Small Satellite
Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA

CLEAR-1: CubeSat for Local Emissions Air Reconnaissance

David Krupp
Undergraduate Student, Mechanical Engineering
University of Georgia
david.krupp@uga.edu

Under

Dr. Vijaya Gallagher,
Sydney Whilden
Chief Architect, Space Segment at Globalstar,
Lab Manager, Small Satellite Research Lab

Table of Contents

Abstract

The CLEAR (CubeSat for Local Emissions Air Reconnaissance) mission will deploy a 6U CubeSat equipped with a compact, MEMS-tunable spectrometer designed to monitor and quantify urban air pollutants from a low-altitude Sun-Synchronous Orbit (SSO). While existing Earth observation assets focus primarily on CO_2 and regional-scale CH_4 emissions, no small-scale system exists to provide daily mapping of multiple trace gases (CH_4, NO_2, SO_2, CO) across urban environments. CLEAR will fill this gap by utilizing a constellation-ready, modular payload that combines narrowband imaging with real-time onboard processing to deliver actionable environmental data.

The primary piece of hardware is a Fabry-Pérot interferometer. It targets narrow absorption bands for each gas species, and can use machine learning (ML) assisted filtering for atmospheric correction and source separation. CLEAR will operate from a 97.5° inclined orbit at approximately 500 km altitude, ensuring almost complete coverage of urban environments across the United States with regular revisit opportunities. The mission will demonstrate not only multi-species detection from a CubeSat-class platform but also the feasibility of local air quality analytics at a metropolitan scale from orbit, forming a scalable path toward environmental transparency and policy support for urban emissions.

Project Narrative

Urban air pollution is a prevalent, yet widely variable threat from city to city. While major satellite missions (GHGSat, OCO-3) provide global context for carbon emissions and climate modeling, they lack the revisit frequency and, most importantly, local specificity needed to support city air quality monitoring and decision-making. Many cities across the globe, particularly in the developing world, do not have access to ground-based air quality sensors at sufficient density to inform local governments or respond to active health threats like NO_2 spikes or SO_2 leakages. Even in regions with advanced technology and infrastructure, such as the United States, current methods for monitoring pollutant leaks are often limited in accuracy. Dr. Greg Rieker of the University of Colorado Boulder has highlighted the strengths and weaknesses of ground-based frequency comb spectroscopy, one of the primary techniques in use. While these systems provide highly accurate gas readings when monitoring a single emission source, their performance declines significantly in environments with multiple overlapping sources. In those cases, the measurements often suffer from data conflation, leading to reduced confidence and reliability in the results (Makowiecki 2020). CLEAR addresses this need by capturing and processing multi-gas concentration data in the visible, near-IR, and mid-IR bands using a tunable MEMS-based interferometric payload. Each gas signature is characterized by a unique spectral absorption band: methane (~1.65 µm), nitrogen dioxide (~0.45 µm), carbon monoxide (~2.3 µm), and sulfur dioxide (~0.31 µm). By leveraging recent advances in compact optics, CLEAR performs selective spectral imaging, compressing and preprocessing data onboard with an NVIDIA Jetson GPU, simplifying downlink.

To bring this mission from concept to orbit, a multi-agency funding structure is proposed. The primary funding agency for mission development is NASA's Earth Science Division, with additional cost-sharing opportunities found through the CubeSat Launch Initiative (CSLI). Institutional support is also anticipated through University of Georgia's Small Satellite Research Lab infrastructure and partnerships with environmental research groups such as Dr. Rieker's company, LongPath Technologies. A full preliminary budget can be found in **Appendix C**.

The CLEAR CubeSat will be launched to Low Earth Orbit as a secondary payload under a rideshare contract through SpaceX's SmallSat Program. The vehicle of record is the Falcon 9, utilizing the standard EELV Secondary Payload Adapter (ESPA) port configuration. CLEAR will be deployed from the EXOpod deployer system, as SpaceX has partnered with Exolaunch for services in conjunction with their launches (Exolaunch). This mission targets a 500 km circular orbit ($e = 0$) at 97.5° inclination to ensure complete continental U.S. urban coverage while maximizing CLEAR's daylight utilization (~65% of orbit in sunlight). Ground support will be provided through the University of Georgia Small Satellite Research Lab (SSRL) ground station, COSMO, for full mission coverage. For details on the full orbit, see **Appendix A**.

The mission will pursue a two-year operational timeline (longest approximate time until deorbit: 2.29 years), targeting daily overpasses of major urban centers in the continental United States. Onboard data collection will enable early detection of emission anomalies and long-term trend mapping with a ground spatial resolution of 100 m, which is very rare for a CubeSat of this size and class. If mission success is achieved, the next steps towards worldwide integration involve setting a constellation of CLEAR satellites through partnering organizations.

System Engineering Questions

1. Who are the Stakeholders?
   The primary customer for CLEAR-1 is NASA's Earth Science Division, with additional stakeholders including environmental research agencies (LongPath Technologies) and city governments seeking access to localized emissions data.
2. What are the Customer Requirements?
   Customer requirements include accurate trace gas mapping at the urban scale, consistent daily observations, and reliable downlink of usable scientific products.
3. How will CLEAR meet these Requirements?
   CLEAR meets these requirements through its MEMS-tunable Fabry-Pérot payload. Alternative technological solutions were considered, such as LiDAR (Light Detection and Ranging) and Multispectral Imagers; however, both ultimately fall short of the

resolution and gas-concentration deliverables targeted for CLEAR-1. System performance will be demonstrated through daily CH_4 and NO_2 retrievals, stable orbital operation over a one-year mission duration, and validated downlink data sets from multiple target regions.

4. What are the Technological Risks, Benefits, and Advancements?
   The technology approach emphasizes COTS integration and modular design, with risks mitigated through the use of flight-heritage components and onboard fail-safes. CLEAR advanced spaceborne air quality monitoring and offers a low-cost, scalable platform for future environmental missions. The main technological advancement CLEAR-1 will test is the 3U Fabry-Pérot Interferometer with a custom detector and MEMS tuning system. Due to its relatively low Technology Readiness Level (TRL), the custom dual-spectrum detector poses the greatest challenge to mission success.

Mission Impact

From a technology standpoint, CLEAR's primary contribution lies in its novel sensing capability. No prior CubeSat has flown with a multi-gas, MEMS-actuated payload capable of urban-scale air quality monitoring. The downstream effects are substantial if CLEAR is successful. From a public health standpoint, CLEAR enables the real-time detection of four compounds (CH_4, NO_2, SO_2, CO), which are respiratory hazards in cities given enough concentration. It offers a new means of infrastructure monitoring by detecting CH_4 leaks in natural gas infrastructure, for example. Monitoring these manufactured gases is relevant for both developed and developing cities, where routine leak detection is often cost-prohibitive.

Beyond the surface applications, CLEAR supports climate policy by offering sub-regional accountability for greenhouse gas emissions and air toxins. CLEAR's 6U size and novel payload enable it to potentially be deployed in constellations, meaning regional agencies, non-government organizations (such as LongPath), or individual cities could buy into their own environmental observation node. In this way, the mission serves as a proof-of-concept for democratizing atmospheric sensing, enabling access to space-collected emissions data for the first time at the municipal scale.

Payload Overview

At the core of the CLEAR payload architecture is a MEMS-tunable Fabry-Pérot interferometer, designed to isolate spectral features associated with trace gas absorption. Unlike traditional dispersive spectrometers, which use prisms or diffraction gratings to spread light spatially across a detector array, the Fabry-Pérot system uses multiple-beam interference within an optical cavity. By adjusting the spacing between two partially reflective mirrors, the interferometer selectively transmits specific wavelengths, allowing it to sweep across a defined spectral range. This tunability makes the system very efficient for small satellite platforms, as a single interferometer can target multiple gas absorption bands: CH_4, NO_2, CO, and SO_2, so long as they fall within the same general optical region.

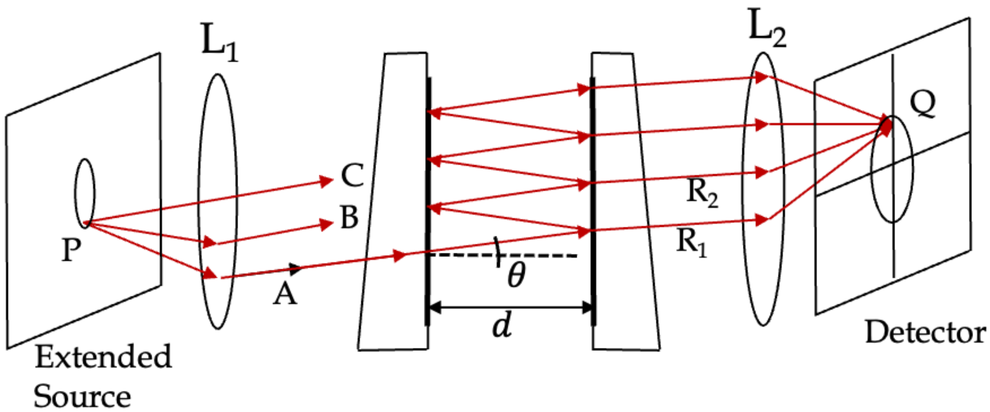

Figure 1 - Fabry-Pérot Interferometer Diagram (Physics Boot Camp)

Variations in ground reflectance do not prevent accurate measurement of gas concentrations, but they do introduce a source of noise that must be corrected in processing. The interferometer is programmed to sample not only at absorption peaks, but also at adjacent non-absorbing reference bands. By comparing the intensity at these points, the system can normalize its readings and isolate the absorption signature from the surface background (Wang 2020). This approach enables accurate gas detection even over non-uniform terrain. Additional corrections for cloud interference and other atmospheric scattering are performed onboard through filtering. Combined, these features allow CLEAR to deliver reliable gas mapping data from orbit using a highly compact and efficient payload. **Table 1** below depicts all the hardware required for the payload assembly.

Component	**Hardware Selection**
Cassegrain Telescope	At 500 km, focal length = 125mm (100m resolution)
Optical Front	25 mm f/2 (AR coated) lens
MEMS system	VTT MEMS etalon
Detector	Hamamatsu InGaAs/CMOS
Analog-to-Digital Converter	Teledyne ePix 14-bit, 50 ksps
Controller	NVIDIA Jetson

Table 1 - Payload Components

Subsystems

Frame and Structure

The CLEAR mission will not deviate from the NASA industry standards for CubeSats laid out in their *6.0 Structures, Materials, and Mechanisms* guide. Along with these requirements, we include the EXOpod requirements to integrate with the deployment system, as well as SpaceX's dedicated specifications for ridesharing. Many current missions in development are beginning to cite magnesium alloys as viable alternatives to the more traditional aluminum structures that most current satellites operate with. While it is true that magnesium alloys like AZ31B and ZK60A have comparable properties to aluminum frames, they also are more reactive metals, which can become combustion hazards in the event of a fire or tank rupture. NASA's STD-6061 standards do not prohibit magnesium alloys aboard launch vehicles but rather flag them as hazardous materials, which must go through more rigorous testing and inspection (NASA). This being the case, CLEAR will operate with a more common aluminum 6061-T6 frame in order to reduce complexity and cost in manufacturing. While CLEAR operates in a 6U form factor, the distinction between these materials will not affect the deorbiting effectiveness nor the 1/10,000 maximum risk acceptable for launch.

All structural surfaces, especially those that interact with EXOpod deployment rails, will undergo anodization to improve wear resistance and comply with outgassing standards. External panels are all to be designed with a 1.5 mm wall thickness for structural integrity. Internal supports and hardware brackets will remain at a 1 mm wall thickness, optimized for weight and thermal management. All structural components will be manufactured via subtractive manufacturing for high precision with machines capable of producing surface finishes +/- 1.6 µm (NASA). CLEAR's total mass should fall at 12 kg, and its center of gravity should be within 2 cm of the geometric center along the Z-axis for stability during deployment and operation. Clyde Space manufactures its ZAPHOD 6U structures, which meet most of these requirements by default while also being compatible with their own PHOTON solar arrays. For a full depiction of the mechanical nature of the system, see **Appendix B**.

Optical Train

The optical train for CLEAR is designed to prioritize compactness and spectral variability within a 3U payload volume. Incoming sunlight reflected from Earth's surface first enters through a Cassegrain Telescope and a 25 mm aperture lens mounted to the nadir face of the bus. This lens serves as both the primary light-collection element and initial collimator, channeling reflected solar radiation into a single beam. The beam is directed through a MEMS-tunable Fabry-Pérot interferometer, where only a specific wavelength (predetermined) of the incoming light is passively transmitted at a time. This filtered light is then refocused by a convex imaging lens onto a thermally stabilized detector array, typically InGaAs for near-infrared or Complementary

Metal-Oxide Semiconductor (CMOS) for visible to ultraviolet bands. The detector's output is routed directly into an analog-to-digital converter with the same optical board (NVIDIA Jetson), minimizing path length and electrical noise (Georgia State University). The entire train must be shielded and housed in an aluminum cowl to reduce stray light and maintain optical alignment once in orbit. This layout ensures that each spectral channel is isolated as cleanly as possible, allowing the payload to meet the high demands required for trace gas detection. Design and fabrication of the detector, in particular, will have to be outsourced to a vendor capable of creating it. Hamamatsu Photonics is a Japanese electronics manufacturer that has made a variety of optical sensors used in state-of-the-art applications for science, medicine, and the space industry. They would likely be a good first point of contact regarding a dual-spectrum detector.

Hardware

CLEAR will utilize the GomSpace NanoMind A3200, a commercially available OBC with a radiation-hardened ARM9 processor and full support for I^2C, SPI, and CAN bus communication (GomSpace). The OBC will serve as the mission's core control system, responsible for interpreting ground commands, maintaining telemetry, coordinating ADCS pointing modes, and executing power control routines. It connects directly with the EPS, ADCS, and communications hardware, and includes multiple fault detection and correction routines supported by a hardware watchdog (more in Flight Software).

Payload data is processed by the NVIDIA Jetson Orion, which is entirely used for gas analysis during overpasses. It receives raw digital output from the Teledyne ePix ADC (Analog-to-Digital Converter) and preprocesses that data (i.e., frame correction, wavelength identification). The Jetson communicates with the OBC via SPI for tasking and data staging, and remains powered down outside of Observation Mode to conserve energy. The Jetson board will be mounted at the top end of the 3U avionics stack, next to the detector in the 3U Optical Train. Support hardware needed for these systems includes a solid-state drive for data and telemetry storage, and current and temperature sensors throughout the avionics stack.

Attitude Determination and Control System

The spacecraft's attitude determination and control is handled by the Blue Canyon Technologies XACT-50 system, which provides up to a hundredth of a degree pointing accuracy and stability necessary for imaging. Apart from the included reaction wheels, this system integrates gyroscopes, magnetometers, and star trackers in a single unit and is compatible with 6U CubeSat buses. The ADCS operates continuously throughout the mission, adjusting spacecraft orientation to align the payload with target cities during overpasses and ensuring that the principal axis remains within tolerance during Observation Mode. The ADCS will also be the primary driver in several of CLEAR's other modes, including Detumble, Stabilization, and Charge Modes.

Communications

The CLEAR communications subsystem is divided into two channels: a UHF uplink for basic command and control, and an S-band downlink for data transmission. The uplink is managed through a compact UHF transceiver module, supporting command uploads and low data rate telemetry. The downlink is handled by a GomSpace SDR module operating in the S-band at 2.2 GHz with a patch antenna. This setup allows for downlink rates of up to 100 kbps during ground station passes, with an average daily data budget tailored to fit within the processing and compression limits of the onboard Jetson module. Communication sessions are scheduled twice per orbit, with the SDR entering standby mode during off-pass periods to conserve power. **Table 2** displays the link budget created based on these properties and yields a fairly high margin of about 5 dB, which has plenty of clearance for any unanticipated interference/rain margin.

Parameter	Value
Transmit Power	30 dBm
Transmit Losses	1.5 dB
Transmit Antenna Gain	4 dBi
EIRP	32.5 dBm
Carrier Frequency	2200 MHz
Range	500 km
Free Space Path Loss	145.5 dB
Receive Antenna Gain (Ground)	30 dBi
System Noise Temperature	290 K
Bandwidth	100 kHz
Data Rate	100 kbps
Achieved Link Margin	~5.3 dB

Table 2 - Link Budget

Electrical Power System

Power for the CLEAR mission is provided by Clyde Space's PHOTON deployable solar panel array rated for approximately 40 W of peak generation under direct sunlight. The panels are mounted along two deployable wings, each containing triple-junction GaAs cells best fit for LEO/SSO operating altitude. Energy is stored in a set of lithium-ion batteries with sufficient capacity to buffer peak draws during payload operation and communications bursts. The EPS includes a power distribution unit that controls voltage to each subsystem and prioritizes core functions in the event of a temporary power loss.

Table 3 outlines the power budget, with the payload optics and Jetson processor drawing the most energy during active observation windows. The ADCS and EPS remain continuously powered, while the S-band transmitter activates only during scheduled downlink sessions. A 25% margin is added across all subsystems to account for minor inefficiencies, temperature effects, and component degradation over the course of the mission.

Subsystem	Avg Power (W)	Peak Power (W)	Duty Cycle (%)	Notes
Payload Optics	6	12	20	Tuned during overpasses only
Onboard Processing (Jetson)	5	10	20	Compression, filtering onboard
ADCS	2	5	100	Continuous for pointing
Communications (S-band)	1.5	4	10	Limited to brief downlink windows
EPS/Housekeeping	2	3	100	
Margin (25%)				Added to all categories
Total (avg/peak)	~11.4 W	~27 W		Solar panel generation ~40 W

Table 3 - Power Budget

Flight Software

Flight software will be built using the Bright Ascension Flight Software development kit. The system is split into two primary areas: the bus-level software stack managed by the onboard computer (OBC) and the optical payload software executed on the NVIDIA Jetson Orion GPU. These two processors operate independently but communicate through a direct SPI link and shared event triggers, allowing for coordination in Observation Mode as well as during Uplink/Downlink.

The OBC software stack handles low-level command and data handling, ADCS mode management, EPS load priorities, and telemetry. It interfaces directly with all satellite subsystems over I^2C bus communication. The OBC maintains a real-time task scheduler for ground station uplinks and orbit-defined events. It also logs system health data and enforces operating limits by placing subsystems in Safe Mode if thresholds are violated. The Jetson flight software operates as an independent controller that is active only during Observation Mode. It controls the Fabry-Pérot MEMS etalon tuning, frame capture with the detector, and processes the collected spectral data. Once target observation is completed, the data is compressed and time-tagged before being stored in the solid-state system before downlink. The OBC is notified once data products are ready for downlink, and it handles the communication handoff to the S-band transceiver.

Concept of Operations (ConOps)

The CLEAR mission is divided into three primary phases: development, integration, and orbital operation. Each phase has critical testing milestones and flight objectives, allowing the mission team to track progress toward a successful flight.

Phase A: Design and Systems Review
During this phase, CLEAR undergoes full system modeling, architecture planning, and subsystem prototyping. A Systems Requirements Review (SRR) and Preliminary Design Review (PDR) are conducted to define technical details and high-level constraints. Vendor coordination for long-lead time payload components, such as the Fabry-Pérot interferometer and custom detector, should begin in this stage.

Phase B: Integration and Pre-Flight Testing
After the Critical Design Review (CDR), CLEAR will move into hardware construction with the Engineering Model being assembled. Fit checks, component-level validation, and full-stack electrical testing are completed. Environmental testing, including thermal vacuum cycling, vibration, and electromagnetic interference testing, is performed to guarantee success with SpaceX and EXOpod deployer specifications. After all testing is completed successfully and the preliminary integration review (PIR) is passed, the Flight Model of CLEAR will be assembled.

Phase C: Launch and Operations
Following a successful launch aboard a Falcon 9, CLEAR begins in-orbit operations. After deployment, the satellite initializes in Detumble Mode and goes through calibration of all major subsystems. Once power, comms, and telemetry systems are verified, science operations begin with daily observations of target urban areas. The mission concludes after a major subsystem failure or when the satellite's natural deorbit time has come. An end-of-mission report will be necessary before potential funding of a CLEAR-2 follow-up mission.

Operational Modes

The CLEAR mission will operate through defined spacecraft modes to ensure mission safety, energy efficiency, and consistent data return. Each mode is autonomous (somewhat autonomous in the case of single and multi-target passes) and monitored by the onboard computer, with modes triggered by onboard schedules or ground commands.

- Detumble Mode - Activated immediately after deployment. The ADCS stabilizes the satellite's spin and aligns it to a sun-pointing attitude using magnetometers and gyros. Transitions to Charge Mode once stable.

- Charge Mode - Solar panels are prioritized to recharge batteries following high-power events (or a voltage drop below 7V). All nonessential subsystems are powered down. The OBC monitors EPS status and transitions to Observation Modes once charge thresholds are met.

- Single Target Pass - The OBC calculates an observation plan based on a set of uplinked coordinates for viewing. The spacecraft aligns with a calculated nadir angle from a set of uplinked coordinates and prepares the payload for a short, single-target observation point.

- Multi-Target Pass - Activated during longer daylight overpasses or regional sweeps. The ADCS guides the satellite to multiple preset coordinates during a single orbit. This mode collects wide-area data and may include overlapping ground tracks.

- Observation Mode - The Fabry-Pérot interferometer is activated. The detector, ADC, and Jetson process wavelength scans and determine which gases are present upon observation and in what quantity. Data is processed, compressed, and stored onboard until downlink.

- Data Downlink - Occurs twice per day during scheduled ground station passes. The OBC compresses and queues data packets for S-band transmission. After transmission, the SDR is powered off, and EPS resumes baseline power distribution.

- Safe Mode - Entered when thermal, power, or bus faults are detected. All nonessential functions shut down, the ADCS points solar panels towards the Sun, and telemetry beacons are sent on a repeating cycle. Recovered by ground command or internal reset timer.

- Idle Mode - This is the default mode the satellite resorts to when none of the other modes occur. Basic subsystems such as guidance/telemetry and comms are still active.

See **Appendix D** for a mode control flow diagram and **Appendix E** for a mode transition table.

Mission Success Criteria

CLEAR's mission success is measured through both operational milestones and data quality benchmarks coming from an instrument of its size and satellite class. The following criteria define a successful mission lifecycle:

1. Detumble mode is successful, and full extension of all subsystems is achieved
2. Successful overpass calibration and data capture from four target gas species
3. Completion of a (minimum one) quality orbital scan per day during normal operations
4. Downlink of compressed data with proper timestamping and location metadata
5. Autonomous execution of mission scripts during ground communication loss
6. Self-maintenance of thermal and power margins during all modes

Policy Implications

Mentioned before as part of its broader impact, the CLEAR mission enables new opportunities in climate transparency and environmental justice by delivering space-based emissions data at a resolution useful to regional governments. The ability to monitor localized pollution events such as methane leaks or nitrogen dioxide hotspots from orbit helps cities identify violators, quantify progress toward environmental goals, and inform public health policies. Additionally, CLEAR supports the development of objective emissions tracking frameworks by offering an independent source of verifiable data in areas where ground-based sensing is unavailable or inaccurate. The mission serves as a demonstration of how compact, modular sensing platforms can support national and eventually international air quality reporting.

Mission Scalability

CLEAR is designed from the start to be scalable and deployable as part of a multi-satellite constellation. Its low mass, compact 6U form factor, and modular payload allow it to be duplicated across multiple orbital planes with minimal adjustments. Each satellite operates autonomously and could coordinate with others through a data-sharing network on the ground. A constellation would enable monitoring target sites in urban areas all across the world, as well as serve to verify results from each pass. The spacecraft bus is compatible with standard CubeSat deployers and rideshare interfaces, making larger production/deployment achievable through existing launch infrastructure. This, along with its several COTS components, makes this mission very easy to scale up following the success of CLEAR-1.

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Appendices

Appendix A: Orbit Parameter Table

Parameter	Value
Height	500 km
Velocity	7,618 m/s
Period	1.5759 hrs
Inclination	97.5 deg
Re-entry (decay)	825.6 days (2.29 years)
Sunlight Percentage	65% of Orbit

***Re-entry time estimation calculated using the *Australian Space Weather Agency* reference.

Parameters include:

Spacecraft Mass: 12 kg

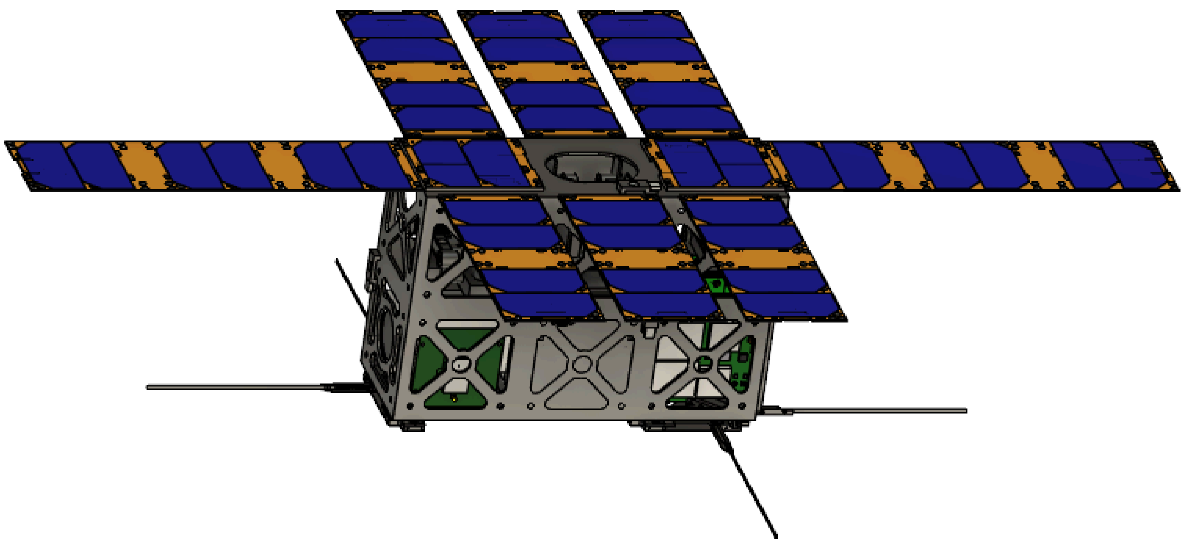
Spacecraft Surface Area: 0.22 m^2

Initial Altitude: 500 km

Solar Radio Flux (F10.7): 150 sfu (solar flux units, where 1 sfu = 10^{-22} $W/m^2/Hz$)

Geomagnetic Index: 15

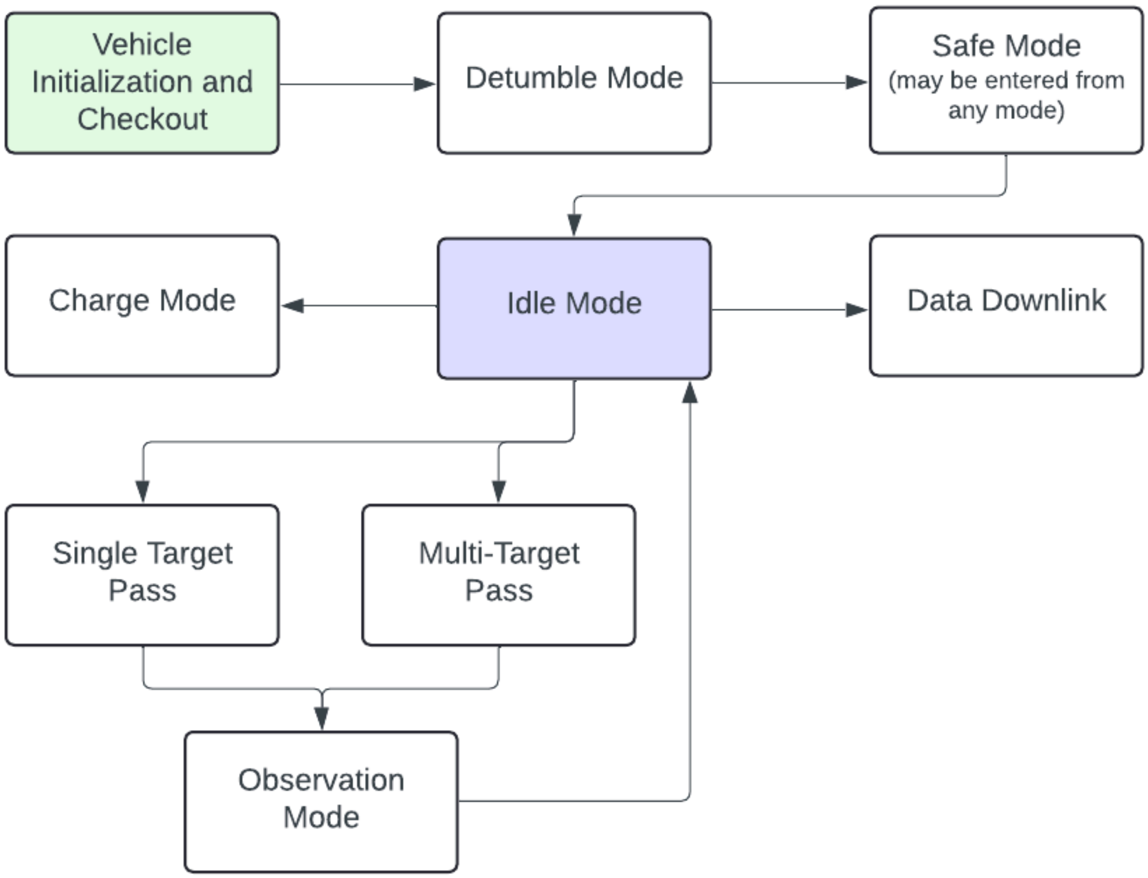
Appendix B: CLEAR-1 Assembly Model



Appendix C: Preliminary Mission Budget

Component	Engineering Model	Flight Model
6U CubeSat Frame	15000	20000
MEMS Fabry-Pérot Interferometer	25000	30000
Custom Detector (0.3 - 1.7 µm)	40000	60000
Focusing Optics	5000	7000
ADC (Teledyne ePix)	2500	2500
Jetson Orin Nano	500	500
GomSpace NanoMind A3200	2000	2000
ADCS (XACT-50)	35000	40000
Solar Panels & EPS	10000	15000
Batteries	5000	7000
S-band Radio (GomSpace SDR)	8000	10000
UHF Backup Comms	2000	3000
Cassegrain Telescope	20000	30000
Software Development & Ops Tools	5000	7000
Launch Services (SpaceX Rideshare)	0	150000
Contingency (15%)		57373
TOTAL COST	$195,725	$441,600

Appendix D: ConOps Diagram - Mode Control



Appendix E: ConOps Mode Transition Criteria

Mode	Entry Criteria	Exit Criteria
Detumble Mode	Automatic activation immediately after deployment.	Satellite spin rate reduced below threshold, and sun vector aligned.
Charge Mode	Triggered after Detumble Mode or low-voltage flag (battery < 7V).	Battery exceeds threshold (e.g., 85%) and next scheduled observation is pending.
Single Target Pass	Scheduled overpass of uplinked target coordinates.	Observation sequence completes or visibility window ends.
Multi-Target Pass	Scheduled overpass of multiple predefined coordinates during daylight.	The final target in the sequence is observed or pass concludes.
Observation Mode	Entered from Target Pass modes when nadir alignment is verified.	Spectral data collection completes or thermal/power threshold is exceeded.
Data Downlink	Ground station pass begins, and data is flagged as ready.	All queued packets are downlinked or pass ends.
Safe Mode	Entered when a thermal, power, or bus fault is detected.	Reset command received or system health returns to nominal levels.
Idle Mode	No active observation, charging, or pass underway. Default standby state.	Any time-based or triggered activity begins.