The Space Weather Atmospheric Reconfigurable Multiscale Experiment (SWARM-EX) Satellite Constellation: Mission Review and Progress Update

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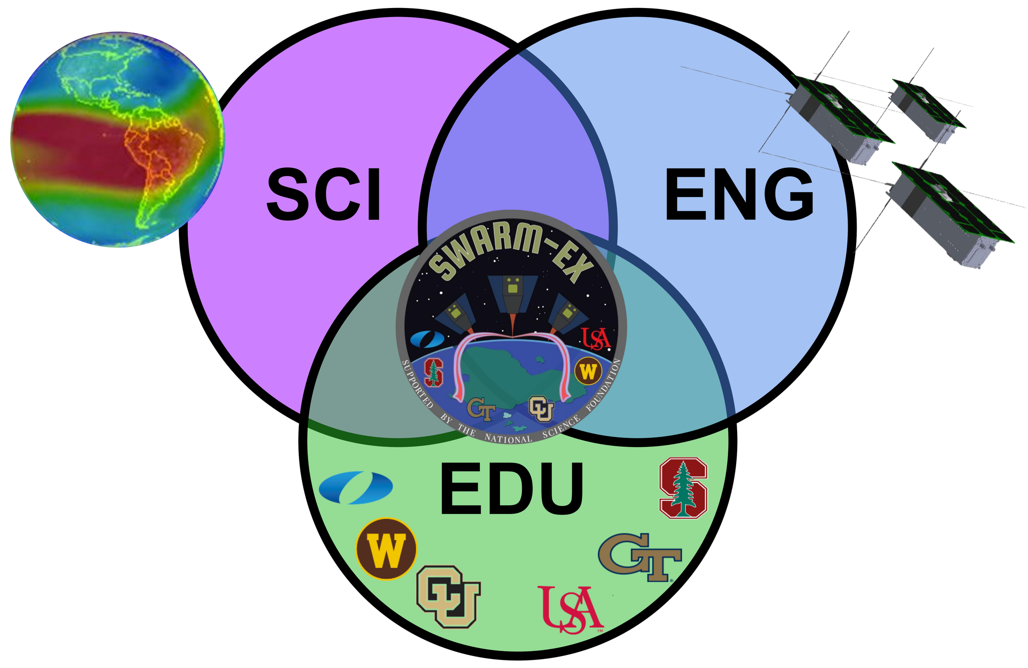
Introduction

SWARM-EX is an inter-collegiate, NSF-funded mission to design, build, and fly a constellation of three identical 3U CubeSats to study spatial and temporal variablility in the Equatorial Ionization Anomaly (EIA) and Equatorial Thermospheric Anomaly (ETA).

SWARM-EX Mission Objectives

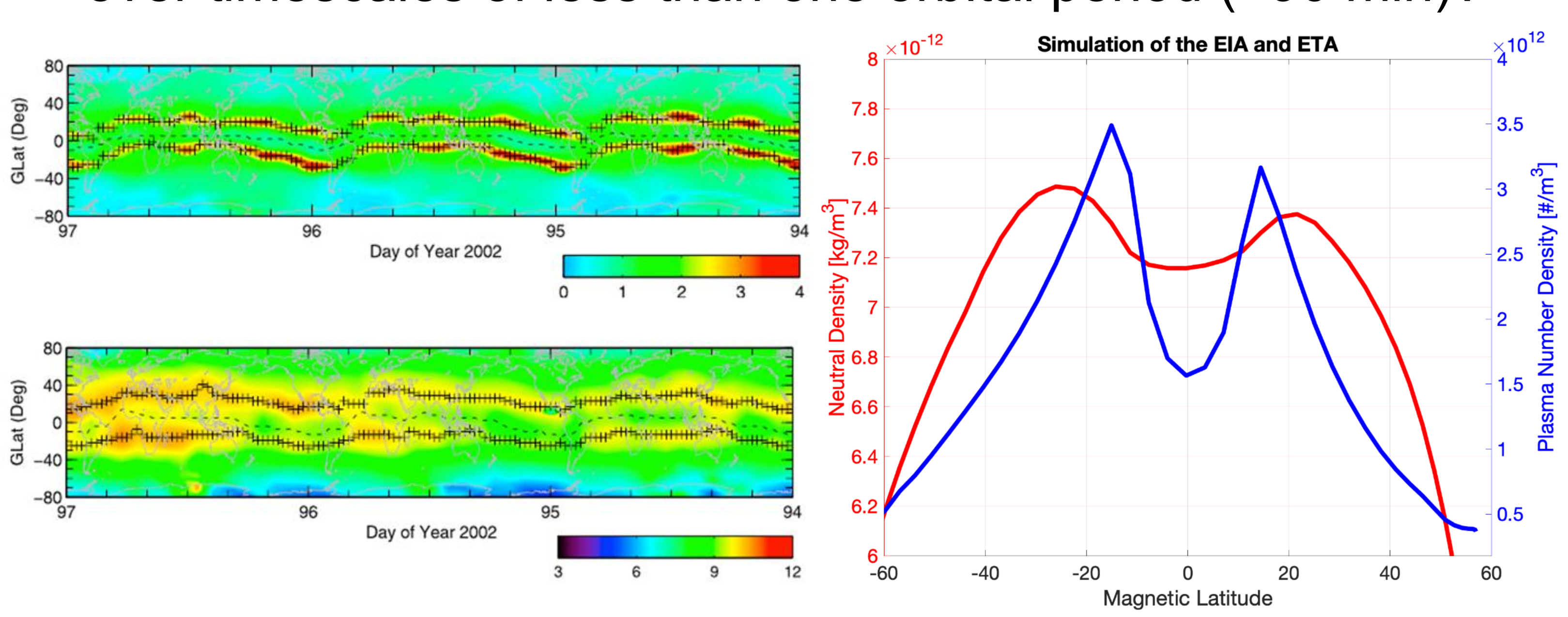
- Measure changes in EIA/ETA
- Determine persistence and correlation in EIA/ETA
- Demonstrate autonomous formation flying capabilities
- Swarm reconfiguration
- Collision avoidance



- Mentorship and collaboration between six U.S. univerisities
- Education and public outreach program

Science Questions

1. How persistent and correlated are the plasma density and neutral oxygen in the EIA and ETA features?
2. What changes in the EIA/ETA properties can we observe over timescales of less than one orbital period (~90 min)?

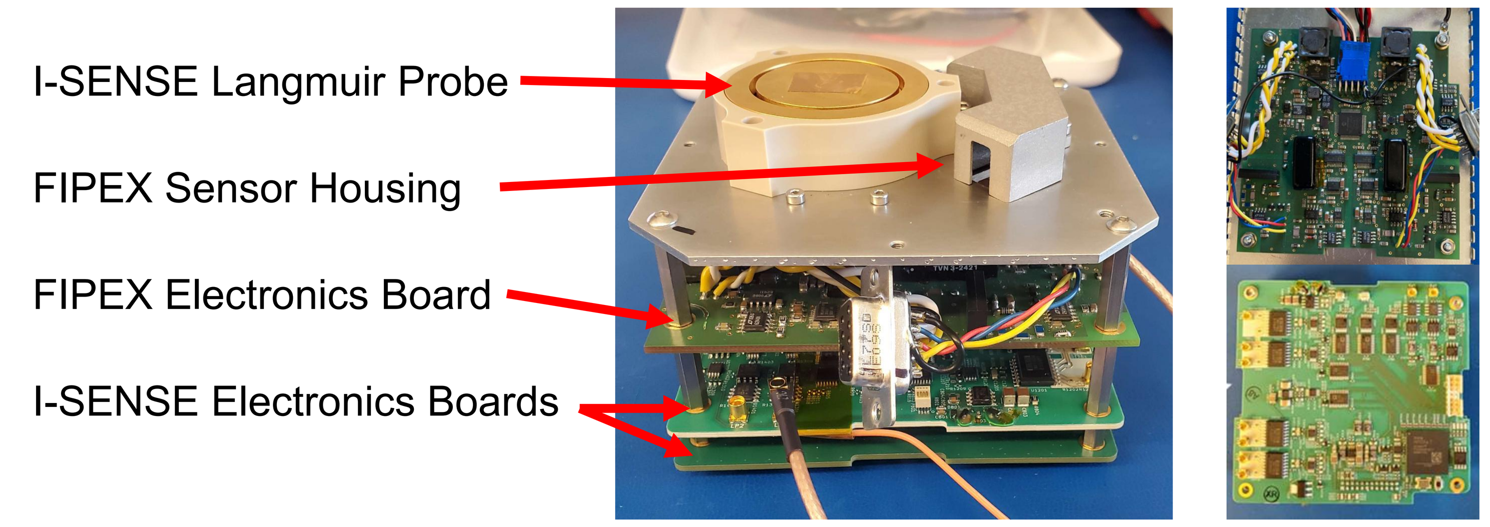


Left: (Top) Electron density (in units of 10^{12} m^{-1}) and (Bottom) neutral mass density (in units of 10^{-12} kg/m^3) at 400 km from CHAMP satellite at about 1800 local time (LT) during days of the year 94-97, 2022. Crosses mark the location of the ETA/EIA crests while the dashed line represents the troughs [1]
Right: Simulated SWARM-EX sampling of the EIA/ETA with the FIPEX sensor and I-SENSE Langmuir Probe [2]

Current State of the Instruments

Each SWARM-EX satellite will be equipped with an I-SENSE Langmuir probe and a FIPEX sensor to measure plasma density and atomic oxygen respectively, enabling the constellation to sample both the EIA and ETA.

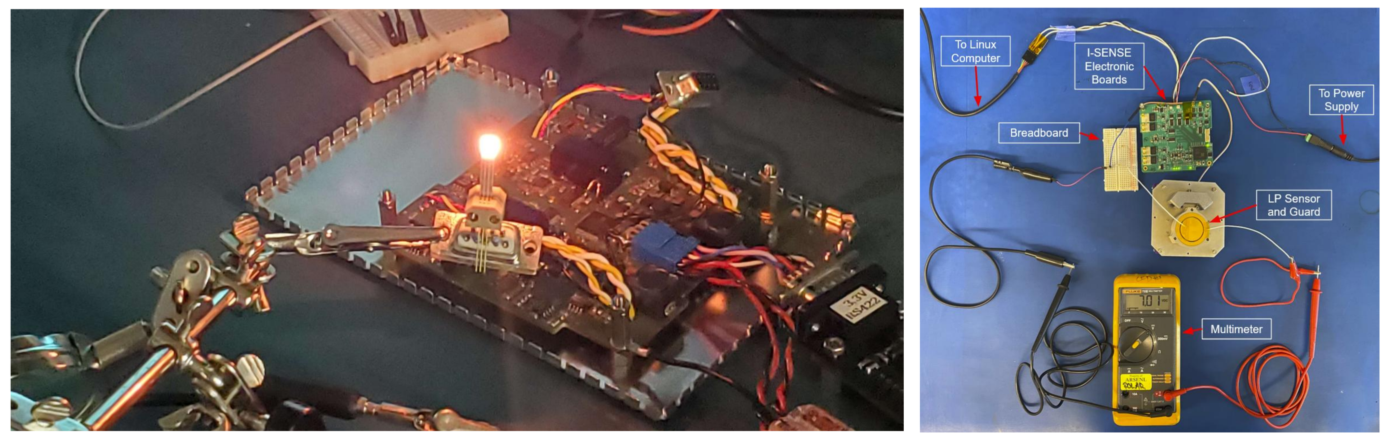
Equipped with formation flying capabilities, the SWARM-EX constellation will be configurable on orbit [2], allowing the mission to investigate the persistence and correlation of atmospheric features on variable time scales less than one orbital period (~90 minutes), and monitor the evolution of the EIA and ETA over the mission duration (> 1 year).



Left: Assembled SWARM-EX Instrument Deck EDU
Right: (Top) FIPEX EDU Electronics Board, (Bottom) I-SENSE EDU Science Board

Safe2Mate procedures for the instrument deck have been developed, and the Engineering Development Units (EDU) have undergone thermal and vacuum tests to validate instrument functionality in space-like environments.

The flight I-SENSE and FIPEX units have been delivered to CU Boulder and are undergoing acceptance testing. Minimum Communications Testing (MCT) is currently being performed with both sets of instruments to ensure that they can be controlled through the Command and Data Handling system [3] flight software on orbit.

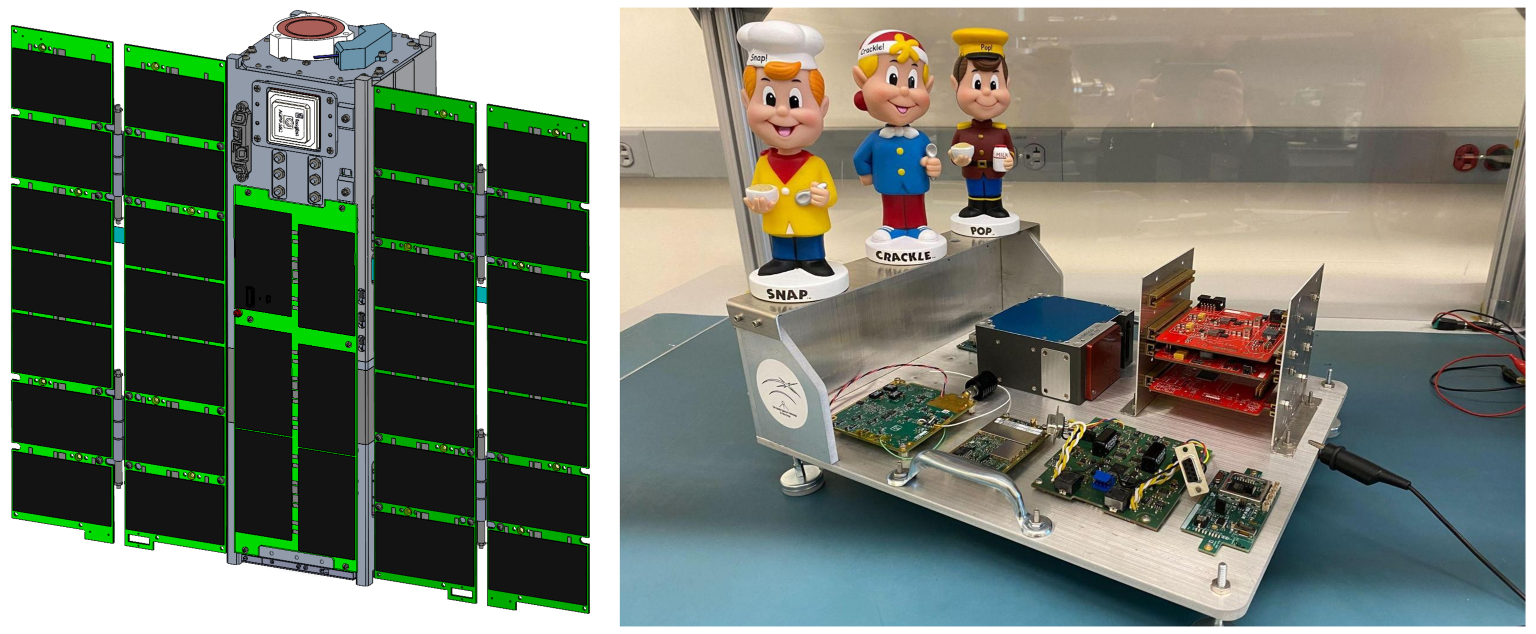


Left: FIPEX Sensor heating up during MCT
Right: I-SENSE Langmuir Probe MCT testing settup

With the flight units delivered, the next steps will be to finish acceptance testing and begin assembly of the flight instrument decks. The EDU instrument deck will be integrated into the SWARM-EX FlatSat to complete software and electrical interface testing of the system.

Current State of the Mission

SWARM-EX is nearing the end of the design phase, with flight components starting to arrive at CU Boulder for integration. Cold gas propulsion units [4] have been delivered by Georgia Tech, and X-Band patch antennas [5] have been manufactured by the University of South Alabama. Orbital Guidance Navigation & Control code developed by Stanford [2] is currently being integrated into hardware at CU Boulder. New electronics for the SWARM-EX FlatSat are being designed to enable fully integrated subsystem development, and final revisions to the spacecraft structure are being made to prepare for the mission's Pre-Integration Review (PIR).



Left: CAD render of the integrated SWARM-EX satellite with solar panels deployed
RIght: Assembled SWARM-EX FlatSat

SWARM-EX Status Summary

SWARM-EX is a three CubeSat conseallation designed to study the EIA and ETA. Each spacecraft will be equiped with a FIPEX sensor and an I-SENSE Langmuir probe, allowing SWARM-EX to take temporal and spatial measurements of the EIA/ETA. Both the EDU and flight instruments have been delivered to CU Boulder, and are undergoing integrated testing with the rest of the system. The mission's next milestone is PIR, which is scheduled for Q1 of 2026. The satellites will then be assembled and undergo enviornemntal testing at CU Boulder, with launch expected roughly one year after completing PIR.

References:
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