SWARM-EX Spring 2023 Mid-Semester Review

3/13/2023

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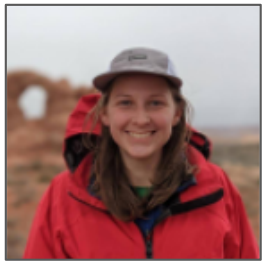


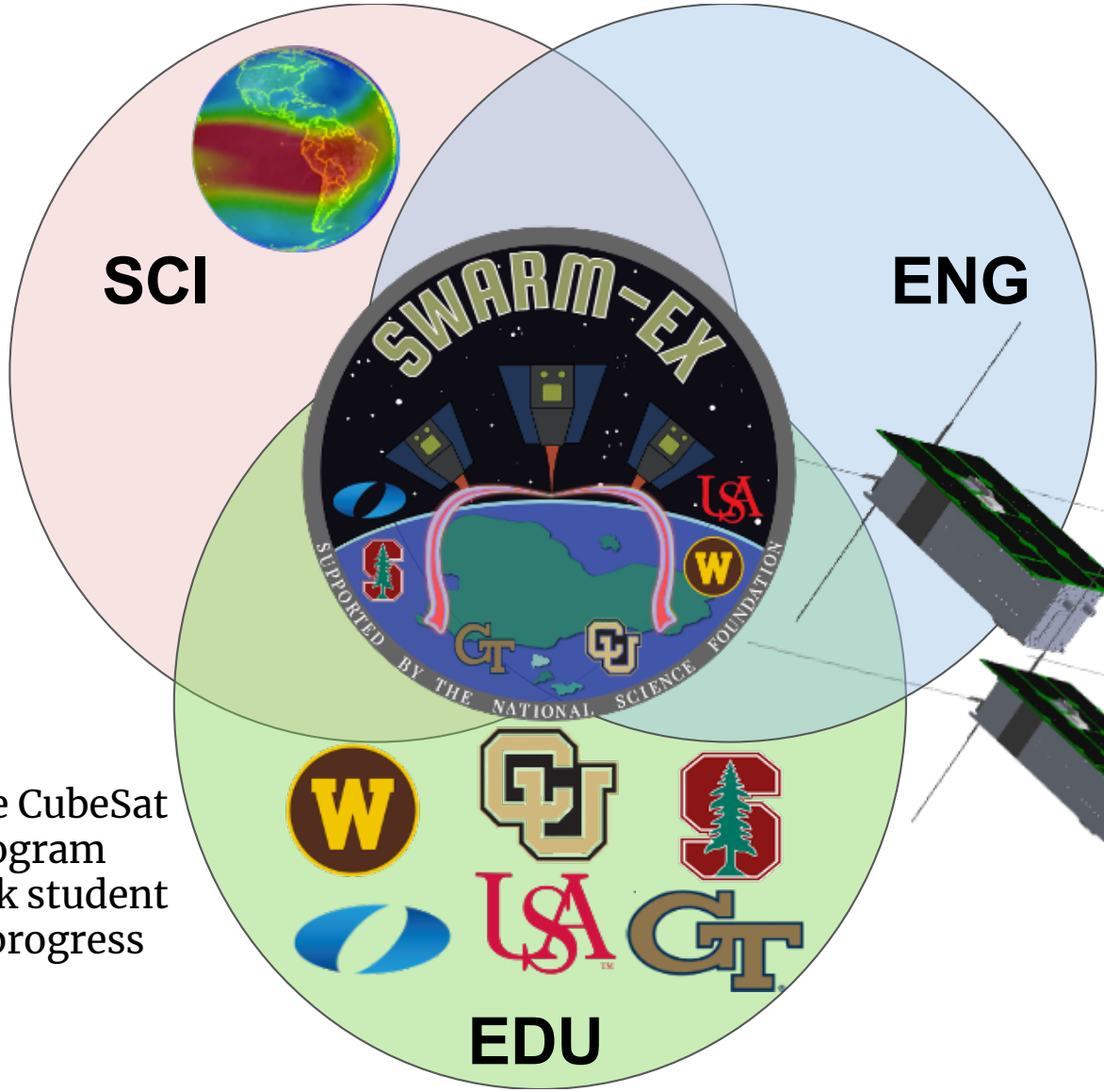
AJ Cuddeback
CDH

Project Overview

SWARM-EX Mission

The Space Weather Atmospheric Reconfigurable Multiscale Experiment (SWARM-EX) is a National Science Foundation (NSF) sponsored CubeSat mission distributed across six colleges and universities in the United States.

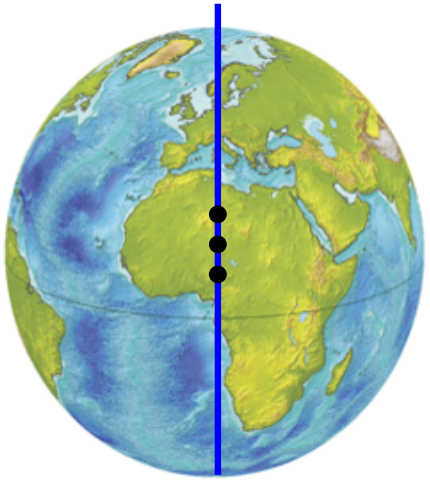
- Persistence and correlation in Equatorial Ionization /Thermospheric Anomaly (EIA/ETA) features
- Changes in EIA/ETA features that occur over timescales of <90 minutes



- Formation flying
- Collision avoidance
- Detach & reconnect
- Propulsion
- UHF crosslink
- CDMA downlink

- Intercollegiate CubeSat Mentoring Program
- Efforts to track student engagement/progress

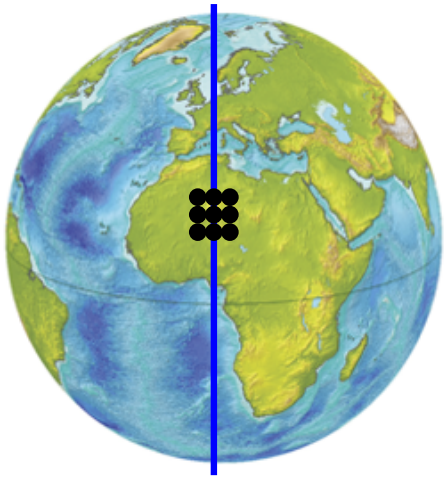
Mini SWARM-EX



(a) Local Scale Measurements

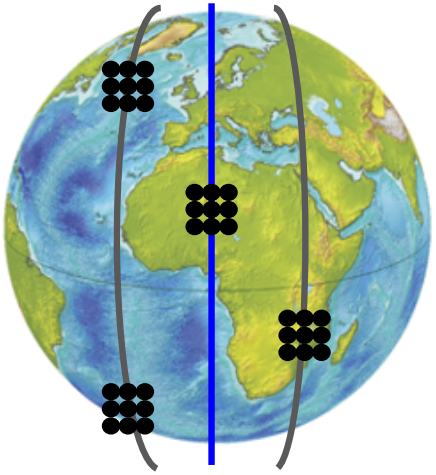
Current Mission

SWARM-EX

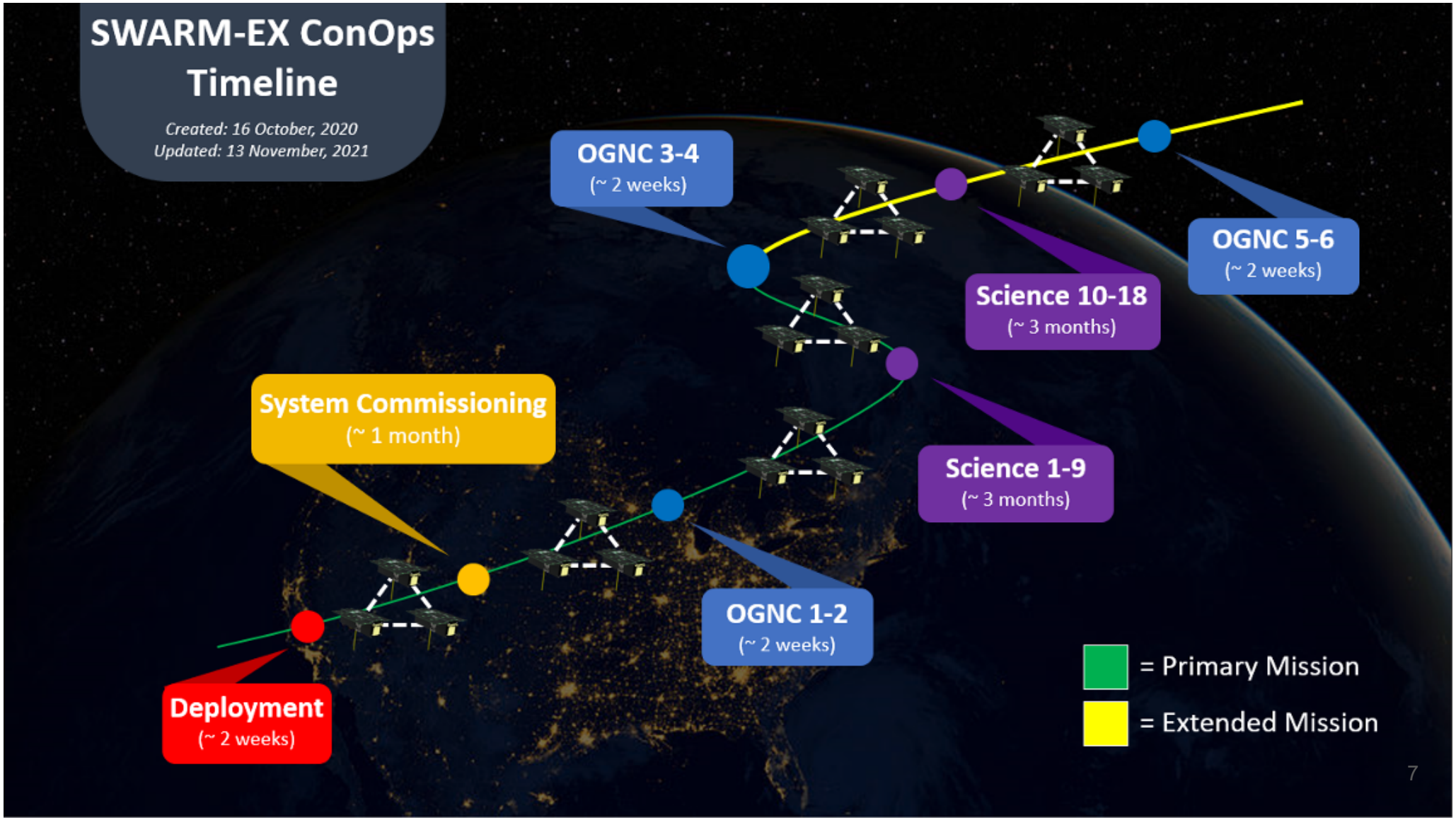


(b) Regional Scale Measurements

CON-SWARM-EX



(c) Global Scale Measurements


SWARM-EX ConOps Timeline
Created: 16 October, 2020
Updated: 13 November, 2021
OGNC 3-4
(~ 2 weeks)
OGNC 5-6
(~ 2 weeks)
Science 10-18
(~ 3 months)
System Commissioning
(~ 1 month)
Science 1-9
(~ 3 months)
OGNC 1-2
(~ 2 weeks)
Deployment
(~ 2 weeks)
= Primary Mission
= Extended Mission

Principal System Requirements

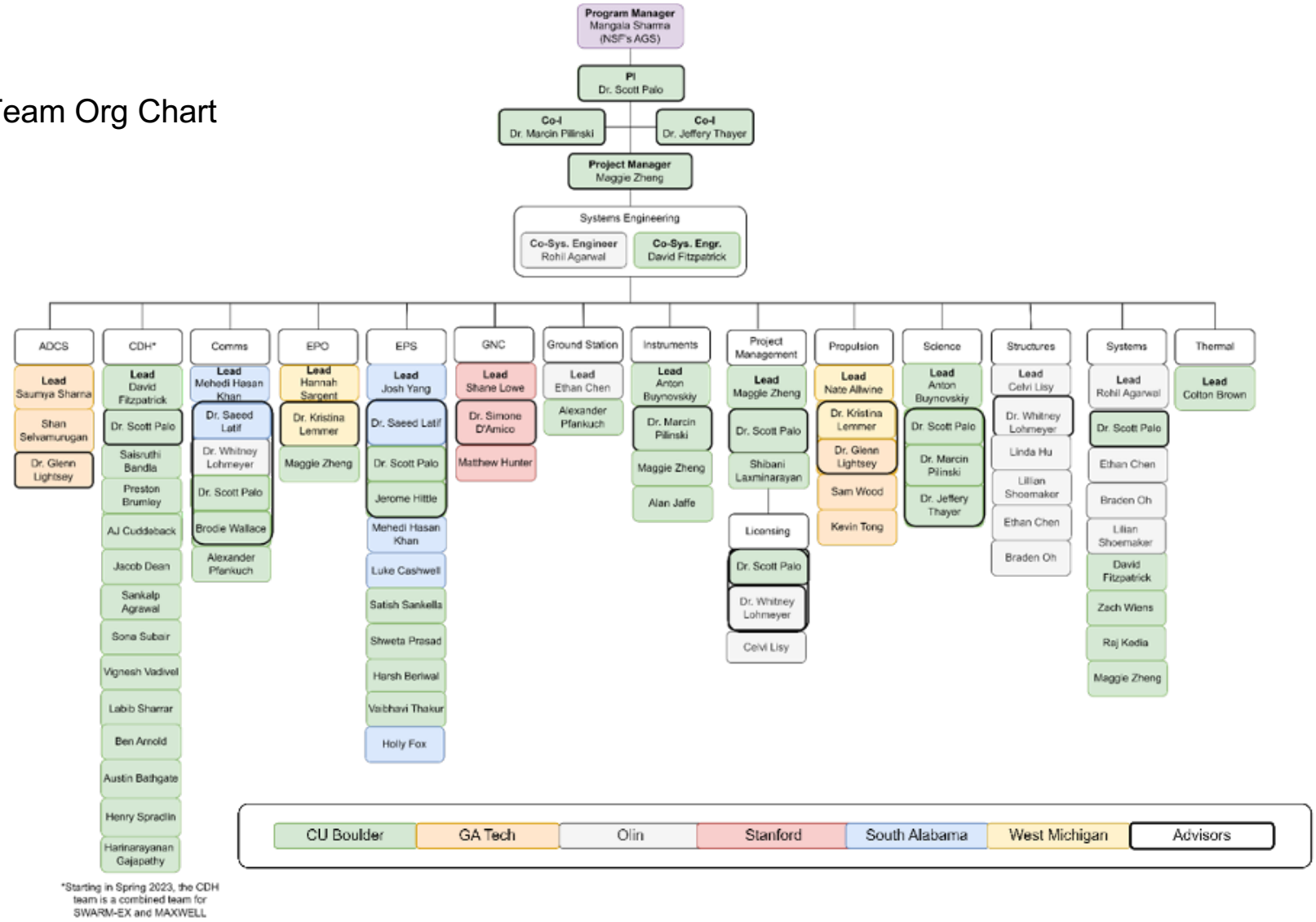
Req. ID	Requirement	Rationale	Parent
SAT-02	The CubeSat shall be designed to meet the selected **dispenser specifications** and requirements	CubeSat must meet dispenser specifications in order to fit, remain protected before deployment, and deploy properly.	Dispenser ICD
SAT-11	**Uplink** communications shall be **encrypted**.	NSA requirement as a result of propulsion.	NSA
SAT-15	The CubeSats shall have an operational on-orbit **lifetime** of approximately 8.5 months (150 days for primary mission, 100 days for extended mission).	The specified mission duration is required for accomplishing all mission objectives.	PSQ-1 & PSQ-2 (**Persistence** & **Timescales)**
SAT-17	The CubeSats shall have a **power positive** orbit configuration.	A power positive orbit configuration is required for achieving all mission objectives.	SAT-16 (**Regulated Power**)
SAT-32	CubeSat design shall adhere to the **preferred practices** listed in this document in the Preferred Practices tab.	Required for successful CubeSat development in accordance with the processes defined by the project's PIs.	PI

Key Requirements Imposed on other Subsystems

Req. ID	Requirement	Driver	Rationale
PROP-03	The **propulsion** subsystem shall be capable of performing all **maneuvers** required by science and technology demonstrations.	SAT-15 & SAT-28 (**Mission Lifetime** & **Propulsion**)	Propulsion system specifications must be sufficient for meeting science measurement and formation flying goals
OGNC-05.3	The formation-keeping and formation reconfiguration functions shall produce closed-form maneuver plans that **minimize delta-v** consumption.	OGNC-05 & SAT-15 (**Mission Lifetime)**	Delta-v usage must be minimized to allow for all mission phases to be met and to leave enough for emergency collision avoidance procedures.
CDH-01.4	The CDH shall be capable of **autonomously switching modes** based on the **State of Charge**.	CDH-01 & SAT-20 (**Safe Mode**)	Autonomous mode switching into the Safe Mode or Phoenix Mode operational orbits is required to occur autonomously to preserve the spacecraft in case of battery discharge and enable recharging.
CDH-02	CDH shall have a **hardware watchdog timer** to reset the CDH.	SAT-18 (**Autonomous non-OGNC Control)**	Required in case of anomalies and to ensure spacecraft can reboot on orbit.

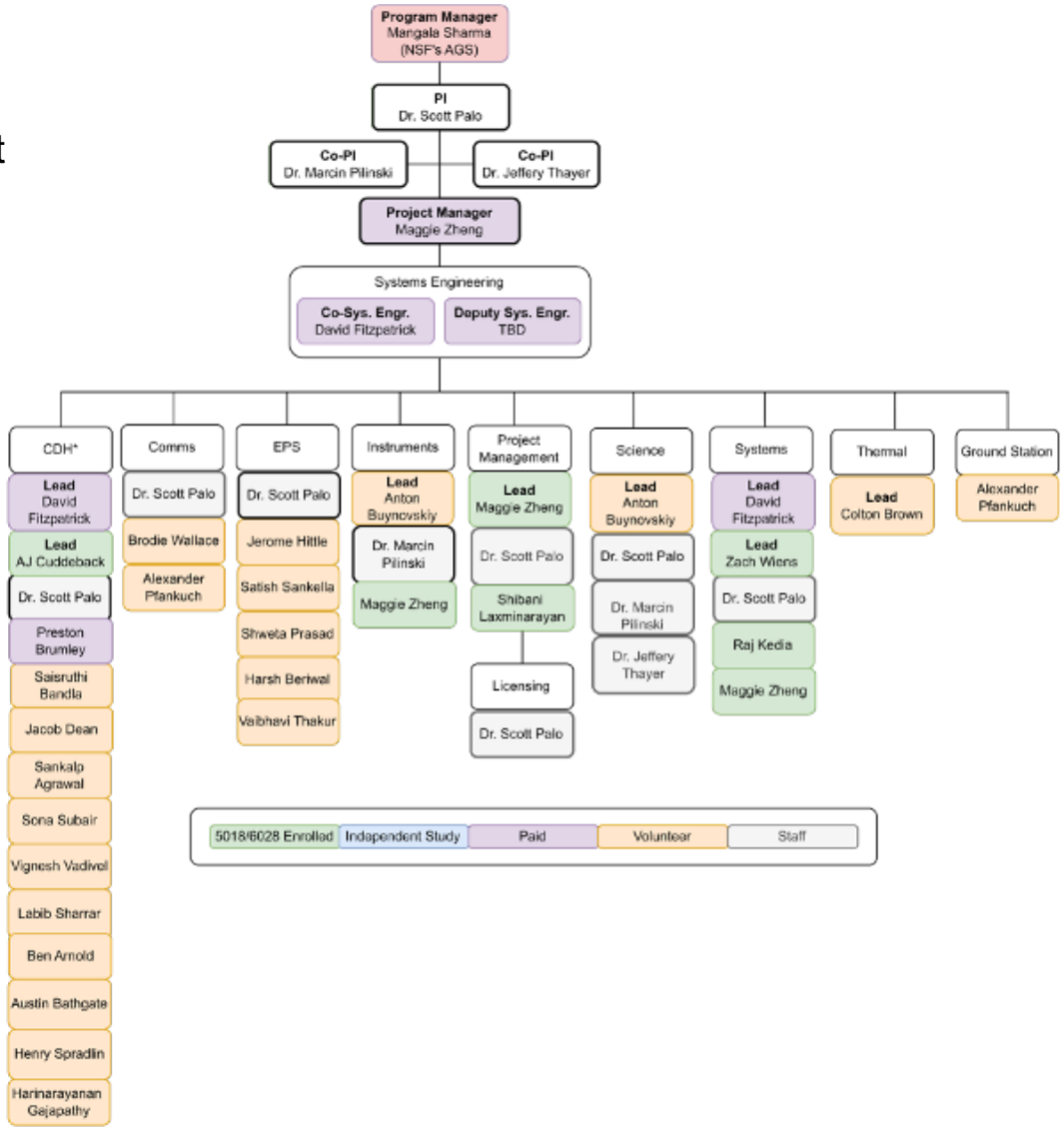
Project Organization

Full Team Org Chart



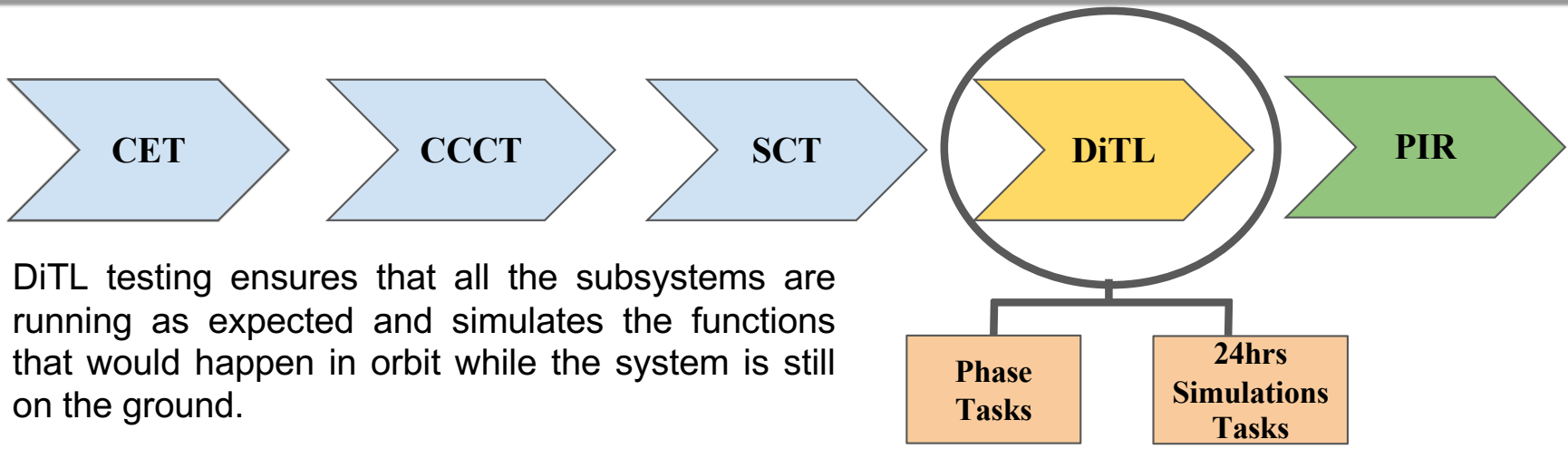
*Starting in Spring 2023, the CDH team is a combined team for SWARM-EX and MAXWELL

CU Team Org Chart

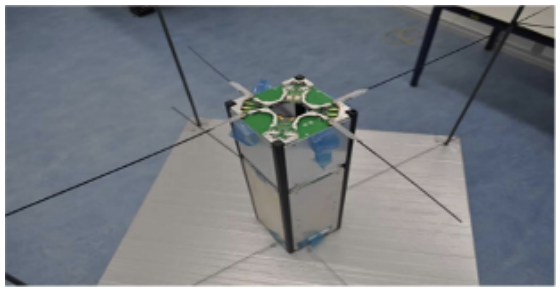


Spring 2023 Deliverables/Milestones

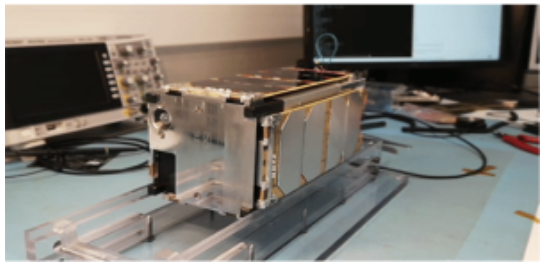
SYS: Day in the Life Test Plan



- DiTL testing ensures that all the subsystems are running as expected and simulates the functions that would happen in orbit while the system is still on the ground.



Antenna Deployment Test

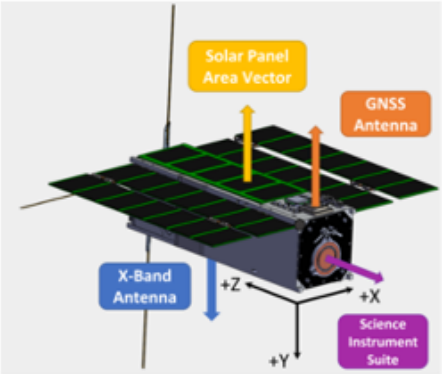


Solar Array Deployment *credit: esa*

SYS: ADCS Task Function

- Logic to determine pointing mode
- Enables autonomous decision making
- Determines inputs to our ADCS system (XACT-15) at any time
  - Primary and secondary pointing vectors
- Completed:
  - Table, Flow Diagram MATLAB scripts
  - **34** paths/outcomes
  - **15** unique pointing modes

Constraint	Pointing Mode
Cone constraint about velocity	Maximize ground station pointing
	Maximize sun pointing
Cone constraint about zenith	Maximize ground station pointing
	Maximize sun pointing
	Maximize velocity pointing
Unconstrained	Pure velocity pointing
	Pure ground station pointing
	Pure zenith pointing
	Pure sun pointing
	[tumbling]



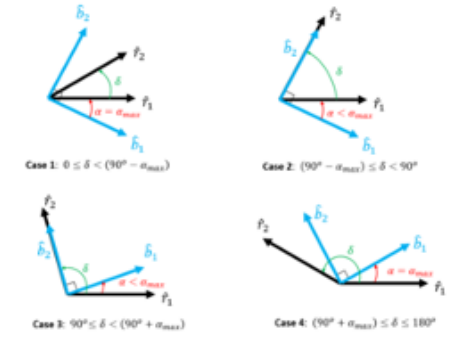
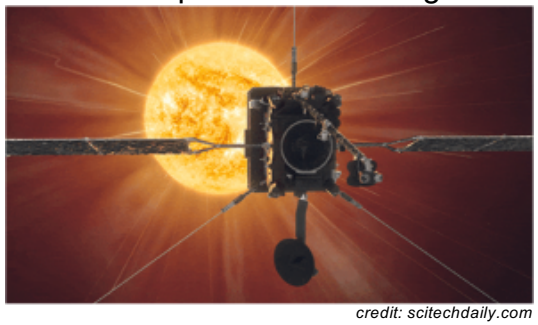


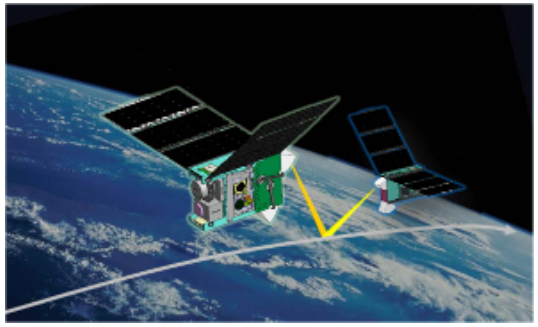
Figure 11: Different cases for the development of the constrained guidance law.

Example of Sun Pointing



credit: scitechdaily.com

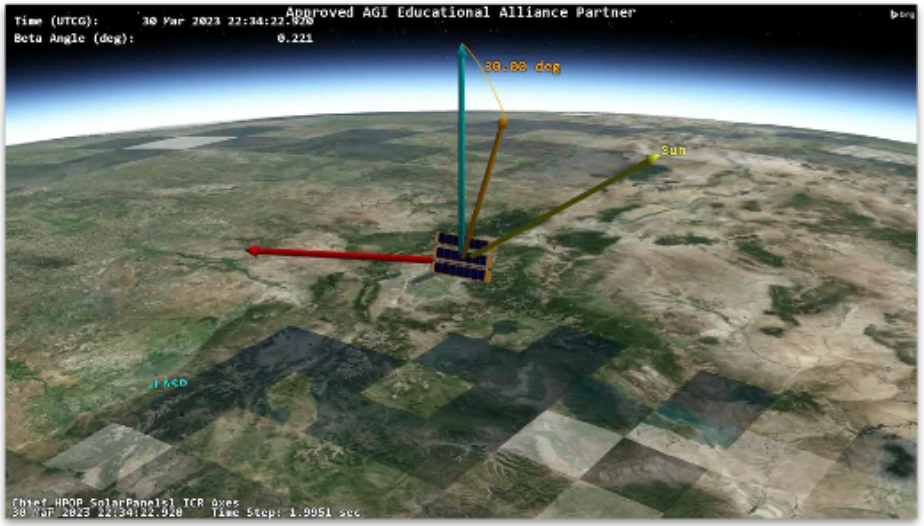
Example of Ground Station Pointing



credit: breakingdefense.com

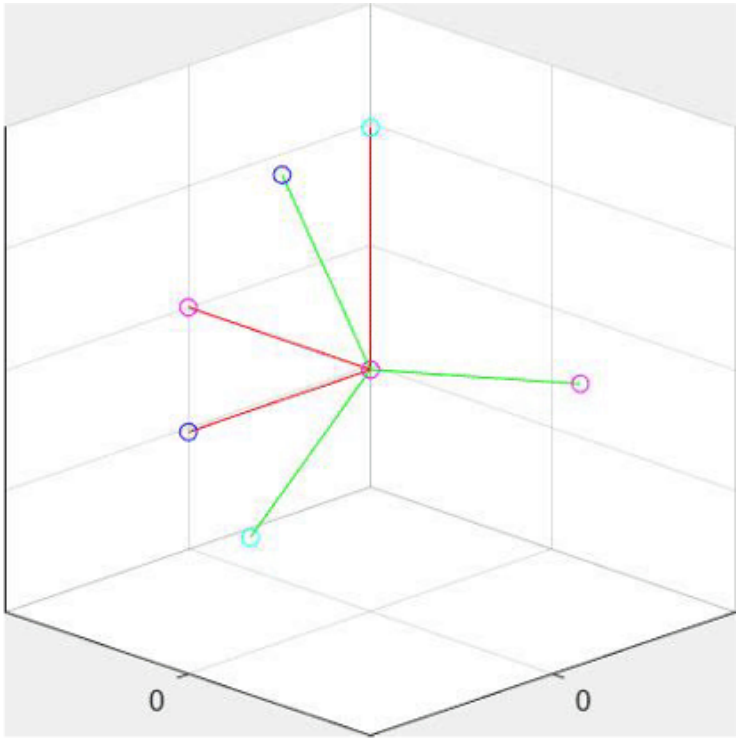
SYS: ADCS Task Function - Next Steps

Simulate the ADCS Task Function in action



STK

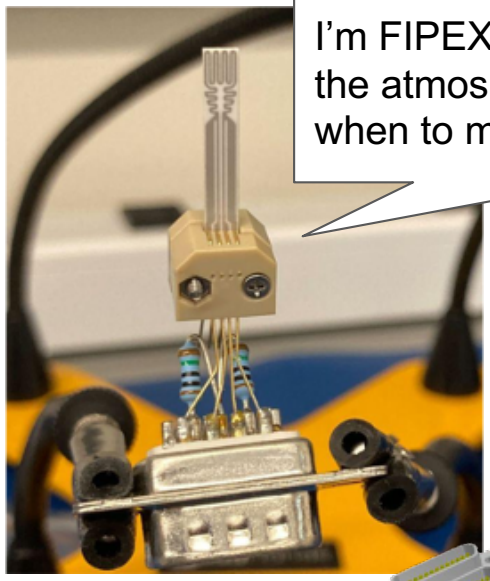
(credit: David Fitzpatrick)



MATLAB

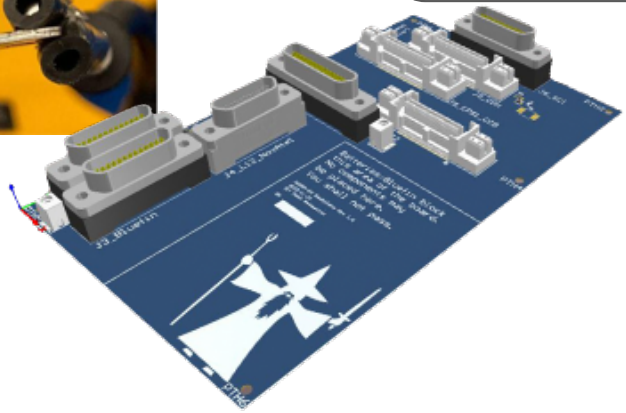
(credit: me from ASEN 5010)

CDH Team Deliverables: System Interfacing

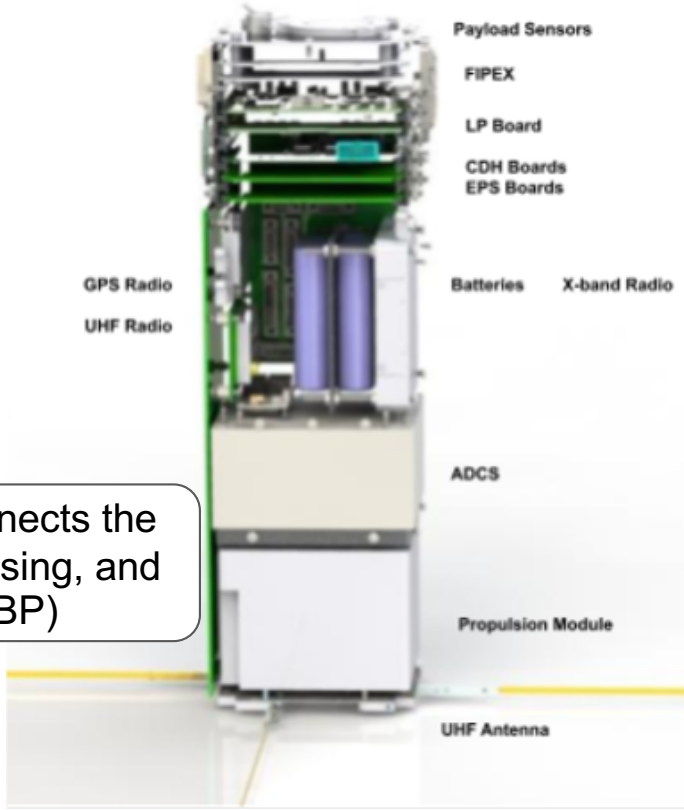


I'm FIPEX! I detect atomic Oxygen in the atmosphere but need to be told when to measure! (Task Function)

I send my data to the Command and Data Handling Board through the backplane (Data Storage Protocol)

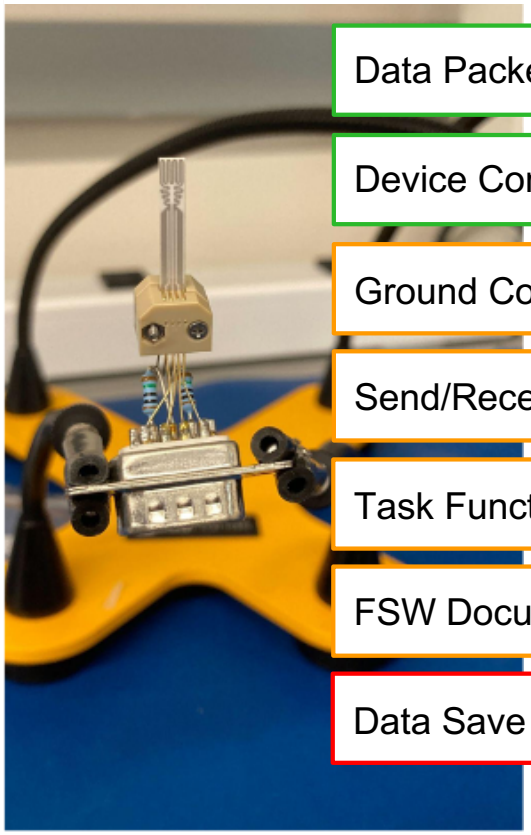


The backplane connects the satellite power, sensing, and handling systems (BP)



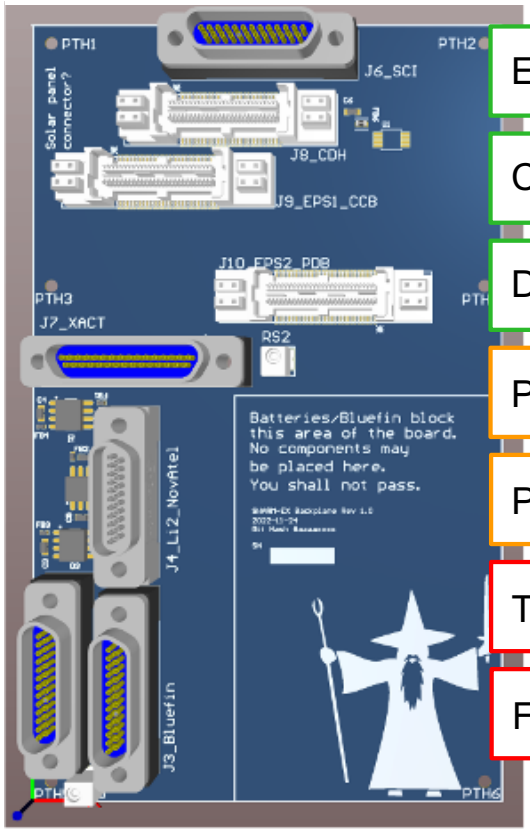
CDH Progress

FIPEX Flight Software (FSW)



- Data Packet Structure ✅
- Device Communication Protocol ✅
- Ground Command Handler - 80%
- Send/Receive Commands - 80%
- Task Function CONOPS - 50%
- FSW Documentation - 25%
- Data Save Routine - 50%

Backplane Development



- ESD Protection Circuitry ✅
- CDH UART Converter ✅
- Device Connections ✅
- Power Connections - 50%
- Pin Mapping - 50%
- Trace Routing - 0%
- Fabrication - 0%

Challenges

Communication

credit: insperity.com

Recruiting/Student Turnover

	Originally Planned Date
Kickoff	10/19
MCR+MRR	2/20
PDR	9/20
CDR	3/21
PIR	12/21
PETR	3/22
PSR	9/22
Launch	3/23

Schedule Shift

Questions?