Vertical Integration of Picosatellites in an NGSS aligned curriculum

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CubeSat Developers Workshop 2021, Cal State Poly

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How can we retain student engagement in science and engineering long enough to turn external motivators into internal ones?

- Overview of curriculum design and critical partners and goals
- Using pico-satellites as a starting point for high school students to explore the interdependence of science and engineering across all four years of high school [1]
- A case study for a systems engineering approach and future goals for the curriculum in an equity lens and funding need[2]

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ThinSat Education Program Critical Partners[3]

Local High School level Education Program Critical Partners

Program Goals

Decrease	The time needed to develop spacecraft for launch
Reduce	Barriers to entry at HS level
Mitigate	Participant loss across four years of high school [4]
Reduce	Participant anxieties related to performance expectations
Increase	Authentic participation in *doing* science and engineering
Create	Communal environment allowing challenge by choice [5]
Engage	Participants to experience a holistic overview (i.e as systems engineers)
Support	Open-ended student science and engineering motivators
Create	Constant cycle of a need to know and need for data that drives engineering design [6]

ThinSats

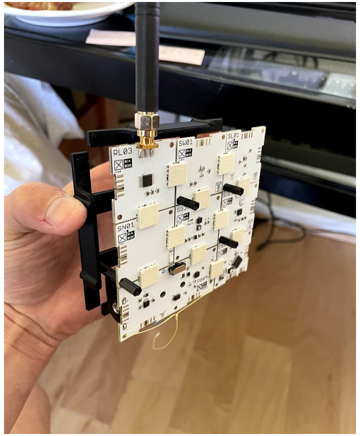

Figure 1 : Student created Phase 1 weather satellite on top of a 3D printed frame that allows students to explore the troposphere with both pre-populated code and/or user defined code and 'plug and play' Xinabox sensors.

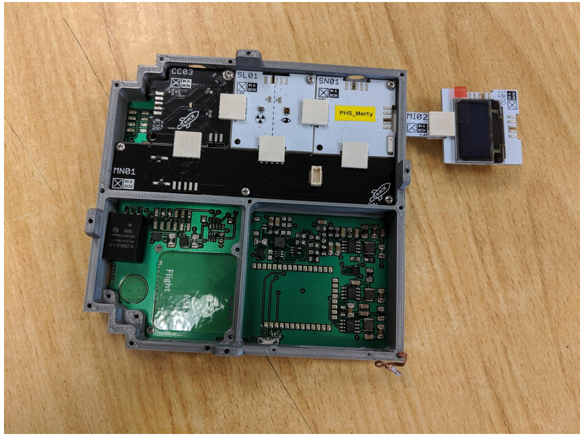

Figure 2 : Example of a Phase 2 ThinSat as an engineering model that is used for a high altitude balloon into the mesosphere. Students analyze packets being streamed by RF and format packets for readouts of data being parsed.

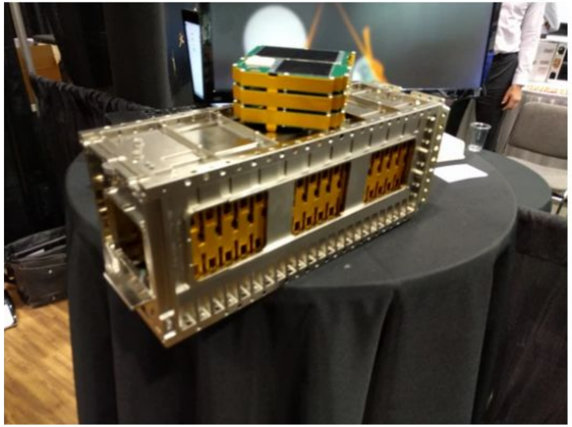

Figure 3: Multiple ThinSat strings that make up a constellation housed inside a modified CubeSat launcher for deployment in extreme low Earth orbit. Strings are made up of a mothersat for attitude control as well as 4-5 individual satellites and are tethered together for the duration of the mission. [1]

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space data dashboard

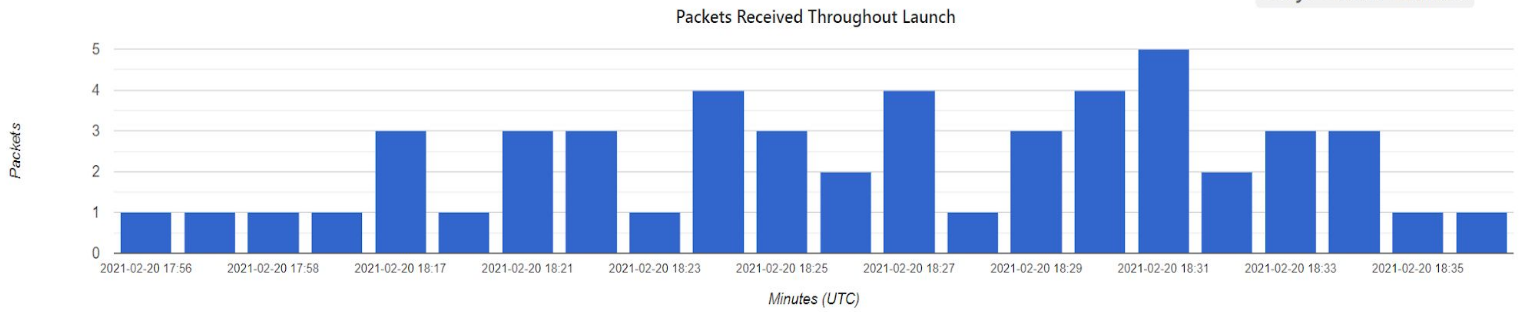
- Home
- Charts
- Launch
- Community
- Resources
- Teams
- Manage

engineering.montg

LOG OUT

Overview | Tracking | Media | Download

Days Hours Minutes



CSD	String	Lead	Team	Satellite Name	ESN	First Packet (UTC)	Last Packet (UTC)	Analogs	Health & Safety	Payload: TSL / Custom	Payload: XinaBox
1	1	LEAD: US Coast Guard Academy	LEAD: US Coast Guard Academy	Coast Guard 1	0-4200824	-	-	0	0	0	0
1	1	LEAD: Princeton University	Princeton Day School	MEDO-1	0-4200766	-	-	0	0	0	0
1	1	LEAD: Old Dominion University	LEAD: Old Dominion University	ODU	0-4200822	-	-	0	0	0	0
1	1	LEAD: Virginia Space	LEAD: Virginia Space	TSL-1	0-4200776	-	-	0	0	0	0
1	1	LEAD: Taylor University	LEAD: Taylor University	TU	0-4200774	-	-	0	0	0	0
1	2	LEAD: George Mason University	LEAD: George Mason University	GMU	0-4200671	-	-	0	0	0	0
1	2	LEAD: Princeton University	Princeton High School	MEDO-2	0-4200771	-	-	0	0	0	0
1	2	LEAD: NSL	Faith Christian School	MS-2	0-4200784	2021-02-20 17:58:32	2021-02-20 18:34:23	4	7	14	0
1	2	LEAD: Virginia Space	LEAD: Virginia Space	TSL-2	0-4200674	-	-	0	0	0	0
1	2	LEAD: Virginia Space	LEAD: Virginia Space	TSL-3 - Gamma Ray	0-4200821	-	-	0	0	0	0
1	3	LEAD: George Mason University	Thomas Jefferson High School	MEDO-3	0-4200775	-	-	0	0	0	0
1	3	LEAD: Virginia Space	LEAD: Virginia Space	MEDO-4	0-4200772	-	-	0	0	0	0
1	3	LEAD: Princeton University	LEAD: Princeton University	MEMSat	0-4200672	-	-	0	0	0	0
1	3	LEAD: NSL	LEAD: NSL	MS-3	0-4200825	2021-02-20 17:56:19	2021-02-20 18:35:18	4	7	14	0
1	3	LEAD: US Coast Guard Academy, LEAD: Virginia Space	LEAD: US Coast Guard Academy, LEAD: Virginia Space	NearSpace Launch NSE	0-4200820	-	-	0	0	0	0
2	4	LEAD: Virginia Space	LEAD: Virginia Space	MEDO-5	0-4200778	-	-	0	0	0	0
2	4	LEAD: Virginia Space	LEAD: Virginia Space	MEDO-6	0-4200683	-	-	0	0	0	0
2	4	LEAD: Virginia Space	LEAD: Virginia Space	MEDO-7	0-4200773	-	-	0	0	0	0
2	4	LEAD: Princeton University	LEAD: Princeton University	ProtoSat	0-4200673	-	-	0	0	0	0
2	4	LEAD: Salisbury University	LEAD: Salisbury University	Salisbury University	0-4200684	-	-	0	0	0	0
2	4	LEAD: Virginia Space	LEAD: Virginia Space	TSL-4	0-4200816	-	-	0	0	0	0
2	4	LEAD: Virginia Space	LEAD: Virginia Space	TSL-5	0-4200818	-	-	0	0	0	0
2	5	LEAD: Virginia Tech	LEAD: Virginia Tech	VATech	0-3208926	-	-	0	0	0	0
2	6	LEAD: NSL	LEAD: NSL	MS-4	0-4200826	2021-02-21 06:51:26	2021-02-21 06:51:26	0	1	0	0
2	6	LEAD: NSL	AFRL	NSL-1	0-4200819	-	-	0	0	0	0
2	6	LEAD: NSL	AFRL	NSL-2	0-4200777	-	-	0	0	0	0
2	6	LEAD: Taylor University, LEAD: NSL	LEAD: Taylor University, Taylor University (NSL)	NSL-3	0-4200813	-	-	0	0	0	0
2	6	LEAD: NSL	Career Academy	NSL-4	0-3216397	-	-	0	0	0	0
2	6	LEAD: NSL	University of Minnesota	NSL-5	0-4200815	-	-	0	0	0	0

?

Example roadmap for a potential 4 year progression

Pathway that meets NJ Science Core requirements

Physics → Chemistry → Biology → iSTEMi (independent Research)

Concurrent Engineering classes and electives pathway for students to take

Engineering I w/Design and Fabrication → Micro-Electronics → Engineering II w/Design and Fabrication → Portfolio Project

ThinSat Club running parallel underneath curriculum

Standard ThinSat Phases 1, 2 and 3 → Novel mission proposals and custom sensor development → CubeSat mission ideation and data analysis → Custom PCB Sensors and CubeSat integration

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Freshmen Year

1. Science Curriculum:
   - Physics
     - Students take physics first in their coursework to create concrete connections between observation and hypothesis based on Modelling and ISLE learning [7]
2. Engineering / Science Elective:
   - Engineering I
     - Introduction to fabrication and rapid prototyping with a focus in software
3. ThinSat Club
   - Introduction to ThinSats and ThinSat Program and University connection
     - Students complete Phases 1-3 with a focus on Phase 1 in particular learning Arduino coding with I2C sensors[8]
   - Mission Proposal development based on Xinabox sensors available in Phase 1
     - Uses abilities developed in classroom coursework to create missions that fundamentally answer a question.

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NG-15 Student Designed and Developed Mission Proposals

Biomedical Engineering

- UVA and UVB rays on astronauts and aeronautic pilots, who travel above 100 km the surface of Earth, and the effect on the retina
  - Secondary research option: see effects of short term UVA and UVB exposure on the genetic makeup of the eye

Physics

- *B*- Field to identify and measure the radius of an object that could be a potential planet.
  - Secondary research option: using magnetic field, create a relationship to measure the angle of tilt the planet is on.

Materials Engineering

- UVA and UVB rays to measure corrosion on materials due to ionization.
  - Secondary research option: determine best materials for use when at specific bands of altitude for prolonged periods of time

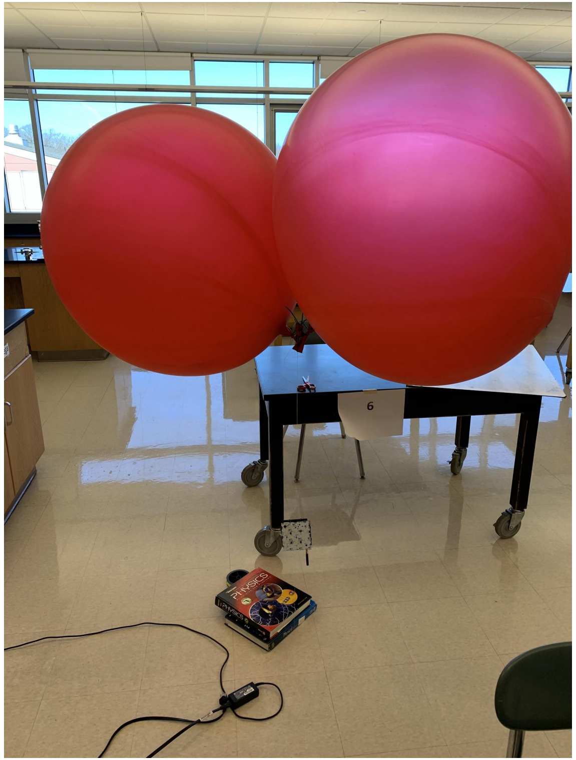

Figure 4 : Low-Altitude Balloon Launch Prep

Figure 5: Low-Altitude Balloon Flight

CubeSat

Sophomore Year

1. Science Curriculum:
    - Chemistry
        - Students take chemistry in their second year with a focus on underlying mechanisms and conservation concepts

2. Engineering / Science Elective:
    - Micro-Electronics
        - Basic circuitry, Arduino use for both software and hardware applications

3. ThinSat Club
    - Novel mission and sensor development for data collection in small groups

    - Mission Proposal development based on any generic Sparkfun or Adafruit sensors available in the market for Custom xChip development

Figure 6 : Student developed SO_2 sensor

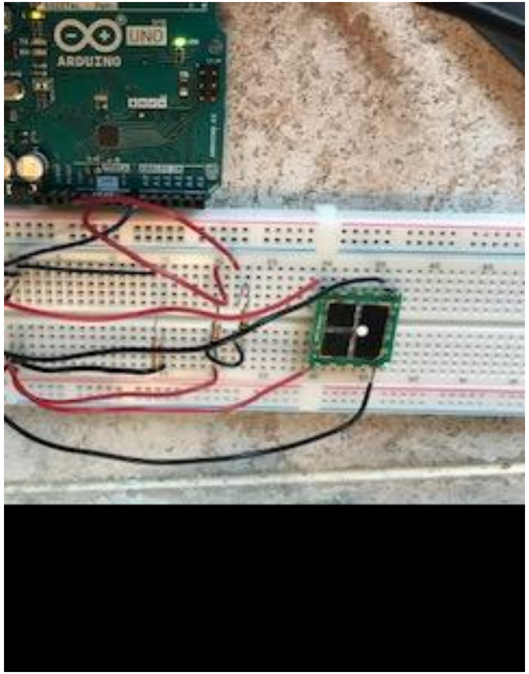

Figure 7 : Sensor readout circuit

Junior Year

1. Science Curriculum:
    - Biology
        - Students utilize their first two years within the science curriculum as a way to explore biology as an applied science.
2. Engineering / Science Elective:
    - Engineering II
        - Continuation of Engineering I with focus on applied rapid prototyping
3. ThinSat Club
    - Continuation of ThinSat payload and integration with opportunities to branch out into CubeSats
    - Application of sensors developed last year in application either through a ThinSat Launch or a CubeSat integration and build.

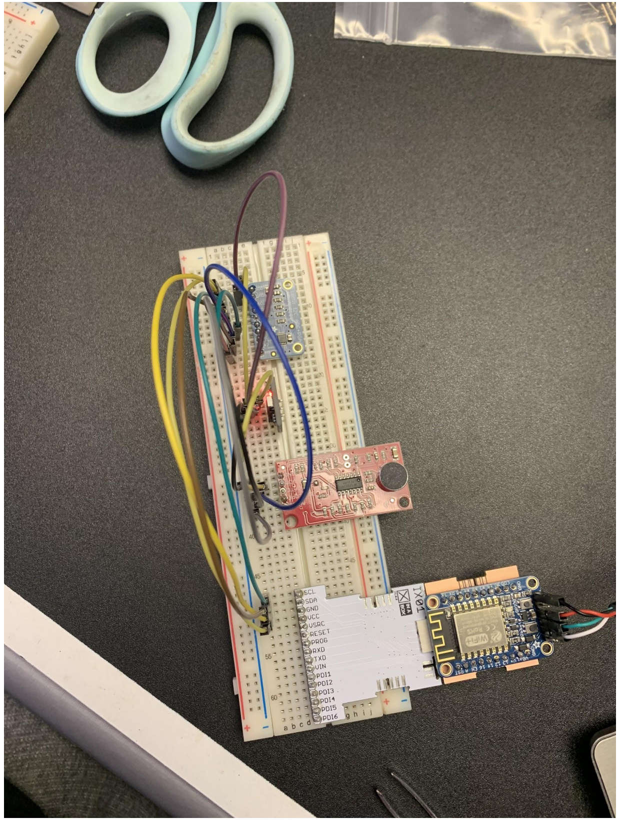

Figure 8 : Custom sound sensor adaptation for Xinabox platform

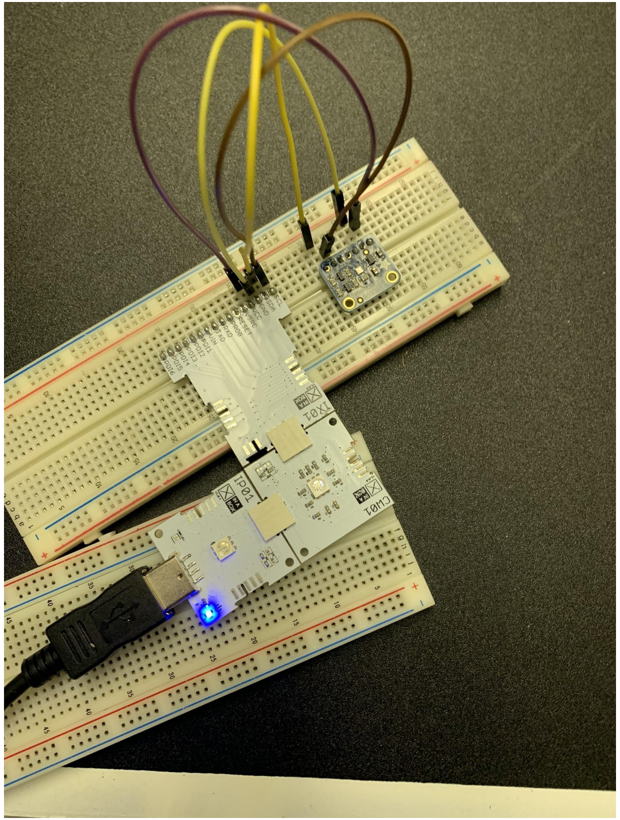

Figure 9 : Custom accelerometer adaptation for Xinabox platform

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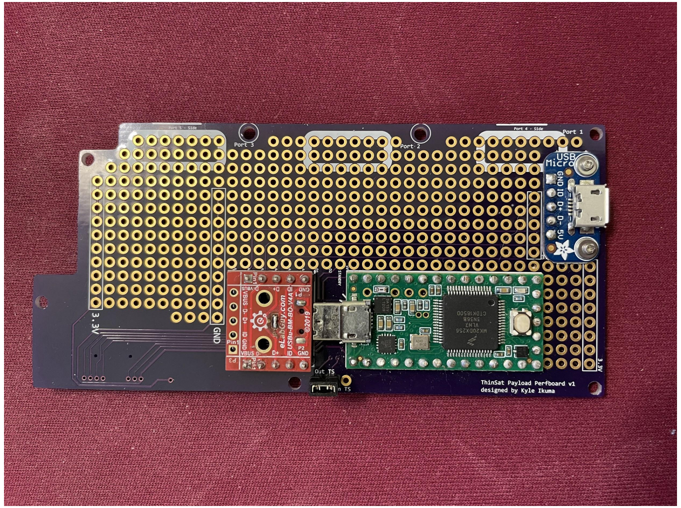

Figure 10: 'Perfboard' designed by Kyle Ikuma at Princeton University MAE Dept.

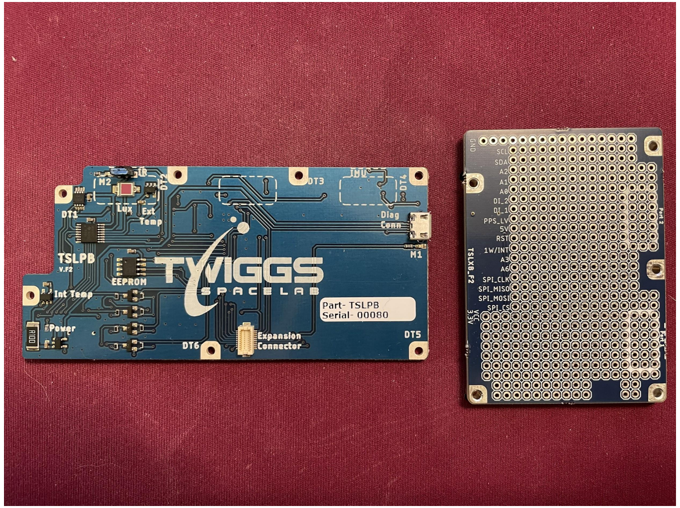

Figure 11: TSL payload board and secondary board

Senior Year

1. Science Curriculum:
    - iSTEM / iSTEMi:
        - Intro class to research methods and data analysis for independent projects.
2. Engineering / Science Elective:
    - Portfolio Project
        - Independent project consisting of highlighting software proficiency as well as real world deliverables fabricated and potentially used.
3. ThinSat Club
    - Custom integrations for ThinSat or CubeSat Prototyping
        - Complete packages for both hardware and software integrations either using existing or custom methodologies
    - Systems Engineering perspective for mission start to payload deployment

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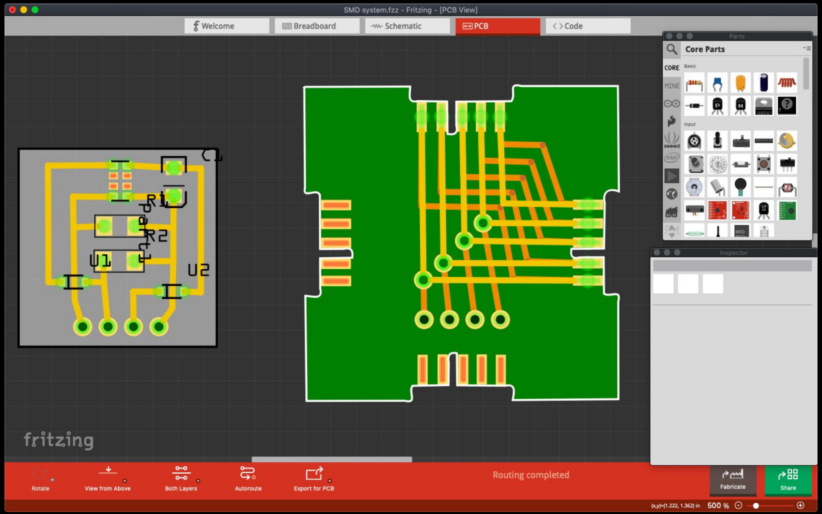

Figure 12: Student designed fritzing model

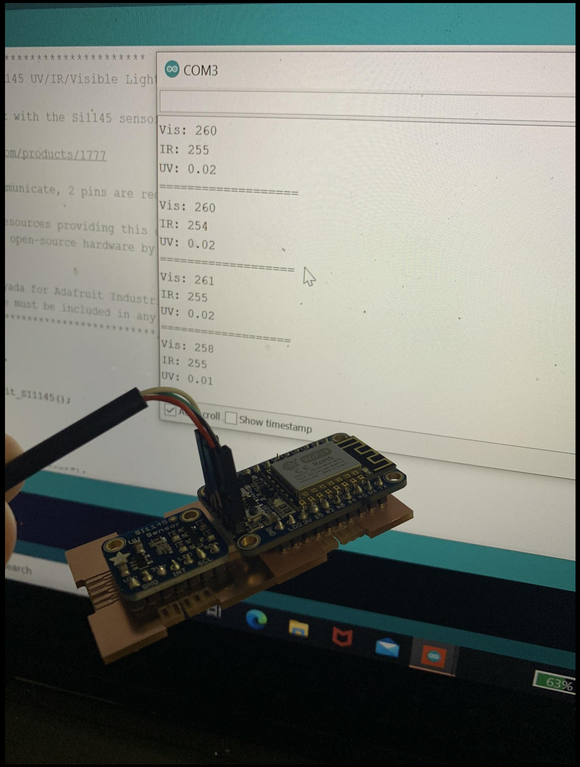

Figure 13: Student fabricated 1x2 xChip

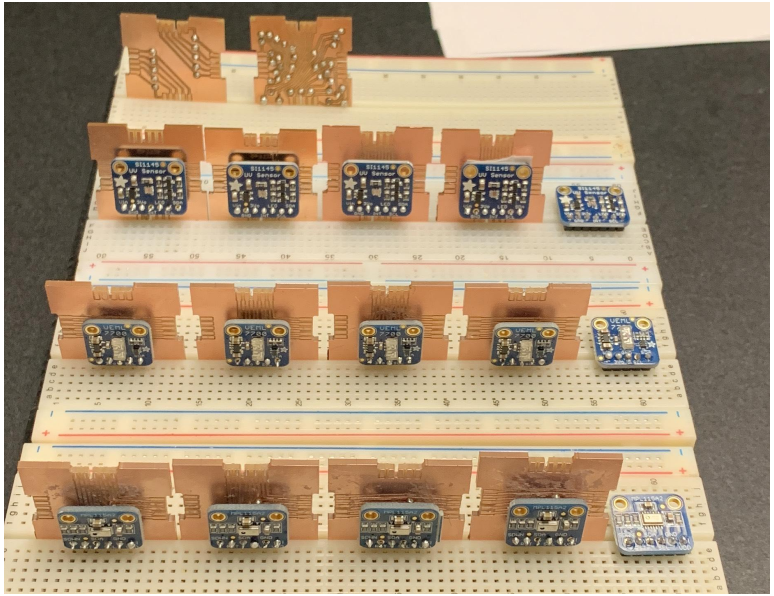

Figure 14: What happens when high school students are allowed to fabricate from home

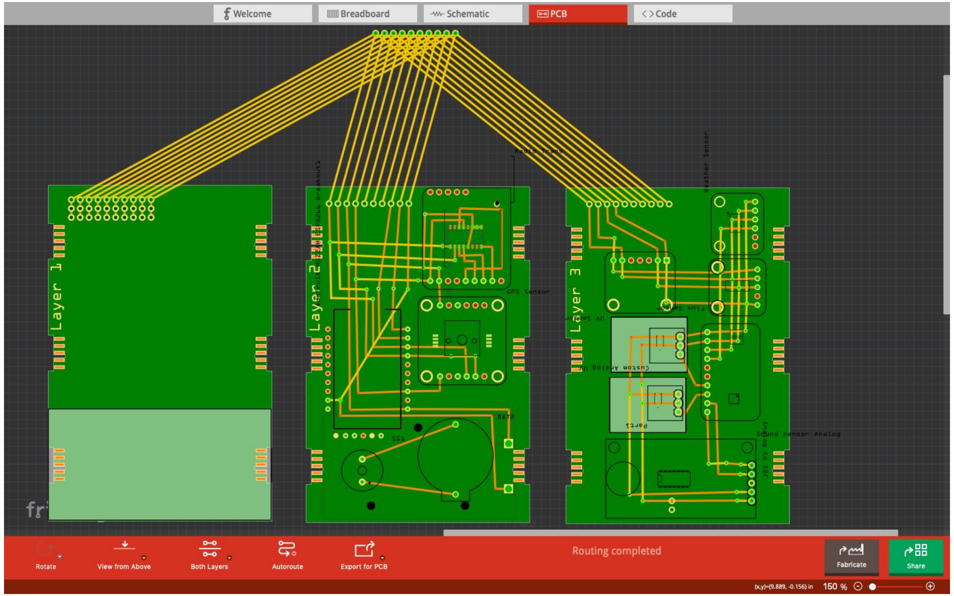

Figure 15: Student developed custom PCB boards for use as CubeSat layers

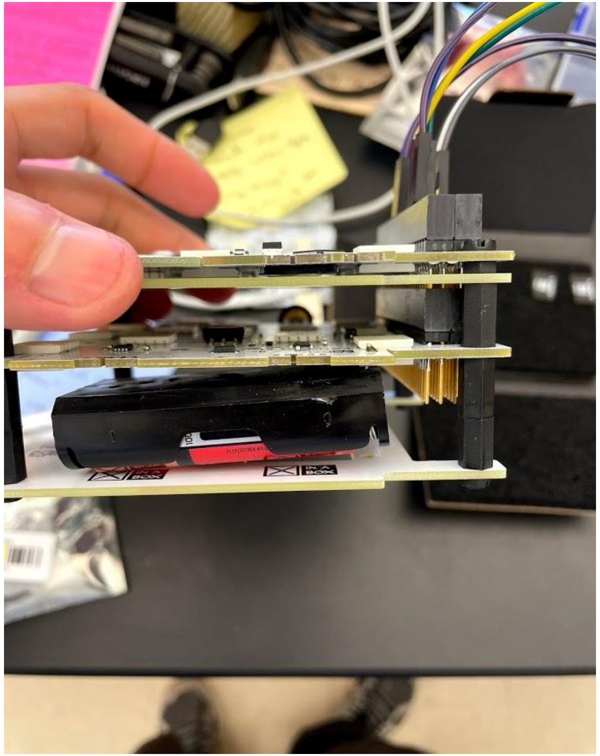

Figure 16: Xinabox CubeSat configuration
XK90

Future work and yearly progression

- Flexibility is key to success
- Talent retention in early years
- Collaboration vs competition [9]
- Current club membership is 7:1 female to male
- Funding involvement from industry and institutions

This work would not be possible without the following groups and people:

- Thank you to Eugenia Etkina, the single most powerful woman I know in academia, and all of the ‘Etkinists’ who have helped me get to this point in my academic career to be able to present on an integrated curriculum at my first professional conference where even if remote, scares the life out of me!
- Thank you to Michael Galvin who three years ago took a chance on a 1st year teacher who had no idea how much a Pico-Satellite / CubeSat could become so critical to the way he teaches not just Physics but science as a whole.
- Thank you to Jason Sullivan, my current supervisor at Montgomery High School who has encouraged me not only with words but with actions and materials whenever the students needed and never made me feel bad about a last minute request.
- Thank you to Joseph Gargione, co-creator of the curriculum idea currently at Princeton High School, for trusting me and willing to put in time into something that I believed *might* work and treating it as if it *did* work; for that I am forever in debt to you!
- Thank you to Edward Cohen, my prior supervisor at Princeton High School who gave me the space to design and implement, from scratch, an entire curriculum built on ThinSats in my second year teaching at the high school level and who always hid the back breaking work that goes on behind the scenes so I could focus solely on teaching and implementing that curriculum.
- Special shout out to the MHS Science Department for being the most supportive group of peers as well as Oren Levi and Jim Smirk for continually guiding me with their experiences and expertise in how to be not just a better scientist but be a better science teacher always putting the students first.

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