



March 11th, 2020

SeaHawk-1: The First dedicated Ocean Color CubeSat

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riverocalles@uncw.edu



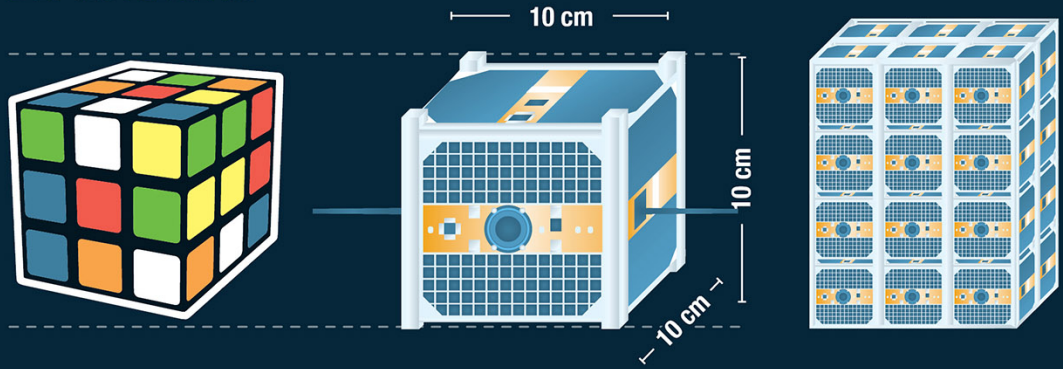
Agenda

- **What is a CubeSat?**
- **Why the SOCON mission?**
- **Key Mission parameters**
- **Platform and sensor details**
- **Integration and launch**
- **Examples of imagery**
- **Data processing and distribution:**
 - SEADAS, ocean color website
- **Next steps**
 - Finish commissioning
 - Open to the community
 - Image requests

What is a CubeSat?

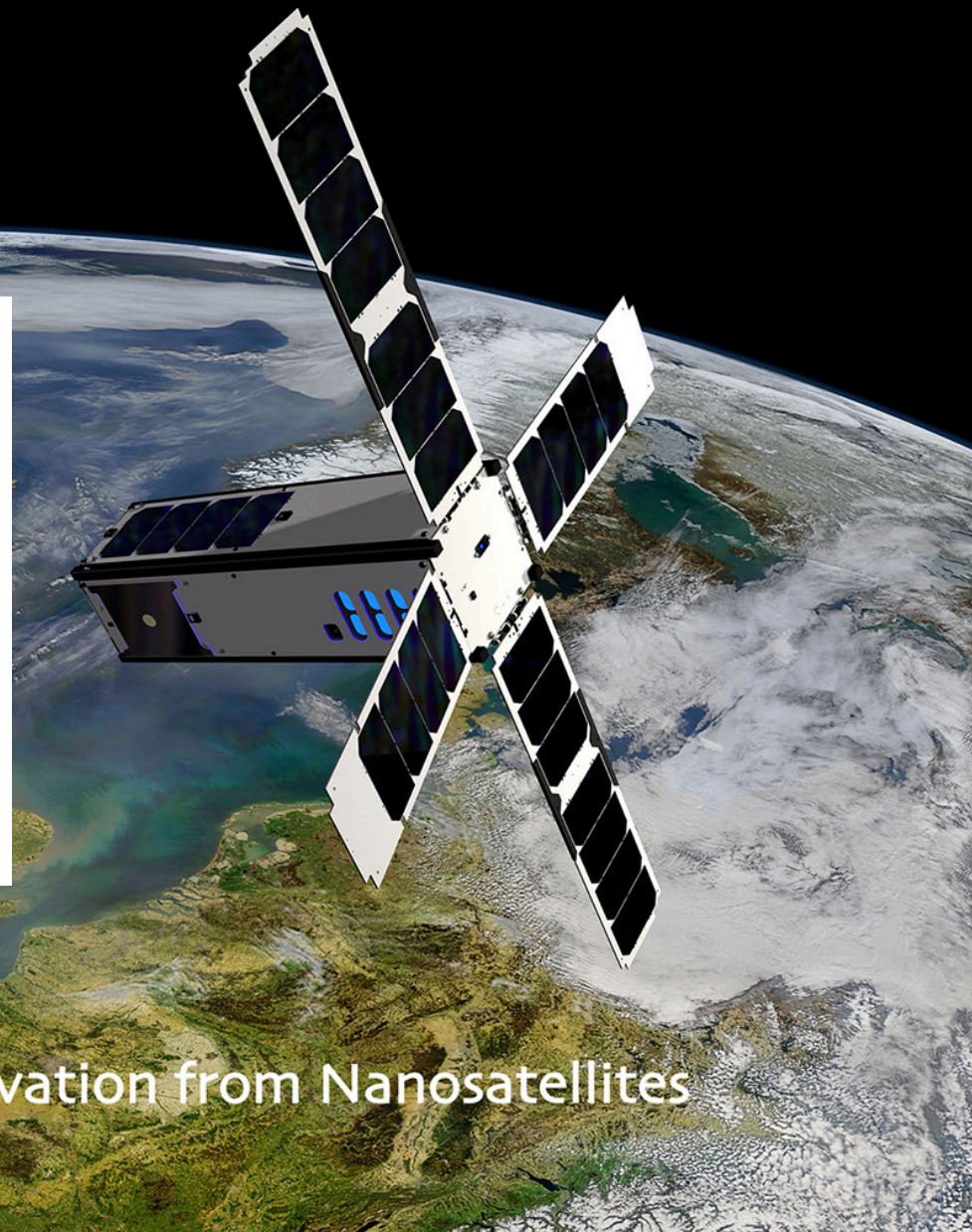
A
CUBESAT
is a
MINIATURE
CUBE-
SHAPED
SATELLITE.

DIMENSIONS



USED ALONE (1 unit) --- OR --- CAN BE STACKED Maximum of **24** units

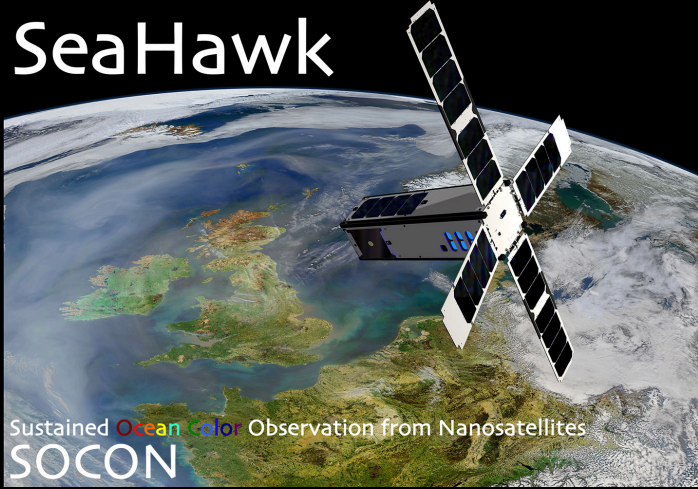
- Proof-of-concept project
- Demonstrate capability to build a low-cost ocean color sensor flown aboard a CubeSat
- Provide high spatial resolution imagery



Sustained Ocean Color Observation from Nanosatellites
SOCON



SeaHawk



GOAL

Construct a launch-ready, high resolution (~120m) proof-of-concept ocean color instruments able to be carried by a 3U CubeSat – **we built 2**



Funded the program in 2015

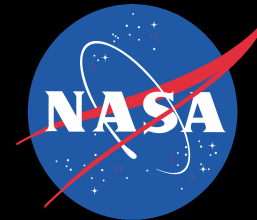
The program is administered by Dr. John Morrison



Hawkeye Sensor



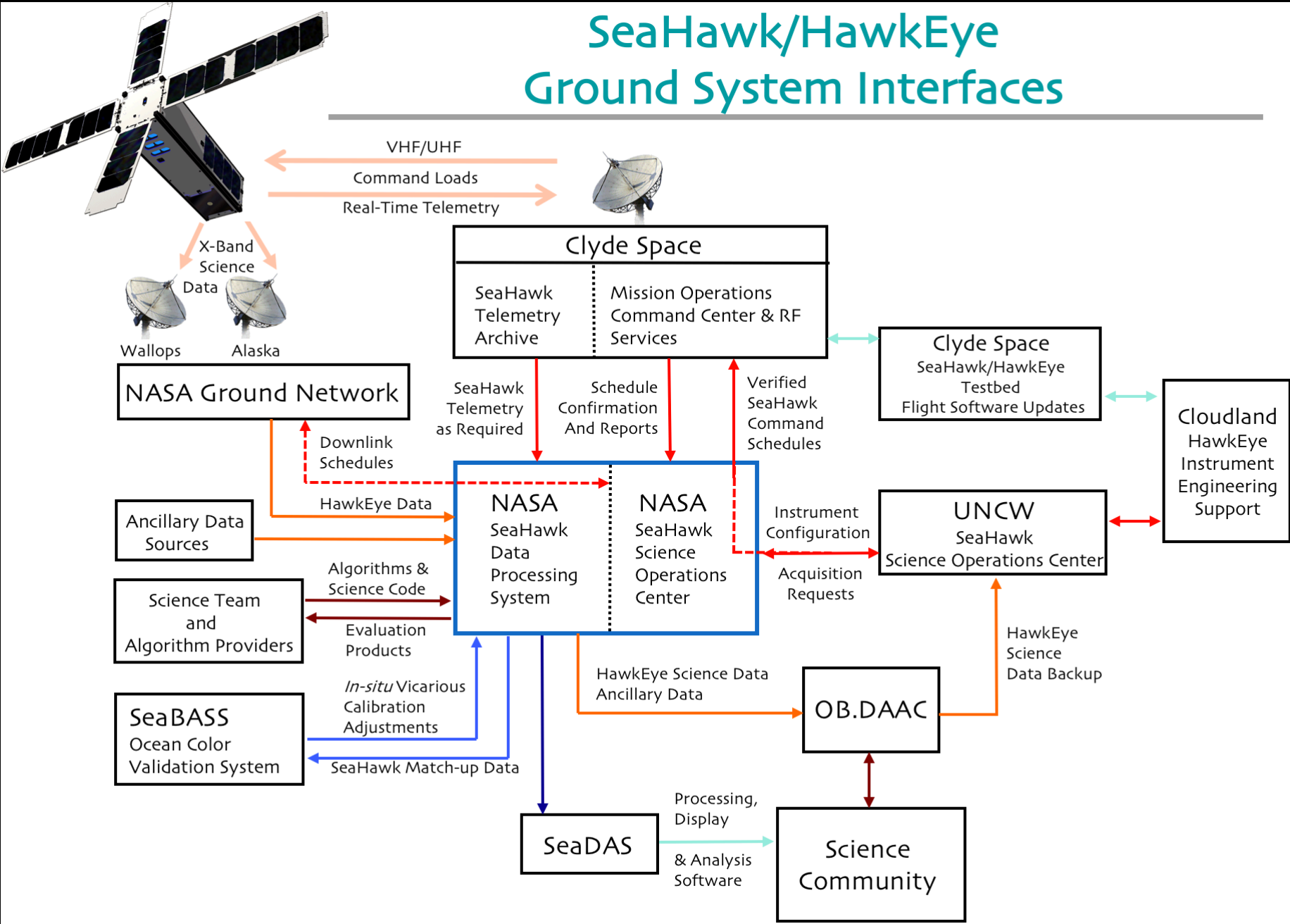
SeaHawk CubeSat bus



- “advice and review” during the development phase.
- support for the collection, processing, calibration, validation, archive and distribution of the data, thanks to a NASA/HQ Space Act Agreement (2017) .

A second Moore Foundation grant was awarded in May 2017 to support the cost of launch and operations for a duration of 2 years each

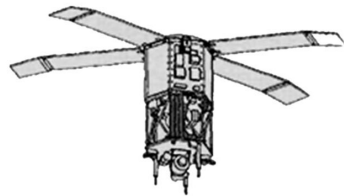
SeaHawk/HawkEye Ground System Interfaces



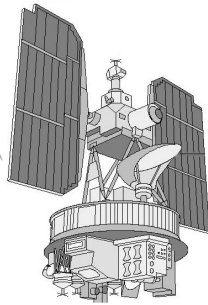
Ocean Color Satellites 1978 - Today



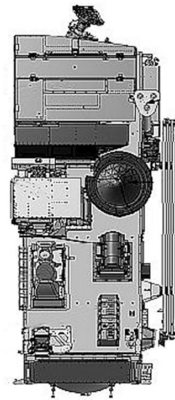
SeaHawk
2018
5 kg



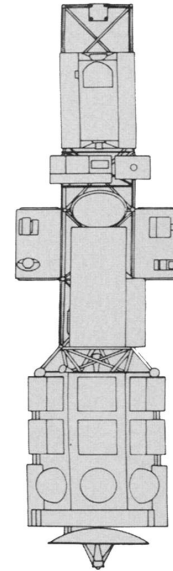
SeaStar
SeaWiFS
1997
309 kg



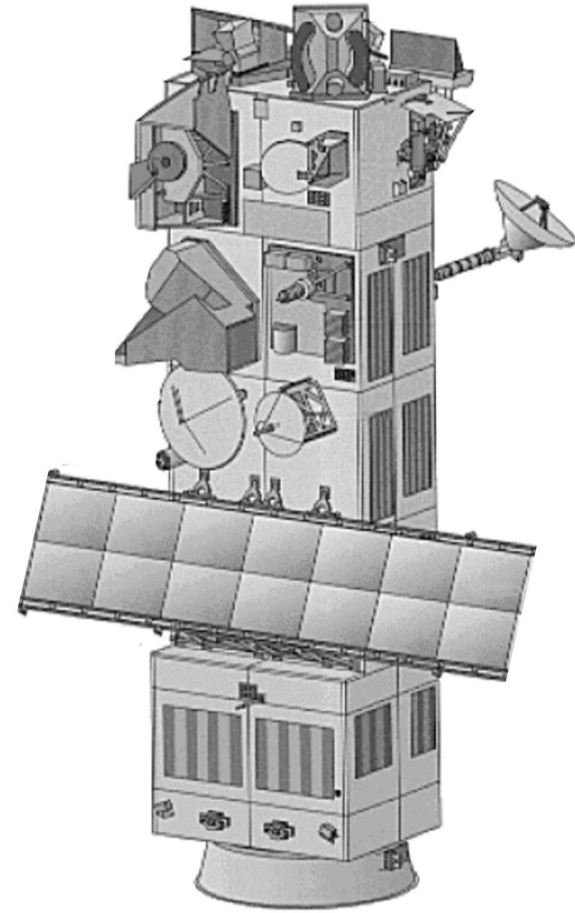
Nimbus-7
CZCS
1978
832 kg



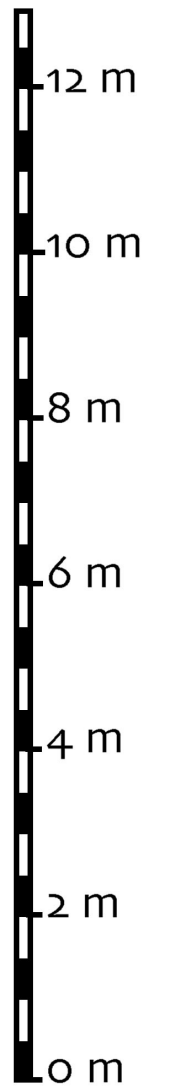
JPSS-1
VIIRS
2017
2294 kg



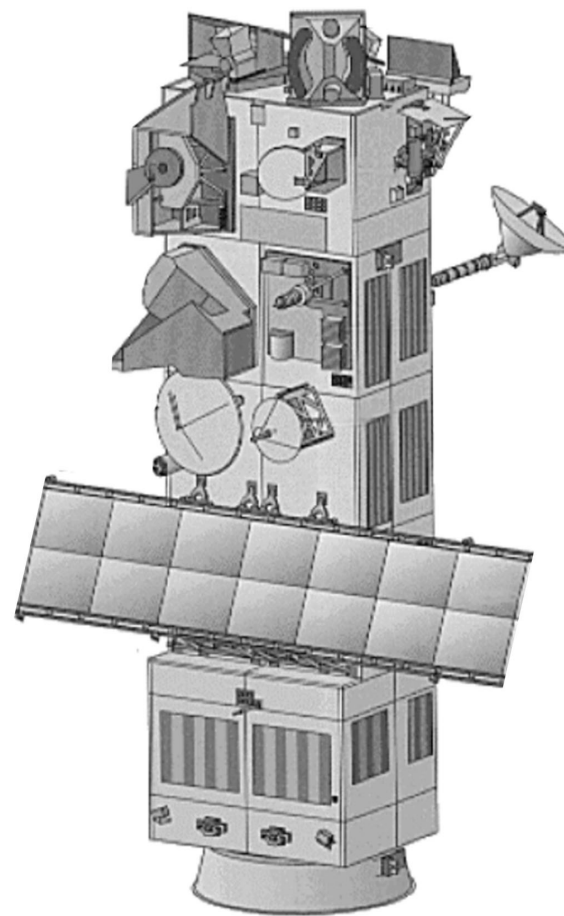
EOS-Terra
MODIS
1999
4,864 kg



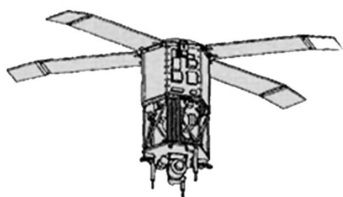
Envisat
MERIS
2002
8140 kg



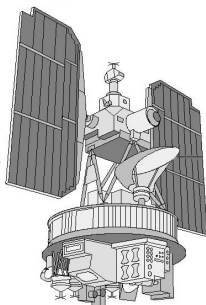
Satellite
Sensor
Launch Date
Weight



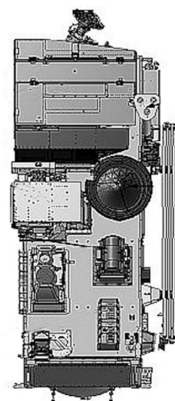

SeaHawk
 2018
 5 kg



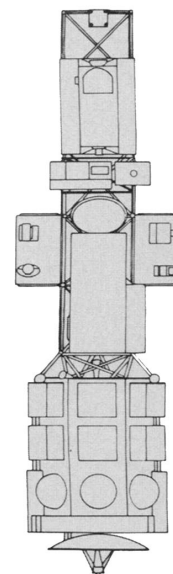
SeaStar
 SeaWiFS
 1997
 309 kg



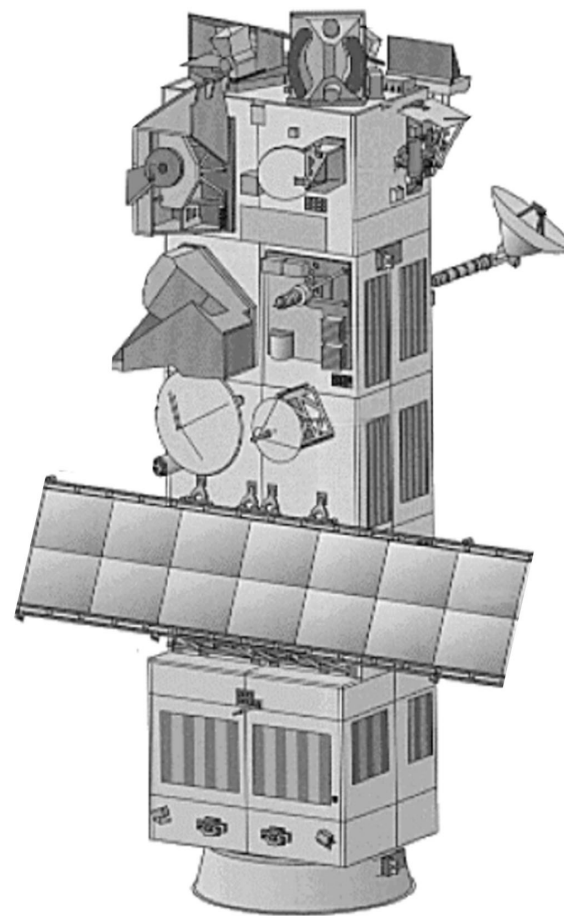
Nimbus-7
 CZCS
 1978
 832 kg



JPSS-1
 VIIRS
 2017
 2294 kg



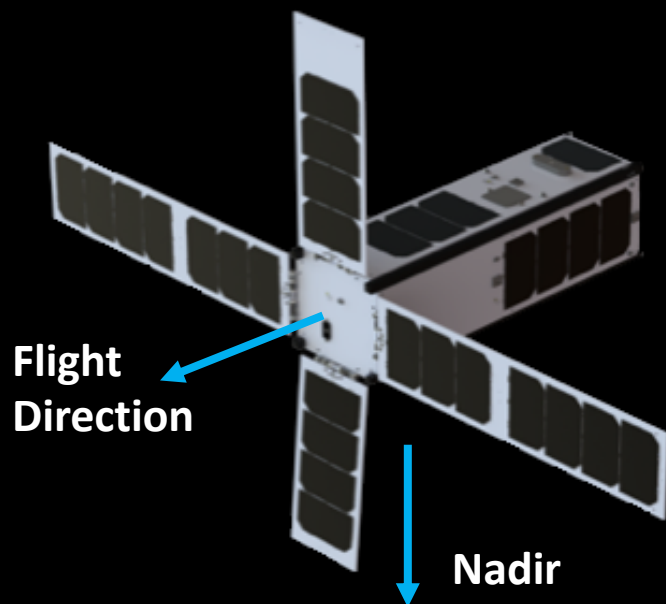
EOS-Terra
 MODIS
 1999
 4,864 kg



Envisat
 MERIS
 2002
 8140 kg

Satellite
 Sensor
 Launch Date
 Weight

Key Mission Parameters



Launched 3 December 2018

Nominal orbital height = 585 km

Sun-synchronous around 10:30am

18-day repeat orbit (one satellite)

Expected orbital lifetime of 5 years

Image size of 216 x 720 km (1800 x 6000 pixels)

Approximately 120 m resolution – 100 MB/scene)

X-band downlink (Wallops & Alaska) data rate of 6 --> 100 Mbps

Weight of instrument is <1 kg

Total weight (spacecraft + instrument) is <5 kg

Multispectral instrument: 8 ocean color bands

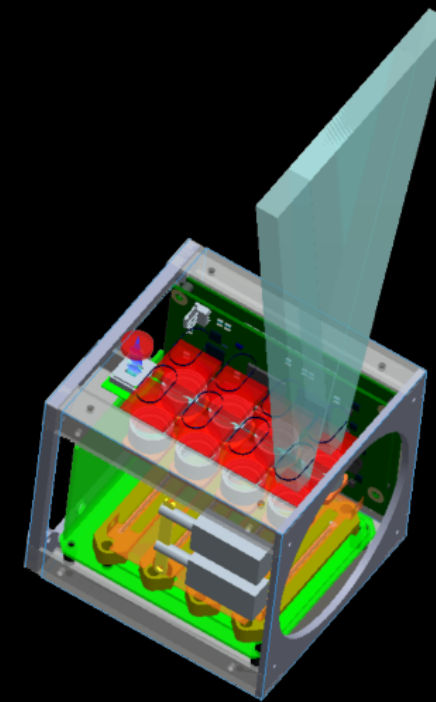
Off-the-shelf CCD arrays

Push-broom design

Sensitivity comparable to SeaWiFS

Open intellectual property and knowledge sharing

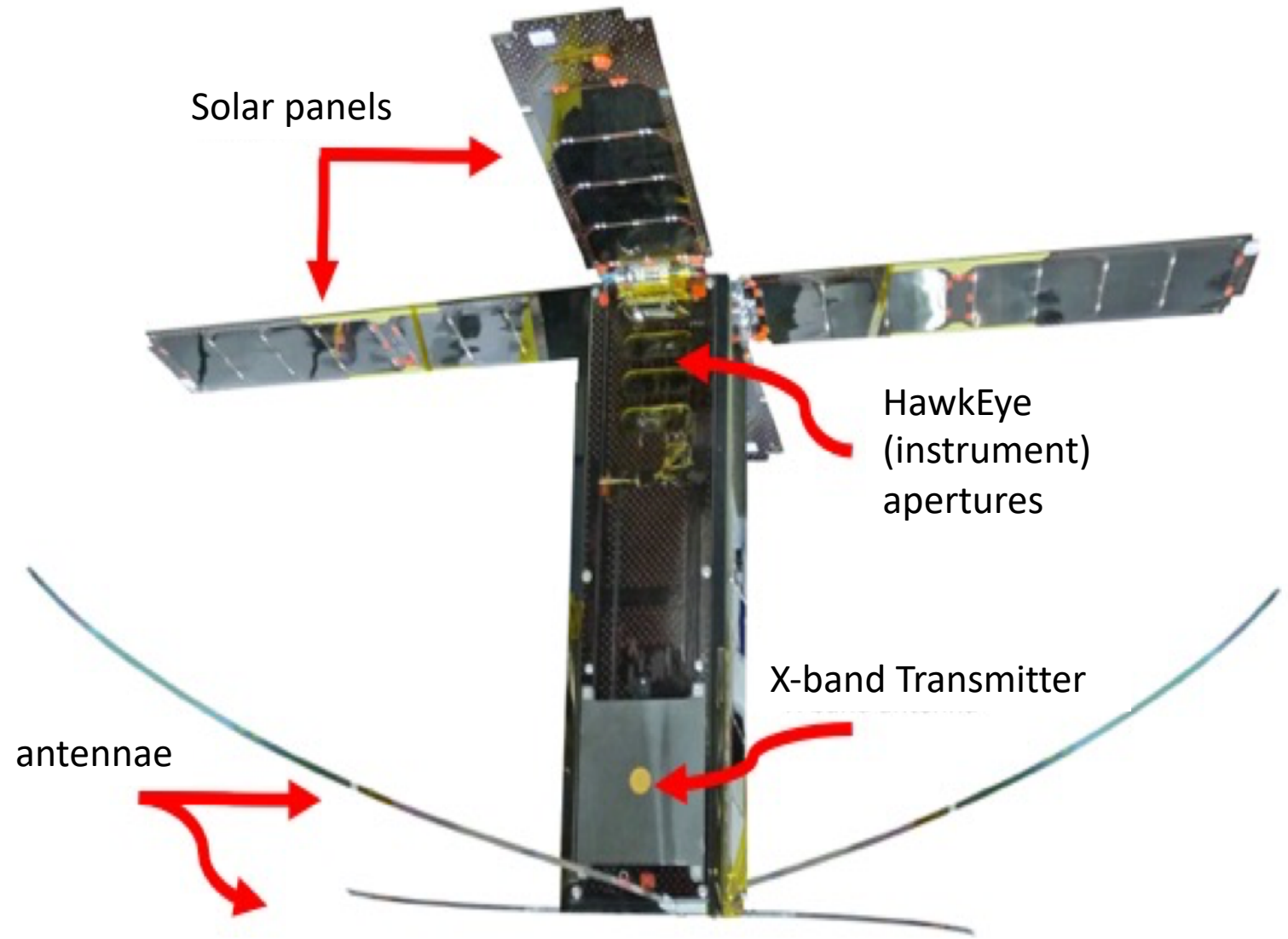
Does not saturate over clouds or land (bi-linear gain technique)



SeaHawk 3U CubeSat



- HawkEye Payload
- Payload Interface Module
- 3G FlexU EPS
- X-Band Transmitter
- 3-Axis Reaction Wheels
- ADCS Motherboard
- 3G Standalone Battery
- On Board Computer
- UHF/VHF Transceiver
- Umbilical Interface Module & GPS
- Antenna
- Deployment Module



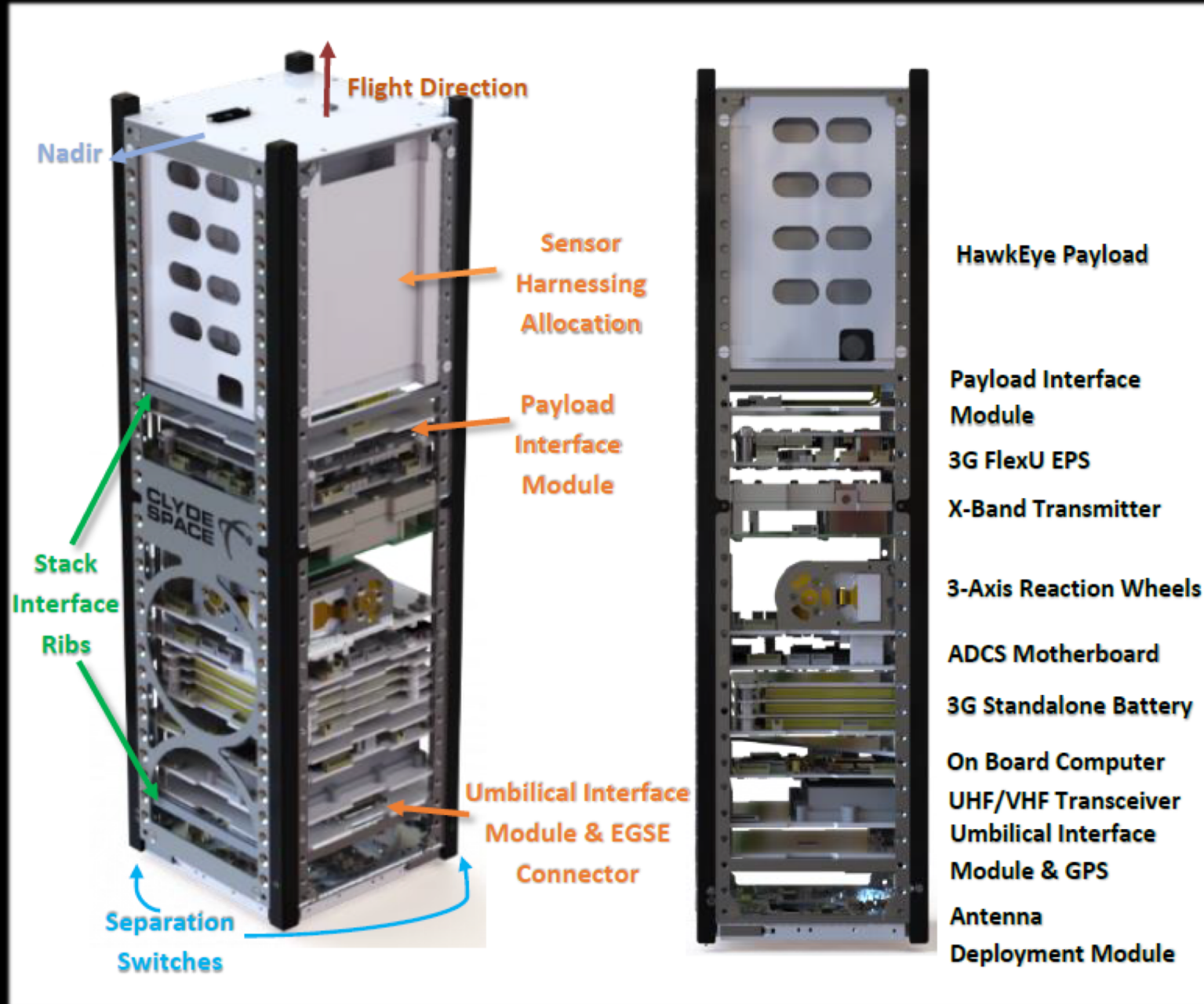
Solar panels

HawkEye (instrument) apertures

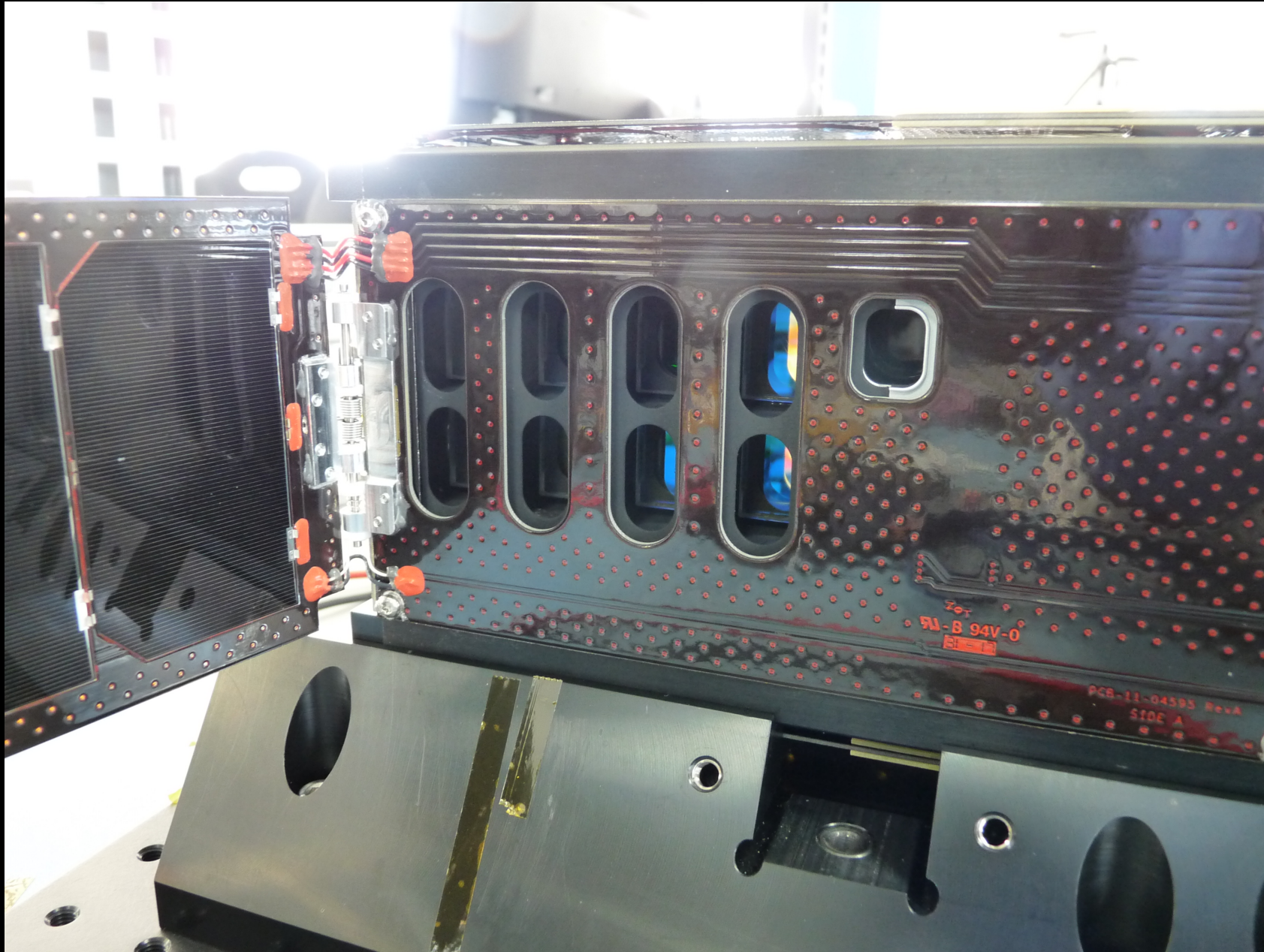
X-band Transmitter

antennae

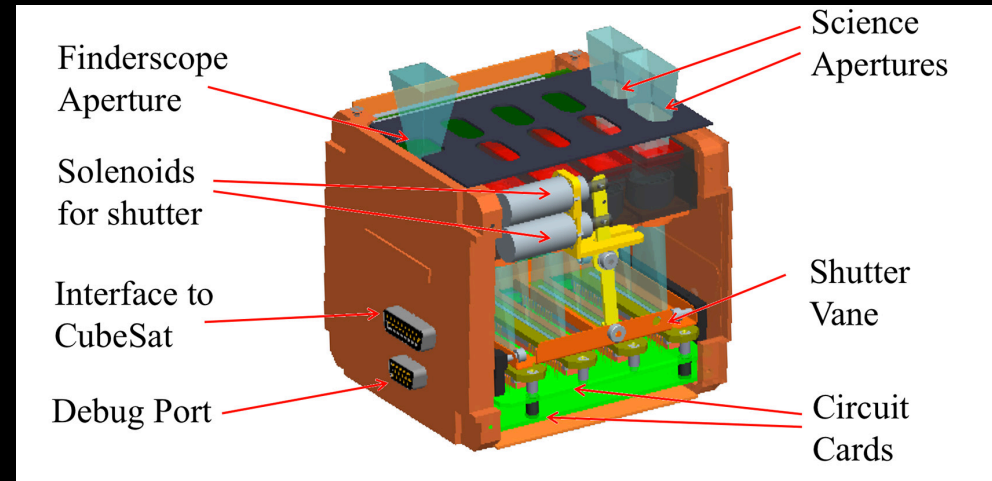
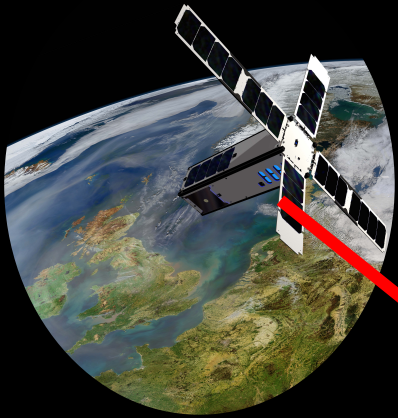
SeaHawk Internal Configuration



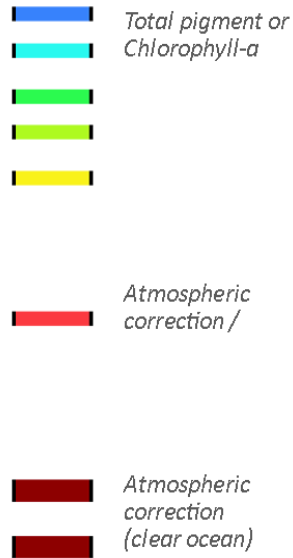
HawkEye Instrument



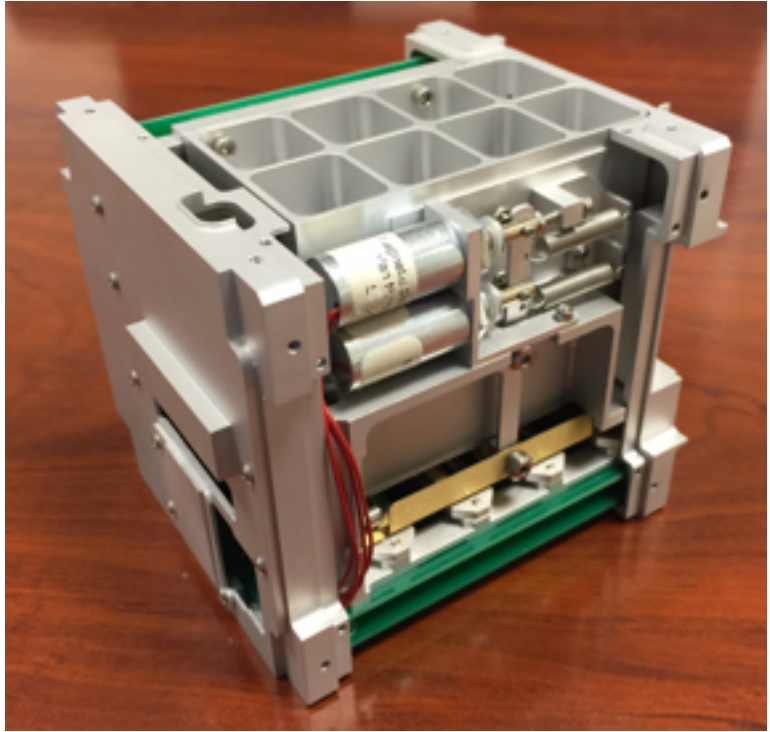
HawkEye Instrument



	Band #	Wavelength (nm)	Band width (nm)
ULTRA-VIOLET	Band 1	412	20
	Band 2	443	20
	Band 3	490	20
	Band 4	510	20
VISIBLE	Band 5	555	20
	Band 6	670	20
NEAR INFRARED	Band 7	750.9	14.7
	Band 8	865	40

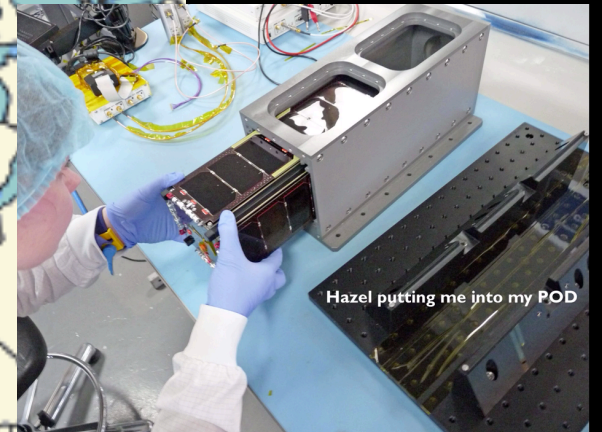


← same design as SeaWiFS except for band 7



Alan Holmes with HawkEye Units 1 & 2

SeaHawk's journey



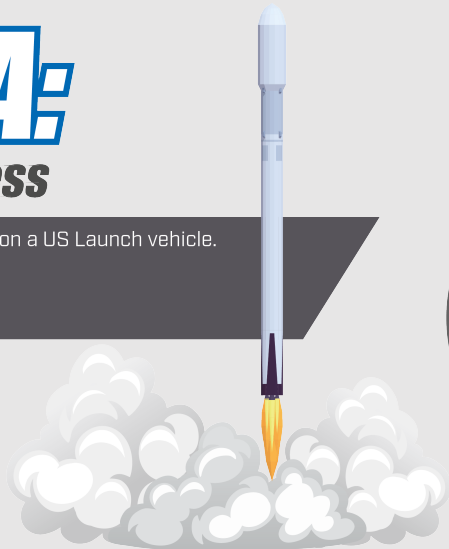


SSO-A: the largest single rideshare mission from a US-based launch vehicle



SSO-A: Smallsat Express

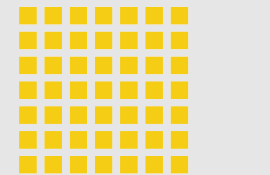
Single largest dedicated rideshare mission on a US Launch vehicle.
 Launch Vehicle: SpaceX Falcon 9
 Launch Site: Vandenberg Air Force Base
 Destination: Sun Synchronous Lower Earth Orbit



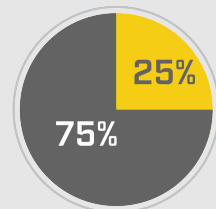
Microsats: 15



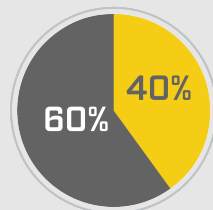
Cubes: 49



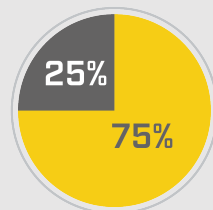
Countries represented: 17



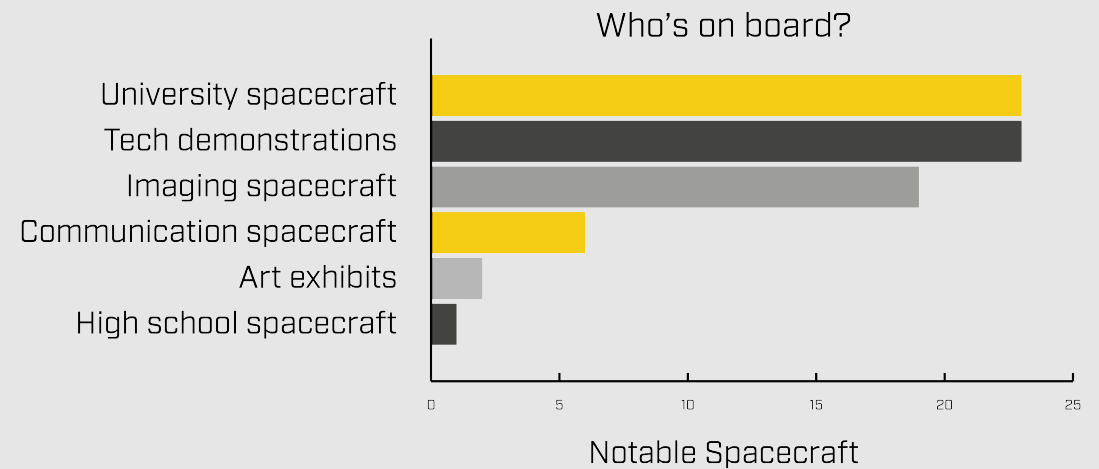
■ First time customers ■ Return customers



■ International ■ Domestic



■ Commercial ■ Government



SeaHawk-1 Integrated into Lower Free Flyer



SeaHawk-1



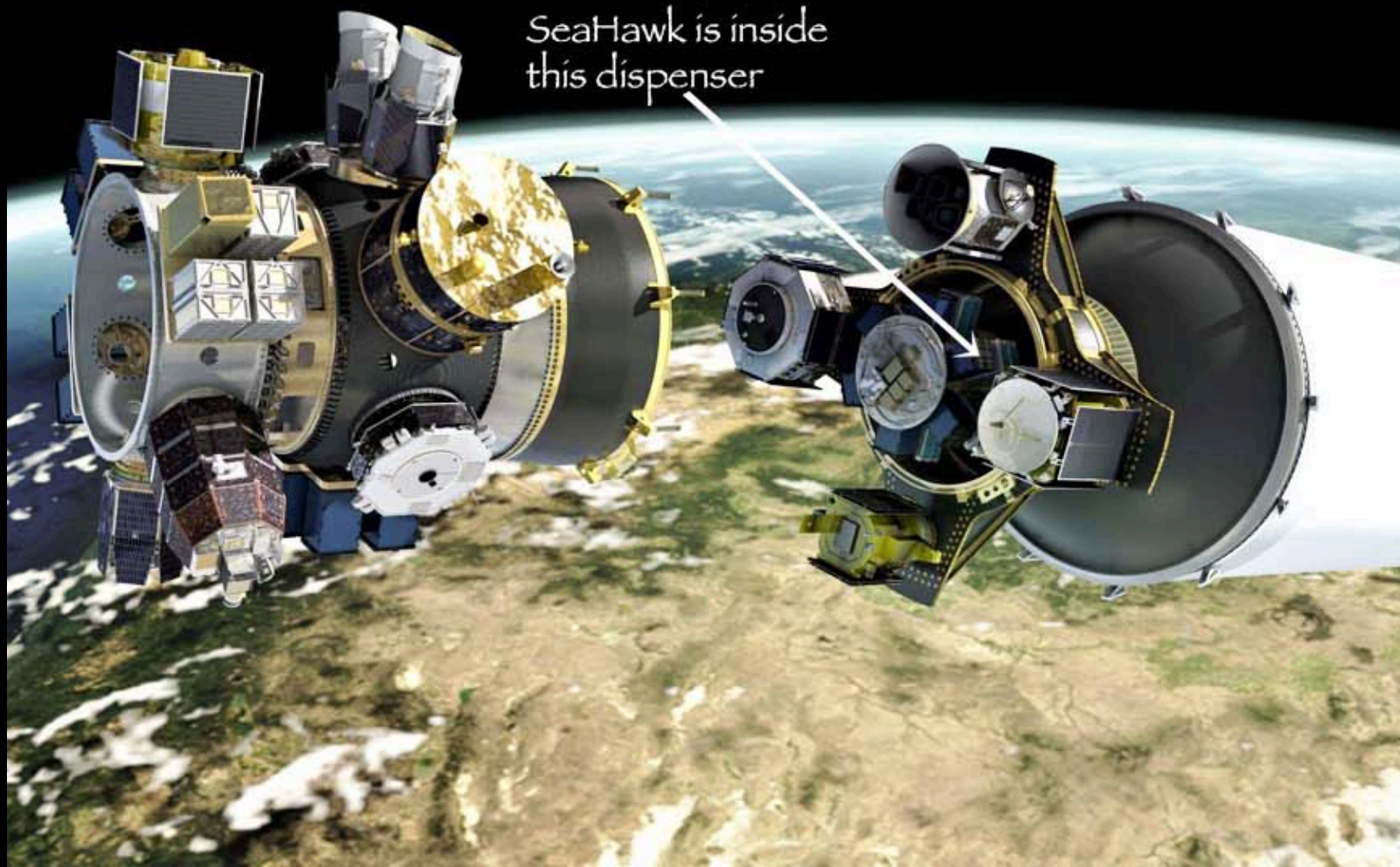
Launch!

On Monday, **December 3rd** at 10:34 a.m. PST, SpaceX successfully launched Spaceflight SSO-A: SmallSat Express to a low Earth orbit from Vandenberg Air Force Base, California.



Detachment

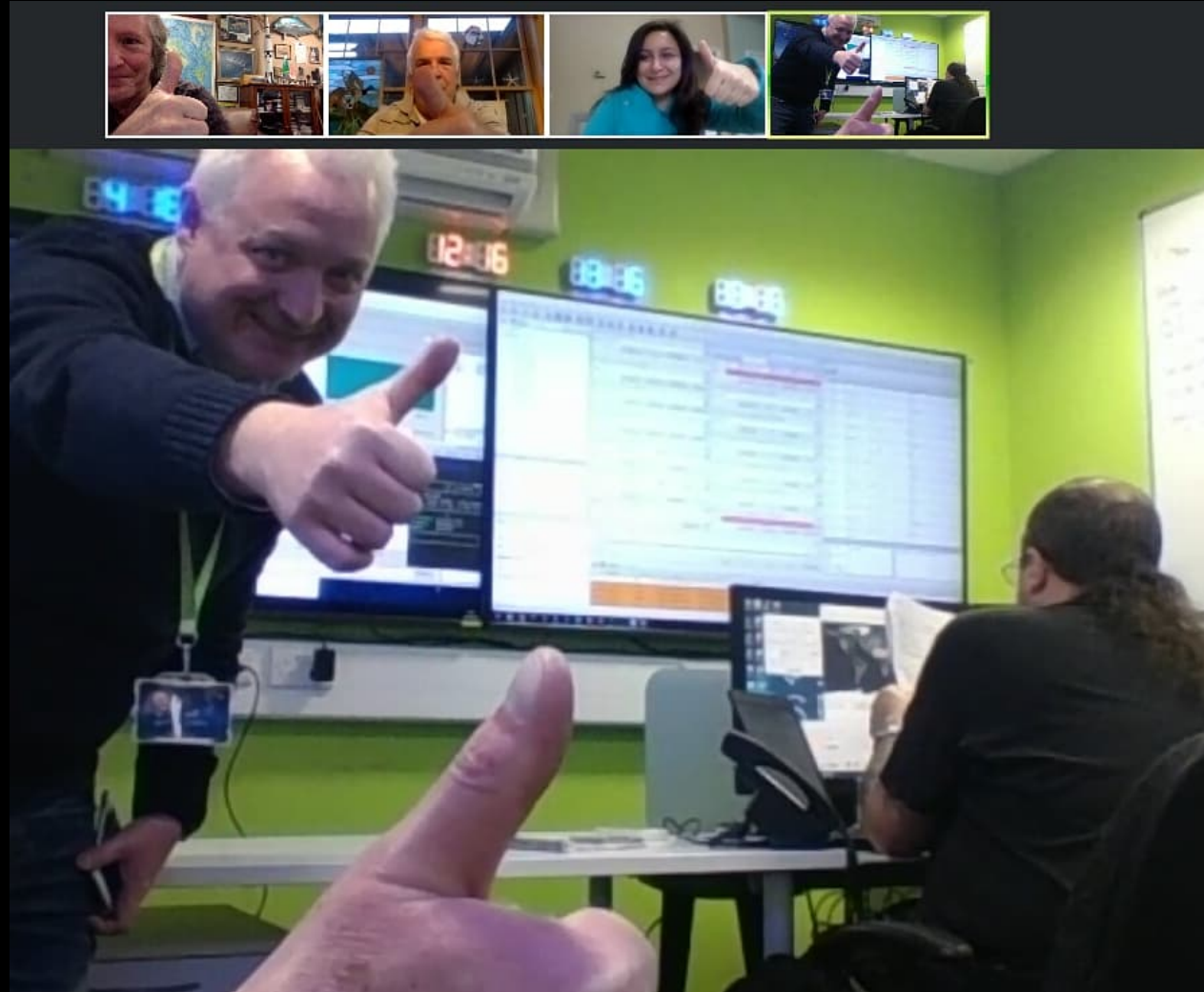
SPACEFLIGHT



Deployment



FIRST CONTACT: Communication with ground station



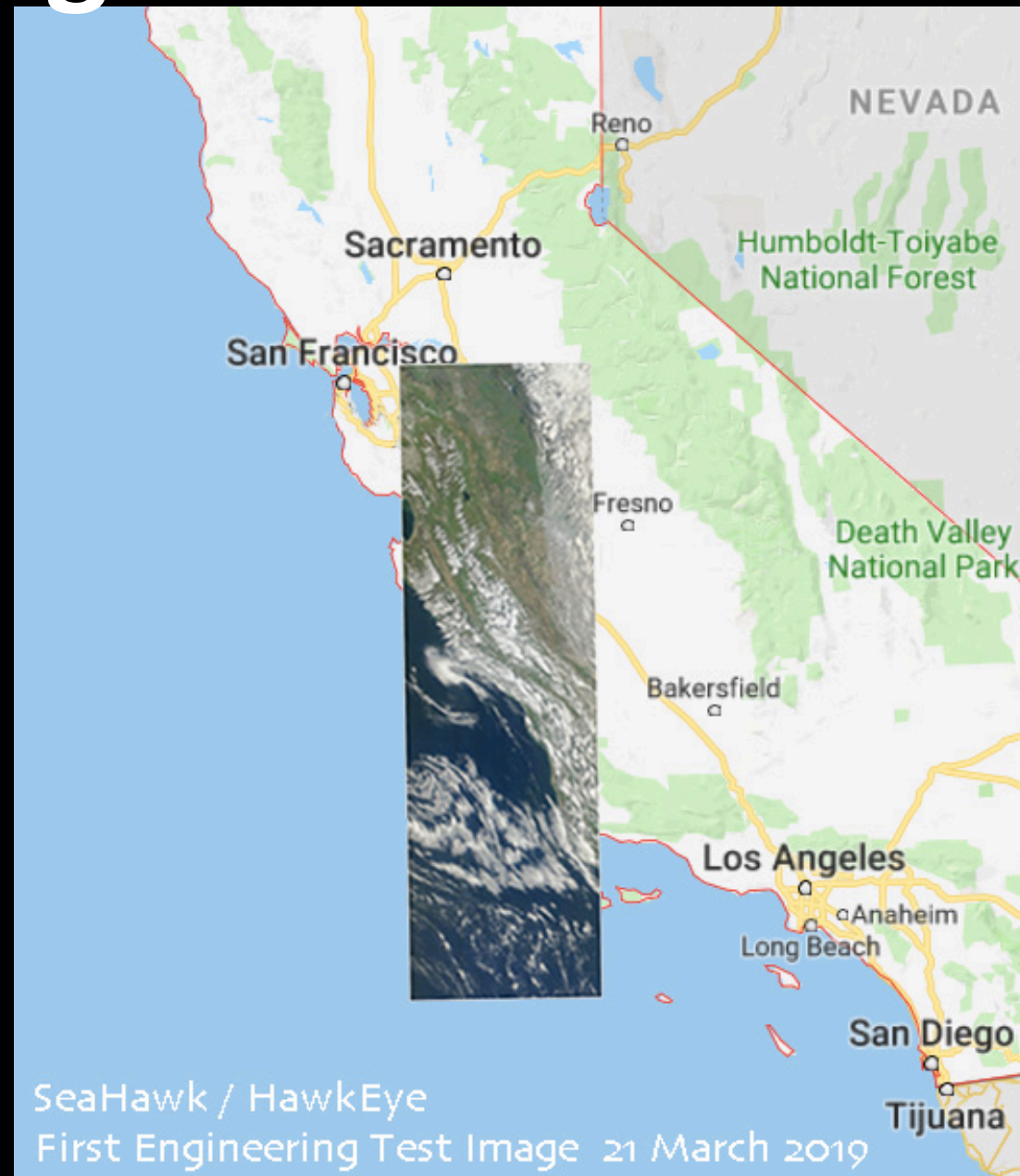
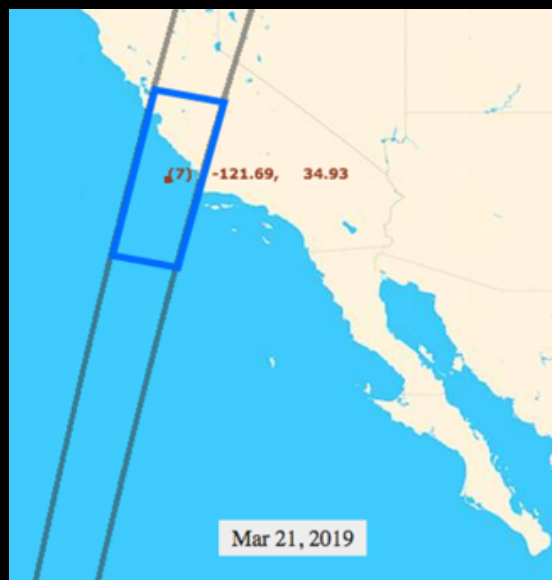
First Light

Sequence of Events:

20 March: X-panels deployed
HawkEye optics exposed

21 March: 1st image acquired

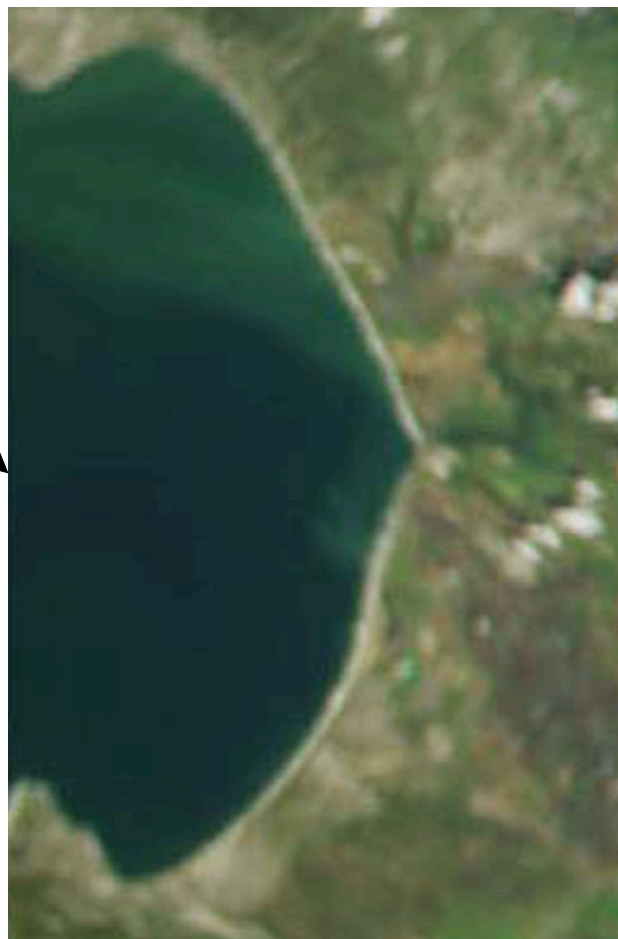
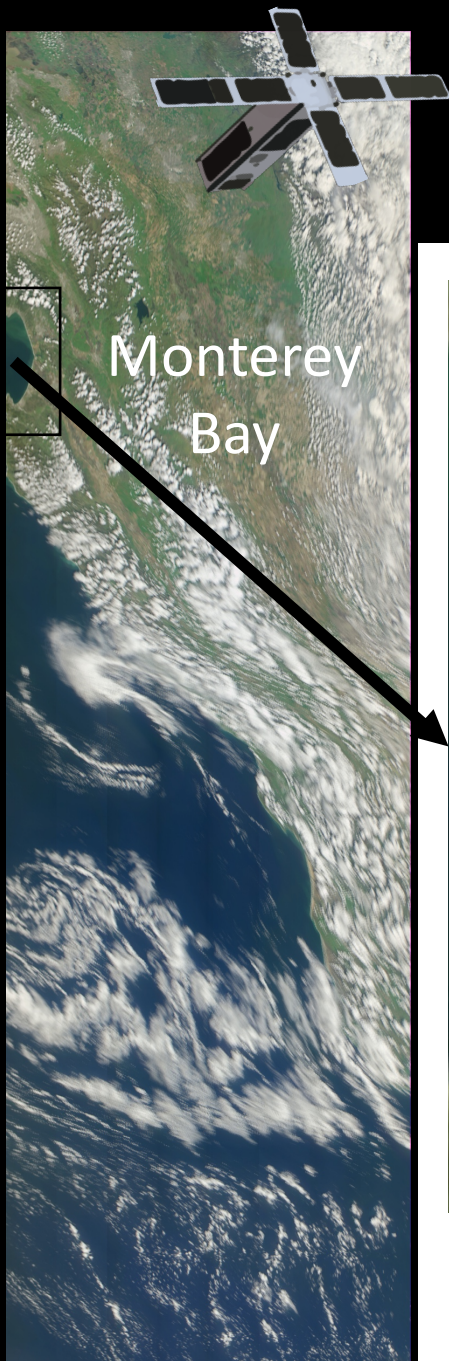
22 March: Wallops X-band downlink 50 mbps



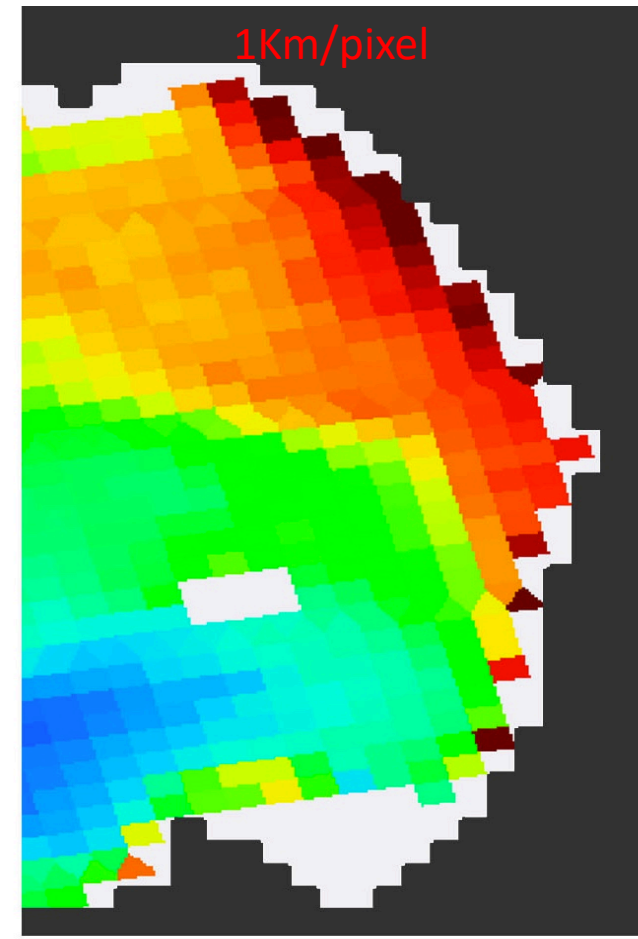
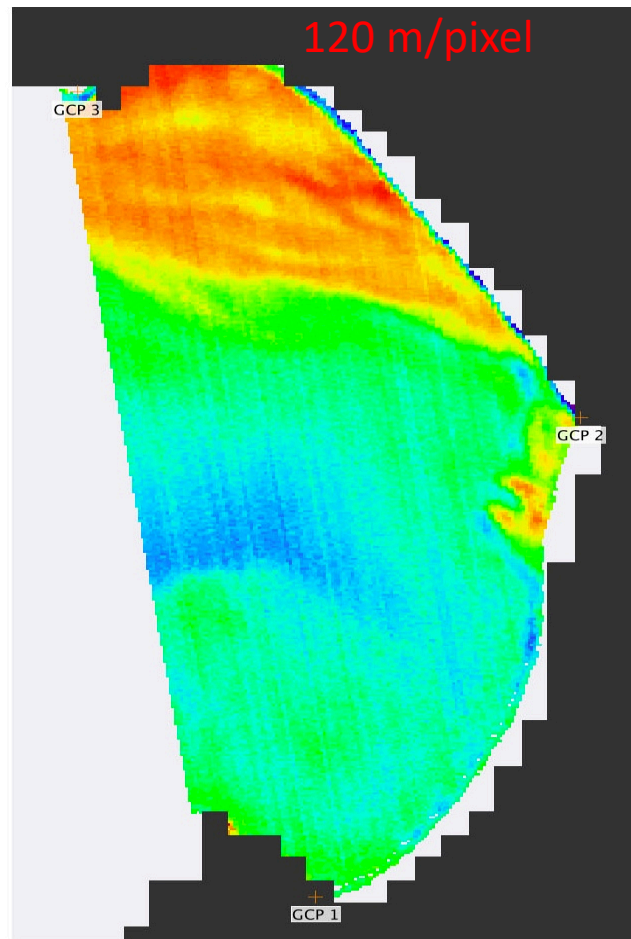
First Engineering Test Image

SeaHawk/HawkEye

MODIS/Aqua

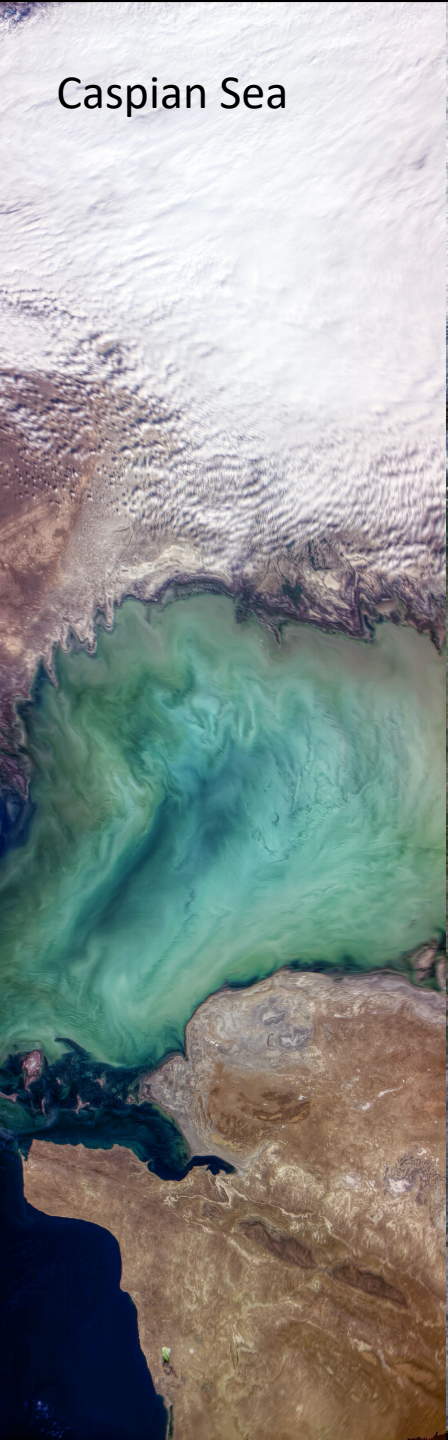


True color
(red band-6 (670nm), green band-5 (555nm)
and blue band-2 (443nm))

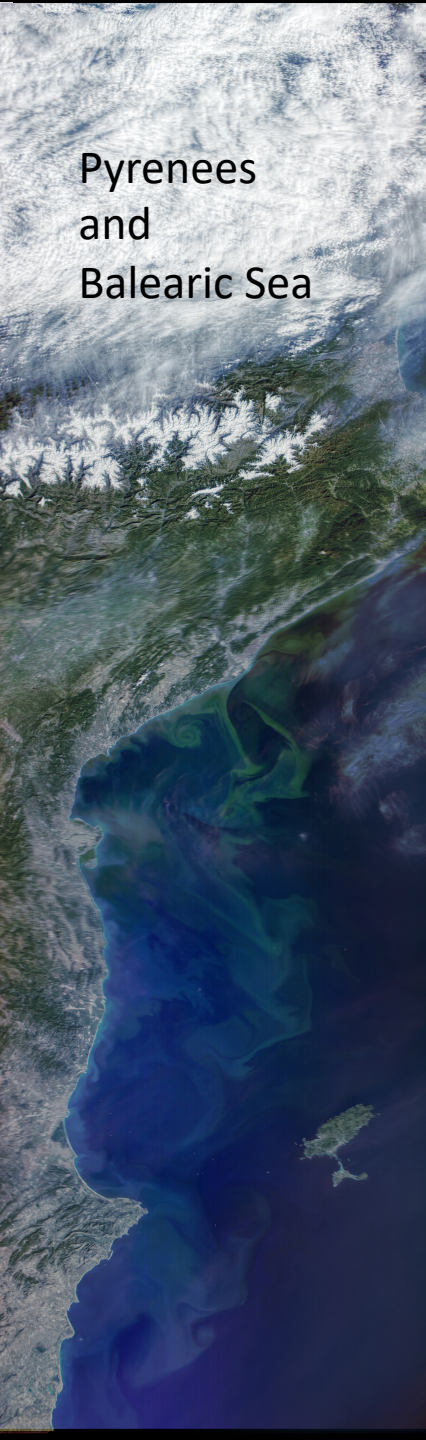


March 21st, 2019

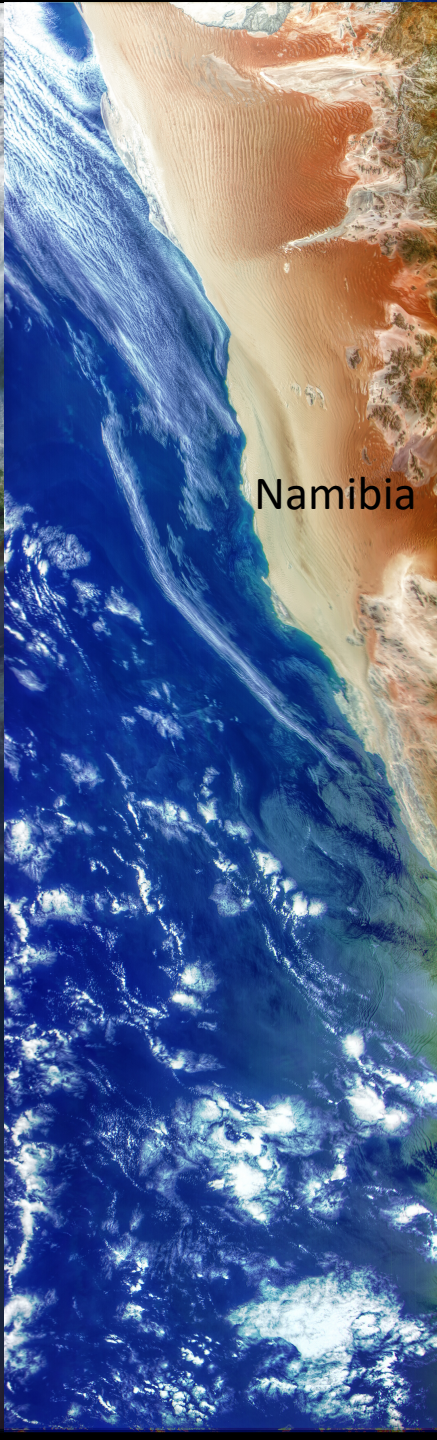
Proof of Concept
CONFIRMED



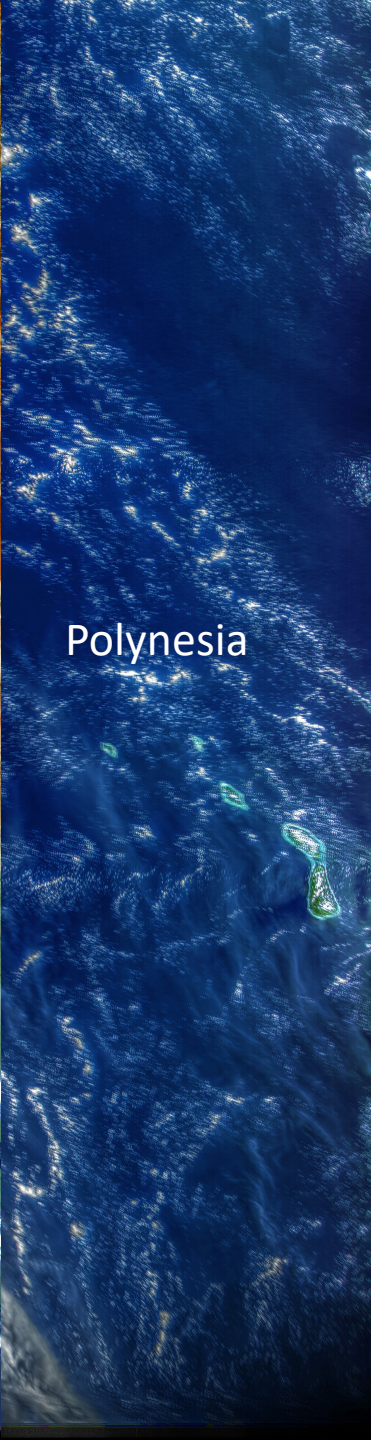
Caspian Sea



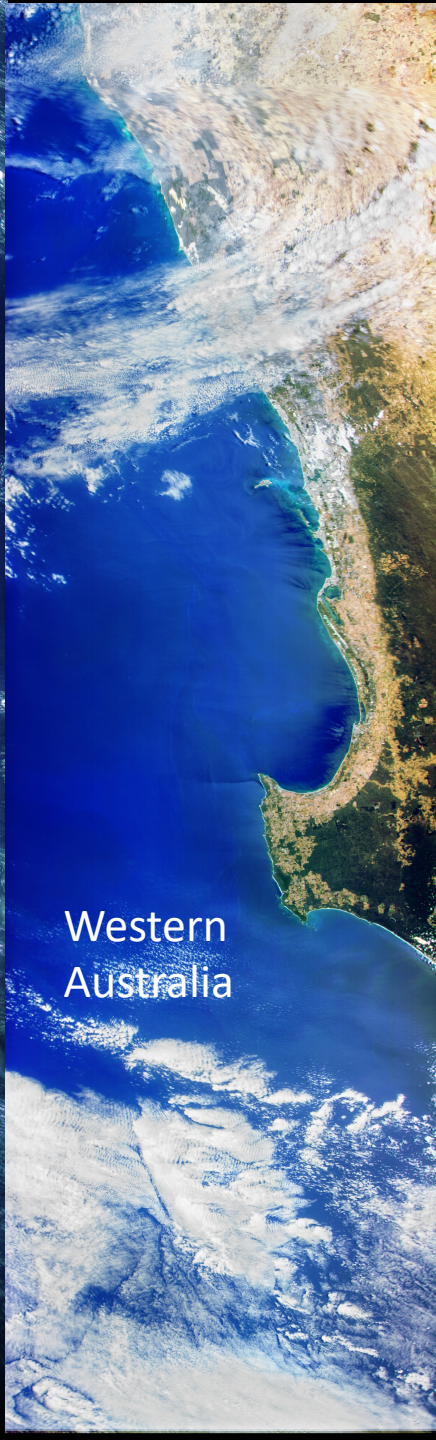
Pyrenees
and
Balearic Sea



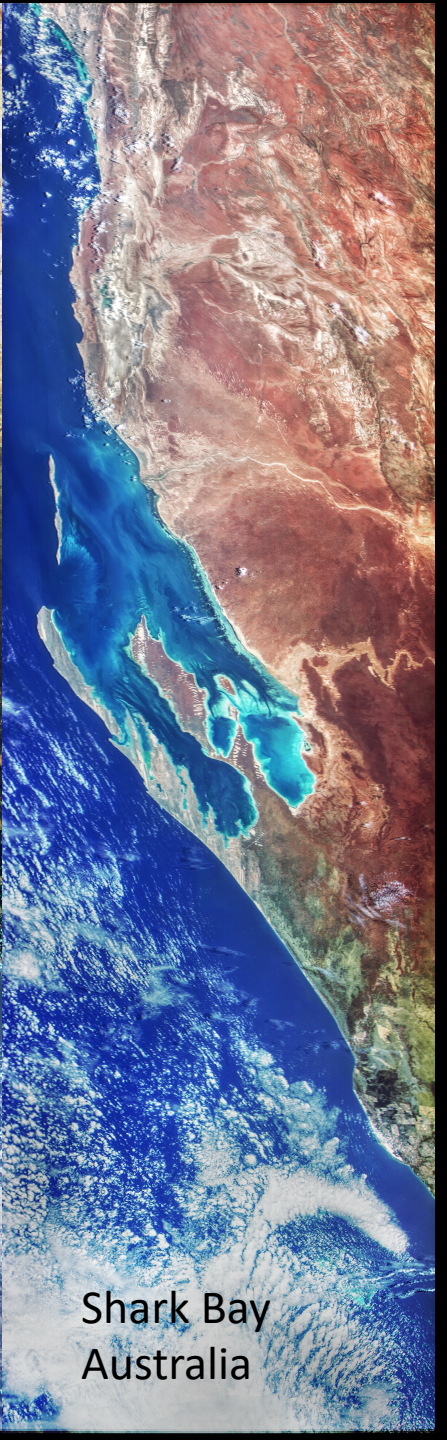
Namibia



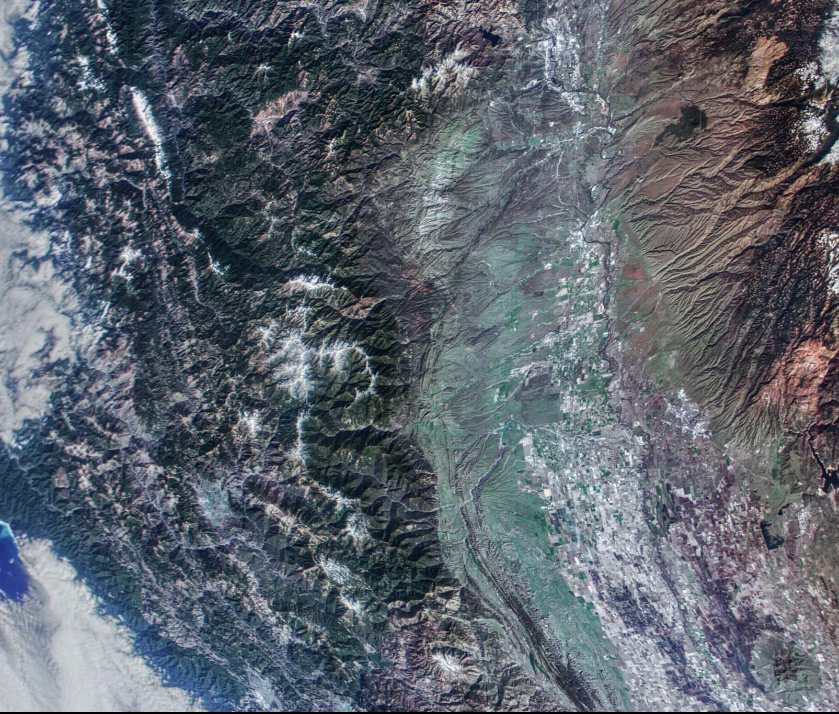
Polynesia



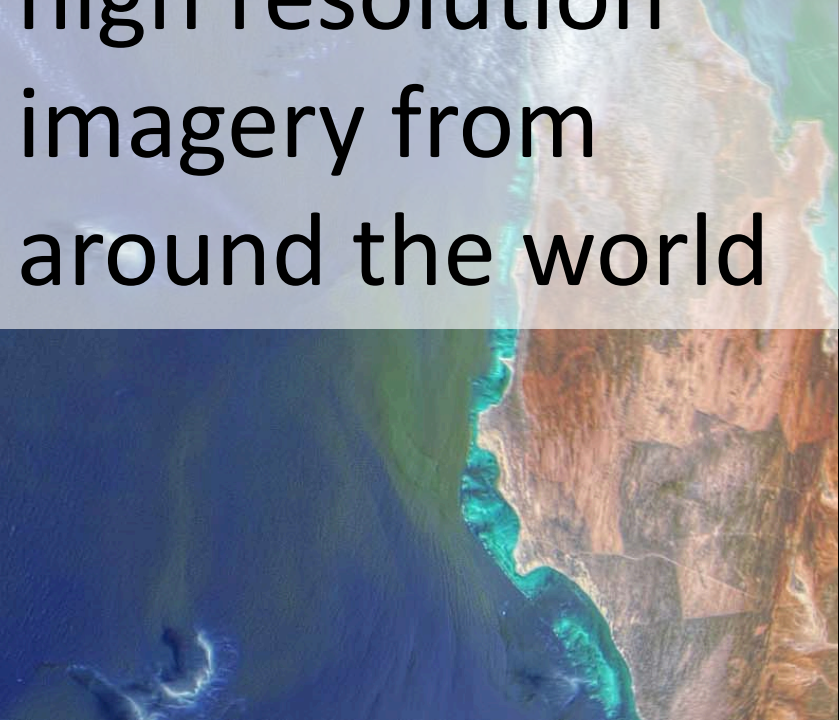
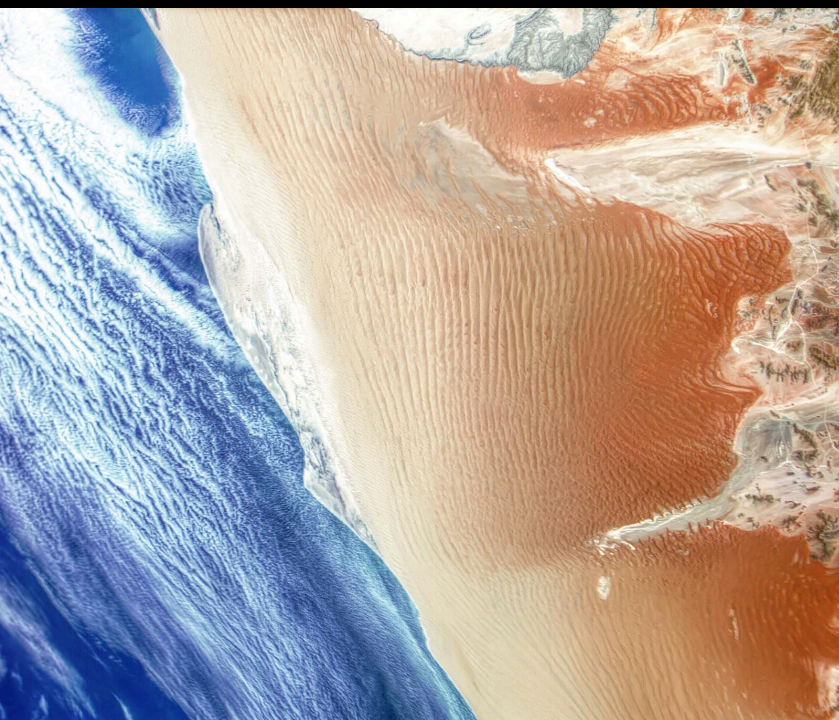
Western
Australia



Shark Bay
Australia

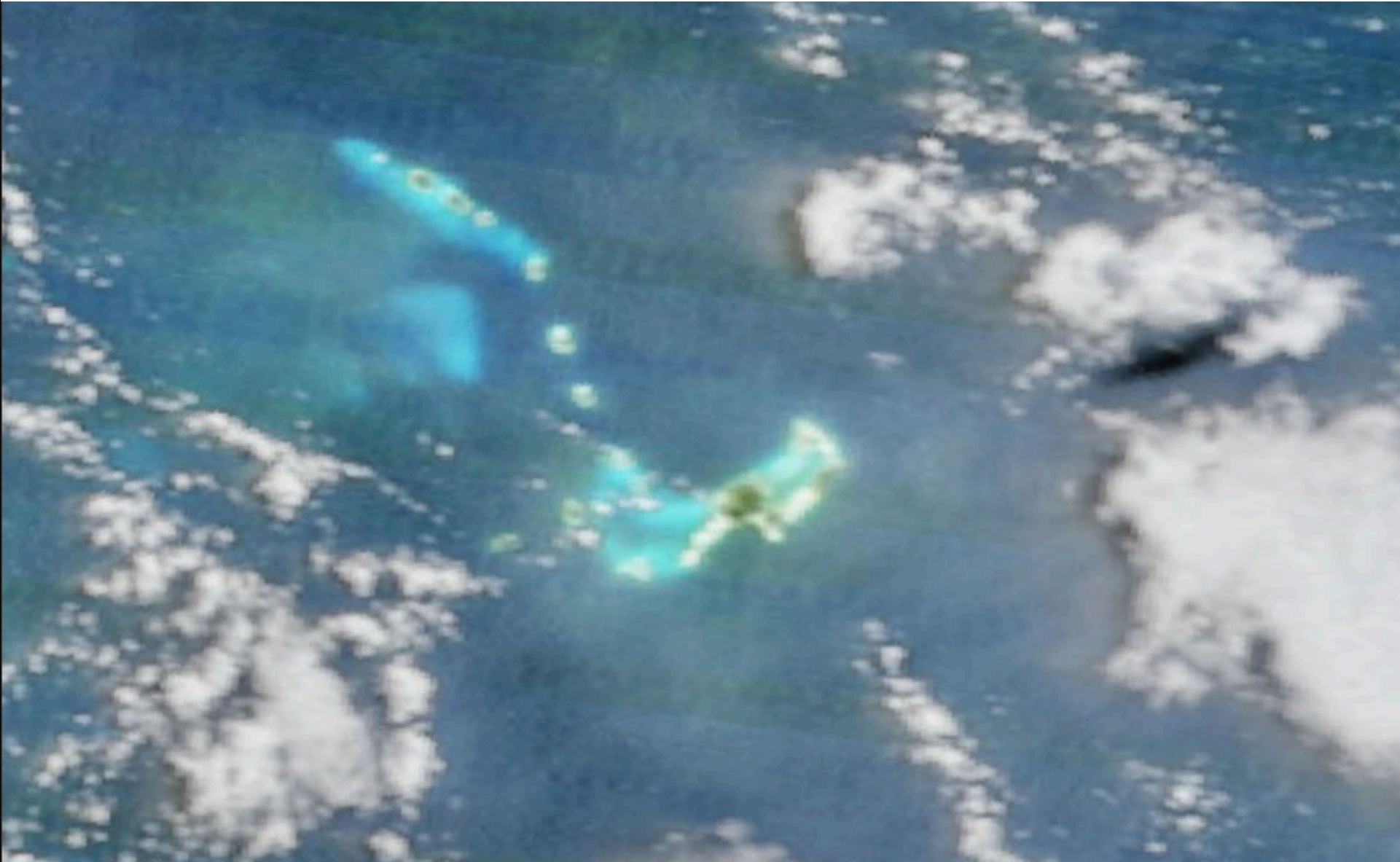


SeaHawk provides
high resolution
imagery from
around the world

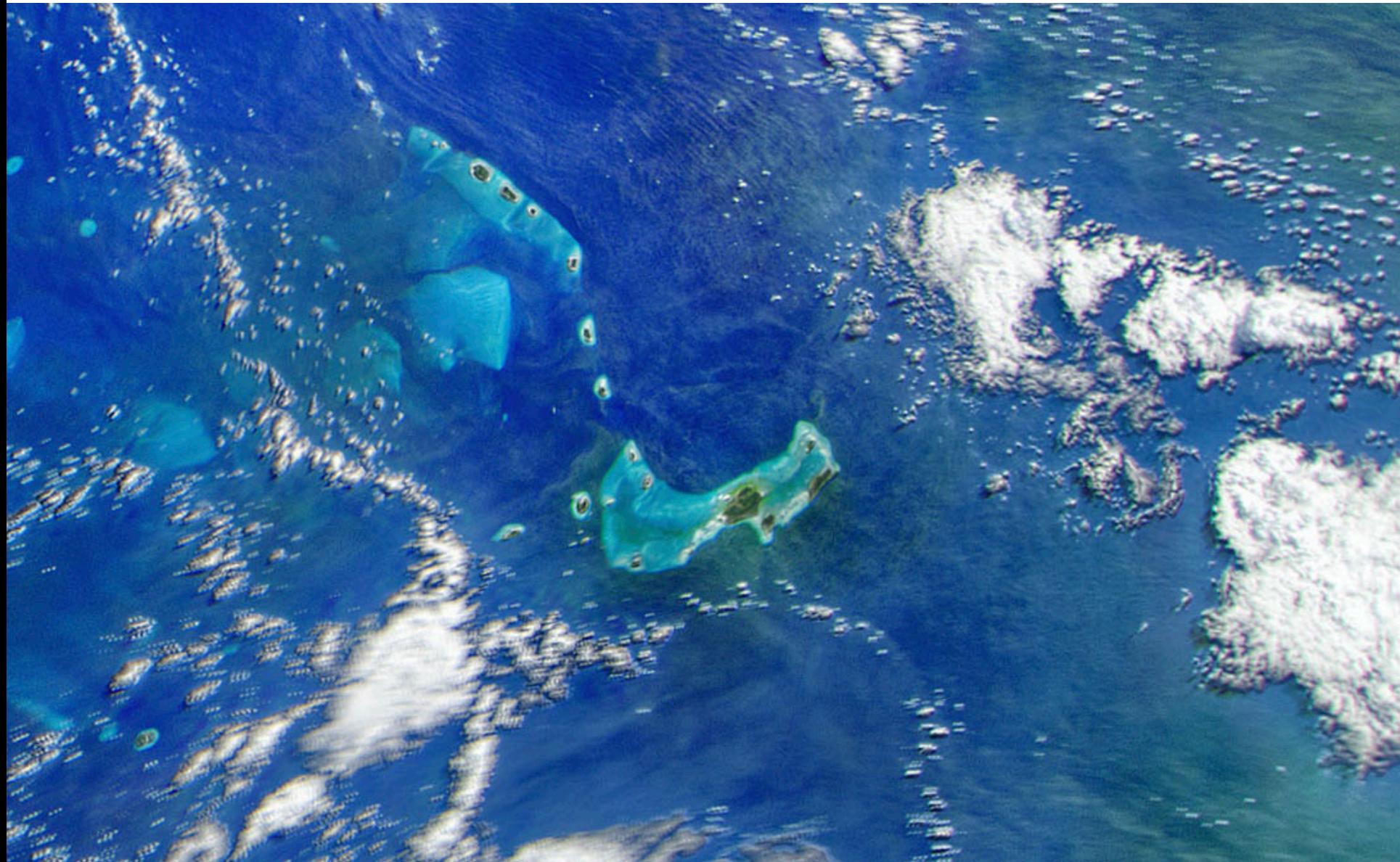




MODIS / Terra 25 May 2019 True Color



HawkEye / SeaHawk 25 May 2019 True Color



Some Applications and Advantages

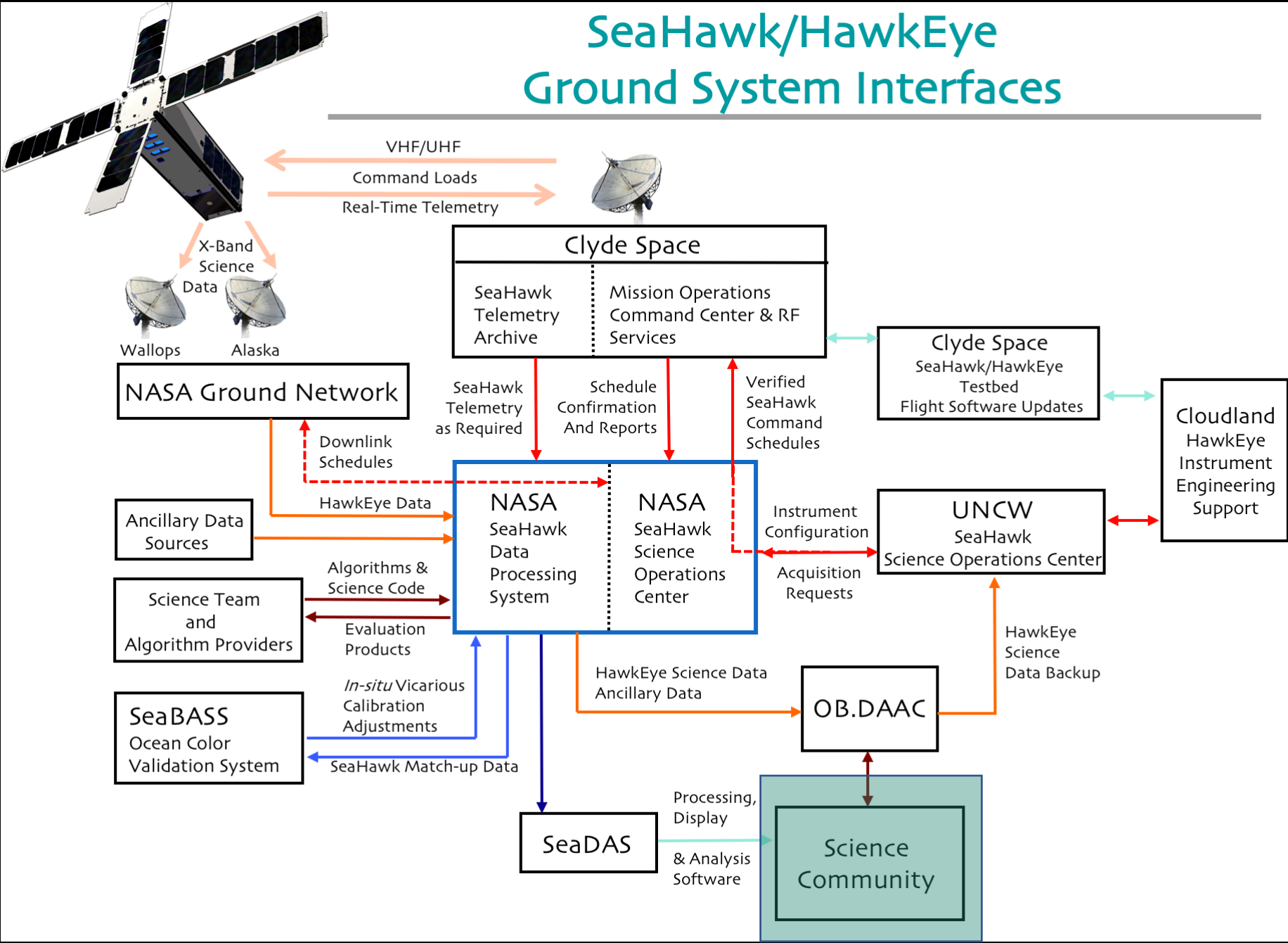
- Coastal ecosystems: sensor does not saturate over land or clouds
- High spatial resolution: Subpixel variability tool
- Already existing SeaWiFS algorithms should be easy to implement
- SeaDAS will provide the processing tools for HawkEye/SeaHawk data
- Cross-calibration with other ocean color satellites
- Instrument has shown no degradation after a year in orbit

SeaHawk-1 Status:

- ✓ **Launched:** Monday, December 3, 2018, 18:34 UTC
- ✓ **Deployed:** Monday December 3, 2018, 21:06:49 UTC
- ✓ **First Contact:** Tuesday, December 4, 2018 12:21:51 UTC
- ✓ **Orbit Identification:** 64 Satellites launched at 15-minute intervals.
- ✓ **Systematically check each satellite component**
- ✓ **Deploy solar panels:** March 20, 2019
- ✓ **First image:** March 21, 2019
- ✓ **X-Band downlink with NASA Near Earth Network:** March 22, 2019
- ✓ **Additional engineering tests**

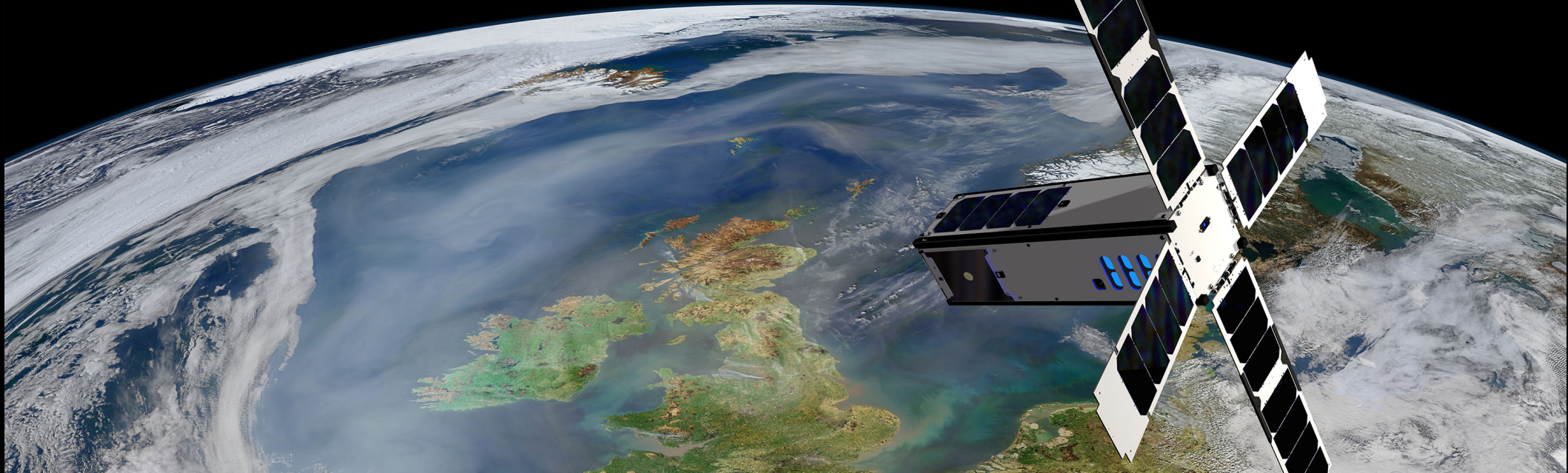
- ❖ **Operational status:** TBD

SeaHawk/HawkEye Ground System Interfaces



NEXT STEPS

1. Complete “Commissioning” phase
2. Verify performance and begin “Nominal Operations” phase of mission
3. Begin distributing data via NASA’s Ocean Biology DAAC
4. Release SeaDAS version supporting HawkEye processing
5. **Open tool for image requests from the community**
6. Assemble all “Lessons Learned” from SeaHawk-1
 1. Hardware
 2. Software
 3. Concept of Operations
 4. Testing
7. Develop workplan and schedule for SeaHawk-2 launch



Scheduling Tool

Apr 23, 2019

▶ Options
 ▼ Calendar

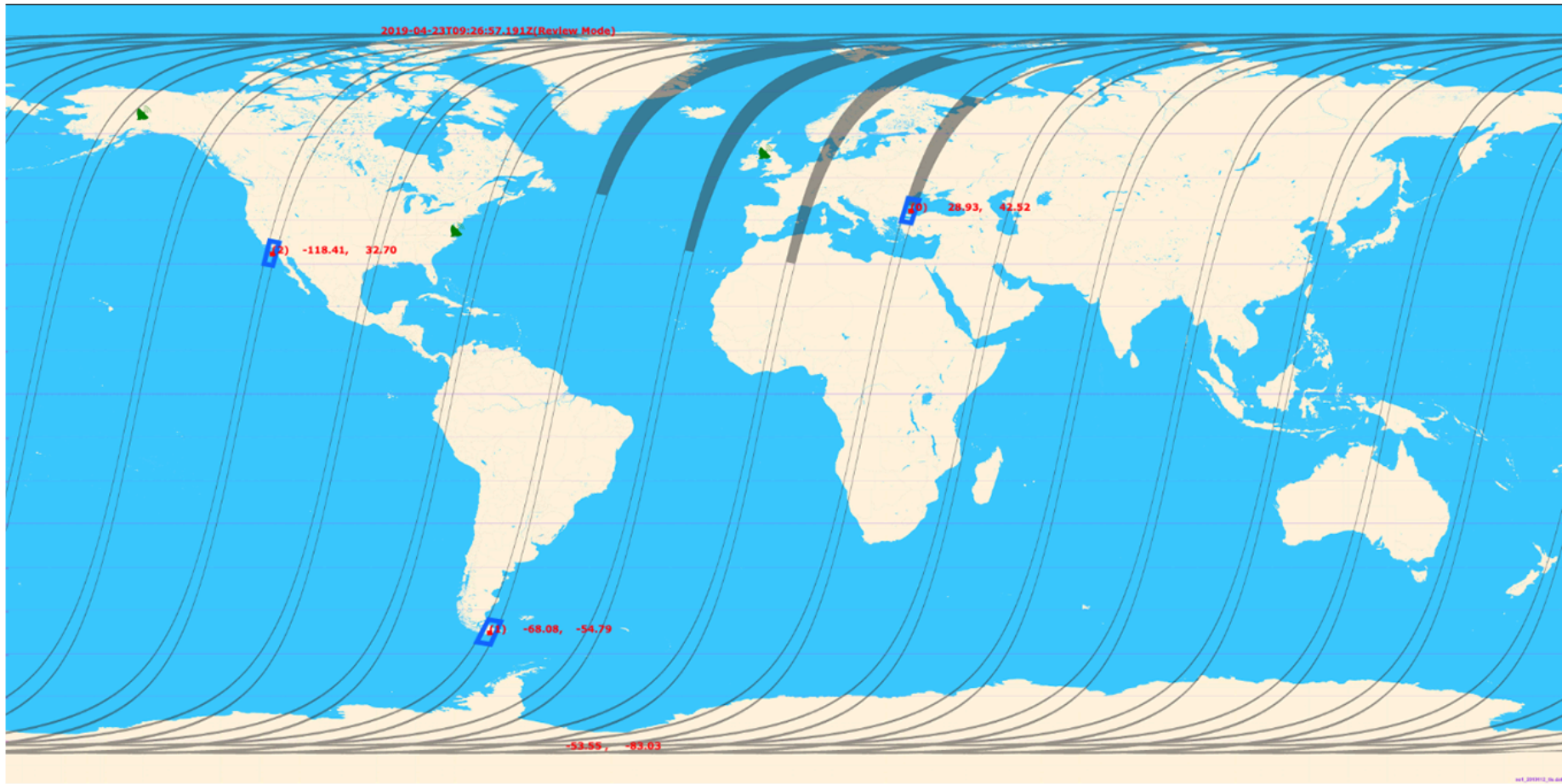
Mon	02/19/18	02/12/18	02/05/18
Tue	02/20/18	02/13/18	02/06/18
Wed	02/21/18	02/14/18	02/07/18
Thu	02/22/18	02/15/18	02/08/18
Fri	02/23/18	02/16/18	02/09/18
Sat	02/24/18	02/17/18	02/10/18
Sun	02/25/18	02/18/18	02/11/18
week	strawman	forecast	operation

▶ POI
 ▶ Scene

ID	OrbID	Time(UTC)	Lon	Lat	Tilt	Note	Priority	Status
191130852	2019042306	2019-04-23 08:51:26	28.93	42.52	0.00		high	2
191131407	2019042309	2019-04-23 14:06:45	-68.08	-54.79	0.00		high	2
191131833	2019042312	2019-04-23 18:32:14	-118.41	32.70	0.00		high	2

▼ Downlink

Facility	AOS	LOS	OrbID	Minutes	Planned
AS1	2018-02-08 01:10:04	2018-02-08 01:19:08	167	9	0
WG1	2018-02-08 02:29:35	2018-02-08 02:41:38	168	12	0



X-band Downlink Ground Stations in Alaska and Wallops
 Grey Mask: range over Glasgow's Mission Operation Control Ground Station
 200km-wide swath

Image Acquisition Requests

https://uncw.edu/socon/image_request.html

uncw.edu/socon/image_request.html

UNCW UNIVERSITY of NORTH CAROLINA WILMINGTON

SOCON: Sustained Ocean Color Observations with Nanosatellites

- Home
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- Project Team
- HawkEye Ocean Color Sensor
- SeaHawk CubeSat Satellite
- Project Schedules
- Sponsor
- IntellectualProperty
- Licensing
- Posters and presentations
- Student Opportunities
- Submit a request for image acquisition
- Photo Gallery
- SeaHawk path and trajectory

SeaHawk Image Requests

As part of our commitment to provide FREE data to the community, we created this portal to request imagery acquisition. However, users must acknowledge the selection criteria and the limitation of the data.

PLEASE READ CAREFULLY BEFORE YOU MAKE A REQUEST

- ❖ Image requests will be considered beginning early 2020.
- ❖ There will be a maximum of 15 images captured per day. Only a fraction of these will be available to the community.
- ❖ Each person can submit only one request per 3-week cycle. Each request may contain up to 15 targets during a 7-day planning period (7 days).
- ❖ Projected orbits will be published 3 weeks in advance.
- ❖ Requests must be made at least a week in advance.
- ❖ There is no express guarantee that the images that users requested will be captured.
- ❖ Requests will be selected based on the following criteria: users justification, priority and availability.
- ❖ A list of the scheduled selected targets will be published here each week.
- ❖ Data will be published on the ocean color website, from where it can be easily downloaded.
- ❖ Email notice will not be given if requests are accepted or rejected. It is the users' responsibility to check the website to see if published data matches their requested target.

EXAMPLE OF STEPS TO SUBMIT A REQUEST

Request SeaHawk Image Acquisition

Step 1

User Information

First Name: * Middle Initial: Organization:

Last Name: * E-mail: *

Affiliation: * Country: * User Type:

Justification/Use of Requested Image*


I'm not a robot 

Image Acquisition Requests

https://uncw.edu/socon/image_request.html

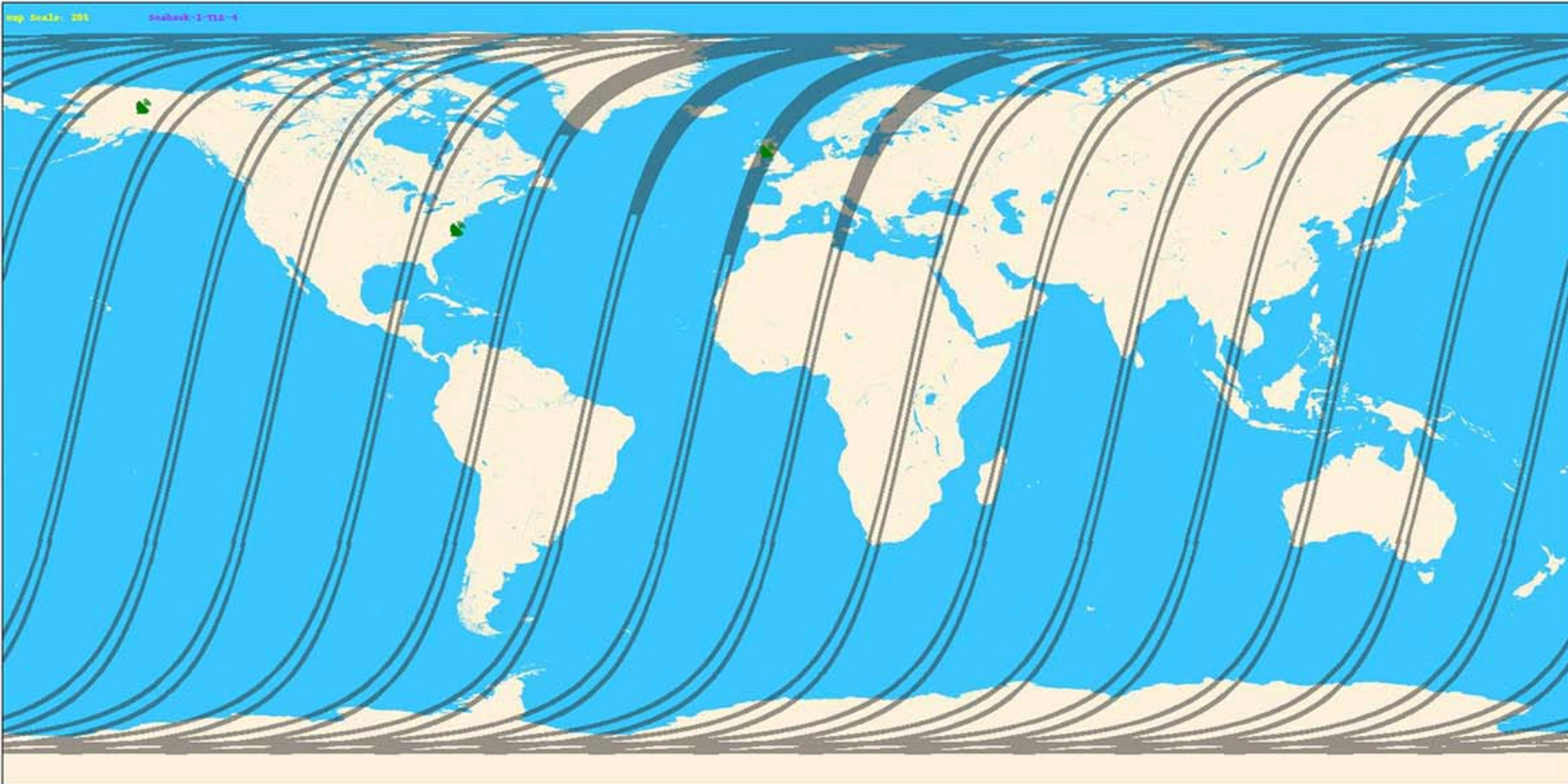
Request SeaHawk Image Acquisition

Step 2

Guest

Nov 8, 2018

map scale: 20% seahawk: 1-112-4



Zoom In

Zoom Out

Save

Reset

The image displays a world map with a grid of curved, parallel lines representing satellite swaths. The map is rendered in a light blue and tan color scheme. On the left side, there is a control panel with a user profile 'Guest', a date selector for 'Nov 8, 2018', navigation arrows, and buttons for 'Zoom In', 'Zoom Out', 'Save', and 'Reset'. The map itself shows several green markers on the North American continent, indicating specific acquisition points. The text 'map scale: 20%' and 'seahawk: 1-112-4' is visible in the top left corner of the map area.

Image Acquisition Requests

https://uncw.edu/socon/image_request.html

Request SeaHawk Image Acquisition

Step 4

The screenshot displays a web interface for requesting a SeaHawk image acquisition. On the left side, there is a control panel with the following elements:

- A dark grey header with the text "Guest".
- A date selector showing "Nov 8, 2018".
- Four green circular navigation buttons (left, left, right, right).
- "Zoom In" and "Zoom Out" buttons.
- "Save" and "Reset" buttons.
- A yellow "Priority" button.

The main area is a map of the United States. A red rectangular bounding box is drawn on the map, centered over the Gulf of Mexico. The bounding box is labeled with the ID "2018110814" and the coordinates "26.81, 28.35". A green antenna icon is positioned on the eastern coast of the United States, near the Florida peninsula.

Image Acquisition Requests

https://uncw.edu/socon/image_request.html

Guest

Nov 28, 2018

Map Scale: 20% SeaHack-1-T1X-6 2018-11-28T07:14:16.456Z

Zoom In

Zoom Out

Save

Reset

Clear

Options

Image: One per Orbit

Image: XTX Conflict

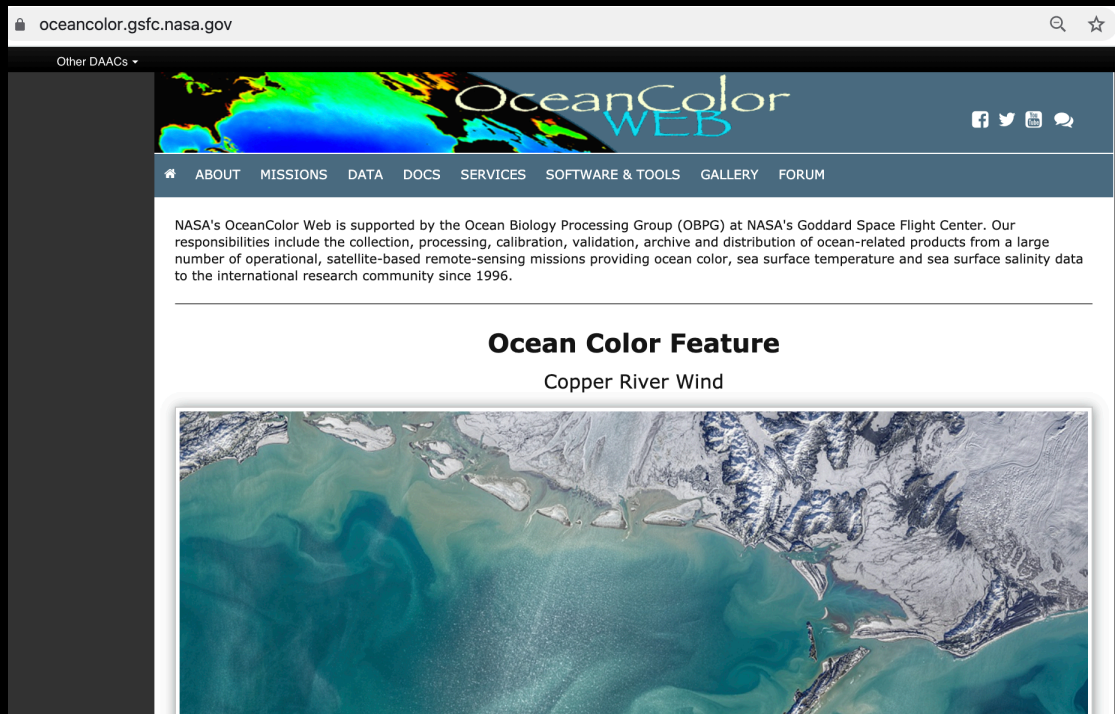
The map displays a global view of satellite orbits. The orbits are represented by curved lines across the map. Acquisition requests are marked with numbered points, each with associated coordinates. The points are numbered 1 through 13. Most points are highlighted with green boxes, while point 5 is highlighted with a red box. The coordinates for each point are as follows:

Point Number	Coordinates (Longitude, Latitude)
1	66.15, -48.21
2	57.15, 16.98
3	39.60, 42.46
4	6.30, 1.46
5	-6.53, 47.25
6	-22.72, -24.75
7	-60.75, -63.37
8	-62.10, 17.13
9	-89.77, -1.82
10	-108.67, 22.42
11	-142.65, -27.54
12	-156.60, 21.45
13	89.32, -50.82

2018112805

-35.32, -90.22

Data Distribution and Processing



oceancolor.gsfc.nasa.gov

Other DAACs ▾

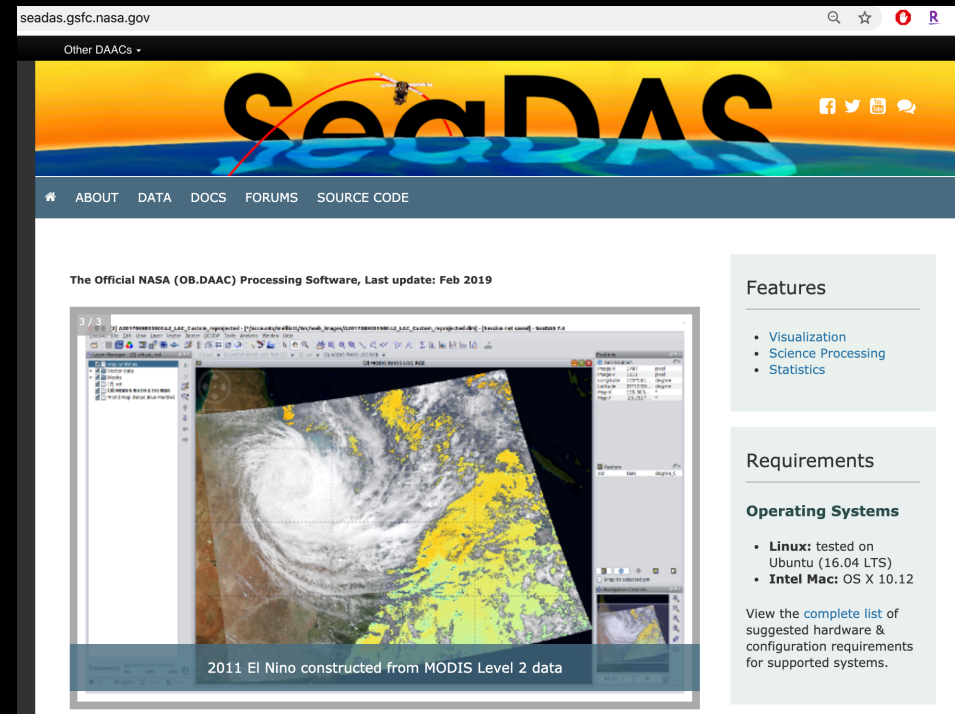

OceanColor WEB

ABOUT MISSIONS DATA DOCS SERVICES SOFTWARE & TOOLS GALLERY FORUM

NASA's OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center. Our responsibilities include the collection, processing, calibration, validation, archive and distribution of ocean-related products from a large number of operational, satellite-based remote-sensing missions providing ocean color, sea surface temperature and sea surface salinity data to the international research community since 1996.

Ocean Color Feature

Copper River Wind



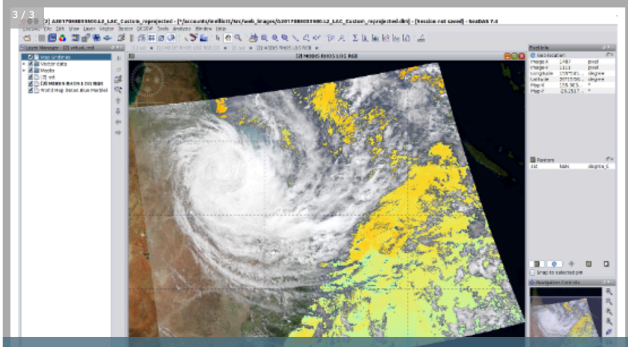
seadas.gsfc.nasa.gov

Other DAACs ▾

SeaDAS

ABOUT DATA DOCS FORUMS SOURCE CODE

The Official NASA (OB.DAAC) Processing Software, Last update: Feb 2019



2011 El Nino constructed from MODIS Level 2 data

Features

- Visualization
- Science Processing
- Statistics

Requirements

Operating Systems

- **Linux:** tested on Ubuntu (16.04 LTS)
- **Intel Mac:** OS X 10.12

View the [complete list](#) of suggested hardware & configuration requirements for supported systems.

NASA OB DAAC will release level 1 and 2 data and the tools to process it

Ongoing work:

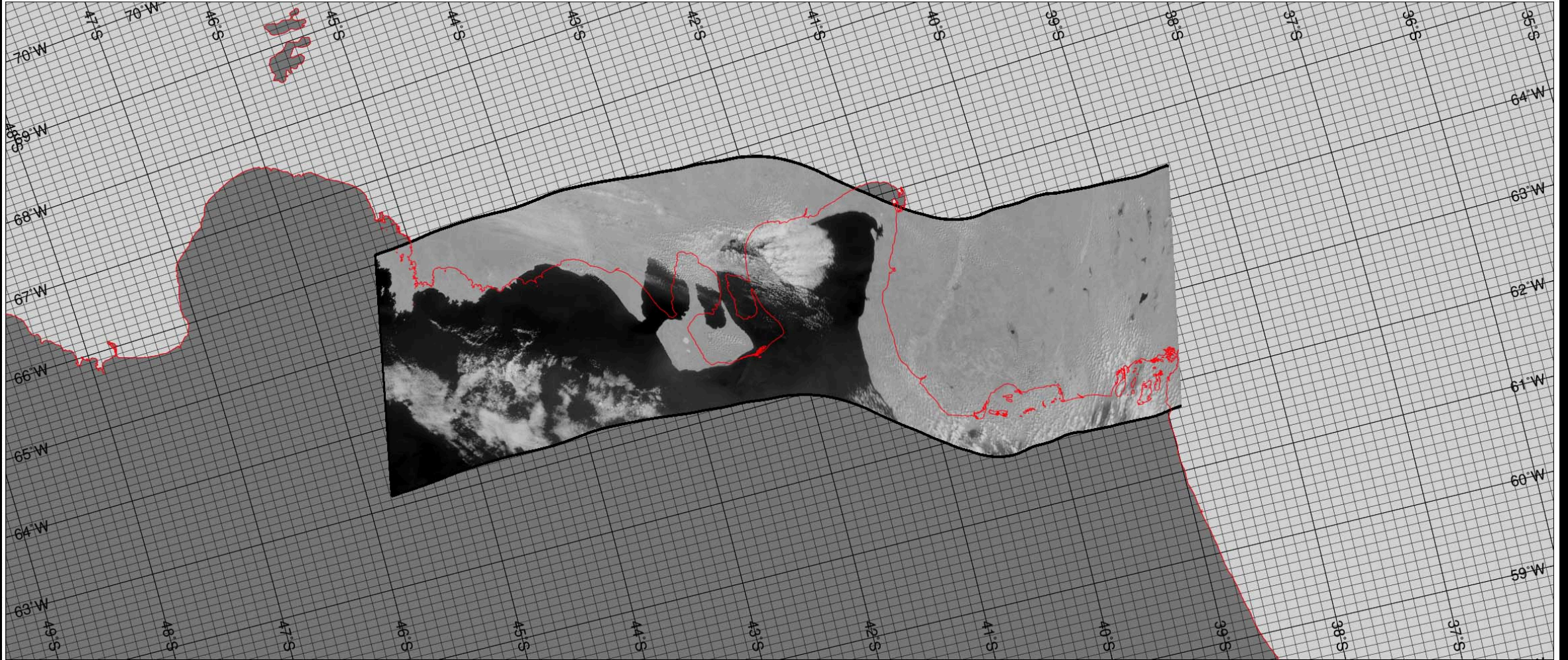
1. Determine final number of images per day (probably 5 or 6)
 2. Geolocation: manually refine navigation
- these issues are due to known problems on seahawk-1 that we intend to mitigate for seahawk-2.

Renavigation tool to geolocate imagery

/web/oceancolor/HawkEye/HWK2020040140634.L2_RENAV.nc

0 (0%) out of 6 scenes disposed of.

Drag the scene to align it with the map. Please wait a few moments for the scene to paint on the map. If the map does not appear at all, then please select "Bad data". This [Google Maps link](#) may help you determine what part of the world you are looking at.



Scene location adjustments

Along track: 0.000 kilometers Cross track: 0.000 kilometers

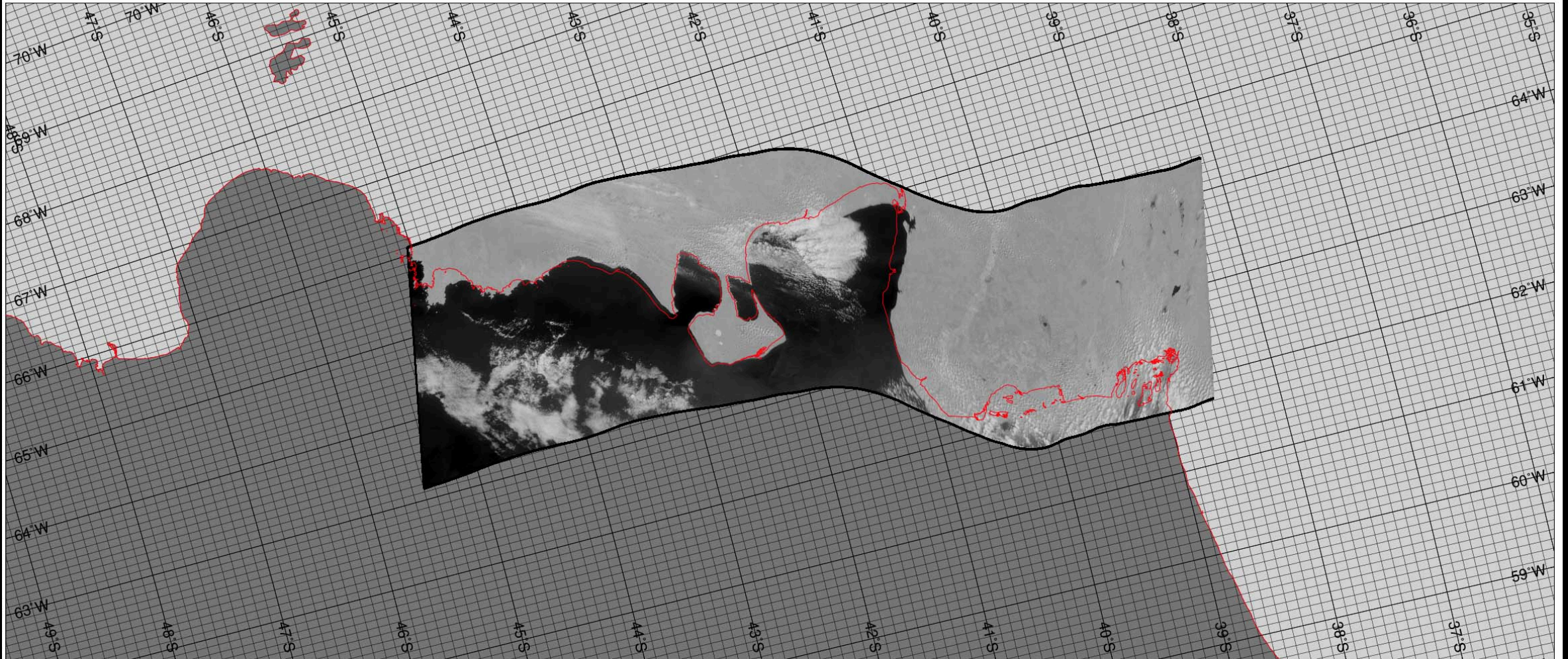
computed pixel resolution: 131 meters

Renavigation tool to geolocate imagery

/web/oceancolor/HawkEye/HWK2020040140634.L2_RENAV.nc

0 (0%) out of 6 scenes disposed of.

Drag the scene to align it with the map. Please wait a few moments for the scene to paint on the map. If the map does not appear at all, then please select "Bad data". This [Google Maps link](#) may help you determine what part of the world you are looking at.



Scene location adjustments

Along track: 31.434 kilometers Cross track: -8.513 kilometers

computed pixel resolution: 131 meters

Lessons Learned

1. Proofed the concept!
2. When we started CubeSat technology was in its infancy, technology is quickly developing – should lead to quicker commissioning
3. Hard to reconcile work ethic between University/Industry/Government
4. Originally the sensor was designed for 25 m resolution --- tremendous amount of data so it was degraded but still had to push the envelope using the first available x-band transmitter small enough for CubeSat.
5. Settled on a 3U design to keep costs down

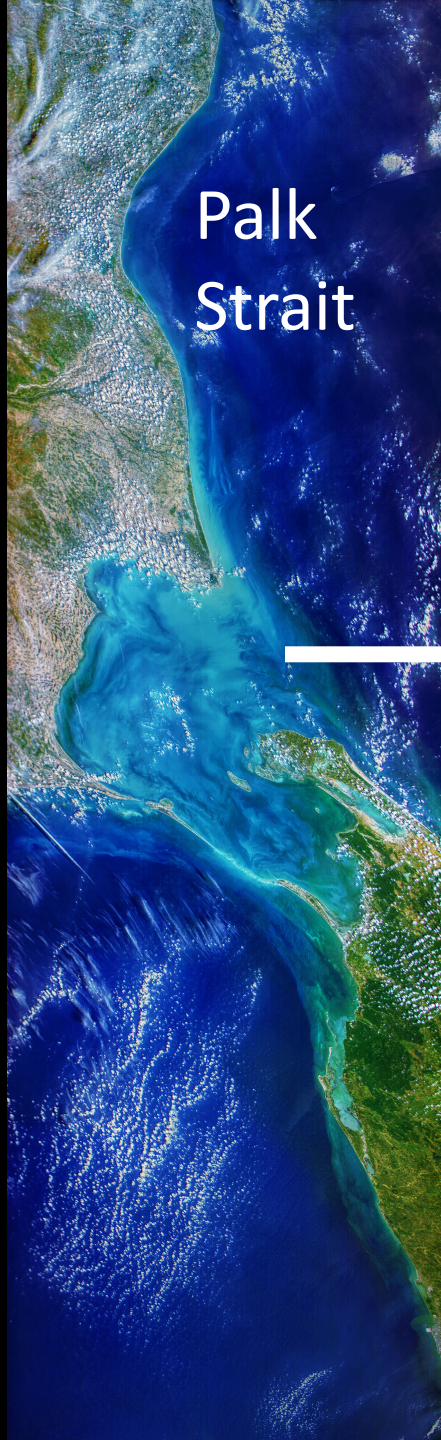
Lessons Learned

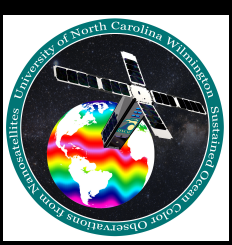
6. BUREAUCRACY....

1. Space ACT 2019
2. FCC licensing for both ground station and satellite
3. Observing the Earth means that you are treated as a COMMERCIAL satellite
4. The higher resolution you go, the more security problems you have
5. Working with International partners increases the difficulty with licensing

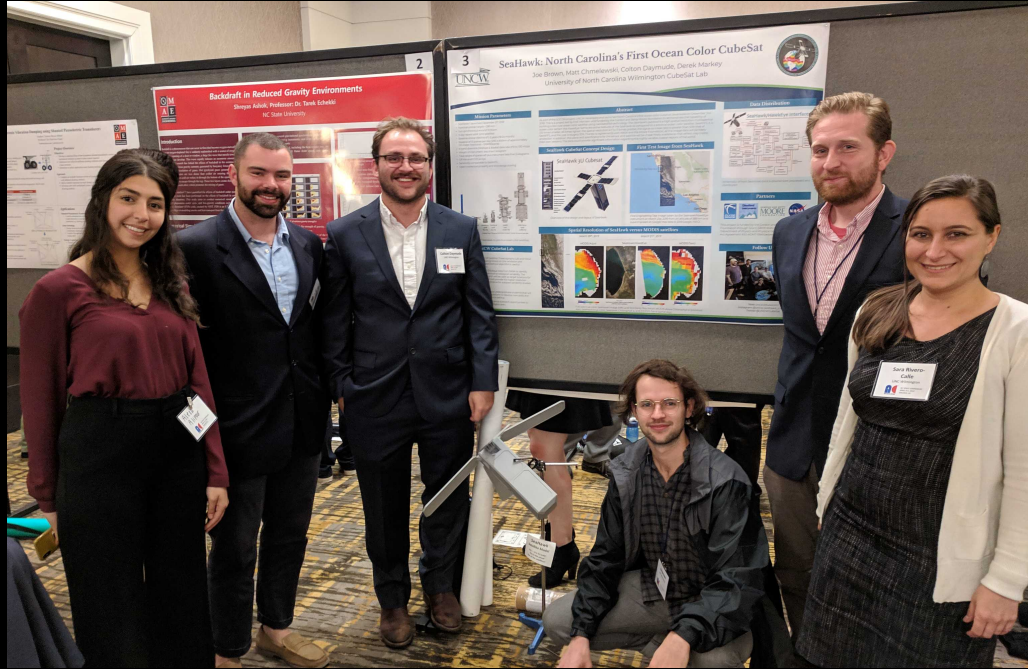
7. Worth the Effort!!!!

1. NASA NEN cannot believe the quality and amount of data we can obtain from a “shoebox”
2. Resulting imagery is EXTRAORDINARY





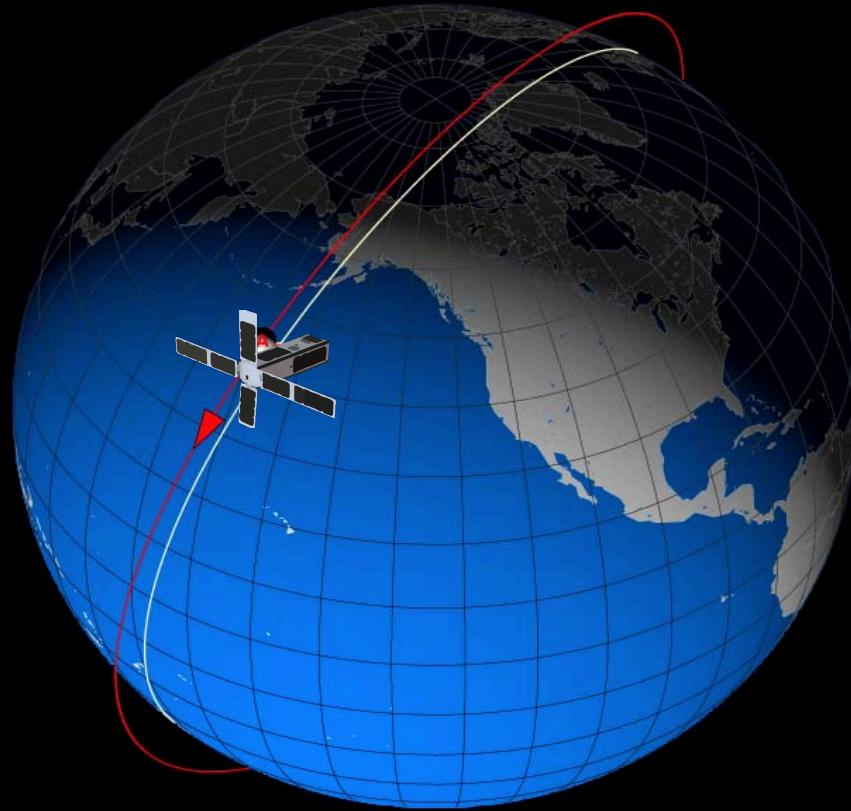
UNCW CubeSat Student Group



UNCW's SeaHawk Ocean Color CubeSat was part of the First Women in Science Event at Fort Fisher Aquarium

Where is SeaHawk-1 now?

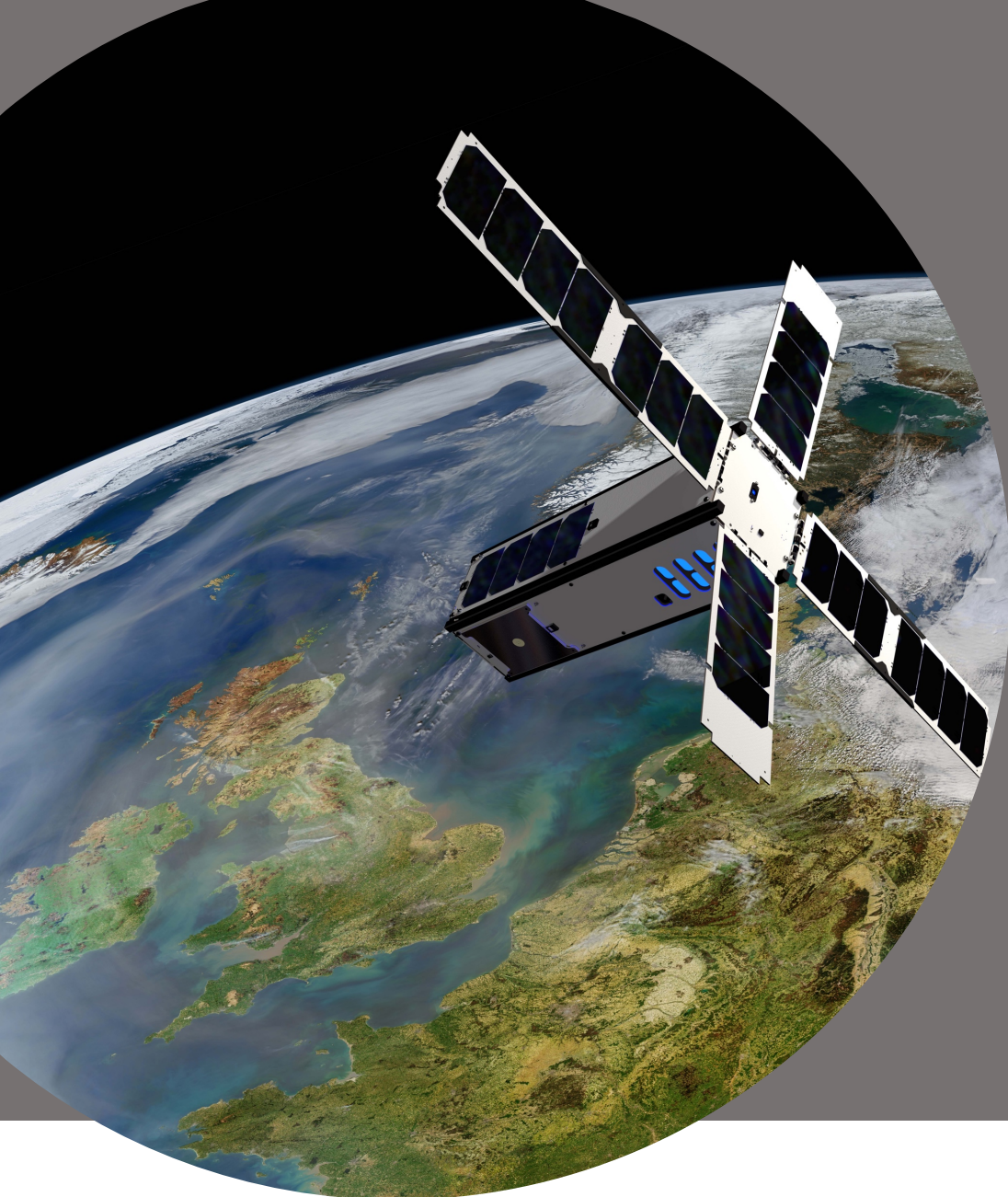
Date/Time	Latitude	Longitude	Altitude	Sub-solar latitude	Sub-solar longitude
Monday, December 3, 2018 at 21:50:33 UT 2018337	44.690 ° N	165.573 ° W	574.163 km	22.182 ° S	150.157 ° W



Select an arbitrary date and time.

Date/Time

https://oceancolor.gsfc.nasa.gov/cgi/whereis_seahawk



Thank you!

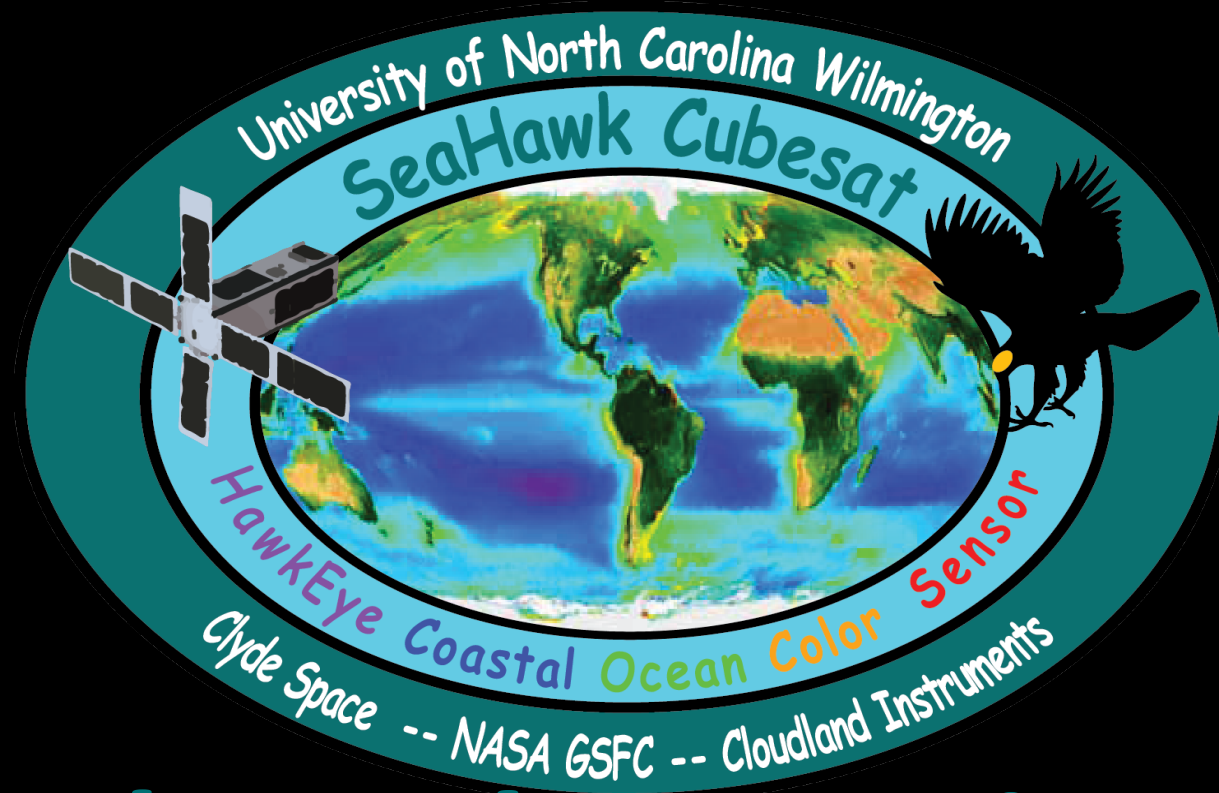
Dr. Sara Rivero-Calle
UNCW Center for Marine Science

riverocalles@uncw.edu

<https://uncw.edu/socon>

Instagram: @UNCW_seahawk_cubesat
Twitter: UNCWCubeSat





Thank you! Questions???

<https://uncw.edu/socon>

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