g. The 2-pt boom antenna mount capacity is defined in Table E-5.

Table E-5. Boom Antenna Mount Capacity

Max W	To Be Added in Rev 6	
Max V		

E.7 Cabling

Only a few cable runs are required for the Stalker. Unfortunately, the small size of Stalker makes the cable runs a bit difficult. The schematic for all MAIM cables is provided in Figure E-15 with further details provided in subsequent sections and RF cables covered in Section E.7.5.

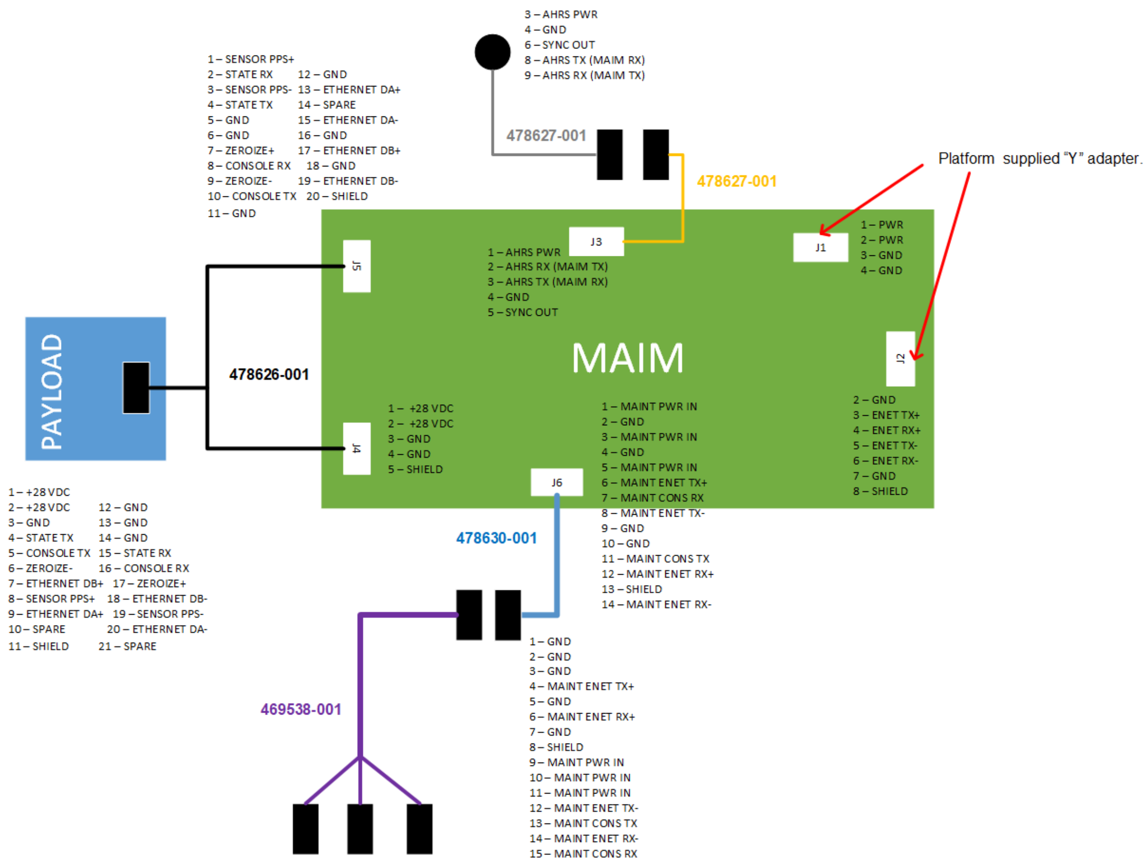


Figure E-15. Stalker MAIM Cabling Schematic

E.7.1 UAS-MAIM Cable

To meet the power requirement for one payload, the MAIM draws power from the main battery. A Y-cable is provided with the platform to split off the power to the MAIM and continue to provide power to the platform avionics. This Y-cable also provides an Ethernet interface to connect the MAIM to the Stalker network. The Y-cable connects directly to the battery and is located in the fuselage bay between the battery and the MAIM. The Y-cable is 12-inches long and weighs 116g.

E.7.2 MAIM-Payload Cable

The MAIM-payload cable is a combination of small gauge twisted shielded pairs with Expando sleeving and terminated as detailed in Figure E-16.

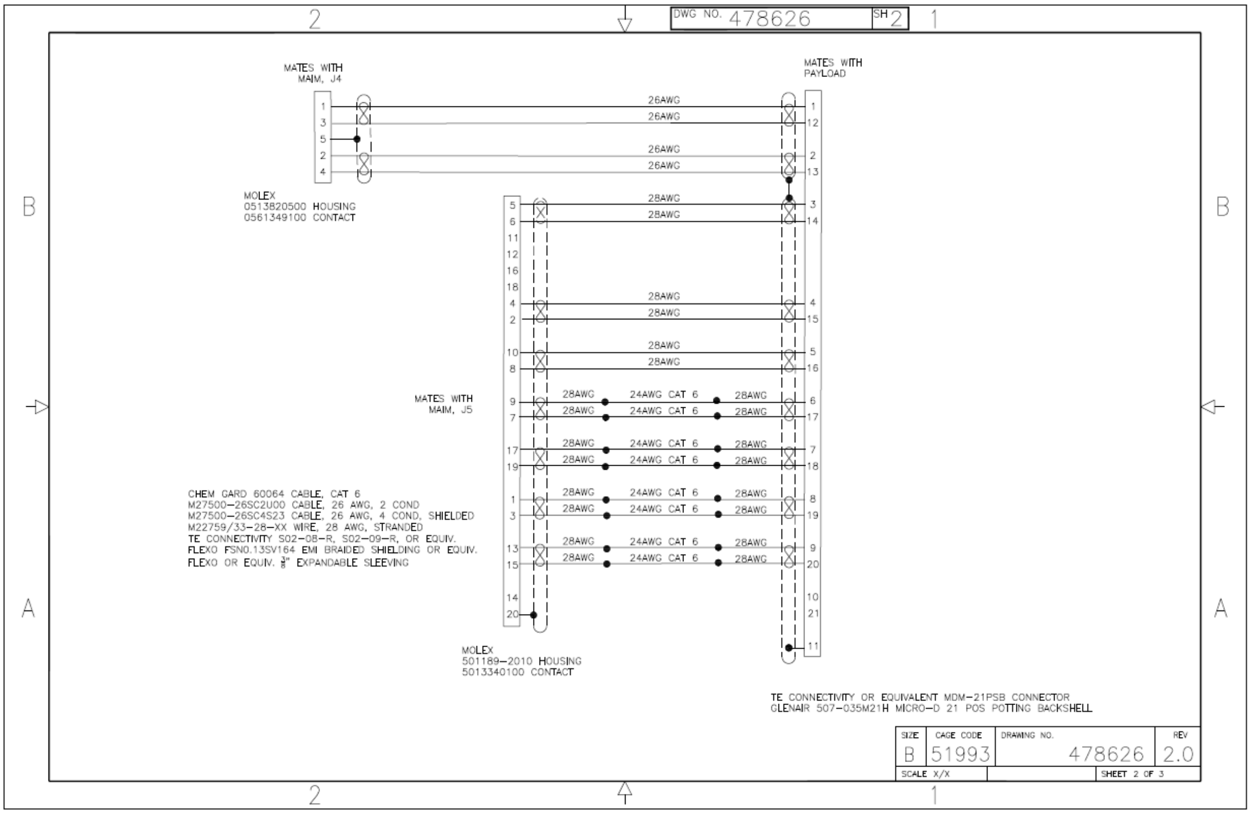


Figure E-16. MAIM-Payload Cable

As illustrated, the MAIM side of the cable uses two small connectors to allow the cable to pass through two small openings. The MAIM-payload cable runs from the front of the payload, underneath it, aft to a small opening on the upper surface of the fuselage, then exits through another small opening in a forward bulkhead to the right of the battery, and finally crosses above the battery to the MAIM to prevent interference with battery removal or installation. Figure E-17 depicts this sequence. The MAIM-payload cable is 29-inches long and weighs 65g.

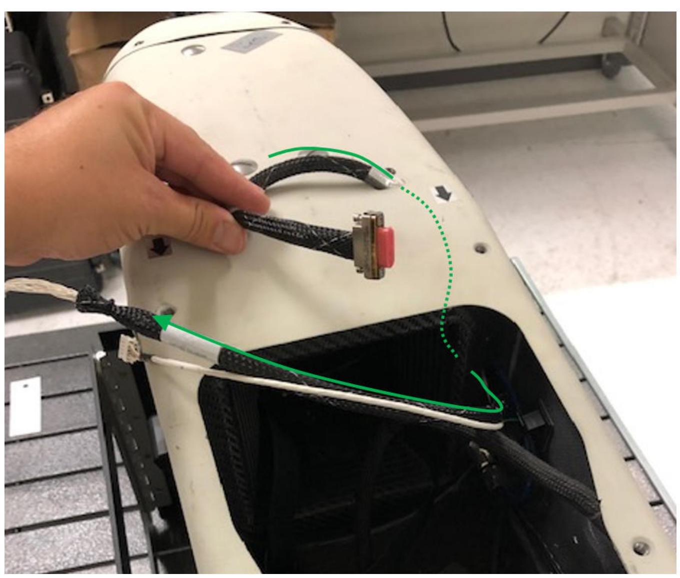


Figure E-17. MAIM-Payload Cable Run

E.7.3 MAIM-AHRS Cables

To support maintenance operations, the MAIM-INS connection is split into two cables. Both MAIM-INS cables consist of a 26AWG twisted shielded pair and a 26AWG twisted shielded triple with Expando sleeving and terminated as detailed in Figure E-18 and Figure E-19.

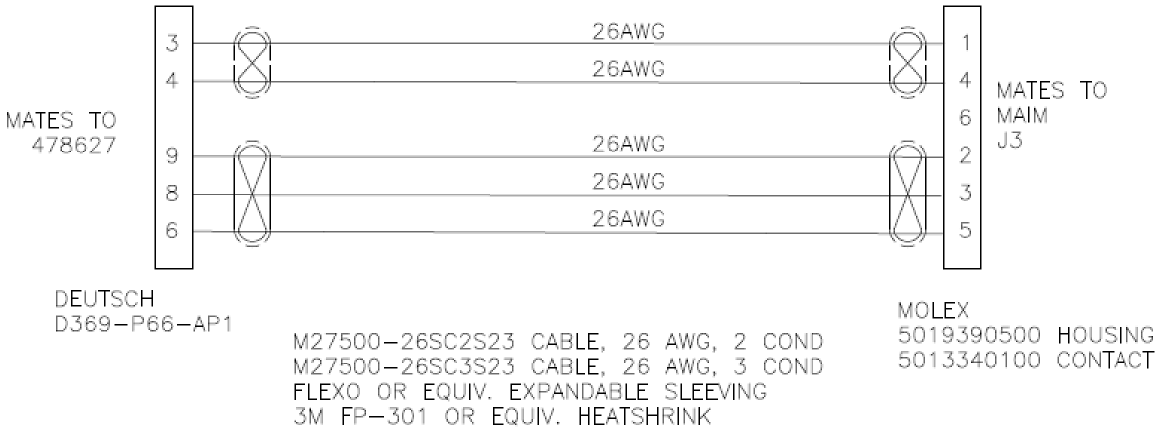


Figure E-18. MAIM to INS Cable (MAIM to Breakpoint)

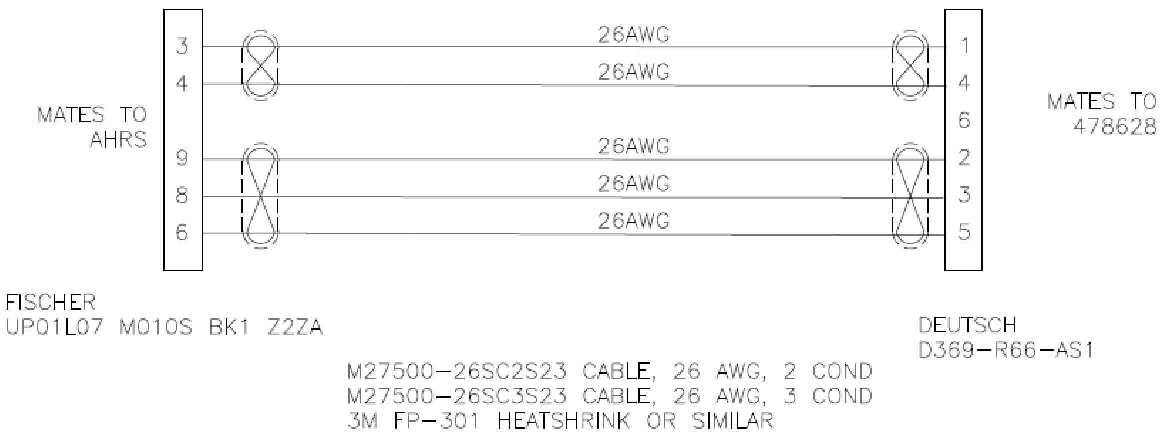


Figure E-19. MAIM to INS Cable (Breakpoint to INS)

As shown in Figure E-20, the MAIM-INS cables run from the top of the MAIM through an exhaust port on the left side of the fuselage, to and along the bottom of the wing to the INS, mounted to the hard point at the left edge of the center wing. The inline breakpoint is located at the wing root. In total, the MAIM-INS cables are 50-inches long and weigh 52g.

Figure E-20. MAIM to INS Cable Run

E.7.4 GPS Antenna Cable

As shown in Figure E-20 above, the GPS antenna cable runs from the INS on the bottom of the left wing to the GPS antenna on the top of the left wing and is taped in place.

E.7.5 Payload RF Cables

The MP-Stalker supports RF cable runs for antennas mounted on the right wing and the boom. However, due to the minimal payload capacity of the Stalker, only one portion of the RF cable run (from the payload to the wing root) is permanently installed. The remainder of the RF cables are run as needed, depending on the payload. All potential cable runs are detailed, based on payload antenna requirements, in the subsequent sections. Additionally, a custom, lightweight, multi-signal connector block used for the inline connection between many of the cables is described in Section E.7.5.6.

E.7.5.1 RF Cable Summary Table

The following table provides useful characteristic and performance information for all RF cable runs.

Table E-6. Stalker RF Cable Summary

Cable Set	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Payload to Wing Root	3	18	36	0.29
Wing Root to Hard Point	1 / 3	25	20 / 50	0.40
Wing Root to Boom	1	33	22	0.53
Hard Point / Boom Y-cable	2	25 / 33	38	0.40 / 0.53
Payload to Boom	1	51	41	0.82

Note 1: Attenuation calculated for a 1GHz signal
Note 2: Weight and attenuation from connectors and inline couplers have been neglected

E.7.5.2 Array Only Configuration

For a payload that requires an array antenna only, three cables are run from the payload to the hard point at the right edge of the center wing. As detailed in Figure E-21, the permanently installed, 3-coax, phase-matched payload to wing root cable is mated to a 3-coax, phase-matched wing root to hard point cable.

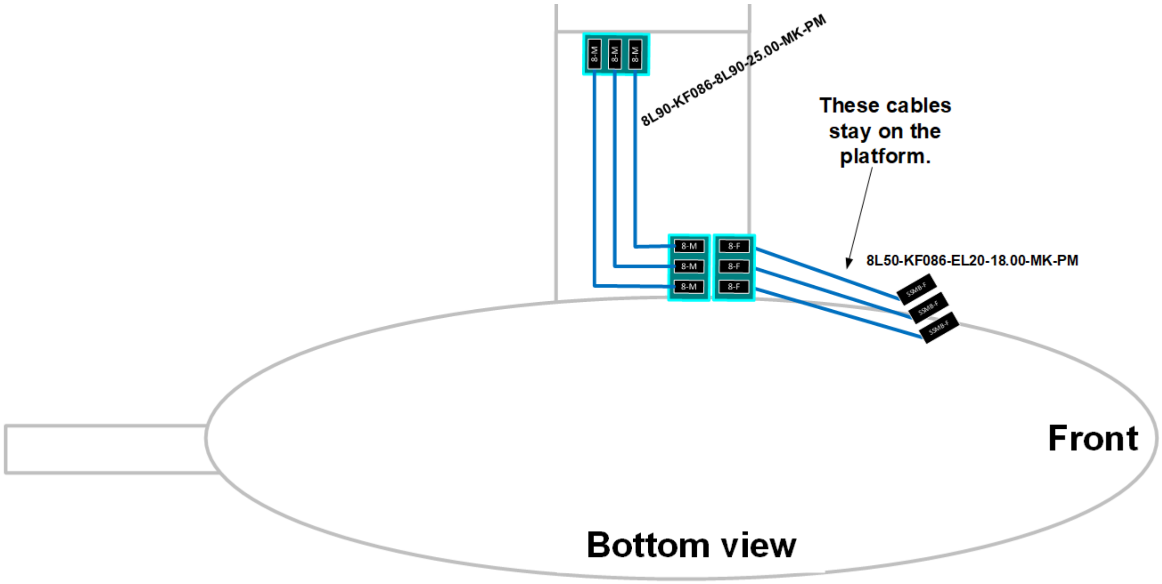


Figure E-21. Stalker RF Cables – Array Configuration

The payload to wing root segment runs from the front of the payload, underneath it aft to a small opening on the upper surface of the fuselage, then exits through another small opening in a forward bulkhead to the right of the battery, and passes immediately back out the fuselage through an exhaust port on the right side of the fuselage, where it mates to the wing root to hard point segment, which runs along the bottom of the wing to the under wing hard point at the right edge of the center wing. At the hard point, the cable attaches via a connector block to the integrated strut cable that ultimately provides the standard array interface. Not counting the strut cable, this run is 43-inches long (0.69 dB attenuation) and weighs 86g.

E.7.5.3 Single Antenna Configuration

For a payload that requires a single up look, down look, side look, or 45° antenna only, a single cable is run from the payload to the boom. As detailed in Figure E-22, the permanently installed, 3-coax, phase-matched payload to wing root is mated to a 1-coax wing root to boom cable, terminating in a single SMA-male connector.

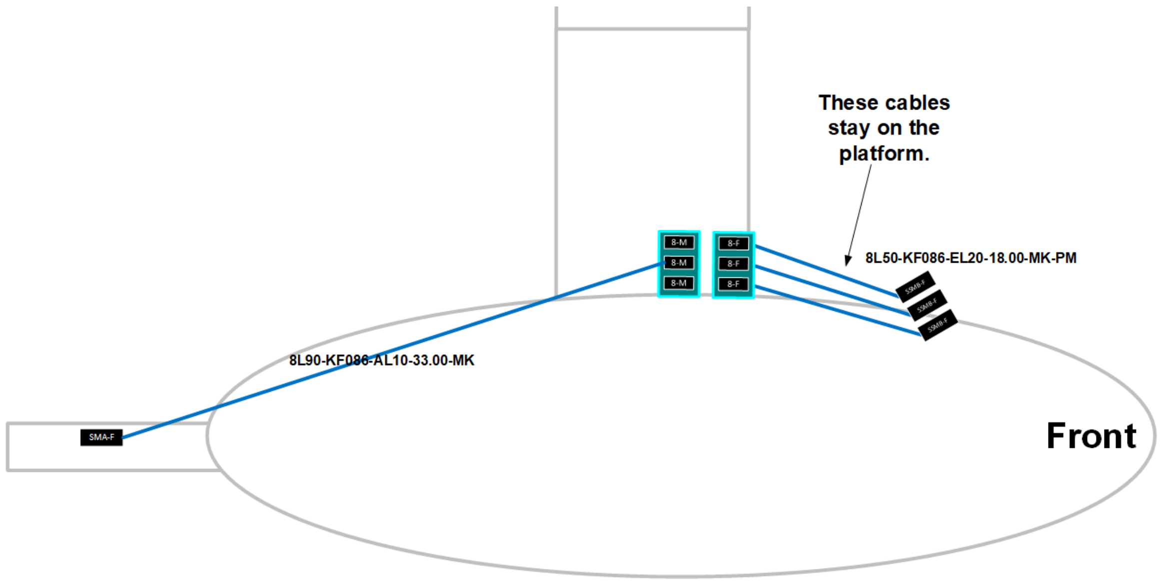


Figure E-22. Stalker RF Cables – Single Antenna Configuration

The payload to wing root segment runs from the front of the payload, underneath it aft to a small opening on the upper surface of the fuselage, then exits immediately back out the fuselage through an exhaust port on the right side of the fuselage, where it mates to the wing root to boom segment, which runs along the side of the fuselage to and along the boom. In total, this run is 51-inches long (0.82 dB attenuation) and weighs 58g.

E.7.5.4 Two Antenna Configuration

For a payload that requires both an up look and down look antenna, a split cable is run from the payload to both the hard point at the right edge of the center wing and to the boom. As detailed in Figure E-23, the permanently installed, 3-cable, phase-matched payload to wing root is mated to a 2-coax cable, terminating in SMA-male connectors and splitting off to the two locations.

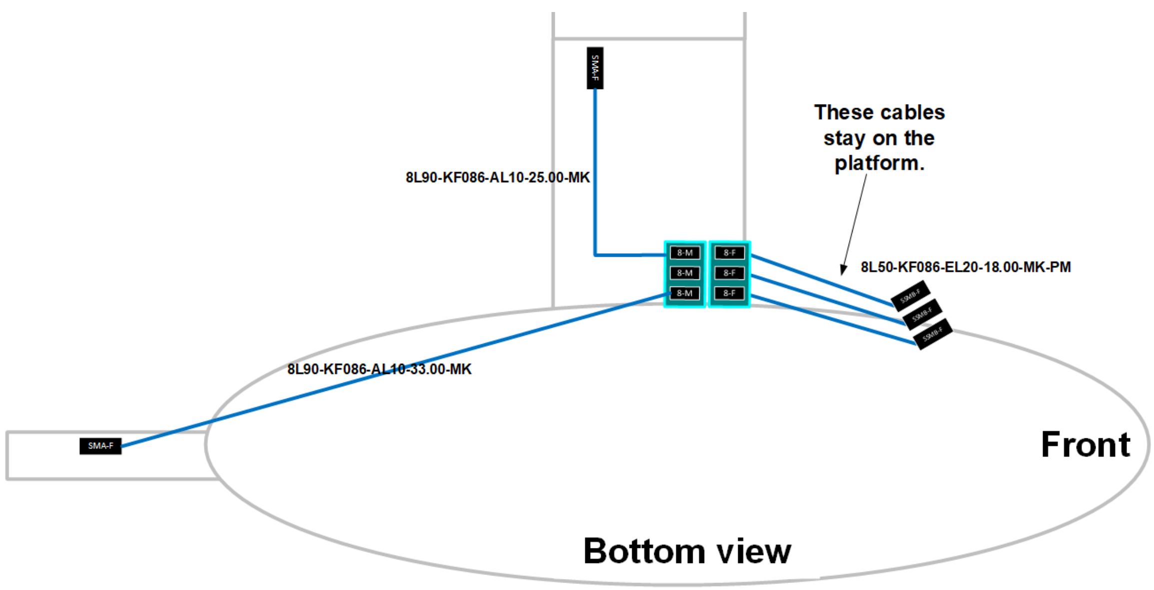


Figure E-23. Stalker RF Cables – Two Antenna Configuration

The payload to wing root segment runs from the front of the payload, underneath it aft to a small opening on the upper surface of the fuselage, then exits through another small opening in a forward bulkhead to the right of the battery, and passes immediately back out the fuselage through an exhaust port on the right side of the fuselage, where it mates to the split cable. One cable of which runs along the bottom of the wing to the under wing hard point at the right edge of the center wing, while the other runs along the side of the fuselage to and along the boom. The cable run to the under wing mount is 43-inches long (0.69 dB attenuation) and the cable run to the boom is 51-inches long (0.82 dB attenuation). In total, the cables constituting both cable runs weigh 72g.

E.7.5.5 Array Plus Configuration

For a payload that requires both an array and an up or down look antenna, the array cables are run just as described in Section E.7.5.2 and second a cable, terminating in an SMA-male connector, is run from the payload to the boom. These cable runs are detailed in Figure E-24.

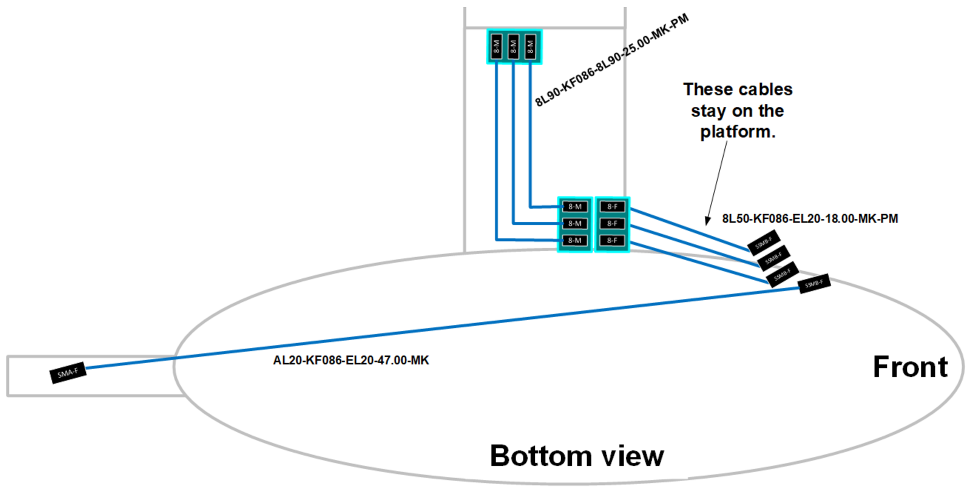


Figure E-24. Stalker RF Cables – Array Plus Configuration

The additional boom cable run is a single cable that runs from the front of the payload, underneath it aft to a small opening on the upper surface of the fuselage, then passes immediately back out the fuselage through an exhaust port on the right side of the fuselage, and continues along the side of the fuselage to and along the boom. This additional boom cable is 51-inches long (0.82 dB attenuation) and weighs 41g. In total, the cables constituting both cable runs weigh 127g.

E.7.5.6 Multi-Signal RF Connector Block

To facilitate the rapid installation and removal of RF cables, a custom, lightweight connector block is used. The connector block can support up to three RF connections. The block halves are incorporated into the RF cable assemblies.

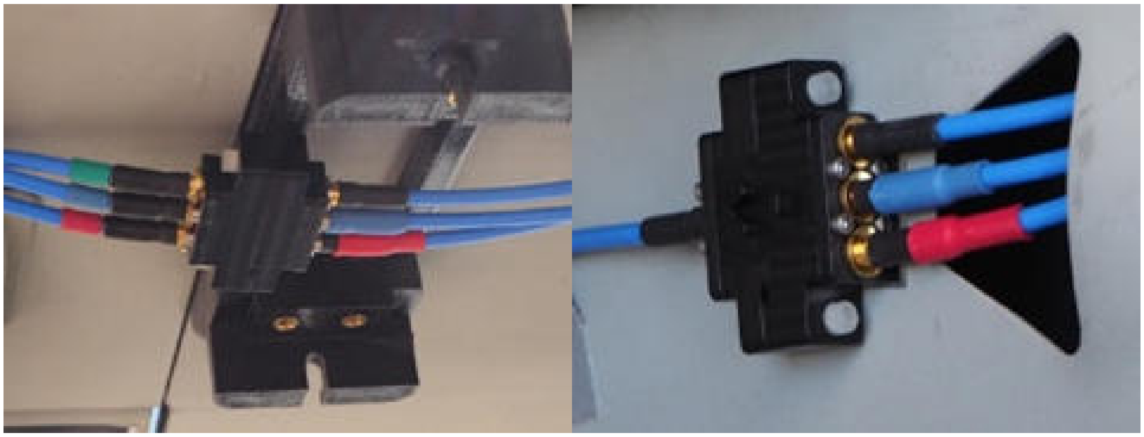


Figure E-25. RF Connector Block – 3-signal (left), 1-signal (right)

E.8 Platform-Payload Concessions

A single concession is documented for the MP-Stalker XE25, and it is payload-specific.

E.8.1 SURFR3B Antenna Array

In lieu of using the MP-compliant array interface, three non-compliant custom antennas brackets (Figure E-26) are permitted to be used to support the SURFR3B paylaod. These brackets have been previously assessed to meet the payload requirements. The MP architecture easily accommodates this deviation – rather than swapping antennas on the hard point mount, when installing the SURFR3B, the three additional antennas and brackets are installed on the wing (using a positioning template) at the locations prescribed in Figure E-27. The custom antennas connect to the MP RF cabling at the wing root breakpoint using the 3-coax, wing root to hard point cable to connect the antenna back to the SURFR3B payload installed on the Primary Mount.

Figure E-26. Non-compliant SURFR3B Antenna Array

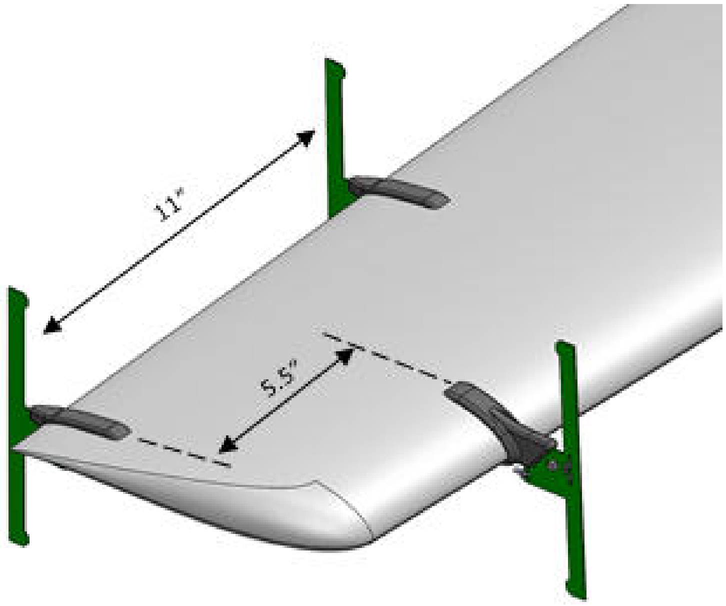


Figure E-27. Non-compliant SURFR3B Antenna Array Spacing

Appendix F. **MP-SkyRaider R80D UAS**

This appendix details the MP implementation on the FLIR SkyRaider R80D UAS.

F.1 Overview

The MP-compliant SkyRaider UAS can support up to 2U of payloads on a custom, external payload assembly. UAS power capacity restricts the platform to a single payload. The MP-SkyRaider R80D UAS is capable of supporting two front/side, two 45°, or one down look antenna mount. A platform-specific MAIM and the MP-compliant INS are both required for this UAS.

F.1.1 MP Architecture

Figure F-1 depicts the architectural layout of the MP implementation on the SkyRaider R80D UAS.

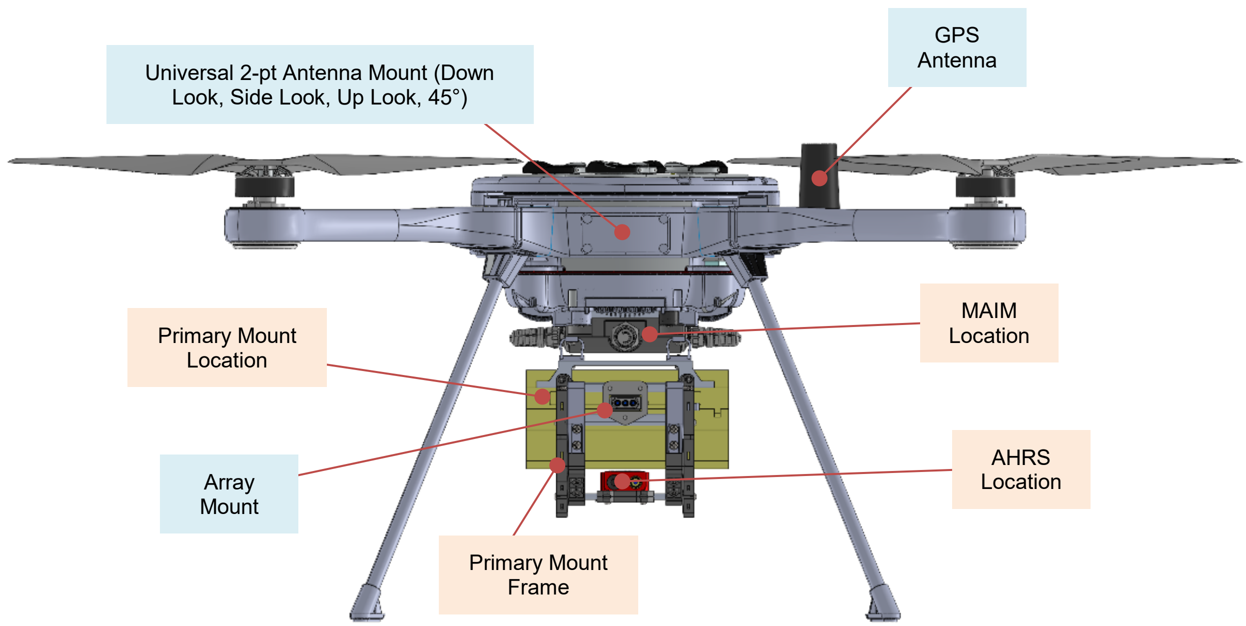


Figure F-1. Architectural Layout of MP-SkyRaider

F.1.2 Compliance / Capability Summary

Table F-1 provides a top-level summary of the MP compliance and capability on the SkyRaider R80D.

Table F-1. MP-SkyRaider Compliance and Capability

MP Components	Location
MAIM	Under Body
Primary Mount	Under MAIM
INS	Primary Mount Bottom
Payload Capacity	**Description**
Number of Payloads	1

Available Payload Power		56 W	
Available Payload Volume		2U	
Available Payload Weight		3.2 lb (1490 g)	
Primary Mount			
Mounting Method		Plate	
Cooling Method		Convection	
Antenna Mounts	**Qty**	**Location**	**Orientation**
Two-point	2 2 1	Fuselage Expansion Mount Antenna Frame Antenna Frame	Up, Down, Side, 45° Side, 45° Down
Four-points	0	N/A	N/A
Array	1	Primary Mount	Side, 45°

F.1.3 System Diagram

Figure F-2 details the system diagram for the MP-compliant SkyRaider R80D UAS.

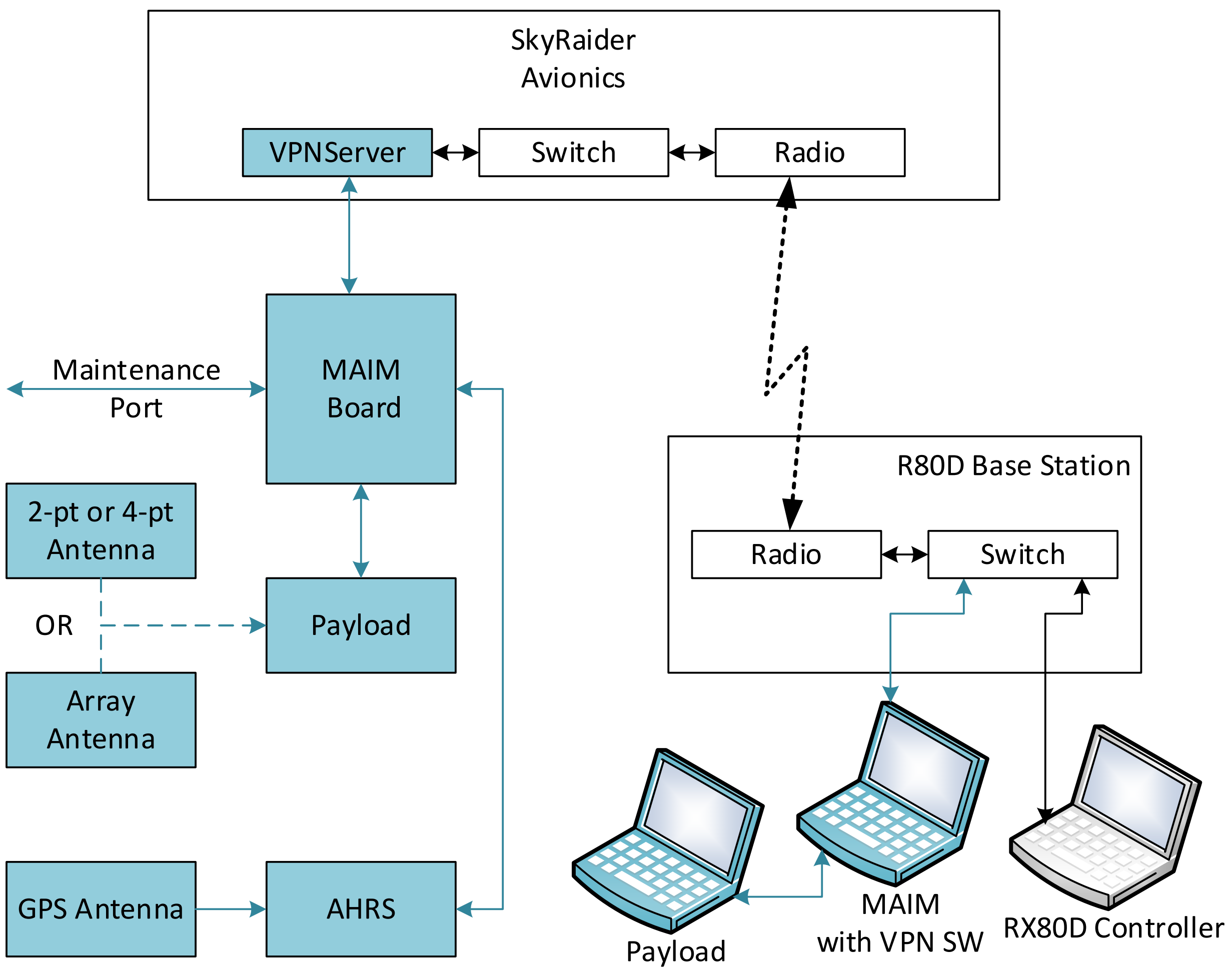


Figure F-2. System Diagram for MP-SkyRaider

F.2 Platform Weight and Power Budgets

As a Group 1 UAS, the SkyRaider is considerably SWAP-constrained. Moreover, the SkyRaider is constrained in each SWAP attribute.

F.2.1 Weight Budget

Discounting payloads (and corresponding antennas, antenna adaptors and optional cabling), the core MP architecture (of MAIM, Primary Mount assembly, INS, GPS antenna assembly, and wire harnesses) adds 510g to the SkyRaider.

F.2.2 Power Budget

The platform is capable of supplying 56W to a payload module, as well as the additional overhead required to power the MAIM and INS.

F.3 MAIM

The MAIM is a custom circuit board in an enclosure installed below the fuselage.

F.3.1 Mechanical Description

The MAIM assembly is a ~4in x ~3in x 1.5in, 180g enclosure housing the MAIM PCB. Figure F-3 shows the SkyRaider MAIM and the MAIM PCB.

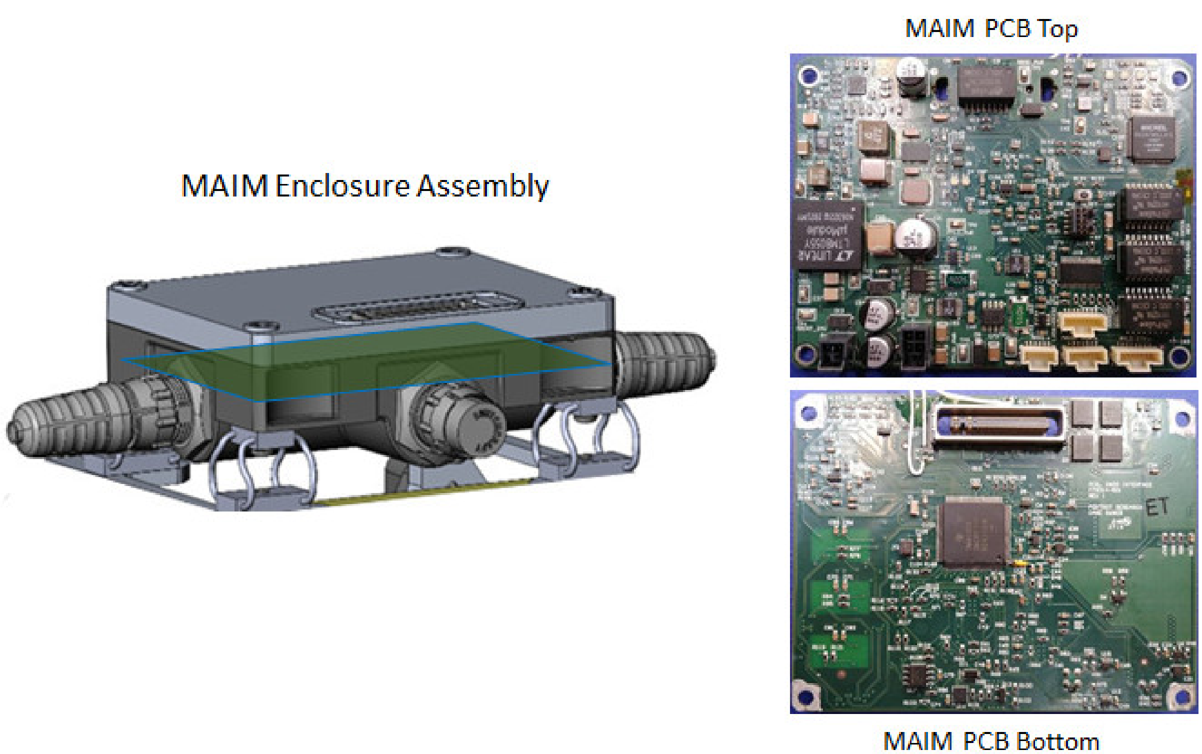


Figure F-3. MAIM for SkyRaider

F.3.2 Electrical Description

The MAIM is a custom PCB designed specifically to interface to the SkyRaider UAS and support full MP functionality. The core of the MAIM is TM4C1292NCPDT microcontroller. As depicted in Figure F-4, the microcontroller along with an Ethernet switch, serial transceivers, and power regulation and sense circuitry allow the MAIM to interface to both the platform and payload.

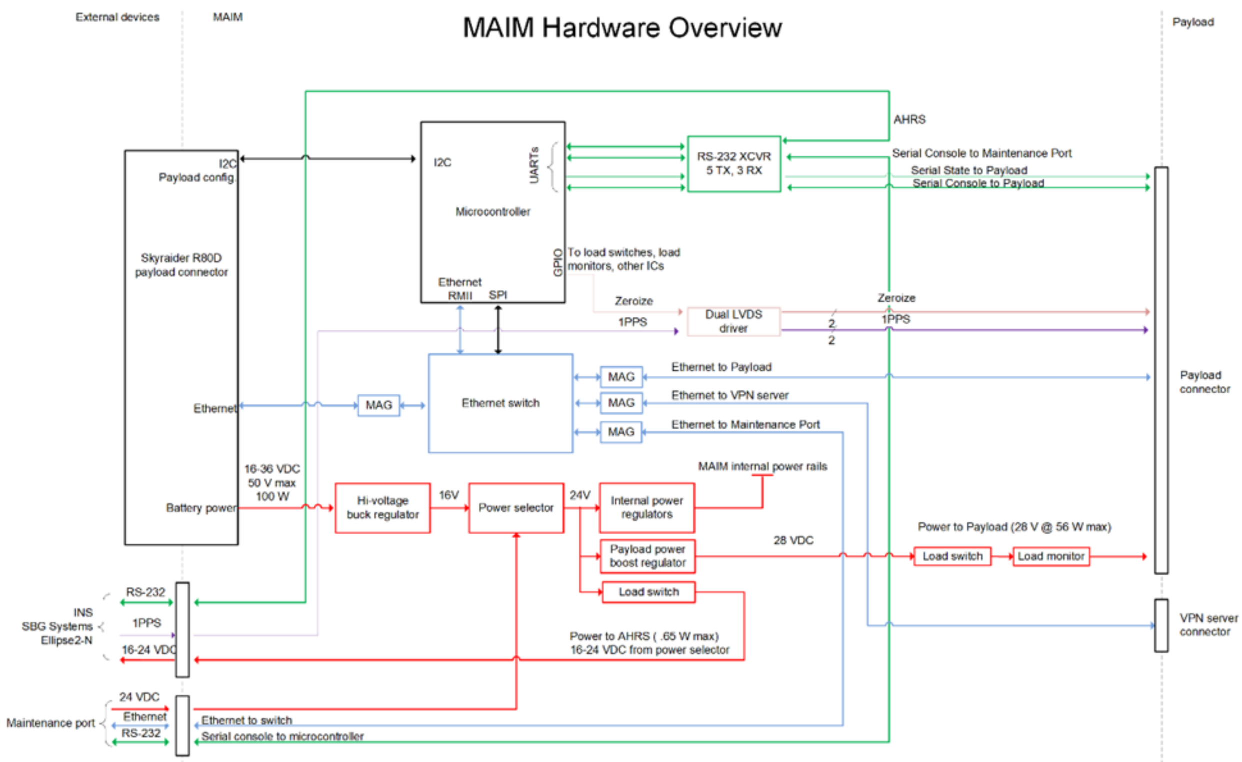


Figure F-4. MAIM Block Diagram for SkyRaider

F.3.2.1 Power Input

The MAIM draws regulated 16VDC power from the SkyRaider. Alternatively, the MAIM can be powered externally through the 24VDC maintenance port.

F.3.2.2 Payload Interface

The MAIM supports one fully compliant payload interface. As required by the standard, the payload interface provides power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides the 28VDC power to the payload and limits the maximum current draw to 2A (continuous).

The MAIM uses an 18-pin Switchcraft connector to interface to the payload. *Note: the MAIM-payload cable (detailed in Section F.7.2), which mates to this interface presents the standard-defined 21-pin Micro-D connector to the payload.*

F.3.2.3 Power Monitoring

In addition to power regulation, the MAIM microcontroller monitors and reports current draws from the INS and the payload as well as its own current draw from the platform. The payload overcurrent will trip at 4.3A after 5ms and then reset after an eight-second cooldown.

F.3.2.4 INS Interface

The MAIM provides power and bi-directional serial communications to the MP-compliant INS. Power is provided at 16VDC, 0.65W. State data and the 1PPS signal are received from the INS, while commands are transmitted to the INS.

F.3.2.5 Maintenance Interface

The MAIM provides a dedicated maintenance port to support required debug efforts. The maintenance interface includes an external 24VDC power hook up, an Ethernet and a serial interface. Hot-swapping between the maintenance port and platform power is supported.

F.3.2.6 Platform Specific Interfaces

To accommodate the SkyRaider network restriction of one IP address and a limited port range for the payload, a virtual private network (VPN) is implemented between the MAIM and the base station. The VPN server is contained within the MAIM package. On the GCS side, the MAIM control laptop runs the VPN software. The Payload control laptop connects to the MAIM laptop or the Payload control software can be run on the MAIM laptop.

F.3.3 MAIM Integration

The MAIM is installed to the bottom of the fuselage mechanically using SkyRaider's slot and latch system and electrically blind-mating to the SkyRaider's bulkhead payload interface connector. Section F.7.1 provides additional information on this electrical connection.

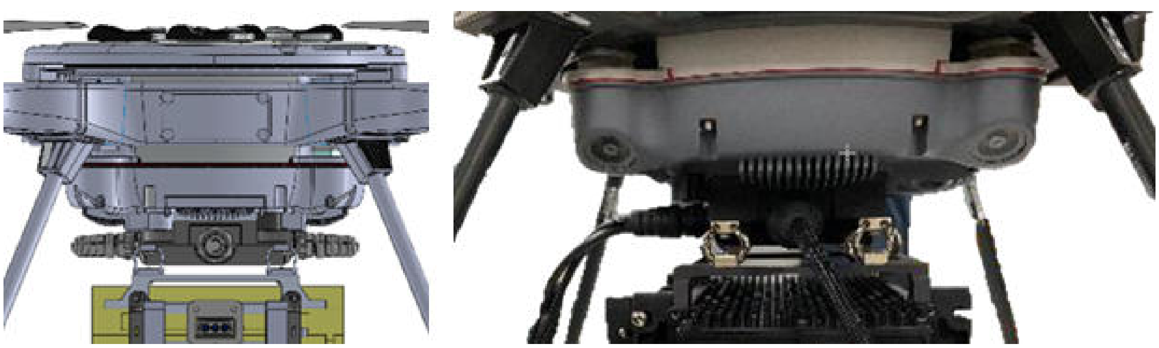


Figure F-5. MAIM Installed on SkyRaider

F.4 Primary Mount

The Primary Mount for the SkyRaider is a hybrid approach using convective cooling, but mounting using the cold plate option. This was done primarily due to the SWAP constraints of such a small platform.

The Primary Mount is a customized frame that accommodates 1U, 1.5U, or 2U payloads installed below the MAIM. Figure F-6 shows the Primary Mount with a 2U payload installed. In addition to supporting a payload module, the Primary Mount also supports the INS and a variety of antenna mounts. Details on the Primary Mount configuration are addressed in the subsequent sections.

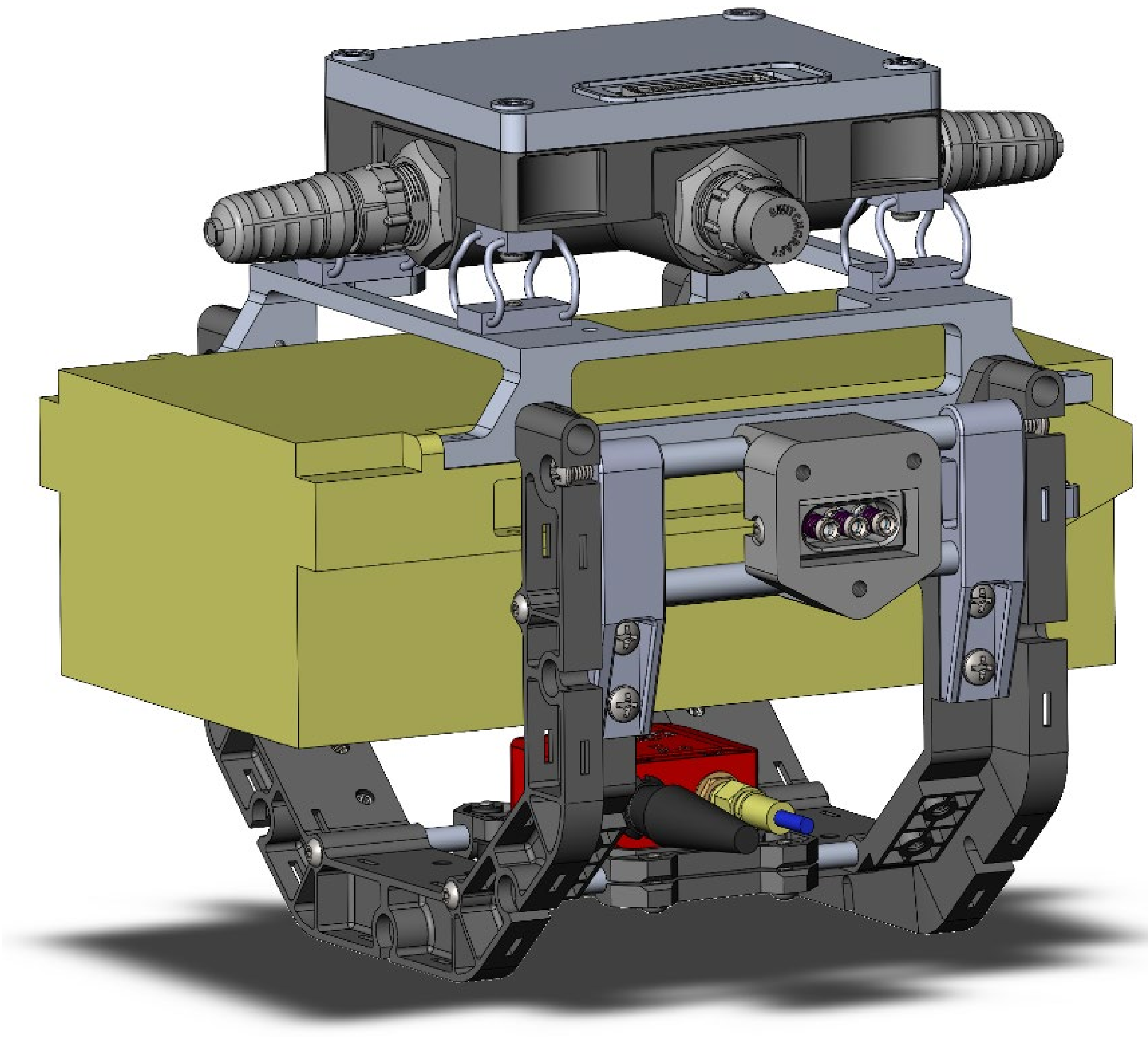


Figure F-6. SkyRaider Primary Mount with 2U Payload and INS

F.4.1 Mechanical Description

The Primary Mount consists of a payload frame, antenna mount frame, tie rods, INS and INS brackets, and vibration isolators. The payload frame is a 7075-T651 machined aluminum bracket. The antenna mount frame and INS mounting brackets are 3D printed, Nylon parts with 18-8 stainless steel Helicoil inserts. The tie rods are 6061-T6 aluminum tubes. The vibration isolators are 302/304 stainless steel wire rope with 6061-T6 aluminum block attachment points. Figure F-7 shows the primary components and materials.

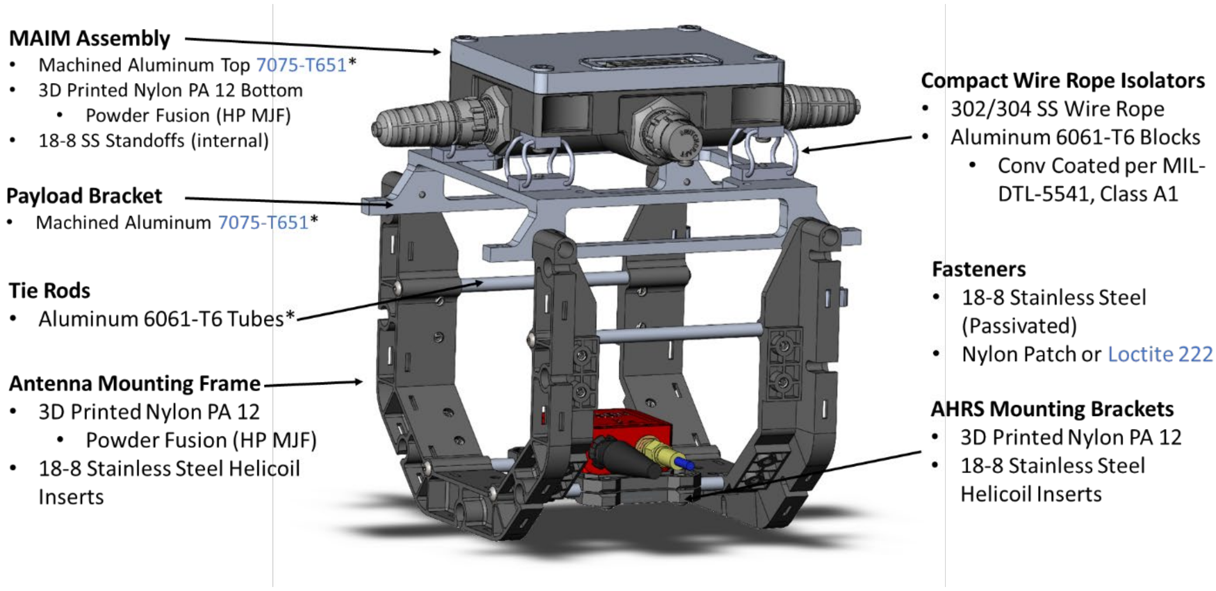


Figure F-7. SkyRaider Primary Mount Construction

F.4.2 Installation

Using the MP cold plate mounting option, a payload is directly bolted to the Primary Mount. Accordingly, before installing the payload, the wedge locks are removed from the payload to expose the two cold plate mounting holes on each rail to be used for this installation. The payload is attached to the payload bracket with four #4-40 mounting bolts as depicted in Figure F-8.

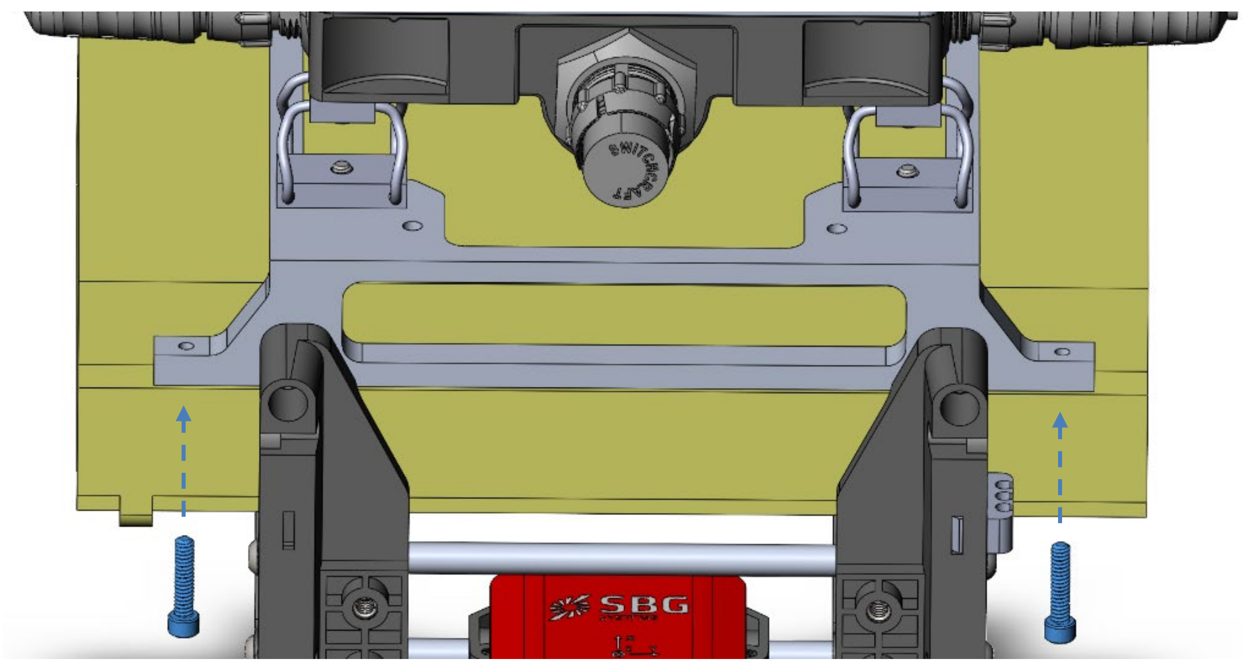


Figure F-8. SkyRaider Primary Mount - Payload Installation

F.4.3 Thermal

Though using the cold plate mounting option, the Primary Mount is designed to use convective cooling, exposing the payload to direct air flow. Thus, unlike a true cold plate configuration, the heatsink is maintained on the payload, as depicted in Figure F-9. Airflow either from forward flight or from the propellers, when in hover, is sufficient to cool a full power payload. The worst case (the SkyRaider at hover) temperature increase above ambient for a 56W payload is 35°C.

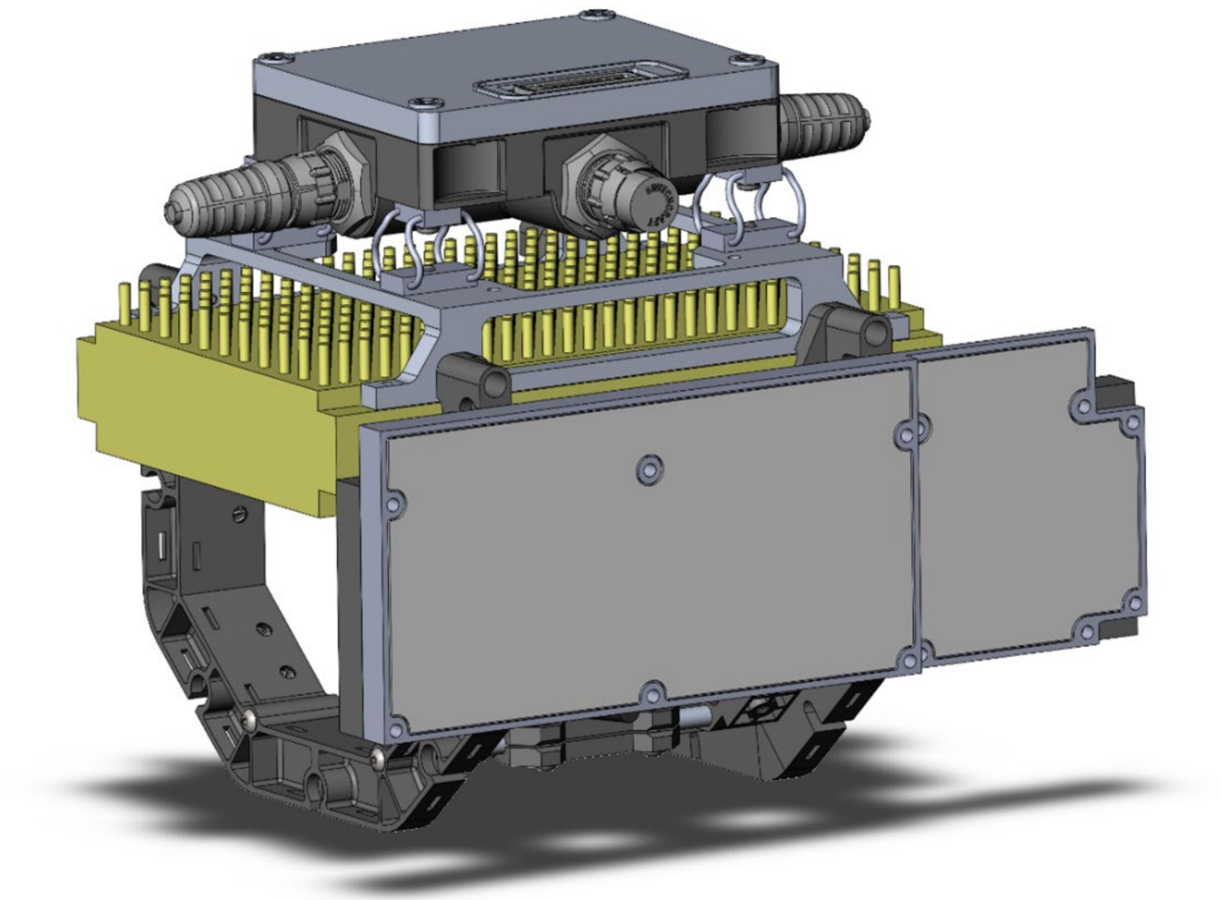


Figure F-9. SkyRaider Primary Mount with Payload Installed with Heatsink

F.5 INS

The Ellipse2-N INS is installed on the INS bracket between the antenna mount brackets at the bottom of the Primary Mount assembly. Its GPS antenna is installed above it on the GPS antenna bracket. Figure F-10 shows the INS and GPS installations.

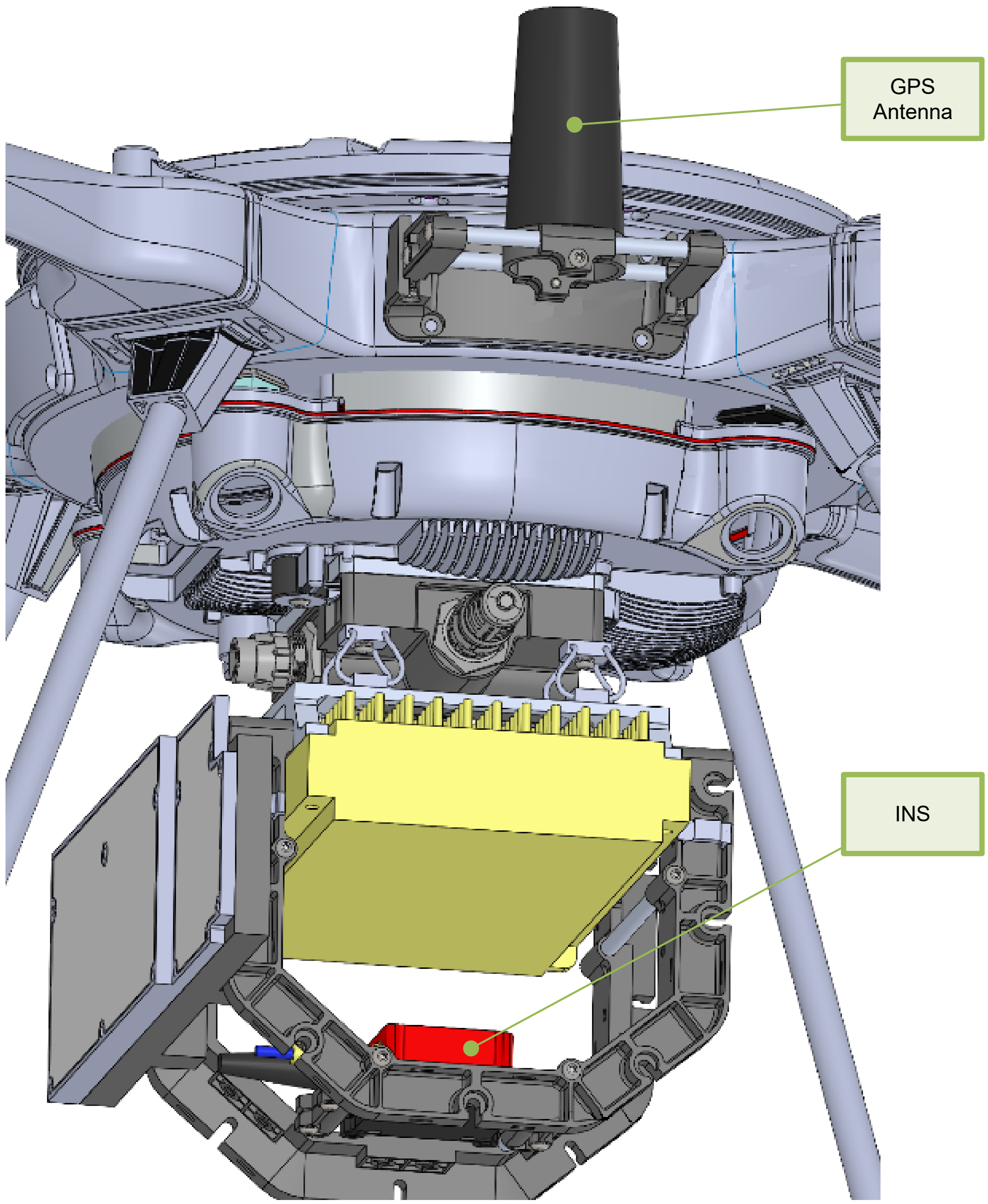


Figure F-10. SkyRaider INS and GPS Antenna

F.6 Antenna Mounts

As depicted in Figure F-11, the MP-SkyRaider supports antenna mounts on the antenna mounting frame and via a universal 2-pt expansion cover mount.

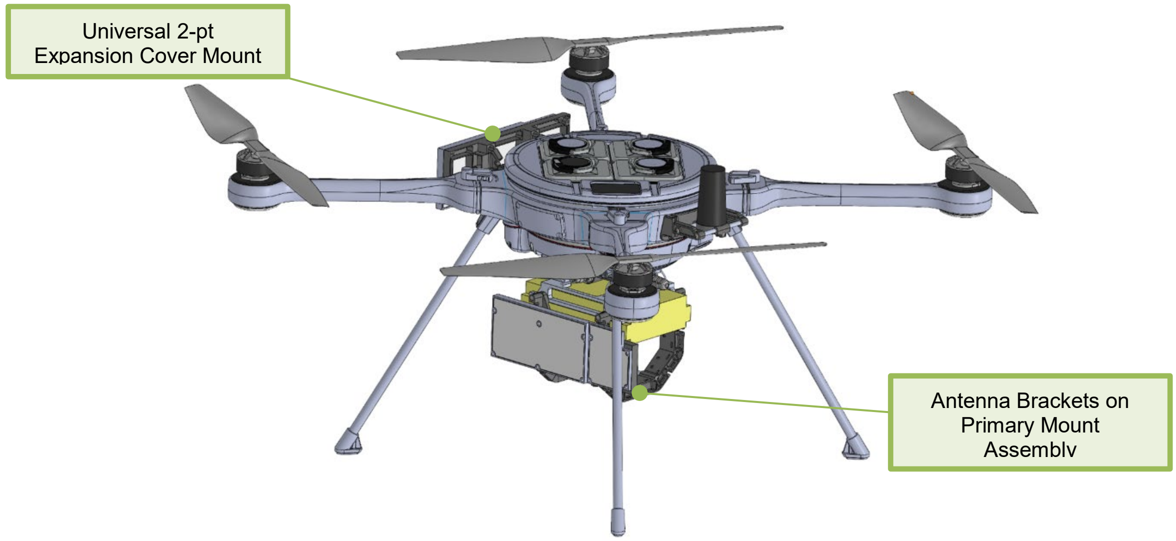


Figure F-11. SkyRaider Antenna Mount Locations

F.6.1 Universal 2-pt Expansion Mount

The universal 2-pt expansion mount replaces an expansion mount cover and provides either an up look, side look, down look, or 45° look antenna mount.

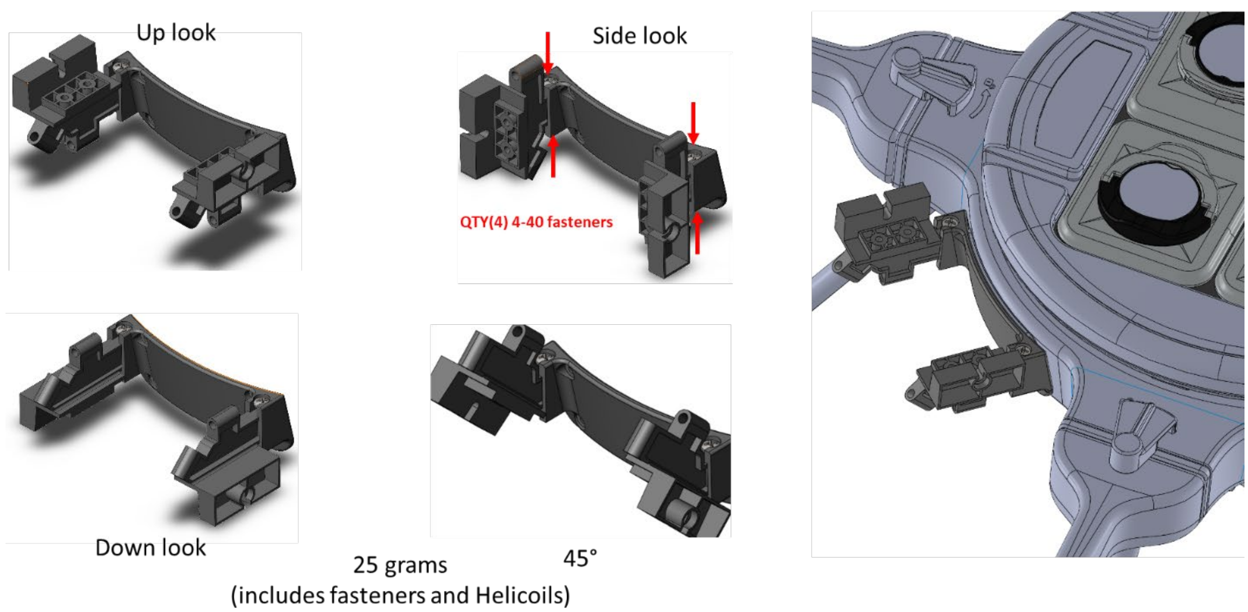


Figure F-12. SkyRaider Universal 2-pt Expansion Mount

The weight of the universal 2-pt expansion antenna mount is 25g. The universal 2-pt antenna mount capacity is defined in Table F-2.

Table F-2. Universal 2-pt Antenna Mount Capacity

Max Weight	150g (0.33lbs)
Max Moment	6 N-cm (0.5 in-lbs)
Max Volume	See Figure F-13[1]

[1] CAD defining volume available upon request

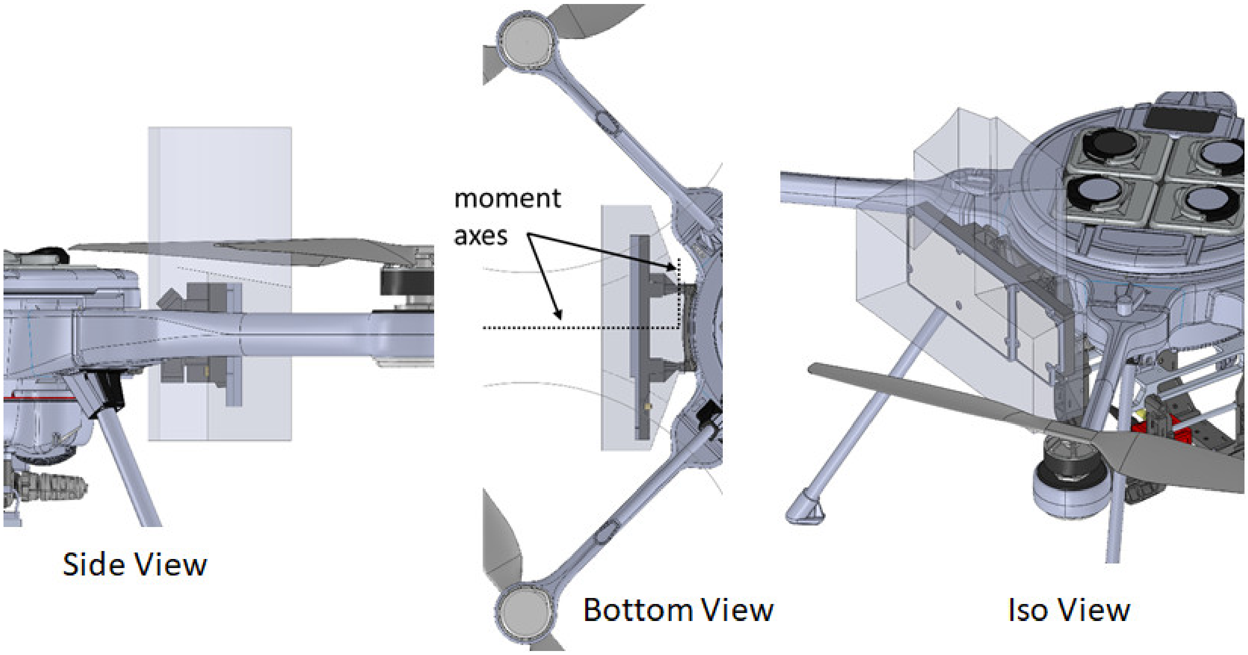


Figure F-13. SkyRaider Universal 2-pt Mount Allowable Antenna Volume

F.6.2 2-pt Antenna Mount on Antenna Mounting Frame

MP-compliant SkyRaider uses an antenna mounting frame suspended below the Primary Mount to support two side/front mounting locations, two 45° mounting locations, and one down look location. As illustrated in Figure F-14, the antenna mounting frame can be oriented with forward facing mounts or rotated 90° for side facing mounts.

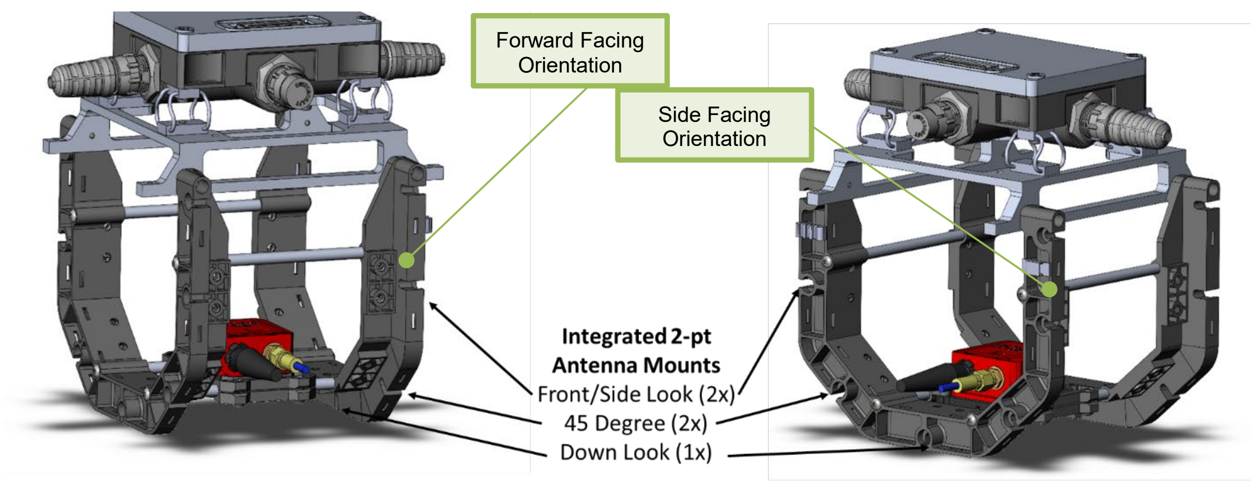


Figure F-14. Mounting Locations on the Antenna Mounting Frame

The antenna mounting frame 2-pt antenna mount capacity is defined in Table F-3.

Table F-3. Antenna Mounting Frame 2-pt Antenna Mount Capacity

Max Weight	227g (0.5lbs)
Max Moment	3.6 N-cm (0.3 in-lbs)
Max Volume	See Figure F-15[1]

[1] CAD defining volume available upon request

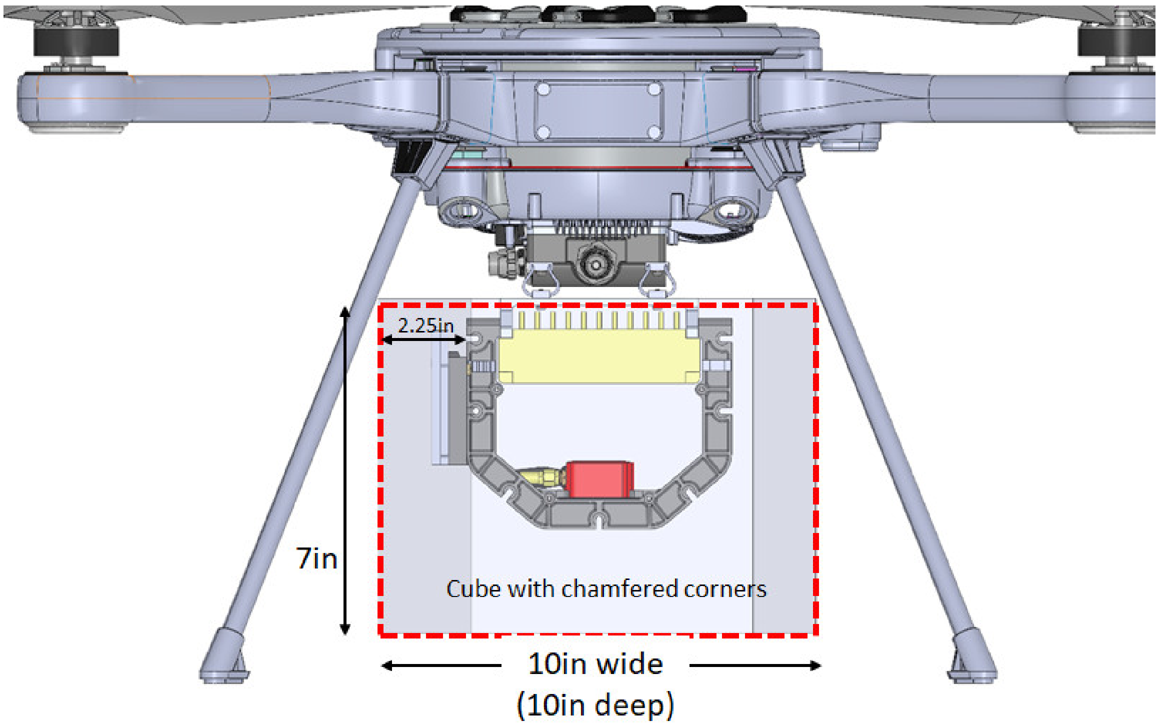


Figure F-15. Antenna Mounting Frame Allowable 2-pt Antenna Volume

F.6.3 Array Mount

As shown in Figure F-16, the Antenna Mounting Frame also supports an additional array mount installation, using the same attachment points as the side look antenna mount location. Alternatively, the array mount could be installed at the 45º antenna mount location, but that position is less likely to be useful for most antennas.

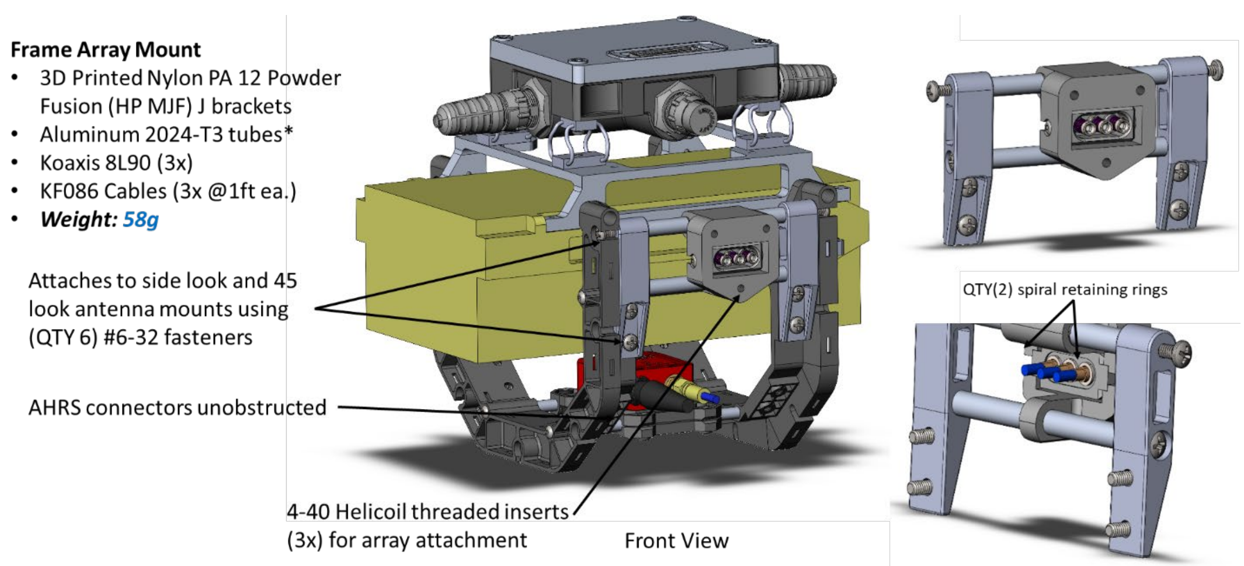


Figure F-16. SkyRaider Array Mount

The weight of the array antenna mount is 58g. The antenna array mount capacity is defined in Table F-4.

Table F-4. Antenna Array Mount Capacity

Max Weight	150g (0.33lbs)
Max Moment	10 N-cm (0.88 in-lbs)
Max Volume	See Figure F-17[1]

[1] CAD defining volume available upon request

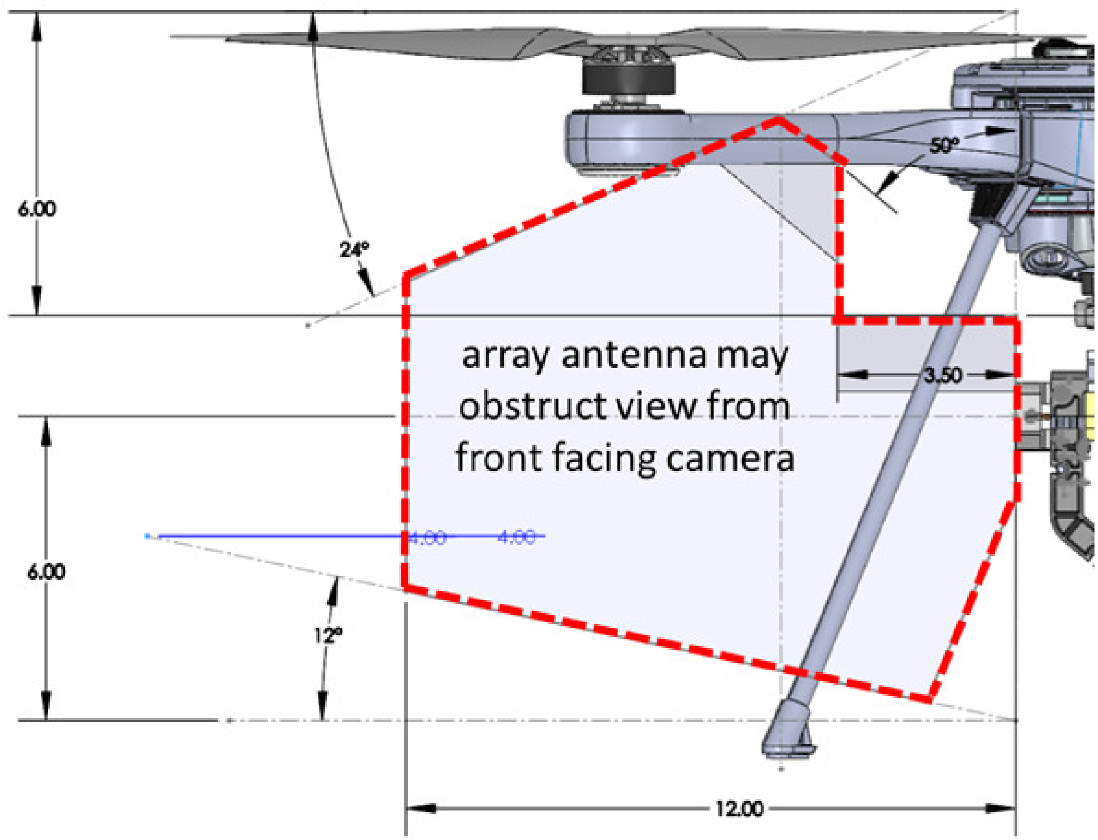


Figure F-17. SkyRaider Allowable Antenna Array Volume

F.7 Cabling

Minimal cable runs are required for the SkyRaider. The MAIM directly connects to UAS via a bulkhead connection, so the only cables installed for flight are: the MAIM-payload cable, the payload RF cable, the MAIM-AHRS cable and the GPS antenna cable. For ground operations, a maintenance cable is also provided. The following sections provide further detail on each of these cables.

F.7.1 UAS-MAIM Connection

The MAIM assembly plugs directly into SkyRaider's bulkhead payload connector using the slot and latch system on the bottom of the fuselage. No cable is required.

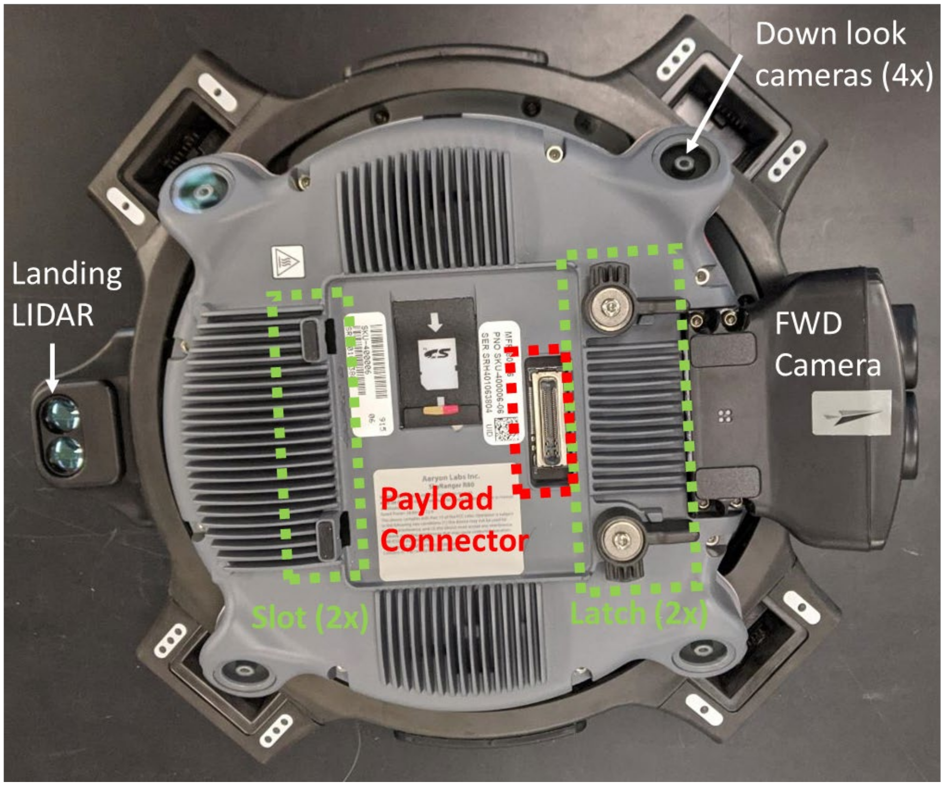


Figure F-18. SkyRaider Slot and Latch System

F.7.2 MAIM-Payload Cable

The MAIM-payload cable is routed as shown in Figure F-19 using tape and cable clips integrated into the Primary Mount to secure the cable.

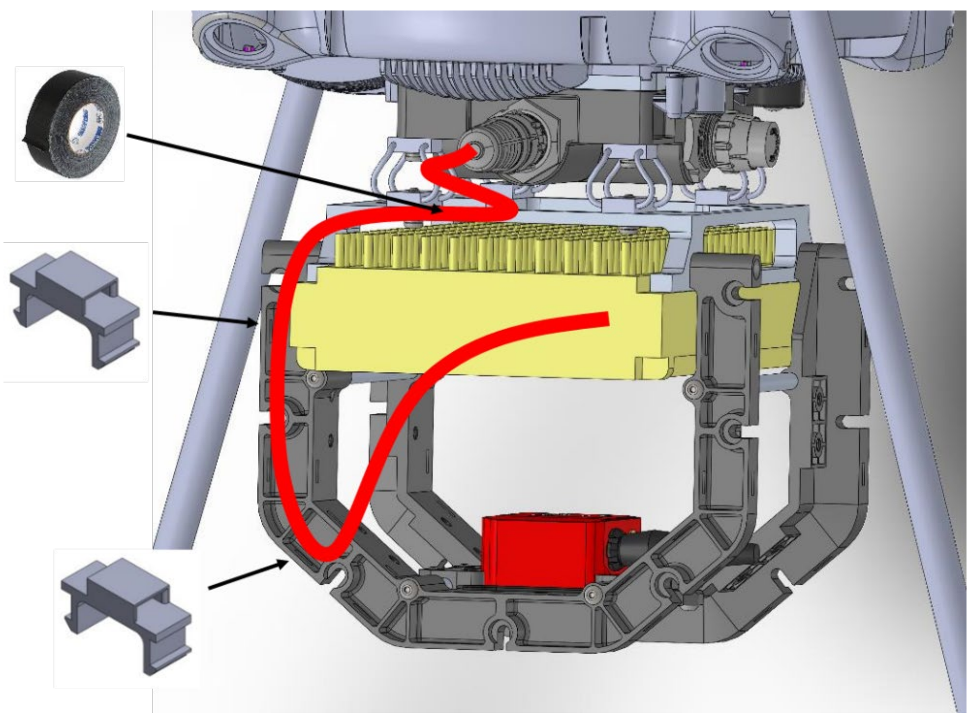


Figure F-19. SkyRaider MAIM-Payload Cable Routing

F.7.3 MAIM-AHRS Cable

The MAIM-AHRS cable is routed as shown in Figure F-20 using tape and cable clips integrated into the Primary Mount to secure the cable.

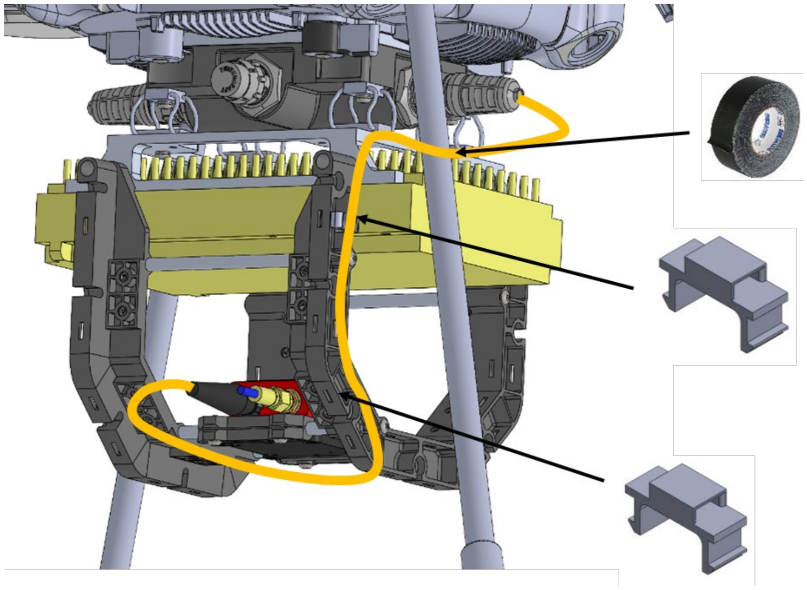


Figure F-20. SkyRaider MAIM-AHRS Cable Routing

F.7.4 GPS Antenna Cable

The GPS antenna cable is routed as shown in Figure F-21 using tape and cable clips integrated into the Primary Mount to secure the cable.

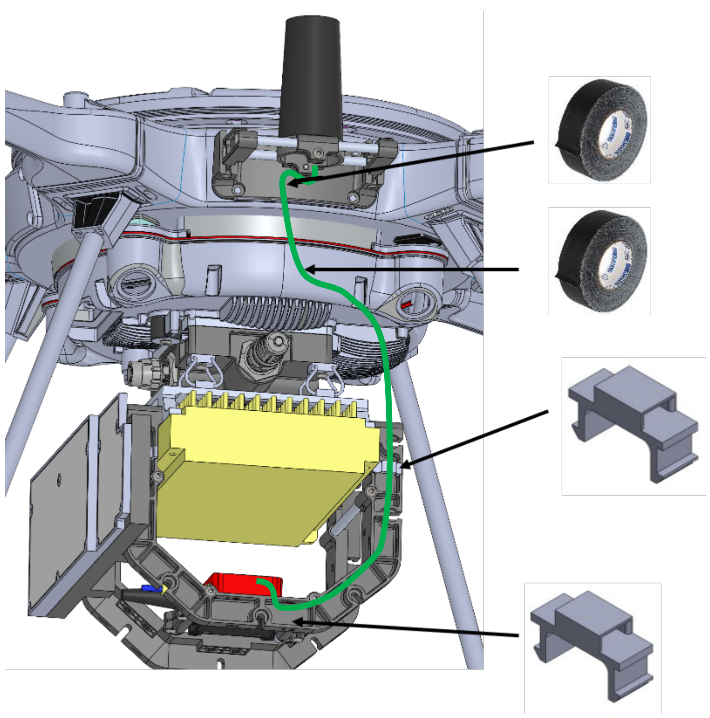


Figure F-21. SkyRaider GPS Antenna Cable Routing

F.7.5 Payload RF Cables

Due to the minimal payload capacity of the SkyRaider and simplicity of RF cable installations, no RF cable runs are permanently installed. All RF cables are run as needed to appropriate antenna installation location, either the antenna mounting frame or the universal 2-pt expansion cover mount, at the time of payload installation.

F.8 Platform-Payload Concessions

Three concessions are documented for the MP-SkyRaider.

F.8.1 Center of Gravity Considerations

While not a direct violation of the standard, the MP-SkyRaider is highly sensitive to center of gravity deviations, which may limit antenna selection for payloads. There are three main restrictions that will be used to determine if an antenna can be supported:

- Size - The mounted antenna must fit within the specified envelope. Detailed envelope information is included for each mounting location in Sections F.6.1 through F.6.3.
- Maximum Weight - The total weight of the antenna, bracket, and fasteners must be below the maximum weight restriction.
- Moment Restriction - The magnitude of the moment applied by the CG under a unit gravity load about the X, Y, Z axes, must all be less than a maximum moment restriction (currently 0.3 in-lbs).

F.8.2 Payload Cable

The SkyRaider MAIM-Payload cable uses an 18-pin Switchcraft connector at the MAIM. Since this is three pins less than the 21-pin payload connector, the two Spare signals (pins 10 and 21 on the payload connector) and the State Transmit signal (pin 15 on the payload connector) are not connected at the MAIM.

F.8.3 Payload Mounting Hardware

The MP cold plate interface was designed to use #6-32 hardware. The MP-SkyRaider instead uses #4-40 hardware to secure payloads to its payload bracket. As a payload is simply required to have clearance holes and the appropriate #4-40 threaded holes are provided by the Primary Mount payload bracket, this does not present a compatibility issue.

Appendix G. **Acronyms and Abbreviations**

AHRS	Attitude and Heading Reference System
COTS	Commercial off the Shelf
DA	Density Altitude
EMI	Electro Magnetic Interference
EW	Electronic Warfare
FMV	Full Motion Video
GTOW	Gross Take-off Weight
GUI	Graphical User Interface
ICD	Interface Control Document
INS	Inertial Navigation System
MAIM	Modular Aircraft Interface Module
MP	Modular Payload
MTOW	Maximum Take-off Weight
PCB	Printed Circuit Board
SIGINT	Signals Intelligence
UAS	Unmanned Aircraft System

Appendix H. **Applicable Government Documents**

The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

MIL-STD-454 Standard General Requirements for Electronic Equipment
MIL-STD-461 Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462 Electromagnetic Interface Characteristics, Measurement of
MIL-STD-810 Environmental Test Methods

Appendix I. **List of Figures**

Appendix J. **List of Tables**

Volume II

Modular Payload Expanded Capability Set (MPx)

Revision 5.1

May 25, 2021

DISTRIBUTION STATEMENT A: Approved for public release: distribution unlimited.

UNCLASSIFIED

This is a DRAFT release of the MPx volume. This volume should NOT be used to design systems, without first contacting Mod Payload management for guidance.

This draft is provided so that the general scope of MPx can be understood for the purpose of planning and proposal generation. Specific information, e.g., pin-outs, dimensions, etc., are all subject to change and will be refined in the next release

Table of Contents:

1. REQUIREMENTS FOR PLATFORMS

A number of requirements are levied on the Platform to support modular payloads. For existing platforms, MPx-compliance will likely require an A-kit to be added to the platform. These modifications will add some weight and complexity to the platform but will provide common mechanical, power, data, and RF interfaces to simplify payload integrations. These modifications include the development and installation of a Platform Interface Module (PIM) and a Primary Mount, the integration of a specific inertial navigation system (INS), provisions for payload antennas and the installation of RF cabling to support the payload antennas. For new Platforms, the same payload accommodations must be made, but MPx-compliance is much less intrusive and can be readily and more efficiently incorporated as part of the initial platform design.

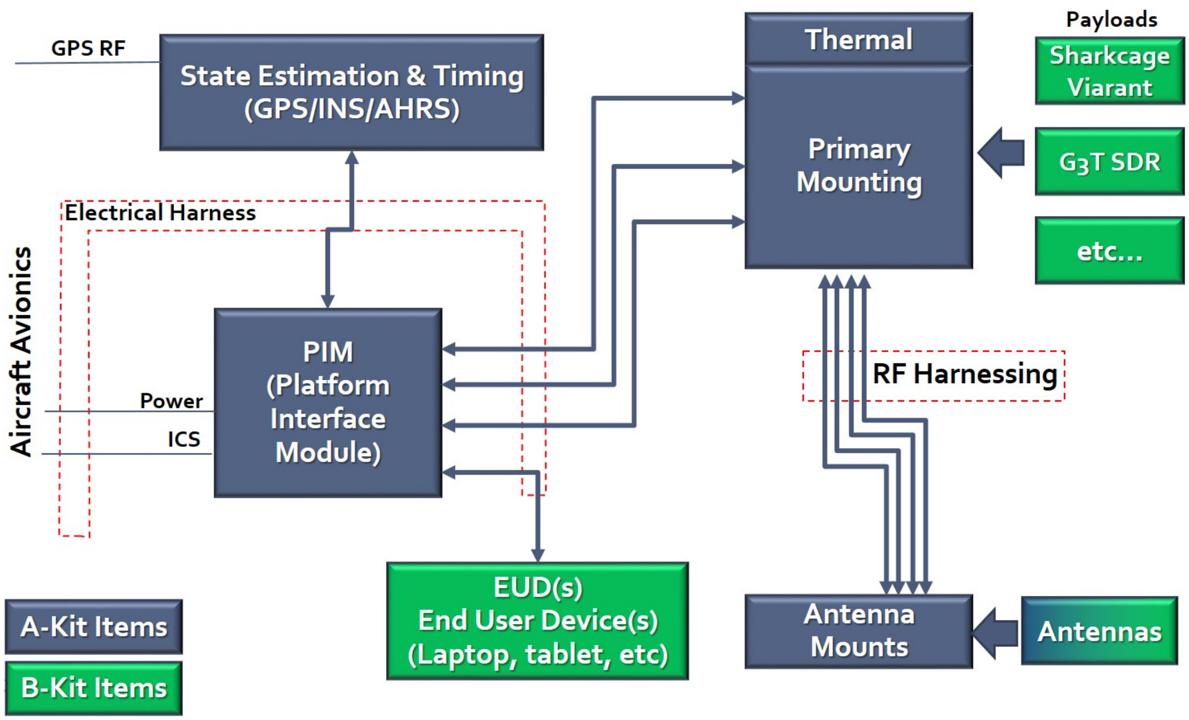


Figure 1-1 MPx System Architecture

1.1 PIM

The PIM provides the interface between the non-compliant host platform and the payload modules. The PIM is a scalable design ***customized for each platform*** to provide the electrical interfaces required for modular payloads.

1.1.1 Applicability

A PIM is only required to bring an existing platform into MPx-compliance. A newly developed platform can support all PIM functionality and requirements with it native avionics suite.

1.1.2 Description

The PIM is an enclosed module, customized to the host platform to provide the required platform and payload interfaces and the required data ingestion, processing and dissemination capabilities to support payload integration and operation. The PIM should be considered an additional avionics component, not a payload itself. As such, the size, weight, and payload capacity of the PIM are not strictly defined, but should be commensurate to the platform capacity. As a result, the PIM may vary substantially for different Platforms.

Figure 1-2 depicts an example PIM. It supports up to 3 payloads.

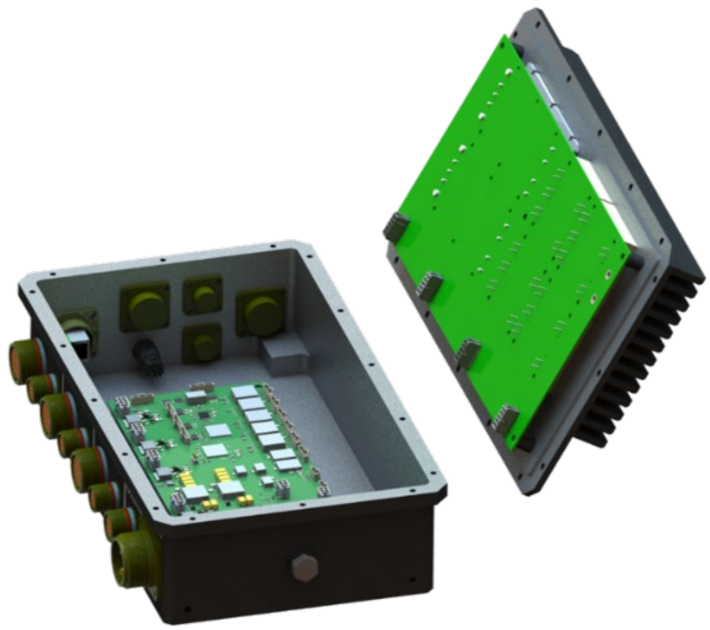


Figure 1-2. Example PIM

1.1.3 Interfaces

The PIM shall provide each payload the following interfaces:

- Power (as described in Section 1.1.4.1)
- Ethernet – state (as described in Section 1.1.4.2)
- Serial – state (as described in Section 1.1.4.4)
- Ethernet (as described in Section 1.1.4.2.1)
- Serial – console (as described in Section 1.1.4.5)
- 1PPS (as described in Section 1.1.4.6.1)
- 10 MHz (as described in Section 1.1.4.6.2)
- Zeroize (as described in Section1.1.4.7)

No specific connector or pinout is mandated for the PIM itself. The interface is only specified on the payload. In some cases, a separate, dedicated connection for each payload is feasible, providing some benefits. In others, it may be preferred to have all payload lines coming from a single physical connector on the PIM. The flexibility to choose is left to the integrator.

1.1.4 Required Functionality

As the platform-payload interface, the PIM must provide power, power switching and monitoring, state distribution, network connectivity, serial console, serial to Ethernet conversion, time synchronization and a zeroize capability for payloads. The requirements for each are detailed in the subsequent sections.

Figure 1-3 illustrates the functionality, major components, and interfaces for an example PIM. PIMs developed for other manned platforms will require customization to address platform-specific needs.

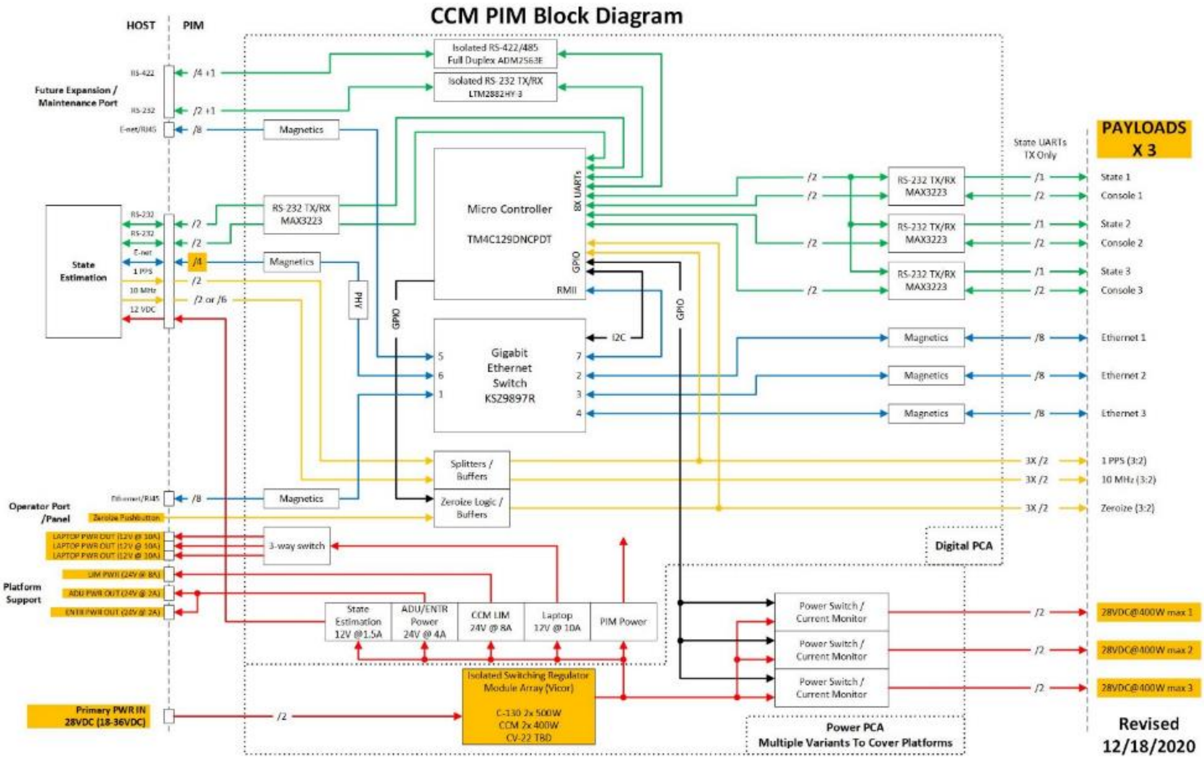


Figure 1-3 Example PIM Block Diagram

1.1.4.1 *Power*

The PIM shall interface to the available platform power and provide up to 400W at 28VDC ±2% to each payload interface. Platform specific power plans are provided in the platform appendix. Where a platform has less than 400W available, MPx can still be implemented. The reduced power capability simply must be documented as an exception to compliance.

Unlike the SUAS system, there ***is*** a direct association between the number of 'U's a primary mounting can support, and the number of payloads that a platform's PIM supports.

However, for a platform which is size constrained, but has excess bulk power, additional power feeds may be reasonable. For example, a platform may only have room to support a primary mount with 1U of capacity, however if it had 1000W available it would make sense that the PIM provide an additional power only feed so that higher power, but single 1U, payloads would be supportable.

Likewise, regardless of power capacity, it is recommended that the Primary Mount accommodate a minimum of at least 2U of payload space. This is counterintuitive. The reason is that for a given platform which has ample room available, but poor power capability, it makes more sense to have flexibility for payloads, even with a limitation on total bulk power draw. For a good example to clarify this concept, see the CCM appendix.

The PIM shall monitor the power draw of each payload separately and generate an alert if a payload is exceeding the allowable power draw. The PIM shall provide the ability to secure power to the payload manually, commanded by the platform operator.

Additionally, for platforms which support more than 1 payload feed, the PIM shall allow for a high power payload to pull more than one power feed, effectively shorting those rails inside the payload.

1.1.4.2 *State Distribution*

The PIM shall interface to the MPx-approved INS* to receive and distribute state data to each payload to which it interfaces. State data shall be provided to each payload over both Ethernet and serial interfaces. The state data provided shall include:

- From GPS: Status, Week, Time of Week, GPS UTC, Latitude, Longitude, Altitude, Velocity, Course, Roll, Pitch, Yaw, Speed Over Ground
- From GYRO: Velocity (North, East, Down), Latitude, Longitude, Altitude

NOTE: Only INS devices approved in this standard (see Section **1.2) are allowed to be used.*

1.1.4.2.1 Ethernet Interface

The PIM shall distribute state data to payloads over the internal Ethernet network using UDP/IP multicast. The default IP address of the multicast group shall be 239.255.1.1. This communications mechanism assumes the recipients have implemented an IP stack and are able to join multicast groups via IGMP.

The PIM shall re-package the state data from the MP-compliant INS into a JavaScript Object Notation (JSON) message structure to distribute the data over Ethernet. The PIM shall transmit these JSON messages at either 1Hz or 10Hz, depending on message. The size of the messages sent over the Ethernet connection shall not exceed the maximum transmission unit (MTU) of 1500 bytes.

The JSON messages are fully detailed in Appendix A, Section A.2.

1.1.4.3 *Network Connectivity*

The PIM shall create a simple switched IP payload network to provide connectivity to the operator station to allow for command, control, configuration, and monitoring of the payload and payload data. The PIM shall provide an Ethernet interface to each payload, to the operator station and for itself. The PIM shall provide full Layer 2 switch functionality, support 10/100/1000BASE-T connections, and allow IGMPv1/v2/v3 snooping for multicast packet filtering.

1.1.4.4 *Serial - State*

The PIM shall distribute state data to payloads using a serial interface in accordance with TIA/EIA-232-F. The operating parameters of this RS-232 interface are 115,200 bps, 8 Data bits, 1 Stop bit, No Parity, and No Flow Control. The direction of data flow shall be from the MAIM to the payloads. There shall be no data flow from the payloads to the PIM over this interface. The following signals shall not be connected at the MAIM: DTR, DCD, DSR, RI, RTS, RTR, CTS.

The PIM shall re-transmit the state data from the MP-compliant INS using the sbgECom binary and NMEA protocols natively output by the MP-compliant INS. The PIM shall transmit the binary messages at the prescribe rates, either 1Hz, 5Hz, or 20Hz, depending on message and shall transmit the NMEA message at 1Hz. The sbgECom binary messages are detailed in Appendix A, Section 2.7.10A.2.2.

1.1.4.5 *Serial – Console*

The PIM shall provide a console serial port to each payload. This interface in accordance with TIA/EIA-232-F for each payload to serve as a data / console / maintenance connection. The operating parameters of this RS-232 interface are 115,200 bps, 8 Data bits, 1 Stop bit, No Parity, and No Flow Control. The data flow is bi-directional between the PIM and the payload. The following signals are not supported: DTR, DCD, DSR, RI, RTS, RTR, CTS.

To provide remote access to this serial console port, the PIM shall create a virtual serial port over UDP for each payload console connection. Requisite IP addresses and ports for the virtual serial ports over UDP are determined by the integrator and shall be part of the configuration software for the PIM.

1.1.4.6 *Time Synchronization*

1.1.4.6.1 1 PPS

The PIM shall receive and re-transmit the 1PPS signal from the INS (or an equivalent 1PPS source native to the platform) to each payload. The 1PPS signal provided by the PIM shall be low voltage differential signal (LVDS) in accordance with the TIA/EIA-644 standard – ground, 3.3V power, 1.0V logic low, 1.4V logic high. A major advantage of LVDS signaling is that only the differential pair (Sensor PPS+, Sensor PPS-) need to be connected between the source and destination.

1.1.4.6.2 10 MHZ

The PIM shall provide a 10MHz Reference signal to each payload. The 10 MHz reference shall have a 50 ohm characteristic impedance, and have a received signal strength of 10dBm at the payload after cable and connector losses.

1.1.4.6.3 NTP

[Future expansion]

1.1.4.7 *Zeroize*

The PIM is required to provide a zeroize signal to all payloads. This can be activated by one of two reasons:

- Operator manually commands the PIM to zeroize
- Platform autonomously signals the PIM to zeroize

An active low signal shall be used as the zeroize signal. The zeroize signal provided by the PIM shall be an LVDS in accordance with the TIA/EIA-644 standard – ground, 3.3V power, 1.0V logic low, 1.4V logic high.

The notion of a zeroizing standard has been discussed for years but has not been implemented. The requirement to implement here is to have ‘hooks in place’ to support this functionality in the future.

1.1.5 Software

The PIM requires both embedded and user software. The embedded component will reside onboard the PIM itself in an embedded processor or a microcontroller. The user component will be the operator’s user interface to communicate with the embedded component.

1.1.5.1 *Embedded*

The PIM embedded software shall provide the following functions:

- Collection and distribution of INS-state data
- Calibration of State subsystem
- Network configuration and management
- Serial console configuration
- Power control and monitoring
- Platform status monitoring

This software should be developed to run on a small microprocessor or microcontroller.

1.1.5.2 *User Interface*

The PIM shall also interface to a user applications for control, monitoring, and maintenance. A PIM graphical user interface (GUI) shall provide this interface to the operator.

1.1.5.2.1 GUI Requirements

The PIM GUI shall provide the following capabilities to the operator:

- Monitor status of PIM – connectivity, temperature, faults
- Energize and secure power to individual payloads
- Monitor connectivity to individual payloads
- Monitor power consumption of individual payloads
- Monitor status of PIM – connectivity, temperature, faults, normalization

- Monitor current PIM data – position, attitude, time
- Calibrate the INS
- Zeroize payloads
- Set and view the PIM network configuration settings

1.1.6 Maintenance

The PIM should support a maintenance connection, as depicted in Figure 1-4 for testing of both the PIM as well as the payloads.

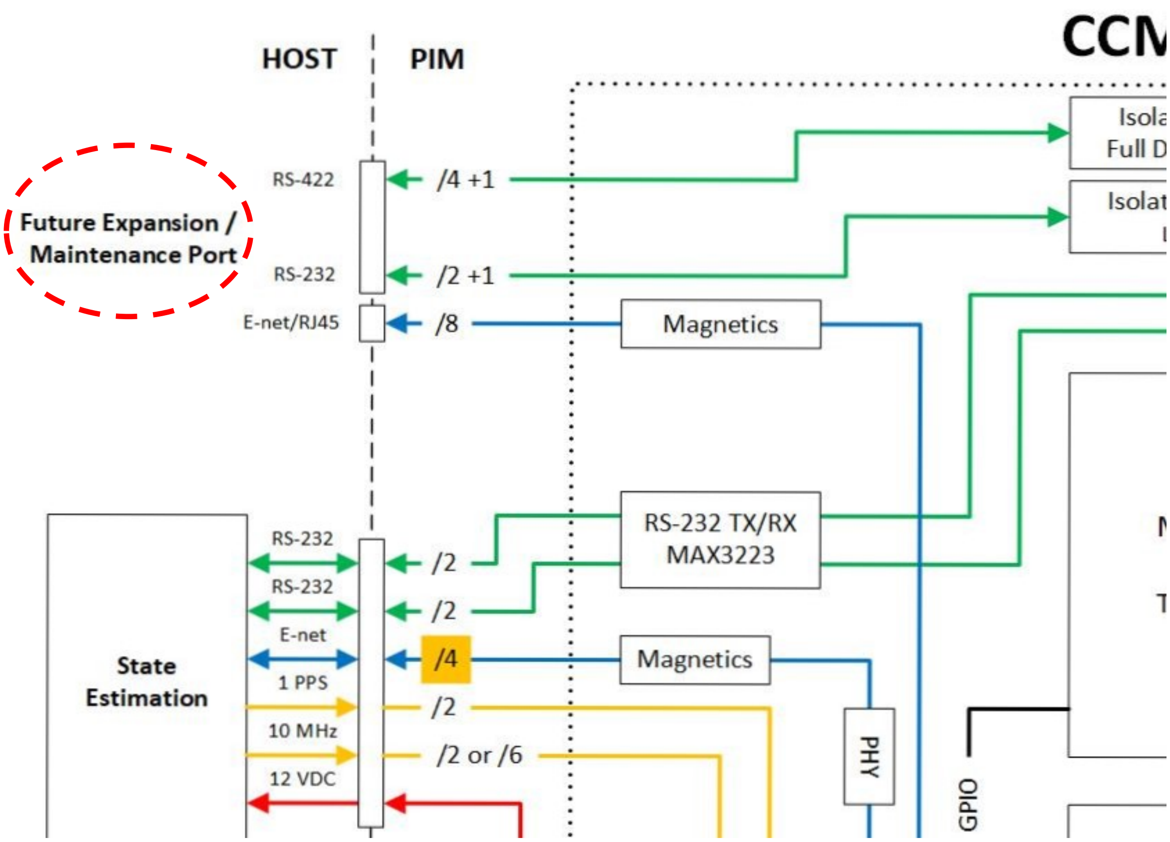


Figure 1-4 Maintenance Connection

The maintenance connection shall have 1x RS-422, 1x RS-232, and one Ethernet connection

1.2 State Estimation and Timing

1.2.1 Overview

The State estimation and timing subsystem is responsible for providing position, attitude, velocity, and timing to the PIM for ultimate distribution to payloads. Within this system may be multiple devices to achieve the full set of telemetry needed

Currently, it is expected that there be an INS and a timing reference for 10MHz which is synchronized to 1PPS.

It is important to note that the State Estimation and Timing subsystem is highly recommended to be a separate subsystem (not buried in the PIM for example). This is because this subsystem is expected to change frequently, with upcoming migrations to M-Code, better INS options, Alt-NAV solutions, etc.

1.2.2 INS

Some payloads require a higher accuracy INS than those native to the platform. Additionally, standardization warrants control of the state source. To meet the requirements of these payloads, a dedicated, high accuracy INS shall be installed on the Platform as part of the MP architecture. Position and attitude information from the MP-compliant INS shall be transmitted to the PIM for distribution to the payloads. Because of its light weight, high performance, and commonality with existing payloads, the only current MP-approved INS is the SBG Systems Ellipse2-N.

Ellipse2-N Specifications
Size: 26.8x18.8x9.5 mm
Weight: 10 g
Input Voltage: 4-17 V
Power consumption: 400 mW
Accuracy: Roll and Pitch 0.1° **Heading 0.8°** **Heave 5 cm**
2m GNSS Position **(GPS, GALILEO, GLONASS, BEIDOU)**
Output Rate: 200Hz
1PPS synchronization output

Figure 1-5. Ellipse2-N INS

1.2.2.1 *INS Utilization*

It is critical that the INS, or Attitude and Heading Reference System (AHRS), for the Modular

Payload Standard provides high accuracy orientation information under dynamic conditions. To meet these stringent requirements, SBG's Ellipse2 was selected due to its exceptional orientation and navigation performance in a miniature and affordable package. In order to ensure full sensor performance, certain guidelines must be adhered to when integrating the AHRS onto new platforms.

1.2.2.2 *INS Vibration Isolation*

Good mechanical isolation from shock and vibration is required to avoid bias in the accelerometer reading. High amplitude vibrations cause the sensor to saturate resulting in large errors in orientation. To mitigate this effect, vibration isolating mounts are required wherever the sensor may experience large vibrations.

1.2.2.3 *Avoiding Magnetic Distortions*

Care should be taken to place the AHRS away from any magnetic distortions that can introduce hard or soft iron interference. Examples of sources of interference include, but are not limited to, large ferromagnetic materials, magnets, high current power supplies, high current carrying wires, or permanently magnetized hardware. Despite the calibration of the AHRS, the presence of these inferences in close proximity to the AHRS can cause the calibration to fail and result in heading inaccuracies. In addition to avoiding the placement of the AHRS near items such as camera gimbals, motors, engines, and servos, several other practices can be observed to avoid disturbing the magnetic field around the AHRS. It is recommended that all high current carrying wires near the AHRS include twisted pairs and shielding. Cables should be routed as far away from the AHRS as possible and retained in a way that prevents them from being moved independently from the AHRS. Lastly, ferrous hardware or hardware that can be easily magnetized should be avoided when designing mounts for the AHRS.

1.2.3 Operating Temperature Consideration for AHRS Operation

The AHRS should be placed in a location that can reliably keep the AHRS within its accepted temperature range; per SBG's User Manual, this is between -40°C and 85°C.

1.2.3.1 *AHRS Physical Orientation*

The AHRS should be mounted in a position that fixes its orientation and position on the platform. The AHRS coordinate frame should be aligned with the platform cardinal points. Any deviation in the AHRS orientation in relation to the platform cardinal points will degrade performance. It is preferable to have the AHRS “x axis” in alignment with the platform’s forward direction. The sensor lever arm (distance from the AHRS to the CG) as well as GPS lever arm (distance from the AHRS to the GPS antenna) should be measured as well. The AHRS placement, orientation, and lever arms should all be documented for reference.

1.2.3.2 *AHRS Placement Testing*

After an AHRS position is selected and all the guidelines are met, AHRS placement testing must be conducted as part of any new integrations on UAS platforms; this includes both a ground test and a flight test. Additionally, AHRS placement testing is required should any major changes be introduced to a platform's configuration or architecture. It is recommended that a ground test is conducted to evaluate potential AHRS location options. The AHRS performance should be assessed by rotating the platform, about its CG, to measure heading and AHRS behavior while powering platform services (engine, camera, servos, strobes, etc.) to see if there are any changes / impacts to AHRS monitored data.

1.2.4 INS Configuration

The SBG Ellipse is designed to be able to operate in a number of dynamic vehicle environments. The aircraft environment poses many unique challenges when trying to achieve optimum INS performance, and so certain settings are recommended. The following configurations should be made to the SBG Ellipse. Refer to the SBG documentation for the exact description of each:

SBG Ellipse Config Routine	Recommended Value
sbgEComCmdGnss1SetLeverArmAlignment †	(platform-dependent)
sbgEComCmdSensorSetAlignmentAndLeverArm	(platform-dependent)
sbgEComCmdSensorSetMotionProfileId	SBG_ECOM_MOTION_PROFILE_AIRPLANE
sbgEComCmdMagSetRejection	SBG_ECOM_AUTOMATIC_MODE
sbgEComCmdMagSetModelId	SBG_ECOM_MAG_MODEL_NORMAL
sbgEComCmdGnss1SetRejection	SBG_ECOM_ALWAYS_ACCEPT_MODE, SBG_ECOM_ALWAYS_ACCEPT_MODE, SBG_ECOM_NEVER_ACCEPT_MODE, SBG_ECOM_AUTOMATIC_MODE
sbgEComCmdGnssSetModelId	SBG_ECOM_GNSS_MODEL_UBLOX_GPS_GLONASS
sbgEComCmdSyncOutSetConf	SBG_ECOM_SYNC_OUT_A, SBG_ECOM_SYNC_OUT_MODE_DIRECT_PPS

† sbgEComCmdGnss1InstallationSet for SBG Ellipse firmware v1.7.1436 & beyond.

Note that the SBG Ellipse has internal memory that stores its configuration across power cycles. The parameters in the table above could potentially be configured once via SBG Center before installation, or they could be configured dynamically after installation via the MAIM firmware.

1.2.5 INS Magnetometer Calibration

In order for the SBG Ellipse to measure a valid magnetic heading, the magnetometer needs to be periodically calibrated. This can be achieved by putting the SBG Ellipse into "magnetometer calibration" mode and executing an acceptable movement pattern. A successful airborne magnetometer calibration typically has these basic requirements:

- Minimize as much large, time-varying magnetic field activity on the platform as possible. If the SBG Ellipse is installed in close proximity to a gimbaled payload, this means minimizing gimbal movement for the duration of the magnetometer calibration.
- Put the SBG Ellipse into magnetometer calibration mode via the sbgEComCmdMagStartCalib command
- Execute an appropriate pattern so that the SBG Ellipse can take measurements across a range of azimuth and roll angles. A time-tested method for achieving this is a "double figure-8" pattern.
- Once the full pattern has been executed, take the SBG Ellipse out of magnetometer calibration mode via the sbgEComCmdMagComputeCalib command.

The magnetometer does not need to be calibrated on every single mission. A real-time indication of the quality of the magnetic calibration, called the AHRS norm, can be computed in the PIM or PIMGUI. If the norm is within limits, a magnetometer calibration need not be performed. If a change to the platform or a change to the location of the platform is significant enough to degrade the quality of the magnetometer calibration, the norm should reflect this. A previously-computed magnetic calibration can be saved to the PIM or PIMGUI, and programmed back into the SBG Ellipse via the sbgEComCmdMagSetCalibData command.

1.2.6 Timing

The timing subsystem can be implemented by the integrator in various ways. One example method is to add a Jackson Labs Firefly – IIA. This device can be used to provide the needed 10MHz.

Figure 1-6 Timing Subsystem Example

1.3 Primary Mount

The Primary Mount is the physical structure that houses the payload modules in the MP architecture.

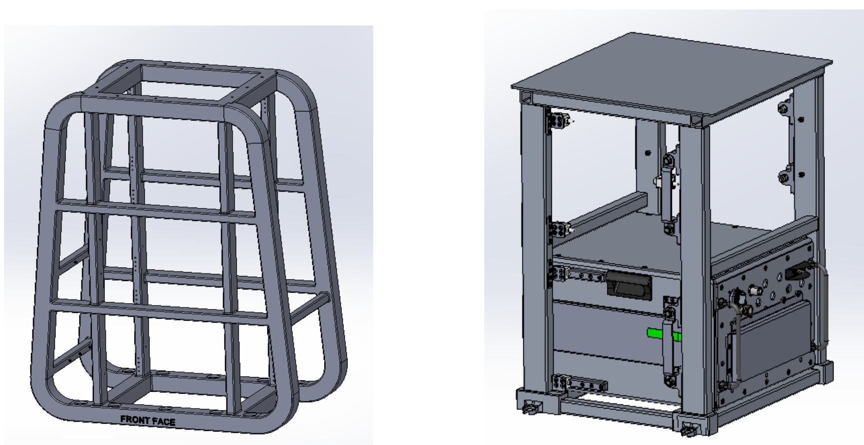


Figure 1-7 Primary Mount Examples

1.3.1 Applicability

An add-on Primary Mount is required for all MPx-compliant platforms. However, a newly developed platform may incorporate the Primary Mount interface into its native platform design to fulfill this requirement.

1.3.2 Description

The Primary Mount is a ***platform-specific*** mechanical assembly, customized to accommodate the physical characteristics of the platform, while providing a standard, simple payload interface to promote rapid installation and removal of payload modules. The Primary Mount shall be designed to provide a standard payload mechanical interface, while minimizing weight and endure platform loading.

The Primary Mount shall support a number of payloads commensurate with the platform capacity. Unlike the SUAS system, there ***is*** a direct association between the number of 'U's a primary mounting can support, and the number of payloads that a platform's PIM supports.

However, for a platform which is size constrained, but has excess bulk power, additional power feeds may be reasonable. For example, a platform may only have room to support a primary mount with 1U of capacity, however if it had 1000W available it would make sense that the PIM provide an additional power only feed so that higher power, but single 1U, payloads would be supportable.

Likewise, regardless of power capacity, it is recommended that the Primary Mount accommodate a minimum of at least 2U of payload space. This is counterintuitive. The reason is that for a given platform which has ample room available, but poor power capability, it makes more sense to have flexibility for payloads, even with a limitation on total bulk power draw. For a good example to clarify this concept, see the CCM appendix.

1.3.3 Requirements

1.3.3.1 *Interface*

The mechanical interfaces for a payload to mount into the Primary Mount are detailed under the payload module requirements in Section **2.3.2**.

1.3.3.2 *Payload Size*

The primary mount shall be designed to accommodate individual 1U MPx modules. Modules larger than 1U are NOT permitted.

The number of U should be selected based on consideration of power (in accordance with guidance in 1.3.2), platform CONOPS (is there a need for more than one system at a time), and platform space/weight limitations.

1.3.3.3 *Thermal Dissipation*

Thermal dissipation under MPx is different than under volume I. Under MPx the responsibility for thermal mitigation lies mostly on the Payload developer via active convection.

That being said, the Primary mounting design and location shall not impede the payloads from proper intake and exhaust airflow.

1.3.3.4 *Structural*

The primary mount shall survive loading, shock, and vibration commensurate with all phases of operation of the specific platform. See Section 2.7 for requirements.

1.3.3.5 *PIM mounting*

In most cases, it appropriate for the PIM to be mounted to the Primary Mount. This should be done in a way that minimizes cable runs and assures easy access to all connectors.

1.3.3.6 *Auxiliary Systems*

Under MPx the platform variation presents more complexities for auxiliary subsystems. For example, ICS distribution, SATCOM terminals, etc…

[This area of MPx, and defining what is within the bounds of this standard, is still in work]

1.4 RF Cabling and Antenna Mounts

As part of the MPx architecture, platforms shall be equipped with RF cable runs and antenna mounts or fixed antennas at various locations along the platform to accommodate payload antennas. The specific location and specifications for the mounts and antennas are located in the platform specific appendix.

1.4.1 Antenna Mount Requirements

The antenna mounting requirements vary under MPx by platform type. In general there are two types of platforms under MPx

- Platforms with provisions to bring onboard antennas as part of the B-kit
- Platforms with strict oversight of antennas where they are treated as A-kit items outside the scope of MPx

For platforms where antennas can be brought onboard and swapped out as B-kit items, MPx defines a set of mechanical interface standards, and flexible provisions on the MPx A-kit to optimize flexibility in the field. Examples would be CCM, or an aircraft Pod.

1.4.1.1 *Interface*

Much like volume I, a mechanical interface boundary is defined for MPx. Because of the large antennas in this class, and the higher mechanical strength required, this interface is different. That being said, backwards compatibility will also be possible.

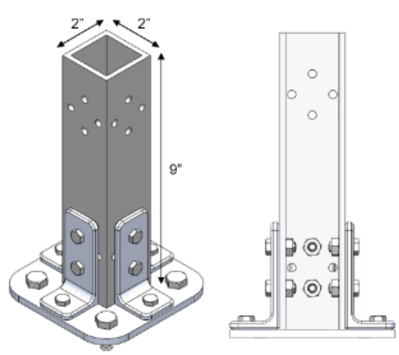


Figure 1-8 A-kit Antenna Bracket Example

In Figure 1-8 an example A-kit bracket is shown. The MPx antenna mount boundary between A-kit and B-kit fitments is the 4 hole configuration near the top. This allows B-kit antennas to be mounted in a variety of ways. An example is as shown in Figure 1-9.

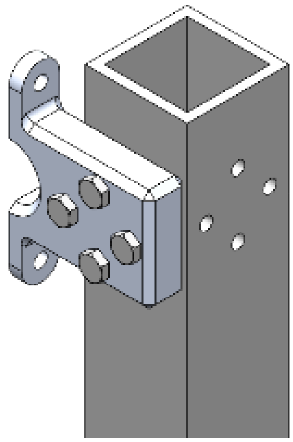


Figure 1-9 B-kit Antenna Mount Example

1.4.1.2 *DF Antennas*

Under MPx there will be a later standardization of the DF antenna interface. This is critical in order to achieve quick swap capability of different technologies on manned aircraft specifically.

In the short term however, the DF antennas will not fall under the MPx standard, but will interoperate with MPx Systems.

For example – A payload uses a special DF antenna on the C130. That payload will be redesigned into compliance with MPx. Its power feeds, communications, state estimation, mechanical form factor, etc. will all be compliant with MPx, affording the ease of installation and removal of that capability. However its DF connection will be controlled via a separate connector(s) on the payload and harnessing to connect to that DF antenna will be provided outside of the MPx spec.

Thus there is a progression for partial MPx compliance today, with a pathway to full compliance and standardization as the DF antenna interface boundary becomes standardized through other efforts under USSOCOM.

1.4.1.3 *Platform Antenna Configurations*

The number of A-kit antenna mounts/locations is a trade space driven by the number of payloads supported, the SWAP constraints of the platform, and the type of platform (e.g. air vs maritime)

Aircraft should consider the need for MPx payloads to have antennas with visibility to the side, up, and down

Maritime platforms are obviously lose the need for a down looking antenna mount, however they present a need in some cases for provisions to cover left AND right (vice just one side as with most airborne systems.

1.4.2 RF Harnessing

A minimum of one RF cable shall be run from the Primary mount to each collection antenna location.

RF cabling should be lightweight to minimize impact on platform. RF cabling shall be low loss, less than 0.2 db/ft attenuation up to 1 GHz and less than 0.5 db/ft up to 6 GHz.

RF cables shall terminate in N type connectors certified to function up to 10GHz

The Payload end of the RF cable shall be Male

The ultimate cable that will connect to the antenna shall be Male. Intermediate connections should be minimized, but the number and type are left to the discretion of the integrator.

1.4.3 DF Harnessing Requirements

[Future expansion]

1.5 Electrical Harnessing

The electrical harnessing scheme within the A-kit will vary by platform, just as the other primary MPx subsystems.

1.5.1 Platform to PIM

This interface is most MPx applications is strictly electrical power

In some applications there may be a specialized desire to add a telemetry connection between the MPx A-kit and the host platform. While MPx implementation does not prevent this, it is not specified nor covered under this standard.

1.5.2 PIM to Payloads

As described in the PIM section, the connectors used on the PIM, and thus the harnessing at that end, are left to the discretion of the integrator. However, the Payload end of the harness must conform to this standard

For pinout information see the Payload section of this volume.

For 1PPS and 10MHz requirements, see the PIM section of this volume

1.5.3 State Estimation to PIM

The State estimation interface boundary is not specified under this document as it is part of the A-kit. The specifications related to these signals are solely focused on the output to the Payload. The upstream formation of these data products is left to the discretion of the integrator.

1.5.4 PIM to EUD

The EUD, or End User Device, will be a ruggedized laptop in most applications.

The harnessing requirement will predominately be an Ethernet cable and power. The power to the EUD should not be overlooked, as it can very quickly overcome power budget for payloads. In some cases novel power charging schemes may be needed to reduce the power burden.

1.5.5 PIM to Auxiliaries

Some platforms require integration of 3rd party systems such as ENTR (SATCOM) or ADU (audio distribution).

[This area of MPx is still being finalized and will be updated in a future release.]

1.5.6 Grounding

The platform grounding scheme must be carefully designed to eliminate ground loops.

2. REQUIREMENTS FOR PAYLOADS (the B-kit)

The following sections specify the electrical, mechanical, thermal, environmental, and RF requirements for a payload to be MP-compliant.

2.1 B-Kit definition

In general the B-kit consists of:

- Payload
- Antenna(s) with brackets and in some cases RF adapters
- EUD (Laptop) and/or Software

2.2 Electrical

The MP standard imposes a common electrical interface on payload modules.

2.2.1 Power

A payload module should draw no more than 400W at 28VDC. This is the power provided by the PIM to each module. If additional power is needed, it must be sourced from a separate PIM payload interface and input though an auxiliary payload module connector. Further, the increased power draw may limit platform compatibility (some platforms will only be capable of providing 400W).

A payload module shall be able to accommodate voltage fluctuations of ±2% from the nominal 28VDC.

A payload module shall have an input capacitance no greater than 3300uF
A payload shall have an inrush current less than 39A
A payload shall have an inrush current duration less than 1 mSec

2.2.2 Communications

A payload module will have one serial and one Ethernet interface provided. In most cases it is expected that the Payload will be controlled via IP communications, up to GbE. However a serial port is also available for console or other operations.

2.2.2.1 *Serial – State Estimation*

The serial connections are used to provide (1) state data to the payload and (2) a console port to access the payload, both via the PIM.

The state serial communications interface is detailed in the State Estimation and Timing section

2.2.2.2 *Serial – Console*

The Payload may choose to use the console serial port. This interface in accordance with TIA/EIA-232-F for each payload to serve as a data / console / maintenance connection. The operating parameters of this RS-232 interface are 115,200 bps, 8 Data bits, 1 Stop bit, No Parity, and No Flow Control. The data flow is bi-directional between the PIM and the payload. The following signals are not supported: DTR, DCD, DSR, RI, RTS, RTR, CTS.

To provide remote access to this serial console port, the PIM shall create a virtual serial port over UDP for each payload console connection. Requisite IP addresses and ports for the virtual serial ports over UDP are determined by the A-kit and will be part of the configuration software for the PIM.

2.2.2.3 *Ethernet*

The Ethernet connection is used to transmit payload data, as well as, command and control the payload, when applicable. State estimation is also available over Ethernet. The Ethernet communications interface is detailed in Section 1.1.4.3.

2.2.3 Other Signals

A payload module can also leverage a 1PPS timing signal, a 10MHz reference, and a zeroize signal from the PIM. The 1PPS signal is detailed in Section 1.1.4.6.1. The 10 MHz Signal is detailed in section 1.1.4.6.2. The zeroize signal is detailed in Section 1.1.4.7.

2.2.4 Electrical Connectors

Under MPx there are two MIL connectors used. One for Ethernet and one for power and all other signaling.

2.2.4.1 *Main Connector*

The primary connector shall be a MIL-DTL-38999/20WE26PN

2.2.4.1.1 *Main Connector Pinout*

Pin	Signal Name
A	+28V
B	+28V
C	+28V
D	+28V
E	+28V
F	Ground
J	Ground
M	Ground
R	Ground
S	Ground
T	Ground
U	Ground
V	Ground
Y	Ground
Z	Ground
N	State RX
P	Console RX
a	Console TX
G	Sensor PPS +
H	Sensor PPS -
K	10MHz +
L	10MHz -
b	Zeroize +
c	Zeroize -
W	Spare
X	Spare

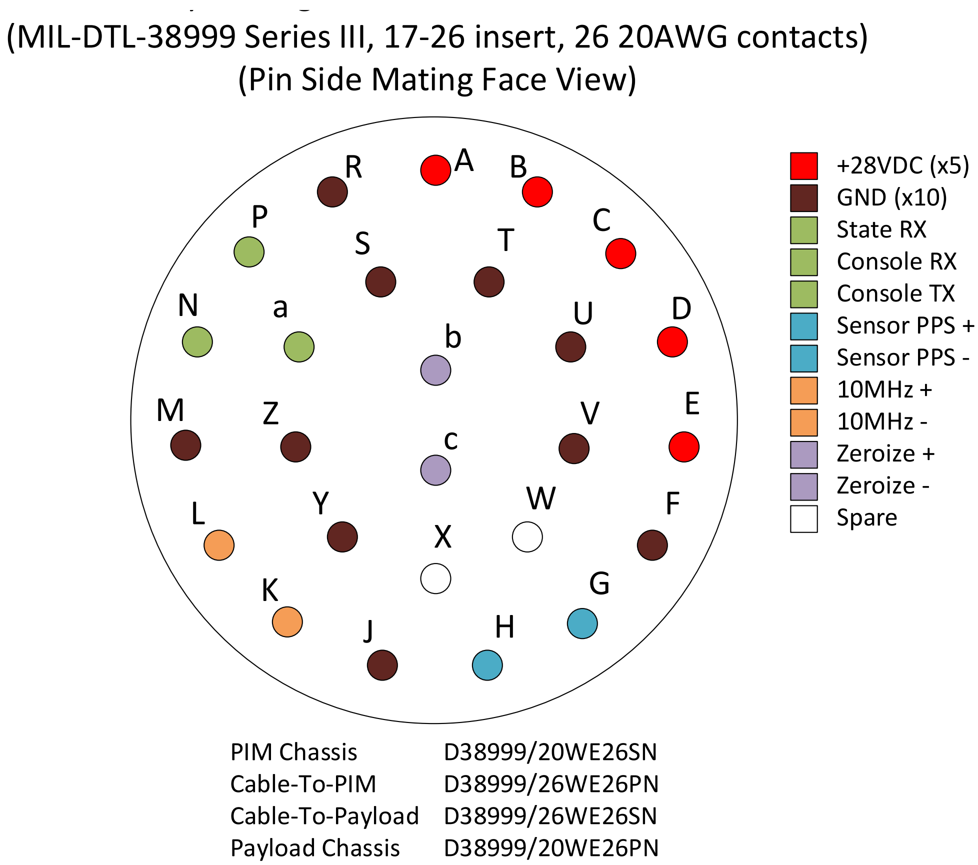


Figure 2-1 Main Connector Pinout

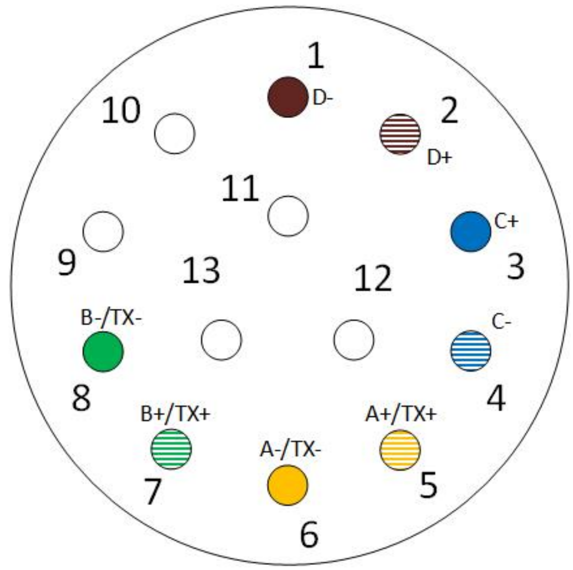
2.2.4.2 *Ethernet Connector*

The Ethernet connector shall be a MIL-DTL-38999 Series III, 11-35 insert, 13 22AWG contacts

2.2.4.2.1 Ethernet Connector Pinout

New Payload/Operator Ethernet Connector Pinout
(MIL-DTL-38999 Series III, 11-35 insert, 13 22AWG contacts)
(Pin Side Mating Face View)

Pin	1000Base-T Signal Name	100Base-T Signal Name	EIA/TIA 586B Pairs	RJ-45 pin (for reference)
1	BI_DD-		Brown	8
2	BI_DD+		White/Brown	7
3	BI_DC+		Blue	4
4	BI_DC-		White/Blue	5
5	BI_DA+	TX+	White/Orange	1
6	BI_DA-	TX-	Orange	2
7	BI_DB+	RX+	White/Green	3
8	BI_DB-	RX-	Green	6
9	Spare			
10	Spare			
11	Spare			
12	Spare			
13	Spare			



Chassis Connector (BOTH sides) D38999/20WB35PN
Cable Connector (BOTH ends) D38999/26WB35SN

Figure 2-2 Ethernet Connector Pinout

2.2.5 **Bonding and Grounding**

Payloads shall NOT use their case as a ground or signal return path

2.3 Mechanical

The MP standard imposes a common mechanical interface on payload modules.

2.3.1 Enclosure

The overall dimensions of a 1U MPx payload are defined in Table 2-1.

Table 2-1. Maximum Module Dimensions

Module Size	Height (in)	Width (in)	Depth (in)
1U	9.625	14.656	16.425

Unlike the SUAS implementation, partial U modules (e.g. 1.25U, 1.5U, 1.75U, etc.) are **NOT currently permitted.**

All items attached to external surfaces must be removable without opening the module.

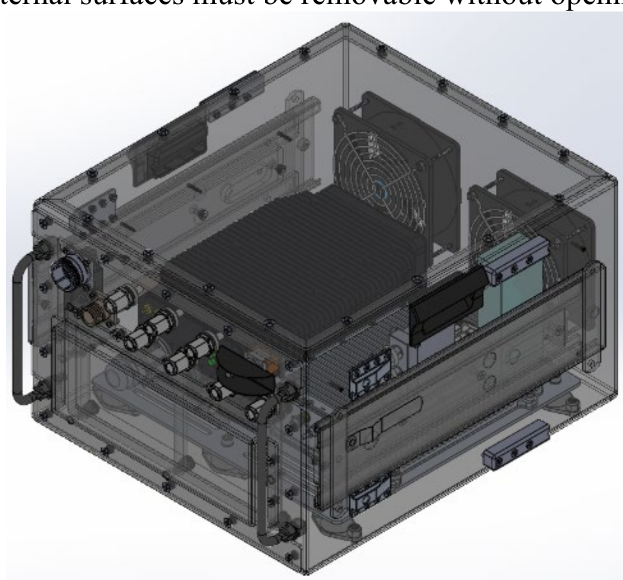


Figure 2-3 Example MPx Module

2.3.1.1 *Larger systems*

For those payload technologies that cannot conform to a single 1U MPx form factor, a two module configuration is acceptable.

For example, a vendor might require a full 1U MPx form factor for the processing and baseband transceiver operations, however the front end amplifier and filter stage might need to be housed in a second module, with interconnects between the two modules.

While single module systems are certainly desired, MPx fully supports these large technologies as well. It should be noted that some platforms cannot support more than 1 MPx module. However many others have 2U or 3U or more capacity.

2.3.1.2 *Connector Locations*

All connectors (both electrical and RF) shall be located and accessible on the front side of the payload module, preferably, located centrally on the module.

2.3.1.3 *Module Weight*

Where possible, module weight should not exceed 62lbs and should be minimized. It is expected that the vendor invest time into optimizing the structural weight of their assemblies. If a capability cannot meet this requirement, it must be noted as an exception. This would simply make it not feasible for some platforms (just as some high power payloads would not be feasible for some platforms)

For reference:
Per MIL-STD-1472G Table XXXVIII (pg 205) Maximum lift for one person (male and female population) is 31 lbs, and a two person lift is 62 lbs

2.3.2 Mounting Configurations

The module design shall be flexible to allow for multiple mounting configurations.
- Rack mount (primary)
- Plate mount (alternate)

2.3.2.1 *Rack Mounting Option*

The primary method shall be a rack mount configuration where mechanical capture is achieved by solid bearing, non-pivoting, stainless steel drawer slides on the sides of the drawer as specified below. In the stowed position the slides are augmented by four spring-loaded retainer pins in the rear corners of the drawer (parallel axes to the slide direction) and four indexing, spring-plunger pins in the front corners of the drawer (normal to the slide direction of the drawer). The spring-plunger pins are released using custom designed handles on either side of the drawer. When the front pins are released, the spring loads of the rear retainer pins bumps the drawer forward for slide out/removal.

The slides are general devices CTH-214 (https://catalog.generaldevices.com/item/solid-bearing-slides/model-cths-br-non-pivoting-slide/pn-1625)

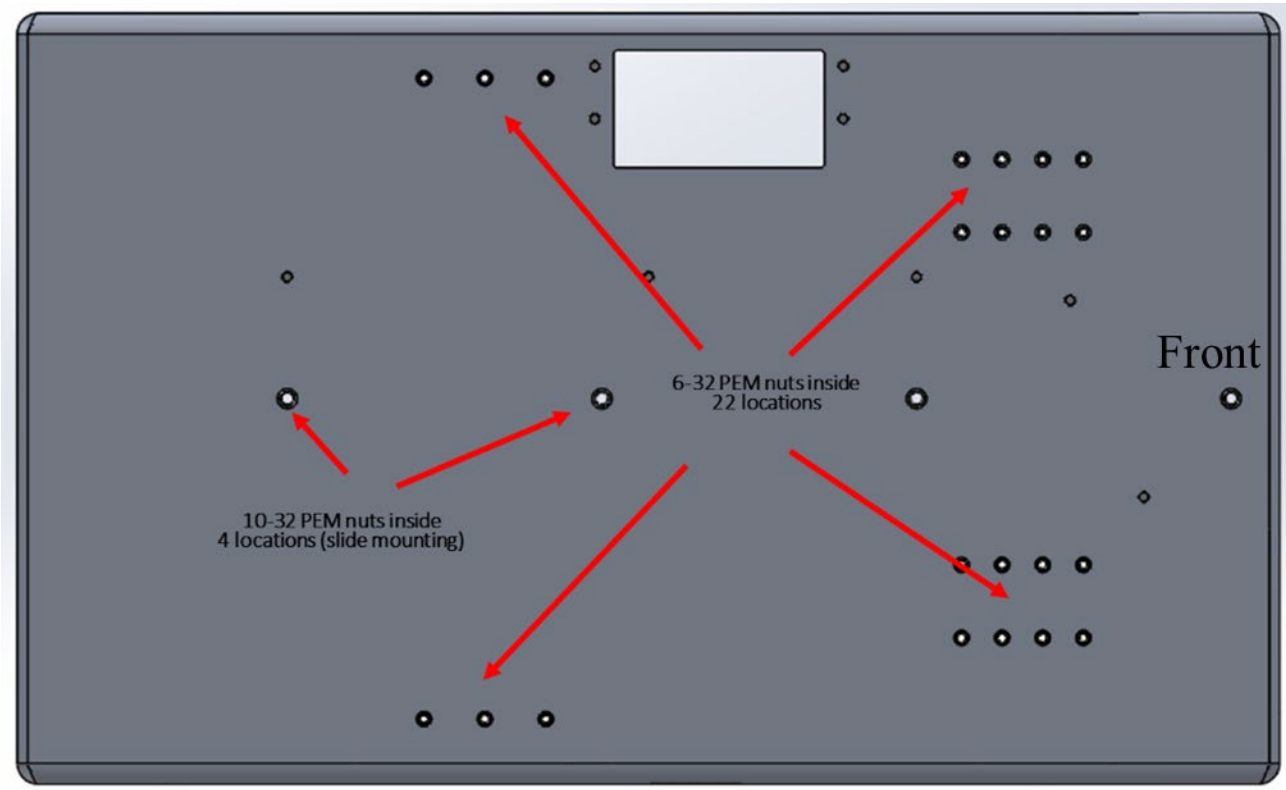


Figure 2-4 1U MPx Left Face (from the front face)

[Further specification of the above fastener locations will be provided in a future release]

2.3.2.2 *Plate Mounting Option*

An alternate mounting shall also be supported (and is required) to accommodate those platforms where a rack is not feasible. Because of this, the rack mount hardware must be removable. The exact mounting method for a payload module shall depend on the platform being configured.

[Further specification of the plate mount fastener locations will be provided in a future release]

Ultimately the A-kit integrator will provide bracketing that picks up fastener points which the rails would have used.

2.3.3 Tooling

No custom tools shall be required for module installation or removal.

2.3.4 Accessibility

Each module shall be provided with means for removal without affecting other adjacent systems, i.e., removal of an individual module shall not require removal of an adjacent module.

2.4 Thermal Design

Unlike volume I, under MPx thermal dissipation is the responsibility of the Payload vendor. It is expected that the Payload will survive in the conditions dictated under Environmental without assistance from the A-kit. Thus, if the payload requires airflow for thermal dissipation, that is left to the payload. For example – a vendor may choose to vent their module pulling air into the front and exhausting out the back. This presents other challenges of internal hardening for the moist salty air.

2.5 RF

2.5.1 RF Cabling

In general, the payload should use the RF cabling integrated into the platform A-kit as part of the MP effort. Platform RF cabling is specified in Section 1.4.

Where additional cabling is required, additional feeds may need to be provided as part of the B-kit.

2.5.2 RF Connectors

Payloads shall use panel mounted Female N-type connectors. Where more than one connector is provided, clear labels shall be present.

2.5.3 Antennas

For platforms that have specified antennas available, the specific antennas and mounting positions are dependent on the platform and contained in the platform specific appendix.

For platforms that allow Antennas to be brought in as part of the B-kit, the following guidance is applicable

Payloads may use a variety of antennas on platforms. The mechanical mounting options are detailed in the platform specific appendices, and the platform capabilities should be considered in developing the payload antenna design(s).

The Antenna shall ultimately present a FEMALE N-type connector to the A-kit

The antenna shall have mechanical adaptations to mate to the MPx mechanical mating as detailed in Section 1.4.1.1.

2.6 EMI

The system shall not have unintentional emissions that interfere with operations onboard systems.

Per MIL-STD-461G all payloads shall comply with CE 102 and RE 102; if a payload has passive antenna ports CE 106 is also required. If the payload actively transmits RE-103 may be substituted for CE 106. Surface ship limits shall apply for RE 102 because they are more stringent than USAF airborne limits

Per MIL-STD-461G for CE106 for the 10kHz to 40GHz range, the second and third harmonics shall be suppressed to a level of -20 dBm and all other harmonics and spurious emissions shall be suppressed to -40 dBm, except if the duty cycle of the emissions are less than 0.2%, then the limit may be relaxed to 0 dBm.

Per MIL-STD-461G for RE103 for the 10kHz to 40GHz range, the second and third harmonics shall be suppressed to a level of -20 dBm and all other harmonics and spurious emissions shall be suppressed to -40 dBm, except if the duty cycle of the emissions are less than 0.2%, then the limit may be relaxed to 0 dBm.

The payload vendor will provide information on the RF behavior of their system to support frequency masking, if required.

All payloads may be subject to on aircraft EMC check prior to final flight clearance

2.7 Environmental

MP-compliant payloads shall adhere to the environmental requirements defined in the subsequent section.

2.7.1 Shock

The payload shall survive MIL-STD-810H Method 516.8 Procedure 1 Functional Shock for High Speed Craft (HSC) as detailed in Table 516.8-V.

2.7.2 Vibration

The Payload should be capable of operating in a vibration environment presented by a 4 bladed C-130, a 6 bladed C-130, and a small maritime craft. The payload is only expected to encounter one of these environments at a time, but might be subjected all 3 throughout its life.

The vibration profile for the maritime platform is contained in MIL-STD-810H Figure 514.8D-11

The vibration profile for the C-130 platforms are contained in MIL-STD-810H Figure 514.8D-2

2.7.3 Operational Temperature

Systems should be operable up to 45C ambient. Operation up to 50C desired

2.7.4 Storage Temperature

The payload shall be able to survive in an off state in external ambient environments ranging from -20°C to 70°C.

2.7.5 Sand and Dust

The payload shall be able to survive blowing dust and sand as would be experienced in a desert environment.

MIL-STD 810G Method 510.7 provides guidance on testing for this requirement, this method is NOT intended to simulate real world environmental conditions and should be tailored to customer requirements.

This standard is still in development, additional details will be provided in a future release

2.7.6 Salt Atmosphere

The payload shall be able to endure marine conditions as would be experienced in a small boat with salt spray. (for example see appendix for CCM)

MIL-STD 810G Method 509.7 provides guidance on testing for this requirement, this method is NOT intended to simulate real world environmental conditions and should be tailored to customer requirements.

This standard is still in development, additional details will be provided in a future release

2.7.7 Humidity

The payload shall be able to endure high humidity conditions as would be experienced in a small boat

MIL-STD 810G Method 507.6 Procedure I Induced Hot Humid (Cycle B3) conditions simulate a worst case scenario, if these conditions are not survivable the payload capability should be documented clearly.

2.7.8 Altitude

The payload should be capable of operation up to 20,000ft Density Altitude (DA).
However, if this altitude is not achievable for a payload, the payload capability should be Documented clearly.

2.7.9 Handling

The payload should be able to be simply installed by a flight team in a tactical environment, (e.g., no ESD straps or other specialized requirements).

2.7.10 Safety

This standard is still in development, additional details will be provided in a future release.

Appendix A. **PIM State Distribution Messages**

A.1 Overview

The PIM distributes state data over two interfaces – serial and Ethernet – to provide flexibility for payloads. The Ethernet interface uses a JSON message format for distribution, while the serial interface uses both the sbgEcom binary and NMEA message formats. This appendix details these message formats.

A.2 State over Ethernet: JSON Messages

JSON is a human-readable text format normally used to exchange data between servers and browsers. It is intended to simplify the interpretation of the communicated data and remove the complexity of interpreting binary quantities due to Endianness, size, and packing differences between hosts.

The PIM distributes state data over Ethernet utilizing the JSON classes:

- PIM_VER
- STATUS
- IMUNAV
- PRESSURE
- TPV
- ATT
- SKY
- ADDL

The subsequent sections define each class.

A.2.1 PIM _VER

The PIM_VER message contains the hardware / software version information for the PIM. The PIM_VER message is distributed by the PIM at 1Hz.

Measurement/Definition	**JSON Field Name**	**Type**	**Units / Notes**
Name of this group	class	string	PIM_VER
Version of the JSON classes	sw	string	string - Major.Minor dot notation
Name of the Sensor	dev	string	string - human readable product code
Sensor Hardware version	devhw	string	string - Major.Minor dot notation
Sensor Firmware version	devsw	string	string - Major.Minor dot notation

Example:

{"class":"PIM_VER","sw":"1.0","dev":"SBG ELLIPSE-N","devhw":"2.4","devsw":"6.5"}

A.2.1.1 MAIM_VER

The MAIM_VER message contains the hardware / software version information for the PIM. The MAIM_VER message is included to maintain compatibility with Mod Payload compliant payloads, in contains the same information as the PIM_VER messageThe MIAM_VER message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	MAIM_VER
Version of the JSON classes	sw	string	string - Major.Minor dot notation
Name of the Sensor	dev	string	string - human readable product code
Sensor Hardware version	devhw	string	string - Major.Minor dot notation
Sensor Firmware version	devsw	string	string - Major.Minor dot notation

Example:

{"class":"MAIM_VER","sw":"1.0","dev":"SBG ELLIPSE-N","devhw":"2.4","devsw":"6.5"}

A.2.2 STATUS

The STATUS message contains the various status fields for the INS. The STATUS message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	STATUS
General status with enums	general	string	Hex characters
Communications status	com	string	Hex characters
Aiding Equipment status	aiding	string	Hex characters
UTC time and clock sync	utc	string	Hex characters
IMU status	imu	string	Hex characters
Magnetometer status	mag	string	Hex characters
Global Solution status	sol	string	Hex characters
GPS velocity fix and status	vel	string	Hex characters
GPS position fix and status	pos	string	Hex characters
Altimeter status	alt	string	Hex characters

Example:

*{"class":"STATUS","general":"7F","com":"17FFFFFF","aiding":"3FFF","utc":"64",
"imu":"17E","mag":"0C5","sol":"1234CC7","vel":"C3","pos":"FFABC","alt":"3"}*

The tables presented below provide information on the bitmasks and enumerations coded into the fields of the STATUS class. The information is taken directly from the corresponding SBG Ellipse sbgECom Binary Protocol LOG message.

A.2.2.1 *STATUS – General*

Description: General status bitmask and enumerations

Bit	Name	Description
0	SBG_ECOM_GENERAL_MAIN_POWER_OK	Set to 1 when main power supply is OK.

1	SBG_ECOM_GENERAL_IMU_POWER_OK	Set to 1 when IMU power supply is OK.
2	SBG_ECOM_GENERAL_GPS_POWER_OK	Set to 1 when GPS power supply is OK.
3	SBG_ECOM_GENERAL_SETTINGS_OK	Set to 1 if settings were correctly loaded.
4	SBG_ECOM_GENERAL_TEMPERATURE_OK	Set to 1 when temperature is within limits.
5	SBG_ECOM_GENERAL_DATALOGGER_OK	Set to 1 the data-logger is working correctly
6	SBG_ECOM_GENERAL_CPU_OK	Set to 1 if the CPU headroom is correct

A.2.2.2 *STATUS – Com*

Description: Communication status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_PORTA_VALID	Set to 0 in case of low level communication error.
1	SBG_ECOM_PORTB_VALID	Set to 0 in case of low level communication error.
2	SBG_ECOM_PORTC_VALID	Set to 0 in case of low level communication error.
3	SBG_ECOM_PORTD_VALID	Set to 0 in case of low level communication error.
4	SBG_ECOM_PORTE_VALID	Set to 0 in case of low level communication error.
5	SBG_ECOM_PORTA_RX_OK	Set to 0 in case of saturation on PORT A input
6	SBG_ECOM_PORTA_TX_OK	Set to 0 in case of saturation on PORT A output
7	SBG_ECOM_PORTB_RX_OK	Set to 0 in case of saturation on PORT B input
8	SBG_ECOM_PORTB_TX_OK	Set to 0 in case of saturation on PORT B output
9	SBG_ECOM_PORTC_RX_OK	Set to 0 in case of saturation on PORT C input
10	SBG_ECOM_PORTC_TX_OK	Set to 0 in case of saturation on PORT C output
11	SBG_ECOM_PORTD_RX_OK	Set to 0 in case of saturation on PORT D input
12	SBG_ECOM_PORTD_TX_OK	Set to 0 in case of saturation on PORT D output
13	SBG_ECOM_PORTE_RX_OK	Set to 0 in case of saturation on PORT E input
14	SBG_ECOM_PORTE_TX_OK	Set to 0 in case of saturation on PORT E output
15	SBG_ECOM_ETH0_RX_OK	Set to 0 in case of saturation on PORT ETH0 input
16	SBG_ECOM_ETH0_TX_OK	Set to 0 in case of saturation on PORT ETH0 output
17	SBG_ECOM_ETH1_RX_OK	Set to 0 in case of saturation on PORT ETH1 input
18	SBG_ECOM_ETH1_TX_OK	Set to 0 in case of saturation on PORT ETH1 output
19	SBG_ECOM_ETH2_RX_OK	Set to 0 in case of saturation on PORT ETH2 input
20	SBG_ECOM_ETH2_TX_OK	Set to 0 in case of saturation on PORT ETH2 output
21	SBG_ECOM_ETH3_RX_OK	Set to 0 in case of saturation on PORT ETH3 input
20	SBG_ECOM_ETH3_TX_OK	Set to 0 in case of saturation on PORT ETH3 output
23	SBG_ECOM_ETH4_RX_OK	Set to 0 in case of saturation on PORT ETH4 input
24	SBG_ECOM_ETH4_TX_OK	Set to 0 in case of saturation on PORT ETH4 output
25	SBG_ECOM_CAN_RX_OK	Set to 0 in case of saturation on CAN Bus output buffer
26	SBG_ECOM_CAN_TX_OK	Set to 0 in case of saturation on CAN Bus input buffer
27-29	SBG_ECOM_CAN_BUS	Enum Define the CAN Bus status (see below)

A.2.2.2.1 CAN BUS Status Enumeration Values

Value	Name	Description
0x0	SBG_ECOM_CAN_BUS_OFF	Bus OFF operation due to too much errors
0x1	SBG_ECOM_CAN_BUS_TX_RX_ERR	Transmit or received error
0x2	SBG_ECOM_CAN_BUS_OK	The CAN bus is working correctly.
0x3	SBG_ECOM_CAN_BUS_ERRORA	General error has occurred on the CAN bus

A.2.2.3 *STATUS – aiding*

Description: Aiding equipment status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_AIDING_GPS1_POS_RECV	Set to 1 valid GPS 1 position data is received
1	SBG_ECOM_AIDING_GPS1_VEL_RECV	Set to 1 valid GPS 1 velocity data is received
2	SBG_ECOM_AIDING_GPS1_HDT_RECV	Set to 1 valid GPS 1 true heading data is received
3	SBG_ECOM_AIDING_GPS1_UTC_RECV	Set to 1 valid GPS 1 UTC time data is received
4	SBG_ECOM_AIDING_GPS2_POS_RECV	Set to 1 valid GPS 2 position data is received

5	SBG_ECOM_AIDING_GPS2_VEL_RECV	Set to 1 valid GPS 2 velocity data is received
6	SBG_ECOM_AIDING_GPS2_HDT_RECV	Set to 1 valid GPS 2 true heading data is received
7	SBG_ECOM_AIDING_GPS2_UTC_RECV	Set to 1 valid GPS 2 UTC time data is received
8	SBG_ECOM_AIDING_MAG_RECV	Set to 1 valid Magnetometer data is received
9	SBG_ECOM_AIDING_ODO_RECV	Set to 1 Odometer pulse is received
10	SBG_ECOM_AIDING_DVL_RECV	Set to 1 valid DVL data is received
11	SBG_ECOM_AIDING_USBL_RECV	Set to 1 valid USBL data is received
12	SBG_ECOM_AIDING_EM_LOG_RECV	Set to 1 valid EM Log data is received
13	SBG_ECOM_AIDING_PRESSURE_RECV	Set to 1 valid Pressure sensor data is received

A.2.2.4 *STATUS – utc*

Description: Time and clock sync status

Bit	Name	Description
0	SBG_ECOM_CLOCK_STABLE_INPUT	Set to 1 when a clock input can be used to synchronize the internal clock.
1-4	SBG_ECOM_CLOCK_STATUS	Define the internal clock estimation status (see below)
5	SBG_ECOM_CLOCK_UTC_SYNC	Set to 1 if UTC time is synchronized with a PPS
6-9	SBG_ECOM_CLOCK_UTC_STATUS	Define the UTC validity status (see below).

A.2.2.4.1 Clock Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_CLOCK_ERROR	An error has occurred on the clock estimation
0x1	SBG_ECOM_CLOCK_FREE_RUNNING	The clock is only based on the internal crystal
0x2	SBG_ECOM_CLOCK_STEERING	A PPS has been detected and the clock is converging to it
0x3	SBG_ECOM_CLOCK_VALID	The clock has converged to the PPS and is within 500s

A.2.2.4.2 UTC Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_UTC_INVALID	The UTC time is not known, we are just propagating the UTC time internally
0x1	SBG_ECOM_UTC_NO_LEAP_SEC	We have received valid UTC time information but we don't have the leap seconds information
0x2	SBG_ECOM_UTC_VALID	We have received valid UTC time data with valid leap seconds.

A.2.2.5 *STATUS - imu*

Description: IMU Status bitmask

Bit	Name	Description
0	SBG_ECOM_IMU_COM_OK	Set to 1 the communication with the IMU is ok.the internal clock.
1	SBG_ECOM_IMU_STATUS_BIT	Set to 1 if internal IMU passes Built In Test (Calibration, CPU)
2	SBG_ECOM_IMU_ACCEL_X_BIT	Set to 1 accelerometer X passes Built In Test
3	SBG_ECOM_IMU_ACCEL_Y_BIT	Set to 1 accelerometer Y passes Built In Test
4	SBG_ECOM_IMU_ACCEL_Z_BIT	Set to 1 accelerometer Z passes Built In Test
5	SBG_ECOM_IMU_GYRO_X_BIT	Set to 1 gyroscope X passes Built In Test
6	SBG_ECOM_IMU_GYRO_Y_BIT	Set to 1 gyroscope Y passes Built In Test
7	SBG_ECOM_IMU_GYRO_Z_BIT	Set to 1 gyroscope Z passes Built In Test
8	SBG_ECOM_IMU_ACCELS_IN_RANGE	Set to 1 accelerometers within operating range
9	SBG_ECOM_IMU_GYROS_IN_RANGE	Set to 1 gyroscopes are within operating range

A.2.2.6 *STATUS – mag*

Description: Magnetometer status bitmask

Bit	Name	Description
0	SBG_ECOM_MAG_MAG_X_BIT	Set to 1 magnetometer X passed the self test.

1	SBG_ECOM_MAG_MAG_Y_BIT	Set to 1 magnetometer Y passed the self test.
2	SBG_ECOM_MAG_MAG_Z_BIT	Set to 1 magnetometer Z passed the self test.
3	SBG_ECOM_MAG_ACCEL_X_BIT	Set to 1 accelerometer X passed the self test.
4	SBG_ECOM_MAG_ACCEL_Y_BIT	Set to 1 accelerometer Y passed the self test.
5	SBG_ECOM_MAG_ACCEL_Z_BIT	Set to 1 accelerometer Z passed the self test.
6	SBG_ECOM_MAG_MAGS_IN_RANGE	Set to 1 magnetometer is not saturated
7	SBG_ECOM_MAG_ACCELS_IN_RANGE	Set to 1 accelerometer is not saturated
8	SBG_ECOM_MAG_CALIBRATION_OK	Set to 1 magnetometer seems to be calibrated

A.2.2.7 *STATUS – sol*

Description: Global solution status.

Bit	Name	Description
0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)
12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)
25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.2.2.7.1 SOLUTION MODE Enumeration

Value	Name	Description
0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.2.2.8 *STATUS – vel*

Description: GPS velocity fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_VEL_STATUS	The raw GPS velocity status (see the 5 below)
6-11	SBG_ECOM_GPS_VEL_TYPE	The raw GPS velocity type (see the 6 below)

A.2.2.8.1 Velocity Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_VEL_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_VEL_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_VEL_LIMIT	Velocity limit exceeded

A.2.2.8.2 Velocity Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_NO_SOLUTION	No valid velocity solution available
0x1	SBG_ECOM_VEL_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_VEL_DOPPLER	A Doppler velocity has been computed
0x3	SBG_ECOM_VEL_DIFFERENTIAL	A velocity has been computed between two positions

A.2.2.9 *STATUS – pos*

Description: GPS position fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_POS_STATUS	The raw GPS position status (see the 7 below)
6-11	SBG_ECOM_GPS_POS_TYPE	The raw GPS position type (see the 8 below)
12	SBG_ECOM_GPS_POS_GPS_L1_USED	Set to 1 if GPS L1 is used in the solution
13	SBG_ECOM_GPS_POS_GPS_L2_USED	Set to 1 if GPS L2 is used in the solution
14	SBG_ECOM_GPS_POS_GPS_L5_USED	Set to 1 if GPS L5 is used in the solution
15	SBG_ECOM_GPS_POS_GLO_L1_USED	Set to 1 if GLONASS L1 is used in the solution
16	SBG_ECOM_GPS_POS_GLO_L2_USED	Set to 1 if GLONASS L2 is used in the solution

A.2.2.9.1 POS Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_POS_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_POS_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_POS_HEIGHT_LIMIT	The height limit has been exceeded

A.2.2.9.2 POS Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_NO_SOLUTION	No valid solution available
0x1	SBG_ECOM_POS_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_POS_SINGLE	Single point solution position
0x3	SBG_ECOM_POS_PSRDIFF	Standard Pseudorange Differential Solution (DGPS)
0x4	SBG_ECOM_POS_SBAS	SBAS satellite used for differential corrections
0x5	SBG_ECOM_POS_OMNISTAR	Omnistar VBS Position (L1 sub-meter)
0x6	SBG_ECOM_POS_RTK_FLOAT	Floating RTK ambiguity solution (20 cms RTK)
0x7	SBG_ECOM_POS_RTK_INT	Integer RTK ambiguity solution (2 cms RTK)
0x8	SBG_ECOM_POS_PPP_FLOAT	Precise Point Positioning with float ambiguities
0x9	SBG_ECOM_POS_PPP_INT	Precise Point Positioning with fixed ambiguities
0x10	SBG_ECOM_POS_FIXED	Fixed location solution position

A.2.2.10 *STATUS – alt*

Description: Pressure status bitmask

Bit	Name	Description
0	SBG_ECOM_PRESSURE_VALID	Set to 1 altimeter was correctly initialized
1	SBG_ECOM_ALTITUDE_VALID	Set to 1 if the altitude output is valid

A.2.3 IMUNAV

The IMUNAV message contains the north, east, down velocity data from the INS. The IMUNAV message is distributed by the PIM at 10Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Velocity in North Direction	veln	numeric	meters per second - North positive
Velocity in East Direction	vele	numeric	meters per second - East positive
Velocity in Down Direction	veld	numeric	meters per second - Down positive

Example:
{"class":"IMUNAV","veln":-175.135,"vele":-22.0,"veld":-4.234}

A.2.4 PRESSURE

The PRESSURE message contains the barometric pressure data from the INS. The PRESSURE message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	PRESSURE
Measured Sensor Pressure	pressure	numeric	Pascals
Altitude from Barometer	alt	numeric	meters

Example:
{"class":"PRESSURE","pressure":101325.0,"alt":0.0}

A.2.5 TPV

The TPV message contains the time, position and course data and their error estimates from the INS. The TPV message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class		TPV
Time	time	string	ISO8601 Format UTC
Estimated Timestamp Error	ept	numeric	nanoseconds
Course over ground	track	numeric	Degrees from true north (0 to 360)
Latitude	lat	numeric	Degrees - North Positive (-90 to +90)
Longitude	lon	numeric	Degrees - East Positive (-180 to +180)
Altitude	alt	numeric	Meters above mean sea level
Status	status	numeric	2 if DGPS used; absent otherwise
Type of Position Fix	mode	numeric	0=Not Available; 1=nofix; 2=2D; 3=3D
Latitude Error Estimate	epx	numeric	meters
Longitude Error Estimate	epy	numeric	meters
Altitude Error Estimate	epv	numeric	meters
Speed of ascent	climb	numeric	meters per second (Down - Positive)
Direction Error Estimate	epd	numeric	Degrees (0 - 360)
Climb/Sink Error Estimate	epc	numeric	meters per second (Down - Positive)

Example:

{"class":"TPV","time":"2017-05-15T10:30:43.123Z","ept":500, "track":123.45,"lat":12.12345,"lon":-12.12345,"alt":12345.12, "mode":3,"epx":12.12,"epy":12.12,"epv":12.12,"climb":-4.234, "epd":12.345,"epc":12.345}

Additional information regarding the stability, error, and synchronization of the clock is provided in the STATUS class. Additional information regarding the GPS position status and type is provided in the STATUS class. Estimated Timestamp Error (ept) shall only be included when the clock has converged to the PPS.

A.2.6 ATT

The ATT message contains the acceleration, attitude, and heading data from the INS. The ATT message is distributed by the PIM at 10Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	ATT
X component of Acceleration	acc_x	numeric	meters per second squared
Y component of Acceleration	acc_y	numeric	meters per second squared
Z component of Acceleration	acc_z	numeric	meters per second squared
X component of Gyroscope	gyro_x	numeric	radians per second
Y component of Gyroscope	gyro_y	numeric	radians per second
Z component of Gyroscope	gyro_z	numeric	radians per second
Temperature at Sensor	temp	numeric	degrees centigrade
X component of Magnetic Field Strength	mag_x	numeric	Atomic Units (a.u)
Y component of Magnetic Field Strength	mag_y	numeric	Atomic Units (a.u)
Z component of Magnetic Field Strength	mag_z	numeric	Atomic Units (a.u)
Roll	roll	numeric	Radians (-3.142 to +3.142)
Pitch	pitch	numeric	Radians (-1.571 to +1.571)
Yaw	yaw	numeric	Radians (-3.142 to +3.142)
Heading	heading	numeric	Degrees from True North (0 to 360)

Example:

{"class":"ATT","acc_x":3.123,"acc_y":2.123,"acc_z":-1.456,"gyro_x":1.456, "gyro_y":2.789,"gyro_z":3.567,"temp":12.12,"mag_x":123.456,"mag_y":234.789, "mag_z":24.223,"roll":3.001,"pitch":-0.345,"yaw":-2.789,"heading":123.45}

Additional information regarding the status of the Accelerometer, Gyroscope, Magnetometer, and Internal Kalman Filter is provided in the STATUS class.

A.2.7 SKY

The SKY message contains the uncertainty estimate from the INS. The SKY message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	SKY
Time	time	string	ISO8601 Format UTC
Horizontal Dilution of Precision	hdop	numeric	Dimensionless

Example:

{"class":"SKY","time":"2017-05-15T10:30:43.123Z","hdop":6.3}

A.2.8 ADDL

The ADDL message contains the GPS-based north, east, and down velocities and their error estimates from the INS. The ADDL message is distributed by the PIM at 1Hz.

Measurement/Definition	JSON Field Name	Type	Units / Notes
Name of this group	class	string	ADDL
Device UP Time	up	numeric	microseconds
GPS Time of Week	tow	numeric	milliseconds
Undulation - Altitude difference between the geoid and the Ellipsoid	und	numeric	Meters (WGS-84 Altitude - MSL Altitude)
GPS North Velocity	gveln	numeric	meters per second (North Positive)
GPS East Velocity	gvele	numeric	meters per second (East Positive)
GPS Down Velocity	gveld	numeric	meters per second (Down Positive)
North Velocity Error Estimate	epn	numeric	meters per second
East Velocity Error Estimate	epe	numeric	meters per second
Down Velocity Error Estimate	epd	numeric	meters per second
Number of space vehicles	nsv	numeric	satellites

Example:

{"class":"ADDL","up":1345786201,"tow":375218453,"und":3.7,"gveln":-175.135, "gvele":-22.0,"gveld":-4.234,"epn":4.75,"epe":1.66,"epd":0.37,"nsv":7}

A.3 State over Serial: sbgECom Binary Protocol Messages

The sbgECom Binary protocol is the native format emitted by the SBG Ellipse-N INS. The PIM distributes state data over serial utilizing the sbgECom messages:

- SBG_ECOM_CMD_INFO (04),
- SBG_ECOM_LOG_STATUS (01)
- SBG_ECOM_LOG_UTC_TIME (02)
- SBG_ECOM_LOG_IMU_DATA (03)
- SBG_ECOM_LOG_MAG (04),
- SBG_ECOM_LOG_EKF_EULER (06)
- SBG_ECOM_LOG_EKF_NAV (08)
- SBG_ECOM_LOG_GPS1_VEL (13)
- SBG_ECOM_LOG_GPS1_POS (14)
- SBG_ECOM_LOG_PRESSURE (36)

Sections A.3.3 - A.3.12 define the messages listed in the message IDs above.

For PIM developers, any other messages received from the SBG can be dropped.

A.3.1 Type Definitions

The following table defines the variable types use by the sbgECom Binary protocol.

Type	Description
Mask	This type defines an unsigned integer variable used to store a set of bit-masks. This type has no pre-defined size and user should refer to each occurrence for corresponding size.
Enum	This type defines a group of several bits defining a list of possible states. Each value corresponds to a state. This type has no pre-defined size and user.
bool	8 bits boolean, 0x00 is FALSE, 0x01 is TRUE uint8 8 bits unsigned integer
int8	8 bits signed integer
uint16	16 bits unsigned integer
int16	16 bits signed integer
uint32	32 bits unsigned integer
int32	32 bits signed integer
uint64	64 bits unsigned integer
int64	64 bits signed integer
float	32 bits single floating point, standard IEEE 754 format
double	64 bits double floating point, standard IEEE 754 format
void[]	Data buffer, with variable length
string	Standard, null terminated ASCII string. String max size is defined in the message

A.3.2 Frame Definition

All frames sent through the sbgECom protocol have a common format. The following table defines the format.

Field	SYNC 1	SYNC 2	MSG	CLASS	LEN	DATA	CRC	ETX
Size (bytes)	1	1	1	1	2	0 to 4086	2	1
Description	Sync. word	Sync. word	Message ID	Message class	Length of DATA section	Payload data	16 bit CRC	End of frame
Value	0xFF	0x5A	-	-	-	-	-	0x33

The LEN field contains the DATA section size in bytes. A 0 LEN field implies that no DATA section is present. Maximum length value is 4086. The whole protocol is defined in LITTLE endian, so LEN and CRC fields are written directly in little endian

Sections A.3.3 through A.3.12 define the various payload data messages. The CRC is defined in Section A.3.13.

A.3.3 SBG_ECOM_CMD_INFO (04)

The SBG_ECOM_CMD_INFO (04) message provides information regarding the attached SBG device, including name, software and hardware versions, and date of the last calibration. The SBG_ECOM_CMD_INFO (04) message is distributed by the PIM only when issued to test for INS presence.

Field	Description	Unit	Format	Size	Offset
productCode	Human readable Product Code	-	string	32	0
serialNumber	Device serial number	-	uint32	4	32
calibationRev	Calibration data revision	-	uint32	4	36
calibrationYear	Device Calibration Year	-	uint16	2	40
calibrationMonth	Device Calibration Month	-	uint8	1	42
calibrationDay	Device Calibration Day	-	uint8	1	43
hardwareRev	Device hardware revision	-	uint32	4	44
firmwareRev	Firmware revision	-	uint32	4	48
				Total size	52

A.3.4 SBG_ECOM_LOG_STATUS (01)

The SBG_ECOM_LOG_STATUS (01) message provides the general, communications, and aiding status information for the attached SBG device. The SBG_ECOM_LOG_STATUS (01) message is distributed by the PIM at 1Hz.

Message name (ID)	SBG_ECOM_LOG_STATUS (01)				
Field	Description	Unit	Format	Size	Offset
TIME STAMP	Time since sensor is powered up	µs	uint32	4	0
GENERAL STATUS	General status bitmask and enums	-	uint16	2	4
RESERVED 1	Reserved status field for future use	-	uint16	2	6
COM STATUS	Communication status bitmask and enums.	-	uint32	4	8
AIDING STATUS	Aiding equipment status bitmask and enums.	-	uint32	4	12
RESERVED 2	Reserved status field for future use	-	uint32	4	16
RESERVED 3	Reserved field for future use	-	uint16	2	20
UP TIME	System up time since the power on.	s	uint32	4	22
				Total size	26

A.3.4.1 *GENERAL_STATUS*

Description: General status bitmask and enumerations

Bit	Name	Description
0	SBG_ECOM_GENERAL_MAIN_POWER_OK	Set to 1 when main power supply is OK.
1	SBG_ECOM_GENERAL_IMU_POWER_OK	Set to 1 when IMU power supply is OK.
2	SBG_ECOM_GENERAL_GPS_POWER_OK	Set to 1 when GPS power supply is OK.
3	SBG_ECOM_GENERAL_SETTINGS_OK	Set to 1 if settings were correctly loaded.
4	SBG_ECOM_GENERAL_TEMPERATURE_OK	Set to 1 when temperature is within limits.
5	SBG_ECOM_GENERAL_DATALOGGER_OK	Set to 1 the data-logger is working correctly
6	SBG_ECOM_GENERAL_CPU_OK	Set to 1 if the CPU headroom is correct

A.3.4.2 *COM_STATUS*

Description: Communication status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_PORTA_VALID	Set to 0 in case of low level communication error.
1	SBG_ECOM_PORTB_VALID	Set to 0 in case of low level communication error.
2	SBG_ECOM_PORTC_VALID	Set to 0 in case of low level communication error.
3	SBG_ECOM_PORTD_VALID	Set to 0 in case of low level communication error.
4	SBG_ECOM_PORTE_VALID	Set to 0 in case of low level communication error.

5	SBG_ECOM_PORTA_RX_OK	Set to 0 in case of saturation on PORT A input
6	SBG_ECOM_PORTA_TX_OK	Set to 0 in case of saturation on PORT A output
7	SBG_ECOM_PORTB_RX_OK	Set to 0 in case of saturation on PORT B input
8	SBG_ECOM_PORTB_TX_OK	Set to 0 in case of saturation on PORT B output
9	SBG_ECOM_PORTC_RX_OK	Set to 0 in case of saturation on PORT C input
10	SBG_ECOM_PORTC_TX_OK	Set to 0 in case of saturation on PORT C output
11	SBG_ECOM_PORTD_RX_OK	Set to 0 in case of saturation on PORT D input
12	SBG_ECOM_PORTD_TX_OK	Set to 0 in case of saturation on PORT D output
13	SBG_ECOM_PORTE_RX_OK	Set to 0 in case of saturation on PORT E input
14	SBG_ECOM_PORTE_TX_OK	Set to 0 in case of saturation on PORT E output
15	SBG_ECOM_ETH0_RX_OK	Set to 0 in case of saturation on PORT ETH0 input
16	SBG_ECOM_ETH0_TX_OK	Set to 0 in case of saturation on PORT ETH0 output
17	SBG_ECOM_ETH1_RX_OK	Set to 0 in case of saturation on PORT ETH1 input
18	SBG_ECOM_ETH1_TX_OK	Set to 0 in case of saturation on PORT ETH1 output
19	SBG_ECOM_ETH2_RX_OK	Set to 0 in case of saturation on PORT ETH2 input
20	SBG_ECOM_ETH2_TX_OK	Set to 0 in case of saturation on PORT ETH2 output
21	SBG_ECOM_ETH3_RX_OK	Set to 0 in case of saturation on PORT ETH3 input
20	SBG_ECOM_ETH3_TX_OK	Set to 0 in case of saturation on PORT ETH3 output
23	SBG_ECOM_ETH4_RX_OK	Set to 0 in case of saturation on PORT ETH4 input
24	SBG_ECOM_ETH4_TX_OK	Set to 0 in case of saturation on PORT ETH4output
25	SBG_ECOM_CAN_RX_OK	Set to 0 in case of saturation on CAN Bus output buffer
26	SBG_ECOM_CAN_TX_OK	Set to 0 in case of saturation on CAN Bus input buffer
27-29	SBG_ECOM_CAN_BUS	Enum Define the CAN Bus status (see below)

A.3.4.2.1 CAN BUS Status Enumeration Values

Value	Name	Description
0x0	SBG_ECOM_CAN_BUS_OFF	Bus OFF operation due to too much errors
0x1	SBG_ECOM_CAN_BUS_TX_RX_ERR	Transmit or received error
0x2	SBG_ECOM_CAN_BUS_OK	The CAN bus is working correctly.
0x3	SBG_ECOM_CAN_BUS_ERRORA	General error has occurred on the CAN bus

A.3.4.3 *AIDING_STATUS*

Description: Aiding equipment status bitmask and enumerations.

Bit	Name	Description
0	SBG_ECOM_AIDING_GPS1_POS_RECV	Set to 1 valid GPS 1 position data is received
1	SBG_ECOM_AIDING_GPS1_VEL_RECV	Set to 1 valid GPS 1 velocity data is received
2	SBG_ECOM_AIDING_GPS1_HDT_RECV	Set to 1 valid GPS 1 true heading data is received
3	SBG_ECOM_AIDING_GPS1_UTC_RECV	Set to 1 valid GPS 1 UTC time data is received
4	SBG_ECOM_AIDING_GPS2_POS_RECV	Set to 1 valid GPS 2 position data is received
5	SBG_ECOM_AIDING_GPS2_VEL_RECV	Set to 1 valid GPS 2 velocity data is received
6	SBG_ECOM_AIDING_GPS2_HDT_RECV	Set to 1 valid GPS 2 true heading data is received
7	SBG_ECOM_AIDING_GPS2_UTC_RECV	Set to 1 valid GPS 2 UTC time data is received
8	SBG_ECOM_AIDING_MAG_RECV	Set to 1 valid Magnetometer data is received
9	SBG_ECOM_AIDING_ODO_RECV	Set to 1 Odometer pulse is received
10	SBG_ECOM_AIDING_DVL_RECV	Set to 1 valid DVL data is received
11	SBG_ECOM_AIDING_USBL_RECV	Set to 1 valid USBL data is received
12	SBG_ECOM_AIDING_EM_LOG_RECV	Set to 1 valid EM Log data is received
13	SBG_ECOM_AIDING_PRESSURE_RECV	Set to 1 valid Pressure sensor data is received

A.3.5 SBG_ECOM_LOG_UTC_TIME (02)

The SBG_ECOM_LOG_UTC_TIME (02) message provides UTC time reference. This frame also provides a time correspondence between the device TIME_STAMP value and the actual UTC Time. Thus, this frame can be used to timestamp all data to an absolute UTC or GPS time reference. The SBG_ECOM_LOG_UTC_TIME (02) message is distributed by the PIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_UTC_TIME (02)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
CLOCK_STATUS	General UTC time and clock sync status	-	uint16	2	4
YEAR	Year	year	uint16	2	6
MONTH	Month in Year [1 ... 12]	month	uint8	1	8
DAY	Day in Month [1 ... 31]	d	uint8	1	9
HOUR	Hour in day [0 ... 23]	h	uint8	1	10
MIN	Minute in hour [0 ... 59]	min	uint8	1	11
SEC	Second in minute [0 ... 60] Note 60 is when a leap second is added.	s	uint8	1	12
NANOSEC	Nanosecond of second.	ns	uint32	4	13
GPS_TOW	GPS Time of week	ms	uint32	4	17
				Total size	21

A.3.5.1 *CLOCK_STATUS*

Description: General UTC time and clock sync status

Bit	Name	Description
0	SBG_ECOM_CLOCK_STABLE_INPUT	Set to 1 when a clock input can be used to synchronize the internal clock.
1-4	SBG_ECOM_CLOCK_STATUS	Define the internal clock estimation status (see below)
5	SBG_ECOM_CLOCK_UTC_SYNC	Set to 1 if UTC time is synchronized with a PPS
6-9	SBG_ECOM_CLOCK_UTC_STATUS	Define the UTC validity status (see below).

A.3.5.1.1 Clock Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_CLOCK_ERROR	An error has occurred on the clock estimation
0x1	SBG_ECOM_CLOCK_FREE_RUNNING	The clock is only based on the internal crystal
0x2	SBG_ECOM_CLOCK_STEERING	A PPS has been detected and the clock is converging to it
0x3	SBG_ECOM_CLOCK_VALID	The clock has converged to the PPS and is within 500ns

A.3.5.1.2 UTC Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_UTC_INVALID	The UTC time is not known, we are just propagating the UTC time internally
0x1	SBG_ECOM_UTC_NO_LEAP_SEC	We have received valid UTC time information but we don't have the leap seconds information
0x2	SBG_ECOM_UTC_VALID	We have received valid UTC time data with valid leap seconds.

A.3.6 SBG_ECOM_LOG_IMU_DATA (03)

The SBG_ECOM_LOG_IMU_DATA (03) message provides status, accelerations and velocities from the IMU. The SBG_ECOM_LOG_IMU_DATA (03) message is distributed by the PIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_IMU_DATA (03)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
IMU_STATUS	IMU Status bitmask	-	uint16	2	4
ACCEL_X	Filtered Accelerometer – X axis	m/s²	float	4	6
ACCEL_Y	Filtered Accelerometer – Y axis	m/s²	float	4	10
ACCEL_Z	Filtered Accelerometer – Z axis	m/s²	float	4	14
GYRO_X	Filtered Gyroscope – X axis	rad/s	float	4	18
GYRO_Y	Filtered Gyroscope – Y axis	rad/s	float	4	22
GYRO_Z	Filtered Gyroscope – Z axis	rad/s	float	4	26
TEMP	Internal Temperature	°C	float	4	30
DELTA_VEL_X	Sculling output – X axis	m/s²	float	4	34
DELTA_VEL_Y	Sculling output – Y axis	m/s²	float	4	38
DELTA_VEL_Z	Sculling output – Z axis	m/s²	float	4	42
DELTA_ANGLE_X	Coning output – X axis	rad/s	float	4	46
DELTA_ANGLE_Y	Coning output – Y axis	rad/s	float	4	50
DELTA_ANGLE_Z	Coning output – Z axis	rad/s	float	4	54
				Total size	58

A.3.6.1 *IMU_STATUS*

Description: IMU Status bitmask

Bit	Name	Description
0	SBG_ECOM_IMU_COM_OK	Set to 1 the communication with the IMU is ok.the internal clock.
1	SBG_ECOM_IMU_STATUS_BIT	Set to 1 if internal IMU passes Built In Test (Calibration, CPU)
2	SBG_ECOM_IMU_ACCEL_X_BIT	Set to 1 accelerometer X passes Built In Test
3	SBG_ECOM_IMU_ACCEL_Y_BIT	Set to 1 accelerometer Y passes Built In Test
4	SBG_ECOM_IMU_ACCEL_Z_BIT	Set to 1 accelerometer Z passes Built In Test
5	SBG_ECOM_IMU_GYRO_X_BIT	Set to 1 gyroscope X passes Built In Test
6	SBG_ECOM_IMU_GYRO_Y_BIT	Set to 1 gyroscope Y passes Built In Test
7	SBG_ECOM_IMU_GYRO_Z_BIT	Set to 1 gyroscope Z passes Built In Test
8	SBG_ECOM_IMU_ACCELS_IN_RANGE	Set to 1 accelerometers within operating range
9	SBG_ECOM_IMU_GYROS_IN_RANGE	Set to 1 gyroscopes are within operating range

A.3.7 SBG_ECOM_LOG_MAG (04)

The SBG_ECOM_LOG_MAG (04) message provides magnetometer and associated accelerometer data. When an internal magnetometer is used, the internal accelerometer is also provided. The SBG_ECOM_LOG_MAG (04) message is distributed by the PIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_MAG (04)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
MAG_STATUS	Magnetometer status bitmask	-	uint16	2	4
MAG_X	Magnetometer output – X axis	a.u	float	4	6
MAG_Y	Magnetometer output – Y axis	a.u	float	4	10
MAG_Z	Magnetometer output – Z axis	a.u	float	4	14
ACCEL_X	Accelerometer output – X axis	m/s²	float	4	18
ACCEL_Y	Accelerometer output – Y axis	m/s²	float	4	22
ACCEL_Z	Accelerometer output – Z axis	m/s²	float	4	26
				Total size	30

A.3.7.1 *MAG_STATUS*

Description: Magnetometer status bitmask

Bit	Name	Description
0	SBG_ECOM_MAG_MAG_X_BIT	Set to 1 magnetometer X passed the self test.
1	SBG_ECOM_MAG_MAG_Y_BIT	Set to 1 magnetometer Y passed the self test.
2	SBG_ECOM_MAG_MAG_Z_BIT	Set to 1 magnetometer Z passed the self test.
3	SBG_ECOM_MAG_ACCEL_X_BIT	Set to 1 accelerometer X passed the self test.
4	SBG_ECOM_MAG_ACCEL_Y_BIT	Set to 1 accelerometer Y passed the self test.
5	SBG_ECOM_MAG_ACCEL_Z_BIT	Set to 1 accelerometer Z passed the self test.
6	SBG_ECOM_MAG_MAGS_IN_RANGE	Set to 1 magnetometer is not saturated
7	SBG_ECOM_MAG_ACCELS_IN_RANGE	Set to 1 accelerometer is not saturated
8	SBG_ECOM_MAG_CALIBRATION_OK	Set to 1 magnetometer seems to be calibrated

A.3.8 SBG_ECOM_LOG_EKF_EULER (06)

The SBG_ECOM_LOG_EKF_EULER (06) message provides the computed orientation of the IMU in a Euler angles format. The SBG_ECOM_LOG_EKF_EULER (06) message is distributed by the PIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_EKF_EULER (06)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
ROLL	Roll angle	rad	float	4	4
PITCH	Pitch angle	rad	float	4	8
YAW	Yaw angle (heading)	rad	float	4	12
ROLL_ACC	1σ Roll angle accuracy	rad	float	4	16
PITCH_ACC	1σ Pitch angle accuracy	rad	float	4	20
YAW_ACC	1σ Yaw angle accuracy	rad	float	4	24
SOLUTION_STATUS	Global solution status. See SOLUTION_STATUS definition for more details.	-	uint32	4	28
				Total size	32

A.3.8.1 *SOLUTION_STATUS*

Description: Global solution status.

Bit	Name	Description

0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)
12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)
25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.3.8.1.1 SOLUTION MODE Enumeration

Value	Name	Description
0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.3.9 SBG_ECOM_LOG_EKF_NAV (08)

The SBG_ECOM_LOG_EKF_NAV (08) message provides velocity in a NED coordinate system, position (Latitude, Longitude, Altitude), and associated accuracy parameters. The SBG_ECOM_LOG_EKF_NAV (08) message is distributed by the PIM at 20Hz.

Message name (ID)	SBG_ECOM_LOG_EKF_NAV (08)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
VELOCITY_N	Velocity in North direction	m/s	float	4	4
VELOCITY_E	Velocity in East direction	m/s	float	4	8
VELOCITY_D	Velocity in Down direction	m/s	float	4	12
VELOCITY_N_ACC	1σ Velocity in North direction accuracy	m/s	float	4	16
VELOCITY_E_ACC	1σ Velocity in East direction accuracy	m/s	float	4	20
VELOCITY_D_ACC	1σ Velocity Down direction accuracy	m/s	float	4	24
LATITUDE	Latitude	°	double	8	28
LONGITUDE	Longitude	°	double	8	36
ALTITUDE	Altitude above Mean Sea Level	m	double	8	44
UNDULATION	Altitude difference between the geoid and the Ellipsoid. (WGS-84 Altitude = MSL Altitude + undulation)	m	float	4	52
LATITUDE_ACC	1σ Latitude accuracy	m	float	4	56
LONGITUDE_ACC	1σ Longitude accuracy	m	float	4	60
ALTITUDE_ACC	1σ Vertical Position accuracy	m	float	4	64
SOLUTION_STATUS	Global solution status. See SOLUTION_STATUS definition for more details.	-	uint32	4	68
				Total size	72

A.3.9.1 *SOLUTION_STATUS*

Description: Global solution status.

Bit	Name	Description
0-3	SBG_ECOM_SOLUTION_MODE	Defines the Kalman filter computation mode (see below)
4	SBG_ECOM_SOL_ATTITUDE_VALID	Set to 1 if Attitude data is reliable (Roll/Pitch error < 0,5°)
5	SBG_ECOM_SOL_HEADING_VALID	Set to 1 if Heading data is reliable (Heading error < 1°)
6	SBG_ECOM_SOL_VELOCITY_VALID	Set to 1 if Velocity data is reliable (velocity error < 1.5 m/s)
7	SBG_ECOM_SOL_POSITION_VALID	Set to 1 if Position data is reliable (Position error < 10m)
8	SBG_ECOM_SOL_VERT_REF_USED	Set to 1 vertical reference used in solution (data used and valid since 3s)
9	SBG_ECOM_SOL_MAG_REF_USED	Set to 1 if magnetometer is used in solution (data used and valid since 3s)
10	SBG_ECOM_SOL_GPS1_VEL_USED	Set to 1 if GPS velocity is used in solution (data used and valid since 3s)
11	SBG_ECOM_SOL_GPS1_POS_USED	Set to 1 if GPS Position is used in solution (data used and valid since 3s)
12	Unused	
13	SBG_ECOM_SOL_GPS1_HDT_USED	Set to 1 GPS True Heading is used in solution (data used and valid since 3s)
14	SBG_ECOM_SOL_GPS2_VEL_USED	Set to 1 if GPS2 velocity is used in solution (data used and valid since 3s)
15	SBG_ECOM_SOL_GPS2_POS_USED	Set to 1 if GPS2 Position is used in solution (data used and valid since 3s)
16	Unused	
17	SBG_ECOM_SOL_GPS2_HDT_USED	Set to 1 GPS2 True Heading is used in solution (data used and valid since 3s)
18	SBG_ECOM_SOL_ODO_USED	Set to 1 if Odometer is used in solution (data used and valid since 3s)
19	SBG_ECOM_SOL_DVL_BT_USED	Set to 1 DVL Bottom Tracking used in solution (data used and valid since 3s)
20	SBG_ECOM_SOL_DVL_WT_USED	Set to 1 DVL Water Layer is used in solution (data used and valid since 3s)
21	Unused	
22	Unused	
23	Unused	
24	SBG_ECOM_SOL_USBL_USED	Set to 1 if USBL / LBL is used in solution (data used and valid since 3s)
25	SBG_ECOM_SOL_PRESSURE_USED	Set to 1 if pressure is used in solution (data used and valid since 3s)
26	SBG_ECOM_SOL_ZUPT_USED	Set to 1 if a ZUPT is used in solution (data used and valid since 3s)
27	SBG_ECOM_SOL_ALIGN_VALID	Set to 1 if sensor alignment and calibration parameters are valid

A.3.9.1.1 SOLUTION MODE Enumeration

Value	Name	Description

0x0	SBG_ECOM_SOL_MODE_UNINITIALIZED	The Kalman filter is not initialized and the returned data are all invalid.
0x1	SBG_ECOM_SOL_MODE_VERTICAL_GYRO	The Kalman filter only rely on a vertical reference to compute roll and pitch angles. Heading and navigation data drift freely
0x2	SBG_ECOM_SOL_MODE_AHRS	A heading reference is available, the Kalman filter provides full orientation but navigation data drift freely.
0x3	SBG_ECOM_SOL_MODE_NAV_VELOCITY	The Kalman filter computes orientation and velocity. Position is freely integrated from velocity estimation.
0x4	SBG_ECOM_SOL_MODE_NAV_POSITION	Nominal mode, the Kalman filter computes all parameters (attitude, velocity, position). Absolute position is provided.

A.3.10 SBG_ECOM_LOG_GPS1_VEL (13)

The SBG_ECOM_LOG_GPS1_VEL (13) message provides velocity and course information from the primary or secondary GNSS receiver. The time stamp is not aligned on main loop but instead of that, it dates the actual GNSS velocity data. The SBG_ECOM_LOG_GPS1_VEL (13) message is distributed by the PIM at 5Hz.

Message name (ID)	SBG_ECOM_LOG_GPS1_VEL (13)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
GPS_VEL_STATUS	GPS velocity fix and status bitmask	-	uint32	4	4
GPS_TOW	GPS Time of Week	ms	uint32	4	8
VEL_N	Velocity in North direction	m/s	float	4	12
VEL_E	Velocity in East direction	m/s	float	4	16
VEL_D	Velocity in Down direction	m/s	float	4	20
VEL_ACC_N	1σ Accuracy in North direction	m/s	float	4	24
VEL_ACC_E	1σ Accuracy in East direction	m/s	float	4	28
VEL_ACC_D	1σ Accuracy in Down direction	m/s	float	4	32
COURSE	True direction of motion over ground (0 to 360°)	°	float	4	36
COURSE_ACC	1σ course accuracy (0 to 360°).	°	float	4	40
				Total size	44

A.3.10.1 *GPS_VEL_STATUS*

Description: GPS velocity fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_VEL_STATUS	The raw GPS velocity status (see the 5 below)
6-11	SBG_ECOM_GPS_VEL_TYPE	The raw GPS velocity type (see the 6 below)

A.3.10.1.1 Velocity Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_VEL_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_VEL_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_VEL_LIMIT	Velocity limit exceeded

A.3.10.1.2 Velocity Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_VEL_NO_SOLUTION	No valid velocity solution available
0x1	SBG_ECOM_VEL_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_VEL_DOPPLER	A Doppler velocity has been computed

0x3	SBG_ECOM_VEL_DIFFERENTIAL	A velocity has been computed between two positions

A.3.11 SBG_ECOM_LOG_GPS1_POS (14)

The SBG_ECOM_LOG_GPS1_POS (14) message provides position information from the primary or secondary GNSS receiver. The time stamp is not aligned on main loop but instead of that, it dates the actual GPS position data. The SBG_ECOM_LOG_GPS1_POS (14) message is distributed by the PIM at 5Hz.

Message name (ID)	SBG_ECOM_LOG_GPS1_POS (14)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
GPS_POS_STATUS	GPS position fix and status bitmask	-	uint32	4	4
GPS_TOW	GPS Time of Week	ms	uint32	4	8
LAT	Latitude, positive North	°	double	8	12
LONG	Longitude, positive East	°	double	8	20
ALT	Altitude Above Mean Sea Level	m	double	8	28
UNDULATION	Altitude difference between the geoid and the Ellipsoid (WGS-84 Altitude – MSL Altitude)	m	float	4	36
POS_ACC_LAT	1σ Latitude Accuracy	m	float	4	40
POS_ACC_LONG	1σ Longitude Accuracy	m	float	4	44
POS_ACC_ALT	1σ Altitude Accuracy	m	float	4	48
NUM_SV_USED	Number of space vehicles used in GNSS solution	-	uint8	1	52
BASE_STATION_ID	ID of the DGPS/RTK base station in use	-	uint16	2	54
DIFF_AGE	Differential data age	0.01 s	uint16	2	56
				Total size	57

A.3.11.1 *GPS_POS_STATUS*

Description: GPS position fix and status bitmask

Bit	Name	Description
0-5	SBG_ECOM_GPS_POS_STATUS	The raw GPS position status (see the 7 below)
6-11	SBG_ECOM_GPS_POS_TYPE	The raw GPS position type (see the 8 below)
12	SBG_ECOM_GPS_POS_GPS_L1_USED	Set to 1 if GPS L1 is used in the solution
13	SBG_ECOM_GPS_POS_GPS_L2_USED	Set to 1 if GPS L2 is used in the solution
14	SBG_ECOM_GPS_POS_GPS_L5_USED	Set to 1 if GPS L5 is used in the solution
15	SBG_ECOM_GPS_POS_GLO_L1_USED	Set to 1 if GLONASS L1 is used in the solution
16	SBG_ECOM_GPS_POS_GLO_L2_USED	Set to 1 if GLONASS L2 is used in the solution

A.3.11.1.1 POS Status Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_SOL_COMPUTED	A valid solution has been computed
0x1	SBG_ECOM_POS_INSUFFICIENT_OBS	Not enough valid SV to compute a solution
0x2	SBG_ECOM_POS_INTERNAL_ERROR	An internal error has occurred
0x3	SBG_ECOM_POS_HEIGHT_LIMIT	The height limit has been exceeded

A.3.11.1.2 POS Type Enumeration

Value	Name	Description
0x0	SBG_ECOM_POS_NO_SOLUTION	No valid solution available
0x1	SBG_ECOM_POS_UNKNOWN_TYPE	An unknown solution type has been computed
0x2	SBG_ECOM_POS_SINGLE	Single point solution position

0x3	SBG_ECOM_POS_PSRDIFF	Standard Pseudorange Differential Solution (DGPS)
0x4	SBG_ECOM_POS_SBAS	SBAS satellite used for differential corrections
0x5	SBG_ECOM_POS_OMNISTAR	Omnistar VBS Position (L1 sub-meter)
0x6	SBG_ECOM_POS_RTK_FLOAT	Floating RTK ambiguity solution (20 cms RTK)
0x7	SBG_ECOM_POS_RTK_INT	Integer RTK ambiguity solution (2 cms RTK)
0x8	SBG_ECOM_POS_PPP_FLOAT	Precise Point Positioning with float ambiguities
0x9	SBG_ECOM_POS_PPP_INT	Precise Point Positioning with fixed ambiguities
0x10	SBG_ECOM_POS_FIXED	Fixed location solution position

A.3.12 SBG_ECOM_LOG_PRESSURE (36)

The SBG_ECOM_LOG_PRESSURE (36) message provides the altitude above reference level and pressure. Altitude is referenced to a standard 1013 hPa zero level pressure. The SBG_ECOM_LOG_PRESSURE (36) message is distributed by the PIM at 1Hz.

Message name (ID)	SBG_ECOM_LOG_PRESSURE (36)				
Field	Description	Unit	Format	Size	Offset
TIME_STAMP	Time since sensor is powered up	µs	uint32	4	0
PRESSURE_STATUS	Altimeter status	-	uint16	2	4
PRESSURE	Pressure measured by the sensor	Pa	float	4	6
ALTITUDE	Altitude computed from barometric almtimeter	m	float	4	10
				Total size	14

A.3.12.1 *PRESSURE_STATUS*

Description: Pressure status bitmask

Bit	Name	Description
0	SBG_ECOM_PRESSURE_VALID	Set to 1 altimeter was correctly initialized
1	SBG_ECOM_ALTITUDE_VALID	Set to 1 if the altitude output is valid

A.3.13 FIREFLY2A_STATUS

Description: Status of Firefly 2A

Note: This message will be on a different IP port to avoid conflicts with legacy Mod Payload

Note: This message is UNAVAIABLE via the state serial interface to avoid conflicts with legacy Mod Payload

This section is still under development

A.3.14 CRC Calculation

The CRC field is computed on [MSG, CLASS, LEN, DATA] fields. The sbgECom protocol uses a 16-bit CRC. This CRC uses a polynomial value of 0x8408.

SBG provides an SDK for use in developing applications to interface with their devices. In the SDK is the sbgECom library source code for computing the CRC. It is in the file misc/sbgCrc.c. The SDK implementation uses a lookup table to optimize the speed of the CRC computation.

A non-optimized, C source code algorithm for computing the CRC is provided below.

```
/*!
*	Compute a CRC for a specified buffer.
*	\param[in] pBuffer Read only buffer to compute the CRC on.
*	\param[in] bufferSize Buffer size in bytes.
*	\return The computed 16 bit CRC.
*/
uint16 calcCRC(const void *pBuffer, uint16 bufferSize)
{
const uint8 *pBytesArray = (const uint8*)pBuffer; uint16 poly = 0x8408;
uint16 crc = 0; uint8 carry; uint8 i_bits; uint16 j;

for (j =0; j < bufferSize; j++)
{
crc = crc ^ pBytesArray[j];
for (i_bits = 0; i_bits < 8; i_bits++)
{
carry = crc & 1; crc = crc / 2; if (carry)
{
crc = crc^poly;
}
}
}
return crc;
```

A.4 State over Serial: SBG NMEA Protocol Messages

The implemented NMEA sentences are based on NMEA 0183 Version 4.1 and will be contained in the payload section of the frame described in Section A.3.2. Each data field is comma separated. Sometimes, a field cannot be defined and can be left empty.

From PIM developers, the NMEA frames are identified in the frame header by the message class SBG_ECOM_CLASS_LOG_NMEA_1 (0x03). As with the binary messages, any other messages received from the SBG can be dropped.

A.4.1.1 *SBG_ECOM_LOG_NMEA_GGA (0x00)*

The GGA log provides detailed Kalman filtered position, altitude and accuracy data. The SBG_ECOM_LOG_NMEA_GGA message is distributed by the PIM at 1Hz.

Field	Name	Format	Description
0	$##GGA	string	Message ID – GGA frame
1	Time	hhmmss.ss	UTC Time, current time
2	Latitude	ddmm.mmmmm	Latitude: degree + minutes
3	N/S	char	North / South indicator
4	Longitude	dddmm.mmmmm	Longitude: degree + minutes
5	E/W	char	East / West indicator
6	Quality	i	Fix status (see definition in Quality indicators section)
7	SV used	ii	Number of satellites used in solution
8	Horizontal DOP	ff.f	Horizontal dilution of precision, 1 (ideal) to > 20 (poor)
9	Altitude MSL	ffff.fff	Altitude above Mean Sea Level in meters
10	M	M	Altitude unit (Meters) fixed field.
11	Undulation	fff.fff	Geoidal separation between WGS-84 and MSL in meters).
12	M	M	Units for geoidal separation (Meters) fixed field.
13	Diff. Age	-	Age of differential corrections. Not filled by the device, always empty.
14	Diff. station ID	-	Differential station id. Not filled by the device, always empty.
15	Check sum	*cs	Xor of all previous bytes except $
16	End of frame	<CR><LF>	Carriage return and line feed

Example:

*$GPGGA,000010.00,4852.10719,N,00209.42313,E,0,00,0.0,-44.7,M,0.0,M,,,*63<CR><LF>*

Integer numbers are represented using the char 'i'. The number of 'i' chars define the maximum number of digits that can be used to represent this integer. Decimal numbers are represented by the char 'f'. The char '.' is used to separate the integer part from the decimal one. The number of 'f' chars define the maximum number of digits that can be used to represent both the integer and decimal part.

Further, complete information regarding the sbgECom Binary Protocol is provided in the Ellipse, Ekinox & Apogee, High performance Inertial Sensors, Firmware Manual available from SBG

Appendix B. **CCM Implementation**

B.1 Overview

The CCM presents a large 3U capacity configuration of MPx.

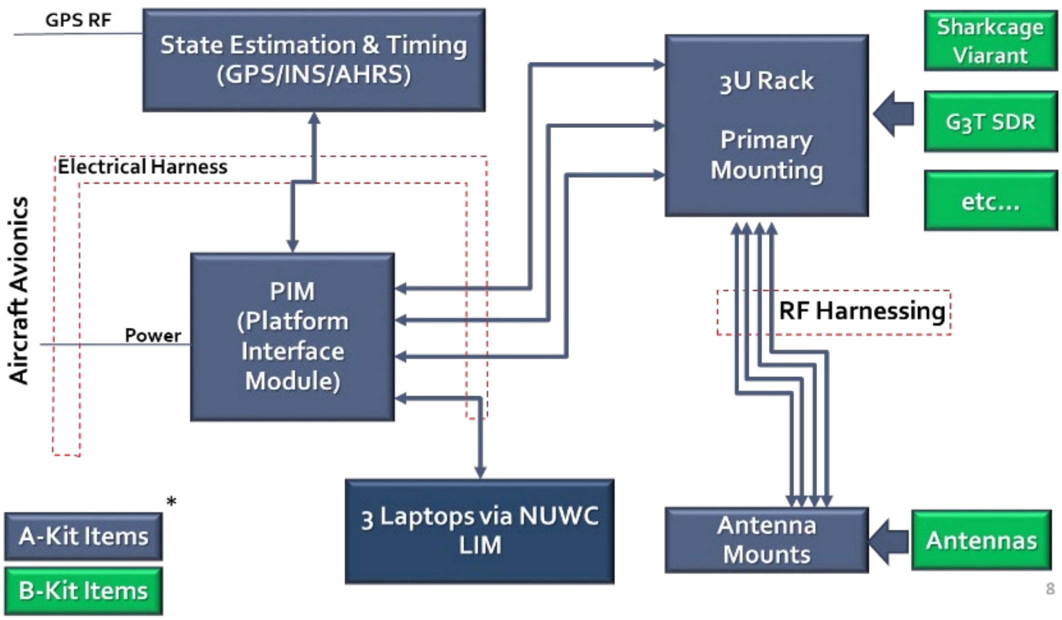


Figure B-1 CCM MPx System Architecture

B.2 Primary Mount

The Primary Mount for CCM has 3U of capacity and a collocated PIM on the forward end of the Rack. This rack is located as shown below

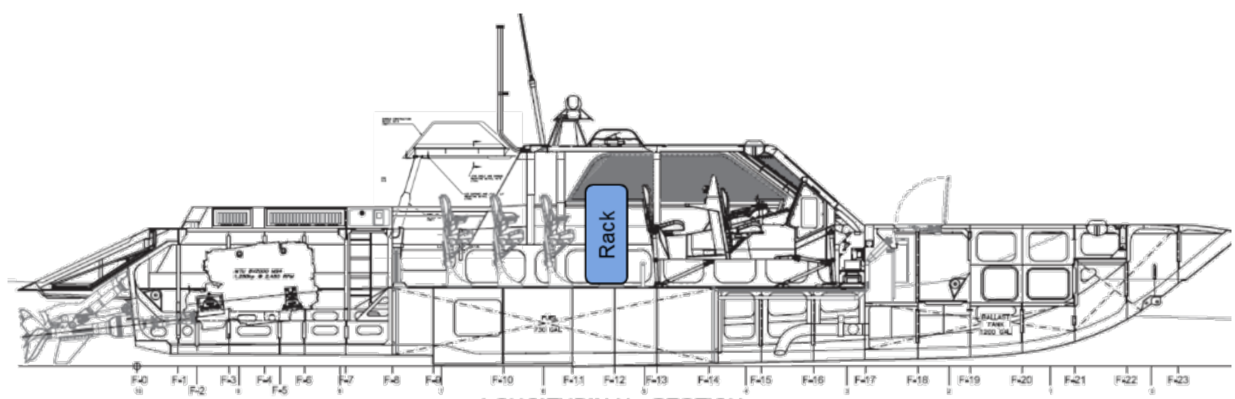


Figure B-2 CCM Installation Location

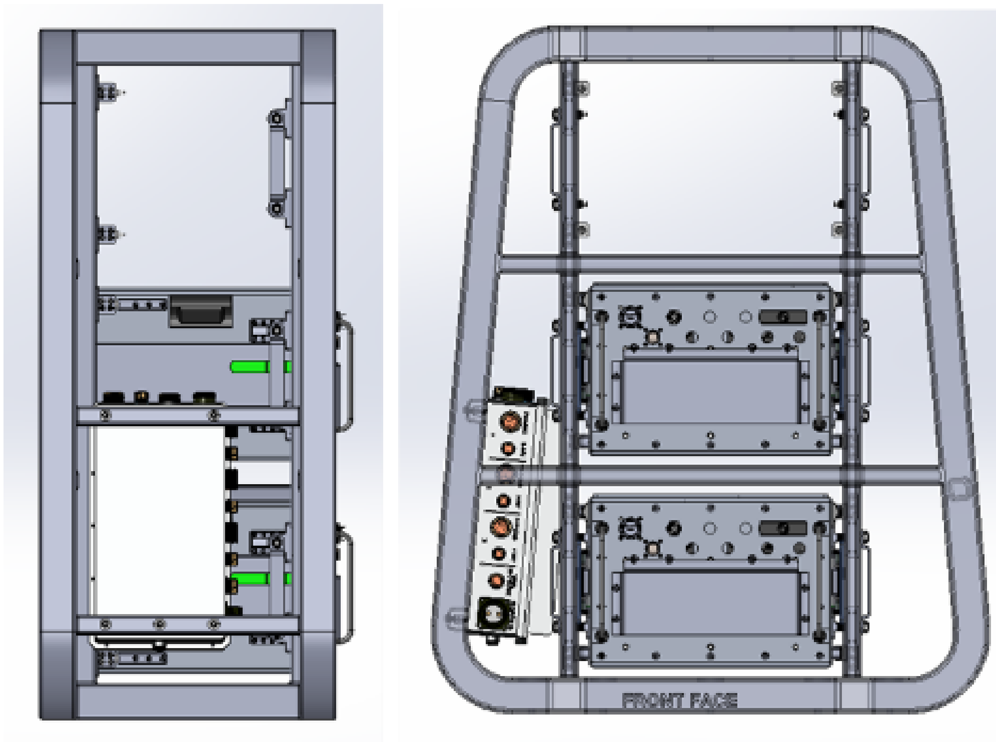


Figure B-3 CCM Primary Mount

B.3 PIM

The PIM pulls up to 600W @24VDC power from the platform and facilitates up to 3 Payloads. Additionally, the PIM supports the EUD subsystem via the LIM from NUWC.

Figure B-4 CCM PIM

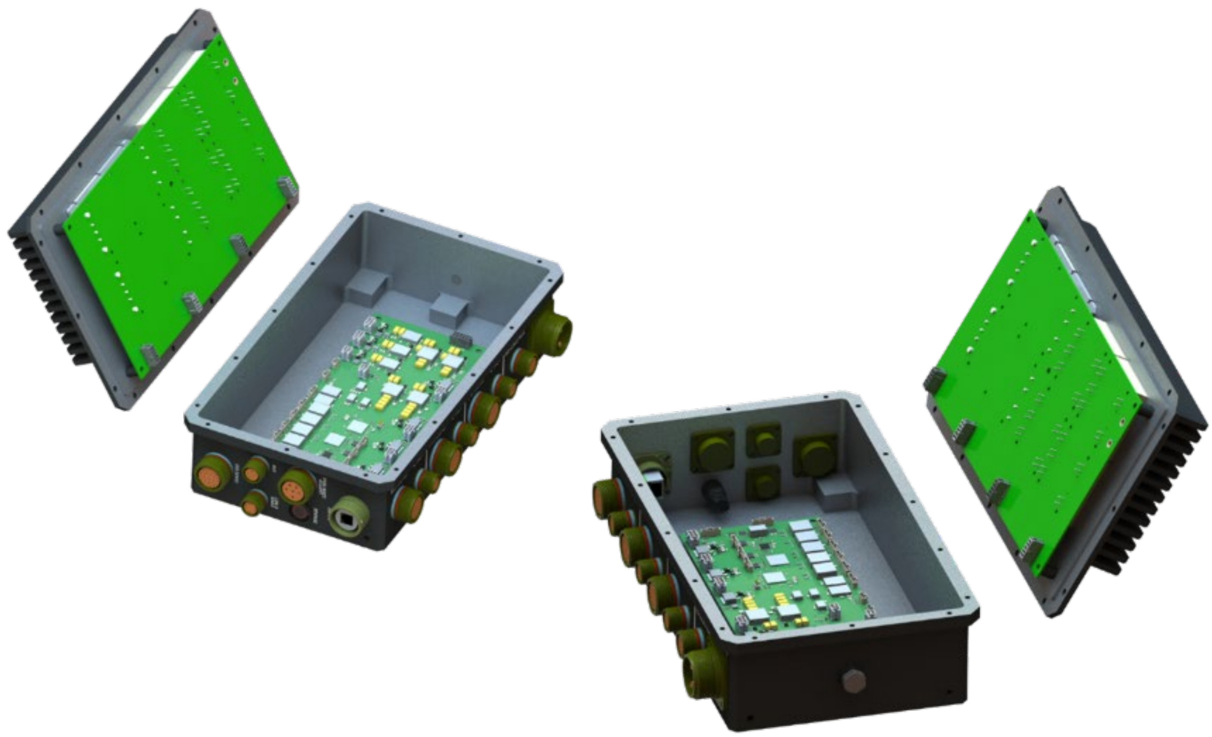


Figure B-5 CCM PIM Internal Views

B.4 Antenna Mounting

B.4.1 Primary Location – the Shroud

The absolute priority for antenna mounting on CCM is within the “shroud”.

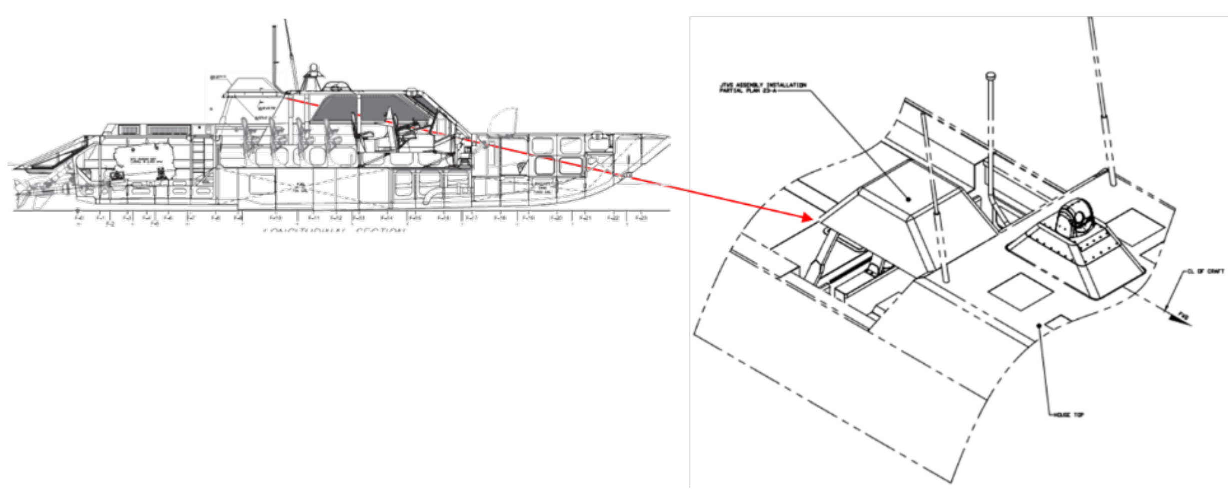


Figure B-6 CCM Primary Antenna Mount

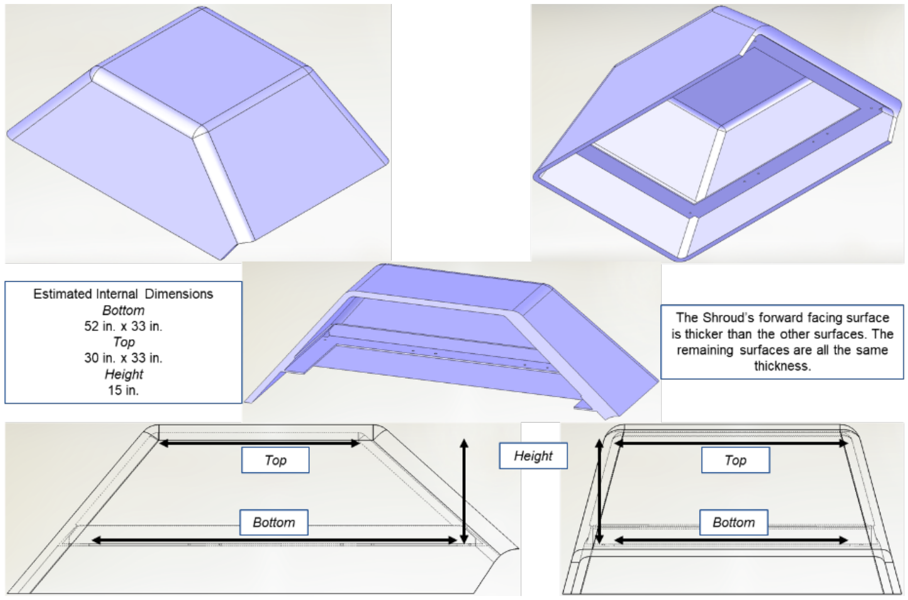


Figure B-7 CCM Shroud Description

Within the shroud a flexible plate will be provided which allows various configurations of antenna mounts and orientations.

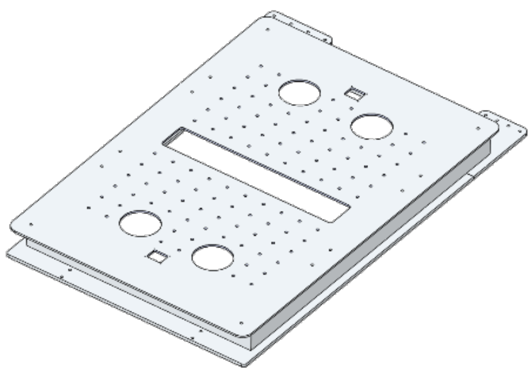


Figure B-8 CCM Ahroud Antenna Mounting Plate

Included in the A-kit will be multiple adapters to expose the MPx interface for the B-kit antennas.

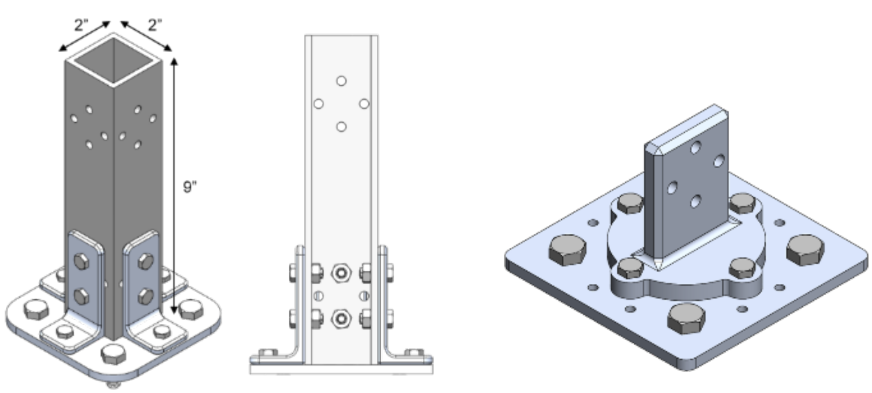


Figure B-9 CCM A-kit Antenna Adapters

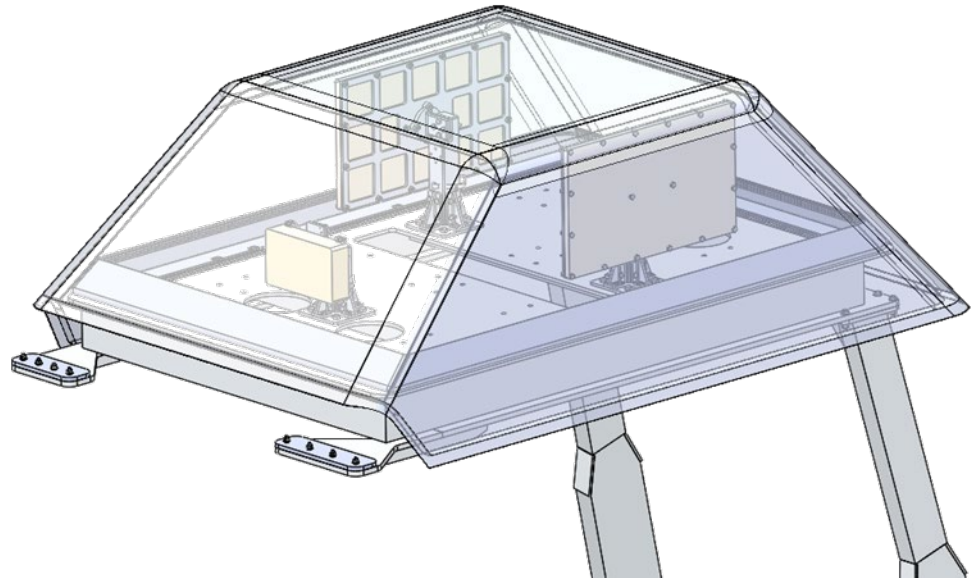


Figure B-10 Shroud Antenna Mount 3D View

B.4.2 Alternate Antenna Mounting

For those payload and/or antenna configurations which cannot be fully supported by the Shroud, additional antenna mounting options are provided. It should be noted that many missions will not be able to leverage these options due to other constraints.

B.4.2.1 *NATO mounts*

For those payload in the rear, the NATO mounts may be used to expose additional antenna mount points.

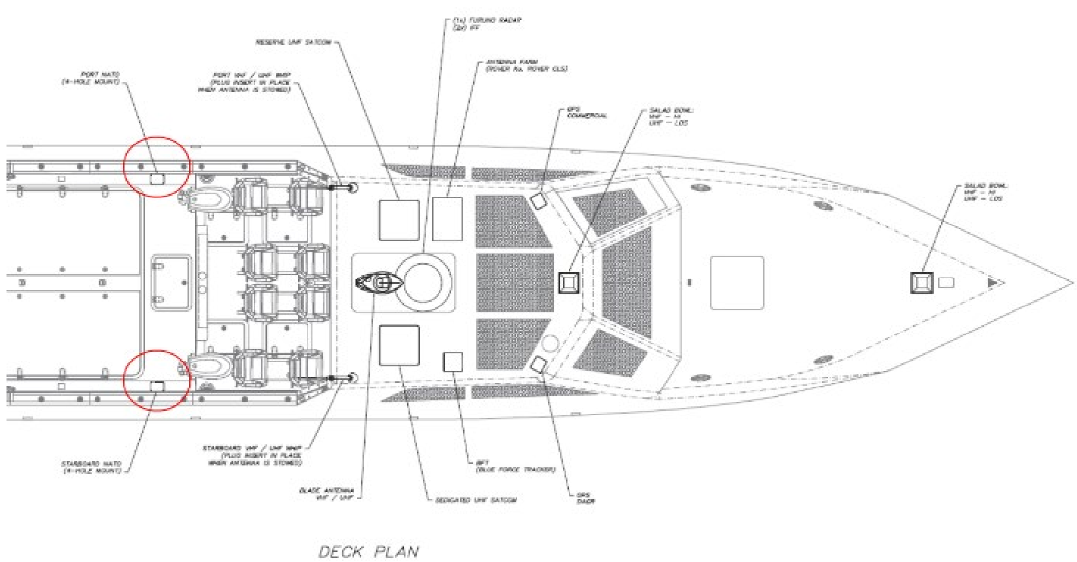


Figure B-11 CCM NATO Antenna Mount Locations

Adapters will be provided to facilitate multiple configurations.

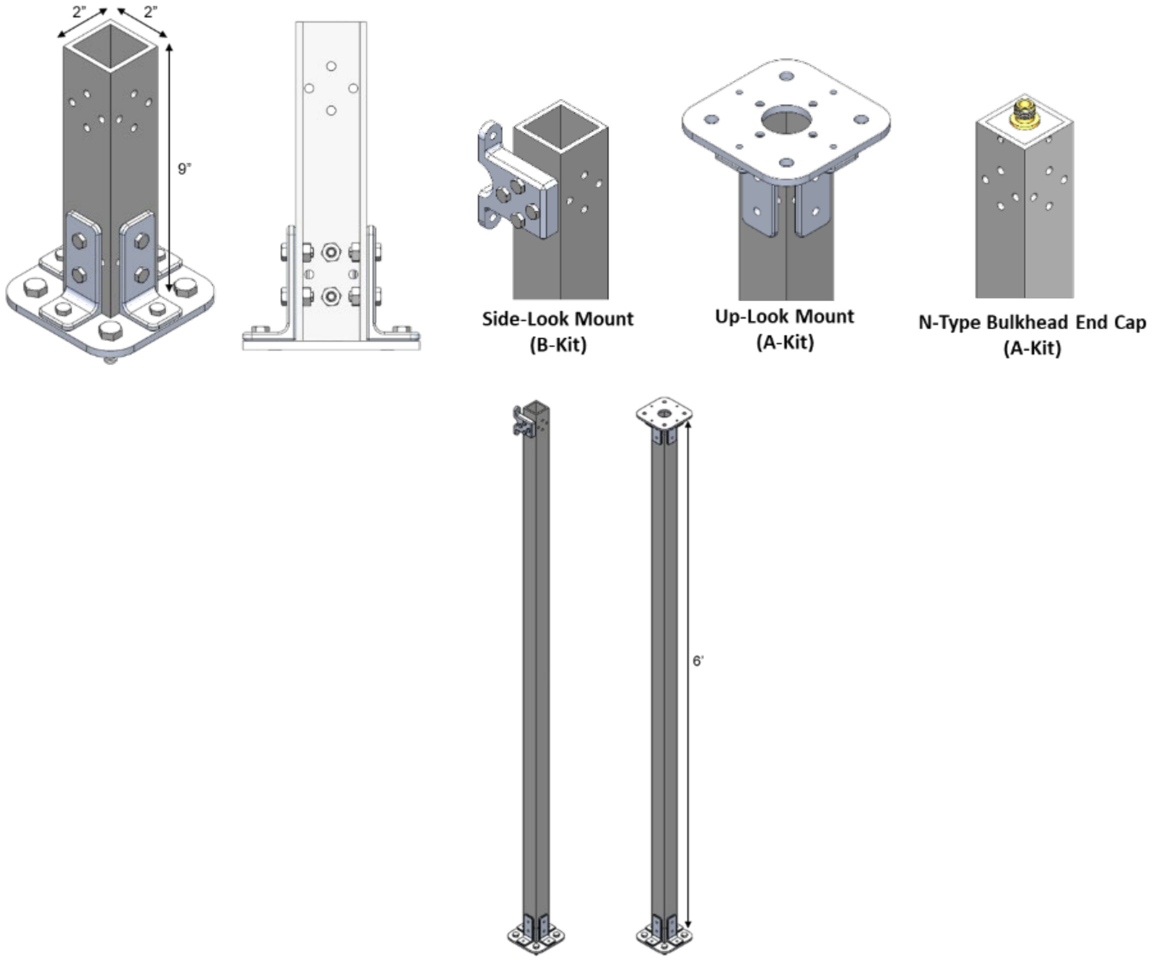


Figure B-12 CCM Antenna Mount Adapters

B.4.2.2 *UHF Mounts*

For additional flexibility the two unused UHF whip mounts just forward of the shroud will be capable of supporting MPx antennas.

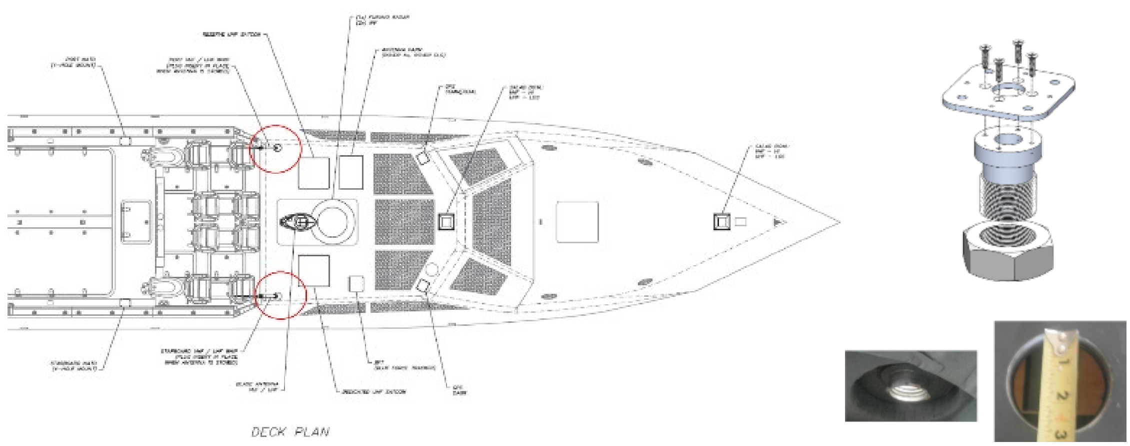


Figure B-13 CCM Whip Antenna Mount Locations

These locations will have similar brackets to support MPx antennas. Additionally one mount will have a side option for GPS antenna to service the State Estimation & Timing subsystem.

B.5 RF Cabling

To be refined

B.6 Harnessing

To be refined

B.7 State Estimation & Timing

The GPS RF feed with be provided by the platform splitter when available. Alternately, when allowable, the GPS feed can be provided by an A-kit antenna added to the UHF position.

B.8 EUD/LIM

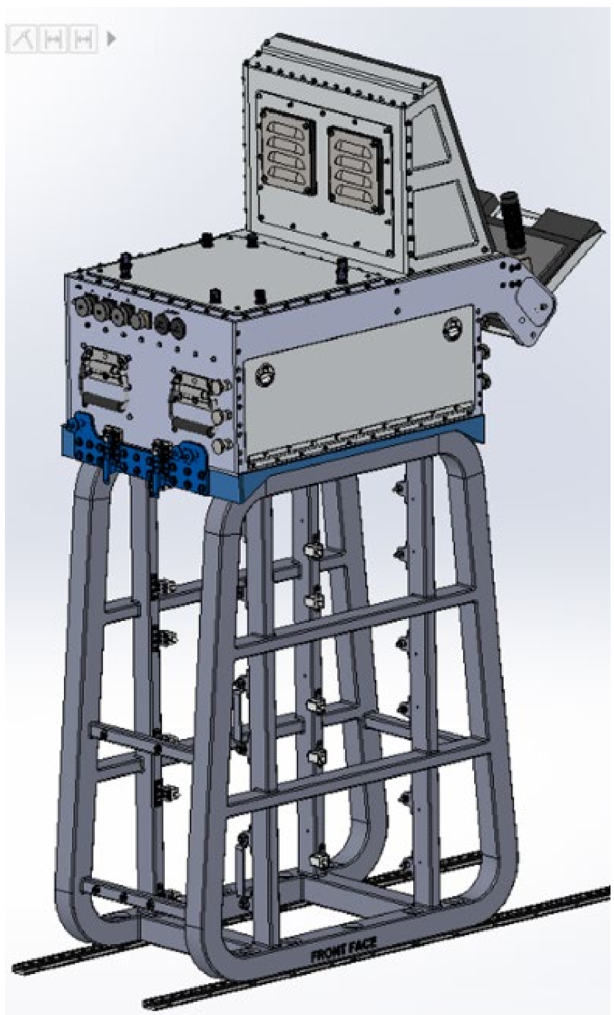


Figure B-14 Need Figure Caption

To be refined

Appendix C. **C130 Implementation**

C.1 Overview

The PIM distributes state data over two interfaces – serial and Ethernet – to provide flexibility for payloads. The Ethernet interface uses a JSON message format for distribution, while the serial interface…

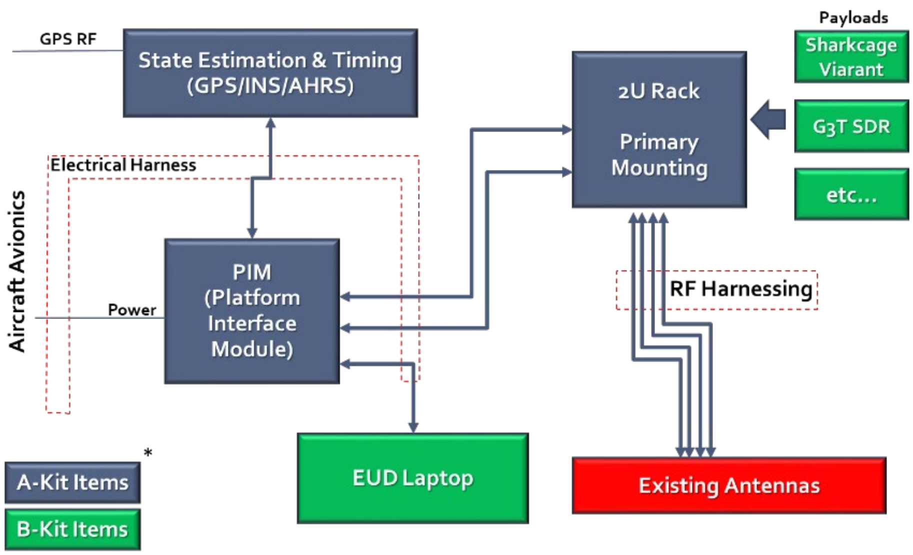


Figure C-1 C130 MPx System Architecture

C.2 Primary Mount

The Primary Mount for the C130 is a 2U capacity system.

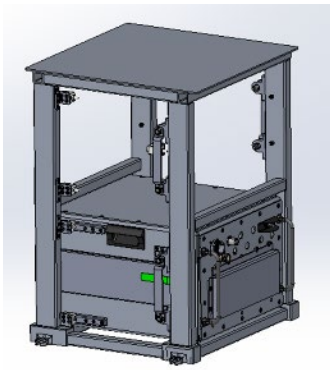


Figure C-2 C130 Primary Mount

This rack mount is designed to either be floor mounted with straps, or to mount to the JTWS Air Heavy attachment onto the seat structures (aka ‘Deer Stand’).

Figure C-3 C130 Primary Mount Installation ("Deer Stand")

C.3 State estimation & Timing

GPS RF will be pulled from an available feed on the platform.

C.4 PIM

The PIM will support up to two payloads and source up to ~840W from the platform via 28VDC.

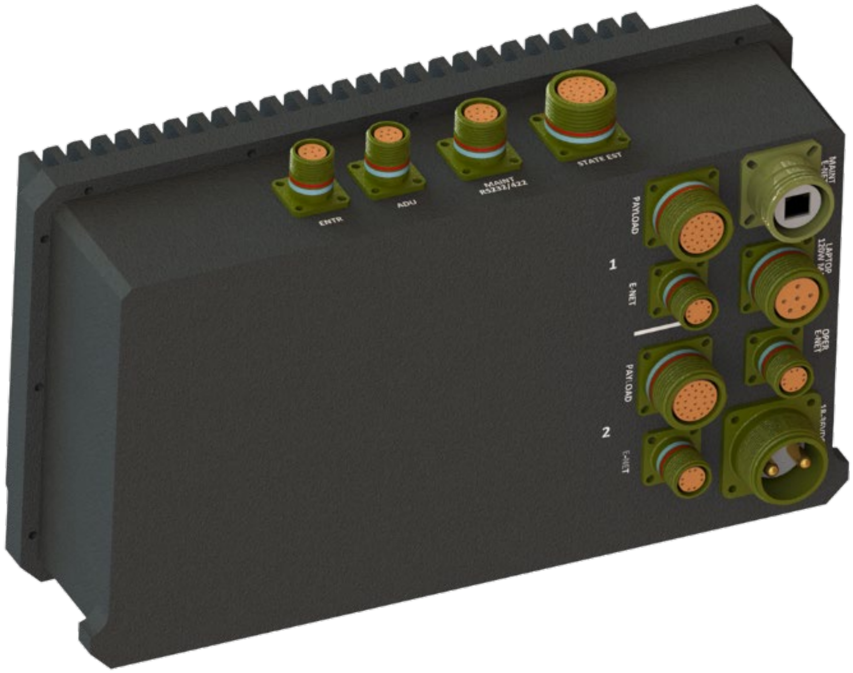


Figure C-4 C130 PIM

C.5 EUD

The PIM facilitates up to one EUD at a time natively. Expansion to multiple laptops is easily done with external provisions.

C.6 Antennas

The configuration of antennas provisioned on different variants of C-130 vary substantially.

Information on specific aircraft will be maintained outside of this specification.

C.7 RF Cabling

To be refined

C.8 Harnessing

To be refined

C.9 Auxiliaries

The A-kit will provide compatibility with the NIWC ADU from JTWS Air Heavy as well as the ENTR subsystem.

Further details TBD

Appendix D. **CV-22 Concept Only**

D.1 Overview

The CV-22 presents the most challenge SWAP constrained platform currently for MPx. Below is a summary.

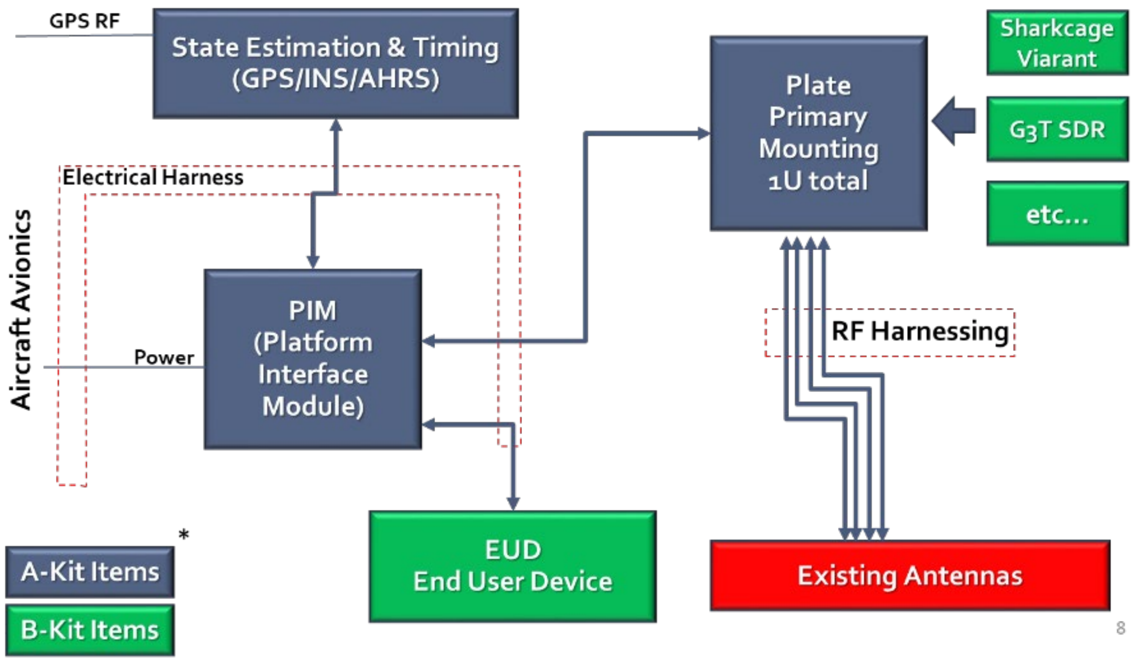


Figure D-1 CV-22 MPx System Architecture Concept

D.2 Primary Mounting

The CV-22 A-kit would be limited to a 1U Plate mounted implementation. On this same plate would need to be the PIM as well as several Auxiliaries. This total weight would be limited to 75lbs

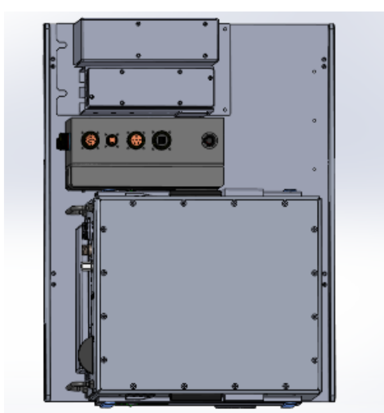


Figure D-2 CV-22 A-kit Installation Concept

Appendix E. **Acronyms and Abbreviations**

AHRS	Attitude and Heading Reference System
COTS	Commercial off the Shelf
DA	Density Altitude
EMI	Electro Magnetic Interference
EW	Electronic Warfare
GTOW	Gross Take-off Weight
GUI	Graphical User Interface
ICD	Interface Control Document
INS	Inertial Navigation System
PIM	Platform Interface Module
MP	Modular Payload
MTOW	Maximum Take-off Weight
PCB	Printed Circuit Board
SIGINT	Signals Intelligence
UAS	Unmanned Aircraft System

Appendix F. **Applicable Government Documents**

The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

MIL-STD-454 Standard General Requirements for Electronic Equipment
MIL-STD-461 Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462 Electromagnetic Interface Characteristics, Measurement of
MIL-STD-810 Environmental Test Methods

Appendix G. **List of Figures**

Appendix H. **List of Tables**