HASP Payload Specification and Integration Plan

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

Payload Class: [✓ Small] Large (circle one)

Payload ID: 3

Institution: University of Minnesota – Twin Cities

Contact Name: Seth Frick

Contact Phone: 651-494-8923

Contact E-mail: frick100@umn.edu

Submit Date: June 27, 2014

I. Mechanical Specifications:

A. Estimated weight of the payload (not including payload plate). The uncertainty in the total payload weight is largely due to the estimates made for the mounting hardware and the note below concerning the top and bottom plates. However, even in the worst case scenario, the payload is within the 3 kg limit for the small payload classification.

Side panels (4)	0.626 kg	Measured
Bottom plate	0.267 kg	Estimated*
Top plate	0.298 kg	Estimated*
Structural angle (4)	0.259 kg	Measured
Novatel OEMStar GNSS receiver	0.023 kg	Measured
GPS/GLONASS antenna	0.021 kg	Measured
Detector front board	0.210 kg	Measured
Peak detector board	0.066 kg	Measured
IMU and mounting plate	0.097 kg	Measured
Detector and housing (2)	0.243 kg	Measured
Power and interface board	0.108 kg	Measured
Primary flight computer (BeagleBone Black)	0.047 kg	Measured
Point Grey Chameleon camera	0.053 kg	Measured
Secondary camera computer (Raspberry Pi)	0.041 kg	Measured

Interconnect cables	0.104 kg	Measured
Mounting hardware	0.250 kg	Estimated
Total	**2.71±0.25 kg**	**Calculated**

Table 1. Weight budget and total payload weight including uncertainty. *Note: the masses of the top and bottom plates are listed as estimated because although they have been machined and their current masses have been measured, the holes for the GNSS antenna cable (in the top plate) and the camera window (in the bottom plate) have yet to be cut out.

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

i. Figure A1. Mechanical drawing of structural angles.
ii. Figure A2. Mechanical drawing showing alterations to HASP mounting plate.
iii. Figure A3. Mechanical drawing of bottom plate of structure.
iv. Figure A4. Mechanical drawing of structure wall. Four of these walls will enclose the structure.
v. Figure A5. Mechanical drawing of top plate of structure.
vi. Figure A6. Mechanical drawing of detector housing.
vii. Figure A7. Mechanical drawing of electromagnetic shields on detector board.
viii. Figure A8. Mechanical drawing of detector board.
ix. Figure A9. Mechanical drawing of full payload assembly.
x. Figure A10. Picture of detector board with dimensions.
xi. Figure A11. Picture of detector with dimensions.
xii. Figure A12. Picture of detector housing.
xiii. Figure A13. Picture of IMU with dimensions.
xiv. Figure A14. Picture of Novatel OEMStar GNSS receiver with dimensions.
xv. Figure A15. Picture of GNSS antenna with dimensions.
xvi. Figure A16. Picture of Point Grey Chameleon camera with dimensions.
xvii. Figure A17. Picture of Raspberry Pi with dimensions.
xviii. Figure A18. Picture of BeagleBone Black with dimensions.

xix. Figure A19. Picture of power and interface board with dimensions.

xx. Figure A20. Picture of power and interface board with flight computer.

xxi. Figure A21. Picture of peak detector 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 a size 4-40 socket head cap screws, while the structure is attached to the HASP mounting plate with a 1¼-inch long bolt with a ¼-inch diameter secured by a locknut. Rubber grommets sit between the mounting plate and structure, while washers sit between the nuts and mounting plate. The 2014 design includes aluminum structural angles to reinforce the payload, especially under compressive loading.

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 OEMStar GNSS receiver	0.65 W	Measured
Analog Devices ADIS16405 IMU	0.35 W	Measured
Point Grey Research Chameleon camera	2.50 W	Estimated
Raspberry Pi	2.75 W	Estimated
BeagleBone Black	2.75 W	Estimated
Detector front board	0.15 W	Measured
Peak detector board	0.75 W	Measured
Total	**9.90 W**	**Calculated**

Table 2. Nominal power consumption for all electrical components. Estimated values are based on datasheet specifications of maximum anticipated power consumption at nominal temperature.

Therefore, the anticipated nominal current draw at 30 VDC is **330 mA**. The power consumption of most of the electrical components in the payload will fluctuate in varying operating and environmental conditions. However, it is expected that the worst-case current draw will not exceed 400 mA.

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 in Figure 2. The power is then grounded through pins T, U, W, and X on the EDAC connector. The power and regulation circuitry provides the payload with regulated 12V and 5V rails. The 12V rail powers the X-ray peak detector and detector front board, and the 5V rail powers the Analog Devices ADIS16405 IMU, the camera logging computer (Raspberry Pi), and the Point Grey Chameleon camera. In addition, the primary flight computer (BeagleBone Black) includes a low-dropout regulator to provide a 3.3V rail, which powers the flight computer itself, the Novatel OEMStar GNSS receiver, and logic-level interfacing circuitry such as the RS-232 transceiver used for serial communications with the HASP flight system.

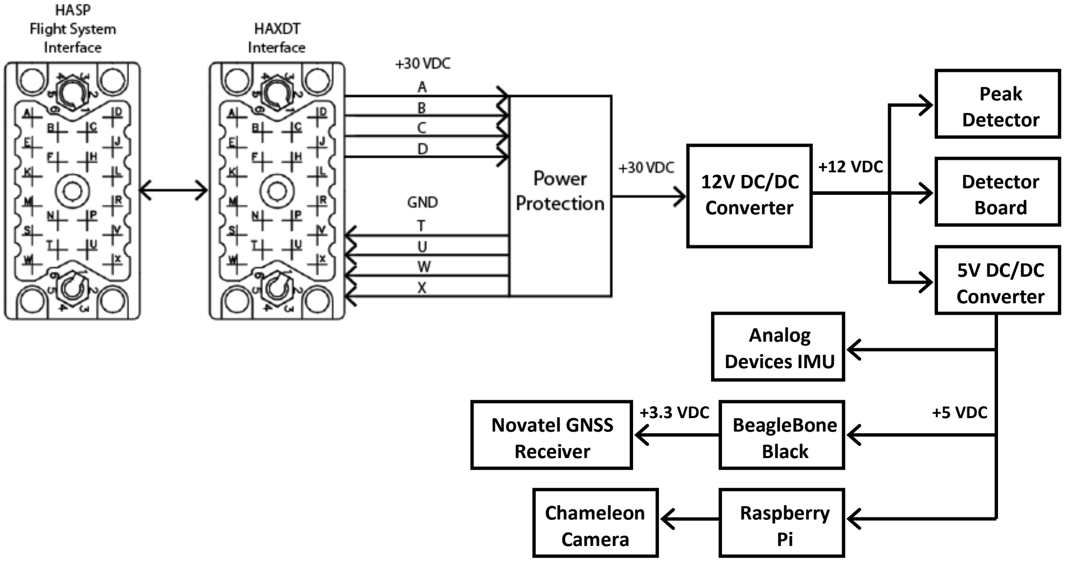

Figure 1. HASP EDAC516 connector interface with the payload power system.

The 30 VDC is converted to 12 VDC using a Texas Instruments PTN78060 integrated switching regulator. The 12 VDC is then regulated further using a Murata OKX-T/3-D12 non-isolated DC/DC converter (which replaced the LM1085 linear regulator shown in the schematic below). The payload is isolated from reverse polarity of input voltage using a bridge rectifier, and limits the current draw of the circuit to 495mA to prevent in-rush current spikes. LEDs are used to indicate stable 30V, 12V, and 5V power.

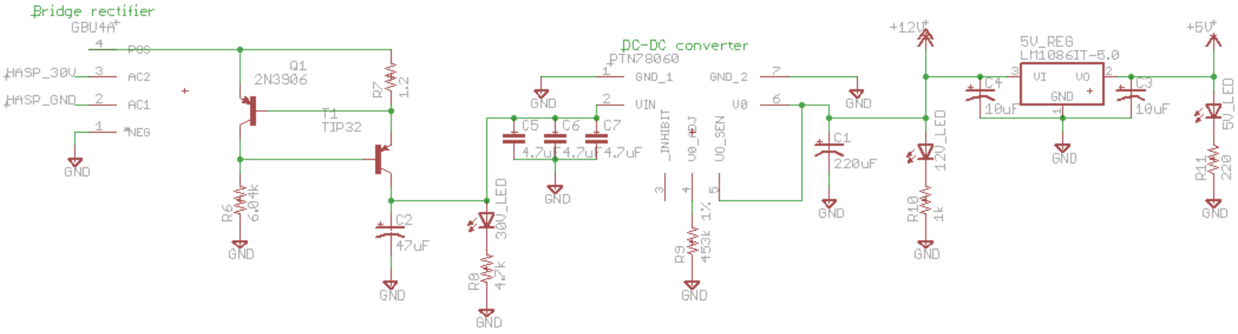

Figure 2. Power regulation and protection circuit.

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 75 byte packet outlined below (plus serial framing bits) will be sent once every five seconds, giving a data rate of 135 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 (meters)
19-27	Y_Pos	Earth-centered Earth-fixed, y coordinate (meters)
28-36	Z_Pos	Earth-centered Earth-fixed, z coordinate (meters)
37-45	A_Events	Cumulative number of events on detector A only
46-54	B_Events	Cumulative number of events on detector B only
55-63	C_Events	Cumulative number of "simultaneous" detector events
64-68	IMU_Temp	Internal payload temperature, measured by IMU (degrees Celsius)
69-73	IMU_Voltage	+5V rail voltage, measured by IMU (volts)
74-75	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?

F. Number of discrete lines being used: 0

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

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

None.

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*)

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.

The payload includes a GNSS receiver and antenna which will be programmed to receive both GPS L1 and GLONASS L1 frequencies. The GPS signal is centered at 1575.42 MHz, and the GLONASS signal is centered at 1602.0 MHz.

F. Other relevant uplink commanding information.

None.

V. Integration and Logistics

A. Date and Time of your arrival for integration:

July 28, 2014, Afternoon / Evening (exact time TBD)

B. Approximate amount of time required for integration:

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

C. Name of the integration team leader: Seth Frick

D. Email address of the integration team leader: frick100@umn.edu

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

Seth Frick	frick100@umn.edu
Alec Forsman	forsm054@umn.edu

Josiah DeLange	delan231@umn.edu
John Jackson	jacks974@umn.edu
Seth Merrifield	merri408@umn.edu

F. Define a successful integration of your payload:

All payload systems power on, the flight computer successfully stores and transmits data in a simulated flight environment, and the payload resets and continues to collect data under the same simulated conditions.

GPS and temperature data will be extracted from the downlinked data packets and plotted to examine loss of data during the thermal / vacuum testing. The cumulative number of photon events recorded on each detector will be observed from the downlinked data as well to verify the proper operation of the detector systems (sans energy measurements). In addition, the SD cards inside the payload (one logging GNSS, IMU, and detector data; and one logging images from the camera) will be checked to evaluate the data from the IMU, the detector systems (including energy measurements), and the camera. If no data loss occurs, then it is assumed the payload is functioning properly and the integration is a success.

It is understood that the thermal/vacuum test chamber includes a GPS repeater antenna to allow for GPS signals to be received during the test. However, it is not known whether or not GLONASS signals can be repeated as well. If not, the performance of the GNSS receiver during the testing can still be validated based on the GPS signals received only. The majority of the channels available on the GNSS receiver will be dedicated to GPS, with only a few channels dedicated to GLONASS to evaluate the increase in performance during flight with an additional satellite constellation available.

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, remove internal SD cards, 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.

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 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 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.

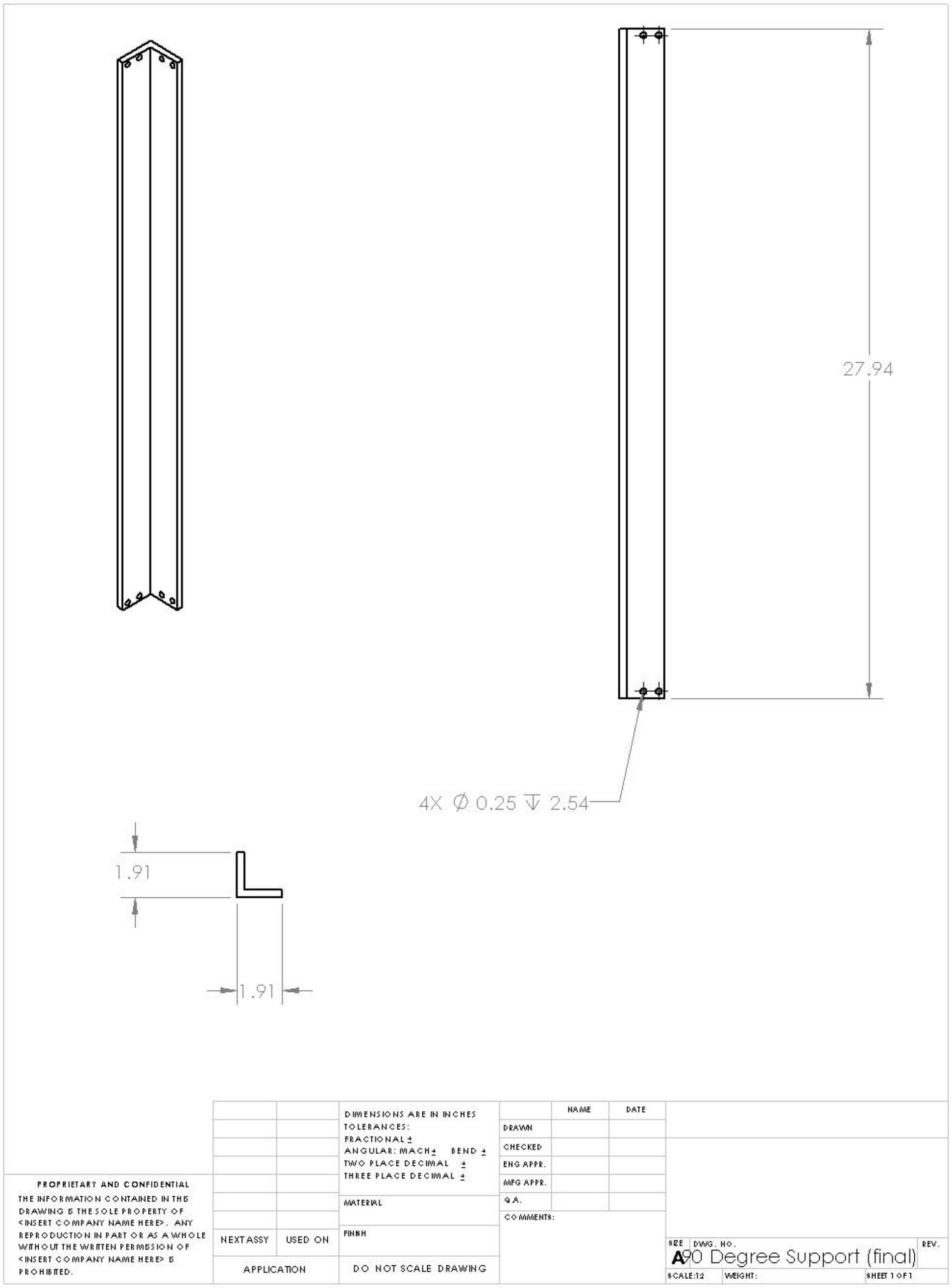

Figure A1. Mechanical drawing of structural angle to reinforce payload with dimensions in centimeters. The four vertical edges of the 2014 payload will utilize the angle as the primary source of structural integrity. Previous iterations directed all loads between the top and bottom plates of the payload through the side panels only.

Appendix: Dimensioned Mechanical Drawings and Pictures of Major Components

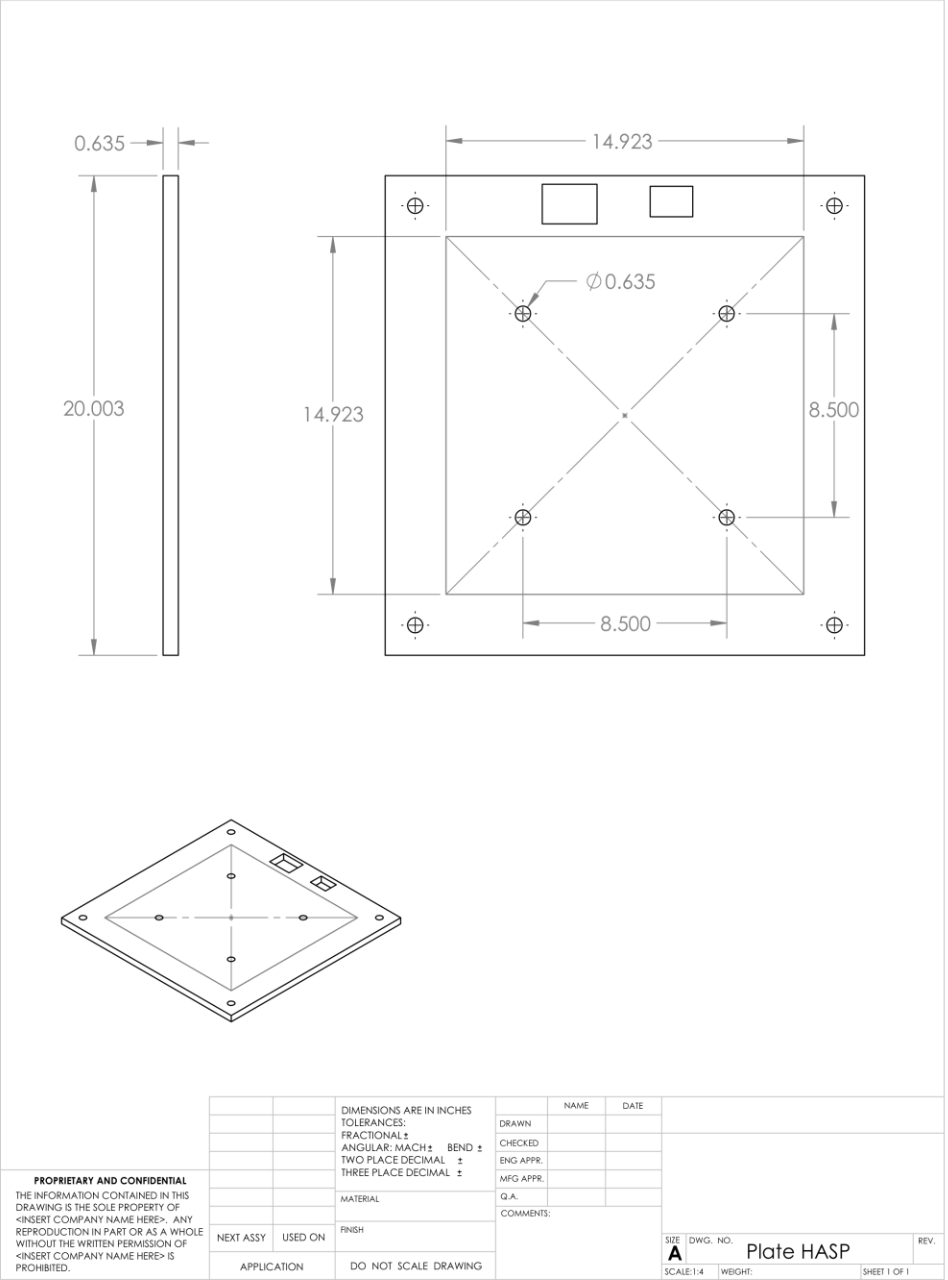

Figure A2. Mechanical drawing showing alterations to HASP mounting plate with dimensions in centimeters. A large hole will also be drilled through the plate to allow the camera to have a downward-looking perspective. This hole will be plugged with an acrylic window to mitigate environmental exposure of the internal components.

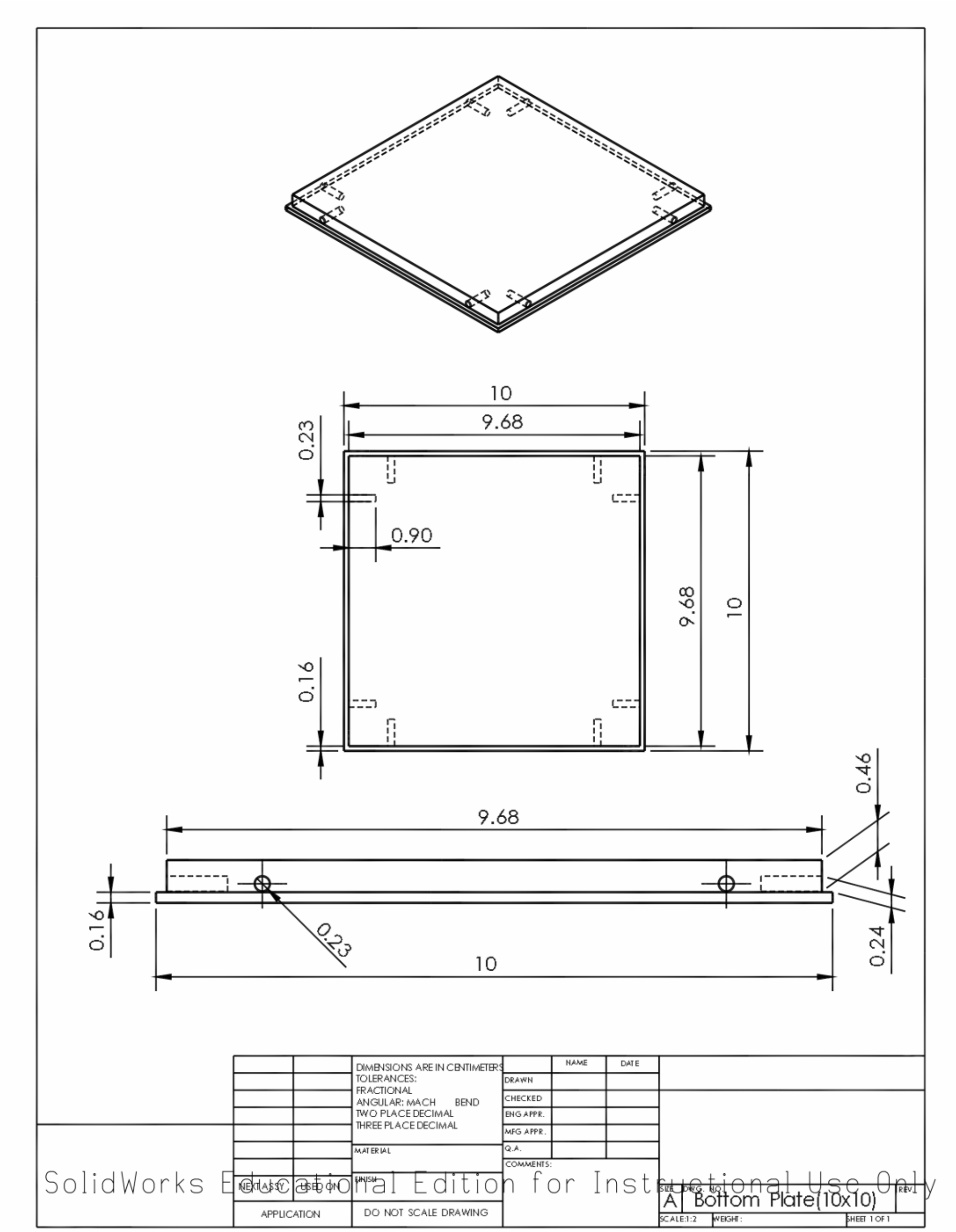

Figure A3. Mechanical drawing of bottom plate of the 2013 HAXDT structure with dimensions in centimeters. This plate attaches to the HASP mounting plate (Fig. A2), and will have the lower detector housing and the camera mounted on it. The bottom plate of the 2014 payload will be nearly identical, but with the 10 cm dimension increased to 13.34 cm, and the 9.68 cm dimension increased to 12.38 cm to accommodate the increased number of internal components and the structural angle reinforcement.

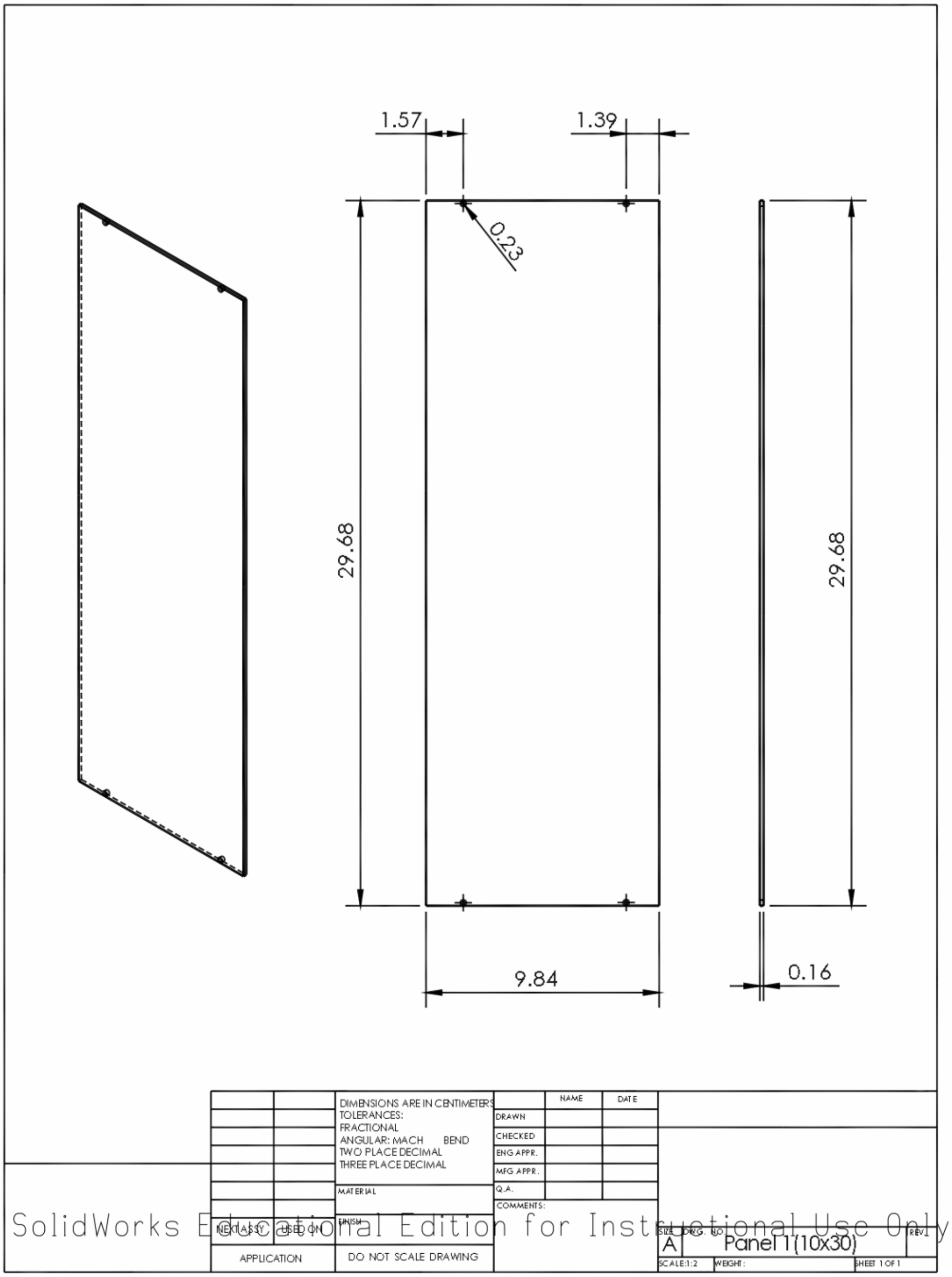

Figure A4. Mechanical drawing of the 2013 HAXDT structure enclosing wall with dimensions in centimeters. Four of these walls mount to the bottom (Fig. A3) and top (Fig. A5) plates to complete the enclosure. The walls of the 2014 payload will have the 9.84 cm dimension increased to 13.18 cm. These walls will be reinforced with structural angle.

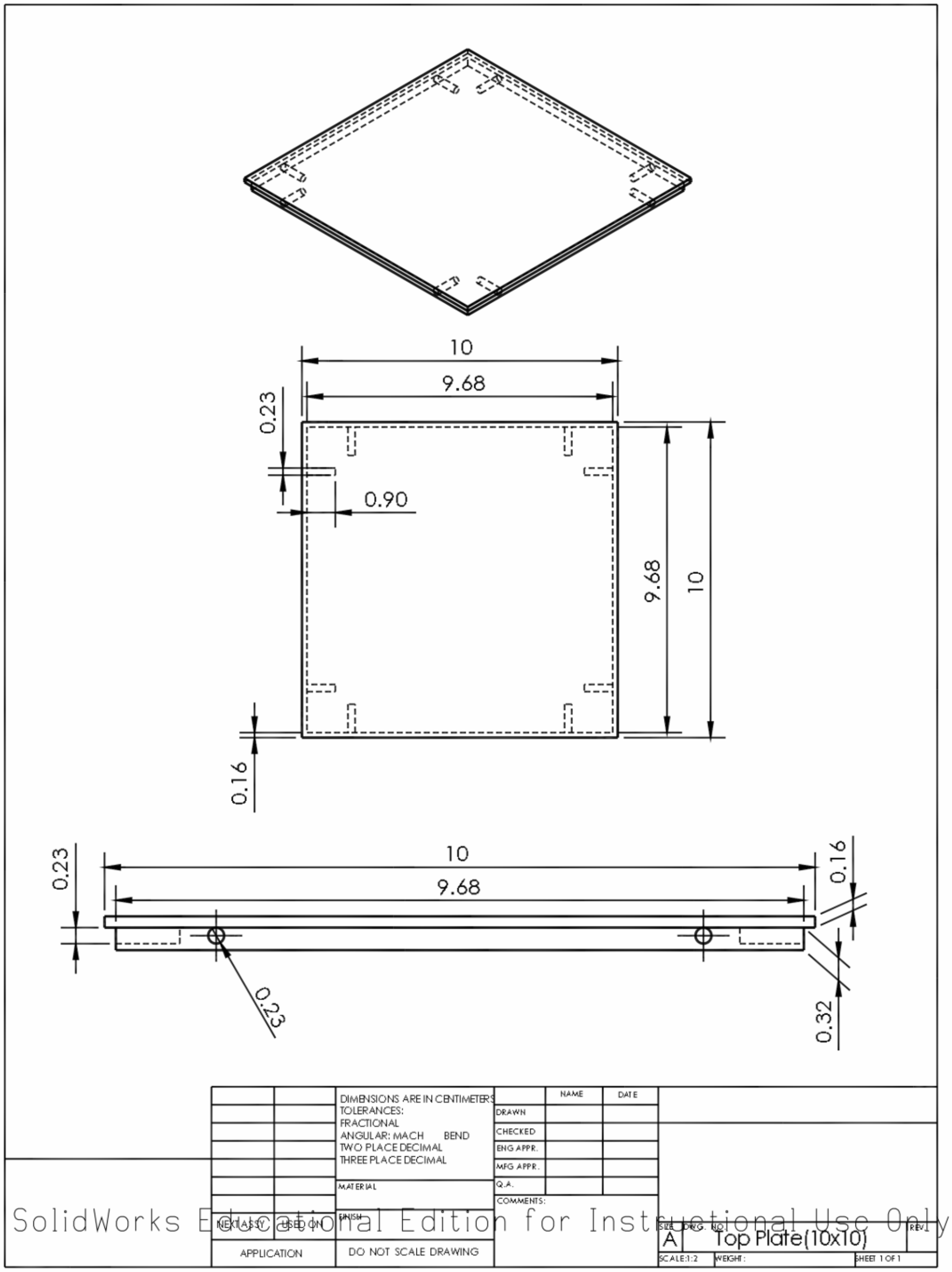

Figure A5. Mechanical drawing of top plate of the 2013 HAXDT structure with dimensions in centimeters. The upper detector housing (Fig. A6) and GPS antenna will be mounted on this plate. The 2014 payload will have the 10 cm dimension increased to 13.34 cm, and the 9.68 cm dimension increased to 12.38 cm.

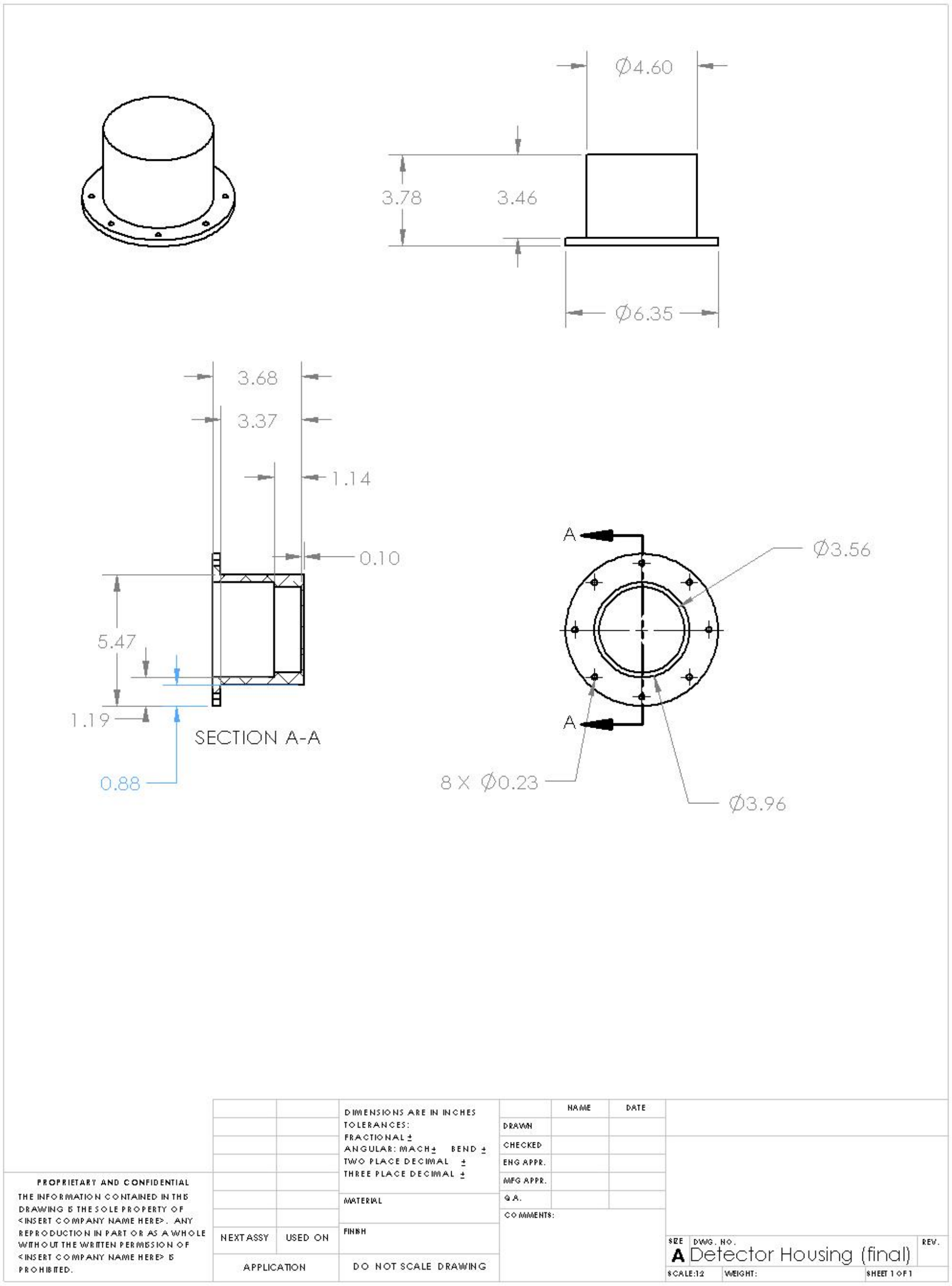

Figure A6. Mechanical drawing of detector housing with dimensions in centimeters. One housing will attach to each of the top and bottom plates (Figs. A5 and A3).

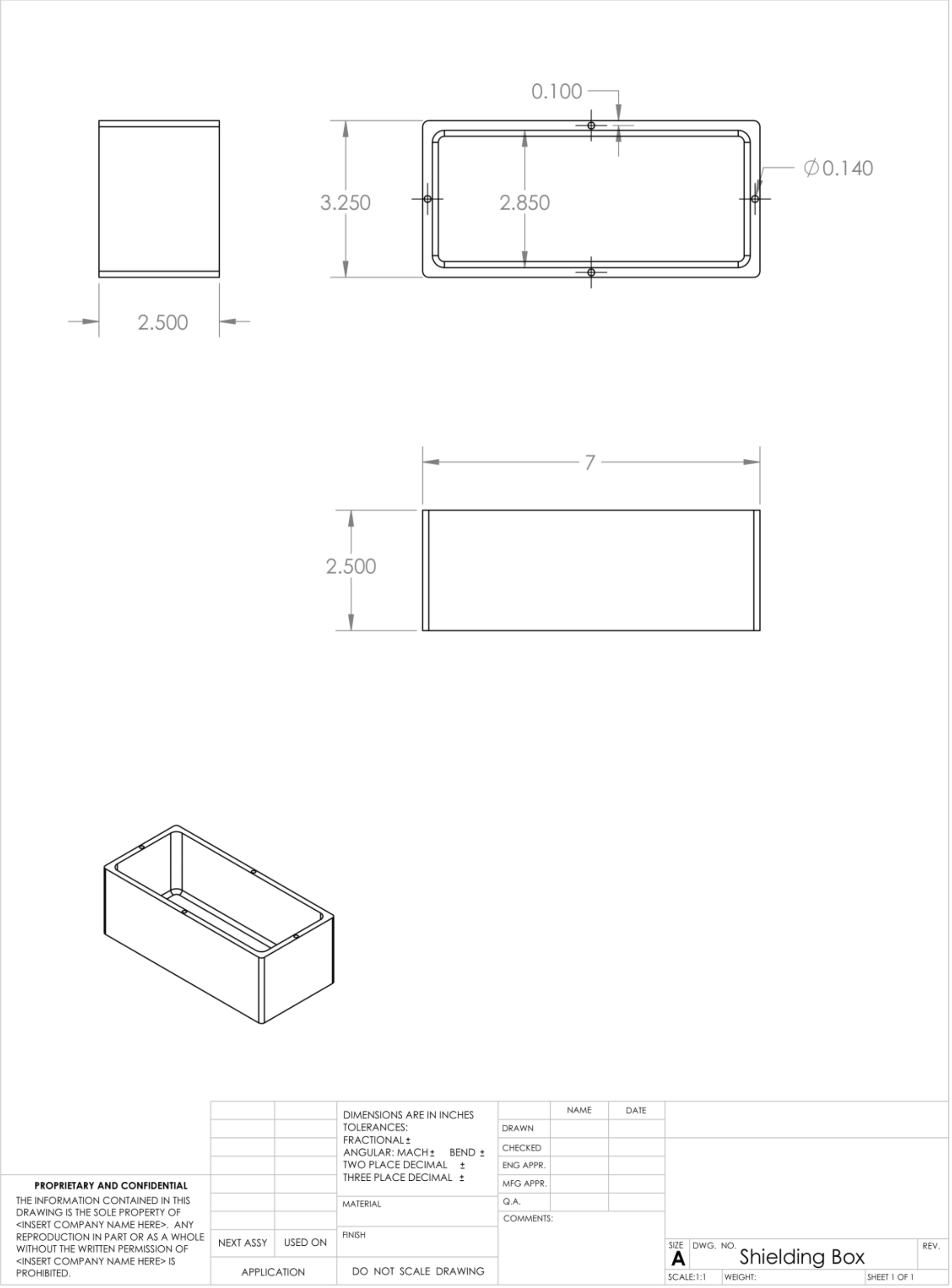

Figure A7. Mechanical drawing of electromagnetic shield for the detector board with dimensions in centimeters. See Figures A8 and A10 for positioning on detector board.

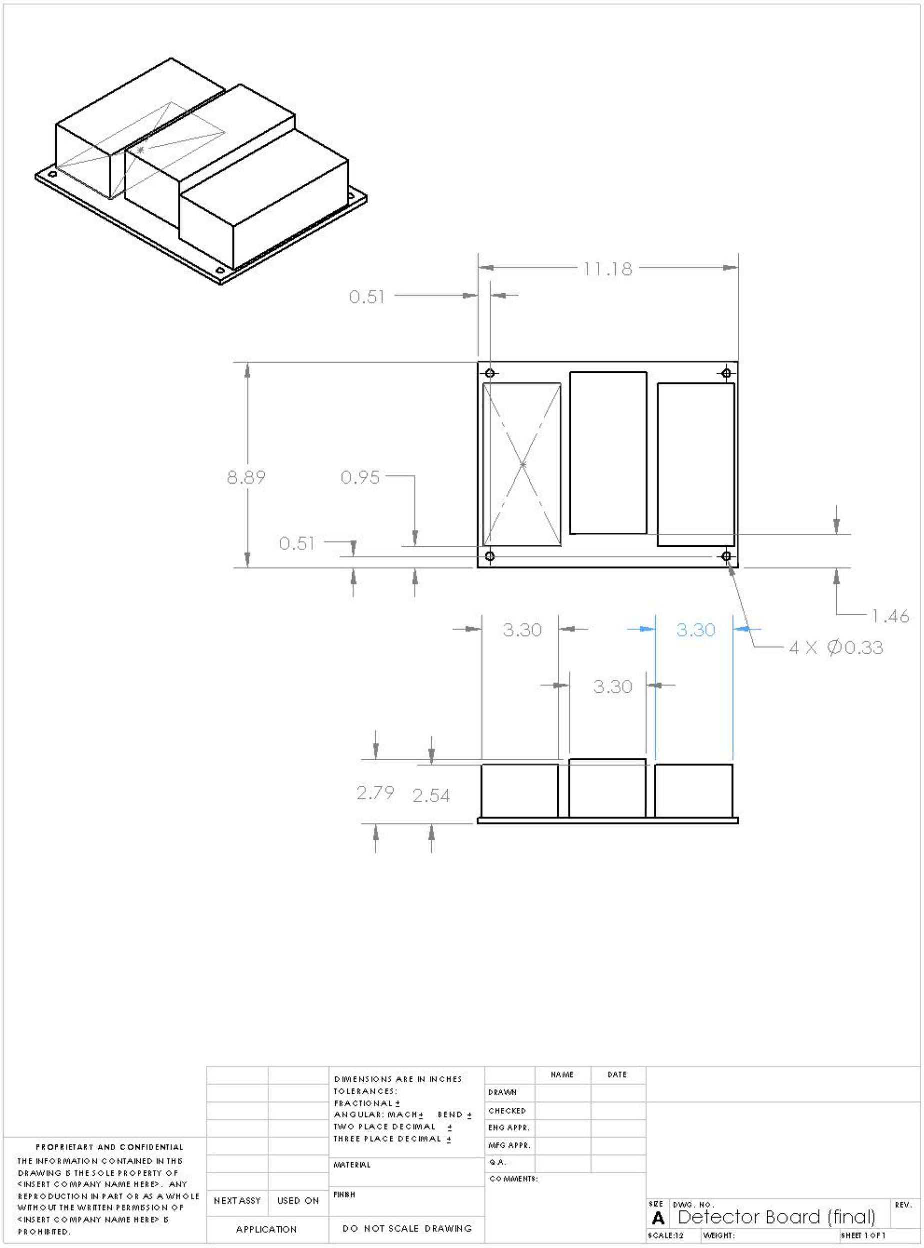

Figure A8. Mechanical drawing of the detector board including the electromagnetic shields with dimensions in centimeters.

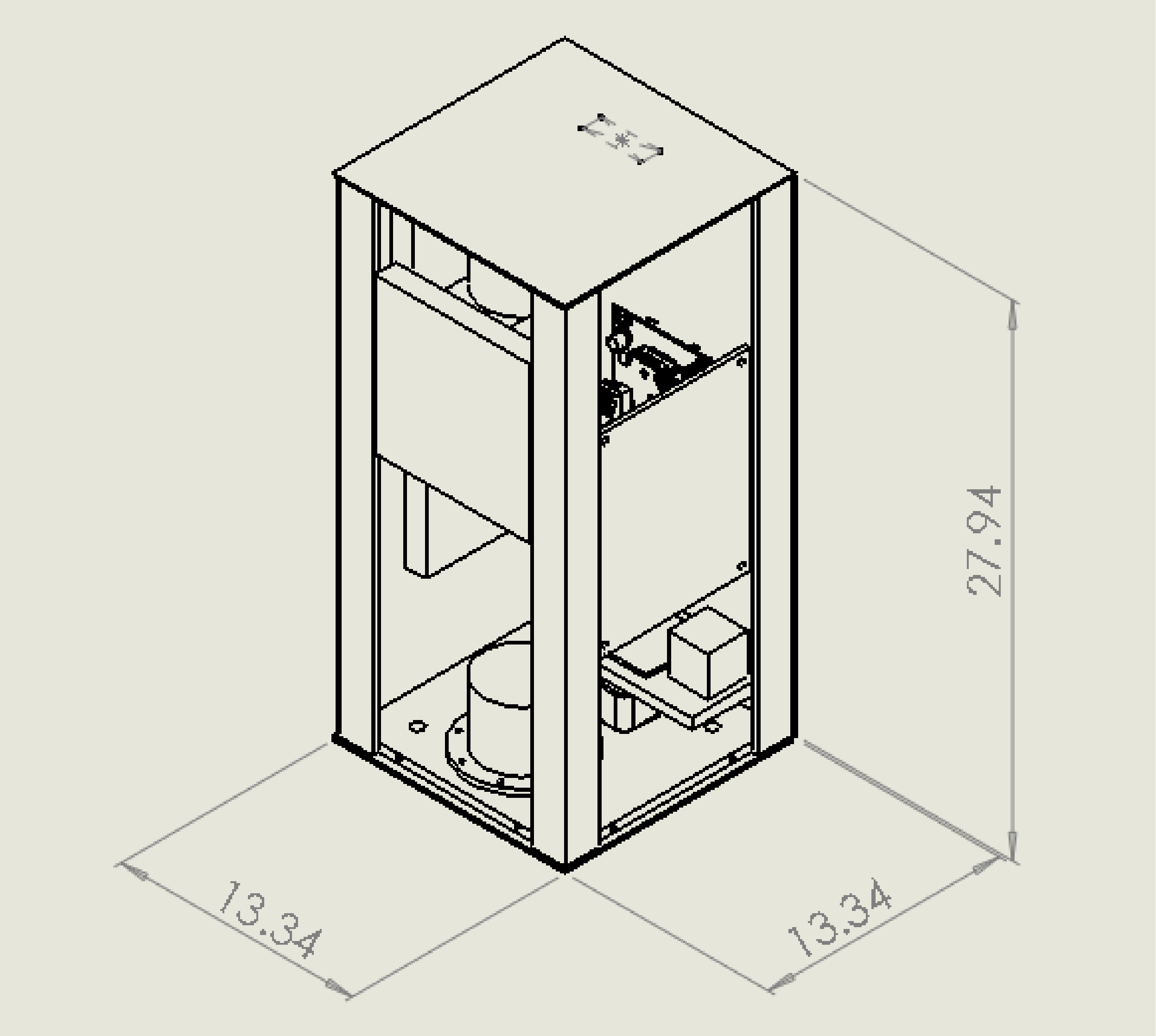

Figure A9. Mechanical drawing of the full payload assembly with dimensions in centimeters. Note that the payload is now reinforced with structural angle on the edges. Inside the payload drawing are mockup components showing their preliminary placement, including both detector housings, the detector board, the peak detector, the IMU, the GNSS receiver, the camera, the Raspberry Pi, and the BeagleBone Black with the power and interface board. The GNSS antenna will sit on top of the payload , but it is not shown here.

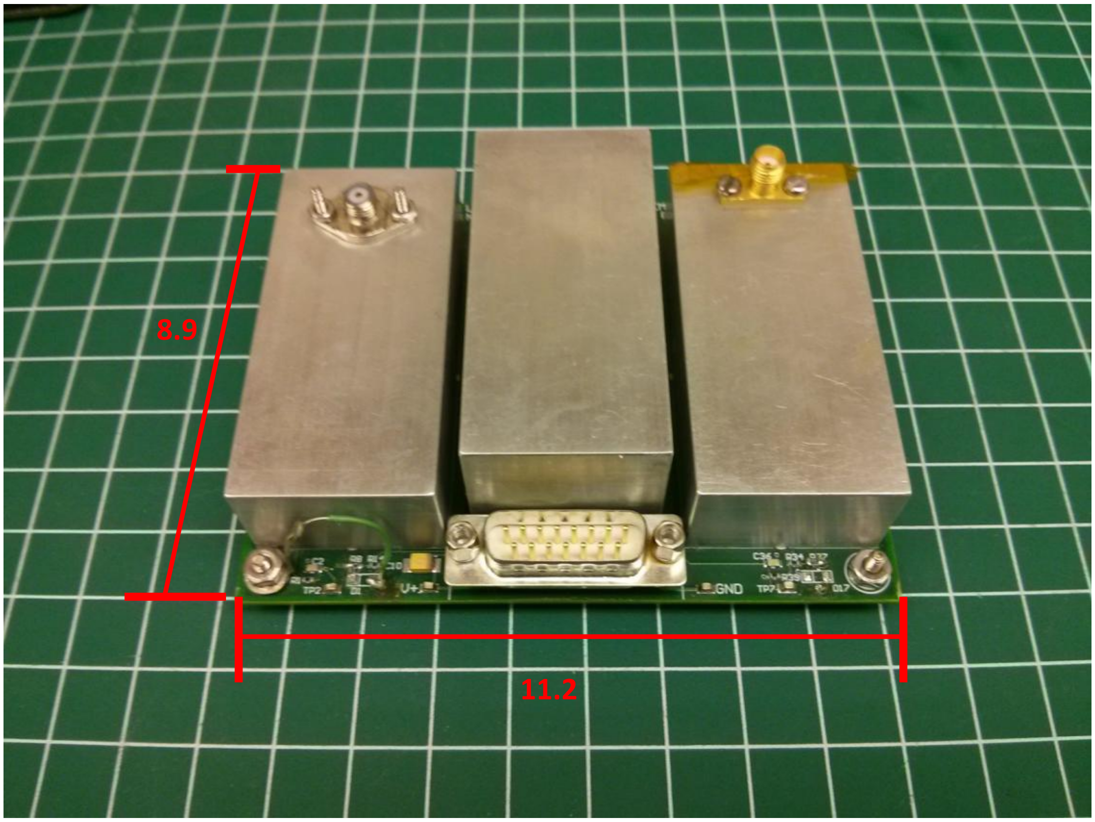

Figure A10. Picture of detector board with dimensions in centimeters.

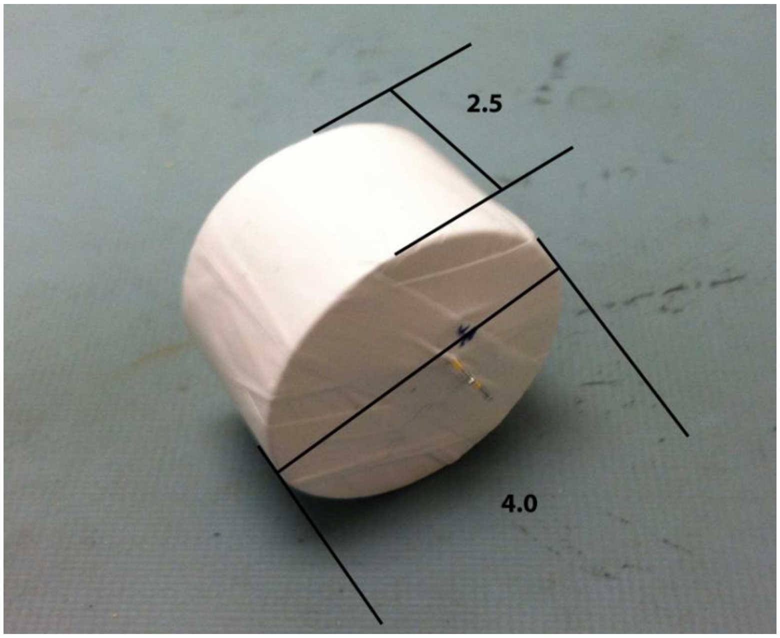

Figure A11. Detector assembly (photodiode affixed to scintillator and wrapped with Teflon tape) with dimensions in centimeters.

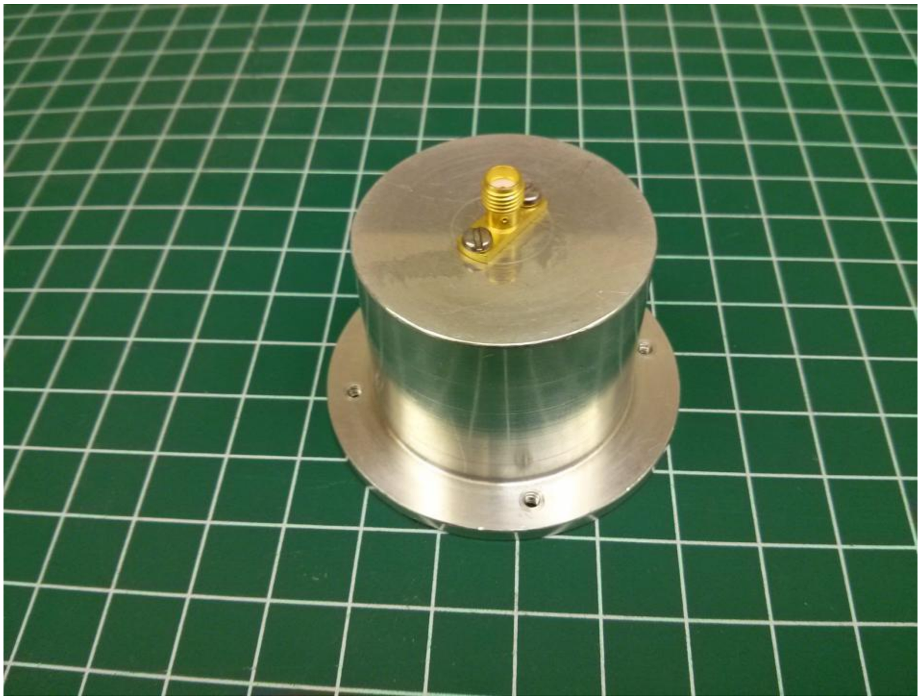

Figure A12. Detector housing is shown with new coaxial connector, which simplifies the connection between the detectors and the detector front board.

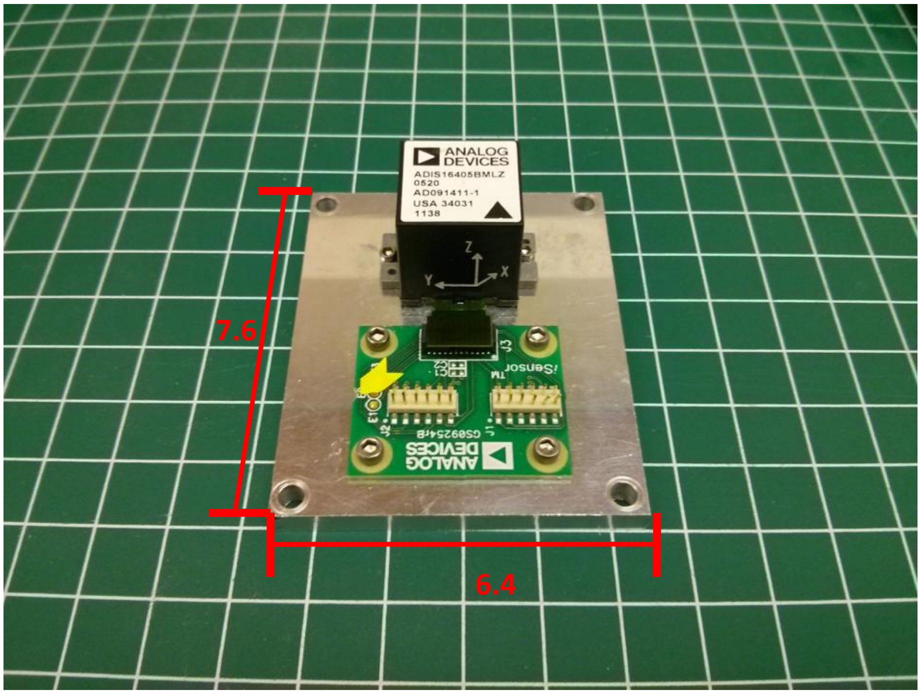

Figure A13. IMU and mounting plate with dimensions in centimeters.

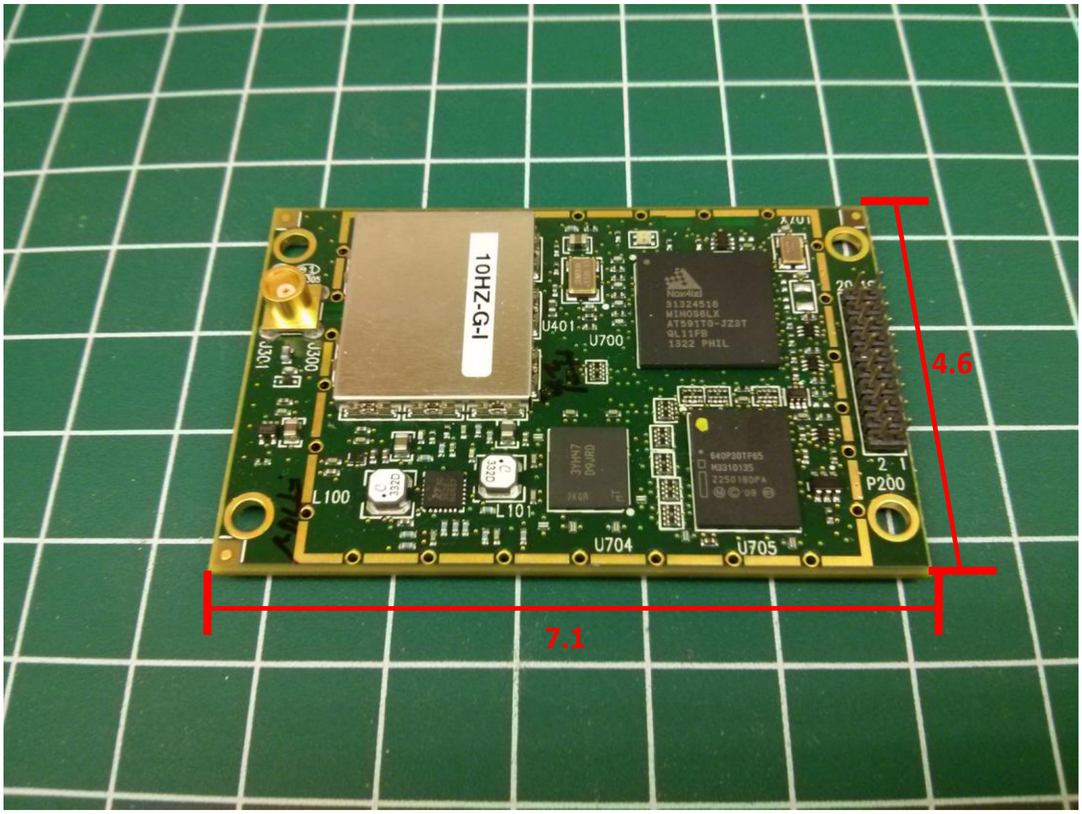

Figure A14. Novatel OEMStar GNSS receiver with dimensions in centimeters.

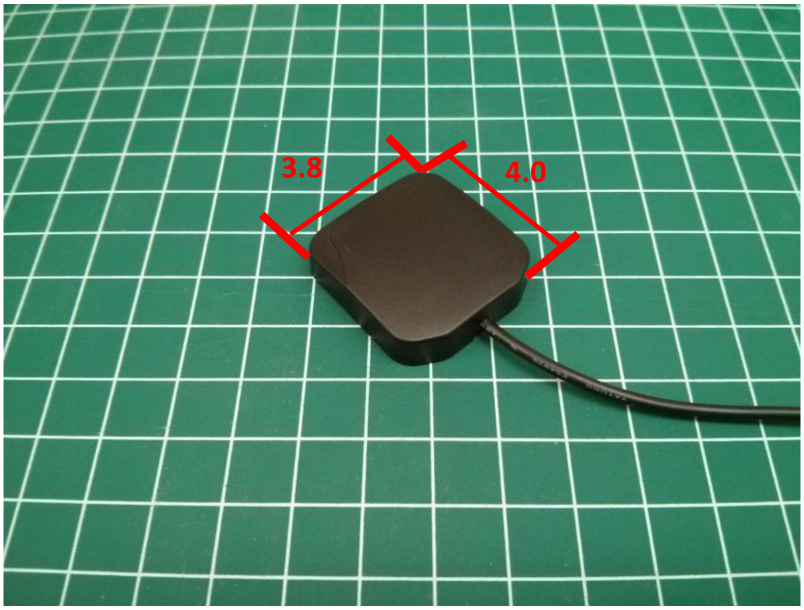

Figure A15. New GNSS antenna with dimensions in centimeters. The antenna is capable of receiving both GPS and GLONASS signals, and is in a protective housing.

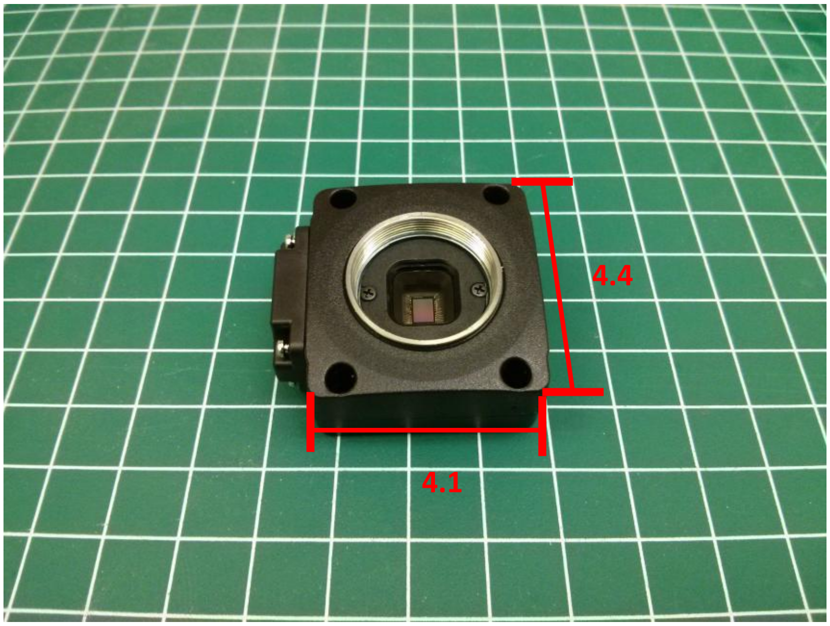

Figure A16. Point Grey Research Chameleon camera with dimensions in centimeters.

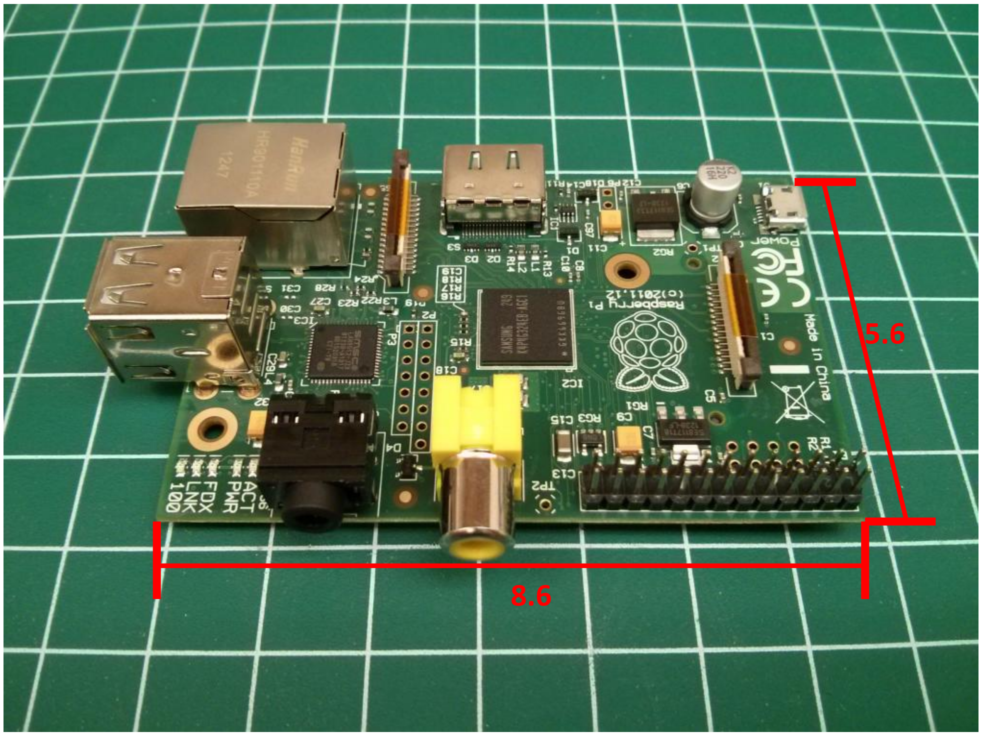

Figure A17. Raspberry Pi with dimensions in centimeters. The sole purpose of the Raspberry Pi will be to interface with the Chameleon camera, providing the necessary power and logging the images (sent over USB) to an SD card.

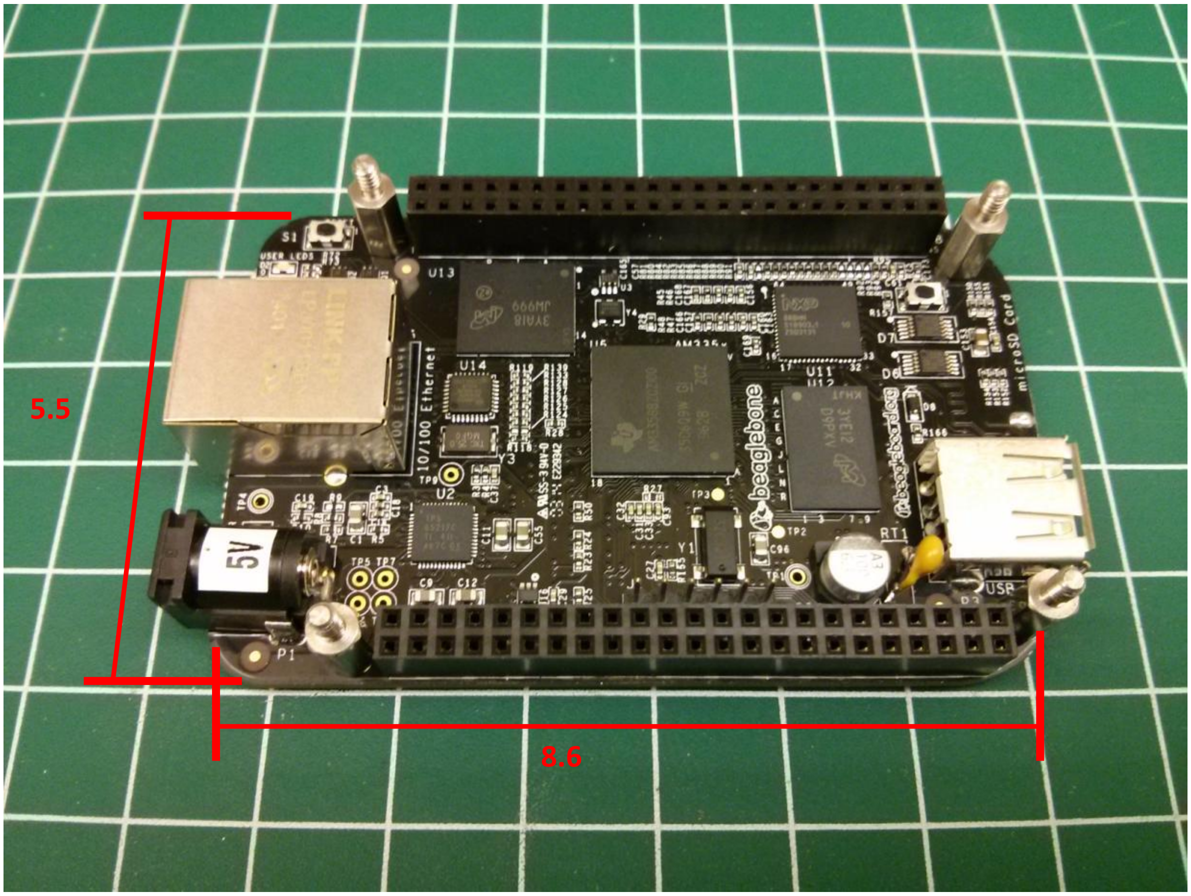

Figure A18. BeagleBone Black with dimensions in centimeters. The BeagleBone will be the primary flight computer, logging data from the IMU, GNSS receiver, and both X-ray detectors (including photon energies from the peak detector) to a microSD card.

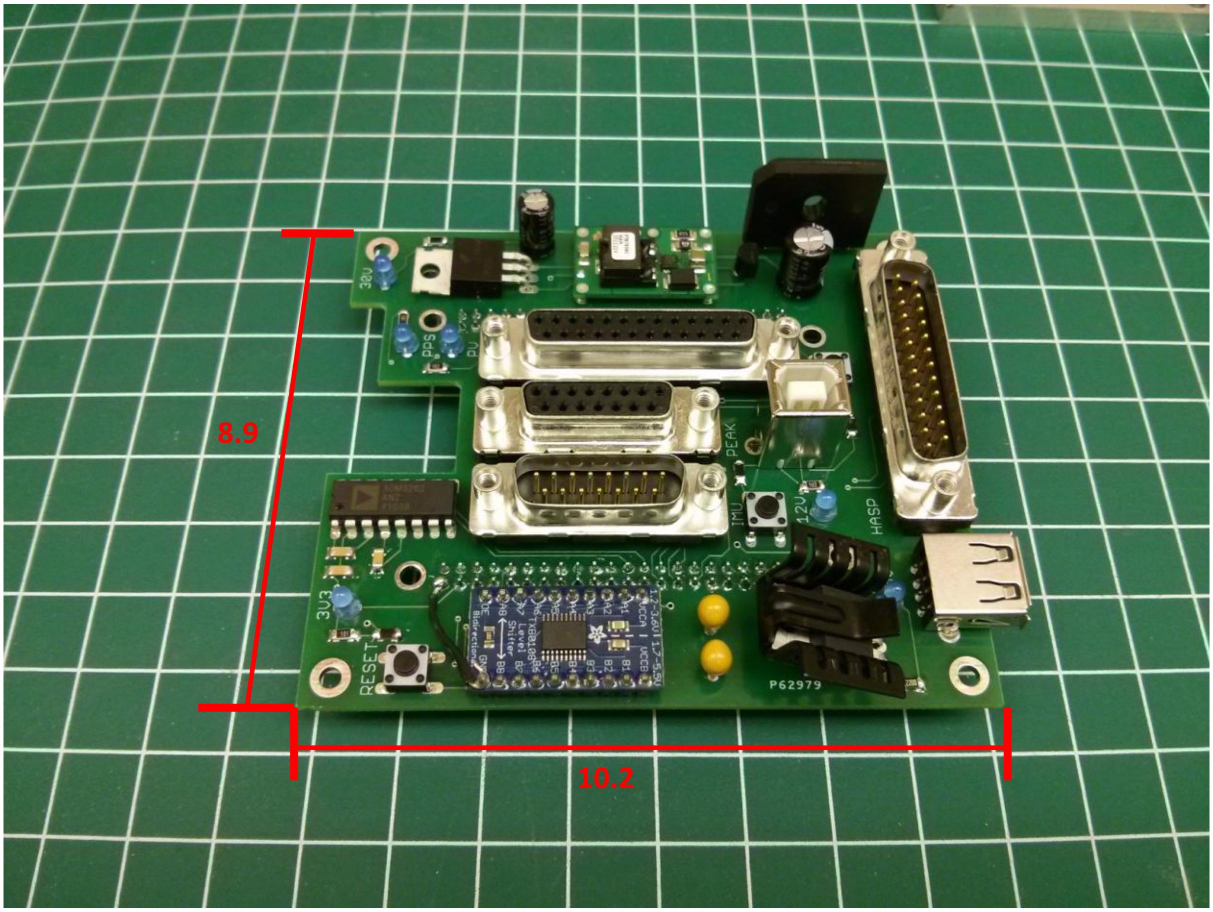

Figure A19. Picture of power and interface board with dimensions in centimeters. This board houses the power regulation and protection systems, and serves as the mounting base for the primary flight computer (see Figure A20).

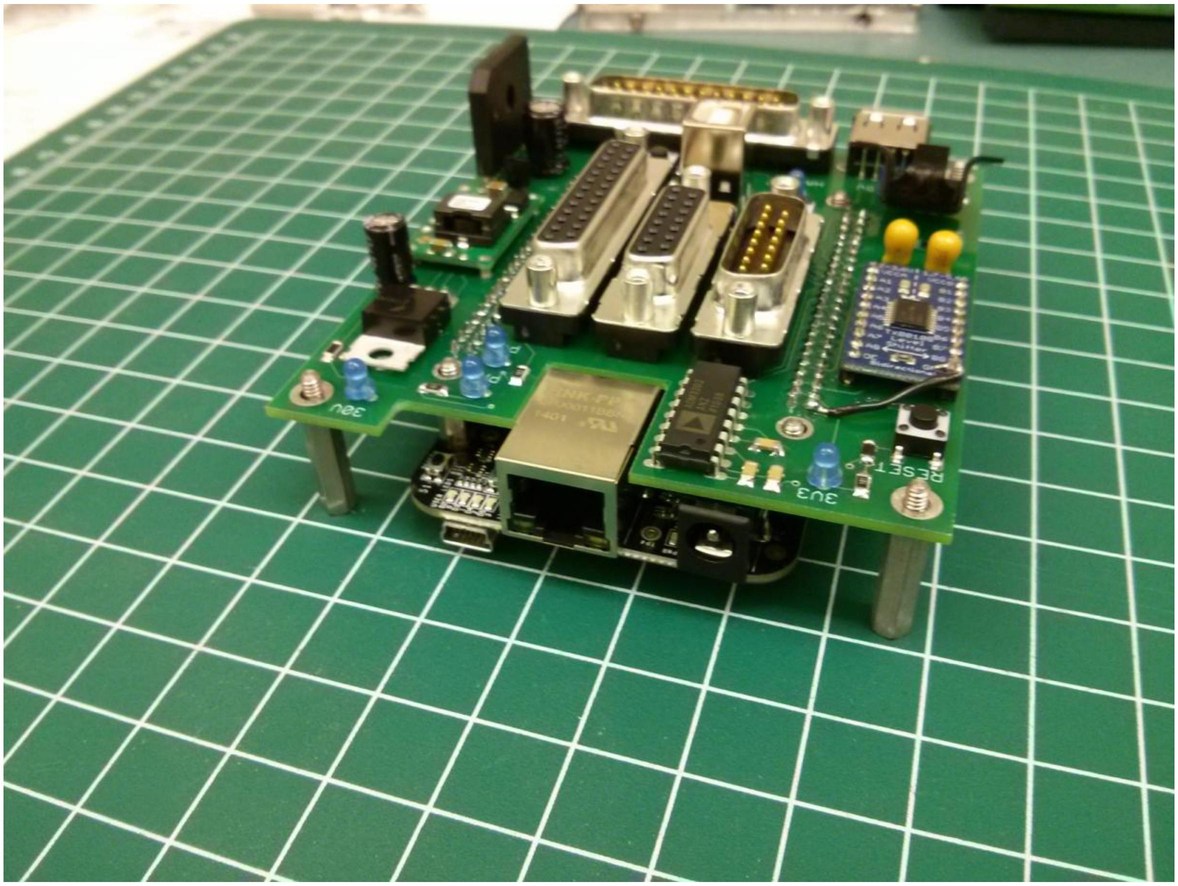

Figure A20. Picture of BeagleBone Black flight computer mounted below the power and interface board.

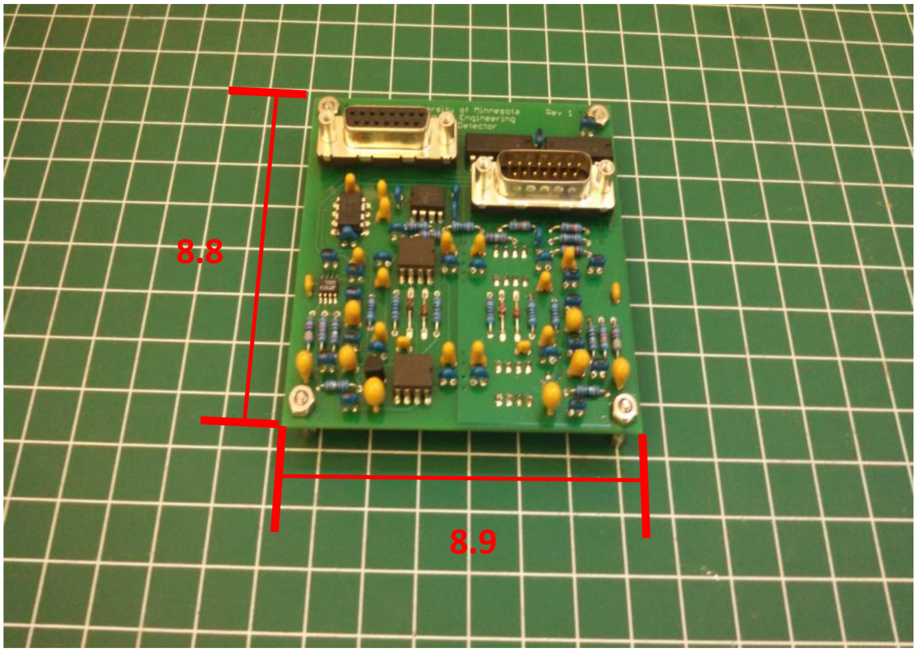

Figure A21. Picture of the custom-designed peak detection circuitry. The board features two sample-and-hold peak detectors built using extremely low-noise op amps to determine peak voltages on the preamp outputs of both channels on the detector front board; a 10-bit high-speed SPI analog-to-digital converter to allow the flight computer to read the voltages; and a logic network which converts the two discriminator outputs of the detector front board into three noncompeting interrupt signals to indicate photon events on the top detector only, bottom detector only, or both detectors "simultaneously" (within 5 microseconds of each other).