Exhibit A – SoFIE Program of Research
7/2/2026

1. Introduction and Program Overview

Saint Francis University (Loretto, PA) requests an Experimental Space Station Authorization (under Part 5 of the FCC Rules) to operate a 3U CubeSat platform designated as the Solar Flare and Ionosphere Explorer (SoFIE).

Targeting an orbital deployment no earlier than spring 2028 into a nominal 500 km Low Earth Orbit (LEO), the SoFIE mission operates as a space-based physics observatory and global citizen science platform. The project is designed to investigate the coupling mechanisms between solar flares, coronal mass ejections (CMEs), and the terrestrial ionosphere. The execution of transionospheric radio propagation experiments between the SoFIE space station and global amateur radio operators is essential to mission success, transforming passive observations into a distributed, worldwide radio science instrument.

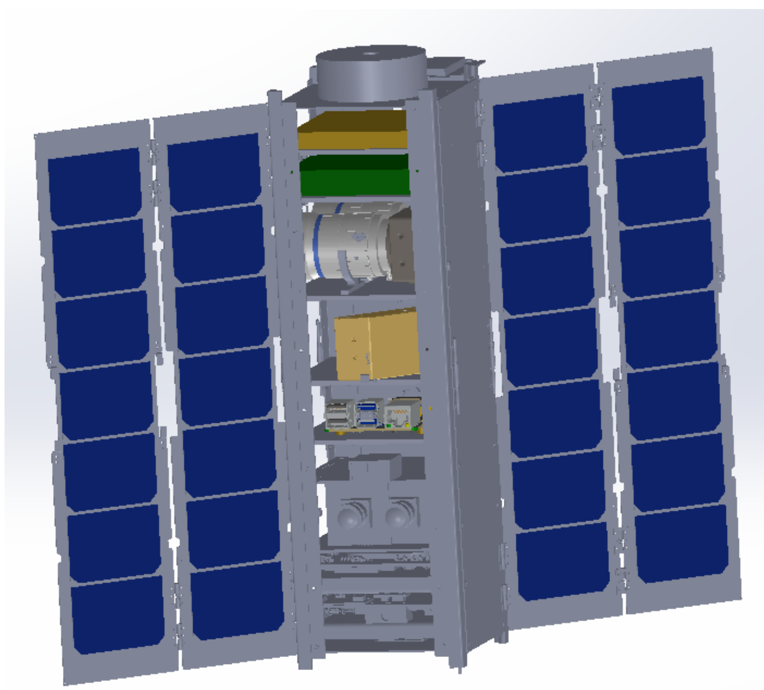

Figure 1: SoFIE CAD model.

2. Core Research Program: Nature of the Experiment

The overarching research program addresses the structural dynamics of the upper atmosphere during highly energetic space weather events. Fundamental mission research questions include:

1. *How does the ionosphere react to solar flares in real time?*
2. *How does the ionosphere recover from solar flares in real time?*

To answer these questions, the SoFIE space station acts as an integrated multi-instrument sensor suite. The spacecraft carries a soft X-ray sensor to detect solar flare activity, two optical cameras to observe auroral emissions (color and the 630-nanometer oxygen line), and a 3–30 MHz High Frequency (HF) radio instrument. Together, these instruments allow investigators to cross-correlate localized variations in ionospheric electron density with solar radiation fluxes and directly quantify the resulting real-world impacts on global radio wave propagation.

3. HF Instrument Operations

The HF instrument will operate as a single frequency topside sounder and as a broadband passive receiver:

- **Topside Ionospheric Sounding:** The HF instrument will execute active topside ionospheric sounding centered at 9.303 MHz (a frequency selected to preserve data continuity with historical Alouette and ISIS space missions). Sounding is a technique for measuring the electron density profile of the ionosphere's D, E, and F layers by analyzing the reflection, refraction, Doppler shift, and time-of-flight of radio waves.

  To maximize scientific return while ensuring strict electromagnetic compatibility with ground-based users, the sounder does not use high-power, unmodulated pulses.
  Instead, it utilizes an advanced Direct Digital Synthesizer (DDS) to generate a highly disciplined Linear Frequency Modulation (LFM) chirp. The transmitter spreads its 1.0 Watt peak power across a broad 125.0 kHz sweep window with an ultra-short 500 microsecond (µs) pulse duration and a low 0.38% operational duty cycle (FCC Emission Designator: 129KQ3N).

- **Integrated Passive HF Receiver Array:** Operating alongside the active sounder, the payload incorporates a sensitive, wideband 3–30 MHz HF Receiver. This specialized receiver subsystem is engineered to passively monitor RF energy from two distinct sources: incoming solar radio bursts directly from the sun, and high-frequency signals transmitted by dedicated ground-based research stations. By operating continuously, the HF receiver captures sudden transionospheric absorption (SIA) events, radio blackout profiles, and real-time alterations in signal polarization caused by traveling ionospheric disturbances (TIDs).

4. Advancement and Improvement of the Radio Art

The SoFIE mission directly improves the radio art in three ways, establishing significant technical advancements over both historical ionospheric sounders and modern commercial space operations:

- **Enhancement in Range Resolution:** Traditional legacy sounding satellites (such as Alouette 1/2 and the NASA ISIS series) utilized long, unmodulated 100 µs monochromatic pulses, which restricted their physical vertical range resolution to 15.0 km. By utilizing a 125.0 kHz LFM digital chirp coupled with digital matched filtering (pulse compression), SoFIE compresses the active echo from a 500 µs block into a sharp 8.0 µs voltage spike. This achieves a physical vertical resolution of 1.20 km. The radio art is improved by demonstrating that a low-power, wideband swept waveform can map fine-grained horizontal plasma structures and micro-scale electron density gradients with over 10 times the fidelity of historical systems.
- **Mitigation of Spectral Interference:** Legacy ionospheric sounders relied on high power pulses, emitting between 100 Watts and 400 Watts of peak power into the shared HF spectrum, risking widespread interference to terrestrial systems. SoFIE improves transmitter technique by achieving superior data metrics using 1.0 Watt peak power. By sweeping the 1.0 Watt signal across 125.0 kHz, the Peak Power Spectral Density is diluted to a 8.0×10^{-6} W/Hz. As mathematically demonstrated in Exhibit D, this places the arriving peak pulse power inside any standard terrestrial 3 kHz communications receiver channel at -89.8 dBm—safely burying the signal 12 to 17 dB *below* the natural ambient ITU-R P.372 rural noise floor. Furthermore, the accelerated sweep rate ensures the signal spends only 12.0 µs inside any individual receiver's passband, proving that wideband scientific sounding can safely co-exist with primary communications services on a zero-interference basis.
- **Global Innovation via Transionospheric Citizen Science Experiments:** The radio art is significantly advanced by engaging a massive, worldwide network of amateur radio operators in active, multi-point transionospheric propagation experiments. By coordinating transmissions between global ham stations and the satellite’s passive 3–30 MHz receiver, the project will map how signals cross the boundary layer under severe solar flare conditions. Coordinated groups can design experiments tracking Faraday rotation, localized absorption, signal attenuation, and ionospheric scintillation individually, as groups, or during high-participation radio events like ARRL Field Day.

Individual operators can simultaneously act as a distributed receiving grid, logging the satellite's 9.303 MHz active pulses to monitor real-time path dynamics. The SoFIE program will openly publish its exact LFM chirp mathematical coefficients, enabling global amateur radio operators and student classrooms to act as a massive, distributed passive receiver grid. By performing coherent integration across a 1-second window (stacking 7 consecutive pulses), ground stations will achieve a processed signal-to-noise ratio (SNR) exceeding +15 dB.

This framework improves the amateur radio art by introducing non-commercial operators to advanced radar techniques, including Doppler phase-compensation loops, Faraday rotation calculations, and time-of-flight ionogram generation, transforming the citizen science community into active space-weather research collaborators and establishing a crowdsourced radio science framework never before realized in a space mission.

5. Open Data Access and Non-Commercial Cooperation

To foster a collaborative research environment, all raw scientific telemetry, orbital tracking logs, and ionospheric profiles collected by the SoFIE space station will be uploaded directly to public, open-access cloud databases provided by the University of Scranton’s HamSCI initiative. This allows participating amateur operators to extend their involvement from data gathering to advanced independent data analysis. This open-source pipeline will facilitate collaborative peer-reviewed papers, strengthen international citizen-science frameworks, and significantly expand global public understanding of space weather dynamics.

A description of SoFIE Earth Station communications architecture may be found in Exhibit B.

A description of SoFIE Space Station communications architecture may be found in Exhibit C.

The mathematical co-channel interference analysis for the 9.303 MHz Topside Sounder may be found in Exhibit D.

The SoFIE UHF link budget may be found in Exhibit E.

The SoFIE S-band link budget may be found in Exhibit F.

The SoFie Topside Sounder link budget may be found in Exhibit G.