THE UNIVERSITY OF TEXAS AT DALLAS

Bringing the CubeSatSim to UT Dallas: Workshop Reflections

Agastya Bose KJ5MSH
PhD Student, Computer Science
The University of Texas at Dallas (agastya@utdallas.edu)
AMSAT Space Symposium, October 18, 2025.

Agenda

1. *About our team*
2. *Preparing for the workshop*
3. *About the workshop*
4. *Activities at the workshop*
5. *Participant feedback on the CubeSatSim*
6. *Future work: Research using the CubeSatSim*

Our “motley crew”

- Dr. Kangkook Jee
- Dr. Robert Baumann (IEEE fellow)
- Timothy Sweet
- Me
- Special thanks: Alan Johnston KU2Y, Ron Dang K5SUS, Ethan Maher, Geonwoo Park, and Dr. Ovidiu Daescu
- An interdisciplinary effort for sure!

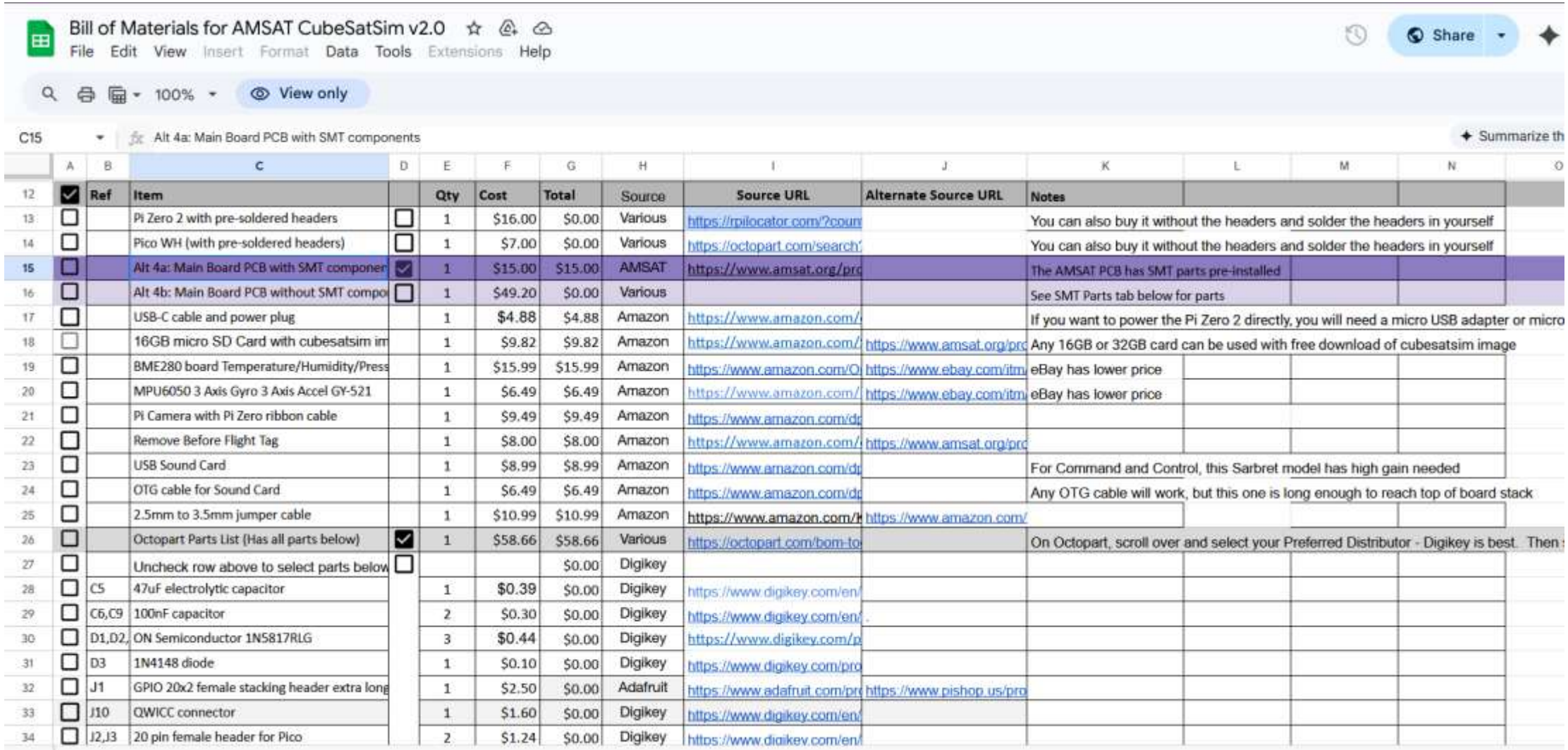
But why?

- We didn't want to do a typical, run-of-the-launchpad satellite workshop
- Different backgrounds: collaboration of academia, industry, and passion!
- Our partnership enabled interesting activities
- …like cooking CubeSatSims in an X-ray chamber? (more on this later)
- Cybersecurity interests in mind

So how did we do it?

- A trove of information:
  https://CubeSatSim.org/
- 10 CubeSatSim kits purchased
  1 prototype, 6 for workshop
- *Planning phase: gathering parts!*
  - Tariffs, tariffs, tariffs (June - July 2025)
  - Alternative vendors in Alan's BOM were a lifesaver

So how did we do it?



Bill of Materials for AMSAT CubeSatSim v2.0

File Edit View Insert Format Data Tools Extensions Help

Share

100% View only

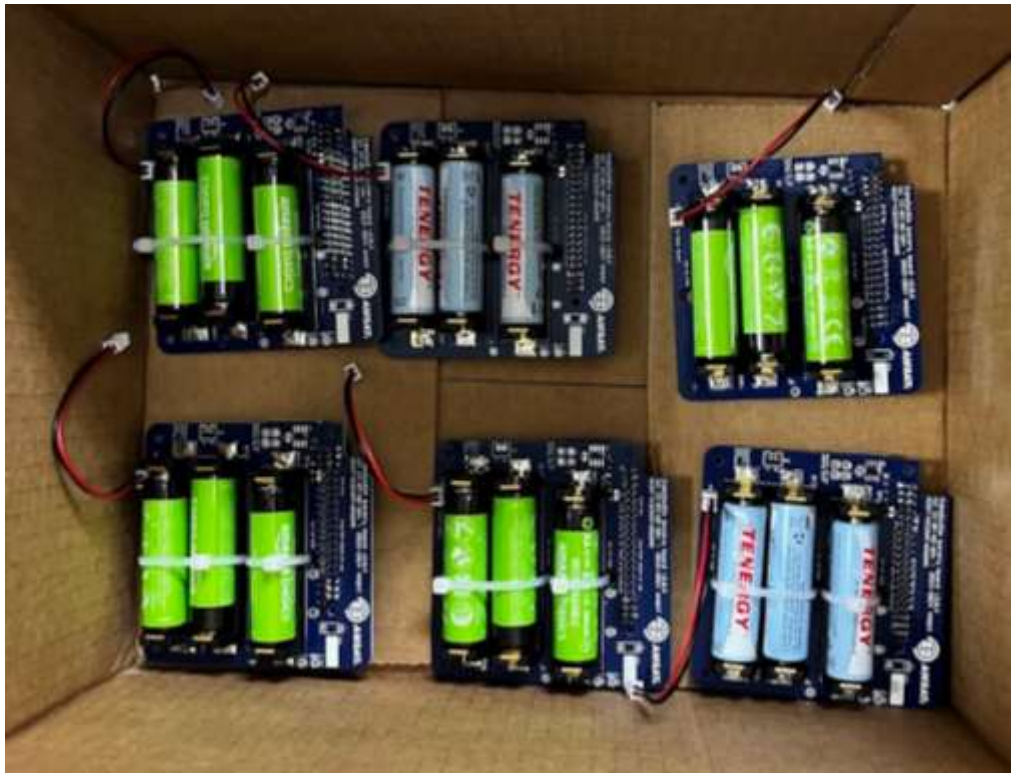
C15 Alt 4a: Main Board PCB with SMT components

Summarize th

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
12	☑	Ref	Item		Qty	Cost	Total	Source	Source URL	Alternate Source URL	Notes				
13	☐		Pi Zero 2 with pre-soldered headers	☐	1	$16.00	$0.00	Various	https://rpilocator.com/?coun		You can also buy it without the headers and solder the headers in yourself				
14	☐		Pico WH (with pre-soldered headers)	☐	1	$7.00	$0.00	Various	https://octopart.com/search?		You can also buy it without the headers and solder the headers in yourself				
15	☐		Alt 4a: Main Board PCB with SMT componer	☑	1	$15.00	$15.00	AMSAT	https://www.amsat.org/pro		The AMSAT PCB has SMT parts pre-installed				
16	☐		Alt 4b: Main Board PCB without SMT compo	☐	1	$49.20	$0.00	Various			See SMT Parts tab below for parts				
17	☐		USB-C cable and power plug		1	$4.88	$4.88	Amazon	https://www.amazon.com/		If you want to power the Pi Zero 2 directly, you will need a micro USB adapter or micro				
18	☐		16GB micro SD Card with cubesatsim im		1	$9.82	$9.82	Amazon	https://www.amazon.com/	https://www.amsat.org/pro	Any 16GB or 32GB card can be used with free download of cubesatsim image				
19	☐		BME280 board Temperature/Humidity/Press		1	$15.99	$15.99	Amazon	https://www.amazon.com/O	https://www.ebay.com/itm	eBay has lower price				
20	☐		MPU6050 3 Axis Gyro 3 Axis Accel GY-521		1	$6.49	$6.49	Amazon	https://www.amazon.com/	https://www.ebay.com/itm	eBay has lower price				
21	☐		Pi Camera with Pi Zero ribbon cable		1	$9.49	$9.49	Amazon	https://www.amazon.com/dp						
22	☐		Remove Before Flight Tag		1	$8.00	$8.00	Amazon	https://www.amazon.com/	https://www.amsat.org/pro					
23	☐		USB Sound Card		1	$8.99	$8.99	Amazon	https://www.amazon.com/dp		For Command and Control, this Sarbret model has high gain needed				
24	☐		OTG cable for Sound Card		1	$6.49	$6.49	Amazon	https://www.amazon.com/dp		Any OTG cable will work, but this one is long enough to reach top of board stack				
25	☐		2.5mm to 3.5mm jumper cable		1	$10.99	$10.99	Amazon	https://www.amazon.com/H	https://www.amazon.com/					
26	☐		Octopart Parts List (Has all parts below)	☑	1	$58.66	$58.66	Various	https://octopart.com/bom-to		On Octopart, scroll over and select your Preferred Distributor - Digikey is best. Then				
27	☐		Uncheck row above to select parts below	☐			$0.00	Digikey							
28	☐	C5	47uF electrolytic capacitor		1	$0.39	$0.00	Digikey	https://www.digikey.com/en/						
29	☐	C6,C9	100nF capacitor		2	$0.30	$0.00	Digikey	https://www.digikey.com/en/						
30	☐	D1,D2,	ON Semiconductor 1N5817RLG		3	$0.44	$0.00	Digikey	https://www.digikey.com/p						
31	☐	D3	1N4148 diode		1	$0.10	$0.00	Digikey	https://www.digikey.com/pro						
32	☐	J1	GPIO 20x2 female stacking header extra long		1	$2.50	$0.00	Adafruit	https://www.adafruit.com/pr	https://www.pishop.us/pro					
33	☐	J10	QWICC connector		1	$1.60	$0.00	Digikey	https://www.digikey.com/en/						
34	☐	J2,J3	20 pin female header for Pico		2	$1.24	$0.00	Digikey	https://www.digikey.com/en/						

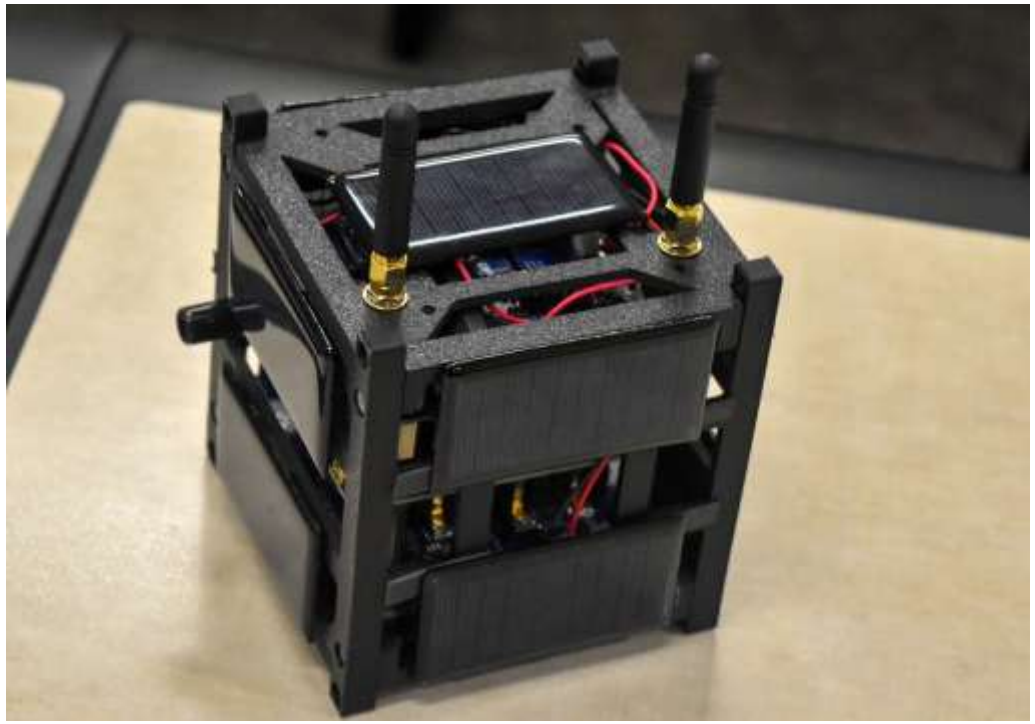
So how did we do it?

- *Planning phase: activities!*
  - Excellent collection of activity guides from AMSAT's CubeSatSim team
  - https://github.com/alanbjohnston/CubeSatSim/wiki/CubeSatSim-Activity-Guides
  - Fast-forwarding through RF fundamentals while dry-running (AFSK? BPSK?? CW???)
  - X-ray TID activity
  - In the next iteration we will surely try more activities!



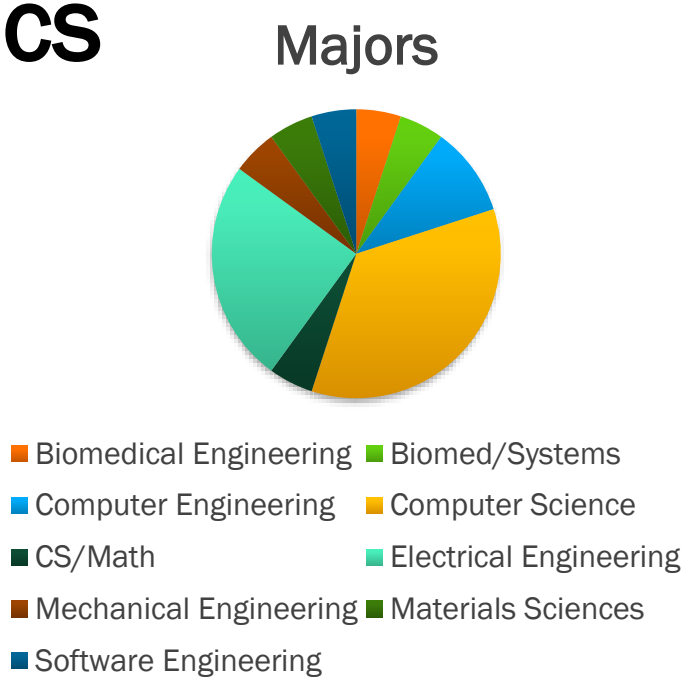
So how did we do it?

- *Planning phase: assembly*!
  - So. Much. Soldering. And I loved it!
  - First prototype took me several hours spread out over ~2 days (my first time soldering).
  - Lots of help over the next week; really saved my life.
  - Word to the wise: sort out all parts beforehand (a lot to work with, especially with 6 kits).



Student demographics

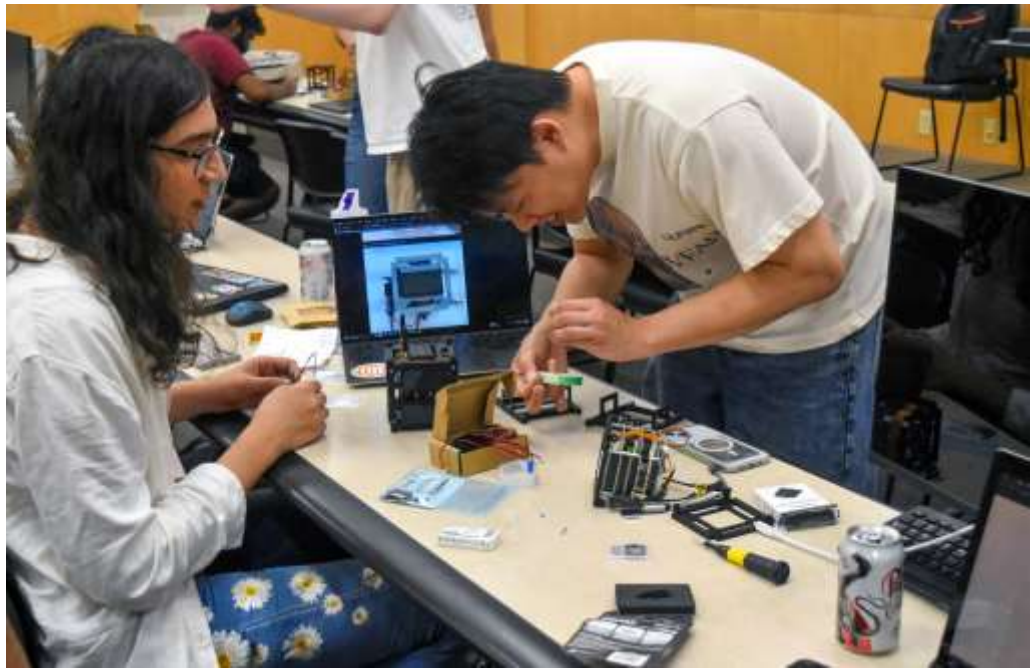
- **Interdisciplinary** to the core.
- 2-3 students had ham licenses.
- We even received an application from faculty.
- Interest even in South Korea. One participant flew out from there.



Program	Count
Bachelor	13
Bachelor, Master	1
Master	3
Ph.D.	3
Total	**20**

The best satellite workshop at UTD yet

- A 3-day affair, each packed with activities and lectures
- Students assembled the models from pre-soldered circuit boards
- Ground station setup
- Lots of students' first time with RF



Day 1

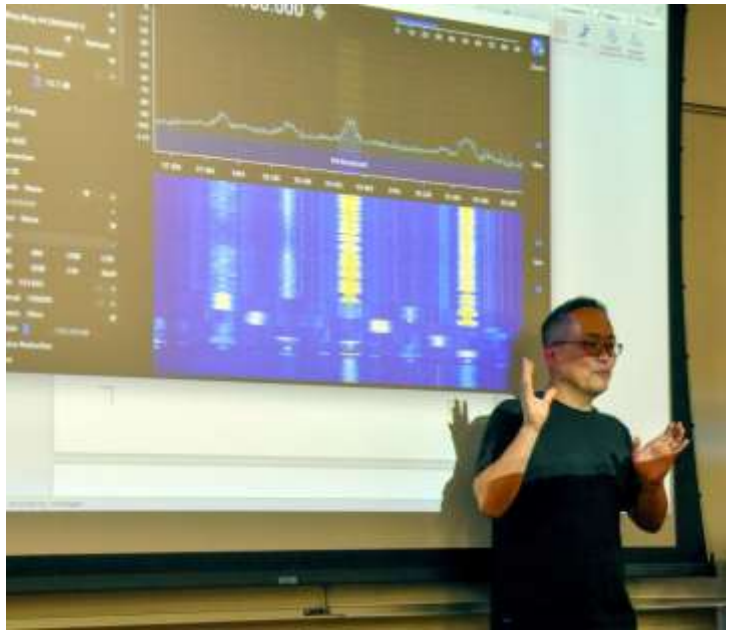
- ❑ Small satellite basics
- ❑ Orbital systems (LEO, MEO, GEO), TLE, satellite tracking
- ❑ Proliferation of COTS designs in modern small satellites
- ❑ The gap between cyber and aerospace
- ❑ Activity: CubeSatSim assembly!

An aside

- Prior experience with CubeSats (IBM Endurance)
- Large gap between cyber and aerospace community's outlook, expectations
- Bridging the gap: motivation for organizing such a workshop!
- Cybersecurity research in space?
- E.g.: robustness and reliability of COTS OBCs in harsh environments
- The CubeSatSim uses COTS (2x Raspberry Pis + terrestrial electronics)
  - How will it fare when exposed to TID radiation?
  - Can we model actual CubeSat operations with it?

Day 2

- ❑ Activity: CubeSatSim assembly continued
- ❑ Activity: Ground station hardware and software set-up
- ❑ Students became familiarized with FoxTelem interface
- ❑ Activity: RF essentials
  - ❑ Students took selfies of themselves with the CubeSatSim and transmitted it via SSTV
- ❑ Activity: Advanced Telemetry



Day 3

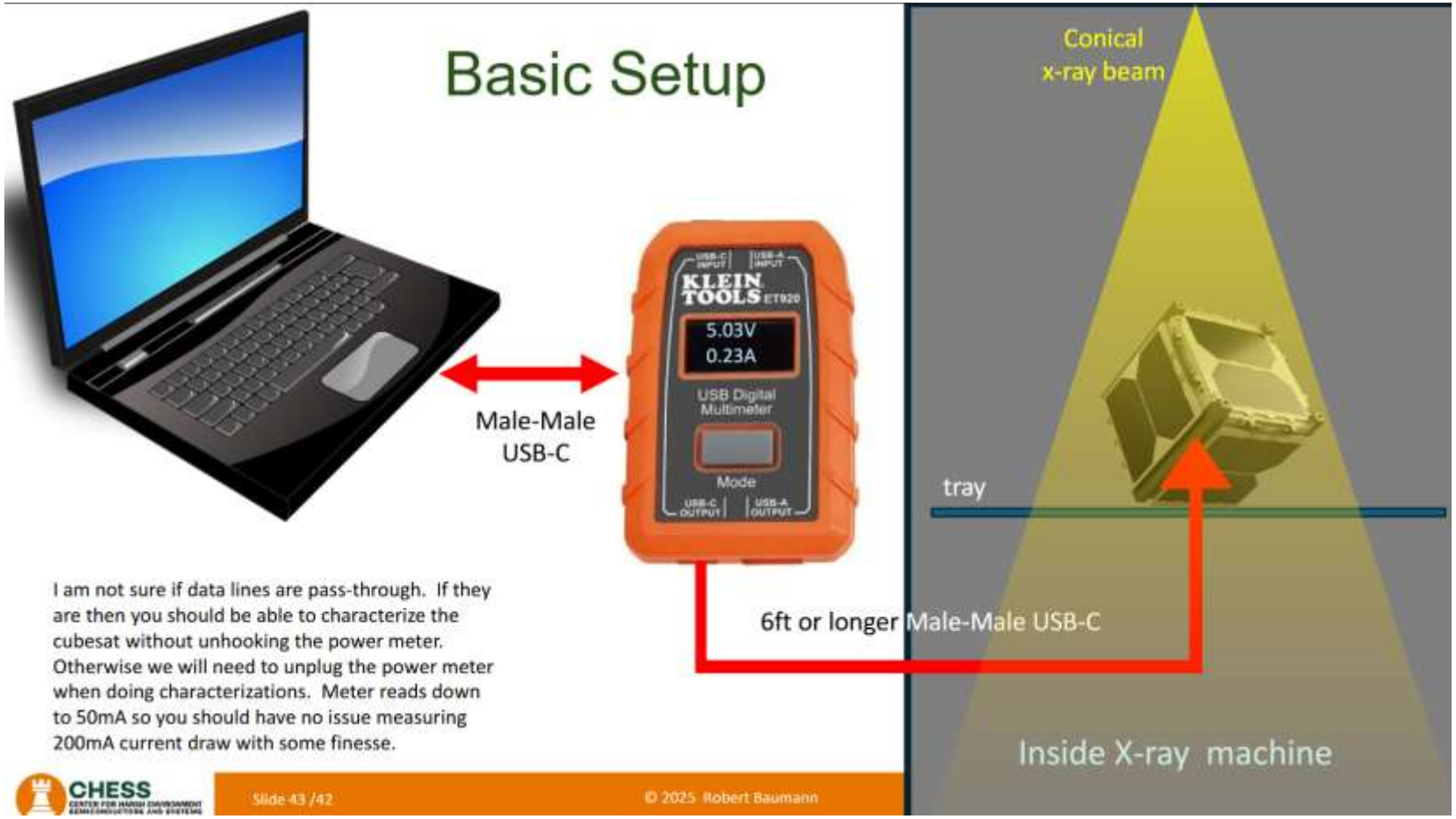
- ❑ Change of venue -> UT Dallas Center for Harsh Environment Semiconductor Systems (CHESS)
- ❑ Space debris
- ❑ Radiation theory
- ❑ Impact of TID, SEEs on semiconductors
- ❑ Judicious use of shielding necessary
  - ❑ Balance between extra weight and effectiveness; diminishing returns

A (rad) final activity

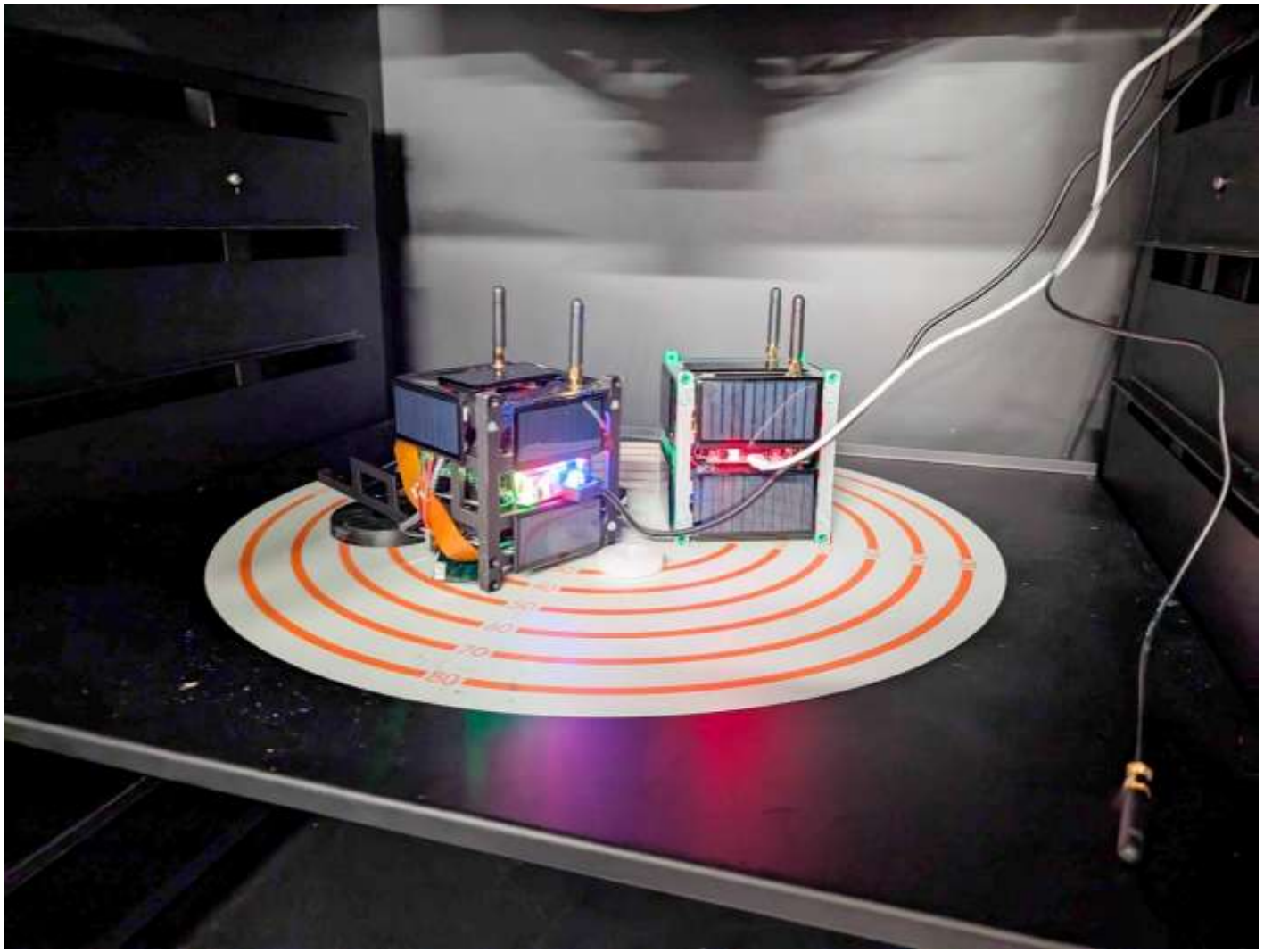
- ❑ Nitty-gritty of rad effects
- ❑ How do SEUs, SEFIs, SELs affect memory chips, for example?
- ❑ Radiation a very common cause for satellite mission failures
  - ❑ Rushed sat designs lead to uncaught mistakes
  - ❑ Deployment shock exposes workmanship flaws
  - ❑ “Biggest Threats to CubeSats = Not trading (mission) scope against [fixed] schedule and cost”
- ❑ We should study this at a system-wide level!
  - ❑ Is the CubeSatSim an acceptable proxy for a CubeSat?

https://nepp.nasa.gov/docs/papers/2021-Guertin-Raspberry-Pi-Guideline-CL-21-5641.pdf

A (rad) final activity



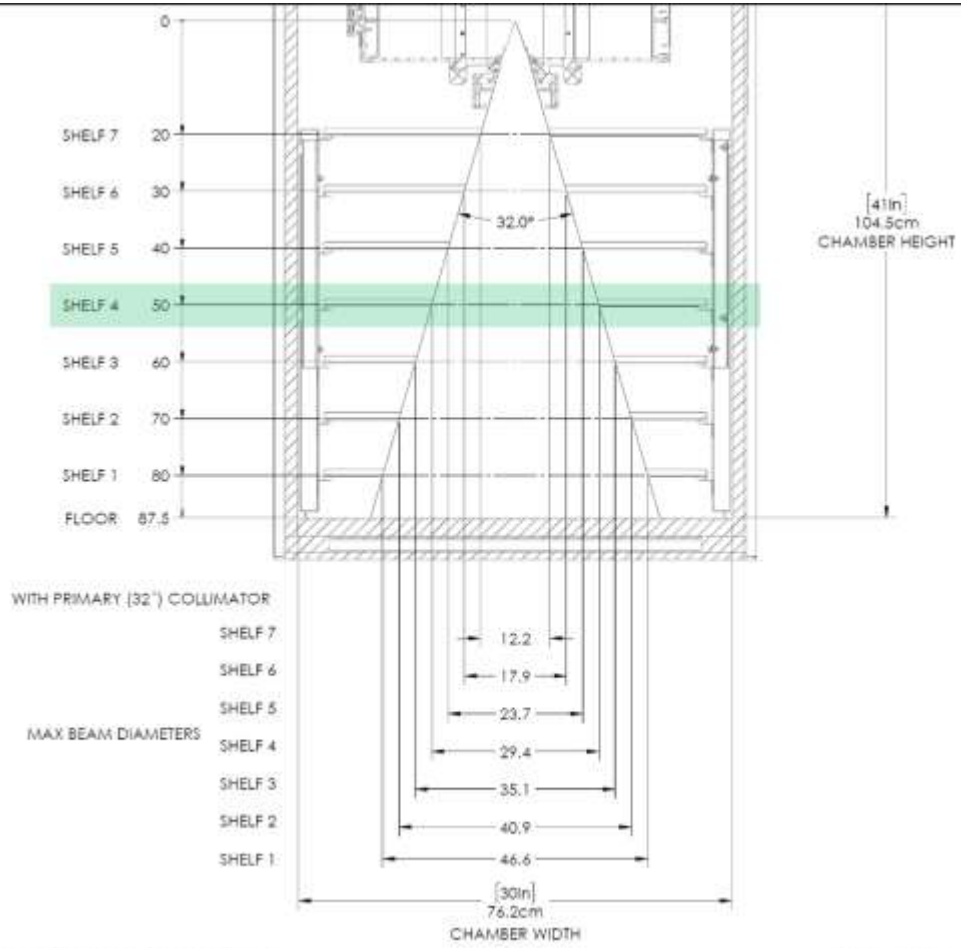
A (rad) final activity



A (rad) final activity

A 1U CubeSat has standard dimensions of 10 cm x 10 cm x 11.35 cm. We want to irradiate two in parallel BUT we want to keep them as close as possible to the source (upper tray positions) to maximize dose rate.

Circle that describes two cubes would be ~ 12”
(2*10cm*sqrt(2)) ~ 30cm



A (rad) final activity

In one hour how much TID will we get?

Filter 1

cGy [Si] = rad [Si]	Dose Rate (cGy/min)			
Position	50keV	80keV	160keV	320keV
30	83.00±0.73	208.29±2.13	555.17±5.31	849.35±8.22
40	45.83±0.45	115.49±0.98	304.13±3.01	469.33±1.24
50	28.83±0.05	72.19±0.66	192.66±1.80	297.22±0.75
60	19.55±0.15	48.60±0.46	130.17±1.08	207.86±0.45
80	10.89±0.02	27.54±0.060	73.74±0.17	113.60±0.87

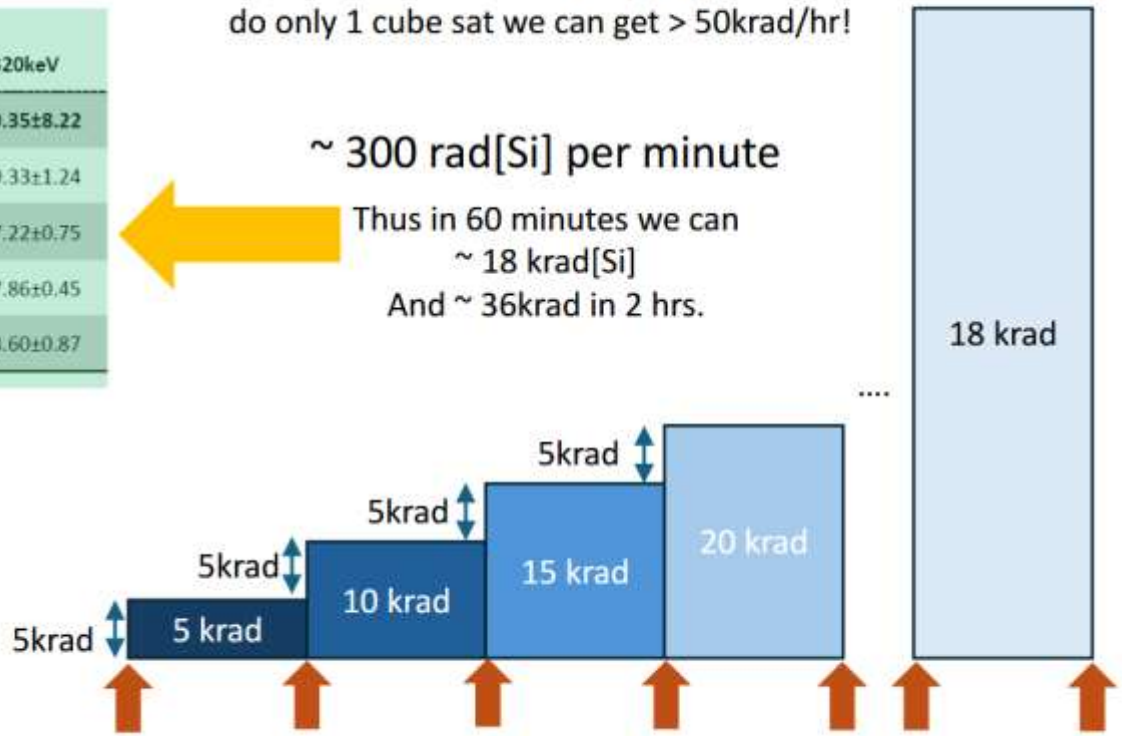
From dosimetric analysis by Dr. Rodolfo Rodriguez-Davila

Since we need to use the SHELF 4 (top is 1) position this is 50cm of spacing. If we do only 1 cube sat we can get > 50krad/hr!

~ 300 rad[Si] per minute

Thus in 60 minutes we can
~ 18 krad[Si]
And ~ 36krad in 2 hrs.

= a characterization step – we halt the x-rays, you run your test program, then we start the x-rays for another step interval.



Attendance survey responses

- Students loved working with the CubeSatSim!
- A lot expressed interest in getting involved with AMSAT
- The (few) complaints were mostly about our logistical limitations
- Great educational activity for hams and non-hams alike
- SSTV's novelty was greatly appreciated

Attendance survey responses

- One student suggested making a GNU Radio plugin for ground station software
- Another student really wanted to acquire their own CubeSatSim kit to solder and build from scratch
- Students wanted more in-depth hands-on activities
  - using CAD to make a 3D model shell for the CubeSatSim
  - more in-depth RF activities
  - PCB design for RF applications

Future plans

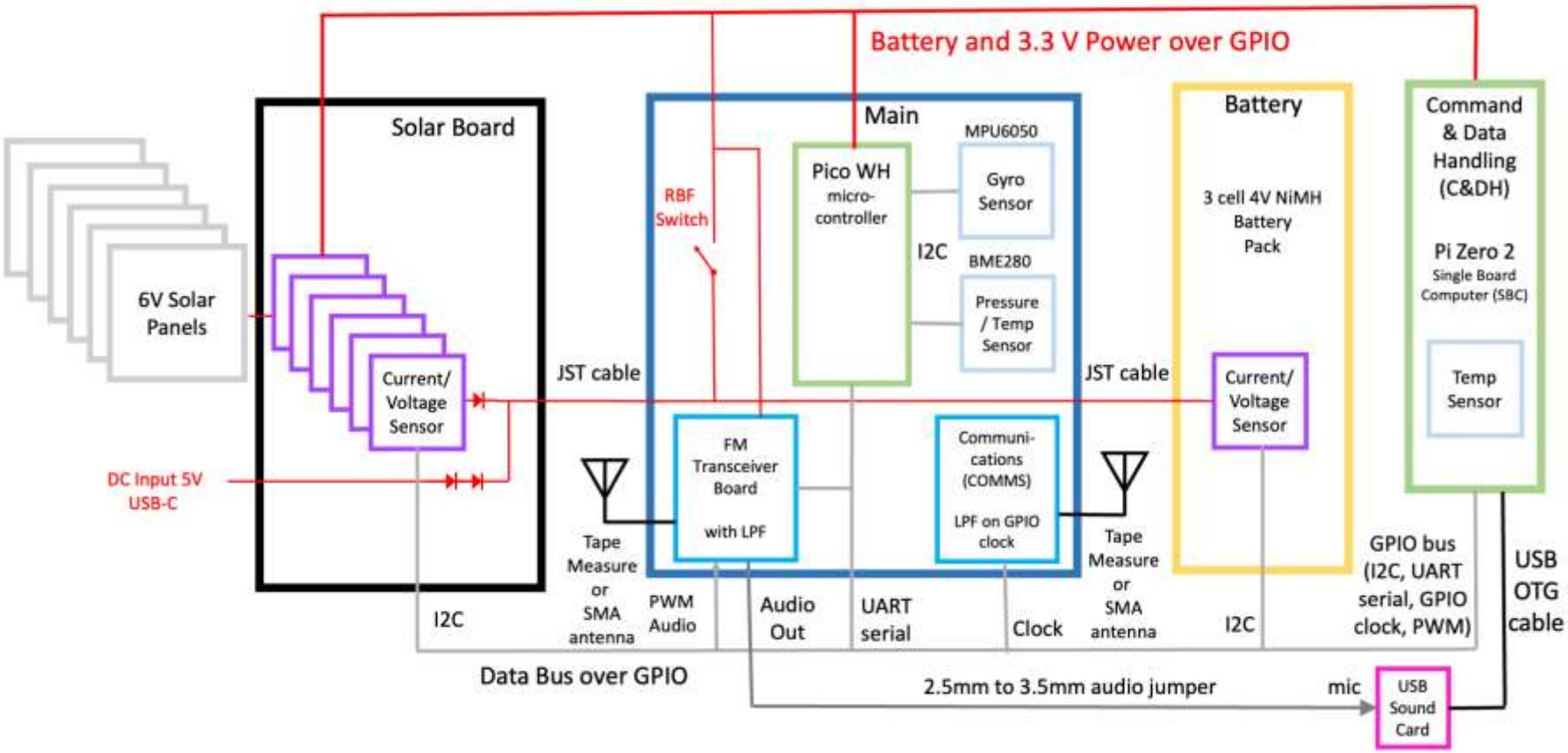
- Short term: a smaller-scale workshop for high school students very soon
- Medium term: a newer and improved summer workshop with more activities for next year, especially with prior student feedback in mind
- Long term: offering semester-long coursework on satellites, especially with a cyber perspective, would be ideal
- Don’t forget research!

The show must go on

- More rigorous testing and data gathering with the CubeSatSim under radiation
- Simulate LEO TID radiation in X-ray chamber
- In general, people do components testing and avoid trying to obtain system-wide test data while subjecting a CubeSat to TID radiation!!
- Aim: Create a suite of software tests to capture parametric shifts in performance, latency, etc. and functional failures in the various components making up the CubeSat ecosystem while testing the system as a whole
  - What a mouthful!

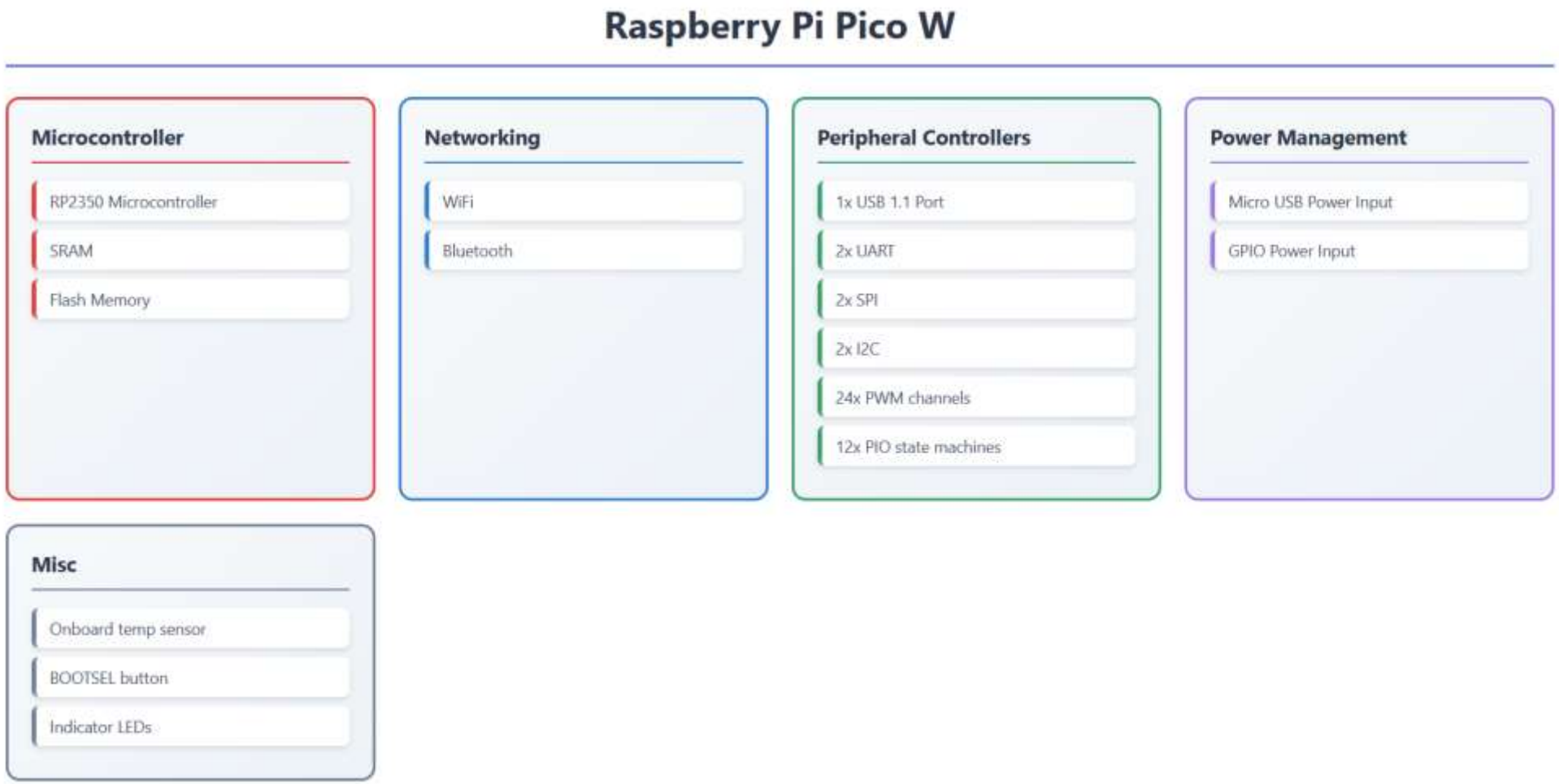
Parts enumeration?

CubeSatSim Block Diagram v2.0



https://github.com/alanbjohnston/CubeSatSim/wiki/

Finer granularity



Finer granularity

Finer granularity

Finer granularity

Finer granularity

Miscellaneous

Sensors

- Direct Current: 6x+1x INA 219
- Temp/Hum/Press: 1x BME280
- Gyro/Accel: 1x MPU6050
- Camera: 1x Arducam OV5647
- Radio: 2x SMA Antenna
- Misc: 10x Solar Cells
- Misc: 2x Qwiic Connectors

Misc Components

- Radio: SR105U Transceiver chip
- DC Power Supply (not used): 3x AA NiMH batteries
- Soldered LEDs
- Soldered diodes
- Soldered resistors
- Soldered capacitors

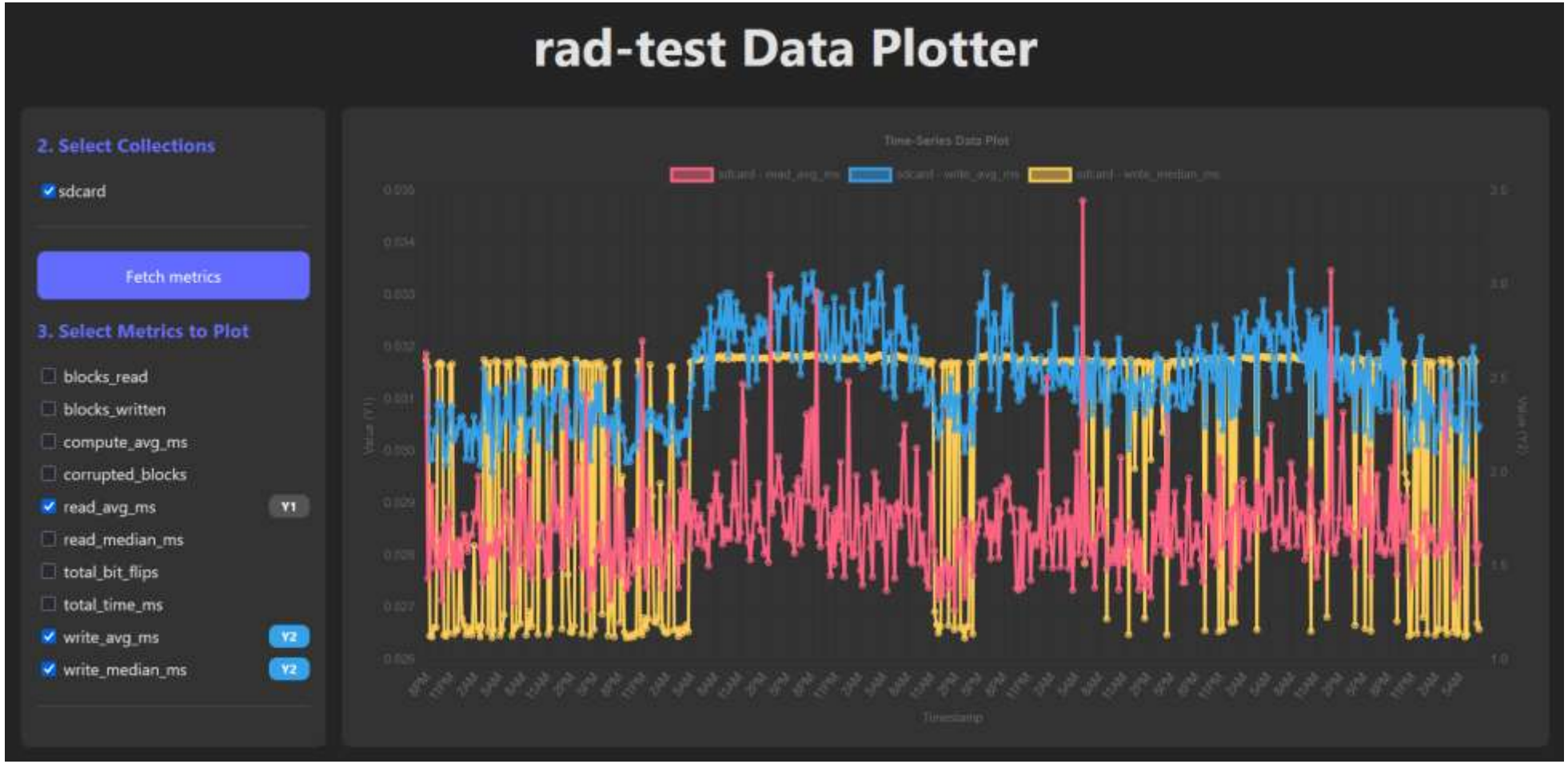
What have I tested so far?

About the micro SD Card

- Out of all the parts enumerated, we have so far performed data gathering on the microSD card
  - Low hanging fruit?
  - You can view our data at monitor.syssec.space
- Testing of many more parts is to come!
- We eventually wish to whittle down to a minimal (tractable) set of components that can characterize radiation-caused failures in a satellite

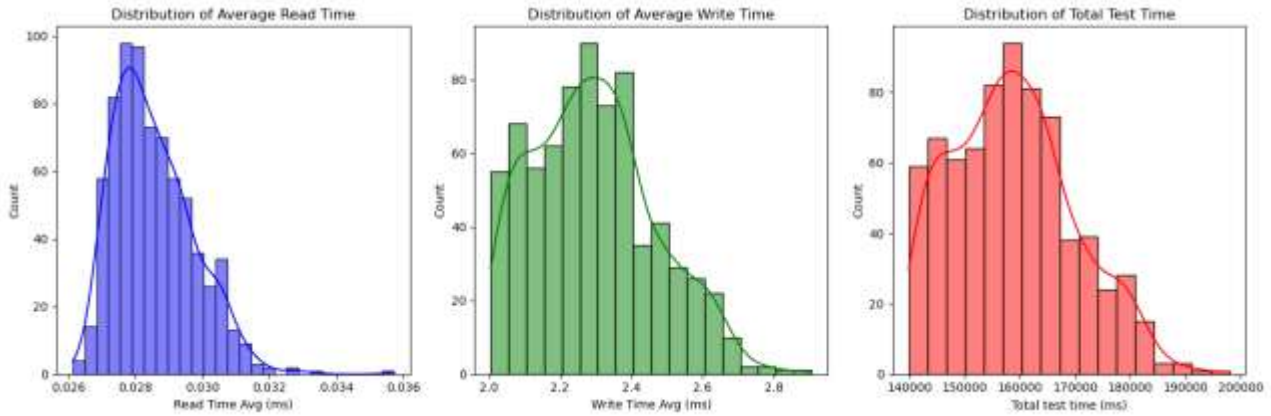
```
def log_summary(summary_data: SummaryDict) -> None:
    """Logs the contents of the summary data dictionary."""
    logging.info("--- Test Run Summary ---")
    logging.info(f"  Blocks Read:       {summary_data['blocks_read']}")
    logging.info(f"  Read Time (ms):    Avg: {summary_data['read_avg_ms']:.6f}, Median: {summary_data['read_median_ms']:.6f}")
    logging.info(f"  Compute Time (ms): Avg: {summary_data['compute_avg_ms']:.6f}")
    if summary_data['blocks_written'] > 0:
        logging.info(f"  Blocks Written:    {summary_data['blocks_written']}")
        logging.info(f"  Write Time (ms):   Avg: {summary_data['write_avg_ms']:.6f}, Median: {summary_data['write_median_ms']:.6f}")
    else:
        logging.info("  Blocks Written:    0")
    logging.info(f"  Corrupted Blocks:  {summary_data['corrupted_blocks']}")
    logging.info(f"  Total Bit Flips:   {summary_data['total_bit_flips']}")
    logging.info(f"Total test time taken = {summary_data['total_time_ms']:.6f} ms")
```

The show must go on



Some statistical inference

- Average write time is the primary bottleneck. It is correlated almost perfectly with total test time. By comparison, average read time is quite weakly correlated to the total test time.
- Write operations in general show high variance. Avg time = 2.29 ms, but many outliers and periods of slower performance.
- Read performance is quite fast, relative to write, perhaps obviously. Avg time = 0.0285 ms. Much less variance than write, however it also has outliers with unusually high read times.



Challenges

- CubeSatSim challenges for research: Pi Zero too weak for reliably running heavy performance tests
  - Possibly the Pico as well? Baremetal microcontroller, no OS either. Not realistic for an OBC.
- Solution: switch out Pi Zero with Pi 4. More processors, more RAM, more better.
- CubeSatSim software will run on the Pi 4 with no major modifications.
  - No such “easy” replacement for the Pico yet
- Eventual goal: switch to Pi 5.
  - Will allow usage of more robust/secure M.2 SSD as compared to microSD for storage
- However, Pi 5 requires Debian 12. CubeSatSim software by default supports only till Debian 11.

Thank you

Agastya Bose KJ5MSH

agastya@utdallas.edu

satworkshop.syssec.org/blog

cs.utdallas.edu