HASP Payload Specification and Integration Plan

Payload Title: High Altitude X-Ray Detector Testbed (HAXDT)

Payload Class: Small Large (circle one)

Payload ID: TBD

Institution: University of Minnesota – Twin Cities

Contact Name: Hannah Weiher

Contact Phone: 612-396-0189

Contact E-mail: weih0016@umn.edu

Submit Date: June 24, 2016

I. Mechanical Specifications:

A. Estimated mass of the payload (not including payload plate). The uncertainty in the total payload mass is largely due to the estimates of the unfinished structural and hardware elements which could not be weighed directly. However, these estimates are based on SolidWorks models which take into account appropriate materials (for structural components); datasheets (for off-the-shelf components which have been ordered but not yet received); and by comparing to similar parts with known masses (for custom electrical components which have not yet been assembled). The uncertainty in the total mass represents the cumulative uncertainty in the estimates. Even in the worst case, the total payload mass remains within the 3 kg limit for a small payload.

Structural Components and Hardware		
U-Shaped Side Panel	0.31 ± 0.001 kg	Measured
Access Panel	0.104 ± 0.001 kg	Measured
Bottom Plate	0.162 ± 0.001 kg	Measured
GPS Antenna Mounting Bracket	0.025 ± 0.001 kg	Measured
PC/104 Standoffs and Hardware	0.136 ± 0.008 kg	Measured
Structure Mounting Hardware	0.054 ± 0.001 kg	Measured
Detector Components		
Detector Housing	0.282 ± 0.001 kg	Calculated
Carbon Fiber Window	0.022 ± 0.001 kg	Measured
Detector Window Clamp	0.045 ± 0.001 kg	Measured

CsI(Tl) Scintillation Crystals (4)	0.575 ± 0.001 kg	Calculated
Avalanche Photodiodes (4)	0.005 ± 0.001 kg	Calculated
Detector Preparation Materials (Silicone, Anti-Static Foam, etc.)	0.080 ± 0.001 kg	Calculated
Detector Mounting Hardware	0.047 ± 0.001 kg	Calculated
Electrical Components		
Detector Front End (Top Board)	0.077 ± 0.001 kg	Measured
Detector Front End (Bottom Board)	0.076 ± 0.001 kg	Measured
Photon Timing/Preprocessor Board	0.059 ± 0.001 kg	Measured
GPS/IMU/ATmega2560 mounting board	0.081 ± 0.001 kg	Measured
Freewave MM2 Radio	0.014 ± 0.001 kg	Measured
NovAtel OEM615 GNSS Receiver	0.021 ± 0.001 kg	Measured
NovAtel GPS Antenna	0.140 ± 0.001 kg	Measured
High Voltage Power Supply Board	0.116 ± 0.001 kg	Measured
WinSystems PPM-DC-ATX-P Power Supply	0.118 ± 0.001 kg	Measured
Total	**2.55 ± 0.029 kg**	**Calculated**

Table 1. Mass budget and total payload mass including uncertainty.

B. Provide a mechanical drawing detailing the major components of your payload and specifically how your payload is attached to the payload mounting plate

See Appendix A for dimensioned mechanical drawings and pictures of major hardware components. Included are the following:

i. Figure A1. Mechanical drawing of bottom plate of structure
ii. Figure A2. Mechanical drawing of U-shaped structural wall
iii. Figure A3. Mechanical drawing of flat structural access panel (fourth wall)
iv. Figure A4. Mechanical drawing of detector housing
v. Figure A5. Mechanical drawing of carbon fiber detector window
vi. Figure A6. Mechanical drawing of detector window clamp
vii. Figure A7. Mechanical drawing of A1 and A2 connections to mounting plate
viii. Figure A8. Mechanical drawing of full payload assembly

ix. Figure A9. Picture of detector front end board
x. Figure A10. Picture of CsI(Tl) scintillation crystal
xi. Figure A11. Picture of VectorNav VN-100 IMU
xii. Figure A12. Picture of NovAtel OEM615 GNSS receiver
xiii. Figure A13. Mechanical drawing of NovAtel GPS antenna
xiv. Figure A14. Picture of FreeWave MM2-T radio transceiver
xv. Figure A15. Picture of WinSystems PPm-DC-ATX-P power supply board

C. If you are flying anything that is potentially hazardous to HASP or the ground crew before or after launch, please supply all documentation provided with the hazardous components (i.e. pressurized containers, radioactive material, projectiles, rockets…)

No hazardous material being flown.

D. Other relevant mechanical information

The structure walls and detector housing are attached using 4-40 socket head cap screws, while the structure is attached to the HASP mounting plate with 1¼-inch long bolts with a ¼-inch diameter secured by a locknut. Rubber grommets will be mounted between the mounting plate and structure, while washers are mounted between the nuts and mounting plate.

II. Power Specifications:

A. Estimated current draw at 30 VDC

The payload's nominal current draw at 30 VDC was estimated using the measured power consumption of each of the electrical components.

NovAtel OEM 615 GNSS Receiver and Antenna	1.30 W	Measured
FreeWave MM2 Radio (Transmitting)	4.28 W	Measured
VectorNav VN-100 IMU	0.35 W	Estimated
ATmega2560	1.10 W	Estimated
Detector Front End Board (Top)	0.40 W	Estimated
Detector Front End Board (Bottom)	0.80 W	Estimated
Photon Timing/Preprocessor Board	0.25 W	Estimated
WinSystems PPm-DC-ATX-P Power Supply	0.21 W	Estimated
High Voltage Power Supply Board	0.50 W	Measured
Total	**9.19 ± 1.50 W**	**Calculated**

Table 2. Nominal power consumption for all electrical components.

Therefore, the anticipated nominal current draw at 30 VDC is **306 mA**. The power consumption of most of the electrical components in the payload will fluctuate in varying operational and environmental conditions. However, it is expected that the worst-case current draw will not exceed 357 mA. This is well below the 500 mA limit for a small payload.

B. If HASP is providing power to your payload, provide a power system wiring diagram starting from pins on the student payload interface plate EDAC 516 connector through your power conversion to the voltages required by your subsystems.

Figure 1 below shows pins A-D from the EDAC 516 connector, which provide the 30 VDC supply to our power protection and regulation circuit as schematically shown. The power is then grounded through pins T, U, W, and X on the EDAC connector. The nominal 30 VDC from the HASP batteries is fed into a commercial off-the-shelf PC/104 power supply, the WinSystems PPM-DC-ATX-P. This power supply accepts any input in the range of 10–50 VDC and provides stable rail voltages of +3.3V, +5V, +12V, and -12V.

These voltages are distributed to the electrical components in the payload using PC/104 stackthrough connectors. The ATmega2560 utilizes the +3.3V and +5V rails; the OEMStar GNSS receiver, VN-100 IMU, MM2-T transceiver, and photon timing/preprocessor board utilize the +5V rail; the detector front end electronics and high voltage power supply utilize the +12V rail; and the detector energy measurement circuitry (incorporated into the bottom front end board) utilizes the +5V, +12V, and -12V rails. The abridged datasheet for the PPM-DC-ATX-P power supply can be found in Appendix B.

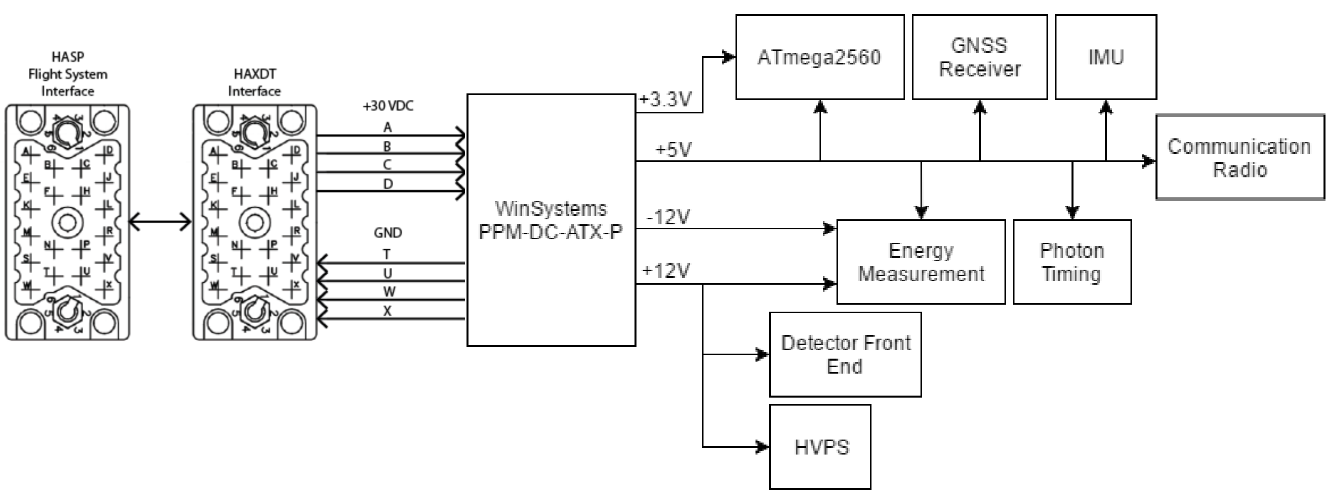


Figure 1. HASP EDAC516 connector interface with the payload power system.

C. Other relevant power information:

None.

III. Downlink Telemetry Specifications:

A. Serial data downlink format: Stream Packetized (circle one)

B. Approximate serial downlink rate (in bits per second)

The serial link is connected at 1200 baud using 8 data bits, no parity, and 1 stop bit as described in the HASP Student Payload Interface Manual. The 89 byte packet outlined below (plus serial framing bits) will be sent once every five seconds, giving a data rate of 149 bps.

C. Specify your serial data record including record length and information contained in each record byte.

Byte	Title	Description
1-2	Header	Indicates beginning of data record
3-9	GPS Time	Seconds since the beginning of the GPS week
10-18	X_Pos	Earth-centered Earth-fixed, x coordinate
19-27	Y_Pos	Earth-centered Earth-fixed, y coordinate
28-36	Z_Pos	Earth-centered Earth-fixed, z coordinate
37-45	A_Events	Cumulative number of events on detector A
46-54	B_Events	Cumulative number of events on detector B
55-63	C_Events	Cumulative number of events on detector C
64-72	D_Events	Cumulative number of events on detector D
73-78	IMU_Temp	Temperature of payload chamber, measured by IMU
79-87	Error Word	32 bits used for error flags
88-89	Footer	Indicates end of complete data record

Table 3. Downlink data packet structure.

D. Number of analog channels being used: 0

E. If analog channels are being used, what are they being used for? NA

F. Number of discrete lines being used: 0

G. If discrete lines are being used what are they being used for? NA

H. Are there any on-board transmitters? If so, list the frequencies being used and the transmitted power.

FreeWave Radio will be transmitting (as well as receiving); see IV. E below.

I. Other relevant downlink telemetry information. None

IV. Uplink Commanding Specifications:

A. Command uplink capability required: Yes No (circle one)

B. If so, will commands be uplinked in regular intervals: Yes No (circle one)

C. How many commands do you expect to uplink during the flight (can be an absolute number or a rate, i.e. *n commands per hour*) N/A

D. Provide a table of all of the commands that you will be uplinking to your payload

E. Are there any on-board receivers? If so, list the frequencies being used.

Receivers	Description	Frequency
GNSS receiver and antenna	NovAtel OEM 615	1575.42 MHz
Communication Radio and antenna	FreeWave MM2	915 MHz

Table 5. On-board receivers and frequencies used.

F. Other relevant uplink commanding information.

None.

V. Integration and Logistics

A. Date and Time of your arrival for integration:

August 1, 2016, Afternoon / Evening

B. Approximate amount of time required for integration:

Nominally 2 hours to test downlink, attach to HASP gondola, and verify data.

C. Name of the integration team leader: Hannah Weiher

D. Email address of the integration team leader: weih0016@umn.edu

E. List **ALL** integration participants (first and last names) who will be present for integration with their email addresses:

Hannah Weiher weih0016@umn.edu

Tim Kukowski kuko0037@umn.edu

Maxwell Yurs yursx002@umn.edu

Luke Granlund lgranlun@cord.edu

Aaron Nightingale takide6of8@gmail.com

F. Define a successful integration of your payload:

All payload systems power on, the flight computer successfully stores and downlinks data in a simulated flight environment and the payload resets and continues to collect data under the same simulated conditions. Test uplink commands to see that it is functioning and downlinking appropriate data. Confirm background data is collected by all four detectors and saved by the flight computer, with reasonable count rates and energy levels observed, suggesting proper operation and configuration of the systems. The IMU and GNSS receiver are verified as operational and collect reasonable data.

During the thermal/vacuum testing, GPS data, temperature data and power status will be extracted from the downlinked data packets and plotted to examine loss of data. After the test, data from the detectors which was stored on the single board computer's Compact Flash card will be examined. If no data loss occurs and the data values (background count rates and energy levels) are within reasonable ranges, then it is assumed the payload is functioning properly and the integration is a success.

G. List all expected integration steps:

i. Power on payload and monitor internal system LED's to verify proper operation.

ii. Collect data for 15 minutes.

iii. Disconnect power and review data to ensure proper data collection.

iv. Troubleshoot any issues and repeat steps ii – iii if necessary.

v. Weigh payload to ensure it does not exceed 3kg.

vi. Attach payload to HASP mock-up.

vii. Provide power and monitor current draw as well as downlink telemetry as well as radio downlink.

viii. Troubleshoot any issues and repeat steps i – vii if necessary.

ix. Attach payload to HASP gondola.

x. Connect EDAC 516 and RS-232 interfaces to payload.

xi. Perform thermal/vacuum testing.

xii. Troubleshoot any issues found during thermal/vacuum test.

xiii. Repeat thermal/vacuum test if necessary.

xiv. High-five team members (in a safe manner) for a job well done.

H. List all checks that will determine a successful integration:

i. Payload successfully interfaces with HASP gondola.

ii. Payload powers on.

iii. Power can be turned on and off to reset system.

iv. Payload successfully stores data.

v. Payload successfully transmits status packets.

vi. Payload operates (remains on, stores, transmits and receives data, and resets) in simulated environment.

vii. Status packets are analyzed and no data loss has occurred during operation.

I. List any additional LSU personnel support needed for a successful integration other than directly related to the HASP integration (i.e. lifting, moving equipment, hotel information/arrangements, any special delivery needs…):

None anticipated.

J. List any LSU supplied equipment that may be needed for a successful integration:

None required.

Appendix A: Dimensioned Mechanical Drawings and Pictures of Major Components

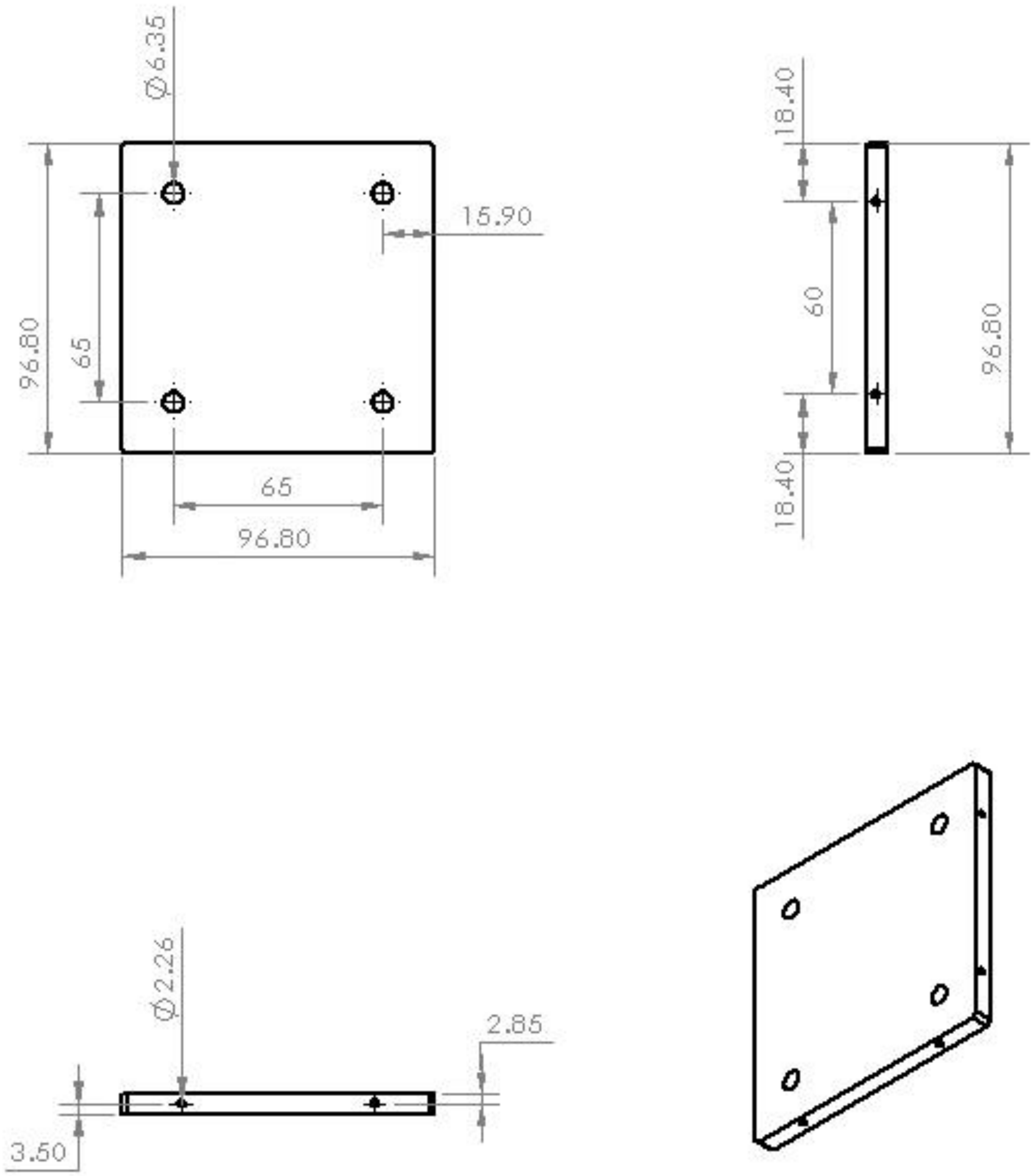


Figure A1. Mechanical drawing of the bottom plate of the structure with dimensions in millimeters. This plate attaches to the HASP mounting plate using ¼-inch diameter bolts and serves as the anchor for the U-shaped wall and access panel (see Figure A2, A3 respectively).

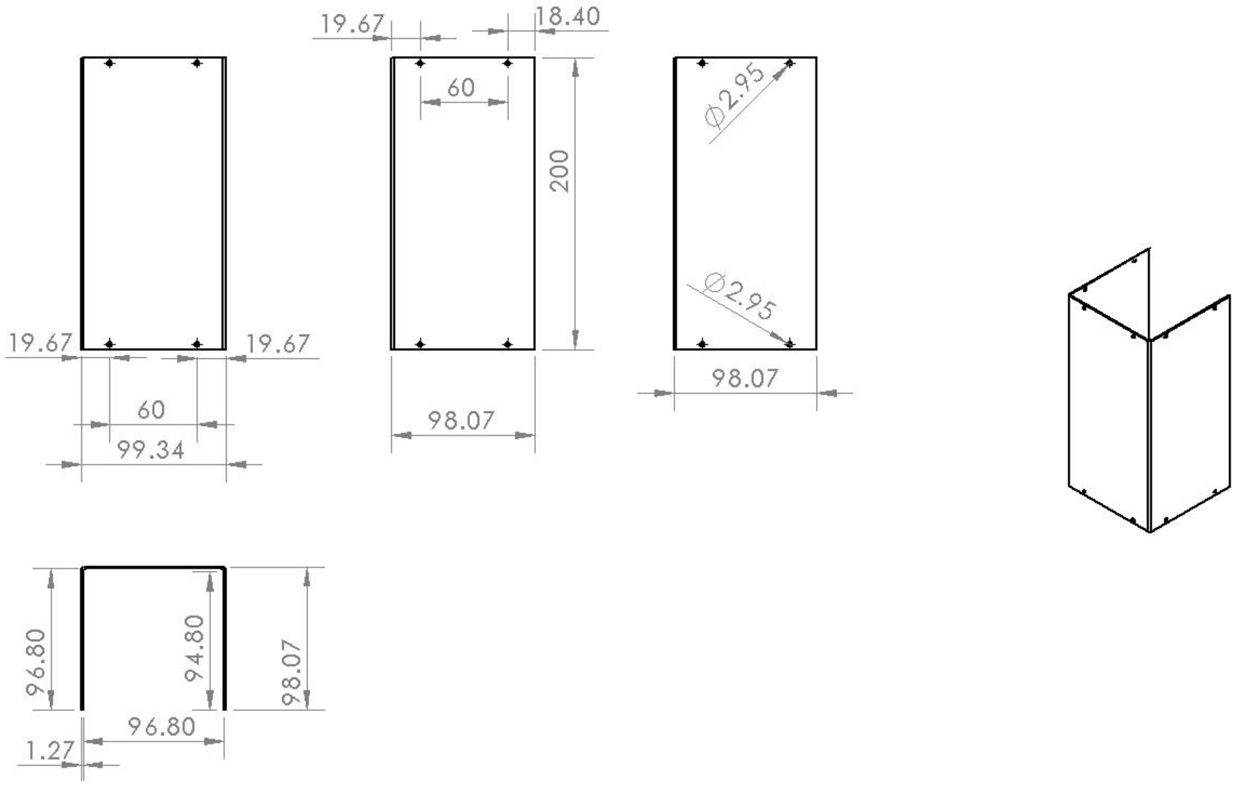


Figure A2. Mechanical drawing of the U-shaped load bearing structural wall with dimensions in millimeters. This wall is bent from a single sheet of 5052-H32 aluminum. The HASP power and downlink signals will also be routed through a connector in this wall, which is not shown here. The walls will have an outer cross section of 10x10 cm in order to simulate CubeSat constraints.

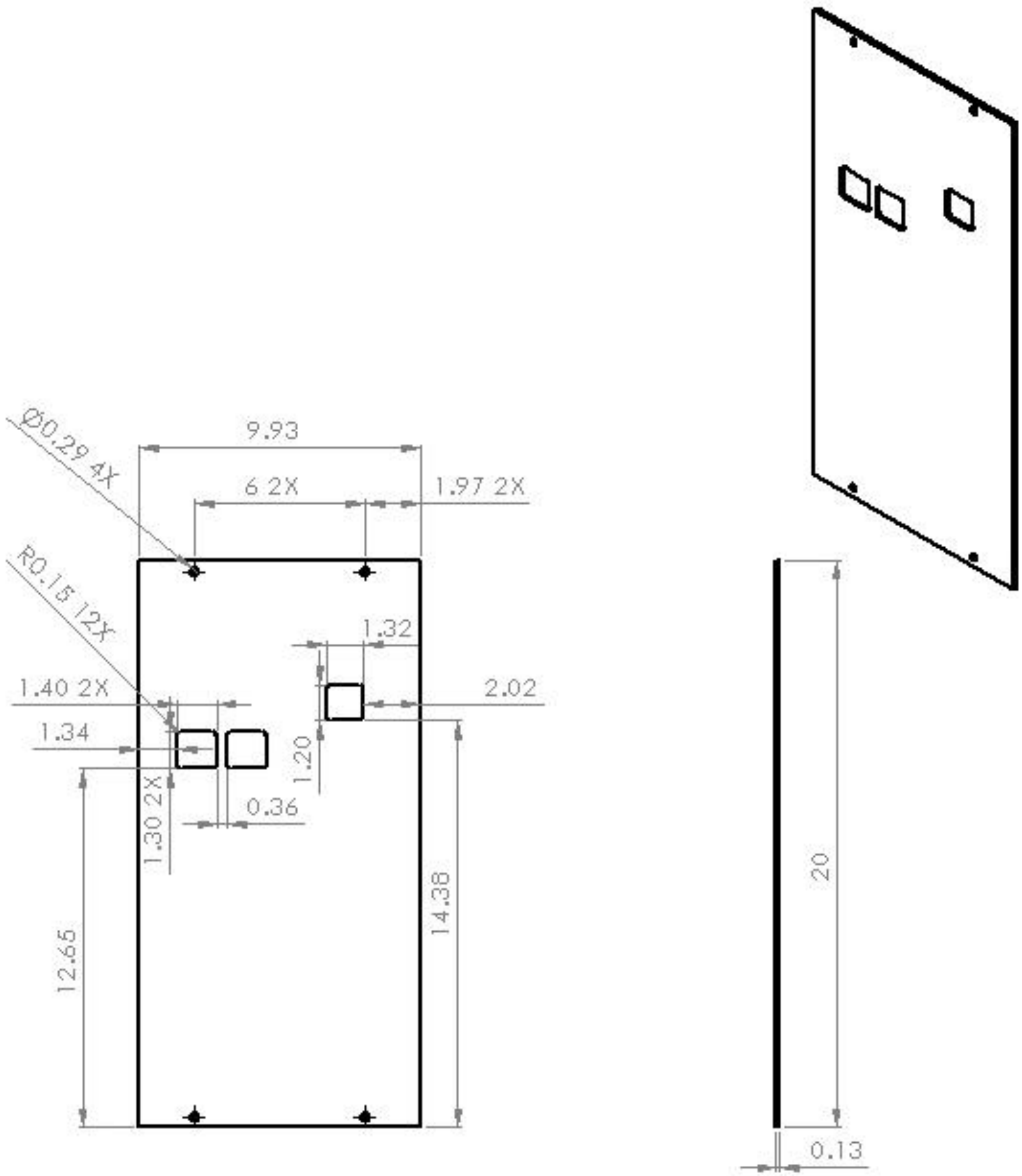


Figure A3. Mechanical drawing of the access panel and structural wall for the 2016 payload, with dimensions in centimeters. The cut-outs in the panel will accommodate the USB connectors on the ATmega2560 flight computer and IMU mounting board, which allow for direct configuration and debugging of each of these devices independent of other payload systems; and the USB connector on the timing/preprocessor board, which allows for programming and debugging of the ATmega2560 microcontroller which is used for photon timestamping and buffering. This entire panel can also be easily removed to allow for access to all payload systems as necessary.

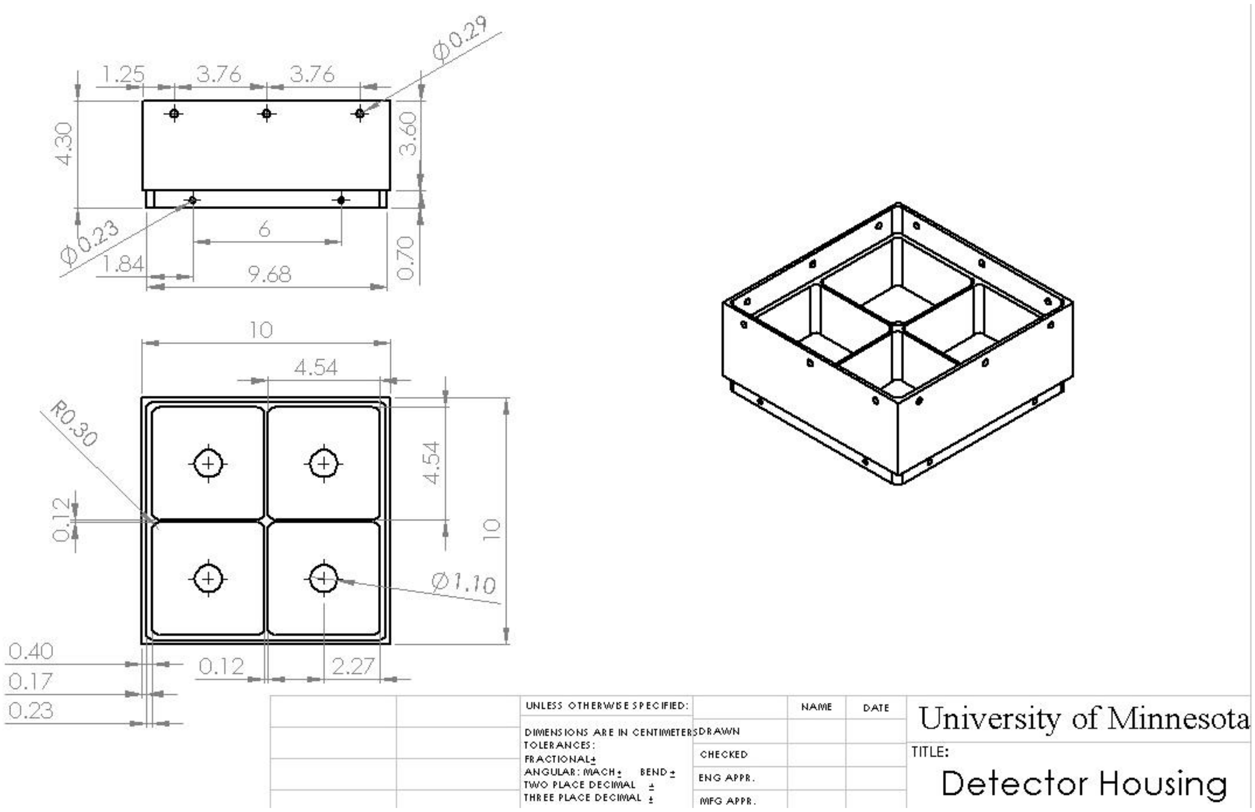


Figure A4. Mechanical drawing of the detector housing with dimensions in centimeters. The housing will be supported by the U-wall and access panel during flight by screws affixing the housing to the walls through the lower set of holes. The housing consists of four independent detector cells. Further, all of the electrical components are suspended from the detector housing using PC/104 standoffs. In order to closely mimic CubeSat standards, the detector housing measures 10x10 cm in its outer cross section.

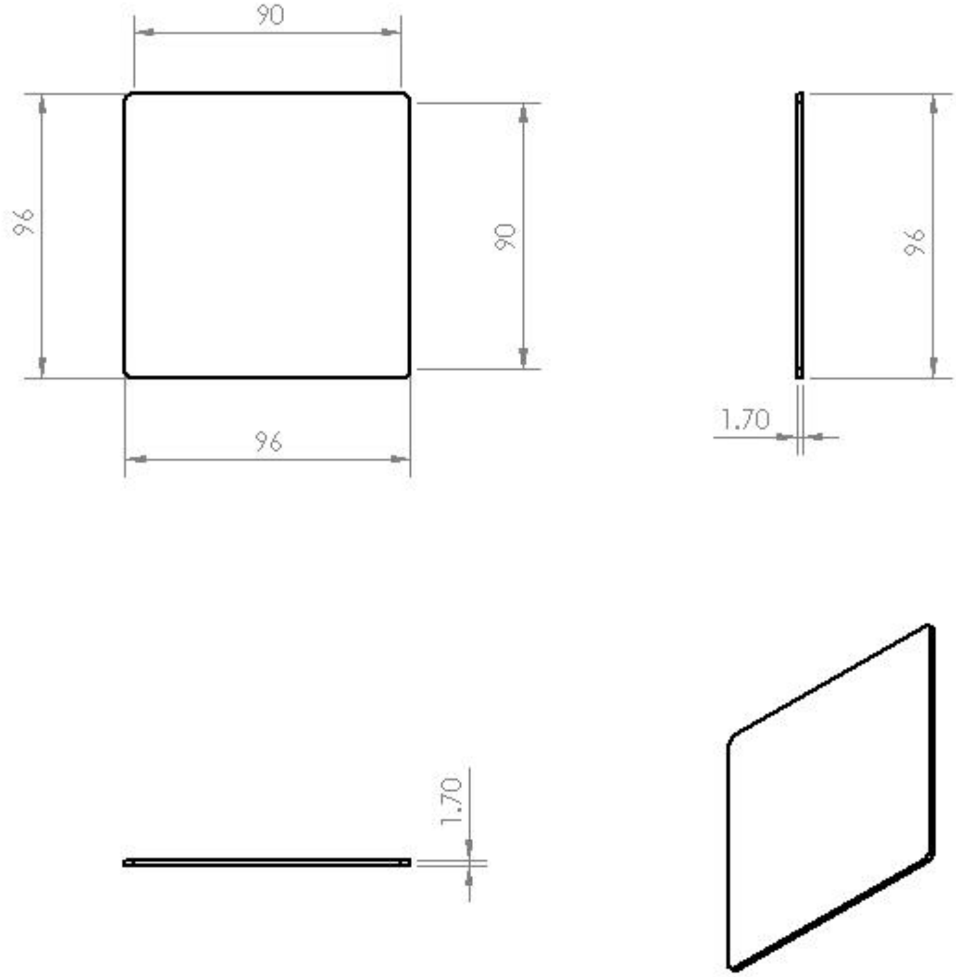


Figure A5. Mechanical drawing of detector window, made from carbon fiber. Dimensions are given in millimeters. This window sits immediately above the detectors in the housing, and minimizes attenuation in the energy bands of interest. The window “floats” between the detector housing and the window clamp, each made of aluminum. The lack of rigid attachment between the carbon fiber and aluminum parts is meant to prevent failure due to the significantly different rates of thermal expansion and contraction between the two materials.

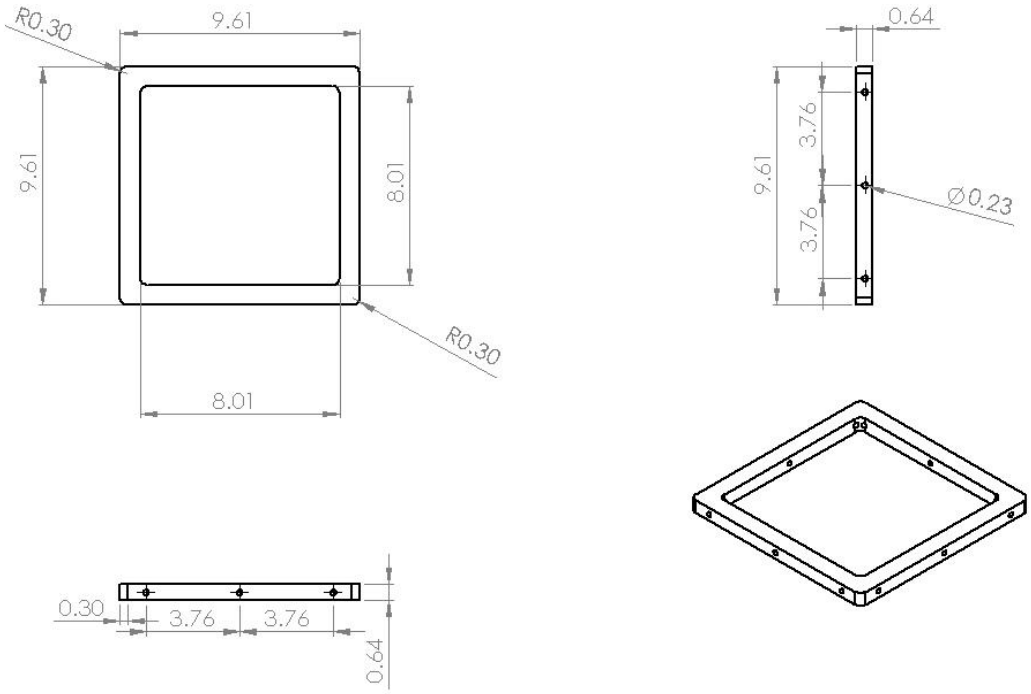


Figure A6. Mechanical drawing of detector window clamp given in centimeters. This part will sit inside the detector housing, above the detector window, and will hold the window in place without the need for rigid attachment of the carbon fiber. It will also serve to press the window into the detectors, holding them firmly in place in their foam-lined enclosures in the detector housing.

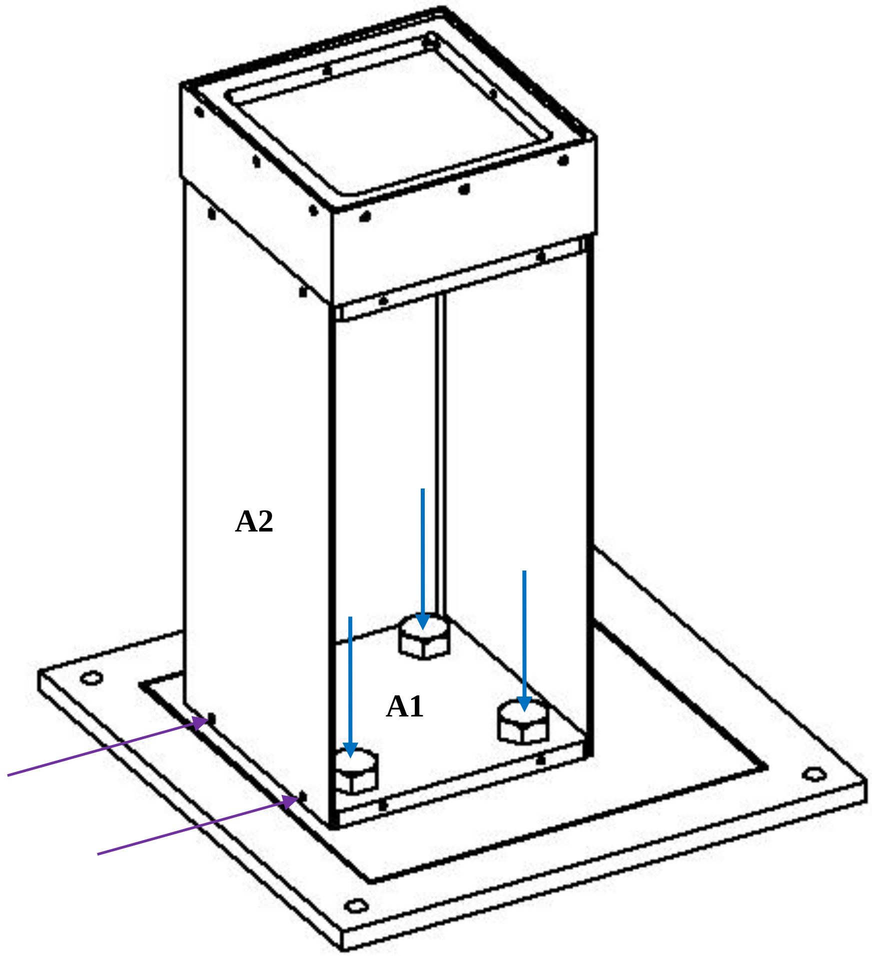
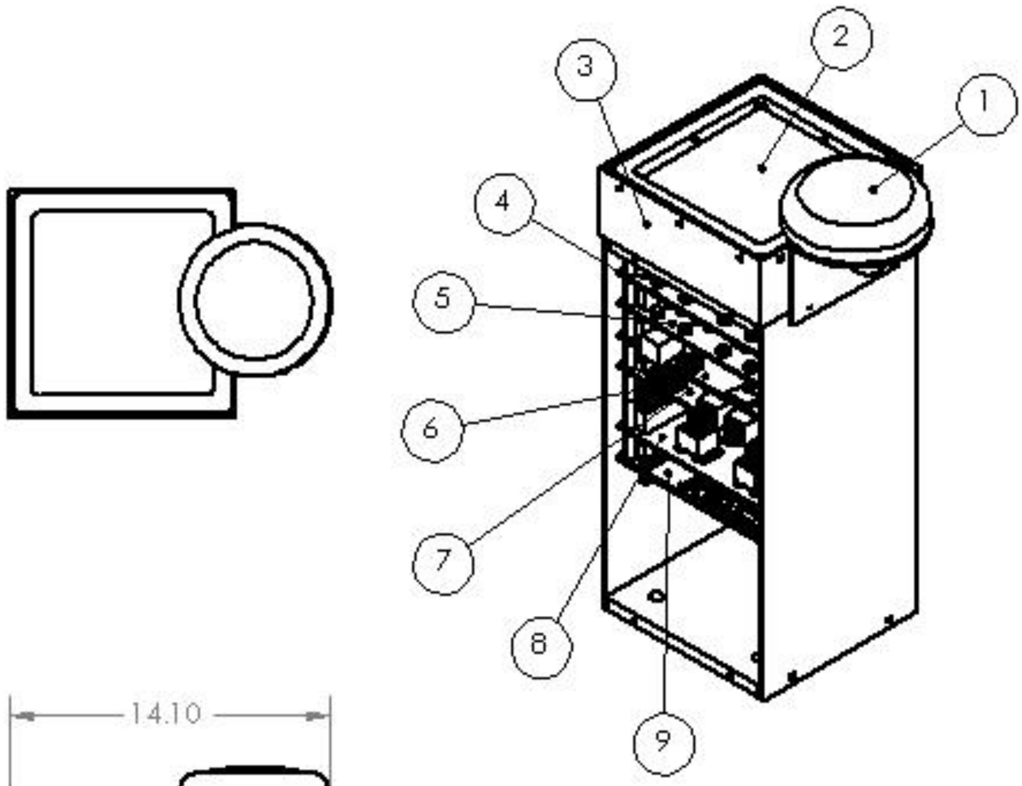
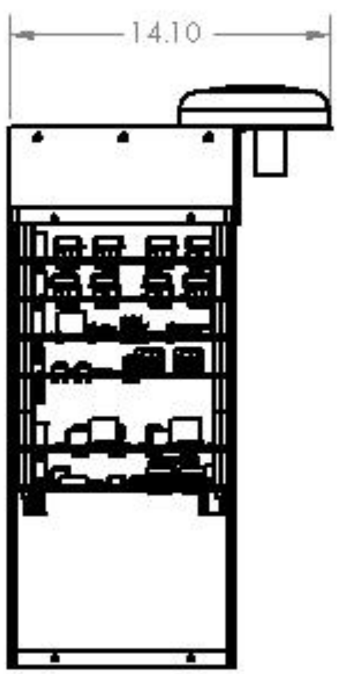


Figure A7. Mechanical drawing of the U-shaped paned (A2) attached to the bottom plate (A1) via screws located at the purple arrows going horizontal to the HASP mounting plate. There will be 2 of these screws on each side of A2 as well as on the access panel (A3, not shown). A1 is attached to the HASP mounting plate by 4 ¼" diameter bolts shown by the blue arrows going perpendicular.





Item No.	Part
1	GPS Antenna
2	Carbon Fiber Window
3	Detector Housing
4	Front End (Top)
5	Front End (Bottom)
6	Preprocessor
7	Flight Computer
8	High Voltage Power Supply
9	Power Supply

Figure A8. Mechanical drawing of the full payload assembly given in centimeters. The access panel is hidden in this viewing, showing the full stack of electrical components suspended from the detector housing. Parts are numerically annotated in relation to the table provided:

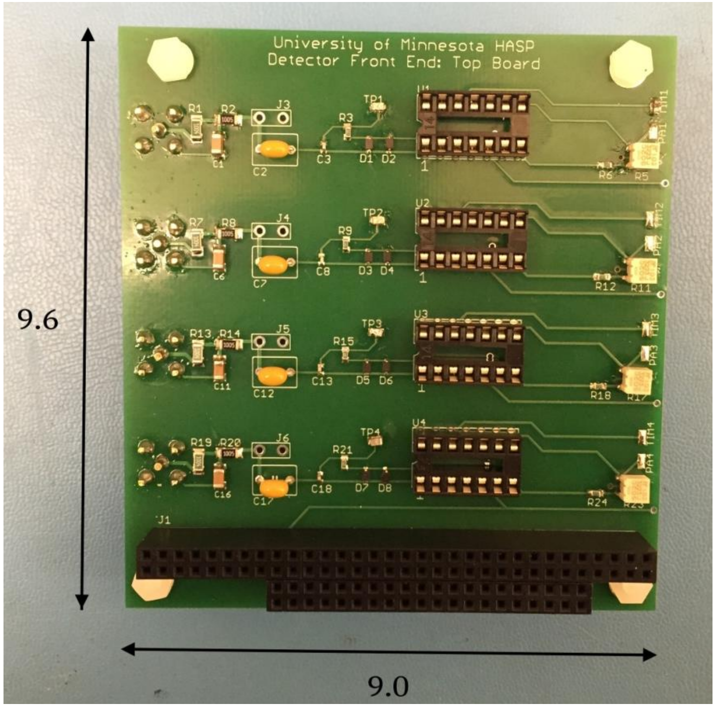


Figure A9. Custom-designed four-channel detector front end board, with dimensions in centimeters. This board will house the Amptek A225 charge-sensitive preamplifier chips (not populated here). A second front end board, not yet completed, will house both the Amptek A206 amplifier/discriminator chips and the peak detector circuits for photon energy measurement.

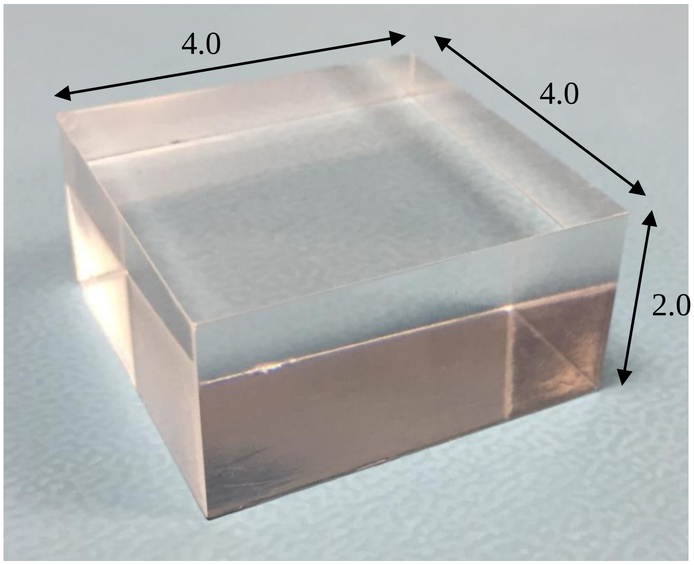


Figure A10. Thallium-doped cesium iodide scintillation crystal with dimensions in centimeters. One of these crystals will be used in each of the four detectors.

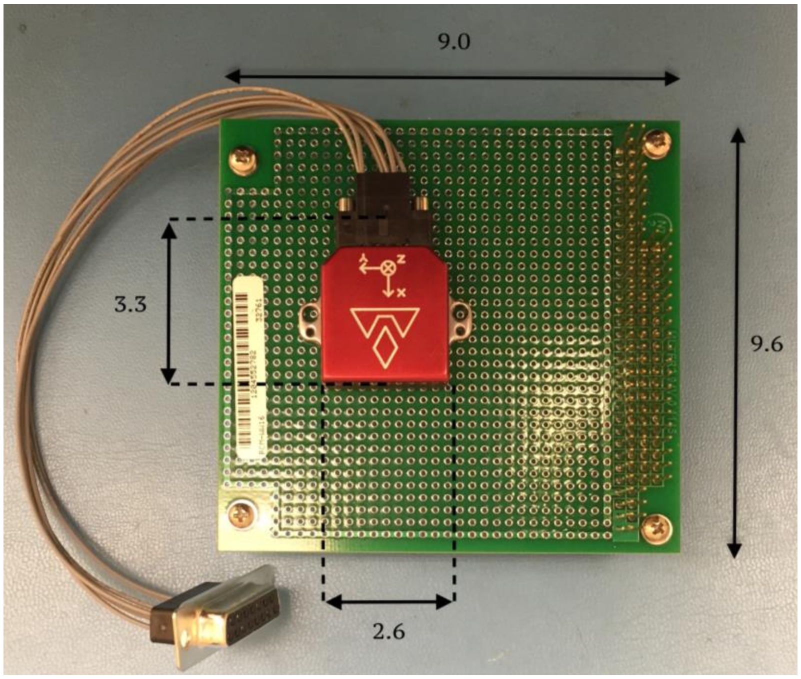


Figure A11. VectorNav VN-100U, shown sitting on top of a PC/104 prototype board for scale

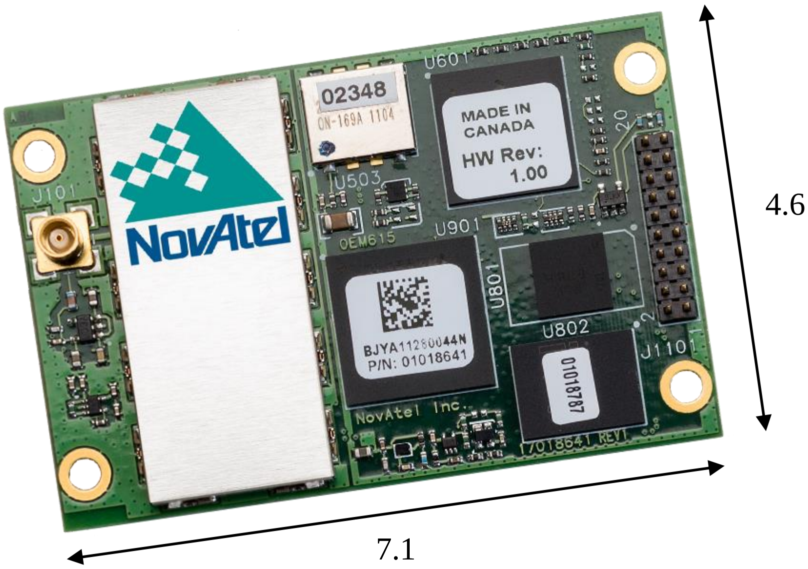


Figure A12. NovAtel OEM615 GNSS receiver with dimensions in centimeters.

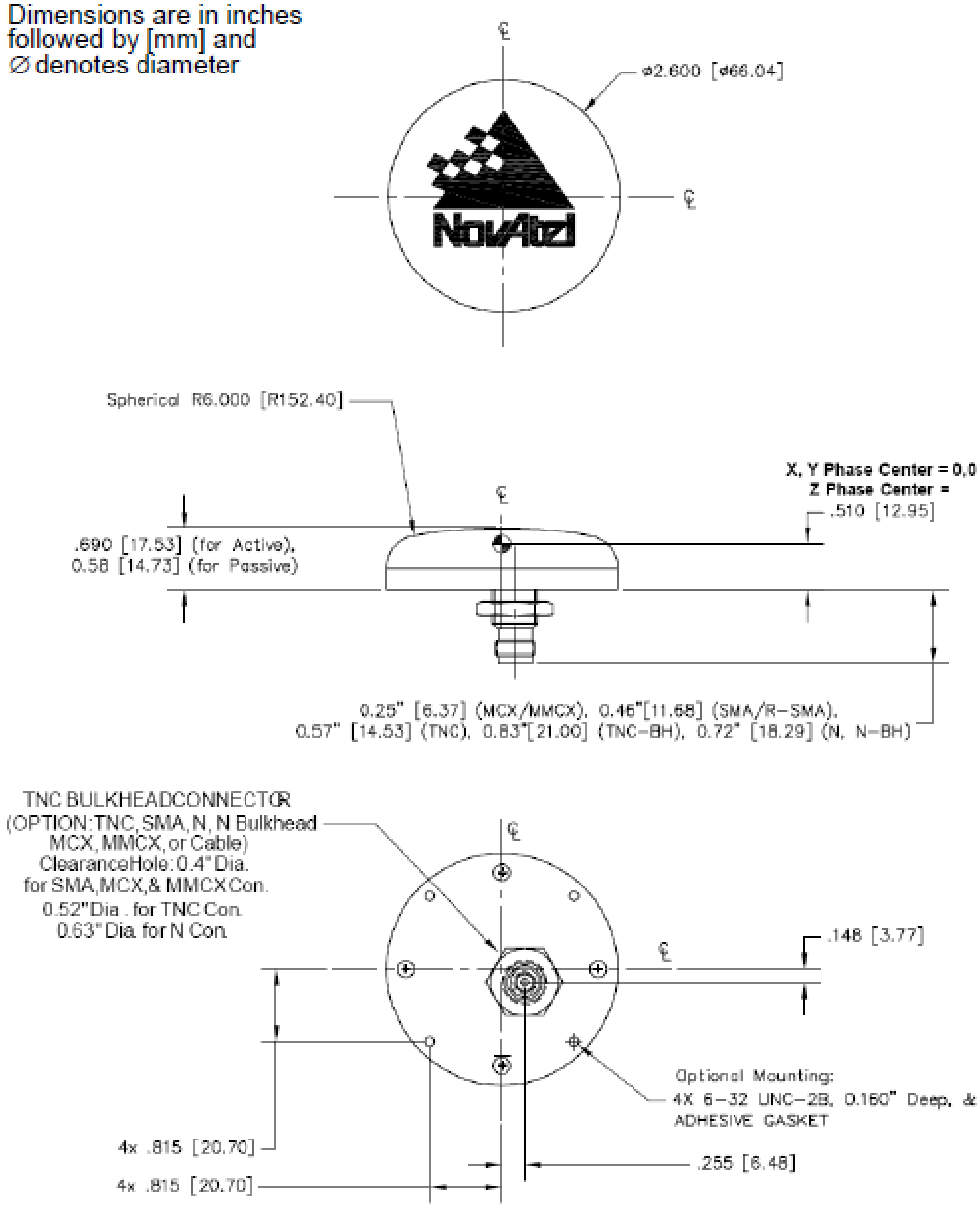


Figure A13. NovAtel GPS antenna.

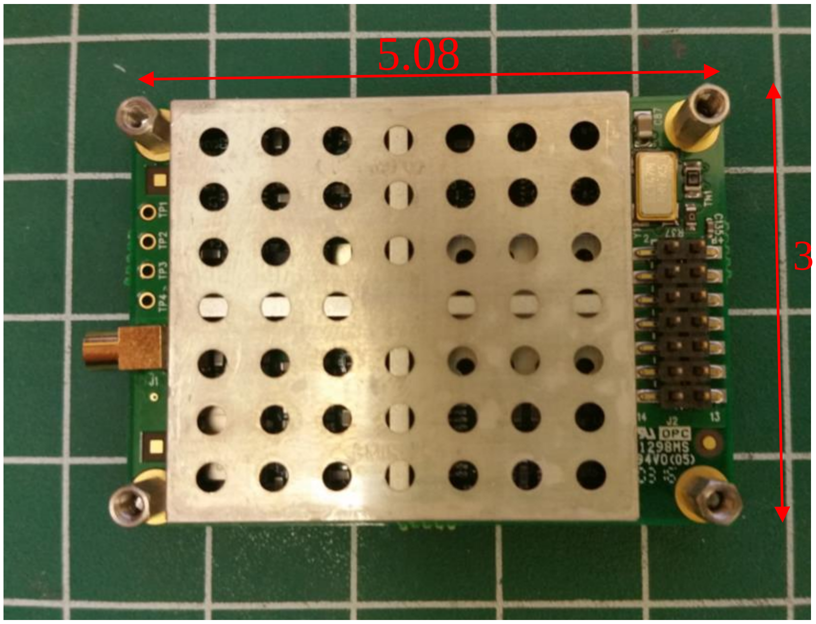


Figure A14. Picture of the FreeWave MM2-T radio transceivers with measurements given in centimeters. The dimensions are 5.08 L x 3.556 W x 0.95 H (cm).

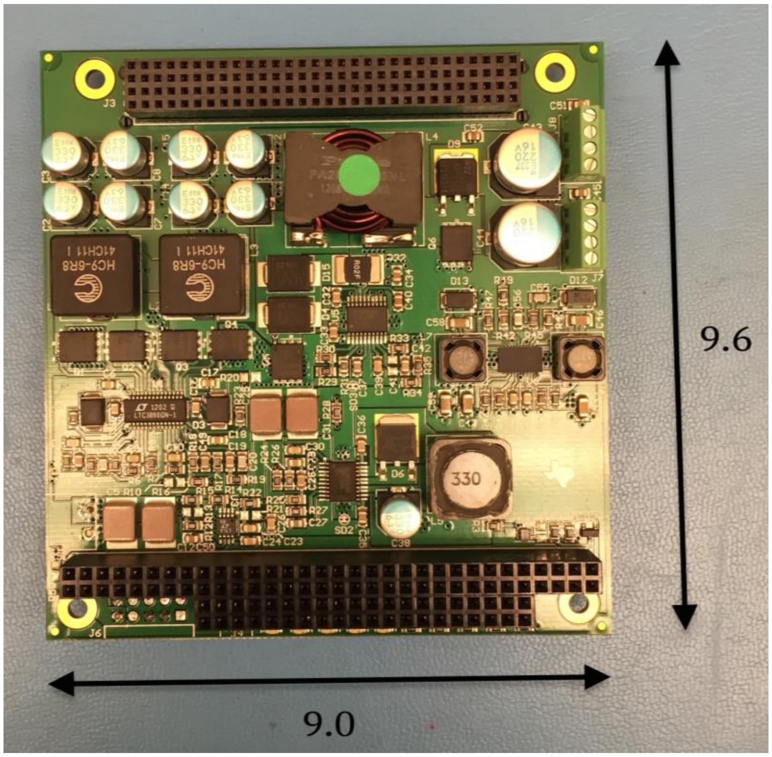


Figure A15. WinSystems PPM-DC-ATX-P power supply board with dimensions in centimeters.

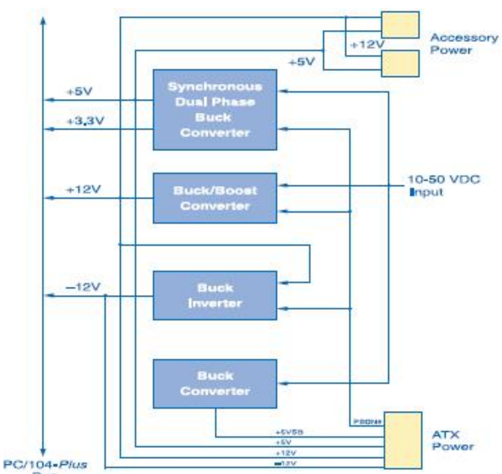
Appendix B: WinSystems PPM-DC-ATX-P Power Supply Datasheet

WinSystems®
An Employee-Owned Company

PPM-DC-ATX-P
PC/104-*Plus* ATX Model
DC/DC Power Supply

Features

- Wide input range: 10V to 50VDC
- Voltage output: +5V, +3.3V, +12V, -12V, and +5VSB
- Power On/Off, Power Good, and +5 VSB supported for power management and sleep modes
- No minimum load required for regulation
- Outputs have short circuit/overload protection
- LEDs provide visual status of power
- Two Phoenix® terminal blocks for accessory power
- High efficiency design
- Fast transient response
- No fan or heatsink required
- Up to -40°C to +85°C operation supported
- Small size: 3.6 x 3.8 inches (90 x 96mm)
- Custom OEM configurations available
- RoHS compliant



PPM-DC-ATX-P Block Diagram

Product Description

WinSystems' PPM-DC-ATX-P is a PC/104-*Plus* module that produces five regulated DC voltages from a common DC input. It features a very wide voltage input range from 10 to 50 volts. This allows the unit to operate with 12, 24, or 48 volt battery or distributed DC power systems.

This high-efficiency power supply design supports ATX-compatible signals so it can use power management modes. ATX mode support Power On/Off, Power Good, and +5VSB to allow software controlled shutdown and sleep modes.

Each output is short circuit protected and current limited. A minimum load is not needed to bring the supply into regulation.

When power is applied to the board, five LEDs will illuminate providing a visual status that power is available for the +5V, +3.3V, ±12V, and +5V standby. If one of these LEDs is not lit or is pulsing ON and OFF, then the respective supply voltage is not in regulation. A pulsating LED is an indication that the respective converter is in current limit.

There is also a connector for an ON/OFF switch for remote shutdown of the system. However, the +5VSB source will continue to be active.

WinSystems | 715 Stadium Drive, Arlington, TX 76011 USA | Tel 817-274-7553 | info@WinSystems.com | www.WinSystems.com

PPM-DC-ATX-P: ATX Model DC/DC PC/104-*Plus* Power Supply

The board is populated with low-profile, soldered down, surface mount components which keep the overall height of the board low.

The PPM-DC-ATX-P is designed to operate at extended temperatures without forced air cooling or heatsink. This maximizes reliability and reduces weight for the module and the system it powers.

Input Connector - A Phoenix Combicon connector allows for power to be easily and securely brought to the board with a quick way to remove it if necessary. The mating connector is shipped with each standard board.

PC/104-*Plus* Connectors - The ground, power and control signals are wired directly to their respective pins on the PC/104 and PCI-104 connectors.

Accessory Power - There are two, four-pin Phoenix Contact terminal blocks at the edge of the board to provide +5V and +12V to accessories.

There is also a microATX connector on the board that allows access to the +5V, +3.3V, +12V, -12V, and +5VSB DC voltages. The Power On/Off and Power Good control signals are also available at this connector.

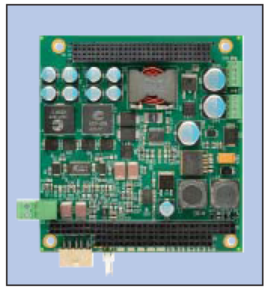
Fanless - No fans or heatsinks are required to meet the extended operating temperature range of -40° to +85°C.

Other Standard Configurations - WinSystems offers other non-ATX versions. All boards can operate over the temperature range of -40°C to +85°C without a fan or heatsink.

ISM-DC-AT512-P is a stand alone DC/DC power supply with +5V and +12V. The PCM-DC-AT500 card is a single +5V PC/104 power supply. The PCM-DC-AT512-P adds a +12V, a -12V converter, and includes accessory power terminals.

Please reference the specific data sheets for details on the other DC/DC power supplies.

Custom Configurations - WinSystems offers additional ruggedized options and custom configurations for OEMs. Please contact an Applications Engineer to discuss your specific requirements.




Front and Back Picture of PPM-DC-ATX-P

Technical Specifications

Electrical

Input	
Voltage (V_{IN})	10 to 50VDC
Output	
Voltage/current (at V_{IN} = +12V)	+5V @ 10A +3.3V @ 10A +12V @ 3A -12V @ 800mA +5VSB @ 2A
Load regulation	30 mV
Line regulation	20 mV
Ripple	<150 mV

Environmental

Operational from -40° to +85°C
RoHS compliant

Mechanical

Dimensions	3.6 x 3.8 inches (90 x 96mm)
PC Board	0.078 inches, four layer FR4
PC/104-*Plus*	120-pin (4 x 30; 2mm) stackthrough
PC/104	16-bit stackthrough
Weight	4.5 oz. (127 gm)

Ordering Information

Visit www.WinSystems.com for complete ordering details.

PPM-DC-ATX-P	PC/104-*Plus* ATX power supply
ISM-DC-AT512-P	Dual output +5V and +12V DC/DC power supply
PCM-DC-AT500	Single +5V output, PC/104 DC/DC power supply
PCM-DC-AT512-P	Triple output +5V and ±12V PC/104 DC/DC power supply

WinSystems®
An Employee-Owned Company