MOD PAYLOAD

A Modular Payload Design Standard

Revision 6.1

August 19, 2024

FOREWORD

This standard contains requirements for the form factor, design, interfaces, and environmental tolerance for EW/SIGINT/communications systems for small uncrewed systems (detailed in Volume I), manned aircraft and small maritime vessels (detailed in Volume II), and highly SWAP-constrained systems (detailed in Volume III). 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.

NOTE: the MPx class/Volume II is no longer supported by the Mod Payload Standard (as of Rev 6.0).

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., radios and radars, and other platforms, e.g., manned aircraft, maritime vessels, USVs, and dismounts. Further expansion to other payload types (e.g., processors) and platforms (e.g., UUVs) is ongoing.

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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.
6.0	06-12-2024	Re-organized sections to discuss payload requirements before platforms. Moved platform implementations out of the appendices. Expanded Volume I to cover USVs and dismounts. Several clarifications to Volume I requirements. Switched to an INS specification rather than approved devices. Added implementations for Adaro, Vapor55, V-BAT and dismount to Volume I. Added Volume III for the MPu Class, including a dismount implementation.
6.1	08-19-2024	Changed to unlimited distribution.

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
	Vol I: 2.1	Major	Better specified power in-rush requirement Clarified higher power payload requirement Clarified IP network responsibility and requirements
	Vol I: 2.2	Major	Added subsections on installation, configuration and calibration of the INS
	Vol I: 2.3	Minor	Better specified primary mount interfaces Clarified primary mount thermal requirements
	Vol I: 2.4	Major	Moved from antenna section to platform section Better defined all antenna mount interfaces
	Vol I: 2.5	Major	Added subsections on MAIM and RF cabling Clarified RF cable and connector requirements Updated platform grounding requirements
	Vol I: 3.1	Major	Better specified power in-rush requirement Updated payload grounding requirements
	Vol I: 3.2	Major	Better specified payload mechanical volumes Added subsections on mechanical variations
	Vol I: 3.3	Minor	Clarified payload thermal requirements
	Vol I: 3.4	Major	Moved from antenna section to payload section Better defined all antenna adaptor interfaces
	Vol I: App A	Minor	Corrected error in SKY message example
	Vol I: App B-E	Minor	Updated overall appendix structure Add Compliance Summary table Removed unnecessary information
	Vol I: App F	Major	New – SkyRaider appendix
	Vol II	Major	New – draft MPx volume
5.1	Whole	Major	Removed distribution restrictions

Revision	Sections Revised	Importance	Description of Changes
	VI: Appx B	Minor	Added descriptive clarifications
6.0	Whole	Major	Re-formatted all Volumes, moved Implementations from Appendices to main sections and reorganized section order.
	Intro	Minor	Updated verbiage, volume definitions Added A-kit / B-kit definitions
	Vol I: Section 1	Minor	Updated verbiage for additional platform types
	Vol I: Section 2	Major	Now discusses payload requirements Added information on TDP availability
	Vol I: 2.1.1	Minor	Clarified additional feed and in-rush requirements
	Vol I: 2.1.5	Major	Updated payload grounding requirement
	Vol I: 2.2.1.1.1	Minor	Added rail requirement on some half U modules
	Vol I: 2.2.1.1.6	Minor	Added graphic depicting heat sink locations
	Vol I: 2.2.2	Minor	Updated notional payload weights
	Vol I: 2.2.3.1	Minor	Added additional wedge lock options
	Vol I: 2.3.1	Minor	Better specified thermal environment requirements
	Vol I: 2.3.2	Minor	Made pinned heatsink requirement more generic
	Vol I: 2.3.3	Minor	Added section on thermal-mechanical pairings
	Vol I: 2.4.2	Major	Added note on higher frequency RF connectors
	Vol I: 2.4.3.1	Minor	Better specified antenna RF connector requirement
	Vol I: 2.5.2	Major	Updated payload vibration requirement
	Vol I: 2.5.6	Minor	Updated to consider USV maritime exposure
	Vol I: Section 3	Major	Now discusses platform requirements Updated verbiage for additional platform types Added information on TDP availability
	Vol I: 3.1.2	Major	Added survivability requirement for MAIM based on platform environment
	Vol I: 3.1.4.1	Major	Expanded / clarified platform power requirements
	Vol I: 3.1.4.2.1	Minor	Better specified state messaging/syncing rates
	Vol I: 3.1.4.2.2	Minor	Better specified state messaging/syncing rates
	Vol I: 3.1.4.3	Minor	Updated verbiage and network requirement for additional platform types
	Vol I: 3.1.4.5	Minor	Better specified 1PPS signal voltage range
	Vol I: 3.1.4.6	Minor	Better specified zeroize signal voltage range
	Vol I: 3.2.1	Major	Defined an INS specification
	Vol I: 3.2.1.1	Major	Provided a list of vetted INS
	Vol I: 3.2.4	Minor	Added calibration descriptions for USV and dismounts
	Vol I: 3.3.5	Major	Better specified thermal environment requirements Added additional requirements for dismounts
	Vol I: 3.3.5.1	Major	Added section on thermal-mechanical pairings
	Vol I: 3.3.6	Minor	Added accessibility requirement
	Vol I: 3.3.7	Minor	Added survivability requirement for Primary Mount based on platform environment

Revision	Sections Revised	Importance	Description of Changes
	Vol I: 3.4.1.1	Major	Expanded minimum antenna mounts requirements based on platform
	Vol I: 3.5.1	Minor	Added cable build requirement based on platform environment
	Vol I: 3.5.2	Major	Added notes on higher frequency RF cabling and connectors Added cable build requirement based on platform requirement
	Vol I: 3.6	Major	Better defined platform grounding scheme
	Vol I: Section 4	Major	Now discusses platform implementations
	Vol I: 4.1.6, 4.2.6, 4.3.6, 4.4.6	Major	Specified max weight and volumes for antenna mounts
	Vol I: 4.3.8	Minor	Removed payload-specific concession
	Vol I: 4.4.8	Minor	Removed payload-specific concession
	Vol I: 4.5.6	Minor	Updated max weight, moments and volumes for antenna mounts
	Vol I: 4.6	Major	New – Vapor 55-M Implementation
	Vol I: 4.7	Major	New – Adaro USV Implementation
	Vol I: 4.8	Major	New – Prototype Dismount Implementation
	Vol I: 4.9	Major	New – MQ-35A V-BAT Implementation
	Vol II	Major	Deleted
	Vol III	Major	New – draft MPu Volume
	Appx A: A.3.12	Minor	Added note on pressure message change
	Appx A: A.4.1	Minor	Corrected message format definition
	Appx B	Minor	Updated Acronym List
	Appx C	Minor	Updated introductory wording
6.1	Whole	Major	Removed distribution restrictions

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 Appendix C.

Table of Contents:

Volume II: No longer supported

Volume III:

Table of Figures:

Volume III:

Volume I:

1. BACKGROUND

The Modular Payload standard, often referred to as "Mod Payload," was originally 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 as well as USVs and dismounts. The Modular Payload Expanded Capability (MPx), developed under the Joint Threat Warning System (JTWS) program, further expanded the Mod Payload standard defining a larger class of payload to support both manned aircraft and maritime platforms. The Modular Payload Micro (MPu) expanded the Mod Payload standard once again defining a smaller class of payloads better suited to support even smaller UAS and dismounts. The Mod Payload 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 Mod Payload 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.**

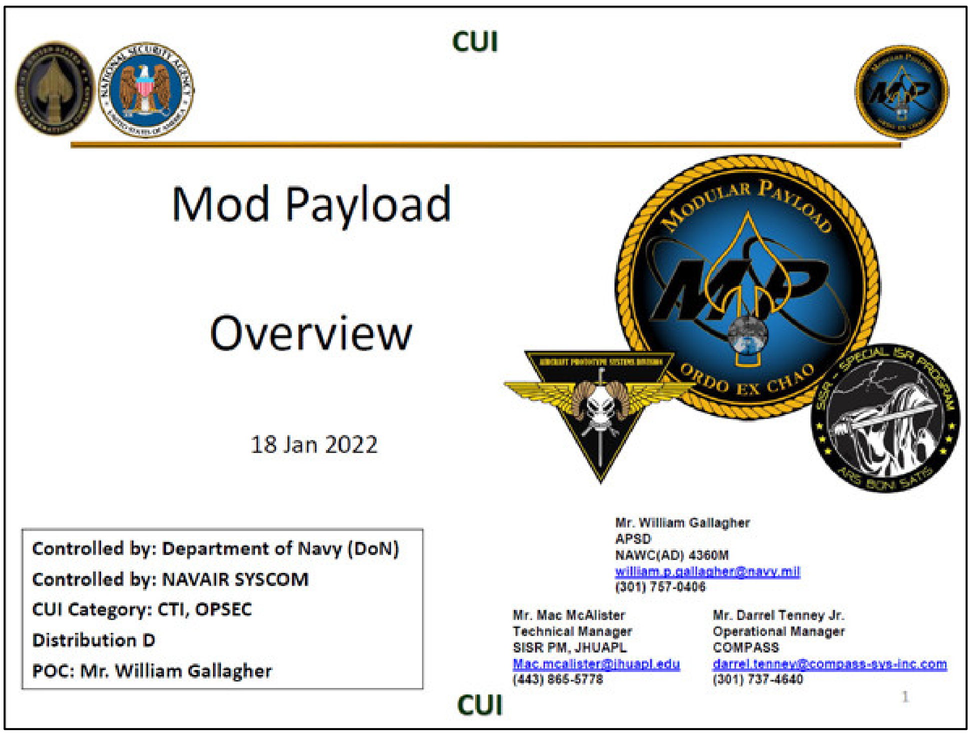


Figure 1-1. MP Overview Briefing

If not already completed, it is highly recommended that the reader first reviews the Mod Payload Overview briefing. This briefing is available over DTIC as well as through the points of contact listed earlier in this document. It provides summary level explanation of the standard, which will make absorbing this more complex document much easier.

Additionally, a repository of reference designs is available upon request as government furnished information (GFI) to payload and platform developers to accelerate development. Requests for the design package should be made to the Mod Payload Technical Manager. As they are Distro D documents, access to the design package and the Overview brief require government sponsorship.

2. SCOPE

The Mod Payload standard defines the requirements for both payloads and platforms to be Mod Payload compliant. To achieve modularity and promote adoption, these requirements are focused on:

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

3. VOLUMES AND PAYLOAD CLASSES

The Mod Payload standard is split into multiple volumes based on the payload class.

3.1 Volume I: MP Class

Volume I of the standard defines the MP class of payloads, primarily focused on UxV operations but also demonstrated on dismounts. The volume details the requirements for the development of the MP class of modular payloads and the architectural modifications levied upon the host UxV platform to accommodate modular payloads. The MP class has been widely adopted by DoD and industry and is generally what is referred to by Mod Payload.

The common infrastructural features of the MP class include the Modular Aircraft Interface Module (MAIM), the Primary Mount, payload modules, antenna mounts, antenna adaptors and cable harnesses. These terms and their requirements will be defined in the body of the volume.

3.2 Volume II: MPx Class

Volume II of the standard defines the MPx class of 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 MP class was also maintained, meaning an MP class payload can also be integrated on an MPx-compliant platform.

The common infrastructural features of the MPx class include the Payload Interface Modular (PIM), the Primary Mount, payload modules, antenna mounts, antenna adaptors and cable harnesses. These terms and their requirements will be defined in the body of the volume.

NOTE: the MPx class is no longer supported by the Mod Payload Standard (as of Rev 6.0).

3.3 Volume III: MPu Class

Volume III of the standard defines the MPu class of payloads, focused on highly SWAP-constrained platforms and dismounted operators. This new MPu class of payload brings the Mod Payload capability to platforms unable to support the MP class.

The common infrastructural features of the MPu class include the Hub, the Primary Mount, the payload module, antenna mounts, antenna adaptors, cabling and an end-user device (EUD). These terms and their requirements will be defined in the body of the volume.

4. A-KIT / B-KIT DEFINITION

All Mod Payload classes adopt an A-kit / B-kit model for platform-payload integrations.

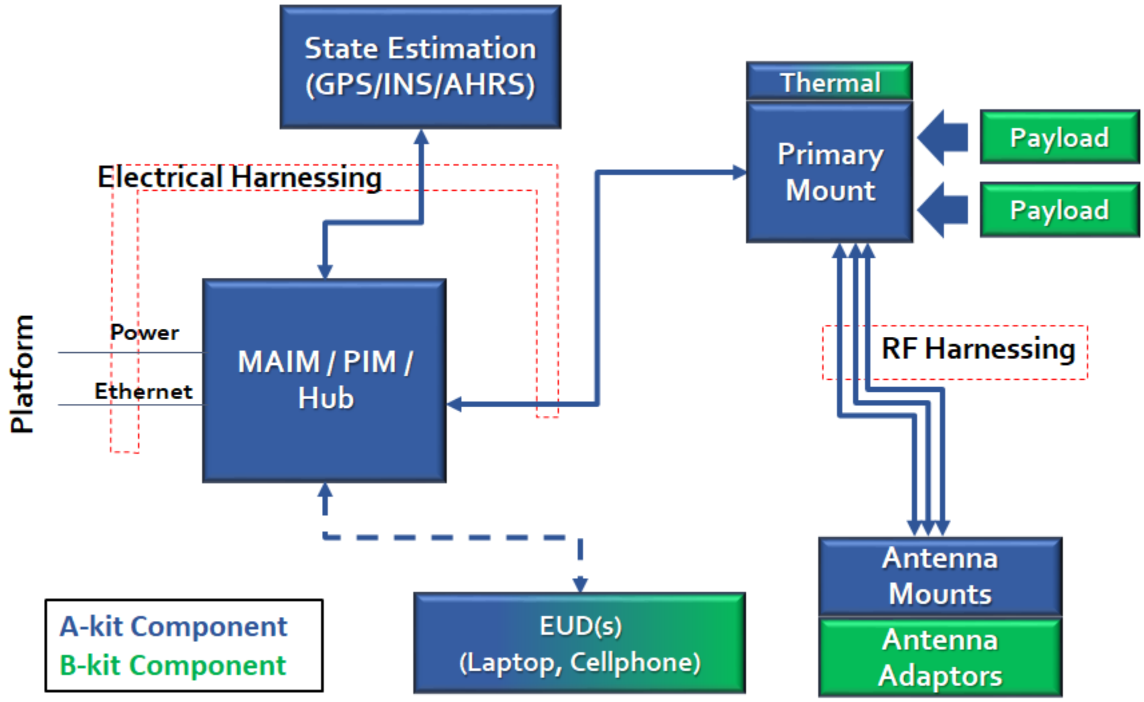


Figure 4-1. Mod Payload Block Diagram

The A-kit is the platform side of the Mod Payload interface. It is provided by the platform vendor or integrator and includes all the hardware and software required to implement the Mod Payload mechanical and electrical interfaces on the platform. A-kit requirements are covered in the Requirements for Platforms section (Section 3) of each volume.

The B-kit is the payload side of the Mod Payload interface. It is provided by the payload vendor and consists of the payload and its antenna. B-kit requirements are covered in the Requirements for Payloads section (Section 2) of each volume.

Mod Payload, Volume I:

Modular Payload Design Standard for Small Systems

Revision 6.1

May 29, 2024

1. OVERVIEW

The MP class of the Mod Payload standard defines the modular payload requirements for a variety of "small" platforms, specifically, Group 1-3 UAS (the original scope of this volume), USVs (expanded scope in this update), UUVs (future update already in development), and dismounted operations (expanded scope in this update). The attributes and interfaces required of a payload for MP-compliance are detailed in Section 2. The attributes and interfaces required of a host platform for MP-compliance are detailed in Section 3. Example MP implementations on specific platforms are provided in Section 4 as an aid to both UxV integrators and payload vendors.

2. REQUIREMENTS FOR PAYLOADS

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

To help developers accelerate the payload development process, a generic Technical Data Package (TDP) containing reference electrical and mechanical designs was developed. This TDP is held at Distribution D and can be provided upon request and confirmation of DoD sponsorship. Similarly, platform simulators are also available to support laboratory development testing. For access to the TDP or to schedule a platform simulator, contact the Mod Payload Technical Manager identified in the front matter of this document.

2.1 Electrical Design

The MP class requires a common electrical interface on payload modules.

2.1.1 Power

A payload module should draw no more than 56W at 28VDC from a single MP feed. This is the maximum power provided by the host platform to each payload interface. If a payload requires additional power, the payload shall include a second (and third, if needed) payload interface connector to mate to and pull from a second payload interface. However, it should be noted that the increased power draw may limit platform compatibility, as some platforms will not have enough power available.

A payload module shall remain operational under voltage fluctuations of ±2% from the nominal 28VDC. Additionally, a payload module shall manage its in-rush, such that it does not exceed 4A per payload interface and does not exceed more than 5ms in duration. When using multiple payload interfaces, a payload shall prevent power from back feeding between interfaces and should balance the load between the interfaces.

2.1.2 Communications

A payload module will have access to the two serial and one Ethernet interfaces provided by the host platform, as described in Section 3.1.3, to transmit and receive communications. A payload module may use any or all of the provided interfaces.

2.1.2.1 Serial

The serial connections can be used to (1) receive state data from the host platform and (2) access the payload for command, control, data or debugging. The state serial communications interface is detailed in Section 3.1.4.2.2. The console serial communications interface is detailed in Section 3.1.4.4. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.2.2 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 3.1.4.3. The state Ethernet communications interface is detailed in Section 3.1.4.2.1. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.3 Other Signals

A payload module can also require a 1PPS timing signal and a zeroize signal from the host platform. The 1PPS signal is detailed in Section 3.1.4.5. The zeroize signal is detailed in Section 3.1.4.6. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.4 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 class.

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

2.1.4.1 Main Connector Pin Out

The required pin out for the payload module main connector is listed in Table 2-1.

Table 2-1. 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
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.

2.1.5 Grounding

The payload shall maintain isolation of power, signal (serial console and state) and payload chassis / RF grounds from each other and platform ground.

Note: the payload RF connector installation into the payload enclosure will tie RF ground to payload chassis ground.

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.

Shield (pin 11) shall be tied to power ground thru an EMI filter (as described above).

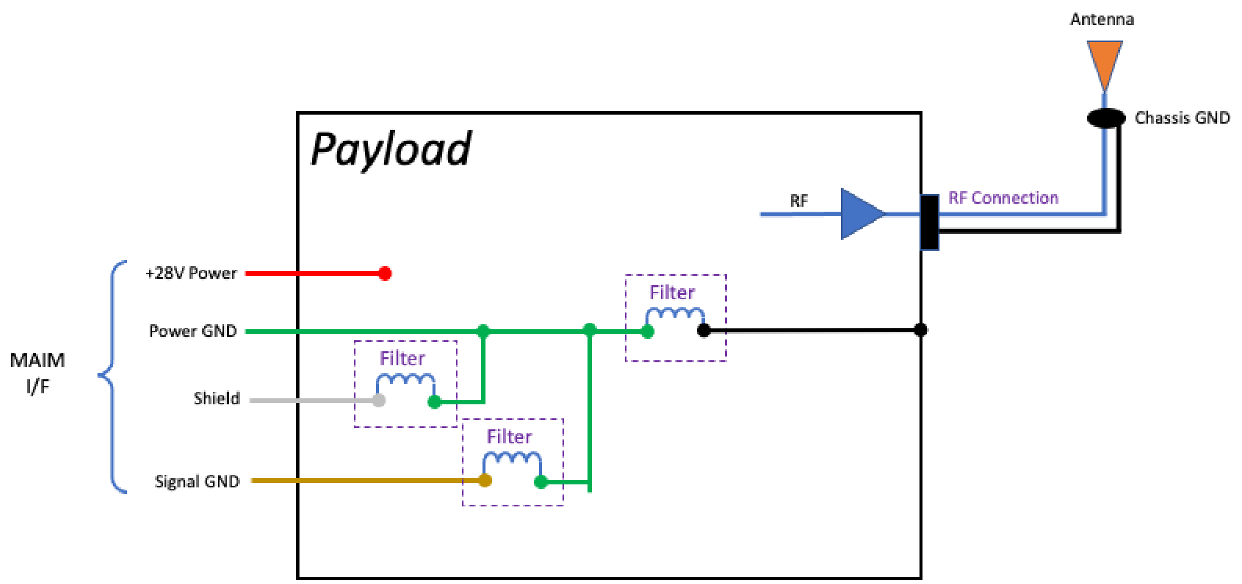


Figure 2-1. Payload Grounding Scheme

The payload grounding scheme is depicted in Figure 2-1 above. The overarching grounding scheme for the MP architecture is detailed in Section 3.6.

2.2 Mechanical Design

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

2.2.1 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

2-2 below.

Table 2-2. 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. Smaller dimensions can be accommodated. See Section 2.2.1.1.1.
[2] Deeper modules can be accommodated if certain conditions are met. See Section 2.2.1.1.2.

Figure 2-2 illustrates the conceptual designs of 1U, 2U and 3U modules. Figure 2-3, Figure 2-4, Figure 2-5, and Figure 2-6 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 2.2.1.1, is permitted.

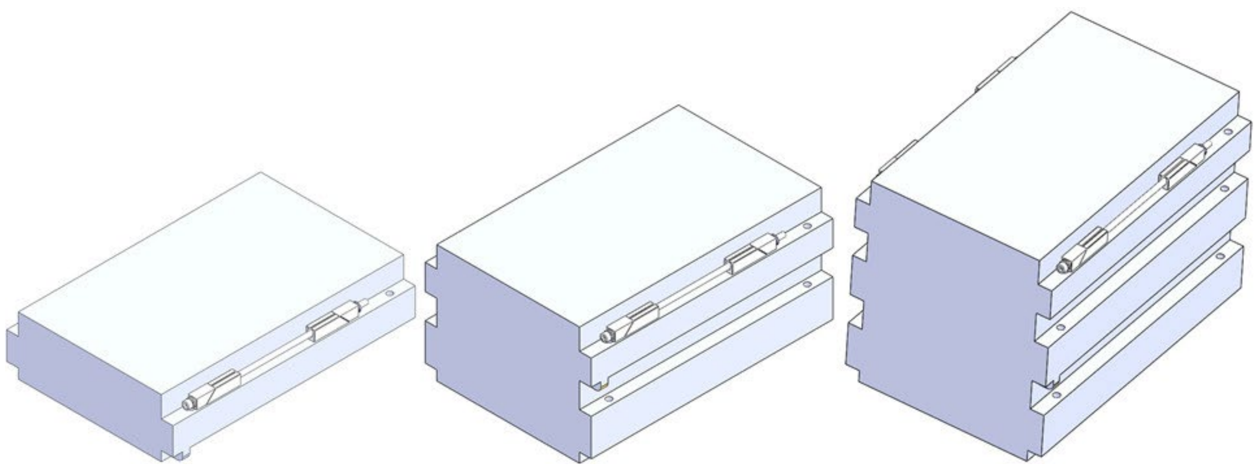


Figure 2-2. 1U, 2U, 3U Module Concepts

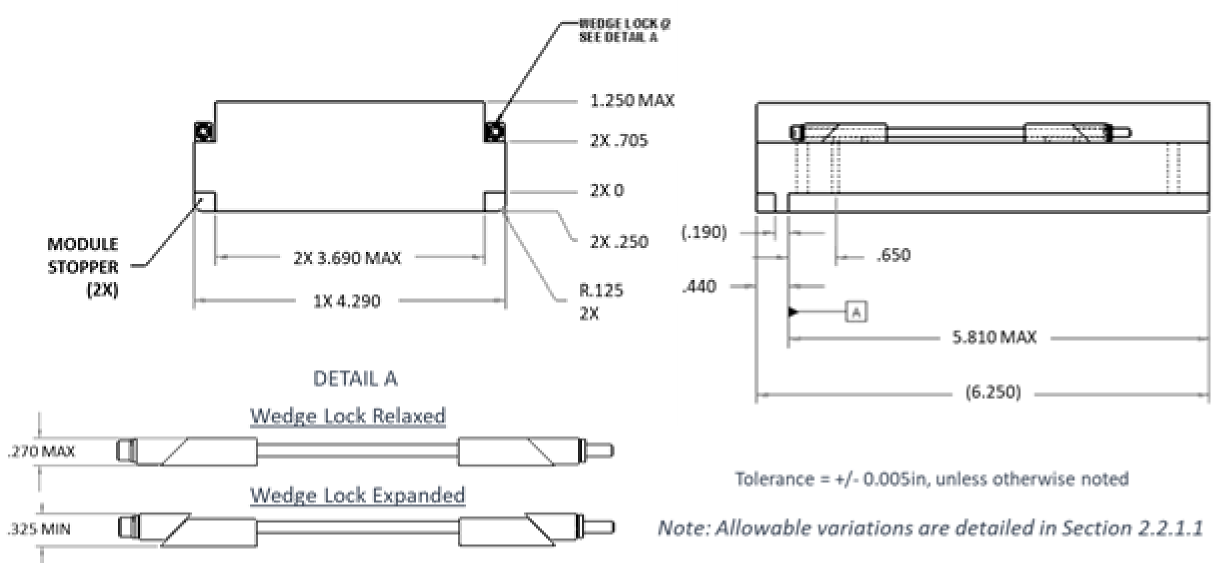


Figure 2-3. Detailed Dimensions of 1U Module

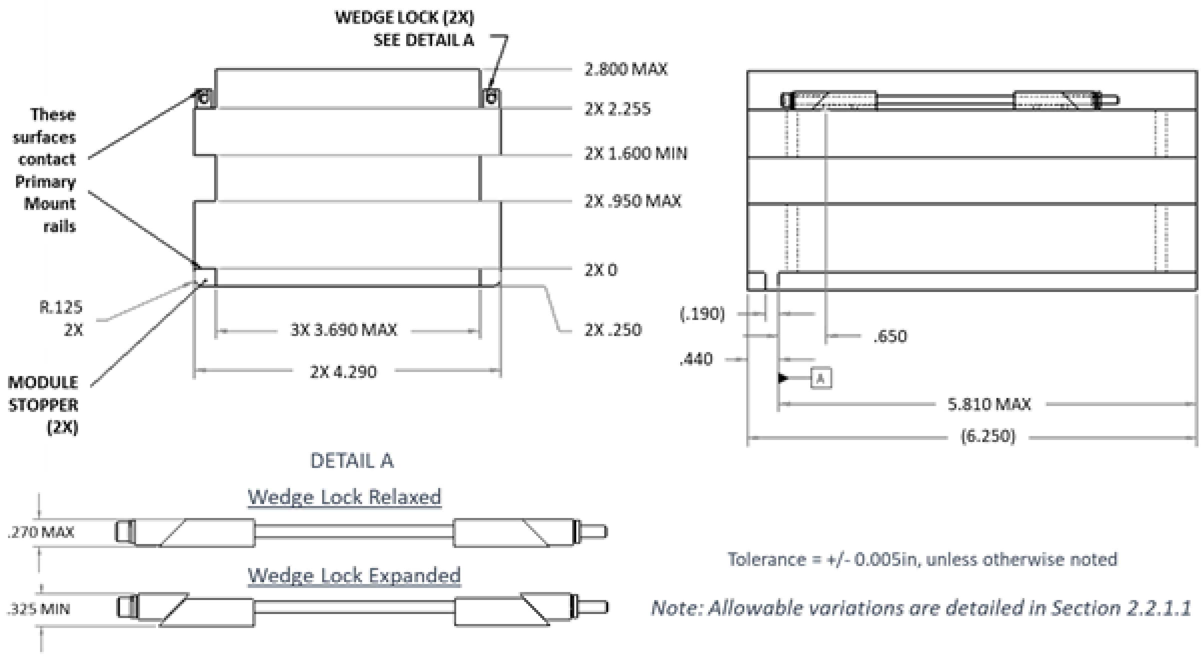


Figure 2-4. Detailed Dimensions of 2U Module

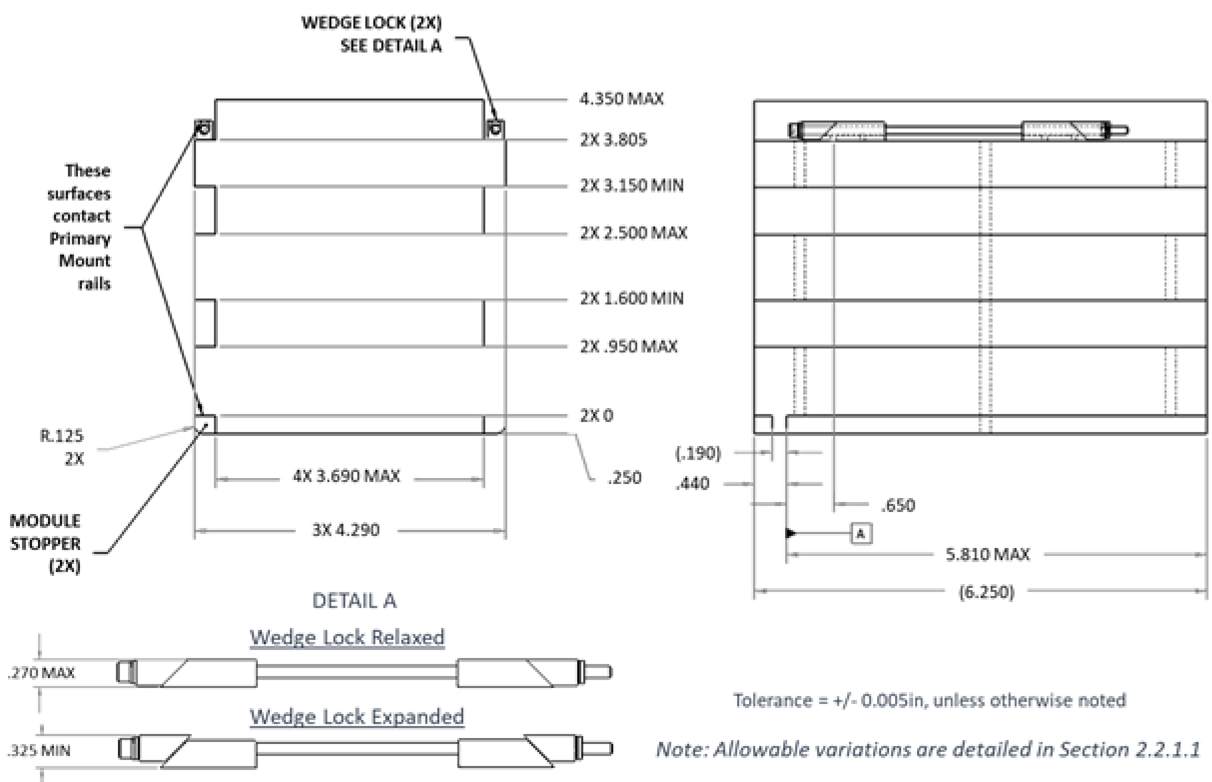


Figure 2-5. Detailed Dimensions of 3U Module

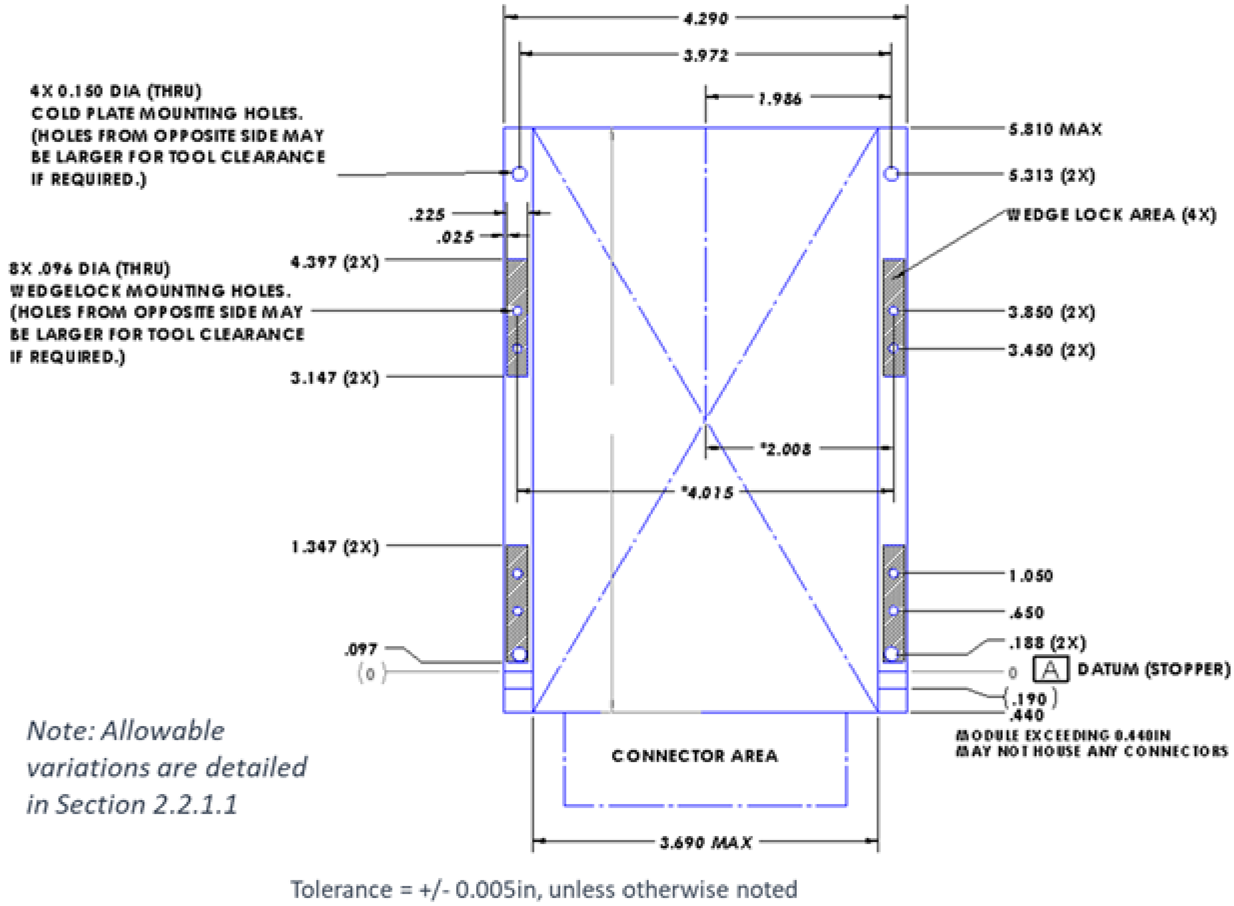


Figure 2-6. Detailed Dimensions of Module (Plan View)

2.2.1.1 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.

2.2.1.1.1 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.

Any half U modules exceeding the max height of the previous full U module by more than 1.005in shall include the additional rail of the next full U module.

2.2.1.1.2 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 2-6 may be extended by 1 inch up to 1.440 inches, 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 2-7.

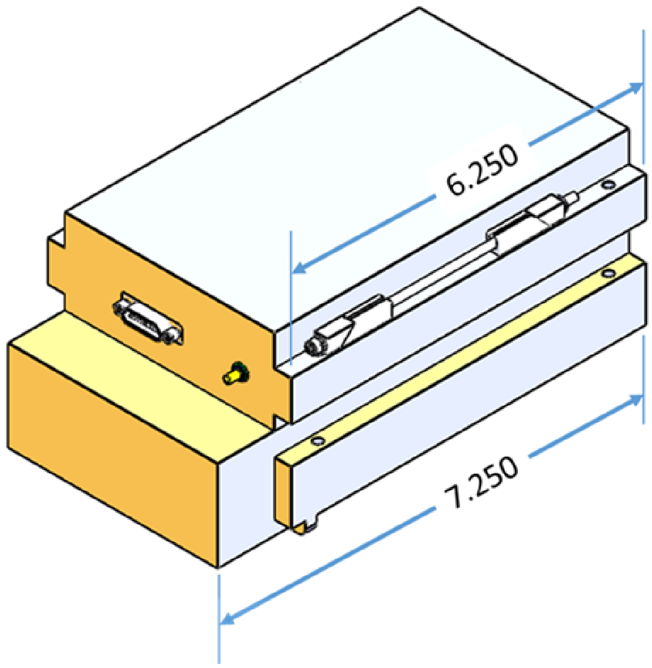


Figure 2-7. Example Extended Length Module

2.2.1.1.3 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 2-6 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 2-6). 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 2-8.

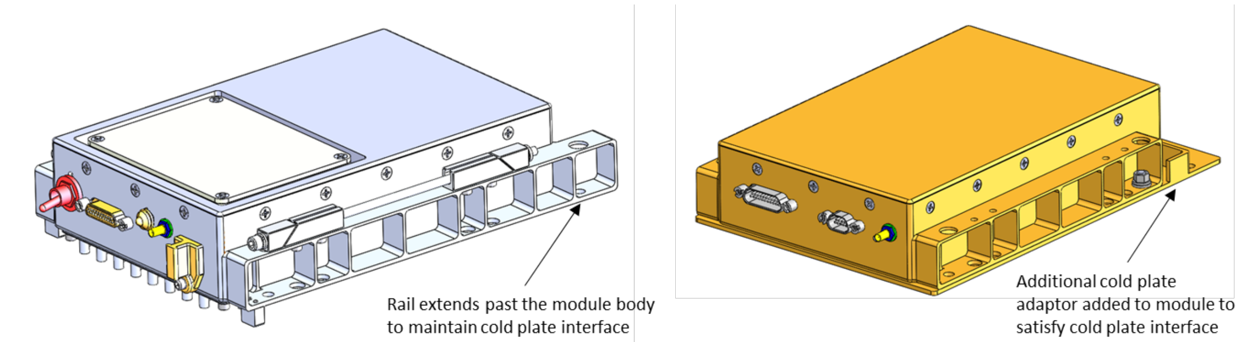


Figure 2-8. Example Reduced Length Modules

2.2.1.1.4 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.

2.2.1.1.5 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 in this manner, 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 2-4 and Figure 2-5) shall no longer be considered a minimum dimension.

2.2.1.1.6 Heatsink Size / Location

To assure thermal performance, a payload module will likely require a heatsink, further discussed in Section 2.3.2. The size/volume of the heatsink is not defined; however, the heatsink may not extend outside the payload volumes identified in Section 2.2.1. Additionally, the heatsink may be installed on either the top (Form A) or bottom (Form B) surface of the payload module, as shown in Figure 2-9.

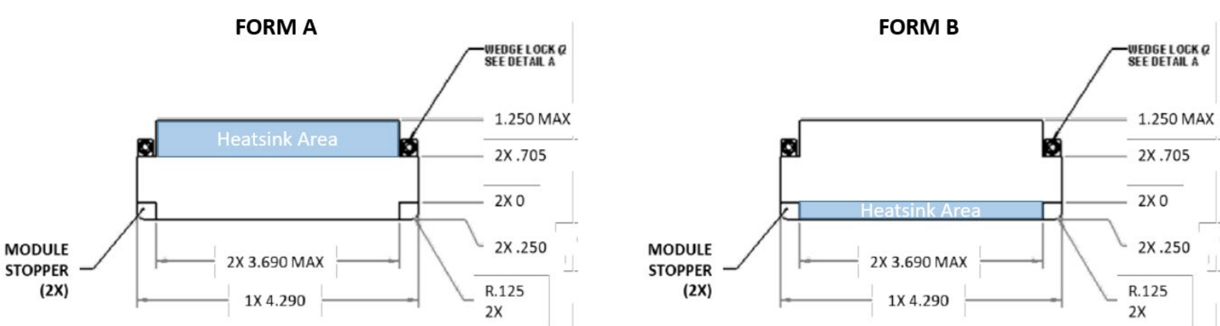


Figure 2-9. Form A and Form B Payloads

2.2.1.2 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 2-10 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), and a 0.750in x 0.880in (from the bottom and side surface).

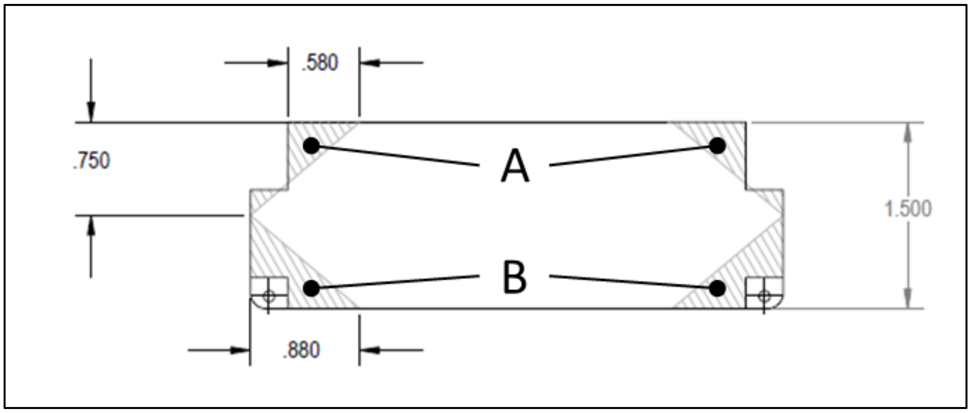


Figure 2-10. Connector Keep Out Zones

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

2.2.2 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 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 (estimated from modules that exist today) are as follows: 605g for a 1U module, 970g for a 2U module, 1160g for 3U module. These are not limits, they are merely provided for reference.

2.2.3 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 by the payload module to accommodate installation on platforms using a plate mount. Plate mounting holes shall be included on each rail. The plate mounting methodology may be used with or without the heatsink installed, typically the latter. The selection of which of the two mounting methods used for a payload module is dictated by the host platform Primary Mount (Section 3.3), so is determined by the platform integrator, not the payload vendor.

2.2.3.1 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 2-11 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.

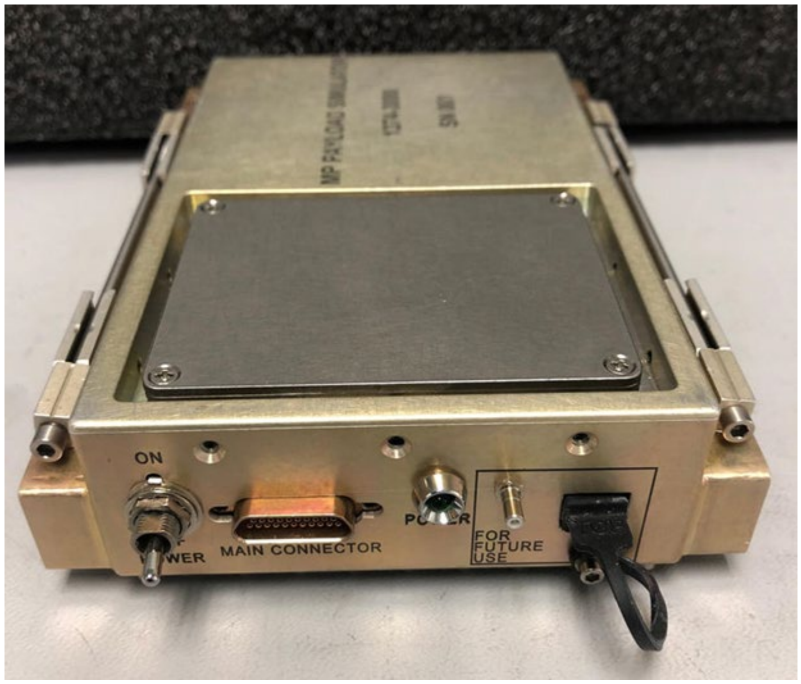


Figure 2-11. Example Payload Module Configured for Rack Mounting

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 2-12 provides the detailed wedge lock design.

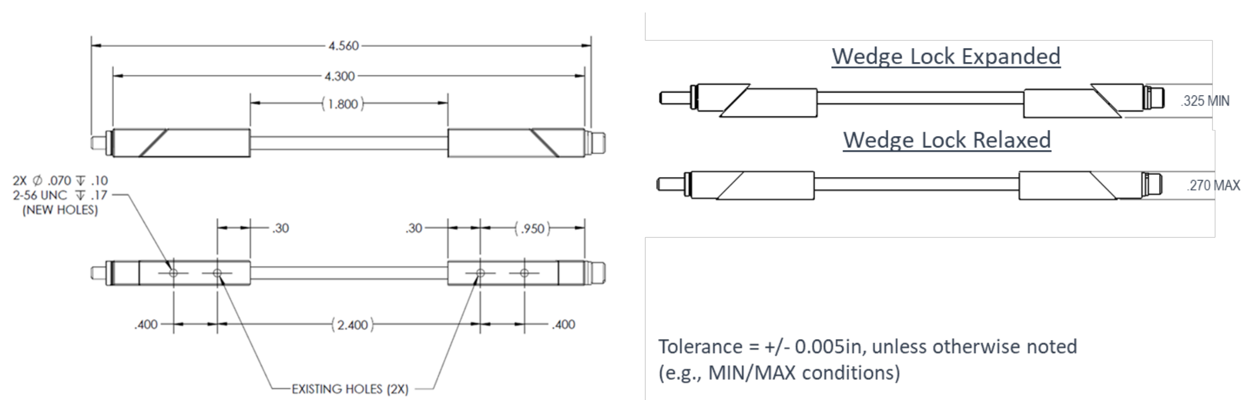


Figure 2-12. Wedge Lock Detailed Design

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

- Wakefield 426B-430SSG-W

- Birtcher 40-5-12-T, modified to be equivalent to Figure 2-12
- Birtcher 40-5-10-LF, modified to be equivalent to Figure 2-12
- Birtcher 225-4.80T2, modified to be equivalent to Figure 2-12

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

2.2.3.2 Plate Mounting Option

Each module shall also be capable of mounting to a plate-style Primary Mount. To support this requirement, the heatsink (if equipped) shall be removable from the module (along with wedge locks), allowing the module to be bolted directly to the plate structure through the mounting holes identified in Figure 2-6. Figure 2-13 illustrates a payload module with its heatsink removed to allow for mounting to a cold plate.

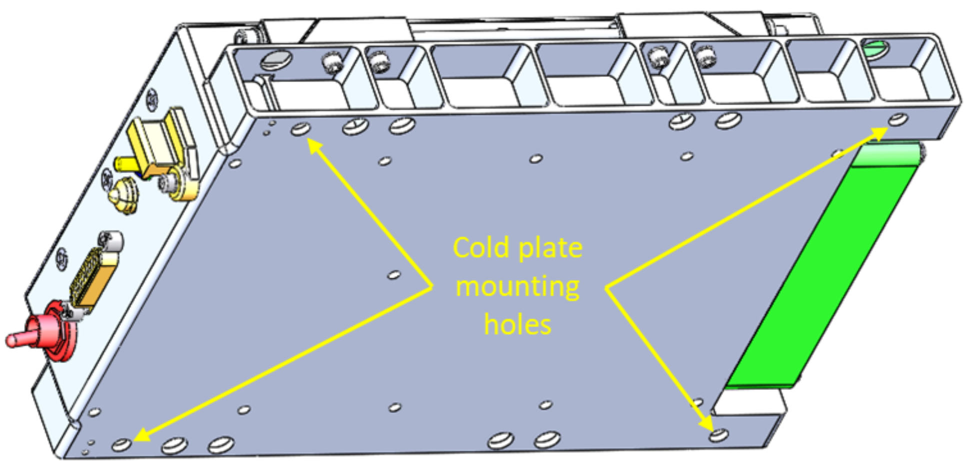


Figure 2-13. Payload Configured for Cold Plate Mounting

2.2.4 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.

2.2.5 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.

2.3 Thermal Design

Thermal design of the payload module shall be flexible to support various host platforms. 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.

2.3.1 Thermal Environment

To support platforms using convective cooling, a payload shall be able to operate at sea-level in an ambient environment of up to 45°C with a minimum of 2.5 CFM airflow over the inlet cross-sectional area of the heatsink.

To support platforms using conductive cooling, a payload shall be able to operate without airflow with a single side of the module attached to a cold plate at up to 65°C surface temperature.

The material thermal conductivity, geometry, and surface finish of the cold plate / heatsink interface surface, as well as the internal thermal design of payload, should be optimized to allow for efficient thermal dissipation to a cold plate / through a heatsink.

2.3.2 Heatsink

A removable heatsink (Figure 2-14) 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 2.2.1) and weight of the module. Since module orientation may differ between platforms, the heatsink shall be designed to function adequately regardless of the direction of airflow.

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 heat 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.

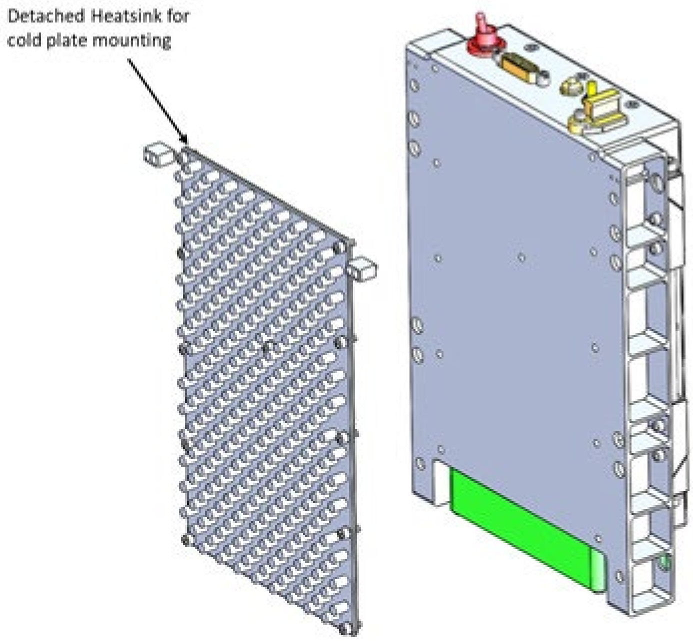


Figure 2-14. Heatsink Detached from the Bottom Surface of a Payload

2.3.3 Mounting-Cooling Pairings

As described in Section 3.3.5.1, differing mounting-cooling combinations can be employed by a platform to mount and cool a payload. Adherence to the mechanical and thermal design requirements in the previous sections should assure the payload supports all of the above mounting-cooling pairings.

2.3.4 Additional Ground Cooling

The payload vendor shall clearly identify to the integrator a payload module that requires forced convection to support bench testing, ground integration testing or pre-mission 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.

2.4 RF Design

2.4.1 RF Cabling

In general, a payload module shall use the RF cabling integrated into the platform as part of the Mod Payload A-kit. Platform RF cabling is specified in Section 3.5.2.

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

2.4.2 RF Connectors

A payload shall use SSMB-male connectors (per MIL-STD-348B Change 3) for RF connectors on the module.

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

Note: SSMB connectors are only rated up to 12 GHz. An alternate connector for higher frequency signals is under investigation and will be addressed in a future revision. In the interim, payload vendors may use their RF connector of choice to support higher frequency signals, while adhering to the above paragraph. Payloads supporting frequencies greater than 12 GHz should be provided with suitably-rated interfacing cables terminated on one side with the chosen RF connector and SMA-female on the other.

2.4.3 Antennas

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

The standard does not dictate the antenna locations on a platform. Antenna locations and orientations are determined by the integrator, so will vary across MP-compliant platforms. However, the minimum number and orientation of antenna mounts that a MP-compliant platform must support is defined in Section 3.4.1. Specific platform antenna mount implementations are documented in the Section 4.

2.4.3.1 Antenna Connectors

A payload antenna shall use either an SMA-female connector or the MP array adaptor (defined in Section 2.4.3.2.3) or be provided with the requisite RF adaptors / cabling to do so.

2.4.3.2 Antenna Adaptors

To interface to the platform antenna mounts, as defined in Section 3.4.1, 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 platform (with sufficient SWAP capacity to carry it). While each antenna adaptor is specific to the particular antenna, there are only three adaptor types supported by the MP class – a two-point (2-pt) adaptor, a four-point (4-pt) adaptor, and an array adaptor – analogous to the three types of antenna mounts to which the adaptors interface. The standardized mechanical interfaces between the platform-provided antenna mounts (A-kit) and the payload-provided antenna adaptor (B-kit) allow for rapid installation and removal and compatibility across platforms.

2.4.3.2.1 2-pt Adaptor

2-pt adaptors, as shown in Figure 2-15, are the simplest and most common (supported on all MP-complaint platform) MP antenna adaptors. They should be used to support the smallest antennas.

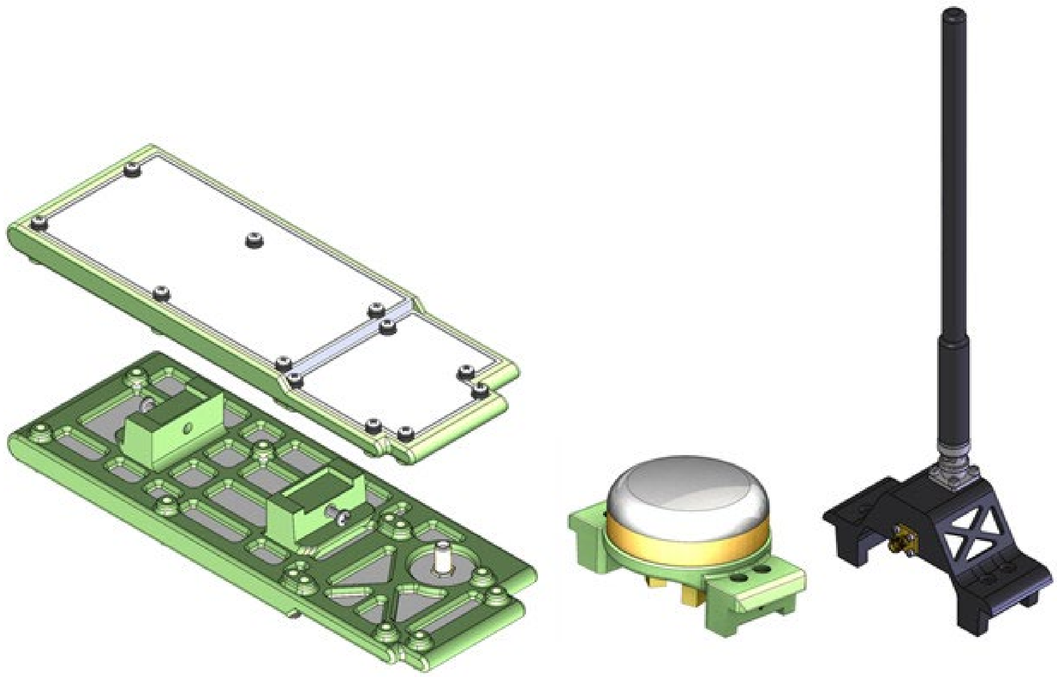


Figure 2-15. Example MP-compliant 2-pt Antenna Adaptor Assemblies

The 2-pt antenna adaptor interface is defined in Figure 2-16. 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.

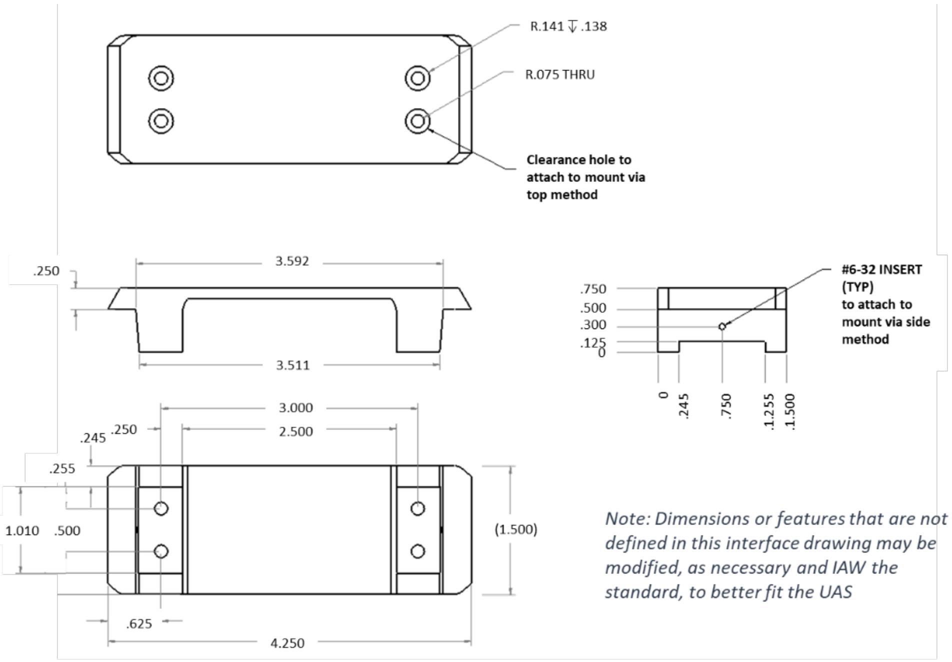


Figure 2-16. 2-pt Antenna Adaptor Interface

As evidenced in Figure 2-15 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 platform.

Note: For UAS platforms, 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.

2.4.3.2.2 4-pt Adaptor

A 4-pt adaptor, as shown in Figure 2-17, is an assembly consisting of two 2-pt adaptors. 4-pt adaptors should be used to support larger antennas on larger platforms.

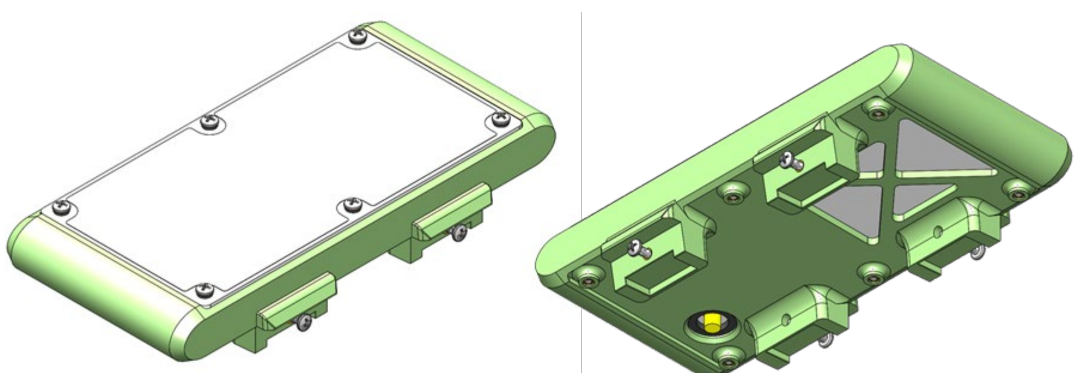


Figure 2-17. Example MP-compliant 4-pt Antenna Adaptor Assembly

The 4-pt antenna adaptor interface is defined in Figure 2-18. 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 2.4.3.2.1.

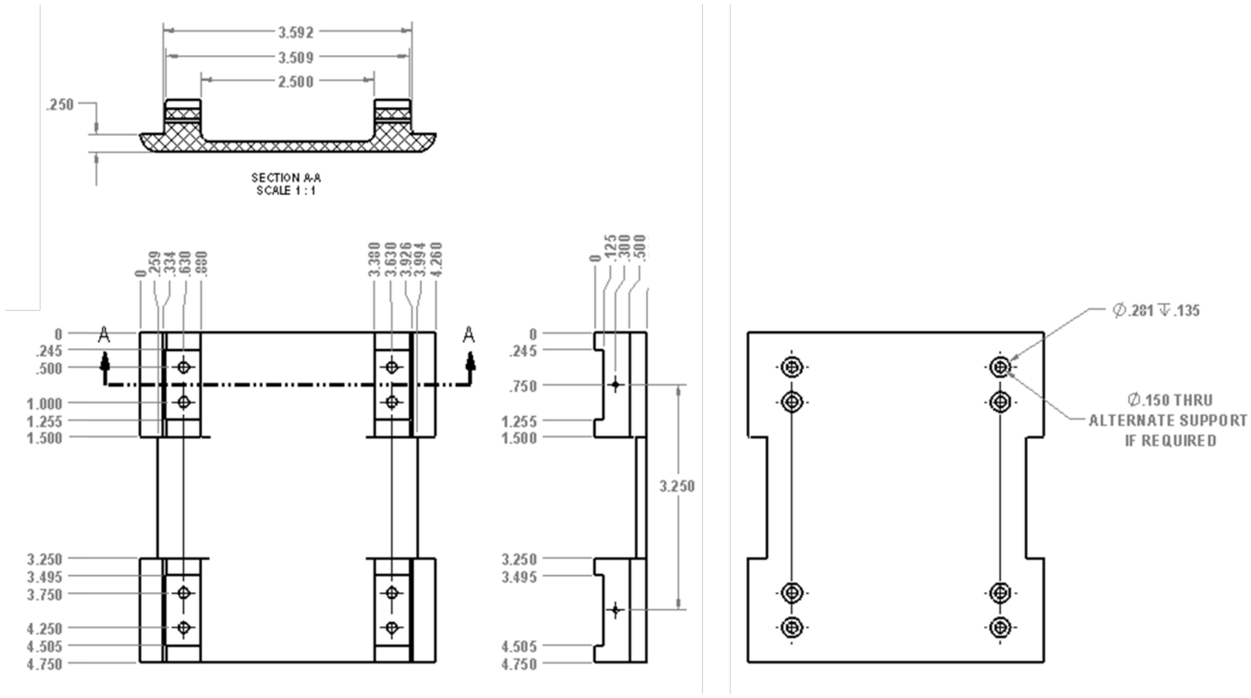


Figure 2-18. 4-pt Antenna Adaptor Interface

As evidenced in Figure 2-17 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 platform.

Note: For UAS platforms, 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.

2.4.3.2.3 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 2-19.

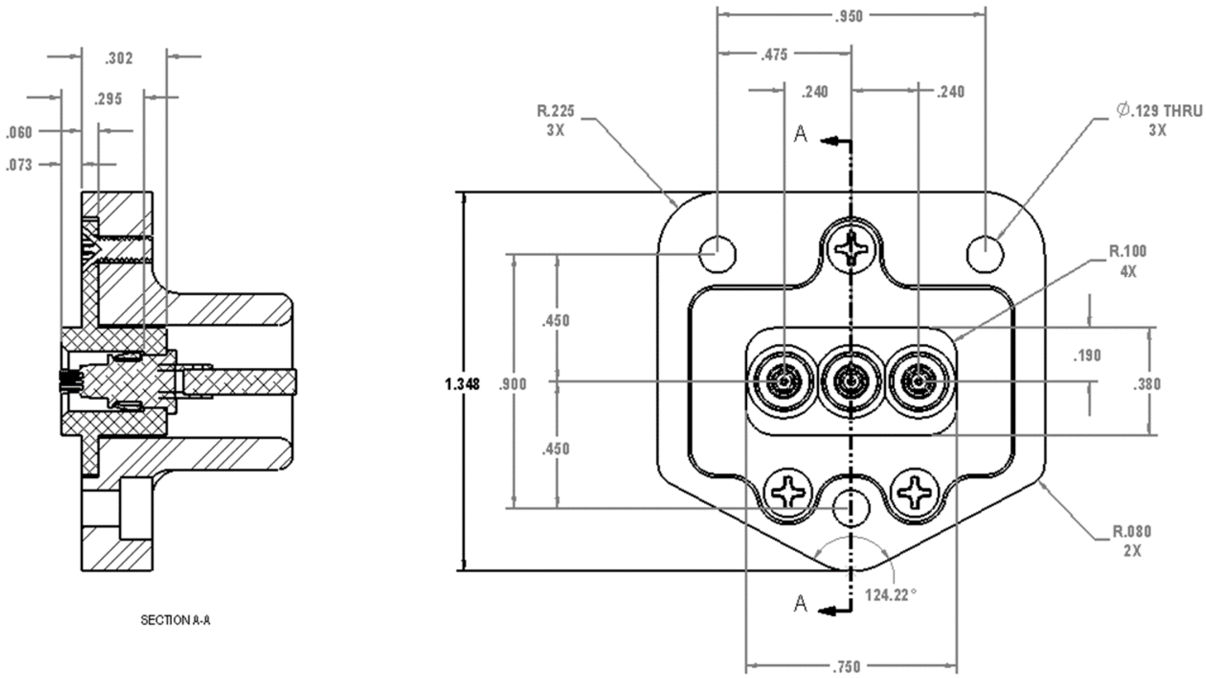


Figure 2-19. Array Adaptor Interface

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 platform. While an array interface is supported on all MP-compliant platforms, the volume available for the array adaptor will vary. Larger arrays may not be able to be installed on smaller MP-compliant platforms. For a 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 platform, whichever is determined more favorable by the integrator.

2.4.4 EMI

A payload should not have unintentional emissions that interfere with operations of major onboard platform 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 payload vendor shall provide information on the RF behavior of their system (particularly noting any deviations to the above guidance) to support frequency masking, if required.

2.5 Environmental

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

2.5.1 Shock

Per MIL-STD-810H, 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.

2.5.2 Vibration

Per MIL-STD-810H Method 514.8 Category 24, the payload shall be able to withstand the general minimum integrity testing profile as shown below. Test duration is one hour in each axis.

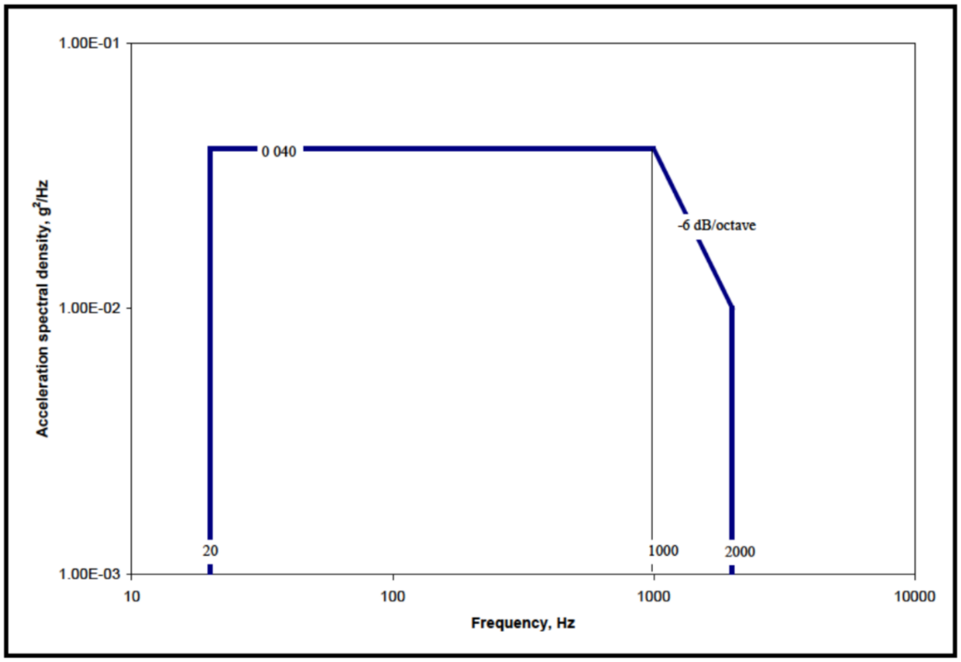


Figure 2-20. Vibration General Minimum Integrity Testing Profile

2.5.3 Ambient Temperature

Ambient temperature requirements are detailed in Section 2.3.1.

2.5.4 Storage Temperature

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

2.5.5 Sand and Dust

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

2.5.6 Salt Atmosphere

The payload should be able to endure marine conditions as would be experienced in a shipboard or littoral environment. For use in a maritime environment (such as a USV), antenna options should be offered that are waterproof (IP67) and the impact to RF performance from splashing salt water onto the antenna should be considered.

2.5.7 Humidity

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

2.5.8 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.

2.5.9 Handling

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

3. REQUIREMENTS FOR HOST PLATFORMS

Note: Platforms supported by the MP class and referenced below include: UAVs, USVs and dismounts (which technically are not platforms).

A number of requirements are levied on the platform to support modular payloads. For existing platforms, MP-compliance will likely require modifications 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 – the Mod Payload A-kit – include the development and installation of a MAIM (Mod Payload Aircraft Interface Module) and a Primary Mount, the integration of an 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 MP-compliance is much less intrusive and can be readily and more efficiently incorporated as part of the initial platform design.

To help developers accelerate the process of bringing a platform into MP-compliance, a generic TDP, containing reference electrical, mechanical and software designs was developed. This TDP is held at Distribution D and can be provided upon request and confirmation of DoD sponsorship. Similarly, payload simulators are also available to support development (laboratory and/or flight) testing. For access to the TDP or to schedule a payload simulator, contact the Mod Payload Technical Manager identified in the front matter of this document.

3.1 MAIM

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

Note: The term MAIM is used for the MP class regardless of platform, whether aircraft, surface vessel or dismount.

3.1.1 Applicability

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

3.1.2 Description

The MAIM is a circuit board or 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 MAIM should be considered an additional platform component, not a payload itself. As such, the size, weight, and payload capacity of the MAIM are not strictly defined, but should be tailored to the specific platform. As a result, the MAIM may vary substantially for different platforms.

The MAIM shall be designed in such a manner to ensure survivability in the anticipated environment on the specific platform. Environmental considerations include, but are not limited to: shock, vibration, temperature, ingress protection (fluids and solids), salt atmosphere, humidity, altitude, and handling requirements. The payload environmental requirements (Section 2.5) should be referenced for guidance.

Figure 3-1 depicts an example MAIM circuit board designed to install inside the avionics bay of a UAS and capable of supporting up to four payloads.

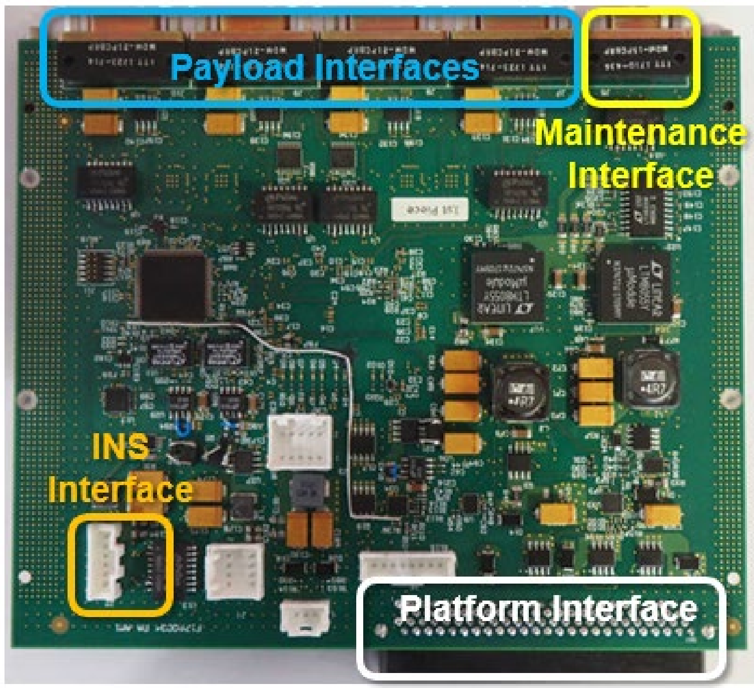


Figure 3-1. Example MAIM

3.1.3 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 section.

Figure 3-2 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.

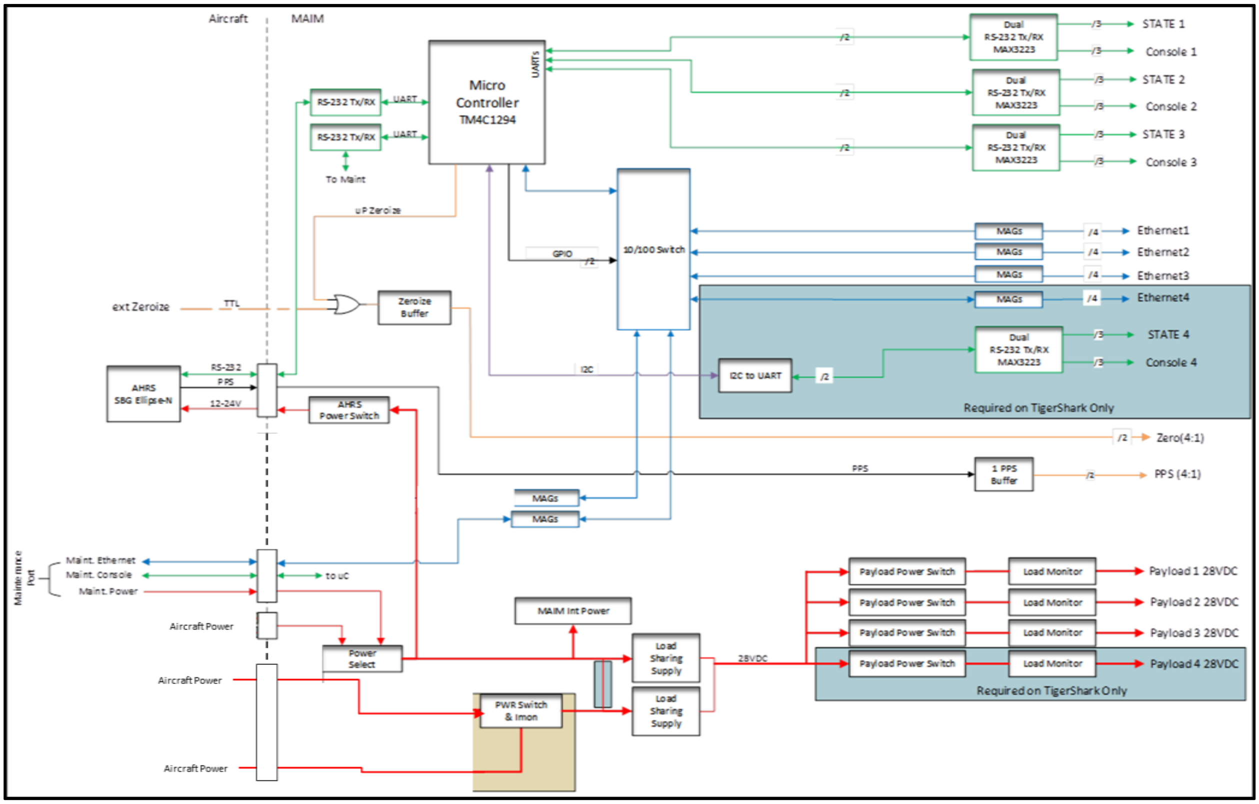


Figure 3-2. Example MAIM Block Diagram

3.1.4 Interfaces

The MAIM shall provide each payload the following interfaces:

- Power (as described in Section 3.1.4.1)
- Serial – state (as described in Section 3.1.4.2)
- Serial – console (as described in Section 3.1.4.4)
- Ethernet (as described in Section 3.1.4.3)
- 1PPS (as described in Section 3.1.4.5)
- Zeroize (as described in Section 3.1.4.6)

No specific connector or pinout is mandated for the MAIM itself. The interface connector is only specified on the payload (Section 2.1.4). 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 platform integrator.

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

3.1.4.1 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 be able to support at least a 4A, 5ms inrush on each payload interface.

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. In some cases, the MAIM should automatically secure power to the payload. Table 3-1 below provides different power states the MAIM may encounter and required / recommended MAIM responses under those conditions.

Note: "Recommendations" can be considered optional – the MAIM can power off any payload in any of the non-compliant power states.

Table 3-1. MAIM Power States

	Compliant States		Non-Compliant States			
Power State	**112W / 4A**	**<= 56W / 2A**	**>56W / 2A <= 84W / 3A**	**> 84W / 3A <= 112W / 4A**	**> 84W /3A <= 112W /4A**	**112W /4A**
Duration	**<= 5 ms**	**Any**	**Any**	**< 5 s**	**>= 5 s**	**> 5 ms**
Description	Max allowable payload in-rush	Max allowable payload steady state	Exceeding max steady state power (minor)	Exceeding max steady state power (major, brief)	Exceeding max steady state power (major, extended)	Exceeding max in-rush
Enforcement	**Required**	**Required**	Recommended	Recommended	Recommended	Recommended
MAIM Electrical Response	None	None	Electrically limit power to prevent damage to interfaces	Electrically limit power to prevent damage to interfaces	Electrically power off	Electrically power off
MAIM GUI Response	None	None	Yellow Alert Notification	Red Alert Notification	Red Alert Notification, Power Indicator OFF	Red Alert Notification, Power Indicator OFF

For platforms supporting more than one payload connection, the MAIM shall support higher power payloads. To support payloads requiring greater than 56W (see Section 2.1.1), 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. The MAIM shall provide this functionality regardless of how the payload uses the multiple interfaces, including, but not limited to, uneven current draw, isolating the interfaces, shorting the interfaces together, or losing connection to one of the interfaces. Additionally, the MAIM shall prevent a payload interface from back feeding into opposing interface ports.

3.1.4.2 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. 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 meeting the specification defined in this standard (see Section 3.2) are approved to be used with Mod Payload compliant payloads. If an alternate INS were to be used that did not meet the specification, this would be an exception to compliance and must be clearly conveyed on all references to Mod Payload compliance.

3.1.4.2.1 State Data over Ethernet

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 platform integrator. To utilize this communications mechanism, the network must have implemented an IP stack supporting multicast groups via IGMP.

The MAIM shall re-package the state data from the INS into a JavaScript Object Notation (JSON) message structure to distribute the data over Ethernet. The MAIM shall transmit these JSON messages at the rates shown in the table below.

Table 3-2. JSON Message Rates

JSON Message	Hz
MAIM_VER	1
STATUS	1
IMUNAV	10
PRESSURE	1
TPV	1
ATT	10
SKY	1
ADDL	1

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

The time between the receipt of the last required incoming message from the INS and the transmission of the outgoing state message from the MAIM shall be minimized. For an outgoing state message rate slower than the incoming INS message rate(s), the last incoming message(s) prior to the outgoing message shall be used to generate the content of the outgoing message. When incoming and outgoing message rates do not align, the transmission of outgoing messages shall be synchronized to the incoming message(s) from the INS such that outgoing messages are sent upon receipt of the last required incoming message. In the event one of the incoming messages that make up the outgoing message is missed or dropped, the entire outgoing message should be dropped.

The size of the messages sent over the Ethernet connection shall not exceed the maximum transmission unit (MTU) of 1500 bytes.

3.1.4.2.2 State Data over Serial

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 serial interface shall be a unidirectional interface from the MAIM to the Payloads. The following signals shall not be connected at the MAIM: DTR, DCD, DSR, RI, RTS, RTR, CTS.

The MAIM shall package the state data from the INS into the sbgECom message structure (regardless of INS used) to distribute the data over serial. The MAIM shall distribute the sbgECom binary state messages at the rates shown in the table below.

Table 3-3. sbgECom Message Rates

sbgECom Message	Hz
SBG_ECOM_CMD_INFO (04),	ON STARTUP
SBG_ECOM_LOG_STATUS (01)	1
SBG_ECOM_LOG_UTC_TIME (02)	20
SBG_ECOM_LOG_IMU_DATA (03)	20
SBG_ECOM_LOG_MAG (04),	20
SBG_ECOM_LOG_EKF_EULER (06)	20
SBG_ECOM_LOG_EKF_NAV (08)	20
SBG_ECOM_LOG_GPS1_VEL (13)	5
SBG_ECOM_LOG_GPS1_POS (14)	5
SBG_ECOM_LOG_PRESSURE (36)	1

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

The MAIM shall also distribute the NMEA state messages at the rates shown in the table below.

Table 3-4. sbgECom NMEA Message Rates

sbgECom NMEA Message	Hz
SBG_ECOM_LOG_NMEA_GGA (0x00)	1

The sbgECom NMEA messages are detailed in Appendix A, Section A.4.

The time between the receipt of the last required incoming message from the INS and the transmission of the outgoing state message from the MAIM shall be minimized. For outgoing state message rate slower than the incoming INS message rate(s), the last incoming message(s) prior to the outgoing message shall be used to generate the content of the outgoing message. When incoming and outgoing message rates do not align, the transmission of outgoing messages shall be synchronized to the incoming message(s) from the INS such that outgoing messages are sent upon receipt of the last required incoming message. In the event one of the incoming messages that make up the outgoing message is missed or dropped, the entire outgoing message should be dropped.

3.1.4.3 Network Connectivity

To support remote operations, typical of most UxV, the MAIM shall create an IP payload network connected to the platform 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 platform integrator; the payload system shall conform to the determined scheme.

For platforms which are not remotely operated (e.g., dismounts, manned platforms) the backhaul connection does not apply, however, the network requirements are otherwise effectively the same in most cases. Figure 3-3 below depicts an example Ethernet network for a MP-compliant platform.

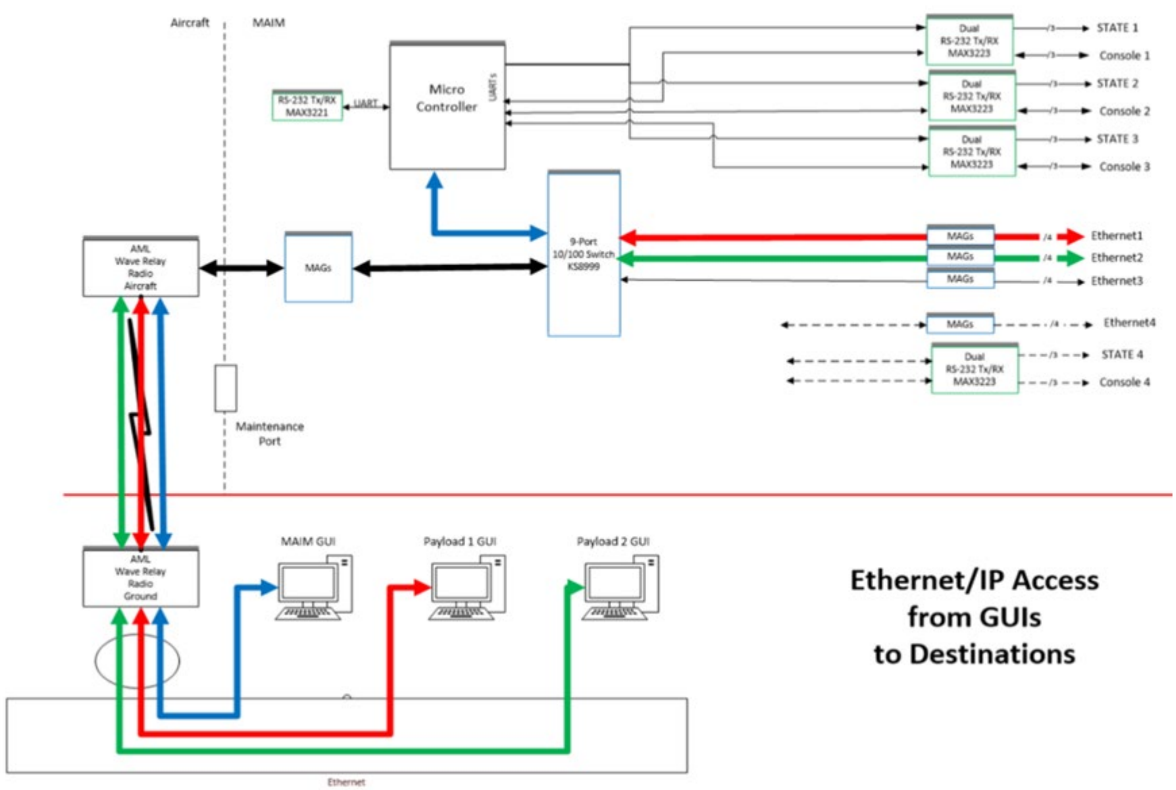


Figure 3-3. Example MAIM-Payload Network Connections

3.1.4.4 Serial Console

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 platform integrator; a payload ground system requiring this connection shall conform to the determined scheme. Figure 3-4 below depicts an example serial console network for a MP-compliant platform.

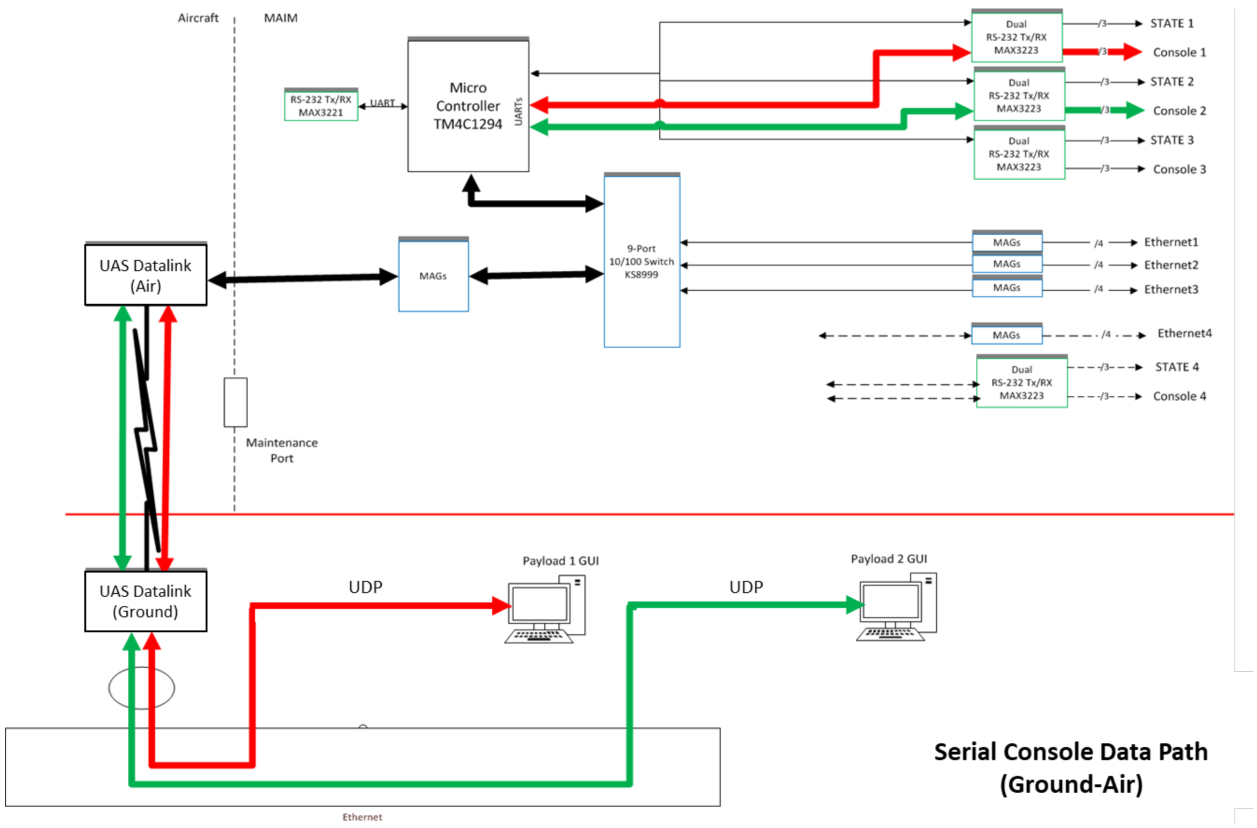


Figure 3-4. Notional Air-Ground Payload Console Connections

3.1.4.5 Time Synchronization

The MAIM shall receive and re-transmit the 1PPS signal from the INS (or an equivalent 1PPS source native to the platform) 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 – a differential signal with a 1.2V offset and a voltage swing of 247-454mV with a load of 100 ohms.

3.1.4.6 Zeroize

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

- Platform 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 – a differential signal with a 1.2V offset and a voltage swing of 247-454mV with a load of 100 ohms.

Note: The notion of a zeroizing standard for the UxV 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.

3.1.5 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.

3.1.5.1 Firmware

The MAIM embedded firmware shall provide the following functions:

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

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

3.1.5.2 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 system 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 operator.

3.1.5.2.1 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 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 3-5, Figure 3-6 and Figure 3-7 below.

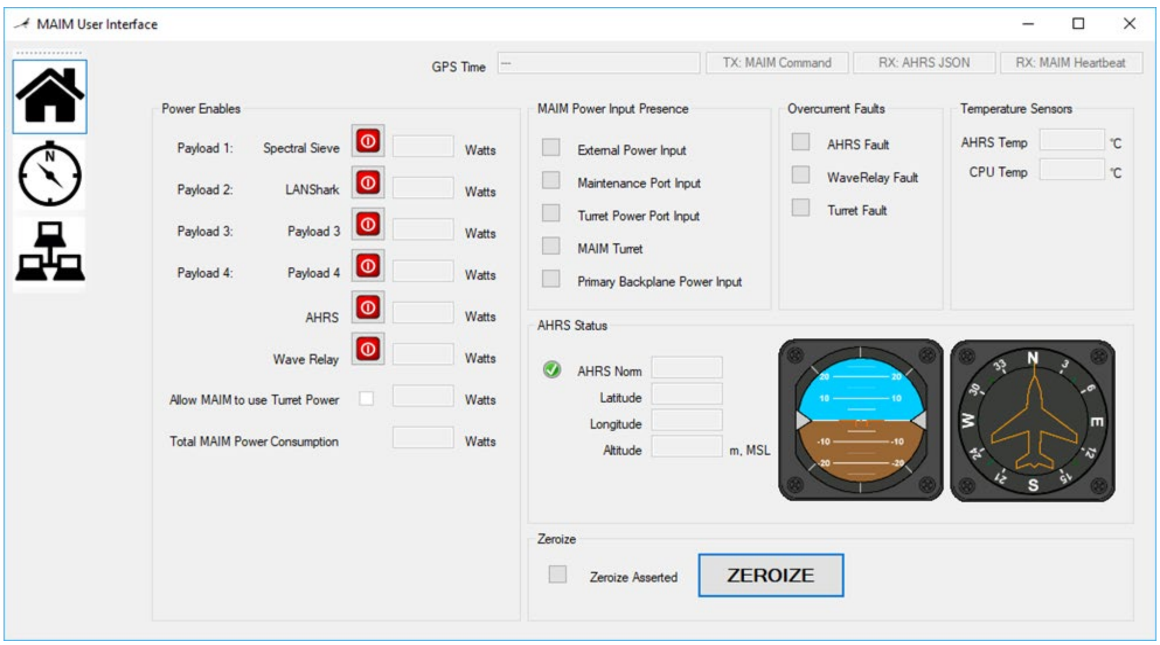


Figure 3-5. Example MAIM GUI Home Page

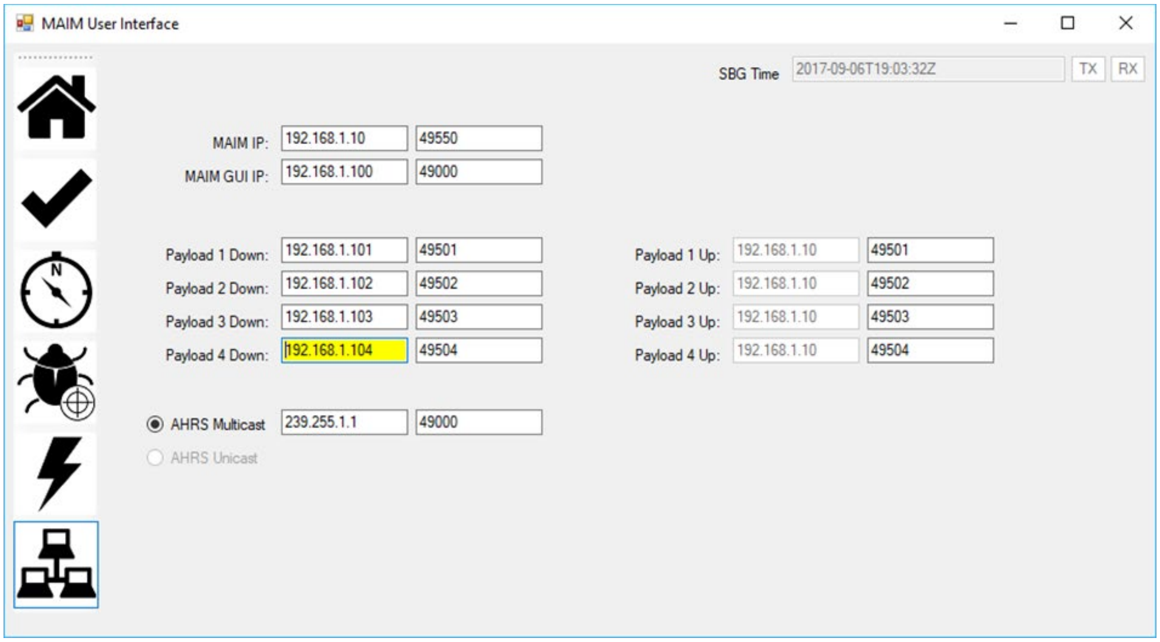


Figure 3-6. Example MAIM GUI Networking Page

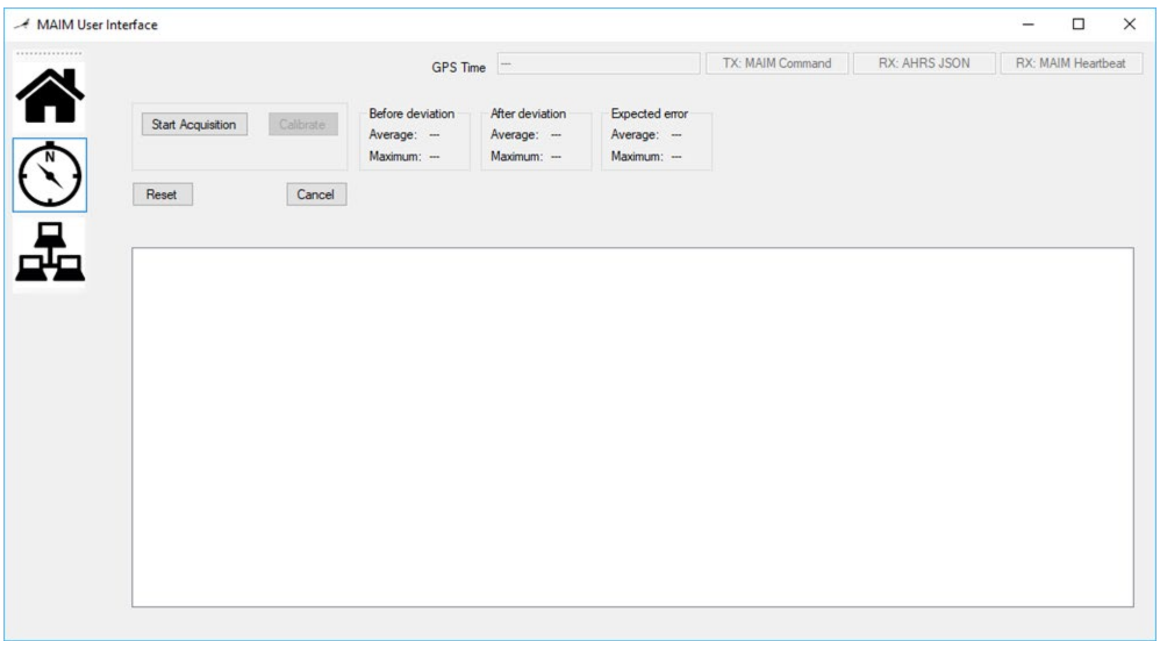


Figure 3-7. Example MAIM GUI INS Calibration Page

3.1.6 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 payloads. This maintenance connection should provide sufficient power to allow the MAIM to power itself, the INS and at least one 56W payload, simultaneously.

3.2 INS

Some MP-compliant payloads require a higher accuracy INS than those native to a platform. To meet the requirements of these payloads, a dedicated, high accuracy INS may need to be installed on the platform as part of the Mod Payload A-kit. Position, velocity, attitude, and timing information from the MP-compliant INS shall be transmitted to the MAIM for distribution to the payloads.

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

3.2.1 Technical Specifications

The INS provided to support Mod Payload must meet the specifications listed in Table 3-5.

Table 3-5. Mod Payload INS Performance Requirements

Data Sheet Parameter	Minimum Spec
2D Position Accuracy	2.0m ,CEP
Altitude Accuracy	2.5m
Yaw Accuracy (1σ)	0.5°
Pitch Accuracy (1σ)	0.1°
Roll Accuracy (1σ)	0.1°
Output Data Rates	iaw Section 3.1.4.2
1PPS Stability	+/- 20ns
1PPS Drift	100µs/hr

Note: INS specifications published on datasheets should not be taken at face value without first validating the position and attitude accuracy of the device in a Mod Payload integration on the candidate platform with representative operational dynamics. Further, different installation environments and operating conditions may lead to differences in a particular INS's expected accuracy.

3.2.1.1 Vetted INS Options

The following INS have been demonstrated to meet the above specification:

Table 3-6. MP-Approved INS

Vendor	Model	Part Number	Firmware
SBG Systems	Ellipse-N v2	ELLIPSE2-N-G4A3-B1	1.3.178-stable
SBG Systems	Ellipse-N v3	ELLIPSE-N-G4A3-B1	2.5.169-stable
VectorNav	VN-200	VN-200T-CR, HW v3	2.0.0.1
VectorNav	VN-210	VN-210, HW v3	1.4.1.0
VectorNav	VN-210E	VN-210E, HW v2	1.4.2.0
Advanced Navigation	Spatial	Spatial, HW v8.0	6.4
Inertial Sense	IMX-5 Dual	IMX, HW v5.0.3	1.11.0 Build 9

While all approved INS are sufficient for MP, each INS has differing attributes. Platform vendors should consider each INS and select the best performer for their specific platform.

3.2.2 INS Installation

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

3.2.2.1 Physical Orientation

The INS should be mounted in a position that fixes its orientation and position on the platform. The INS coordinate frame should be aligned with the platform cardinal points. Any deviation in the INS orientation in relation to the platform 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 platform'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.

3.2.2.2 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, vibration isolating mounts should be utilized to mitigate the negative effects.

3.2.2.3 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.

3.2.2.4 Temperature Consideration

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

3.2.2.5 Installation Testing

After an INS position is selected and all the guidelines are met, INS placement testing should be conducted as part of the platform integration / compliance effort; this includes both a ground test and a flight or sea test. Additionally, INS placement testing should be repeated should any major changes be introduced to the platform configuration or architecture. 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.

3.2.3 INS Configuration

Each MP-compliant INS is designed to be able to operate in a number of dynamic vehicle environments. The various platform environments pose many unique challenges when trying to achieve optimum INS performance. The INS vendor's documentation should be consulted to determine the configuration that optimizes INS performance for the specific platform operations. As a reference, Table 3-7 provides the configuration settings demonstrated to achieve this performance with one of the MP-approved INS on a UAS (refer to the SBG documentation for the exact description of each setting).

Table 3-7. INS Configuration Summary

SBG Ellipse Configuration Settings	Value
SBG Ellipse Firmware	V.1.9.618 (dated March 2020)
SBG Ellipse World Magnetic Model	WMM2020
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

3.2.4 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 executing a platform-appropriate calibration routine.

A successful UAS magnetometer calibration typically has these basic requirements:

- Set the INS into magnetometer calibration mode

- 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 INS out of magnetometer calibration mode

A successful USV magnetometer calibration typically has these basic requirements:

- Set the INS into magnetometer calibration mode
- 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.
- Conduct an appropriate pattern so that the INS can take measurements across a range of azimuth and roll angles. Small, low speed circles (both clockwise and counterclockwise) are the recommended calibration pattern. On a typical small USV (~6ft class), this consists of small, manually controlled repeated circles at a low speed (nominally ~1-2kts) of a small diameter (nominally 2-3m). This is first completed in a clockwise direction (~5 circles) followed by the counterclockwise direction (~5 circles).
- Once the full pattern has been completed, take the INS out of magnetometer calibration mode.

A successful magnetometer calibration on a dismount typically has these basic requirements:

- Set the INS into magnetometer calibration mode
- Minimize large, time-varying magnetic field activity in the area, as possible
- Conduct an appropriate pattern so that the INS can take measurements across a range of azimuth and roll angles. Assuming the INS is installed centered on the back of the dismount, the operator should bend forward at the waist and rotate slowly (both clockwise and counterclockwise), then repeat bending backwards and sideways
- Once the full calibration pattern has been completed, take the INS out of magnetometer calibration mode.

The magnetometer does not need to be calibrated on every mission, unless the local magnetic environment has changed significantly. 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.

3.3 Primary Mount

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

3.3.1 Applicability

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

3.3.2 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 interface, minimize weight, provide sufficient thermal dissipation for payloads, and endure platform loading.

The Primary Mount shall support a total volume, as well as a number of payloads commensurate with the platform capacity. There is NO direct association between the volume 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 in use across the community. A robust implementation would be 6U of capacity or more.

Example Primary Mounts are illustrated in Figure 3-8 below.

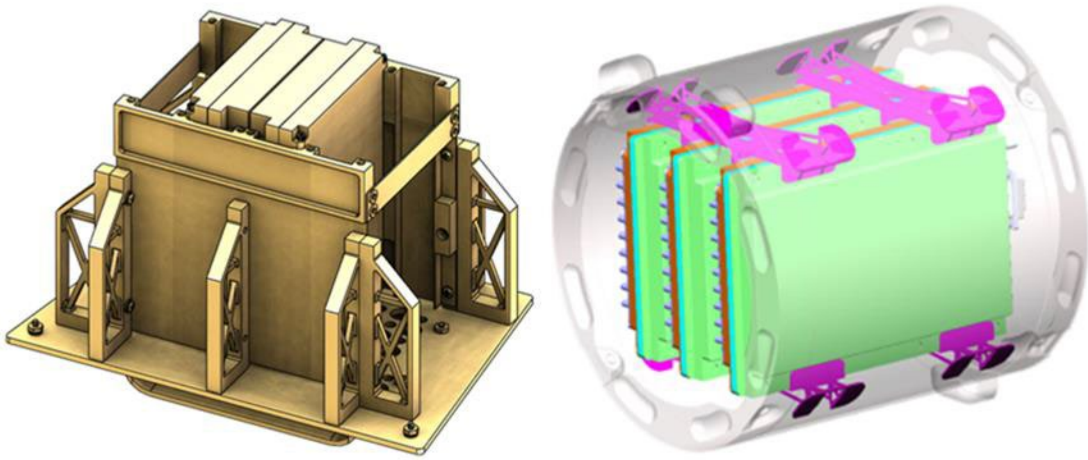


Figure 3-8. TigerShark 4U (left) and ScanEagle 3U (right) Primary Mounts

3.3.3 Mechanical Interfaces

The Primary Mount shall provide one of two mechanical 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 2.2. However, to assure the Primary Mount accommodates MP-compliant payloads and reduce the design efforts of the platform integrator, Figure 3-9 provides a reference design for an MP-compliant rack interface and Figure 3-10 provides a reference design for an MP-compliant plate interface. Necessary hardware for mounting to a plate interface is provided by the platform vendor. If not specified by the standard, any fastener attributes (e.g., bolt length, head style) are also determined by the platform vendor.

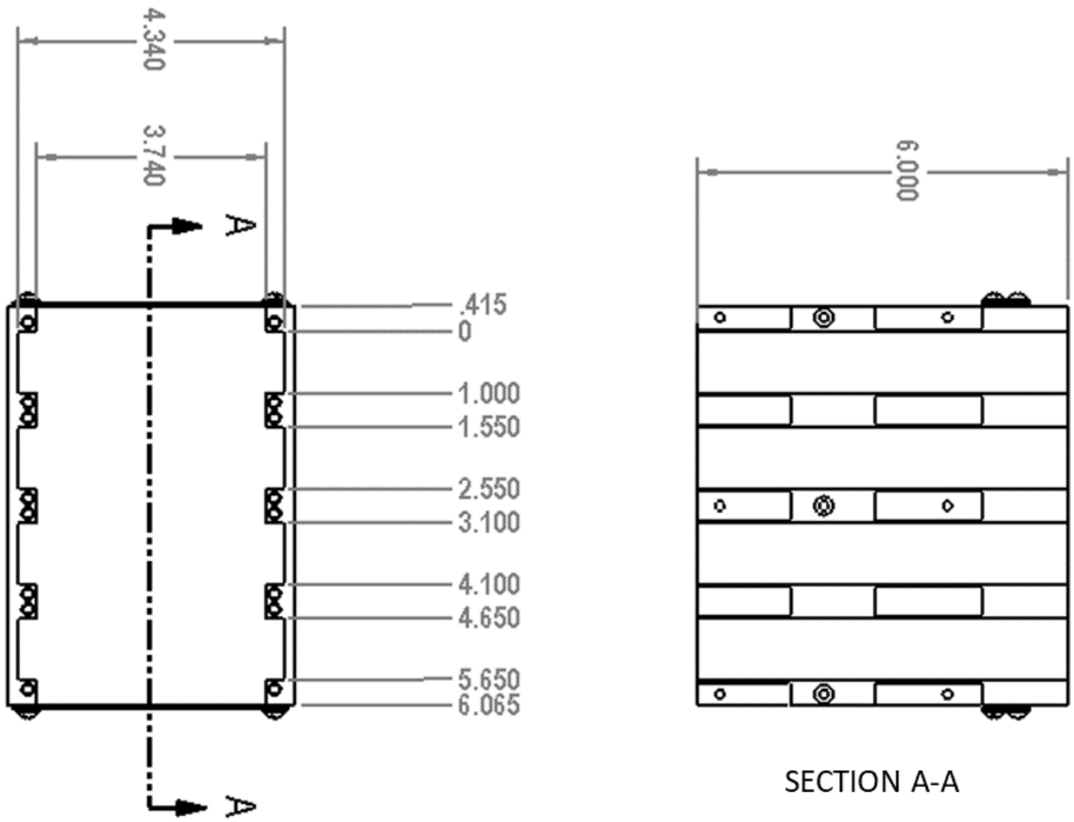


Figure 3-9. MP-compliant Rack Primary Mount Interface

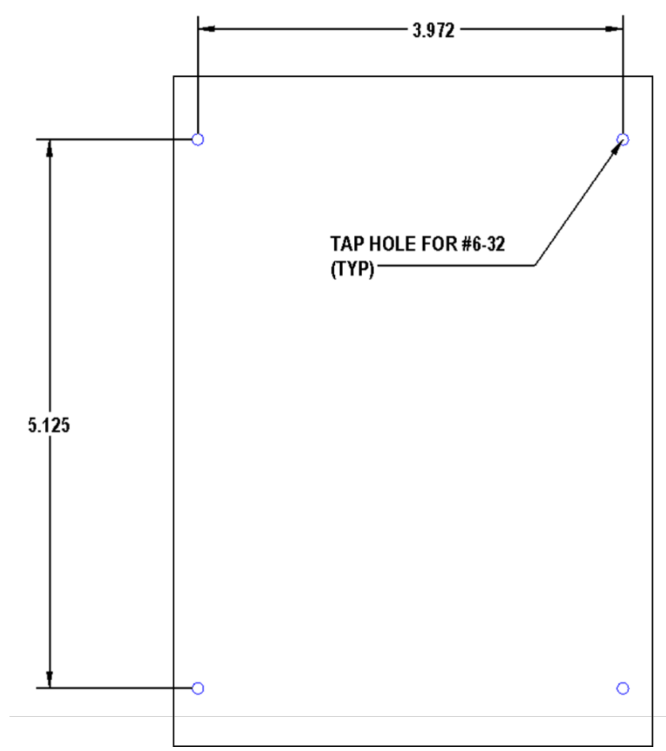


Figure 3-10. MP-compliant Plate Primary Mount Interface

3.3.4 Module Compatibility

The Primary Mount shall be designed to accommodate all sizes of modules, up to the maximum size supported by the platform. 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.

3.3.5 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 airflow of 2.5 CFM at no greater than 45°C shall be provided over the inlet cross-sectional area of the payload heatsink. If the location of the heatsink as installed in the Primary Mount is ***not*** dictated by the Primary Mount design (it is recommended to ***not*** dictate payload heatsink location as payload heatsink location can be on either the top or bottom surface of the payload), this minimum airflow shall be provided over all possible payload heatsink locations.

Note: the 2.5 CFM requirement applies only over the payload heatsink cross-sectional area not over the whole cross-sectional area of the Primary Mount. The total airflow through the Primary Mount will likely need to be significantly higher to achieve the 2.5 CFM over the heatsink cross-sectional area, as most of the airflow will pass through the unoccupied space in the Primary Mount.

If a fan is employed to provide the required airflow, as would be the case for a dismount A-kit, the acoustic signature of such a fan shall be characterized and documented. For dismount operations, consideration should be made to select a fan with a low acoustic signature. Additionally, the fan shall be controllable (able to turn on / off) by the operator via the EUD.

For conductive cooling, a cold plate shall 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.

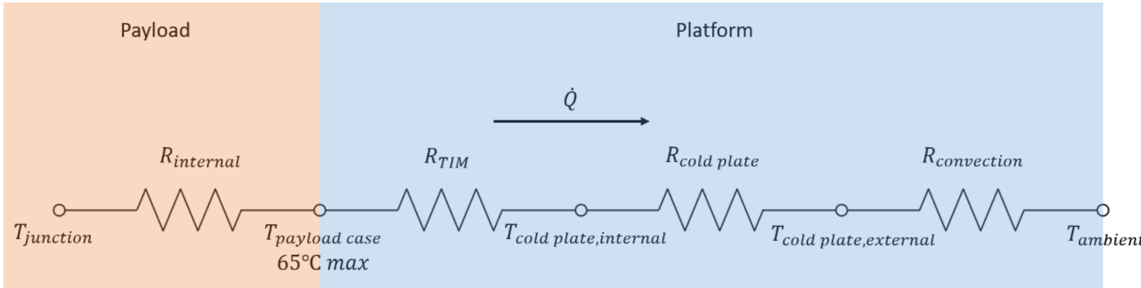


Figure 3-11. Cold Plate Thermal Resistance Diagram

The complete thermal resistance path (Figure 3-11) should be considered when designing a cold plate, including material thermal conductivities, geometry, and surface finish of interfacing surfaces. Additionally, it is recommended to provide sufficient applicable thermal interface material (thermal gap pad, thermal grease, etc.) for application between payload and cold plate.

Note: when using thermal interface material, its thermal resistance shall be considered when designing to ensure that the maximum payload power available for the platform can be transferred through the thermal resistance path while not exceeding the cold plate temperature limit at the payload interface location.

3.3.5.1 Mechanical-Thermal Pairings

The heat dissipation method was intended to be specifically coupled to the mechanical interface method – rack-style mount for convective cooling and plate-style mount for conductive cooling. These pairings, however, are not explicitly required. A plate-style mount has also been shown to be effective for convective cooling, though this method is less straightforward and requires extra consideration during the design process (and possibly additional parts) to support all payload sizes. For example, the Stalker UAS utilizes plate mounting points, but retains the heatsink on the payload (see Section 4.4). There have been no implementations of a rack-style mount with conductive cooling, and this method is not considered acceptable.

Table 3-8 summarizes the acceptable mounting-cooling pairings a platform may use.

Table 3-8. Payload Mounting-Cooling Pairings

Primary Mount	Mechanical Interface	Thermal Dissipation Method
Rack	Rack (wedgelock)	Convection
Cold Plate	Plate	Conduction
Hybrid	Plate	Convection

3.3.6 Accessibility

When supporting multiple payloads, a Primary Mount shall provide a means for installation / removal of a payload without affecting other payloads, i.e., removal of an individual module shall not require removal of an adjacent module.

3.3.7 Environmental Requirements

The Primary Mount shall survive loading, shock, and vibration commensurate with all phases of operation of the specific platform – launch, recovery, and mission. The Primary Mount should provide the payloads with necessary environmental protection based upon the expected operational environment of the platform. As an example, if Primary Mount location is expected to be exposed to splashing water, the Primary Mount design shall include IP64 splash-proof protection for payloads.

Additionally, Section 2.5 defines the environmental requirements for MP-compliant payloads, the platform integrator should reference these requirements for further guidance.

3.4 Antenna Mounts

As part of the MP architecture, platforms shall be equipped with antenna mounts at various locations along the platform to accommodate payload antennas. Antenna mounts are the platform (A-kit) side of the MP antenna interface, while antenna adaptors (defined in Section 2.4.3.2) are the payload (B-kit) side of the MP antenna interface. Figure 3-12 illustrates a number of *potential* antenna mount locations on a notional UAS.

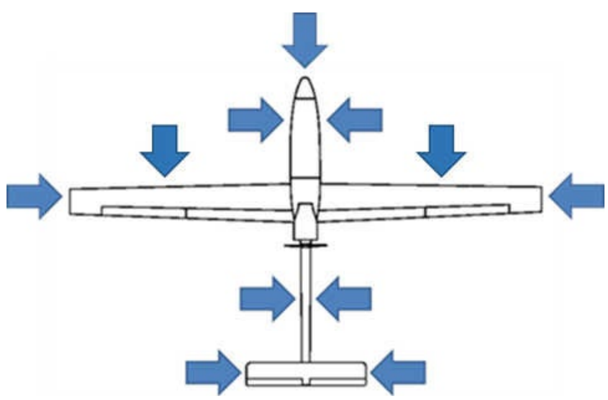


Figure 3-12. Possible MP Antenna Placements

3.4.1 Antenna Mount Requirements

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

3.4.1.1 Configurations

Table 3-9 defines the minimum antenna mount configuration required by platform type. These configurations are driven by the antenna requirements of the various MP-compliant payloads. Additional mounts are recommended for platforms capable of carrying multiple payloads concurrently.

Table 3-9. Minimum Antenna Mount Requirements

UAS	USV	Dismount
1 side look or 45° 2-pt or 4-pt	1 side look 2-pt or 4-pt	1 forward look 2-pt or 4-pt
1 up look, 1 down look (concurrent) 2-pt or 4-pt	1 up look 2-pt or 4-pt	1 up look 2-pt or 4-pt
1 array	1 array	1 array

For examples of the dynamic range of antenna mount provisions across very different platforms, see the implementations in Section 4.

3.4.1.2 Two-Point Mount

2-pt mounts, as shown in Figure 3-13, are the simplest and most common MP antenna mount. 2-pt mounts should be used to support the smallest antennas.

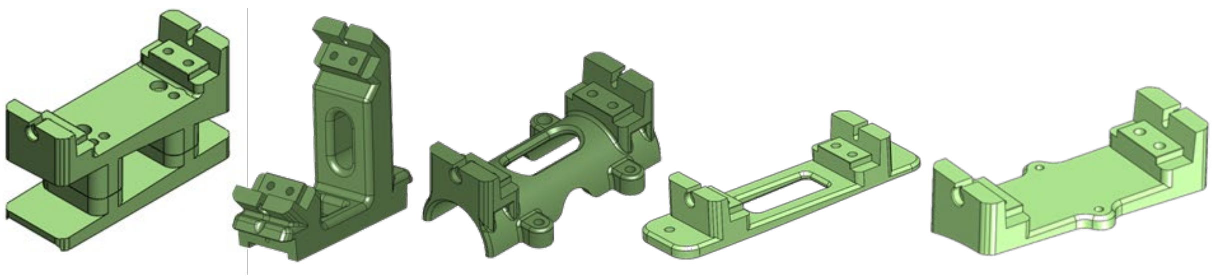


Figure 3-13. Example MP-compliant A-kit 2-pt Mounts

The 2-pt antenna mount interface is defined in Figure 3-14. 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.

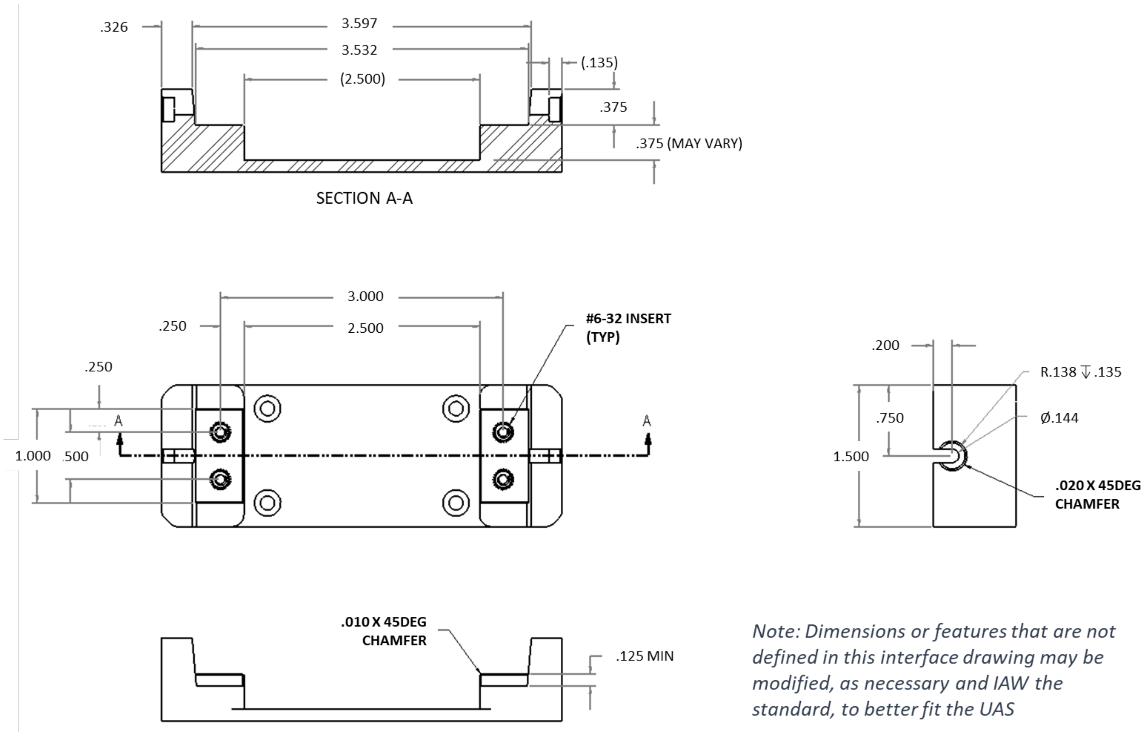


Figure 3-14. MP-compliant 2-pt Antenna Mount Interface

Though shown with a flat base in Figure 3-14, the antenna mount interface is only defined by the opposing facets and the separation between them. As evidenced in Figure 3-13 above, the requisite 2-pt mount interface should be incorporated into a platform-specific mount to best conform to the platform design. Whenever possible, a 2-pt mount should be oriented with its two facets along the fore-aft axis of the platform, as shown in Figure 3-15.

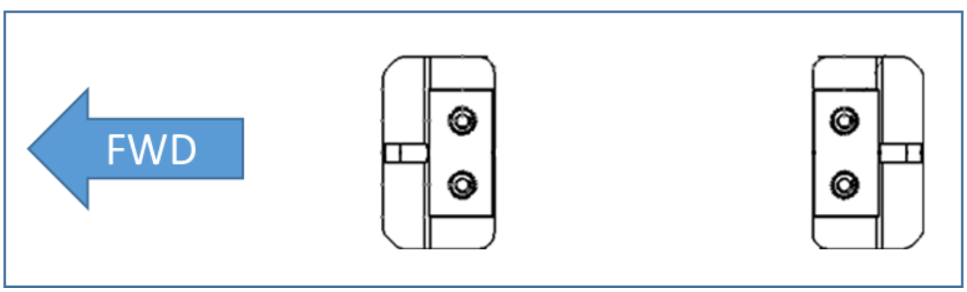


Figure 3-15. MP-compliant 2-pt Mount Preferred Orientation

3.4.1.3 Four-Point Mount

A 4-pt mount, as shown in Figure 3-16, is simply a pair of 2-pt mounts. 4-pt mounts should be used to support larger antennas on larger platforms.

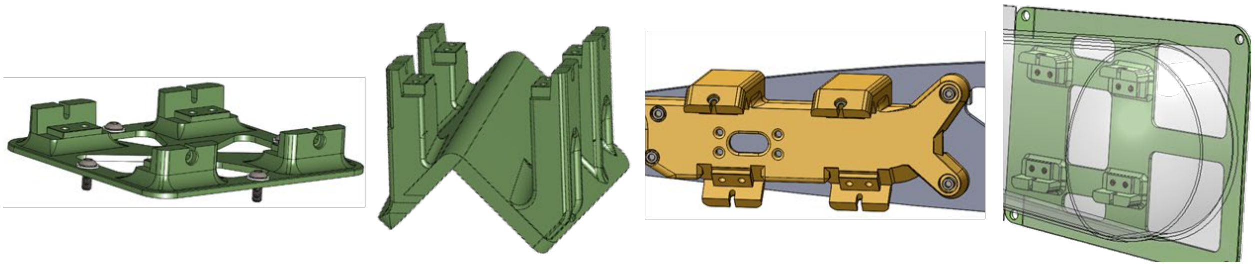


Figure 3-16. Example MP-compliant 4-pt Mounts

The 4-pt antenna mount interface is defined in Figure 3-17. 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.

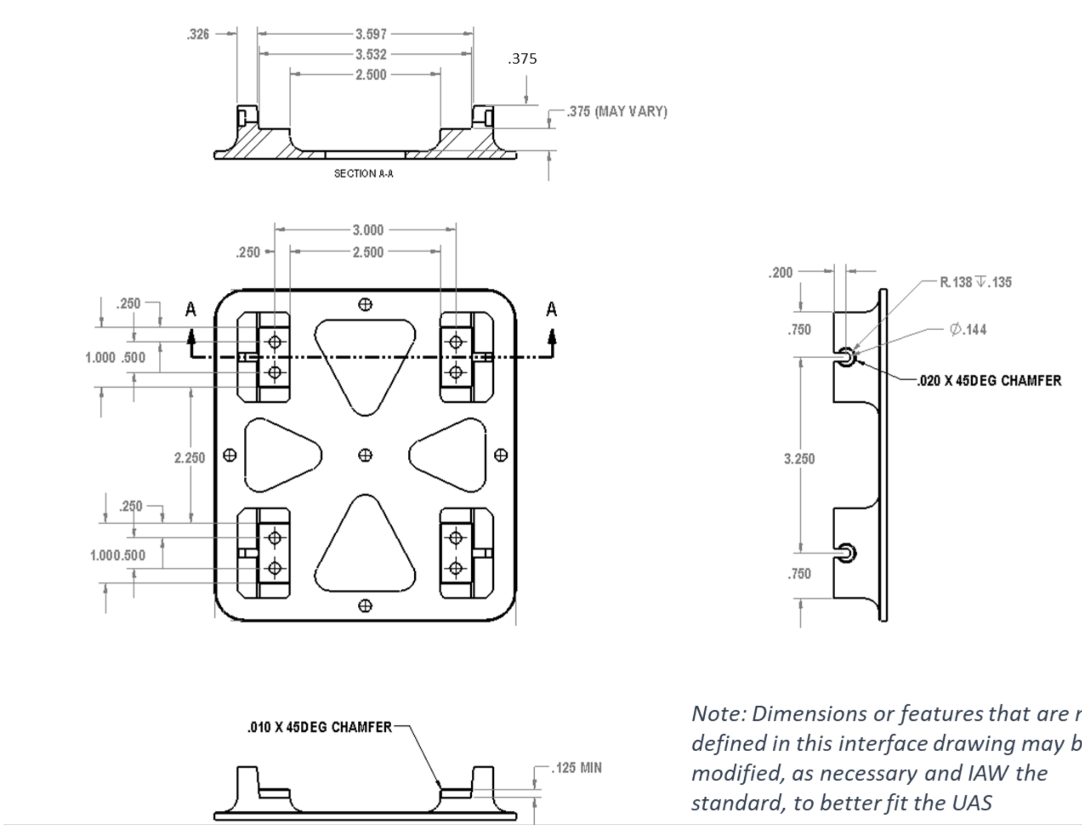


Figure 3-17. MP-compliant 4-pt Mount Interface

Though shown with a flat base in Figure 3-17, the antenna mount interface is only defined by the facets and the separation between them. As evidenced in Figure 3-16 above, the requisite 4-pt mount interface should be incorporated into a platform-specific mount to best conform to the platform 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 platform, as shown in Figure 3-18.

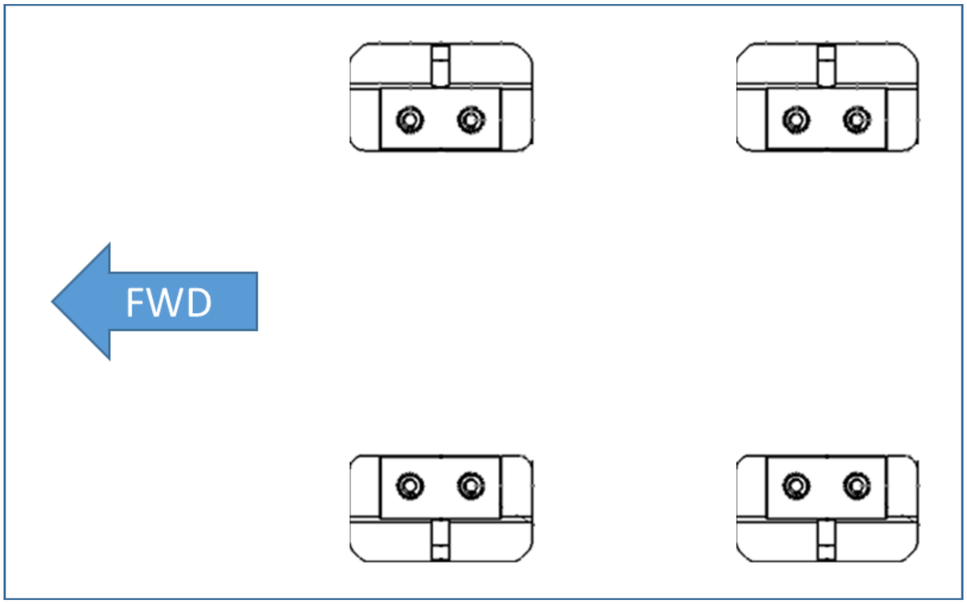


Figure 3-18. MP-compliant 4-pt Mount Preferred Orientation

3.4.1.4 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 3-19. The requisite array mount interface should be incorporated into a platform-specific mount to best conform to the platform design. The array mount is typically oriented with the array mount interface facing either forward or aft on the platform, whichever is determined more favorable by the integrator. The position of the array mount interface should be such that it provides sufficient space, as is reasonable for the specific platform, for a wide variety of mating payload antenna arrays.

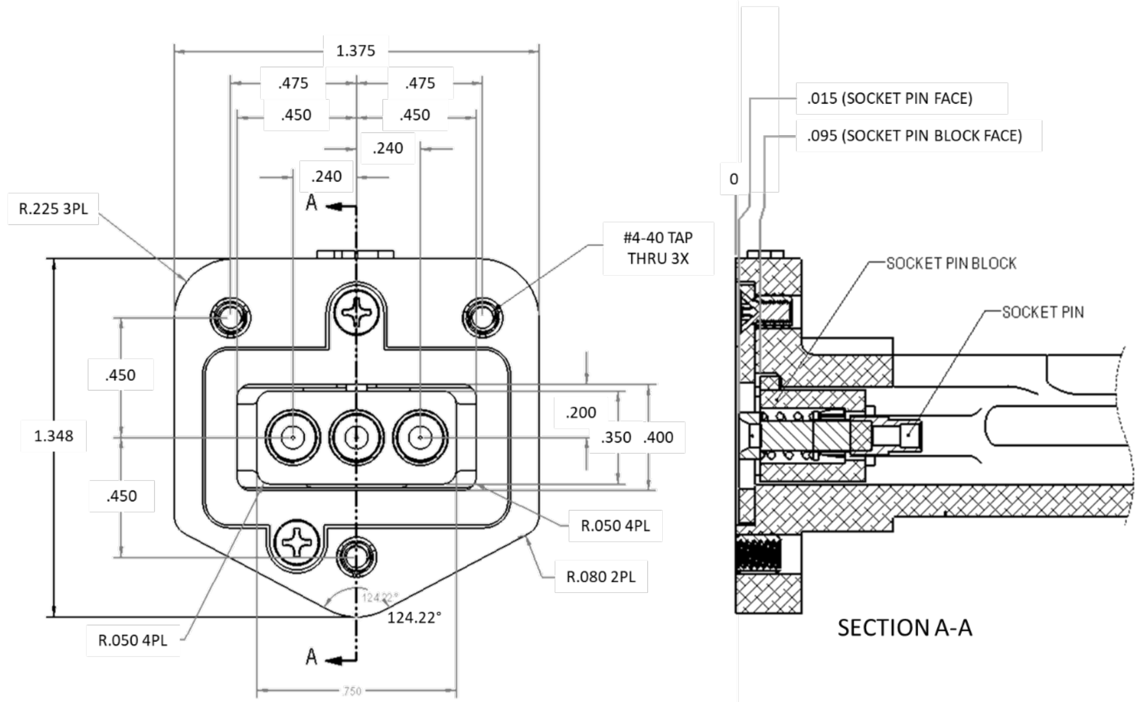


Figure 3-19. MP Array Antenna Mechanical Interface

3.5 Cabling

3.5.1 MAIM Cabling

A number of cables will need to run to/from the MAIM as part of the Mod Payload A-kit. These cables include the interfaces between the MAIM and the platform, the INS, and payloads. The MAIM-platform cable(s) shall provide power to the MAIM and Ethernet connectivity to the platform network. 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 3.1.4. All MAIM cables should be permanently installed into the platform at appropriate locations as determined by the 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-platform cable(s) are at the discretion of the 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 dictated by the INS. 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 3-10. While the recommended connectors do not include jack screws, male jack screws using #2-56 threads are required. The integrator may select jack screws compatible with the selected connector that best fit the platform design and do not violate any other requirements of the MP class.

Table 3-10. 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.
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.

All cables shall be built in a manner to survive the environmental conditions of the platform. As an example, if the cable location is expected to be exposed to splashing water, cables shall be built in an IP64 splash-proof manner.

3.5.2 RF Cabling

A minimum of one RF cable shall 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 run from the Primary Mount location to each array mount location. Cables should be color coded or labeled on both ends for ease of installation. 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 the 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. Depending on platform capacity for heavier cabling, lower loss RF cables can be considered to improve payload performance.

Note: Expanding the A-kit RF cables to cover frequencies greater than 6 GHz is under investigation and will be addressed in a future revision. In the interim, if a platform vendor intends to support frequencies greater than 6 GHz, cables should be selected to minimize attenuation at those higher frequencies while balancing the impact on payload capacity.

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 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 2.4.3.2.3) using three SMPM-male connectors. Additionally, the three cables run to the array interface should be phase-matched to within 0.5° per GHz (the three cables should have an electrical length within 0.41 mm of each other). The actual phase-match shall be measured and documented by the integrator to be provided to payload vendors, as needed.

Note: SSMB connectors are only rated up to 12 GHz. An alternate connector for higher frequency signals is under investigation and will be addressed in a future revision. In the interim, if a platform vendor intends to support frequencies greater than 12 GHz, suitably-rated RF cables should be terminated SMA-male on the payload side.

All RF cables shall be capable of survival in the anticipated environmental conditions of the platform. If particular risk of degradation of performance exists around RF connections between RF cables and payload antennas (such as water intrusion in a marine environment), the design shall include protection against the environmental hazard.

3.6 Grounding

The host platform and Modular Payload grounding scheme must be carefully designed to eliminate ground loops. The platform power ground should only have a single connection path to the MAIM. Payloads should maintain isolation between all payload ground returns (power, signal, and RF) and the platform chassis ground (refer to Section 2.1.5). The platform/MAIM is therefore responsible for tying these grounds together. As the payload power and signal grounds are collocated within the MAIM, it is the logical point to make these grounds common and tied to platform power ground. This common ground should then be tied to platform chassis ground at a single point, dictated by the platform design.

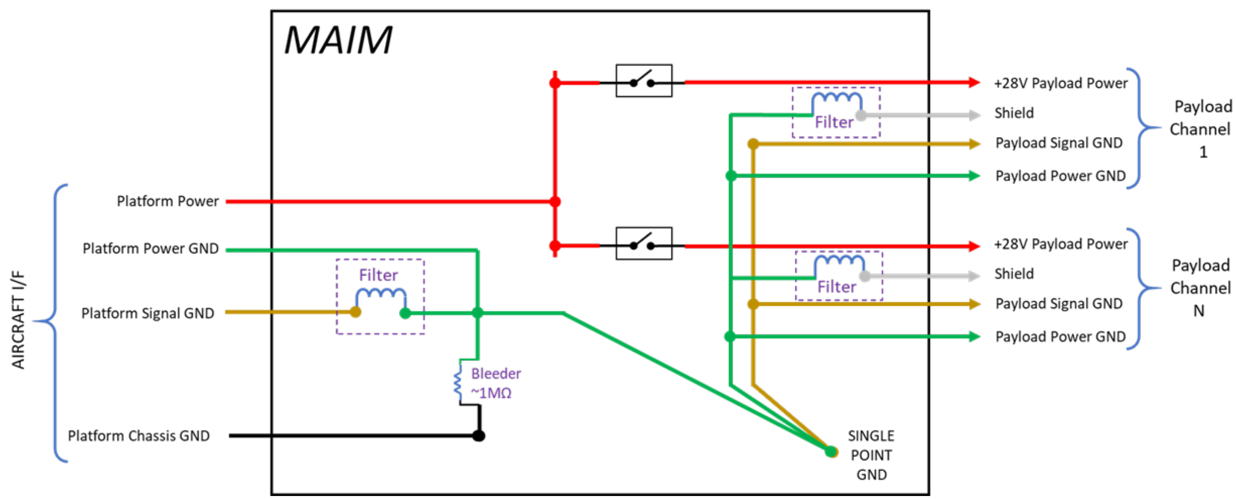


Figure 3-20. MAIM Grounding Scheme

Cable shielding is an area of particular concern in order to minimize EMI. All shielded MAIM cables should have the shield either referenced to the above common ground at the MAIM or at the payload, but not both as that would create a ground loop. All shielded RF cables should have the shield referenced to platform chassis ground via the payload chassis. There shall be no current flow in the shield.

To prevent additional connections to platform chassis ground, antenna mounts shall be made of non-conductive materials.

4. IMPLEMENTATIONS

The following sections detail MP implementations on specific platforms. These should be used as a reference for payload vendors, platform vendors and system integrators.

4.1 ScanEagle Block D UAS

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

4.1.1 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.

4.1.1.1 MP Architecture

Figure 4-1 depicts the architectural layout of the MP implementation on the ScanEagle UAS.

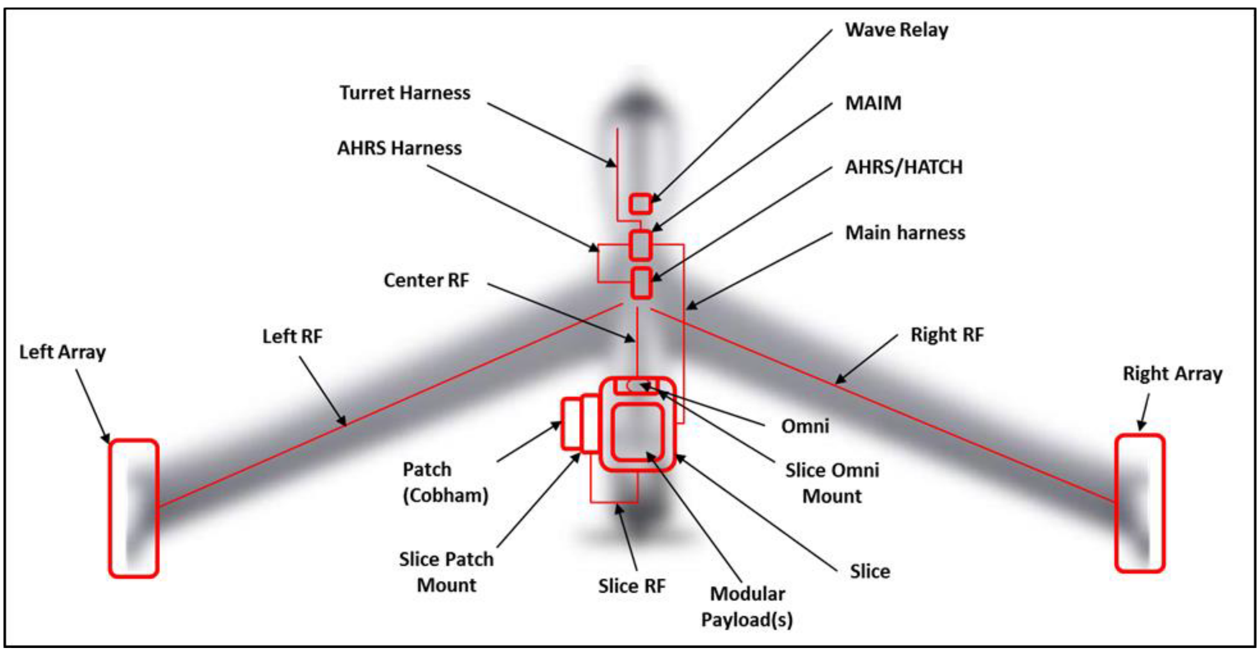


Figure 4-1. Architectural Layout for MP-ScanEagle

4.1.1.2 Compliance / Capability Summary

Table 4-1 provides a top-level summary of the MP compliance and capability on the ScanEagle UAS.

Table 4-1. 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.

4.1.1.3 System Diagram

Figure 4-2 details the system diagram for the MP-ScanEagle UAS. MP-specific additions are highlighted in teal.

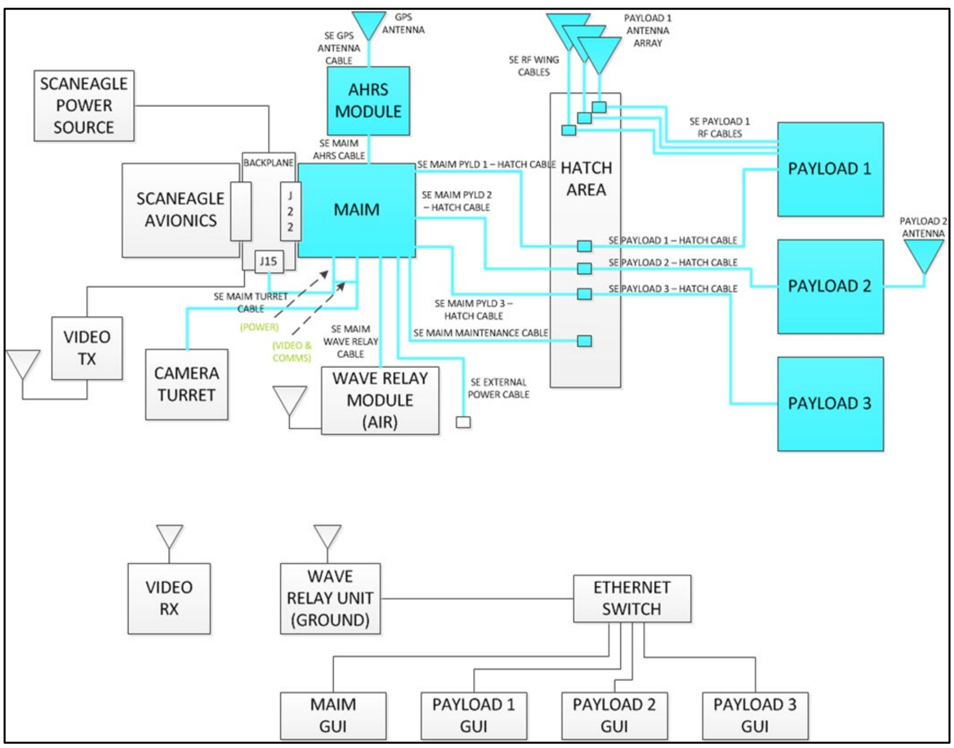


Figure 4-2. System Diagram for MP-ScanEagle

4.1.2 Platform Weight and Power Budgets

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

4.1.2.1 Weight Budget

The Mod Payload A-kit (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.

4.1.2.2 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, and 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.

4.1.3 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.

4.1.3.1 Mechanical Description

The MAIM board is 6.25in x 5in x 0.73in and weighs 192g. Figure 4-3 shows the MAIM.

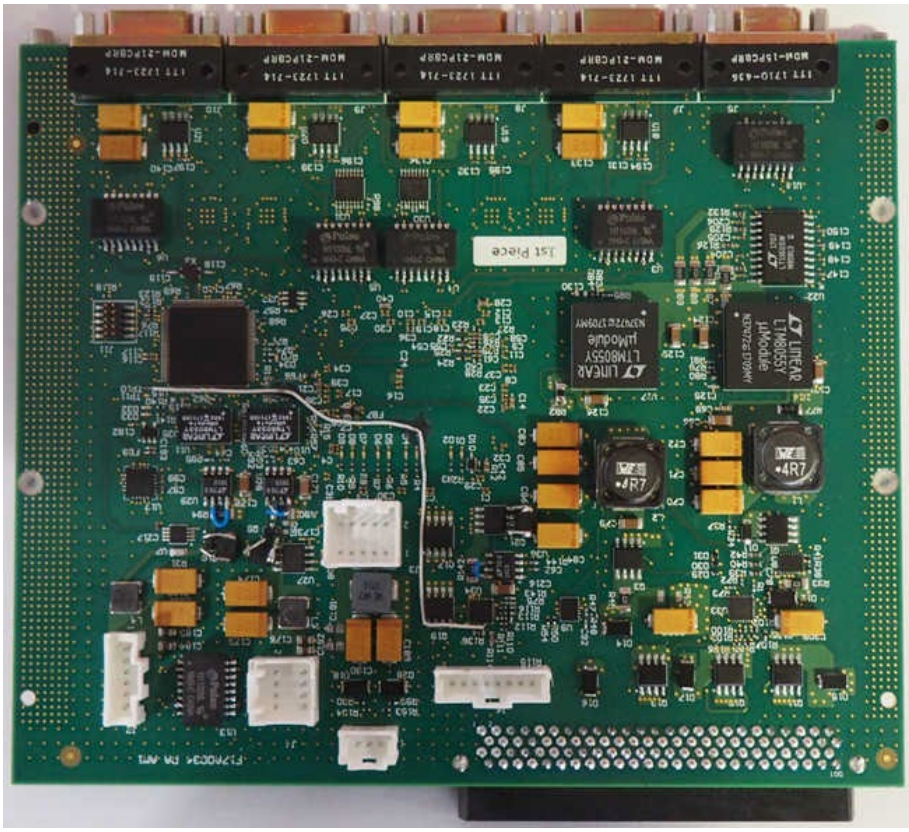


Figure 4-3. MAIM for ScanEagle

4.1.3.2 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 4-4, 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.

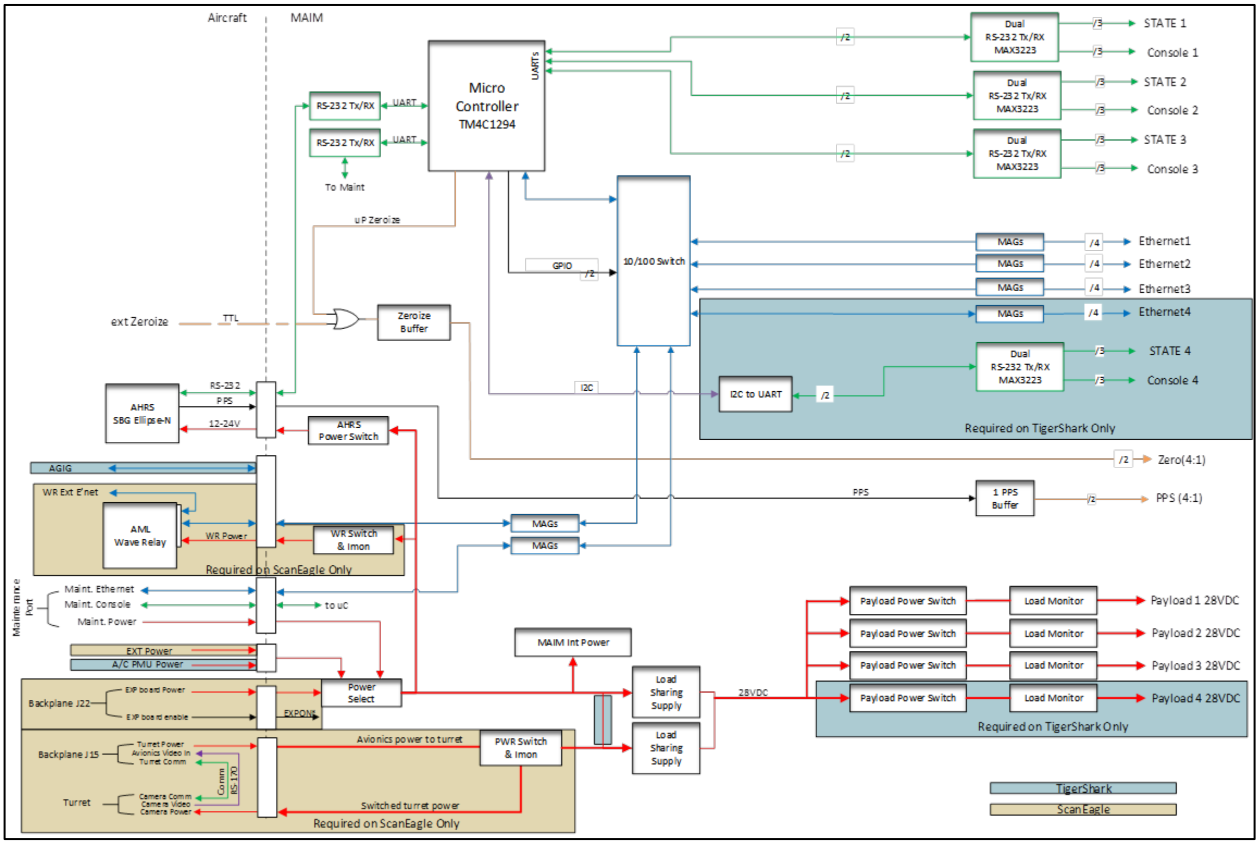


Figure 4-4. MAIM Block Diagram for ScanEagle

4.1.3.2.1 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.

4.1.3.2.2 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).

4.1.3.2.3 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 4-5.

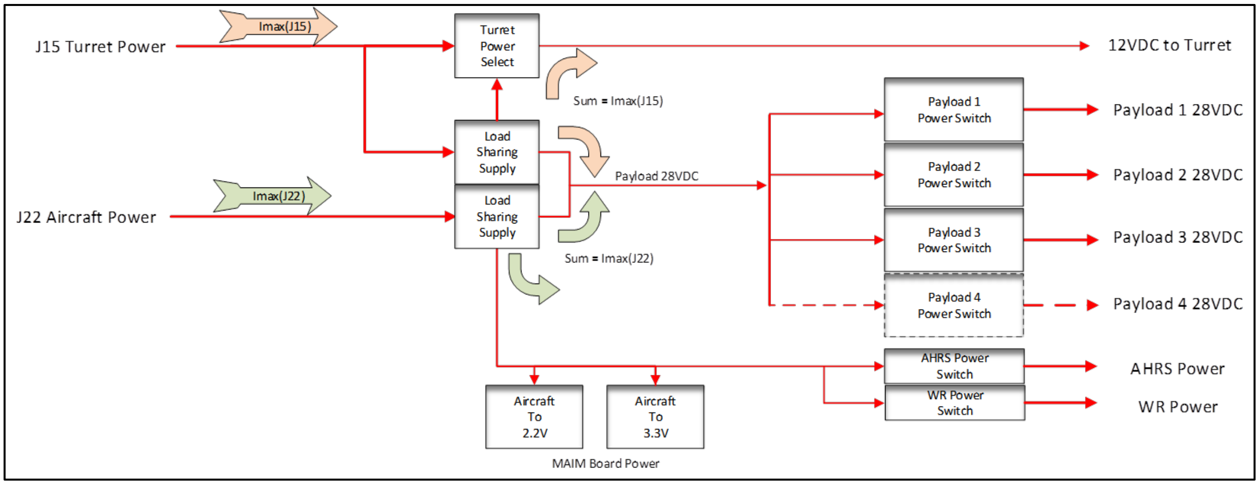


Figure 4-5. MAIM Power Circuitry Block Diagram

4.1.3.2.4 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.

4.1.3.2.5 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.

4.1.3.2.6 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 4.1.3.2.1 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.

4.1.3.3 MAIM Integration

The MAIM is installed in the upper card slot in the Avionics Module (Figure 4-6). The entire Avionics Module must be removed to install the MAIM. A maintenance cable (Section 4.1.7.9) 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.

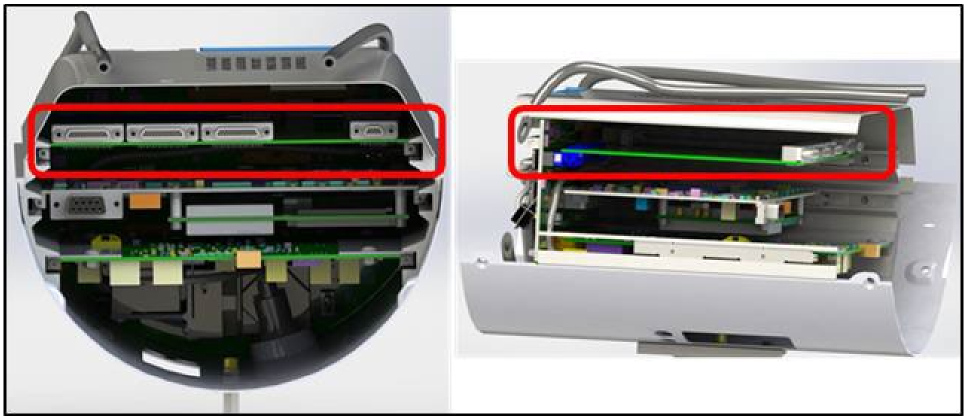


Figure 4-6. MAIM Installed in ScanEagle

4.1.4 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 4-7 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.

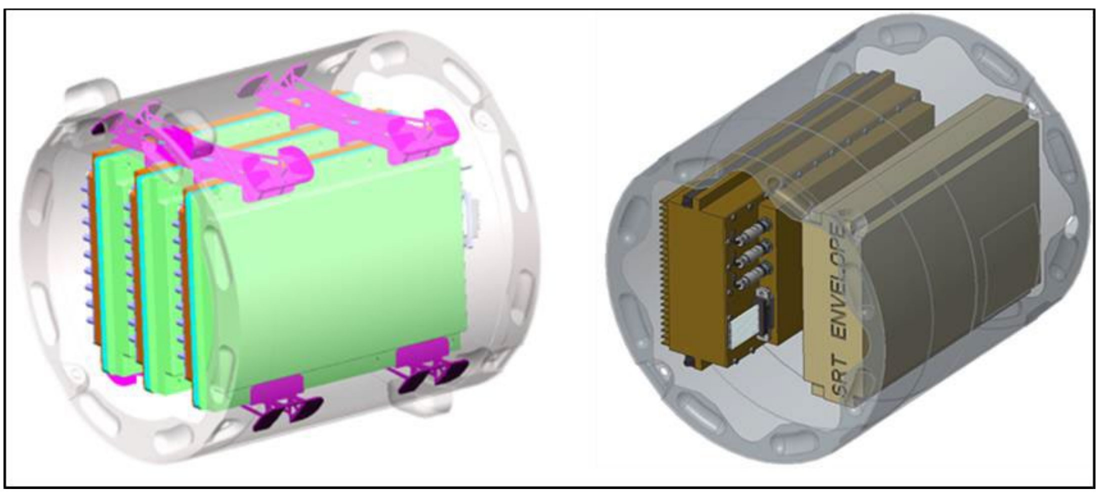


Figure 4-7. ScanEagle Primary Mount Aft Slice with Payloads

4.1.4.1 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.

4.1.4.2 Installation

The Primary Mount is installed just as a normal aft slice on the ScanEagle. The Primary Mount is oriented as shown in Figure 4-8. 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.

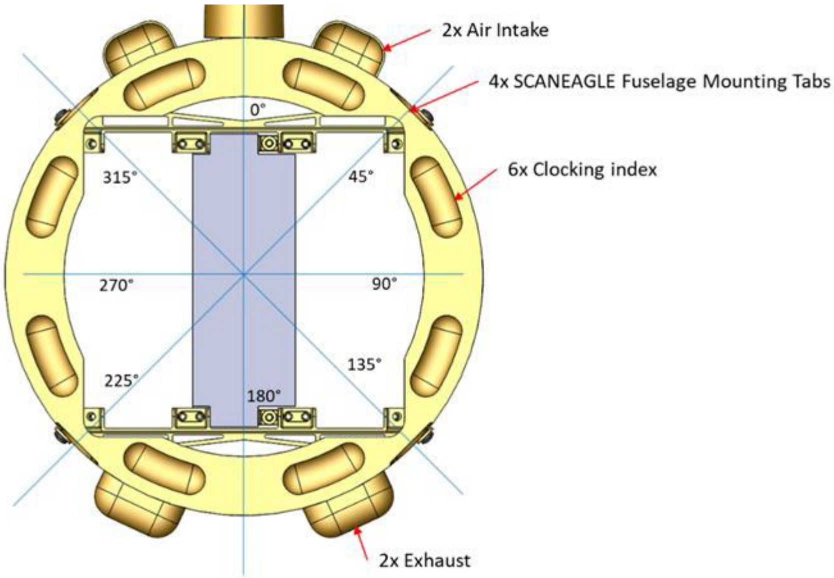


Figure 4-8. ScanEagle Primary Mount Orientation

4.1.4.3 Thermal

Air ducts on the slice surface provide the requisite airflow 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.

4.1.5 INS

The ScanEagle center wing hatch is replaced with a custom hatch accommodating the Ellipse2-N INS and a small GPS antenna (Figure 4-9). The custom hatch (including the INS) weighs 245g (a 109g delta to the standard hatch).

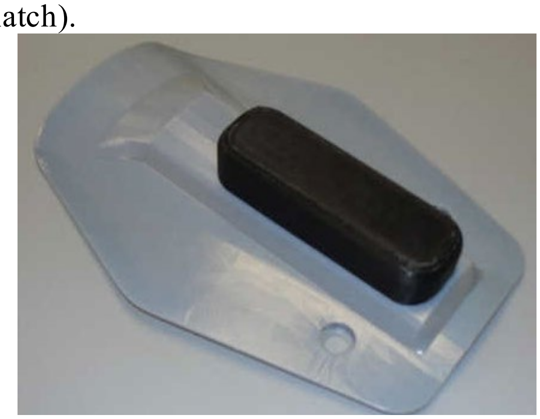


Figure 4-9. Custom Hatch for MP-ScanEagle

4.1.6 Antenna Mounts

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

4.1.6.1 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.

4.1.6.1.1 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 4-10) 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.

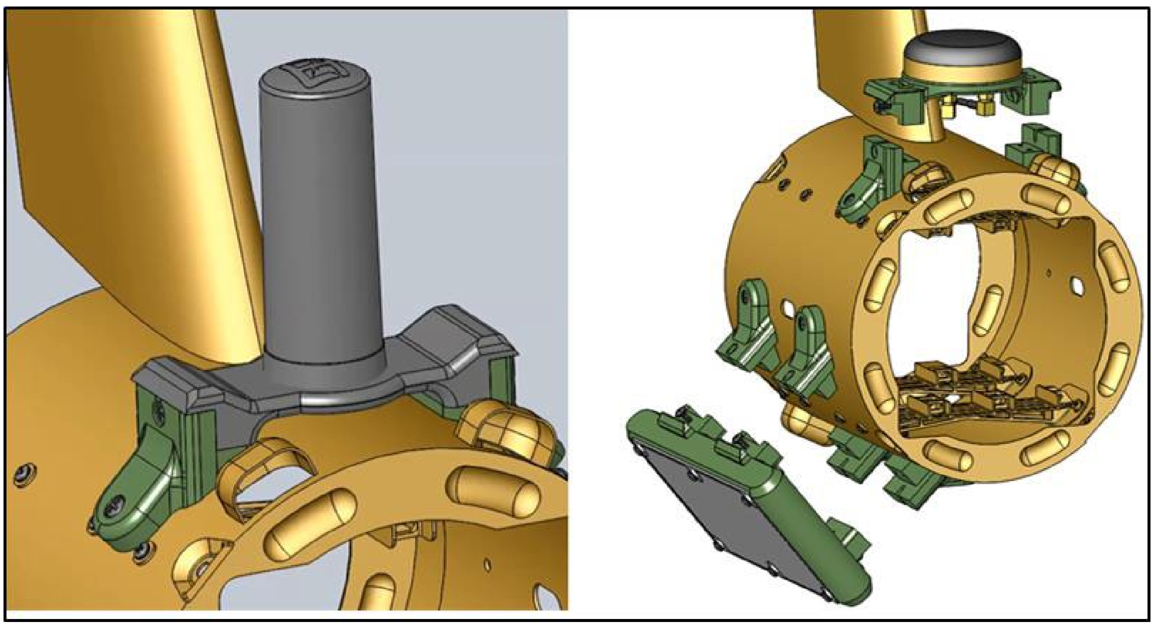


Figure 4-10. Feet Antenna Mounts on the Aft Slice Primary Mount

The mount capacity of the feet is defined in Table 4-2.

Table 4-2. Feet Mount Capacity

Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in Section 4.1.2.1)
Max Volume	Defined in Figure 4-11

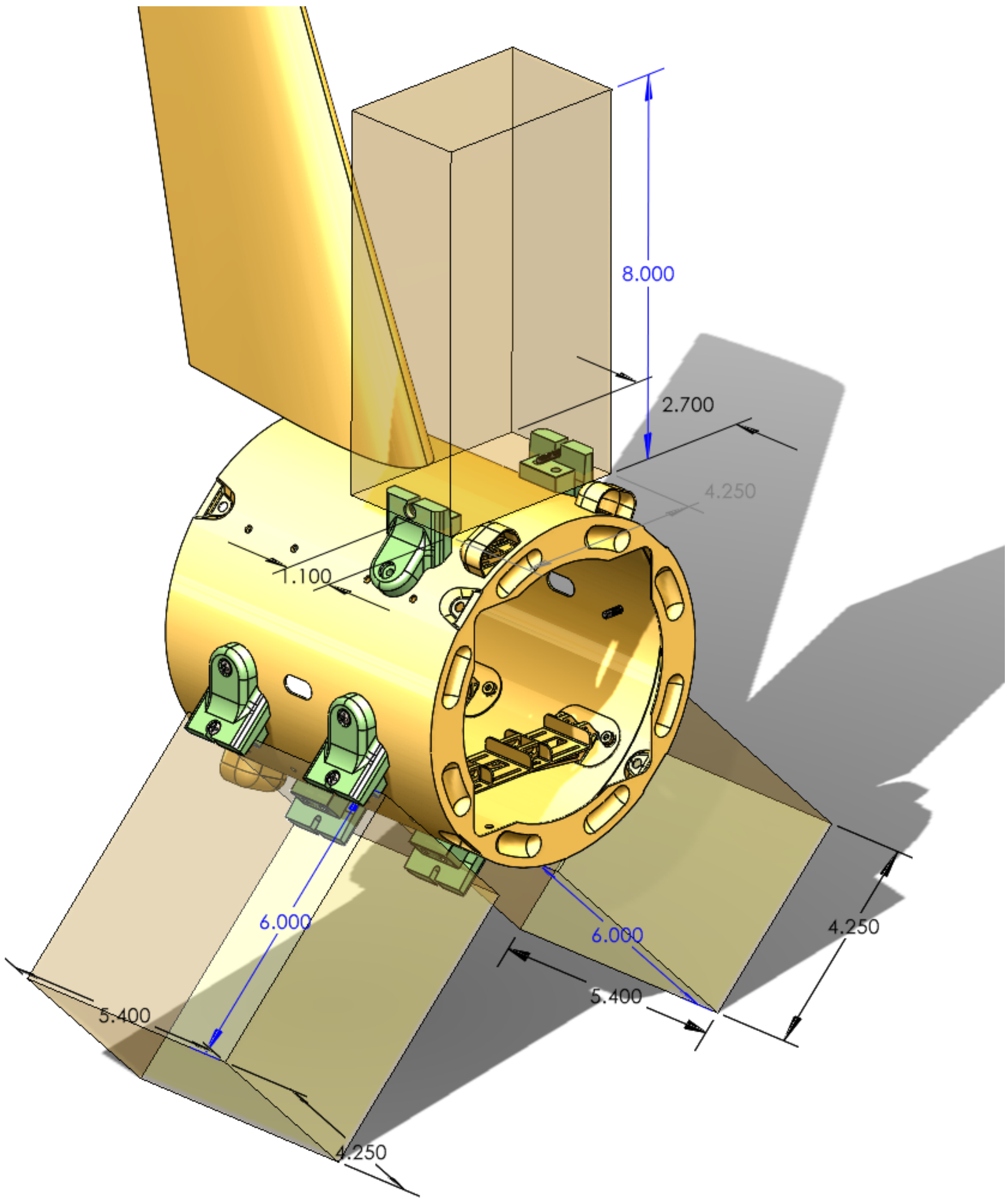


Figure 4-11. Feet Maximum Volume

4.1.6.1.2 Sled

A sled antenna mount (Figure 4-12) is a second ScanEagle adaptation of the 2-pt mount interface to support antenna installations at 180° and 270° orientations.

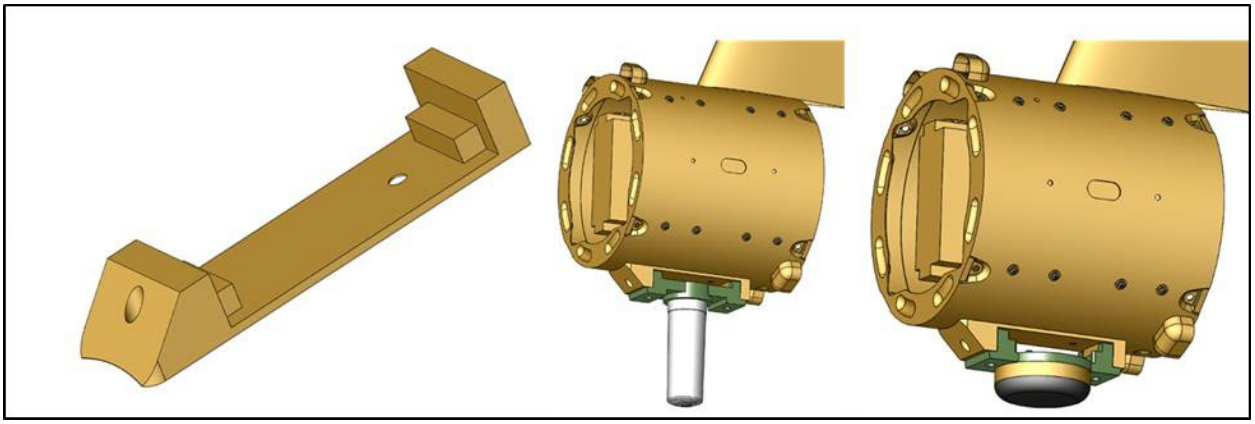


Figure 4-12. Sled Antenna Mounts on the Aft Slice Primary Mount

A 2-pt sled weighs 33g. The aft slice antenna mount capacity is defined in Table 4-3.

Table 4-3. Aft Slice Antenna Mount Capacity

Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in Section 4.1.2.1)
Max Volume	Defined in Figure 4-13

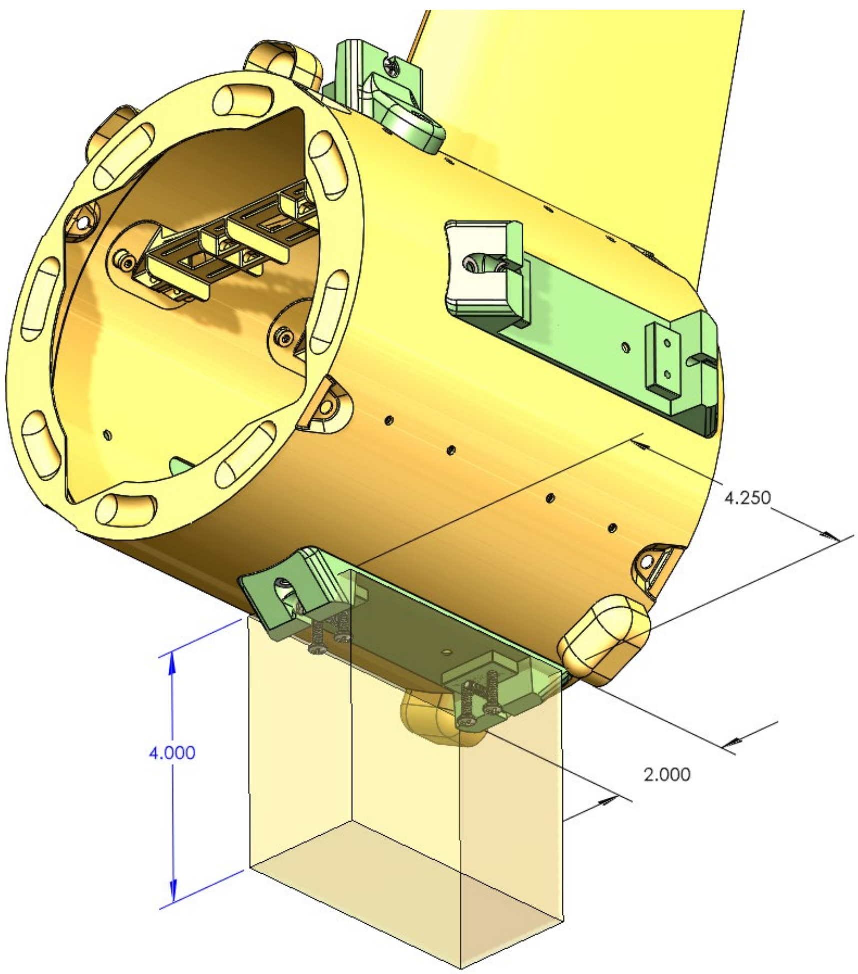


Figure 4-13. Antenna Mount Volume

4.1.6.2 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.

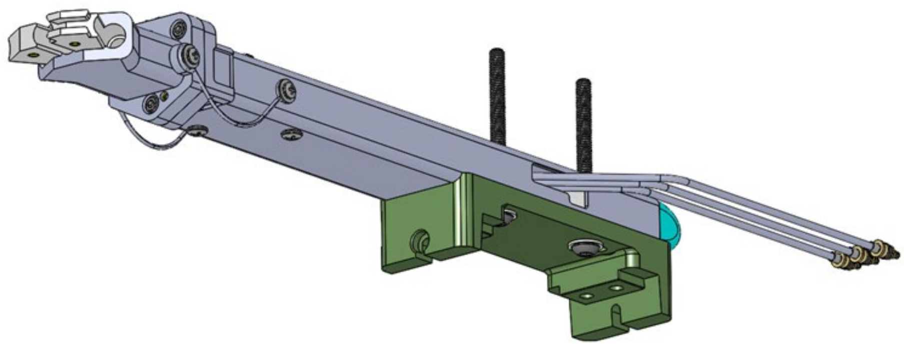


Figure 4-14. Wingtip Antenna Mount

The strut weighs 100g and the 2-pt. down look mount weighs 45g. The wingtip antenna mount capacity is defined in Table 4-4.

Table 4-4. Wingtip Antenna Mount Capacity

	2-pt	Array
Max Weight	373 g	208g (total weight budget of B-kit must not exceed that outlined in Section 4.1.2.1)
Max Volume	Defined in Figure 4-15	

[1] CAD defining volume available upon request

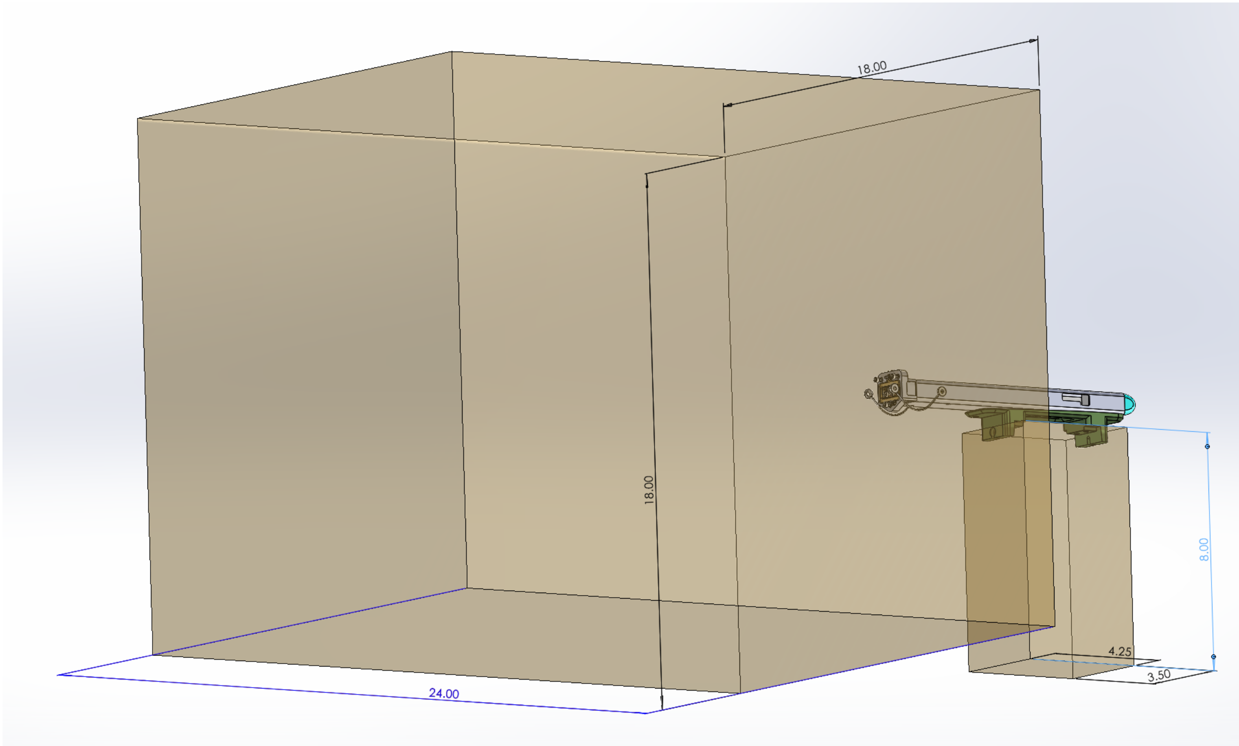


Figure 4-15. Wingtip Antenna Mount Volume

4.1.7 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 4-16, while the MAIM cable diagram is detailed in Figure 4-17. The following sections provide further detail on each cable installed. RF cables are detailed in Section 4.1.7.8.

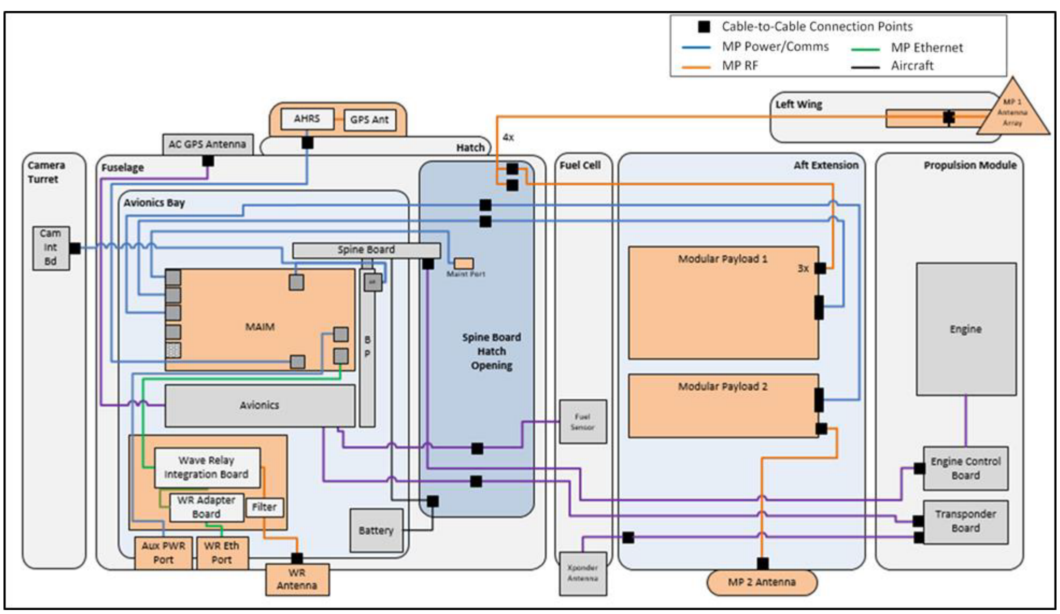


Figure 4-16. MP Cables and Routing for ScanEagle

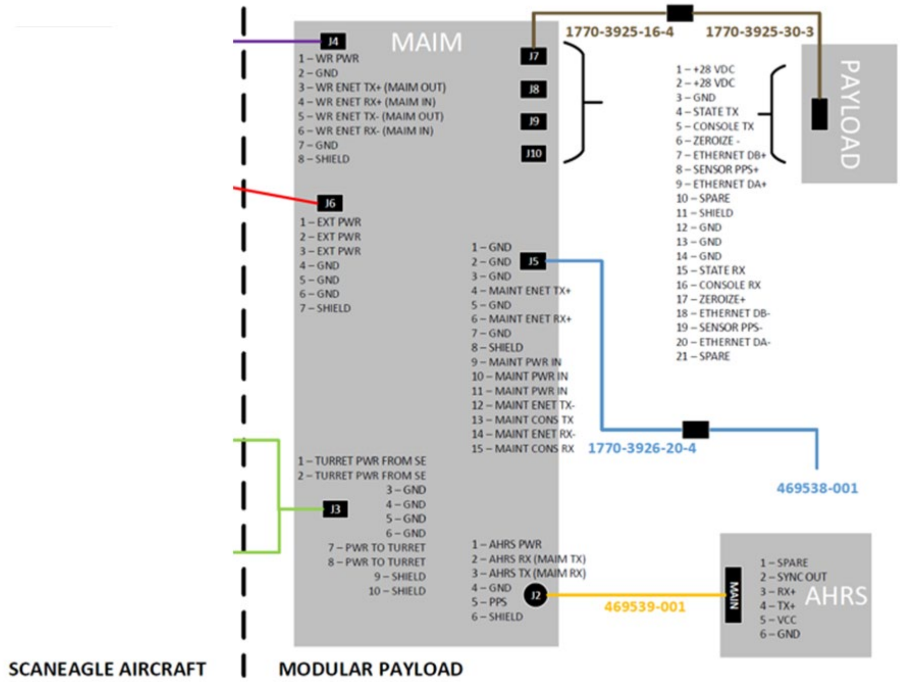


Figure 4-17. ScanEagle MAIM Cable Diagram

4.1.7.1 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.

4.1.7.2 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 4-18. 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).

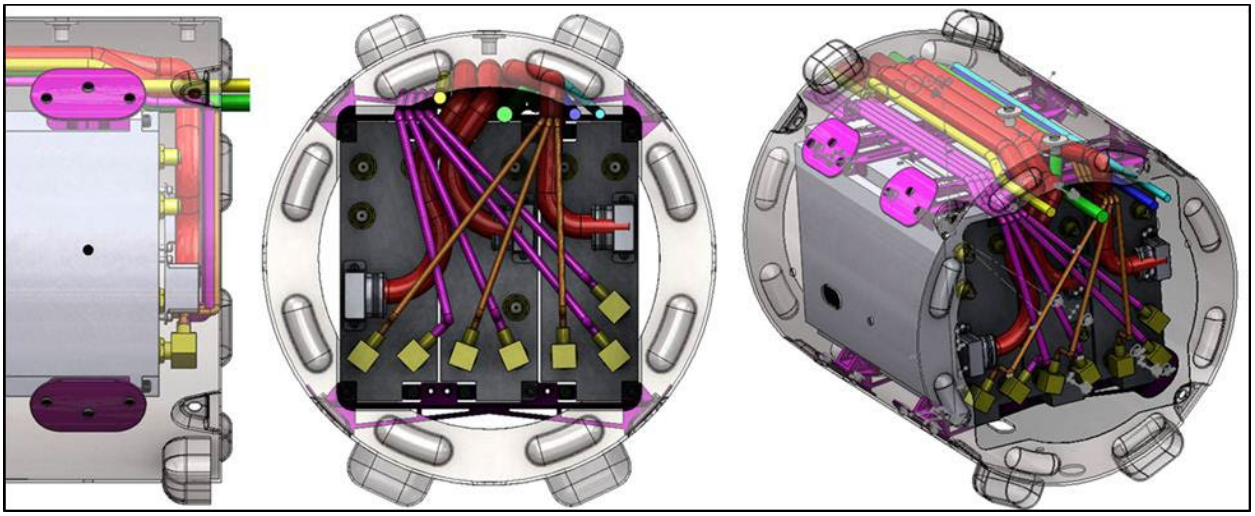


Figure 4-18. Payload Cable Runs over the Primary Mount

4.1.7.3 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 4-19. 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.

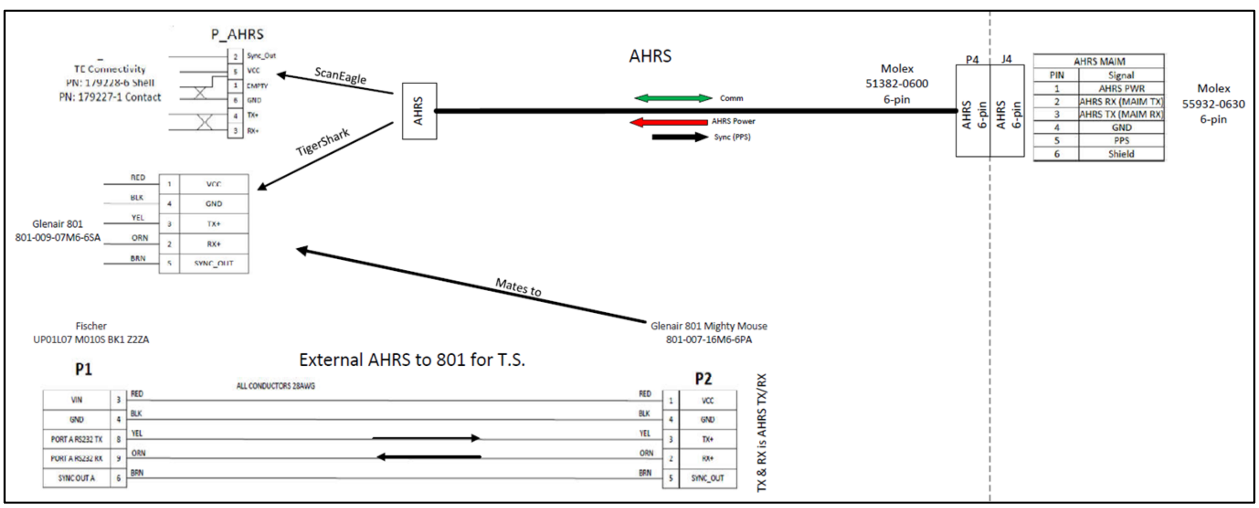


Figure 4-19. MAIM to INS Cable

4.1.7.4 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 4.1.5.

4.1.7.5 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.

4.1.7.6 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 4-20. 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.

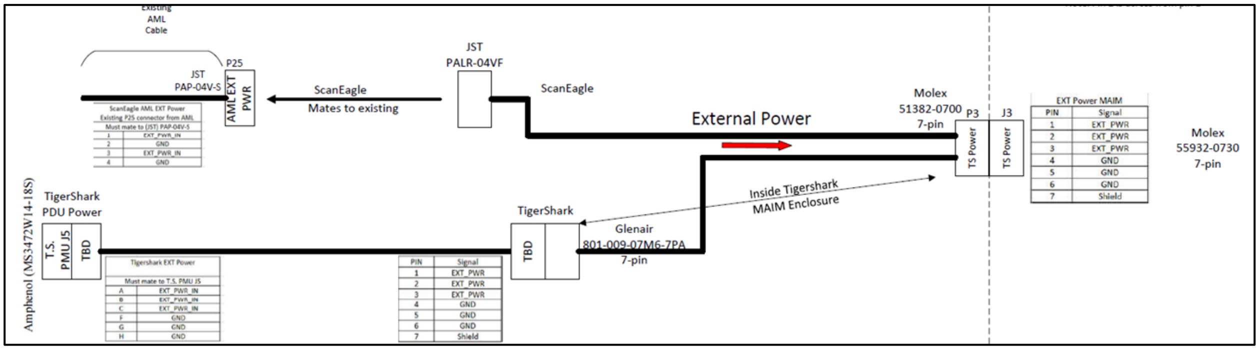


Figure 4-20. MAIM External Power Cable

4.1.7.7 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.

4.1.7.8 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 4-21.

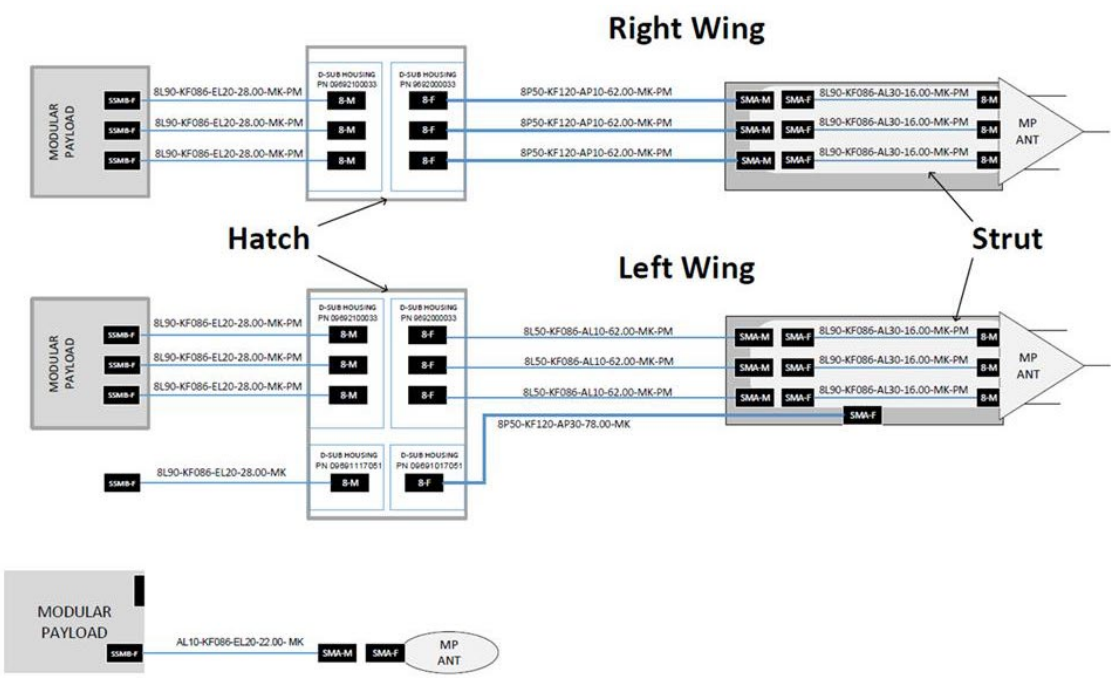


Figure 4-21. MP-ScanEagle RF Schematic

4.1.7.8.1 RF Cable Summary Table

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

Table 4-5. 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

4.1.7.8.2 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 4-21 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.

4.1.7.8.3 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 4-21 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.

4.1.7.8.4 Aft Slice Cables

Aft slice cables are used to connect a payload to its aft slice antenna. Figure 4-21 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.

4.1.7.9 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 4-22. 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.

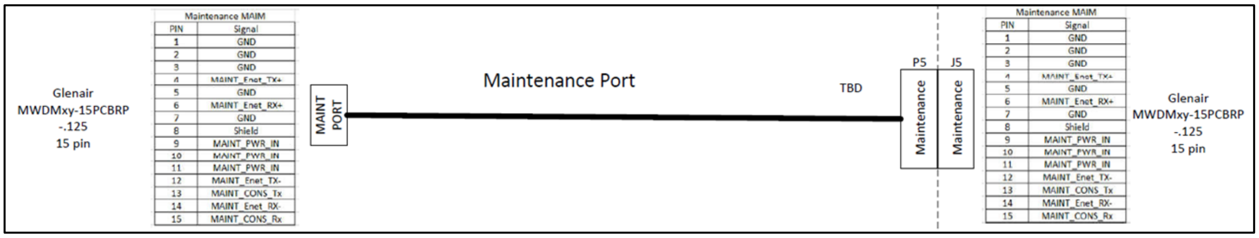


Figure 4-22. MAIM Maintenance Cable

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

4.1.8 Concessions to the Standard

As noted in Table 4-1 and Section 4.1.2.2, 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. Additionally, while two payload feeds are supported, the power to the payloads is limited by the total power available in Table 4-1.

4.2 RQ23A TigerShark UAS

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

4.2.1 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.

4.2.1.1 MP Architecture

Figure 4-23 illustrates the architectural layout of the MP implementation on the TigerShark UAS.

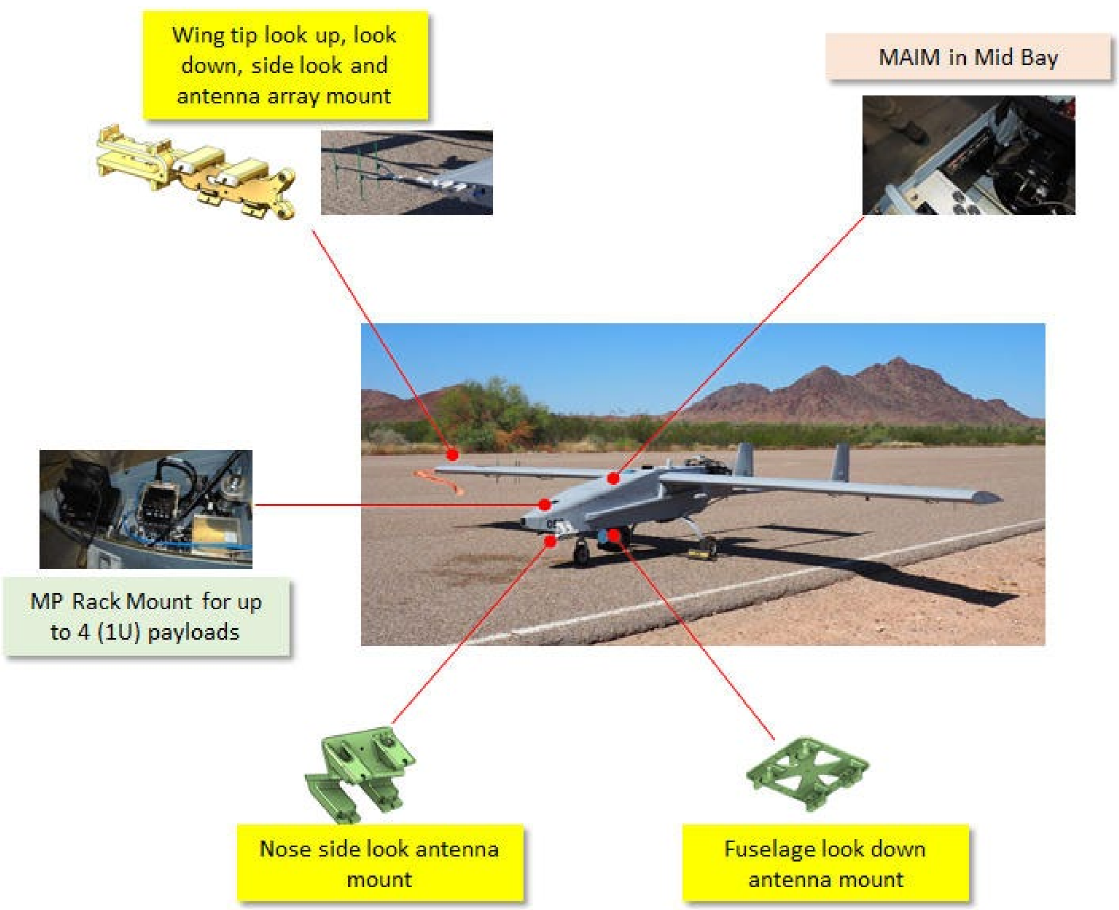


Figure 4-23. Architectural Layout for MP-TigerShark

4.2.1.2 Compliance / Capability Summary

Table 4-6 provides a top-level summary of the MP compliance and capability on the TigerShark UAS.

Table 4-6. MP-TigerShark Compliance and Capability

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

4.2.1.3 System Diagram

Figure 4-24 details the system diagram for the MP-TigerShark UAS. MP-specific additions are highlighted in teal.

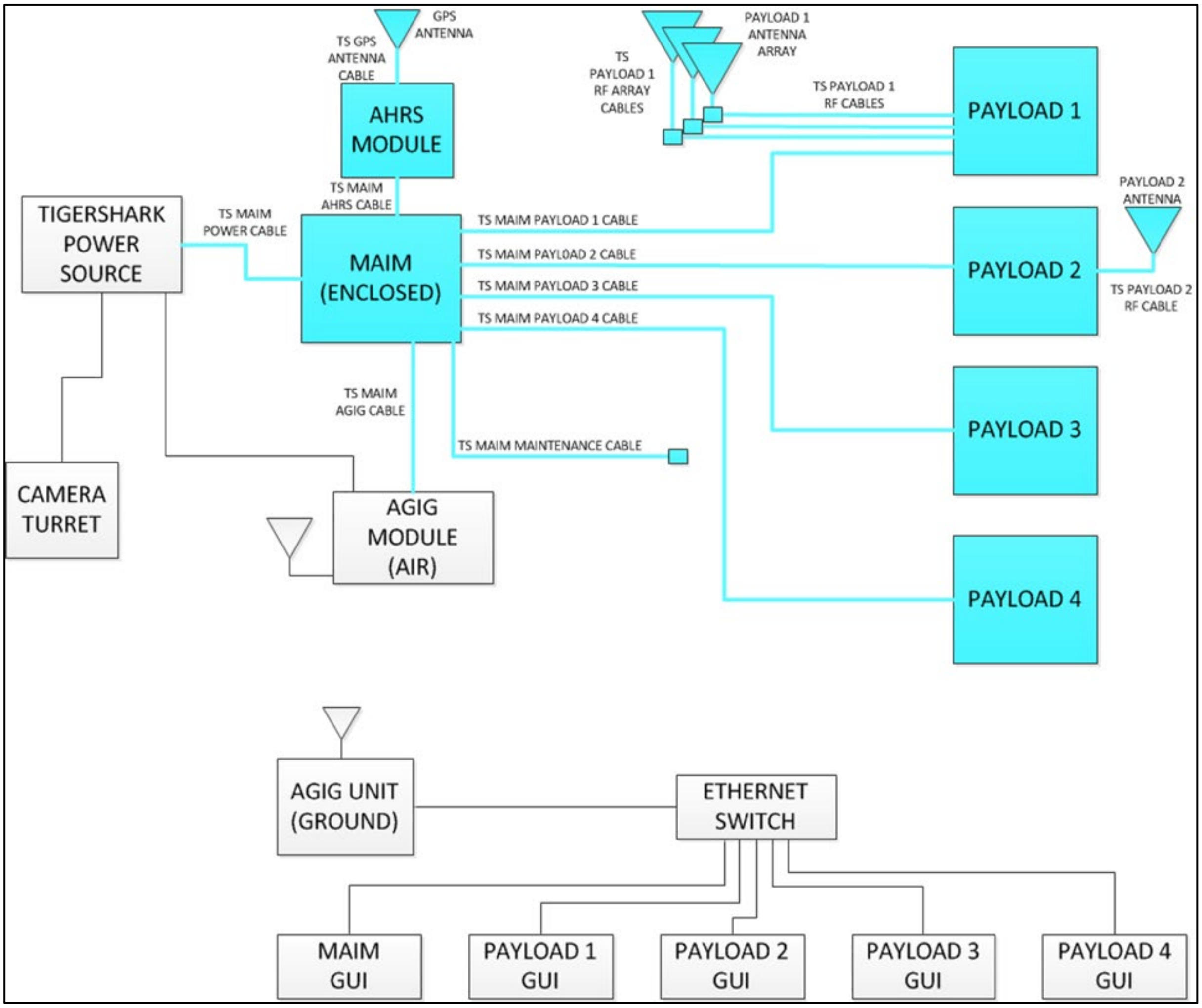


Figure 4-24. System Diagram for MP-TigerShark

4.2.2 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.

4.2.2.1 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. The Mod Payload A-kit adds 5.7kg to the TigerShark.

4.2.2.2 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).

4.2.3 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.

4.2.3.1 Mechanical Description

The MAIM enclosure is 8.1in x 5.6in x 1.6in and weighs 1.44kg. Figure 4-25 shows the MAIM enclosure (left) and the MAIM board (right).

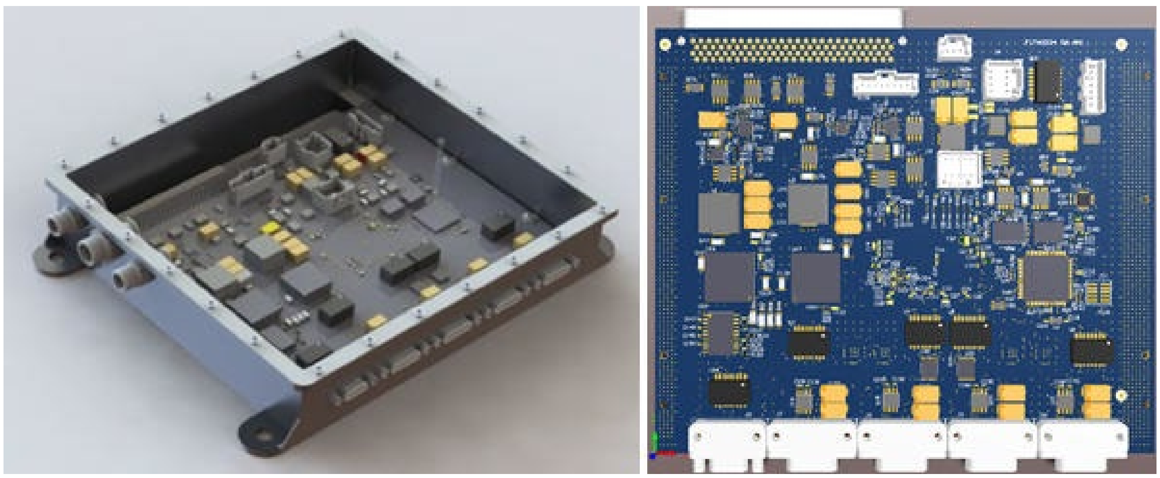


Figure 4-25. MAIM for TigerShark

4.2.3.2 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 4-26, 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.

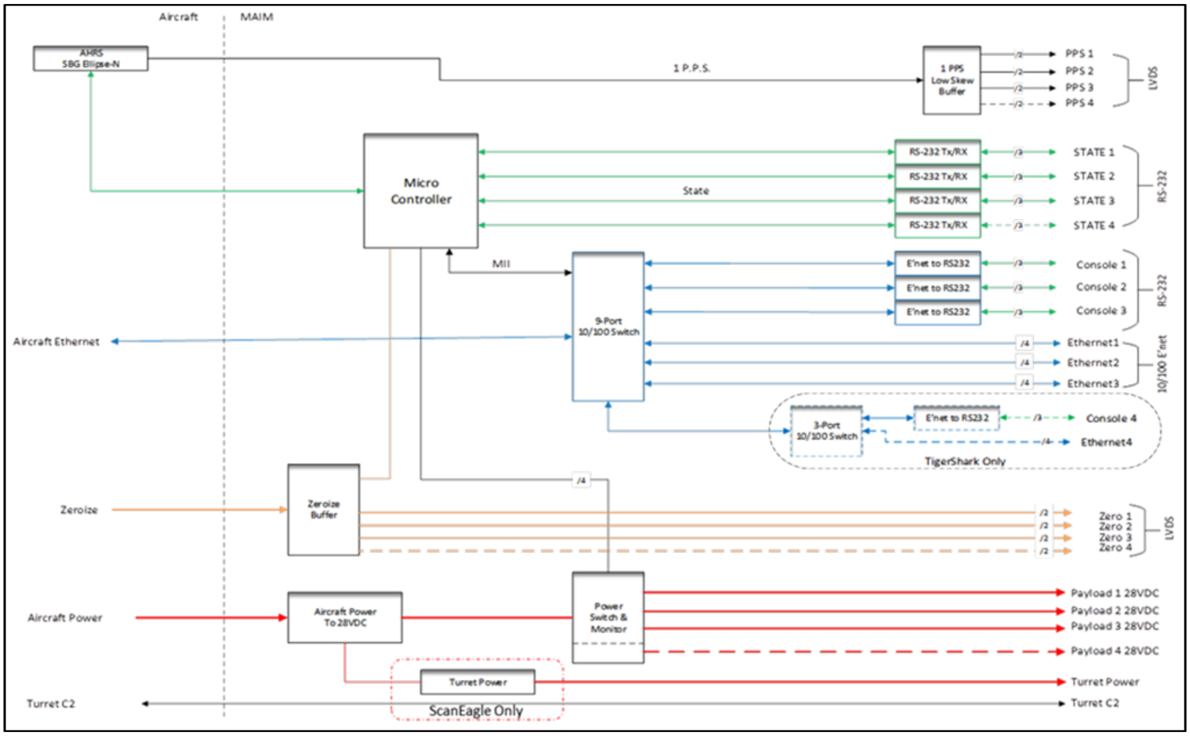


Figure 4-26. MAIM Block Diagram for TigerShark

4.2.3.2.1 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.

4.2.3.2.2 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).

4.2.3.2.3 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 4-27.

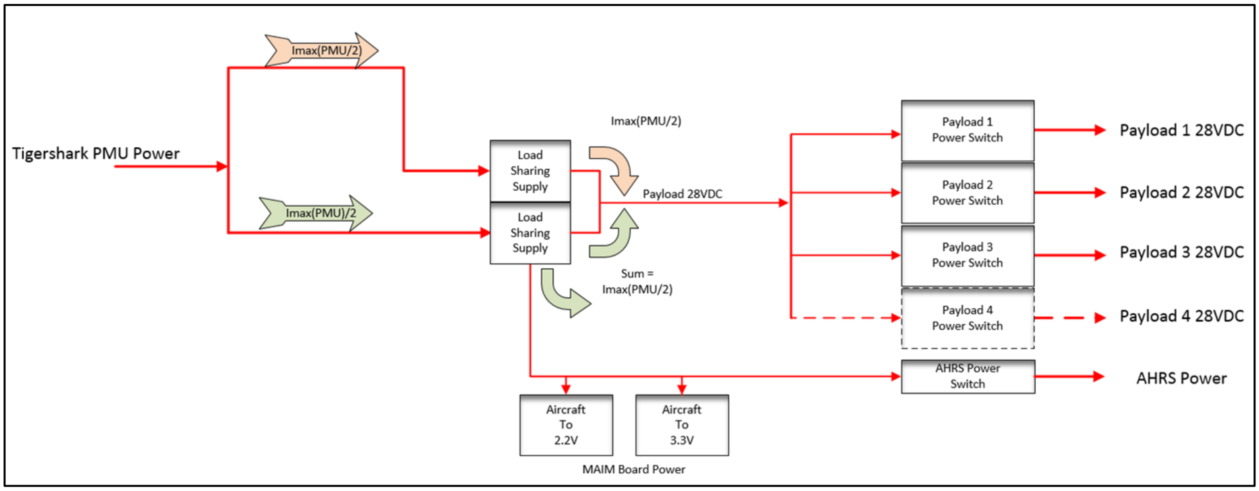


Figure 4-27. MAIM Power Circuitry Block Diagram

4.2.3.2.4 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.

4.2.3.2.5 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.

4.2.3.2.6 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.

4.2.3.3 MAIM Integration

The MAIM enclosure is installed to the right side of the fuselage in the primary payload bay (Figure 4-28). The MAIM is directly bolted to the fuselage, adding mounting holes where necessary.

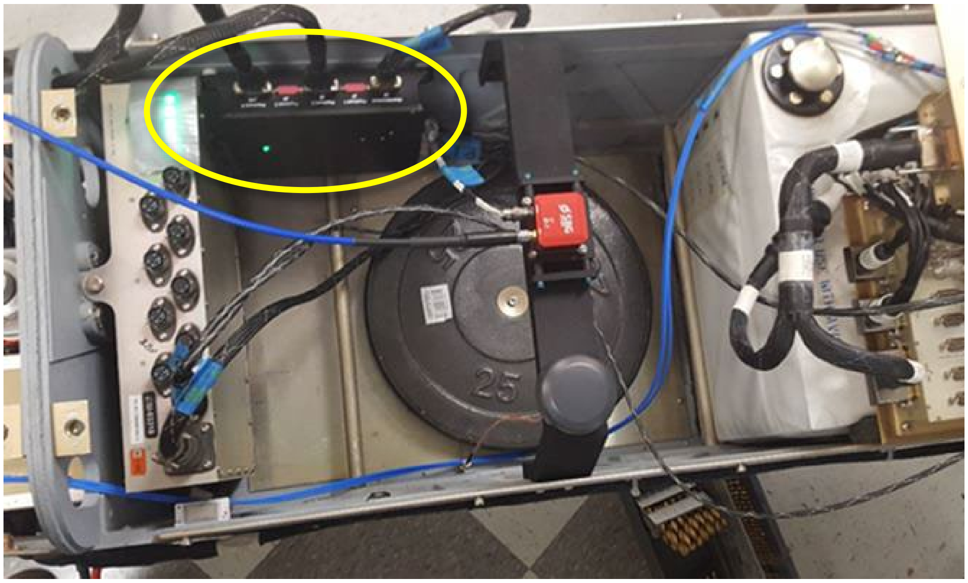


Figure 4-28. MAIM Installed in TigerShark Payload Bay

4.2.4 Primary Mount

The Primary Mount for the TigerShark is a 4U rack installed in the nose payload bay. Figure 4-29 shows the Primary Mount with a 1.5U and a 1U payload installed.

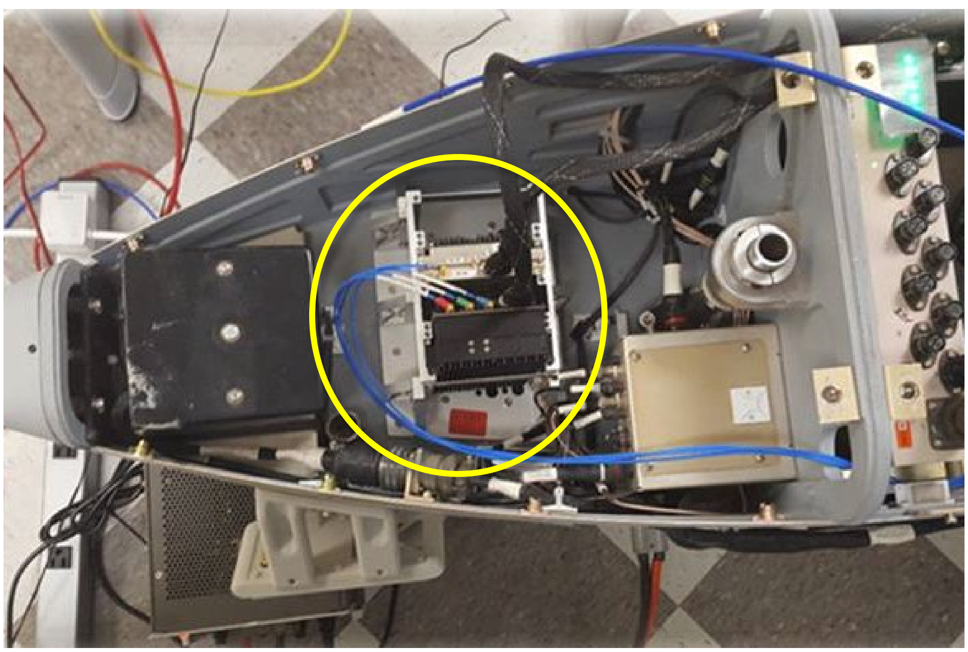


Figure 4-29. TigerShark Primary Mount with Two Payloads

4.2.4.1 Mechanical Description

The Primary Mount as illustrated in Figure 4-30 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.

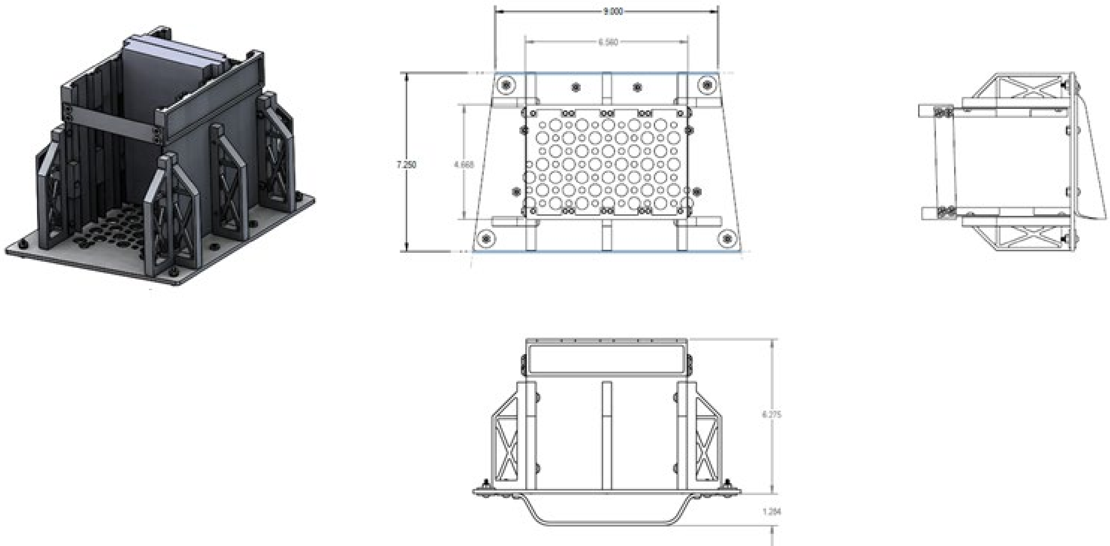


Figure 4-30. TigerShark Primary Mount Assembly

4.2.4.2 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 4-31, 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.

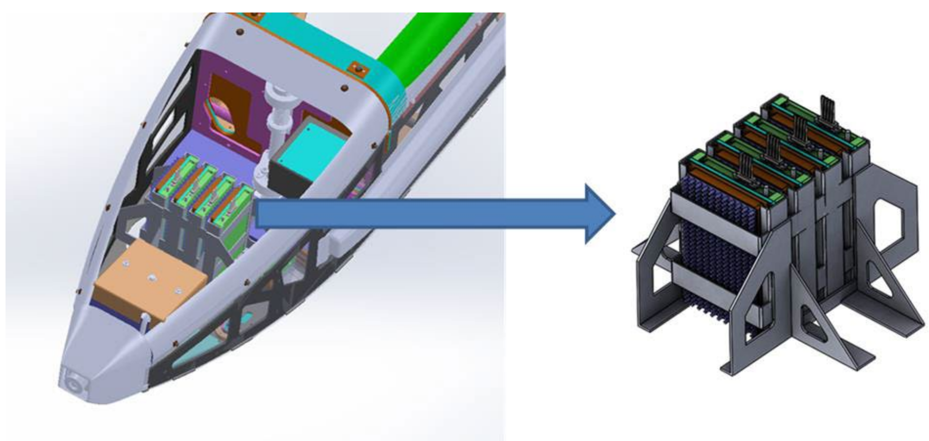


Figure 4-31. TigerShark Primary Mount Installation

4.2.4.3 Thermal

Multiple considerations are made to and around the Primary Mount to provide the requisite airflow 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 4-32.

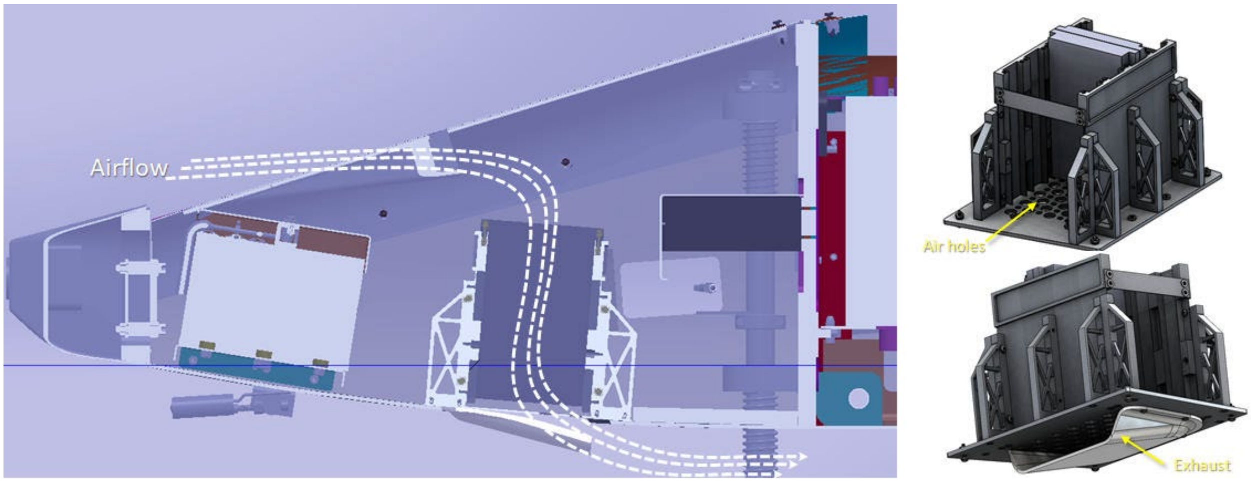


Figure 4-32. TigerShark Thermal Considerations

4.2.5 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 4-33 shows the INS installation.

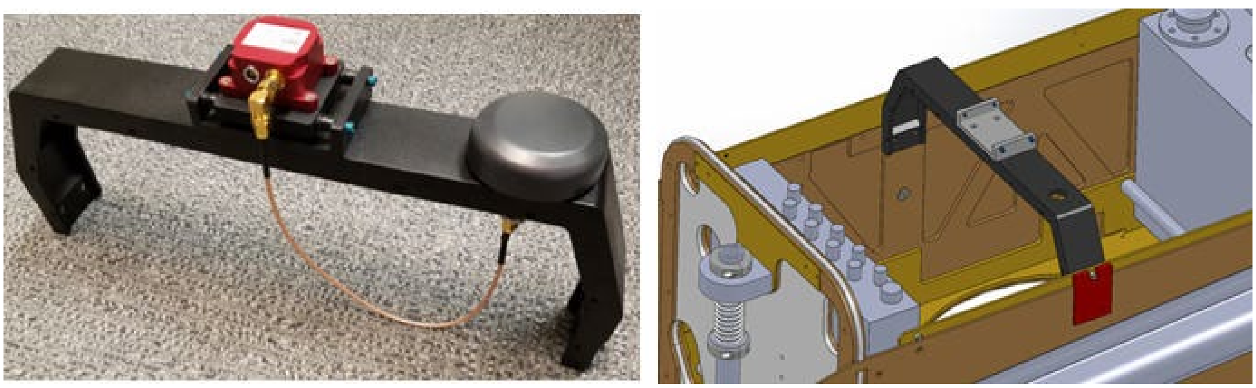


Figure 4-33. TigerShark INS Installation

4.2.6 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.

4.2.6.1 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 4.2.7.5.2). 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.

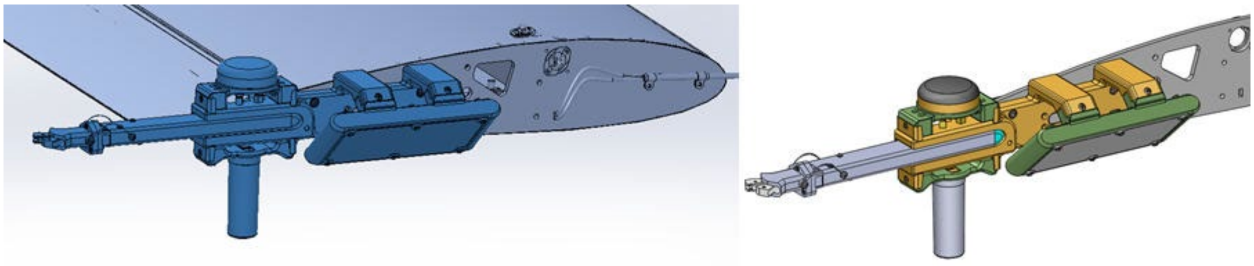


Figure 4-34. TigerShark Wingtip Antenna Mount

The wingtip platform mount weighs 445g. The wingtip antenna mount capacity is defined in Table 4-7.

Table 4-7. Wingtip Antenna Mount Capacity

	Total	Array	2-pt Up Look	2-pt Down Look	4-pt 45° Look
Max Weight	1327 g (total of all 4 possible antenna locations)	208 g	373 g	373 g	373 g
Max Volume	N/A	Defined in Figure 4-35	Defined in Figure 4-35	Defined in Figure 4-35	Defined in Figure 4-35

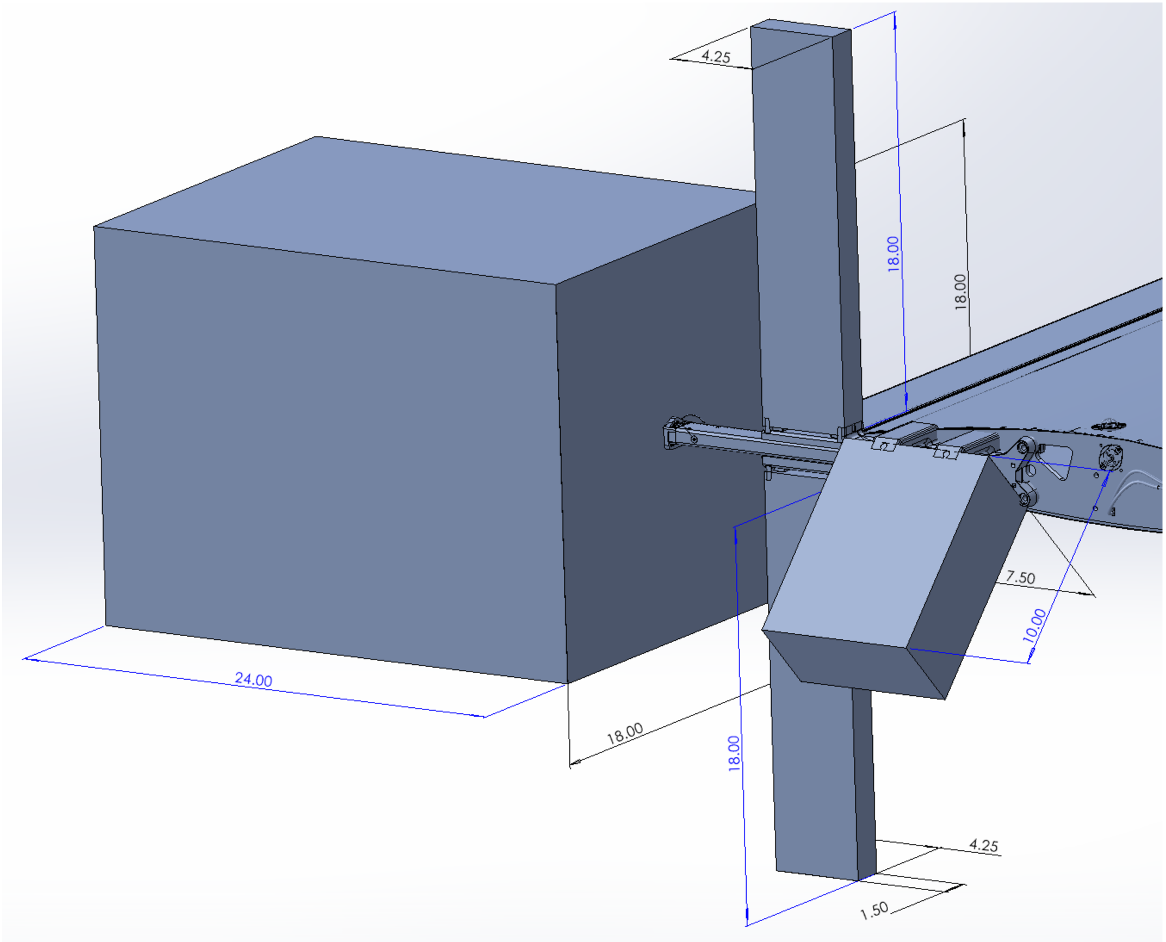


Figure 4-35. Wingtip Antenna Mount Maximum Volume

4.2.6.2 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 4-36 illustrates the 45° mount with a patch antenna installed.

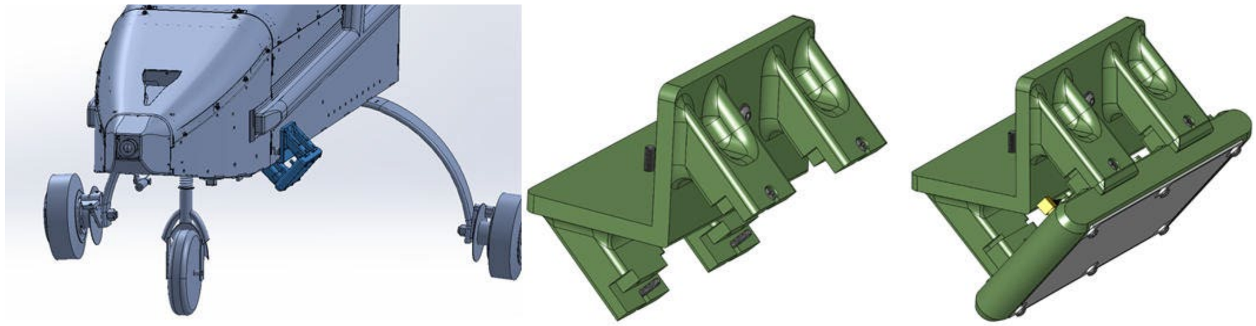


Figure 4-36. TigerShark Main Payload Bay 45° Antenna Mount

Figure 4-37 illustrates the down look mount with both a puck and omni antenna installed.

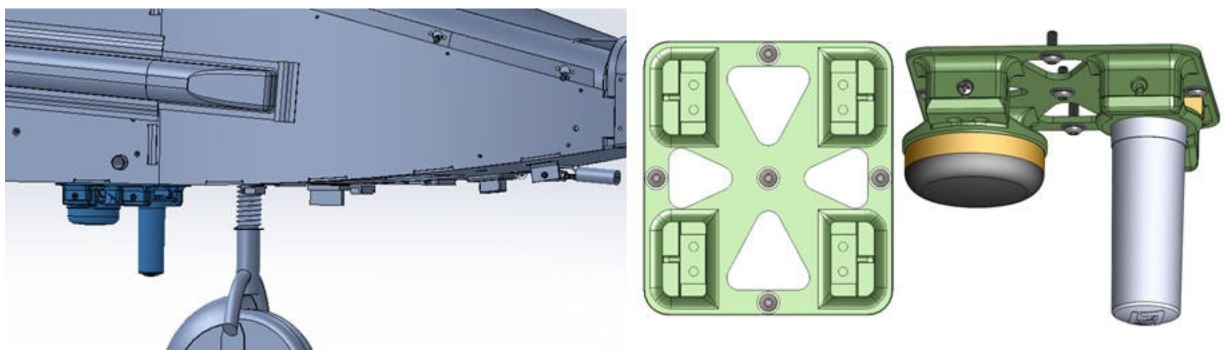


Figure 4-37. TigerShark Main Payload Bay Down Look Antenna Mount

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 4-8.

Table 4-8. Main Payload Bay Antenna Mount Capacity

	45° Look Mount	Down Look Mount
Max Weight	746 g (total of both possible antenna locations), maximum 373 g at each location	
Max Volume	Defined in Figure 4-38	

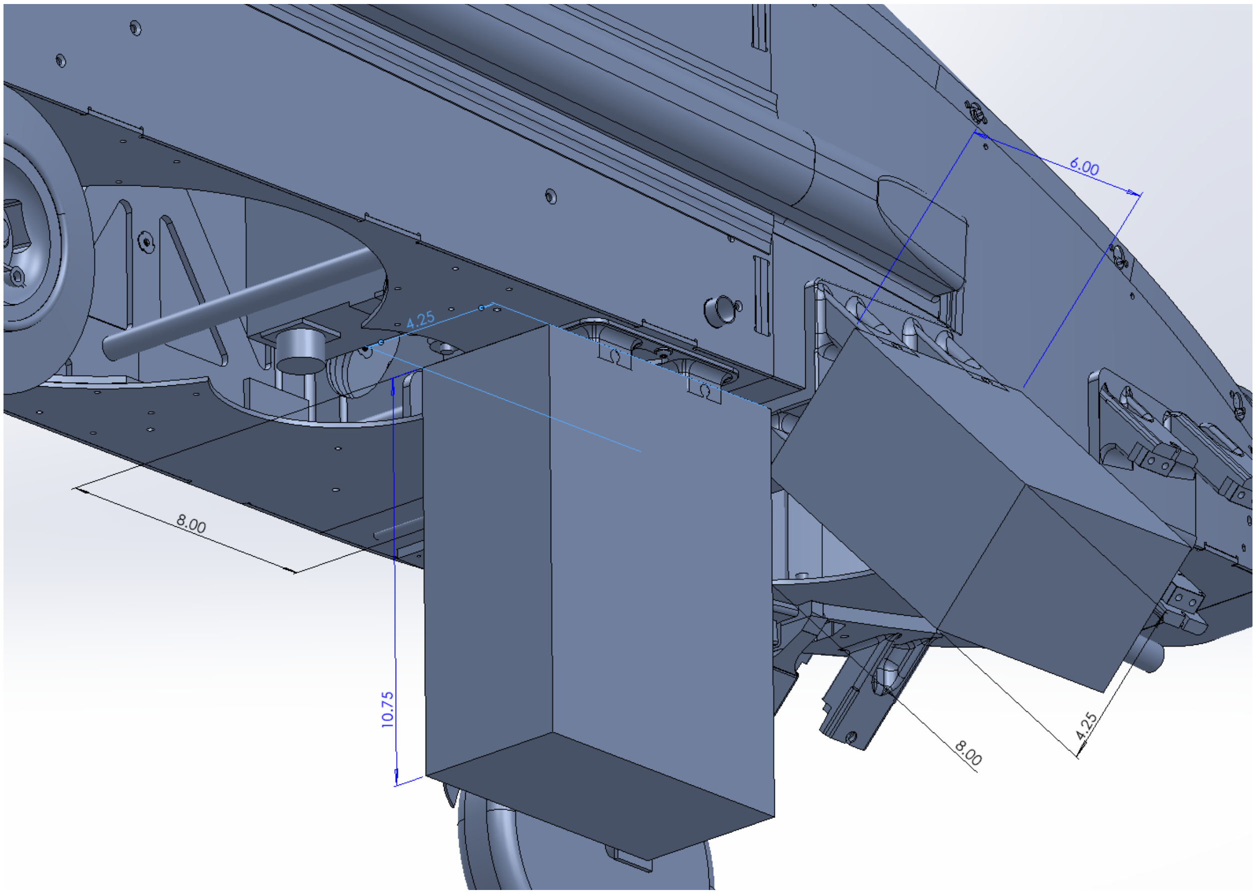


Figure 4-38. Main Payload Bay Mount Maximum Volume

4.2.6.3 Nose Mount

To minimize cable runs for sensitive payloads, the TigerShark also supports a 4-pt 45° antenna mount on the nose. Figure 4-39 illustrates the 45° mount with a patch antenna installed.

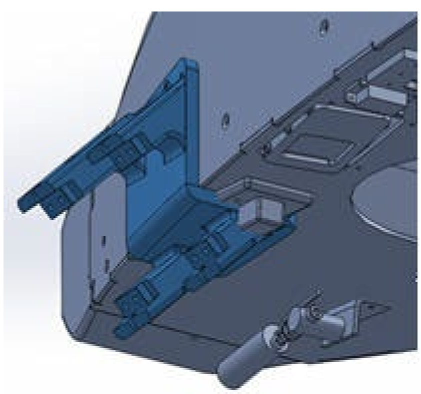


Figure 4-39. TigerShark Nose Bay 45° Antenna Mount

The nose 45° antenna mount weighs 455g. The nose antenna mount capacity is defined in Table 4-9.

Table 4-9. Nose Antenna Mount Capacity

Max Weight	373 g
45° Look Mount Max Volume	Defined in Figure 4-40

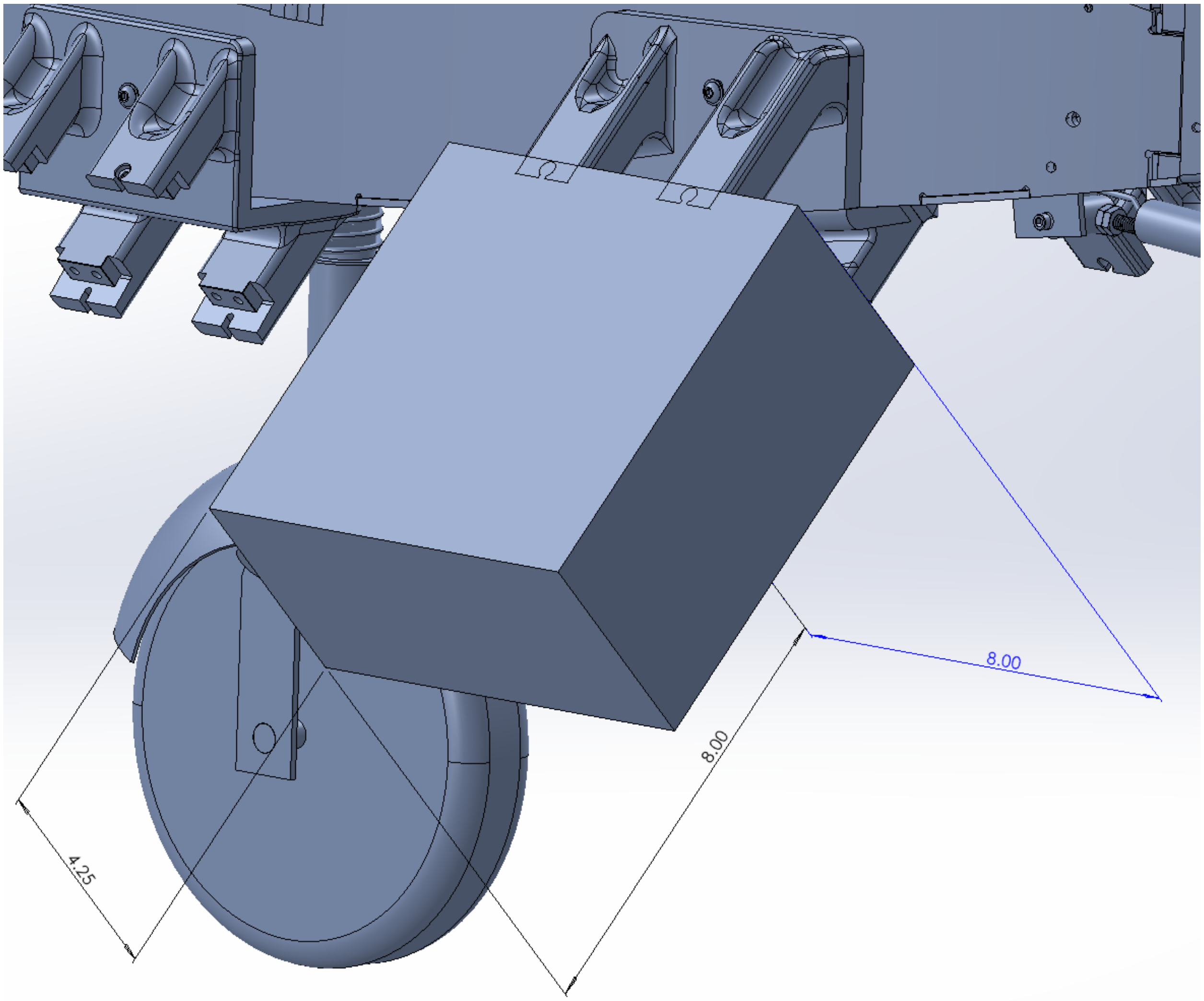


Figure 4-40. Nose Antenna Mount Maximum Volume

4.2.7 Cabling

The schematic for all MAIM cables is provided in Figure 4-41. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.2.7.5.

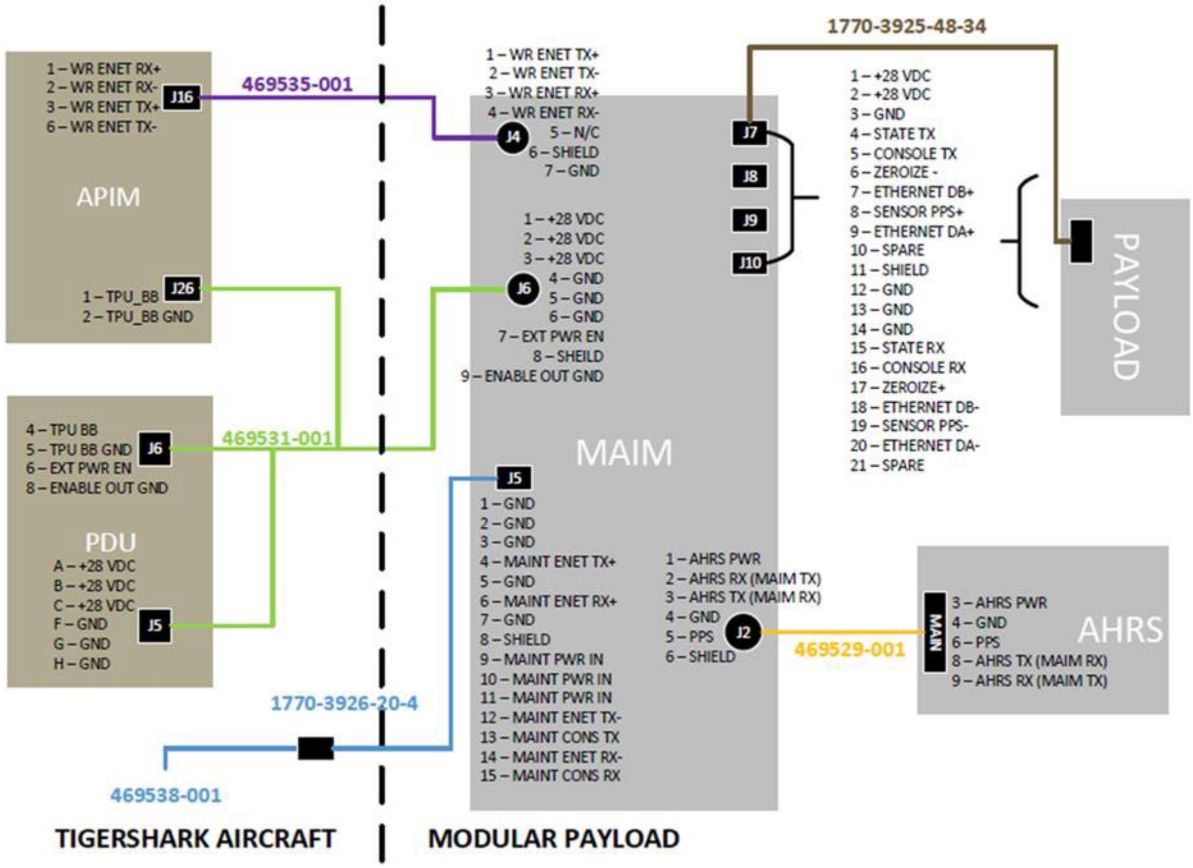


Figure 4-41. TigerShark MAIM Cabling Schematic

4.2.7.1 UAS-MAIM Cables

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

4.2.7.1.1 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 4-42. 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.

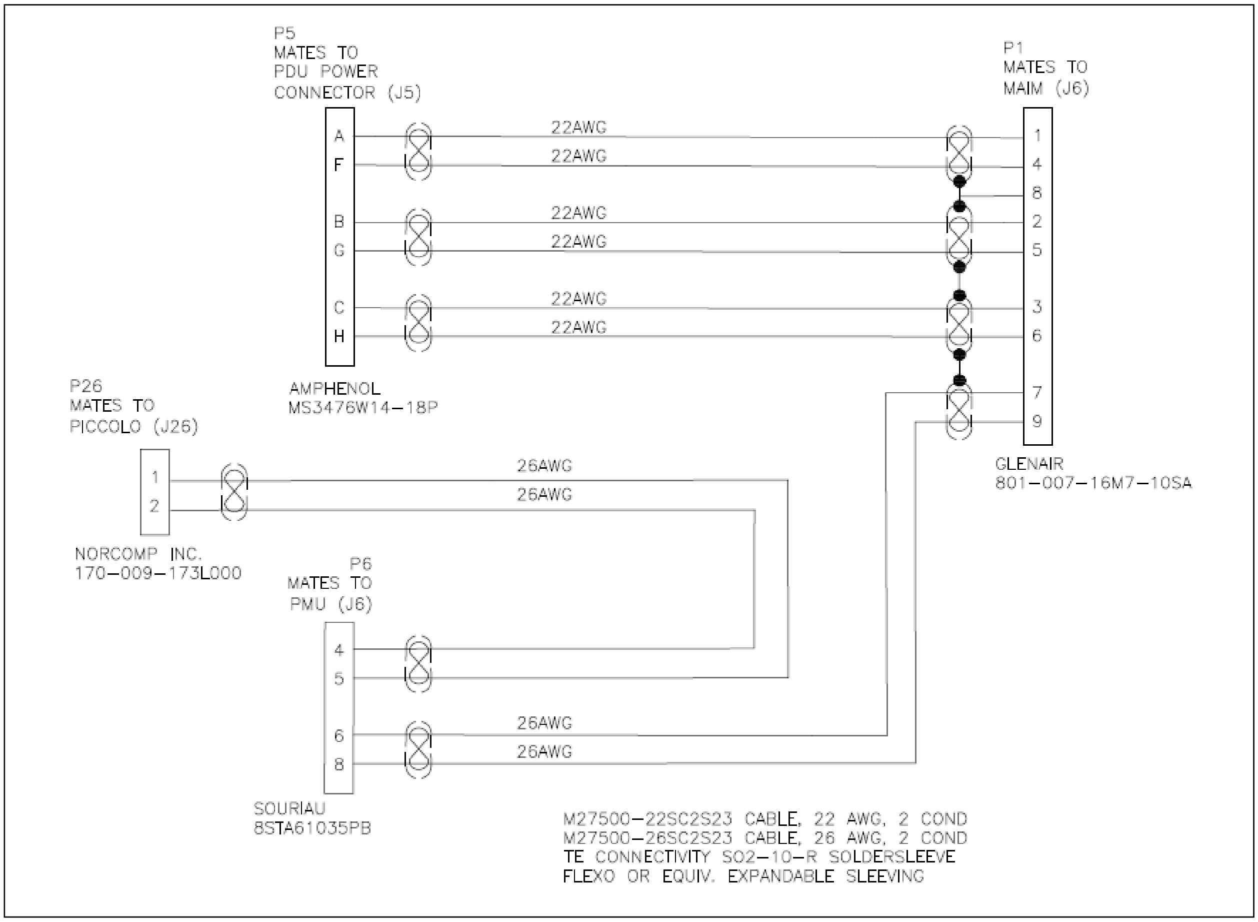


Figure 4-42. MAIM Power Cable

4.2.7.1.2 MAIM Network Cable

The MAIM Network cable is two 28AWG twisted shielded pairs with Expando sleeving and terminated as detailed in Figure 4-43. 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.

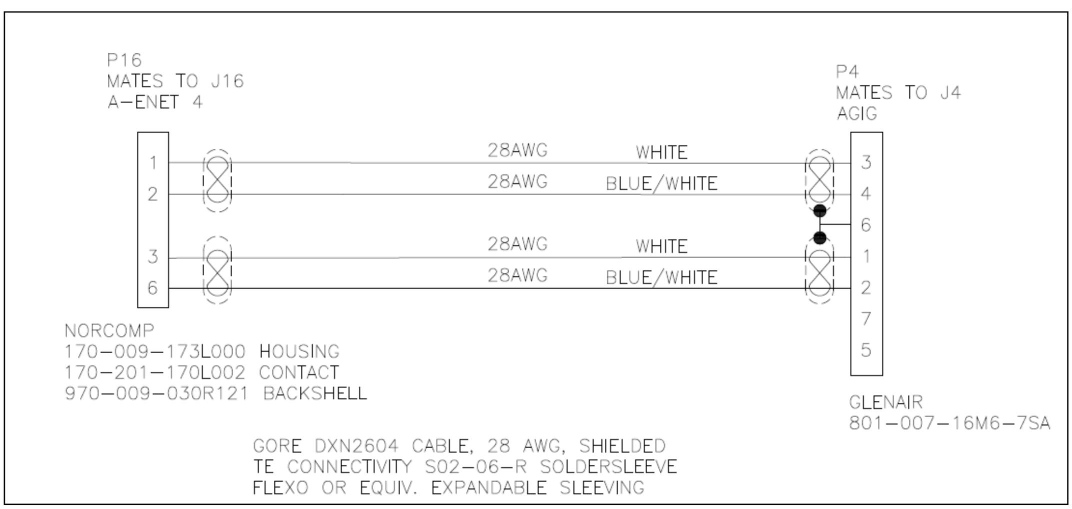


Figure 4-43. MAIM Network Cable

4.2.7.2 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.

4.2.7.3 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 4-44. 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.

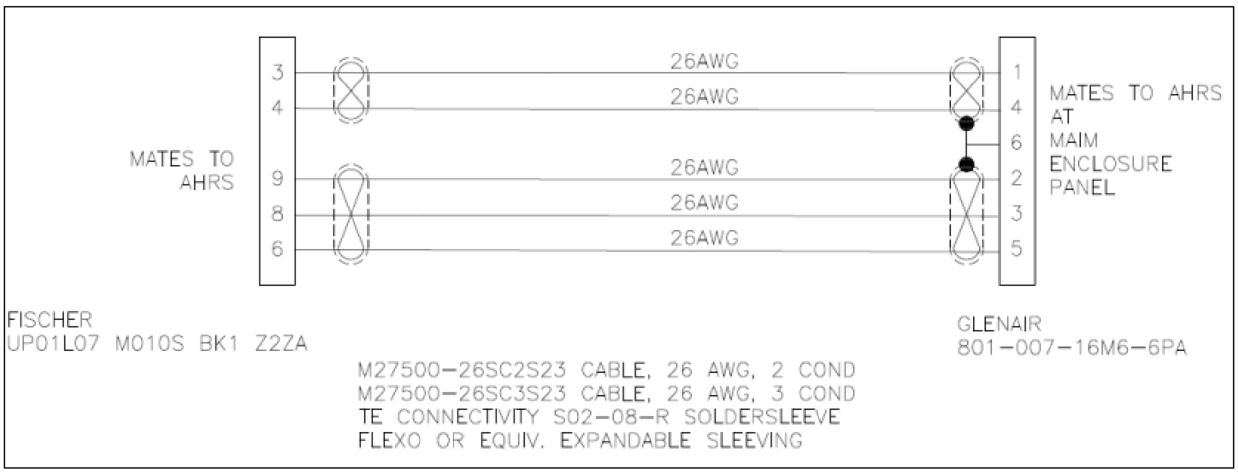


Figure 4-44. MAIM to INS Cable

4.2.7.4 GPS Antenna Cable

The GPS antenna cable is part of the INS installation (see Section 4.2.5) and is depicted in Figure 4-33 in that section.

4.2.7.5 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 4-45 and are detailed further in the subsequent sections.

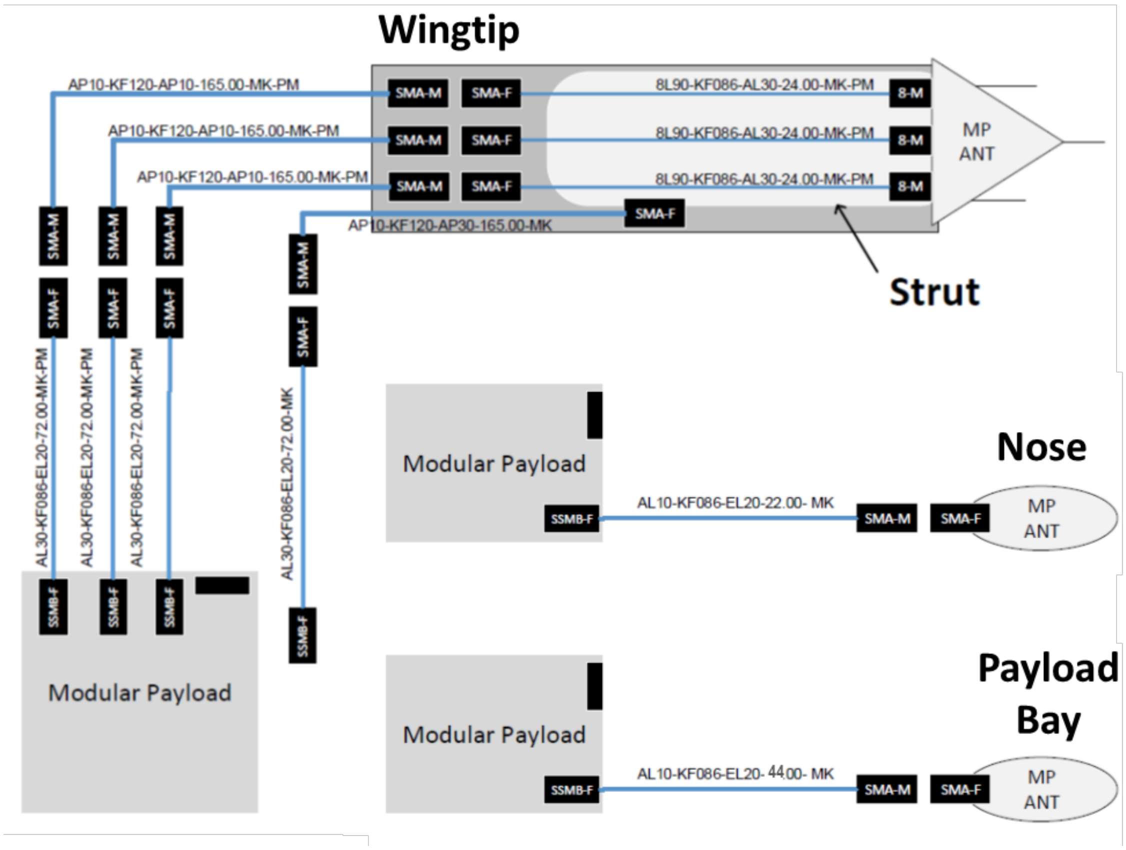


Figure 4-45. TigerShark RF Cable Runs

4.2.7.5.1 RF Cable Summary Table

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

Table 4-10. 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

4.2.7.5.2 Wingtip Cables

The cables that make up the wingtip cable set are low-loss, lightweight coax. As detailed in Figure 4-45, 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.

4.2.7.5.3 Main Payload Bay Cables

The main payload bay RF cable run, shown in Figure 4-45, 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.

4.2.7.5.4 Nose Cables

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

4.2.8 Concessions to the Standard

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

4.3 Jump-20 UAS

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

4.3.1 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.

4.3.1.1 MP Architecture

Figure 4-46 depicts the architectural layout of the MP implementation on the Jump-20 UAS.

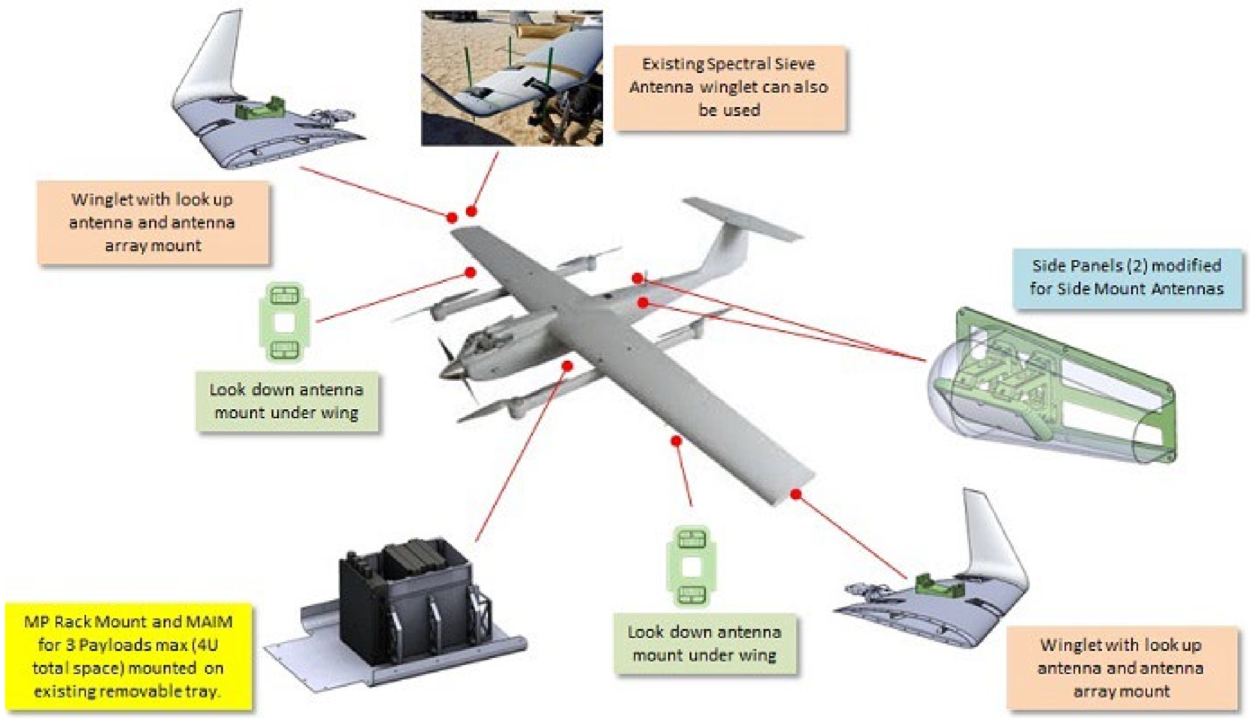


Figure 4-46. Architectural Layout for MP-Jump-20

4.3.1.2 Compliance / Capability Summary

Table 4-11 provides a top-level summary of the MP compliance and capability on the Jump-20 UAS.

Table 4-11. MP-Jump20 Compliance and Capability

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

4.3.1.3 System Diagram

Figure 4-47 details the system diagram for the MP-Jump-20 UAS. MP-specific additions are highlighted in teal.

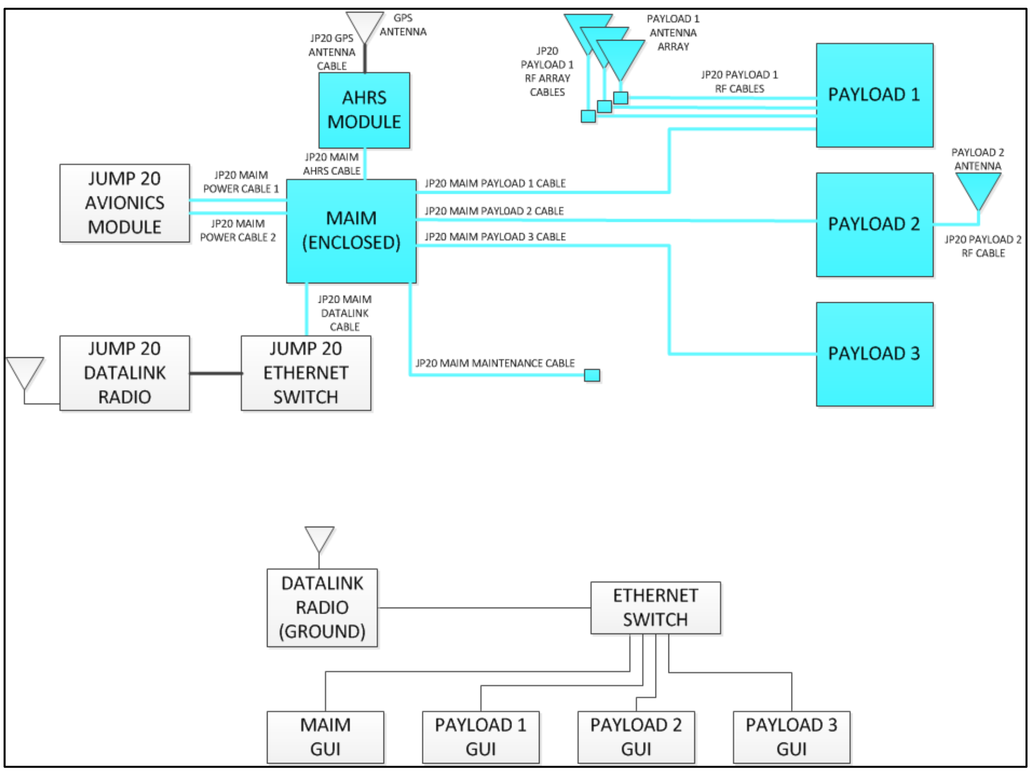


Figure 4-47. System Diagram for MP-Jump-20

4.3.2 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.

4.3.2.1 Weight Budget

The Mod Payload A-kit 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.

4.3.2.2 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.

4.3.3 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.

4.3.3.1 Mechanical Description

The MAIM enclosure is 6.6in x 5in x 1.7in and weighs 485g. Figure 4-48 shows the MAIM enclosure (left) and the MAIM board (right).

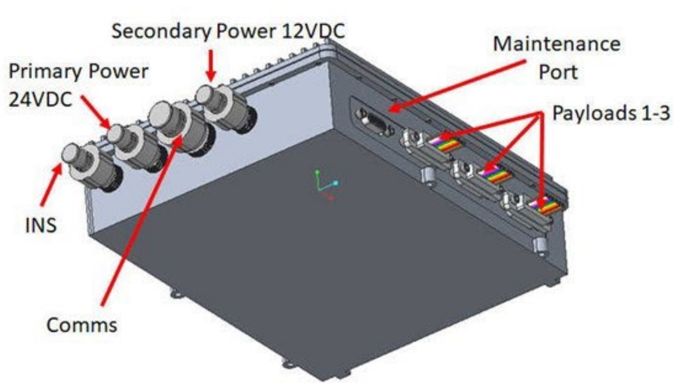


Figure 4-48. MAIM for Jump-20

4.3.3.2 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 4-49, 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.

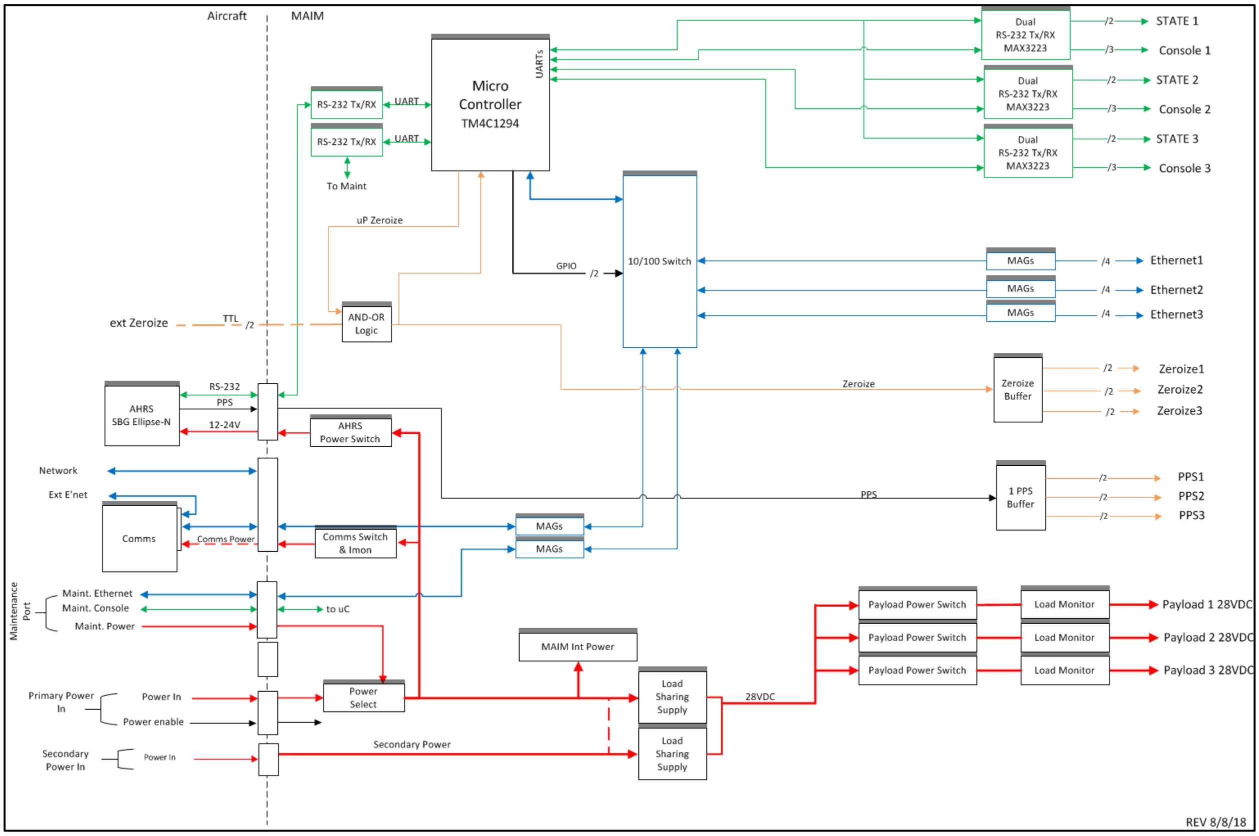


Figure 4-49. MAIM Block Diagram for Jump-20

4.3.3.2.1 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.

4.3.3.2.2 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).

4.3.3.2.3 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 4-50.

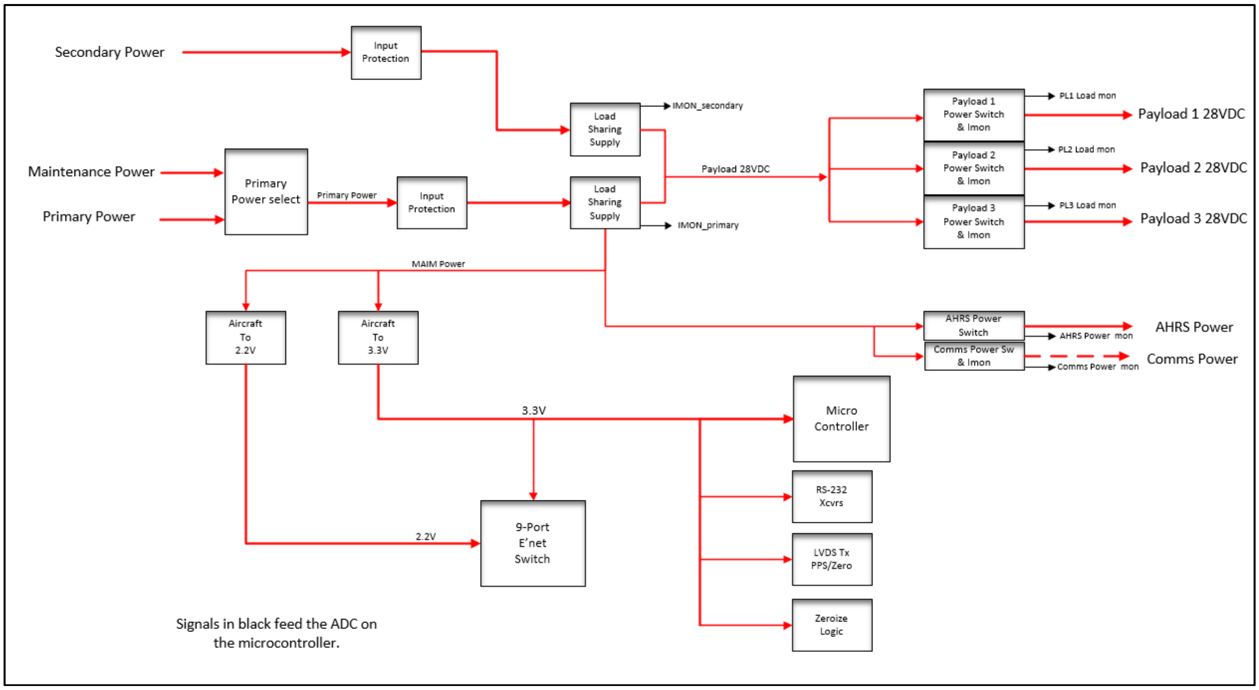


Figure 4-50. MAIM Power Circuitry Block Diagram

4.3.3.2.4 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.

4.3.3.2.5 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.

4.3.3.2.6 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.

4.3.3.3 MAIM Integration

The MAIM enclosure is installed to the forward face of the Primary Mount (Figure 4-51). 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.

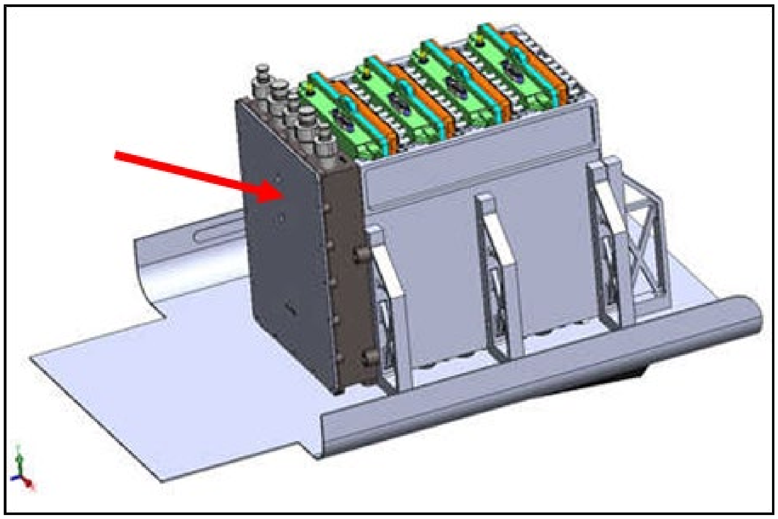


Figure 4-51. MAIM Installed on Jump-20 MP Payload Tray

4.3.4 Primary Mount

The Primary Mount for the Jump-20 is a 4U rack installed on a modified aft payload tray. Figure 4-52 shows the Primary Mount with the MAIM, a 1.5U and a 1U payload installed.

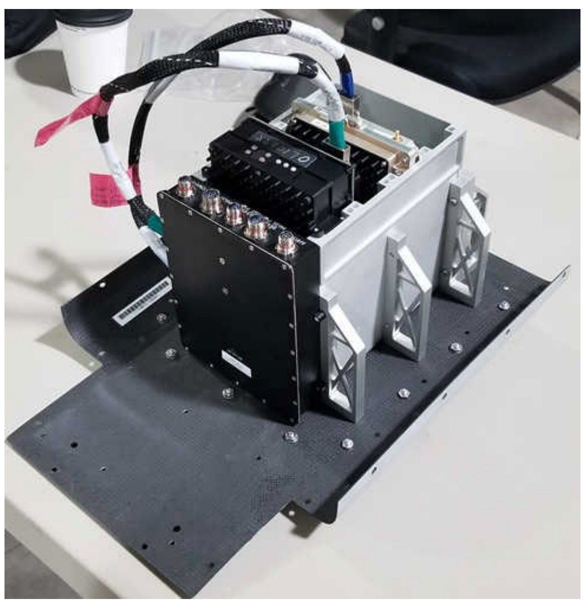


Figure 4-52. Jump-20 Primary Mount with MAIM and Two Payloads

4.3.4.1 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 4-53.

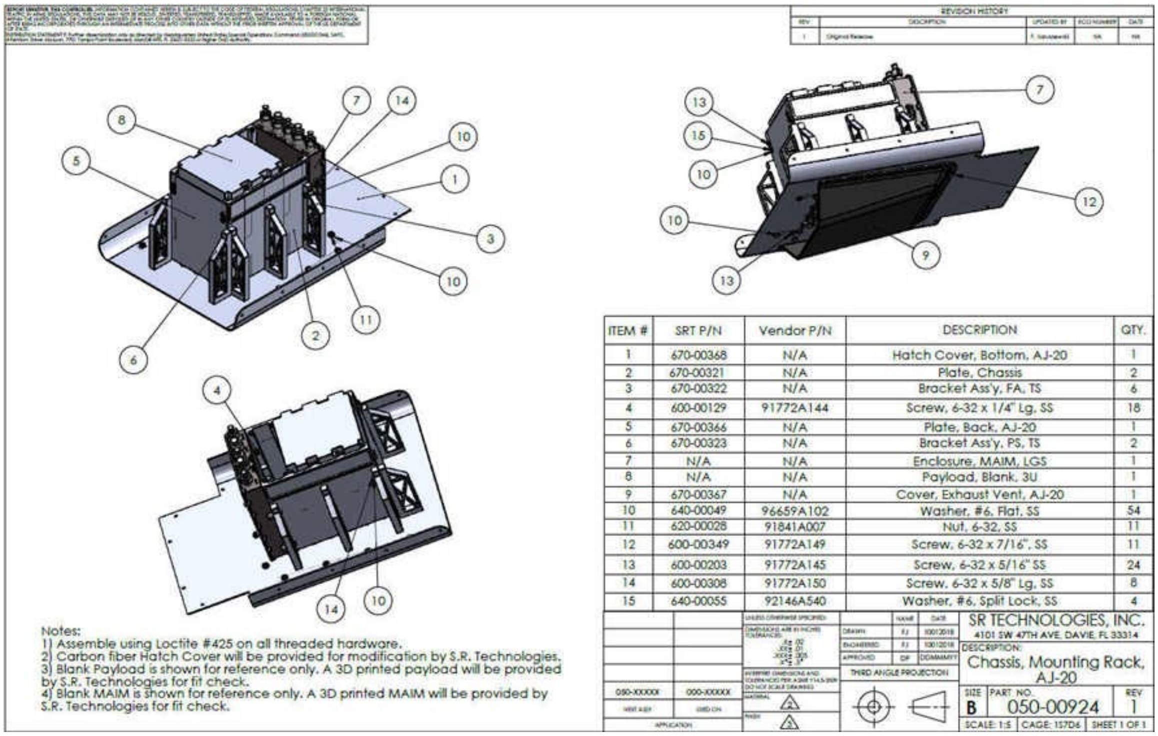


Figure 4-53. Jump-20 Primary Mount Assembly Drawing

4.3.4.2 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 4.3.3.3, prior to installation into the aircraft. As depicted in Figure 4-54, 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.

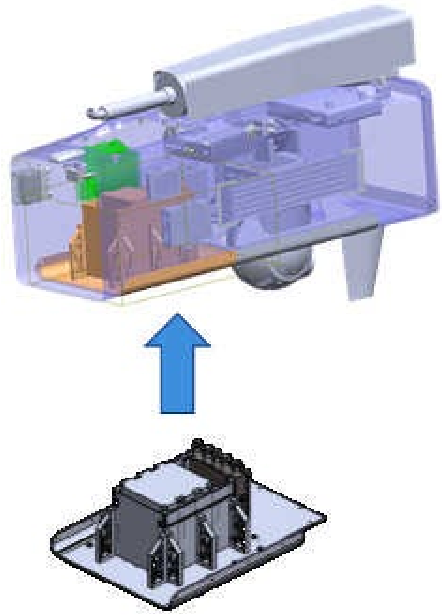


Figure 4-54. Jump-20 Primary Mount Installation

4.3.4.3 Thermal

Multiple considerations are made to and around the Primary Mount to provide the requisite airflow 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 4-55.

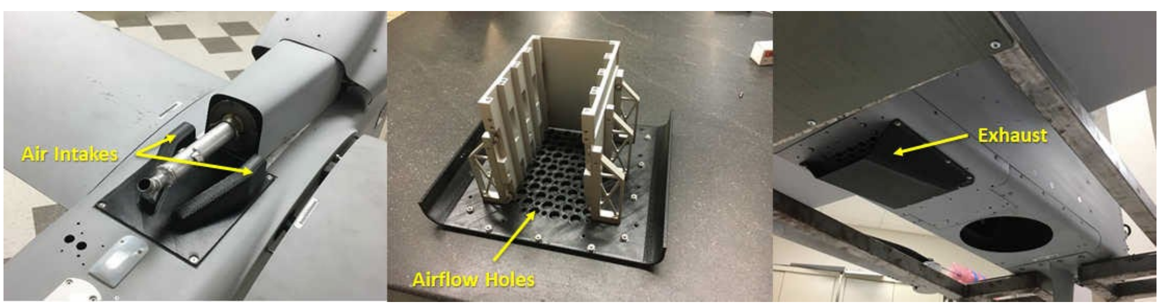


Figure 4-55. Forced Convection Modifications

4.3.5 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 4-56 shows the INS installation location and the platform payload antenna farm.

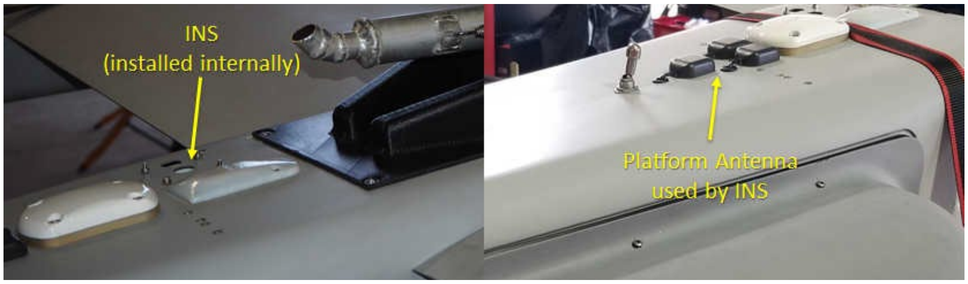


Figure 4-56. Jump-20 INS Location and GPS Antenna

4.3.6 Antenna Mounts

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

4.3.6.1 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 4-57, Figure 4-58, and Figure 4-59 show each wingtip configuration.

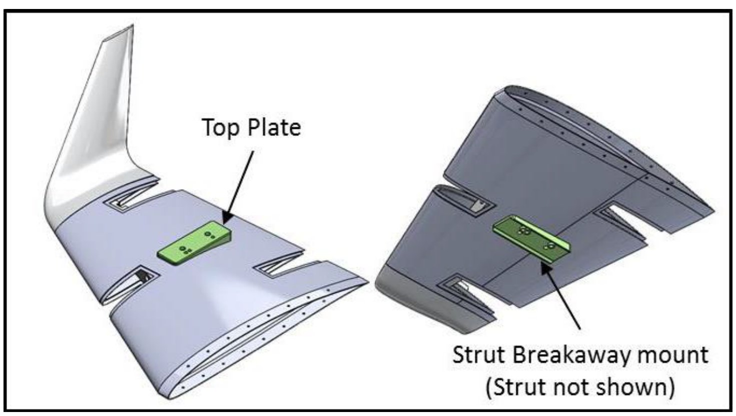


Figure 4-57. Jump-20 Wingtip – Array Configuration

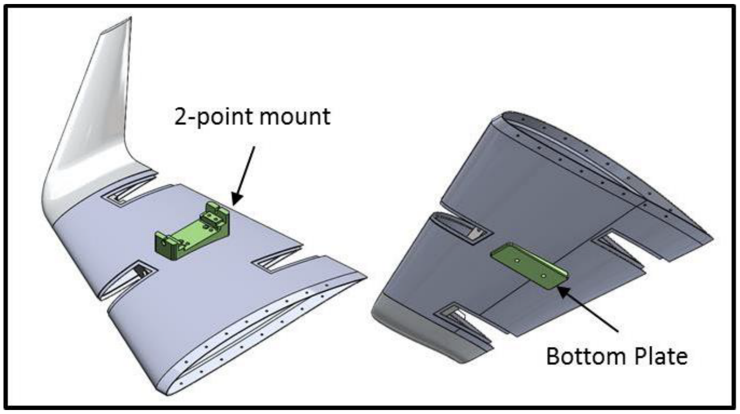


Figure 4-58. Jump-20 Wingtip – 2-pt Up Look Configuration

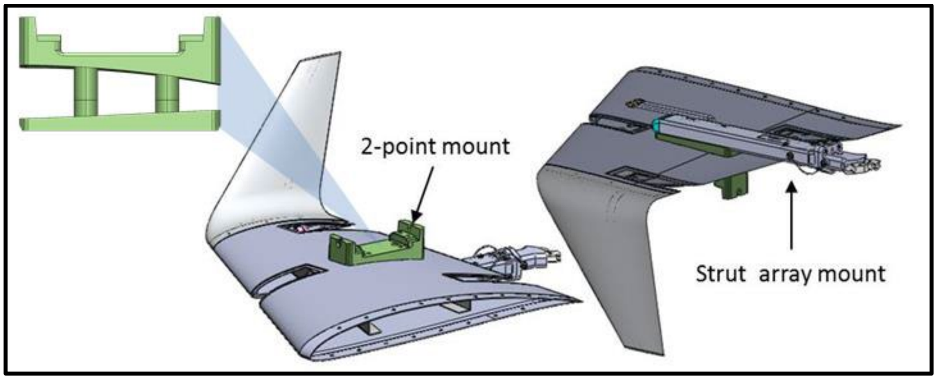


Figure 4-59. Jump-20 Wingtip – Array and 2-pt Up Look Configuration

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 4-12.

Table 4-12. 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 4-13.

Table 4-13. Antenna Mount Capacity

Antenna Array Mount	
Max Weight	208 g
Max Volume	Defined in Figure 4-60
2-pt Up Look Antenna Mount	
Max Weight	373 g
Max Volume	Defined in Figure 4-60

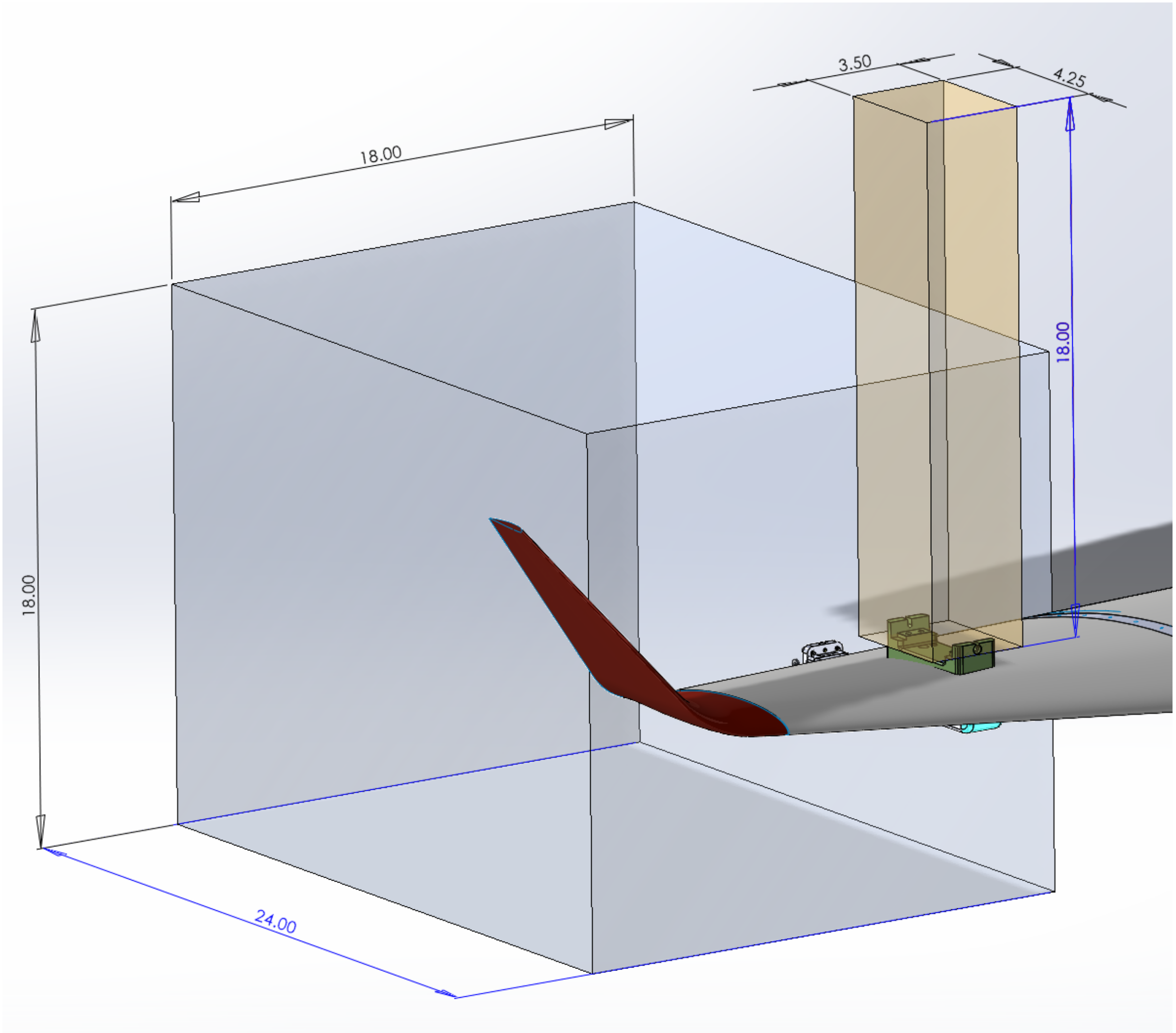


Figure 4-60. Antenna Mount Maximum Volume

4.3.6.2 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 4-61.

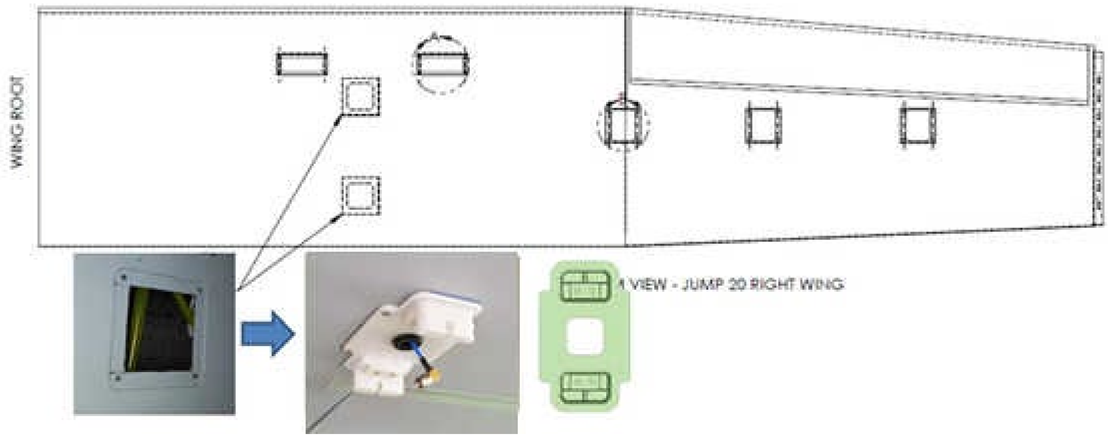


Figure 4-61. Jump-20 Mid-wing 2-pt Down Look Mount

The 2-pt down look mount weighs 60g. The 2-pt down look antenna mount capacity is defined in Table 4-14.

Table 4-14. Down Look Antenna Mount Capacity

Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in 4.3.2.1)
Max Volume	Defined in Figure 4-62

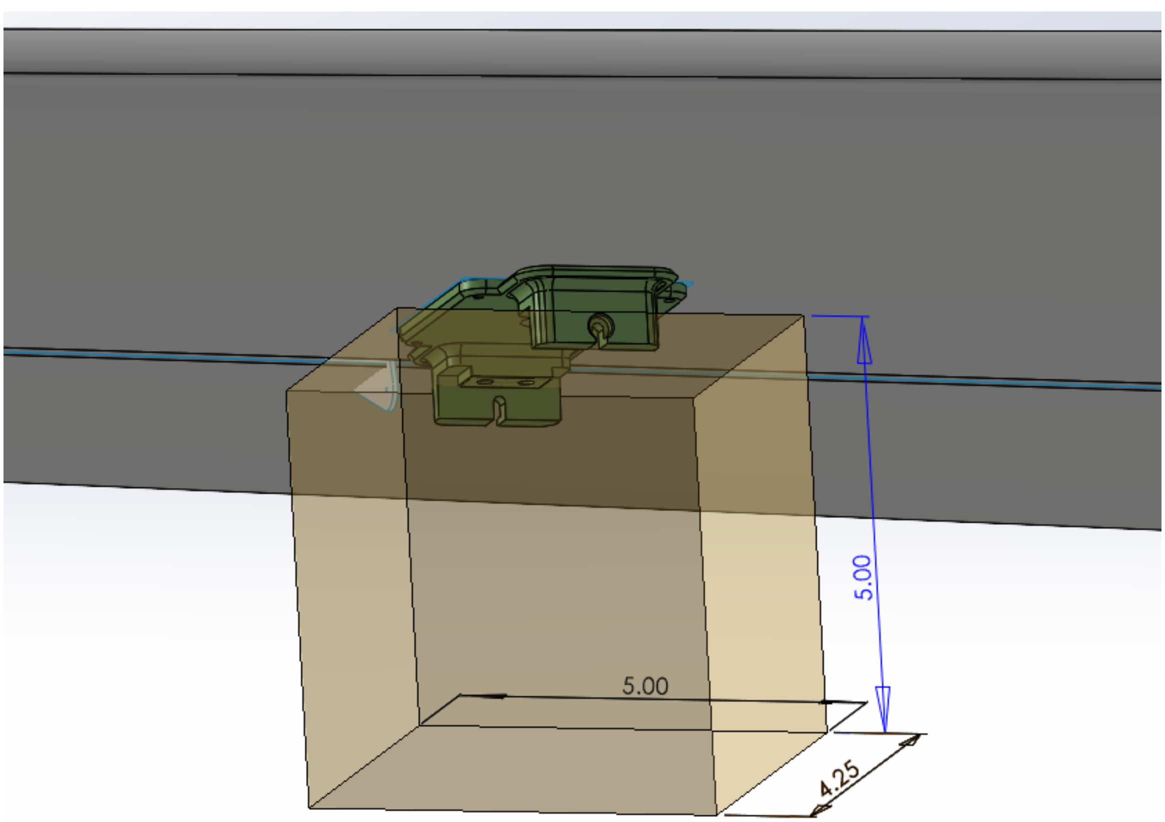


Figure 4-62. Mid Wing Mount Maximum Volume

4.3.6.3 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 4-63 shows the antenna mount assembly both with and without the radome.

Figure 4-63. Jump-20 Side Hatch Antenna Mount – With and Without Radome

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 4-15.

Table 4-15. 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 4-16.

Table 4-16. Jump-20 Hatch Antenna Mount Capacity

2-pt Side Look Antenna Mount		4-pt Side Look Antenna Mount	
Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in 4.3.2.1)	Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in 4.3.2.1)
Max Volume	Defined in Figure 4-65	Max Volume	Defined in Figure 4-65
2-pt 45° Antenna Mount		**4-pt 45° Antenna Mount**	
Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in 4.3.2.1)	Max Weight	373 g (total weight budget of B-kit must not exceed that outlined in 4.3.2.1)
Max Volume	Defined in Figure 4-64	Max Volume	Defined in Figure 4-64

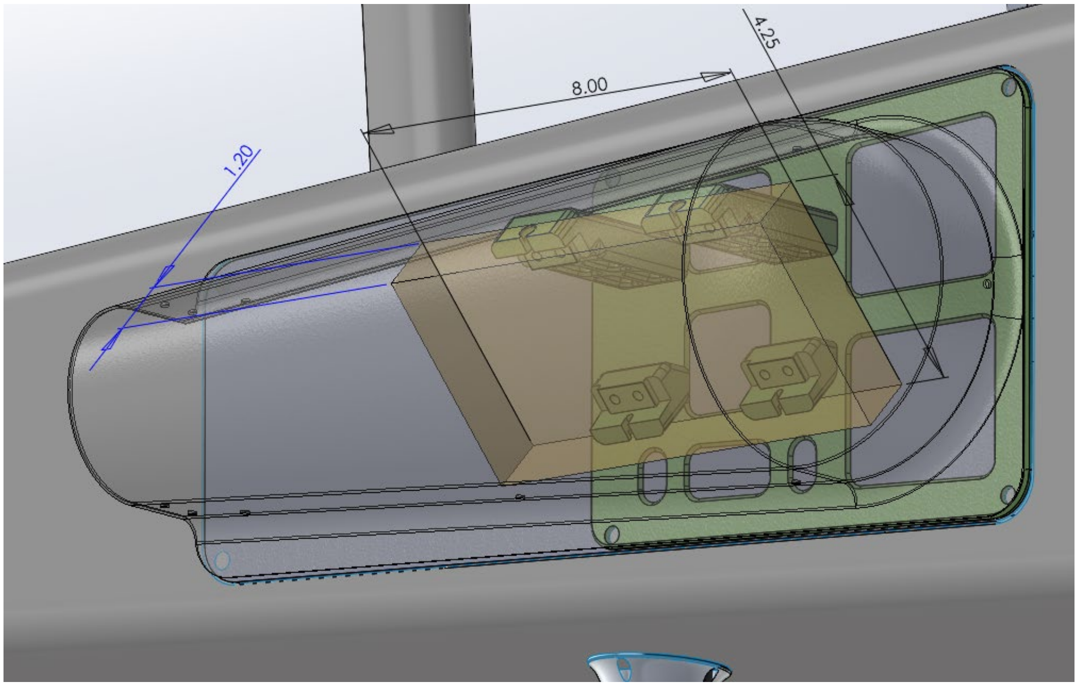


Figure 4-64. 45° Look Mount Maximum Volume

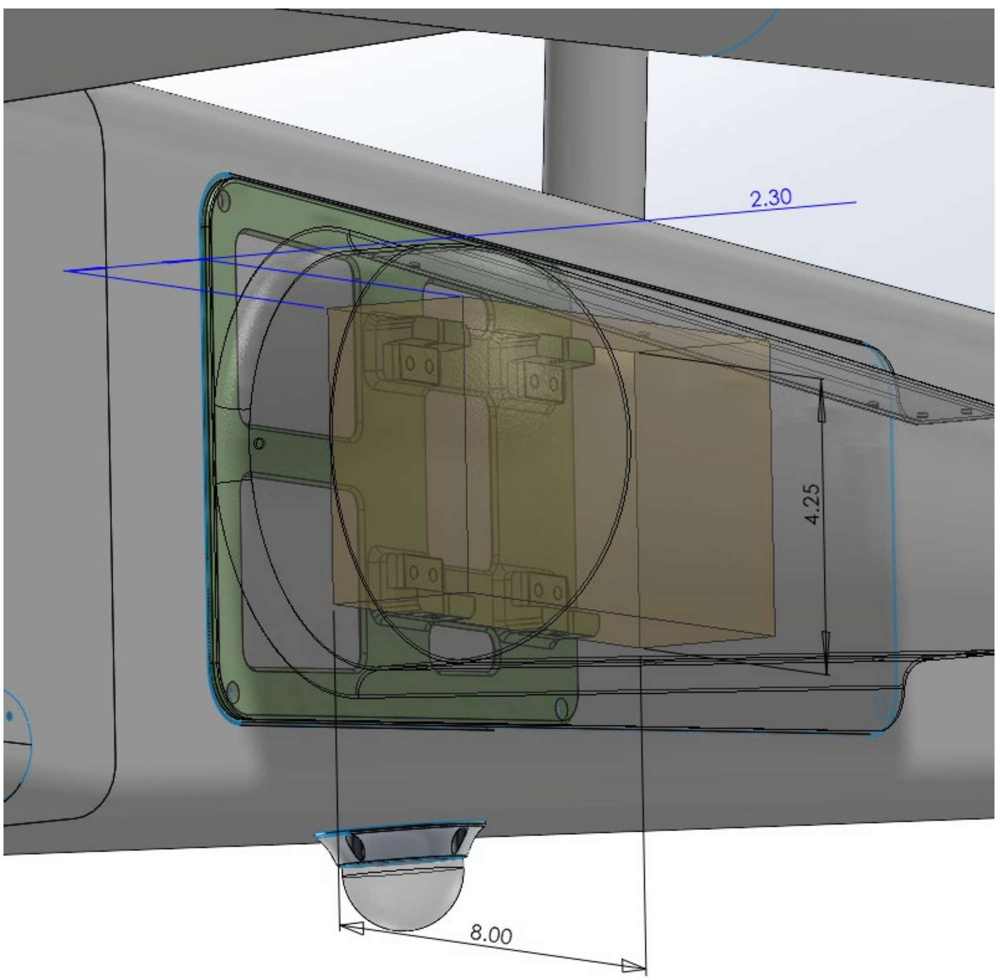


Figure 4-65. Sidelook Mount Maximum Volume

4.3.7 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 4-66. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.3.7.6.

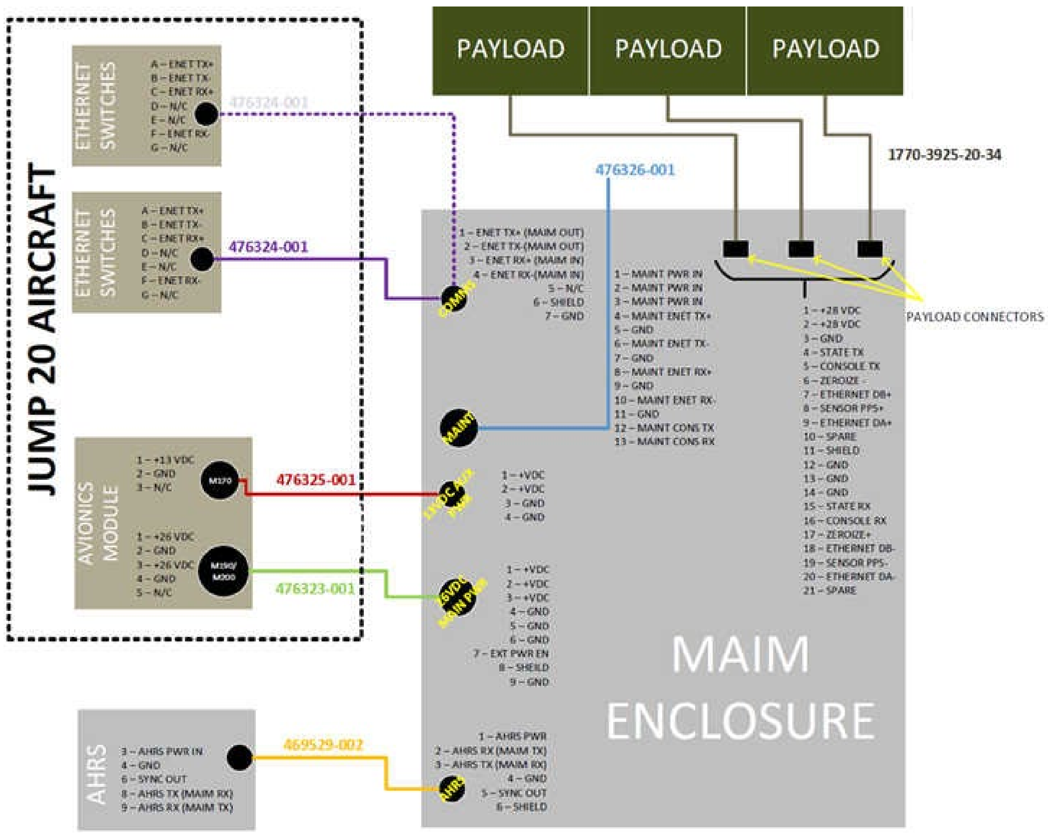


Figure 4-66. Jump-20 MAIM Cabling Schematic

4.3.7.1 Primary Power Cable

The MAIM primary power cable is two 22AWG twisted shielded pairs with Expando sleeving terminated as detailed in Figure 4-67. 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.

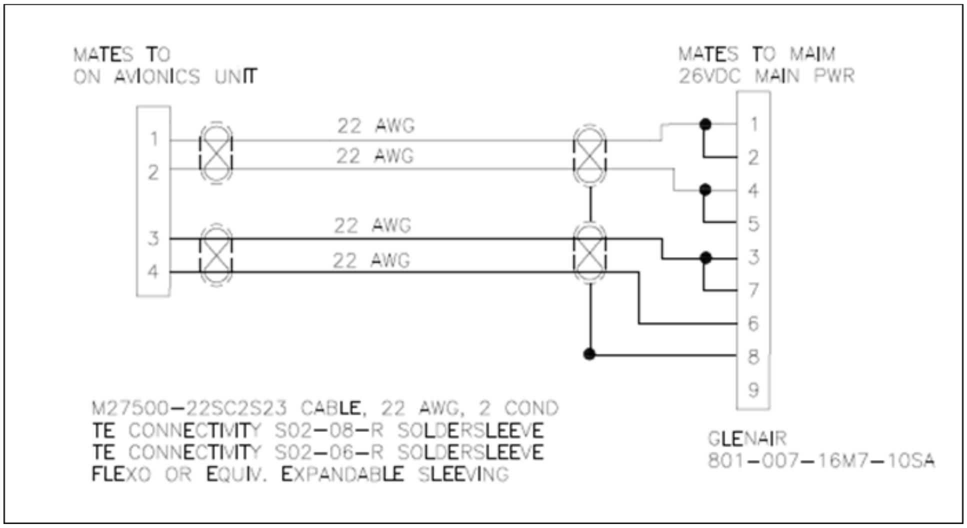


Figure 4-67. MAIM Primary Power Cable Pinout

4.3.7.2 Secondary Power Cable

The MAIM secondary power cable is one 22AWG twisted shielded pair with Expando sleeving terminated as detailed in Figure 4-68. 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.

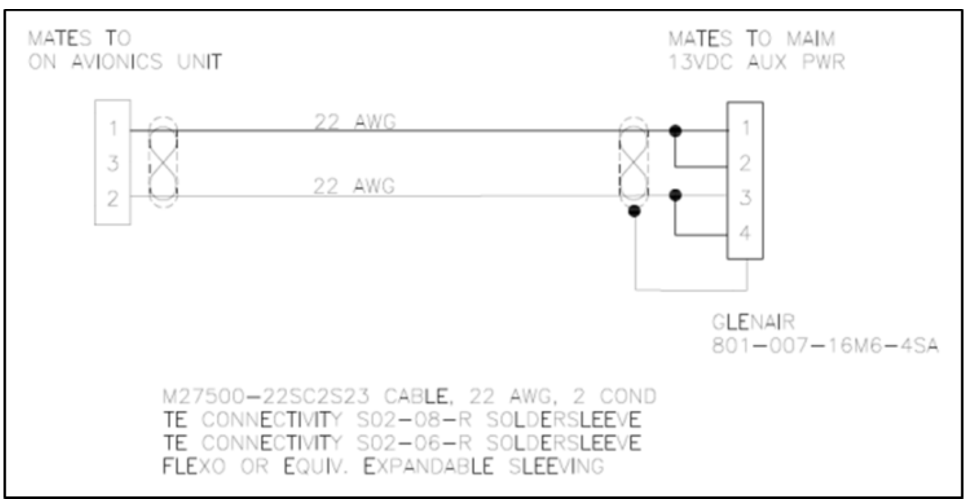


Figure 4-68. MAIM Secondary Power Cable Pinout

4.3.7.3 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 4-69 depicts this cable run, but with only two MAIM-payload cables. Each MAIM-payload cable is 20-inches long and weighs 47g.

Figure 4-69. MAIM-Payload Cable Runs

4.3.7.4 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 4-70. 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.

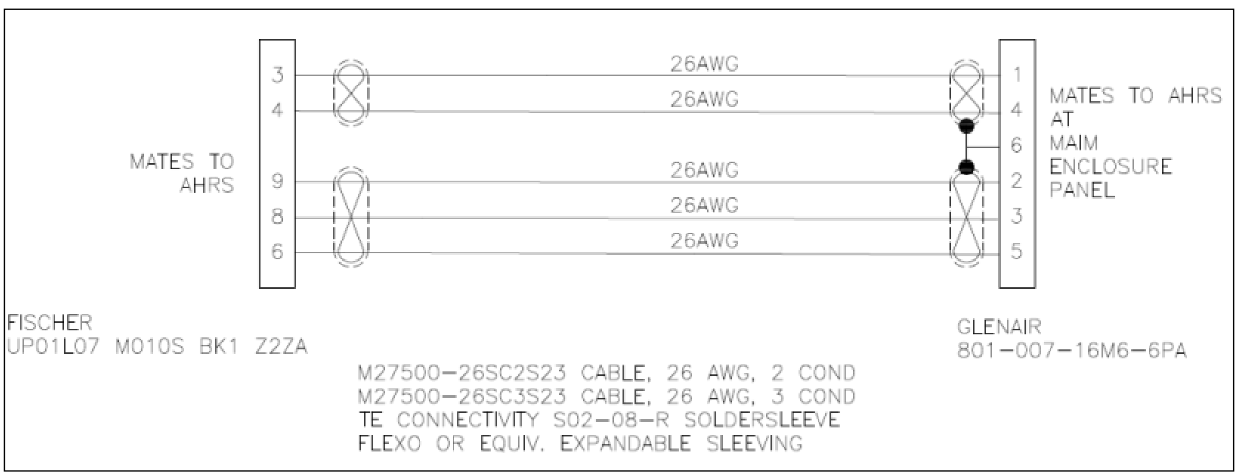


Figure 4-70. MAIM to INS Cable

4.3.7.5 Network Cable

The MAIM network cable is two 28AWG twisted shielded pairs with Expando sleeving and terminated as detailed in Figure 4-71. 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.

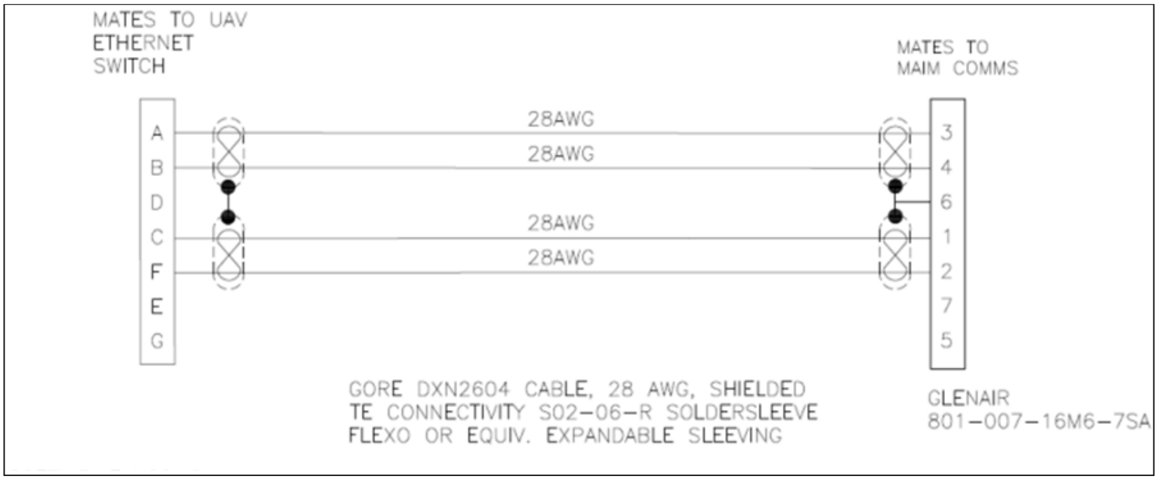


Figure 4-71. MAIM Network Cable

4.3.7.6 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.

4.3.7.6.1 RF Cable Summary Table

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

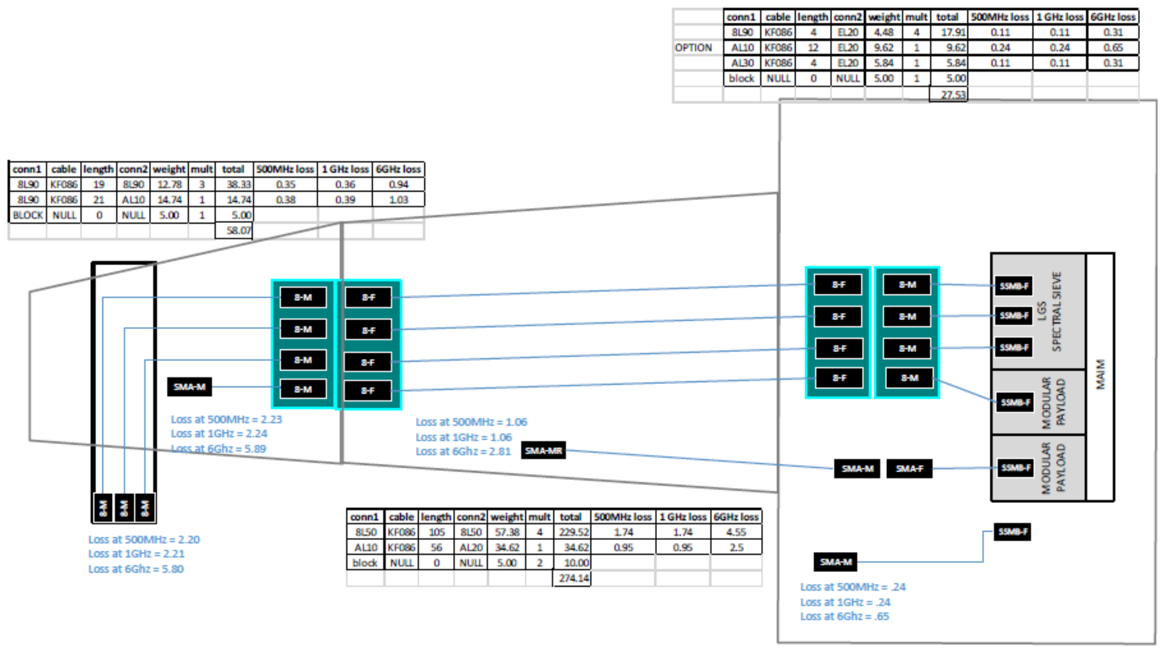
Table 4-17. Jump-20 RF Cable Summary

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

4.3.7.6.2 Left Side Cables

The cables that make up the left side cable set are low-loss, lightweight coax. As detailed in Figure 4-72, the left cable set consists of four cable runs that terminate in four different antenna mount locations along the left 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
OPTION	AL10	KF086	12	EL20	9.62	1	9.62	0.24	0.24	0.65
	AL30	KF086	4	EL20	5.84	1	5.84	0.11	0.11	0.31
	block	NULL	0	NULL	5.00	1	5.00			
							27.53			

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			

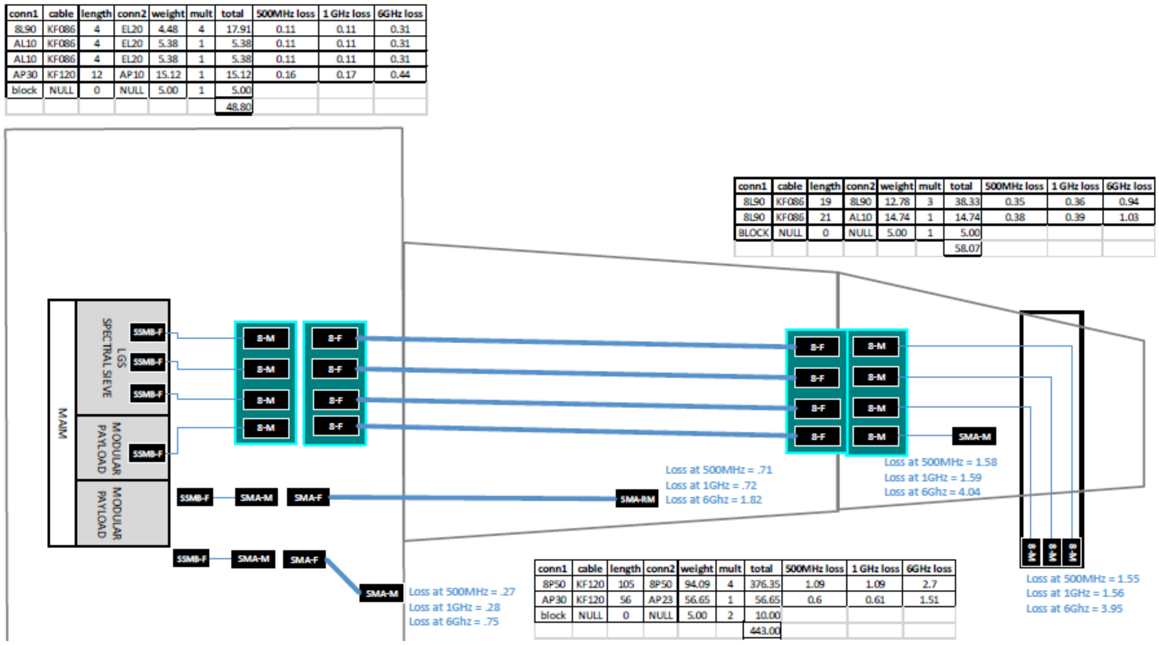
conn1	cable	length	conn2	weight	mult	total	500MHz loss	1 GHz loss	6GHz loss
8L50	KF086	105	8L50	57.38	4	229.52	1.74	1.74	4.55
AL10	KF086	56	AL20	34.62	1	34.62	0.95	0.95	2.5
block	NULL	0	NULL	5.00	2	10.00			
						274.14			

Figure 4-72. 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.

4.3.7.6.3 Right Side Cables

The cables that make up the right side cable set are lower-loss, heavier-weight coax. As detailed in Figure 4-73, 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 4-73. 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.

4.3.8 Concessions to the Standard

No concessions are required for the MP-Jump-20.

4.4 Stalker XE25 UAS

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

4.4.1 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.

4.4.1.1 MP Architecture

Figure 4-74 depicts the architectural layout of the MP implementation on the Stalker XE25 UAS.

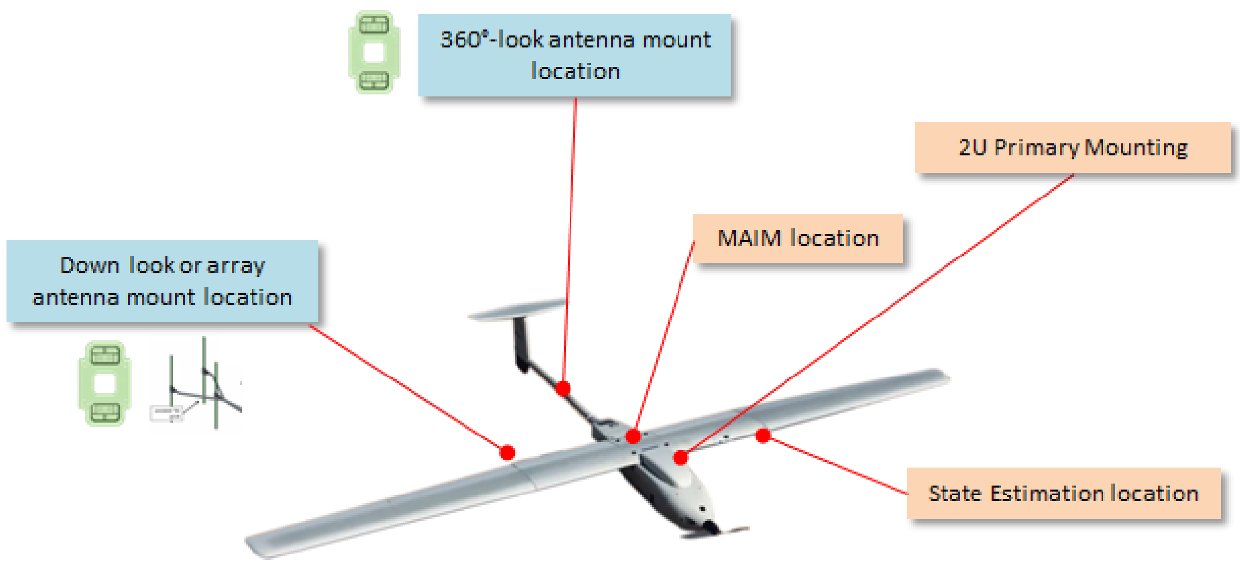


Figure 4-74. Architectural Layout for MP-Stalker

4.4.1.2 Compliance / Capability Summary

Table 4-18 provides a top-level summary of the MP compliance and capability on the Stalker XE25 UAS.

Table 4-18. MP-Stalker 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">Fuselage, Mid-bay</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">Nose (External)</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Wing, Left Hard Point</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">1</td></tr>
<tr><td colspan="2">Available Payload Power</td><td colspan="2">56W</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">2U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">Varies – 3.0 lbs (1.3 kg) minimum</td></tr>
<tr><th colspan="2">Primary Mount</th><th colspan="2"></th></tr>
<tr><td colspan="2">Mounting Method</td><td colspan="2">Plate</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>Two-point</td><td>2</td><td>Boom
Wing, Right Hard Point</td><td>360º
Down</td></tr>
<tr><td>Four-points</td><td>0</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Array</td><td>1</td><td>Wing, Right Hard Point</td><td>Forward</td></tr>
</table>

4.4.1.3 System Diagram

Figure 4-75 details the system diagram for the MP-Stalker XE25 UAS. MP-specific additions are highlighted in teal.

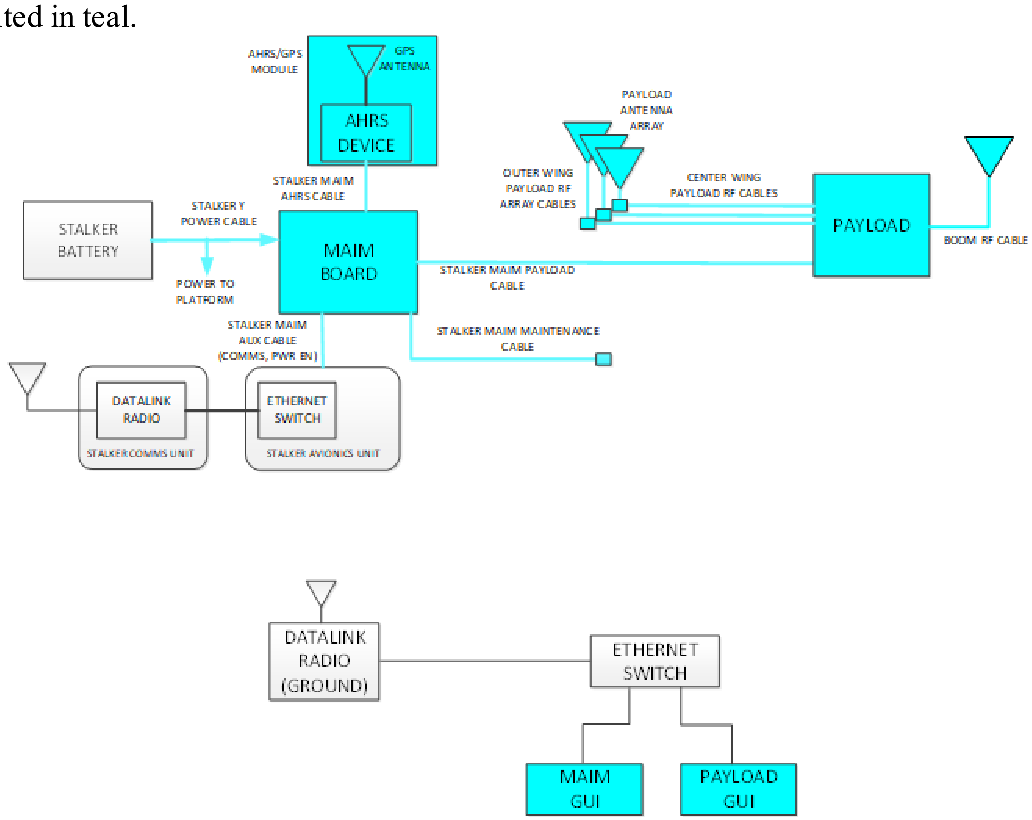


Figure 4-75. System Diagram for MP-Stalker

4.4.2 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.

4.4.2.1 Weight Budget

The Mod Payload A-kit (MAIM, Primary Mount Assembly, INS, INS mount, GPS Antenna, antenna mounts, and cabling) adds 708g to the Stalker. This leaves an allowance of 1.3kg for MP-compliant payloads, while maintaining the platform's primary FMV turret.

4.4.2.2 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.

4.4.3 MAIM

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

4.4.3.1 Mechanical Description

The MAIM board is 5.7in x 2.5in x 0.5in board and weighs 72g. Figure 4-76 shows the MAIM.

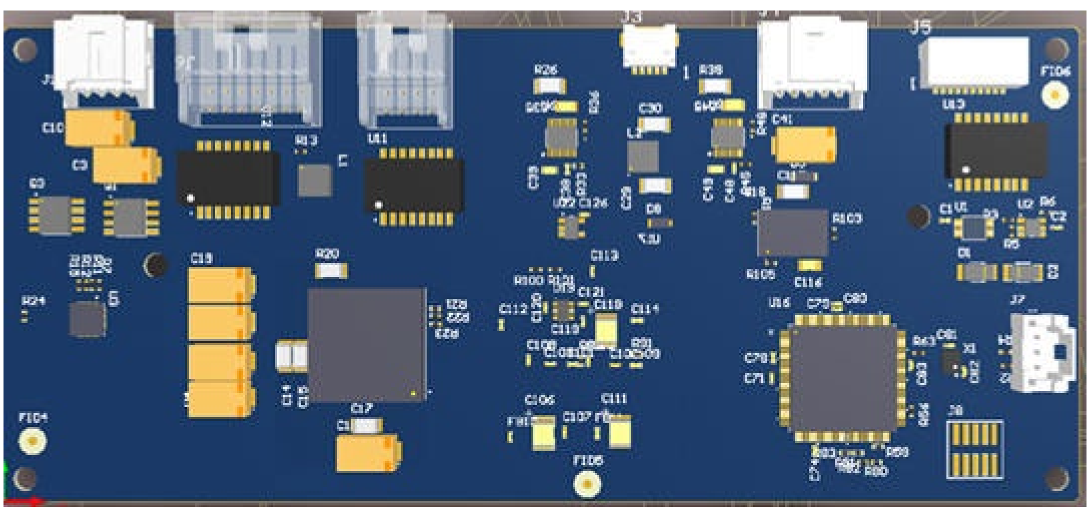


Figure 4-76. MAIM for Stalker

4.4.3.2 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 4-77, 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.

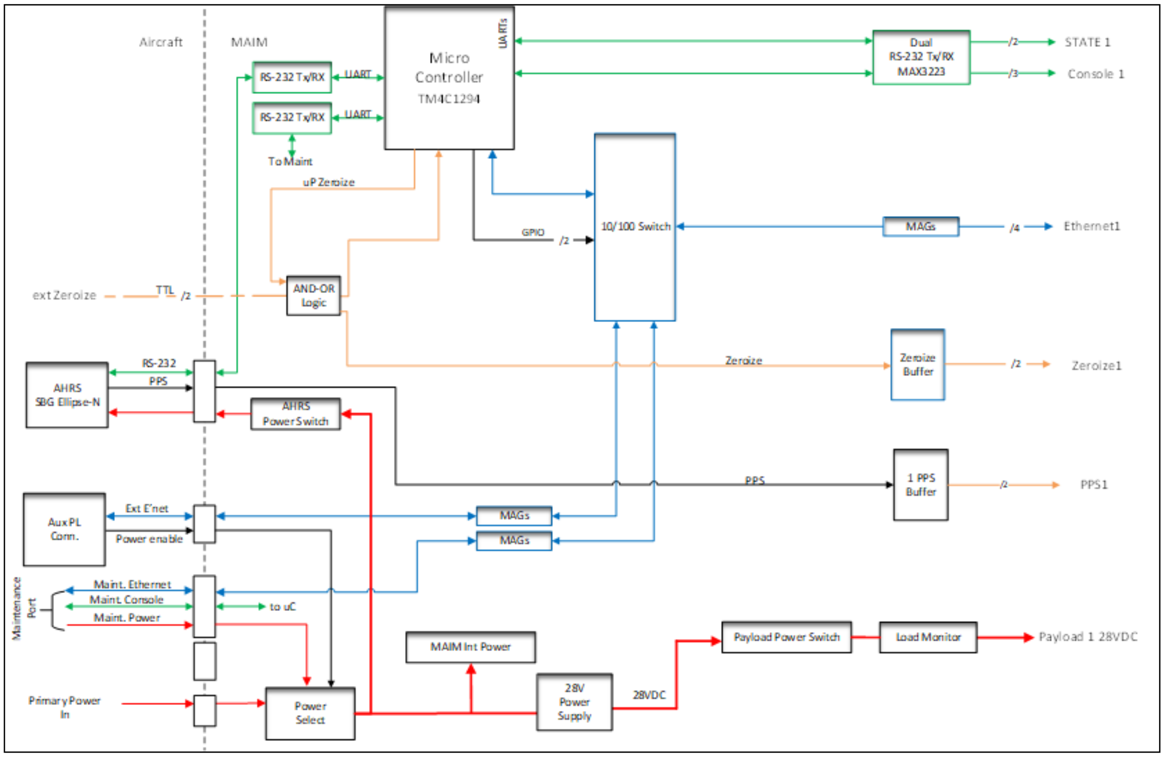


Figure 4-77. MAIM Block Diagram for Stalker

4.4.3.2.1 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.

4.4.3.2.2 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).

4.4.3.2.3 Power Monitoring

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

4.4.3.2.4 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.

4.4.3.2.5 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.

4.4.3.2.6 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.

4.4.3.3 MAIM Integration

The MAIM is installed in the mid bay to the side of the fuselage (Figure 4-78), using existing holes in the airframe. The MAIM is oriented with connectors facing up to allow for the easy installation and removal of cables.

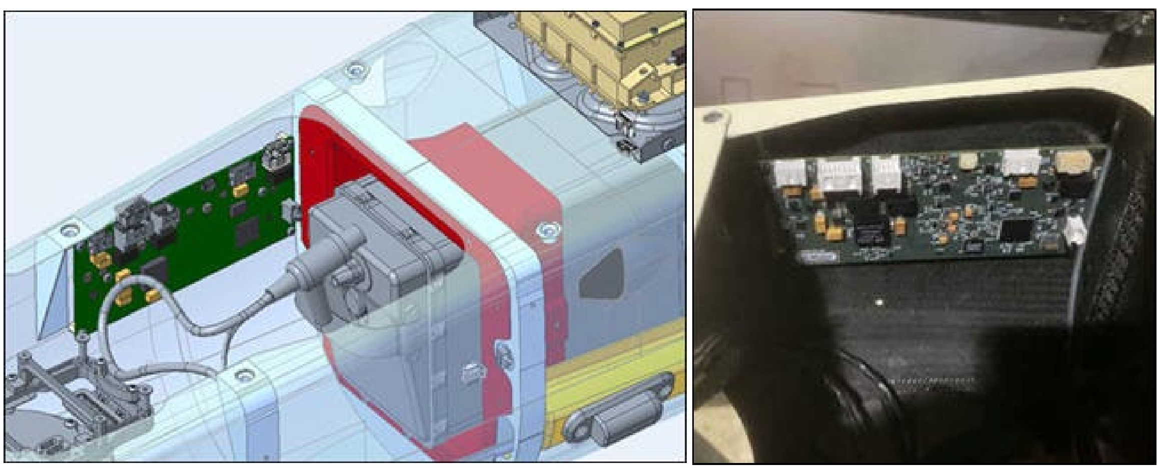


Figure 4-78. MAIM Installed on Stalker

4.4.4 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 4-79 shows the Primary Mount with a 1U payload installed. Details on the various

Primary Mount configurations are addressed in the subsequent sections.

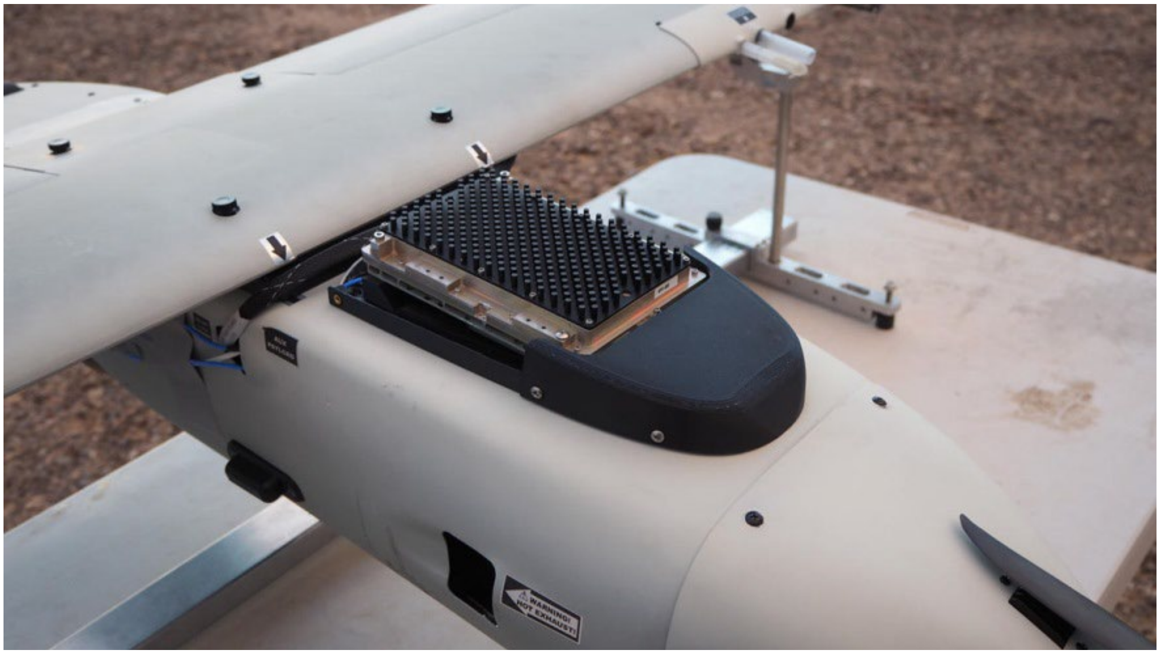


Figure 4-79. Stalker Primary Mount with 1U Payload

4.4.4.1 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 4-19 summarizes the height and weight of the Primary Mount in the current configuration options. The Primary Mount assembly is detailed in Figure 4-80.

Table 4-19. Stalker Primary Mount Weights

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

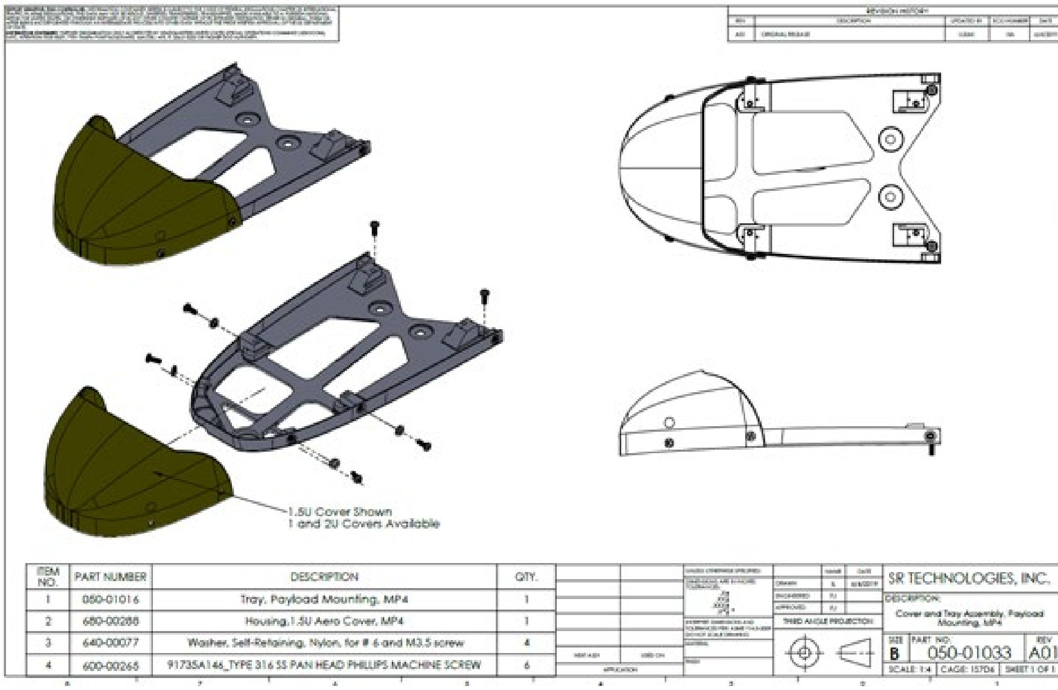


Figure 4-80. Stalker Primary Mount Assembly Drawing

4.4.4.2 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 4.4.7.2 and Section 4.4.7.3) are connected to the payload and positioned between the payload and payload tray, as shown in Figure 4-81.

Figure 4-81. 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 4-82). 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 4-83).

Figure 4-82. Stalker Primary Mount – Payload Installation (2 of 3)

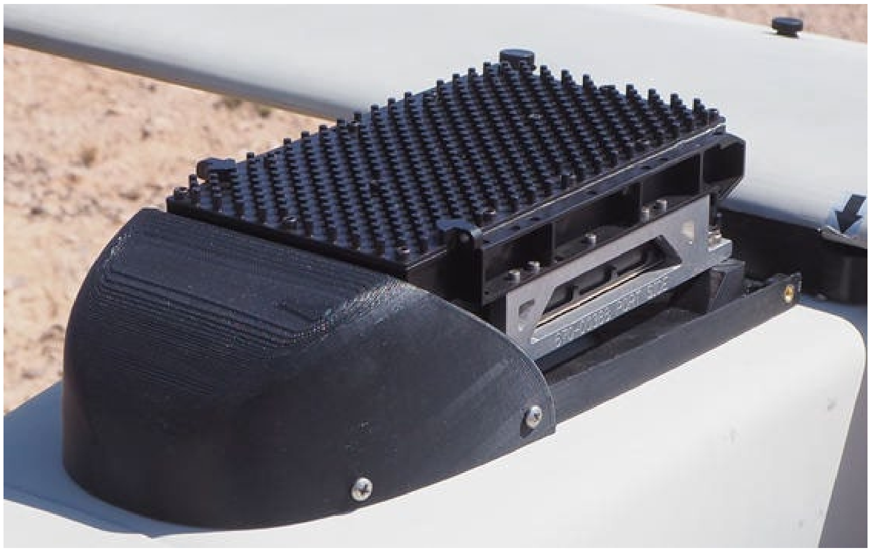


Figure 4-83. Stalker Primary Mount – Payload Installation (3 of 3)

4.4.4.3 Thermal

The Primary Mount is designed to expose the payload heatsink to direct airflow, as evident in Figure 4-83 above.

4.4.5 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 4-84 shows the INS and GPS installations.

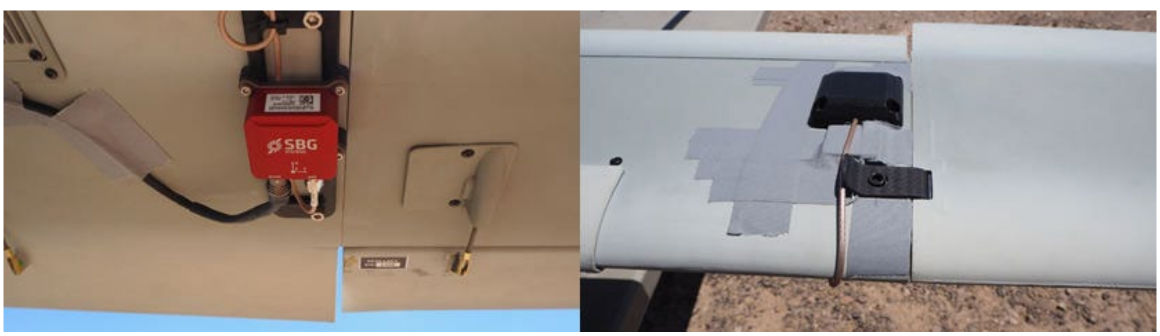


Figure 4-84. Stalker INS and GPS Antenna

4.4.6 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.

4.4.6.1 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 4-85, unlike other MP implementations, the strut is oriented to place the array facing forward (in front of the wing).

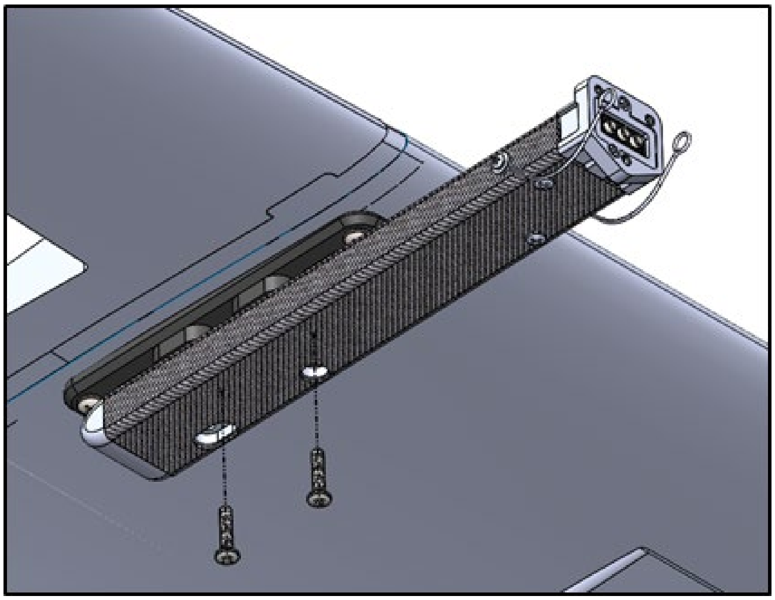


Figure 4-85. Stalker Array (Strut) Mount

The weight of the array antenna mount is 130g. The array antenna mount capacity is defined in Table 4-20.

Table 4-20. Array Antenna Mount Capacity

Max Weight	208g (total weight budget of B-kit must not exceed that outlined in Section 4.4.2.1, CG should not violate limits outlined in Stalker XE25 Operator's Manual)
Max Volume	Defined in Figure 4-86

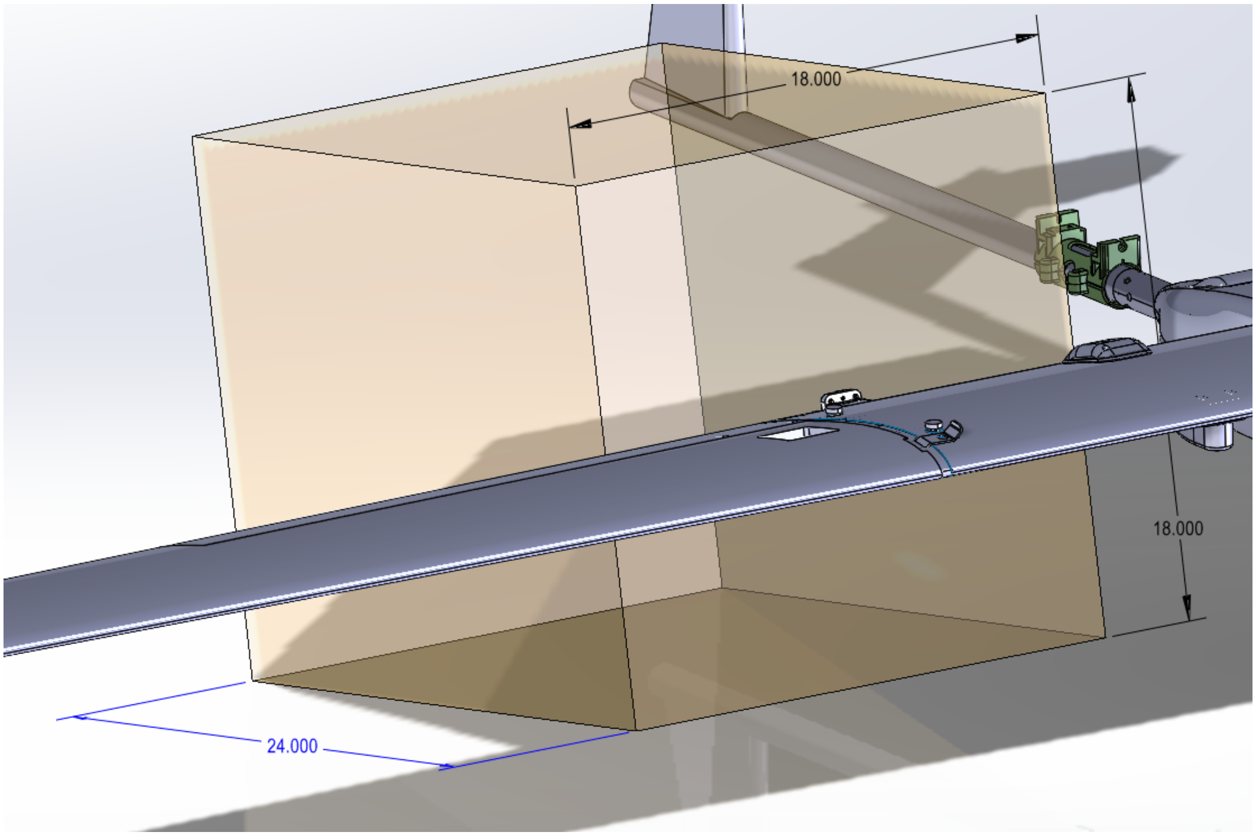


Figure 4-86. Array Antenna Mount Maximum Volume

4.4.6.2 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.

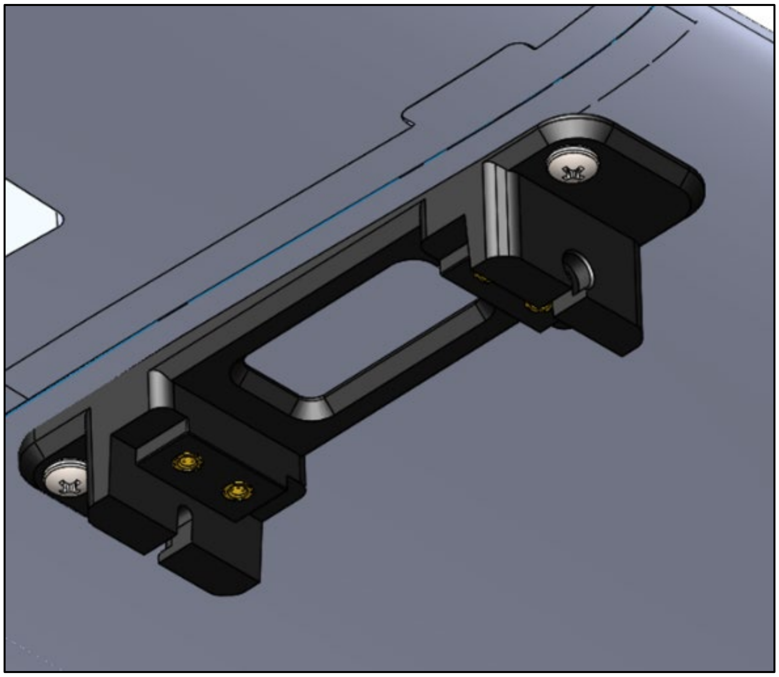


Figure 4-87. Stalker 2-pt Down Look Mount

The weight of the 2-pt down look antenna mount is 38g. The 2-pt down look antenna mount capacity is defined in Table 4-21.

Table 4-21. 2-pt Hard Point Antenna Mount Capacity

Max Weight	373g (total weight budget of B-kit must not exceed that outlined in Section 4.4.2.1, CG should not violate limits outlined in Stalker XE25 Operator's Manual)
Max Volume	Defined in Figure 4-88

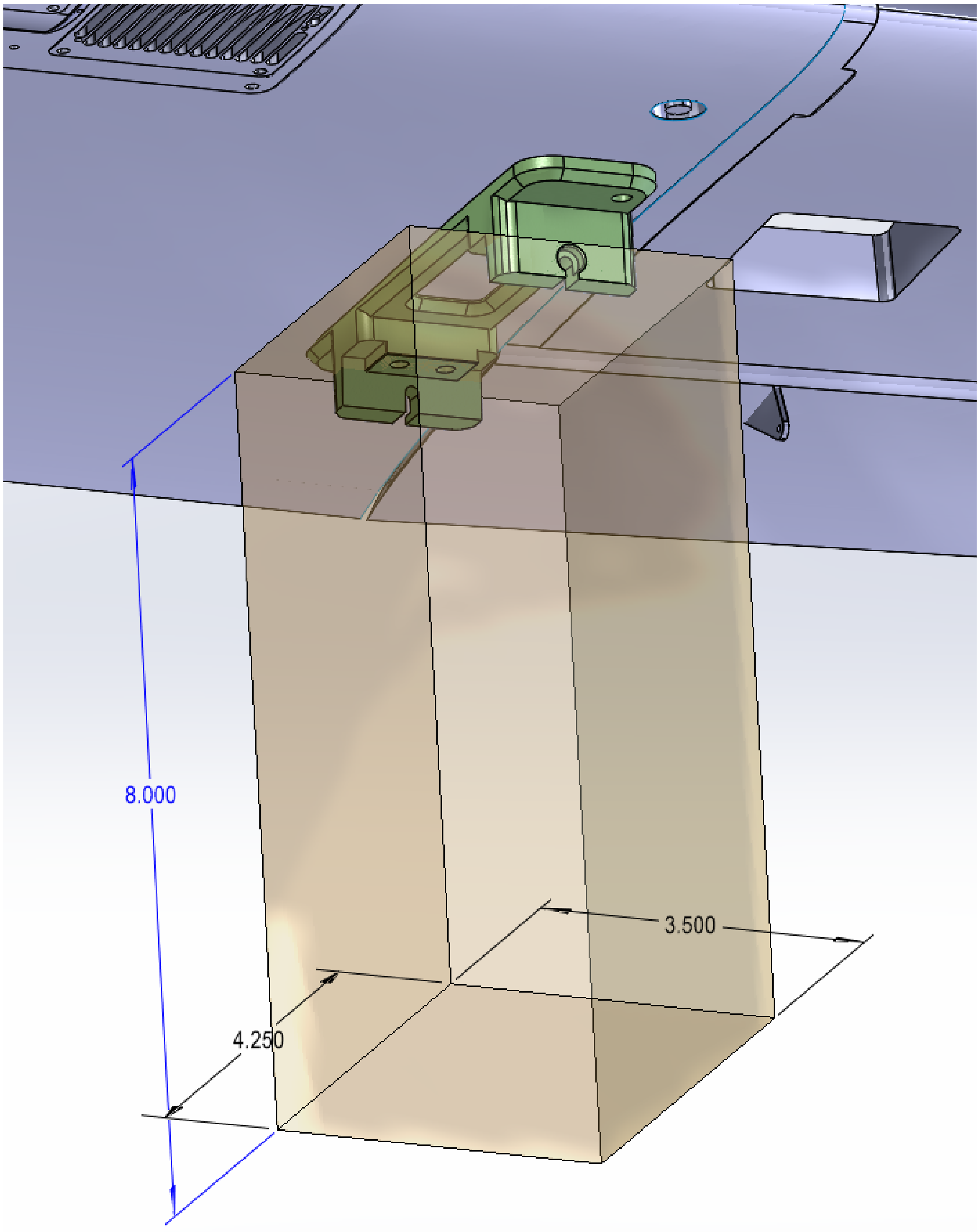


Figure 4-88. Hard Point Antenna Mount Maximum Volume

4.4.6.3 Boom Mount

The Stalker boom can be equipped with a 2-pt antenna mount, as shown in Figure 4-89. 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 4-89. Stalker Boom Mount

The weight of the boom mount assembly is 75g. The 2-pt boom antenna mount capacity is defined in Table 4-22.

Table 4-22. Boom Antenna Mount Capacity

Max Weight	373g (total weight budget of B-kit must not exceed that outlined in Section 4.4.2.1, CG should not violate limits outlined in Stalker XE25 Operator's Manual)
Max Volume	Defined in Figure 4-90

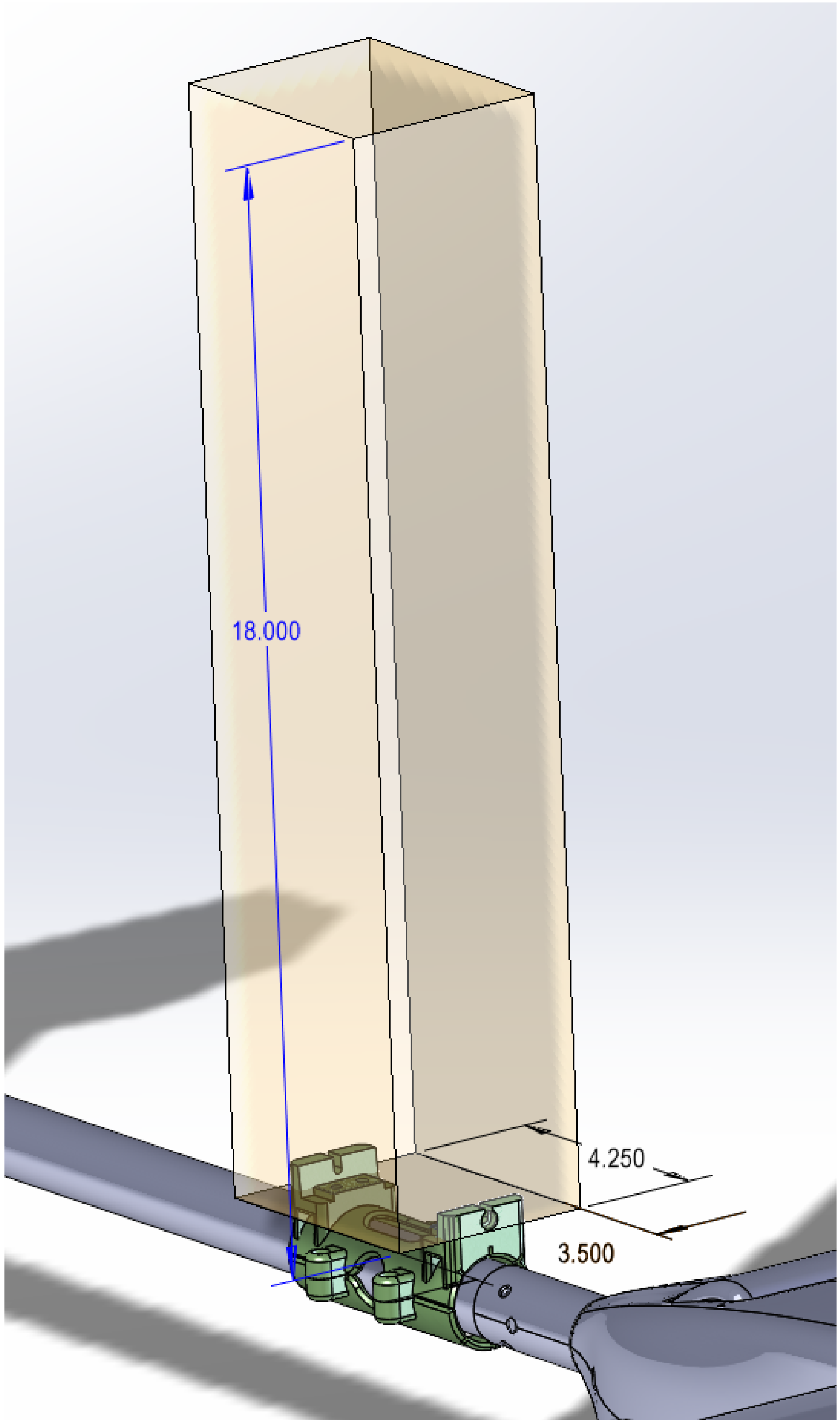


Figure 4-90. Boom Antenna Mount Maximum Volume

4.4.7 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 4-91 with further details provided in subsequent sections and RF cables covered in Section 4.4.7.5.

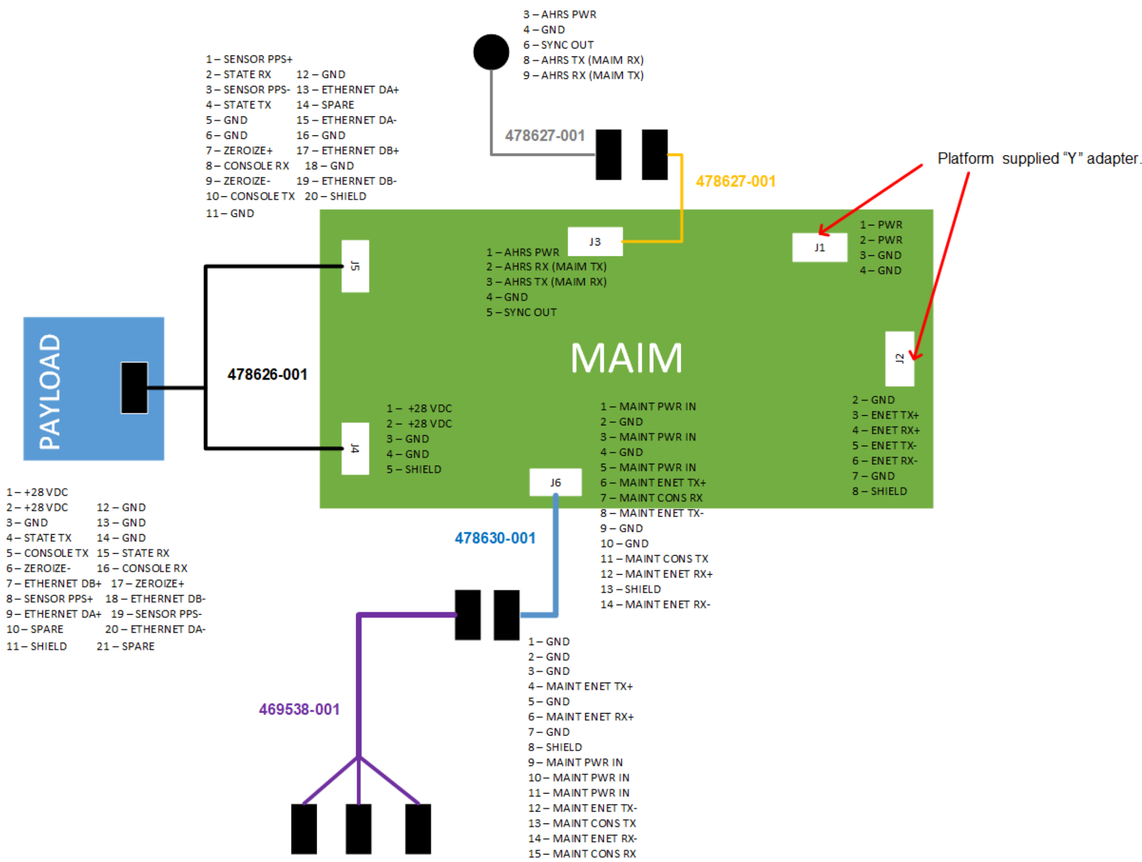


Figure 4-91. Stalker MAIM Cabling Schematic

4.4.7.1 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.

4.4.7.2 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 4-92.

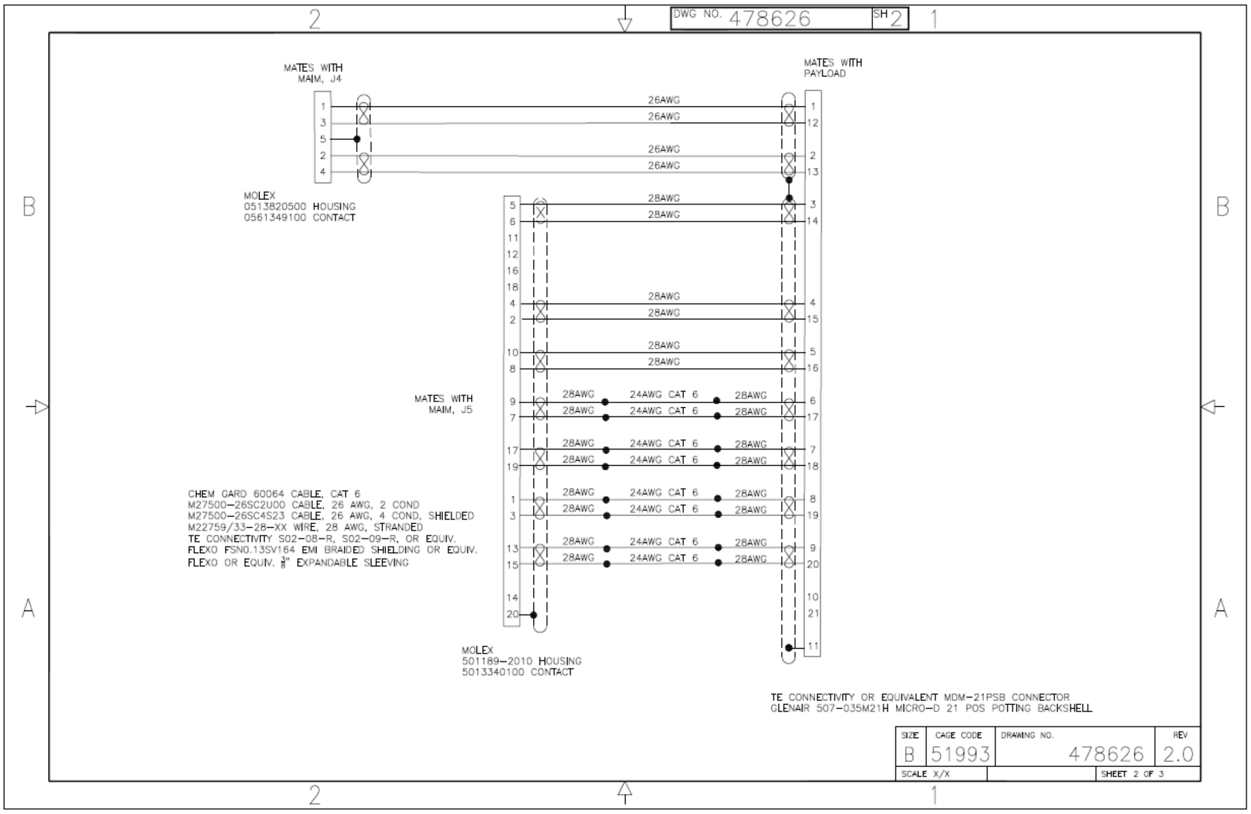


Figure 4-92. MAIM-Payload Cable

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 4-93 depicts this sequence. The MAIM-payload cable is 29-inches long and weighs 65g.

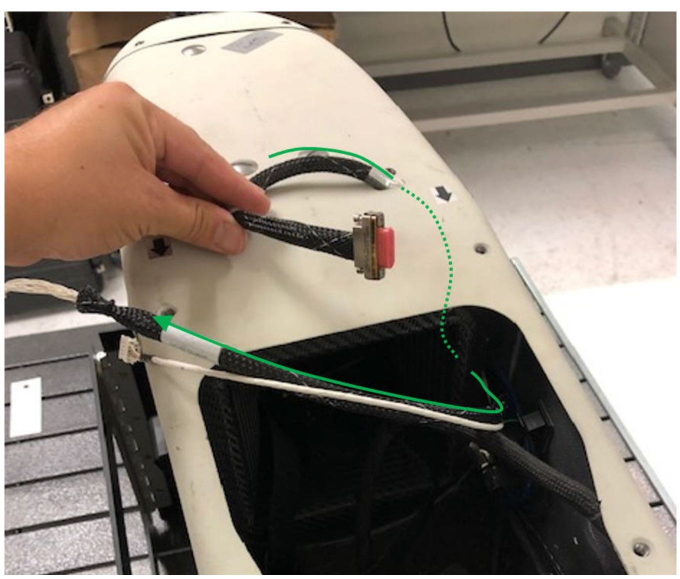


Figure 4-93. MAIM-Payload Cable Run

4.4.7.3 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 4-94 and Figure 4-95.

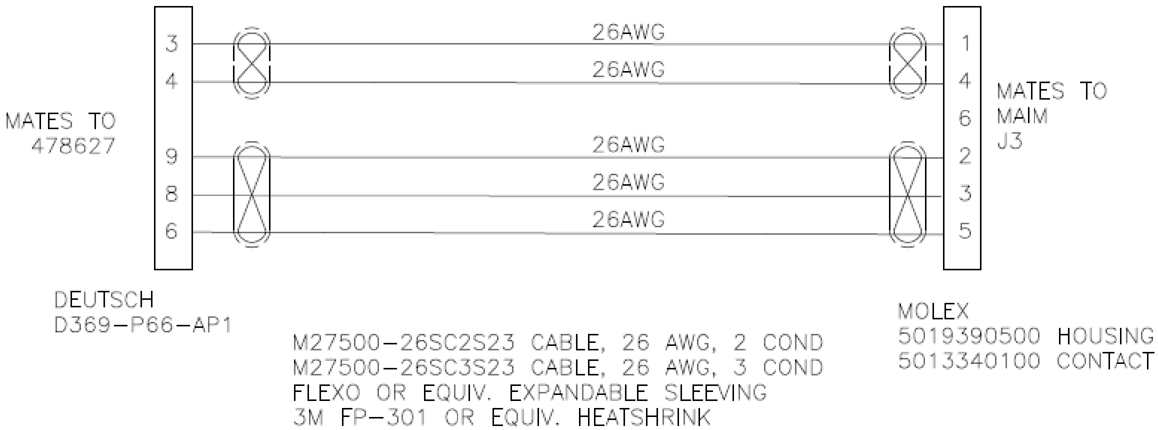


Figure 4-94. MAIM to INS Cable (MAIM to Breakpoint)

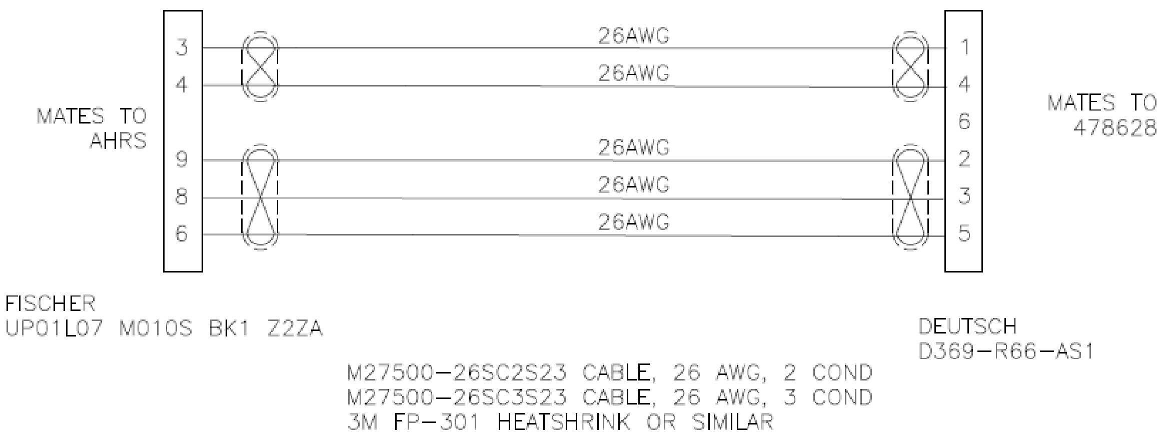


Figure 4-95. MAIM to INS Cable (Breakpoint to INS)

As shown in Figure 4-96, 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 4-96. MAIM to INS Cable Run

4.4.7.4 GPS Antenna Cable

As shown in Figure 4-96 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.

4.4.7.5 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 4.4.7.5.6.

4.4.7.5.1 RF Cable Summary Table

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

Table 4-23. MAIM to INS Cable Run

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

4.4.7.5.2 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 4-97, 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.

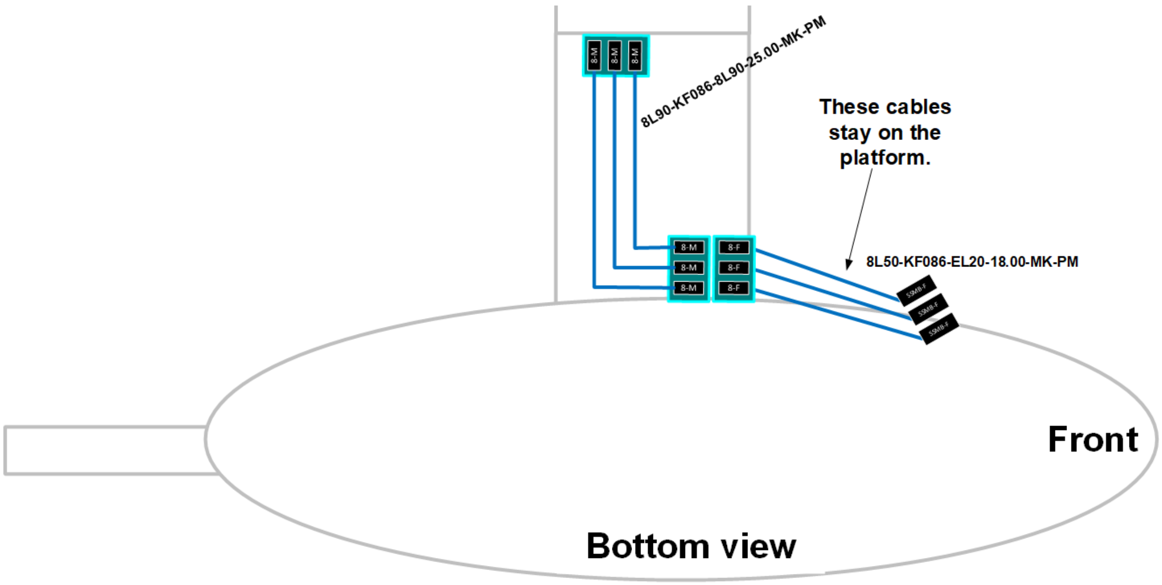


Figure 4-97. Stalker RF Cables – Array Configuration

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.

4.4.7.5.3 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 4-98, 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.

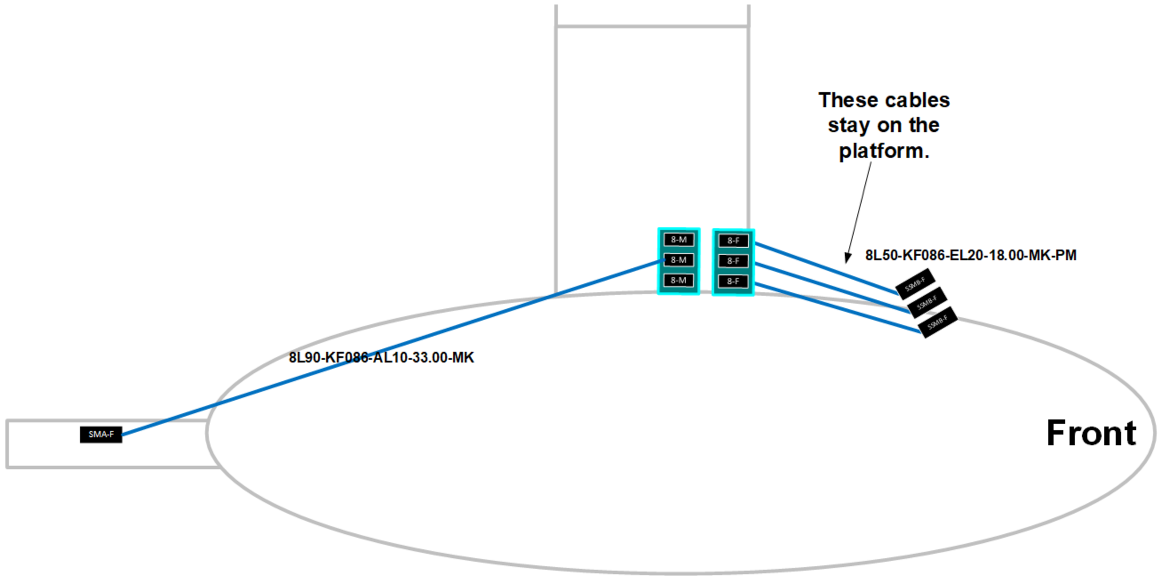


Figure 4-98. Stalker RF Cables – Single Antenna Configuration

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.

4.4.7.5.4 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 4-99, 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.

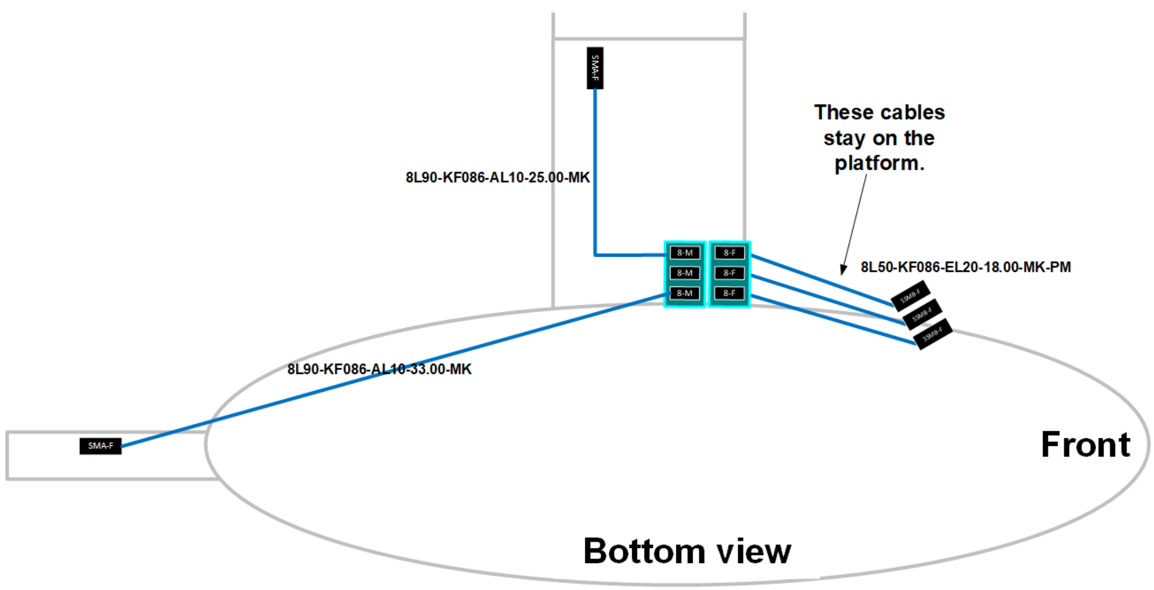


Figure 4-99. Stalker RF Cables – Two Antenna Configuration

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.

4.4.7.5.5 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 4.4.7.5.2 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 4-100.

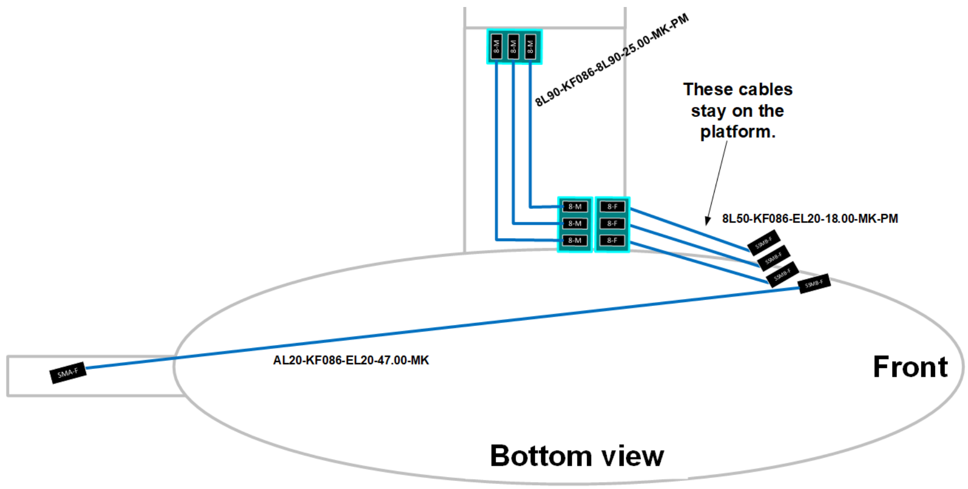


Figure 4-100. Stalker RF Cables – Array Plus Configuration

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.

4.4.7.5.6 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.

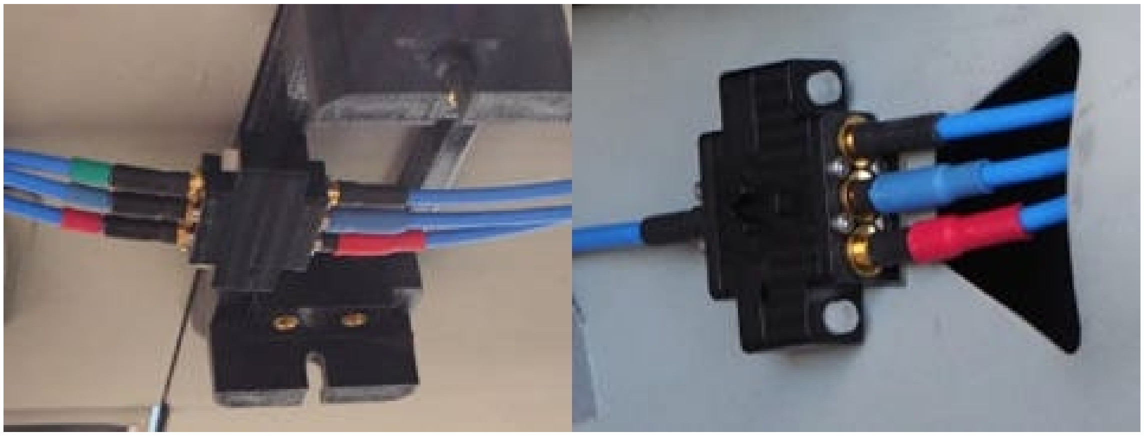


Figure 4-101. RF Connector Block – 3-signal (left), 1-signal (right)

4.4.8 Concessions to the Standard

No concessions are required for the MP-Stalker XE25

4.5 SkyRaider R80D UAS

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

4.5.1 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.

4.5.1.1 MP Architecture

Figure 4-102 depicts the architectural layout of the MP implementation on the SkyRaider R80D UAS.

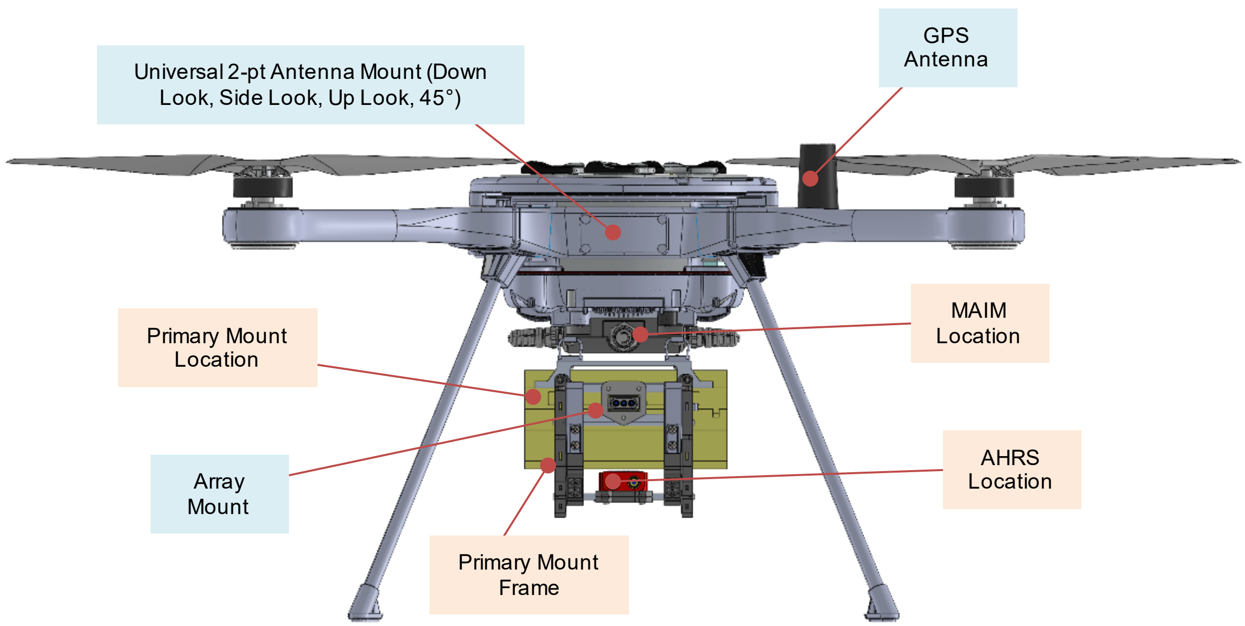


Figure 4-102. Architectural Layout of MP-SkyRaider

4.5.1.2 Compliance / Capability Summary

Table 4-24 provides a top-level summary of the MP compliance and capability on the SkyRaider R80D.

Table 4-24. MP-SkyRaider Compliance and Capability

<table>
<tr><th>MP Components</th><th colspan="3">Location</th></tr>
<tr><td>MAIM</td><td colspan="3">Under Body</td></tr>
<tr><td>Primary Mount</td><td colspan="3">Under MAIM</td></tr>
<tr><td>INS</td><td colspan="3">Primary Mount Bottom</td></tr>
<tr><th>Payload Capacity</th><th colspan="3">Description</th></tr>
<tr><td>Number of Payloads</td><td colspan="3">1</td></tr>
<tr><td>Available Payload Power</td><td colspan="3">56 W</td></tr>
<tr><td>Available Payload Volume</td><td colspan="3">2U</td></tr>
<tr><td>Available Payload Weight</td><td colspan="3">3.2 lb (1490 g)</td></tr>
<tr><th>Primary Mount</th><th colspan="3"></th></tr>
<tr><td>Mounting Method</td><td colspan="3">Plate</td></tr>
<tr><td>Cooling Method</td><td colspan="3">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>Fuselage Expansion Mount</td><td>Up, Down, Side, 45°</td></tr>
<tr><td>2</td><td>Antenna Frame</td><td>Side, 45°</td></tr>
<tr><td>1</td><td>Antenna Frame</td><td>Down</td></tr>
<tr><td>Four-points</td><td>0</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Array</td><td>1</td><td>Primary Mount</td><td>Side, 45°</td></tr>
</table>

4.5.1.3 System Diagram

Figure 4-103 details the system diagram for the MP-compliant SkyRaider R80D UAS.

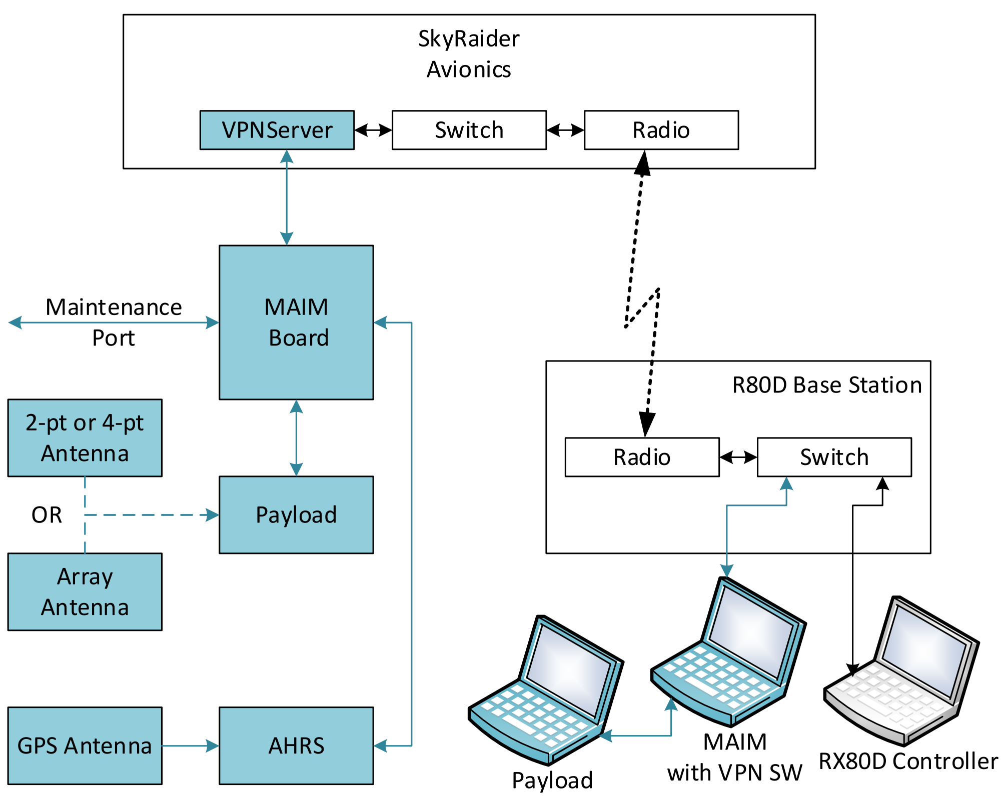


Figure 4-103. System Diagram for MP-SkyRaider

4.5.2 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.

4.5.2.1 Weight Budget

The Mod Payload A-kit (MAIM, Primary Mount assembly, INS, GPS antenna assembly, and cabling) adds 510g to the SkyRaider.

4.5.2.2 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.

4.5.3 MAIM

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

4.5.3.1 Mechanical Description

The MAIM assembly is a ~4in x ~3in x 1.5in, 180g enclosure housing the MAIM PCB. Figure 4-104 shows the SkyRaider MAIM and the MAIM PCB.

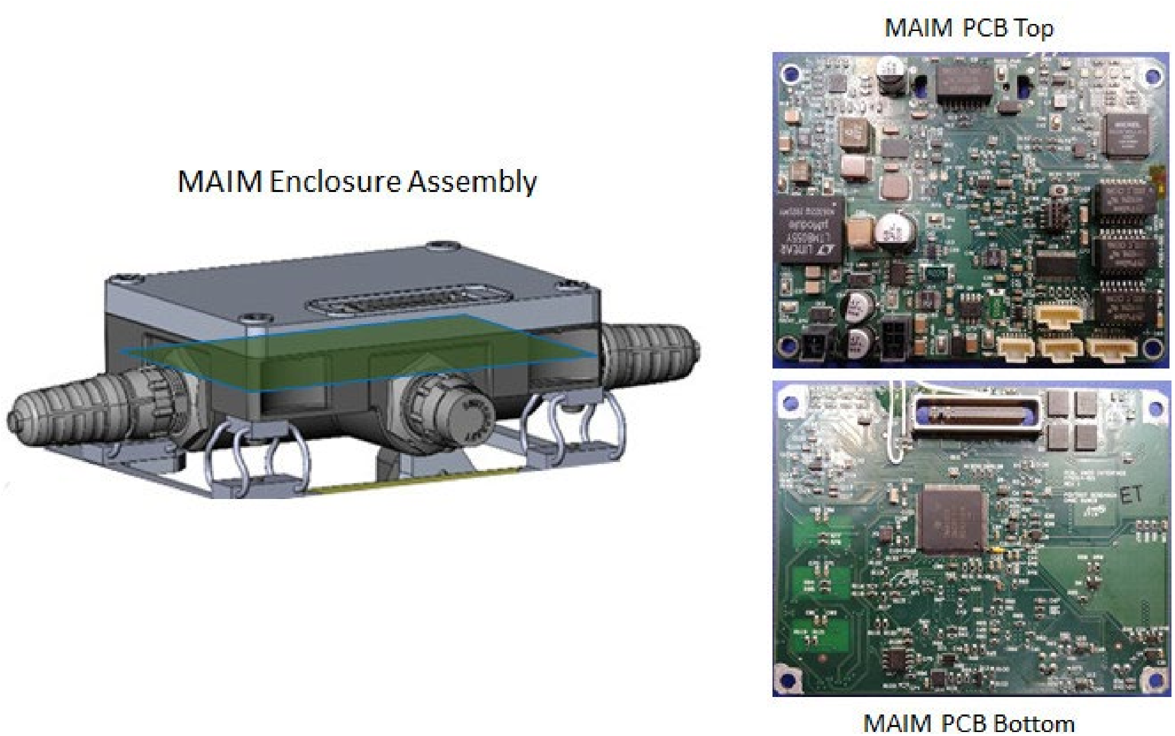


Figure 4-104. MAIM for SkyRaider

4.5.3.2 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 4-105, 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.

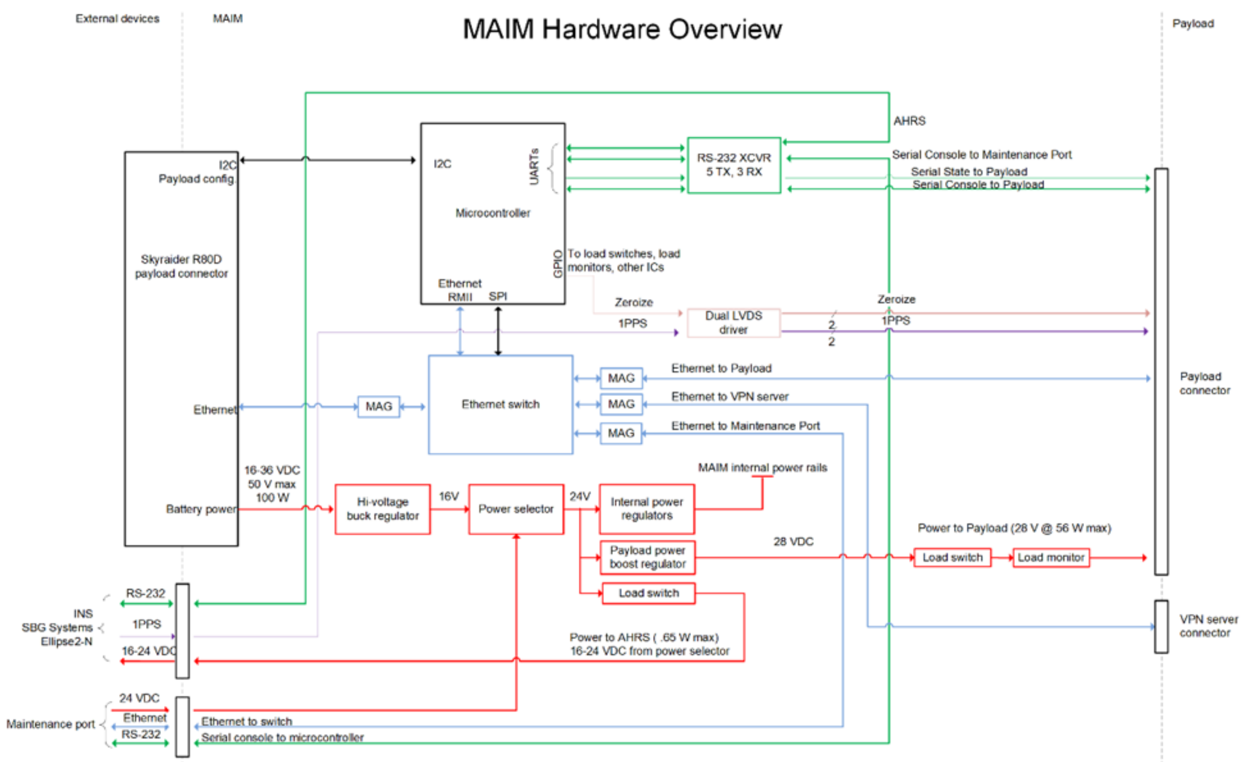


Figure 4-105. MAIM Block Diagram for SkyRaider

4.5.3.2.1 Power Input

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

4.5.3.2.2 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).

4.5.3.2.3 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.

4.5.3.2.4 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.

4.5.3.2.5 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.

4.5.3.2.6 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.

4.5.3.3 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 4.5.7.1 provides additional information on this electrical connection.

Figure 4-106. MAIM Installed on SkyRaider

4.5.4 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 4-107 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.

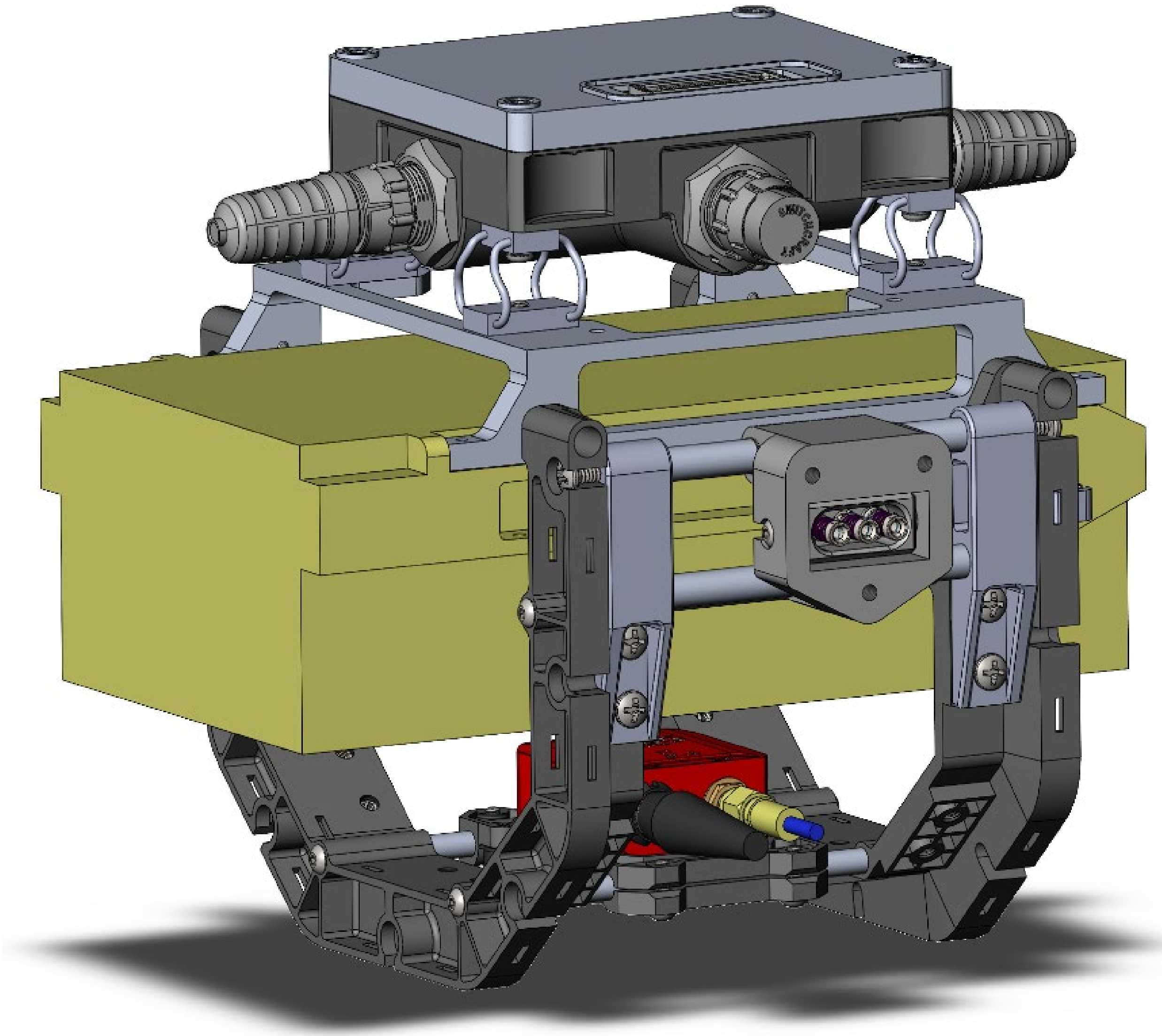


Figure 4-107. SkyRaider Primary Mount with 2U Payload and INS

4.5.4.1 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 4-108 shows the primary components and materials.

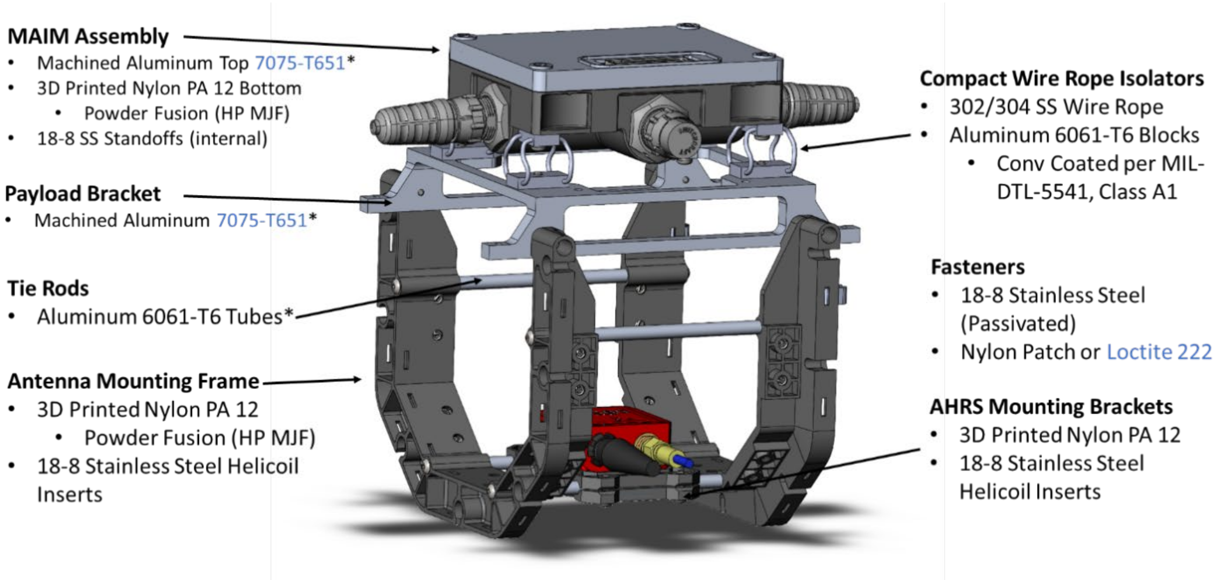


Figure 4-108. SkyRaider Primary Mount Construction

4.5.4.2 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 4-109.

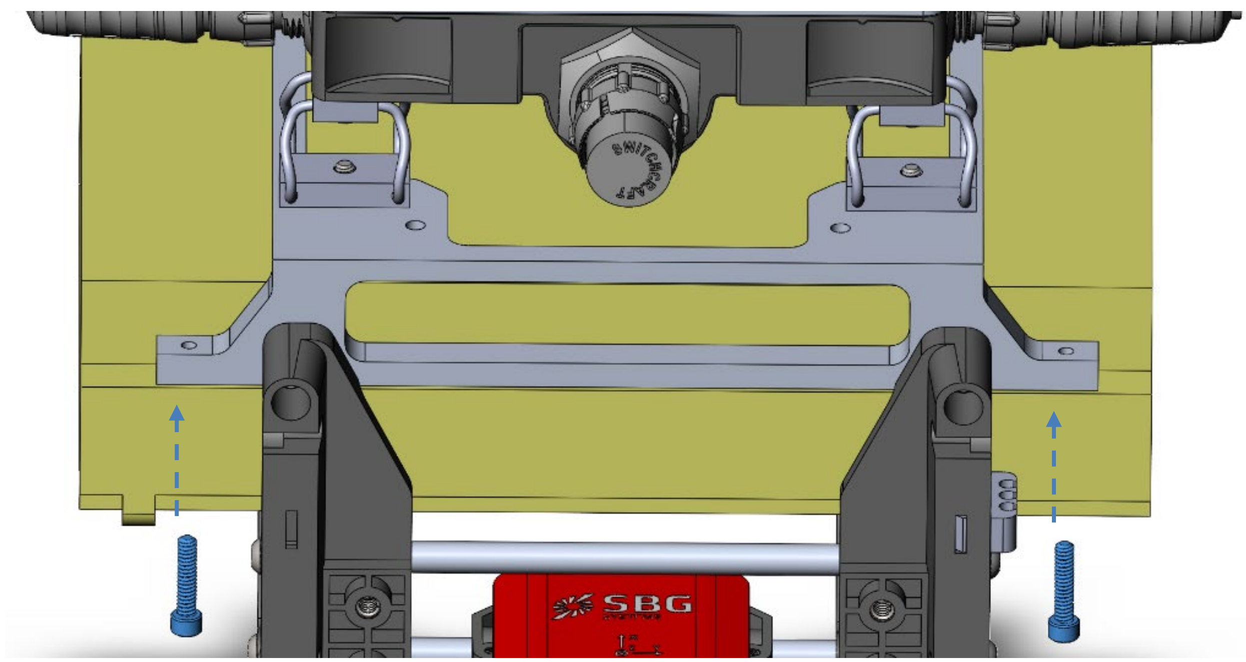


Figure 4-109. SkyRaider Primary Mount - Payload Installation

4.5.4.3 Thermal

Though using the cold plate mounting option, the Primary Mount is designed to use convective cooling, exposing the payload to direct airflow. Thus, unlike a true cold plate configuration, the heatsink is maintained on the payload, as depicted in Figure 4-110. 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.

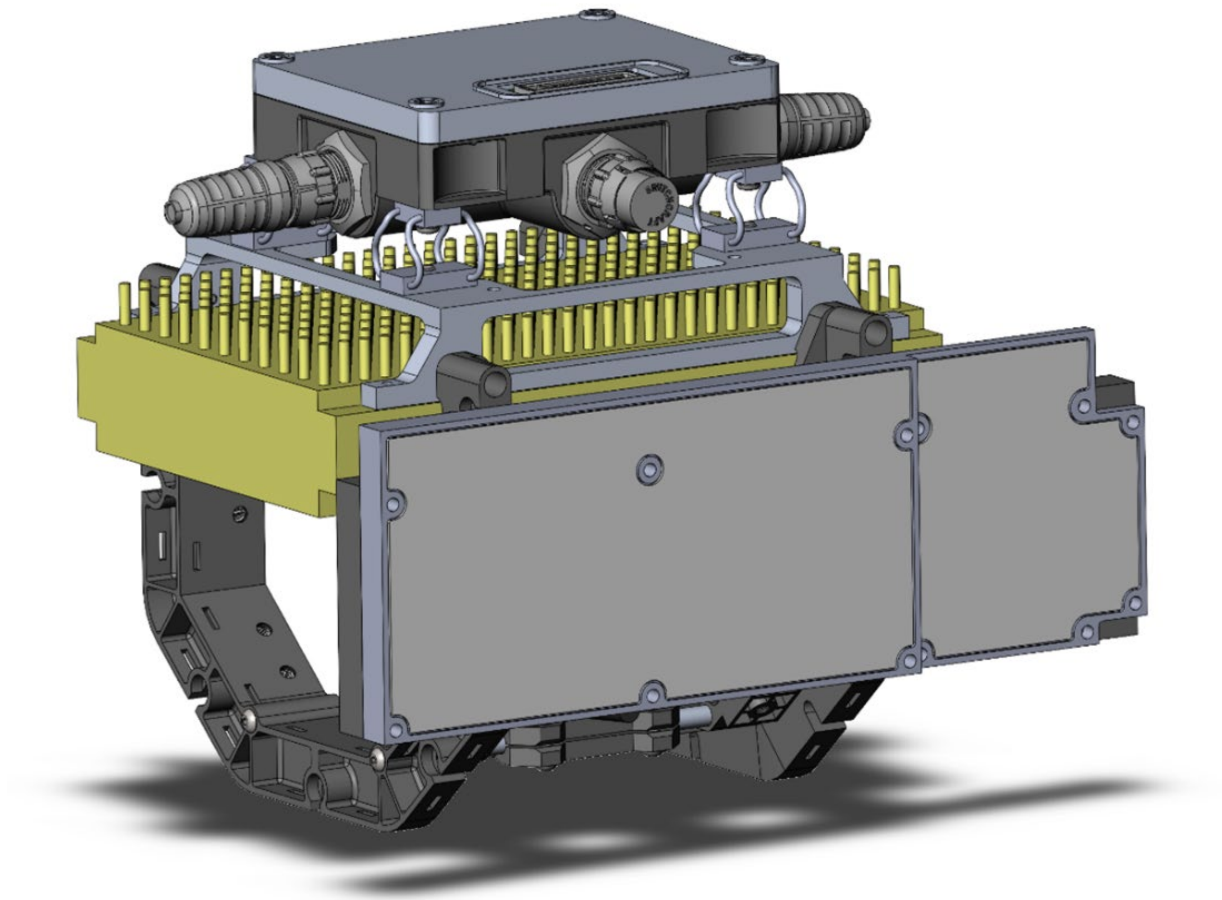


Figure 4-110. SkyRaider Primary Mount with Payload Installed with Heatsink

4.5.5 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 4-111 shows the INS and GPS installations.

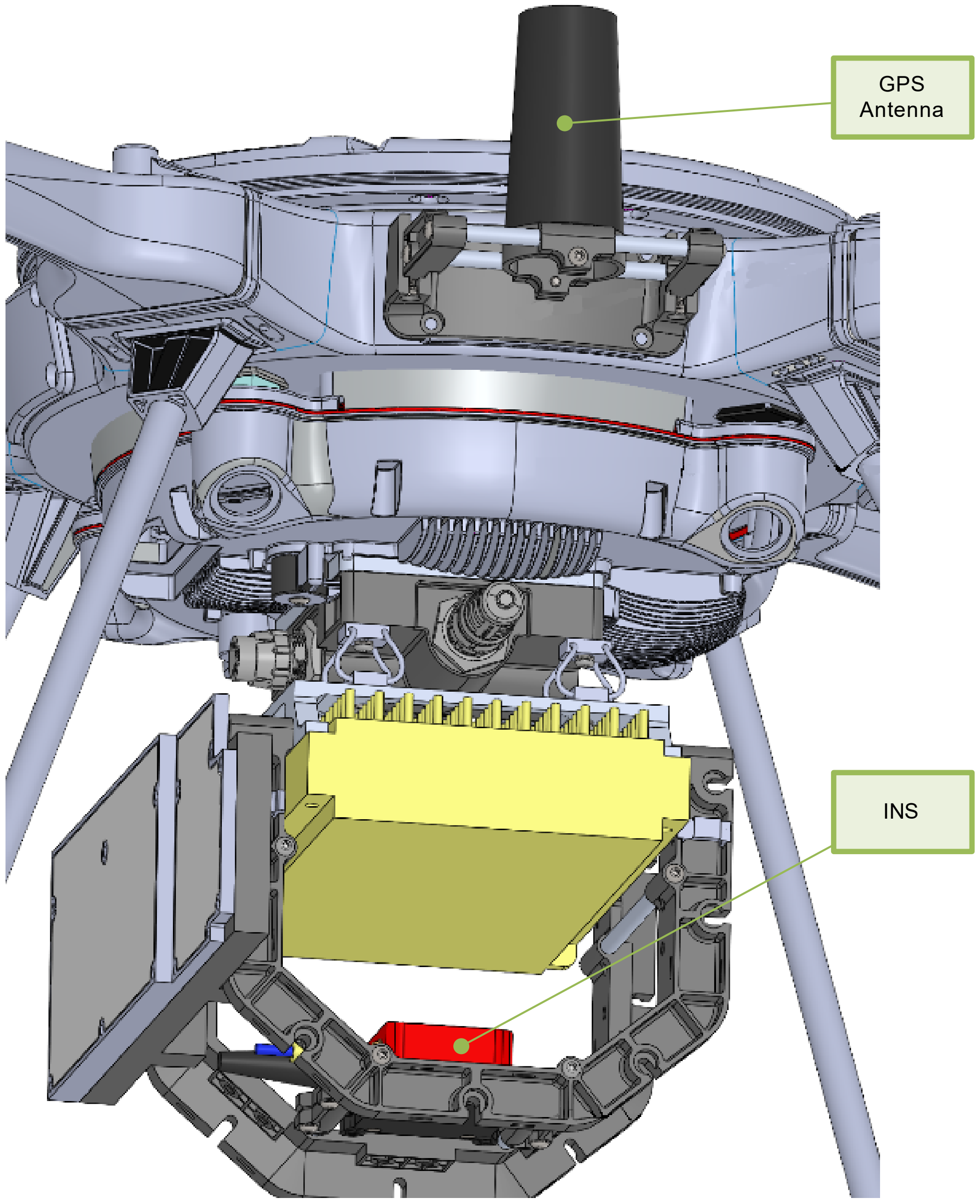


Figure 4-111. SkyRaider INS and GPS Antenna

4.5.6 Antenna Mounts

As depicted in Figure 4-112, the MP-SkyRaider supports antenna mounts on the antenna mounting frame and via a universal 2-pt expansion cover mount.

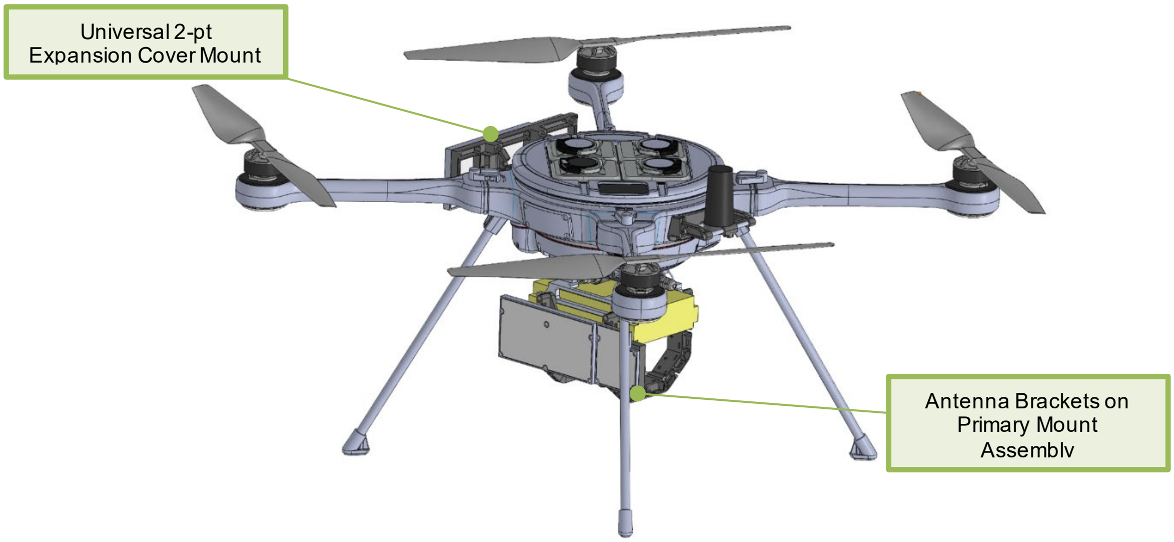


Figure 4-112. SkyRaider Antenna Mount Locations

4.5.6.1 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.

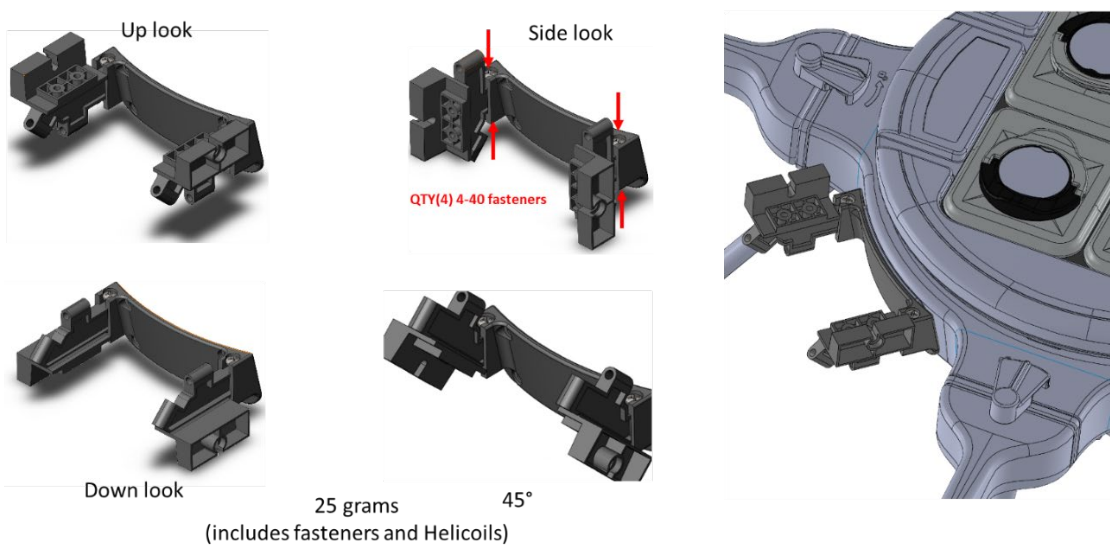


Figure 4-113. SkyRaider Universal 2-pt Expansion Mount

The weight of the universal 2-pt expansion antenna mount is 25g. The universal 2-pt antenna mount capacity is defined in Table 4-25.

Table 4-25. Universal 2-pt Antenna Mount Capacity

Max Weight	188g (0.41lbs)
Max Moment	x/y: 2.3 N-cm (0.2 in-lbs) z: 4.7 N-cm (0.4 in-lbs)
Max Volume	See Figure 4-114[1]

[1] CAD defining volume available upon request

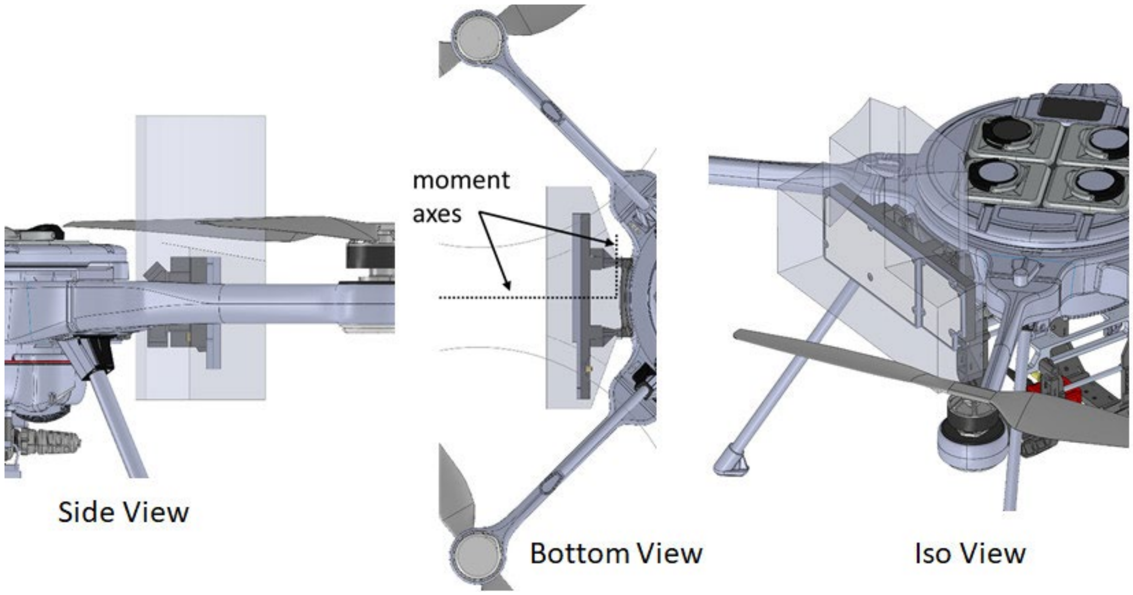


Figure 4-114. SkyRaider Universal 2-pt Mount Allowable Antenna Volume

4.5.6.2 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 4-115, the antenna mounting frame can be oriented with forward facing mounts or rotated 90° for side facing mounts.

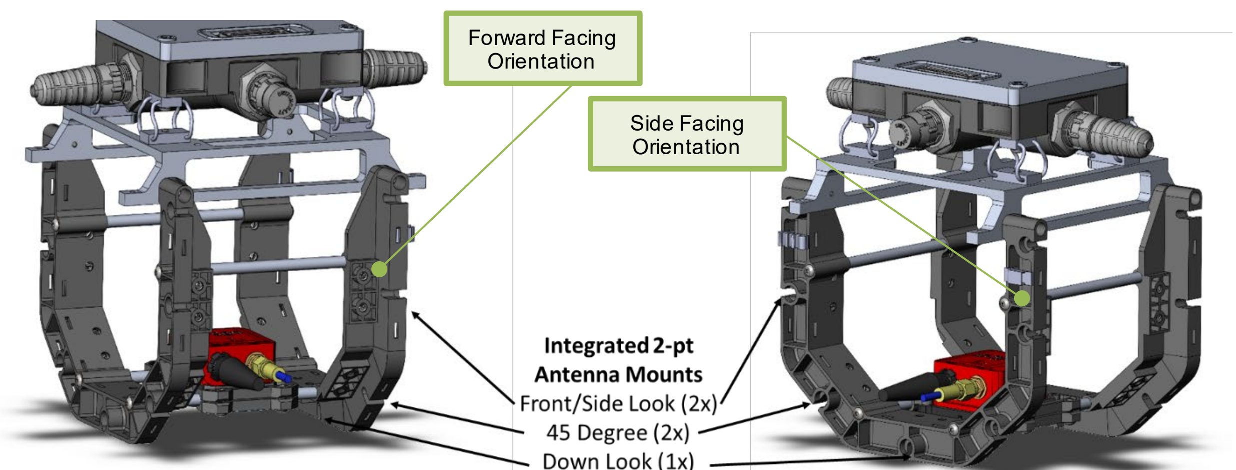


Figure 4-115. Mounting Locations on the Antenna Mounting Frame

The antenna mounting frame 2-pt antenna mount capacity is defined in Table 4-26.

Table 4-26. Antenna Mounting Frame 2-pt Antenna Mount Capacity

Max Weight	373g (0.8lbs)
Max Moment	x/y: 4.6 N-cm (0.4 in-lbs) z: 11.1 N-cm (1.0 in-lbs)
Max Volume	See Figure 4-116[1]

[1] CAD defining volume available upon request

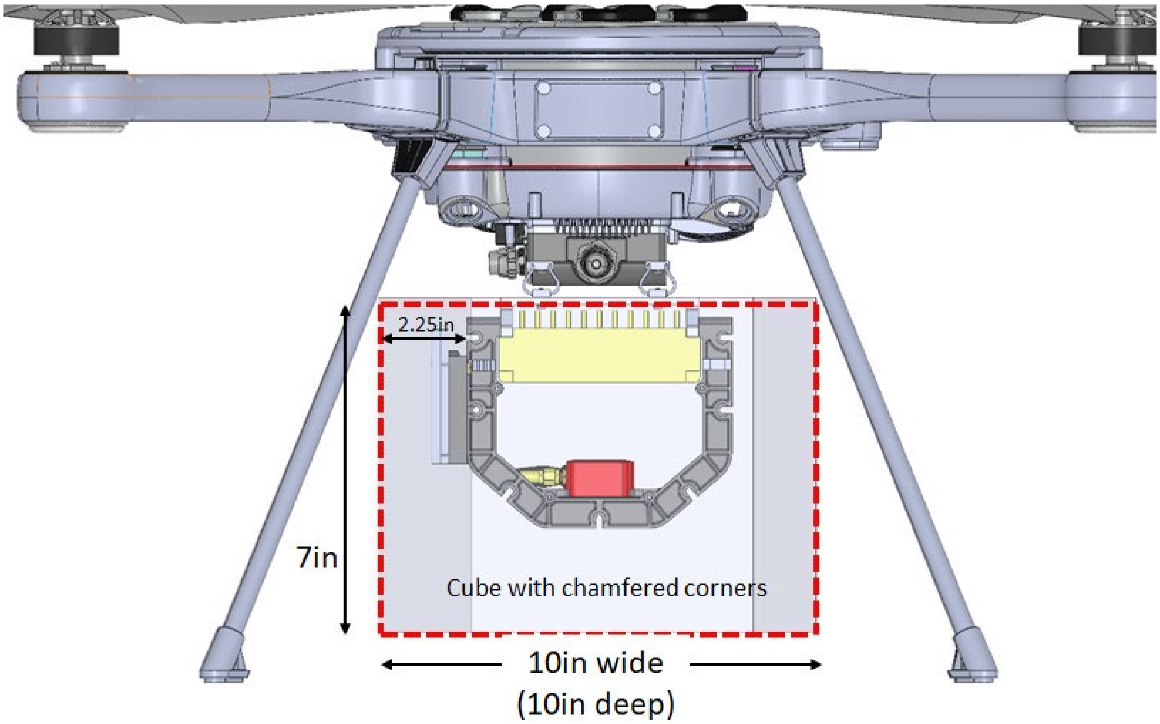


Figure 4-116. Antenna Mounting Frame Allowable 2-pt Antenna Volume

4.5.6.3 Array Mount

As shown in Figure 4-117, 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 45° antenna mount location, but that position is less likely to be useful for most antennas.

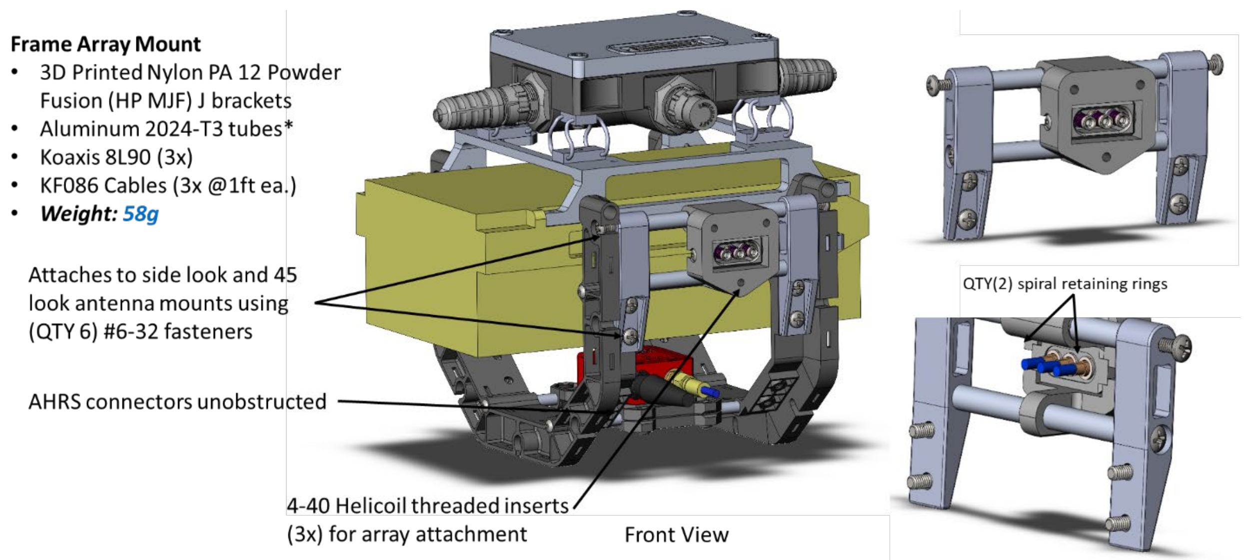


Figure 4-117. SkyRaider Array Mount

The weight of the array antenna mount is 58g. The antenna array mount capacity is defined in Table 4-27.

Table 4-27. Antenna Array Mount Capacity

Max Weight	220g (0.49lbs)
Max Moment	x/y: 2.7 N-cm (0.2 in-lbs) z: 37.8 N-cm (3.3 in-lbs)
Max Volume	See Figure 4-118[1]

[1] CAD defining volume available upon request

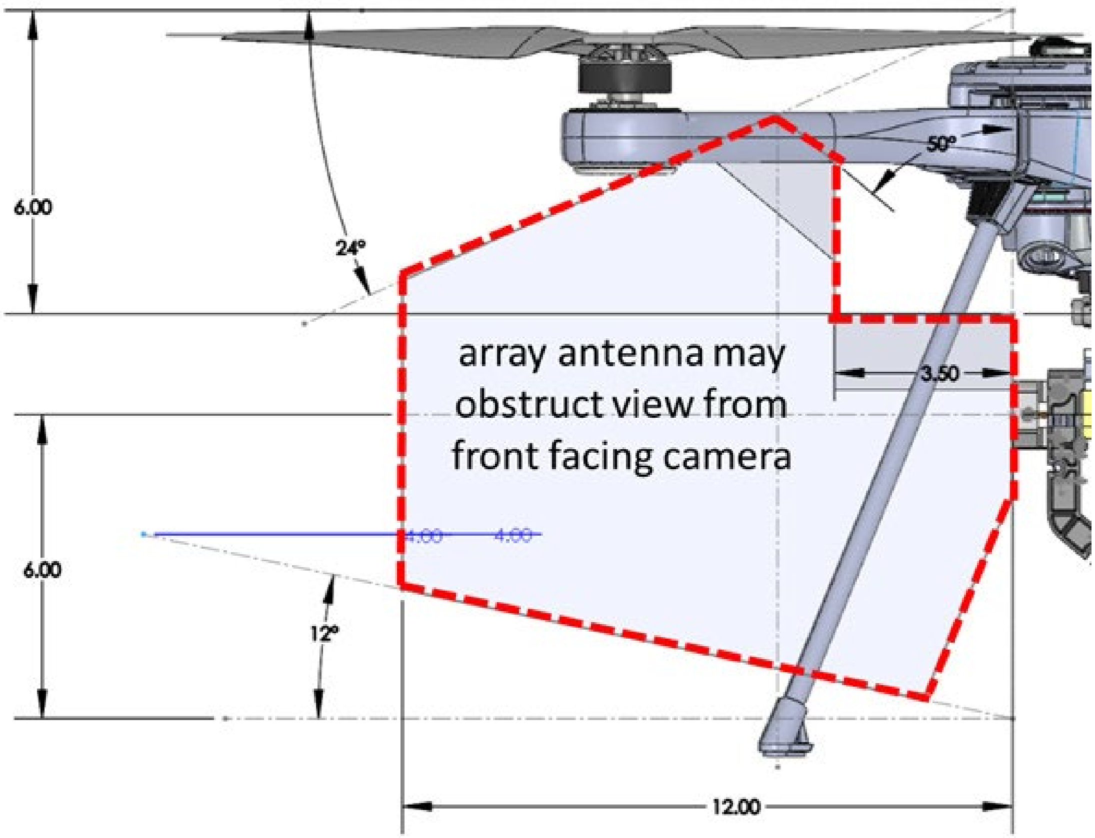


Figure 4-118. SkyRaider Allowable Antenna Array Volume

4.5.7 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.

4.5.7.1 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.

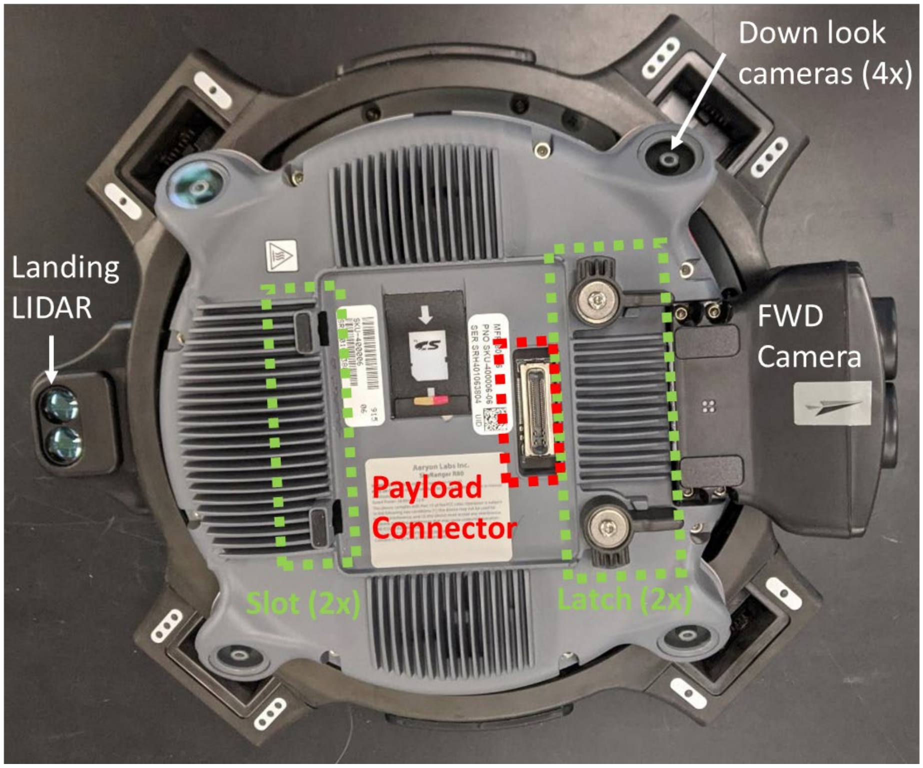


Figure 4-119. SkyRaider Slot and Latch System

4.5.7.2 MAIM-Payload Cable

The MAIM-payload cable is routed as shown in Figure 4-120 using tape and cable clips integrated into the Primary Mount to secure the cable.

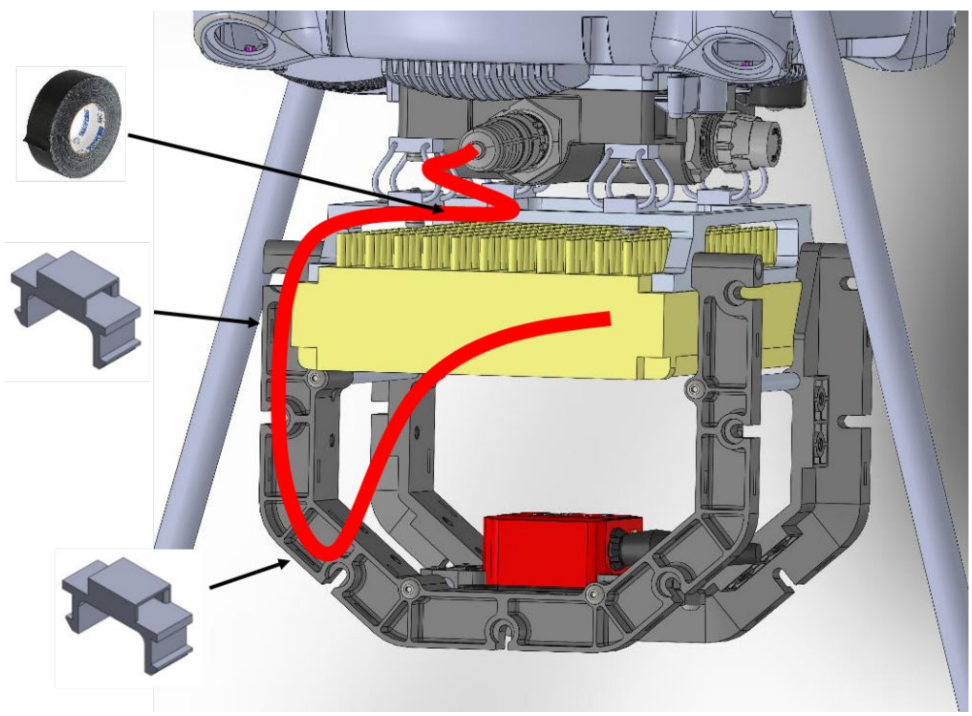


Figure 4-120. SkyRaider MAIM-Payload Cable Routing

4.5.7.3 MAIM-AHRS Cable

The MAIM-AHRS cable is routed as shown in Figure 4-121 using tape and cable clips integrated into the Primary Mount to secure the cable.

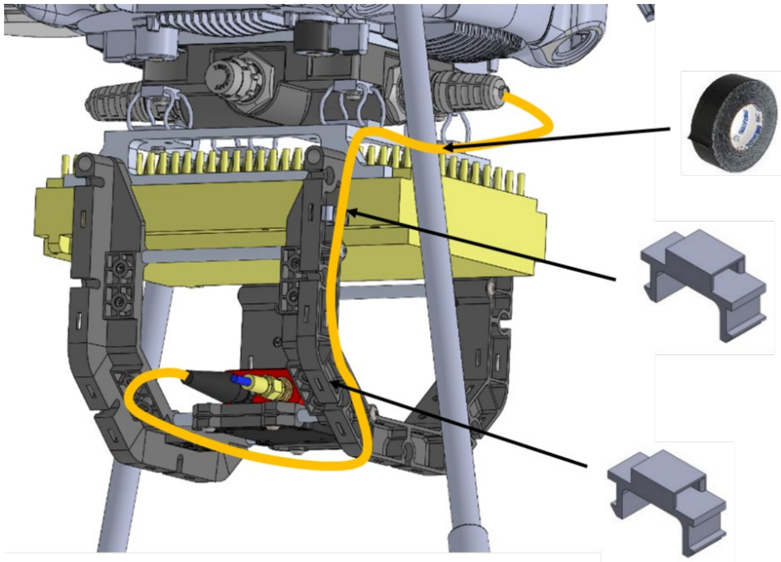


Figure 4-121. SkyRaider MAIM-AHRS Cable Routing

4.5.7.4 GPS Antenna Cable

The GPS antenna cable is routed as shown in Figure 4-122 using tape and cable clips integrated into the Primary Mount to secure the cable.

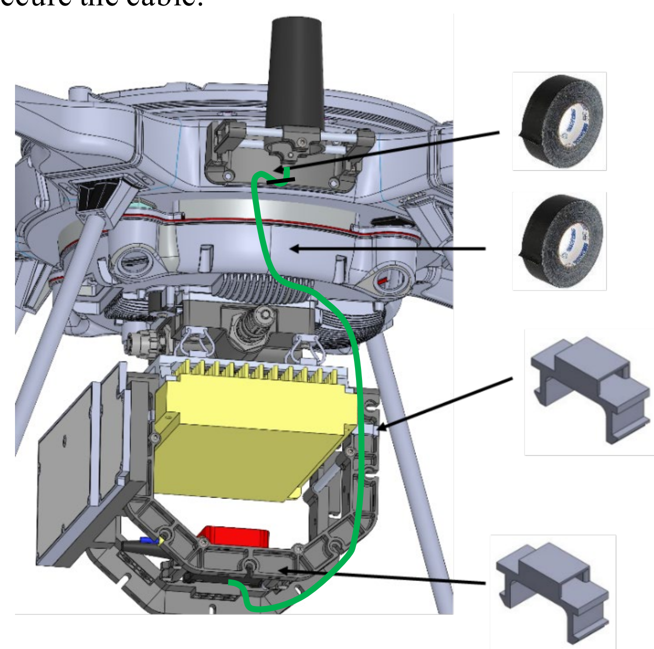


Figure 4-122. SkyRaider GPS Antenna Cable Routing

4.5.7.5 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.

4.5.8 Concessions to the Standard

Three concessions are documented for the MP-SkyRaider.

4.5.8.1 Center of Gravity Considerations

While not a direct violation of the standard, the MP-SkyRaider is highly sensitive to center of gravity deviations, as such, it is critical to adhere to the limitations defined in Sections 4.5.6.1 through 4.5.6.3 when selecting an antenna for a payload. There are three main restrictions that will be used to determine if an antenna can be supported:

4.5.8.2 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.

4.5.8.3 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.

4.6 Vapor 55-M UAS

This section details the Mod Payload implementation on the Vapor 55-M.

4.6.1 Overview

The MP-compliant Vapor 55-M UAS can support one payload up to 2U size on a custom, external payload tray. The Vapor 55-M UAS is equipped to support the following antenna mounts:

- 2-pt downlook for longer whip antennas
- 2-pt uplook on boom
- 2-pt downlook for puck antennas
- 2-pt sidelook (45deg)
- Array mount

The MAIM capability and the MP-compliant INS are native to this UAS, implemented within the vehicle's Avionics Processor Module (APM) and the Payload Processor Module (PPM).

4.6.1.1 MP Architecture

Figure 4-123 depicts the architectural layout of the MP implementation on the Vapor 55-M.

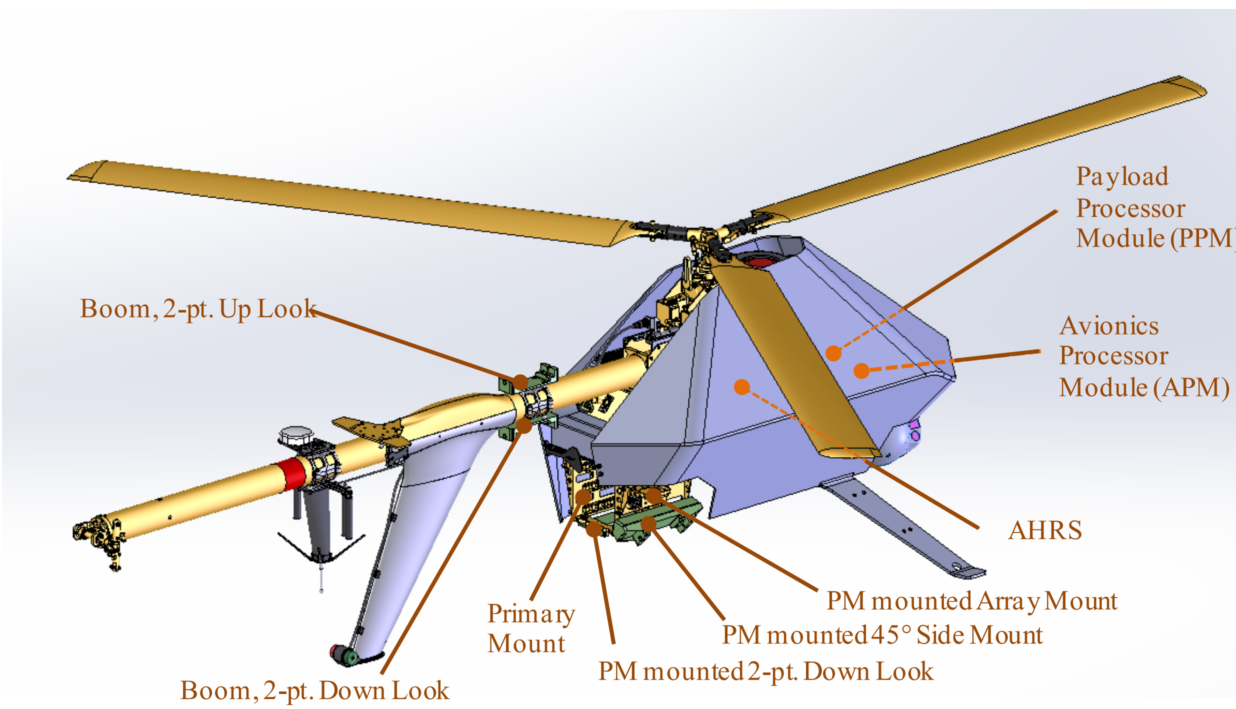


Figure 4-123. Architectural Layout for Vapor 55-M

4.6.1.2 Compliance / Capability Summary

Table 4-28 provides a top-level summary of the MP compliance and capability on the Vapor 55-M UAS. The Vapor 55-M has considerable modularity, so the base configuration can vary significantly. The weight and power constraints on the MP payload will vary accordingly. See Section 4.6.8.2 for example configurations and corresponding constraints.

Table 4-28. Vapor 55-M 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">Built into PPM</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">Mounts to Payload Rails</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Fuselage, Right Shoulder</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">1</td></tr>
<tr><td colspan="2">Available Payload Power</td><td colspan="2">Varies – 20W to 56W*</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">2U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">Varies – 4.7 to 10.87 lbs (2.13 to 4.93 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>Two-point</td><td>2</td><td>Boom
Primary Structure</td><td>Up Look or Down Look
Down Look or 45° Side Look</td></tr>
<tr><td>Four-points</td><td>0</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Array</td><td>1</td><td>Primary Structure</td><td>See Section 4.6.6.1</td></tr>
</table>

** See Section 4.6.8.2 for example configurations and corresponding constraints.*

4.6.1.3 System Diagram

Figure 4-124 details the system diagram for the Vapor 55-M. MP-specific additions are highlighted in teal. The Ground Control Station is detailed in Figure 4-125 with the same highlighting of the MP specific units.

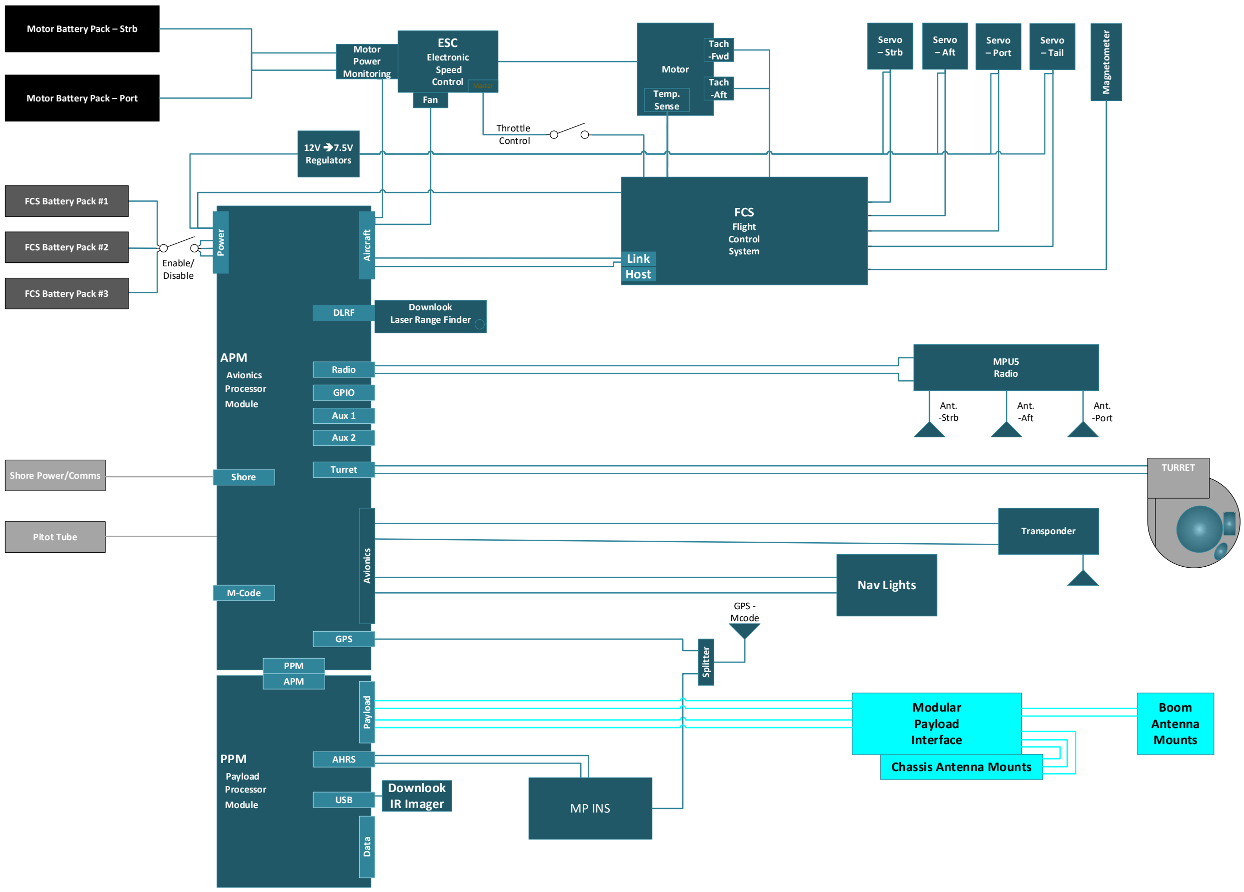


Figure 4-124. System Diagram for Vapor 55-M

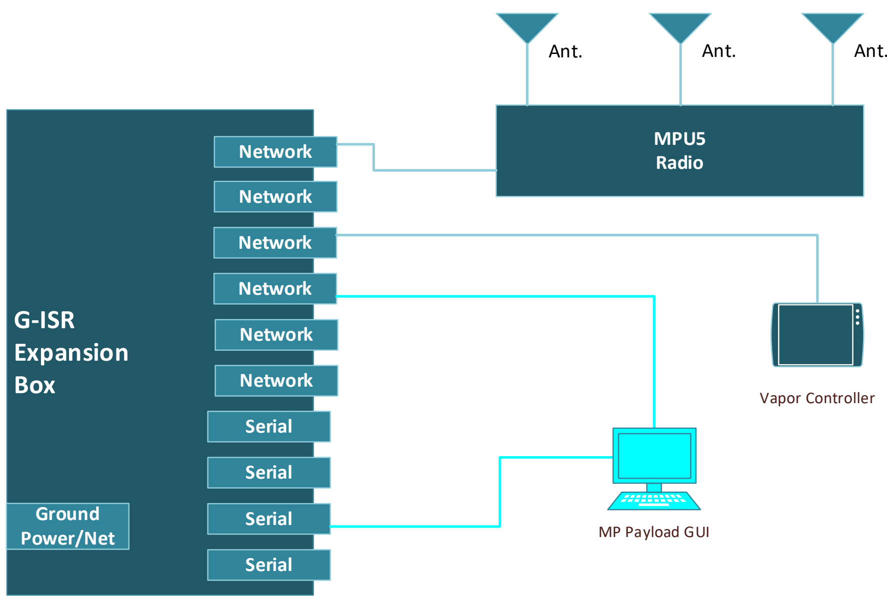


Figure 4-125. Ground Control Station for Vapor 55-M

4.6.2 Platform Weight and Power Budgets

As a small UAV, the Vapor 55-M is constrained in all SWAP attributes.

4.6.2.1 Weight Budget

The ModPayload A-kit (the Primary Mount Assembly, antenna mounts, and RF and Payload cables) adds 594g to the Vapor 55-M. Section 4.6.8.2 details weight constraints for several popular configurations. For some missions, the turret may be removed for a significant weight savings, but at the cost of reduced functionality of the vehicle. In addition, because the vehicle is so SWAP constrained, the nonessential antenna mounts and cables can be left off for a smaller weight savings.

4.6.2.2 Power Budget

The platform power available to support the MP architecture is 56W (pulled from the FCS batteries), which may be further constrained by the configuration of the base vehicle (similar to the weight constraints above). Section 4.6.8.2 details power constraints for several popular configurations. Also, see Section 4.6.8.1 regarding the inrush current capacity.

4.6.3 MAIM

The MAIM capability is built into the Avionics Processor Module (APM) and Payload Processor Module (PPM) installed inside the fuselage. The APM draws power from the FCS batteries and provides power (through the PPM) to the payload. The PPM handles the network and serial communications as well as the discrete logic interfaces.

4.6.3.1 Mechanical Description

The APM is a 6.1 in. x 4.7 in. x 7.6 in. module and weighs 1180g. The APM is shown in Figure 4-126.

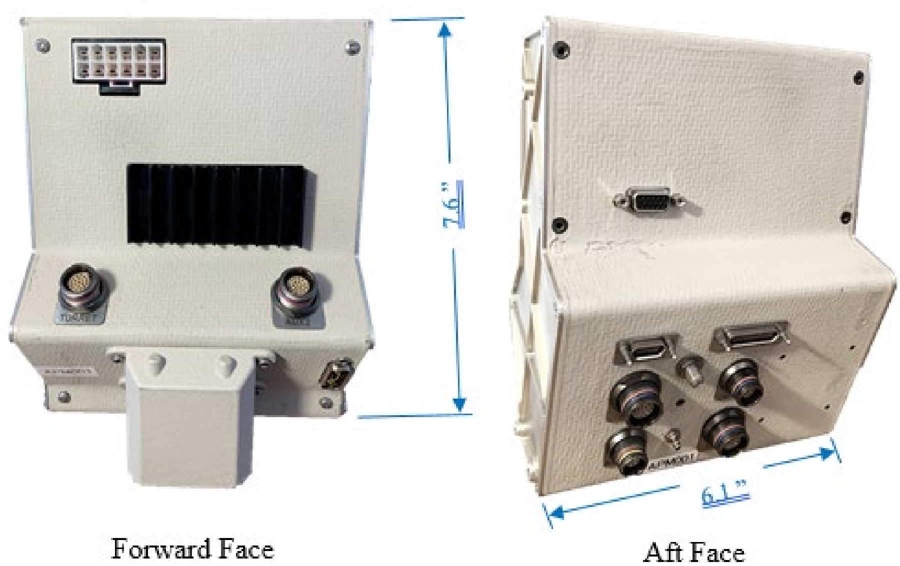


Figure 4-126. Vapor 55-M APM

The PPM is a 5.9 in x 3.5 in x 3.0 in module and weighs 450g. Figure 4-127 shows the PPM.

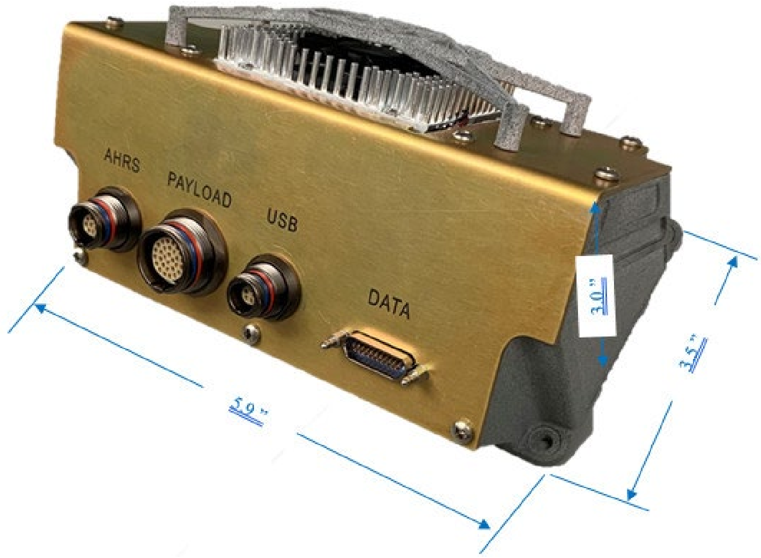


Figure 4-127. Vapor 55-M PPM

The PPM is mounted to the APM, which is mounted on the underside of the fuselage, as shown in Figure 4-128.

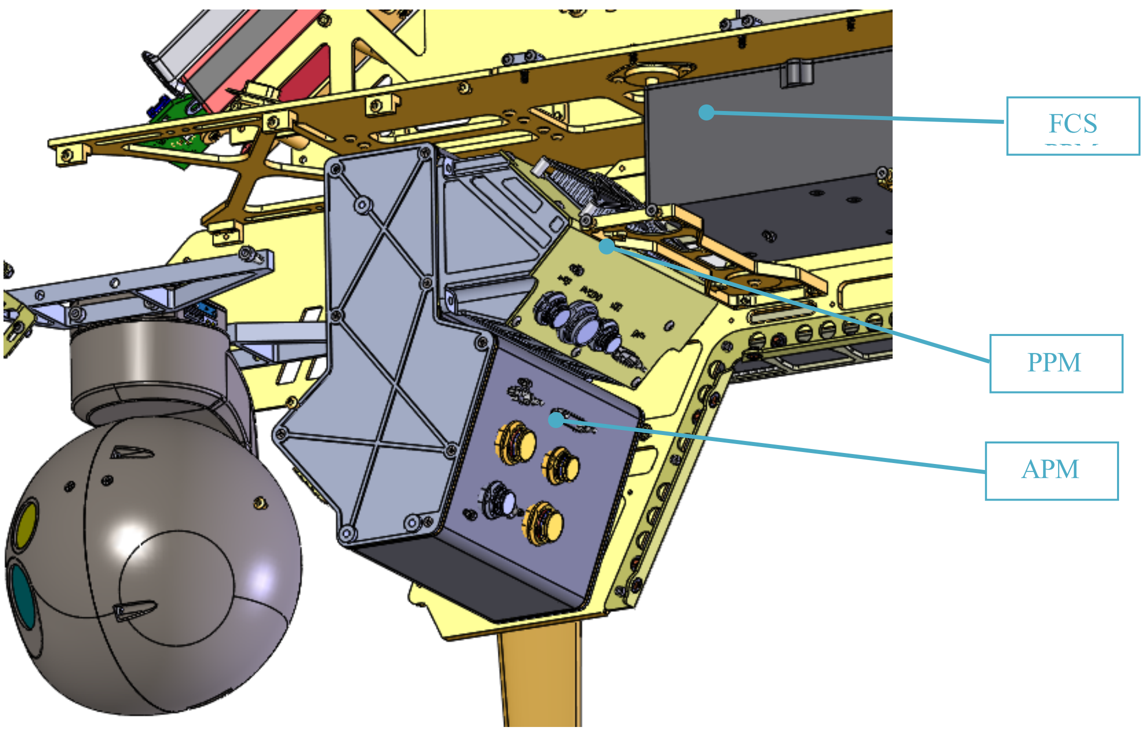


Figure 4-128. Cutaway View of APM and PPM Mounted

4.6.3.2 Electrical Description

The full MAIM functionality is built into the Vapor 55-M APM and PPM, therefore a separate MAIM module is not required for this aircraft. The Vapor 55-M Mod Payload configuration block diagram is shown in Figure 4-129.

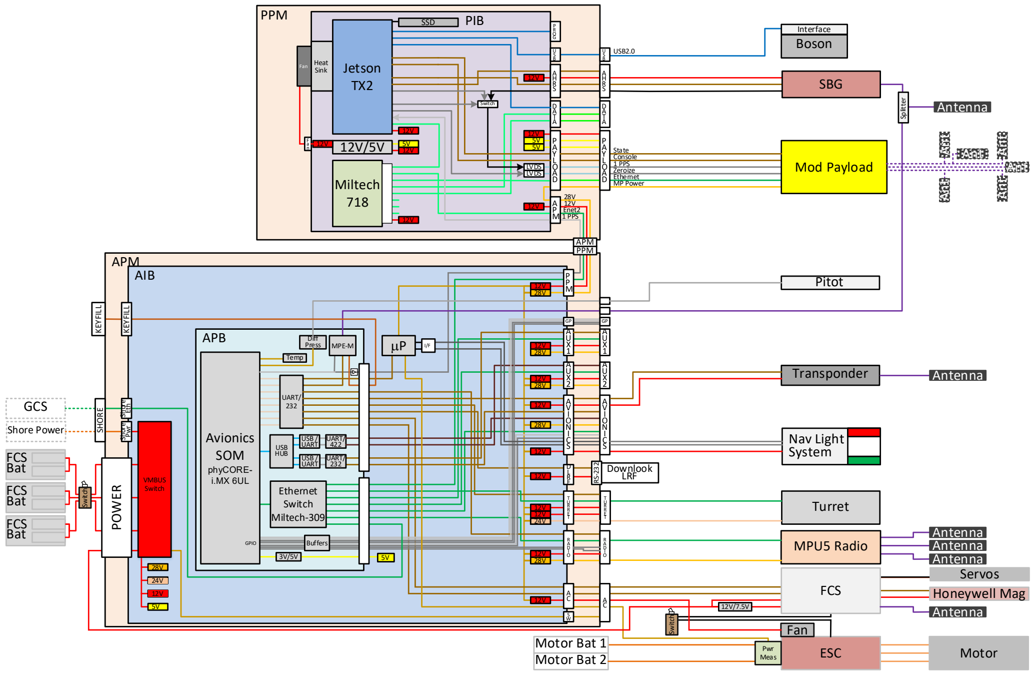


Figure 4-129. Vapor 55-M Electronics Block Diagram

4.6.3.2.1 Power Input

The APM draws power from the FCS batteries. The platform can support two or three FCS batteries depending on the power required for the mission, but an additional weight of 490g is incurred for the third battery. The APM provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on the power input. The APM and PPM can also be powered externally through the vehicle's maintenance port.

4.6.3.2.2 Payload Interfaces

The APM and PPM support 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 APM provides the 28VDC power (140mV load regulation, 25mV ripple) to the payload via the PPM and limits the maximum current draw to 2A (continuous).

4.6.3.2.3 Power Monitoring

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

4.6.3.2.4 INS Interface

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

4.6.3.2.5 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the PPM connects the payload to the Vapor 55-M network. An MPU-5 radio also tied to that network provides the UAS backhaul to the ground station.

4.6.3.3 APM and PPM Integration

The APM and PPM are integral to the Vapor 55-M vehicle and do not require a separate installation.

4.6.4 Primary Mount

The Primary Mount for the Vapor 55-M is mounted to the vehicle using four M4 x 8 socket head screws. The PM can mount in several positions along the vehicle's payload rails, but is typically mounted in the aft most position for center of gravity considerations, especially if the Trillium HD55-MV turret is installed.

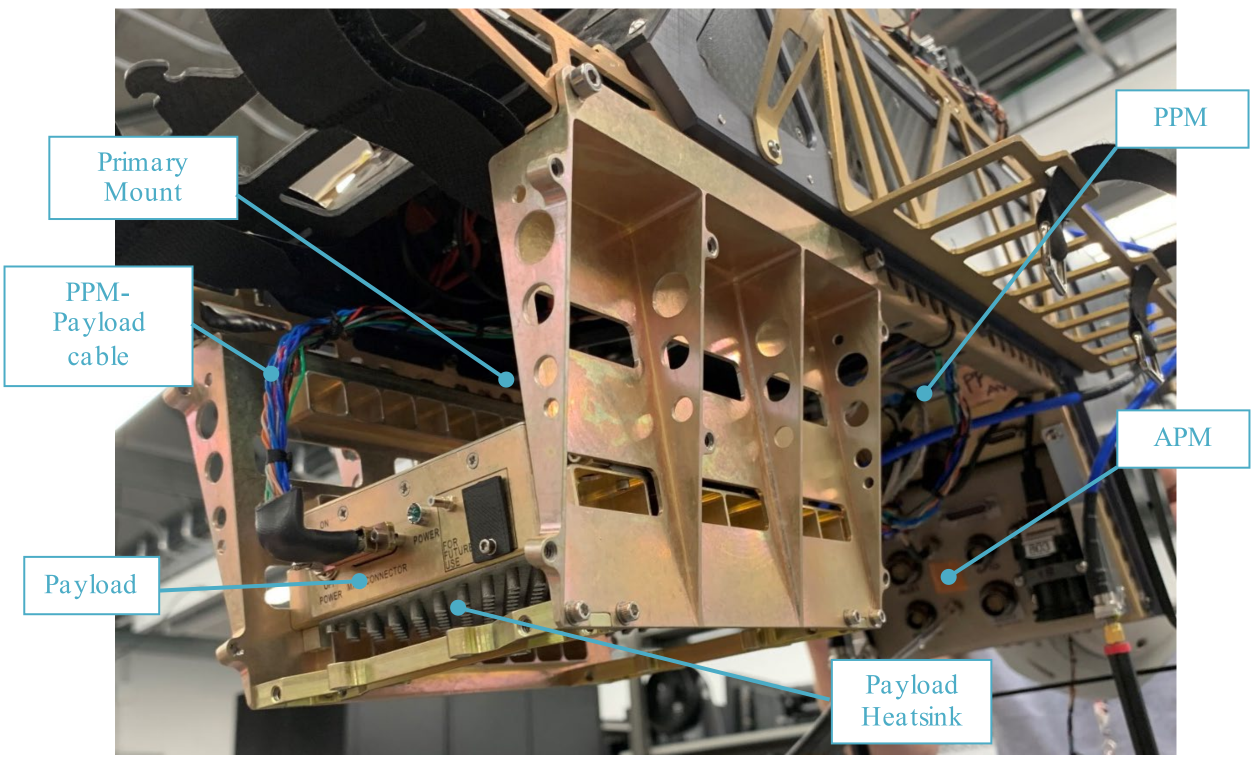


Figure 4-130. PPM and APM on Vapor 55-M

4.6.4.1 Installation

Payloads are installed using the wedge lock system and are easily accessed from the rear, permitting rapid exchange of payload modules.

At this point all payload cables (see Section 4.6.7.2, Section 4.6.7.3, and Section 4.6.7.5) are connected to the payload. The PPM-Payload cable is positioned above the payload as shown in

Figure 4-130.

4.6.4.2 Thermal

The Primary Mount is designed to expose the payload heatsink to direct airflow, as evident in Figure 4-130 above.

4.6.5 INS

The Ellipse2-N INS is native to the vehicle and does not require a separate installation. It is located on the right aircraft shoulder, forward of the Primary Mount.

4.6.6 Antenna Mounts

The MP-Vapor 55-M supports antenna mounts in two locations: attached to the Primary Mount Structure and on the boom. The boom supports up look and down look 2-point mounts while the Primary Structure supports a 2-point side 45° mount, a 2-point down look mount, and an array mount (see Figure 4-132).

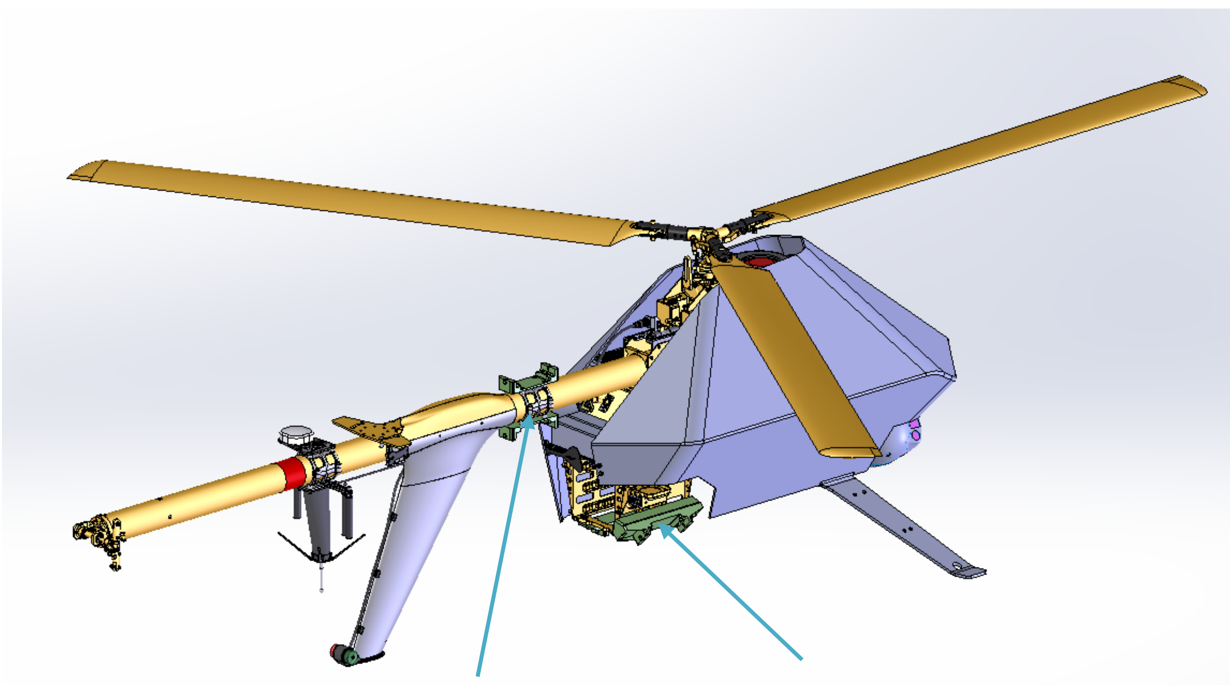


Figure 4-131. Antenna Mount Locations

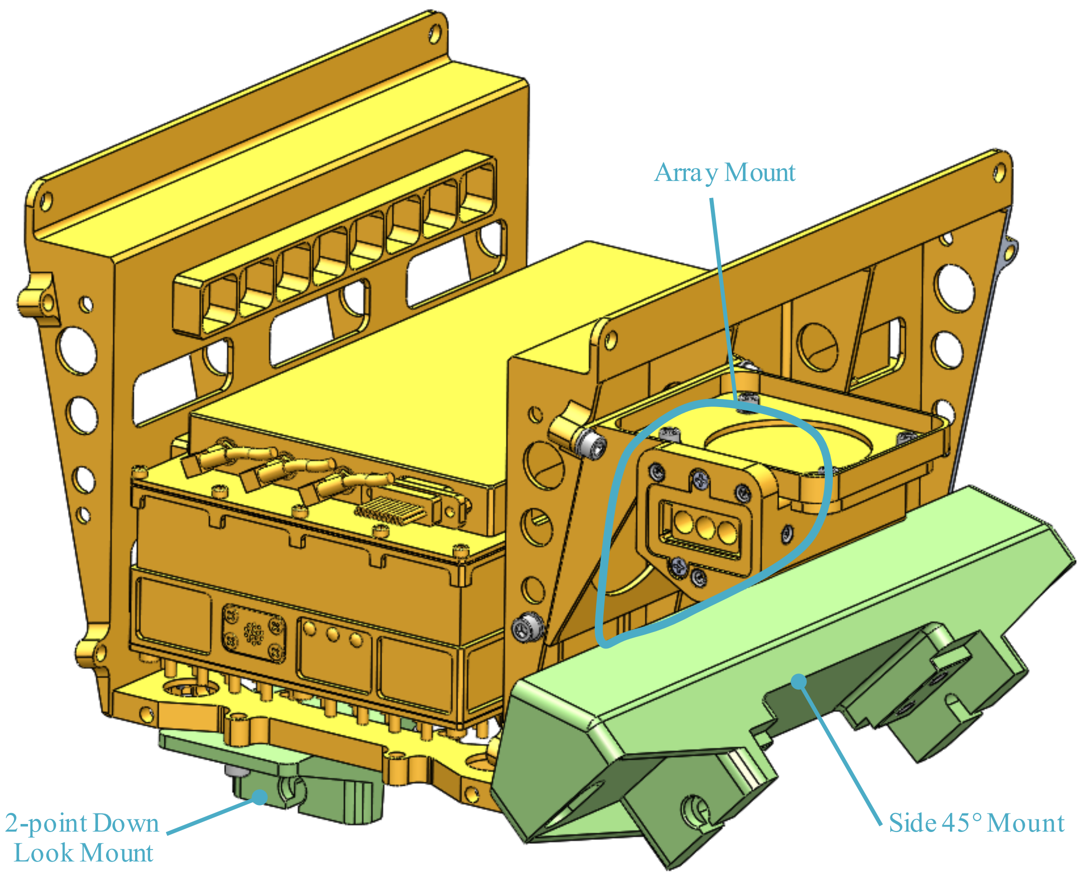


Figure 4-132. Prime Structure Antenna Mounts

4.6.6.1 Array Mount

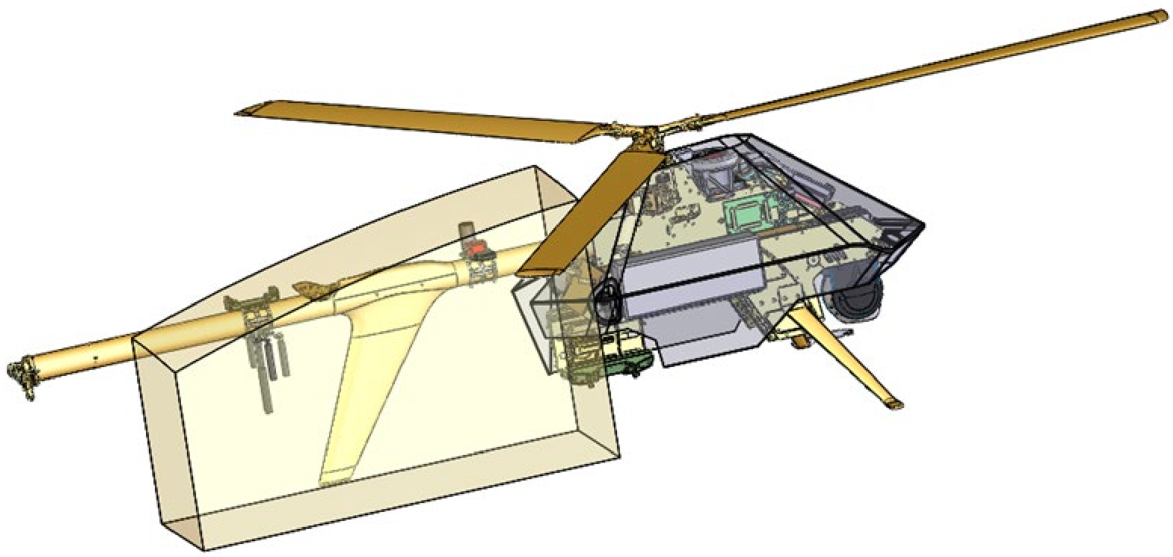
The array mount assembly (array mount and bracket) is mounted to the side of the Primary Mount and provides the standard-defined antenna array interface as shown in Figure 4-132.

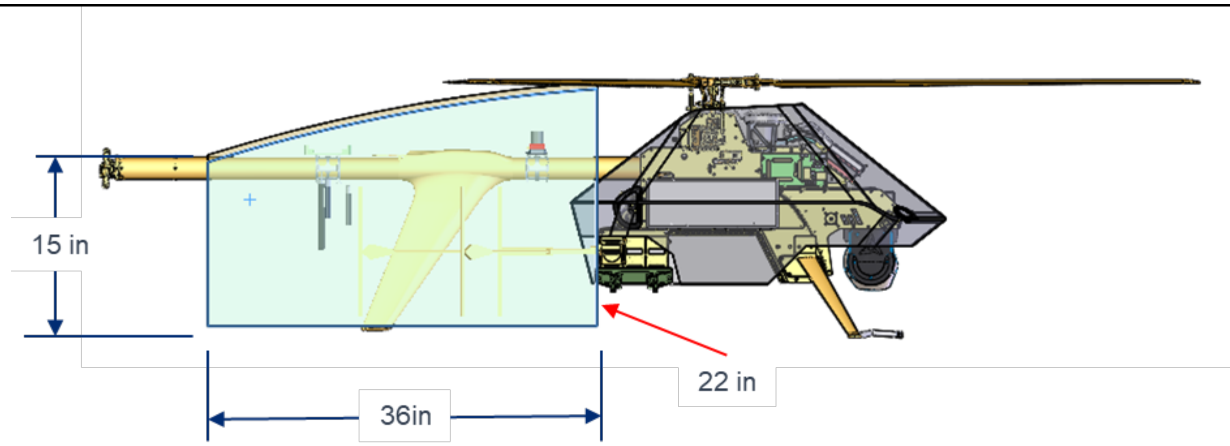
The weight of the array mount assembly is 111g. The array antenna mount capacity is defined in Table 4-29. Note that the antenna array weight may be further constrained by the overall vehicle weight limits and/or CG limits. The antenna array volume is defined in Table 4-30.

Table 4-29. Array Antenna Mount Capacity

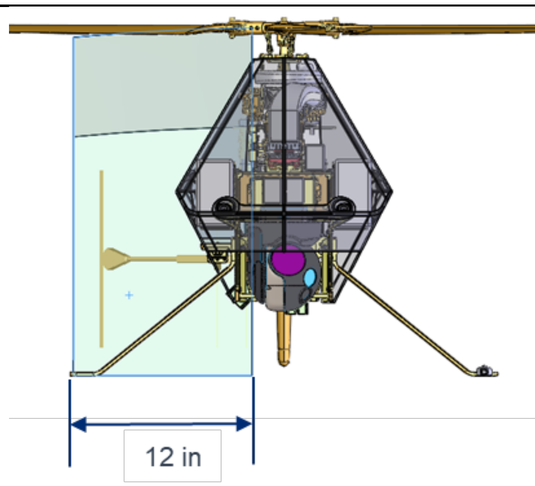
Max Weight	20+ lb., 6 in antenna CG to bracket 17.5 lb., 12 in antenna CG to bracket 10 lb., 24 in antenna CG to bracket 7 lb., 36 in antenna CG to bracket
Max Volume	7992 in^3.

Table 4-30. Array Antenna Volume

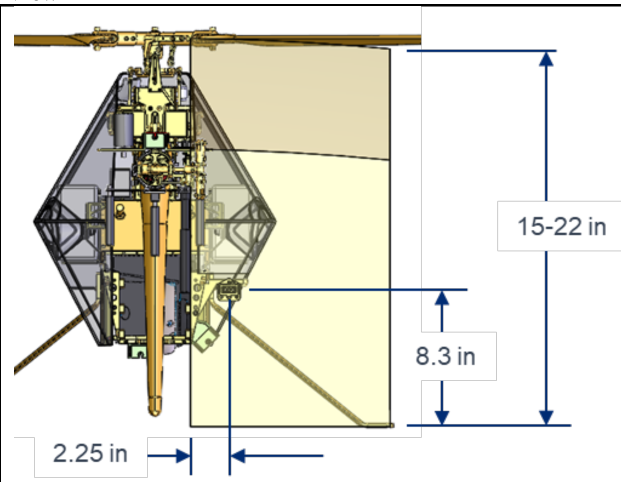




Side View



Front View



Rear View

4.6.6.2 Boom Mount

The Vapor 55-M boom can be equipped with a 2-pt antenna mount, either up look or down look. The weight of the boom mount assembly is 14g. The 2-point boom mount capacity is defined in Table 4-31 and Figure 4-133.

Table 4-31. Boom Antenna Mount Capacity

Max Weight	330g
Max Volume	Up: 4” Down: 12” Fwd/Aft: 6”

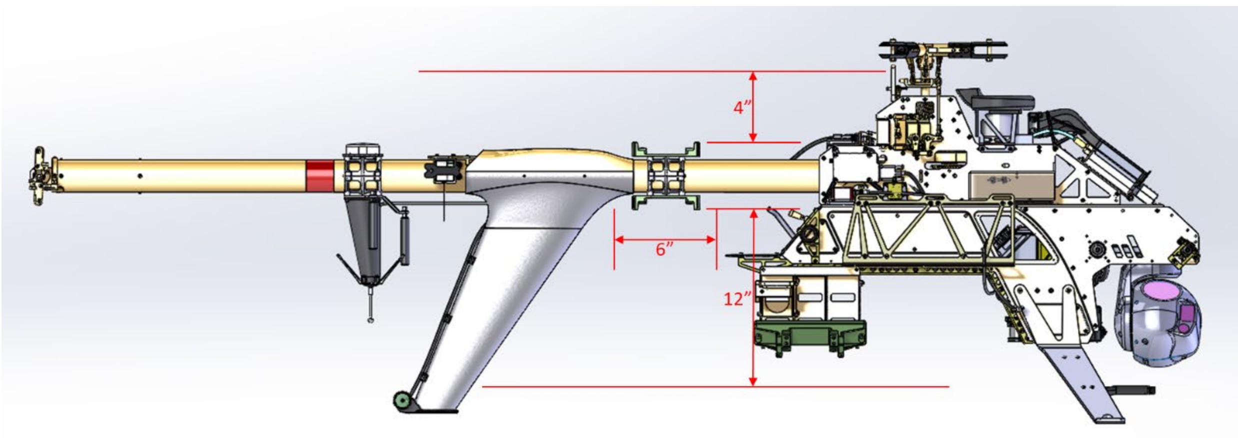


Figure 4-133. 2 Point Boom Antenna Mount Volumes

4.6.6.3 Primary Structure Mount

The Vapor 55-M Primary Mount can be equipped with a 2-pt, down look antenna mount or a 2-point side 45° mount. The weight of the down look mount is 17g and the side 45° mount is 30g. The mount capacities are defined in Table 4-32 and Figure 4-134.

Table 4-32. Primary Structure Antenna Mount Capacity

Max Weight	330g
Max Volume Down Look	Down: 2.5” Fwd/Aft: n/a
Max Volume 45° mount	Down: 3.5” Fwd/Aft: 6”

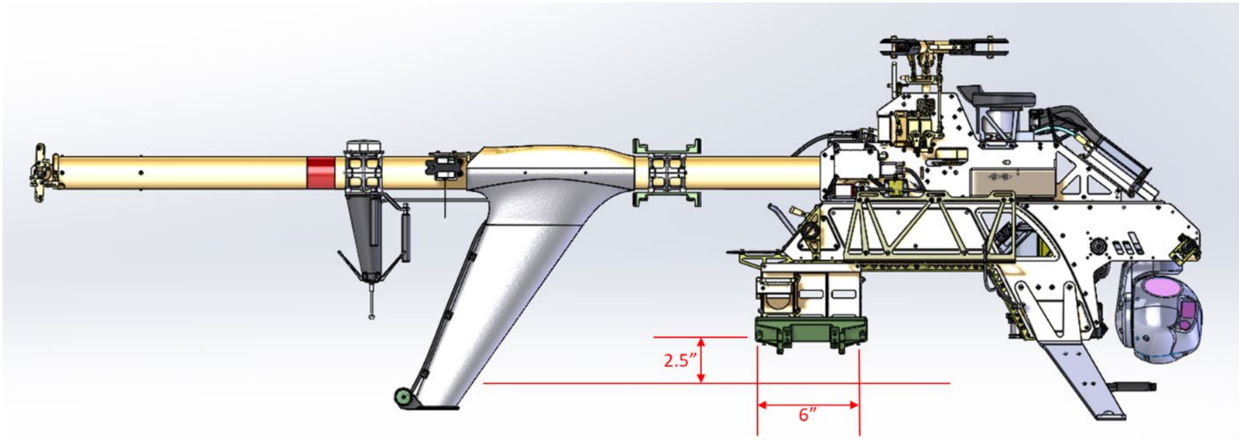


Figure 4-134. 2 Point Chassis Antenna Mount Volumes

4.6.7 Cabling

Mod Payload cabling for the Vapor 55-M consists of the PPM-Payload cable and the payload specific antenna cables. Due to the vehicle's SWAP constraints, only the mission-specific RF cables are installed for the antenna mount(s) used.

4.6.7.1 UAS-PPM Cable

The PPM is an integral part of the vehicle and does not require any additional cabling for Mod Payload.

4.6.7.2 PPM-Payload Cable

The PPM-payload cable is a combination of small gauge twisted shielded pairs and single wires with Expando sleeving and terminated as detailed in Figure 4-135.

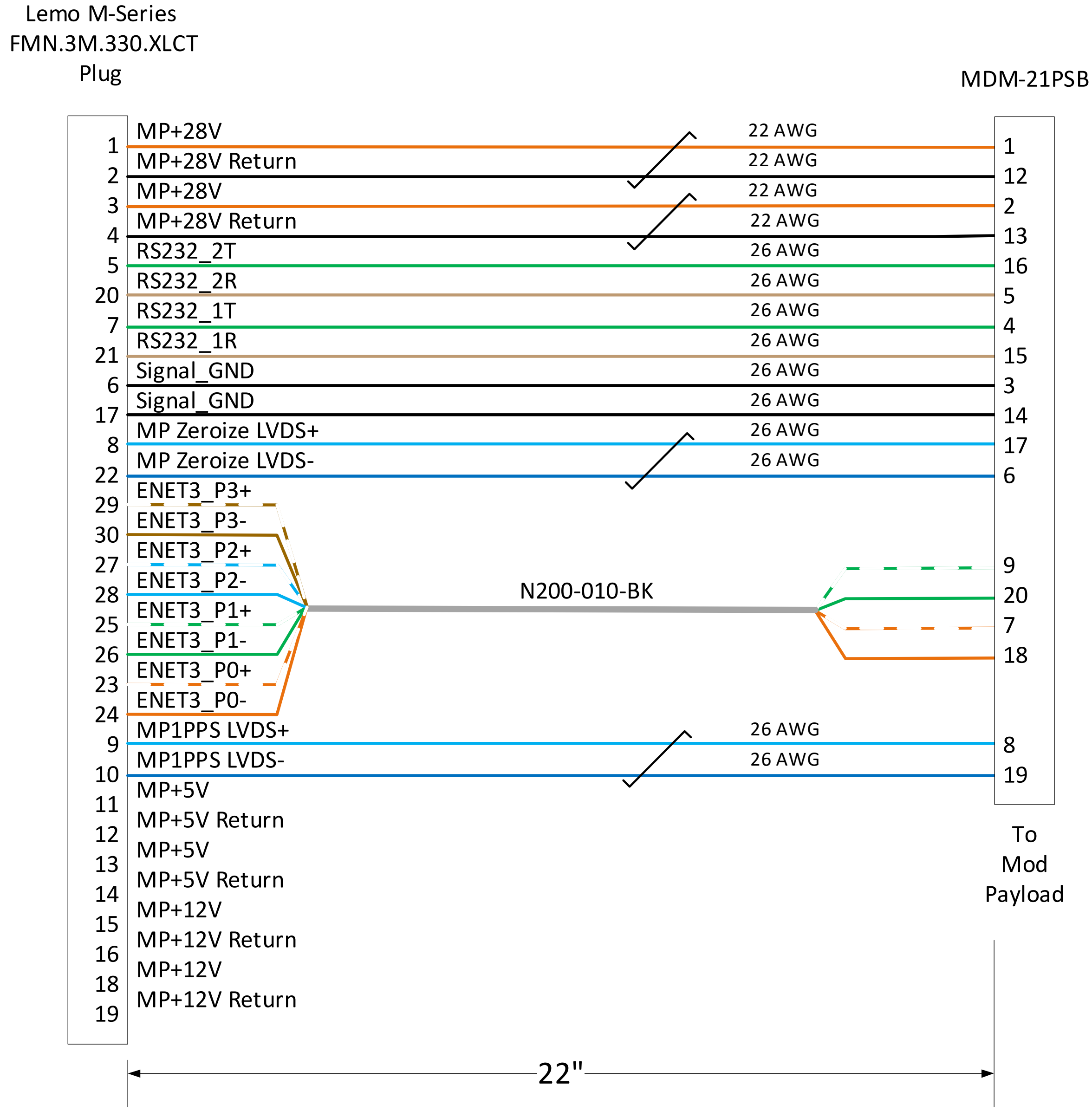


Figure 4-135. PPM-Payload Harness

The PPM-payload cable runs from the front of the payload, over the top of it, aft to the PPM Payload connector. The MAIM-payload cable is 22-inches long and weighs 65g.

4.6.7.3 PPM-AHRS Cable

The PPM-AHRS cable is native to the vehicle and does not require installation for Mod Payload. The schematic is shown in Figure 4-136 for reference only.

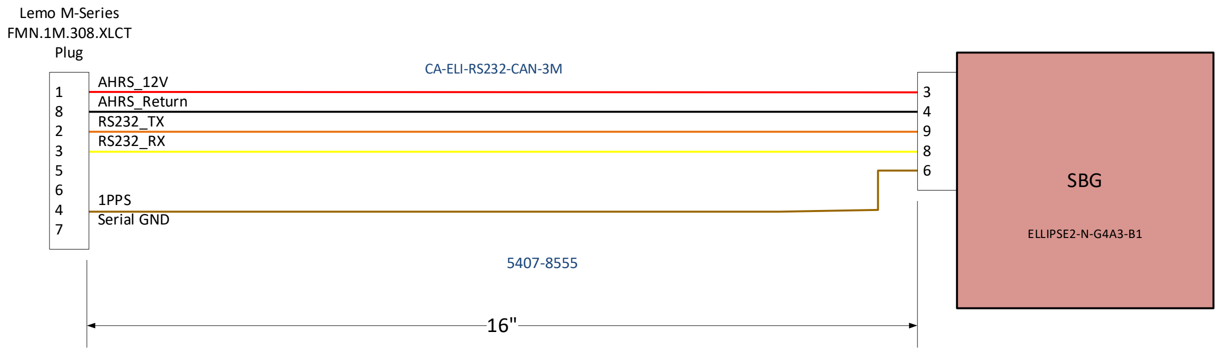


Figure 4-136. PPM AHRS Harness

4.6.7.4 GPS Antenna Cable

The GPS Antenna cable is native to the vehicle and does not require installation for Mod Payload. The GPS antenna is shared with the M-code receiver in the APM. The GPS antenna cable runs from the INS on the right shoulder to an RF splitter.

4.6.7.5 Payload RF Cables

The MP-Vapor 55-M supports RF cable runs for antennas mounted on the Primary Structure and the tail boom. However, due to the limited payload capacity of the Vapor 55-M, none of these cables is permanently installed. The RF cables are run as needed, depending on the payload and mission requirements.
The following table provides useful characteristic and performance information for all RF cable runs.

Table 4-33. Vapor 55-M RF Cable Summary

Cable Set	Cables	Length (in)	Weight (g)	Attenuation (dB)
Payload to Array Mount	3	18	46.3	0.29
Payload to Primary Structure 2-point Down Look Mount	1	12	14.6	0.19
Payload to Primary Structure 2-point 45° Side Look Mount	1	11	14.1	0.18
Payload to Tail Boom 2-point Up Look Mount	1	30	24.1	0.48
Payload to Tail Boom 2-point Down Look Mount	1	28	23.1	0.45

Note 1: Attenuation calculated for a 1GHz signal
Note 2: Attenuation from connectors has been neglected

4.6.8 Concessions to the Standard

A single concession is documented for the MP-Vapor 55-M.

4.6.8.1 Payload Inrush Current

In real world testing, it has been documented that the full 4Amp, 5mSec inrush current permitted under the MP Standard will cause a sag of ~2VDC (~7%) for ~300 µsec on the 28VDC power lines.

4.6.8.2 Payload Power/Weight Constraints

The Vapor 55-M is a modular and highly flexible system. As such, the base configuration significantly affects the weight and power constraints on MP payloads. While not a platform concession, these constraints may affect the implementation details of some payloads. Table 4-34 details the constraints for several of the more popular configurations.

Table 4-34. Payload Weight and Power Constraints

AV Config	# of FCS Batteries	Payload Weight Max	Power Draw (max) for typical duration flight
Basic MP	2	4.93 kg (10.87 lb.)	20 W
	3	4.44 kg (9.79 lb.)	56 W
Basic MP + turret	2	Not a valid configuration – insufficient battery capacity	
	3	2.50 kg (5.52 lb.)	52 W
Basic MP + turret + Xponder + Nav Lights	2	Not a valid configuration – insufficient battery capacity	
	3	2.13 kg (4.70 lb.)	38 W

4.7 Adaro USV

The following details the MP implementation for the SeaLandAire Technologies, Inc. ADARO USV.

4.7.1 Overview

The MP-compliant ADARO USV can support up to 9U total (3x 3U) payloads in a custom Primary Mount located in the main payload bay. The ADARO USV power capacity can support three concurrent payloads drawing 82W each (an additional payload connection must be leveraged to exceed the standard 56W payload limitation). The MP-ADARO USV is equipped to support a number of mounting locations, including the top of the aft mast, the top of the forward mast, mid-height on the aft mast, and directly mounting to the vessel. A platform-specific MAIM and the MP-compliant INS are both required for this USV.

4.7.1.1 MP Architecture

Figure 4-137 illustrates the architectural layout of the MP implementation on the ADARO USV.

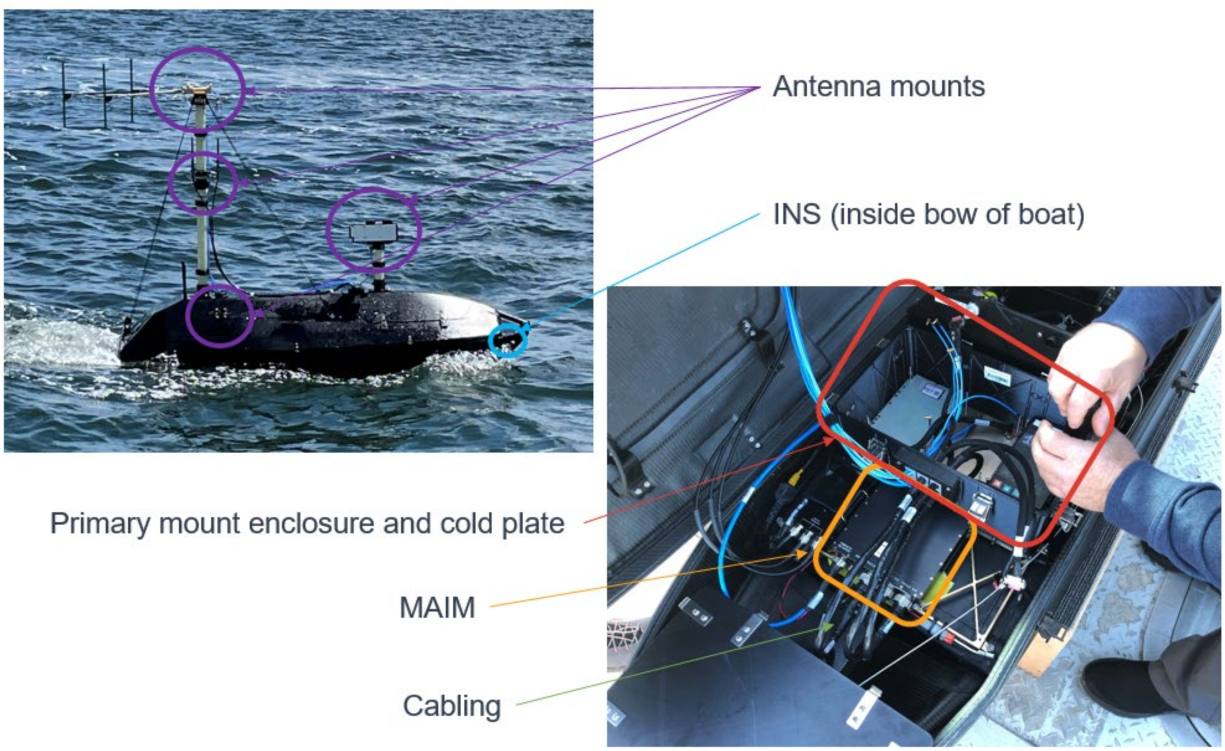


Figure 4-137. Architectural Layout for ADARO USV

4.7.1.2 Compliance / Capability Summary

Table 4-35 provides a top-level summary of the MP compliance and capability on the ADARO USV.

Table 4-35. ADARO USV 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">Main Payload Bay</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Bow</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">247 W (6 payload feeds)</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">9U total (3x 3U)</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">23.6 lbs (shared between payloads and fuel)</td></tr>
<tr><th colspan="2">Primary Mount</th><th colspan="2"></th></tr>
<tr><td colspan="2">Mounting Method</td><td colspan="2">Plate</td></tr>
<tr><td colspan="2">Cooling Method</td><td colspan="2">Conduction</td></tr>
<tr><th>Antenna Mounts</th><th>Qty</th><th>Location</th><th>Orientation</th></tr>
<tr><td rowspan="4">Two-point</td><td>1</td><td>Forward Mast</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Aft Mast</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Vessel Mount</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Mid-height Aft Mast</td><td>45° Up or Side</td></tr>
<tr><td rowspan="4">Four-points</td><td>1</td><td>Forward Mast</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Aft Mast</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Vessel Mount</td><td>Up, 45° Up, or Side</td></tr>
<tr><td>1</td><td>Mid-height Aft Mast</td><td>45° Up or Side</td></tr>
<tr><td rowspan="2">Array</td><td>1</td><td>Forward Mast</td><td>Fwd, Aft, Port, or Stbd</td></tr>
<tr><td>1</td><td>Aft Mast</td><td>Fwd, Aft, Port, or Stbd</td></tr>
</table>

4.7.1.3 System Diagram

Figure 4-138 details the system diagram for the ADARO USV. MP-specific additions are highlighted in teal.

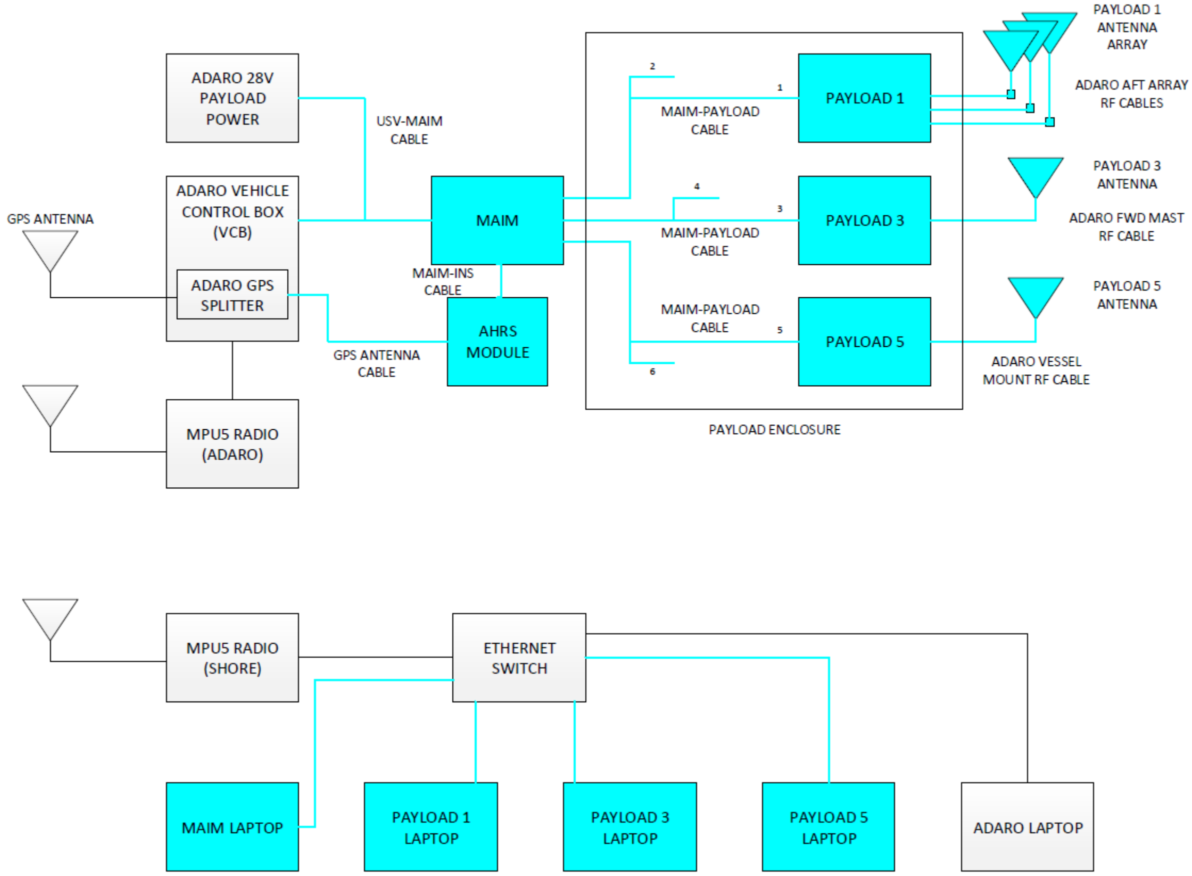


Figure 4-138. System Diagram for ADARO USV

4.7.2 Platform Weight and Power Budgets

Although the ADARO USV is SWAP-constrained, it has ample volume, power, and weight capacity for the MP architecture.

4.7.2.1 Weight Budget

The Mod Payload A-kit adds 12.4lbs to the ADARO USV, leaving 23.6lbs for B-kit payloads and fuel. 2.6 lbs are available for B-kit payloads without any impact to the ADARO's maximum fuel capacity. Beyond that 2.6lbs, any additional B-kit payload weight will reduce the ADARO's maximum fuel capacity.

4.7.2.2 Power Budget

Currently, 247W have been budgeted for payloads. This includes extra margin to support the future addition of higher power payloads. Additional payload cables are provided from the MAIM to allow a payload to pull more than the standard-defined 56W. This power can be fully accommodated by the ADARO payload power rail.

4.7.3 MAIM

The MAIM is a custom circuit board housed in custom enclosure. The enclosure design was updated for the ADARO USV to include an additional gasket to meet the required IP64 (splash-proof) rating. The MAIM enclosure is mounted to the cold plate in front of the primary mount enclosure.

4.7.3.1 Mechanical Description

The MAIM enclosure is 6.13in x 5.85in x 1.55in and weighs 1.3lb. Figure 4-139 shows the MAIM enclosure (left) and the MAIM board (right).

Top Bottom

Figure 4-139. MAIM for ADARO USV

4.7.3.2 Electrical Description

The MAIM is a legacy PCB designed for MP-compliant UAS that has been adapted for the ADARO USV and supports full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure 4-140, 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 5.6W.

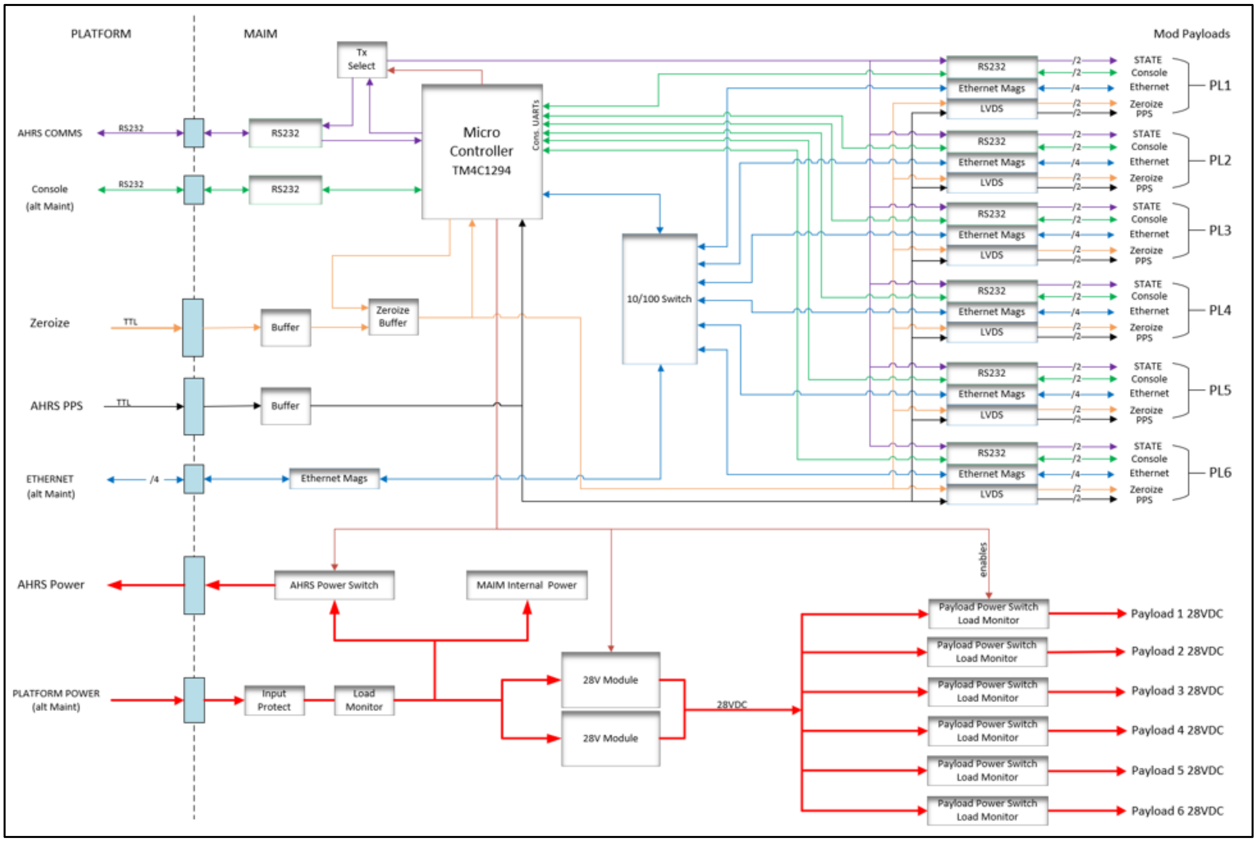


Figure 4-140. MAIM Block Diagram for ADARO USV

4.7.3.2.1 Power Input

The MAIM draws 28VDC power from the ADARO payload power rail connection in the payload bay. 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 by the maintenance cable via the Power/Ethernet connector.

4.7.3.2.2 Payload Interfaces

The MAIM provides connections to the INS and up to six Mod Payload modules (in three connectors). 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).

4.7.3.2.3 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 4-141.

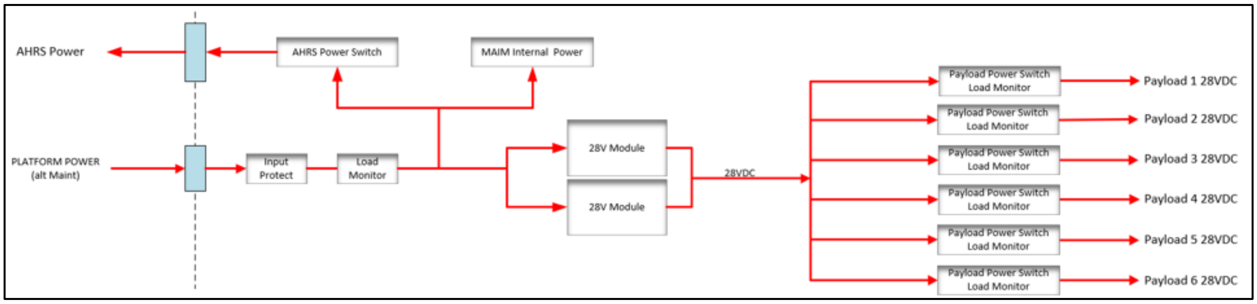


Figure 4-141. MAIM Power Circuitry Block Diagram

4.7.3.2.4 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.

4.7.3.2.5 Maintenance Interface

The MAIM provides a maintenance port via the Power/Ethernet connector to support required debug efforts. The maintenance interface includes an external power hook up, an Ethernet and a serial interface.

4.7.3.2.6 Platform Specific Interfaces

To transmit payload communications to operators on the ground, the MAIM connects to an onboard Ethernet switch. An MPU5 radio also tied to that network provides the USV backhaul to the ground station.

4.7.3.3 MAIM Integration

The MAIM enclosure is installed in front of the primary mount enclosure, as seen in Figure 4-142.

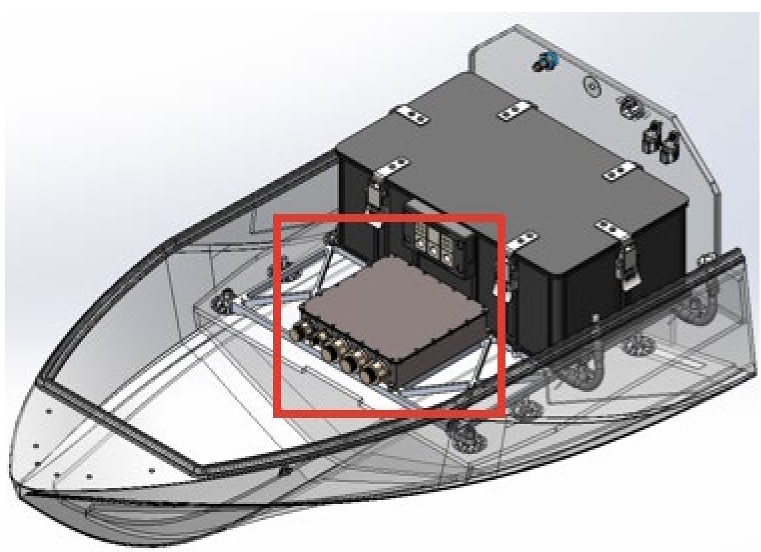


Figure 4-142. MAIM Installed in ADARO USV

4.7.4 Primary Mount

The Primary Mount design for the ADARO USV follows the cold-plate requirements set forth in the standard, allowing for payloads to be fastened to a cold-plate via four screws. An additively manufactured enclosure was designed to provide IP64 (splash-proof) protection for installed payloads. Figure 4-143 shows the Primary Mount installed.

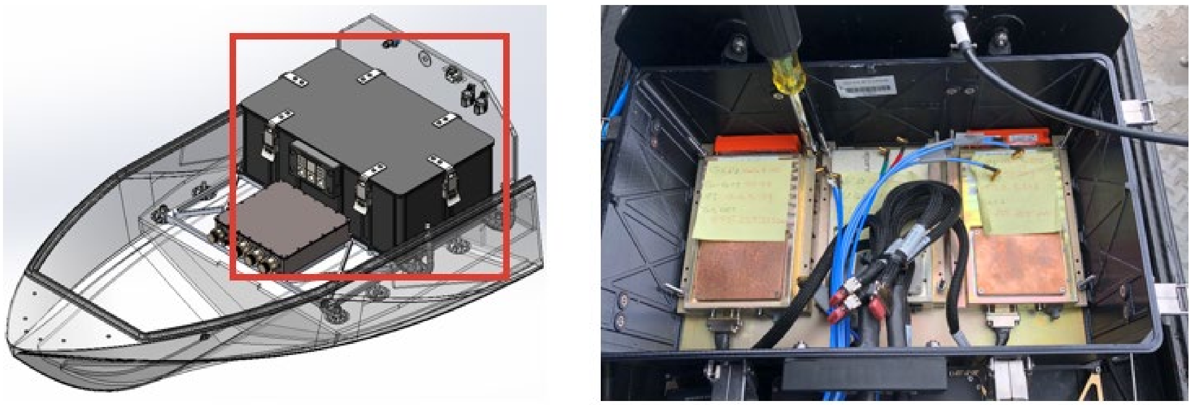


Figure 4-143. ADARO USV Primary Mount Installed

4.7.4.1 Mechanical Description

The Primary Mount as illustrated in Figure 4-143 consists of the cold plate assembly and the enclosure. The cold plate is manufactured from bent aluminum pipe pressed into the base plate and secured with thermal epoxy. It is 15.0 in (width) x 14.7 in (length) x 0.56 in (height). The cold plate details are shown in Figure 4-144.

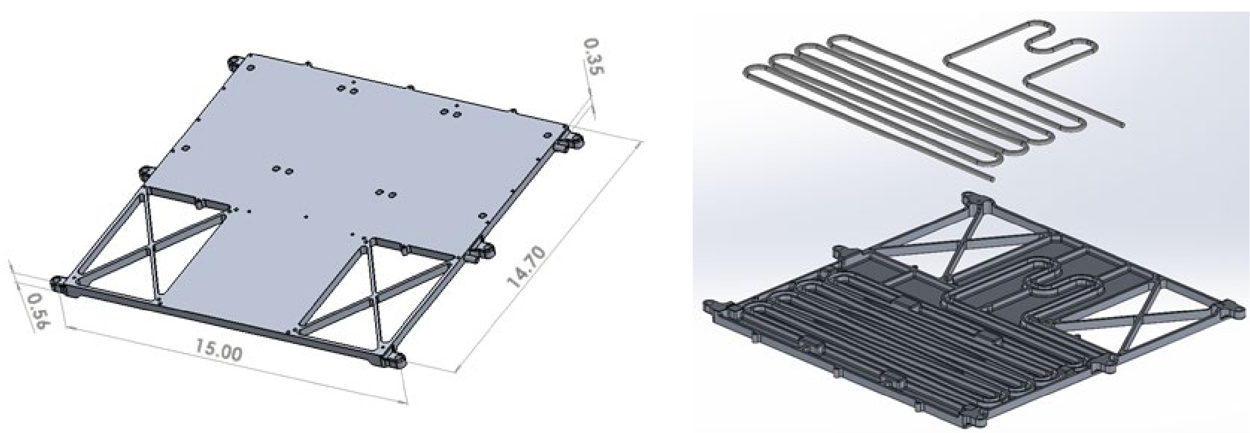


Figure 4-144. Cold Plate Details

The enclosure is mounted directly to the cold plate around the perimeter, and is 5.25in (length) x 14.75in (width) x 5.25in (height). The Primary Mount weighs 4.9lbs. The primary mount is shown in Figure 4-145.

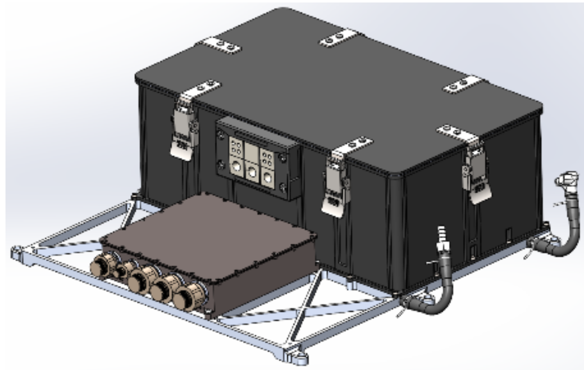


Figure 4-145. ADARO Primary Mount Assembly

4.7.4.2 Installation

As depicted in Figure 4-146, the Primary Mount is installed in the payload bay. The Primary Mount should be fully assembled, i.e., enclosure mounted to cold plate, prior to installation into the USV. Modules are installed after the Primary Mount is installed into the USV by folding open the deck of the vehicle.

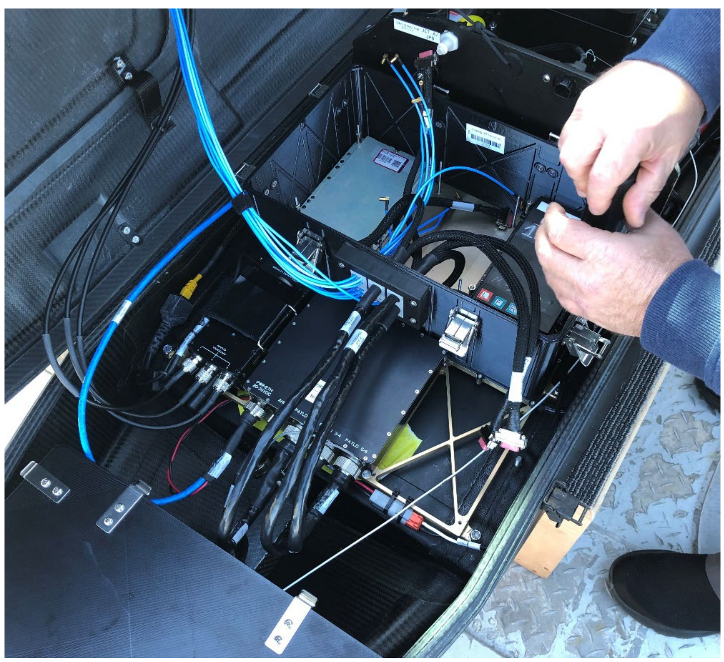


Figure 4-146. ADARO Primary Mount Installation

4.7.4.3 Thermal

To maintain the necessary 65°C maximum cold plate temperature, the ADARO electronics coolant loop is plumbed in and used as liquid cooling. One of the two heat exchangers was placed just before the Mod Payload cold plate to reduce the coolant temperature and maximize the heat transfer out of the cold plate.

Through simulation, it was observed that at worst case sea surface temperature (37°C) and three payloads operating at the max de-rated power (82.3W per payload), the cold plate maintains a maximum temperature lower than 65°C. The results are shown in Figure 4-147.

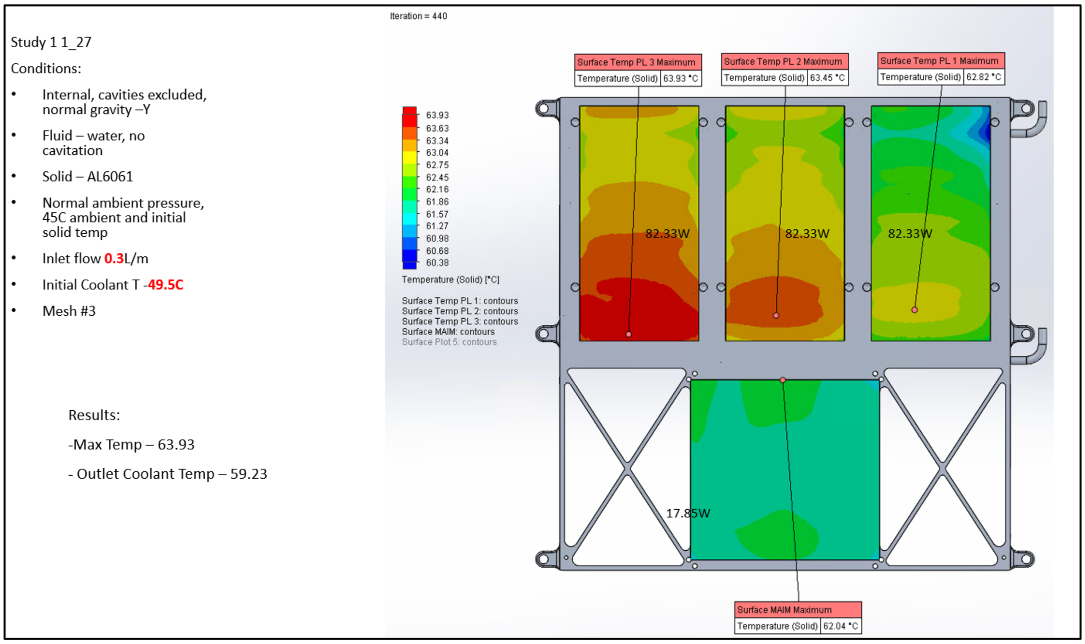


Figure 4-147. ADARO Cold Plate Thermal Analysis

4.7.5 INS

An Ellipse2-N INS is installed collocated with the ADARO native INS in order to minimize proximity to potential EMI noise sources (engine, high power conductors, etc.). GPS is provided to the antenna via the ADARO's native GPS splitter in the Vehicle Control Box (VCB). Figure 4-148 shows the INS installation.

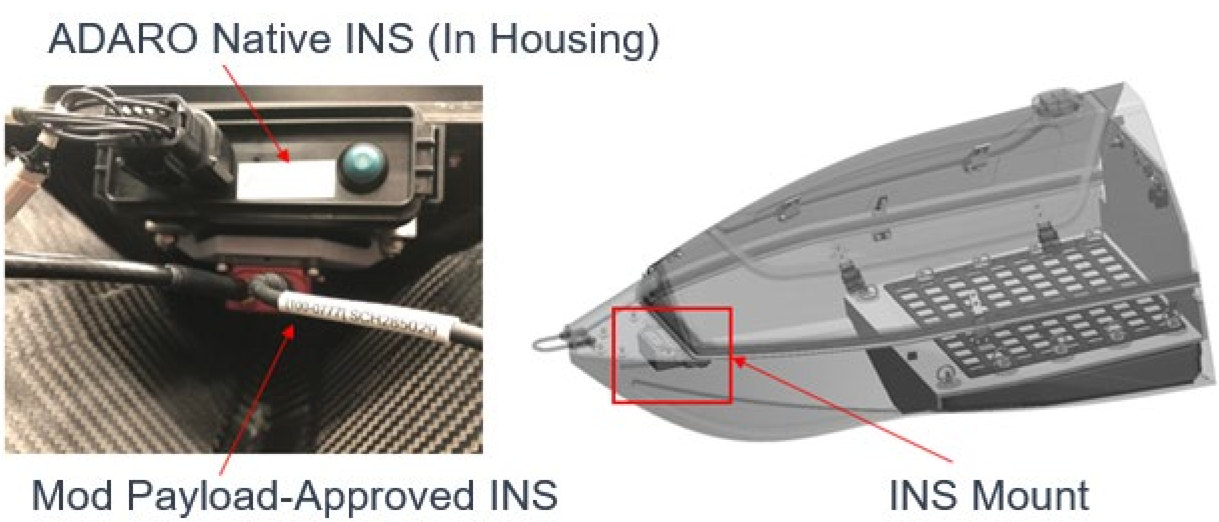


Figure 4-148. ADARO INS Installation

4.7.6 Antenna Mounts

The MP-ADARO USV supports antenna mounts in four locations: the top of the aft mast, the top of the forward mast, mid-height on the aft mast, and mounted directly onto the vessel. These locations are shown in Figure 4-149 below.

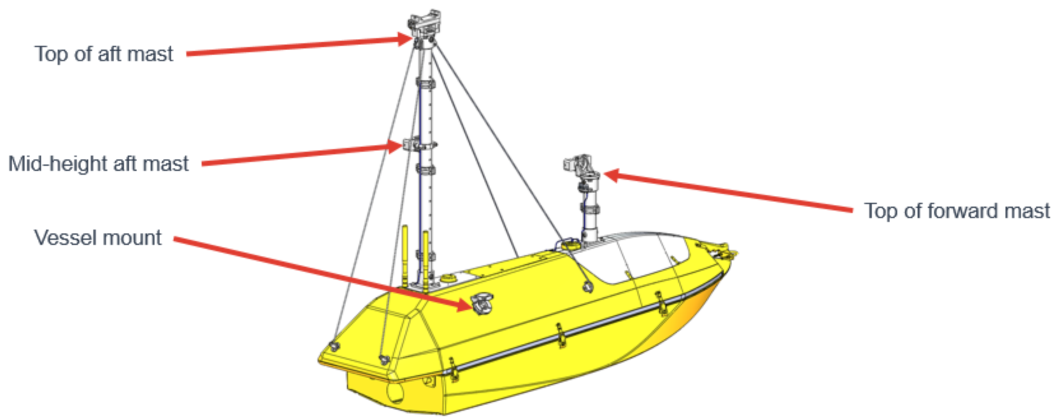


Figure 4-149. Antenna Mount Locations

In each of these locations, a universal 4-hole pattern is available onto which the desired MP-compliant mount (2-pt, 4-pt, or array, as shown in Figure 4-150) can be installed. These mounting locations are shown in Figure 4-151 below.

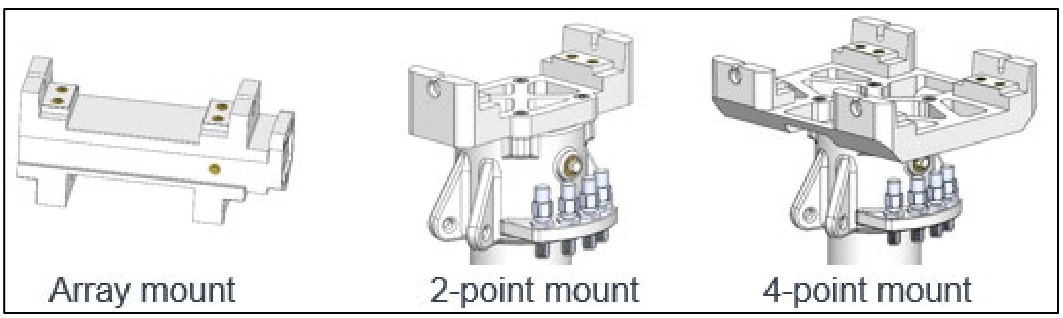


Figure 4-150. Mod Payload Compliant Mounts

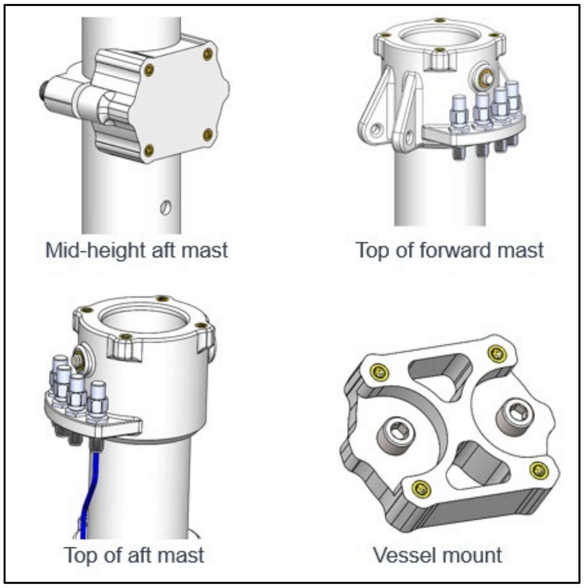


Figure 4-151. Mounting Locations

Additional adapters shown in Figure 4-152 are also included to allow for different antenna elevation angle options.

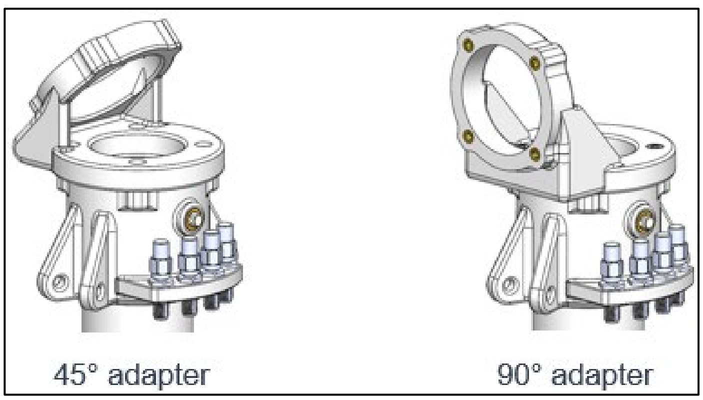


Figure 4-152. Antenna Adapters

4.7.7 Cabling

The schematic for all MAIM cables is provided in Figure 4-153. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.7.7.5.

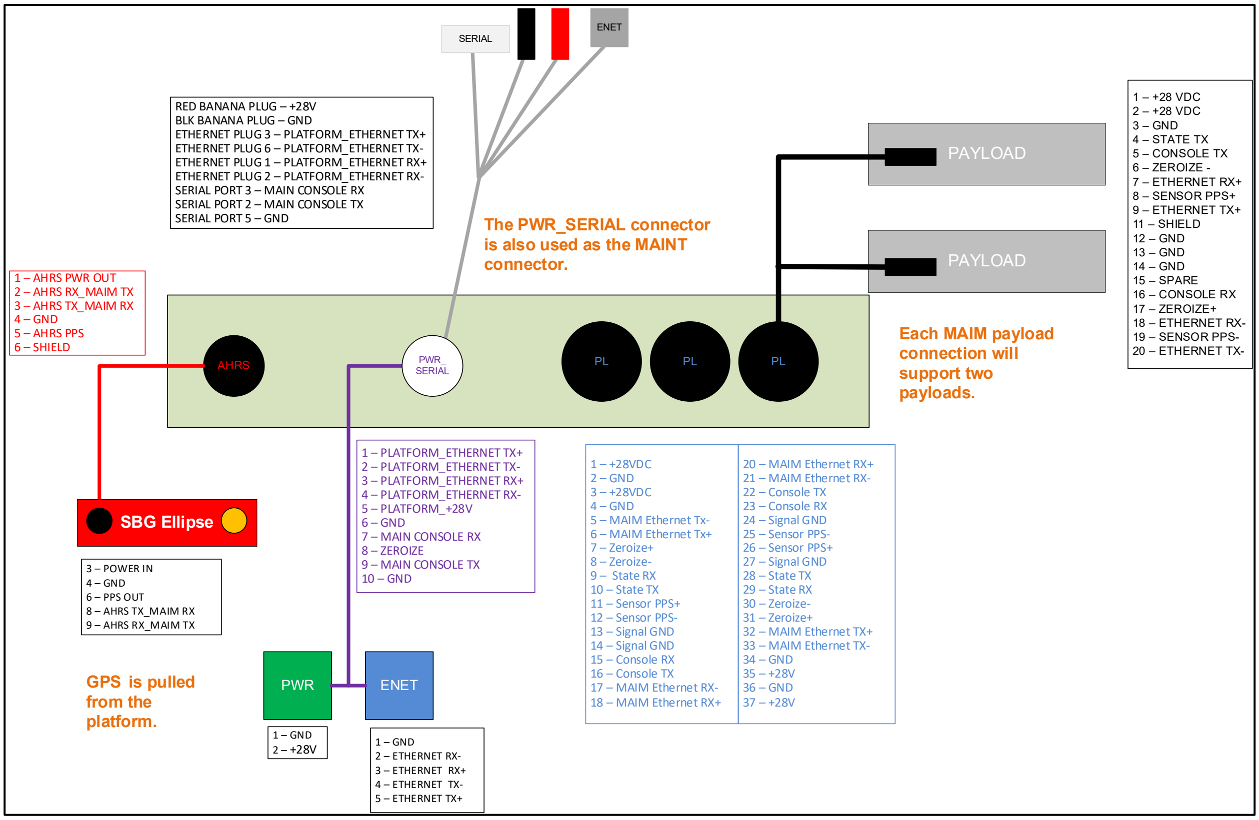


Figure 4-153. ADARO USV MAIM Cabling Schematic

4.7.7.1 USV-MAIM Cable

The USV-MAIM cable is a custom Y-cable with a Glenair connector for connection to the MAIM with 16 AWG twisted pair marine power wire for the power branch terminating in the mating connector for connection with the 28V ADARO payload power rail. The Ethernet branch is constructed of COTS Cat 6 Ethernet cable terminated in the same Glenair connector on the MAIM end and terminating in the mating connector to the ADARO VCB on the USV end as depicted in Figure 4-154. The USV-MAIM cable runs from the MAIM to the ADARO payload power connector on the aft bulkhead of the payload bay. The Ethernet comms branch runs around the payload bay bulkhead back to the VCB in the range extender/electronics bay. The USV-MAIM cable is 17-inches long on the power branch and 50-inches long on the Ethernet branch and weighs 105g.

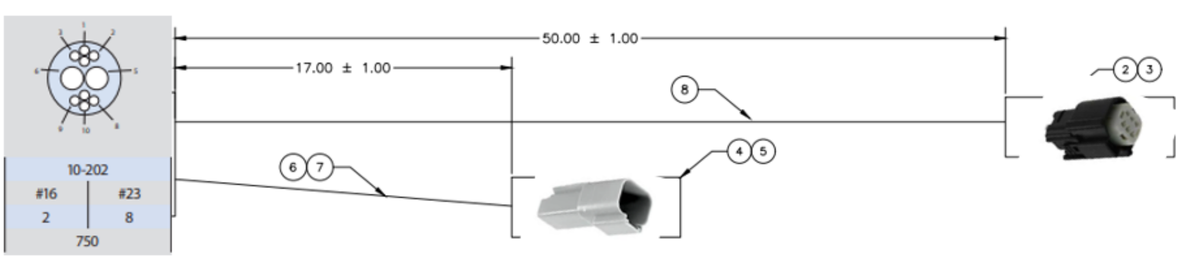


Figure 4-154. USV-MAIM Cable

4.7.7.2 MAIM-Payload Cables

The MAIM-payload cable is a custom Y-cable with a Glenair connector for connection with the MAIM with EMI shielding and 26 AWG UTP terminated straight thru at each end in the standard-defined 21-pin, Micro-D connector as depicted in Figure 4-155. The portion of the cable outside of the payload enclosure has adhesive lined heat shrink over EMI braided shielding to provide IP64 protection, while the portion inside the enclosure has expandable sleeving over EMI braided shielding. MAIM-payload cables run from the MAIM into the payload enclosure via an IP64 rated cable pass through gland. Each MAIM-payload cable is 27-inches long and weighs 110g.

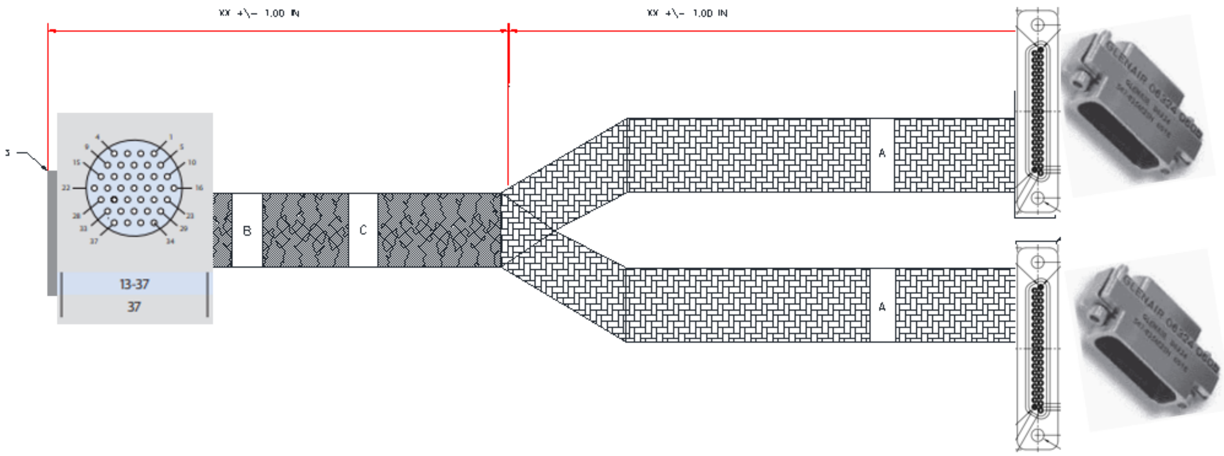


Figure 4-155. MAIM-Payload Cable

4.7.7.3 MAIM-INS Cable

The MAIM-INS cable is constructed by using a standard pigtail cable for the SBG Ellipse2-N INS and terminating the other end in a Glenair connector for connection to the MAIM as depicted in Figure 4-156. The MAIM-INS cable runs from the MAIM in the payload bay forward to the INS located in the bow of the ADARO. The MAIM-INS cable is 45-inches long and weighs 41g.

Figure 4-156. MAIM-INS Cable

4.7.7.4 GPS Antenna Cable

The GPS antenna cable is part of the INS installation (see Section 4.7.5). The GPS antenna cable runs from the INS in the bow to the GPS splitter cable just outside of the ADARO's Vehicle

Control Box (VCB).

4.7.7.5 Payload RF Cables

Nine RF cables are installed to support the four antenna mount locations on the USV. Four RF cables are run from the Primary Mount to the top of the aft mast, with 3 cables supporting an array mount and one supporting a 2-pt or 4-pt mount. Four additional RF cables are run from the Primary Mount to the top of the forward mast, with 3 cables supporting an array mount and one supporting a 2-pt or 4-pt mount. The final RF cable is run from the Primary Mount to either mid-height of the aft mast or the vessel mounting location. All cable runs are depicted in Figure 4-157 and are detailed further in the subsequent sections.

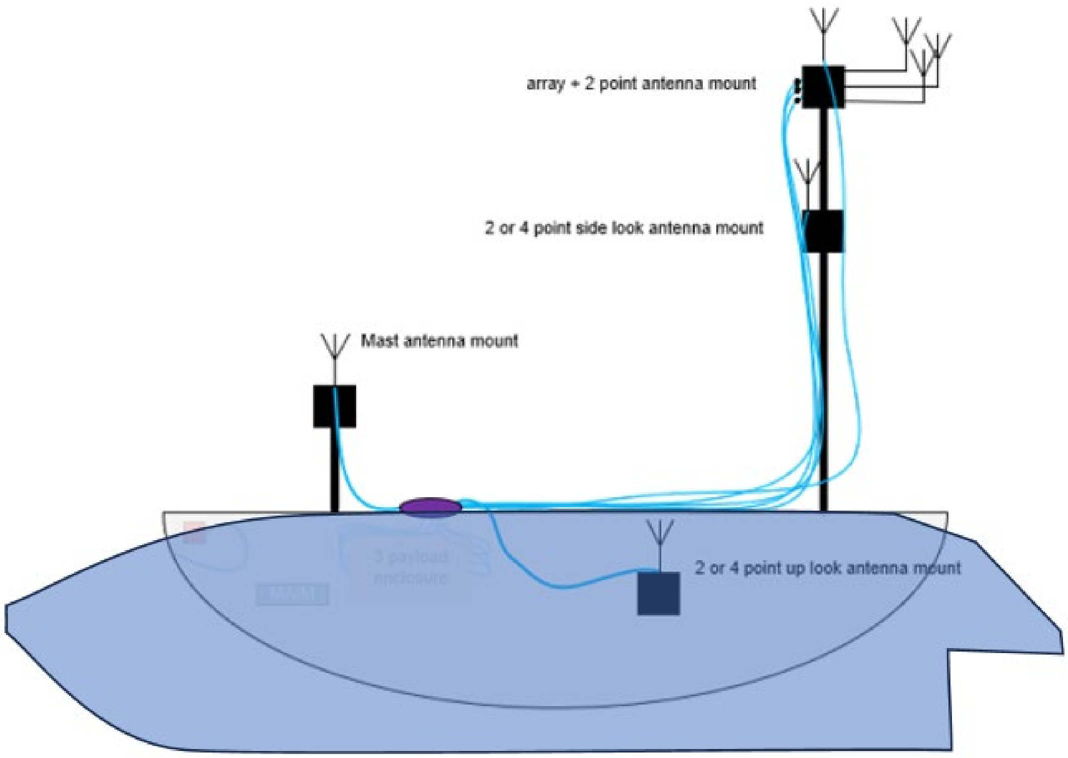


Figure 4-157. ADARO USV RF Cable Runs

4.7.7.5.1 RF Cable Summary Table

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

Table 4-36. ADARO RF Cable Summary

Cable Set	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Aft Mast	4	96	51	1.55
Forward Mast	4	40	27	0.65
Mid-height Aft Mast or Vessel Mounted	1	77	45	1.24

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

4.7.7.5.2 Aft Mast Cables

The cables that make up the wingtip cable set are low-loss, lightweight coax. The Aft Mast 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, side look, or 45° up look antenna.

4.7.7.5.3 Forward Mast Cables

The cables that make up the wingtip cable set are low-loss, lightweight coax. The Forward Mast 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, side look, or 45° up look antenna.

4.7.7.5.4 Additional Cable

The final RF cable run is run from the Primary Mount forward to either mid-height of the aft mast or the vessel mounting location to support an up look (vessel mount only), side look, or 45° look antenna.

4.7.7.5.5 RF Cable Waterproofing

Additional considerations have been added to ensure IP64 (splash-proof) protection for all RF cables. RF cables are fed through two sets of grommets (Figure 4-158) – on the front of the primary mount enclosure and through the ADARO deck – to connect payloads to their antennas while maintaining water integrity. When RF cables are not in use, SMA bulkhead connectors and 50Ω terminators are provided to maintain IP64 ingress protection for the RF cables.

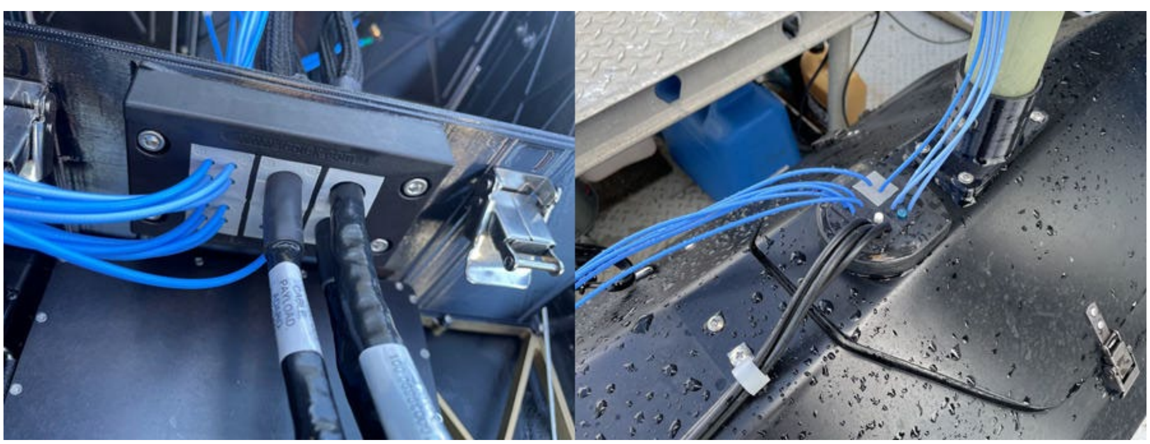


Figure 4-158. Cable Glands on the Payload Enclosure (left) and Deck (right)

4.7.8 Concessions to the Standard

As referenced in Table 4-35 and Section 4.7.2.1, the ADARO USV is weight constrained and beyond a total B-kit payload weight of 2.6lbs, fuel must be removed which impacts vehicle endurance and range proportional to the amount of fuel removed. Payload power also impacts range and endurance proportionally, with up to 10% reduction at 247W (Max).

4.8 Prototype MP Dismount Implementation

4.8.1 Tactical Plate Carriers

The following details the prototype MP dismount implementation on a tactical, MOLLE-compatible plate carrier.

Note: A-kit was demonstrated on multiple tactical, MOLLE-compatible plate carriers.

4.8.1.1 Overview

The prototype MP dismount operator A-kit can support 1 MP payload in a custom 2U Primary Mount rack installed on the operator's plate carrier. The dismount A-kit is configurable to support antennas on both a mast (provided as part of the A-kit) or directly to the plate carrier. A body-worn MAIM, an MP-compliant INS, an end-user device (EUD) and batteries are also required and provided.

4.8.1.2 MP Architecture

Figure 4-159 illustrates the architectural layout of the MP dismount A-kit on a plate carrier.

Figure 4-159. MP A-kit Layout for a Dismount

4.8.1.3 Compliance / Capability Summary

Table 4-37 provides a top-level summary of the compliance and capability of MP dismount A-kit.

Table 4-37 Dismount A-kit 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">On Plate Carrier (operator's discretion)</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">On Plate Carrier – Back</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Mast or Mid-back (if no mast)</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">1</td></tr>
<tr><td colspan="2">Available Payload Power</td><td colspan="2">112W</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">2U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">N/A</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>1</td><td>Mast</td><td>Up or Forward</td></tr>
<tr><td>1</td><td>Shoulder Strap</td><td>Up</td></tr>
<tr><td>1</td><td>Plate Carrier Chest</td><td>Forward</td></tr>
<tr><td rowspan="2">Four-points</td><td>1</td><td>Mast</td><td>Up or Forward</td></tr>
<tr><td>1</td><td>Plate Carrier Chest</td><td>Forward</td></tr>
<tr><td>Array – MPu</td><td>1</td><td>Mast</td><td>Any</td></tr>
</table>

4.8.1.4 System Diagram

Figure 4-160 details the MP system diagram for the dismount operator's plate carrier.

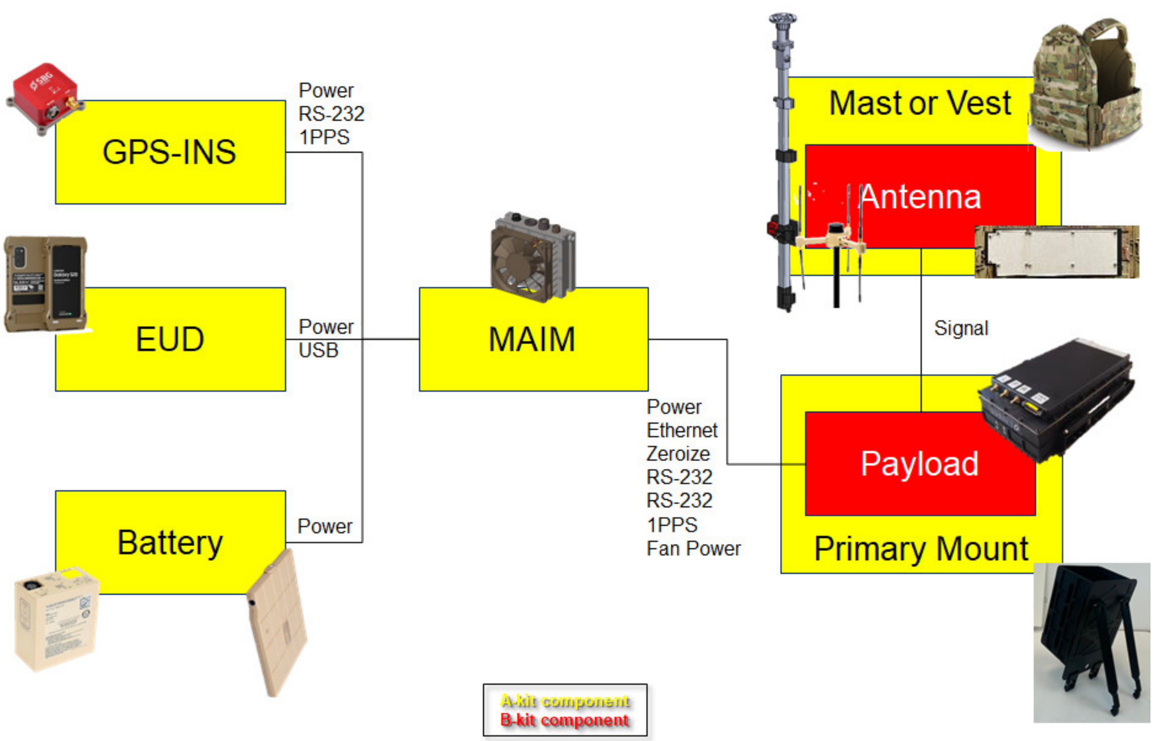


Figure 4-160. MP System Diagram for a Plate Carrier

4.8.2 Platform Weight and Power Budgets

A dismount operator's plate carrier is already heavily burdened with a variety of other operationally necessary tactical gear; thus, it is limited in size, weight and power capacity.

4.8.2.1 Weight Budget

There is no specific total weight budget for payloads for the plate carrier; however, as this is body-worn gear that will be worn operationally, weight must be minimized.

4.8.2.2 Power Budget

The MAIM for the MP dismount A-kit can provide 112W power for the payload when the A-kit is using a UB-2590 battery or 50W power for the payload when using BB-2525u battery. Both types of battery are supported by the prototype MP dismount A-kit.

4.8.3 MAIM

The MAIM is a custom circuit board housed in a custom enclosure. The MAIM is mounted into a Primary Mount holster that attaches to the plate carrier.

4.8.3.1 Mechanical Description

For design commonality, the MAIM (Figure 4-161) enclosure adheres to the MPu payload definition (Volume III Figure 2-4).

Note: this was only done to reduce the design effort, this form factor should not be used for production MAIMs.

Figure 4-161. Prototype Plate Carrier MAIM

4.8.3.2 Electrical Description

The MAIM is a custom PCB designed specifically for a dismount operator and to support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure 4-162, the microcontroller along with an Ethernet switch, serial transceivers, USB converter and power regulation and sense circuitry allow the MAIM to interface to both the platform and payloads. The MAIM itself draws ~13W (including the power to charge the EUD).

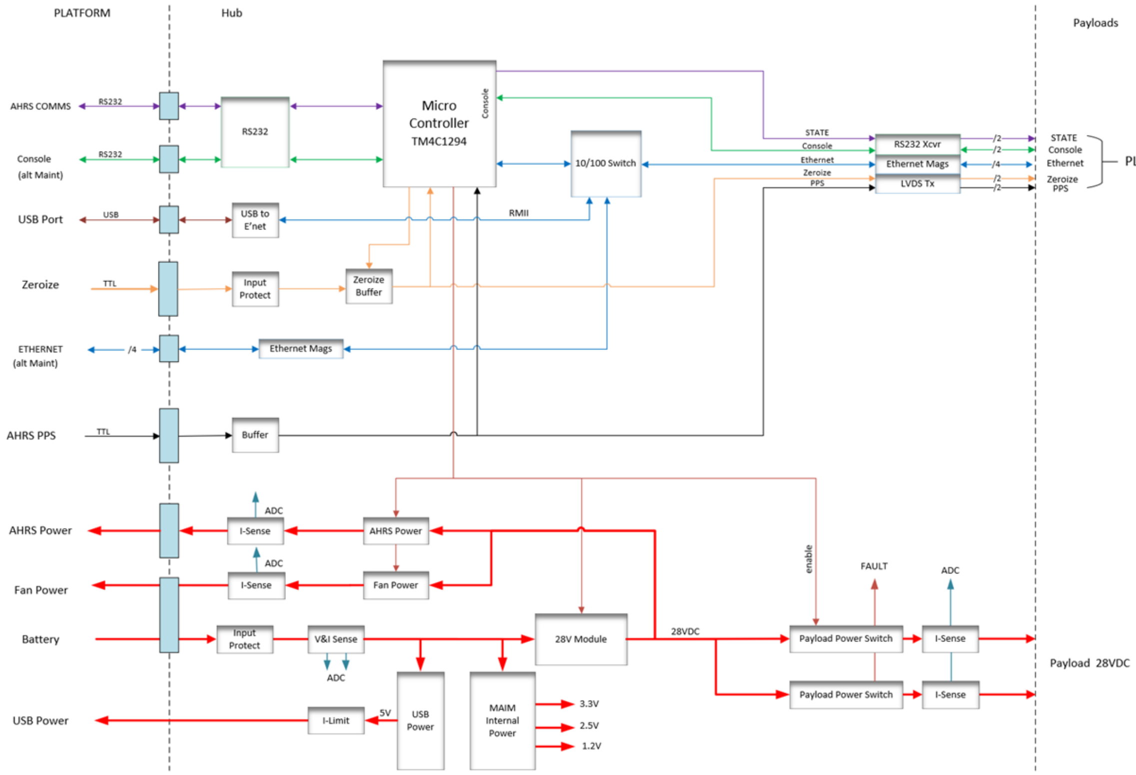


Figure 4-162. MP Dismount MAIM Block Diagram

4.8.3.2.1 Power Input

The MAIM supports one 12-34VDC battery input. 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.

4.8.3.2.2 Payload Interfaces

The MAIM supports one payload with a fully MP-compliant interface. As required by the standard, the payload interface provides payload power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The MAIM provides 28VDC and limits the maximum current draw to 2A for the payload. The MAIM also provides and an additional 500mA at 24VDC to power the Primary Mount fan.

4.8.3.2.3 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.

4.8.3.2.4 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.

4.8.3.2.5 Platform Specific Interfaces

For the dismount MP system, the operator will use a Samsung S20TE to monitor and control the MAIM and payload. To support this, the MAIM provides a USB-C interface to communicate with and charge the phone EUD.

4.8.3.3 MAIM Integration

The MAIM is installed into an MPu Primary Mount holster (Volume III Figure 3-9), which is installed to the plate carrier via MOLLE straps (Figure 4-163).

Figure 4-163. MAIM Installed on the Primary Mount

4.8.4 Primary Mount

The Primary Mount for the plate carrier is a custom 2U rack installed via MOLLE straps.

Figure 4-164. MP Primary Mount

4.8.4.1 Mechanical Description

The Primary Mount is an aluminum assembly that is 9.3in x 4.9in x 4.1in and weighs ~903g. The

Primary Mount assembly is detailed in Figure 4-165.

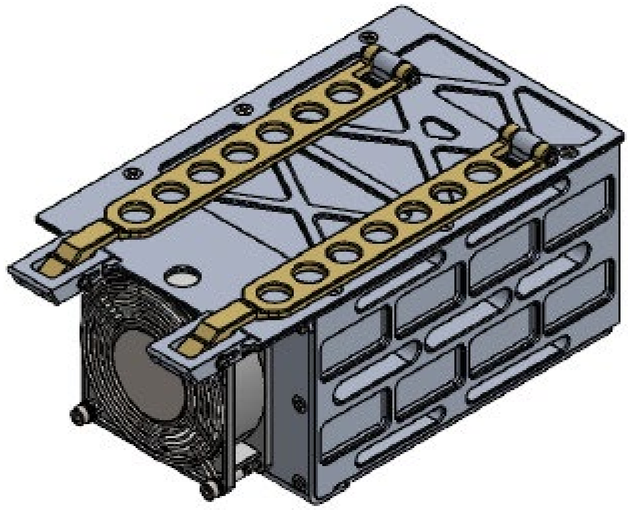


Figure 4-165. MP Primary Mount Assembly

4.8.4.2 Installation

The Primary Mount is installed into the plate carrier via MOLLE straps (Figure 4-166). Once the Primary Mount is installed into the plate carrier, payloads can be installed into the rack, sliding in from the top of the rack and retained using wedge locks.

Figure 4-166. MP Primary Mount Installed on Plate Carrier

4.8.4.3 Thermal

The Primary Mount is equipped with a fan to generate the requisite airflow needed to cool the payload. The Primary Mount should be installed on rear external surface of the plate carrier such that its fan is exposed to ambient air. The Primary Mount fan has been demonstrated to limit the temperature increase of a 56W payload to 22°C above ambient. The fan is controlled (turned on / off) from the EUD via the MAIM GUI.

4.8.5 INS

An SBG ELLIPSE2-N-G4A3-B1 INS is used for the MP dismount A-kit. When the mast is used, the INS is installed to it, as shown in Figure 4-167, to assure alignment to any mast-mounted antenna. If the mast is not used, the INS is installed directly to the plate carrier at the center of the operator's back via MOLLE straps. The INS uses a GNSS antenna mounted to a shoulder strap of the plate carrier.

Figure 4-167. Mast-mounted INS Location

4.8.6 Antenna Mounts

The MP dismount A-kit supports antenna mounts in two locations: on its mast and directly to the plate carrier. Whenever possible, mast antenna mounts should be employed to improve payload performance.

4.8.6.1 Mast Antenna Mounts

A lightweight mast is provided as part of the dismount A-kit to raise payload antennas, increasing their line of sight. The mast is installed to the back of the plate carrier via MOLLE straps. The body-worn mast supports any one of the following antenna mounts:

- 1 up look mount (2-pt or 4-pt)
- 1 forward look mount (2-pt or 4-pt)
- 1 MPu class array mount (Volume III Figure 3-22)

Note: the MP class array mount is NOT supported.

Prior to the mission, the desired mast mount should be selected and installed atop the mast (along with any antenna). Figure 4-168 shows all mast mount options.

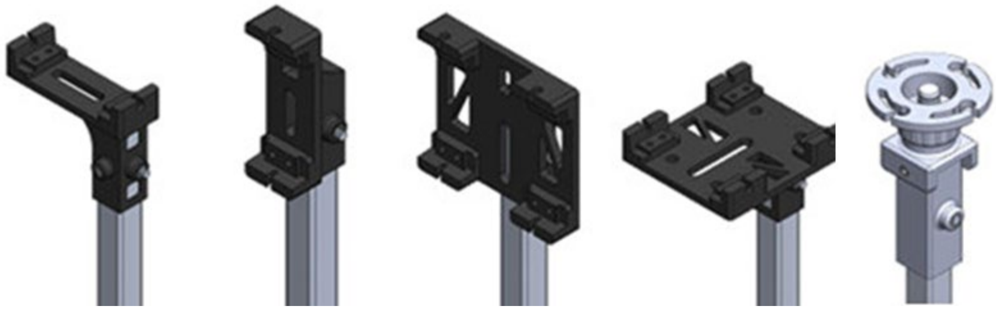


Figure 4-168. Mast Antenna Mount Options

The 2-pt and 4-pt mounts provide the antenna interfaces as defined for the MP class, but the only array mount supported provides the antenna interface as defined for the MPu class. The mast mount antenna capacity is defined in Table 4-38.

Table 4-38. Mast Antenna Mount Capacities

Antenna Mount	Max Weight	Max Volume
Array Mount	300g	12in x 12in x 12in
2-pt Up Look	400g	12in x 12in x 12in
2-pt Forward Look	400g	12in x 4in x 2in
4-pt Up Look	600g	12in x 12in x 12in
4-pt Forward Look	600g	18in x 8in x 2in

Note: weights and volumes are rough estimates only and have not been demonstrated.

4.8.6.2 Plate Carrier Mounts

The plate carrier cans support the following antenna mounts:

- 1 up look mount (2-pt)
- 1 forward look mount (2-pt, 4-pt)

Prior to the mission, the desired antenna mounts should be selected and installed to the plate carrier using MOLLE straps at any location that is both suitable for payload operation and compatible with other mission-critical tactical gear. Figure 4-169 shows several plate carrier mount options.

Figure 4-169. Plate Carrier Antenna Mount Options

The 2-pt and 4-pt mounts provide the antenna interfaces as defined for the MP class. The plate carrier antenna mount capacity is defined in Table 4-39.

Table 4-39. Plate Carrier Antenna Mount Capacities

Antenna Mount	Max Weight	Max Volume
2-pt Up Look	400g	4in x 4in x 8in
2-pt Forward Look	400g	12in x 4in x 2in
4-pt Forward Look	600g	18in x 8in x 2in

Note: weights and volumes are rough estimates only and have not been demonstrated.

4.8.7 Cabling

The schematic for all MAIM cables is shown in Figure 4-170. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.2.7.5.

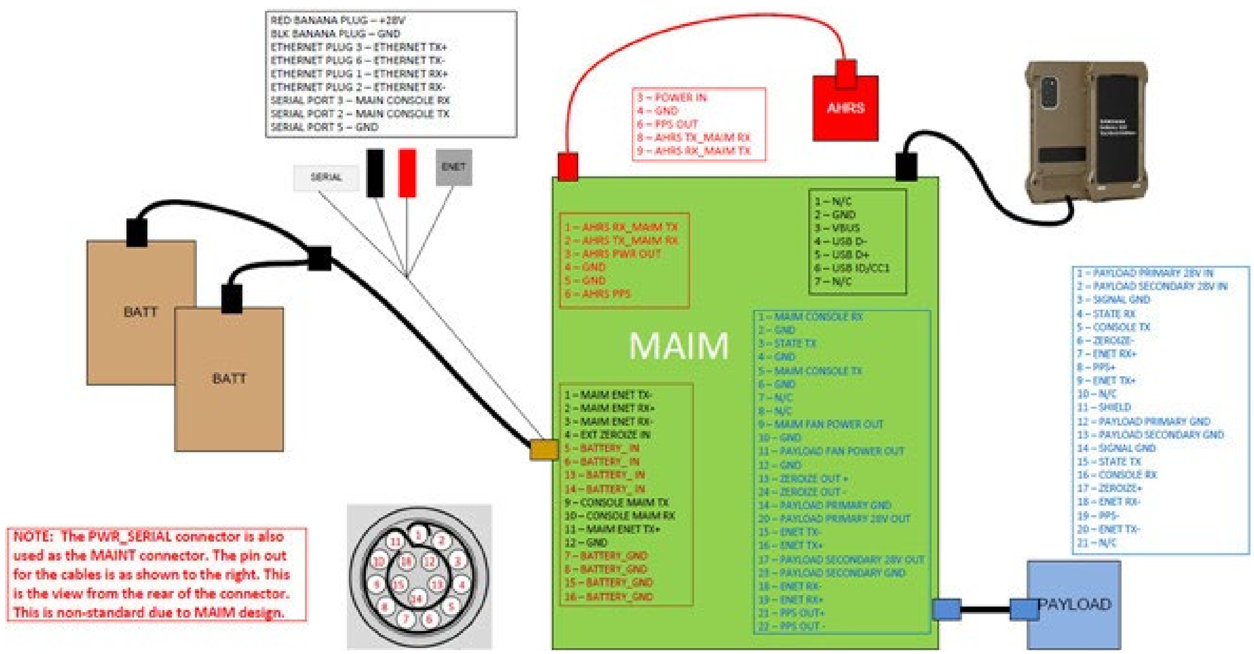


Figure 4-170. MAIM Cabling Schematic

4.8.7.1 MAIM-Battery Cable

As two battery options are supported by the MP dismount A-kit, two different MAIM-Battery power cables are provided. Each battery cable is a custom cable assembly terminated on one end to mate to two of the respective batteries (using the appropriate battery connector) and on the other end to the MAIM using an ODU (A11YBR-P16XCDO) connector. The MAIM-battery cables are 30in long. The MAIM-battery cable should be run between the MAIM and batteries at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.2 MAIM-Payload Cable

The MAIM-payload cable is a custom cable assembly terminated at the MAIM end in a 24-pin Fischer MiniMax connector and at the payload end in two standard-defined MDM-21 connector. One payload connector is fully populated, the other just has the power pins populated. Additionally, fan power is also provided from this cable via two 3mm jack connectors. The MAIM-payload cable is 30in long. The MAIM-payload cable should be run between the MAIM and payload at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.3 MAIM-INS Cable

The MAIM-INS cable is a custom cable assembly terminated on one end to mate to the SBG Ellipse V2 (using the appropriate ODU connector) and on the other end to the MAIM using an ODU (S10YAR-P07XCDO) connector. The MAIM-INS cable is 30in long. The MAIM-INS cable should be run between the MAIM and INS at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.4 MAIM-EUD Cable

The MAIM-EUD cable is COTS cable assembly (JG.CBL.QDPD.01) terminated on one end with Juggernaut SLEEV-specific USB-C connector and on the other end with a Nett Warrior connector (Glenair 807-871-06ZNU6-6PY). The MAIM-EUD cable is 30in long. The MAIM-EUD cable should be run between the MAIM and EUD at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.5 Payload RF Cables

RF cables are installed to support the various payload antenna options. When using the mast, a set of four RF cables should be run from the Primary Mount to the top of the mast. When using plate carrier mounted antennas, a single RF cable should be run from the Primary Mount to the antenna mount location. Both cable runs are detailed in the subsequent sections.

4.8.7.5.1 RF Cable Summary Table

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

Table 4-40. Dismount A-kit RF Cable Summary

Cable	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Payload to Array Mount	3	30	60	0.46
Payload to Mast Mount (non-array)	1	30	20	0.46
Payload to Plate Carrier Mount	1	12	8	0.18
	1	24	16	0.37
	1	36	24	0.55

Note 1: Attenuation calculated for a 1GHz signal

4.8.7.5.2 Array Mount RF Cables

The array mount cable set consists of three phase-matched cables to support an antenna array. They are terminated on the payload end with 3 SSMB-female connectors and on the array end with a multi-conductor Mighty Mouse (Glenair 803-001-06NF12-203AN) connector. The array mount cables are 30in long. The array mount cable should be run from the Primary Mount thru the mast to the array mount atop the mast or at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.5.3 Mast Mount RF Cable

The mast mount cable is a single (fourth mast) cable to support an up look or forward look antenna. It is terminated on the payload end with an SSMB-female connector and on the antenna end with an SMA-male connector. The mast mount cable is 30in long. The mast mount cable should be run from the Primary Mount thru or along the mast to the antenna mount atop the mast or at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.7.5.4 Plate Carrier RF Cable

Three RF cables of varying lengths are provided as part of the MPu dismount A-kit. Each cable is terminated on the payload end with an SSMB-female connector and on the antenna end with an SMA-male connector. Multiple lengths are provided to allow the operator flexibility on where to install the body-worn antenna mount. The plate carrier RF cable should be run from the Primary Mount to the selected antenna mount location at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

4.8.8 Additional A-kit Components

Dismount payload operations require some additional A-kit components (not normally required on uncrewed systems) to be provided. These are discussed in the following subsections.

4.8.8.1 Batteries

Two batteries were identified as relevant for dismount operations and are supported by the MP dismount A-kit – UB-2590 and the BB-2525u.

Figure 4-171. Dismount Battery Options: UB-2590 (left), BB-2525u (right)

The UB-2590 is a more traditional battery used in many military applications. It supports higher current draw and prolonged endurance at the expense of increased weight and bulkiness. The BB-2525u is a conformal wearable battery designed to be worn in a plate carrier; however, it provides a reduced current draw and endurance. Details are provided in Table 4-41 below.

Table 4-41. Dismount MPu A-kit Battery Comparison

Battery	Chemistry	Weight	Average Voltage	Max Current	Max Power	Energy	Duration
UB-2590	Li-ion	1.4kg	28.8V	10A	139W	250W-hr	1.8 hrs
					79W		3.2 hrs
BB-2525u	Li-ion	1.2g	14.8V	5A	73W	148W-hr	2.0 hrs

Note: Max power differs between the two batteries. The BB-2525u is limited by its max continuous current. The UB-2590 is not as constrained. Its max power equates to the max power needed for the entire MPu dismount system – 56W or 112W for the payload (depending on the number of feeds), 10W for the Primary Mount fan, 8W to charge the EUD and 5W or 10W to power the MAIM (depending on the number of feeds).

4.8.8.2 EUD

As there is not an EUD native to every operator's tactical kit, a Samsung S20TE phone in a Juggernaut SLEEV case is provided as part of the MP dismount A-kit, along with a chest-mounted MOLLE phone holder (Figure 4-172).

Figure 4-172. MP Dismount A-kit EUD

4.8.8.3 Pouches

To support the UB-2590 batteries, two MOLLE battery pouches (BDAT BA-5590/2590) are also provided with the MP dismount A-kit.

4.8.9 Concessions to the Standard

Two concessions are documented for the MP dismount A-kit.

4.8.9.1 Array interface

The array interface as defined by the MP class is not supported for the dismount A-kit. Alternatively, the MPu class array interface is supported as it was deemed more appropriate for dismount operations.

4.8.9.2 Grounding

The MAIM does not provide a connection between platform power ground and the platform chassis ground as there is no platform chassis ground on a dismount. Platform power ground simply interfaces to battery ground.

4.9 MQ-35A V-BAT UAS

The following details the MP implementation for the MQ-35A V-BAT Blk A-M5.1 (V-BAT) UAS.

4.9.1 Overview

The V-BAT UAS is a rapidly deployable, expeditionary, Vertical Take-Off and Landing (VTOL) Group 3 UAS with a maximum gross takeoff weight of 125 pounds. The aircraft can launch and land from an elevation equivalent to 8,000 feet density altitude and can provide up to 10 hours of endurance with demonstrated operational altitudes of 18,000 feet.

The V-BAT UAS can support up to 3U of payloads in a custom primary mount in the aft slice. The V-BAT is equipped to support one wingtip array, two wingtip 2-pt up or down look antennas, three aft slice 2-pt antennas (1 each up/side/down look), and one 4-pt, 45° antenna. A platform-specific MAIM and an MP-compliant INS are both required.

4.9.2 MP Architecture

Figure 4-173 illustrates the architectural layout of the MP implementation on the V-BAT UAS.

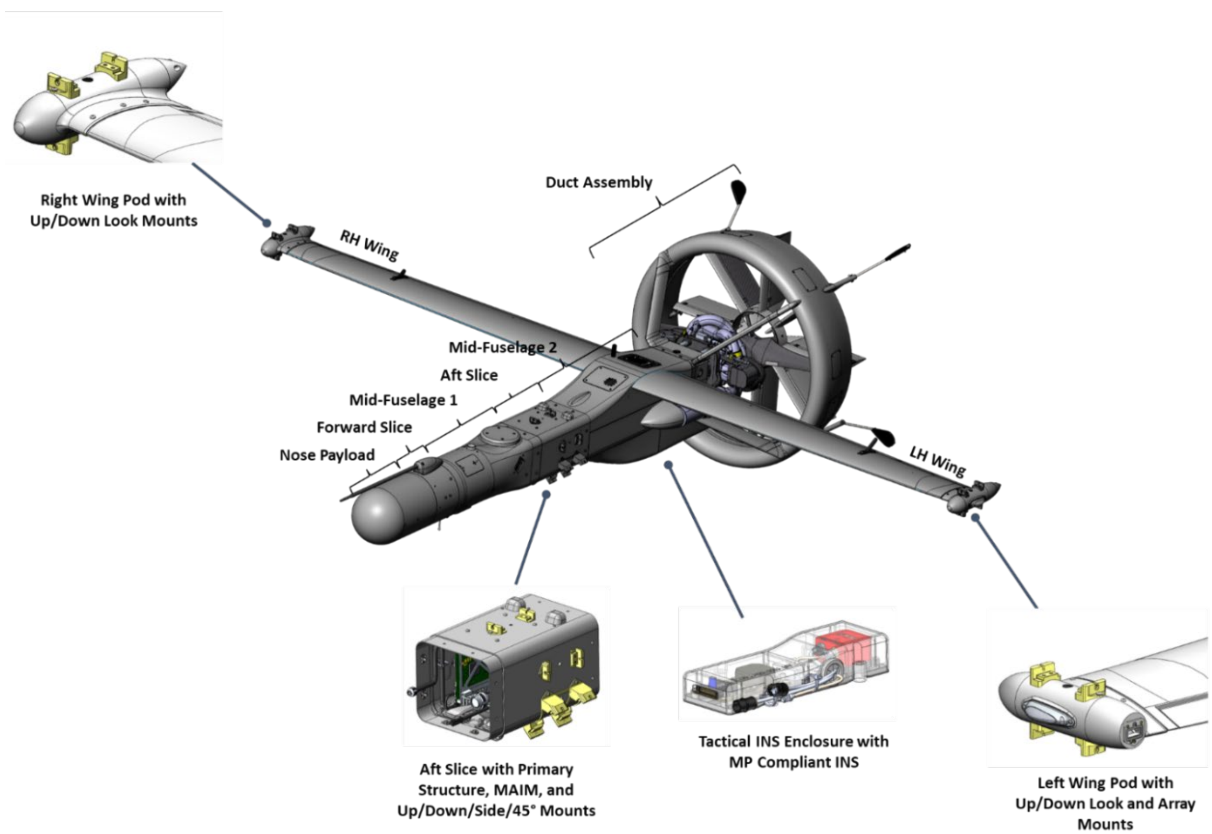


Figure 4-173. Architectural Layout for V-BAT

4.9.3 Compliance / Capability Summary

Table 4-42 provides a top-level summary of the MP compliance and capability on the V-BAT UAS.

Table 4-42. V-BAT 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 Slice</td></tr>
<tr><td colspan="2">Primary Mount</td><td colspan="2">Aft Slice</td></tr>
<tr><td colspan="2">INS</td><td colspan="2">Midfuse 2 Tactical INS Enclosure</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">150W</td></tr>
<tr><td colspan="2">Available Payload Volume</td><td colspan="2">3U</td></tr>
<tr><td colspan="2">Available Payload Weight</td><td colspan="2">4.5lb</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>1</td><td>Right Wingtip</td><td>Up or Down</td></tr>
<tr><td>1</td><td>Left Wingtip</td><td>Up or Down</td></tr>
<tr><td>3</td><td>Aft Slice</td><td>Up, Down, Side</td></tr>
<tr><td>Four-points</td><td>1</td><td>Aft Slice</td><td>45°</td></tr>
<tr><td>Array</td><td>1</td><td>Wingtip</td><td>Aft</td></tr>
</table>

4.9.4 System Diagram

Figure 4-174 details the Mod Payload system diagram for the V-BAT UAS.

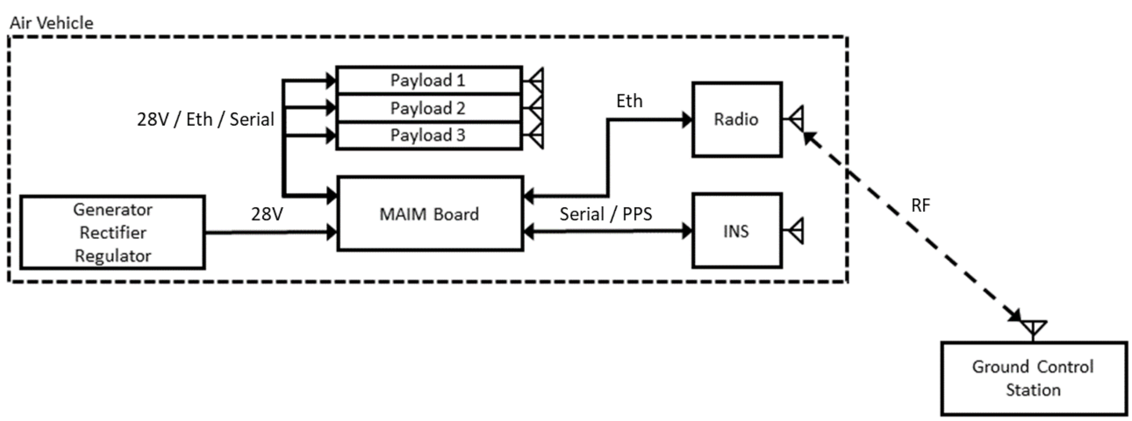


Figure 4-174. System Diagram for V-BAT

4.9.5 Platform Weight and Power Budgets

The V-BAT UAS has ample volume, but limited power and weight capacity.

4.9.5.1 Weight Budget

The total weight budget for V-BAT is 125lbs, inclusive of the aircraft, all payloads, enhancement, and fuel. The Mod Payload A-Kit adds 1.44lbs to support MP-compliant payloads. The V-BAT dry-weight with the Mod Payload A-Kit added is 90lbs. This leaves an allowance of 35lb total for additional payloads, antennas, and fuel. The Primary Mount is slated to support approximately 1.5lbs in each of the three 1U payload slots (or a total of 4.5lbs). Any additional payload and antennas need to be evaluated for weight and balance, and as a direct tradeoff with endurance.

4.9.5.2 Power Budget

After accounting for MAIM and INS power draw (16W), the platform power available/remaining for payloads is limited to 150W total and subject to thermal limitations described in Section 4.9.11.2.

Note: this is less than the 168W required to support three payloads drawing the max allowable power.

4.9.6 MAIM

The MAIM is a custom circuit board mounted to the Primary Mount in the aft slice.

4.9.6.1 Mechanical Description

The MAIM board is 5.7in x 4.7in x 0.7in and is mounted to the aft slice Primary Mount. Figure 4-175 shows the top-down view of the MAIM board (left) and a side view of the MAIM attached to the Primary Mount (right).

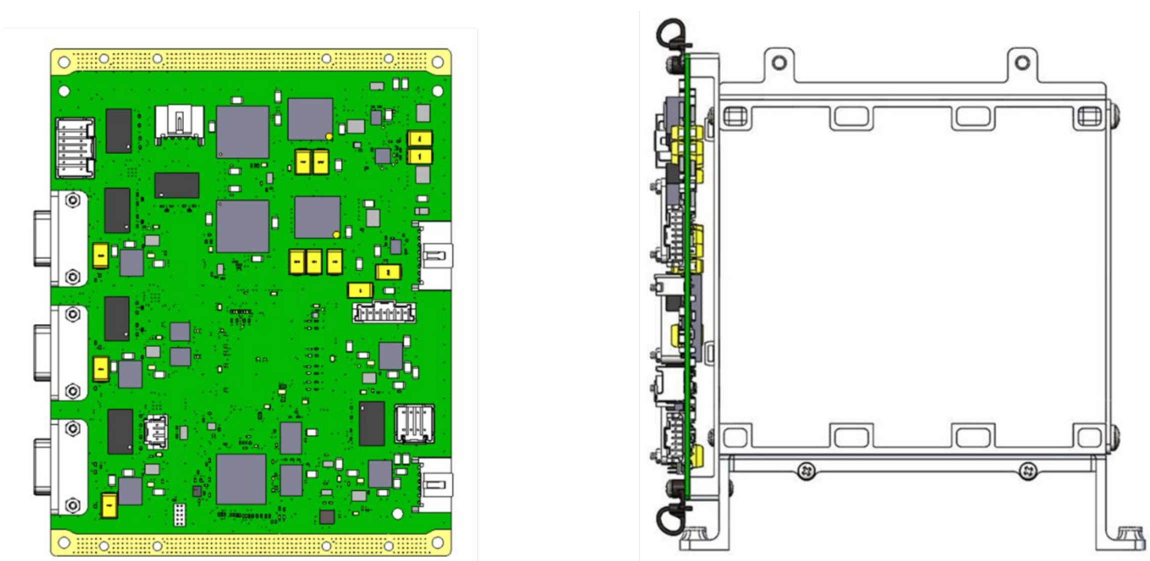


Figure 4-175. MAIM for V-BAT

4.9.6.2 Electrical Description

The MAIM is a custom PCB designed specifically to interface to the V-BAT UAS and support full MP functionality. The core of the MAIM is TM4C1294 microcontroller. As depicted in Figure

4-176, 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.

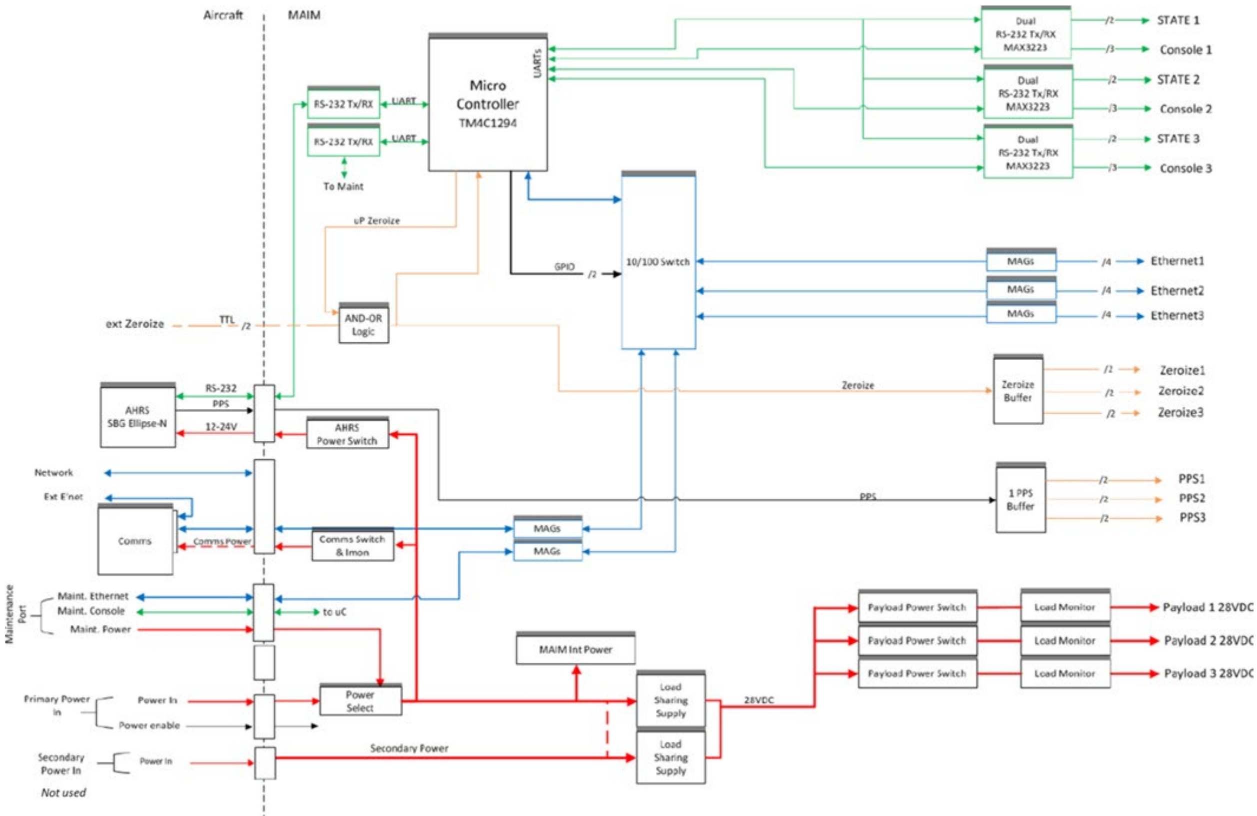


Figure 4-176. MAIM Block Diagram for V-BAT

4.9.6.2.1 Power Input

The MAIM draws 28VDC power from the V-BAT payload rail. The payload rail is the non-battery backed rail in the V-BAT avionics. 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.

4.9.6.2.2 Payload Interfaces

The MAIM supports three payloads with identical MP-compliant 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 28 VDC and limits the maximum current draw to 2A for each payload.

The MAIM load regulation does not quite meet the 28V +/- 2% requirement of the Mod Payload Standard. At low current (<200mA) MAIM load regulation is 28V +/- 5% or 1400mV load regulation. Above 200mA, it is 28V +/- 2.5% or 700mV load regulation.

4.9.6.2.3 Power Sharing and Monitoring

The MAIM power circuitry manages load sharing between two different power supplies. Additionally, the microcontroller monitors current draw from each module. The block diagram for the MAIM power circuitry is given in Figure 4-177.

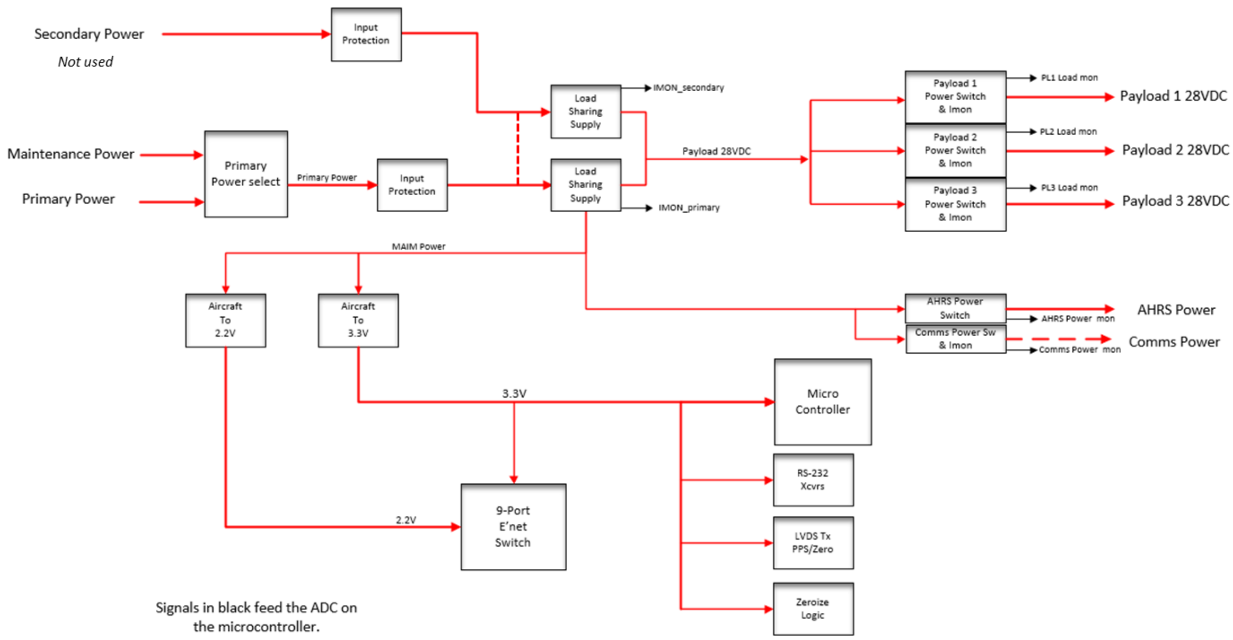


Figure 4-177. MAIM Power Circuitry Block Diagram

4.9.6.2.4 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.

4.9.6.2.5 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.

4.9.6.2.6 Platform Specific Interfaces

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

4.9.6.3 MAIM Integration

The MAIM is installed to the right face of the Primary Mount (Figure 4-178). The entire MP primary mount must be removed to install/remove the MAIM. All three payload cables are installed on the MAIM and secured to the MP primary mount prior to payload tray installation.

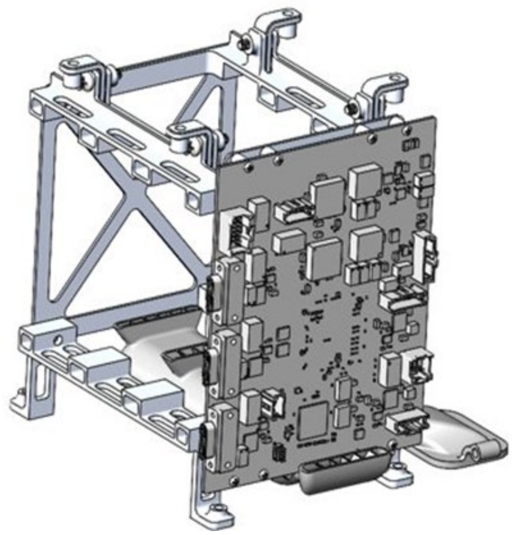


Figure 4-178. MAIM Installed on the Primary Mount

4.9.7 Primary Mount

The Primary Mount for the V-BAT UAS is a 3U rack installed into the aft slice. Figure 4-179 provides an overview of the components in the aft slice and the location of the Primary Mount.

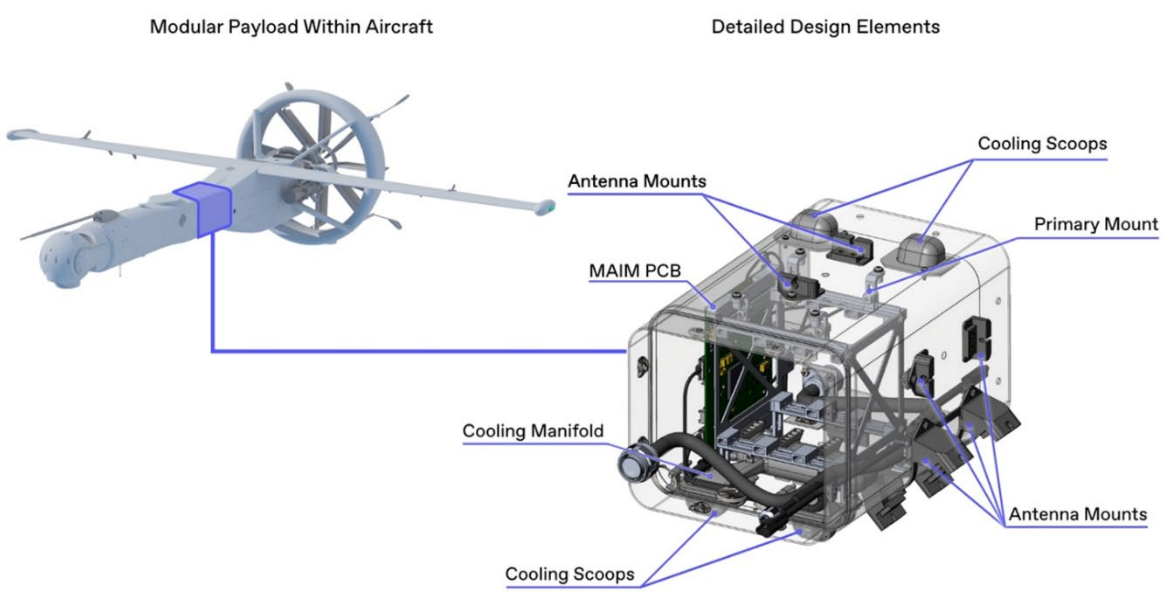


Figure 4-179. V-BAT Aft Slice with MP A-kit Components Installed

4.9.7.1 Mechanical Description

The Primary Mount is the rack that holds modular payloads, the MAIM and the cooling manifold. The Primary Mount resides in the aft slice of the aircraft. The Primary Mount is an aluminum assembly that is 6.4in x 6.3in x 5.3in. Including the MAIM and the cooling manifold, the primary mount weighs ~650 g. The Primary Mount assembly is detailed in Figure 4-180.

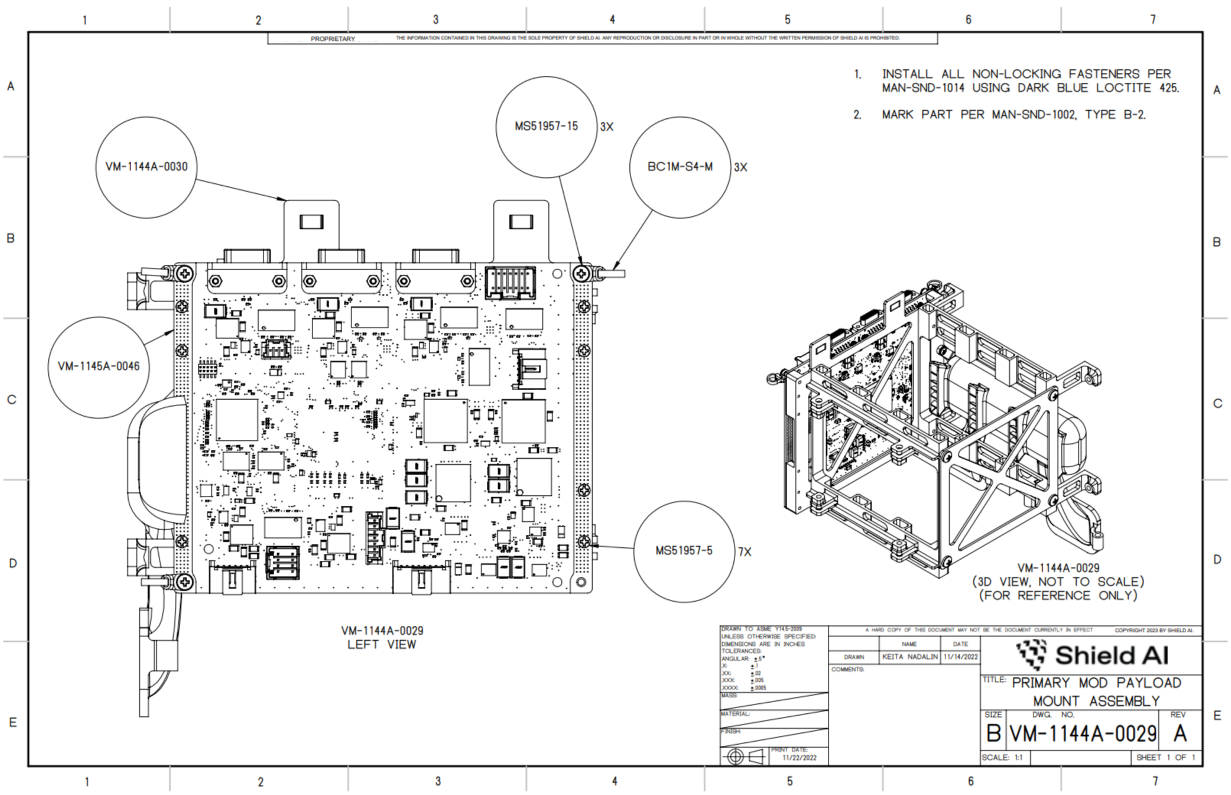


Figure 4-180. **V-BAT Primary Mount Assembly Drawing**

4.9.7.2 Installation

The Primary Mount should be fully assembled with the MAIM and cooling manifold attached to it prior to installation into the aft slice of the aircraft. Once the Primary Mount is installed in the aft slice, payloads can either be installed at this time or installed later through aft side using wedge locks.

4.9.7.3 Thermal

Multiple considerations are made to and around the Primary Mount to provide the requisite airflow for forced air convection cooling of the payloads. The aft slice contains two inlet scoops and two exhaust scoops that provide forced air cooling of the MAIM and the payloads. The inlet scoops are on the bottom of the aft slice and are connected to a cooling manifold that limits water ingestion and provides distributed airflow across all payloads surfaces and the MAIM during forward flight. The exhaust scoops are on the top of the aft slice that exhaust air through the scoops and limits water ingestion. Figure 4-181 depicts the V-BAT MP cooling design.

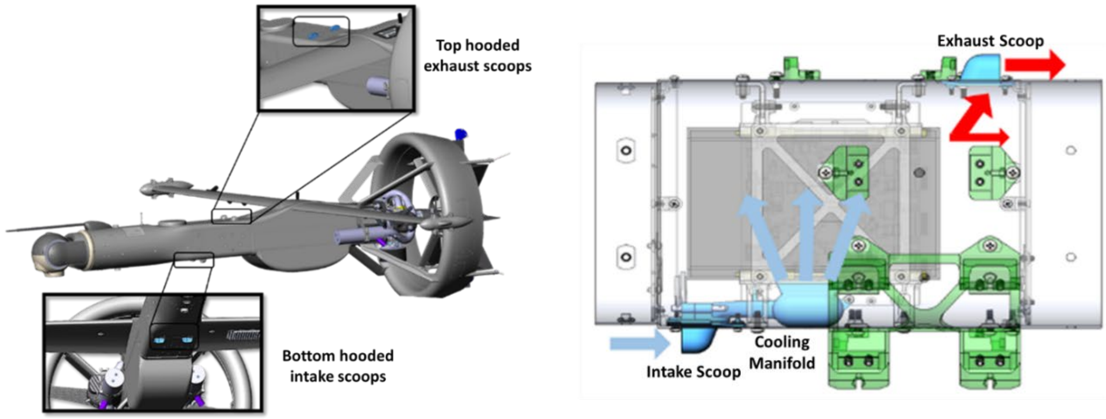


Figure 4-181. V-BAT MP Cooling Design

4.9.8 INS

The SBG ELLIPSE2-N-G4A3-B1 INS is installed inside the tactical INS enclosure. The tactical INS enclosure is sandwiched between the belly bay and Midfuse 2. The INS uses the existing right wing GNSS antenna, via a GNSS splitter located under the Midfuse 2 hatch. Figure 4-182 shows the INS installation location and GNSS splitter location.

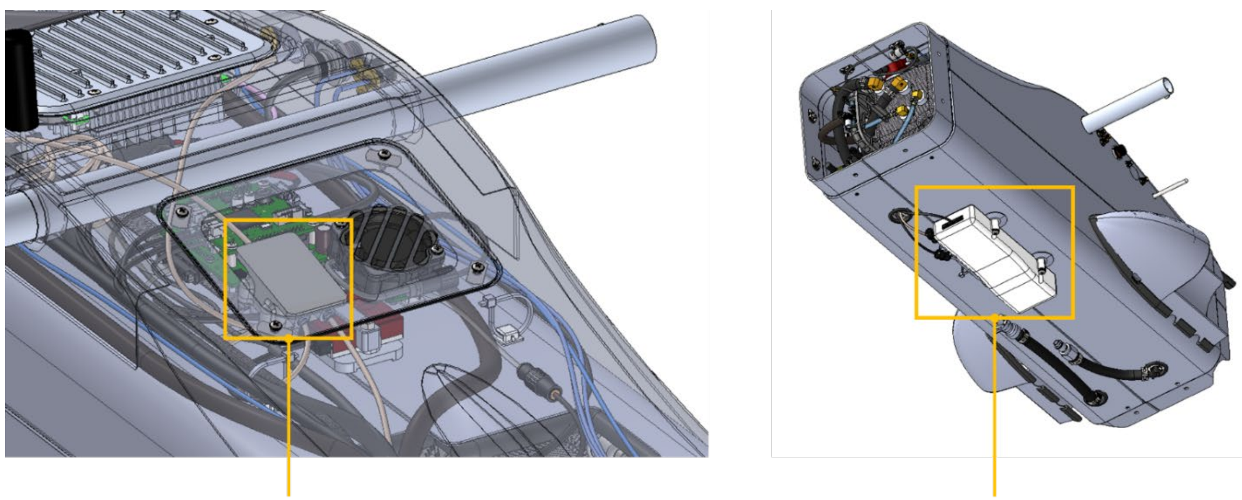


Figure 4-182. V-BAT MP GNSS Splitter and INS Location

4.9.9 Antenna Mounts

The V-BAT supports antenna mounts in 3 locations: aft slice and on both the left and right wingtip pods.

4.9.9.1 Left Wingtip Mounts

The V-BAT left wingtip pod supports the following antenna mounts:

- An array
- A 2-pt up look or down look

All configurations use the same customized wingtip pod. This wingtip pod allows for different antenna mounts to be installed through it to support the requisite antenna configuration. Figure 4-183 shows the three antenna mounting points for the left wingtip.

Note: A total of 4 RF cables are run to the left wingtip pod. Three RF cables are run to support the array interface, only one additional RF cable is run to support either a 2-pt up look or down look antenna.

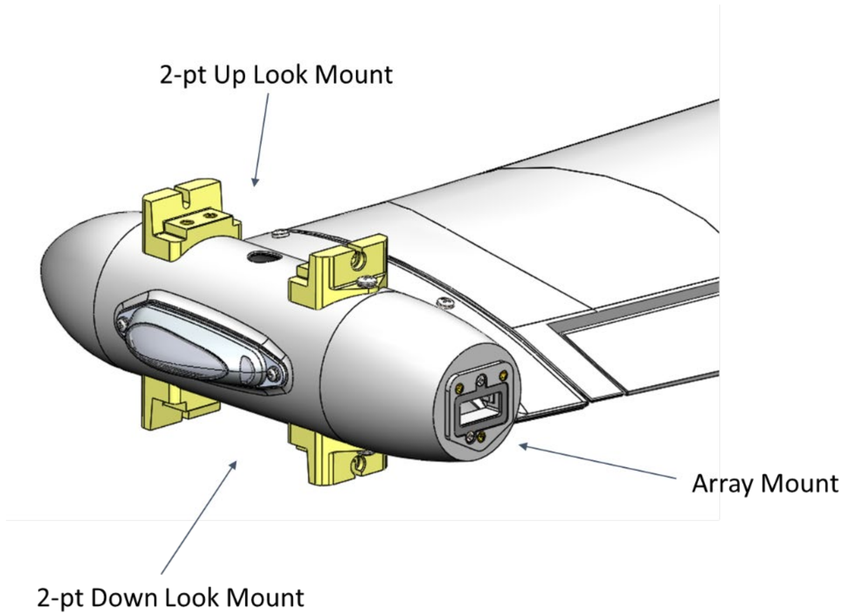


Figure 4-183. V-BAT Left Wingtip Antenna Mount Locations

The array and 2-pt up/down look mounts provide the standard-defined antenna interfaces. The array mount weight is included as part of the native aircraft empty weight; each 2-pt mount weighs 27g. The left wingtip mount antenna capacity is defined in Table 4-43.

Table 4-43. Left Wingtip Antenna Mount Capacity

Antenna Mount	Max Weight	Max Volume
Array Mount	To Be Added in Rev 7.0	
2-pt Up Look		
2-pt Down Look		

4.9.9.2 Right Wingtip Mounts

The V-BAT right wingtip pod supports the following antenna mounts:

- A 2-pt up look or down look

All configurations use the same customized wingtip pod. This wingtip pod allows for different antenna mounts to be installed through it to support the requisite antenna configuration. Figure 4-184 shows the two antenna mounting points for the right wingtip.

Note: A single RF cable is run to the right wingtip pod to support either a 2-pt up look or down look antenna.

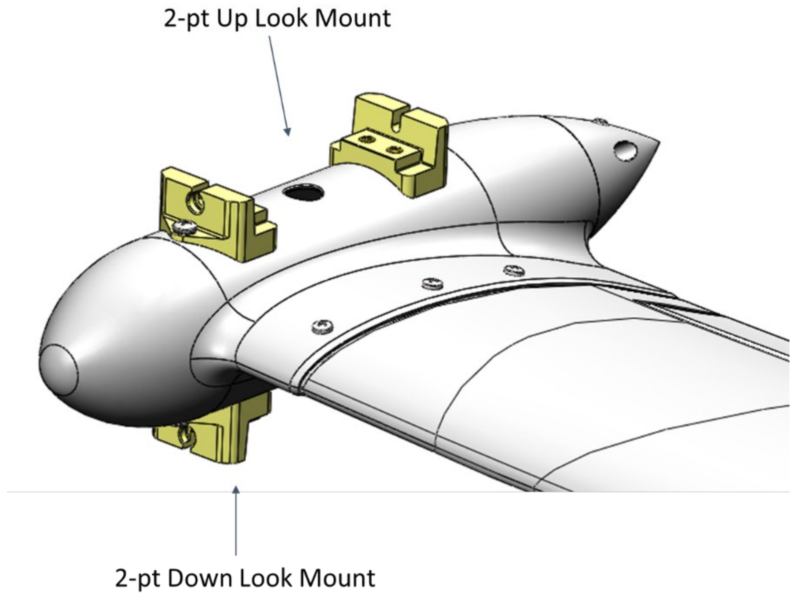


Figure 4-184. V-BAT Right Wingtip Antenna Mount Locations

The 2-pt up/down look mounts provide the standard-defined antenna interfaces. Each 2-pt mount weighs 27g. The right wingtip mount antenna capacity is defined in Table 4-44.

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 4-44.

Table 4-44. Right Wingtip Antenna Mount Capacity

Antenna Mount	Max Weight	Max Volume
2-pt Up Look	To Be Added in Rev 7.0	
2-pt Down Look		

4.9.9.3 Aft Slice Mounts

The V-BAT supports multiple antenna mount locations on the aft slice:

- 2-pt up look
- 2-pt side look
- 2-pt down look
- 4-point 45° antenna mount

The aft slice allows for different antenna mounts to be installed through it to support the requisite antenna configuration. Figure 4-185 shows the four antenna mount options that can be installed on the aft slice.

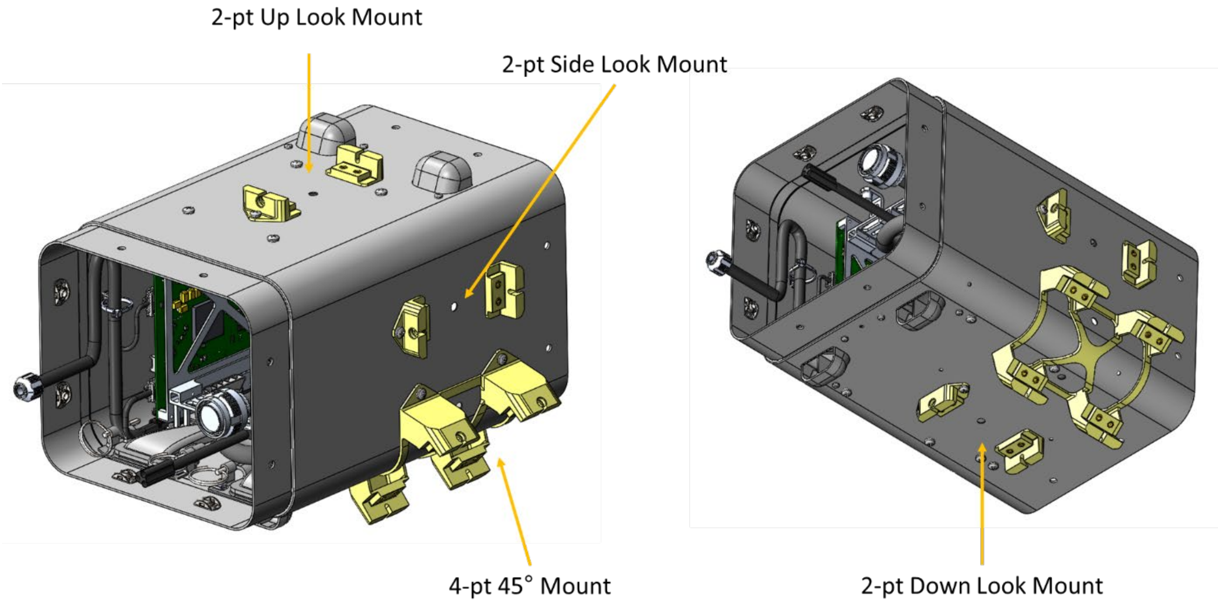


Figure 4-185. V-BAT Aft Slice Antenna Mount Locations

All mounts on the aft slice provide the standard-defined antenna interfaces. Each 2-pt mount weighs 24g, while the 4-pt mount weighs 85g. The aft slice antenna mount capacities are defined in Table 4-45.

Table 4-45. Aft Slice Antenna Mount Capacity

Antenna Mount	Max Weight	Max Volume
2-pt Up Look		
2-pt Down Look	To Be Added in Rev 7.0	
2-pt Side Look		
4-pt 45°		

4.9.10 Cabling

The schematic for all MAIM cables is provided in Figure 4-186. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.9.10.5.

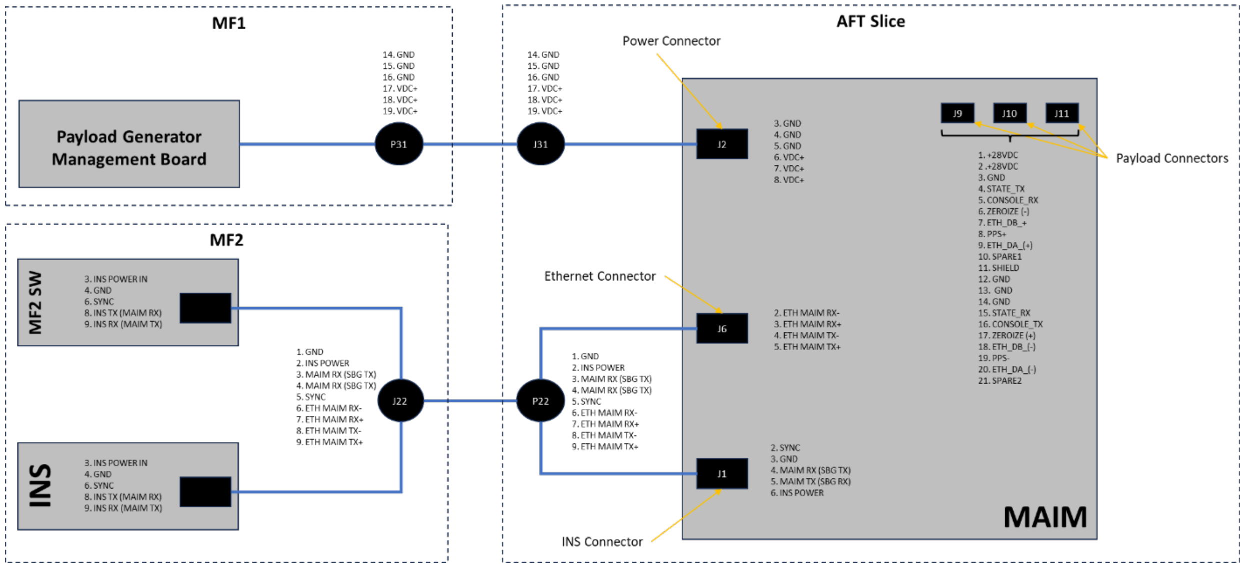


Figure 4-186. V-BAT MAIM Cabling Schematic

4.9.10.1 Primary Power Cable

The MAIM primary power cable is three 22AWG twisted pairs. The MAIM primary power cable runs from Payload Generator Management Board in Midfuse 1 to a Midfuse 1 bulkhead 19-pin Glenair connector (801-009-02M9-19SA). The Midfuse 1 bulkhead connector connects to a bulkhead 19-pin Glenair connector (801-007-26M9-19PA) in the aft slice. The connector branches off to J2 on the MAIM to provide power to the MAIM. The MAIM power cable between the aft slice branch to the J2 connector on the MAIM is 13-inches long.

4.9.10.2 MAIM-Payload Cables

The MAIM-payload cable is composed of 26AWG terminated straight thru at each end in the standard-defined, 21-pin Micro-D connector. Three MAIM-payload cables run from the MAIM to the three furthest payload positions in the Primary Mount. Each MAIM-payload cable is 8in long.

4.9.10.3 MAIM-INS Cable

The MAIM-INS cable is a 22AWG twisted pair and a 22AWG twisted triple. The MAIM-INS cable runs from the MAIM in the aft slice to an aft slice bulkhead 19-pin Glenair connector (801-009-02M9-19SA). The aft slice bulkhead connector connects to a bulkhead 19-pin Glenair connector (801-007-26M9-19PA) in Midfuse 2. This connector then branches to the MP INS in the tactical INS enclosure under Midfuse 2.

4.9.10.4 MAIM Network Cable

The MAIM network cable is a 22AWG twisted pair. The MAIM network cable runs from the MAIM in the aft slice to an aft slice bulkhead 19-pin Glenair connector (801-009-02M9-19SA). The aft slice bulkhead connector connects to a bulkhead 19-pin Glenair connector (801-007-26M9-19PA) in Midfuse 2. This connector then branches to the Midfuse 2 network switch.

4.9.10.5 Payload RF Cables

Two sets of RF cables are installed to support the various payload antenna options. One set runs to the right wing of the aircraft with endpoints at the wingtip. The second set runs to the left wing of the aircraft with endpoints at the wingtip. Both right and left wing cable runs are detailed in the subsequent sections.

4.9.10.5.1 RF Cable Summary Table

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

Table 4-46. V-BAT RF Cable Summary

Cable	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Payload to Right Wing Root	1	31	19.6	0.74
Right Wing Root to 2-pt Up or Down	1	64	36	1.26
Payload to Left Wing Root	4	31	19.6	0.74
Left wing Root to 2-pt Up or Down	1	64	36	1.26
Left Wing Root to Array	3	66	35.6	1.30
Payload to Aft Slice	See Note 2			

Note 1: Attenuation calculated for a 1GHz signal
Note 2: Payload to aft slice antenna mounts cables are not currently included as part of V-BAT A-kit. This oversight is being corrected, as described in Section 4.9.10.8.

4.9.10.6 Right Wingtip Cables

The right wingtip cables are low-loss, lightweight coax. As detailed in Figure 4-187, the right wingtip cable set consists of one cable that runs from the aft slice to a bulkhead on Midfuse 2connected to one cable that runs from the Midfuse 2 bulkhead to the right wingtip to support either a 2-pt up or down look antenna.

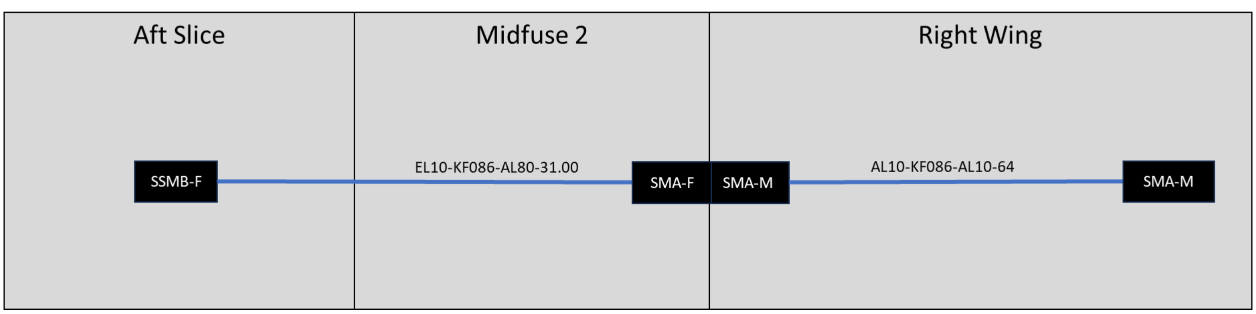


Figure 4-187. V-BAT Right Wingtip Cables

4.9.10.7 Left Wingtip Cables

The left wingtip cables are low-loss, lightweight coax. As detailed in Figure 4-188, the left wingtip cable set consists of four cables that run from the aft slice to a bulkhead on Midfuse 2 connected to four cables that run from the Midfuse 2 bulkhead to the left wingtip. Three of these cable runs are phase-matched to support an antenna array, while the fourth cable run can support an additional 2-pt up or down look antenna.

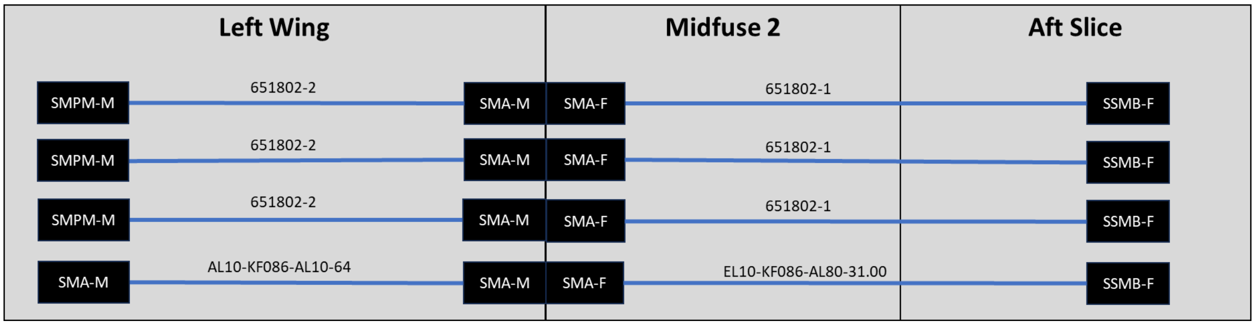


Figure 4-188. V-BAT Left Wingtip Cables

4.9.10.8 Aft Slice Cables

Three aft slice RF cables will be provided as part of the V-BAT MP A-kit. These RF cables are only installed to support a payload using an aft slice antenna mount. In this case, the requisite RF cable will be run directly from the payload to its antenna.

4.9.11 Platform-Payload Concessions

There are two MP concessions documented for the MQ-35A V-BAT. See details below.

4.9.11.1 MAIM Load Regulation Limitation

The V-BAT MAIM does not meet the standard payload voltage regulation requirement to “supply up to 56W at 28VDC ±2% to each payload interface (provided at the payload)”. For the V-BAT MAIM, the low current (<200mA) load regulation to each payload interface is 28VDC +/- 5% or 1400mV load regulation and higher current load regulation (>200mA) is 28VDC +/- 2.5% or 700mV load regulation.

4.9.11.2 MAIM Thermal Limitation

The MAIM board has thermal limitations when large loads are attached to it. Two components on the MAIM, both the buck/boost converters (herein referred to as U14/U15) have a maximum junction temperature of 125°C. The V-BAT is rated for 43°C with full solar loading of 1120 W/m^2, so the aircraft can only provide 110W of payload power before exceeding the U14/U15 junction temperature. The documented 150W of power to modular payloads can be supplied when ambient temperatures are at 20°C (or below) with full solar loading.

Note: This analysis presents a worst-case scenario and temperature at operational flight altitudes decreases ~2°C for every 1000ft in altitude.

Mod Payload, Volume II:

Modular Payload Expanded Capability Set (MPx)

Revision 6.1

May 29, 2024

NOTIFICATION:

MPx is no longer a part of the Mod Payload standard.

Mod Payload, Volume III:

Modular Payload Micro (MPu)
Design Standard for Highly SWAP-Constrained Systems

Draft MPu Standard – do NOT yet build to, specification may change

Revision 6.1

May 29, 2024

1. OVERVIEW

1.1 Description

Volume III of the Mod Payload Standard defines the requirements for Modular Payload Micro (MPu) class. This is a new, smaller class of payload to support platforms, such as Group 1 UAS or dismounted operators, that are too constrained to support or too adversely impacted by the SWAP requirements of the MP class of payload. Although this class is expected to expand onto other platforms like group 1 UAS, the initial implementation is focused on dismounted operators. As such, this initial draft of Volume III is highly focused on this use case. However, the payload requirements are being developed in a way to also satisfy the future sUAS use case. This expansion onto other platforms is expected to be in the formal release of this volume in the next version (Rev 7.0) of the Mod Payload Standard.

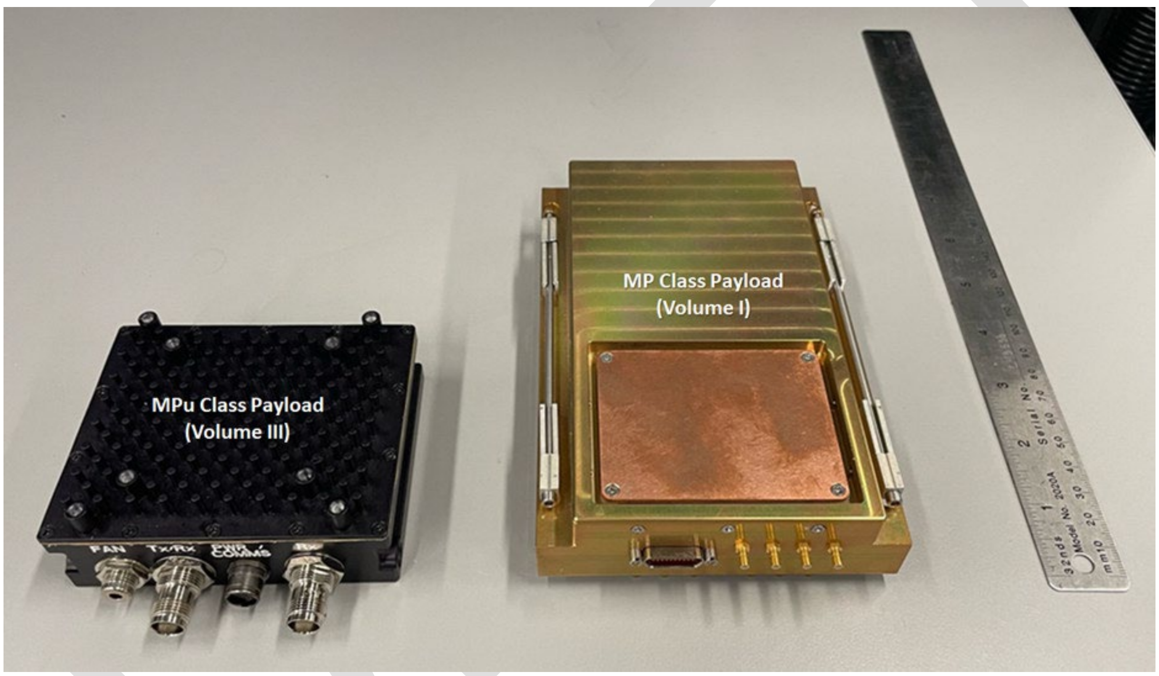


Figure 1-1. Payload Comparison – MPu and MP Classes

> **CAUTION:** because of the above, this Volume is considered 'in work' and it is not recommended to build to this specification without first reaching out for status on final revision and potential changes.

Like the previous volumes, this volume is broken into several sections. Section 2 details the attributes and interfaces required for MPu-compliance for the payload B-kit (the payload module and its antenna). Section 3 details the attributes and interfaces required for MPu-compliance for a dismount or body-worn A-kit. Section 4 will detail the attributes and interfaces required for MPu-compliance for an unmanned or other platform A-kit. Finally, example MP implementations on specific platforms (currently just dismounts) are provided in Section 5 as an aid to both platform integrators and payload vendors.

1.2 Architecture

The architecture for the MPu class, depicted in Figure 1-2, follows the A-kit / B-kit construct used throughout the Mod Payload standard. While some aspects and terminology are specific to the MPu class, the underlying philosophy of Mod Payload remains – to provide a standard mechanical and electrical interface for payloads and antennas to reduce time, cost and complexity for new platform-payload integrations.

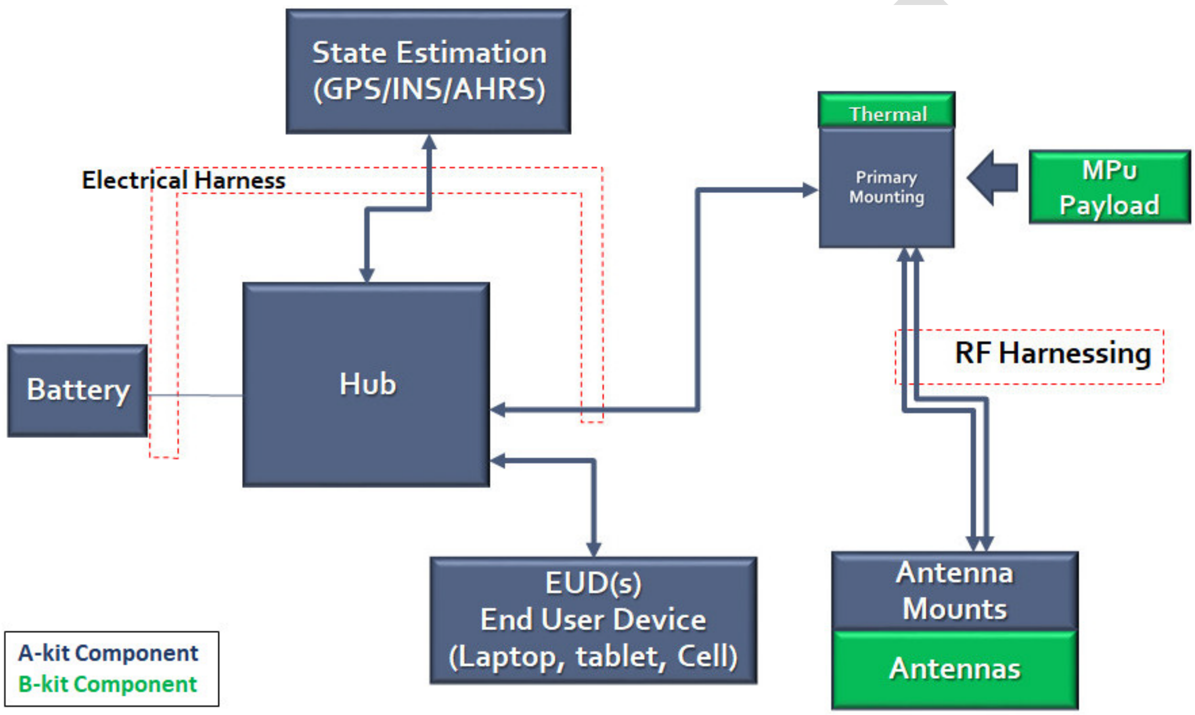


Figure 1-2. MPu Block Diagram

2. REQUIREMENTS FOR PAYLOADS

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

Figure 2-1. Example MPu Payload

2.1 Electrical Design

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

2.1.1 Power

A payload module should draw no more than 56W at 28VDC. This is the power provided by the Hub to each payload interface. However, it should be noted that the increased power draw may limit operation time (battery life) and may generate too much heat to dissipate in the MPu form factor / environment.

A payload module shall remain operational under voltage fluctuations of ±2% from the nominal 28VDC. Additionally, the payload module shall manage its in-rush, such that it does not exceed 4A per payload interface and does not exceed more than 5ms in duration.

2.1.2 Communications

A payload module will have access to two serial and one Ethernet interfaces provided by the Hub, as described in Section 3.1.4, to transmit and receive communications. A payload module may use either or both of the provided interfaces.

2.1.2.1 Serial

The serial connections can be used to (1) receive state data from the Hub and (2) access the payload for command, control, data or debugging. The state serial communications interface is detailed in Section 3.1.3.2.2. The console serial communications interface is detailed in Section 3.1.3.4. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.2.2 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 3.1.3.4. The state Ethernet communications interface is detailed in Section 3.1.3.2.1. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.3 Other Signals

A payload module can also require a 1PPS timing signal and a zeroize signal from the Hub. The 1PPS signal is detailed in Section 3.1.4.5. The zeroize signal is detailed in Section 3.1.3.6. A payload module that requires the use of either of these interfaces shall adhere to the requirements detailed in the appropriate referenced section.

2.1.4 Fan Power

An MPu payload module can also require additional fan power from the Hub. The fan power is detailed in Section 3.1.3.7. A payload module that requires the use of this interface shall adhere to the requirements detailed in the appropriate referenced section. Additionally:

- Fan power shall remain separate from payload power
- Fan power shall **NOT** be used to power the payload
- Payload power shall **NOT** be used to power the fan.

2.1.5 Main Connector

An MPu payload module shall use a single 24-pin Fischer MiniMax connector (part numbers below) as its main power and signal connector.

- Connector, Panel Mount: MR11WL08 0420 AN E1AS, or equivalent

When necessary, additional connectors can be added to the payload, provided they do not violate any other requirements of the MPu class. Any additional connectors must be clearly identified as deviations, and any required interfacing cables shall be provided by the payload vendor.

Example: A payload works with an active DF antenna. That active DF interface is not covered by MPu and can be added as a separate connector.

The required pin out for the MPu payload module main connector is listed in Table 2-1.

Table 2-1. MPu Payload Module Main Connector Pin Out

Signals & Direction Relative to Payload					
Pin	*Direction*	*Pin Type*	*Signal Type*	*Signal Name*	*Description*
1	OUT	Socket	RS232	Console_TX	Console RS232
2	GND	Socket	GND	GND	DC/signal GND
3	IN	Socket	RS232	State_RX	State RS232
4	GND	Socket	GND	GND	DC/signal GND
5	IN	Socket	RS232	Console_RX	Console RS232
6	GND	Socket	GND	GND	DC/signal GND
7	X	Pin	X	N/C	Unused
8	X	Pin	X	N/C	Unused
9	X	Socket	X	N/C	Unused
10	X	Socket	X	N/C	Unused
11	IN	Pin	24VDC-PWR	Fan_Power	24V Fan Power
12	GND	Pin	GND	GND	Fan Power GND
13	IN	Socket	LVDS	Zeroize+	Zeroize Positive Signal
14	GND	Socket	GND	GND	Second Power Channel GND
15	IN	Socket	ETHERNET	Ethernet_RX-	Ethernet Rx-
16	IN	Pin	ETHERNET	Ethernet_RX+	Ethernet Rx+
17	IN	Pin	28VDC-PWR	SecondaryPower_28V	Secondary Power 28V
18	OUT	Pin	ETHERNET	Ethernet_TX-	Ethernet Tx-
19	OUT	Socket	ETHERNET	Ethernet_TX+	Ethernet Tx+
20	GND	Socket	GND	GND	Primary Power Channel GND
21	IN	Socket	LVDS	PPS+	PPS Positive Signal
22	IN	Pin	LVDS	PPS-	PPS Negative Signal
23	IN	Pin	28VDC-PWR	PrimaryPower_28V	Primary Power 28V
24	IN	Pin	LVDS	Zeroize-	Zeroize Negative Signal
Shield	GND	Case	GND	Enclosure_GND	Shield to enclosure

2.1.6 Grounding

The payload shall maintain isolation of power, signal (serial console and state) and payload chassis / RF grounds from each other.

Note: the payload RF connector installation into the payload enclosure will tie RF ground to payload chassis ground.

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.

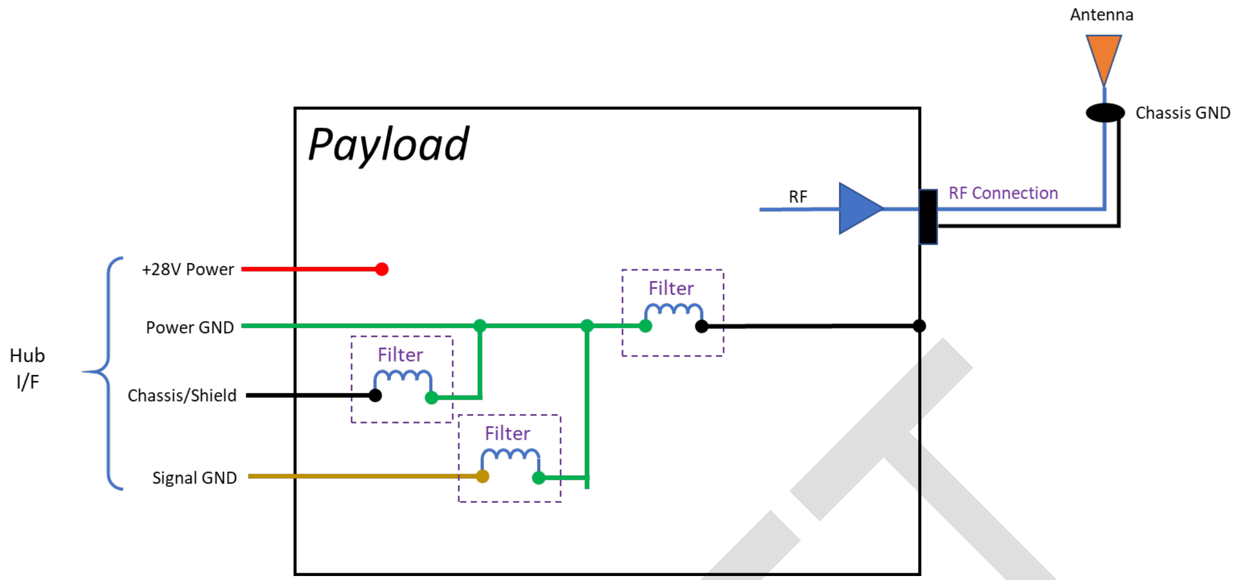


Figure 2-2. MPu Payload Grounding Scheme

The payload grounding scheme is depicted in Figure 2-2 above. The overarching grounding scheme for the MPu architecture is detailed in Section 3.7.

2.2 Mechanical Design

The MPu class imposes a common, relatively strict mechanical interface on payload modules to assure compatibility.

2.2.1 Enclosure

Payload modules shall be lightweight, IP68 enclosures of a defined size. Unlike the MP class, only a single size payload module is allowed. The maximum volume of the MPu payload module is defined in Table 2-2 below.

Table 2-2. Maximum Module Dimensions

Module Size	Length (in)	Width (in)	Height (in)
Micro	3.175[1]	3.850	1.200[1,2]

[1] Maximum dimension. See Section 2.2.1.1.1
[2] Height does not include optional heatsink or fan-heatsink assembly. See Section 2.2.1.1.2.

Figure 2-3 depicts an MPu module and Figure 2-4 provides the detailed dimensions of the module. These enclosure definitions constitute the standard volumes a module can be. However, some variability in the module design, as detailed in Section 2.2.1.1, is permitted.

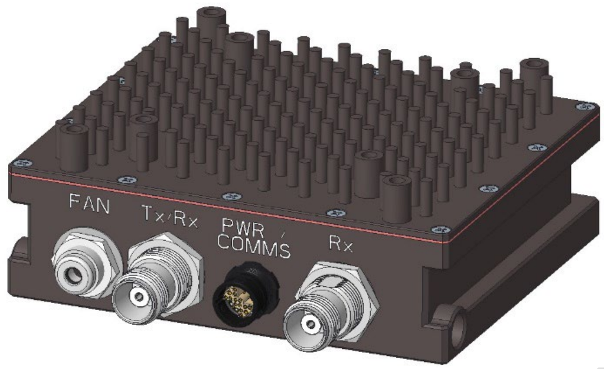


Figure 2-3. MPu Module Concept

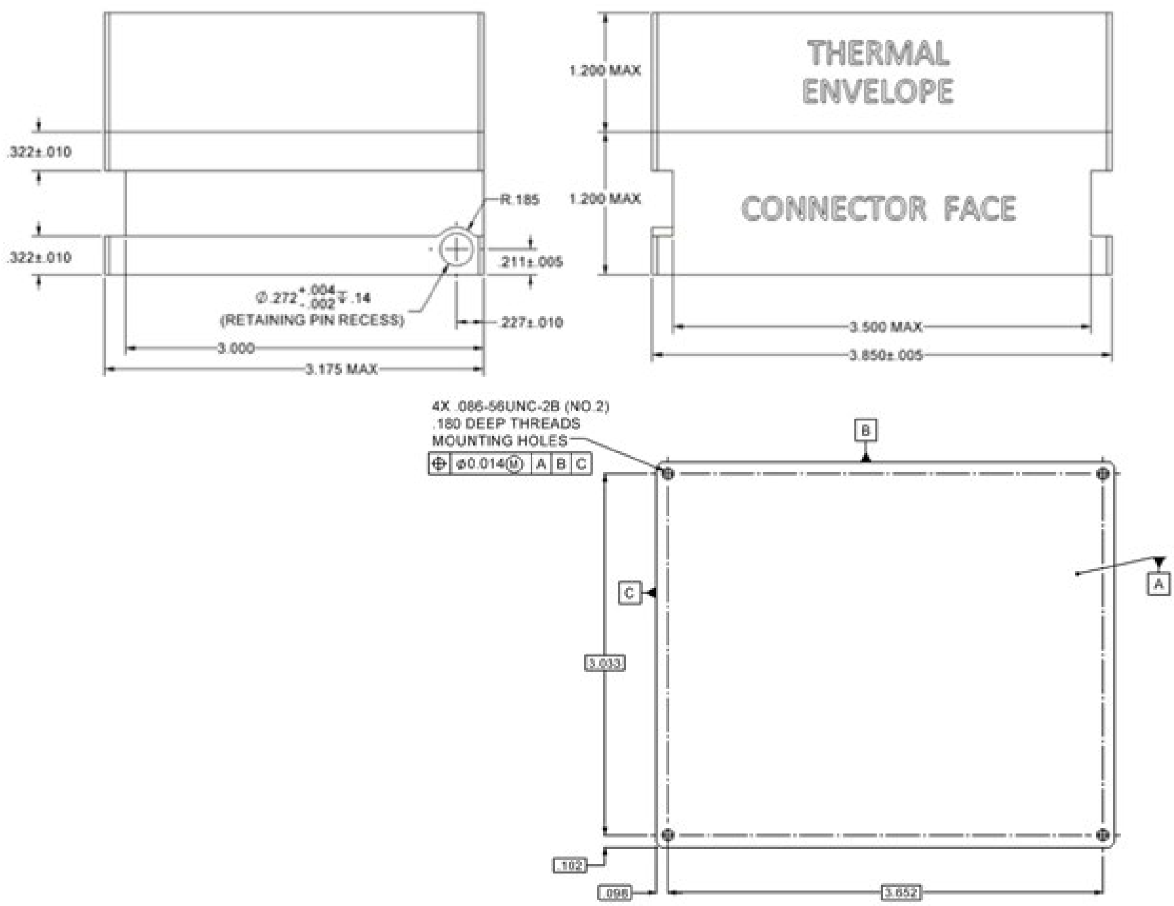


Figure 2-4. Detailed Dimensions of MPu Module

2.2.1.1 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.

2.2.1.1.1 Reduced Height Modules

The height dimension of a payload module is defined as a maximum height. Non-maximum height modules, referred to as reduced height modules are permitted. This reduced height allowance helps reduce the overall weight of the payload.

2.2.1.1.2 Fan – Heatsink Assembly

To assure thermal performance, a payload module may add a fan-heatsink assembly (or just a passive heatsink), as discussed in Section 2.3.2. The size/volume of the fan-heatsink assembly may not extend outside the payload top surface area nor extend more than 1.200-inch in height above the payload top surface (as illustrated in Figure 2-3).

A payload with a fan will be much less desirable. Thus, it is highly recommended that due diligence be put into thermal analysis and verification of exactly what is required.

For example, it could be found that the module design is sufficiently cooled without the fan up to 40°C and only above 40°C the operator needs to install or run the fan. This would be much preferred over always requiring a fan.

2.2.1.2 Connector Locations

All connectors shall be located and accessible on the connector face (identified in Figure 2-3) of the payload module, preferably, located centrally on the module. Debug connectors on other faces are permissible, but use of or access to them shall not be required for operations.

2.2.2 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. Any excess weight from payloads is an added burden on the operator, making non-optimized payloads less desirable.

2.2.3 Mounting Configurations

To promote platform flexibility, two mounting configurations shall be supported by an MPu payload. Each are detailed in the subsequent sections.

2.2.3.1 Pinned Mount Interface

Each module shall have a ledge as its bottom surface containing a recessed feature to secure the module into the Primary Mount, as shown in Figure 2-5 below. The locations and dimensions of the recessed features are detailed above in Figure 2-4.

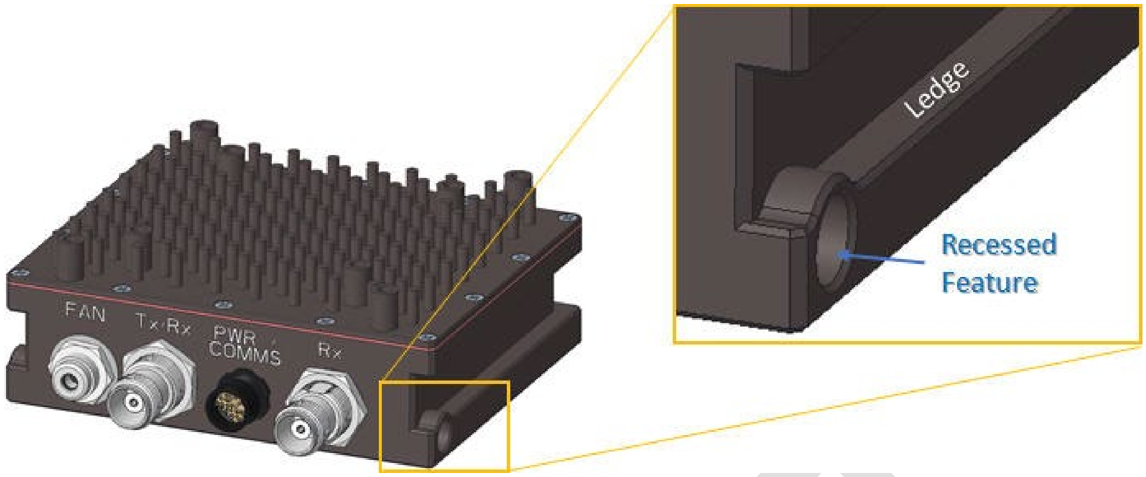


Figure 2-5. Mechanical Interface – Pinned

2.2.3.2 Bolted Mount Interface

Each module shall have a ledge as its bottom surface containing four tapped holes to secure the module to the Primary Mount using 2-56 bolts, as shown in Figure 2-6 below. The locations and dimensions of the clearance holes are detailed above in Figure 2-4.

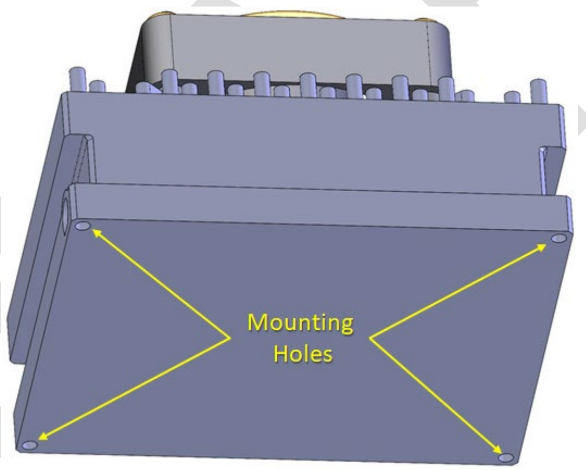


Figure 2-6. Mechanical Interface – Bolted

2.2.4 Tools for Integration and Removal

No tools (other than a single hex driver, if using the bolted interface) shall be required for module integration or removal.

2.3 Thermal Design

The payload vendor is responsible for the payload thermal design and verification to ensure that it is operating within its allowable limits.

2.3.1 Thermal Environment

Payloads shall be able to operate in an ambient environment of up to 45°C with minimal (1 m/s) ambient airflow. The payload vendor is responsible for maintaining operational temperatures of the payload.

2.3.2 Heatsink

A heatsink can be added to the module for thermal convection enhancement, if required. The heatsink shall install on the top surface of the module and shall neither exceed the area of that surface nor 1.200 inch above that surface, as illustrated in Figure 2-4. Since module orientation may differ between platforms, the heatsink shall be designed to function adequately regardless of the direction of airflow.

2.3.3 Fan

If a heatsink by itself is insufficient to cool the payload, a fan can be added to the module to force air across the heatsink. The fan should install on the top of the heatsink, as illustrated in Figure 2-7. The total height of the fan-heatsink assembly is still restricted to not exceed 1.200 inch above that surface, as illustrated in Figure 2-4.

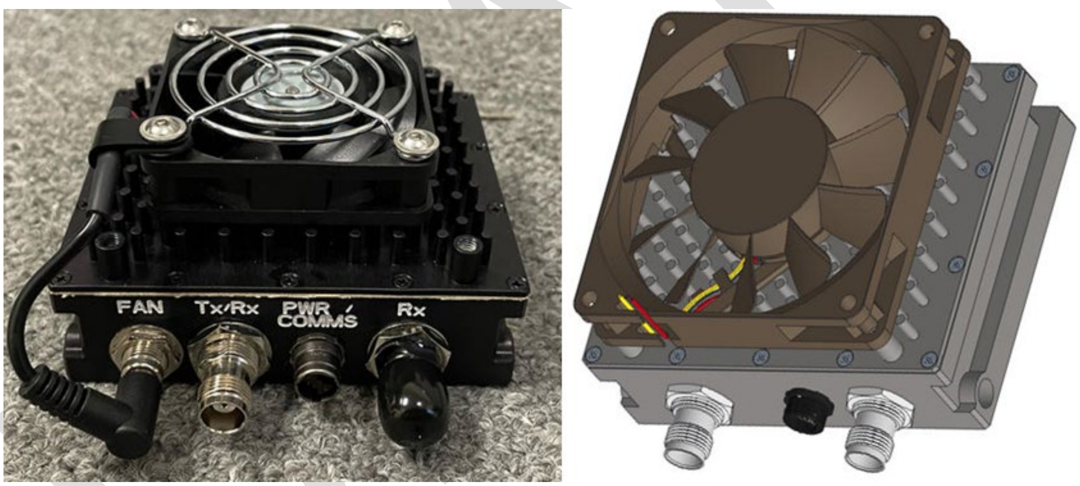


Figure 2-7. Fan Installation

If a fan is required, fan power shall be sourced from the Hub as detailed in Section 2.1.4. The payload should monitor its temperature and only energize the fan when required. Additionally, the payload shall monitor its own temperature and self-protect against overheating (this could be due to excessive power use, excessive ambient air temperature, obstruction of airflow, EUD-commanded removal of fan power, or fan failure).

2.4 RF Design

2.4.1 RF Cabling

In general, a payload module shall use the RF cabling provided by the A-kit. A-kit RF cabling is specified in Section 3.6.2.

When necessary, additional RF cabling can be utilized, provided it can be easily integrated and does not violate any other requirements of the MPu class. Any additional cables must be clearly identified as deviations, and shall be provided by the payload vendor.

2.4.2 RF Connectors

Payload modules shall use TNC-female connectors for RF connections to the payload antennas.

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

2.4.3 Antennas

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

A minimum number and orientation of antenna mounts that a MPu-compliant A-kit must support is defined in Section 3.5.1. However, some locations / orientations may not be suitable for certain payloads. Any such constraints shall be identified by the payload vendor.

2.4.3.1 Antenna Connectors

As RF cabling to antennas will terminate in either an TNC-male connector or an array connection (defined in Section 2.4.2), payload antennas shall either be able to directly accept these connections or be provided with the requisite RF adaptors / cabling to do so.

2.4.3.2 Antenna Adaptors

To interface to the MPu antenna mounts, as defined in see Section 3.5.1, 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 an MPu-compliant A-kit (with sufficient SWAP capacity to use it). While each antenna adaptor is specific to the particular antenna, there are only four adaptor types supported by the standard – the MPu twist and array adaptor and the legacy 2-pt adaptor and 4-pt adaptor (defined for the MP class) – analogous to the four types of antenna mounts to which the adaptors interface. The standardized mechanical interfaces between the A-kit-provided antenna mounts and the payload-provided antenna adaptor allow for rapid installation and removal and compatibility across A-kits.

2.4.3.2.1 Twist Adaptor

Twist adaptors, as shown in Figure 2-8, are the predominant MPu antenna adaptors for dismount applications. They allow for rapid, one- hand installation and removal of antennas. They should be used to support all body-worn, non-array MPu antennas.

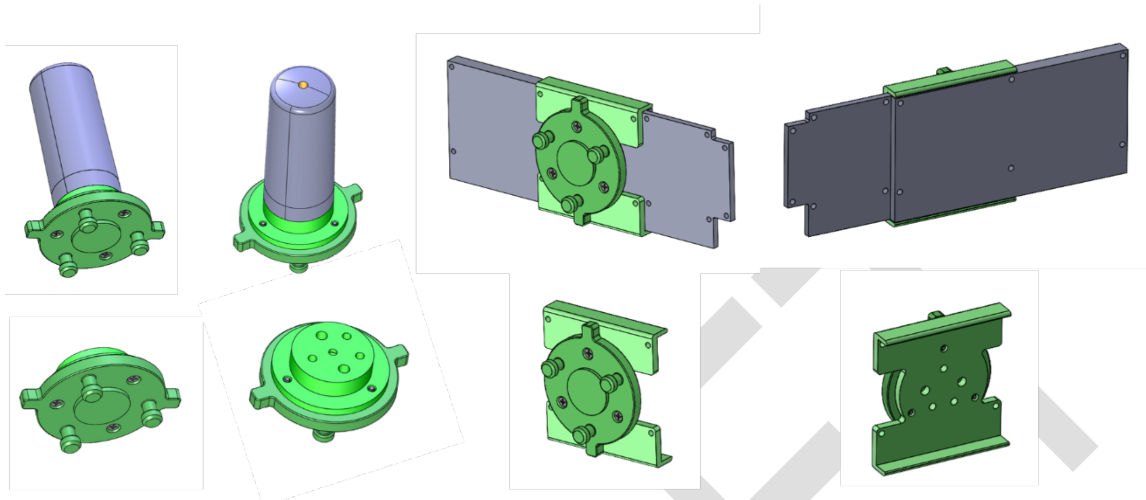


Figure 2-8. Example Twist Antenna Adaptor Assemblies – with and without Antennas

The twist antenna adaptor interface is defined in Figure 2-9. Payload antennas employing a twist antenna adaptor shall adhere to this interface. Twist adaptors should be fabricated from 3D-printed Nylon 12, Onyx or other material with similar mechanical properties and UV resistance.

Note: a deliberate, slight interference fit is used to attach a twist adaptor to its mount. The three posts of the adaptor are nominally 0.010in shorter and 0.010in wider than the thickness of the mount and diameter of the slot to which they insert. This interference compresses the 3D-printed adaptor / mount material to provide a secure fit.

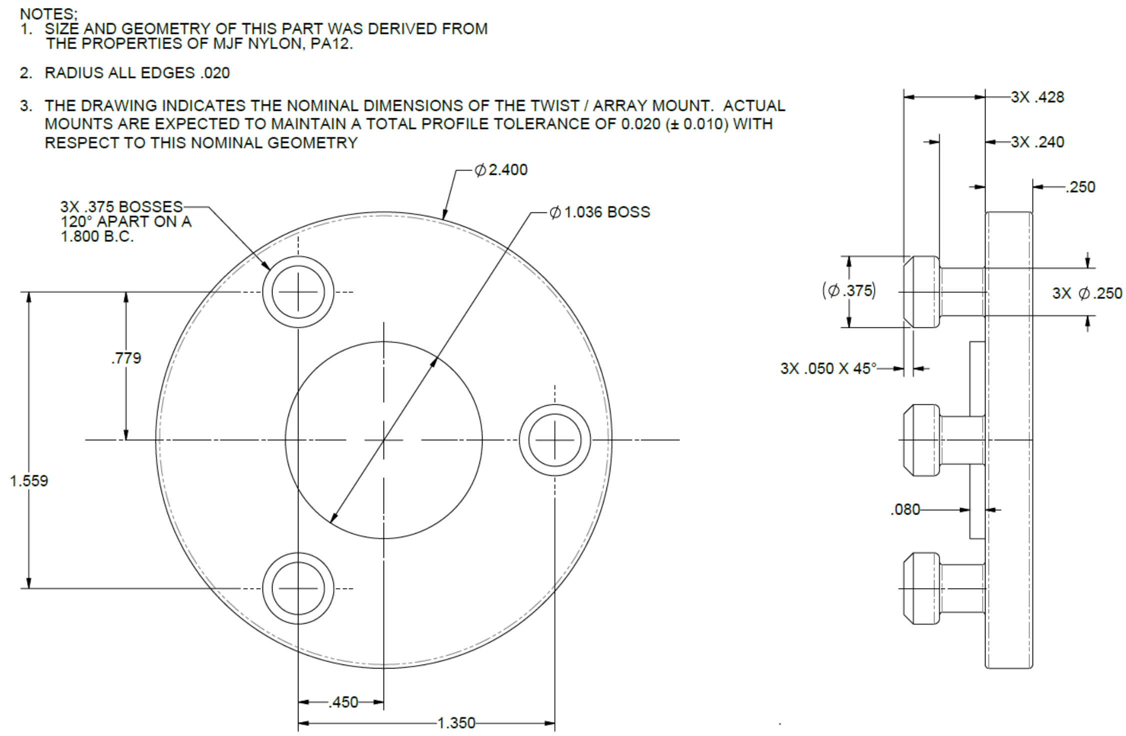


Figure 2-9. Twist Antenna Adaptor Interface

As evidenced in Figure 2-8 above, the requisite twist adaptor interface should be incorporated into an antenna-specific adaptor to conform to the antenna design, while also considering potential impact to the operator.

2.4.3.2.2 Array Adaptor

As an electro-mechanical interface, the array adaptor is the more complicated MPu antenna adaptor. An array adaptor should be used to support body-worn payloads requiring multiple phase-matched antennas or an antenna array. The array adaptor interface consists of multi-conductor Mighty Mouse (Glenair 803-005-07NF12-203FN) connector positioned at the center of twist adaptor.

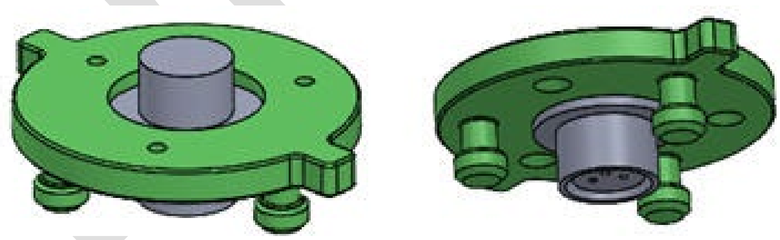


Figure 2-10. Example Array Antenna Adaptor Assembly – without Antennas

The array adaptor interface is defined in Figure 2-11. Payload antennas employing an array antenna adaptor shall adhere to this interface. Array adaptors should be fabricated from 3D-printed Nylon 12, Onyx or other material with similar mechanical properties and UV resistance.

Note: a deliberate, slight interference fit is used to attach an array adaptor to its mount. The three posts of the adaptor are nominally 0.010in shorter and 0.010in wider than the thickness of the mount *and diameter of the slot to which they insert. This interference compresses the 3D-printed adaptor / mount material to provide a secure fit.*

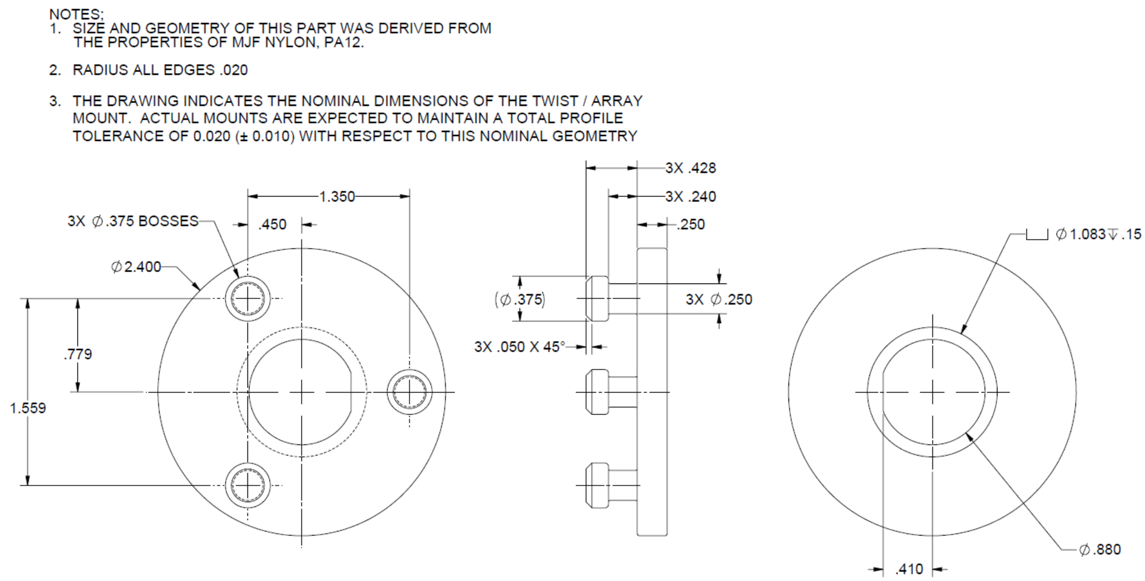


Figure 2-11. Array Adaptor Interface

As evidenced in Figure 2-10 above, 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 operator. Larger arrays may not be feasible.

Installation of the array adaptor is two-step process, first the array cable is connected to the array adaptor, then the antenna adaptor is mated to the antenna mount using the mechanical twist interface

2.4.3.2.3 2-pt Adaptor

MP 2-pt adaptors, as detailed in Section 3.4.3.2.1 of Volume I of this Standard, are also supported by MPu, they should be used to support small airborne antennas for sUAS application.

2.4.3.2.4 4-pt Adaptor

MP 4-pt adaptors, as detailed in Section 3.4.3.2.2 of Volume I of this Standard, are also supported by MPu, they should be used to support larger airborne antennas for sUAS applications.

2.4.4 EMI

The payload should not have unintentional emissions that interfere with operations of other body-worn or platform systems, specifically, military and platform command / control radios. 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 payload vendor shall provide information on the RF behavior of their system (particularly notating any deviations to the above guidance) to support frequency masking, if required.

2.5 Environmental

MPu-compliant payloads and antennas shall adhere to the environmental requirements defined in the subsequent section.

2.5.1 Shock

Per MIL-STD-810H, 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.

2.5.2 Vibration

Per MIL-STD-810H Method 514.8 Category 24, the payload shall be able to withstand the general minimum integrity testing profile as shown below. Test duration is one hour in each axis.

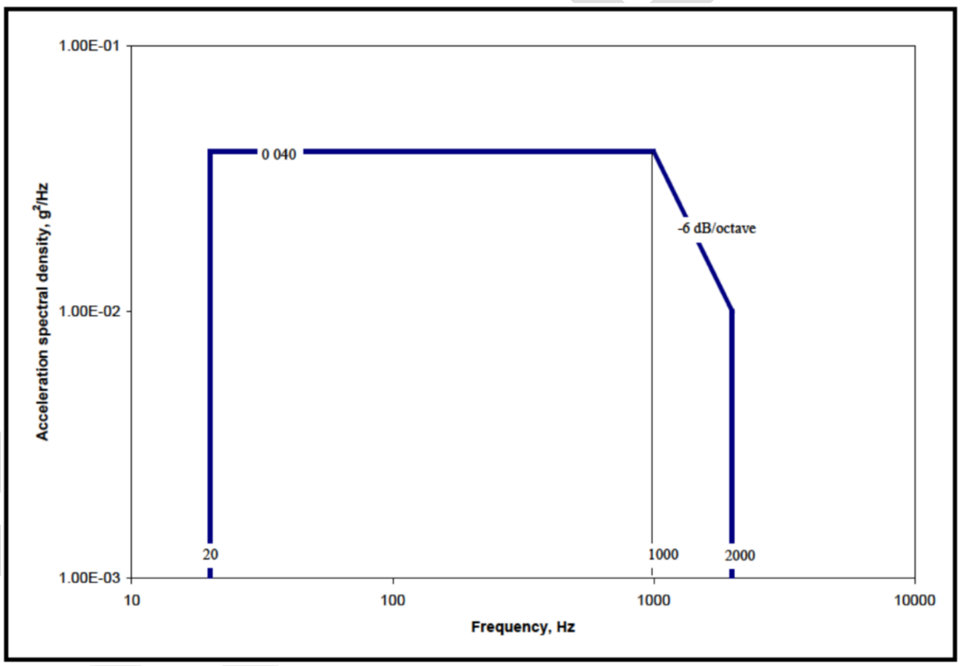


Figure 2-12. Vibration General Minimum Integrity Testing Profile

2.5.3 Ambient Temperature

Ambient temperature requirements are detailed in Section 2.3.1.

2.5.4 Storage Temperature

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

2.5.5 Sand and Dust

The payload shall be IP68 rated.

2.5.6 Salt Atmosphere

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

2.5.7 Humidity and Water Ingress

The payload shall be IP68 rated.

2.5.8 UV Exposure

The payload shall be able to withstand prolonged UV exposure with no degradation to material integrity.

2.5.9 Handling

The payload shall be able to be handled and installed by an operator in a tactical environment, (e.g., no ESD straps or other specialized requirements).

3. REQUIREMENTS FOR DISMOUNT/BODY WORM PLATFORMS

The MPu A-kit shall install to an operator's existing plate carrier. The MPu A-kit adds some weight and complexity to an operator's already encumbered tactical kit, but provides a flexible, SIGINT capability with common mechanical, power, data, and RF interfaces to support a variety of payloads. The MPu A-kit installation includes a Hub, an inertial navigation system (INS)[1], an end user device (EUD) suitable for dismount operations (e.g., a phone or tablet), cables connecting the above electronics, a Primary Mount, provisions for payload antennas and cabling to support both a payload and its antennas.

[1] *Accurate INS solutions on humans is a technical challenge area in itself that is being attacked in other areas of DoD. As such, MPu does not take on that challenge, but rather focuses on getting a current MP INS solution in place and operable for the purpose of testing the architecture. Expectation is that when fielded higher accuracy solutions come along, they will be adopted into MPu architectures in later releases.*

3.1 Hub

The Hub is a ruggedized electronics module customized to provide the requisite interfaces to the EUD, INS and payload(s) to support the power, data ingestion, translation and dissemination capabilities required for payload integration and operation. This device is analogous to the MAIM of the MP class in Vol I, except with some different characteristics.

Figure 3-1 shows two varying concepts for the Hub. The left is the **prototype** Hub developed in order to prove out the architectural concept of MPu. Out of convenience and cost reduction, this prototype used the MPu payload form factor. This is **neither a requirement nor a desire**, but simply a prototyping choice. On the right is a proven, fielded, body-worn device (the Black Diamond APEx I 4-port hub). While this specific device is not MPu-compliant, it is an accurate example of what an MPu Hub is envisioned to be.

Figure 3-1. Prototype Hub (left), Future Hub Concept (right)

3.1.1 Mechanical Design

The Hub shall be designed to support dismount operations. However, since it is not a payload, the mechanical constraints are less specific. The intent is that much like the MP paradigm, multiple vendors could develop their own A-kit designs with multiple variations of Hubs, mounts and harnessing with the intent that all are MPu-compliant and accept MPu B-kits.

3.1.1.1 Size

As MPu installs onto an operator's plate carrier (along with other tactical gear), the Hub size should be minimized.

*Note: while the prototype Hub was designed in accordance with the MPu payload dimensional requirements for convenience of sharing the same holster, this is **not** required.*

3.1.1.2 Weight

As MPu is a body-worn system, the Hub weight should be minimized. It is expected that the Hub vendor invest time into optimizing the structural weight of the enclosure to reduce burden on the operator.

3.1.1.3 Interface

The Hub should be MOLLE-compliant in most cases to support mounting to a wide variety of plate carriers. However, this is not strictly required as some systems may have alternate methodologies and this does not impact MPu B-kit interfaces.

3.1.1.4 Ruggedization

The dismount environment is a difficult environment for electronics. The Hub shall be designed in such a manner to ensure survivability in the anticipated environment. Environmental considerations include, but are not limited to: shock, vibration, ingress protection (fluids and solids), salt atmosphere, UV exposure, humidity, and handling requirements.

3.1.1.5 Thermal

The Hub shall be able to operate in up to a 45°C ambient environment, while providing a full payload power draw (Section 3.1.3.1) with minimal (~1m/s) airflow.

If necessary, the Hub may include a small, external fan. The acoustic signature of such a fan shall be characterized and documented. Consideration should be made to select a fan with a low acoustic signature. Additionally, the Hub fan shall be controllable (able to turn on / off) by the operator via the EUD. It is also recommended that the fan be removable and only used to support high power payloads.

3.1.2 Electrical Interfaces

The Hub shall provide each payload the following interfaces:

- Power (as described in Section 3.1.3.1)
- Serial – state (as described in Section 3.1.3.2.2)
- Serial – console (as described in Section 3.1.3.4)
- Ethernet (as described in Section 3.1.3.2.1)
- 1PPS (as described in Section 3.1.3.5)
- Zeroize (as described in Section 3.1.3.6)
- Fan Power ((as described in Section 3.1.3.7)

The Hub shall provide the required interfaces to the other MPu A-kit components:

- EUD (as described in Section 3.1.4.2)
- INS (as described in Section 3.1.4.3)
- Battery (as described in Section 3.1.4.1)

3.1.2.1 Connectors

No specific connectors or pinouts are mandated for the Hub itself. The interface connector is only specified on the payload (Section 2.1.5). However, to support dismount operations, ruggedized (IP68), push-pull style, quick-disconnect connectors shall be used. A non-exhaustive list of example connectors is provided in Table 3-1 below.

Table 3-1. Hub Candidate Connector List

Vendor	Connector Series
Fischer	Minimax
Glenair	807 (Nett Warrior)
ODU	AMC

3.1.3 Required Functionality to Support Payloads

As the payload interface, the Hub 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 3-2 illustrates the functionality, major components, and interfaces for an example Hub.

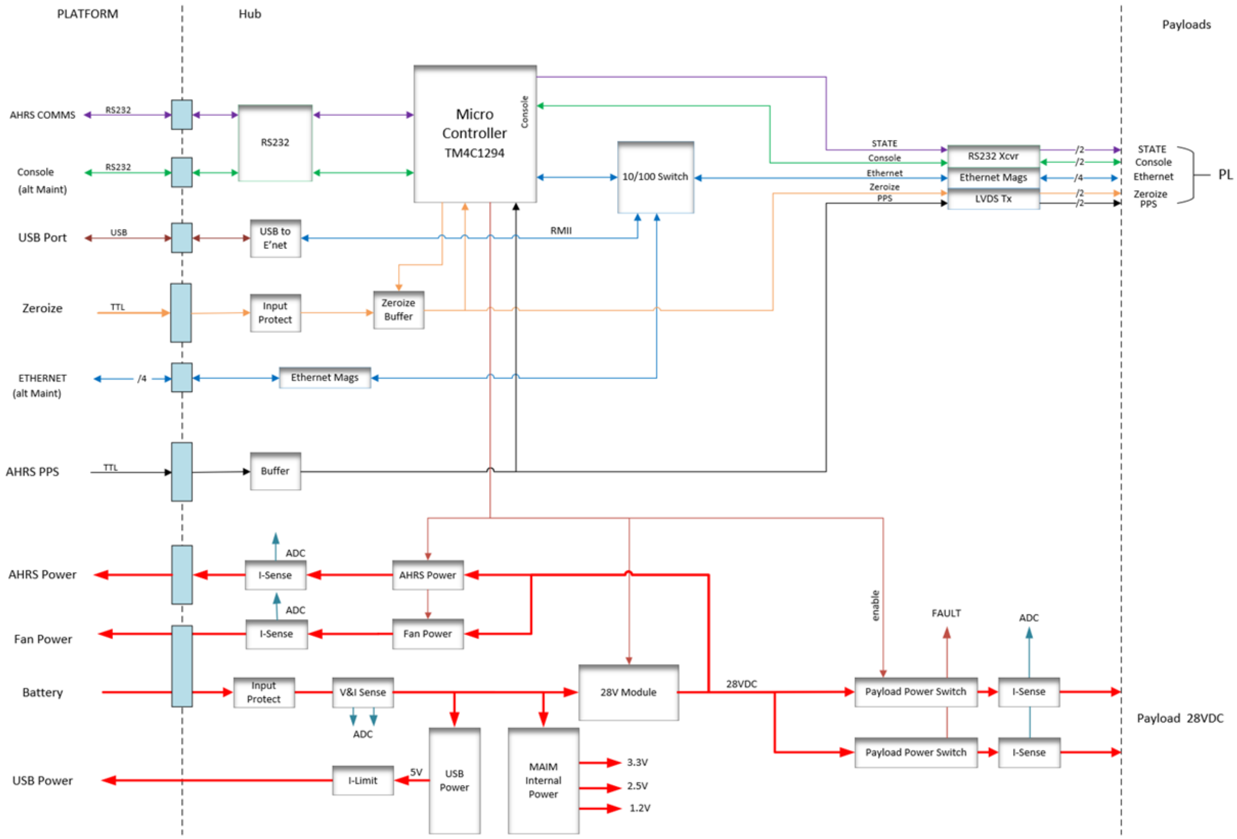


Figure 3-2. Example Hub Block Diagram

3.1.3.1 Power

The Hub shall interface to the A-kit battery and supply up to 56W at 28VDC ±2% to each payload interface (provided at the payload). The Hub shall monitor the power draw of the payload and generate an alert if a payload is exceeding the allowable power draw. The Hub shall provide the ability to secure power to the payload manually, commanded by the operator. In some cases, the Hub should automatically secure power to the payload. Table 3-2 below provides different power states the Hub may encounter and required / recommended Hub responses under those conditions.

Note: Recommendations can be considered optional – the Hub can power off any payload in any of the non-compliant power states.

Table 3-2. Hub Power States

	Compliant States		Non-Compliant States			
Power State	112W / 4A	<= 56W / 2A	>56W / 2A <= 84W / 3A	> 84W / 3A <= 112W / 4A	> 84W /3A <= 112W /4A	112W /4A
Duration	<= 5 ms	Any	Any	< 5 s	>= 5 s	> 5 ms
Description	Max allowable payload in-rush	Max allowable payload steady state	Exceeding max steady state power (minor)	Exceeding max steady state power (major, brief)	Exceeding max steady state power (major, extended)	Exceeding max in-rush
Enforcement	Required	Required	Recommended	Recommended	Recommended	Recommended
MAIM Electrical Response	None	None	Electrically limit power to prevent damage to interfaces	Electrically limit power to prevent damage to interfaces	Electrically power off	Electrically power off
MAIM GUI Response	None	None	Yellow Alert Notification	Red Alert Notification	Red Alert Notification, Power Indicator OFF	Red Alert Notification, Power Indicator OFF

If providing multiple payload interfaces, the Hub shall prevent a payload interface from back feeding into opposing interface ports.

3.1.3.2 State Distribution

The Hub shall interface to the MPu-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 meeting the specification defined in this standard (see Volume I, Section 3.2.1) are allowed to be used for MPu.

3.1.3.2.1 State Data over Ethernet

The Hub 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 MPu integrator. To utilize this communications mechanism, the MPu network must have implemented an IP stack supporting multicast groups via IGMP.

The Hub shall re-package the state data from the INS into a JSON message structure to distribute the data over Ethernet. The Hub shall transmit these JSON messages at the rates shown in the table below:

Table 3-3. JSON Message Rates

JSON Message	Hz
HUB_VER	1
STATUS	1
IMUNAV	10
PRESSURE	1
TPV	1
ATT	10
SKY	1
ADDL	1

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

The time between the receipt of the last required incoming message from the INS and the transmission of the outgoing state message from the MAIM shall be minimized. For an outgoing state message rate slower than the incoming INS message rate(s), the last incoming message(s) prior to the outgoing message shall be used to generate the content of the outgoing message. When incoming and outgoing message rates do not align, the transmission of outgoing messages shall be synchronized to the incoming message(s) from the INS such that outgoing messages are sent upon receipt of the last required incoming message. In the event one of the incoming messages that make up the outgoing message is missed or dropped, the entire outgoing message should be dropped.

The size of the messages sent over the Ethernet connection shall not exceed the maximum transmission unit (MTU) of 1500 bytes.

3.1.3.2.2 State Data over Serial

The Hub 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 serial interface shall be a unidirectional interface from the Hub to the Payloads. The following signals shall not be connected at the Hub: DTR, DCD, DSR, RI, RTS, RTR, CTS.

The Hub shall package the state data from the INS into a sbgECom message structure (regardless of INS used) and distribute the data over serial. The Hub shall distribute the sbgECom binary state messages at the rates shown in the table below.

Table 3-4. sbgECom Message Rates

sbgECom Message	Hz
SBG_ECOM_CMD_INFO (04),	ON STARTUP
SBG_ECOM_LOG_STATUS (01)	1
SBG_ECOM_LOG_UTC_TIME (02)	20
SBG_ECOM_LOG_IMU_DATA (03)	20
SBG_ECOM_LOG_MAG (04),	20
SBG_ECOM_LOG_EKF_EULER (06)	20
SBG_ECOM_LOG_EKF_NAV (08)	20
SBG_ECOM_LOG_GPS1_VEL (13)	5
SBG_ECOM_LOG_GPS1_POS (14)	5
SBG_ECOM_LOG_PRESSURE (36)	1

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

The Hub shall also distribute the NMEA state messages at the rates shown in the table below.

Table 3-5. sbgECom NMEA Message Rates

sbgECom NMEA Message	Hz
SBG_ECOM_LOG_NMEA_GGA (0x00)	1

The sbgECom NMEA messages are detailed in Appendix A, Section A.4.

The time between the receipt of the last required incoming message from the INS and the transmission of the outgoing state message from the MAIM shall be minimized. For outgoing state message rate slower than the incoming INS message rate(s), the last incoming message(s) prior to the outgoing message shall be used to generate the content of the outgoing message. When incoming and outgoing message rates do not align, the transmission of outgoing messages shall be synchronized to the incoming message(s) from the INS such that outgoing messages are sent upon receipt of the last required incoming message. In the event one of the incoming messages that make up the outgoing message is missed or dropped, the entire outgoing message should be dropped.

3.1.3.3 Network Connectivity

The Hub shall create a local IP payload network for the dismount operator to provide connectivity to allow for the command, control, configuration, and monitoring of the payload and payload data via the EUD. The Hub shall provide an Ethernet interface to each payload, to the EUD, and for itself. The Hub 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 MPu integrator; the payload system shall conform to the determined scheme. Figure 3-3 below depicts an example Ethernet network for MPu.

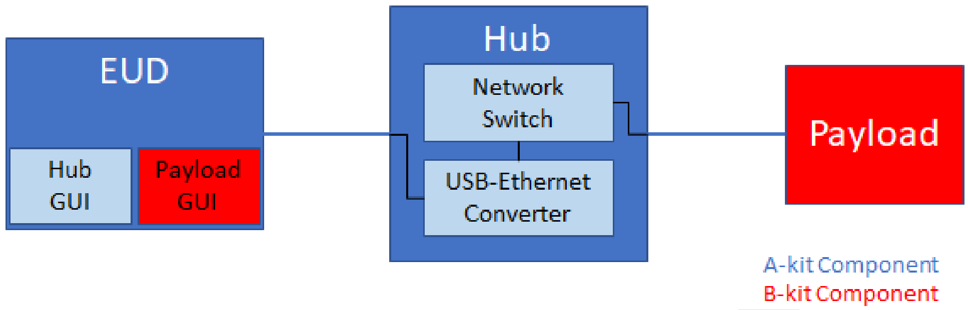


Figure 3-3. Notional MPu Network

3.1.3.4 Serial Console

The Hub 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 Hub and the payloads. The following signals shall not be connected at the Hub: DTR, DCD, DSR, RI, RTS, RTR, CTS.

To provide remote access to this serial console port, the Hub 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 MPu integrator; a payload requiring this connection shall conform to the determined scheme. Figure 3-4 below depicts an example serial console network for a MP-compliant MPu.

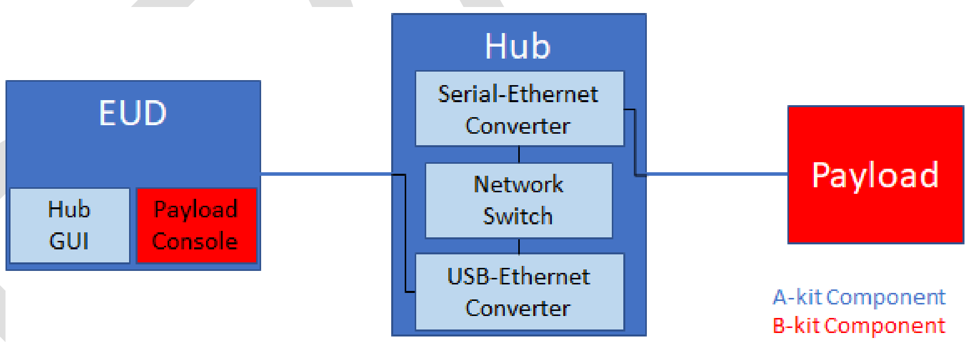


Figure 3-4. Example MPu Serial Console Connection

3.1.3.5 Time Synchronization

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

3.1.3.6 Zeroize

The Hub is required to provide a zeroize signal to each payload. This shall be activated manually by the operator via the EUD. An active low signal shall be used as the zeroize signal. The zeroize signal provided by the Hub shall be an LVDS in accordance with the TIA/EIA-644 standard – 1.0V logic low, 1.4V logic high.

3.1.3.7 Fan Power

The Hub shall provide up to 500mA at 24VDC to each payload to support a fan. While not all MPu payloads will require a fan, some may. The Hub shall provide the ability to secure power to the fan manually, commanded by the MPu operator via the EUD.

3.1.4 Required Functionality to Support Other A-kit Components

In addition to the required payload functionality, the Hub must provide power ingestion and regulation from the battery, USB to Ethernet conversion and power charging for the EUD, power, power switching and monitoring, state data and time sync ingestion from the INS. The requirements for each are detailed in the subsequent sections.

3.1.4.1 Battery

The Hub shall support a battery voltage range commensurate with the battery(ies) selected for the MPu A-kit. The Hub shall regulate the battery voltage as required to meet the payload power requirement (Section 3.1.3.1). The Hub should support the hot-swapping of batteries.

Note: alternatively, the hot swapping capability can be accomplished in the A-kit battery cable, as in a BDAT CB-0323-00 Dual 5590 cable.

3.1.4.2 EUD

The Hub shall provide a USB interface into the EUD. Through this USB interface, the Hub shall provide power and the ability to charge the EUD. The Hub shall also provide USB comms to the EUD, which it shall convert internally to Ethernet to allow communications between the EUD and payloads.

3.1.4.3 INS

The Hub shall provide the requisite power and comms for the selected INS. The Hub shall ingest state data from the INS and supply to the payloads as required to meet the payload state distribution requirement (Section 3.1.3.2). The Hub shall receive the 1PPS signal from the INS and supply to the payloads as required to meet the payload time synchronization requirement (Section 3.1.3.5).

3.1.5 Software / Firmware

To achieve the above functionality, the Hub requires both firmware, embedded on its processor / microcontroller, and user interface (UI) software, run on or accessible from the EUD.

3.1.5.1 Firmware

The Hub embedded firmware shall provide the following functions:

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

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

3.1.5.2 User Interface

The Hub shall also interface to a software application for remote control, monitoring, and maintenance. This software application shall serve as the UI for the MPu operator. This software application can either be a stand-alone application run on the EUD or an application run on the Hub that hosts a web server accessible via a web browser on the EUD.

3.1.5.2.1 UI Requirements

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

- Monitor status of Hub – connectivity, temperature, faults
- Energize and secure power to individual payloads
- Energize and secure power to Hub fan
- Energize and secure power to payload fan
- 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 Hub network configuration settings
- Calibrate the INS (optional, can also be done by a stand-alone application)
- Set the Hub network configuration (optional, if settings are configurable)
- Console access to the Hub for debug activity (restrict to a super user)

For reference, screenshots from a prototype Hub Web UI are shown in Figure 3-5, Figure 3-6, and Figure 3-7 below.

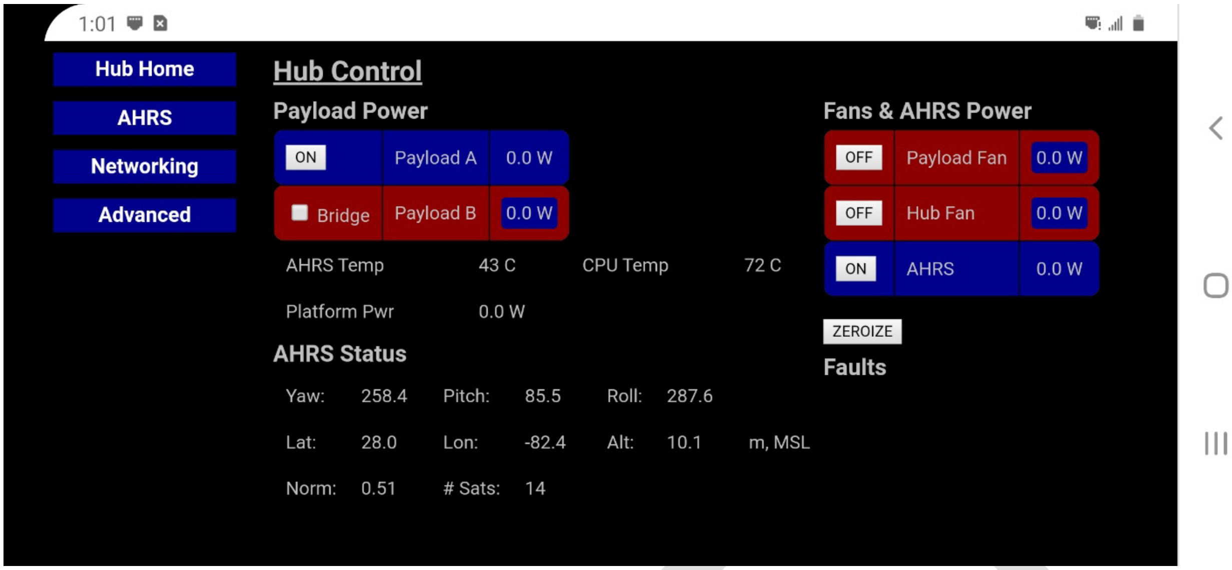


Figure 3-5. Example Hub GUI Home Page

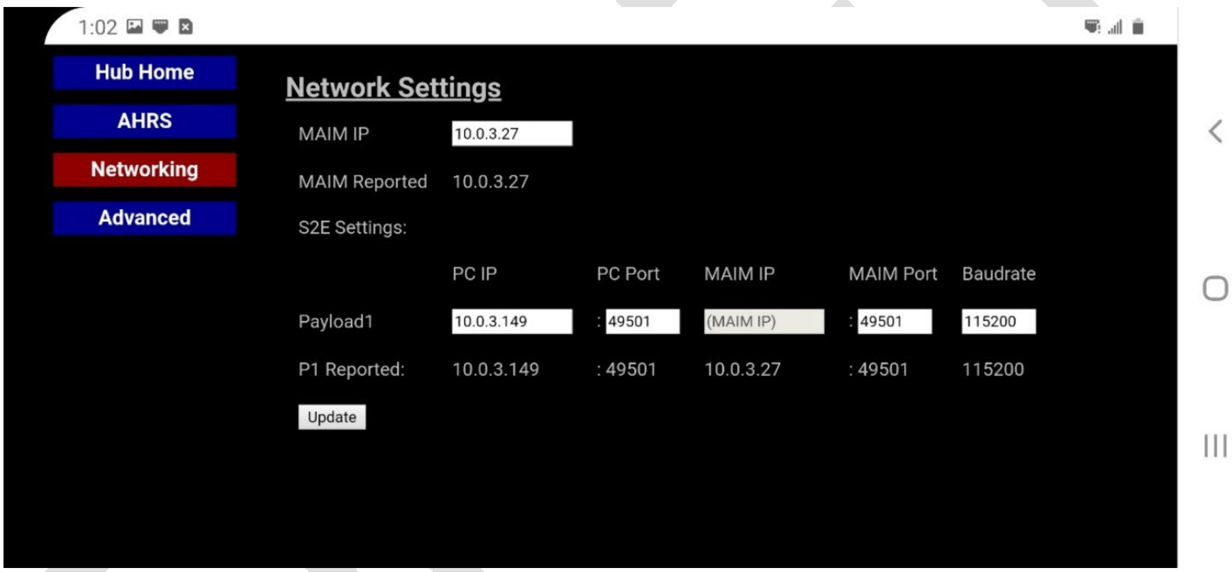


Figure 3-6. Example Hub GUI Networking Page

Figure 3-7. Example Hub GUI INS Calibration Page

3.1.6 Maintenance

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

3.2 INS

A dedicated, high accuracy INS shall be installed as part of the MPu A-kit. Position, velocity, accelerations, attitude, angular velocities and timing information from the MPu-compliant INS shall be transmitted to the Hub for distribution to the payloads.

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

An accurate INS solution on humans is a technical challenge area in itself that is being investigated in other areas of DoD. As such, MPu does not take on that challenge, but rather focuses on getting a current MP INS solution (Section 3.2.1) in place and operable for the purpose of testing the architecture. The expectation is that when fielded higher accuracy solutions come along, they will be adopted into MPu architectures in later releases.

3.2.1 INS Installation

INS performance is contingent upon proper installation. To assure performance, the selected INS shall be integrated in accordance with INS-vendor-supplied documentation and the following sections.

3.2.1.1 Physical Orientation

The INS should be mounted in a position that fixes its orientation and position; however, assuring proper and consistent position and orientation on a dismount is more difficult than on a vehicle – most vehicles have a fixed structure whereas a human is able to move body parts independent of one another. The INS coordinate frame should be aligned as much as possible with the operator's cardinal points. Any deviation in the INS orientation in relation to the cardinal points will degrade performance. To minimize this deviation, it is recommended that the INS is installed on the torso, ideally, the back, or on a fixed mast aligned with the torso. It is also preferable to have the INS z-axis in alignment with the front of the body (see Figure 3-8). However, misalignments can be addressed using appropriate Euler angles. The sensor lever arm, the distance from the INS to the operator's center of mass (navel at mid-body depth), as well as GPS lever arm, the distance from the INS to the GPS antenna, should be measured. Rather than measuring these distances for each operator, fixed values should be used assuming a 50th percentile person from the ANSUR II database. The INS placement, orientation, and lever arms should all be documented for reference.

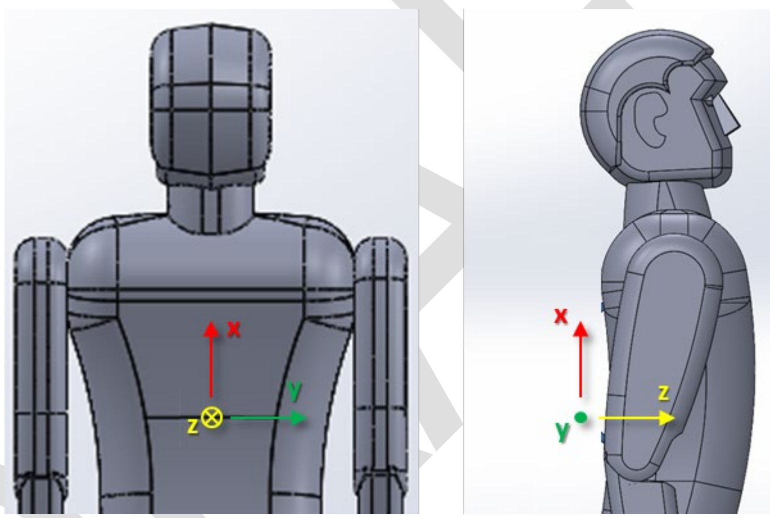


Figure 3-8. INS Orientation

3.2.1.2 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.

3.2.1.3 Magnetic Distortion 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. This, of course, is a major challenge on a dismount operator with a heavily equipped tactical kit. 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:

- 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.

3.2.1.4 Temperature Consideration

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

3.2.1.5 Installation Testing

After an INS position is selected and all the guidelines are met, INS placement testing should be conducted. Additionally, INS placement testing should be repeated should any major changes be introduced to the operator's tactical kit.

The INS performance should be assessed by rotating the INS in roll, pitch and yaw and verifying measurements are reasonable / accurate. *Note: this likely means the operator's bending forward / backward, leaning left / right and turning to face different directions.*

3.2.2 INS Configuration

Each MPu-compliant INS is designed to be able to operate in a number of dynamic environments. The dismount environment poses some unique challenges for an INS. The INS vendor's documentation should be consulted to determine the configuration to optimize INS performance for dismount operations.

3.2.3 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 executing a calibration routine.

A successful magnetometer calibration on a dismount typically has these basic requirements:

- Set the INS into magnetometer calibration mode
- Minimize large, time-varying magnetic field activity in the area, as possible
- Conduct an appropriate pattern so that the INS can take measurements across a range of azimuth and roll angles. Assuming the INS is installed centered on the

back of the dismount, the operator should bend forward at the waist and rotate slowly (both clockwise and counterclockwise), then repeat bending backwards and sideways

- Once the full calibration pattern has been completed, take the INS out of magnetometer calibration mode.

The magnetometer should not need to be calibrated prior to every mission, unless the local magnetic environment has changed significantly.

Note: a major modification to operator's tactical kit could warrant a re-calibration.

To aid the operator in determining whether a calibration is needed, a real-time indication of the quality of the magnetic calibration, referred to as the AHRS normalization (AHRS-norm), shall be computed and displayed in the Hub UI. 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 local environment is significant enough to degrade the quality of the magnetometer calibration, the norm should reflect this.

3.3 Primary Mount

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

3.3.1 Description

The Primary Mount is a mechanical assembly, customized to install on a dismount operator's tactical kit to provide a standard, simple payload interface to promote rapid installation and removal of payload modules. The two styles of Primary Mount supported by the MPu class – holster and plate – are defined in the following sections.

3.3.2 Holster

The holster Primary Mount shall be designed to provide a standard mechanical interface to support an MPu payload, minimize weight, and endure mission operations. The holster Primary Mount shall support at least one MPu payload. Supporting additional payloads is allowable, but the added size required to do so will restrict the installation flexibility on the operator's tactical kit. An example holster Primary Mount is illustrated in Figure 3-9 below.

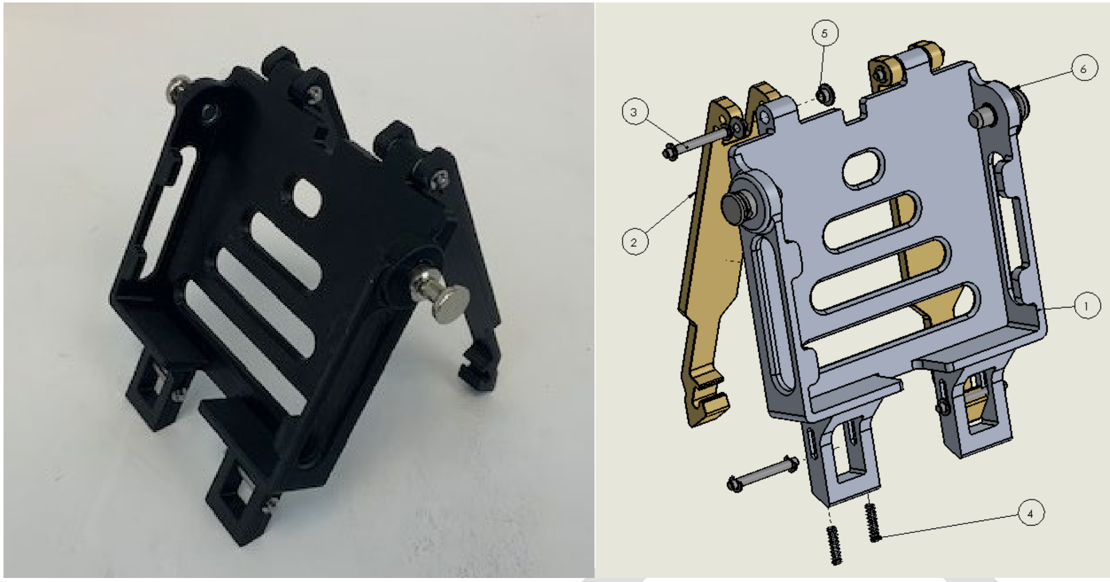


Figure 3-9. Holster Primary Mount

The holster Primary Mount shall be designed to positively retain an MPu payload using the payload's pinned interface, allowing the payload to be installed or removed without the use of tools. An example of this is illustrated in Figure 3-10.

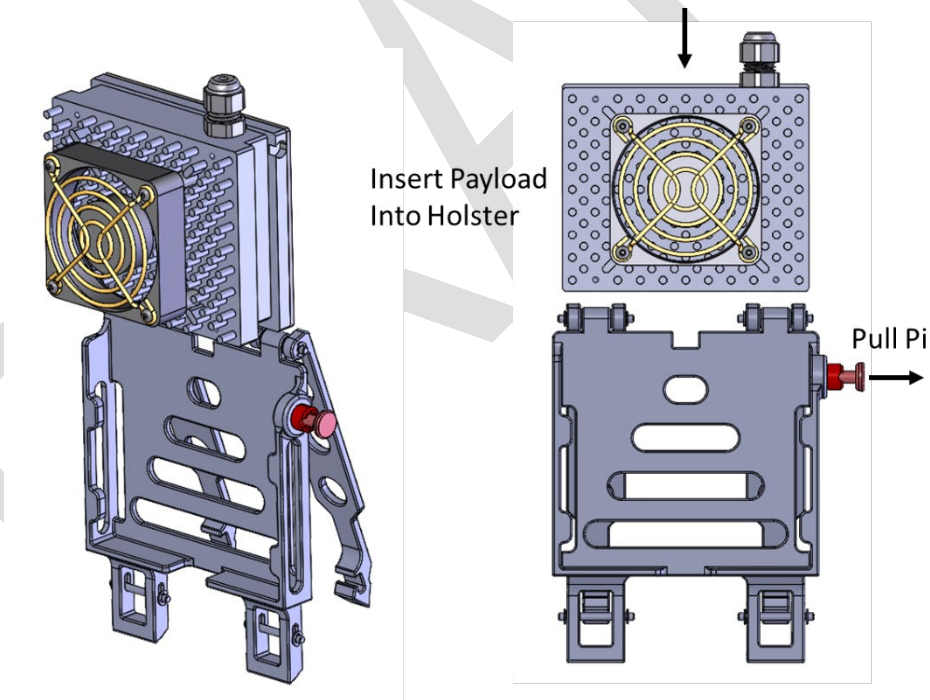


Figure 3-10. Payload Installation – Holster Primary Mount

As the holster Primary Mount must support MPu-compliant payloads, the mechanical interface for the Primary Mount is actually defined by the payload module requirements in Section 2.2.3. However, to assure the holster Primary Mount accommodates MPu-compliant payloads and reduce the design efforts of the MPu integrator, Figure 3-11 provides a reference design for an MPu-compliant holster interface.

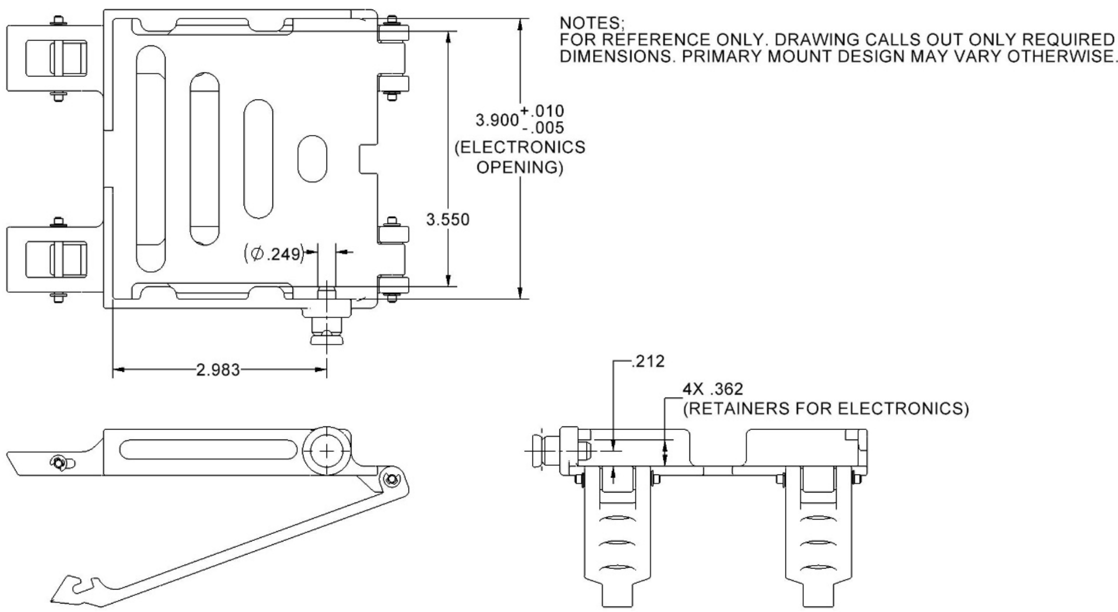


Figure 3-11. MPu-compliant Holster Primary Mount Interface

3.3.3 Plate

The plate Primary Mount shall be designed to provide a standard mechanical interface to support an MPu payload, minimize weight, and endure mission operations. The plate Primary Mount shall support at least one MPu payload. Supporting additional payloads is allowable, but the added size required to do so will restrict the installation flexibility on the operator's tactical kit.

The plate Primary Mount shall be designed to positively retain an MPu payload using the payload's bolted interface, securing the payload with four small bolts. An example of this is illustrated in Figure 3-12.

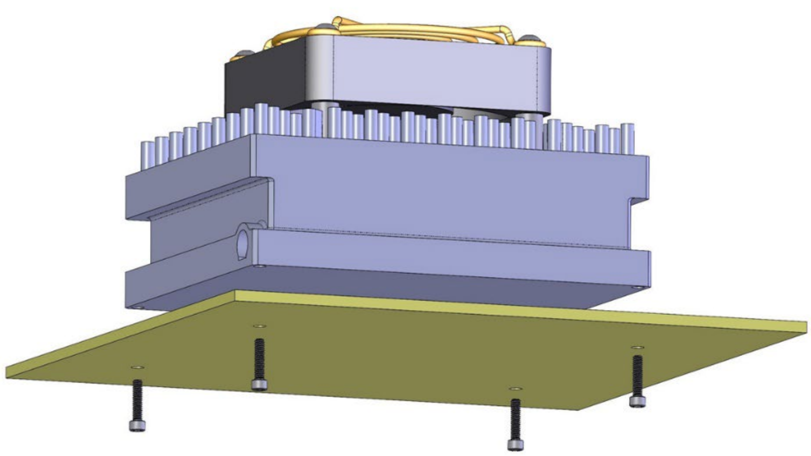


Figure 3-12. Payload Installation – Plate Primary Mount

As the plate Primary Mount must support MPu-compliant payloads, the mechanical interface for the Primary Mount is actually defined by the payload module requirements in Section 2.2.3. However, to assure the plate Primary Mount accommodates MPu-compliant payloads and reduce the design efforts of the MPu integrator, Figure 3-13 provides a reference design for an MPu-compliant plate interface.

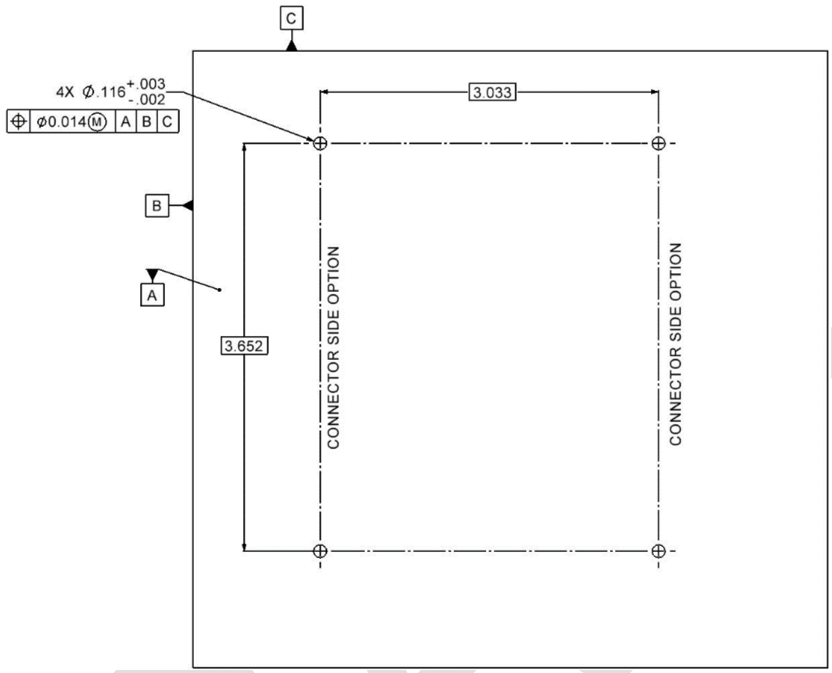


Figure 3-13. MPu-compliant Plate Primary Mount Interface

3.3.4 Thermal Dissipation

The Primary Mount is not required to provide forced air cooling to the payload. If a payload requires additional cooling to meet its operational temperature requirement (Section 2.3), the payload shall provide its own fan (Section 2.3.3). As such, the responsibility of thermal control on the A-kit is solely the Fan power feed.

For an sUAS application, as an alternative to requiring the use of the payload fan, the Primary Mount can be designed to leverage airflow from platform motion. To do so, the Primary Mount shall expose the payload heatsink to the airstream, either directly (ideally) or indirectly such that a minimum airflow of 5.7 CFM at no greater than 45°C over the inlet cross-sectional area of the payload heatsink is provided.

Note: the 5.7 CFM requirement applies only over the payload heatsink cross-sectional area not over the whole cross-sectional area of the Primary Mount. If exposing the heatsink directly to the airstream, the 5.7 CFM requirement should be easily met by the forward motion of the platform, as this equates to 1 m/s airspeed. If mounting internally, the total airflow through the Primary Mount will likely need to be significantly higher to achieve the 5.7 CFM over the heatsink cross-sectional area, as most of the airflow will pass through the unoccupied space around the Primary Mount.

3.3.5 Accessibility

When supporting a payload, a Primary Mount shall provide a means for installation / removal of the payload without affecting other adjacent systems, i.e., removal of an individual module shall not require removal of an adjacent module.

3.3.6 Additional Requirements

The Primary Mount shall survive loading, shock, and vibration commensurate with dismount operations. Additionally, Section 2.5 defines the requirements for MPu-compliant payloads, the MPu integrator should reference these requirements for further guidance.

3.4 EUD

An EUD shall be provided as part of the MPu A-kit. The EUD is the operator interface to the Hub and the payloads. The EUD shall be a DoD-approved phone or tablet, e.g., a Samsung S20 Tactical Edition. The EUD shall be housed in a ruggedized case sufficient to survive the dismount operations and shall be provided with a mount to attach to the chest of the operator's plate carrier, as shown in Figure 3-14.

Figure 3-14. EUD in a Ruggedized Case Installed on a Plate Carrier

3.5 Antenna Mounts

As part of the MPu architecture, antenna mounts shall be added to the operator's tactical kit to accommodate payload antennas. Antenna mounts are the A-kit (dismount) side of the MPu antenna interface, while antenna adaptors (defined in Section 2.4.3.2) are the B-kit (payload) side of the MPu antenna interface. Potential antenna mount locations (Figure 3-15) on a dismount operator include the front, back or shoulder strap of the plate carrier or on a supplemental, telescoping mast, provided as part of the A-kit, which attaches to the plate carrier.

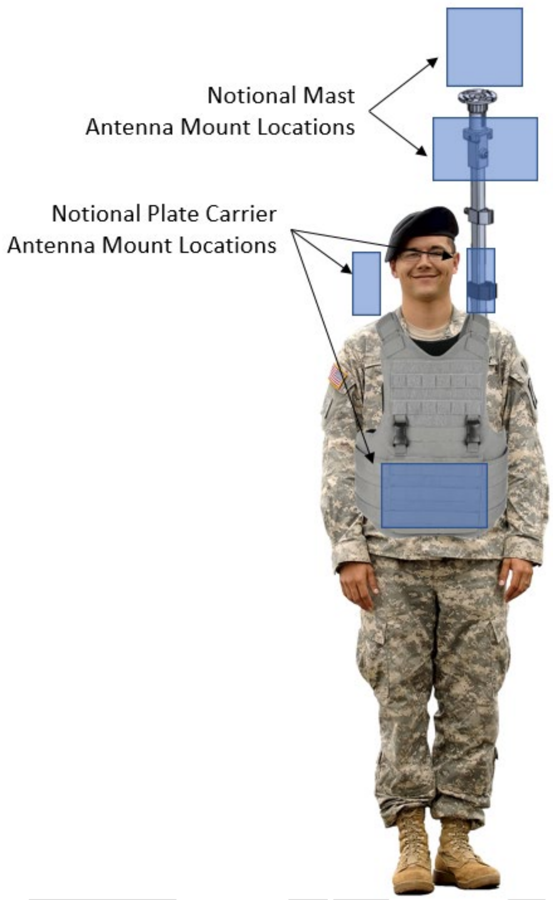


Figure 3-15. Potential Mount Locations

3.5.1 Antenna Mount Requirements

Four types of antenna mounts are currently supported by the MPu architecture:

- MP class two-point (2-pt) mounts for smaller antennas
- MP class four-point (4-pt) mounts for larger antennas
- A new twist mount for smaller antennas
- a new array mount for multi-antenna arrays.

Antenna mounts should be customized depending on install location, but a common mechanical interface is mandated for any antenna mount.

CAUTION: Antenna mounting is arguably the most challenging part of dismounted A-kit design. In isolation, it is often possible to get a custom antenna onto a person in a way that is both pleasing from the operator perspective and also effective to the technical performance of the antenna. However, the need for flexibility within a modular standardization effort like MPu makes this exceptionally challenging. As such, this section is an area of Vol III which could very likely see change between this DRAFT and final.

3.5.1.1 Configurations

At a minimum, a MPu A-kit should provide antenna mounts to support the following antenna configurations:

- 1 up look mast mount (2-pt or 4-pt)
- 1 forward look mast mount (2-pt or 4-pt)
- 1 up look mount and 1 forward look mount, concurrently (twist)
- 1 up look plate carrier mount (2-pt or twist)
- 1 forward look plate carrier mount (2-pt or 4-pt or twist)
- 1 array mast mount

These configurations are driven by the antenna requirements of the various MPu-compliant payloads and the flexibility needed to support various tactical kit configurations. All configurations need not be supported concurrently.

3.5.1.2 Two-Point Mount

2-pt mounts, as shown in Figure 3-16, are the simplest and most common MPu antenna mount. 2-pt mounts should be used to support small MP class antennas.

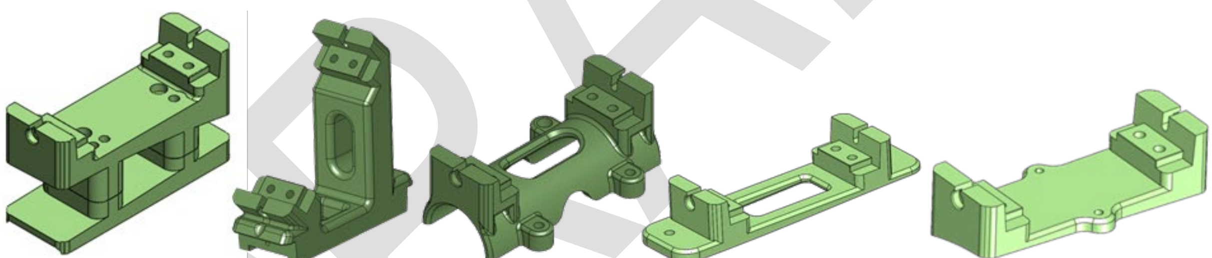


Figure 3-16. Example MP-compliant 2-pt Mounts

The 2-pt antenna mount interface is defined in Figure 3-17. A-kits 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.

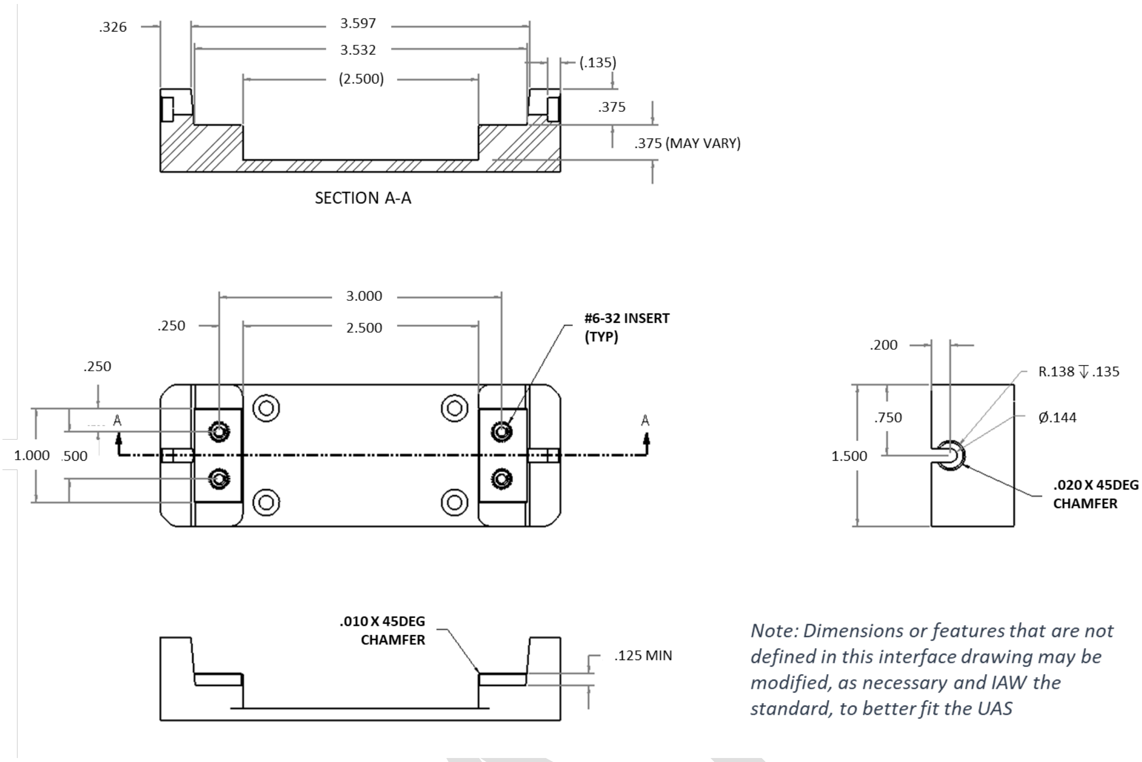


Figure 3-17. MP-compliant 2-pt Antenna Mount Interface

Though shown with a flat base in Figure 3-17, the antenna mount interface is only defined by the opposing facets and the separation between them. As evidenced in Figure 3-16 above, the requisite 2-pt mount interface should be incorporated into a mount to best conform to installation on a dismounted operator. Specifically, to install to the front or back of the plate carrier, the antenna mounts shall also include a MOLLE interface on the face opposite the antenna mount interface.

3.5.1.3 Four-Point Mount

A 4-pt mount, as shown in Figure 3-18, is simply a pair of 2-pt mounts. 4-pt mounts should be used to support larger MP class antennas.

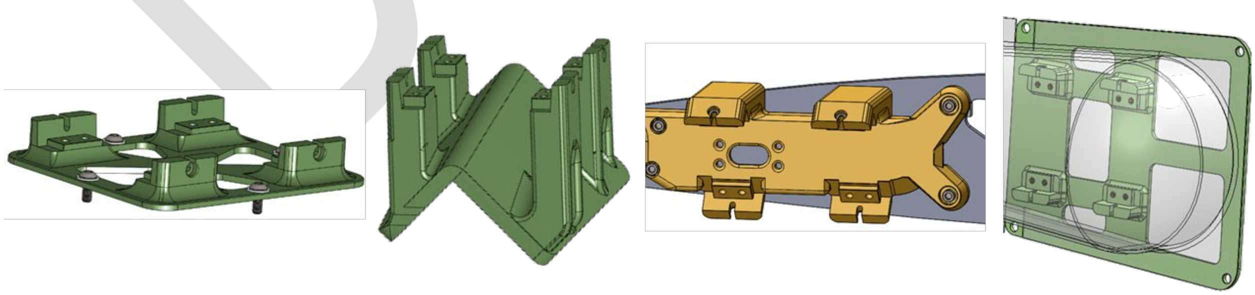


Figure 3-18. Example MP-compliant 4-pt Mounts

The 4-pt antenna mount interface is defined in Figure 3-19. A-kits 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.

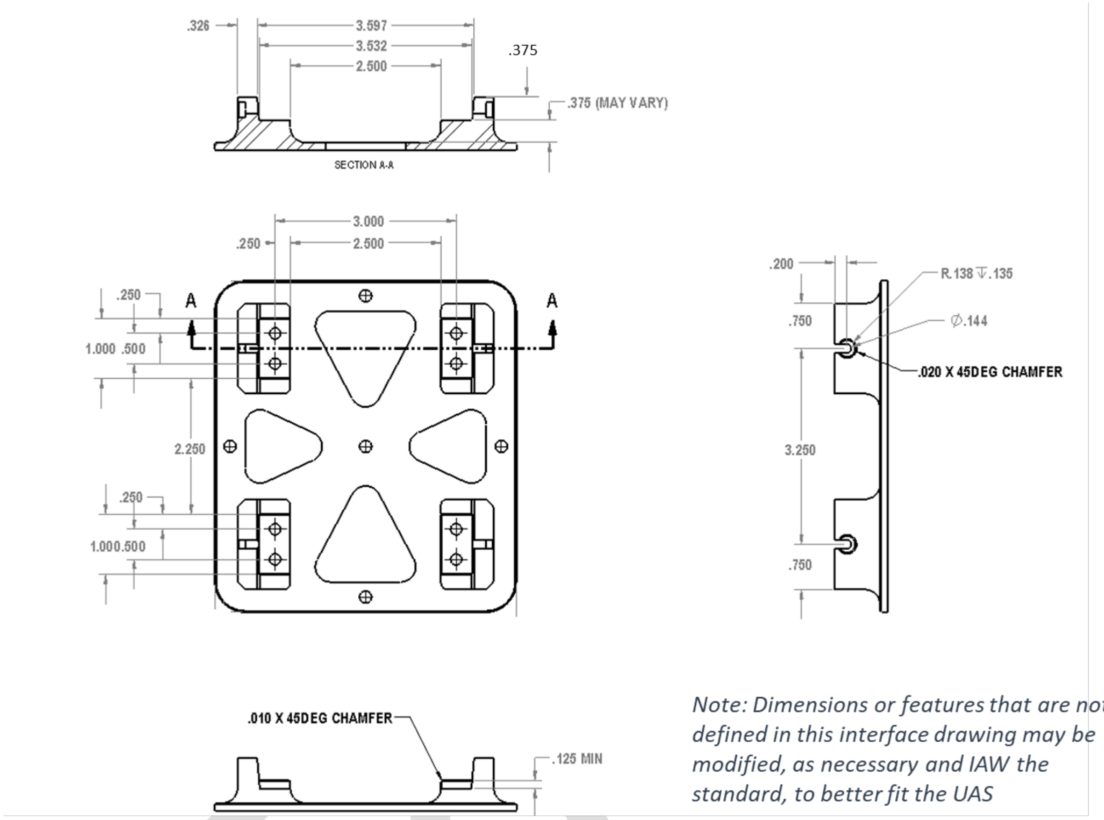


Figure 3-19. MP-compliant 4-pt Mount Interface

Though shown with a flat base in Figure 3-19, the antenna mount interface is only defined by the facets and the separation between them. As evidenced in Figure 3-18 above, the requisite 4-pt mount interface should be incorporated into a mount to best conform to installation on a dismounted operator. Specifically, to install to the front or back of the plate carrier, the antenna mounts shall also include a MOLLE interface on the face opposite the antenna mount interface.

3.5.1.4 Twist Mount

The twist mount, as shown in Figure 3-20, is a new antenna interface developed to better support dismount operations. The twist mount allows for rapid, tool-less, one-hand installation of antennas.

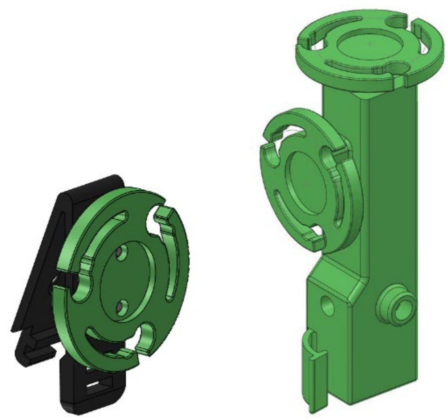


Figure 3-20. Example MPu-compliant Twist Mounts

The twist antenna mount interface is defined in Figure 3-21. Twist mounts should be fabricated from 3D-printed Nylon 12, Onyx or other material with similar mechanical properties and UV resistance.

Note: a deliberate, slight interference fit is used to attach a twist adaptor to its mount. The three slots in the mount are nominally 0.010in deeper and 0.010in narrower than the height and diameter of the mating posts on the adaptor. This interference compresses the 3D-printed adaptor / mount material to provide a secure fit.

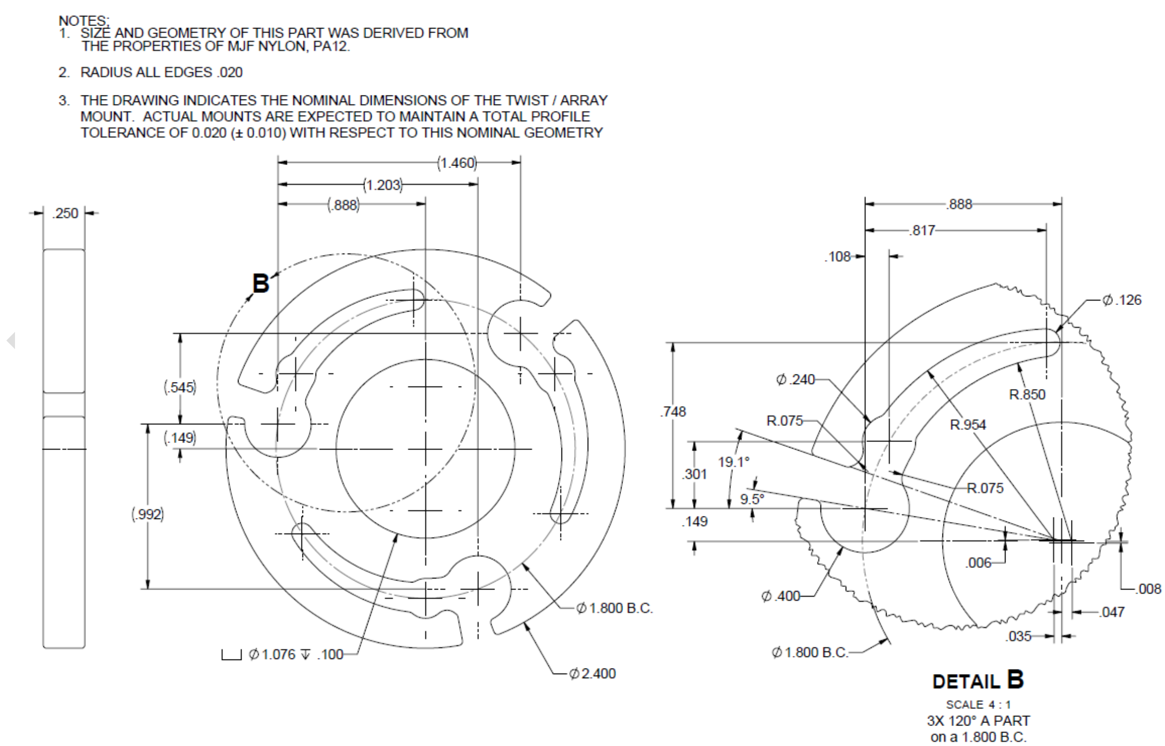


Figure 3-21. MPu-compliant Twist Mount Interface

Though shown with a flat base in Figure 3-21, the antenna mount interface is only defined by the top surface and the three slots (size, shape and the separation between them). As evidenced in Figure

3-20 above, the requisite twist antenna mount interface can be implemented to support either plate carrier or mast installations. To install to the front or back of the plate carrier, the antenna mounts shall also include a MOLLE interface on the face opposite the antenna mount interface

3.5.1.5 Array Mount

As an electro-mechanical interface, the array mount is the most complicated MPu antenna mount. An array mount should be used to support body-worn payloads requiring a multiple antenna array. The array interface pairs a multi-conductor Mighty Mouse (Glenair 803-001-06NF12-203AN) with a modified twist antenna mount. The array mount interface is defined in Figure 3-22.

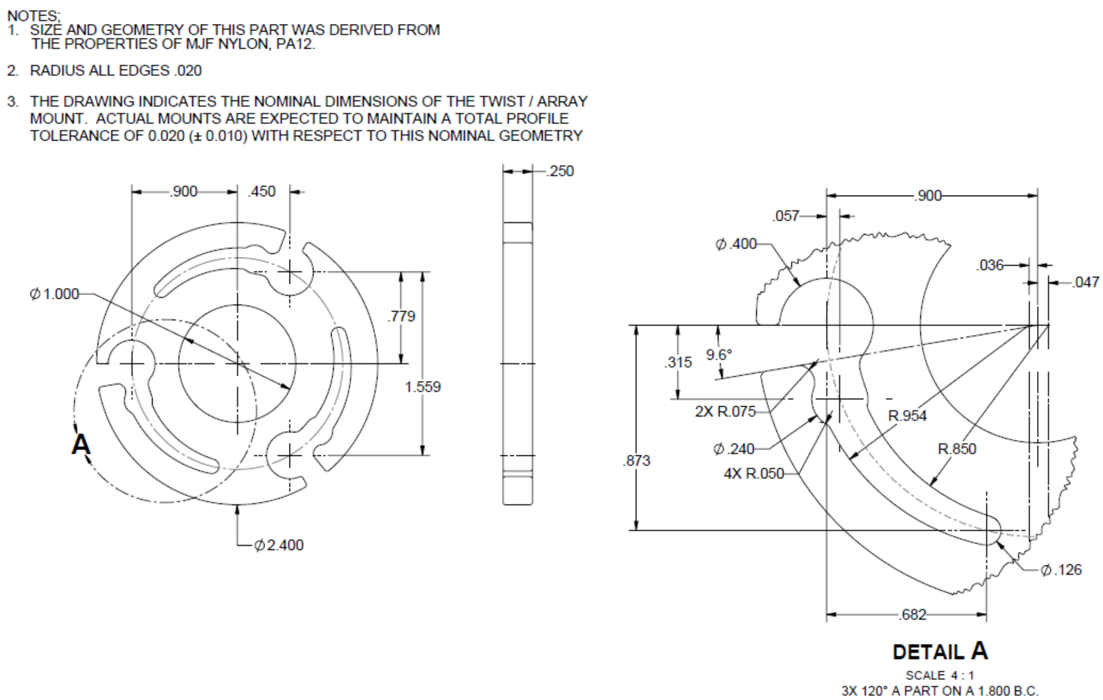


Figure 3-22. MPu Array Antenna Mechanical Interface

Though shown with a flat base, the antenna mount interface is only defined by the top surface and the three slots (size, shape and the separation between them). Array mounts should be fabricated from 3D-printed Nylon 12, Onyx or other material with similar mechanical properties and UV resistance.

Note: a deliberate, slight interference fit is used to attach an array adaptor to its mount. The three slots in the mount are nominally 0.010in deeper and 0.010in narrower than the height and diameter of the mating posts on the adaptor. This interference compresses the 3D-printed adaptor / mount material to provide a secure fit.

The requisite array antenna mount interface should be implemented to support a mast installation.

The Mighty Mouse connector is not depicted in the array mount interface, as the connector simply passes through the center of the mount and is connected to the payload antenna. The RF cable is then fed back through the hole in the mount and the antenna adaptor is then mated to the mount using the mechanical twist interface.

3.6 Cabling

3.6.1 Hub Cabling

A number of cables will need to run to/from the Hub. These cables include the interfaces to the battery, the INS, the EUD and the payloads. All Hub cables should be permanently installed onto the operator's plate carrier at appropriate locations as determined by the operator. All cables shall be built to an IP68 rating to survive the environmental conditions of the dismount operations.

3.6.1.1 Hub-Battery Cables

The Hub-battery cable(s) shall provide power to the Hub from the battery (or batteries) as required to support the MPu A-kit.

The specific connectors and pinouts on the Hub side for the Hub-battery cables are at the discretion of the MPu integrator; the battery side is dictated by the battery, which is also selected at the discretion of the MPu integrator.

3.6.1.2 Hub-INS Cable

The Hub-INS cable shall provide power to and bi-directional communications to/from the INS.

The specific connector and pinout on the Hub side for the Hub-INS cable are at the discretion of the MPu integrator; the INS side is dictated by the INS, which is also selected at the discretion of the MPu integrator in accordance with Section 3.2.

3.6.1.3 Hub-EUD Cable

The Hub-EUD cable shall provide power to and bi-directional communications to/from the EUD.

The specific connector and pinout on the Hub side for the Hub-INS cable are at the discretion of the MPu integrator; the EUD side is dictated by the EUD case, which is also selected at the discretion of the MPu integrator.

3.6.1.4 Hub-Payload Cables

The Hub-payload cable(s) shall provide all interfaces to the payload as identified in Section 3.1.3. A Hub-payload cable should be run for each payload the Hub can support and be positioned such that connection to the payload can be achieved rapidly.

The specific connectors and pinouts on the Hub side for the Hub-payload cables are at the discretion of the MPu integrator. For MPu payloads, the Hub-Payload cable shall terminate at the payload in 24-pin Fischer MiniMax connector (MP11ZL08 0420 AN1 Z1AS-1), using the pinout defined in Table 3-6.

Table 3-6. Hub-Payload Connector Pinout

Signals & Direction Relative to Payload					
Pin	*Direction*	*Pin Type*	*Signal Type*	*Signal Name*	*Description*
1	OUT	Socket	RS232	Console_TX	Console RS232
2	GND	Socket	GND	GND	DC/signal GND
3	IN	Socket	RS232	State_RX	State RS232
4	GND	Socket	GND	GND	DC/signal GND
5	IN	Socket	RS232	Console_RX	Console RS232
6	GND	Socket	GND	GND	DC/signal GND
7	X	Pin	X	N/C	Unused
8	X	Pin	X	N/C	Unused
9	X	Socket	X	N/C	Unused
10	X	Socket	X	N/C	Unused
11	IN	Pin	24VDC-PWR	Fan_Power	24V Fan Power
12	GND	Pin	GND	GND	Fan Power GND
13	IN	Socket	LVDS	Zeroize+	Zeroize Positive Signal
14	GND	Socket	GND	GND	Second Power Channel GND
15	IN	Socket	ETHERNET	Ethernet_RX-	Ethernet Rx-
16	IN	Pin	ETHERNET	Ethernet_RX+	Ethernet Rx+
17	IN	Pin	28VDC-PWR	SecondaryPower_28V	Secondary Power 28V
18	OUT	Pin	ETHERNET	Ethernet_TX-	Ethernet Tx-
19	OUT	Socket	ETHERNET	Ethernet_TX+	Ethernet Tx+
20	GND	Socket	GND	GND	Primary Power Channel GND
21	IN	Socket	LVDS	PPS+	PPS Positive Signal
22	IN	Pin	LVDS	PPS-	PPS Negative Signal
23	IN	Pin	28VDC-PWR	PrimaryPower_28V	Primary Power 28V
24	IN	Pin	LVDS	Zeroize-	Zeroize Negative Signal
Shield	GND	Case	GND	Enclosure_GND	Shield to enclosure

3.6.2 RF Cabling

A minimum of one RF cable shall run from the Primary Mount location to the top of the mast and to any other support antenna mount location. A minimum of three RF cables shall run from the Primary Mount location to the top of the mast. All RF cables should be permanently installed onto the operator's plate carrier at appropriate locations as determined by the operator.
Note: If needed, swapping out RF cables when switching between the MPu and Legacy MP configurations, is acceptable.

RF cabling shall be built to an IP68 rating to survive the environmental conditions of the dismount operations. RF cabling should be lightweight and flexible to minimize burden on the operator, yet rugged enough to endure dismount operations.

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. Additionally, the three cables run to the array interface should be phase-matched to within 0.5° per GHz (the three cables should have an electrical length within 0.41 mm of each other). The actual phase-match shall be measured and documented by the MPu integrator to be provided to payload vendors, as needed.

Note: Expanding the A-kit RF cables to cover frequencies greater than 6 GHz is under investigation and will be addressed in a future revision. In the interim, if an A-kit vendor intends to support frequencies greater than 6 GHz, cables should be selected to minimize attenuation at those higher frequencies while balancing the impact to the operator.

To support MPu payloads using a twist, 2-pt or 4-pt antenna, RF cables shall terminate in TNC-male at both the payload and the antenna mount. For MPu payloads using an array antenna, RF cables shall terminate in TNC-male at the payload and in a multi-pin (male) Mighty Mouse connector (Glenair 803-001-06NF12-203AN) at the antenna mount.

Note: TNC connectors are only rated up to 18 GHz. An alternate connector for higher frequency signals is under investigation and will be addressed in a future revision. In the interim, if an A-kit vendor intends to support frequencies greater than 12 GHz, suitably-rated RF cables should be terminated SMA-male on the payload side.

To support Legacy MP payloads using a twist, 2-pt or 4-pt antenna, RF cables shall terminate in SSMB-female at the payload and in TNC-male at the antenna mount. For Legacy MP payloads using an array antenna, RF cables shall terminate in SSMB-female at the payload and in a multi-pin (male) Mighty Mouse connector (Glenair 803-001-06NF12-203AN) at the antenna mount.

3.7 Grounding

The MPu grounding scheme must be carefully designed to eliminate ground loops. The chassis ground should only have a single connection path to the Hub. Payloads should maintain isolation between all payload ground returns (power, signal and RF) and the chassis ground (refer to Section 2.1.6). The Hub is therefore responsible for tying these grounds together. As the power and signal grounds are collocated within the Hub, it is the logical point to make these grounds common and tied to chassis ground.

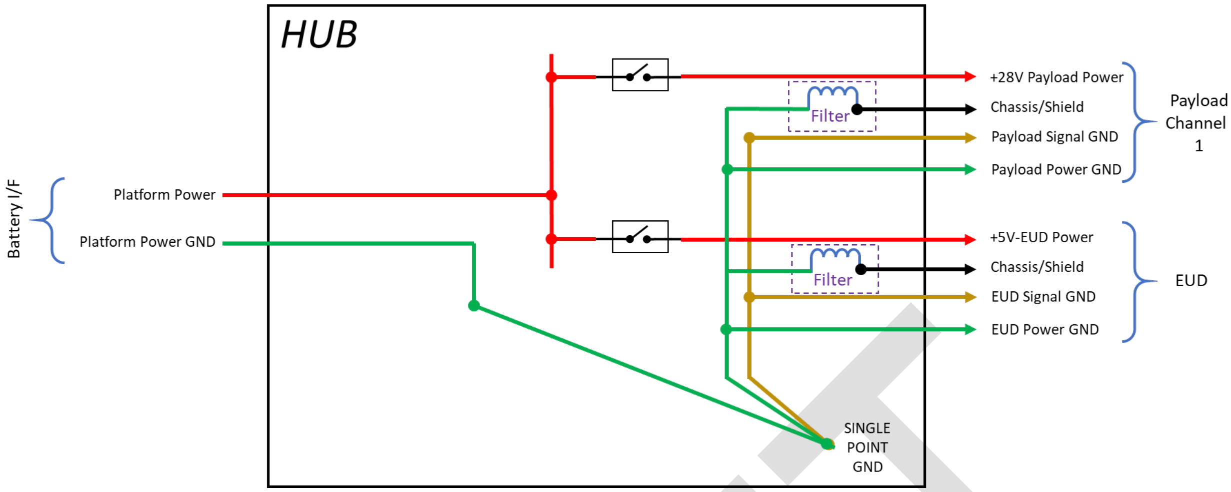


Figure 3-23. Hub Grounding Scheme

Cable shielding is an area of particular concern in order to minimize EMI. All shielded Hub cables should have the shield referenced to the above common ground at the Hub. All shielded RF cables should have the shield referenced to chassis ground via the payload chassis connection to the Hub. There shall be no current flow in the shield.

To prevent additional connections to chassis ground, antenna mounts shall be made of non-conductive materials.

4. REQUIREMENTS FOR UNMANNED AND OTHER PLATFORMS

This section is currently just a placeholder to indicate that MPu will be expanded to support small uncrewed systems in the next update to this standard (Revision 7.0). It should be anticipated that some MPu requirements will need to be adjusted in the next release to bring MPu to these additional platforms. However, the majority of the Sections 2 and 3 of this Volume should still be applicable.

5. IMPLEMENTATIONS

5.1 Prototype MPu Dismount Implementation

5.1.1 Tactical Plate Carriers

The following details the prototype MPu dismount implementation on a tactical, MOLLE-compatible plate carrier.

Note: A-kit was demonstrated on multiple tactical, MOLLE-compatible plate carriers.

5.1.1.1 Overview

The prototype MPu dismount operator A-kit can support 1 MPu payload in a custom Primary Mount holster installed on the operator's plate carrier. The dismount A-kit is configurable to support antennas on both a mast (provided as part of the A-kit) or directly to the plate carrier. A body-worn Hub, an MPu-compliant INS, an end-user device (EUD) and batteries are also required and provided.

5.1.1.2 MP Architecture

Figure 5-1 illustrates the architectural layout of the MPu dismount A-kit on a plate carrier.

Figure 5-1. MPu A-kit Layout for a Dismount

5.1.1.3 Compliance / Capability Summary

Table 5-1 provides a top-level summary of the compliance and capability of MPu dismount A-kit.

Table 5-1. Dismount A-kit Compliance and Capability

MPu Components	**Location**		
Hub	On Plate Carrier (operator's discretion)		
Primary Mount	On Plate Carrier (operator's discretion)		
INS	Mast or Mid-back (if no mast)		
Payload Capacity	**Description**		
Number of Payloads	1		
Available Payload Power	56W		
Available Payload Volume	MPu		
Available Payload Weight	N/A		
Primary Mount			
Mounting Method	Pinned		
Cooling Method	Convection		
Antenna Mounts	**Qty**	**Location**	**Orientation**
Twist	2 1 1	Mast Shoulder Strap Plate Carrier Chest	Up and Forward Up Forward
Two-point	1 1 1	Mast Shoulder Strap Plate Carrier Chest	Up or Forward Up Forward
Four-points	1 1	Mast Plate Carrier Chest	Up or Forward Forward
Array	1	Mast	Any

5.1.1.4 System Diagram

Figure 5-2 details the MPu system diagram for the dismount operator's plate carrier.

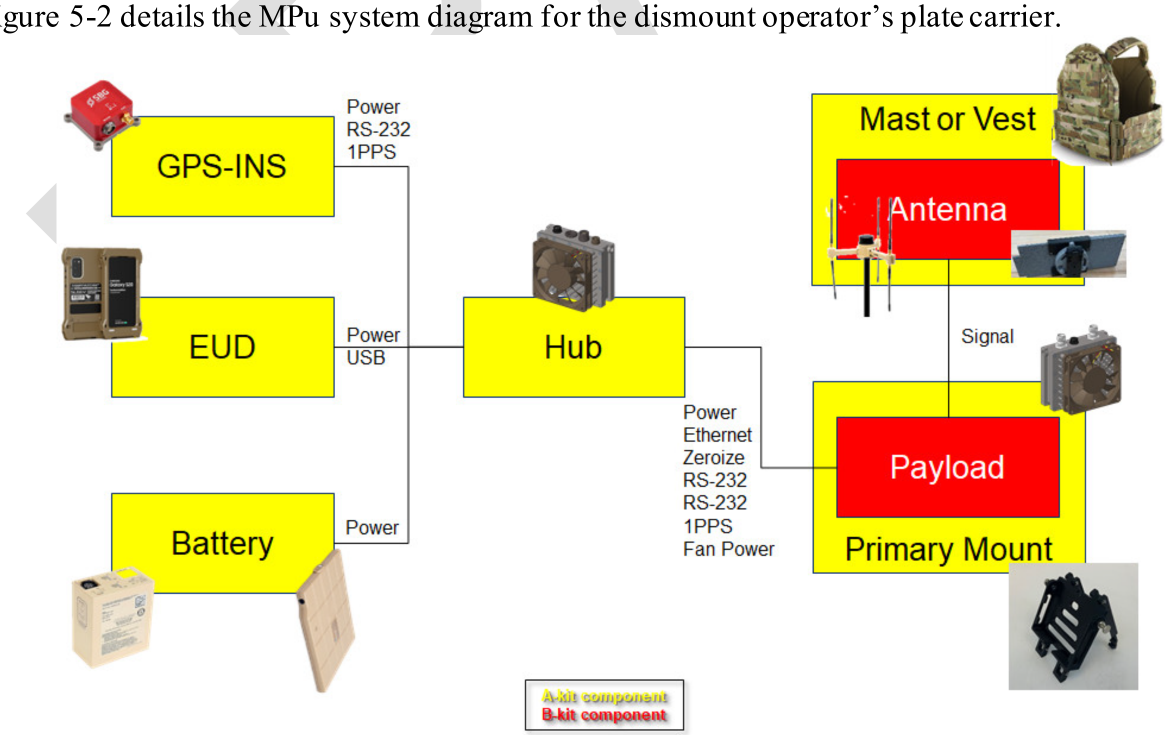


Figure 5-2. MPu System Diagram for a Plate Carrier

5.1.2 Platform Weight and Power Budgets

A dismount operator's plate carrier is already heavily burdened with a variety of other operationally necessary tactical gear; thus, it is limited in size, weight and power capacity.

5.1.2.1 Weight Budget

There is no specific total weight budget for payloads for the plate carrier; however, as this is body-worn gear that will be worn operationally, weight must be minimized.

5.1.2.2 Power Budget

The Hub for the MPu dismount A-kit can provide 56W power for the payload when the A-kit is using a UB-2590 battery or 50W power for the payload when using BB-2525u battery. Both types of battery are supported by the prototype MPu dismount A-kit. An additional 10W of power is provided for fan power.

5.1.3 Hub

The Hub is a custom circuit board housed in a custom enclosure. The Hub is mounted into a Primary Mount holster that attaches to the plate carrier.

5.1.3.1 Mechanical Description

For design commonality, the Hub (Figure 5-3) enclosure adheres to the MPu payload definition.

Note: this was only done to reduce the design effort, this form factor should not be used for production Hubs.

Figure 5-3. Prototype Plate Carrier Hub

5.1.3.2 Electrical Description

The Hub is a custom PCB designed specifically for a dismount operator and to support full MPu functionality. The core of the Hub is TM4C1294 microcontroller. As depicted in Figure 5-4, the microcontroller along with an Ethernet switch, serial transceivers, USB converter and power regulation and sense circuitry allow the MAIM to interface to both the platform and payloads. The Hub itself draws ~13W (including the power to charge the EUD).

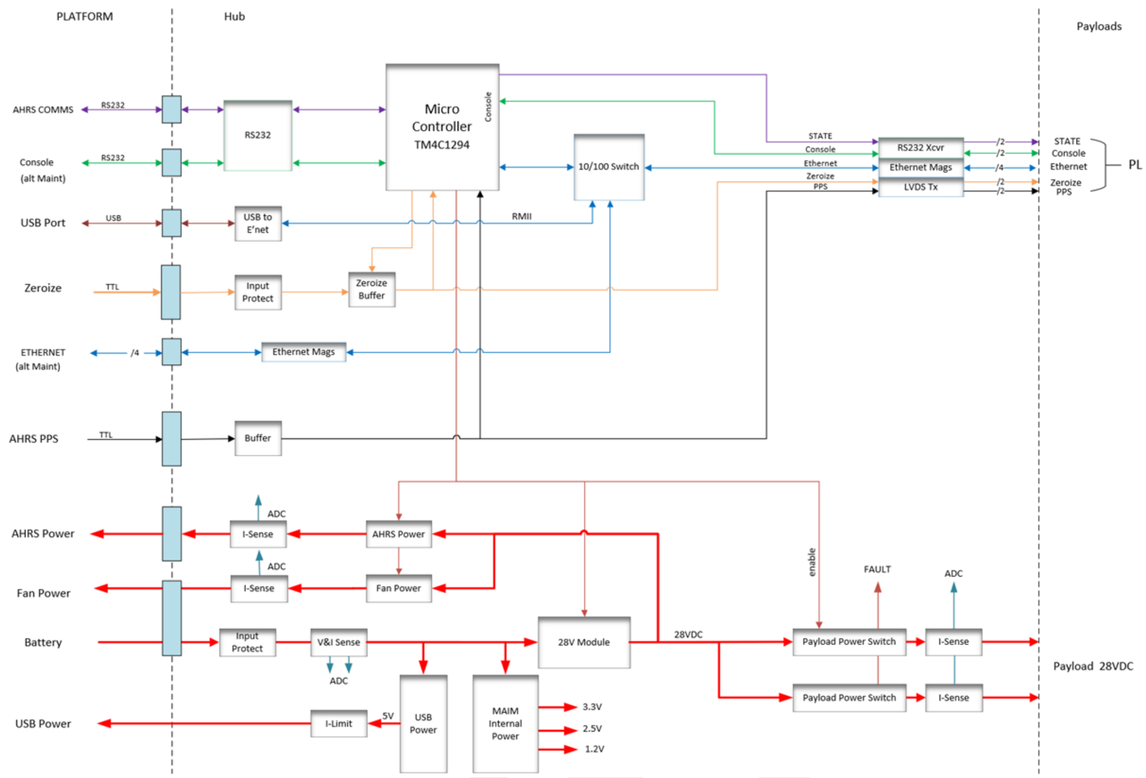


Figure 5-4. MPu Dismount Hub Block Diagram

5.1.3.2.1 Power Input

The Hub supports one 12-34VDC battery input. The Hub provides reverse polarity, over-voltage, under-voltage, and transient voltage suppression protection on all power inputs. The Hub can also be powered externally though the maintenance port.

5.1.3.2.2 Payload Interfaces

The Hub supports one payload with a fully MPu-compliant interface. As required by the standard, the payload interface provides payload power, fan power, a state serial interface, a console serial interface, an Ethernet interface, a 1PPS signal, and a zeroize signal. The Hub provides 28VDC and limits the maximum current draw to 2A for the payload and an additional 500mA at 24VDC for the fan.

5.1.3.2.3 INS Interface

The Hub provides power and bi-directional serial communications to the MPu-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.

5.1.3.2.4 Maintenance Interface

The Hub 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.

5.1.3.2.5 Platform Specific Interfaces

For the dismount MPu system, the operator will use a Samsung S20TE to monitor and control the Hub and payload. To support this, the Hub provides a USB-C interface to communicate with and charge the phone EUD.

5.1.3.3 Hub Integration

The Hub is installed into a Primary Mount holster, which is installed to the plate carrier via MOLLE straps (Figure 5-5).

Figure 5-5. Hub Installed on the Primary Mount

5.1.4 Primary Mount

The Primary Mount for the plate carrier is a holster installed via MOLLE straps and capable of supporting a single MPu payload.

Figure 5-6. MPu Primary Mount Holster

5.1.4.1 Mechanical Description

The Primary Mount is an aluminum assembly that is 4.2in x 5.1in x 0.9in and weighs ~175g. The Primary Mount assembly is detailed in Figure 5-7.

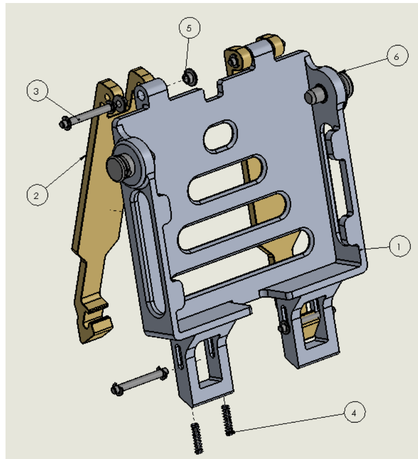


Figure 5-7. MPu Holster Primary Mount Assembly

5.1.4.2 Installation

The Primary Mount is installed into the plate carrier via MOLLE straps (Figure 5-8). Once the Primary Mount is installed into the plate carrier, payloads can be installed into the holster, sliding in from the top of the holster and retained by a pin on the side of the holster (Figure 5-9).

Figure 5-8. MPu Holster Installed on Plate Carrier

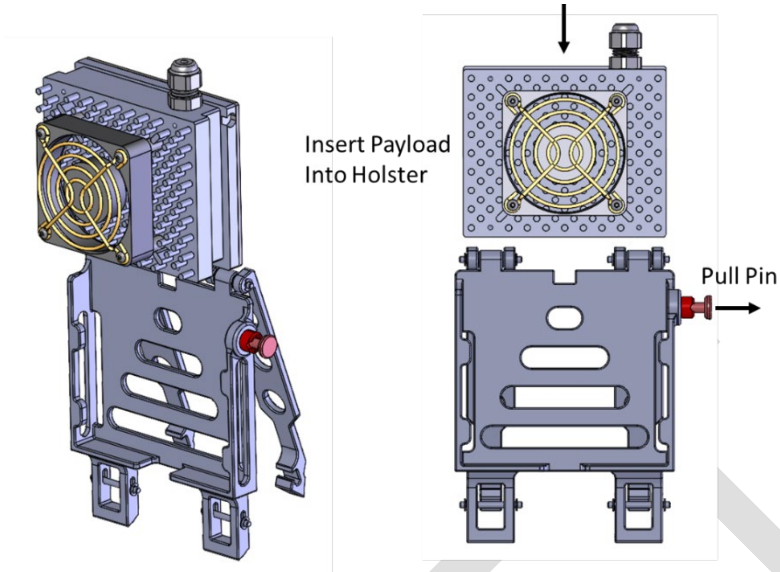


Figure 5-9. Payload Installation into the Holster

5.1.4.3 Thermal

The Primary Mount should be installed on an external surface of the plate carrier such that payloads are exposed to ambient air. No other thermal considerations are required of / provisioned by the holster.

5.1.5 INS

An SBG ELLIPSE2-N-G4A3-B1 INS is used for the MPu dismount A-kit. When the mast is used, the INS is installed to it, as shown in Figure 5-10, to assure alignment to any mast-mounted antenna. If the mast is not used, the INS is installed directly to the plate carrier at the center of the operator's back via MOLLE straps. The INS uses a GNSS antenna mounted to a shoulder strap of the plate carrier.

Figure 5-10. Mast-mounted INS Location

5.1.6 Antenna Mounts

The MPu dismount A-kit supports antenna mounts in two locations: on its mast and directly to the plate carrier. Whenever possible, mast antenna mounts should be employed to improve payload performance.

5.1.6.1 Mast Antenna Mounts

A lightweight mast is provided as part of the dismount A-kit to raise payload antennas, increasing their line of sight. The mast is installed to the back of the plate carrier via MOLLE straps. The body-worn mast supports any one of the following antenna mounts:

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

Prior to the mission, the desired mast mount should be selected and installed atop the mast (along with any antenna). Figure 5-11 shows all mast mount options.

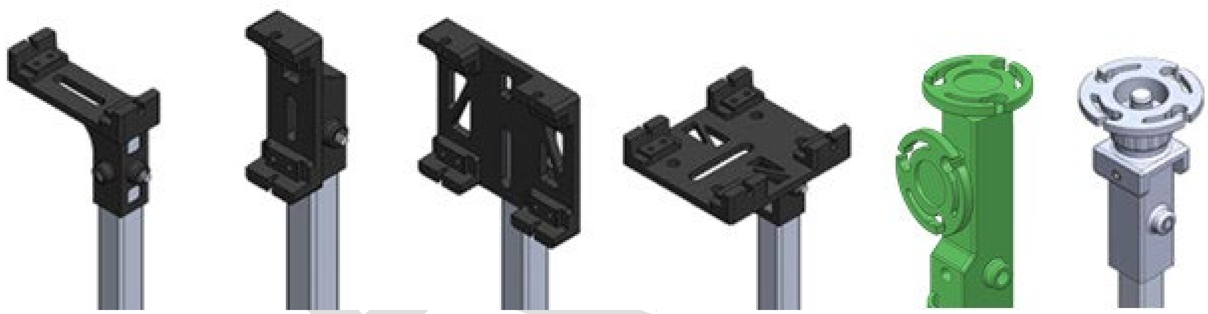


Figure 5-11. Mast Antenna Mount Options

The twist and array mounts provide the antenna interfaces as defined for the MPu class, while the 2-pt and 4-pt mounts provide the antenna interfaces as defined for the MP class. The mast mount antenna capacity is defined in Table 5-2.

Table 5-2. Mast Antenna Mount Capacities

Antenna Mount	Max Weight	Max Volume
Array Mount	300g	12in x 12in x 12in
Twist Up Look	300g	12in x 12in x 12in
Twist Forward Look	300g	12in x 4in x 2in
2-pt Up Look	400g	12in x 12in x 12in
2-pt Forward Look	400g	12in x 4in x 2in
4-pt Up Look	600g	12in x 12in x 12in
4-pt Forward Look	600g	18in x 8in x 2in

Note: weights and volumes are rough estimates only and have not been demonstrated.

5.1.6.2 Plate Carrier Mounts

The plate carrier cans support the following antenna mounts:

- 1 up look mount (2-pt or twist)
- 1 forward look mount (2-pt, 4-pt or twist)

Prior to the mission, the desired antenna mounts should be selected and installed to the plate carrier using MOLLE straps at any location that is both suitable for payload operation and compatible with other mission-critical tactical gear. Figure 5-12 shows several plate carrier mount options.

Figure 5-12. Plate Carrier Antenna Mount Options

The twist mount provides the antenna interface as defined for the MPu class, while the 2-pt and 4-pt mounts provide the antenna interfaces as defined for the MP class. The plate carrier antenna mount capacity is defined in Table 5-3.

Table 5-3. Plate Carrier Antenna Mount Capacities

Antenna Mount	Max Weight	Max Volume
Twist Up Look	300g	4in x 4in x 8in
Twist Forward Look	300g	12in x 4in x 2in
2-pt Up Look	400g	4in x 4in x 8in
2-pt Forward Look	400g	12in x 4in x 2in
4-pt Forward Look	600g	18in x 8in x 2in

Note: weights and volumes are rough estimates only and have not been demonstrated.

5.1.7 Cabling

The schematic for all Hub cables is shown in Figure 5-13. The following sections provide further detail on each of these cables. RF cables are covered in Section 4.2.7.5.

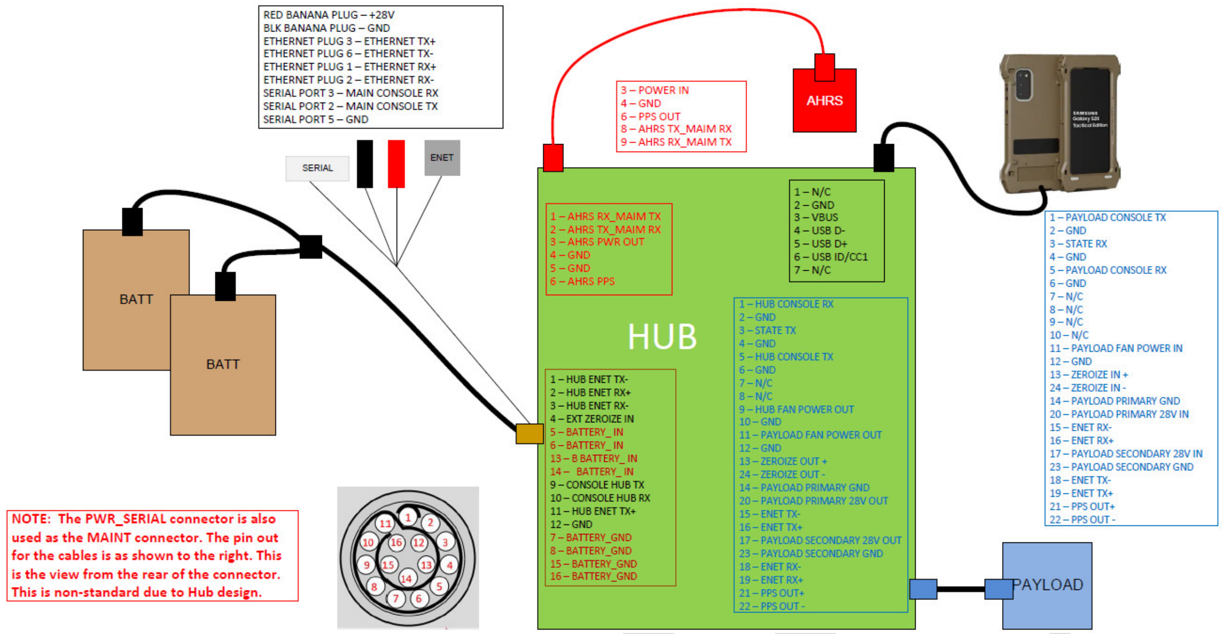


Figure 5-13. Hub Cabling Schematic

5.1.7.1 Hub-Battery Cable

As two battery options are supported by the MPu dismount A-kit, two different Hub-Battery power cables are provided. Each battery cable is a custom cable assembly terminated on one end to mate to two of the respective batteries (using the appropriate battery connector) and on the other end to the Hub using an ODU (A11YBR-P16XCDO) connector. The Hub-battery cables are 30in long. The Hub-battery cable should be run between the Hub and batteries at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.2 Hub-Payload Cable

The Hub-payload cable is a custom, straight thru cable assembly terminated at each end in the standard-defined, 24-pin Fischer MiniMax connector. The Hub-payload cable is 30in long. The Hub-payload cable should be run between the Hub and payload at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.3 Hub-INS Cable

The Hub-INS cable is custom cable assembly terminated on one end to mate to the SBG Ellipse V2 (using the appropriate ODU connector) and on the other end to the Hub using an ODU (S10YAR-P07XCDO) connector. The Hub-INS cable is 30in long. The Hub-INS cable should be run between the Hub and INS at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.4 Hub-EUD Cable

The Hub-EUD cable is COTS cable assembly (JG.CBL.QDPD.01) terminated on one end with Juggernaut SLEEV-specific USB-C connector and on the other end with a Nett Warrior connector

(Glenair 807-871-06ZNU6-6PY). The Hub-EUD cable is 30in long. The Hub-EUD cable should be run between the Hub and EUD at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.5 Payload RF Cables

RF cables are installed to support the various payload antenna options. When using the mast, a set of four RF cables should be run from the payload holster to top of the mast. When using plate carrier mounted antennas, a single RF cable should be run from the payload holster to the antenna mount location. Both cable runs are detailed in the subsequent sections.

5.1.7.5.1 RF Cable Summary Table

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

Table 5-4. Dismount A-kit RF Cable Summary

Cable	Cables Run	Length (in)	Weight (g)	Attenuation (dB)
Payload to Array Mount	3	30	60	0.46
Payload to Mast Mount (non-array)	1	30	20	0.46
Payload to Plate Carrier Mount	1	12	8	0.18
	1	24	16	0.37
	1	36	24	0.55

Note 1: Attenuation calculated for a 1GHz signal

5.1.7.5.2 Array Mount RF Cables

The array mount cable set consists of three phase-matched cables to support an antenna array. They are terminated on the payload end with 3 TNC-male connectors and on the array end with a multi-conductor Mighty Mouse (Glenair 803-001-06NF12-203AN) connector. The array mount cables are 30in long. The array mount cable should be run from the Primary Mount thru the mast to the array mount atop the mast or at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.5.3 Mast Mount RF Cable

The mast mount cable is a single (fourth mast) cable to support an up look or forward look antenna. It is terminated on both ends with a TNC-male connector. The mast mount cable is 30in long. The mast mount cable should be run from the Primary Mount thru or along the mast to the antenna mount atop the mast or at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.7.5.4 Plate Carrier RF Cable

Three RF cables of varying lengths are provided as part of the MPu dismount A-kit. Each cable is terminated on both ends with a TNC-male connector. Multiple lengths are provided to allow the operator flexibility on where to install the body-worn antenna mount. The plate carrier RF cable should be run from the Primary Mount to the selected antenna mount location at the discretion of the operator to best accommodate mission-critical tactical gear on the plate carrier.

5.1.8 Additional A-kit Components

Dismount payload operations require some additional A-kit components (not normally required on uncrewed systems) to be provided. These are discussed in the following subsections.

5.1.8.1 Batteries

Two batteries were identified as relevant for dismount operations and are supported by the MPu dismount A-kit – UB-2590 and the BB-2525u.

Figure 5-14. Dismount Battery Options: UB-2590 (left), BB-2525u (right)

The UB-2590 is a more traditional battery used in many military applications. It supports higher current draw and prolonged endurance at the expense of increased weight and bulkiness. The BB-2525u is a conformal wearable battery designed to be worn in a plate carrier; however, it provides a reduced current draw and endurance. Details are provided in Table 5-5 below.

Table 5-5. Dismount MPu A-kit Battery Comparison

Battery	Chemistry	Weight	Average Voltage	Max Current	Max Power	Energy	Duration
UB-2590	Li-ion	1.4kg	28.8V	10A	79W	250W-hr	3.2 hrs
BB-2525u	Li-ion	1.2g	14.8V	5A	73W	148W-hr	2.0 hrs

Note: Max power differs between the two batteries. The BB-2525u is limited by its max continuous current. The UB-2590 is not as constrained. Its max power equates to the max power needed for the entire MPu dismount system – 56W for the payload, 10W for the payload fan, 8W to charge the EUD and 5W to power the Hub.

5.1.8.2 EUD

As there is not an EUD native to every operator's tactical kit, a Samsung S20TE phone in a Juggernaut SLEEV case is provided as part of the MPu dismount A-kit, along with a chest-mounted MOLLE phone holder (Figure 5-15).

Figure 5-15. MPu Dismount EUD

5.1.8.3 Pouches

To support the UB-2590 batteries, two MOLLE battery pouches (BDAT BA-5590/2590) are also provided with the MPu dismount A-kit.

5.1.9 Concessions to the Standard

No concessions are required for the MPu dismount A-kit.

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.

Note: For this appendix, MAIM and PIM are used interchangeably. For the MPu, all references to MAIM within this appendix also refer to PIM.

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 through 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 uint88 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
calibrationRev	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.3.4.3 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.3.4.4 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.3.5.2 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.3.5.3 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.3.8.2 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.3.9.2 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.3.10.2 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.3.10.3 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.3.11.2 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.3.11.3 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.

In later versions of the SBG, the message with ID 36 has changed. While the message still has the pressure data, the message also contains additional information. This newer pressure message format is not supported. If the newer SBG is used, the MAIM shall convert the newer pressure message to comply to the standard message listed below.

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 NMEA message format is a text-based format that is separate from the sbgECom format, but both message formats are received over the same serial line. The implemented NMEA sentences are based on NMEA 0183 Version 4. Unlike the binary sbgECom messages, the NMEA messages are NOT contained in an sbgECom frame.

Each data field in an NMEA message is comma separated. Sometimes, a field cannot be defined and can be left empty. Any other NMEA messages received from the INS can be dropped.

A.4.1 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 parts.

Appendix B. **Acronyms and Abbreviations**

Acronyms	
ABS	Acrylonitrile Butadiene Styrene
AGIG	Airborne Global Information Grid
AHRS	Altitude and Heading Reference System
AML	Avionics Module Lower
APIM	AGIG Payload Integration Module
APM	Avionics Processing Module
AWG	American Wire Gauge
CAD	Computer Aided Design
CG	Center of Gravity
CONOPS	Concept of Operations
COTS	Commercial Off the Shelf
CUI	Controlled Unclassified Information
DA	Density Altitude
DF	Direction Finding
DoD	Department of Defense
DTIC	Defense Technical Information Center
EMI	Electro Magnetic Interference
ESD	Electrostatic Discharge
EUD	End User Device
EW	Electronic Warfare
FCS	Flight Control System
FDM	Fused Deposition Modeling
FMV	Full Motion Video
GCS	Ground Control System
GFI	Government Furnished Equipment
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GTOW	Gross Take-off Weight
GUI	Graphical User Interface
GYRO	Gyroscope
HSC	High Speed Craft
ICD	Interface Control Document
IGMP	Internet Group Management Protocol
INS	Internal Navigation System
IP	Internet Protocol
ISS	Integrated Sensor Systems
JHUAPL	Johns Hopkins University Applied Physics Lab
JSON	JavaScript Object Notation
JTWS	Joint Threat Warning System
LVDS	Low Voltage Differential Signaling
MAIM	Modular Aircraft Interface Module

MIL-STD	Military Standard
MOLLE	Modular Lightweight Load Carrying Equipment
MP	Modular Payload
MPu	Modular Payload Micro
MPx	Modular Payload Expanded Capability
MTOW	Maximum Take-off Weight
MTU	Maximum Transmission Unit
NAVAIR	Naval Air Systems Command
NMEA	National Marine Electronics Association
NUWC	Naval Undersea Warfare Center
PCB	Printed Circuit Board
PIM	Platform Integration Module
PDU	Power Distribution Unit
PMU	Power Module Unit
POC	Point of Contact
PPM	Payload Processor Module
PPS	Pulse per Second
RF	Radio Frequency
SAFC	Special Applications for Contingencies
SATCOM	Satellite Communications
SIGINT	Signals Intelligence
SMA	Sub-Miniature Type A
SMPM	Sub-Miniature Push-On Micro
SSMB	Small Sub-Miniature Type B
SUAS	Small Unmanned Aerial Systems
SWAP	Size, Weight, and Power
TDP	Technical Data Package
TIA/EIA	Telecommunications Industry Association/Electronics Industry Association
UAS	Unmanned Aircraft System
UDP	User Datagram Protocol
UI	User Interface
USB	Universal Serial Bus
USC	United States Code
USSOCOM	United States Special Operations Command
USV	Unmanned Surface Vehicle
UTC	Coordinated Universal Time
UTP	Unshielded Twisted Pair
UUV	Unmanned Underwater Vehicle
UV	Ultraviolet
UxV	Unmanned Vehicle
VCB	Vehicle Control Box
VPN	Virtual Private Network
VTOL	Vertical Take-Off and Landing
WR	Wave Relay

Unit Abbreviations

CFM	Cubic Feet per Minute
dB	Decibels
dBm	Decibel Miliwatts
GHz	Gigahertz
MHz	Megahertz
Hz	Hertz
VDC	Volts Direct Current
W	Watts

Signal Types

CTS	Clear to Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready
RI	Ring Indicator
RTR	Real Time Report
RTS	Request to Send

Appendix C. **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-348C Radio Frequency Connector Interfaces
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