SeaHawk - HawkEye

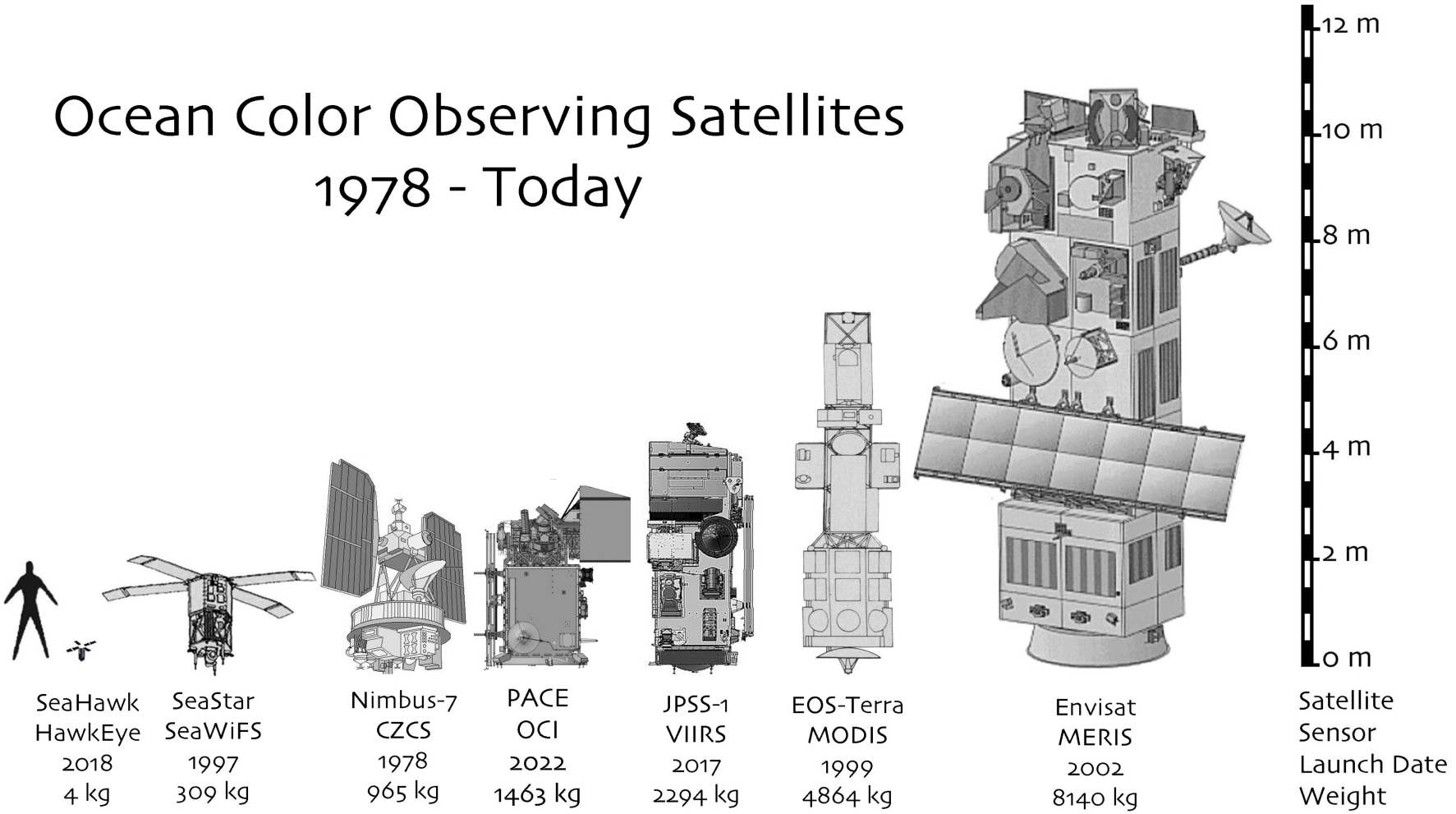
Background, Overview and Status

28 May 2020

SOCON

Sustained Ocean Color Observation from Nanosatellites

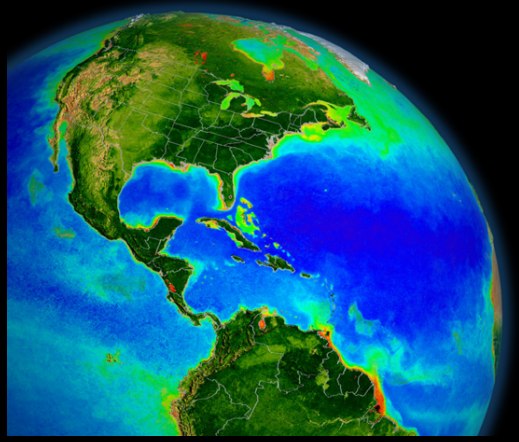
Ocean Color Observing Satellites
1978 - Today



SeaHawk HawkEye	SeaStar SeaWiFS	Nimbus-7 CZCS	PACE OCI	JPSS-1 VIIRS	EOS-Terra MODIS	Envisat MERIS	Satellite Sensor
2018	1997	1978	2022	2017	1999	2002	Launch Date
4 kg	309 kg	965 kg	1463 kg	2294 kg	4864 kg	8140 kg	Weight

Goal:

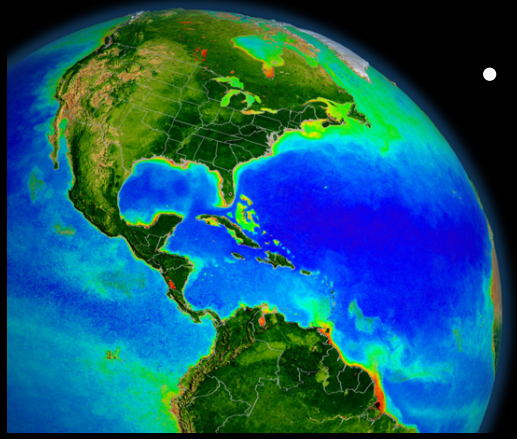
Proof of Concept program to demonstrate whether it is possible to obtain high quality, high resolution (~100m) ocean color imagery using a low-cost miniature ocean color sensor carried aboard a CubeSat.



- Program was funded (2015) by the Gordon and Betty Moore Foundation - *Phase 1:* Design and Construction of SeaHawk Satellite Bus and HawkEye Ocean Color Sensor
  - Clyde Space (Scotland) provides the CubeSat bus named SeaHawk-1 and SeaHawk-2
  - Alan Holmes and his team at Cloudland Instruments (Calif) provides the Hawkeye Sensors
- The program is administered by Dr. John Morrison – UNCW

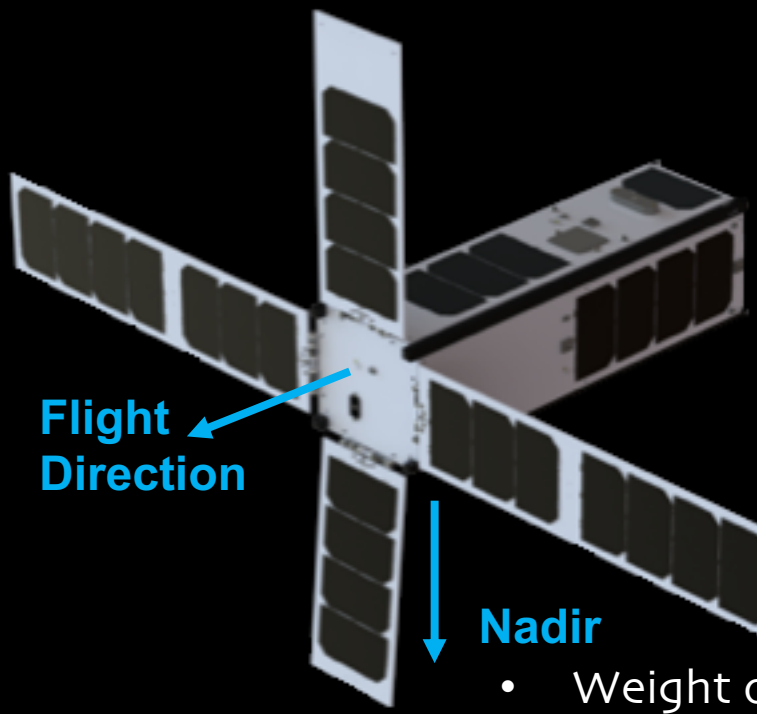
https://uncw.edu/socon/

- NASA provided "advice and review" during the development phase and with formal NASA/HQ Space Act Agreement (2017), provides support for the collection, processing, calibration, validation, archive and distribution of the data (see backup for details)

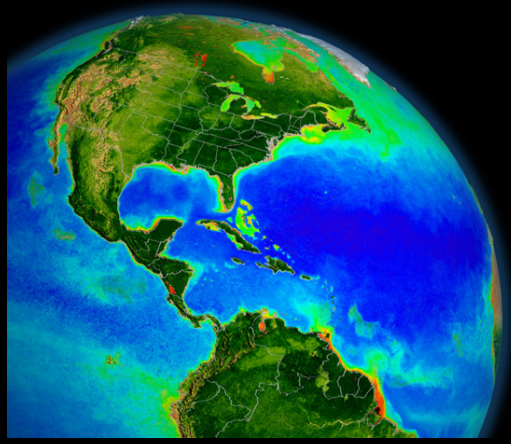


- A second Moore Foundation grant was awarded in June 2017 for *Phase 2* to support the commercial launch and operations of both spacecraft and instruments for duration of 2 years each.

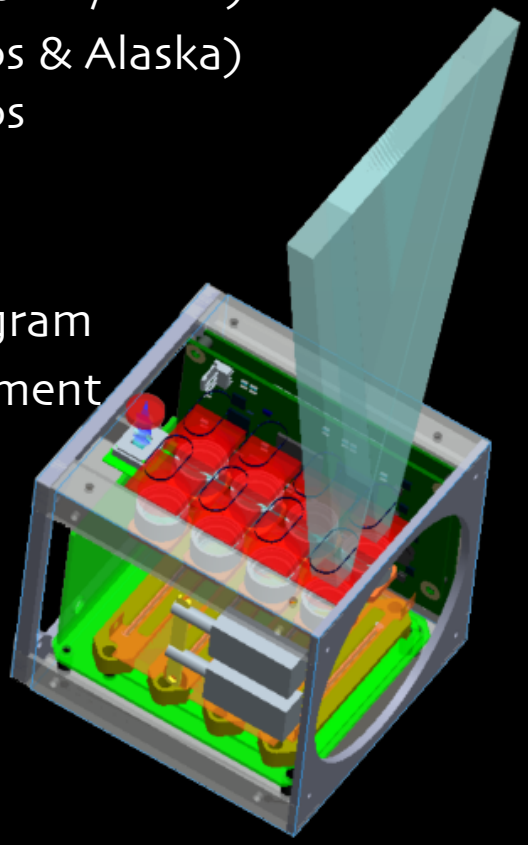
Key Mission Parameters



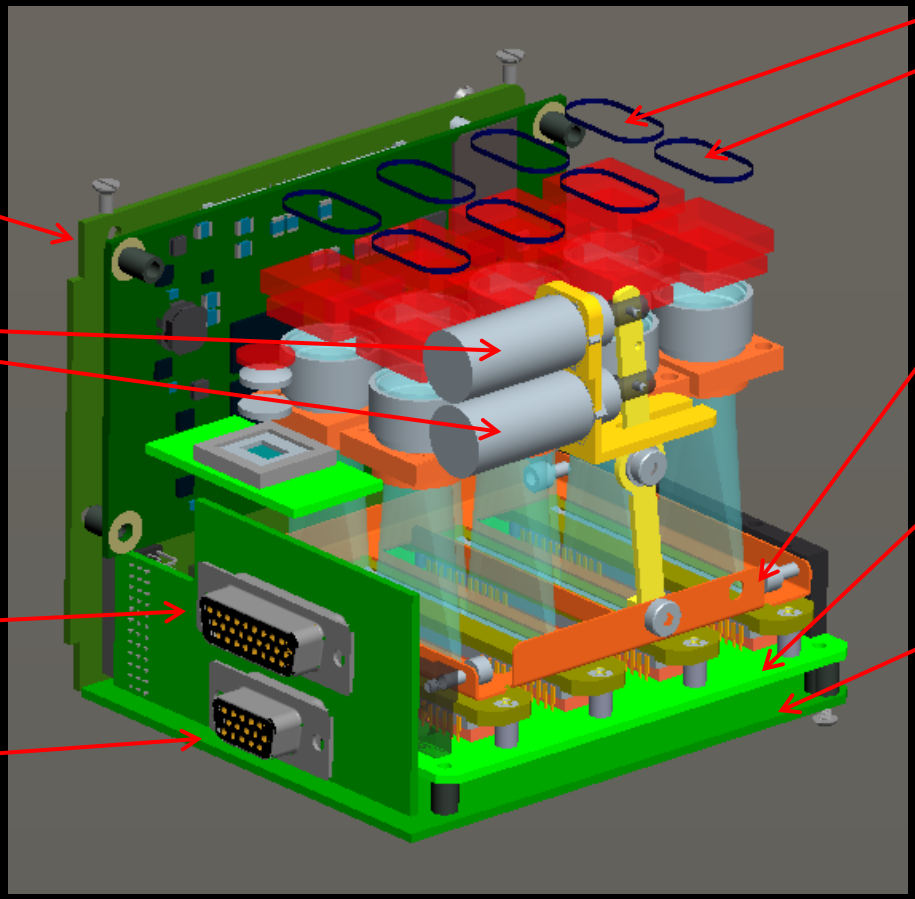
1. Launched 3 December 2018 (3 weeks before government shutdown)
2. Nominal orbital height = 585 km (- 1 km today)
3. Sun-synchronous around 10:30am
4. 18 day repeat orbit (one satellite)
5. Baseline orbital lifetime of 1 year (18-24 month)
6. Image size of 200 x 600km of approximately 120 meter resolution - 100MB/scene)
7. X-band downlink (Wallops & Alaska) data rate of 6 --> 100mbs

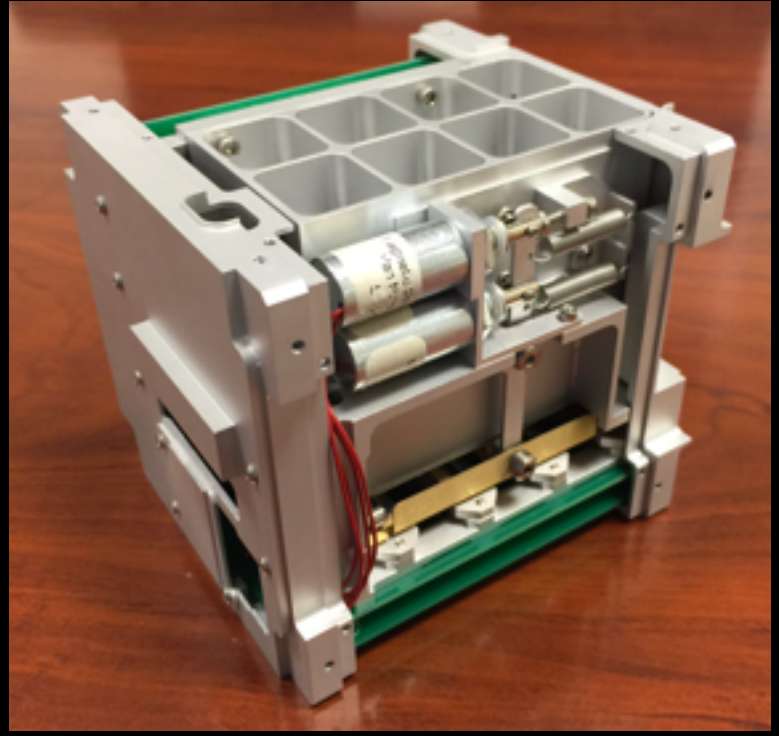


- Weight of instrument less than 1 kilogram
- Total weight of spacecraft plus instrument less than 5 kilograms
- Off-the-shelf CCD arrays used
- Sensitivity comparable to SeaWiFS
- 8 SeaWiFS Bands (see backup)
- Open intellectual property and knowledge sharing



HawkEye


Science Apertures
Motherboard
Solenoids for shutter
Shutter Vane
CCD Board
Interface to CubeSat
Analog Board
Debug Port



Alan Holmes with HawkEye Units 1 & 2

SeaHawk Internal Configuration

Power Subsystem:

- Clyde Space 3G EPS Motherboard with a Flex daughterboard
- 3G 30 Whr Clyde Space battery
- Solar Arrays

Communications Subsystem:

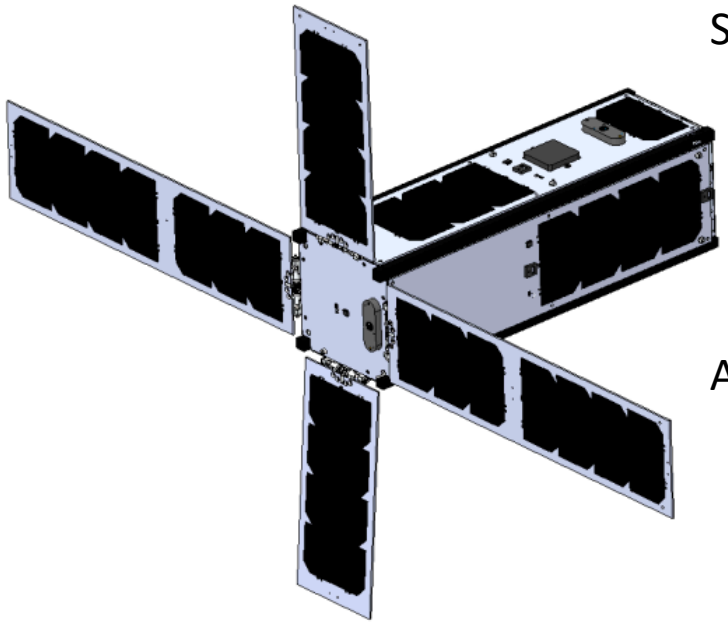
- VHF uplink at 1200 bps and UHF downlink at 9600 bps
- Syrlinks X-band Transmitter (3-50Mbps / 6-100Msps)

On Board Computer:

- Clyde Space on-board computer (OBC) provide up to 1.8 GB payload data storage

Attitude Determination & Control:

- Clyde Space ADCS Motherboard

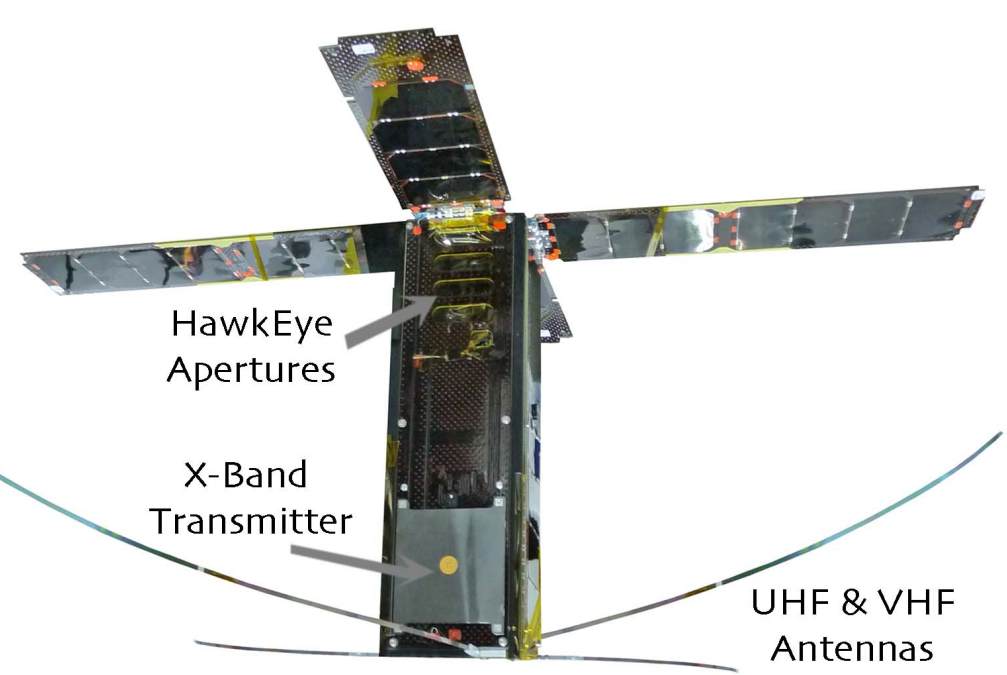


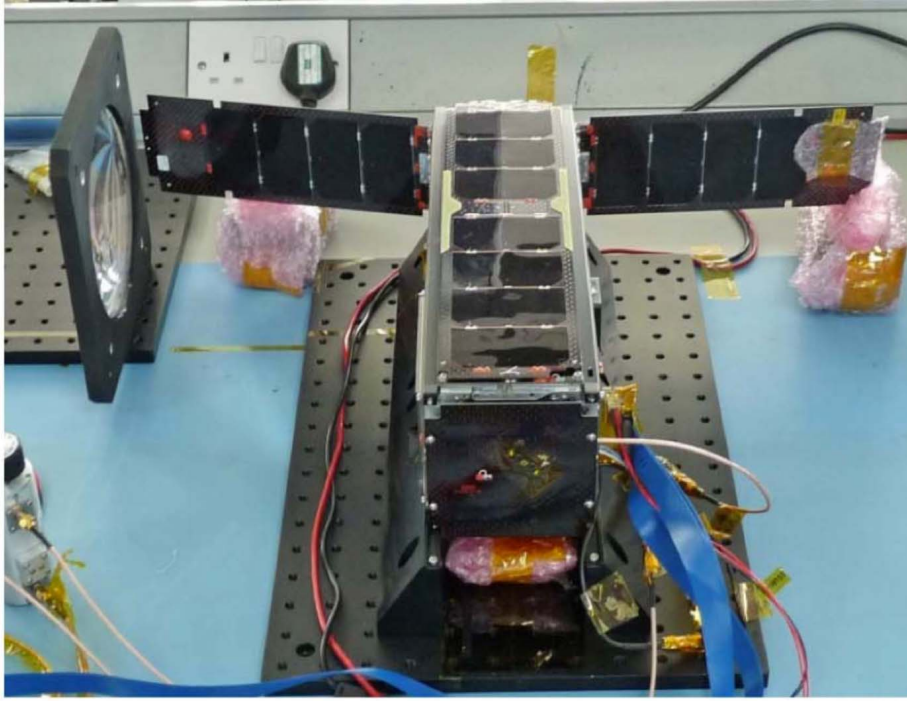
Sensors:

- Course sun sensors
- Three 2 Axis Digital Fine Sun Sensors
- Magnetometers
- Rate Gyroscopes
- GPS

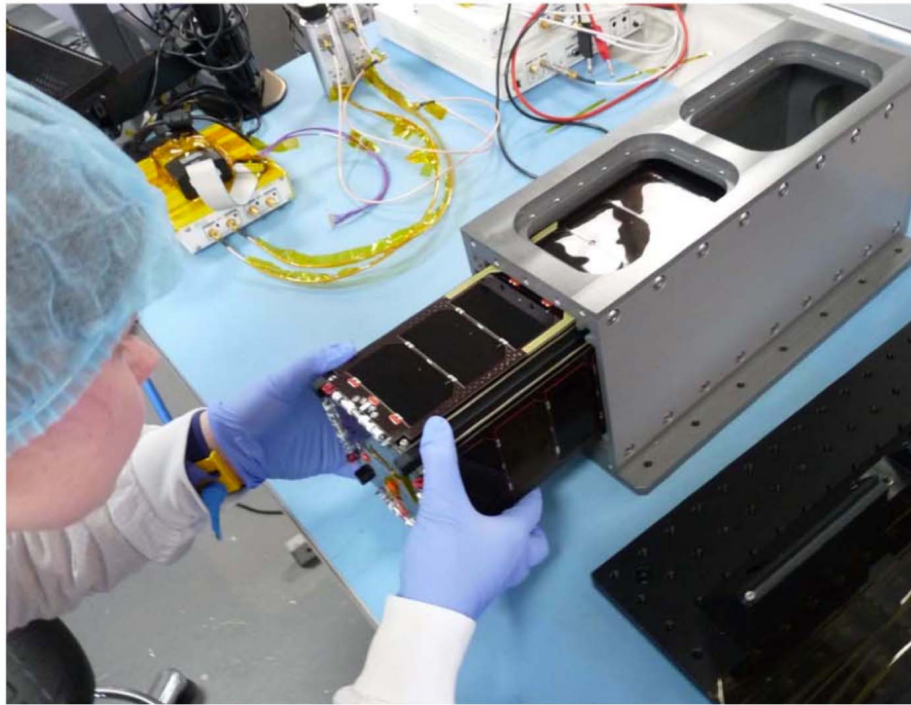
Actuators:

- Three Axis Reaction Wheels
- Three Axis Magnetorquers (MTQ)

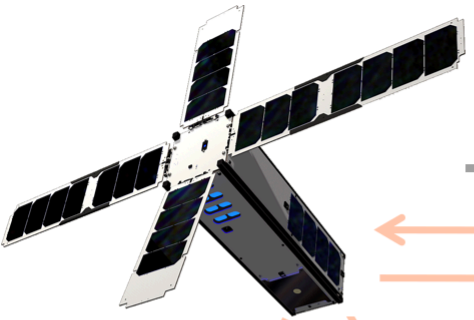

HawkEye
Apertures
X-Band
Transmitter
UHF & VHF
Antennas




X-Band
Transmitter



SeaHawk/HawkEye Ground System Interfaces



VHF/UHF
Command Loads
Real-Time Telemetry

X-Band Science Data

Wallops

Alaska

Clyde Space

SeaHawk Telemetry Archive

Mission Operations Command Center & RF Services

Clyde Space
SeaHawk/HawkEye Testbed
Flight Software Updates

Cloudland
HawkEye Instrument Engineering Support

NASA Ground Network

SeaHawk Telemetry as Required

Schedule Confirmation And Reports

Verified SeaHawk Command Schedules

Downlink Schedules

HawkEye Data

Ancillary Data Sources

NASA
SeaHawk
Data
Processing
System

NASA
SeaHawk
Science
Operations
Center

Instrument Configuration

Acquisition Requests

UNCW
SeaHawk
Science Operations Center

Algorithms & Science Code

Science Team and Algorithm Providers

Evaluation Products

HawkEye Science Data
Ancillary Data

HawkEye Science Data Backup

In-situ Vicarious Calibration Adjustments

SeaBASS
Ocean Color Validation System

SeaHawk Match-up Data

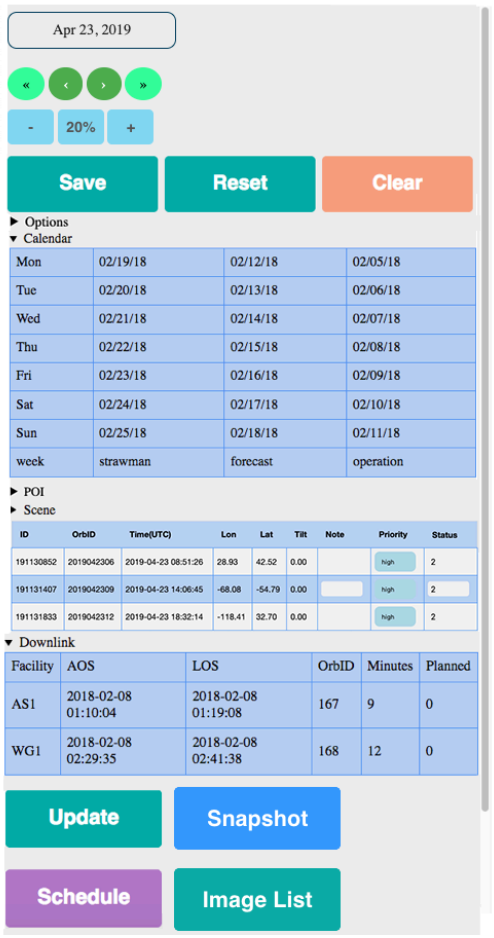
OB.DAAC

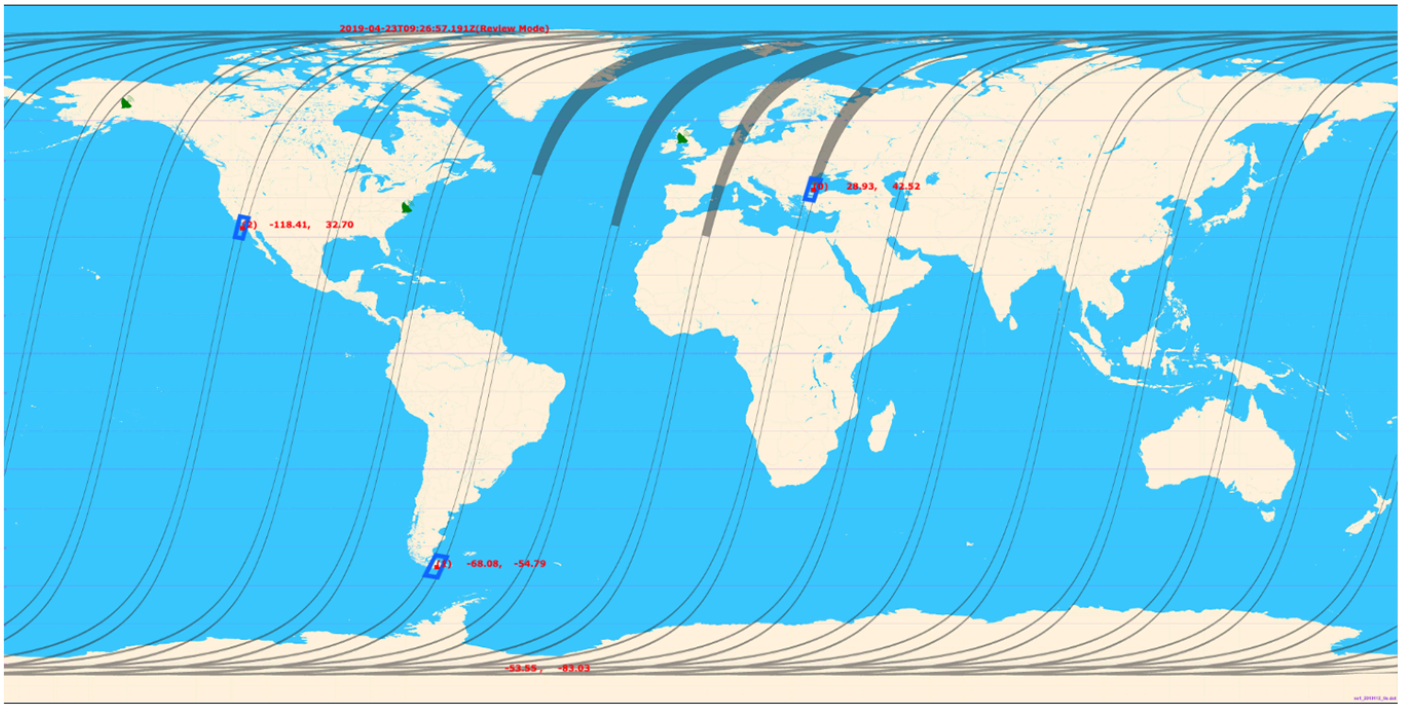
SeaDAS

Processing, Display & Analysis Software

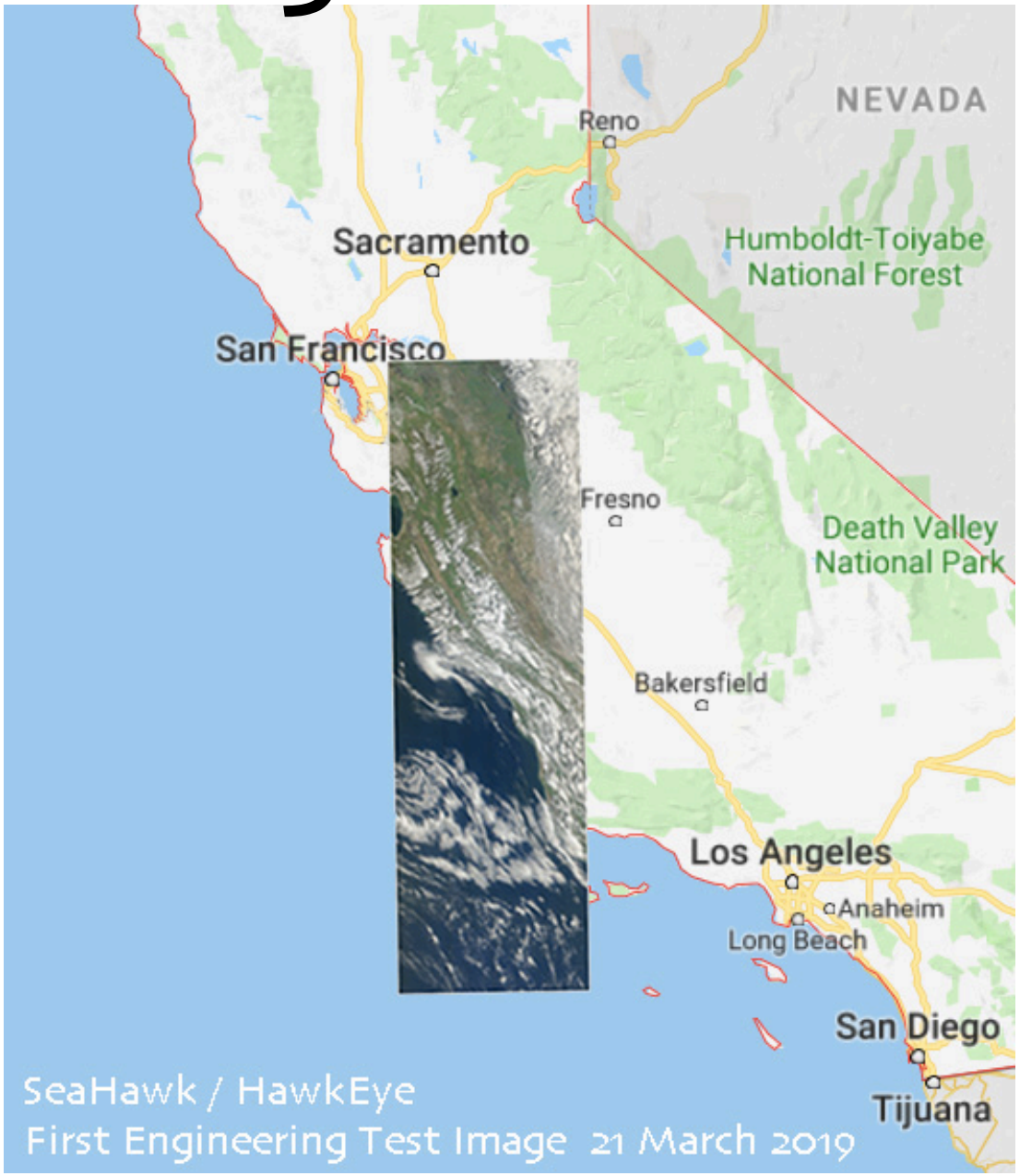
Science Community

HawkEye Instrument
&
SeaHawk X-band Downlink Scheduling Tool





First Light



Sequence of Events:

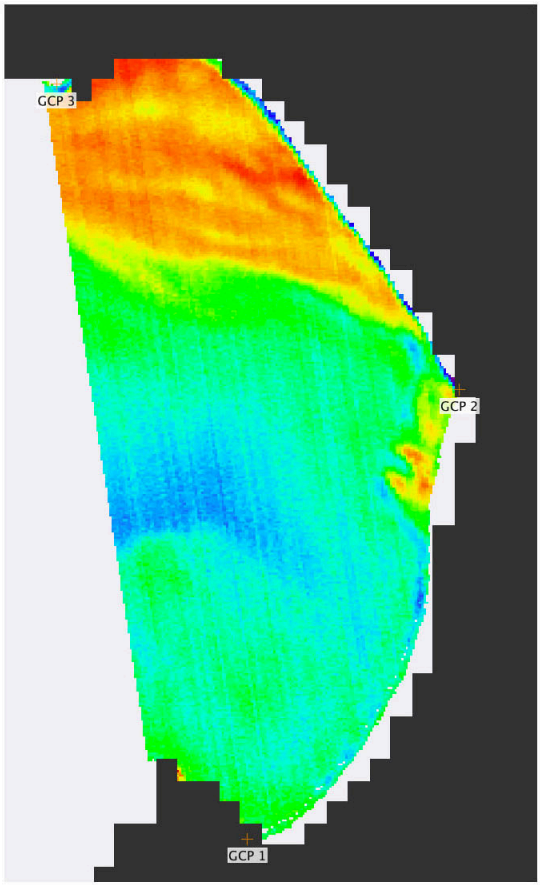
20 March: x-panels deployed
HawkEye optics exposed

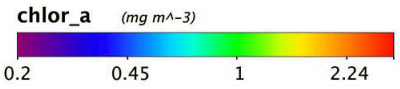
21 March: 1st image acquired

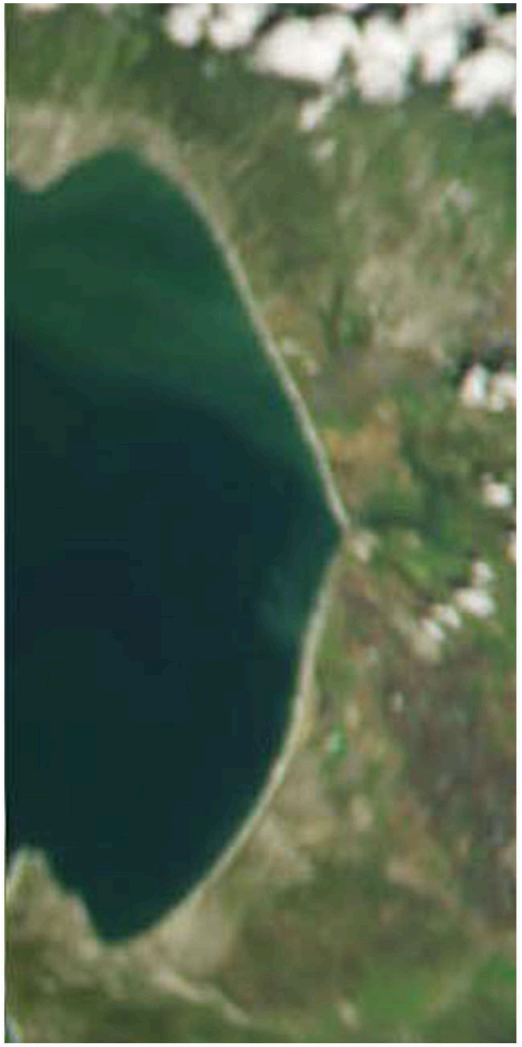
22 March: Wallops X-band downlink
50 mbps

Chlorophyll-a Concentration

HawkEye / SeaHawk
21 March 2019

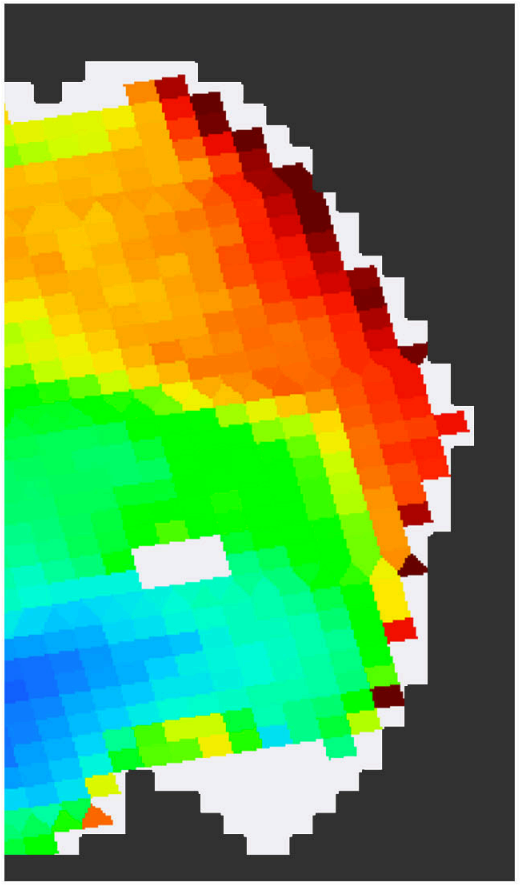


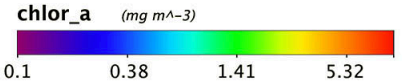




HawkEye True Color
Monterey Bay

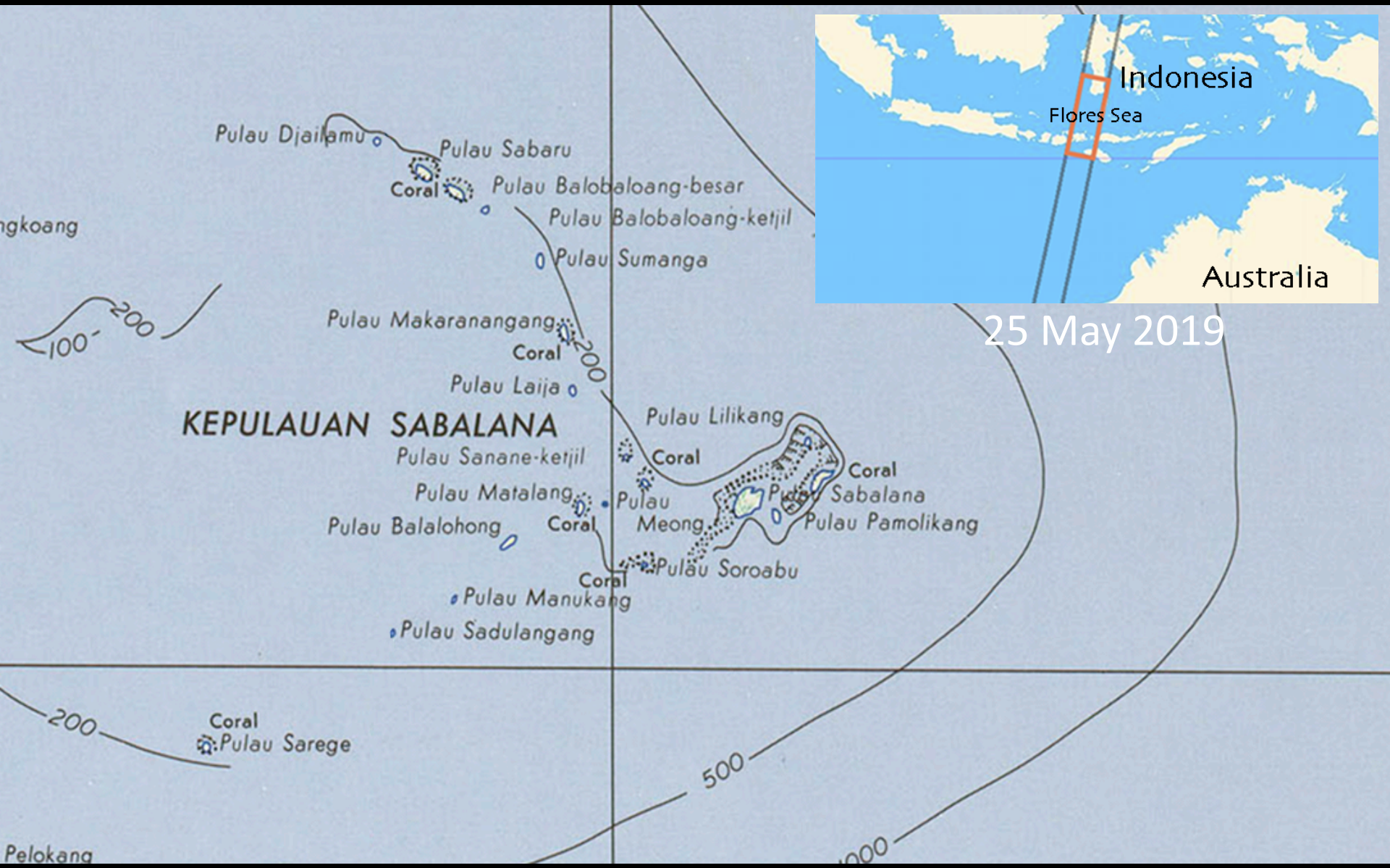
MODIS / Aqua
20 March 2019



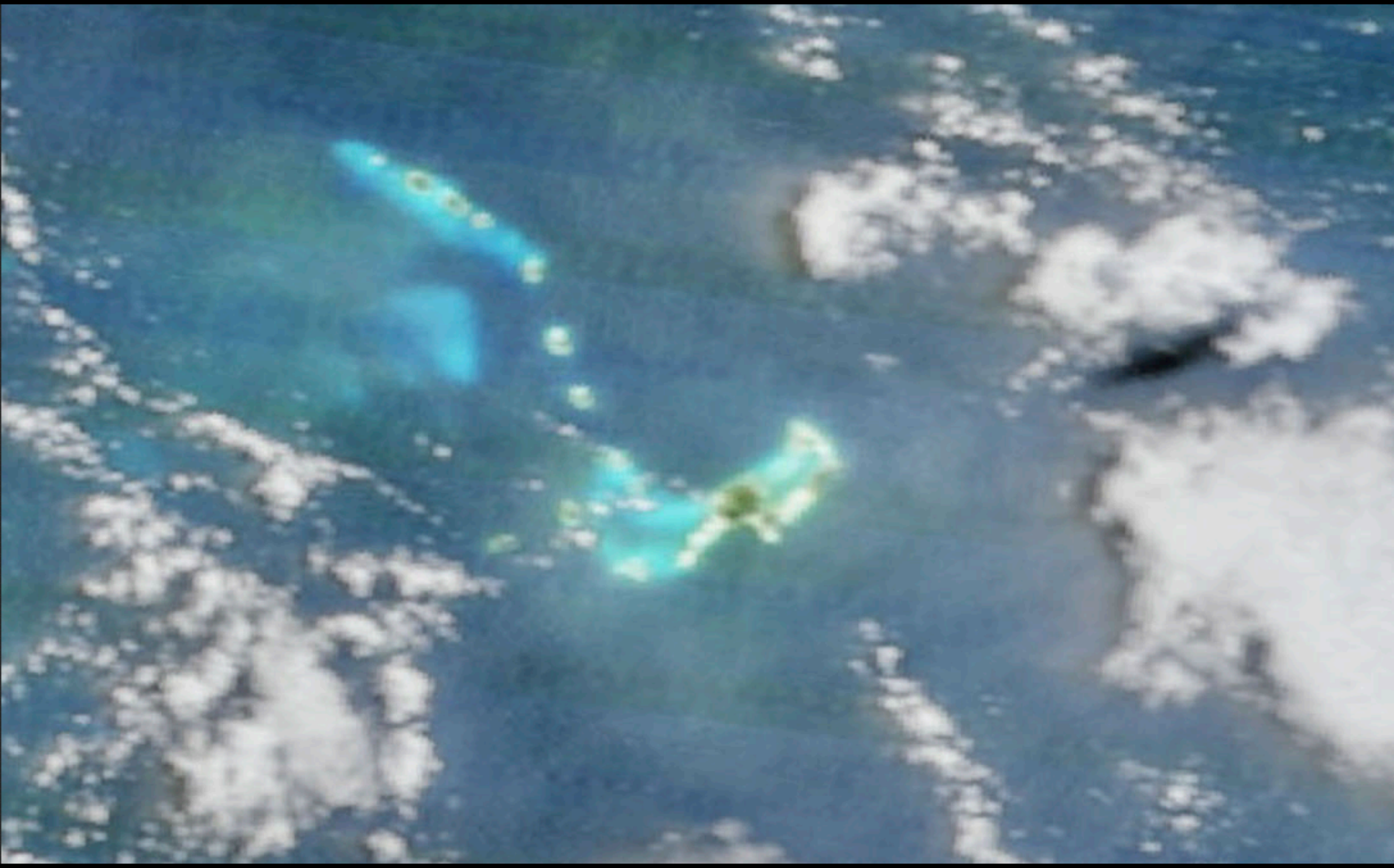


Proof of Concept

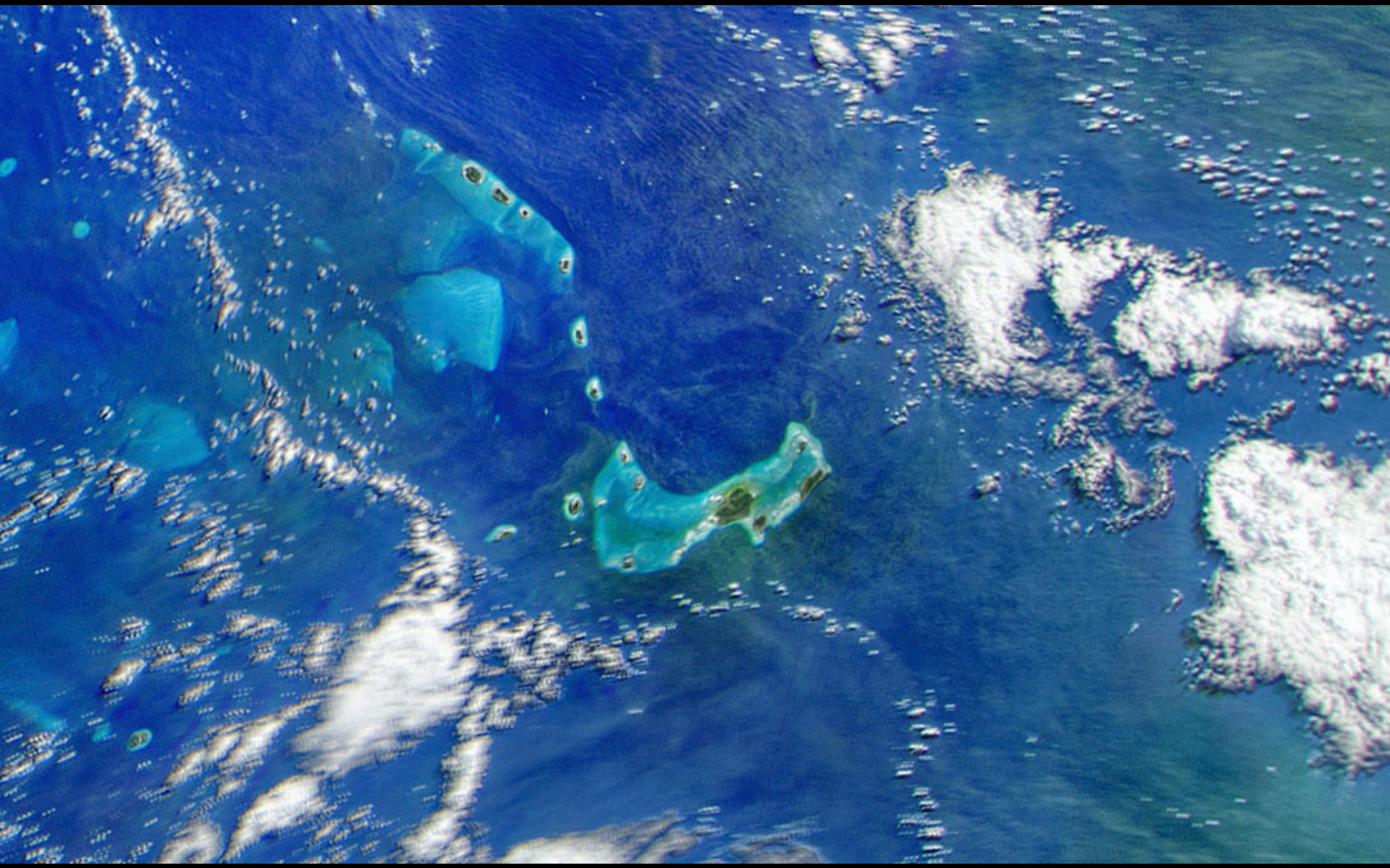
CONFIRMED

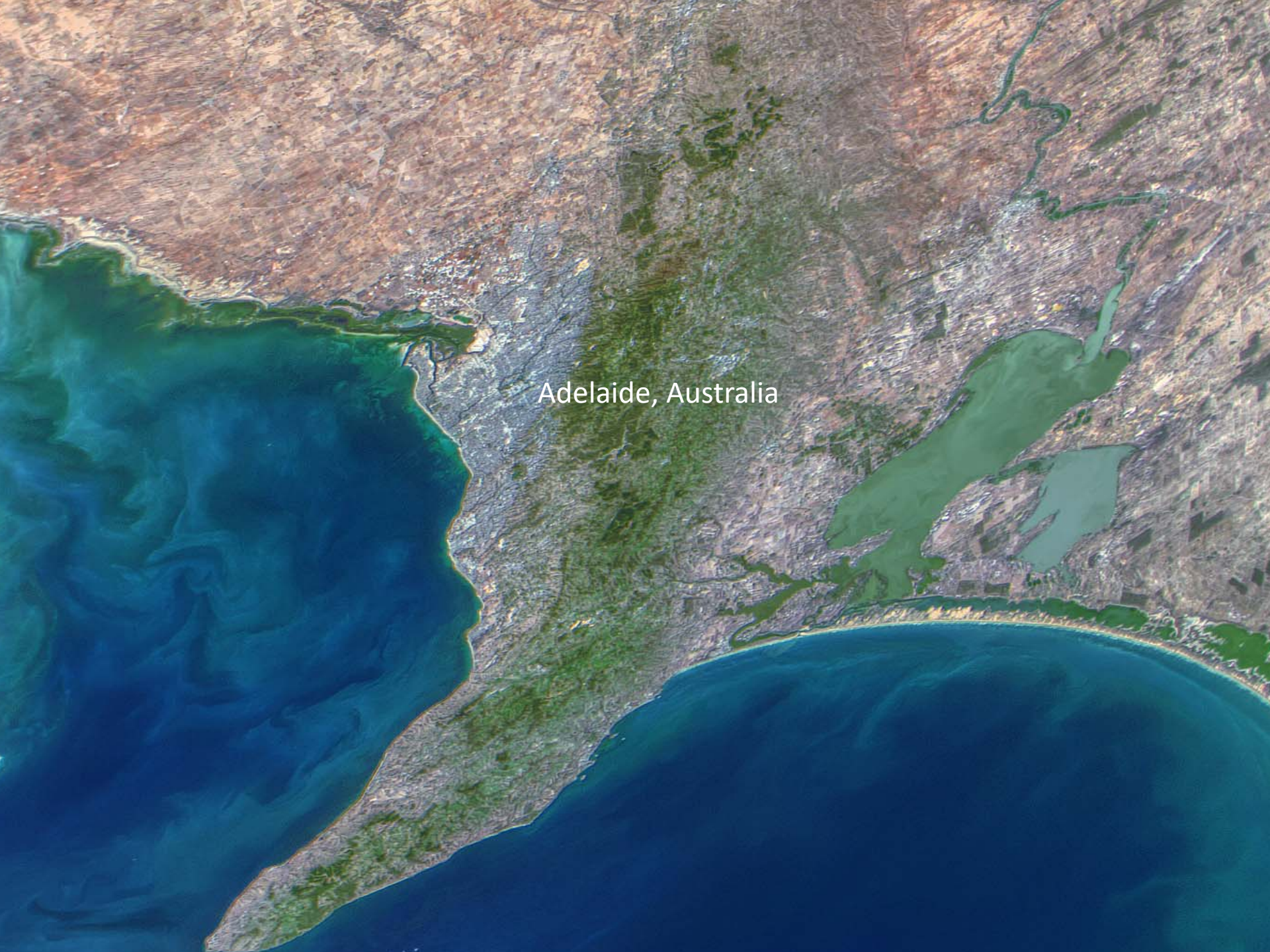

Indonesia
Flores Sea
Australia
25 May 2019
Pulau Djailamu
Pulau Sabaru
Coral
Pulau Balobaloang-besar
Pulau Balobaloang-ketjil
Pulau Sumanga
ngkoang
200
100
Pulau Makaranangang
Coral
200
Pulau Laija
KEPULAUAN SABALANA
Pulau Lilikang
Pulau Sanane-ketjil
Coral
Coral
Pulau Matalang
Pulau
Pulau Sabalana
Pulau Balalohong
Coral
Meong
Pulau Pamolikang
Pulau Soroabu
Coral
Pulau Manukang
Pulau Sadulangang
200
Coral
Pulau Sarege
500
Pelokang

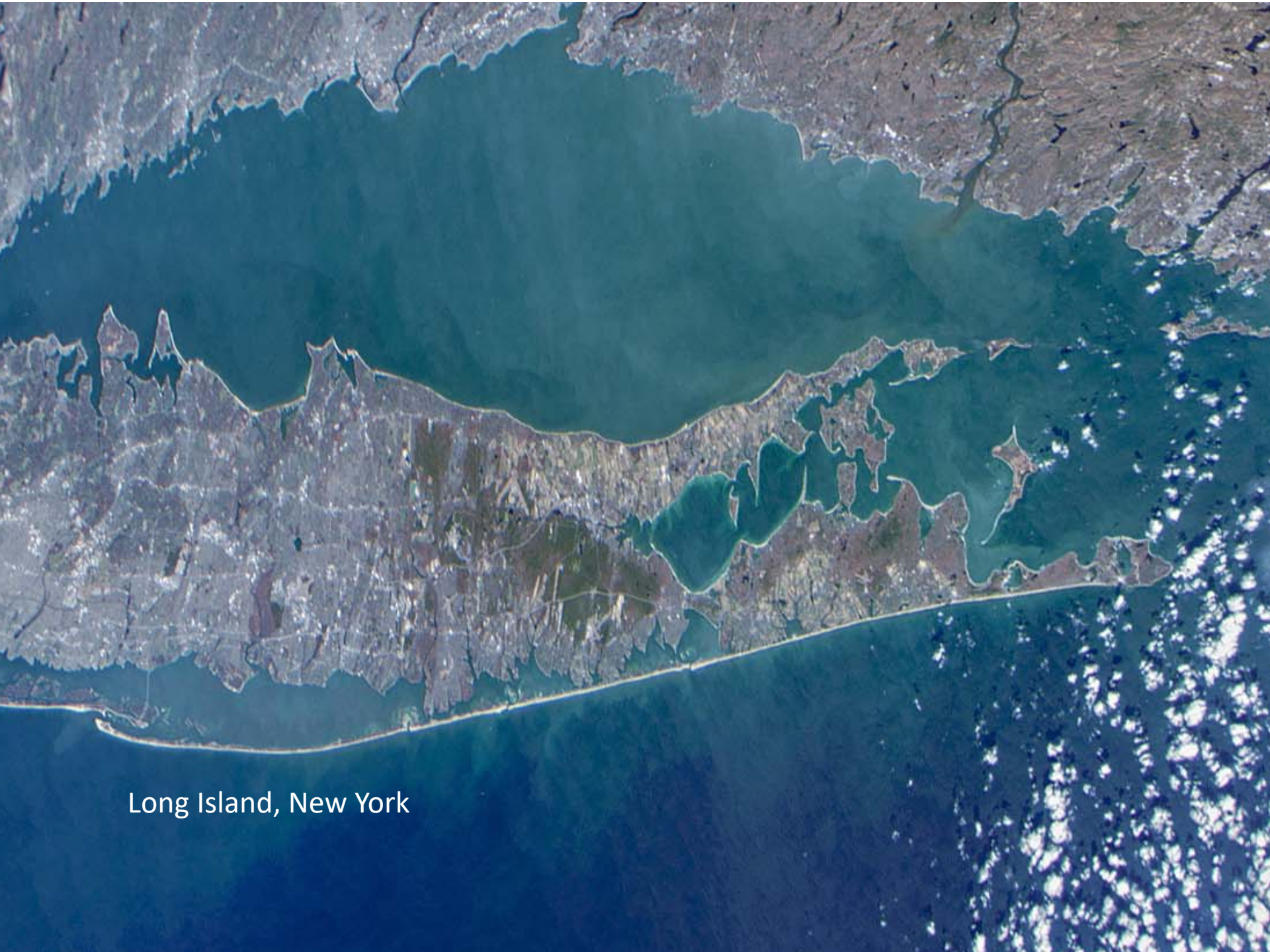
MODIS / Terra 25 May 2019 True Color



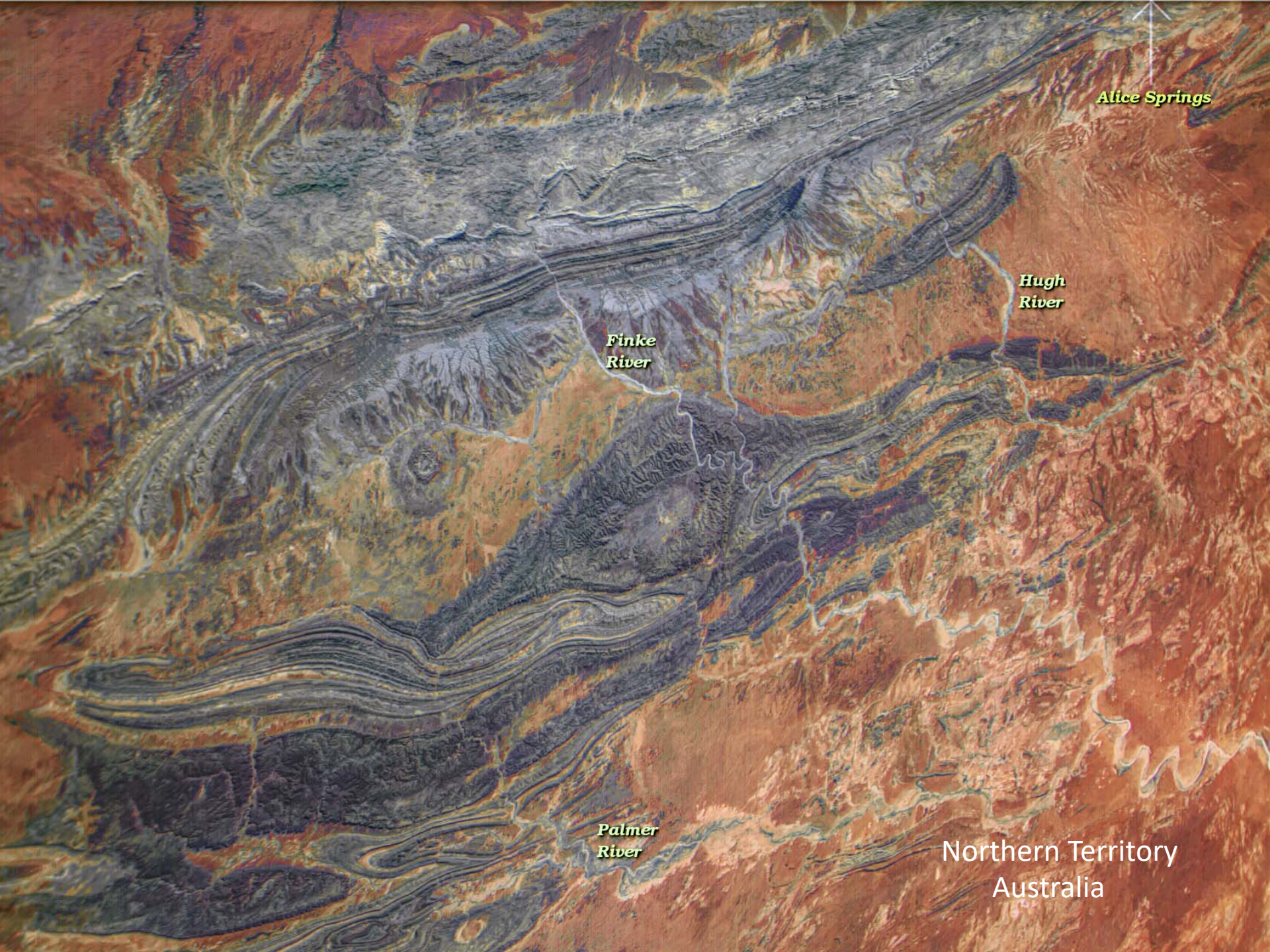
HawkEye / SeaHawk 25 May 2019 True Color

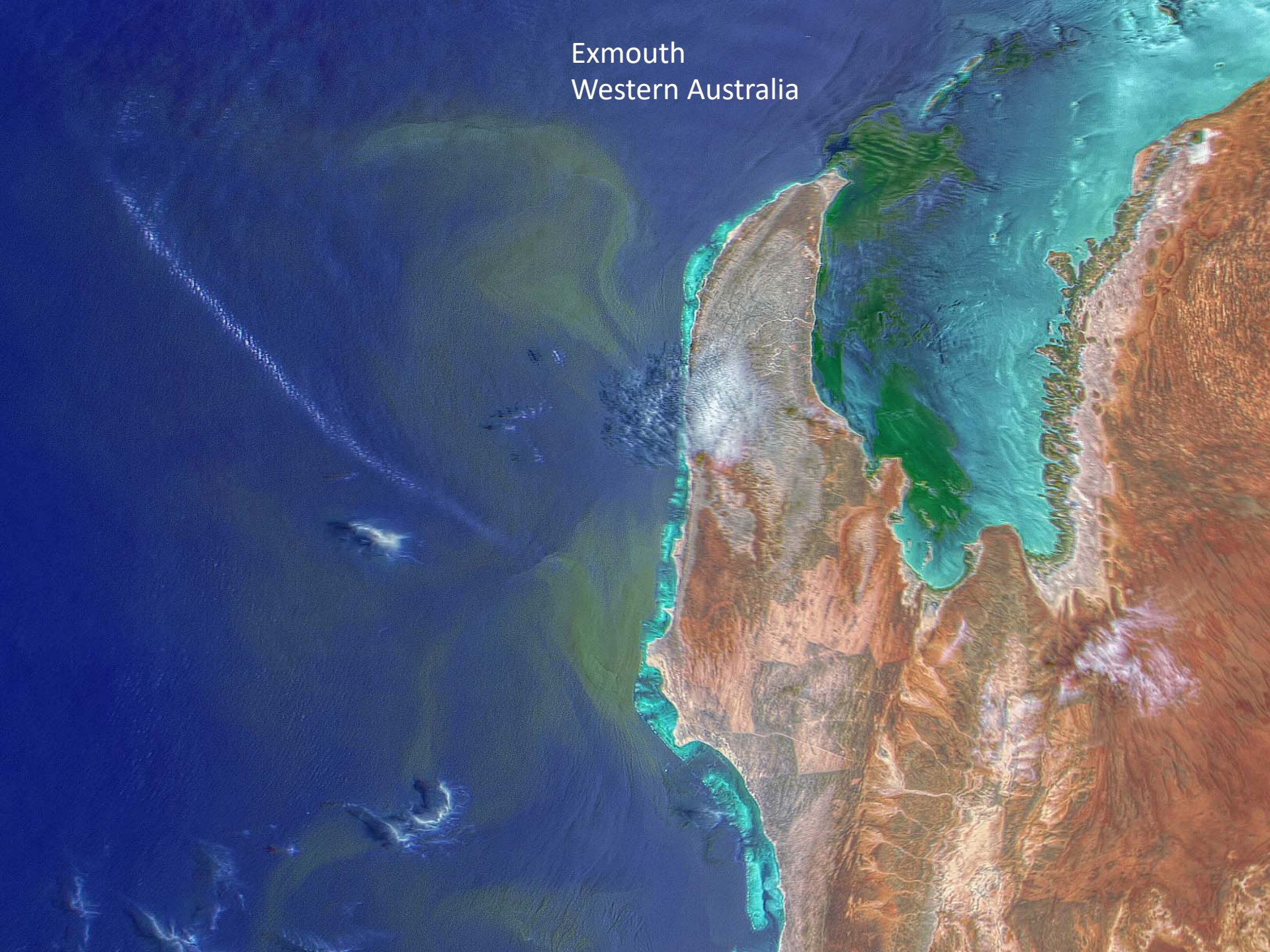



Adelaide, Australia

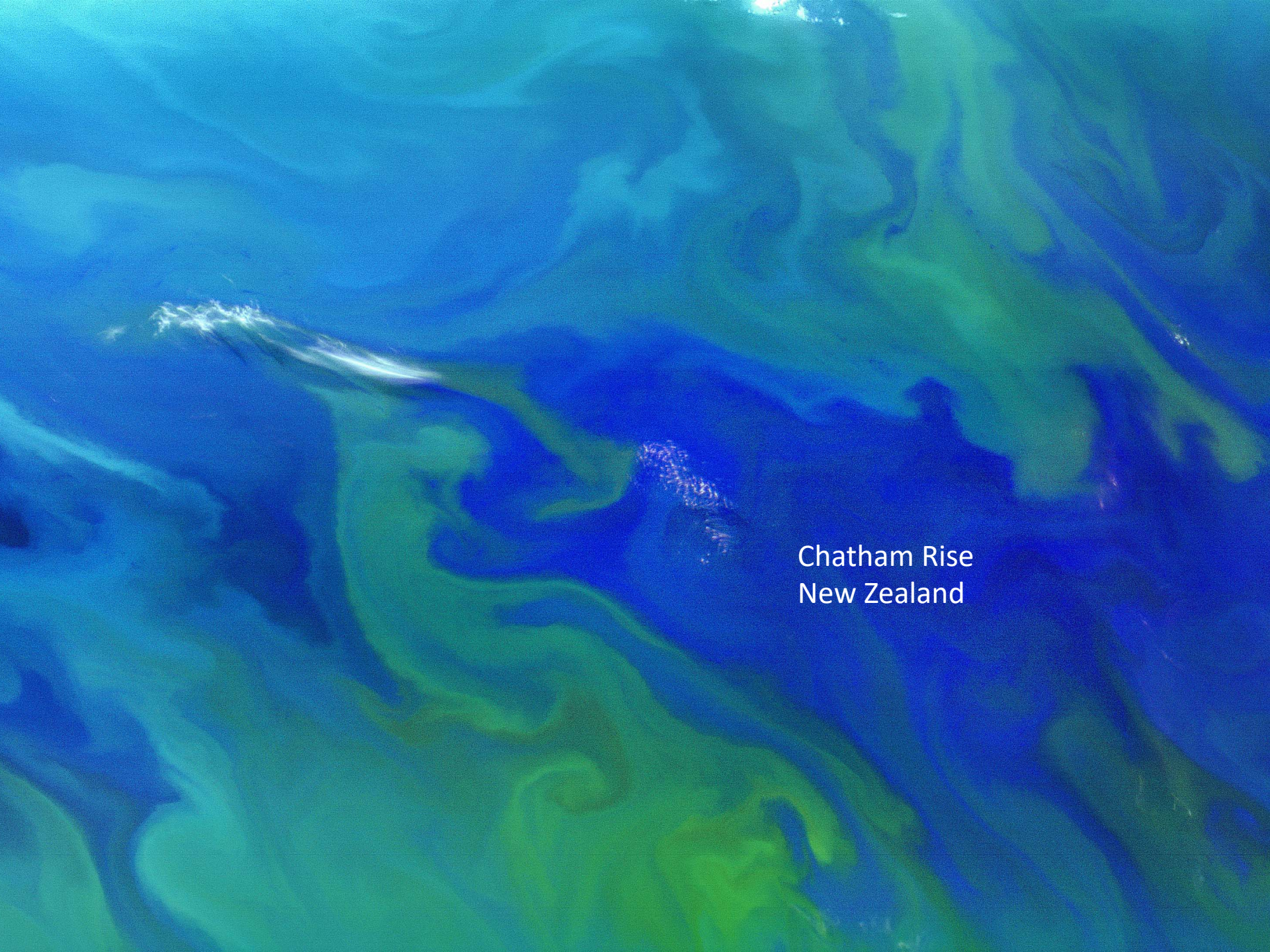

Long Island, New York


Gulf of
Carpentaria


Alice Springs
Hugh River
Finke River
Palmer River
Northern Territory
Australia

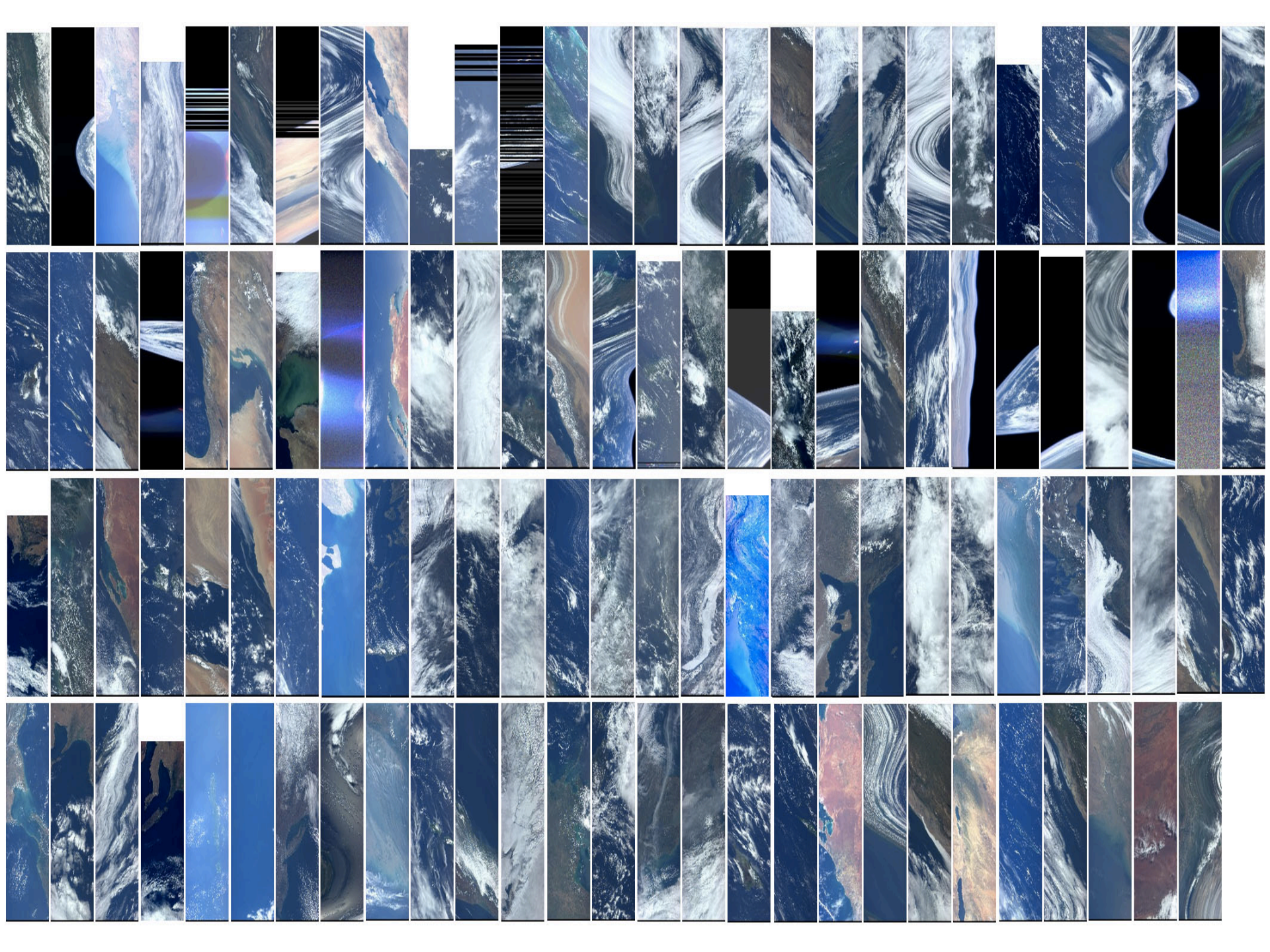

Exmouth
Western Australia


Western Greece


Chatham Rise
New Zealand

Current Status

1. Nearly 18 months of on-orbit operations
2. 135 HawkEye images collected, downlinked and processed to Level-1a
3. 27 successful x-Band data downlinks at NASA/Wallops (100mbps)
4. Automated data processing in place from downlink to Level-2
5. HawkEye instrument has shown no signs of on-orbit degradation
6. SeaHawk spacecraft has only lost 1 km of orbital altitude since launch.
7. No end of mission trends observed in spacecraft systems
8. As yet unresolved spacecraft stability issue believed related to the coupling between the onboard attitude sensors and the control system.

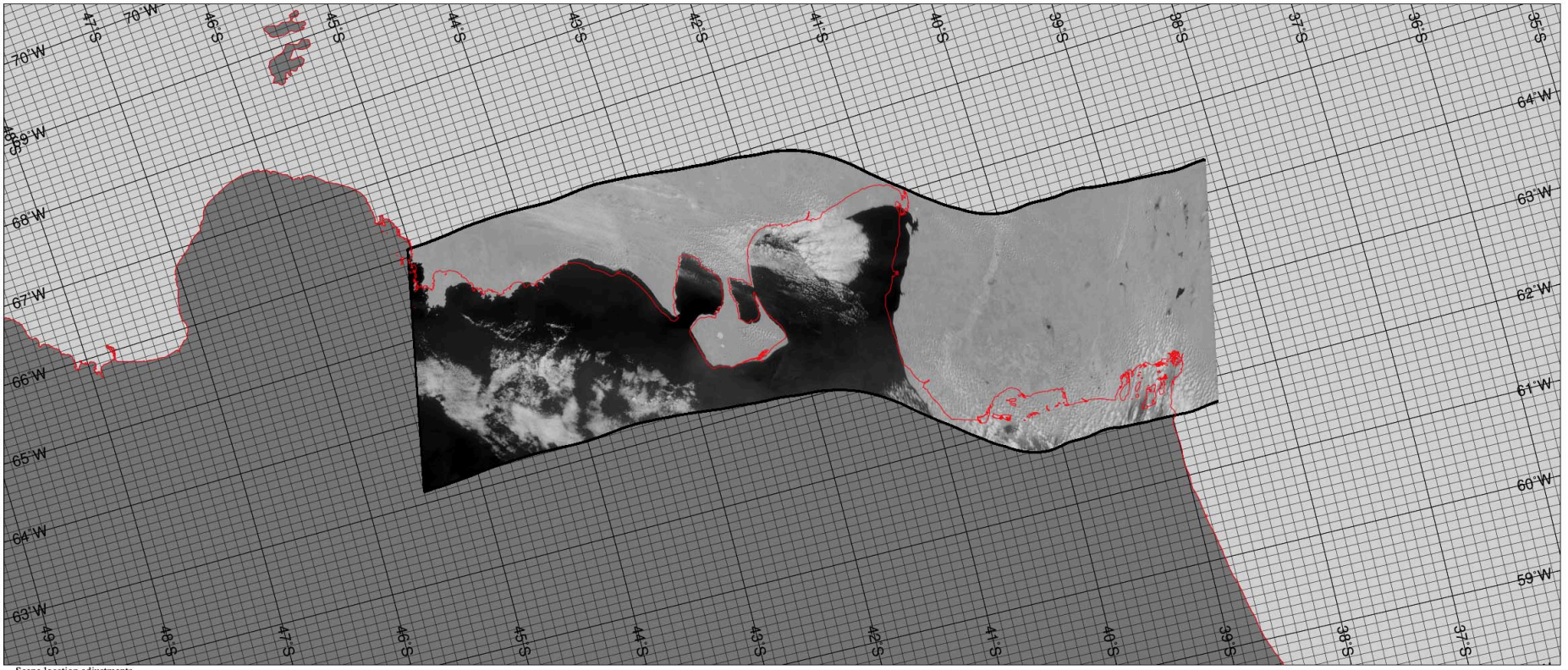


Renavigation tool to geolocate imagery

/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.



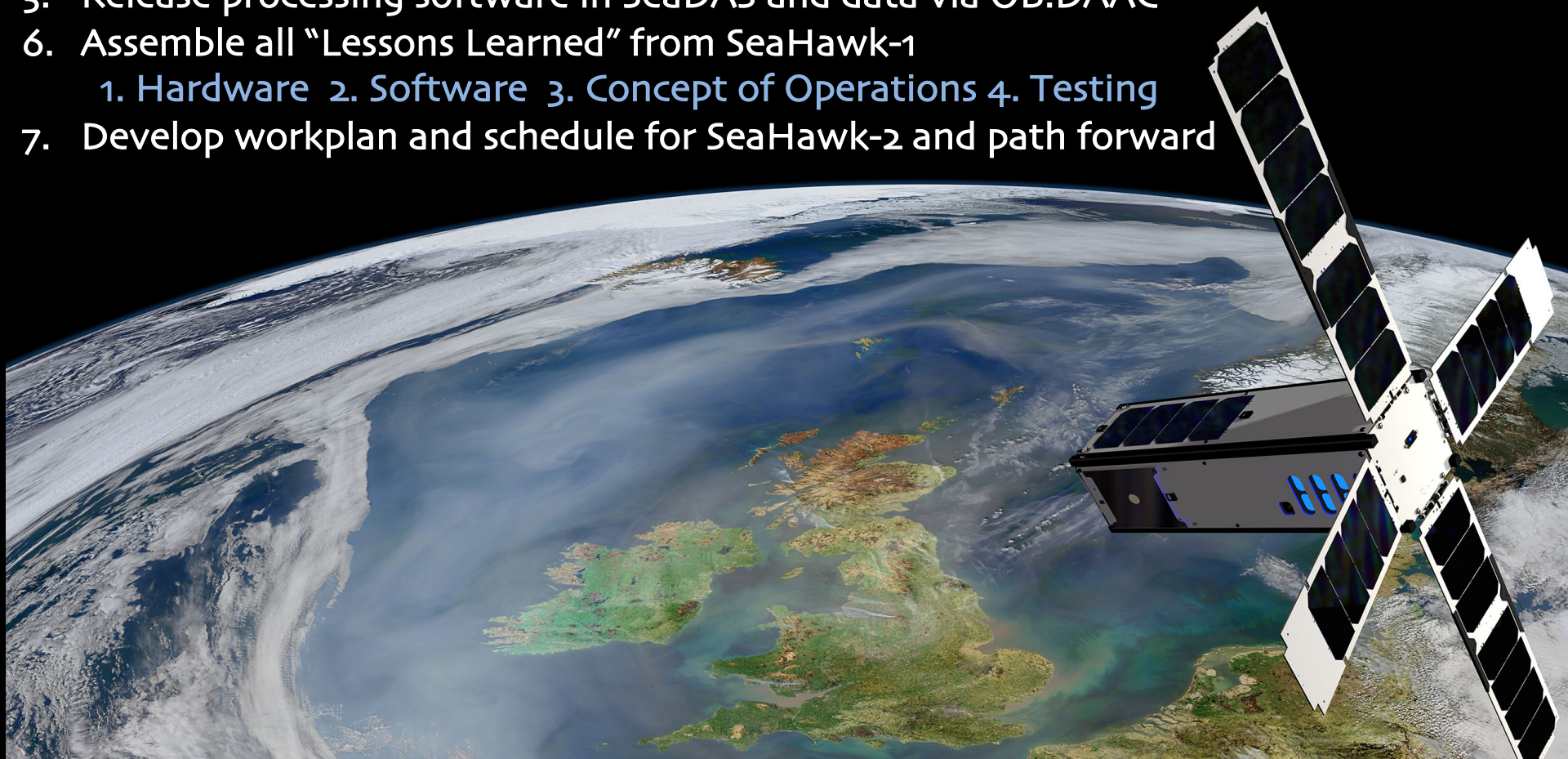
Scene location adjustments

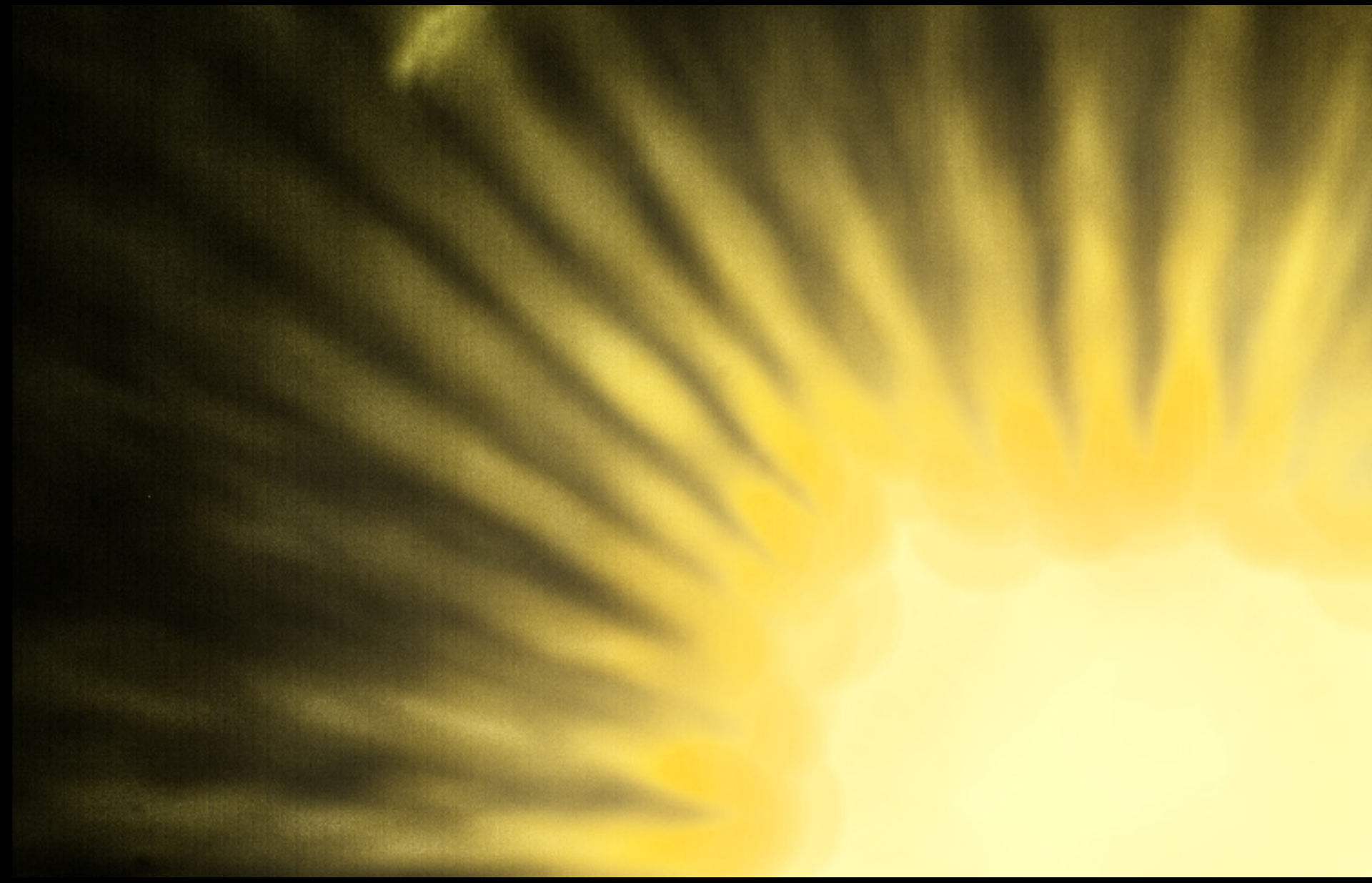
Along track: 31.434 kilometers Cross track: -8.513 kilometers Skip Bad data Water only Land only Cannot discern coastline No fix by translation alone Submit Adjustments

computed pixel resolution: 131 meters

NEXT STEPS

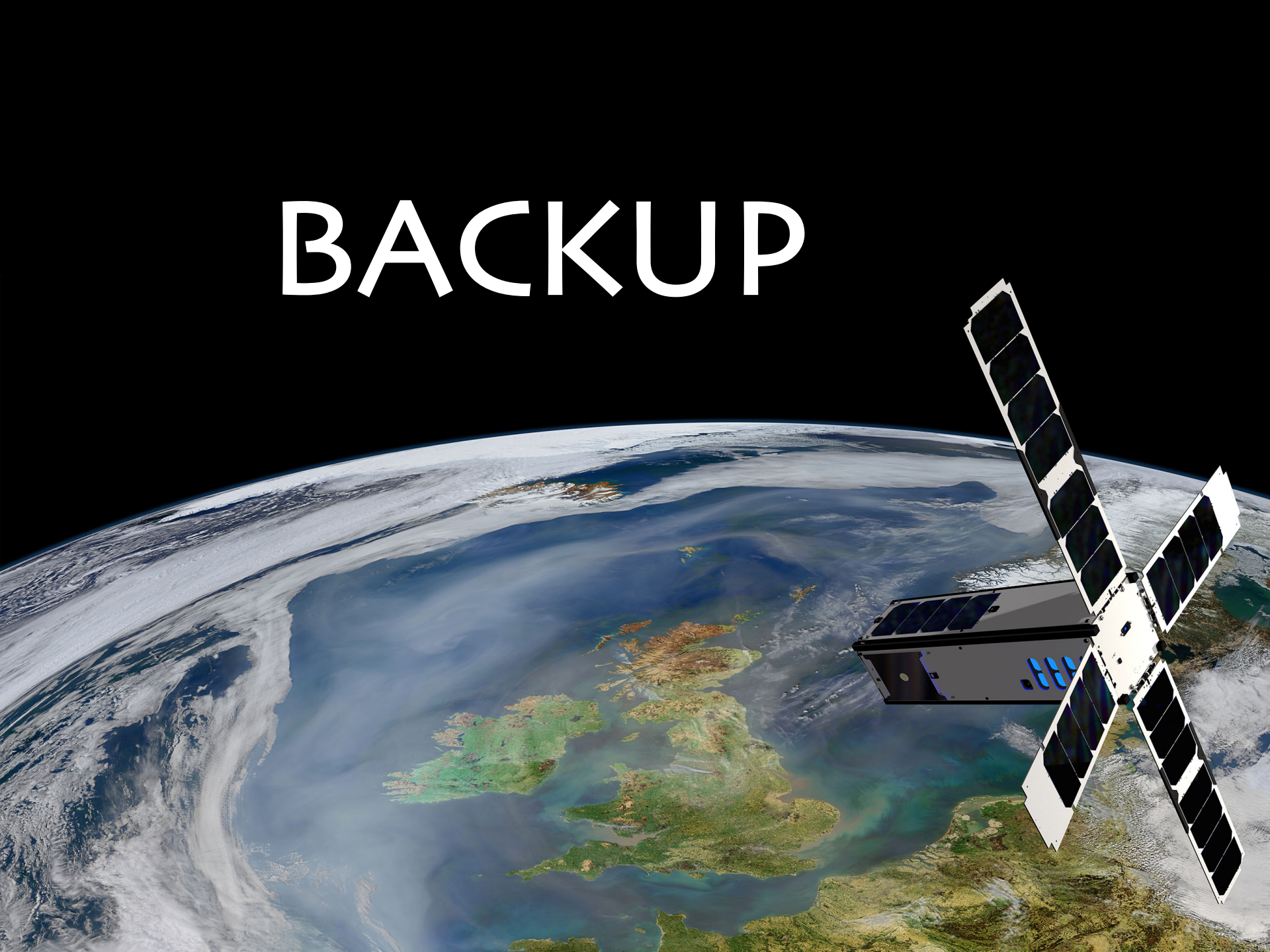
1. Identify and Verify Attitude Control root cause and implement required fix
2. Define revised *Nominal Operations* concept for SeaHawk-1
3. Verify and transition to *Nominal Operations* phase of mission
4. Begin soliciting image requests from the Community (see backup)
5. Release processing software in SeaDAS and data via OB.DAAC
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 and path forward





Finderscope Image 26 April 2016

BACKUP



INSTRUMENT DETAILS

The HawkEye Instrument is designed to capture an image of the oceans and earth with 120 meter per pixel resolution from a 575 km nominal orbit. Each image will have dimensions of 1800x 6000 pixels, 8 bands deep. The bands are similar to those used by the **SeaWiFS instrument**. The instrument is of push-broom design, with 4 linear array CCDs, each containing 3 rows of detectors, scanning the field of view as the satellite passes overhead. The instrument is designed to not saturate on either the land or clouds using a technique called bi-linear gain. The ground swath imaged will be approximately 216 x 720 km in extent (134 x 448 miles).

Band	Wavelength	Bandwidth
	in nm	in nm
SeaWiFS 1	412	20
SeaWiFS 2	443	20
SeaWiFS 3	490	20
SeaWiFS 4	510	20
SeaWiFS 5	555	20
SeaWiFS 6	670	20
New 7	750.9	14.7
SeaWiFS 8	865	40

Optical Design and Radiometric Considerations…

Lessons from Prototype Testing…

CCD University – How to implement a CCD…

Mechanical Design…

Electronics Design…

Software Implementation…

Presentations available at: http://cloudlandinstruments.com/?page_id=188

NONREIMBURSABLE SPACE ACT AGREEMENT BETWEEN NASA/SMD and UNIVERSITY OF NORTH CAROLINA AT WILMINGTON

EFFECTIVE DATE 6/1/2017 EXPIRATION DATE 6/1/2022

NASA Responsibilities:

Mission Planning & Integration and NEN

Coverage and loading analyses

Networks Documentation and Reviews

RF Compatibility Testing and Reports

On-Orbit Services

NEN Aperture Fees are based upon 4 passes per day

NEN Mission Configuration and Test Services

Ocean Biology Processing Group

Prelaunch advisors to the HawkEye instrument and SeaHawk cubesat

Develop Level 0-to-2 processing software

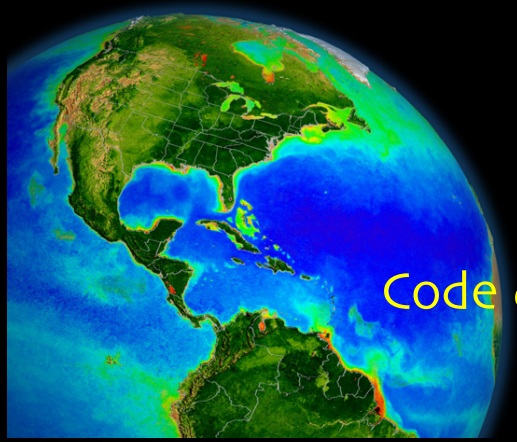
Pre-launch characterization of the Hawkeye with Cloudland Instruments

Instrument scheduling procedures with Clyde Space

Downlink scheduling with NASA/NEN

Data processing of the SeaHawk

Archive and distribution of SeaHawk data to the research community



Code 618 Calibration Facility

Use of NASA Portable integrating sphere for pre-launch calibration

135 Targets imaged by HawkEye

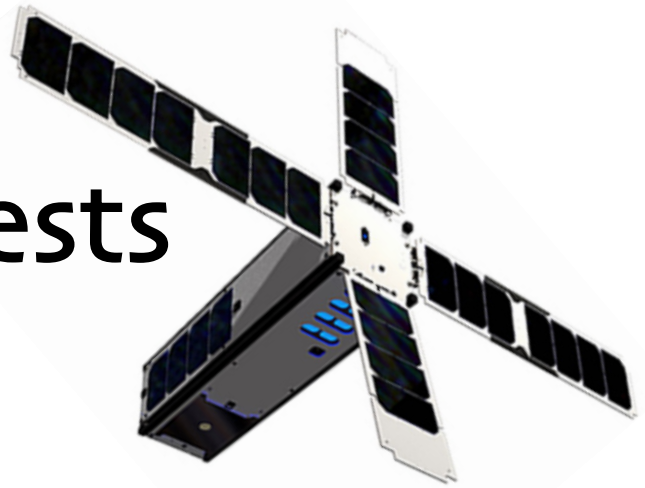
- Monterey Bay
- North Carolina Coast
- India (Mumbai)
- Cape Horn
- Long Island
- Tasmania
- San Francisco
- Gulf of Suez
- Puerto Rico
- Baja California
- Flores Sea
- Rio de la Plata
- Southern CA
- Gulf of Mexico
- Lake Maracaibo
- Cuba and Jamaica
- New York Bight
- Mid-Atlantic
- South Atlantic Bight
- Scotland
- MOBY
- Scotland
- Lake Titicaca
- Scotland
- Scotland
- Scotland
- Lake Michagan
- Samoa
- West Coast Australia
- Buenos Aires
- Nova Scotia
- India, Gulf of Khambhat
- Catalina Islands
- Yangtse River
- Crete
- Gulf of Maine
- Eastern Long Island
- MOBY
- Townsville Australia
- Galapagos

- Ireland Northern Scotland
- Lake Atitlan Guatamala
- San Franciso and Monterey Bay
- Outer banks
- Chesapeake
- Florida
- Hawaii
- MOBY Hawaii
- Lake Titicaca
- Galapagos
- Eastern Med.
- strait of Hormuz
- Caspian Sea
- Chesapeake
- Western Australia
- French Polynesia
- Cook Straight - New Zealand
- Java Sea
- Red Sea
- Cuba - Jamaica
- Fiji - Center
- Zaire Congo River
- Fiji - West
- Java Sea
- Lake Malawi
- Gulf of Aden (UFOs)
- Peru Upwelling
- Tahiti
- Gulf of Aden
- Cook Straight
- Bangladesh
- Panama
- Ganges
- Congo River
- Ganges
- Vietnam
- Southwest Australia
- South Africa
- southwest australia

- south georgia
- Torres Straight
- Shark Bay
- Bali Sea
- Gulf of Aden
- Namibia
- Bora Bora
- Argentina
- Aegean Sea
- Chesapeake Bay
- Christmas Island
- Kerguelen Island
- Orinoco Delta
- Great Barrier Reef
- Cameroon
- Lake Baikal
- Gulf of Khambhat
- Western Nova Scotia
- Valdes Peninsula
- Baleric Sea
- Gold Coast Australia
- Sydney Australia
- Ganges Mouth
- Greece
- San Franciso Bay
- Japan
- Red Sea
- Big Island Hawaii
- Sri Lanka
- Adelaide Aust
- Falklands
- Spencer Gulf Aust
- Western Black Sea
- Andaman Islands
- Cook Straight
- Long Island Sound
- Fraser Island Aust
- Ganges
- Samoa
- Gulf of Tehuantepec

- Kodiak
- Gulf of Carpentaria
- Tasmania
- English Channel
- Chesapeake Outer Banks
- Big Island Hawaii
- Samoa East
- Northwest Australia
- Southern Florida
- Lake Titicaca
- Israel – Jordan
- French Polynesia
- Coastal Peru
- Gulf of Khambhat
- Ayres Rock Aust
- San Francisco

Image Acquisition Requests



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