RamSat

Oak Ridge Schools - Robertsville Middle School

Oak Ridge, Tennessee

A mentor's view of STEM success built on NASA's Cubesat Launch Initiative

Peter Thornton, Todd Livesay, Ian Goethert, David Andrews, Melissa Dumas, Ed Dumas, Jim Bogard, Eli Manning, Holly Cross

A brief history of RamSat…

- Began as an enrichment class in 2015
- Students designed their science mission in 2016
- Proposal submitted to NASA's CubeSat Launch Initiative in 2017
- RamSat mission selected by NASA in 2018
- Spacecraft design finalized and initial purchasing in 2019
- (a global pandemic arrives)
- Software designed and first full build of hardware in 2020
- *Second* full build of hardware in 2021
- Launched in June 2021
- Successful mission operation from June 2021 to October 2022 (16 months)
- RamSat deorbited on 11 October 2022, burning up over Southern Indian Ocean

> 200 students engaged over eight years

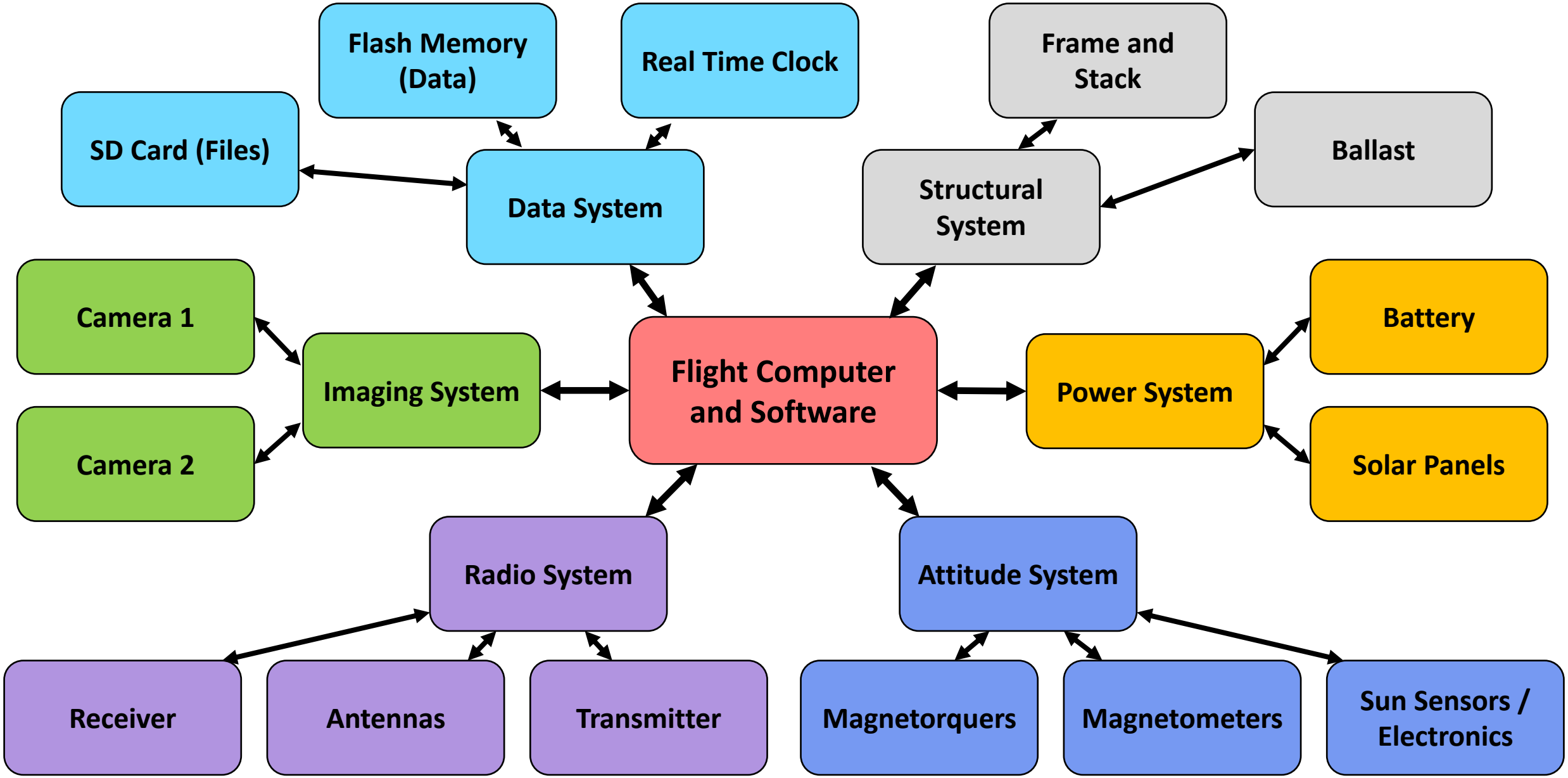
Classroom:
Grades 6-8

Peer mentoring:
Grades 9-12

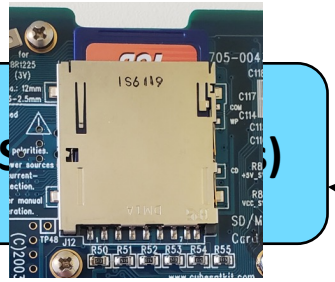
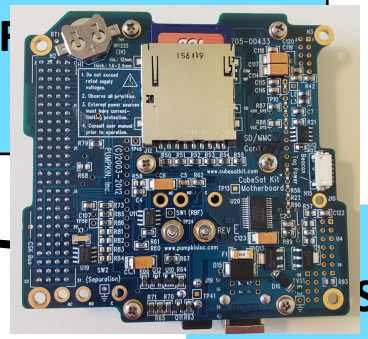
Student-defined mission motivated by local disaster: Gatlinburg wildfires, November 2016

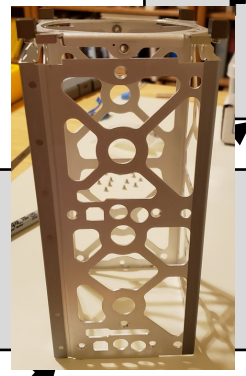
Students learned to present their ideas to panels of scientists and engineers, and to receive and respond to feedback

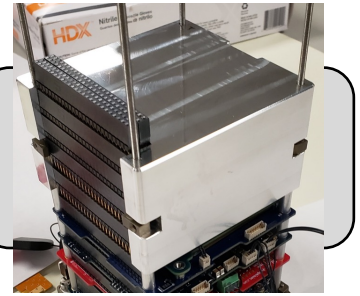
RamSat is a “System of Systems”

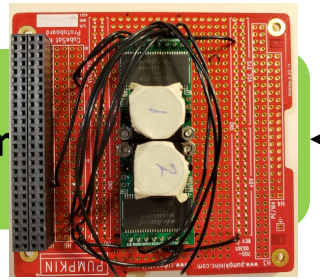


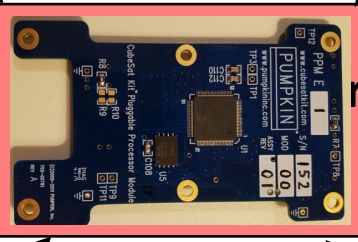
RamSat is a “System of Systems”

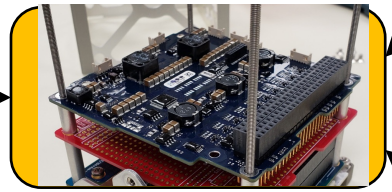
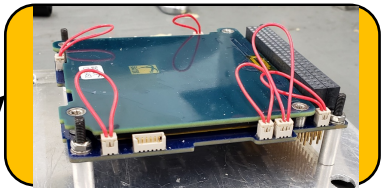
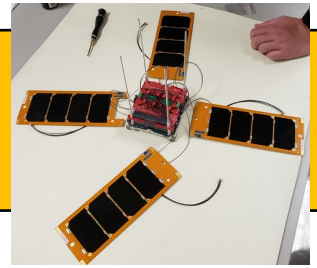
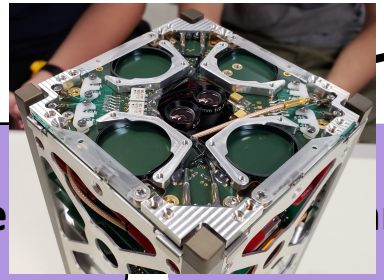
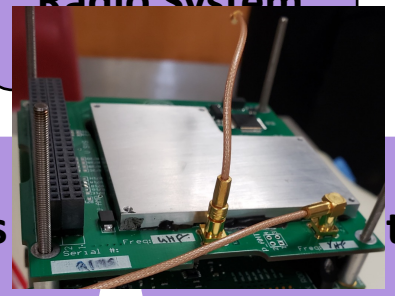
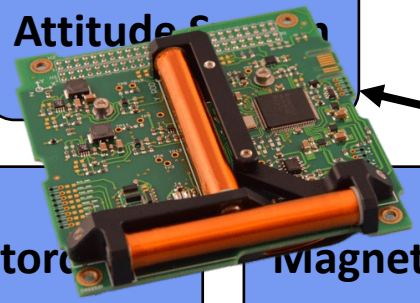
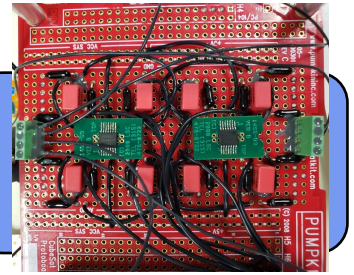



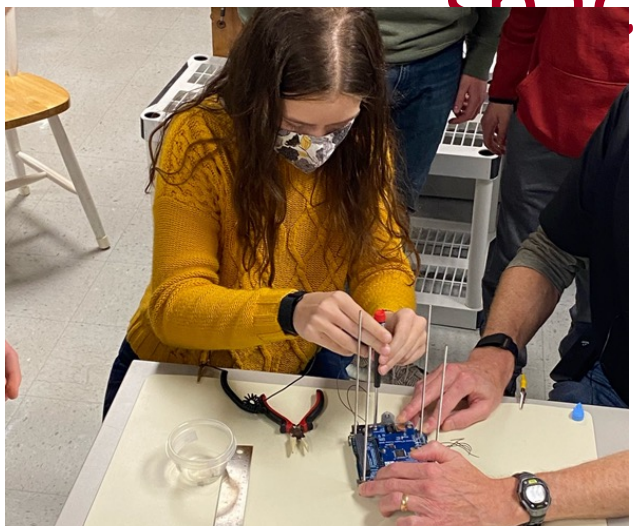


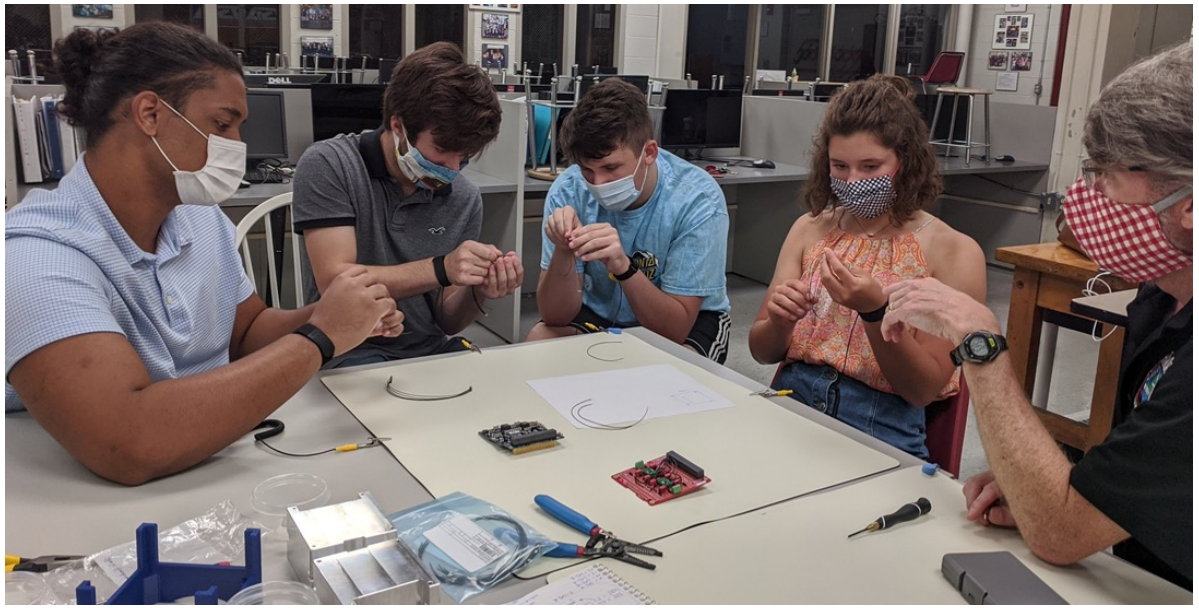



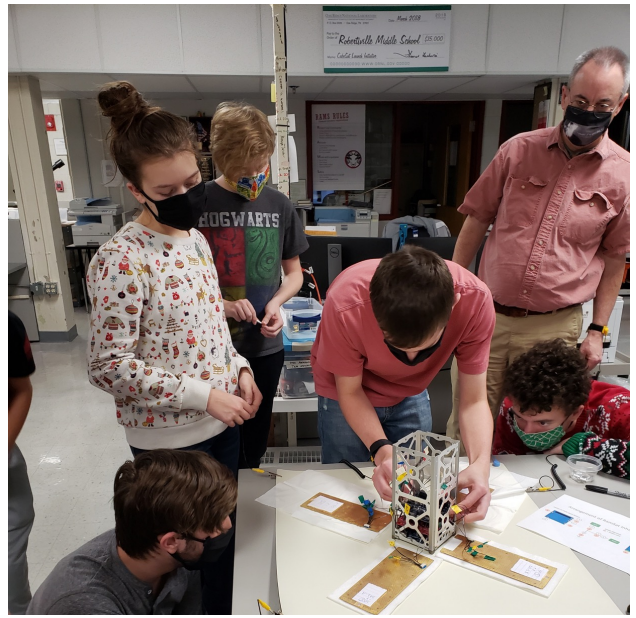


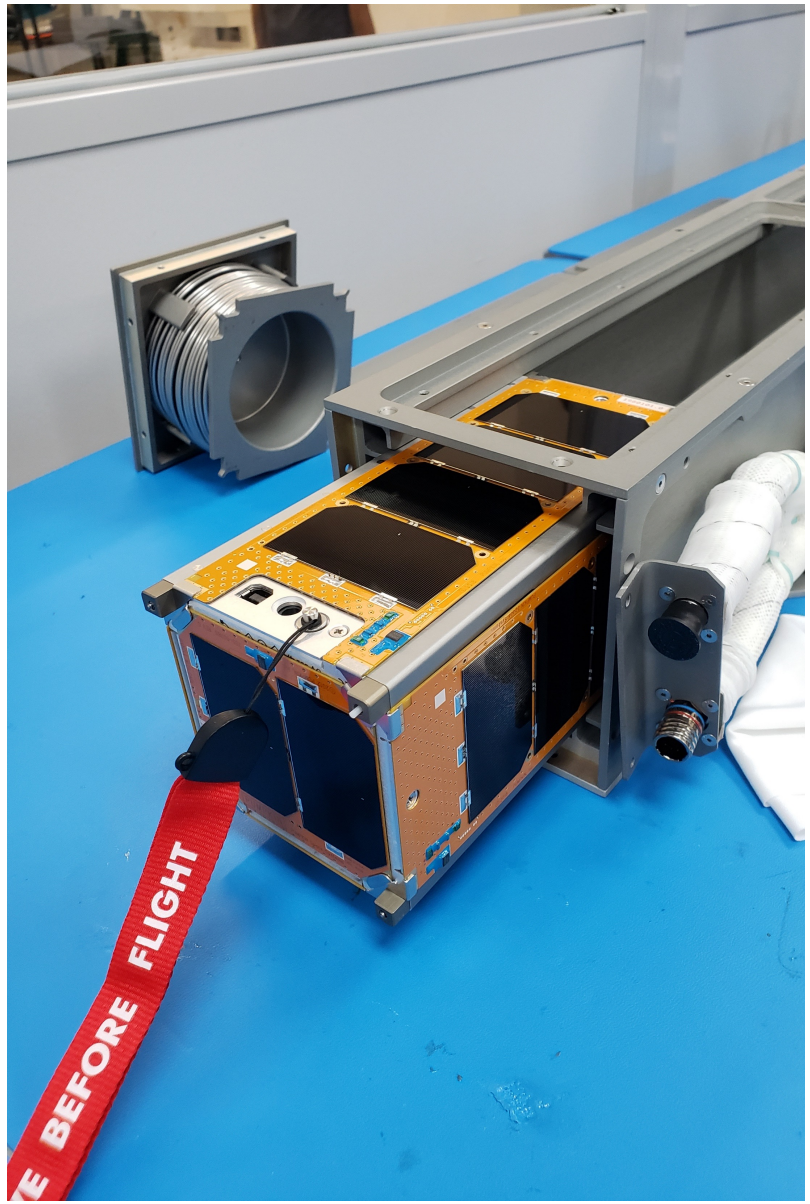
All students had hands-on experience with flight hardware, while building and testing the spacecraft

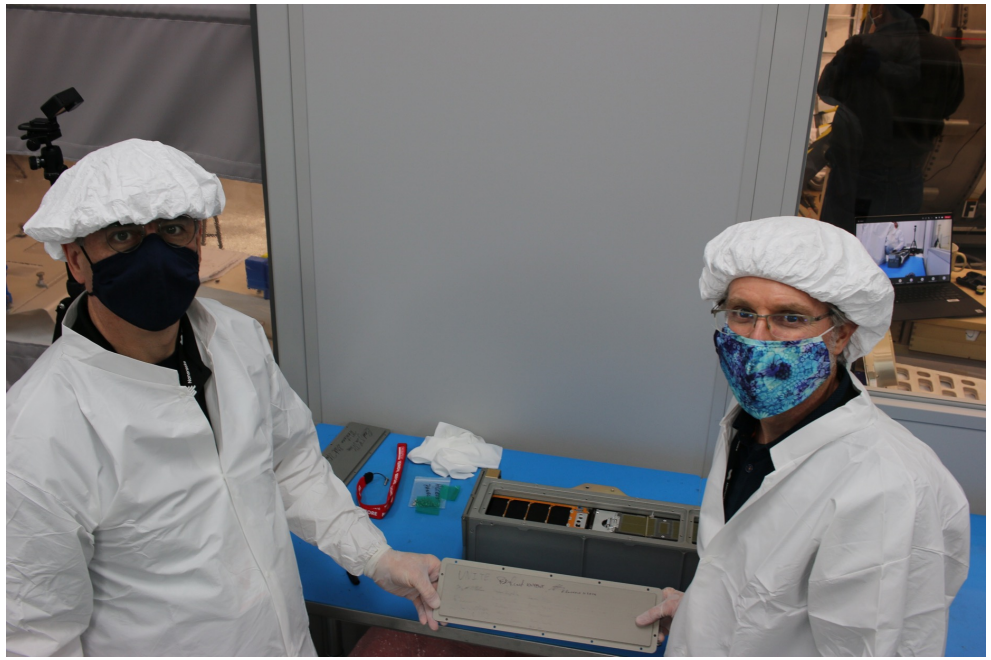




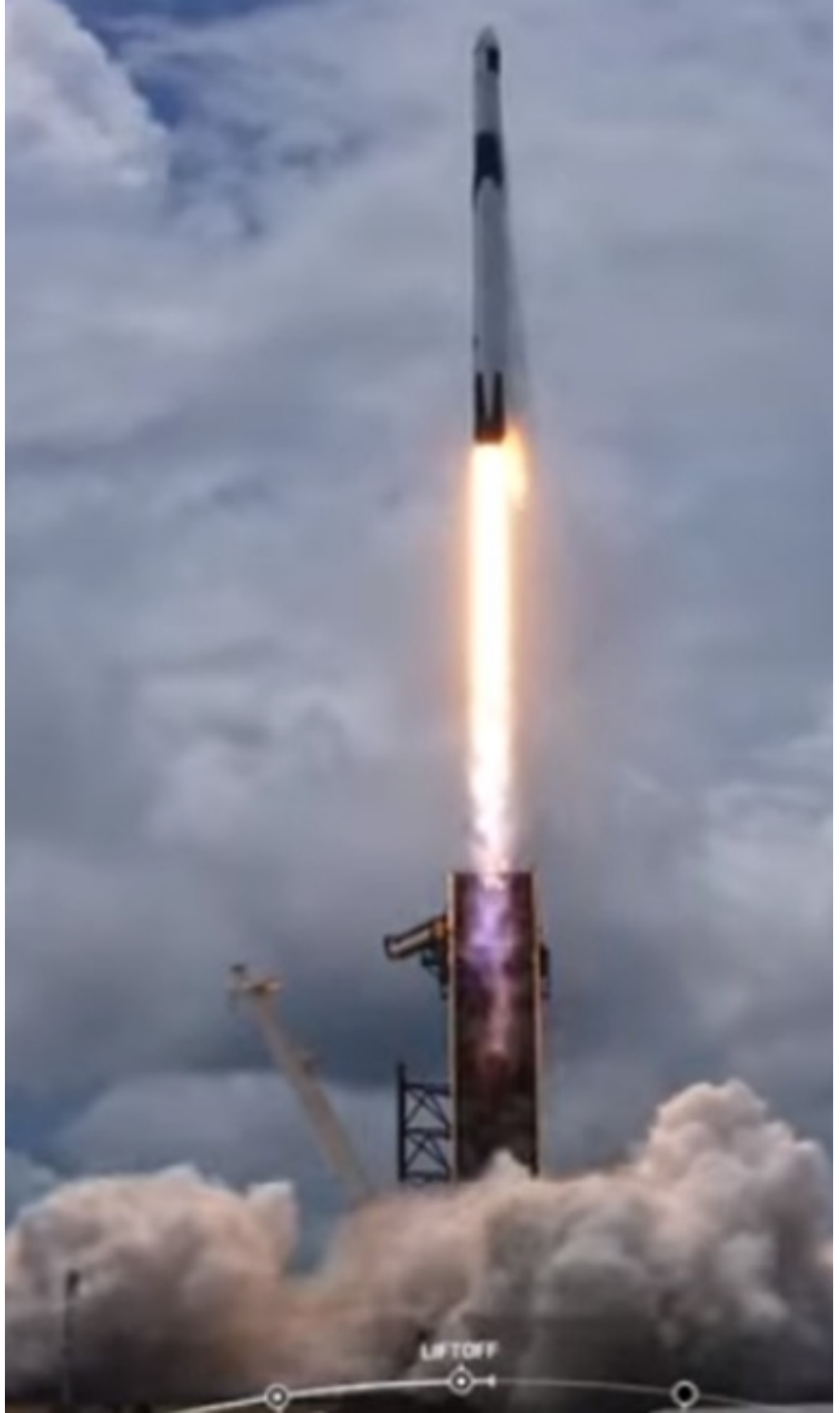


Integration, March 2021

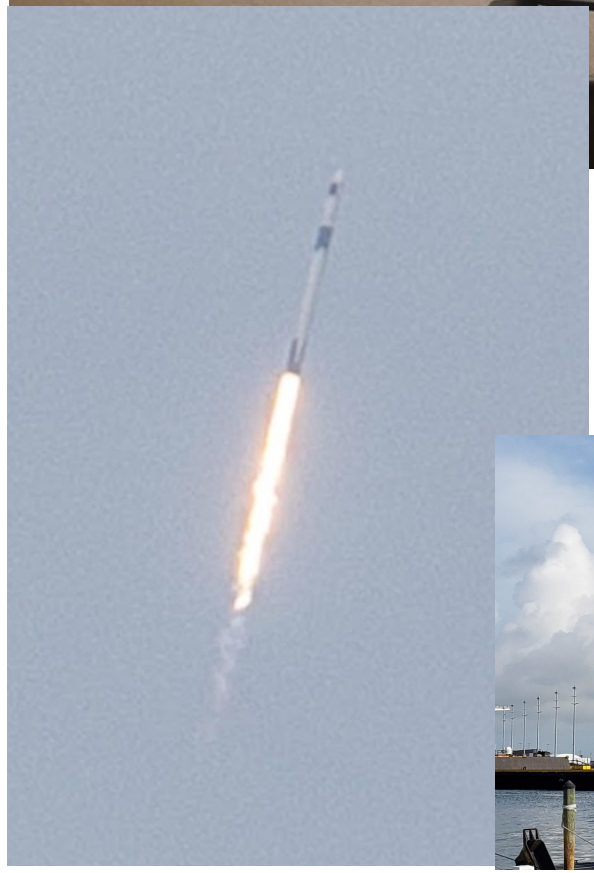




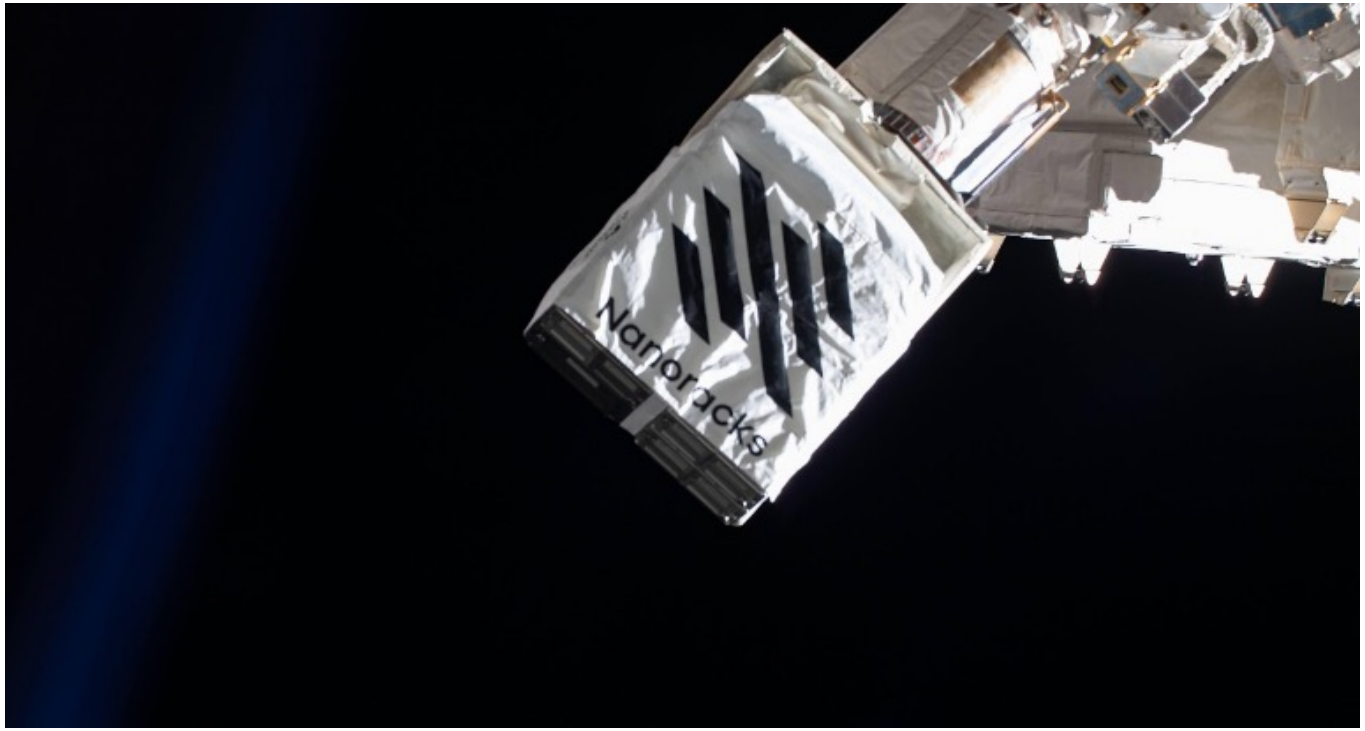
Launch Day, 3 June 2021
1:29 pm EDT, Cape Canaveral

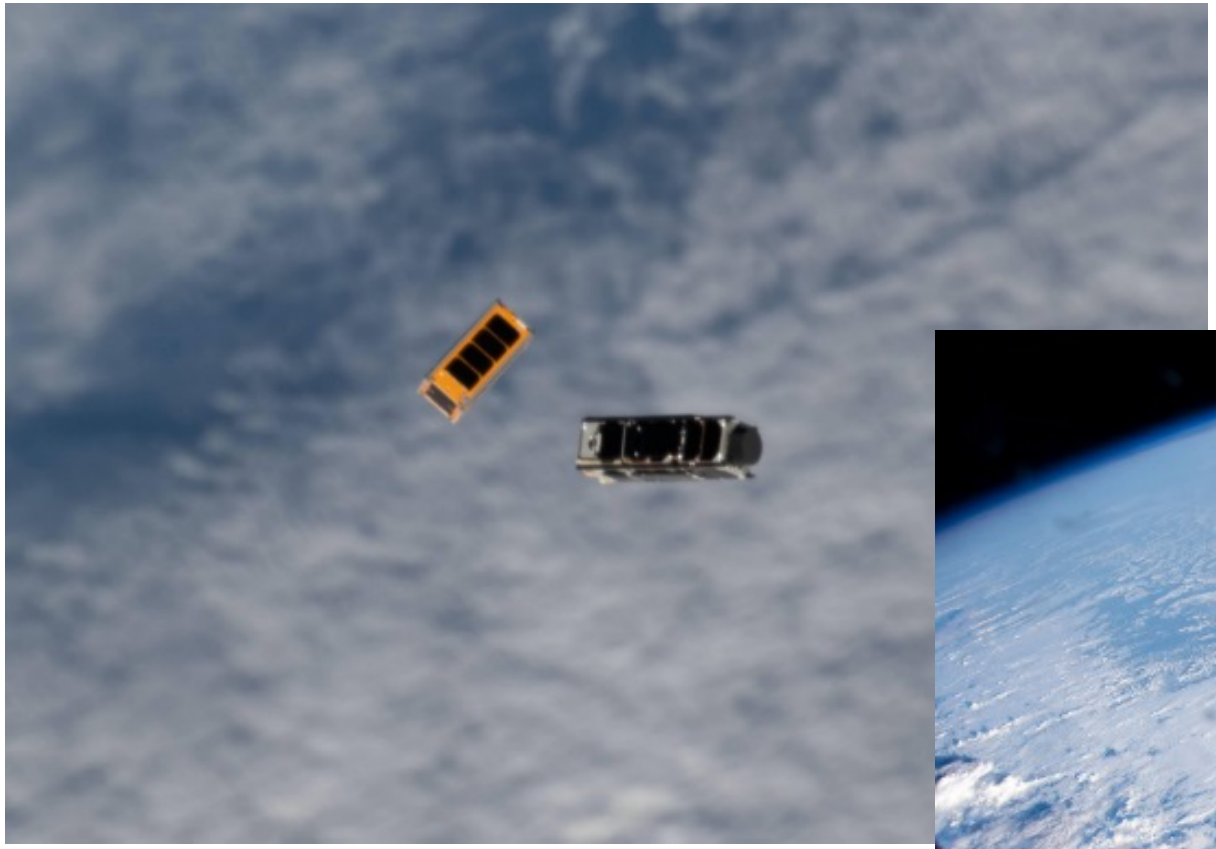

LIFTOFF


NASA

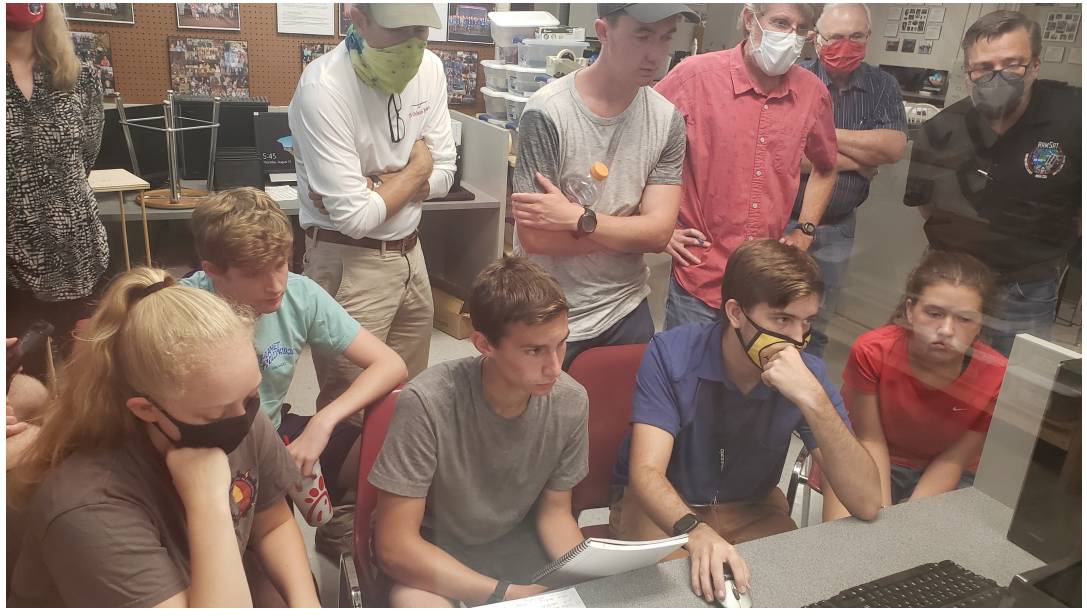


RamSat Deployment from ISS
14 June 2021, 5am EDT

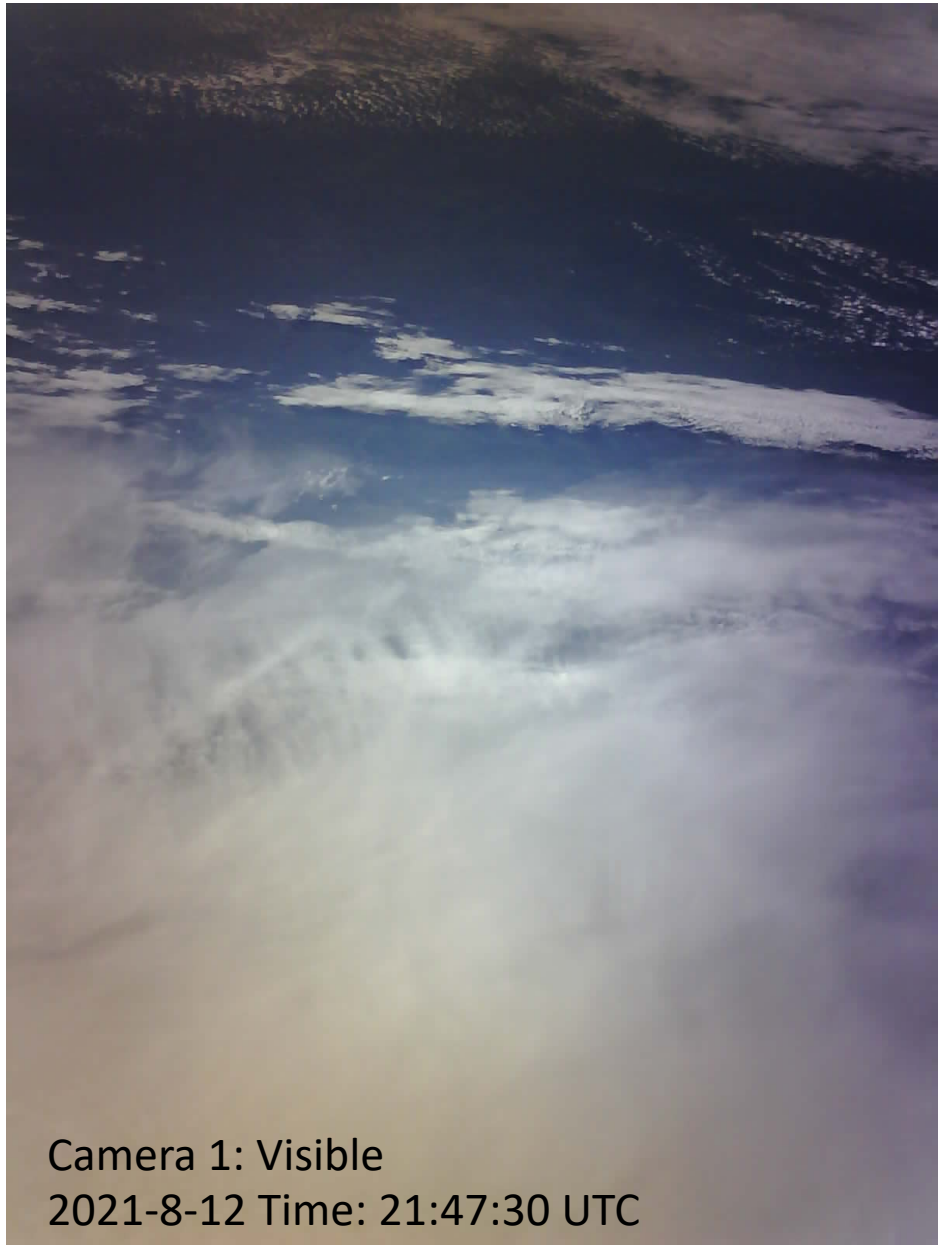




First radio contact and command uplink



First images, August 2021

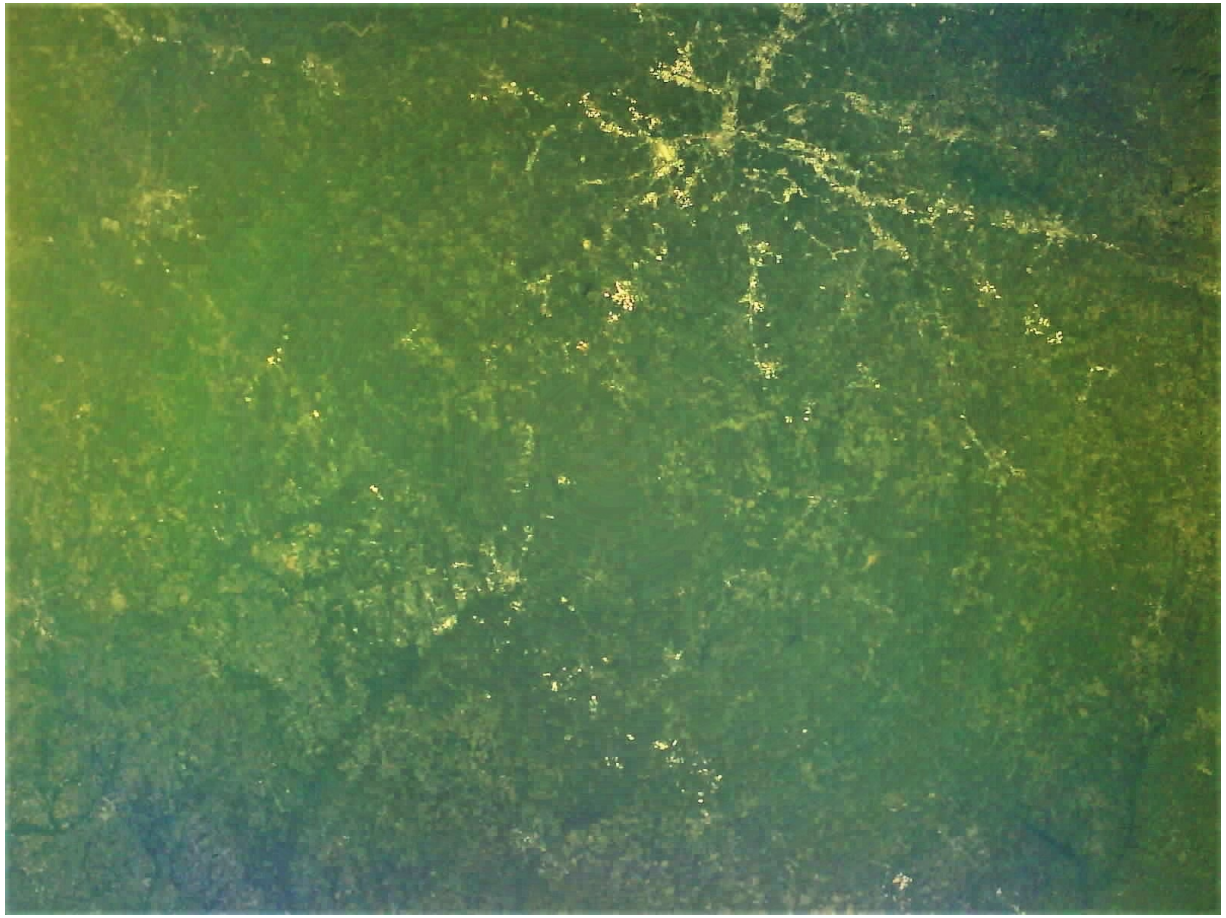


Camera 1: Visible
2021-8-12 Time: 21:47:30 UTC

Camera 2: Visible + NIR
2021-8-12 Time: 21:47:32 UTC

Many images looked like this…

First cloud-free nadir-pointing images, September 2021



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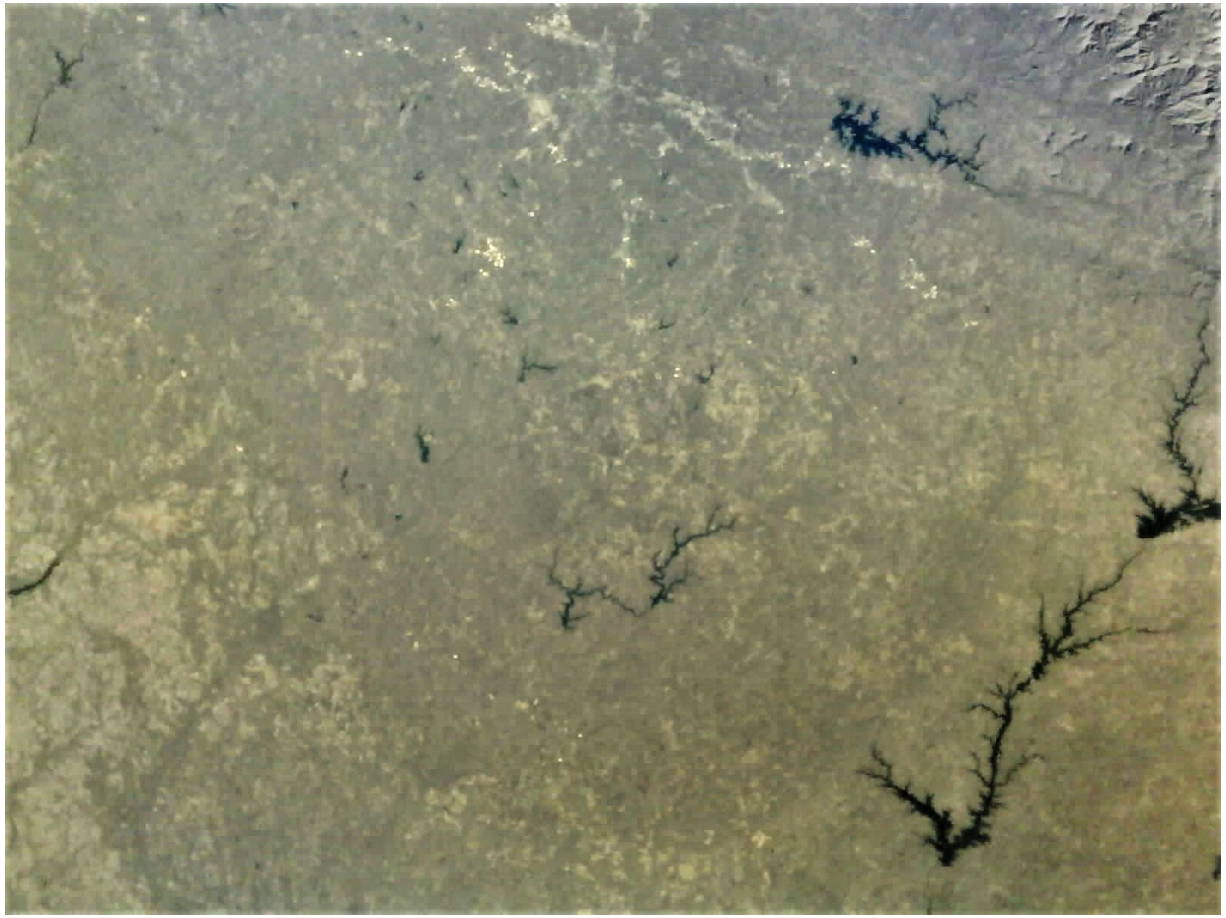
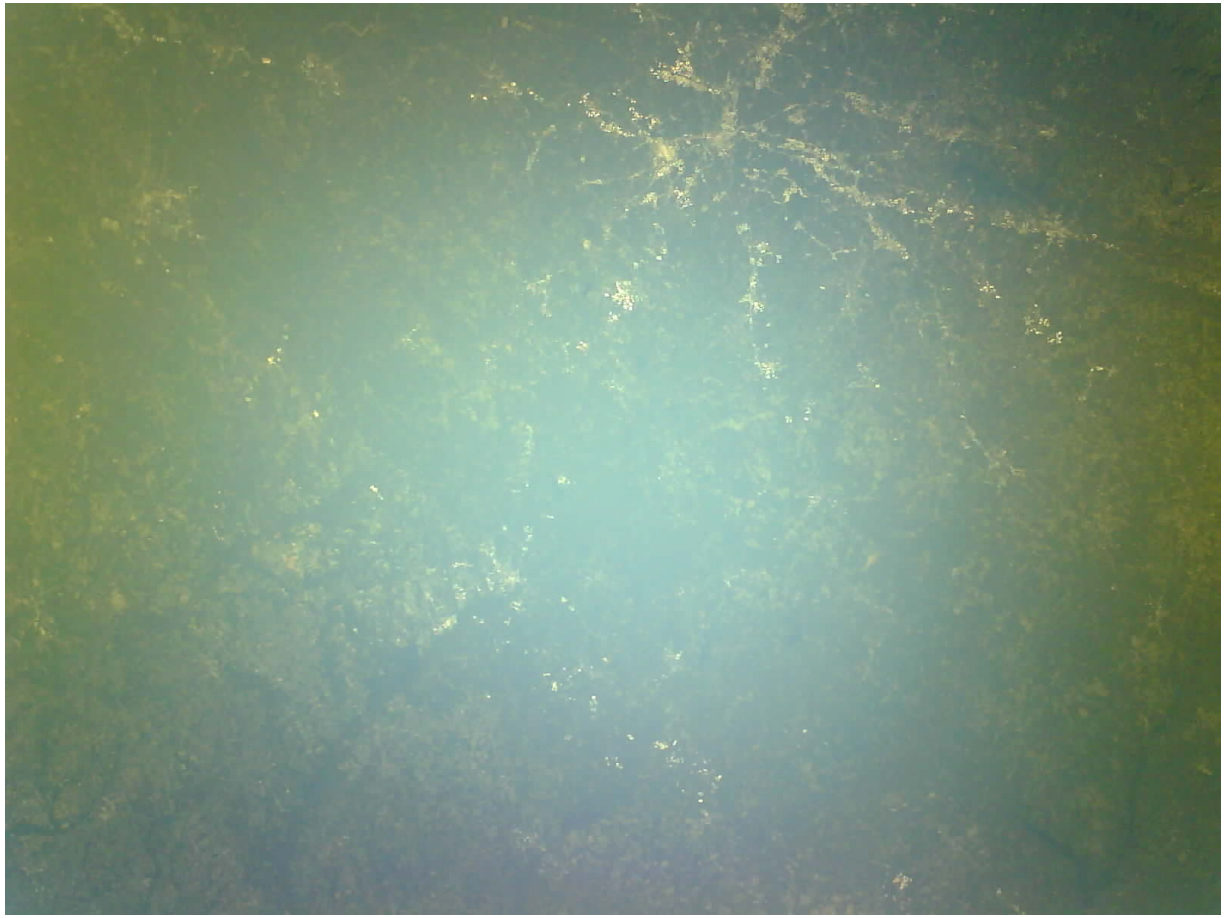


Visible + NIR

Original images…



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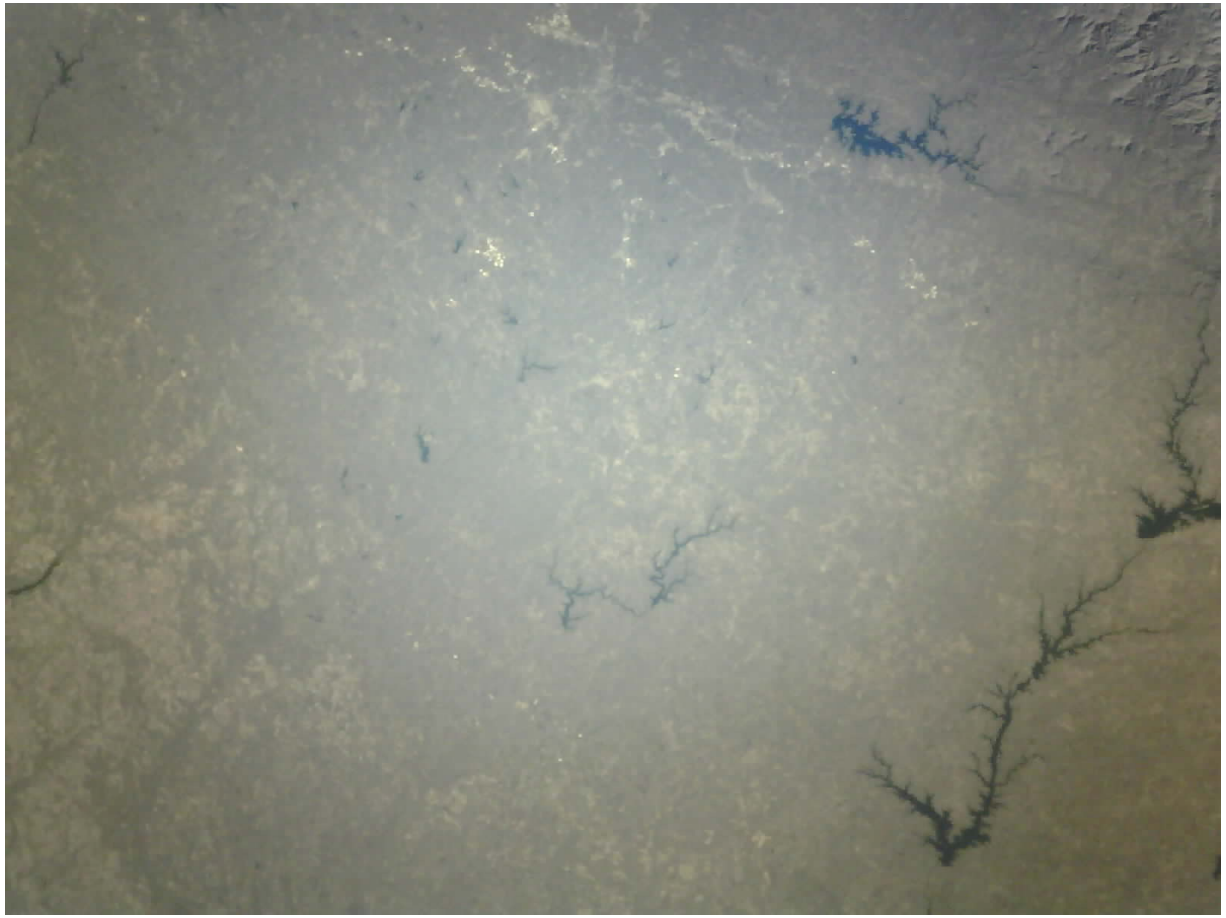
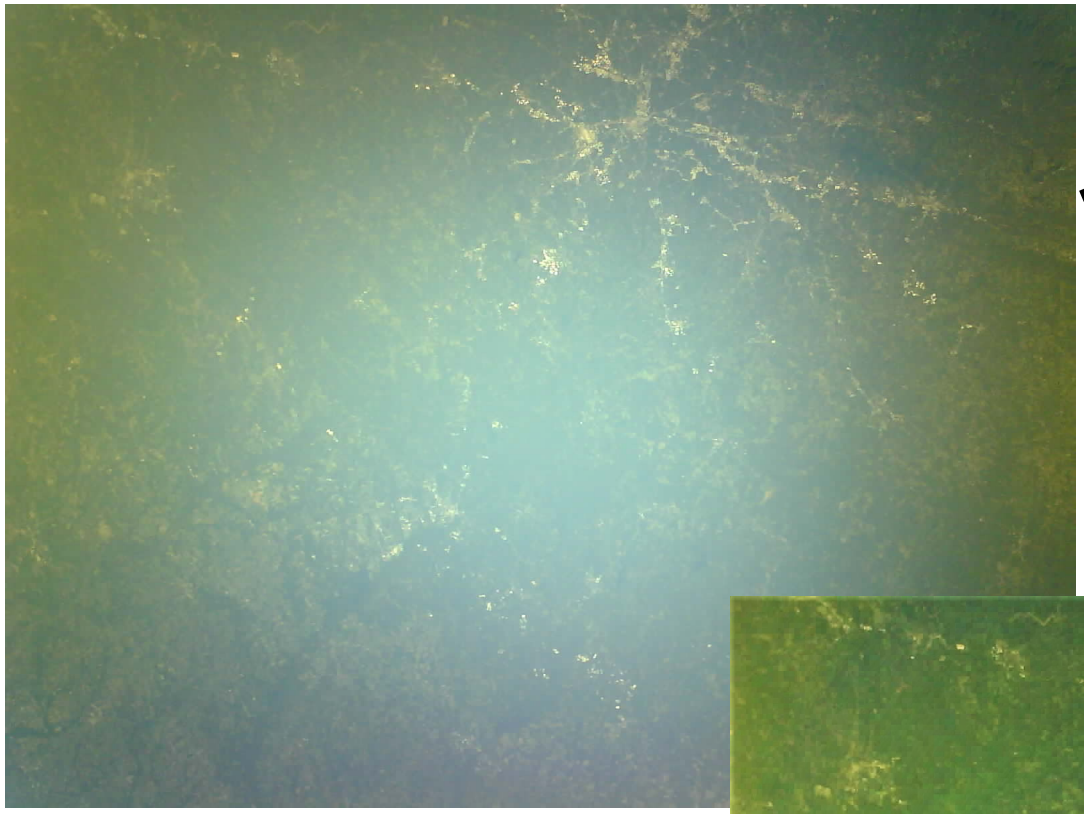
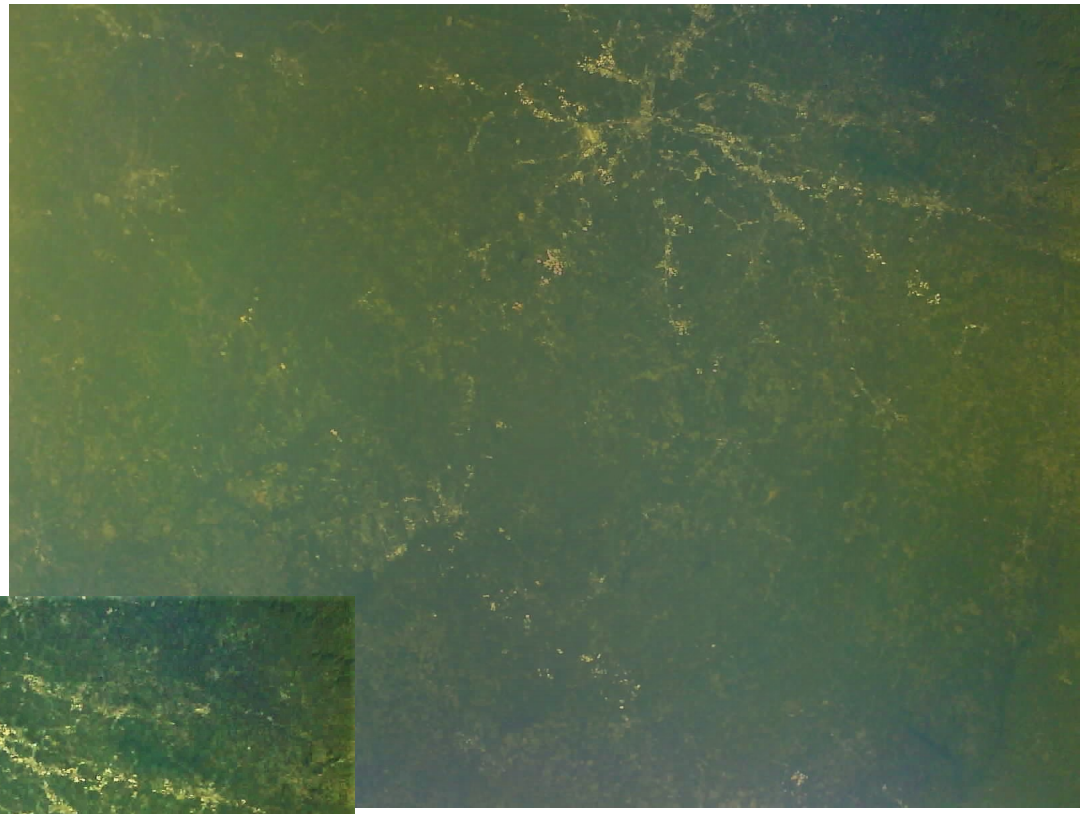
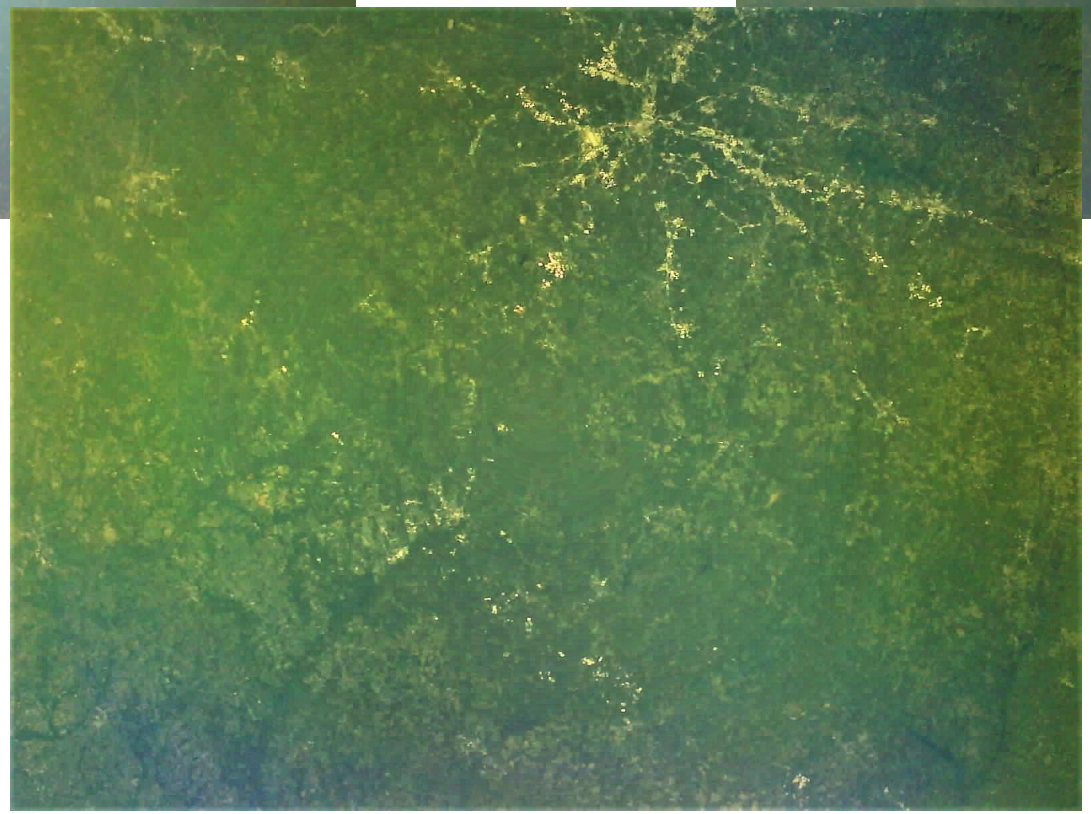


Visible + NIR





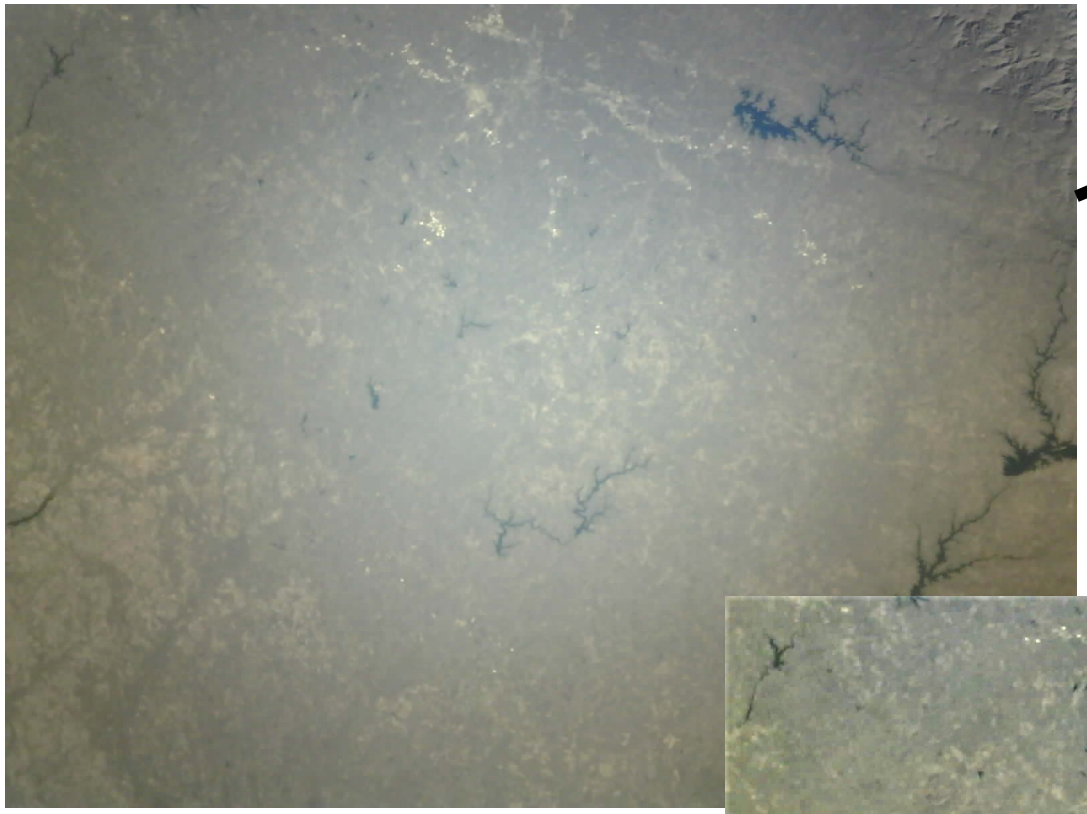


#1: Original image

#2: Corrected center glare

Visible

#3: Increased contrast



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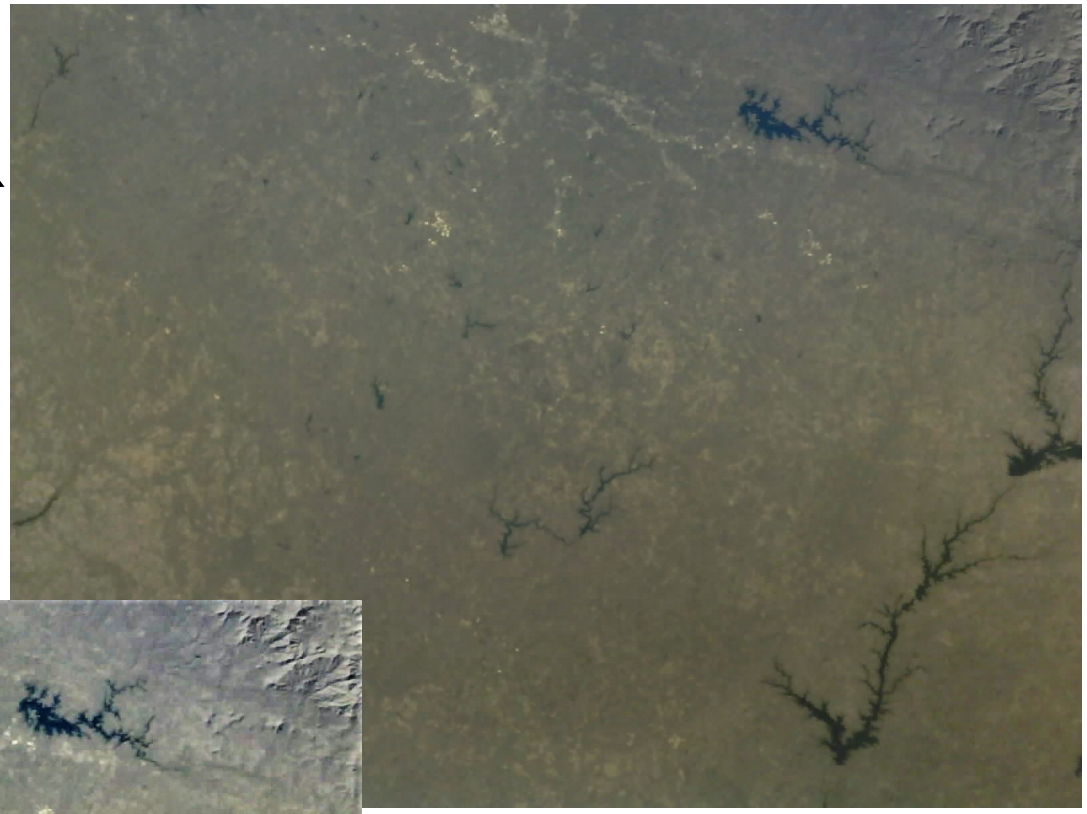
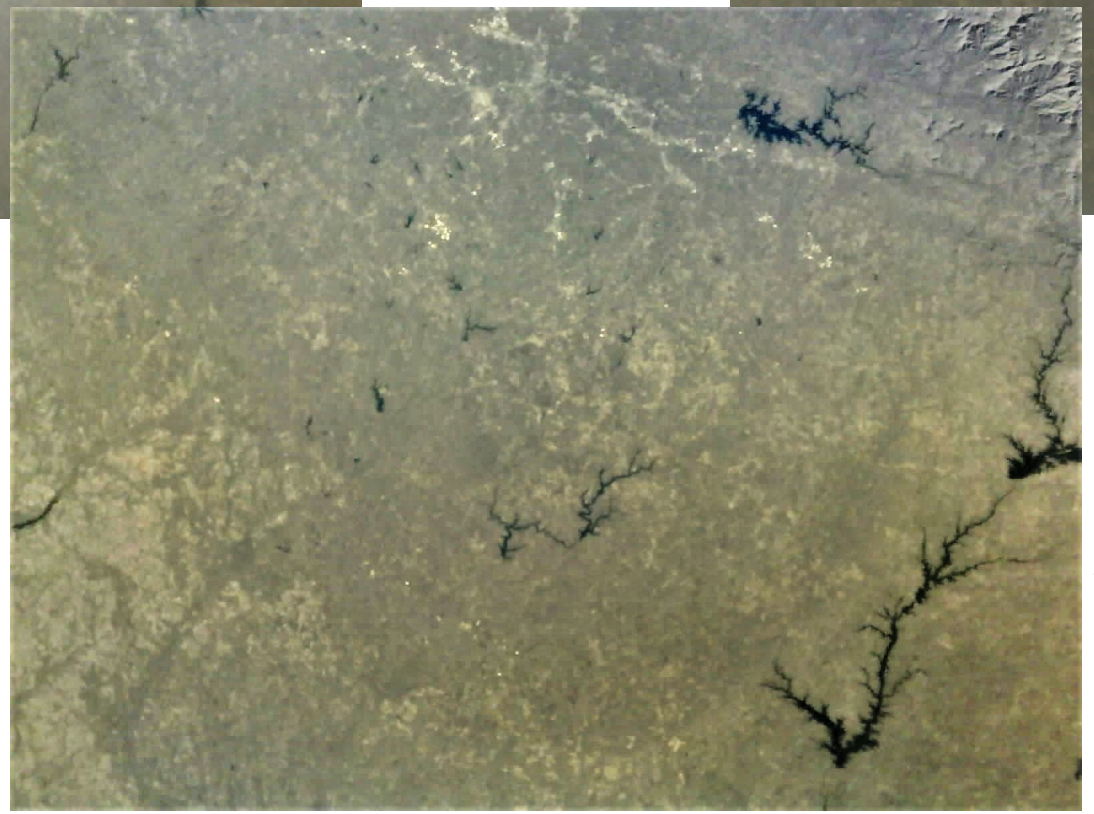


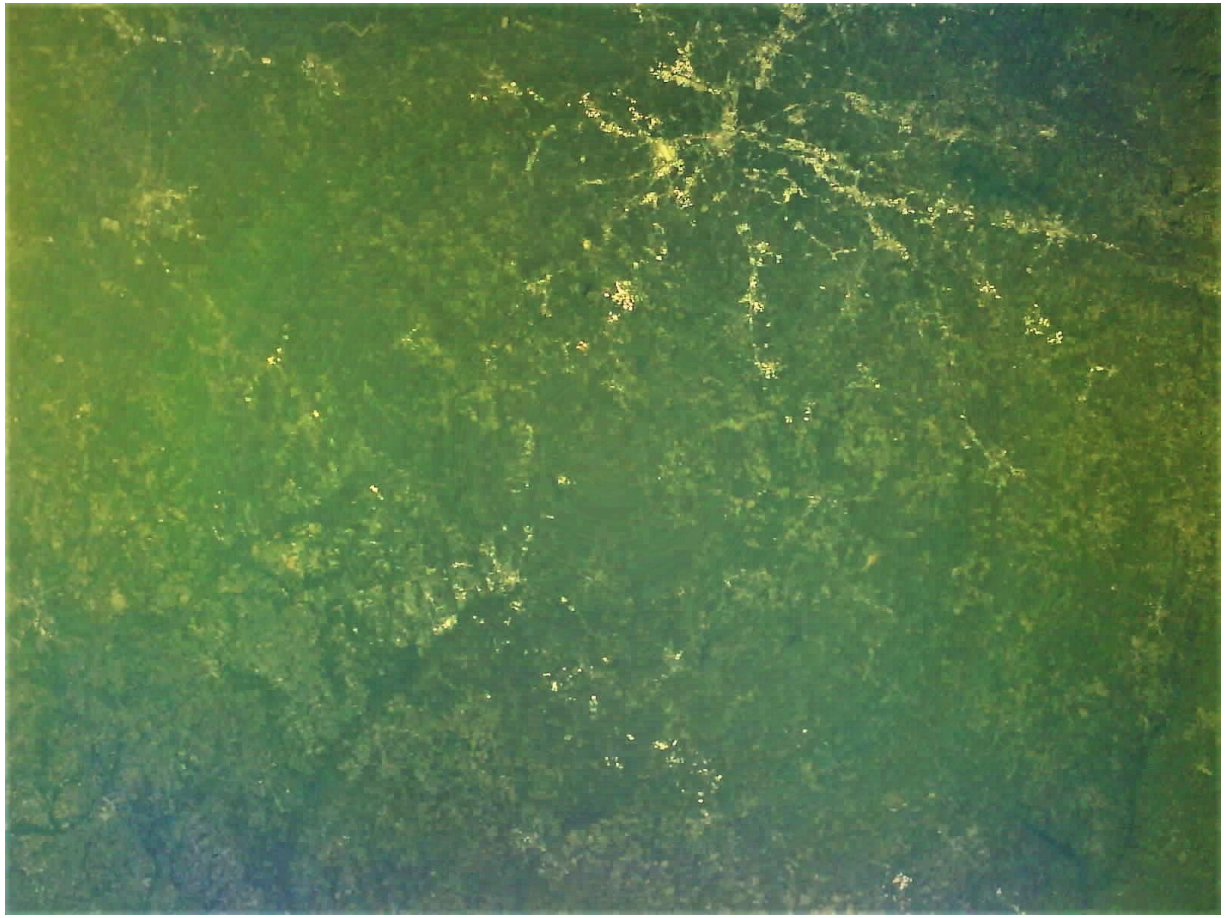
#2: Corrected center glare



#3: Increased contrast

Visible + NIR

Corrected images…



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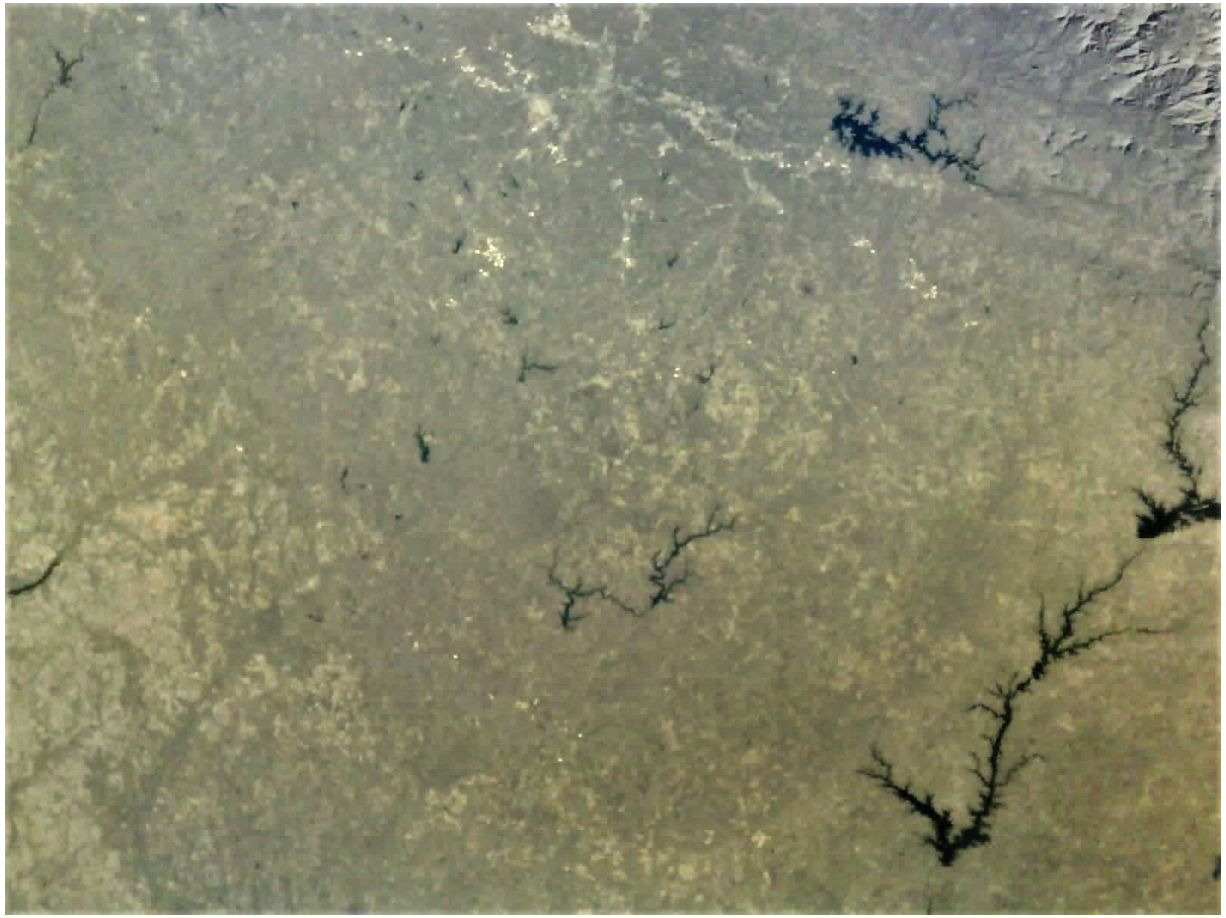
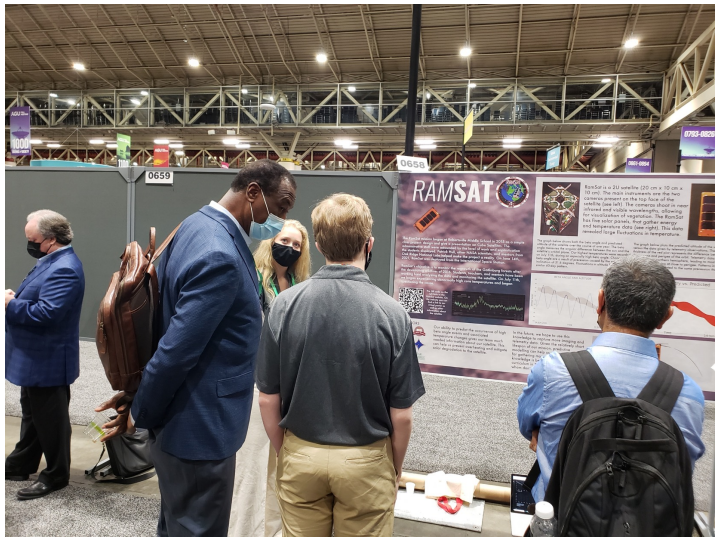
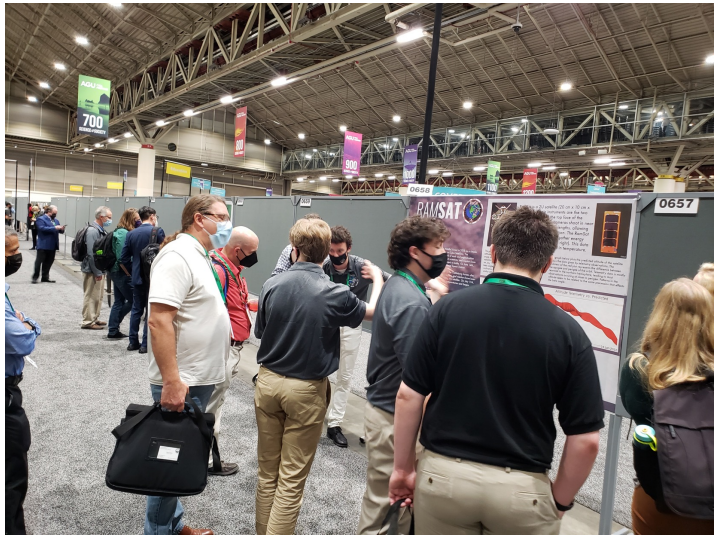


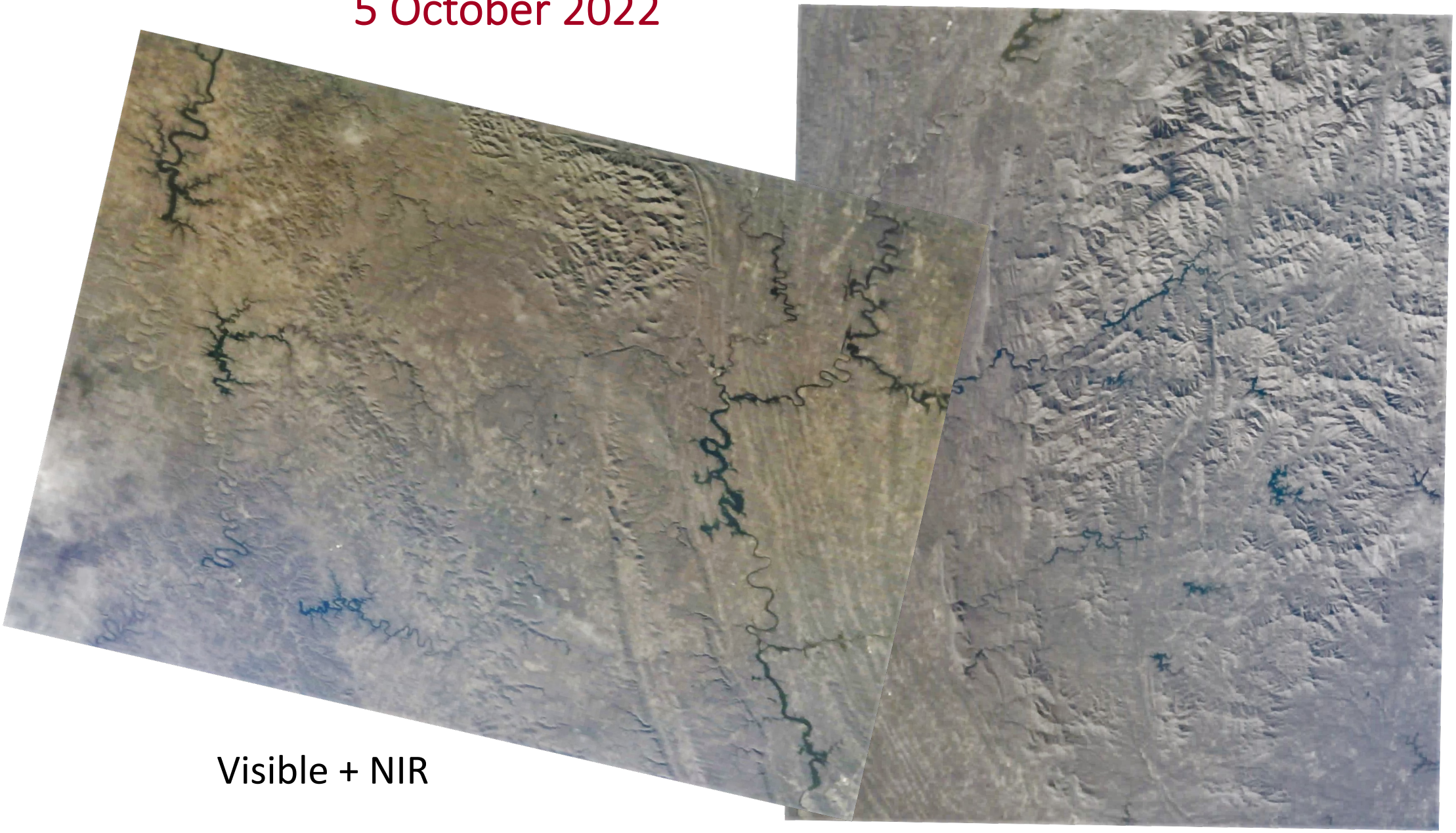
Visible + NIR

Students present RamSat poster at AGU, December 2021



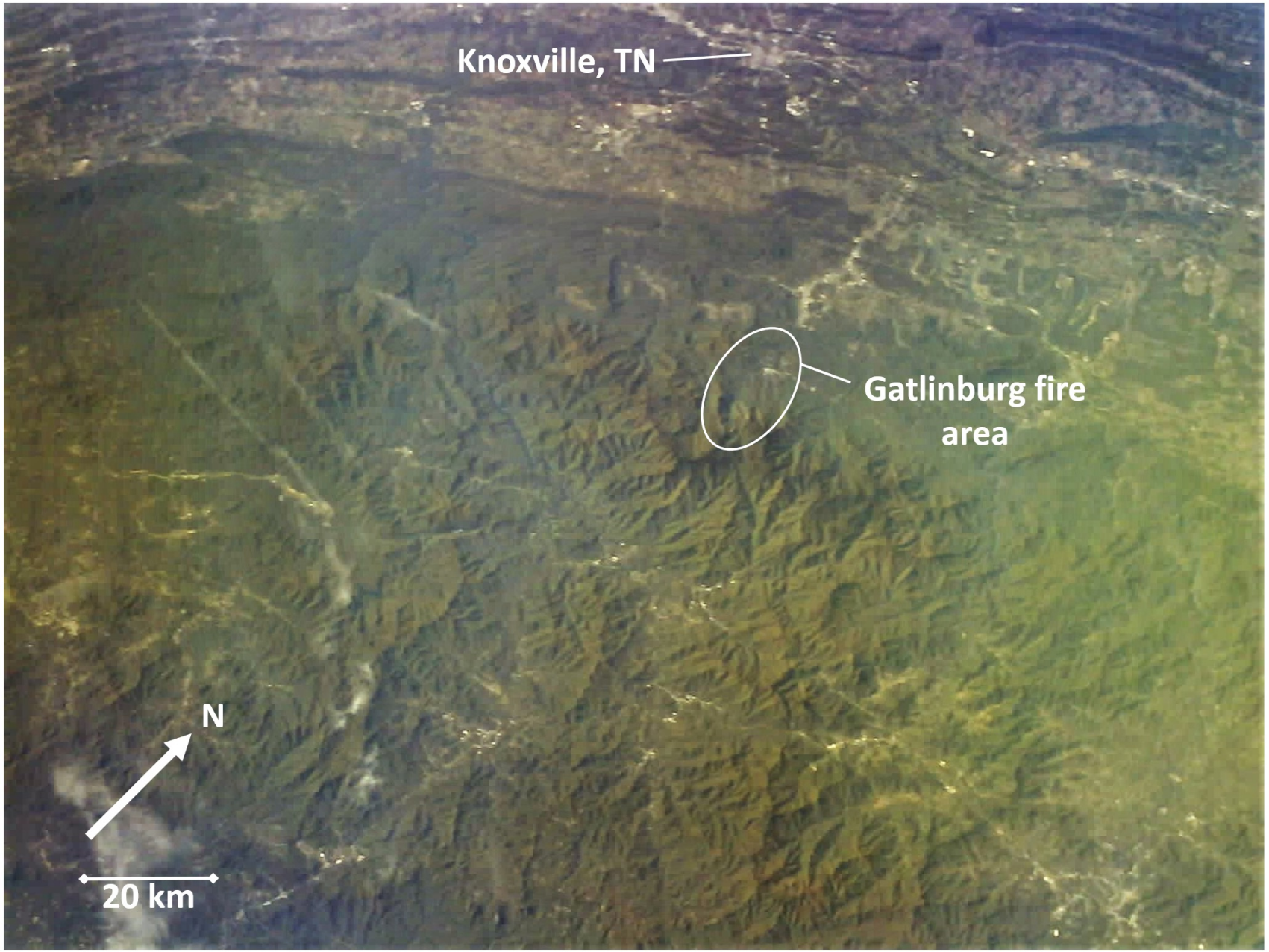


First good images over Gatlinburg fire region: 5 October 2022



Visible + NIR

First good images over Gatlinburg fire region: 5 October 2022



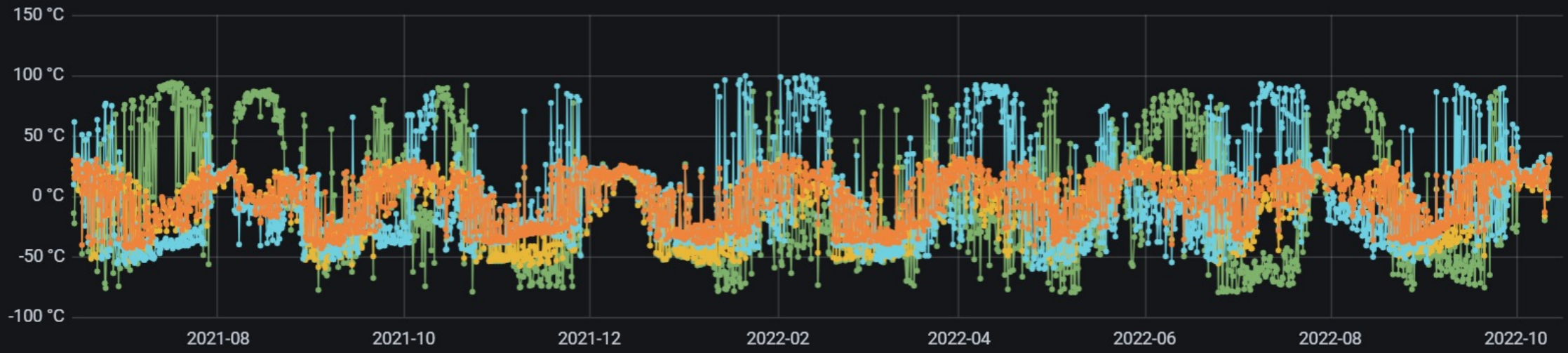
Students present RamSat poster at AGU, December 2022

Open science supported by the SatNOGS community

Core Temperatures

	min	max	avg
Battery Daughterboard Temperature	-1.00 °C	35.80 °C	11.79 °C
Battery Motherboard Temperature	-1.70 °C	34.70 °C	10.60 °C
EPS Temperature	-2.80 °C	32.50 °C	9.92 °C

Panel Temperatures

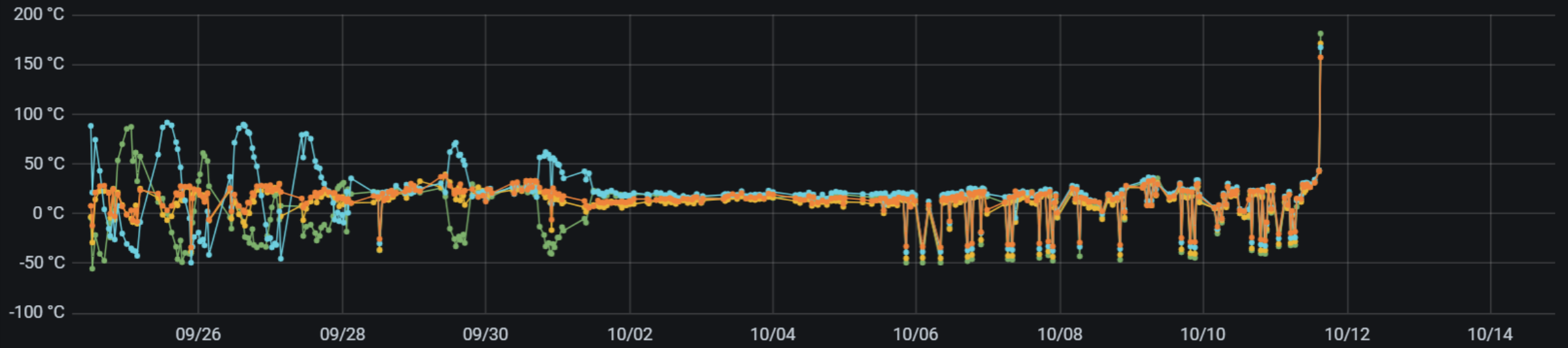


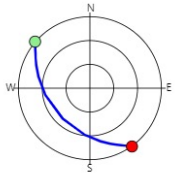
min max avg

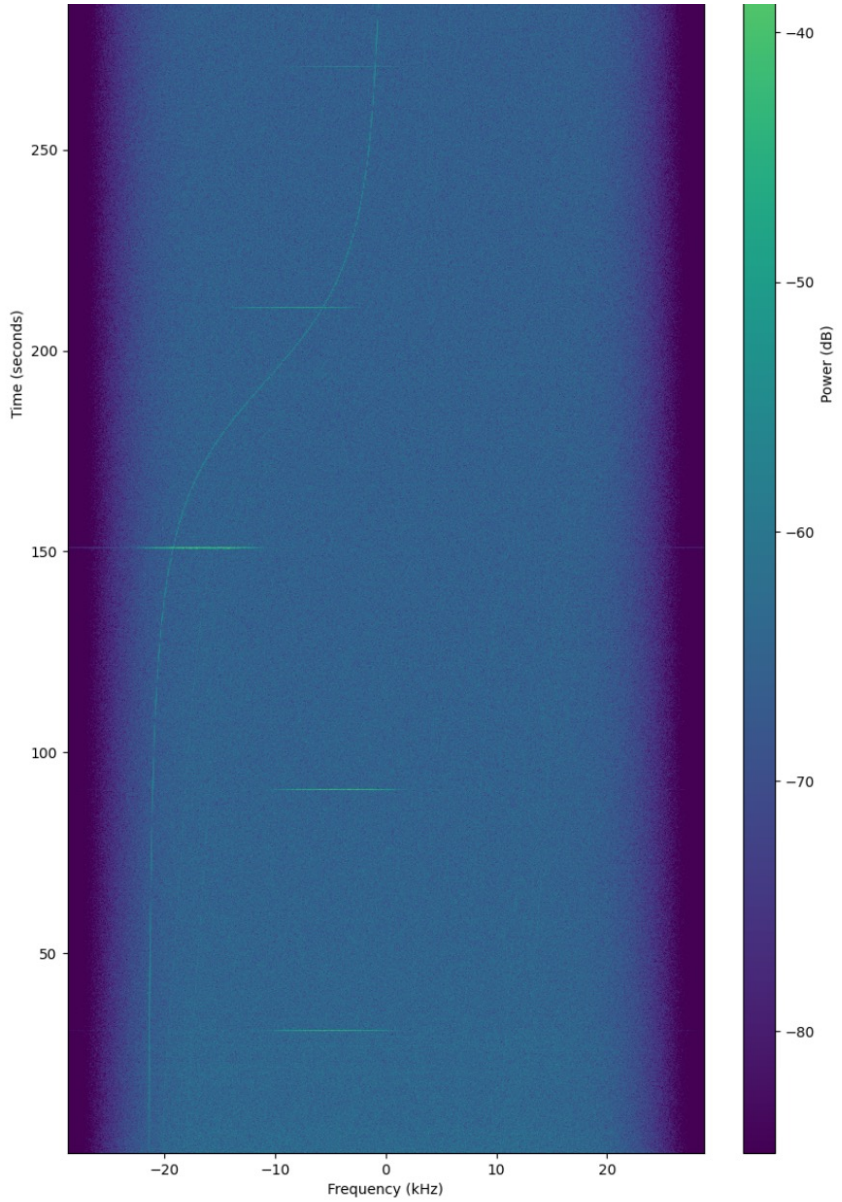
Core Temperatures

	min	max	avg
Battery Daughterboard Temperature	7.50 °C	41.00 °C	13.75 °C
Battery Motherboard Temperature	6.60 °C	40.20 °C	12.68 °C
EPS Temperature	5.20 °C	45.40 °C	12.68 °C

Panel Temperatures



Satellite	48850 - RamSat
Station	1089 - ZR6AIC Ground Station
Station Owner	Anton Janovsky
Observer	Fredy Damkalis
Status	Good
Transmitter	Mode U - FSK9k6
Transmitter Status	Unknown
Transmitter Frequency	436.300 MHz
Observation Frequency	436.300 MHz
Transmitter Mode	FSK 9600
Timeframe	2022-10-11 15:13:17 2022-10-11 15:19:55
Rise	310.0°
Max	39.0°
Set	144.0°
Client Version	1.4+12.gf5eb4c4
Polar Plot	
Downloads	Audio Waterfall



Waterfall | Audio | Data 2 | Metadata

ASCII | HEX | AX.25

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Waterfall | Audio | Data 2 | Metadata

ASCII | HEX | AX.25

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TLE used fetched from SatNOGS Team 8 months, 1 week ago

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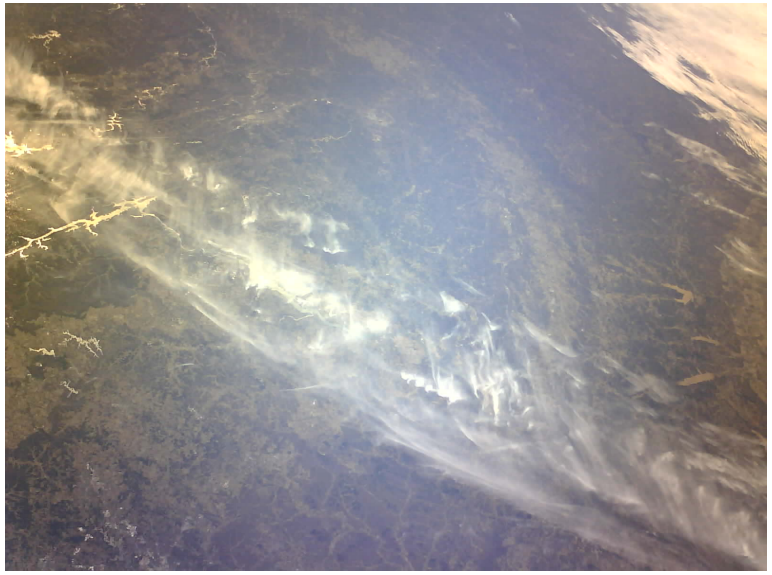
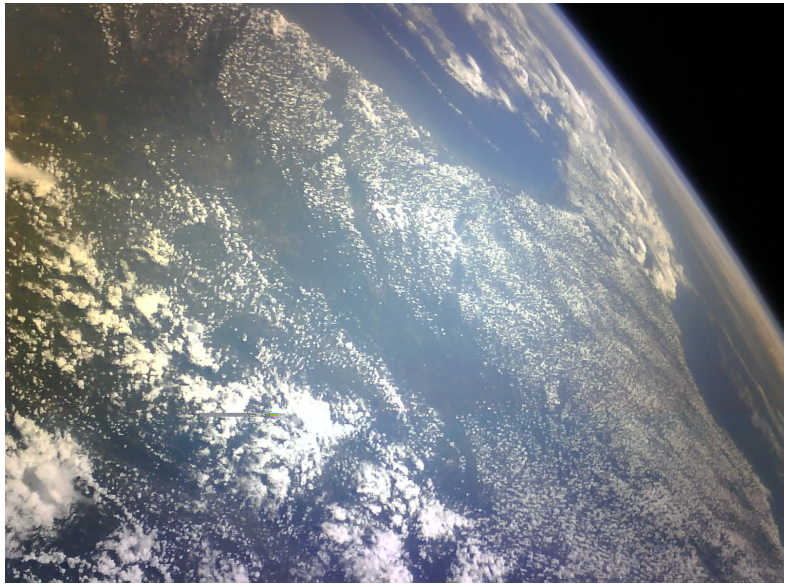
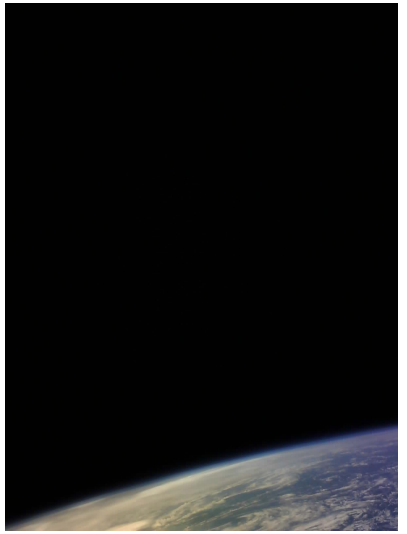
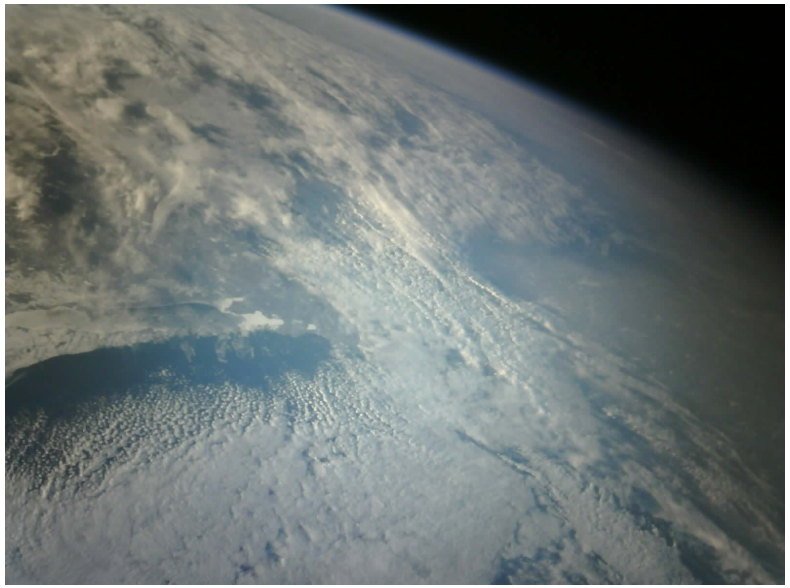
Ingredients for Success…

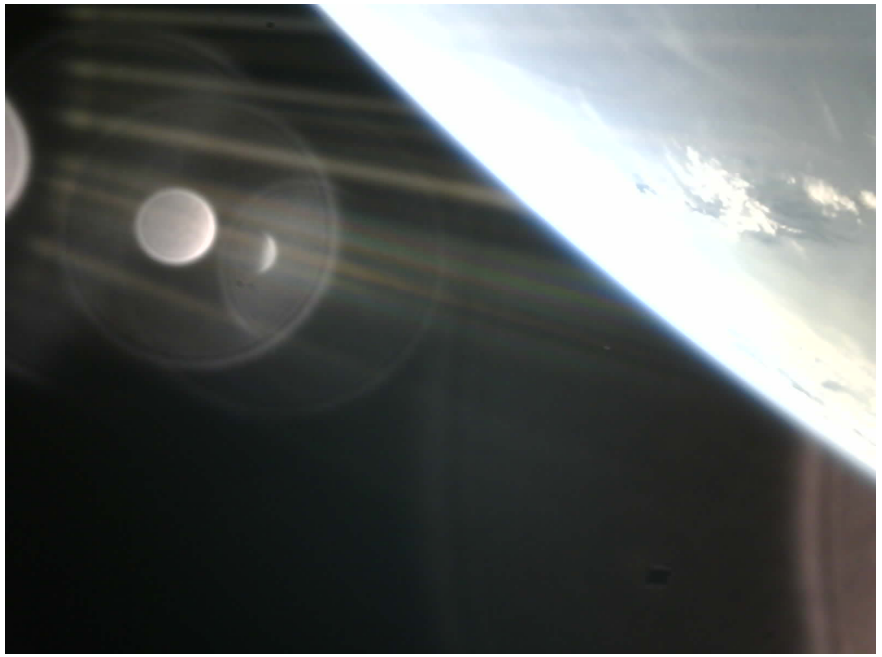
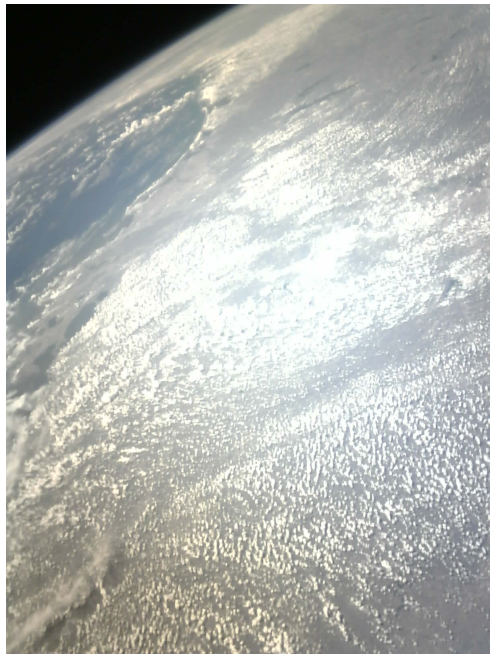
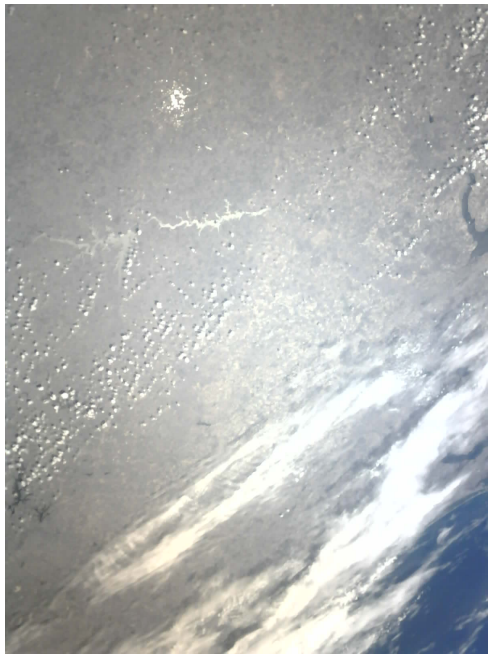
- Student-driven mission, problem-based learning
- Systems approach to mission planning and execution
- Collaboration and communication
- Regular engagement with sponsors, vendors, and flight partners
- Students, instructors, and mentors as a community of learning
- Open science consortium engaged a global community








Thank you!

Hardware specs

- Frame: Pumpkin 2U skeletonized
- Flight Computer: Pumpkin 2E motherboard, PIC24FJ256GB210 microcontroller
- EPS: Clyde Space 3rd Generation EPS
- Battery: Clyde Space 10WH
- Solar Panels: Pumpkin 2U (x4), 1U (x1).
- Coarse Sun Sensors: Integrated on Pumpkin 2U solar panels
- Op-Amps: project-built to support the sun sensors, based on Pumpkin schematic. Mounted on Pumpkin prototyping board.
- Magnetometer-Magnetorquer: iMTQ from ISIS
- Flight Radio: Helium-100 from Astronautics Development, Inc.
- Flight Antenna: ANTS UHF/VHF dual dipole, from ISIS
- Cameras: Arducam 2MP-Plus (2x), project-mounted to Pumpkin prototyping board

Hardware Specs (continued)

- Lenses: Lensagon BM10M5425, from Lensation. Low distortion, 40° field of view. One with NIR-cut filter, one without.
- Ballast: project-designed and locally machined aluminum block
- Wiring: PTFE insulated wiring and connectors sourced through Digikey. PTFE shrink tubing from FIT.
- SD Card: Delkin Devices 2GB (manufactured of PTFE)
- Serial Flash Memory: integrated on Pumpkin motherboard
- Button-Cell Battery: Panasonic BR-1225 3V
- Ground Station: Kenwood TS-2000 transceiver, Kantronics 9612 XE TNC, Yaesu G-5500 Az/El controller, M2 LEO-Pack VHF/UHF antenna array (student-designed and manufactured antenna stand on roof), SSB SP-70 pre-amp

Software

- Flight software is interrupt-driven, written from scratch, in C, and available on github
  - thorntonpe/RamSat_flight: Flight software for RamSat mission (github.com)
  - Executes at about 20 Hz
  - Custom implementation of SGP4 for on-board orbital calculation, with uplinked TLE
  - Custom implementation of World Magnetic Model for magnetic field calculations based on calculated position
- Ground station command and control software is custom written in C#
  - Supports one-click common commands, and custom commands
  - Includes security features
  - Includes image stitching capability