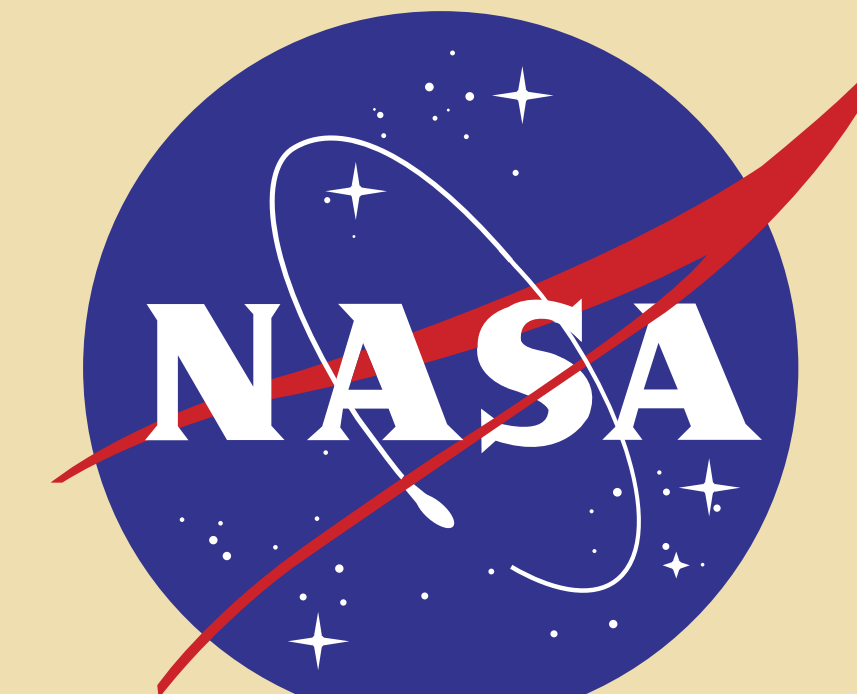


# Mission SCOUT:

## Satellite Collision Observation & Unified Tracking

Linnea Berger, Zachary Dyre, Lujan Leal de Ibarra, Will Jolley, Mansi Pahade, Rohan Patel, Shellene Redhorse, Frankie Sharman, Timothy Suxe, Lauren Ward, Ayush Srivastava and Barbra Sobhani, University of Colorado Boulder, Colorado Space Grant Consortium



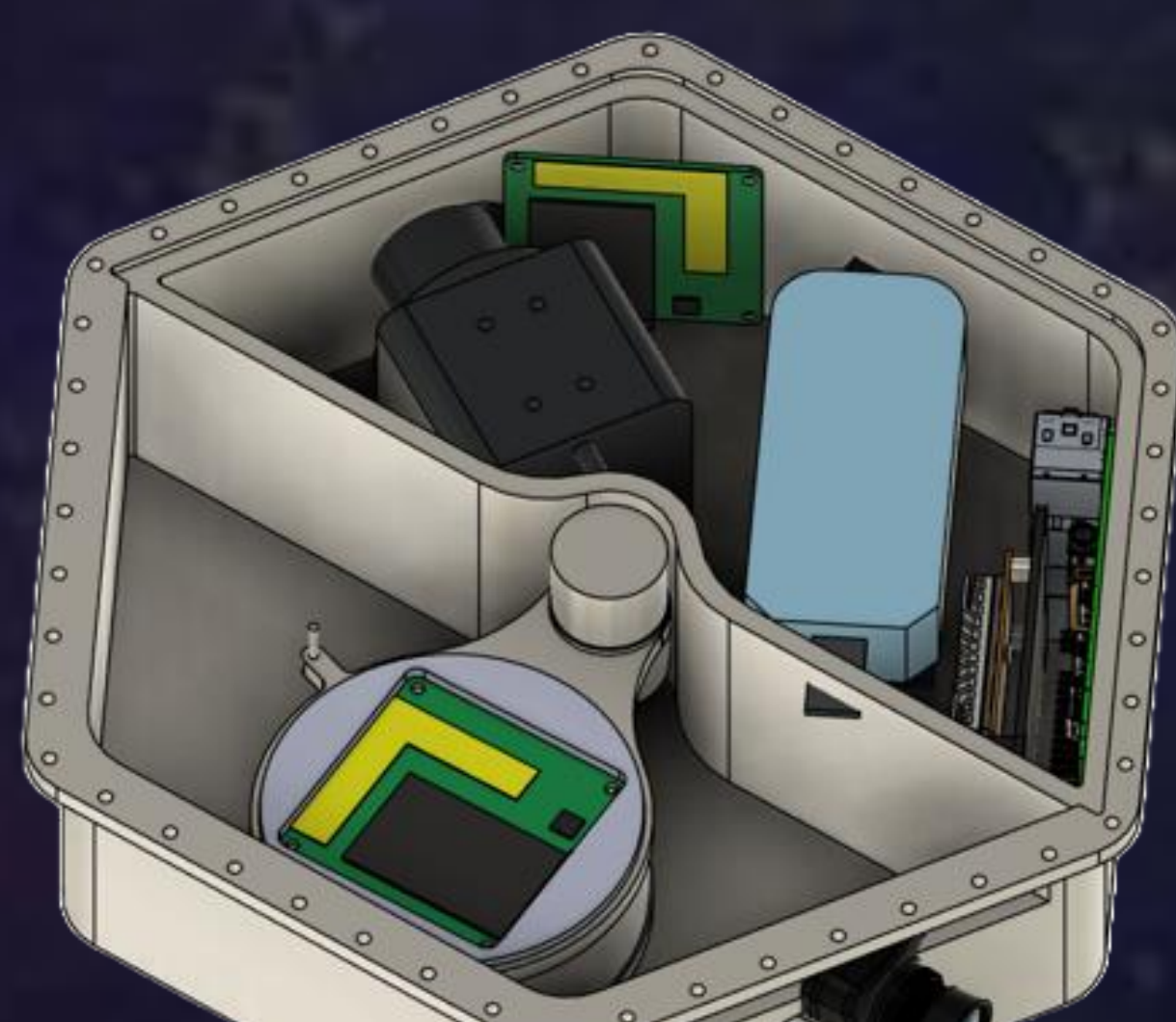
### Mission Overview

PULSAR is a flat-quarter-can RockSat payload composed of two integrated missions:

- o GLEE (Great Lunar Expedition for Everyone)
- o SCOUT (Satellite Collision Observation and Unified Tracking)

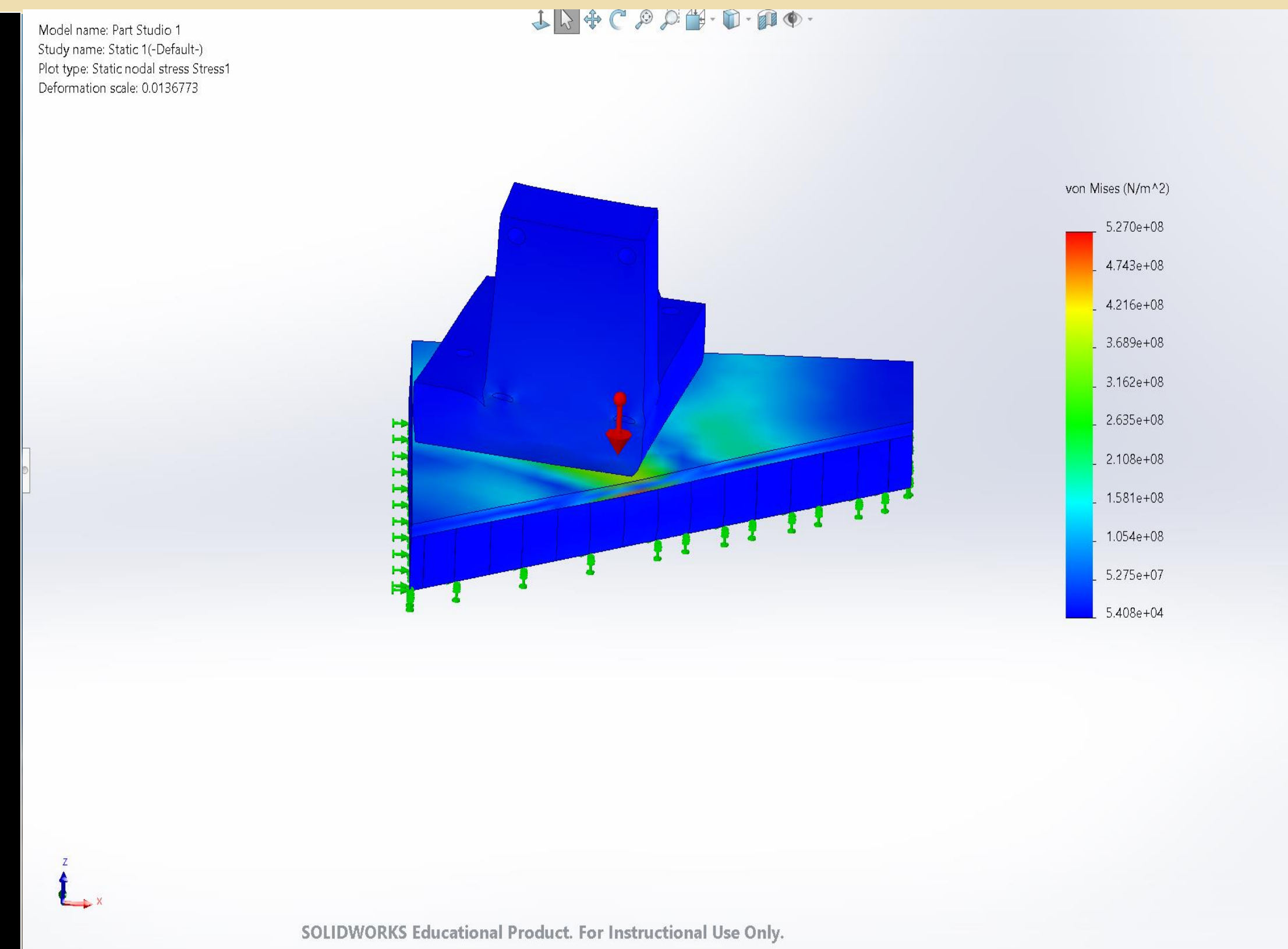
The SCOUT subsystem focuses on computer vision-based detection and tracking of LunaSats, supporting overall payload validation in a space environment.

- Primary Goal:
  - o Raise SCOUT technology readiness level (TRL) to 5 through relevant environment validation and in-flight data collection.



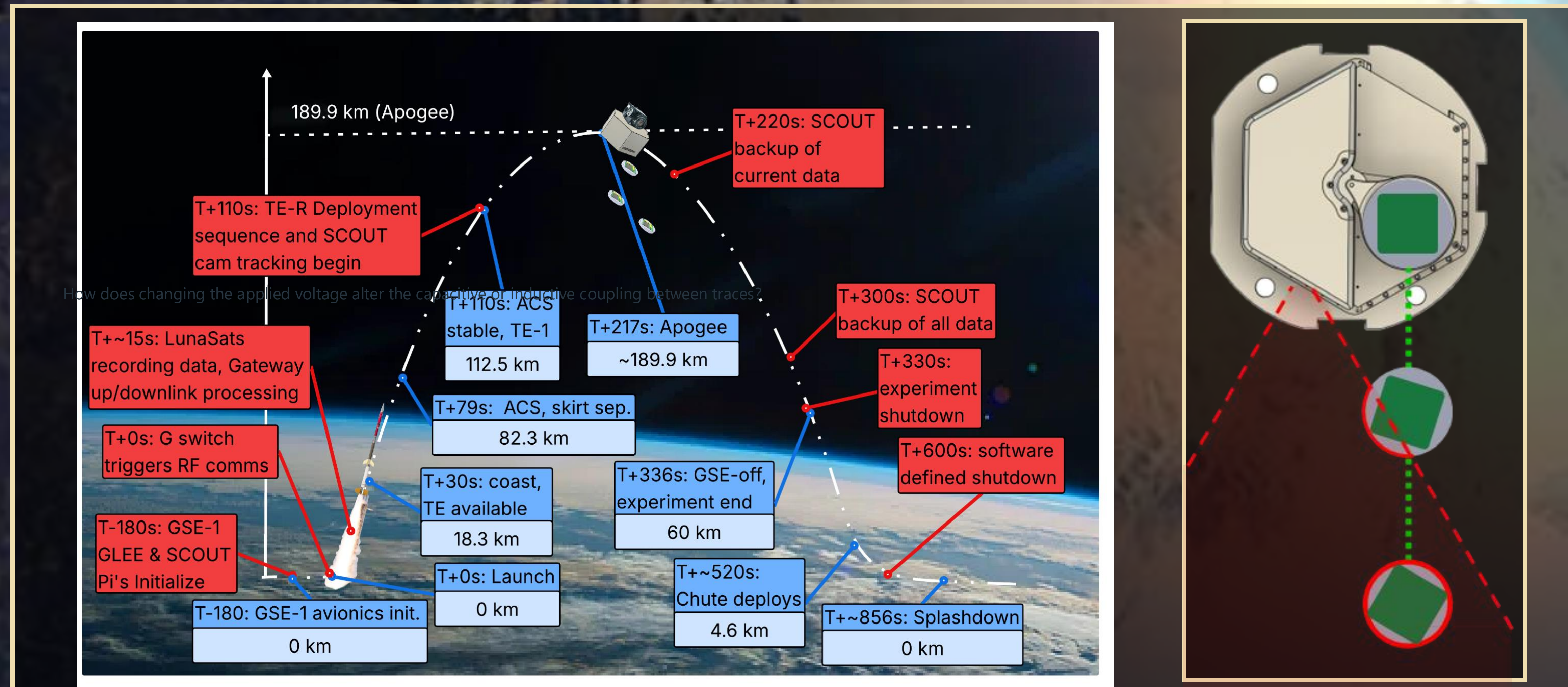
### Rocksat Overview

- The previous plans involved utilizing onboard processing in conjunction with interior camera capturing.
- Due to recent scope reductions, the current approach is to mount a camera externally on the sealed can, to capture a wider field of view.
- Data will be processed on the ground.
- Sufficient testing and design development have been conducted to establish a camera mounting system and integration points for interior electronics.
- These efforts include finite element analysis (FEA) simulations, material research, and CAD modeling.



### Abstract

SCOUT is a mission developed to improve space situational awareness by detecting and cataloging orbital debris through the use of RGB filtering and advanced image processing techniques. SCOUT will participate in a ROCKSAT-X 2026 mission alongside GLEE to test the optical system by detecting LunaSats ejected from the rocket. The mission will collect data about the LunaSats' velocity and position. By utilizing computer vision algorithms, SCOUT aims to provide accurate and timely debris characterization.

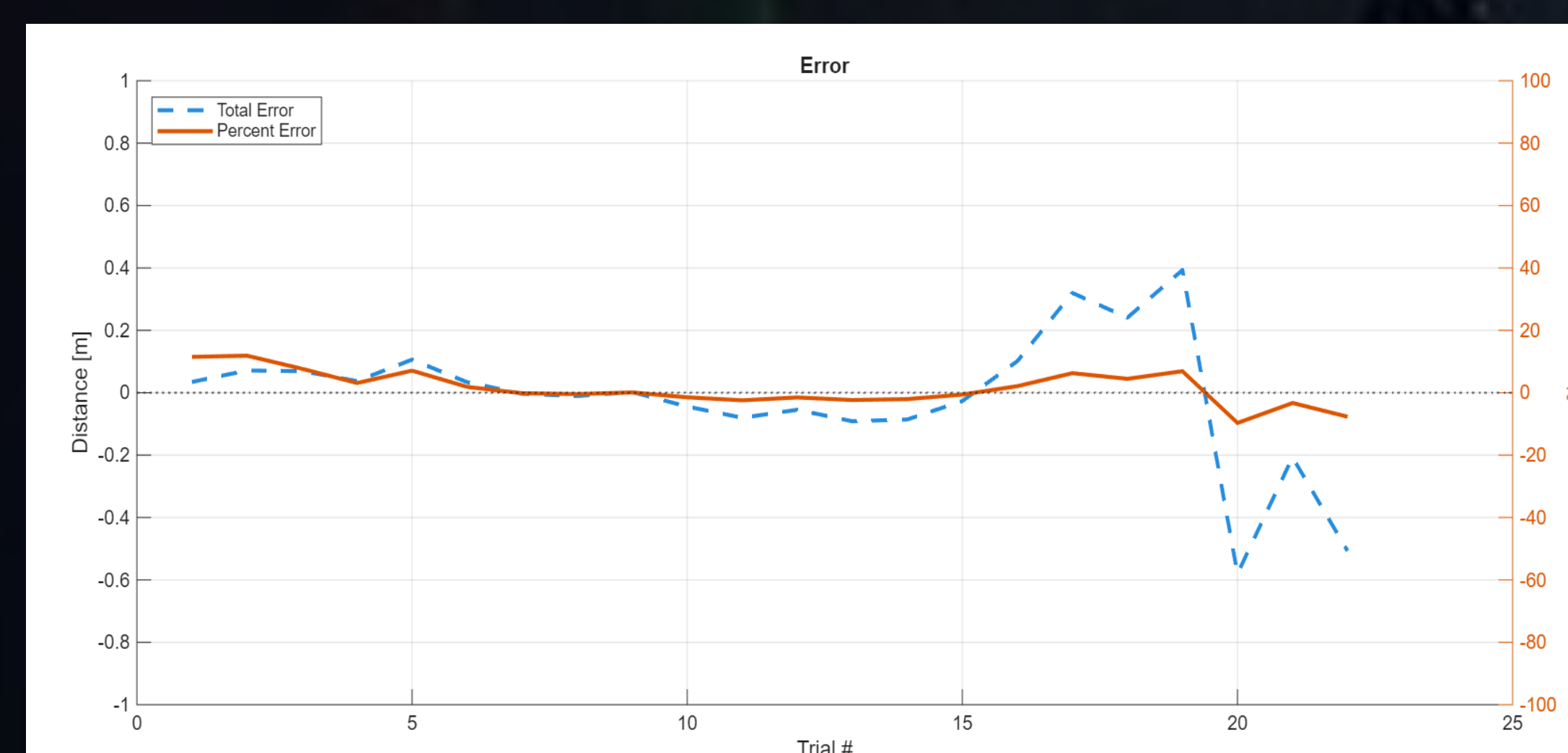
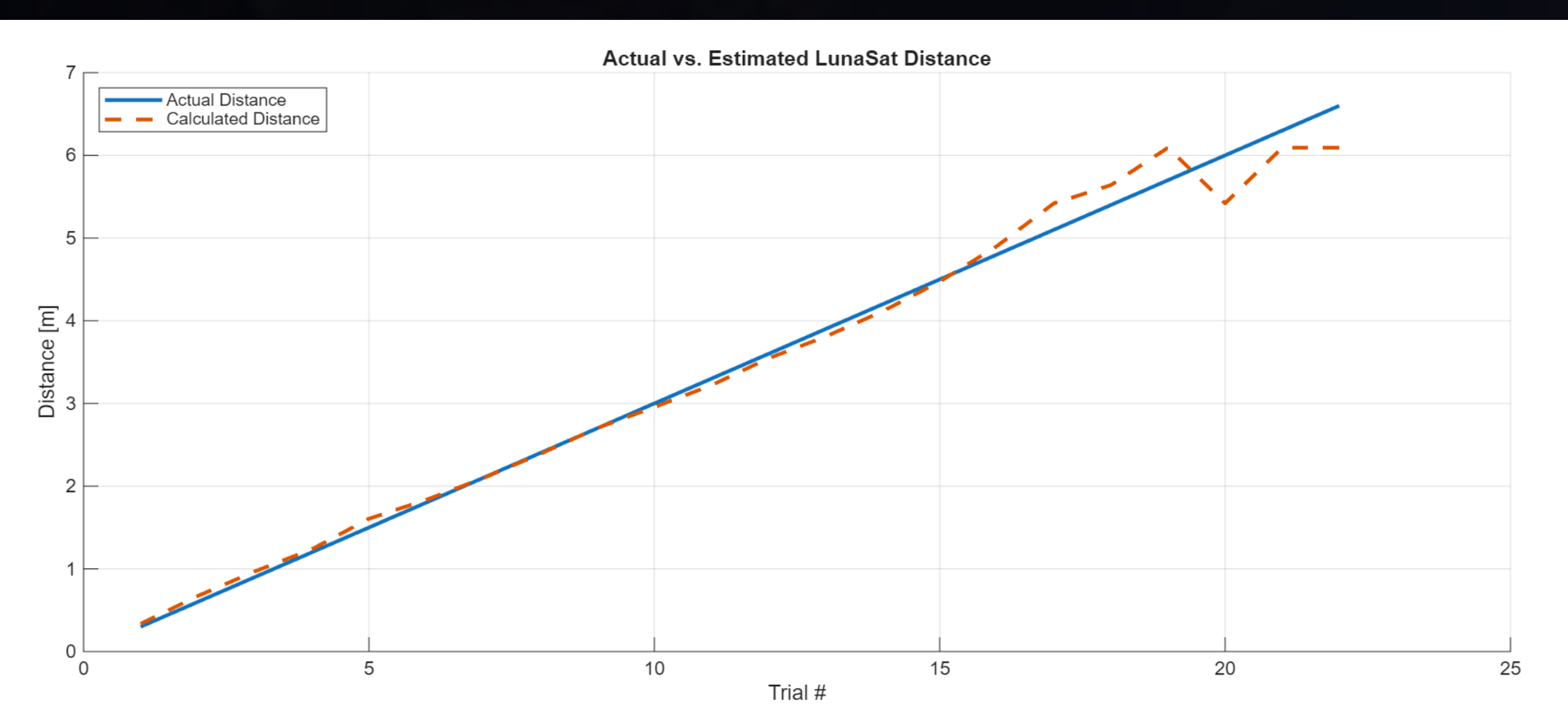


### Mission Objectives

- Objective 1: SCOUT Detection and Tracking**  
Detect LunaSats using computer vision within 50 meters and maintain reliable tracking.
- Objective 2: Velocity Calculation Accuracy**  
Calculate LunaSat velocities with  $\pm 10\%$  accuracy using onboard processing.
- Objective 3: Data Collection and Storage**  
Maintain continuous visual data capture and storage throughout the mission.
- Objective 4: Autonomous Operation**  
Operate the SCOUT subsystem autonomously for the full mission duration.
- Objective 5: Mission Support Data**  
Provide tracking data to support overall mission verification and post-flight analysis.

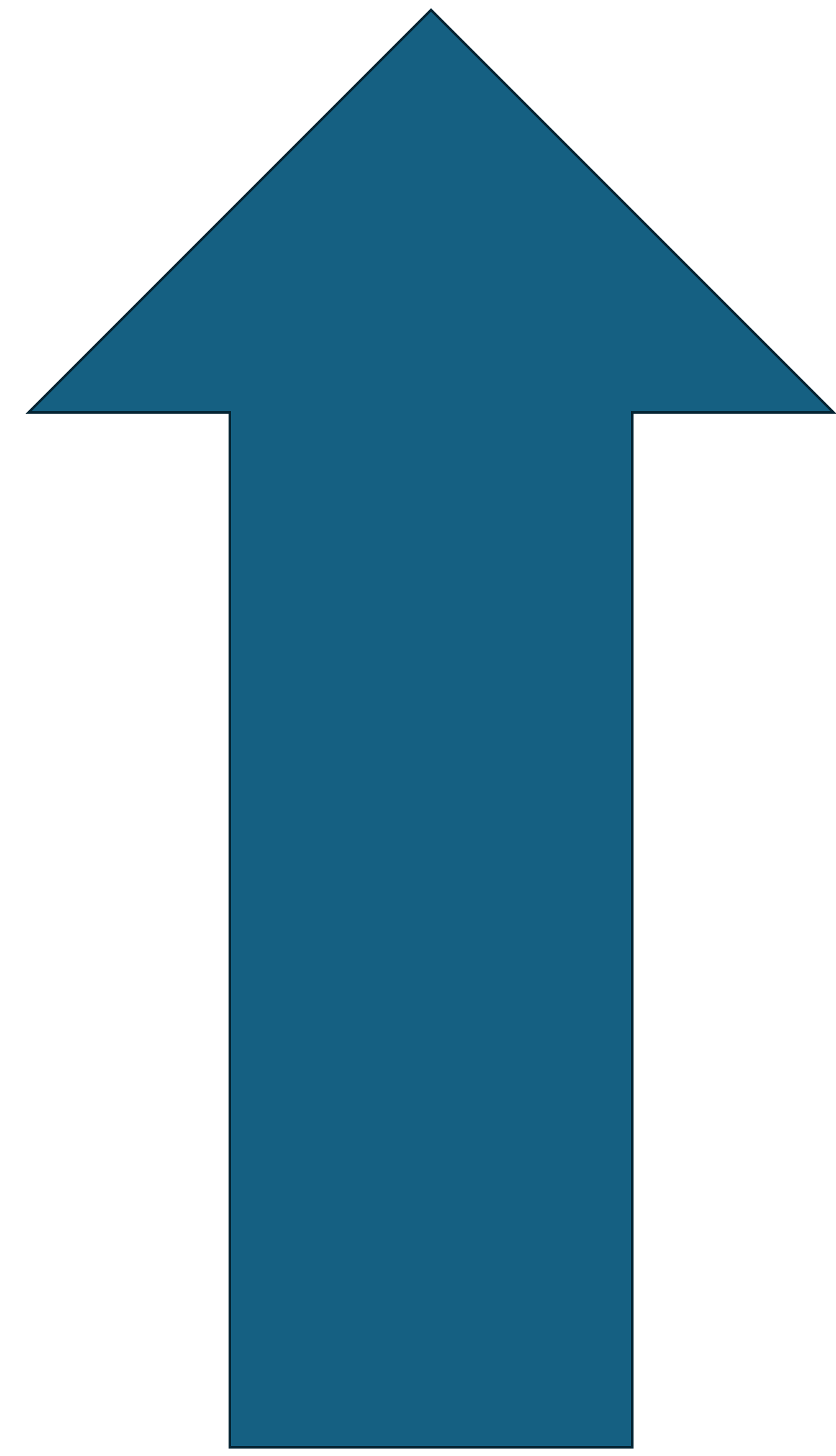
### Research

To characterize the data from the onboard camera, there is a number of processing and filtering steps each frame will go through. The first step is to undistort the frame as the wide-angle camera lens warps the camera image significantly around the edges. This allows us to treat the undistorted image as a plane in cartesian space where we can determine the position with trigonometry. To separate the LunaSat target from the background, we apply a color filter and a light intensity filter. Once the object has been found, we can use its relative size along with its known size to determine its distance from the camera. Our model then combines a Kalman Filter with a Hungarian Selector to track the targets across frames and determine their velocities. Validation of our model is shown below.



### Future Steps

- Future steps involve the upcoming RockSat launch scheduled for the end of June.
- This will include further development of the computer vision program.
- Incorporating advanced filtering algorithms such as the Kalman filter and light centroiding techniques.
- Subsequently, we plan to design a space-rated CubeSat payload.
- Additionally, we will identify a suitable launch provider.
- Complete all testing procedures for the selected launch vehicle.
- Our goal is to achieve these milestones within approximately six years.



NEW  
VERSION  
Spring 26

OLD VERSION  
Summer 25

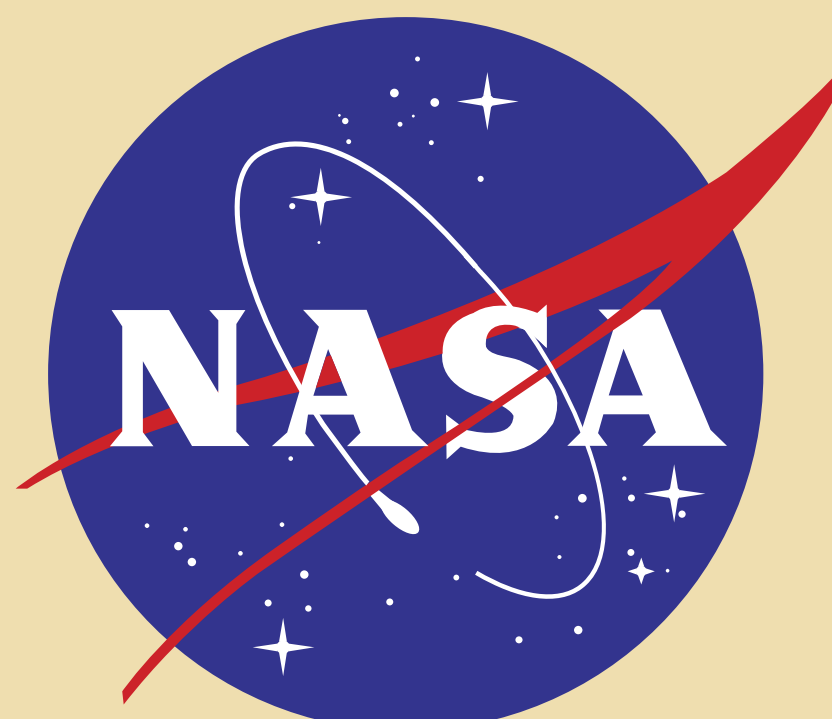




# Mission SCOUT:

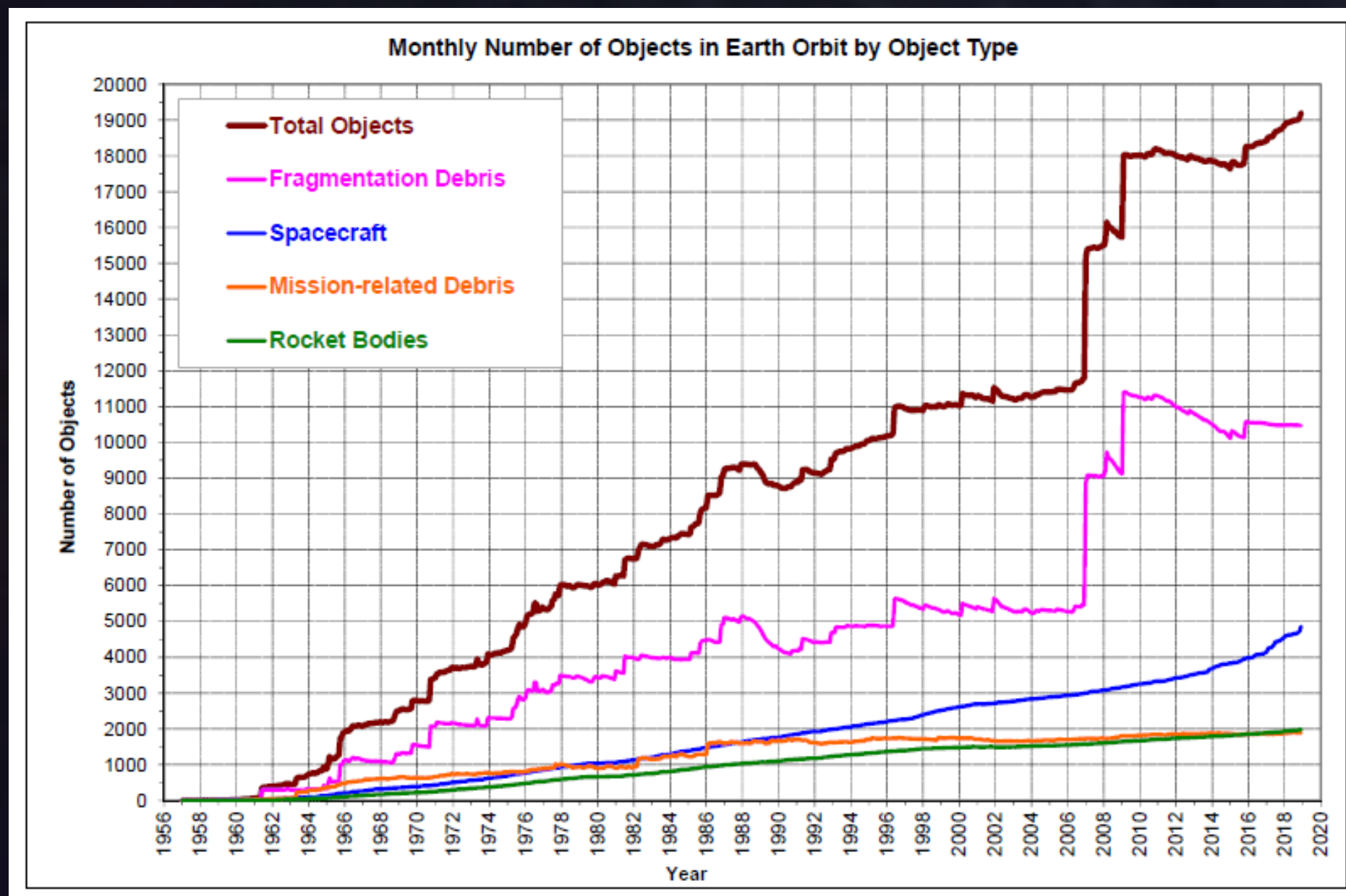
## Satellite Collision Observation & Unified Tracking

Timothy Suxe, Linnea Berger, Rohan Patel, Lauren Ward, Frankie Sharman, Griffin McKay, Shellene Redhorse, Ayush Srivastava and Barbra Sobhani, University of Colorado Boulder, Colorado Space Grant Consortium



### Space Debris

- Space debris moves at an average of 7 km/s which can cause damage to other objects
- Estimates place losses at over \$100 million annually.
- As the space industry grows, there is a need to prevent collisions to ensure the accessibility of specific orbits and increase mission success rate



### Abstract

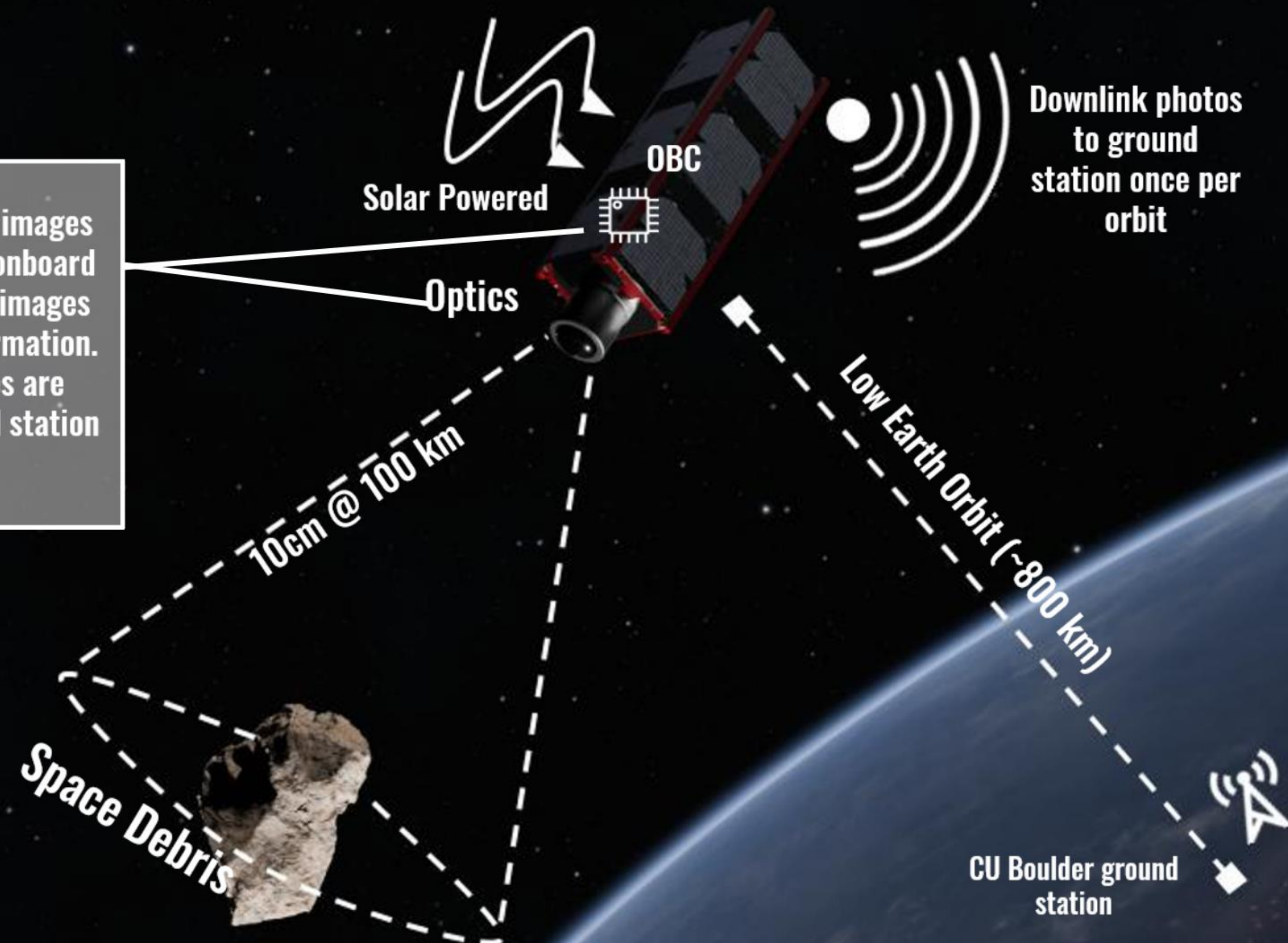
SCOUT is a CubeSat-based mission developed to improve space situational awareness by detecting and cataloging orbital debris through the use of RGB imaging and advanced image processing techniques. The mission focuses on identifying the position, velocity, and orbital trajectories of debris smaller than 10 centimeters. This data will be collected, analyzed, and made publicly available to support future collision avoidance efforts and promote transparency in orbital debris monitoring. The system's core component is an RGB camera mounted on the CubeSat, which enables real-time visual tracking of objects within the field of view. By utilizing computer vision algorithms, SCOUT aims to provide accurate and timely debris characterization while maintaining a lightweight, low-power design suitable for small satellite platforms.

### Findings

- Detect space debris and collected data such as its size, position, and velocity
- Transmit collected data to receiving ground stations.
- Provide a cheaper alternative to detecting space debris

### CONOPS

Optical sensor takes images of space debris. The onboard computer processes images to isolate useful information. Compressed images are downlinked to ground station for analysis.



### Mission Objectives

**Goal 1: Characterize Orbital Debris in LEO**  
Identify and record small orbital debris objects in LEO within the sensor's field of view.

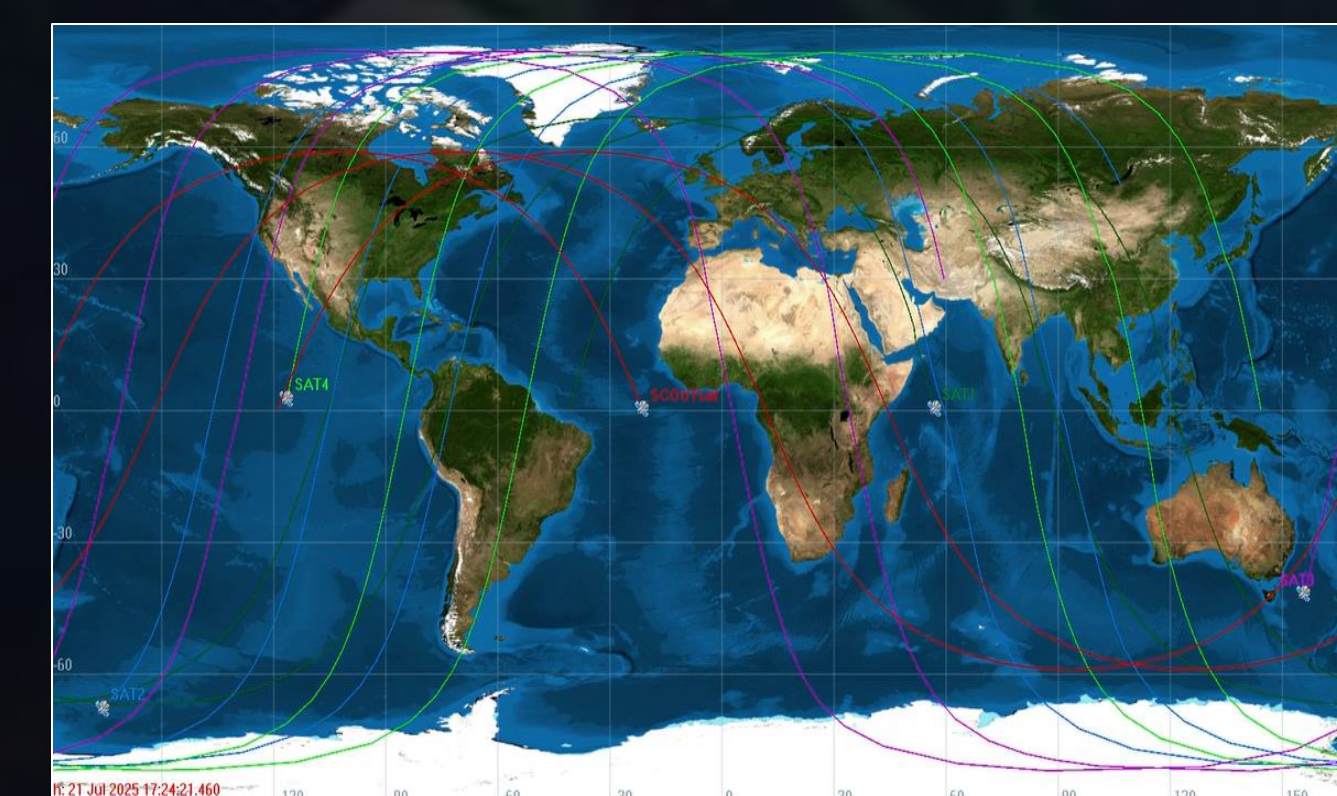
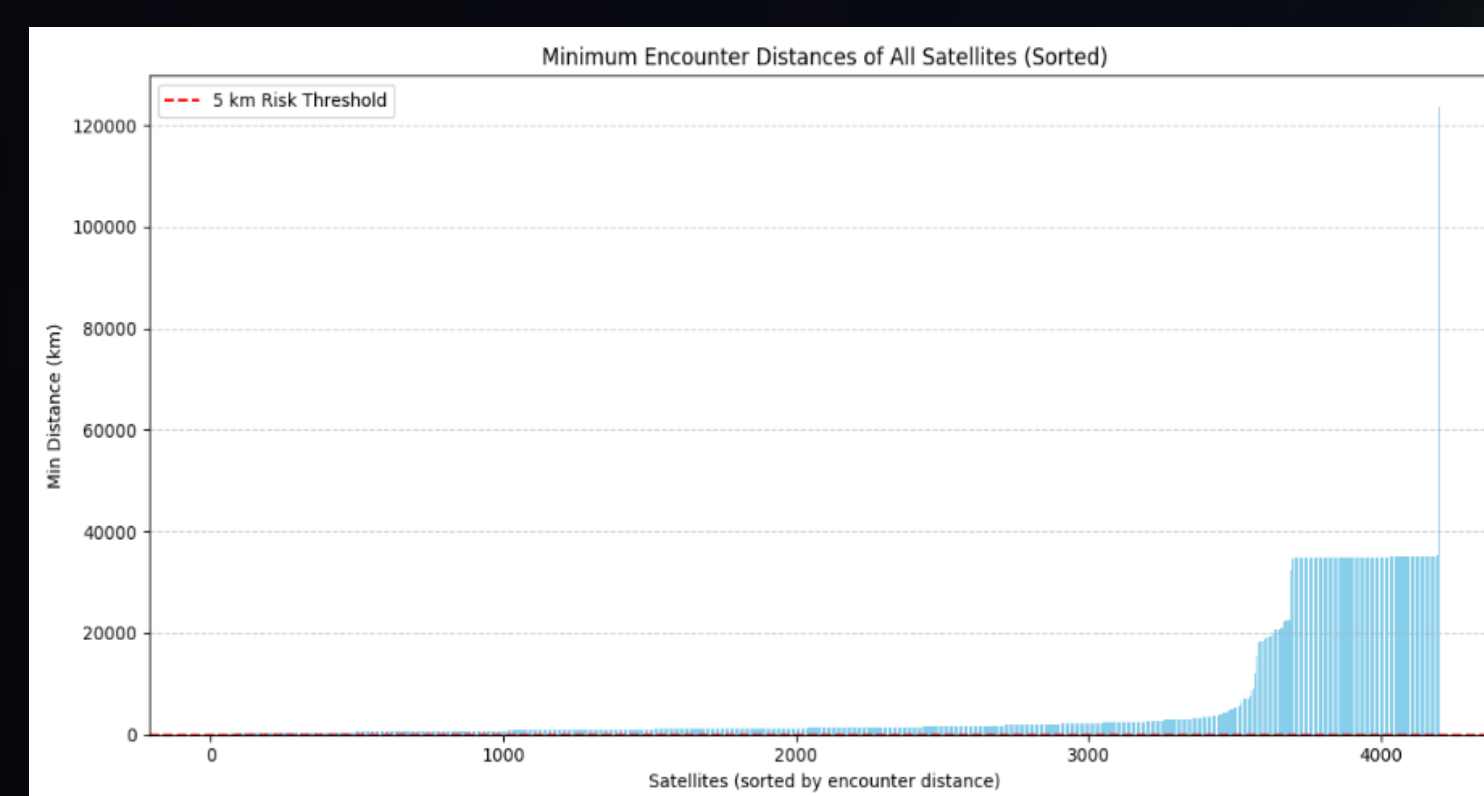
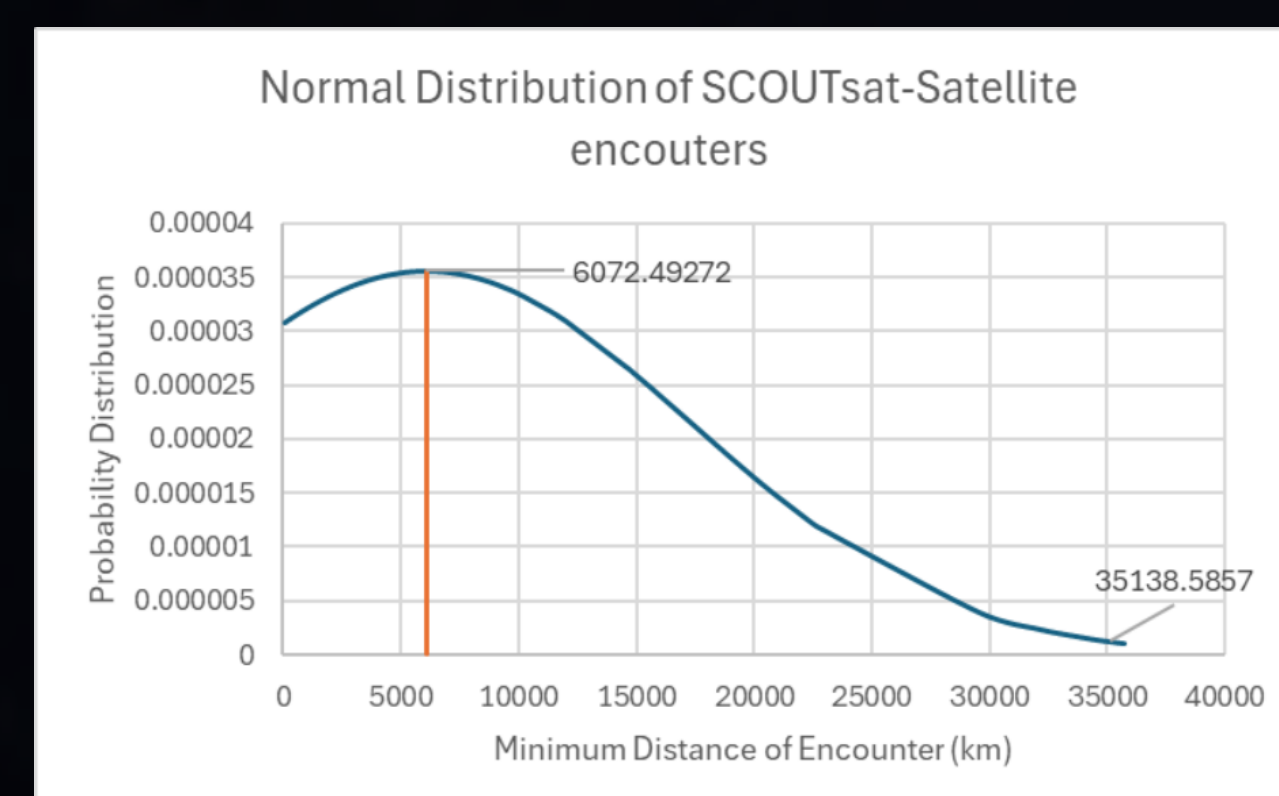
**Goal 2: Measure Debris Size**  
Estimate the size of orbital debris using measurements of brightness, contrast, and spatial distribution across the sensor's field of view.

**Goal 3: Estimate Debris Position and Trajectory**  
Determine the position of space debris relative to the spacecraft and calculate its path over time. Include analysis of velocity components to refine classification.

**Goal 4: Validate Detection Accuracy Using Known Objects**  
Confirm system performance by detecting orbital debris that is already tracked by existing catalogs. Use matched detections to evaluate accuracy in position, size, and motion.

### Research

To evaluate the impact of placing SCOUTsat in the orbital environment of the Low Earth Orbit (LEO), a high-fidelity simulation has been developed by permutating orbital parameters, varying altitude (450, 650, 850 km), and RAAN (0, 90, 180, and 270 degrees) at a fix inclination of 59 degrees to maximize the rate of pass over the ground station in Boulder. Each configuration has been propagated over a 24-hour period using 10-minute interval steps and compared against a catalog of 4,200 active LEO satellites. The simulation computes relative position, velocity, and minimum encounter distance for each satellite. The results show a range of encounter between 60km and 35,000 km, with an average and high encounter rate at ~6,000km.



**RockSat Test: SCOUT**  
will participate in a ROCKSAT-X 2026 mission alongside GLEE to test the optical system by detecting LunaSats ejected from the rocket.



### Future Steps:

- Component specifications
- Company Partnerships
- Improve ground station
- Solve Data Handling Issue



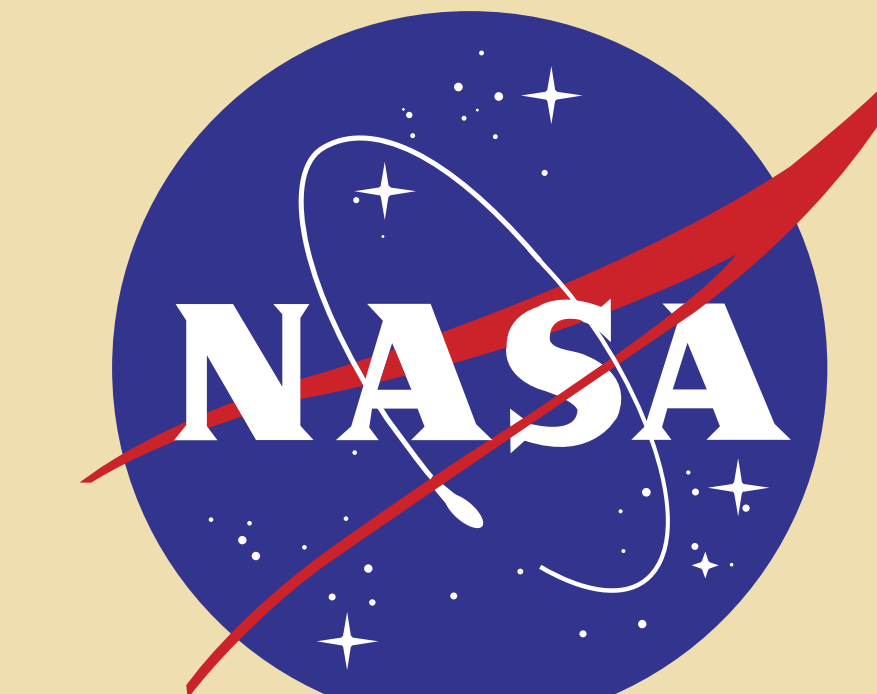
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Summer 25

OLD OLD  
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May 25



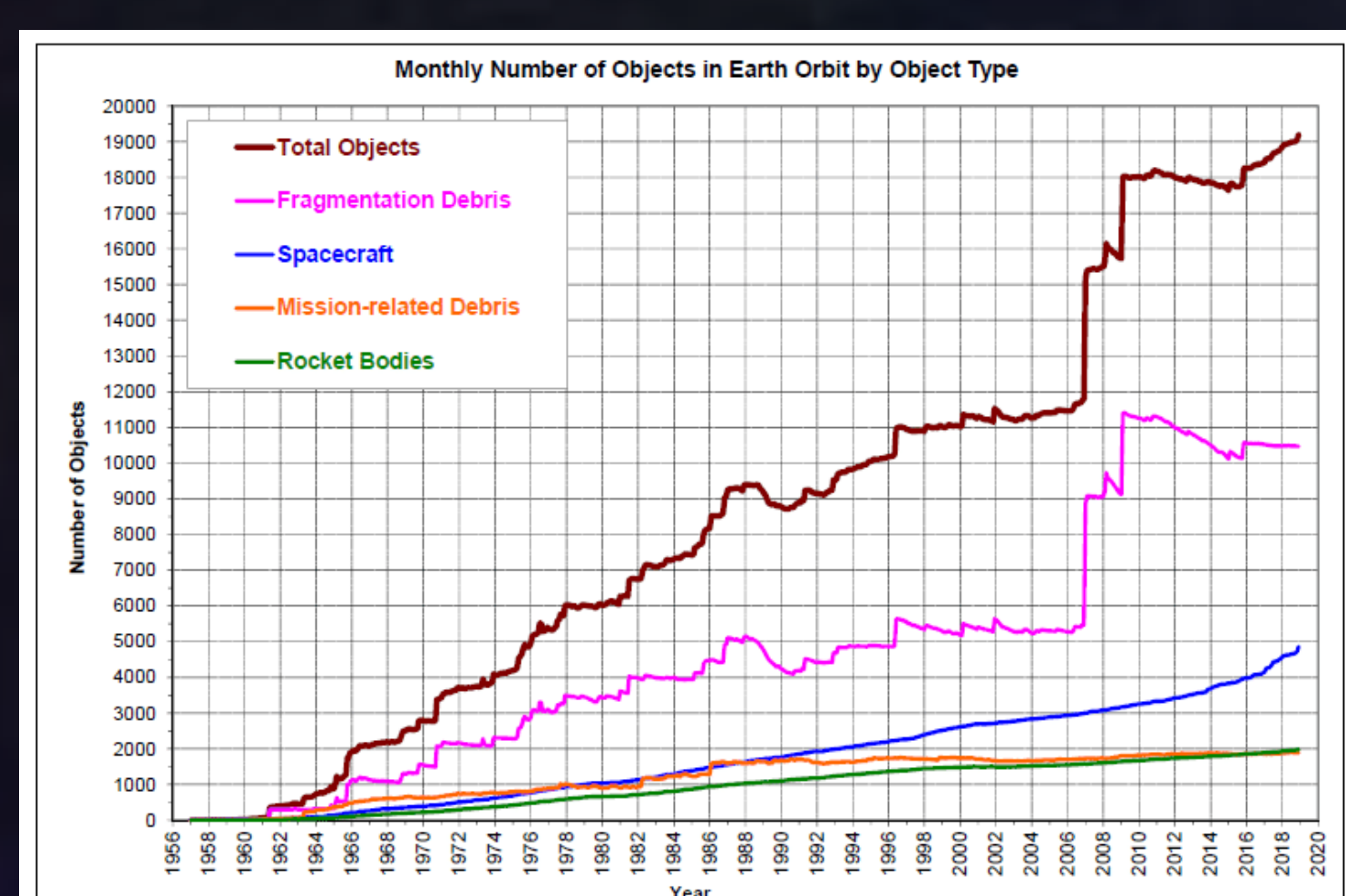


# Mission SCOUT: Satellite Collision Observation & Unified Tracking



## Background

Space missions continually reuse orbital paths without plans for de-orbiting, This creates cluttered orbits, increasing the chances for collisions to occur between orbital objects. Estimates place losses at over \$100 million annually. As the space industry grows, there is a need to prevent collisions to ensure the accessibility of specific orbits and increase mission success rate



## Abstract

SCOUT will identify objects approaching commercial satellites and notify ground services by transmitting large streams of data, thereby advancing collision avoidance protocols that could play a pivotal role in the future of space exploration. Preventing collisions between objects in space will ensure the success of the current mission and maintain the future viability of space. SCOUT will revolutionize space situational awareness by implementing real-time object tracking and collision avoidance algorithms through event-driven sensors. At the core of our project are two advanced neuromorphic cameras strategically positioned on the CubeSat to monitor and capture event data as objects enter their field of view. These cameras will enhance the efficiency and accuracy of object detection, decrease power consumption, and reduce data transmission, offering a favorable alternative to traditional CCD cameras.

## Findings

- Determining the effectiveness of neuromorphic sensors for future missions
- Collection of relevant data such as space debris' trajectory, density per orbital period, relative mass and composition and flux.
- Finding and tracking the different parameters and trajectories of space debris, while transmitting the collected data to receiving ground stations.

## Research

Neuromorphic sensors can detect and track objects regardless of background brightness. Western Sydney University for example, has pioneered the use of event-based sensors on mobile telescopes to track real-time orbital objects day and night. These sensors from Western Sydney University consisted of an asynchronous array of detectors for light intensity changes, and the use of neuromorphic algorithms (Fig. 1). These cameras can be used for high-speed imaging, object tracking, and autonomous navigation, all being great capabilities for collision avoidance in orbit. The Neuronics Lab has used the data from a neuromorphic camera to develop an AI algorithm that detects different kinds of movement (Fig 2).

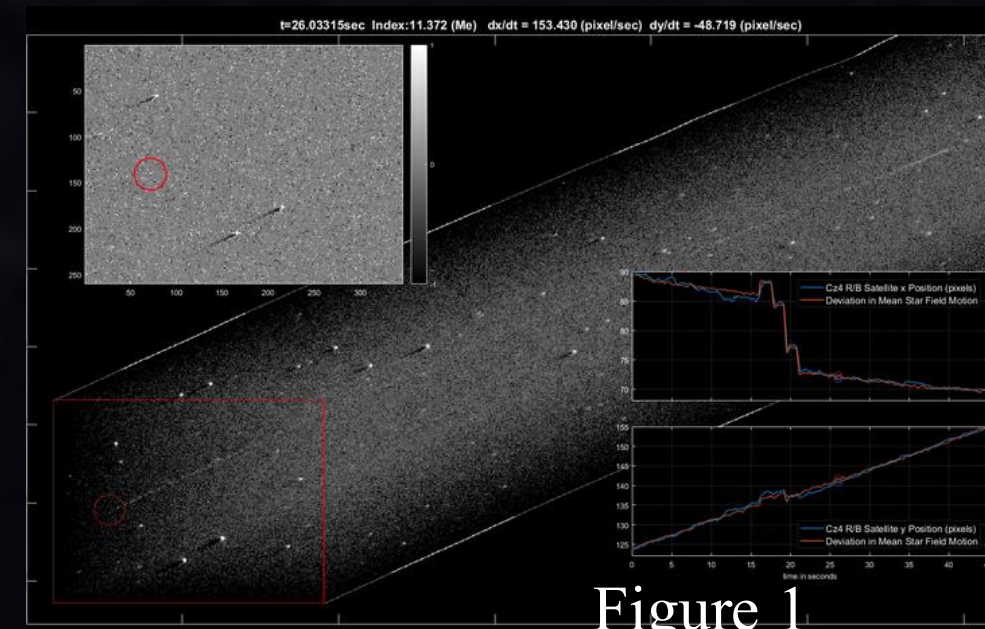


Figure 1

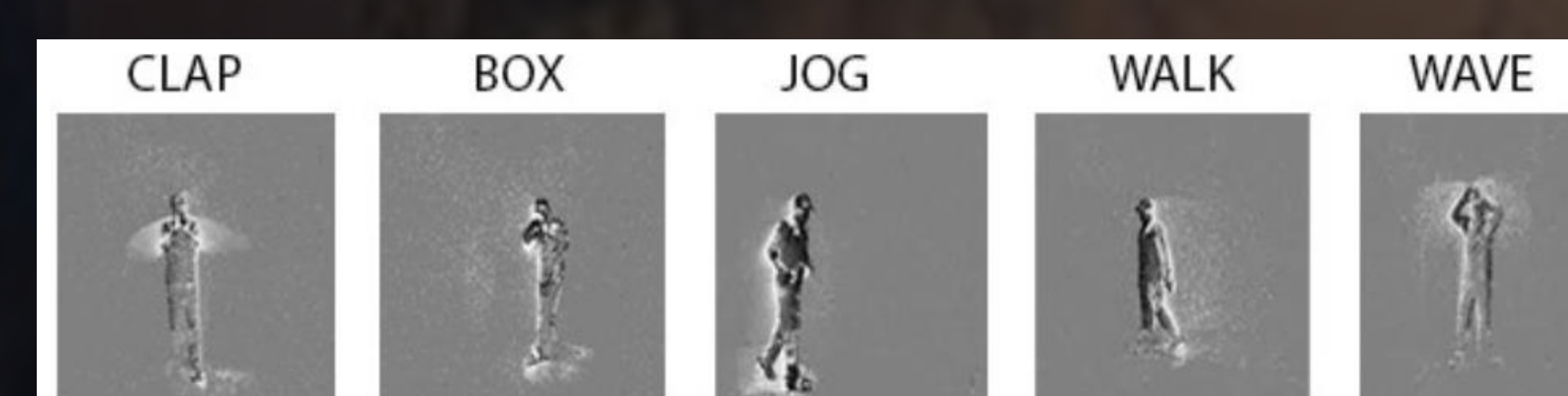


Figure 2

## Mission Objectives

### Goal 1: Conduct Testing of Event-Driven Sensors

Evaluate the sensitivity of the sensors to different types of stimuli, test the sensors' resilience to potential interference.

### Goal 2: Optimize Event Data Processing

Identify the most effective methods for processing the event data, and implement real-time data analysis techniques, enhance software capabilities to distinguish between satellites and space debris of differing sizes.

### Goal 3: Conduct Performance Metrics Assessment

Identify and define key performance metrics that will be used to evaluate the effectiveness of event-driven sensors.

### Goal 4: Support Collaborative Data Sharing

Explore frameworks for processed event data with other satellites or ground stations to enhance situational awareness

## Conclusion

Mission SCOUT aims to develop an algorithm for event-driven object tracking that demonstrates its potential for future low-orbit CubeSat missions. Implementing event-driven sensors will :

- ⑩ enhance the accuracy of object detection
- decrease power consumption
- reduce data transmission

offering a favorable alternative to traditional CCD cameras.

## Future Applications

Research into event-driven sensors could provide the necessary groundwork for adjacent scientific research such as:

- distributed CubeSat networks
- real-time orbital adjustment
- Reconnaissance
- AI image recognition
- space debris recovery

## S.C.O.U.T. Mission

Satellite Collision Observation & Unified Tracking

**The growing threat of space debris collisions**  
On average, there are 110 to 111 satellite-space debris collisions per year, costing around \$100 M in economic losses.

### Sensors:

Neuromorphic cameras  
LIDAR  
Spectrometer

### Data collection methods:

- Space debris trajectory
- Space debris density per orbital period
- Space debris relative mass and composition.
- Space debris flux over time

### Ground Control Data Analysis

The payload will send a continuous flow of data that will be analyzed in ground control to determine the correlation between relevant independent and dependent

### Data processing

The neuromorphic cameras capture the change in brightness per pixel whenever it encounters a space debris on its course.

