High-Altitude Radiation Detector (HARD) for Undergraduate R&D Experience

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Outline

- Overview of the Project - Lee
- Enhancing Student Learning Experience - Lee
- Student Design Activities - Neiman
- Payload Data & Next Steps – Neiman, Lawrence
- Concluding Remarks

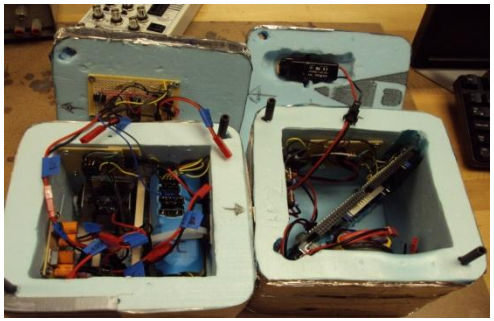
Overview of the Projects

Gannon's Ballooning: Past, Present, & Future

- High-altitude weather ballooning (AY 09-10)
  - To develop an entire ballooning system via a complete top-down design process, from req. spec.
- High-altitude radiation detector (HARD)(AY 10-11, 11-12, 12-13)
  - To design electronic subsystems to explore E-W asymmetry of cosmic rays' arrivals
- Undergraduate Student Instrument Project (USIP) (AY 13-14, AY 14-15)
  - To measure the proton-to-helium ratio of cosmic rays

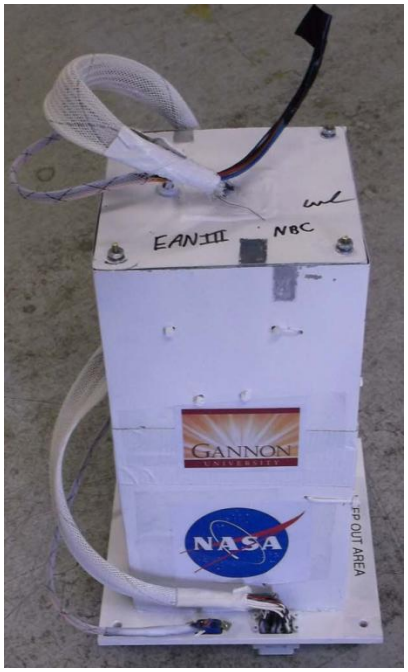
High-altitude Weather Ballooning

- Sr. Design Projects,10 students (AY 09-10)
  - On-board data processing and solar panel (ODSP) subsystem – payloads for various experiments
  - Command pod subsystem – payload for telemetry
  - Ground station subsystem – for tracking and recovery

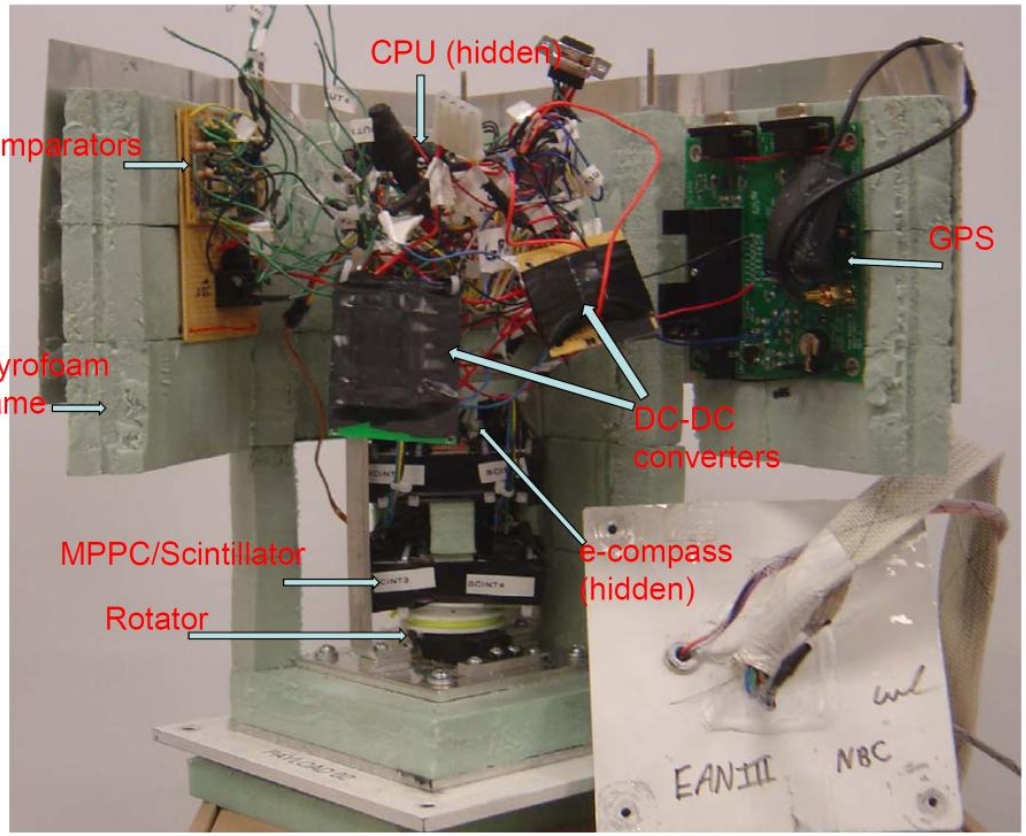


High-altitude Radiation Detector (HARD)

- HASP payload (small)
- Integration test at NASA's CSBF lab



< A completed, sealed payload >



< Interior view of the payload >

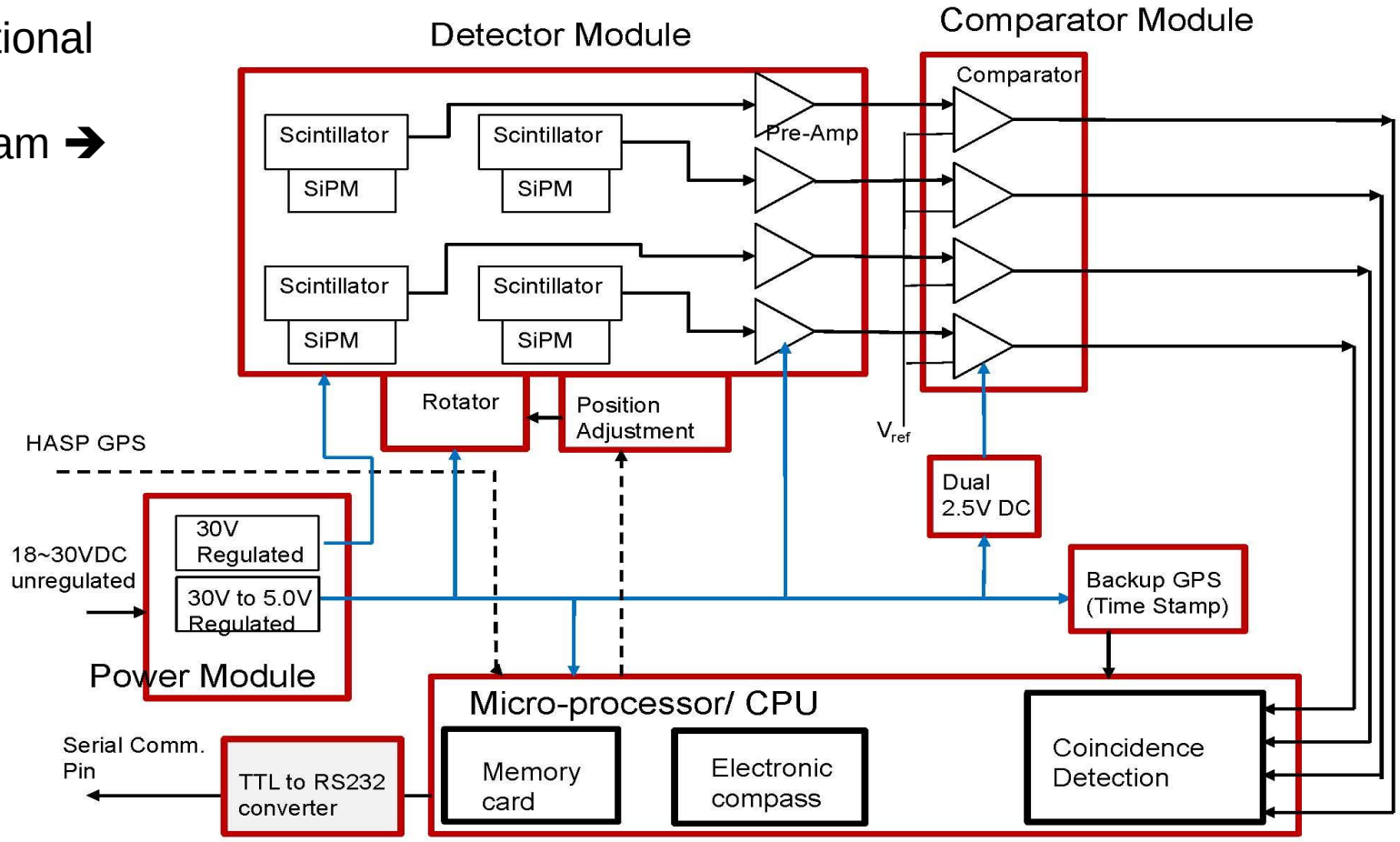
HARD: Enhancing Student Learning Experience

- ECE Courses vs Key Knowledge Required
  - 60-64 credit hours of engineering courses in a total of 131 credit hours (EE) or 132 credit hours (CE).
  - Related materials from ~50% of the engineering courses in our ECE curriculum (see next slide)
- Observations
  - Participation in this (or a similar) project helps students build/refine technical knowledge from a large percentage of their courses via hands-on experience
  - Students with two years of study would have most of the technical knowledge needed to carry out the project

Q#	Strongly Disagree	Moderately Disagree	Neutral	Moderately Agree	Strongly Agree	Not Applicable	# of Comments	# of students answered
1	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	n/a	9
2	0.0%	0.0%	0.0%	22.2%	77.8%	0.0%	4	9
3	0.0%	0.0%	0.0%	11.1%	88.9%	0.0%	n/a	9
4	0.0%	0.0%	0.0%	33.3%	66.7%	0.0%	4	9
5	0.0%	0.0%	0.0%	33.3%	66.7%	0.0%	n/a	9
6	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	4	9
7	0.0%	0.0%	11.1%	11.1%	77.8%	0.0%	n/a	9
8	0.0%	0.0%	11.1%	22.2%	66.7%	0.0%	4	9
9	0.0%	0.0%	0.0%	22.2%	77.8%	0.0%	n/a	9
10	0.0%	0.0%	0.0%	11.1%	88.9%	0.0%	5	9
11	0.0%	0.0%	0.0%	0.0%	88.9%	11.1%	n/a	9
12	0.0%	0.0%	0.0%	11.1%	77.8%	11.1%	4	9
13	0.0%	0.0%	0.0%	11.1%	88.9%	0.0%	n/a	9
14	0.0%	0.0%	0.0%	22.2%	77.8%	0.0%	5	9
15	0.0%	0.0%	0.0%	11.1%	66.7%	22.2%	n/a	9
16	0.0%	0.0%	0.0%	11.1%	66.7%	22.2%	3	9
17	0.0%	0.0%	0.0%	11.1%	77.8%	11.1%	n/a	9
18	0.0%	0.0%	0.0%	11.1%	77.8%	11.1%	3	9
19	0.0%	0.0%	11.1%	22.2%	44.4%	22.2%	n/a	9
20	0.0%	0.0%	11.1%	22.2%	44.4%	22.2%	2	9
21	0.0%	0.0%	11.1%	33.3%	55.6%	0.0%	n/a	9
22	0.0%	0.0%	11.1%	33.3%	55.6%	0.0%	5	9

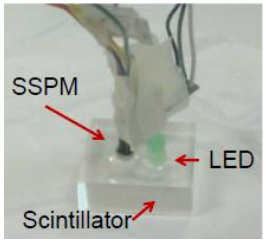
High-altitude Radiation Detector (HARD)

Functional block diagram ➔

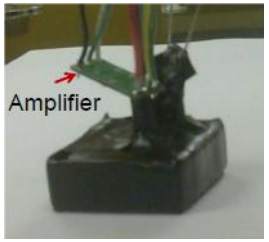


HARD: Detector Module

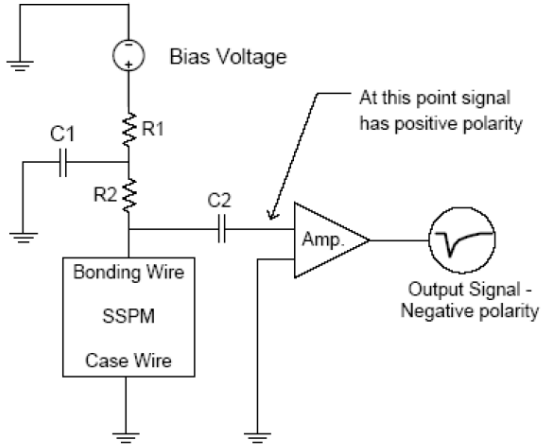
- Four active detector elements arranged in a square for detection of cosmic rays in the east-west plane
- Photonique SSPM 0905V13MM silicon photomultiplier (SiPM) attached via optical epoxy to a 3×3×1 cm^3 CsI(TI) scintillating crystal
- A negative pulse with a magnitude ranging from 0 to about -1.0V output from the pre-amplifier



< Photo diode and scintillator >



< Fully wrapped with a preamplifier >



< Application circuit diagram of the pre-amplifier for SiPM >

HARD: Other Subsystems

- Comparator Module

An inverting OP amp with a high voltage gain and large bandwidth operating at a frequency of up to 20 MHz to invert and amplify

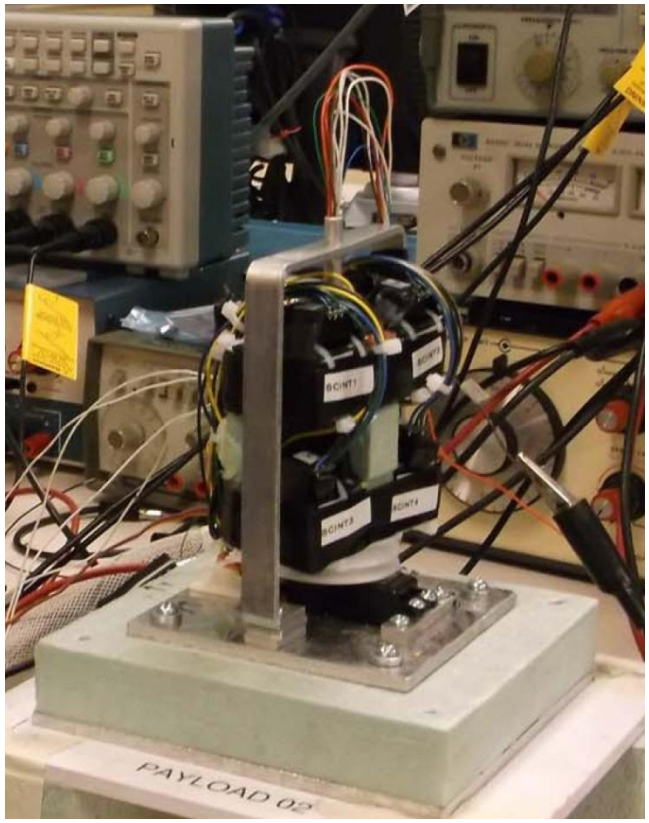
- Coincidence Detector
  - The comparator output is supplied to the digital inputs of the microprocessor.
  - The microprocessor polls these inputs approximately once each microsecond

- Microprocessor/CPU
  - A chipKIT Uno32 Prototyping Platform
  - Serial communication with HASP
  - Monitoring temperature
  - Controlling the servo to adjust detector orientation
  - GPS time
  - Recording data to an SD card

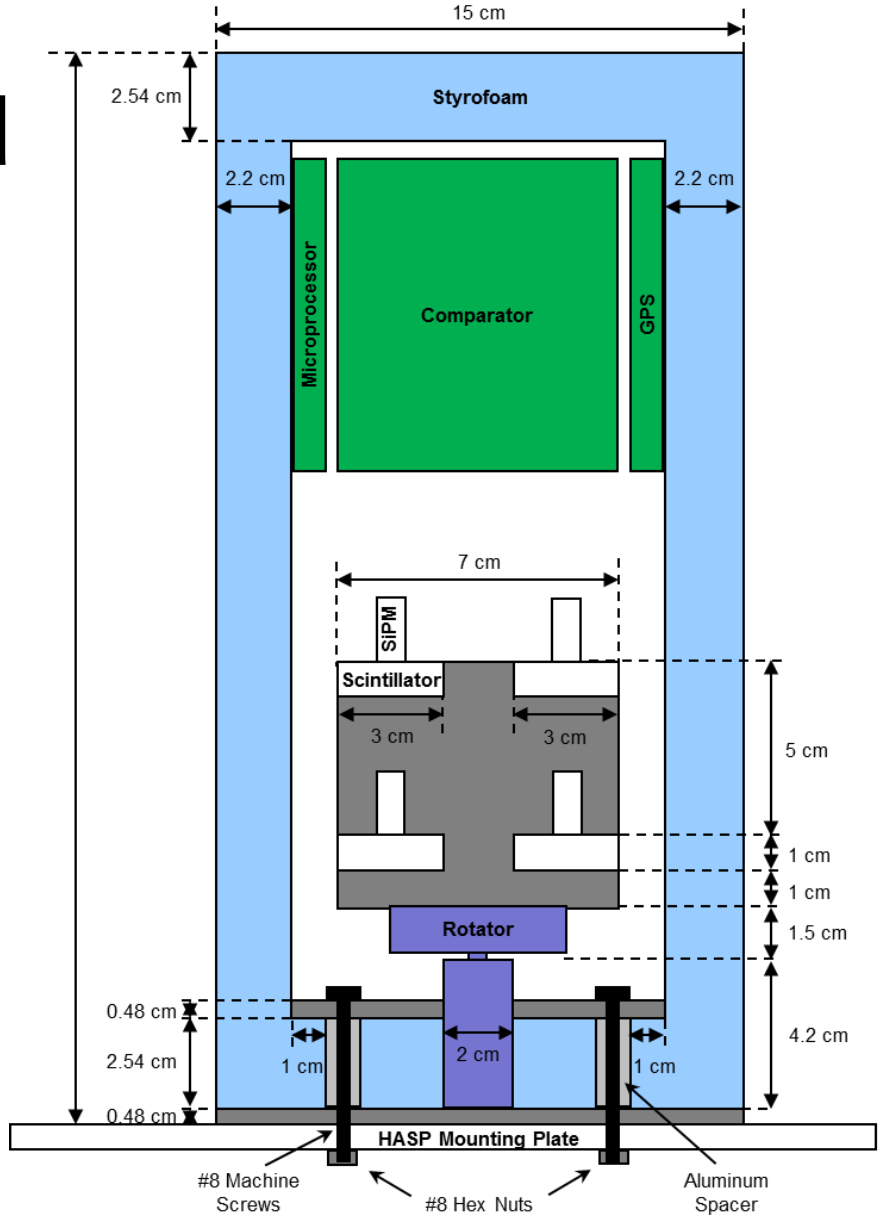
HARD: Other Subsystems (2)

- Power Module
  - 5Vdc (Murata NDY2405C DC-DC converter) for microprocessor, GPS, SiPM pre-amplifiers, temperature sensor, & rotator
  - 3.3 Vdc (Uno32's built-in, regulated 3.3Vdc) for e-compass and SD card
  - Dual ±2.5Vdc for comparator from a second NDY2405C in conjunction with a voltage divider

HARD:Payload

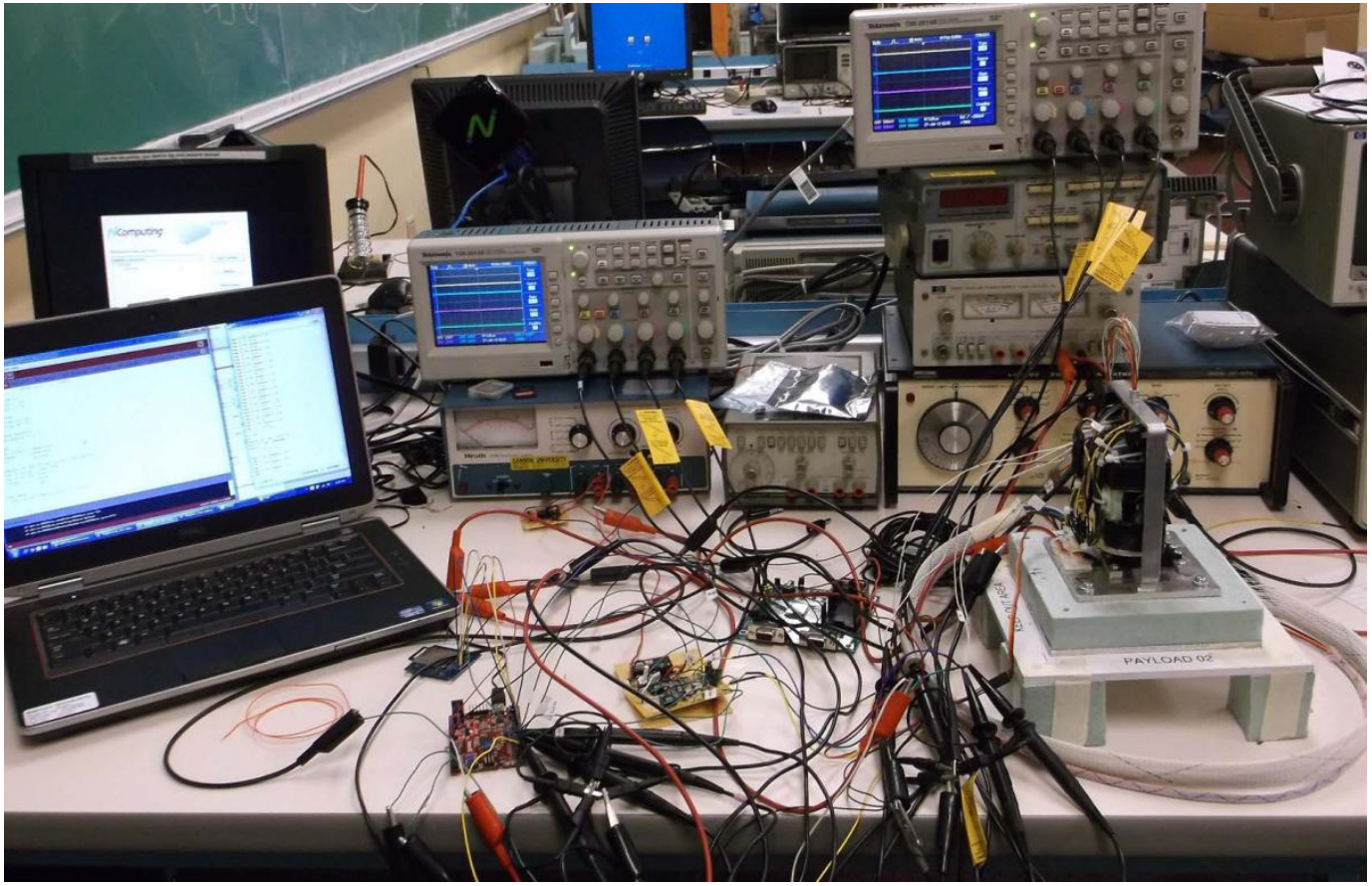


< Fully assembled detector module with the rotator module >



HARD: Experimental Setup

Setup for lab testing ➔



HARD: Experimental Data

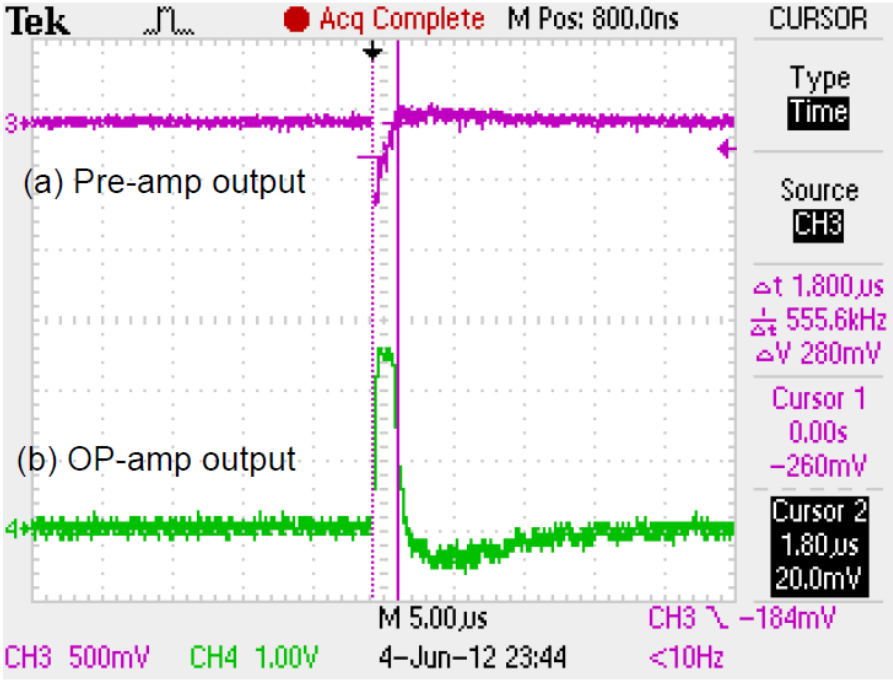
- Preamp

The pulse period was about 1.8 µs while its amplitude was -640 mV

- Comparator

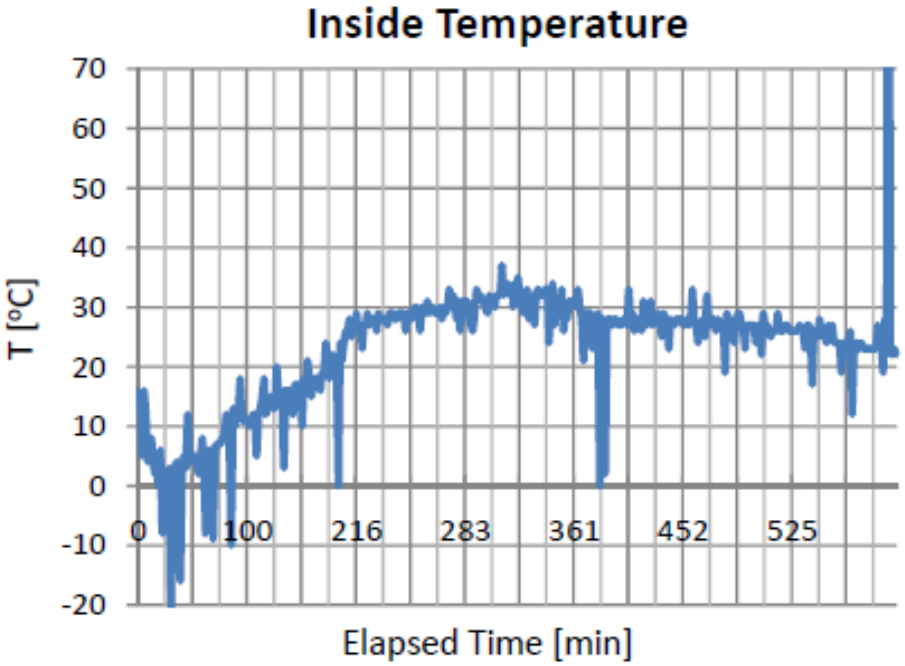
Successfully process the short negative pulse from the pre-amplifier and produces a positive output of similar duration; the output* of ~2.5V

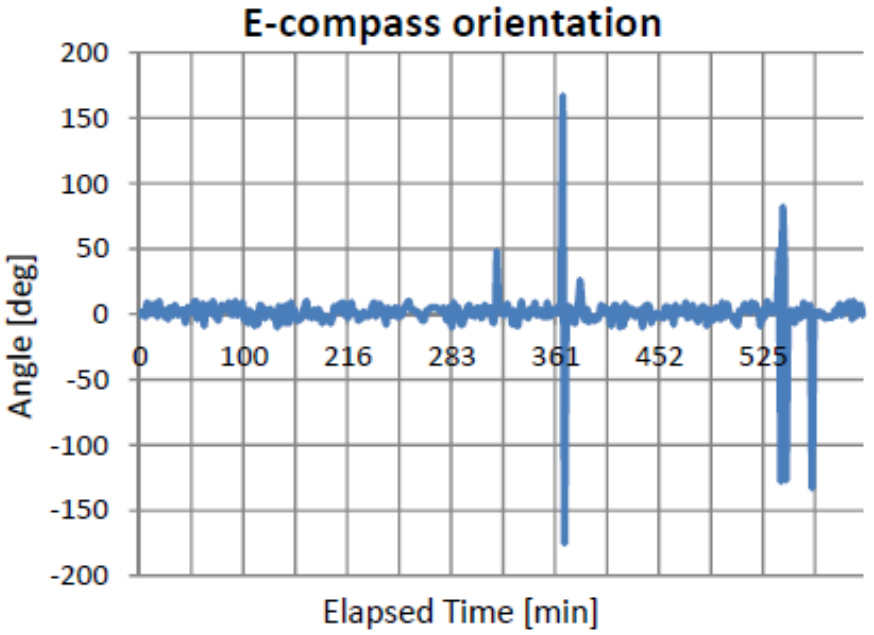
* Needs to exceed microcontroller's TTL logic threshold of 2.4 Vdc



< Output signals: (a) pre-amplifier (b) OP amp (comparator) >

HARD PL02: In-flight Data

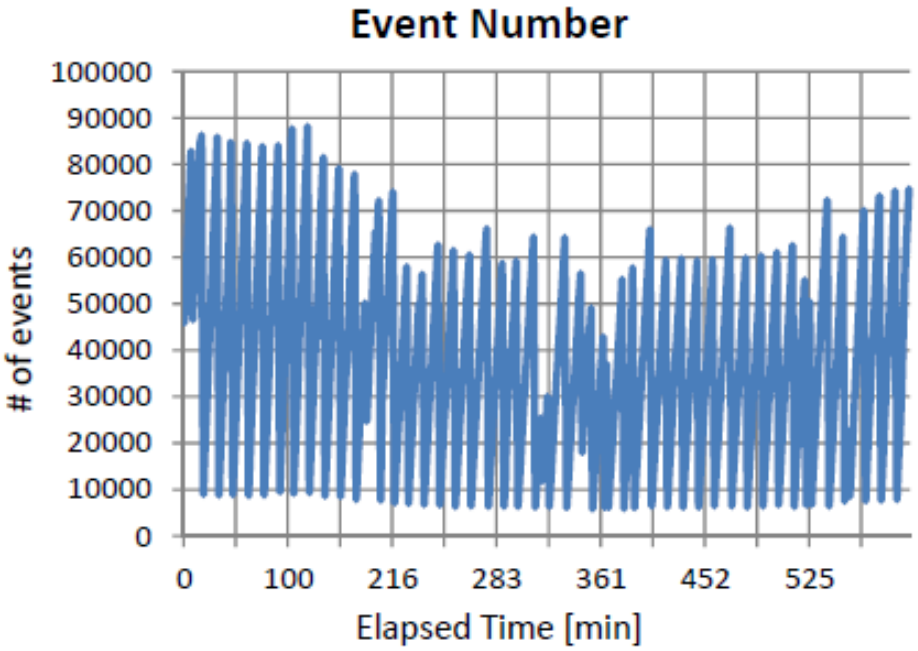


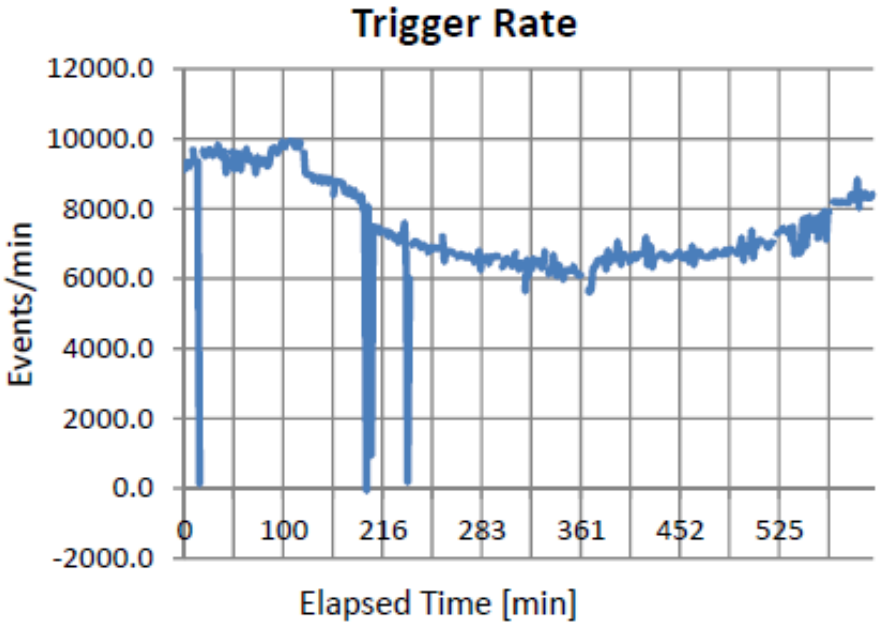


temperature in the range of -20 °C ~ +38 °C except for one data point which shows a temperature of 233 °C (from raw data) ~ corrupted data?

The payload orientation in reference to the East-West (E-W) plane; correction if a deviation of more than 10 degrees in either clockwise (negative) or counter-clockwise (positive) direction occurred.

HARD PL02: In-flight Data (2)





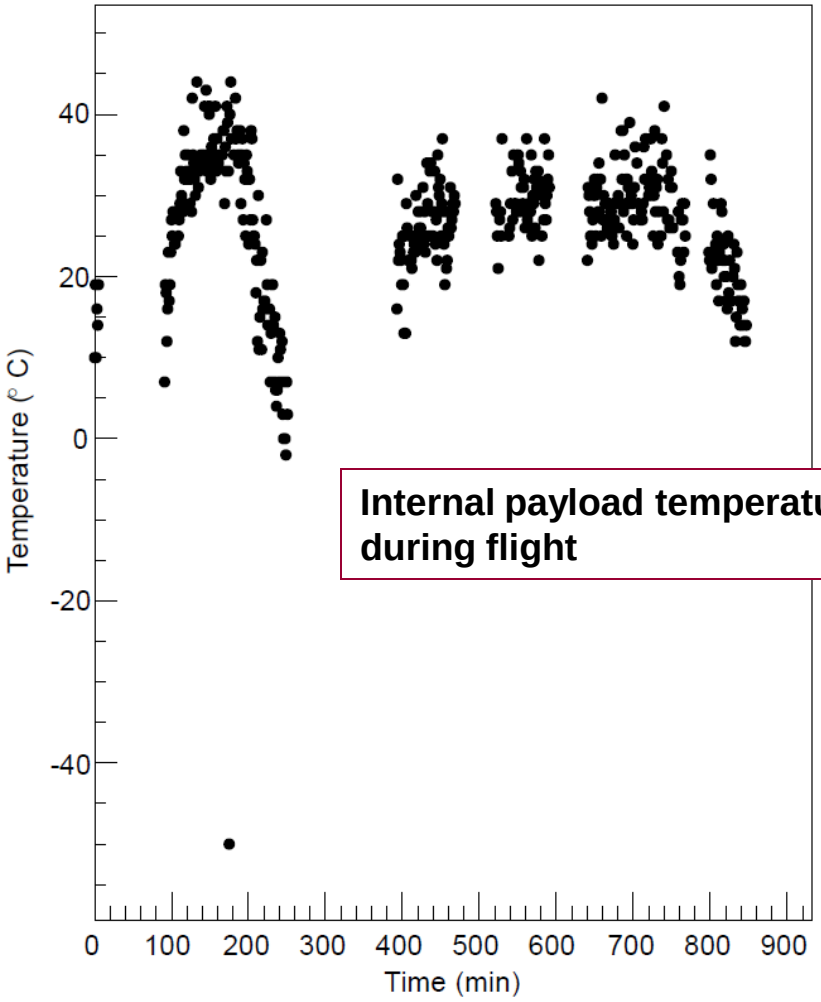
Problem!! The event number should monotonically increase, as the total number of events is accumulating over the flight. This situation can only happen when the micro-controller regularly resets the event number; a failure mode not observed in the lab.

HARD PL02: Failure Mode and Effect Analysis (Qualitative)

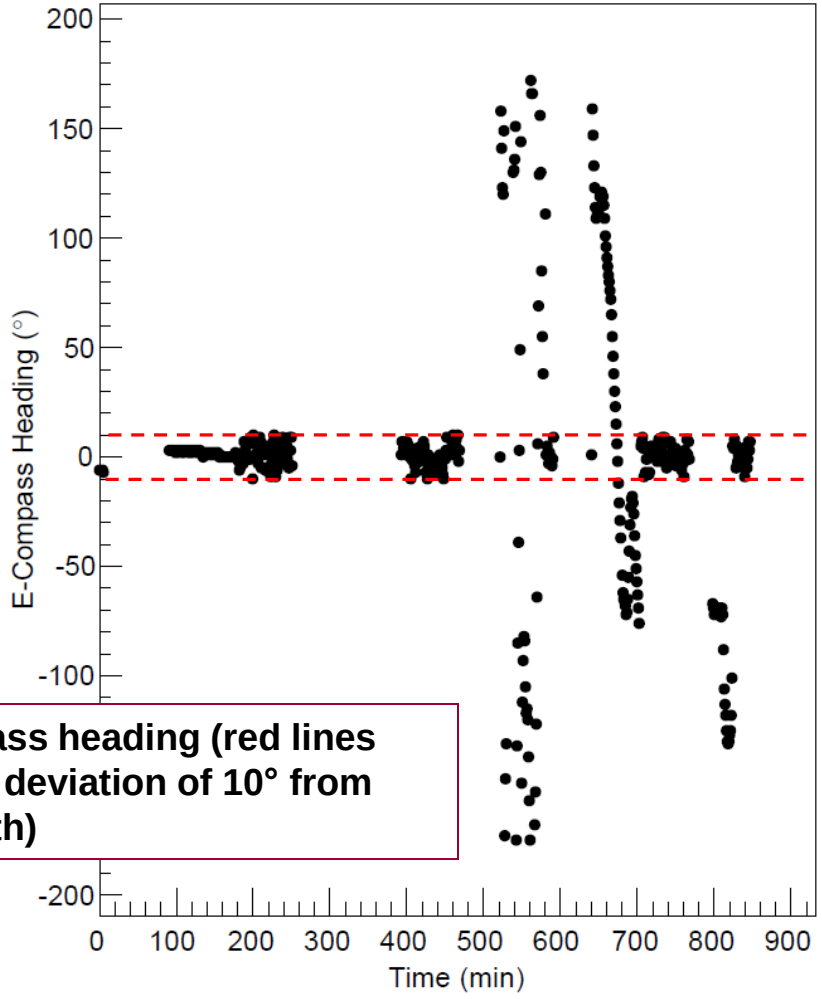
- Pin-pointing an exact cause was difficult because the failure didn't seem reproducible in the lab:
  - SiPM
  - Comparator
  - Microcontroller
  - Power module

➔ With much more careful design and rigorous testing in the lab, HARD PL03 (AY 12-13) resolved all issues.

HARD PL03: In-flight Data



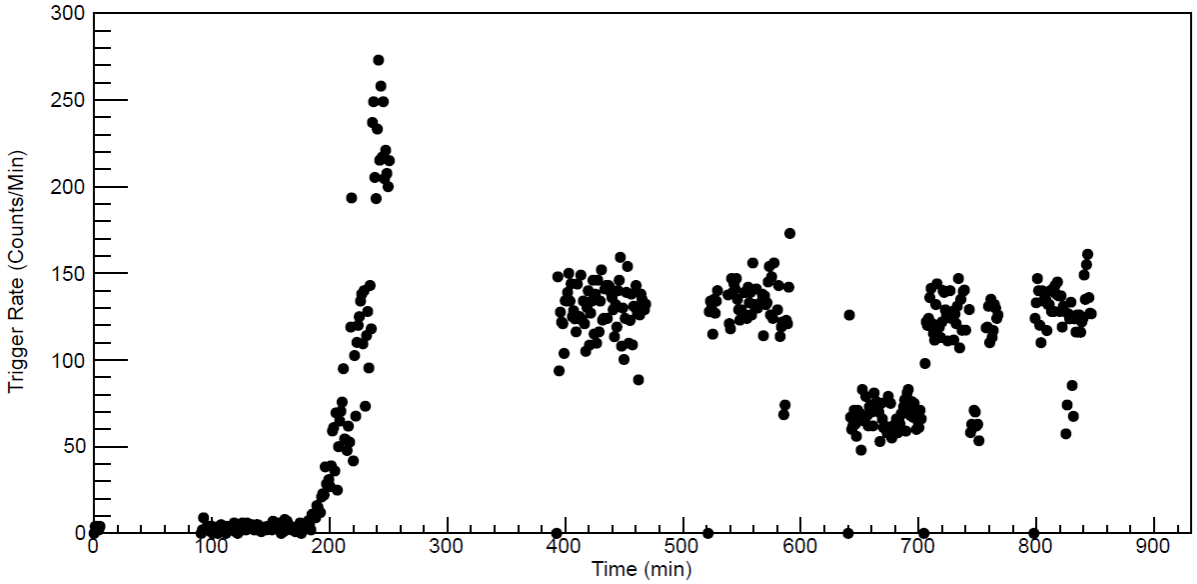
Internal payload temperature during flight

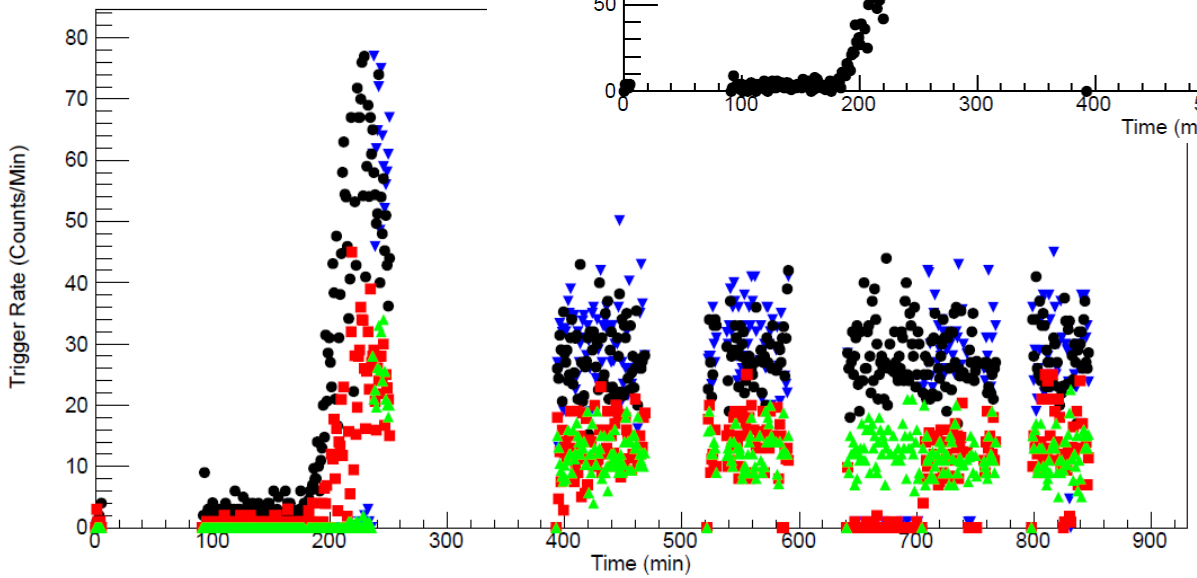


e-compass heading (red lines indicate deviation of 10° from due north)

HARD PL03: In-flight Data (2)

Total event rate (in counts per minute) for all directions





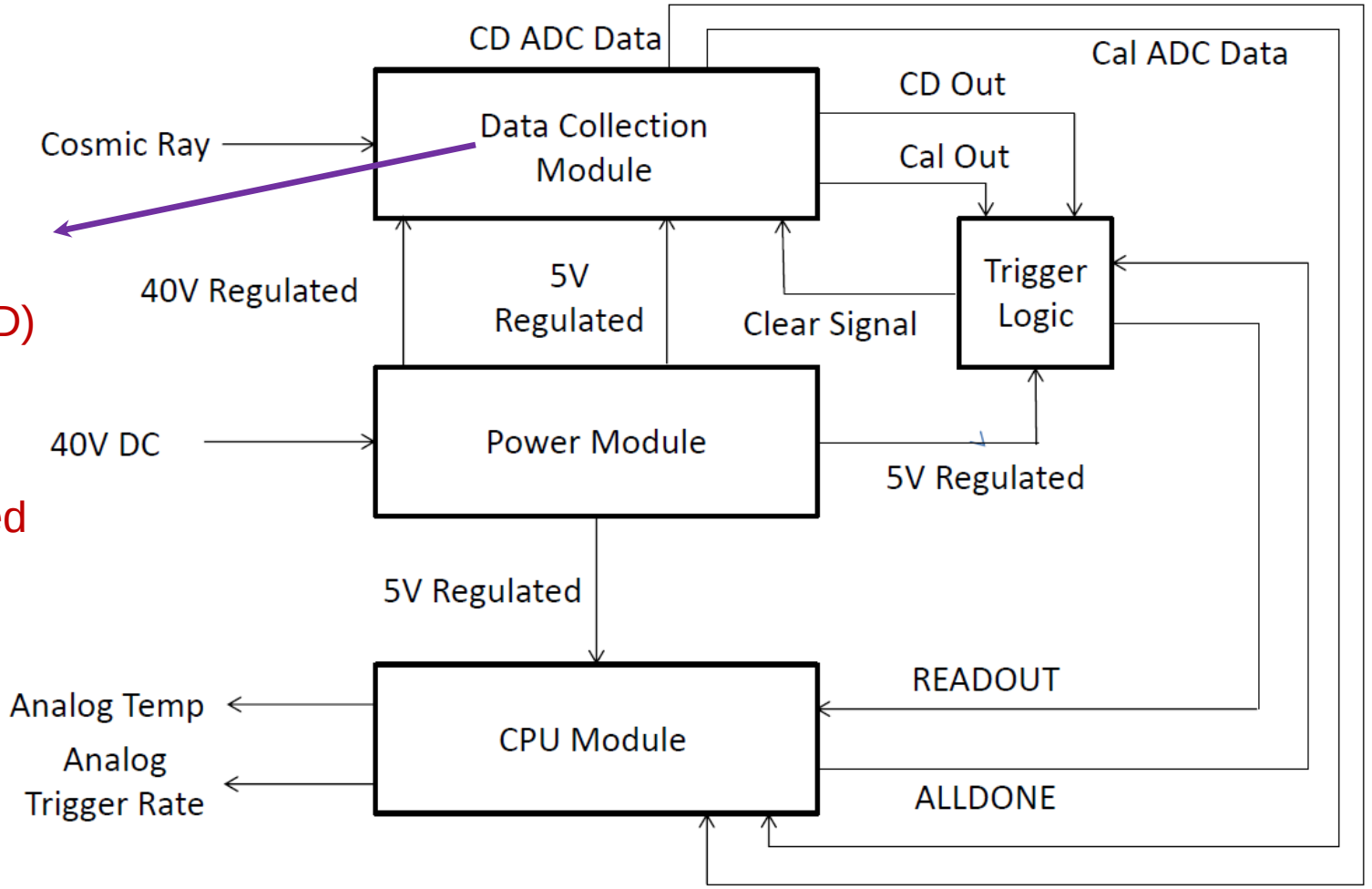
Event rate

- **downward events (blue downward triangles)**
- **downward events (black circles)**
- **east going events (red squares)**
- **west-going events (green upward triangles)**

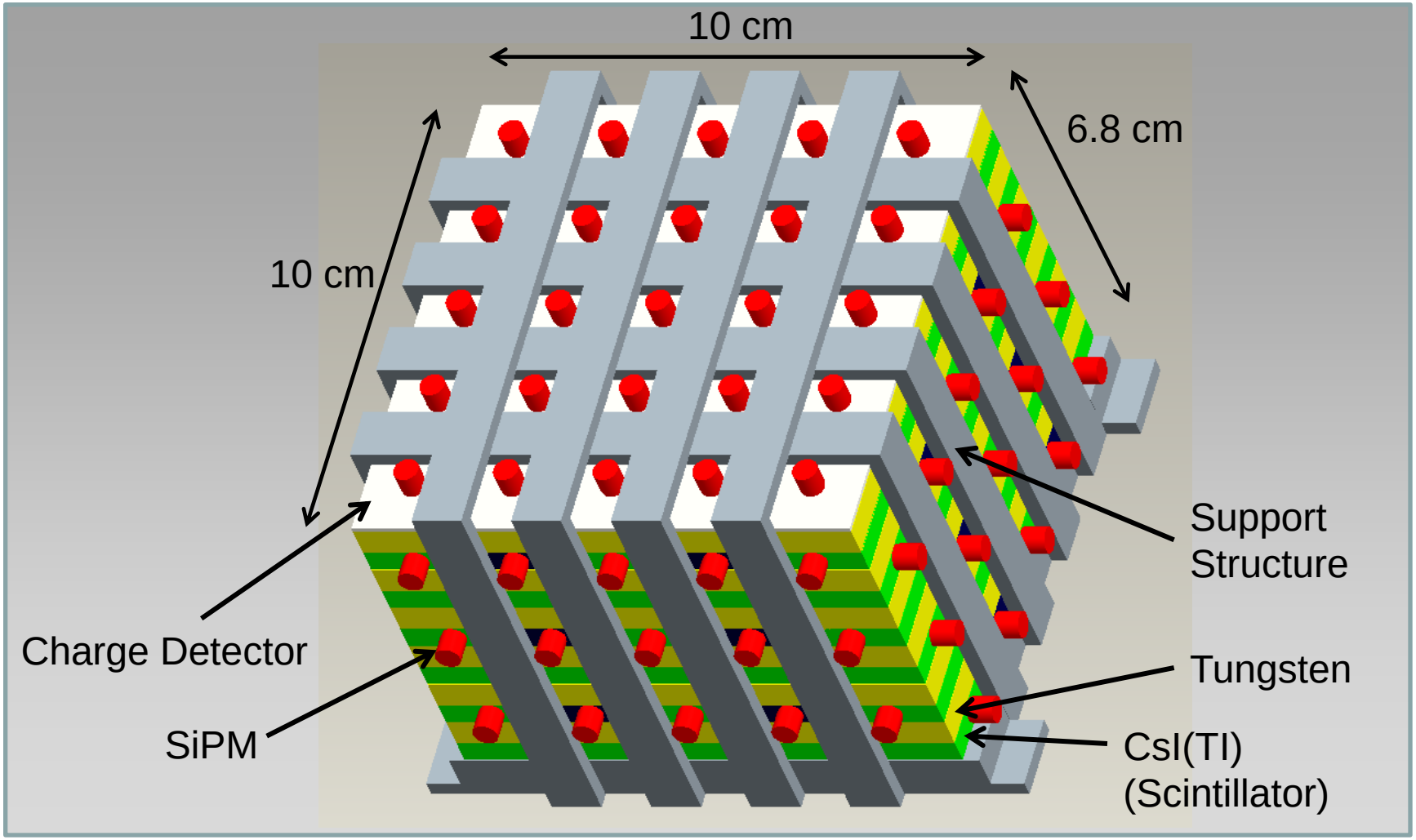
Next Steps: USIP

Functional block diagram ➔

- **55** SiPMs (4 SiPMs in HARD)
- Launch planned in spring 2015

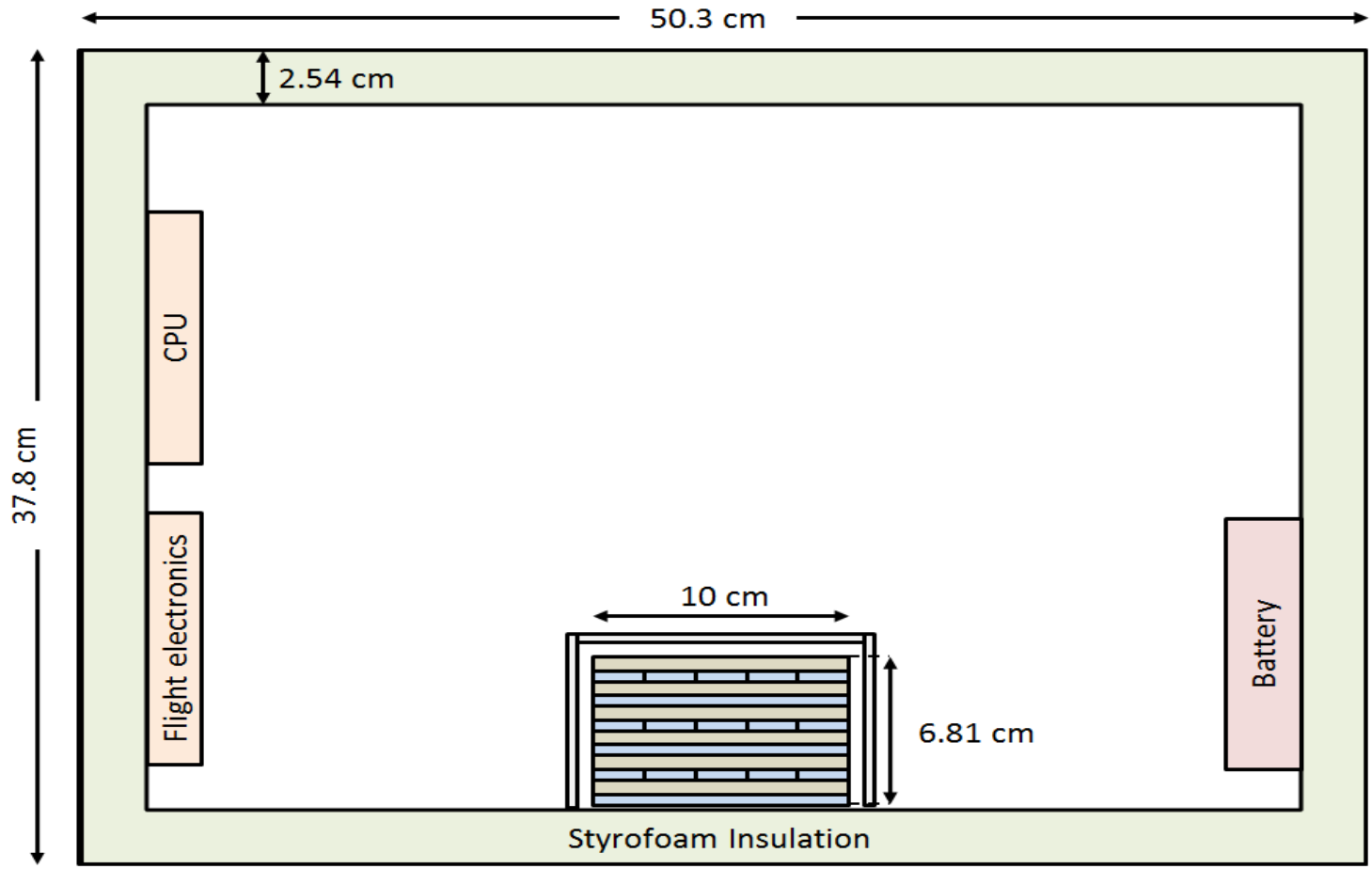


USIP: Physical Model of Calorimeter



USIP: Mechanical Interface

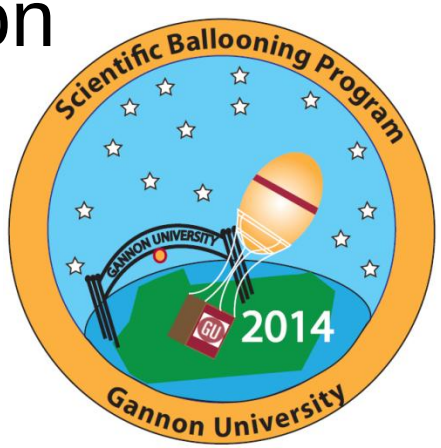
* Only for illustration purposes ➔



Concluding Remarks

- Described our UG R&D projects (Sr. Design, HARD, and USIP) over the past 5 years
- Scientific ballooning as an excellent learning framework for all levels of STEM students
- Collectively referred to as the Scientific Ballooning Program (SBP) at Gannon

Team logo designed by a communications arts student ➔ (contest winner)



Q & A

Backup Slides

HARD: Enhancing Student … (2)

	Fall Semester	Spring Semester	Credit Hours
Fresh-men	Eng Tools Applications (1 cr)	Intro. to C Programming (3 cr)	13 cr (for both EE and CE)
	Eng Tools Applications Lab (1 cr)	Digital Logic Design (3 cr)	
		Digital Logic Design Lab (1 cr)	
		Circuits I (3 cr)	
		Circuits I Lab (1 cr)	
Sopho more	Circuits II (3 cr) – EE only	Electronics I (3 cr)	14 cr (EE) 12 cr (CE)
	Circuits II Lab (1 cr) – EE only	Electronics I Lab (1 cr)	
	Prob Solving with Object-Oriented Programming (3 cr) – CE only	Data Structure & Algorithms (3 cr) – CE only	
	Test & Measurement (3 cr)		
	Microprocessor (2 cr)		
	Microprocessor Lab (1 cr)		
Junior	Electronics II (2 cr) – EE only	Rapid Prototyping with FPGA (3 cr) – CE only	3 cr (EE) 6 cr (CE)
	Electronics II Lab (1 cr) – EE only		
	Advanced Digital Design (2 cr) – CE only		
	Advanced Digital Design Lab (1 cr) – CE only		
		Subtotal:	30 cr (EE) 31 cr (CE)

Enhancing Student … (3)

- Q's on Student Learning Outcomes

Q1&2: (a) an ability to apply knowledge of mathematics, science, and …
Q3&4: (b) an ability to design and conduct experiments, as well as to …
Q5&6: (c) an ability to design a system, component, or process to meet …
Q7&8: (d) an ability to function on multidisciplinary teams
Q9&10: (e) an ability to identify, formulate, and solve engineering problems
Q11&12: (f) an understanding of professional and ethical responsibility
Q13&14: (g) an ability to communicate effectively
Q15&16: (h) the broad education necessary to understand the impact of …
Q17&18: (i) a recognition of the need for, and an ability to engage in life-long …
Q19&20: (j) a knowledge of contemporary issues
Q21&22: (k) an ability to use the techniques, skills, and modern engineering …