ZoomSat

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Schools Represented:

Harvard, UCLA, Stanford, Cal Poly Pomona

Mission Statement

Devastating forest fires, with billions in damage and claiming dozens of lives, are becoming more common from climate change. Monitoring and predicting where such fires begin is difficult, and it is difficult to distinguish forest fire risk by eye alone.

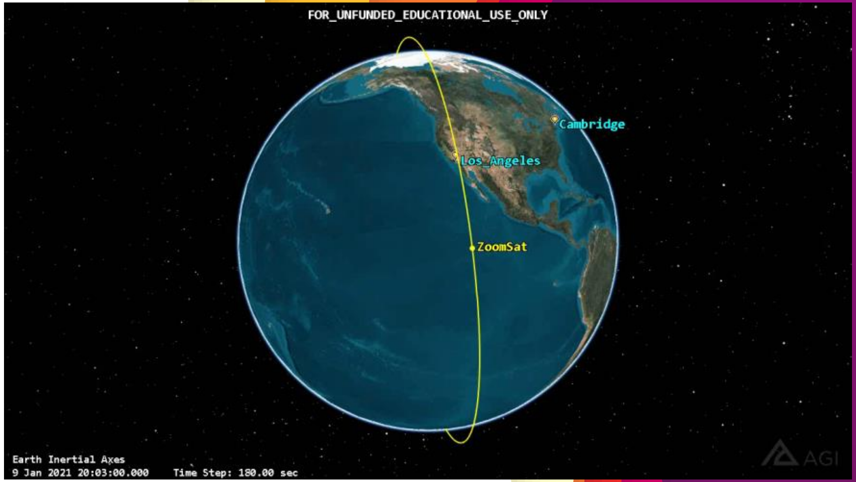
The evapotranspiration of plants is correlated with forest fire risk. Healthy-looking plants that evaporate **less** water are **more** likely to burn. However, there are very few IR sensors in orbit that measure evapotranspiration.

We propose to launch ZoomSat into Low Earth Orbit to collect evapotranspiration data and predict forest fire risk in California and the United States.

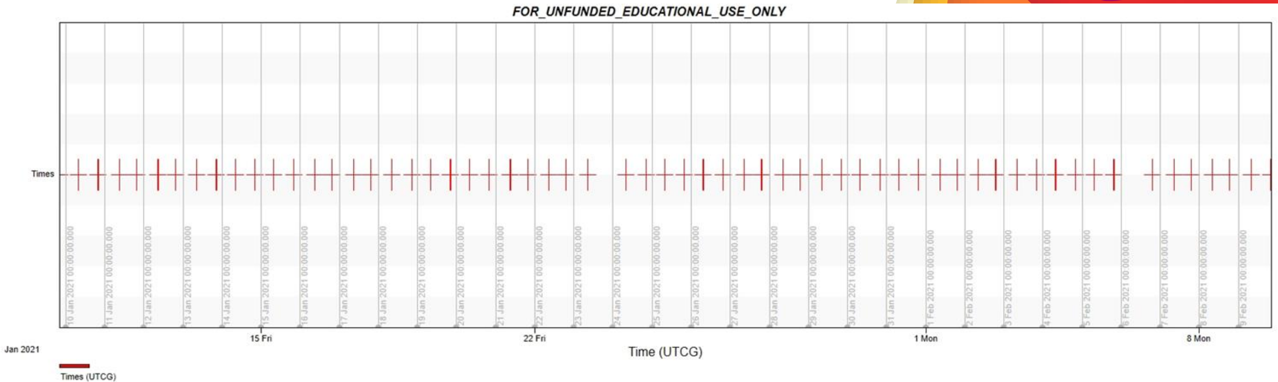
Proposed Orbit

Circular Polar Orbit

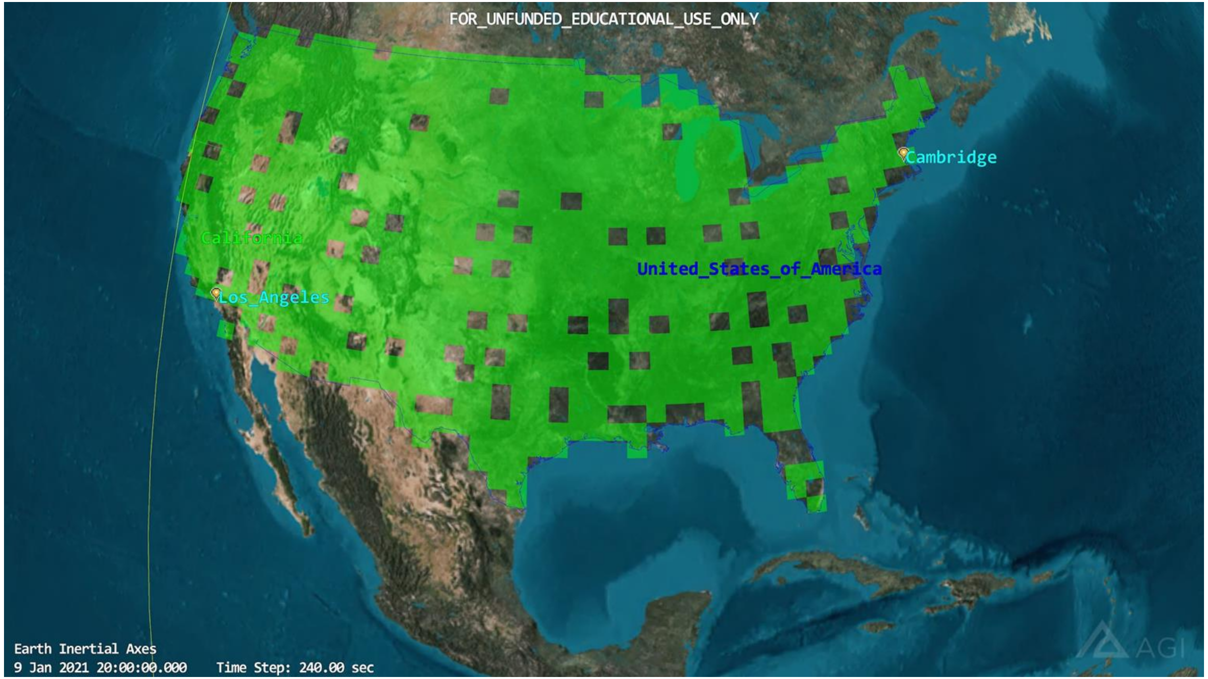
- Altitude: 500 km
- Inclination: 95 degrees
- RAAN (Right Ascension of Ascending Node): -64 degrees
- Semimajor axis: 6878.14 km
- Accessible orbit, good orbit track cover (targets, stations)



Access from Los Angeles to ZoomSat



Coverage of the United States Over 1 Month

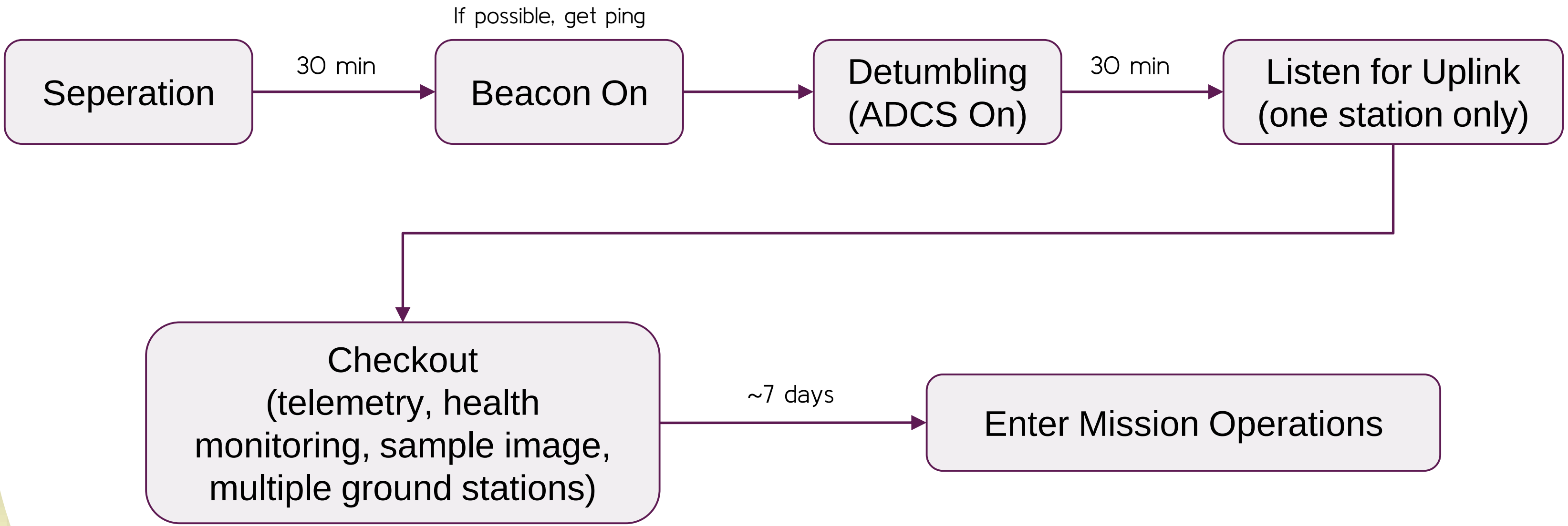


% Covered	Area Covered(km^2)
87.54	7022270.43

Concept of Operations

Slides 5–12

Deployment and Startup



ZoomSat's Operational Modes

Idle

ZoomSat will spend most of its time in idle mode, during which its solar panels would be pointed toward the Sun to charge the batteries. The satellite will also continue to collect basic telemetry data, as it will send out basic health packets to any listeners every 30 seconds.

Safe

The satellite will also be able to enter safe mode should the system face any issues that require limited operation until resolved. During this time, operators from the ground would troubleshoot and potentially resolve the issue. Issue could include components reaching their Allowable Flight Temperature (AFT), loss of communications with components, or off-nominal telemetry or power draw.

Sensing Mode

Sensing mode occurs when the satellite collects thermal infrared data from a target location, which would be specified through latitude/longitude coordinates uplinked from the ground. The satellite would track these coordinates and take images when located above them, with ADCS aiding in pointing the camera toward the target. Each image would be tagged with the current date and time, and stored in the OBC to await for downlink. Additionally, status logs would be prepared after each imaging pass to note any errors in the process.

Calibration images will also be taken before and after each imaging pass. These will be of large bodies of water – their surface temperature can be easily found and their infrared emissivity is close to a blackbody, which can help with calibration.

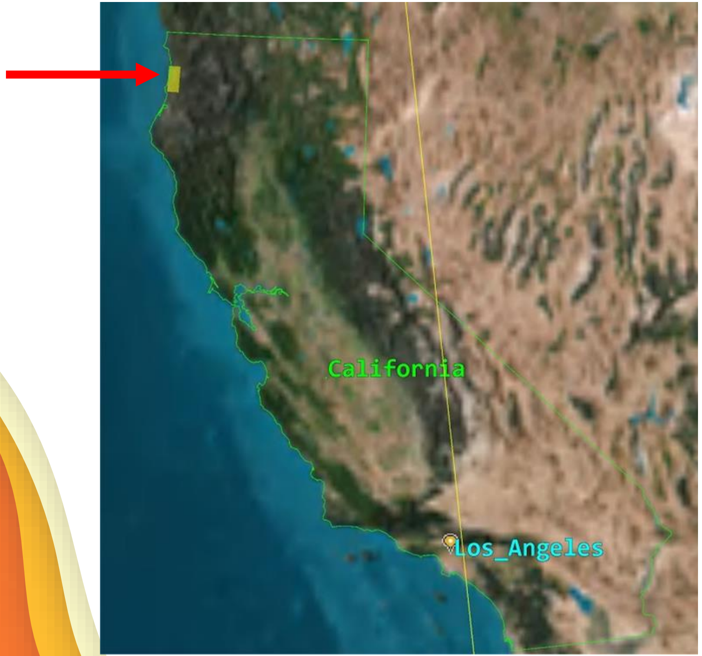
Downlink and Uplink - Ground Stations

The satellite will enter downlink mode to relay science images to the ground as soon as it is able to establish communication with a ground station. We have assumed the availability of the Harvard University and UCLA ground stations, but would attempt to leverage the ground station network of the Blue Dot Consortium.

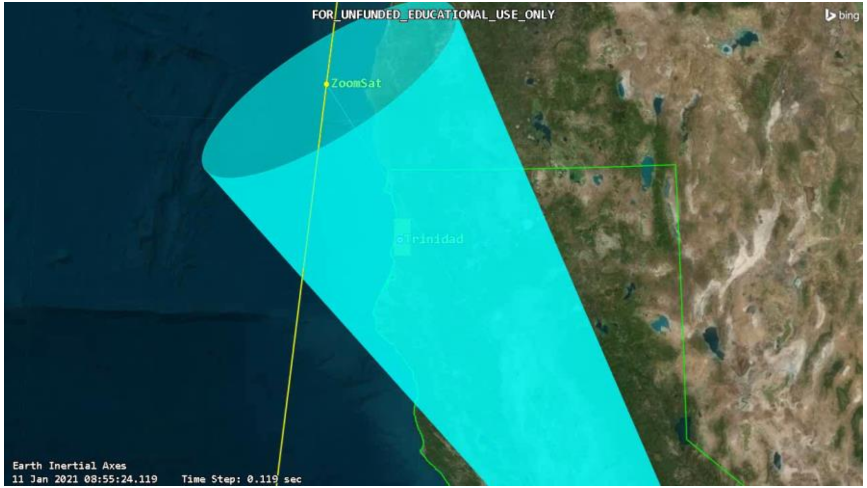
The satellite would downlink during longer passes over available ground stations once passing a **minimum 20 deg elevation level** for signal strength. Based on the image size created by our payload, **~537 kB per image**, each image would take approximately **7.5 minutes to downlink at a 9600 bps**. This means each image would take multiple passes over a ground station to downlink, and we will split image files up into smaller chunks as necessary before attempting to downlink.

However, time during each pass over a ground station also will be alloted to uplinking commands, updating target coordinates, requesting specific files, or troubleshooting errors.

Example



Pass over Redwood Forest



Start: 11 Jan 08:55:27:810
End: 11 Jan 08:55:46:857

Example Contd.

Communication times for downlinking data and telemetry after pass

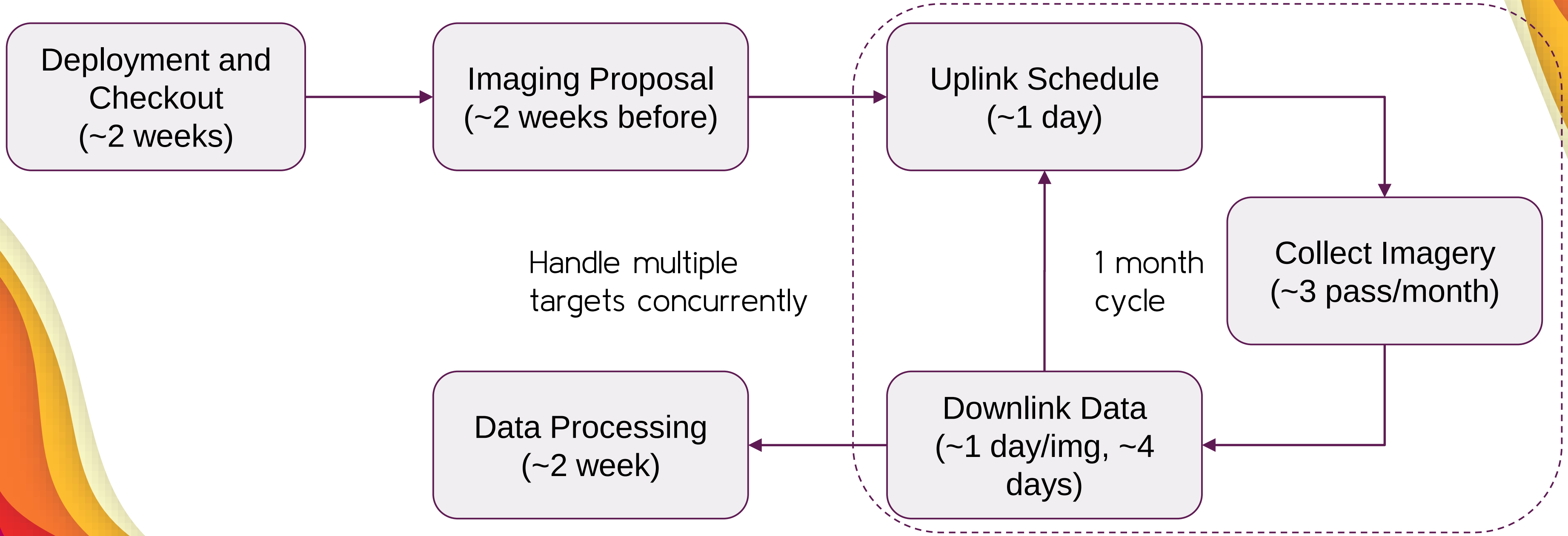
Los_Angeles-To-ZoomSat

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
5	11 Jan 2021 19:29:35.094	11 Jan 2021 19:33:35.300	240.206
6	12 Jan 2021 08:36:11.771	12 Jan 2021 08:40:55.585	283.814
7	12 Jan 2021 19:12:17.740	12 Jan 2021 19:13:40.631	82.891
8	13 Jan 2021 08:17:25.105	13 Jan 2021 08:22:21.653	296.549
9	13 Jan 2021 20:26:23.455	13 Jan 2021 20:29:57.044	213.589

Cambridge-To-ZoomSat

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
4	11 Jan 2021 16:21:57.156	11 Jan 2021 16:26:29.321	272.165
5	12 Jan 2021 05:24:28.602	12 Jan 2021 05:29:25.687	297.085
6	12 Jan 2021 16:03:55.782	12 Jan 2021 16:07:16.277	200.495
7	13 Jan 2021 05:05:49.284	13 Jan 2021 05:10:40.962	291.679
8	13 Jan 2021 17:19:11.182	13 Jan 2021 17:22:35.596	204.414

Mission Schedule



*Assuming 2 ground stations

Imaging Proposal Requirements

Imaging	Target (coordinates, size); Calibration Process
Satellite	Power; ADCS/Orientation; Image Storage; System Health
Downlink	Schedule; Image Queueing; Link Budget
Misc	Failure Modes; Science Impact

Budget

Part Name	TRL Level	Operating Temperature	Mass (in grams)	Qty	Cost ($)
Infrared Camera Lens		-10C to 80C	461	1	2500
Infrared Camera Core			72	1	6000
GOMSpace Motherboard					3300
GOMSpace On-Board Computer			24		7250
	9	-40 to 85C	30	1	4000
GOMSpace AX100 Transceiver	8	-30 to 85C	24.5	1	4600
adcs			694	1	
Tier 2 CRSRA Imaging License					
GOMSpace SDK Licensing					1250
Batteries- OPTIMUS 40		-10°C to +50°C	335	1	3000
structure itself (Aluminum 5052 H32)			727.12	1	1200
gps module					
GPS antenna					
magnetorquer rods		-35 to 75C	30	3	3600
solar panels			127	4	20000
IMU					8.26
EPS					4000
Sun Sensors					3300
Total:			2524.62		$64,008.26

$21,333/u

Includes some conservative estimates for components that need quotes

Licensing

RF

In order to use UHF amateur band:

- Coordinate frequency with International Amateur Radio Union (IARU)
- Apply for FCC Experimental Licensing, which is common for university CubeSats on 435-438 MHz amateur band. This application would include an Orbit Debris Assessment Report.
- Ground operators would need to acquire amateur radio licenses.

NOAA CRSRA

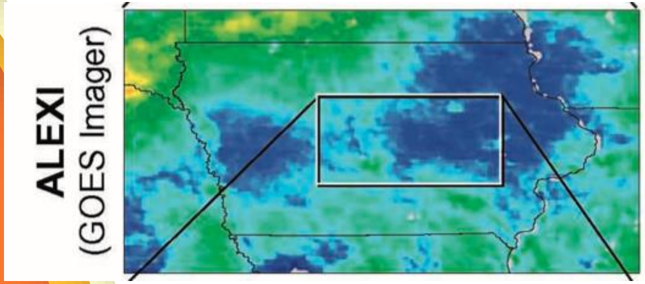
In order to operate a remote sensing satellite in space, we will apply for the Tier 2 NOAA Commercial Remote Sensing Regulatory Affairs license.

GOMSpace SDK

This license allows us to use the GOMSpace software. Licensing costs vary per mission, but previous missions estimate to around $1250

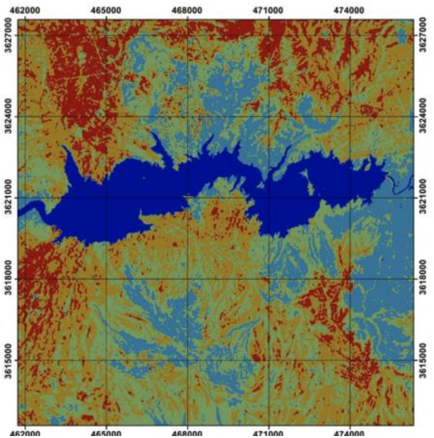
Payload Definition

Main scientific tool: FLIR Infrared Thermal Imaging Camera + Germanium Lens



Thermal Imaging Picture
From Space

Camera will be used to take thermal images of forested or agricultural regions across America



Evapotranspiration Chart
From Satellite Data

Payload Specs

FLIR Camera Capabilities:

Spectral response range: 7-15 micrometers

Horizontal Field of View: 54.4km x 40.8 km

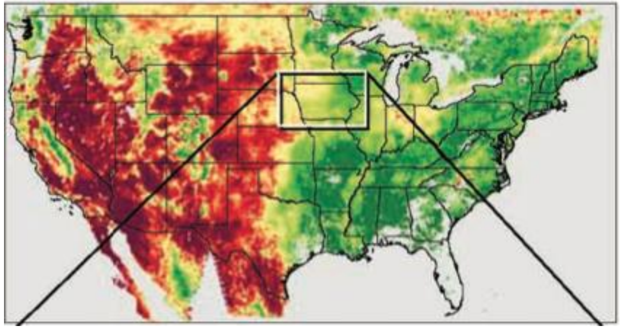
- Camera angle of 6.2°
- Image Resolution of 640 x 512 pixels
- Ground Sample Distance: 85m per pixel
- Thermal sensitivity: 50mK
- Image File Size of: 0.5376MB

Scientific Analysis

Using thermal data from the payload, we can calculate the evapotranspiration rates of target areas using the SEBS Algorithm

Using:

- Land Surface Temperature
- Spectral Radiance Data
  - Calibrated before/after each science-pass



Previous discontinued usage of Algorithm to map evapotranspiration from dry to wet

Onboard Computers

- GOMSpace Motherboard with 4 Mounted Components
  - GOMSpace Nanomind A3200 OBC
  - GOMSpace ANT430 UHF Antenna
  - GOMSpace AX100 Transceiver

Flight-proven, built in software development platform For speedy development, parts integrate well with each other

Flight Software Stack

- NanoMind Built-in Board Support Package
- NASA core Flight System
  - Core Flight Executive

GomSpace SDK For Communication With Hardware

Expansive Flight Heritage, Scalability, and Minimized Development Cost favors the usage of the NASA cFS framework

Mission Specific Flight Software: Develop with cFE Platform Support Package to interface with our Specific Payload

Memory Budget Using Redwood Forest Target Area Scenario For Example

Best Case Scenario

Flight Software	20MB
Data Collection	(3 images) * 0.5376MB per image = 1.6128MB
Housekeeping Telemetry	1MB per week: 1 Week
Total Memory Used	22.6128MB

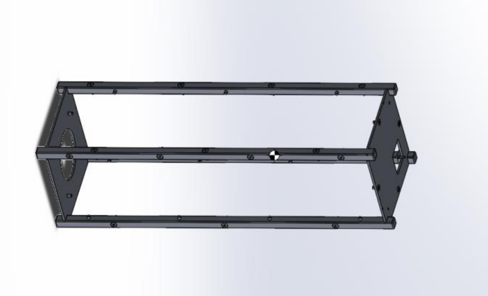
Worst Case Scenario

Flight Software	20 MB
Data Collection	(3 Images * 2 Passes) * 5 images
Housekeeping Telemetry	1MB per week: 4 weeks
Total	40MB

Total Storage Within NanoMind OBC: 128MB NOR Flash Storage

Cubesat Size and Mass

Size: 3u (30x10x10 cm)

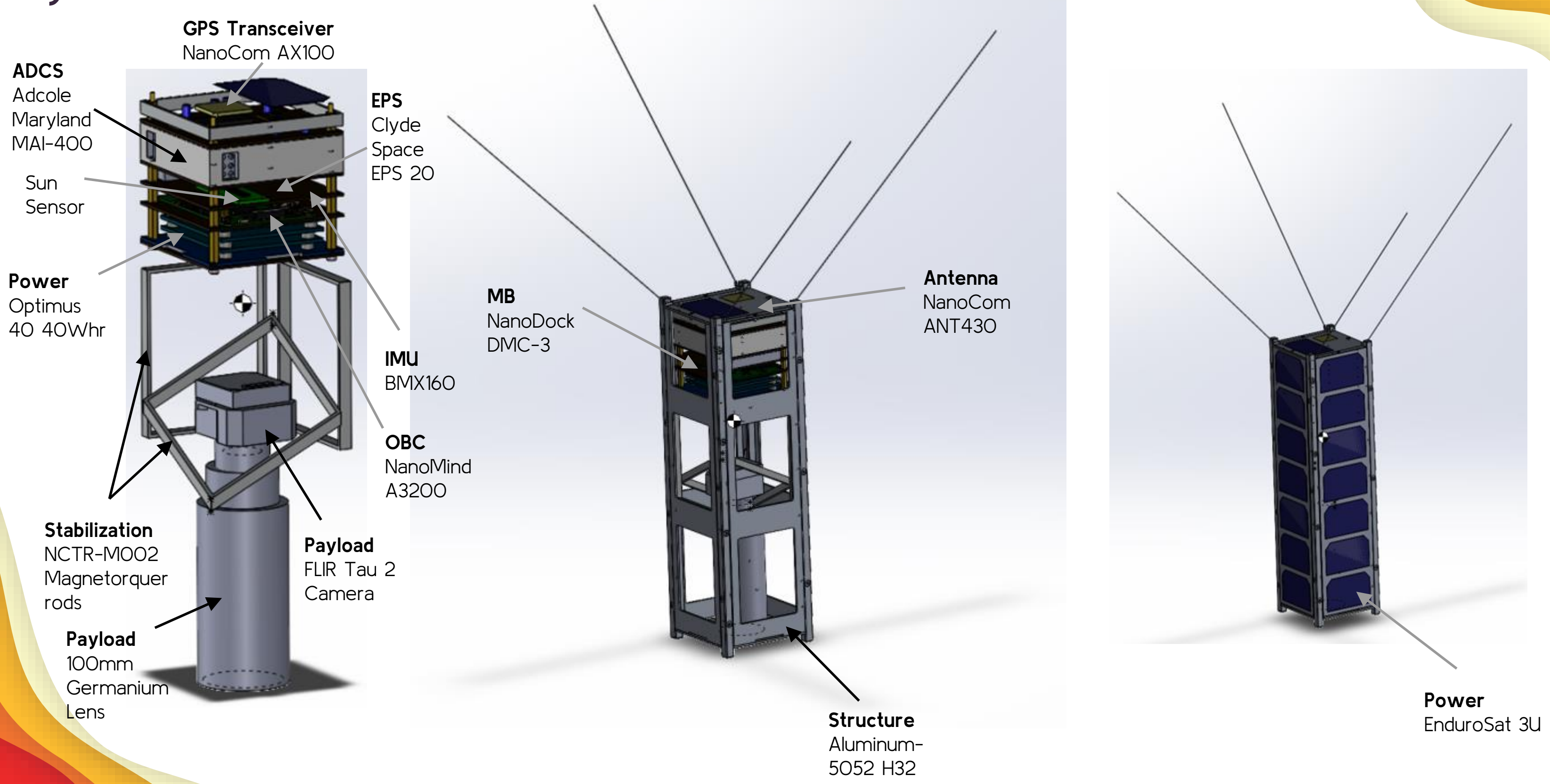


Total Mass with Components: 3125.26 grams

Weight Breakdown on Page 1 of Spreadsheet

COM (mm): X = 165.27 Y = -83.55 Z = 184.25

Physical Render

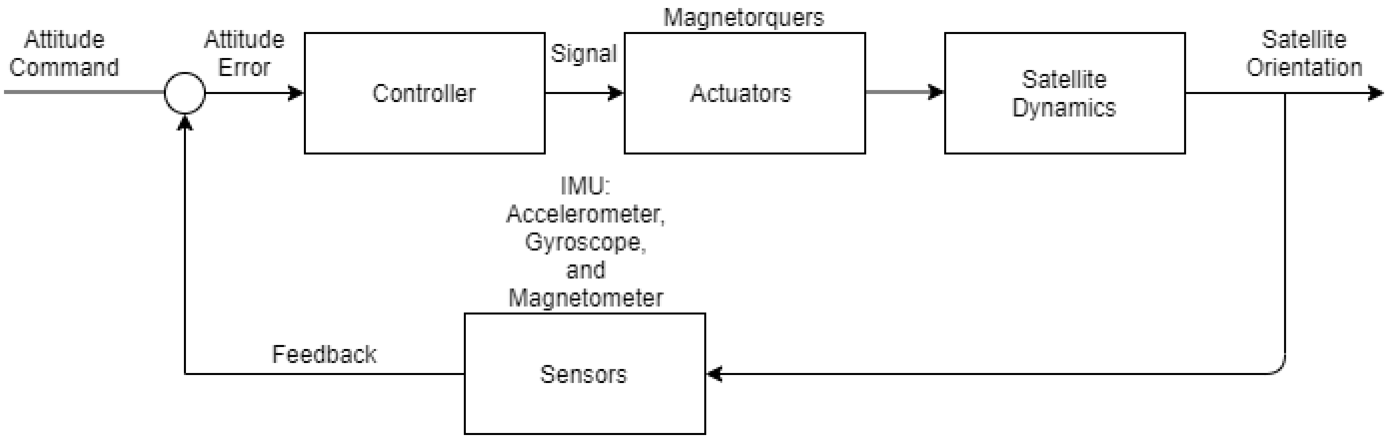


ADCS (Attitude Determination and Control System)

Control Modes:

- Detumbling
  - Mitigating the tumble of ZoomSat by mitigating the angular rate
- Attitude Stabilization
  - Shall maintain the proper orientation “attitude” of ZoomSat to allow fluid communication
- Thermal Control
  - Shall distribute the thermal mass to maintain the operating range of the subsystems
- Sun-sensing
  - Shall point ZoomSat in the optimal position for the solar panels

ADCS Block Diagram



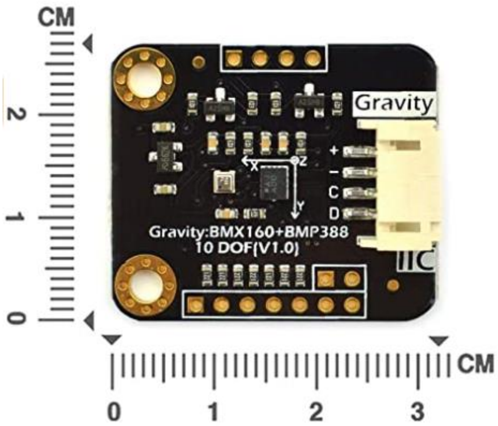
NCTR-M002 Magnetorquer Rod

- Flight Heritage:
  - 2014 SaudiSat-4
  - DX-1 Missions
- 3 Magnetorquers with Inductor Rods
  - Actuator for control modes
- Purpose:
  - Shall allow manoeuvrability for the ZoomSat necessary for the various control modes

Dimensions:
70mm (length) by 9mm (diameter)

BMX160 (Inertial Measurement Unit)

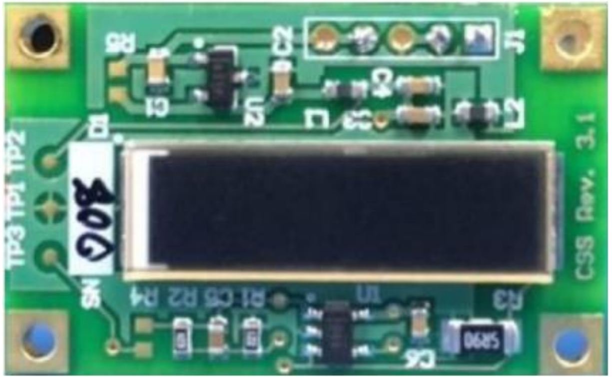
- Accelerometer, Gyroscope, and Magnetometer
- Purpose:
  - Shall provide acceleration, angular rate and geomagnetic measurements



Dimensions:
3mm by 2.5mm by .95mm

MAI Sun Sensor

- Flight Heritage:
  - Juno
  - Cassini- Huygens
  - New Horizons
- Shall be placed on all 6 ZoomSat faces
- Purpose:
  - Determining the position of ZoomSat relative to the sun and maintaining orientation with the magnetorquers



Dimensions: 50.80 mm x 19 mm x 2.03 mm

Communications System

<u>GOMSpace ANT430 UHF Antenna</u>

Communication between ZoomSat and the ground will occur at a frequency of 437.5 MHz on the UHF amateur radio band. The GOMSpace ANT430 was selected to provide omnidirectional capabilities at a circular polarization, as well as impedance matching up to 50 ohms. It This antenna has a TRL rating of 9, and has proven effective on previous CubeSat missions.

Communications System

GOMSpace AX100 UHF Transceiver

This transceiver was selected mainly due to its seamless integration with ZoomSat's OBC; they will live on a GOMSpace motherboard and communicate using I2C. Messages will be downlinked at a 9600 baud rate with GMSK modulation, an established choice for satellite communication. Though the details of communications protocols between ZoomSat and the ground haven't been explored, the Phoenix Mission of Arizona State University utilized the AX.25 protocol with HDLC encapsulation, something ZoomSat could utilize as well.

Link Budget

Downlink Margin: 22.13dB

Uplink Margin: 35.49dB

Full details on our link budget can be found on the ZoomSat Budget Lists spreadsheet. Several assumptions and estimates had to be made, particularly with the specifications of our ground station, so the accuracy would improve with updated information.

Electrical Power System and Battery

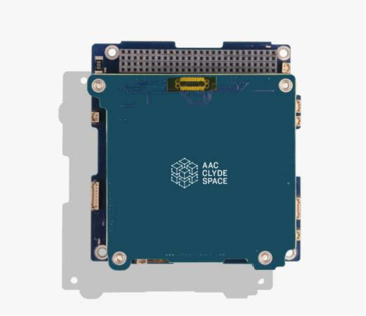
EPS: Clyde Space Starbuck-Nano

Battery: Clyde Space Optimus-40

Solar Panel: Endurosat 3U Solar Panels

Starbuck-Nano is a well flown EPS board with flight heritage and rated for the ISS. Optimus-40 is a battery pack that works well - the 40 Whr capacity is enough for keeping the cubesat powered through downlinking.

Solar Panels are Endurosat panels with extensive flight heritage and good efficiency - matches EPS constraints



Power Budget

Total Baseline Draw:	2.209
Draw w/o Photography	2.089
Battery Life in Hours	19.14791766
Solar Panel Output in Watts (max)	8.4
Battery Charge:	
Watt-hours:	40
Rated Voltage:	8.26
Charge/discharge current	2.6
Estimated Hours for full charge:	12.38520463

Total Downlink Draw:	13.149
Draw w/o Photography	13.149
Battery Life in Hours	3.04205643
Solar Panel Output in Watts (max)	8.4
Battery Charge:	40
Watt-hours:	8.26
Rated Voltage:	2.6
Charge/discharge current	-0.4590591537
Estimated Hours for full charge:	-1.458395619

Full Breakdown of Power Budget
on Page 6 of spreadsheet

Thermal Analysis

“That’s pretty hot”