Forest Fires, Sunglint and a Solar Eclipse: Responsive Remote Sensing with AeroCube-4

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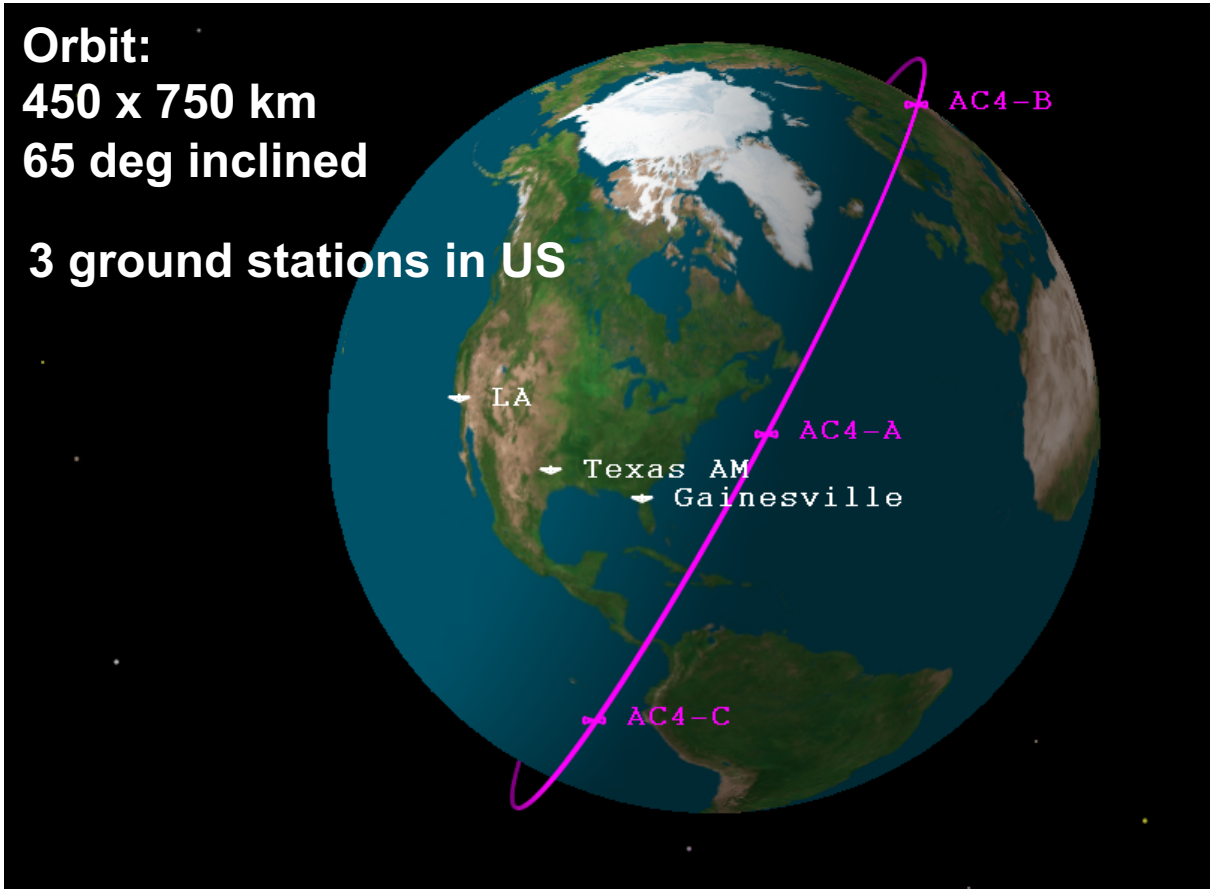
The Aerospace Corporation

CubeSat Developers' Workshop
San Luis Obispo, CA
23–25 April 2014

AeroCube-4

Three-Satellite Constellation



Launched on Atlas V, 13 September 2012

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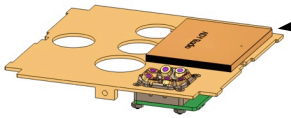
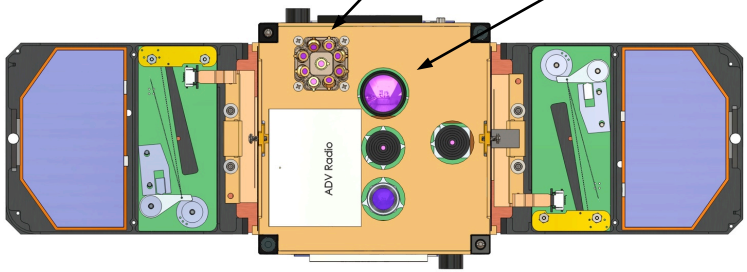
AeroCube-4: Redefining the 1U Form Factor

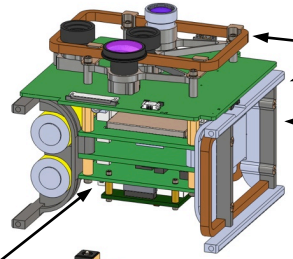


Custom 914.7 MHz Radio with encryption & download speeds up to 500 kbps

Earth sensor

3 Visible cameras

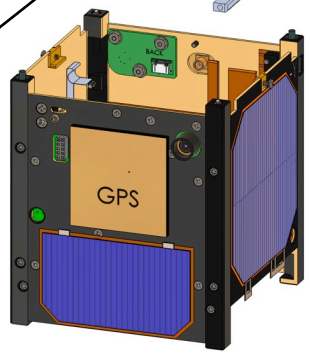


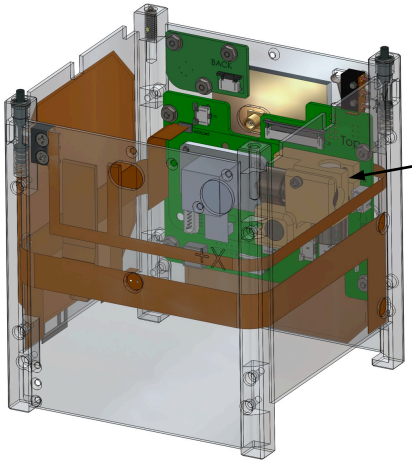


Magnetic Coils

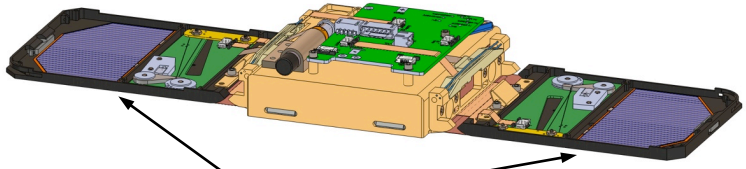
Electronics stack

Custom Designed GPS Receiver



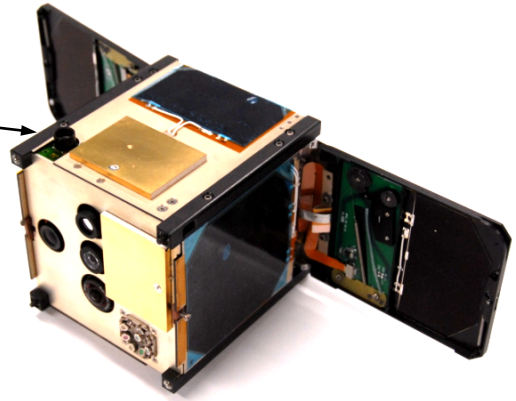


Reaction wheels hard-mounted to satellite body



Deployable Solar Wings

Sun sensor



Satellite is 10 x 10 x 10 cm and weighs < 1.5 kg

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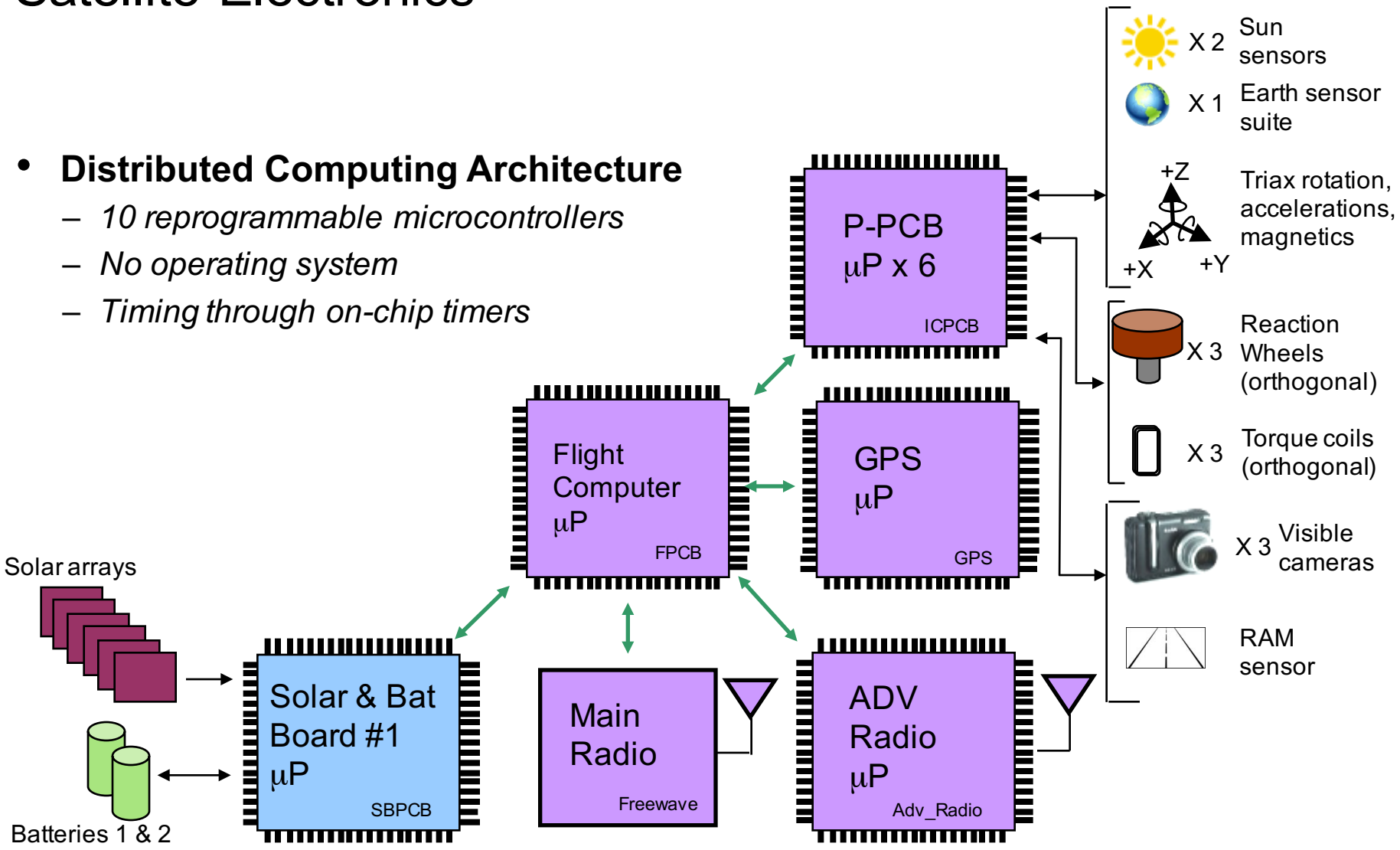
Satellite Electronics

- **Distributed Computing Architecture**
  - *10 reprogrammable microcontrollers*
  - *No operating system*
  - *Timing through on-chip timers*



AeroCube-4 Capabilities and Statistics

- **On-orbit reprogrammable software has proven to be invaluable**
  - *150 software updates in 18 months*
  - *Several software updates replaced greater than 75% of prior binary*
  - *Allowed for alternate attitude control methodology to overcome on-orbit anomalies*

- **Ground Planning Software Supports Complex Mission Operations**
  - *570 data collection experiments involving attitude control planned & executed*
  - *Over 11,000 high resolution images collected & downloaded (greater than 1 GB data)*
  - *Planning software includes ephemeris propagation and attitude trajectory profiling*
  - *Plan outputs can be run through Simulink Simulation prior to upload for verification & to estimate predicted performance*

- **Lights-out Ground Station Network**
  - *Data upload & download pre-planned and scheduled for multiple remote ground antennas*

- **Robust Power System & Reset Logic**
  - *Survived 7 latch-up events induced by solar radiation*
  - *Combination of battery under-voltage protection & daily resets of all electronics*

Complex & Reliable Operations are Possible with a 1U Vehicle

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AeroCube-4
Tracking Ground Target

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Tracking Yorke Peninsula, South Australia

AeroCube-4 can slew and maintain pointing at a specific ground target

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AeroCube-4
Responsive Fire Detection

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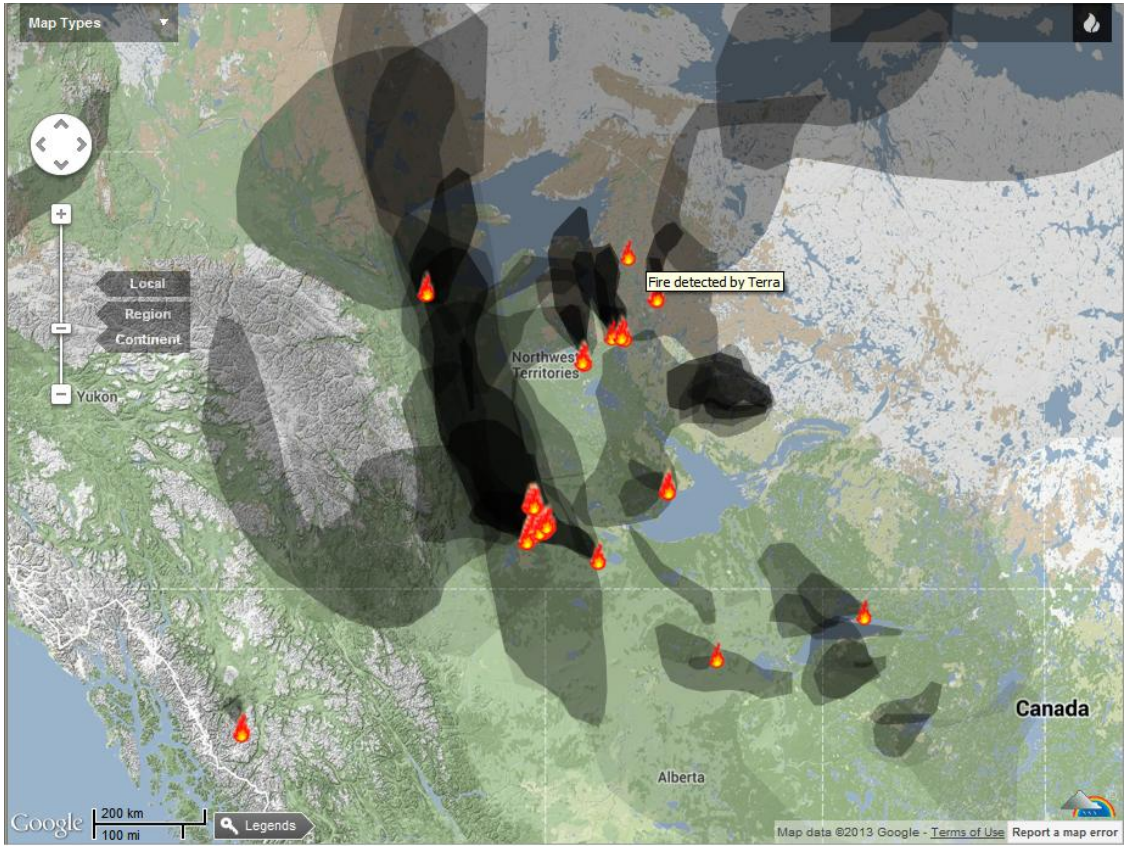
AC4 – Forest Fire Imaging

Available Predictive Data



Sources

- MODIS (Moderate Resolution Imaging Spectroradiometer)
- AVHRR (Advanced Very High Resolution Radiometer)
- GOES (Geostationary Operational Environmental Satellite)

Combined Data Source

- wunderground.com
  - *Simple user interface*
  - *Lat/Lon Predictions*
  - *Utilizes MODIS, AVHRR, & GOES*

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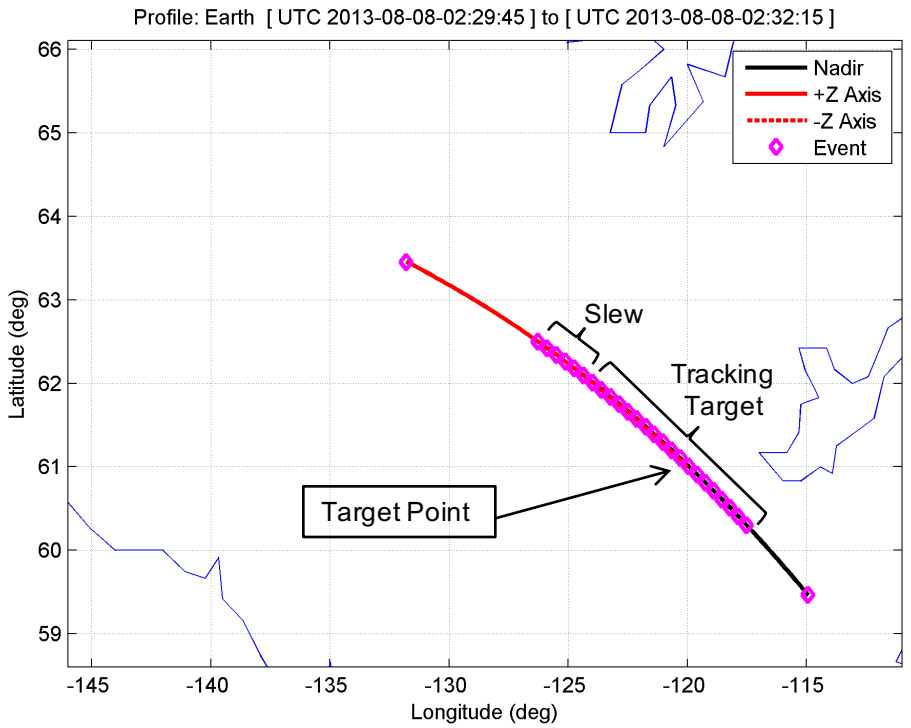
AC4 – Forest Fire Imaging

Mission Plan

Event	Time (sec)
Start Earth Acquisition	0
Complete Earth Acquisition	117
Start Z-axis Sun Search	176
Complete Sun Acquisition	283
Attitude Determination Initialization	313
Transition to Inertial Track Mode - Maintain Nadir-Sun Attitude	366
Slew to Ground Target (Fire in NWT, Canada)	411
Start Image Collection, 25 Photos, 3 Second spacing in-between pictures	411
Track Ground Target	456
End of Image Collection	490
End Inertial Track Profile & Test	516



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AC4 – Forest Fire Imaging

Development Timeline

Event	Time (PST)
Target Identification	07:00, 8/7/2013
Weather Verification	07:30, 8/7/2013
Mission Development	07:45, 8/7/2013
Review & Approval	09:10, 8/7/2013
Upload Mission - Texas	10:40, 8/7/2013
Mission Start	19:24, 8/7/2013
Mission End	19:32, 8/7/2013
Download 1– Florida (Telemetry & Thumbnails)	19:40, 8/7/2013
Download 2 – Texas (Pictures)	21:00, 8/7/2013
Download 3 – Florida (Pictures)	09:20, 8/8/2013

Total Mission Time – 26 Hours 20 Minutes

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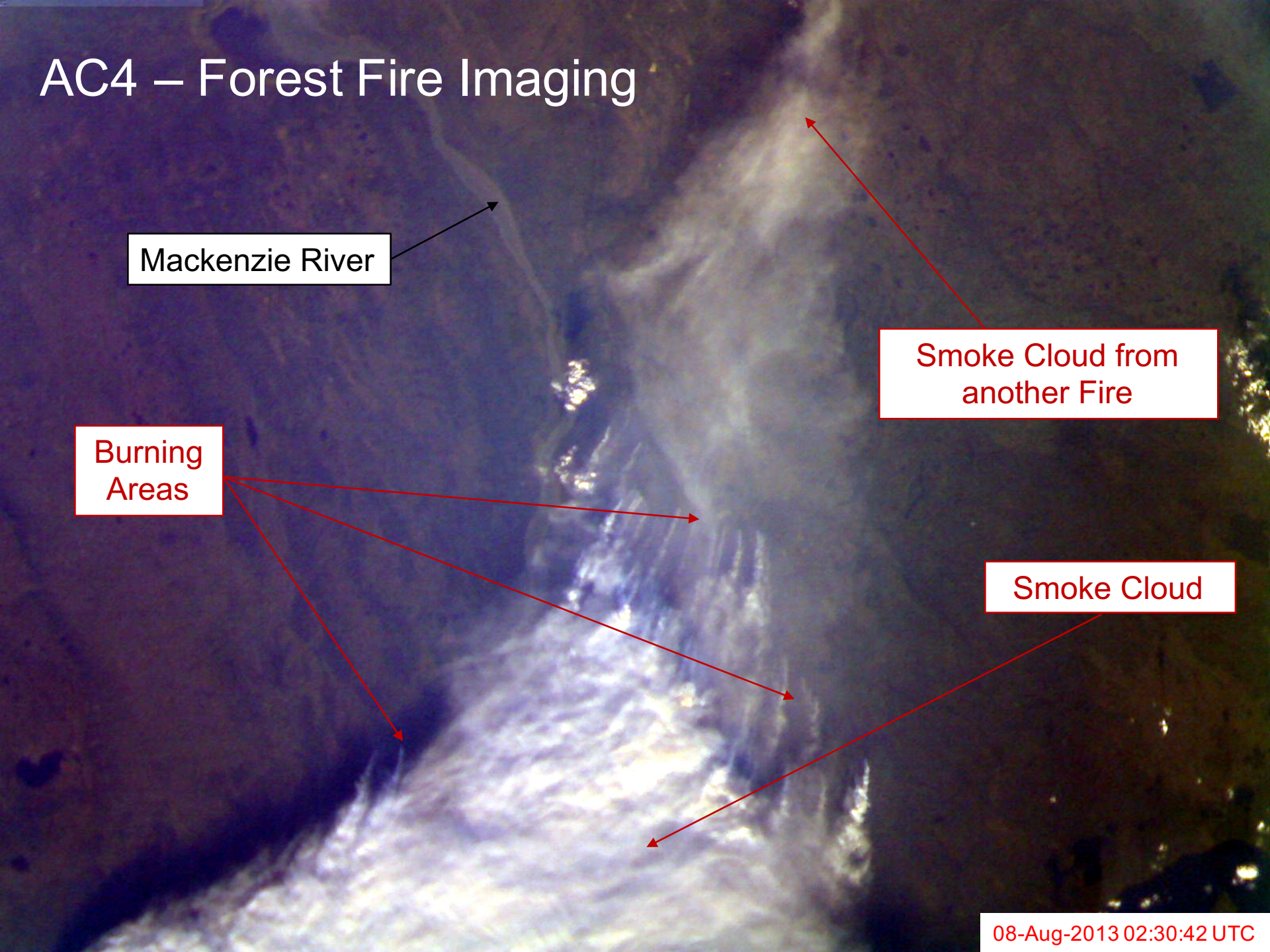
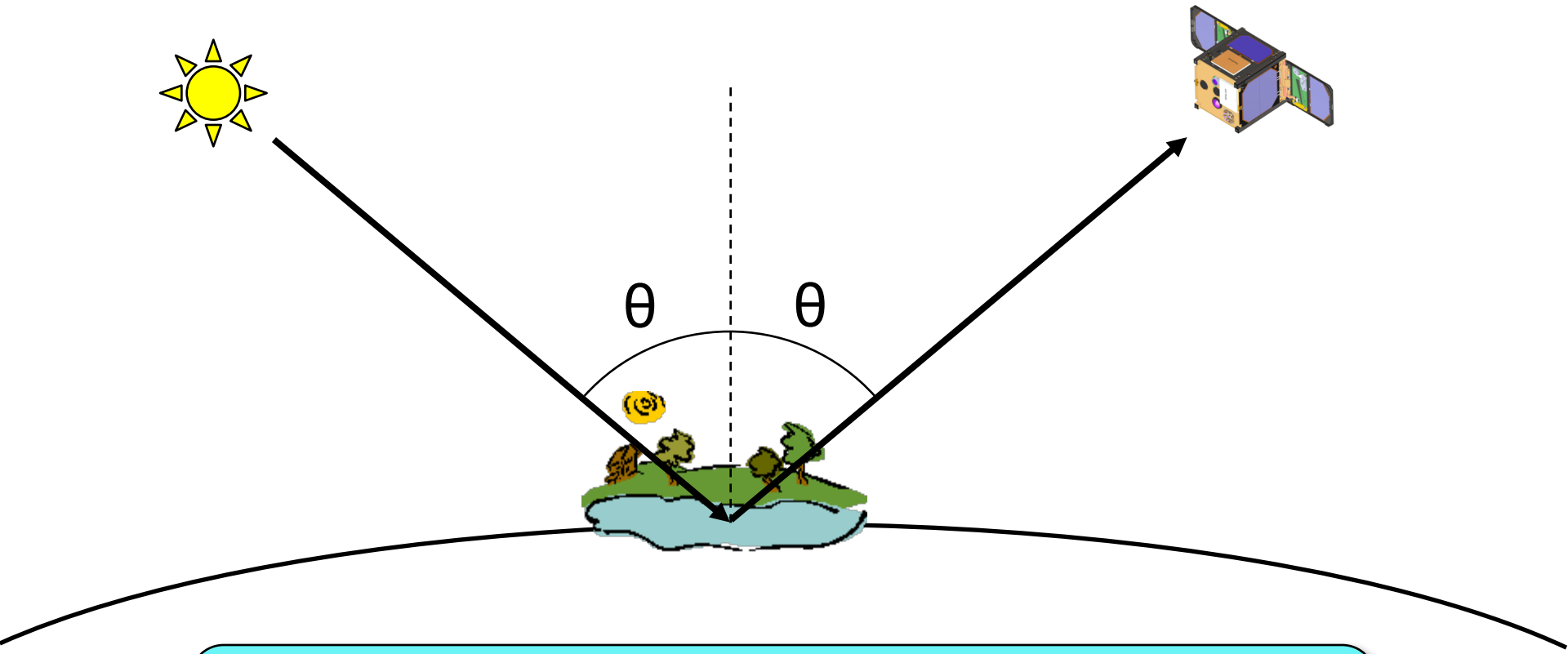
AC4 – Forest Fire Imaging



AeroCube-4
Sunglint

Specular Reflection of Sunlight



Reflection of sunlight off water can yield valuable insight into ocean circulation, local wind speed, wave detection, and wetland extent. This reflection is called “sunglint.”

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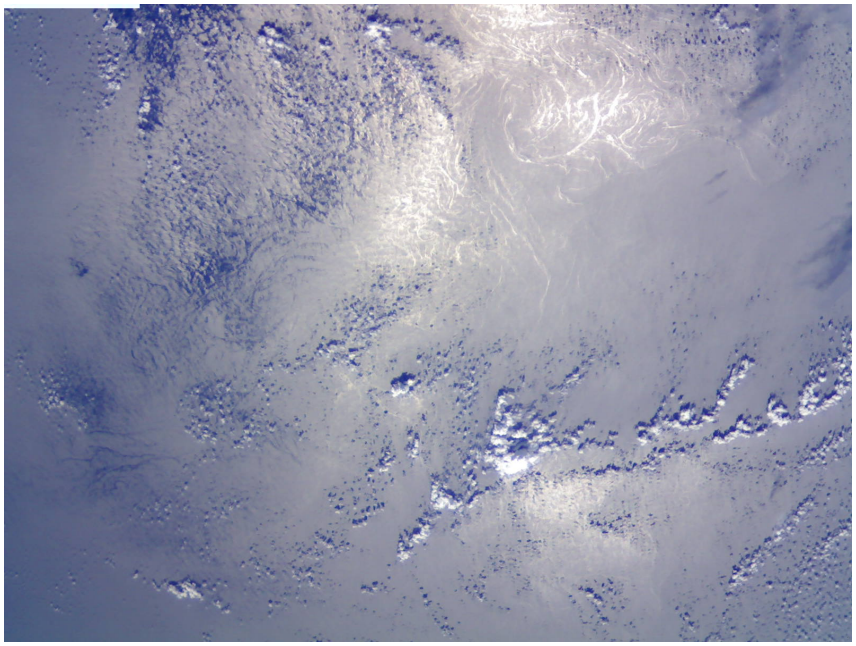
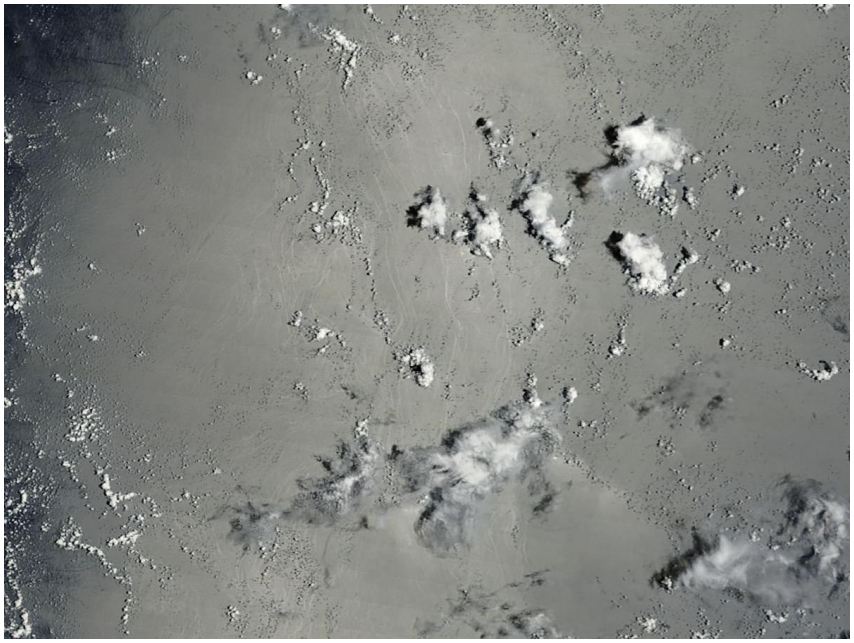
Comparison: AeroCube-4 and MODIS





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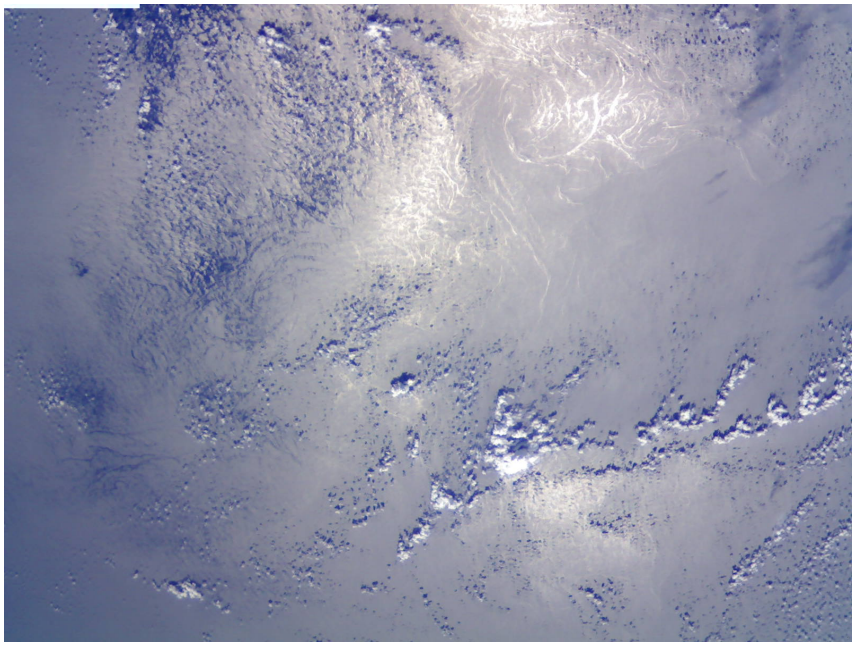
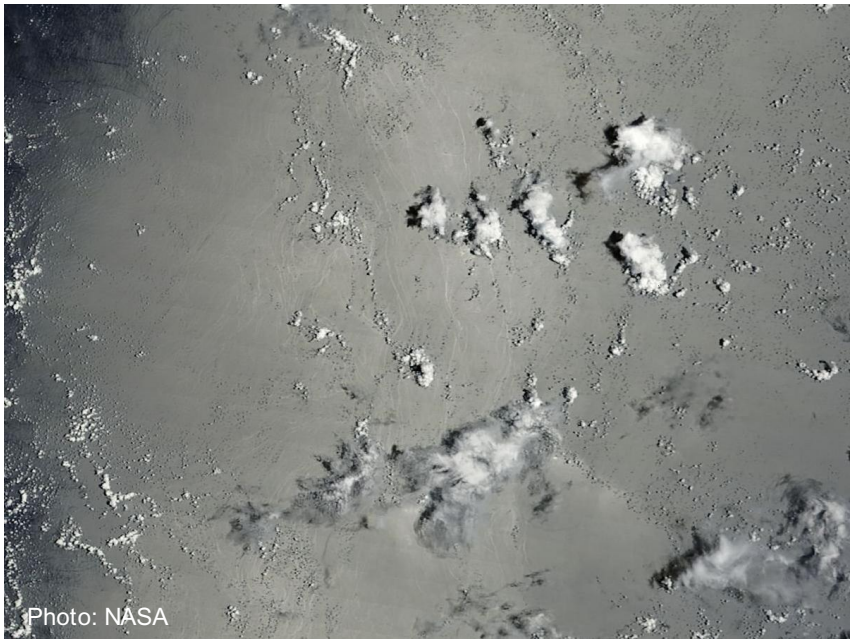
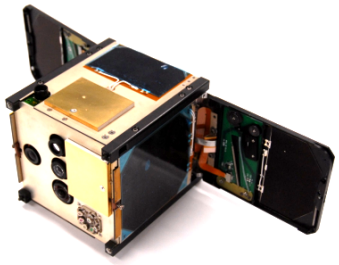
Comparison: AeroCube-4 and MODIS

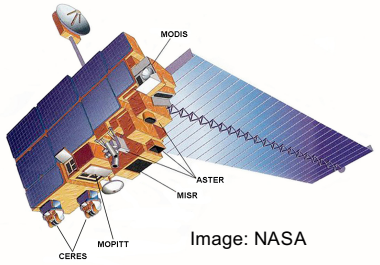


AeroCube-4



MODIS-Terra





AeroCube-4 and MODIS have comparable image resolution.

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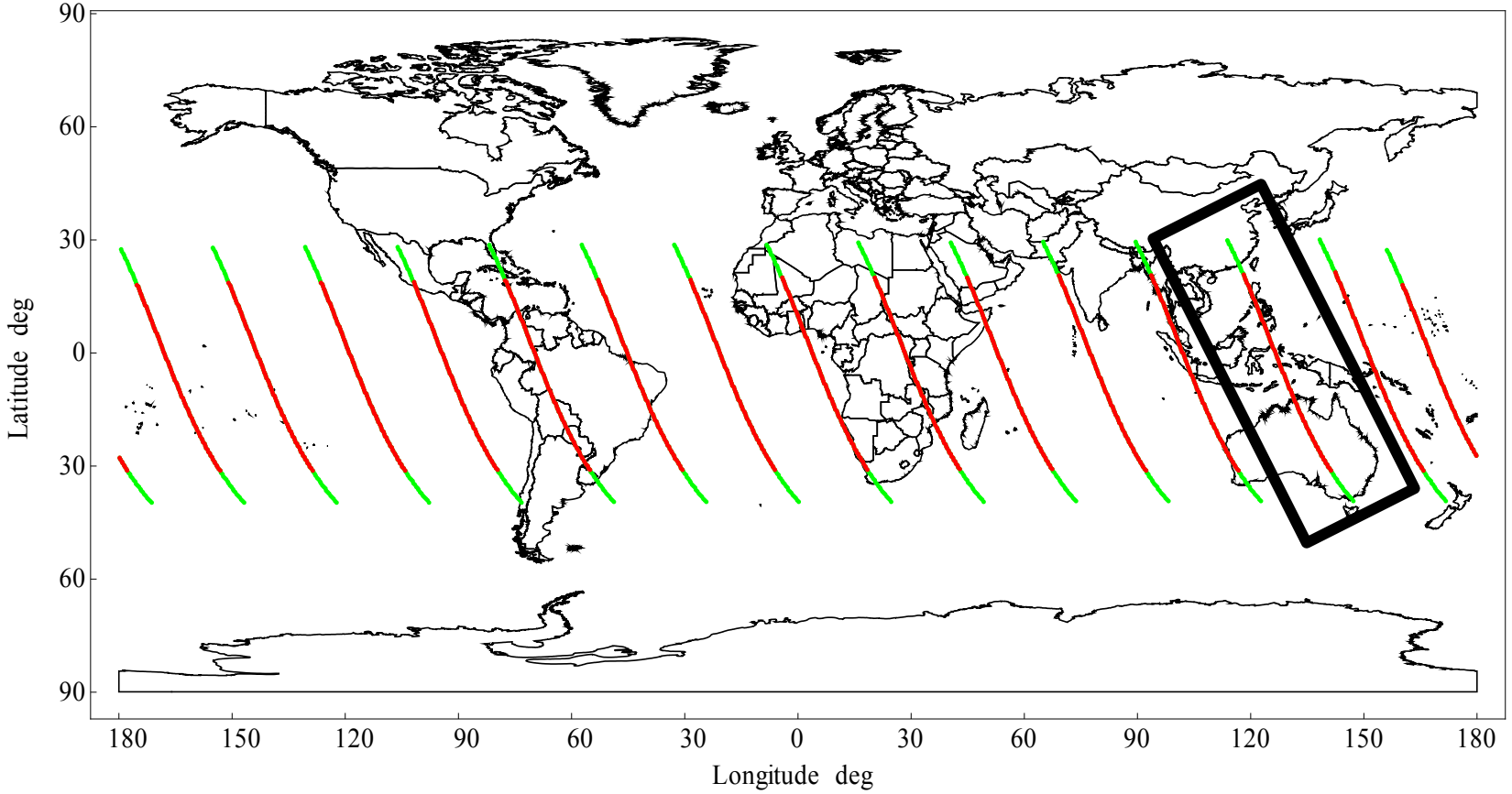
Specular Reflection Points: **20 September 2013**



Red = Sun-Earth-Satellite angle < 35 deg

Green = Sun-Earth-Satellite angle < 45 deg

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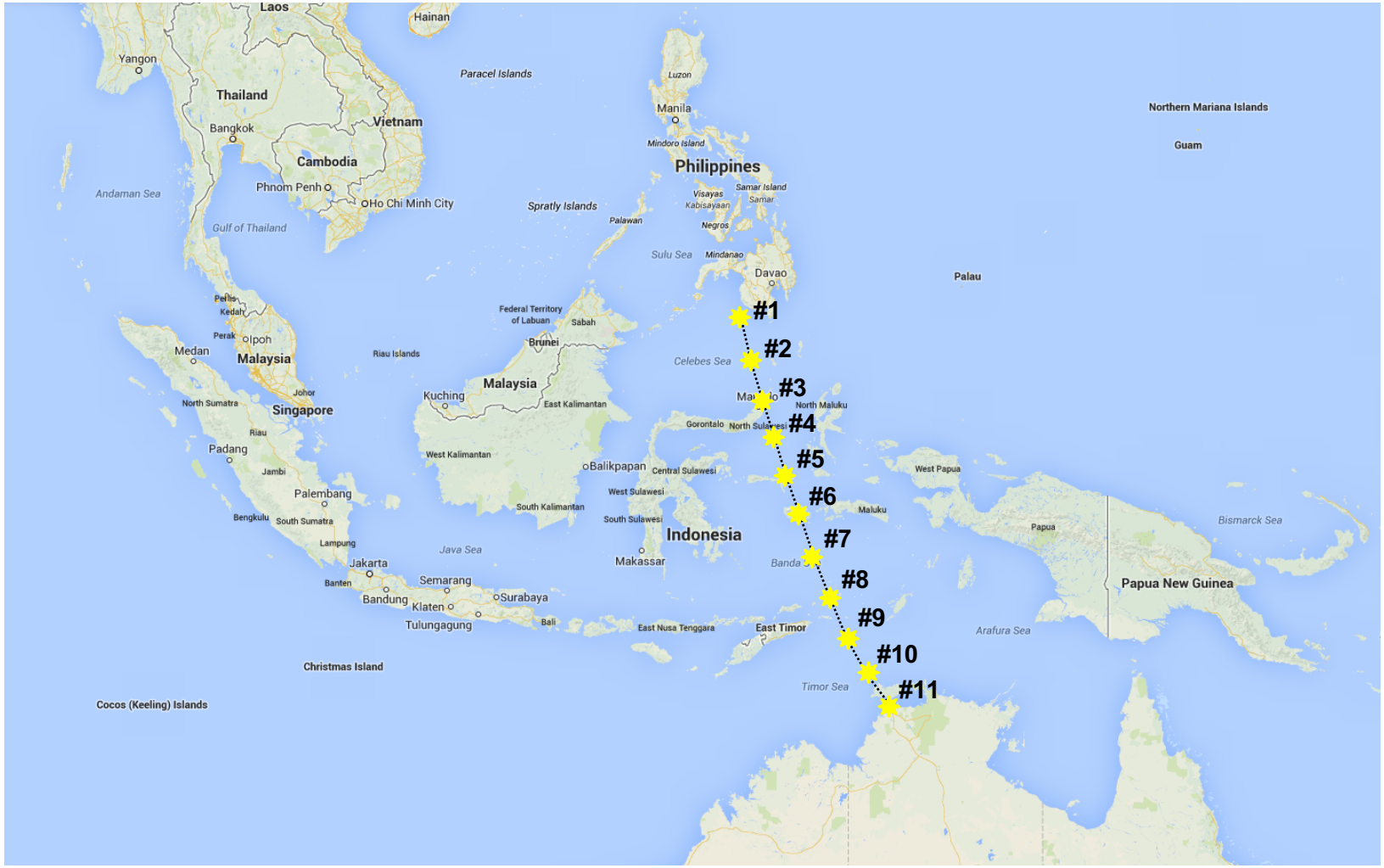
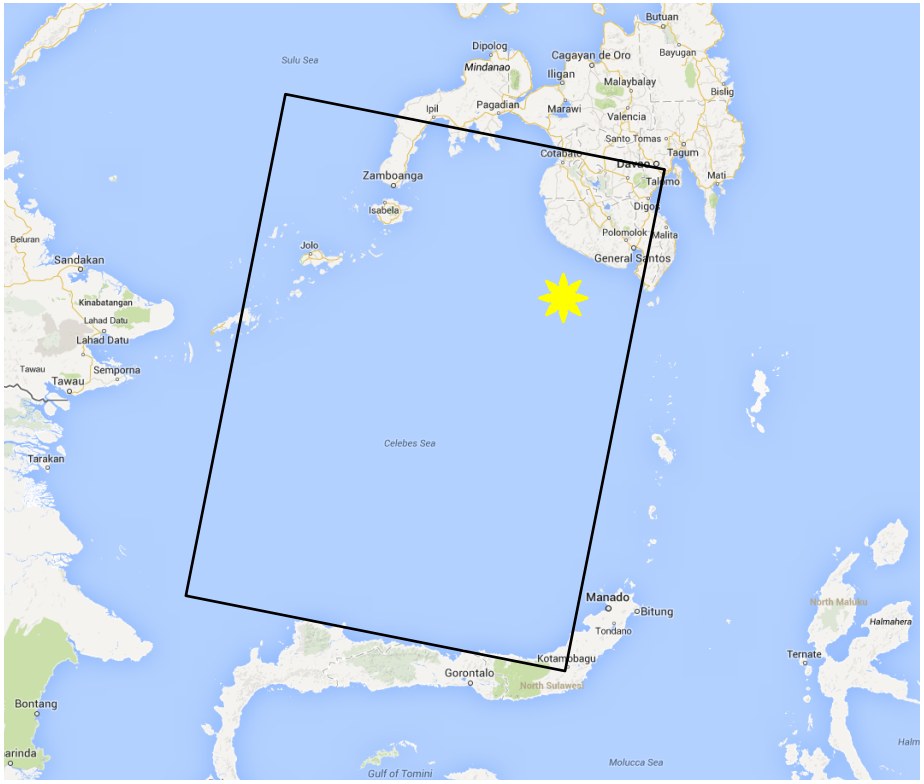
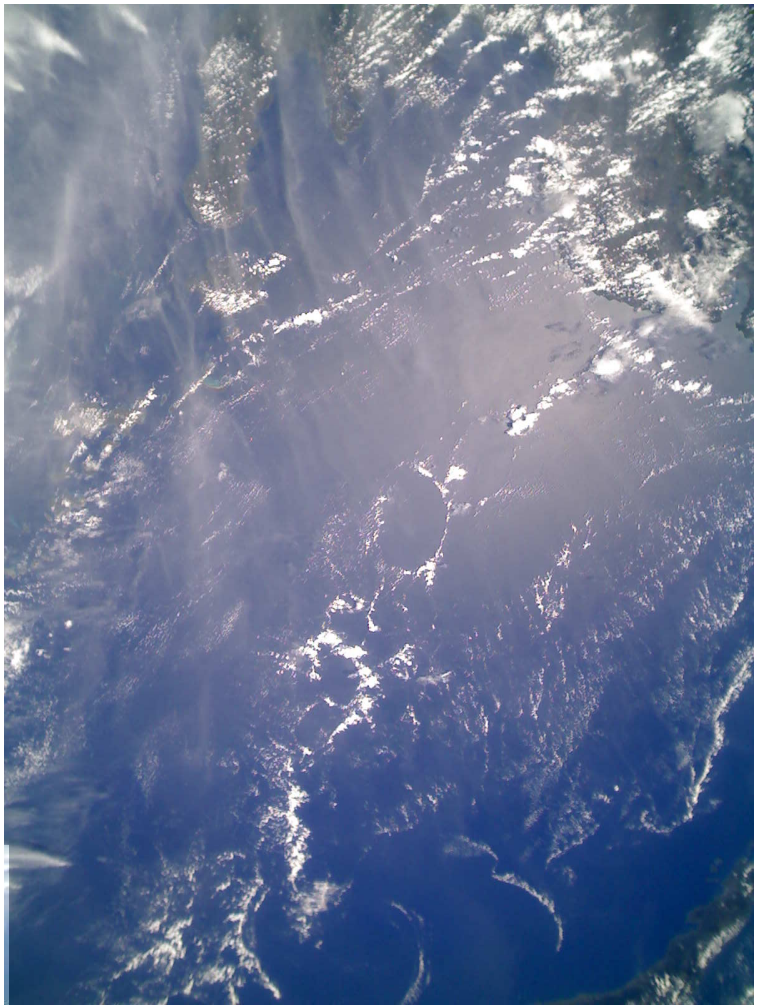
Path of Sunglint Images

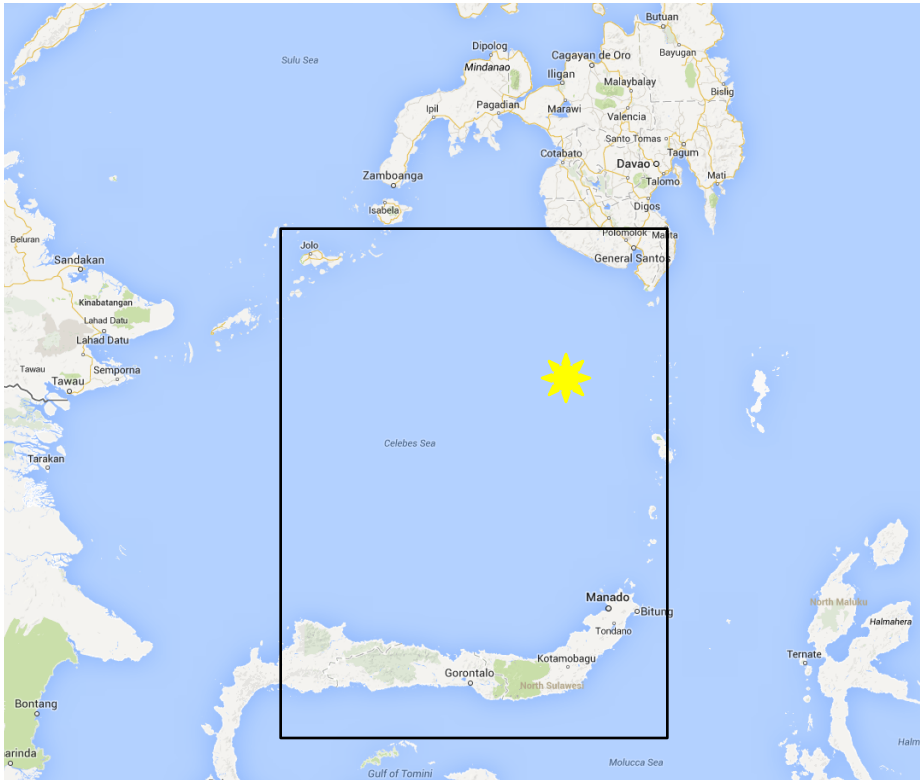


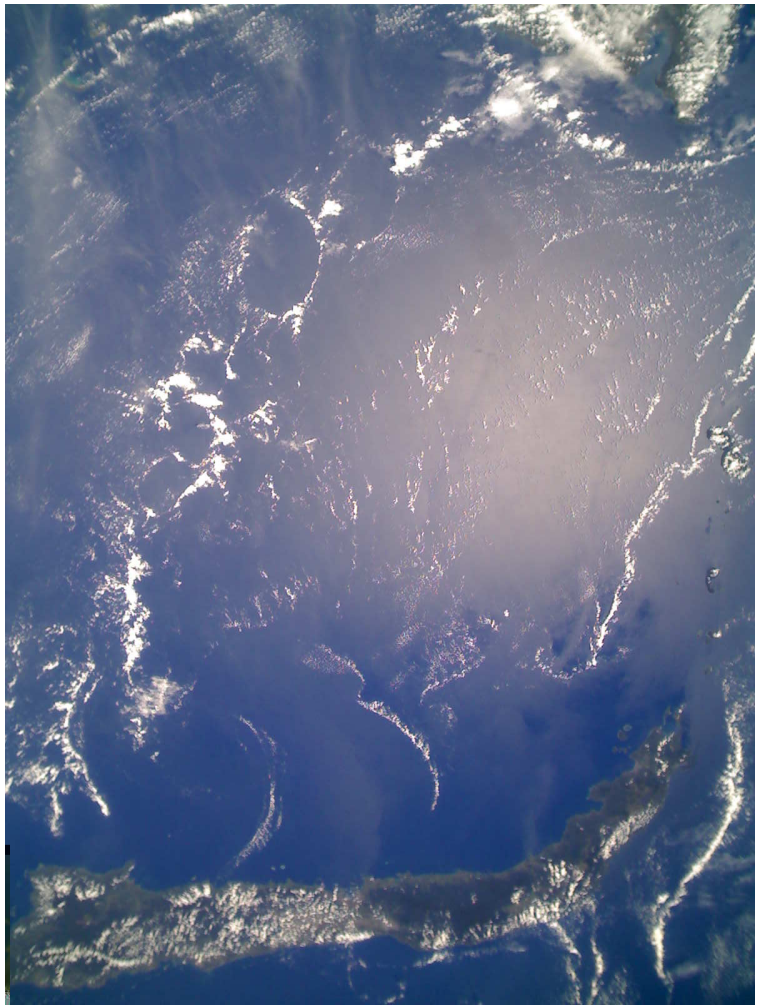
#1: Celebes Sea, 1 of 2, 02:25 UTC



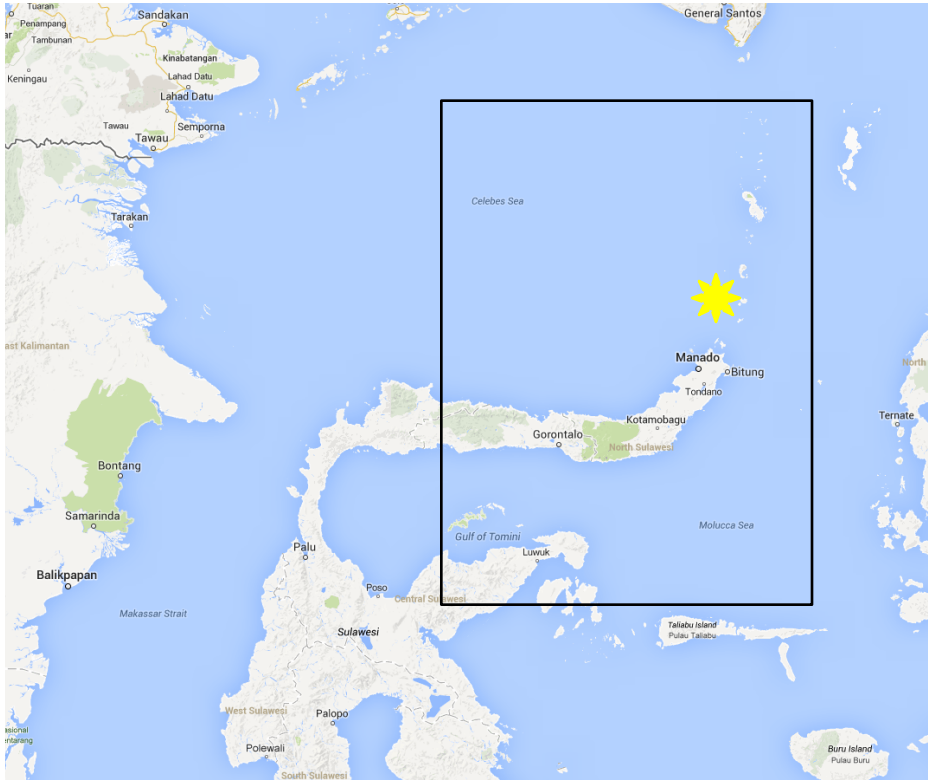


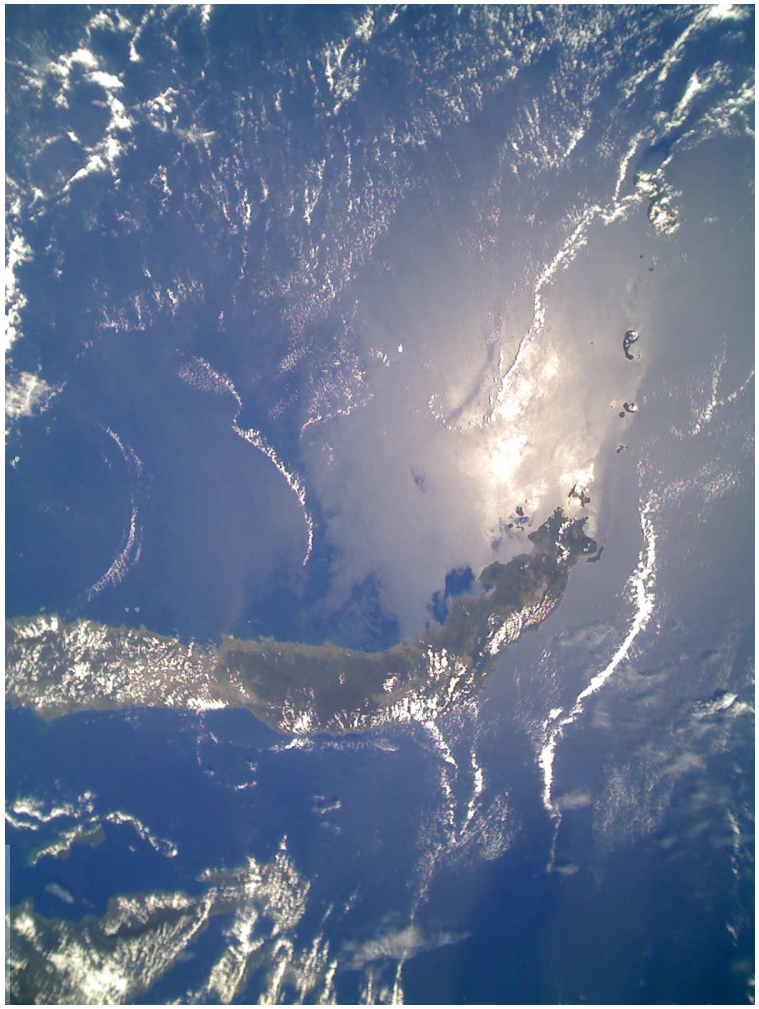
#2: Celebes Sea, 2 of 2, 02:25 UTC



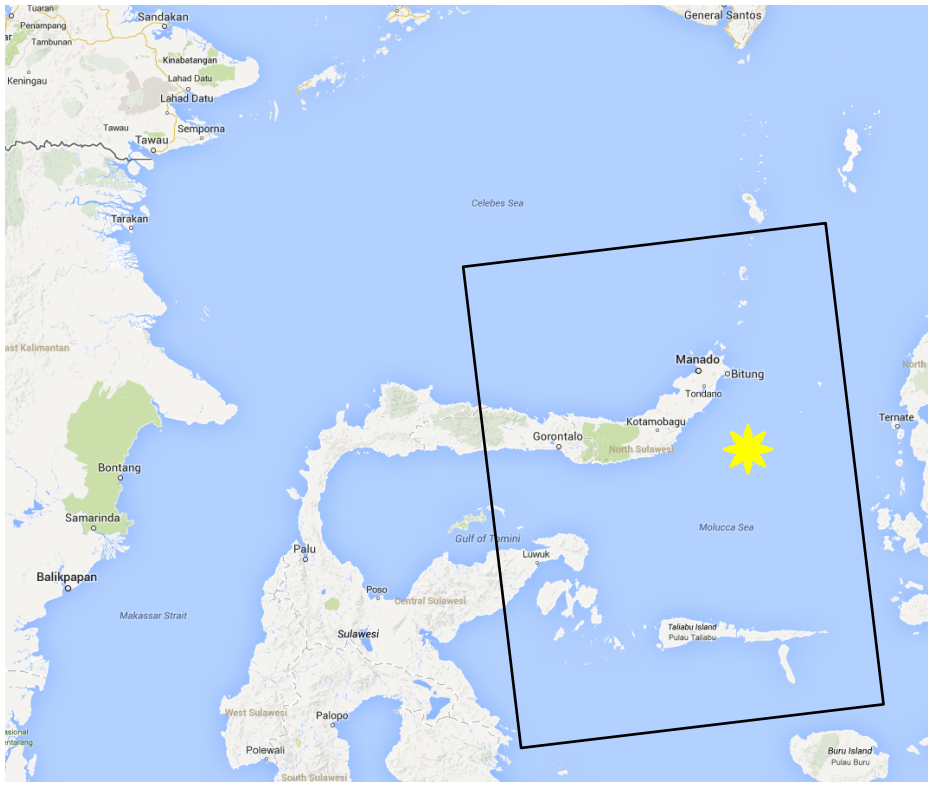


#3: Minahassa Peninsula, Sulawesi, 1 of 2, 02:26 UTC





#4: Minahassa Peninsula, Sulawesi, 2 of 2, 02:26 UTC



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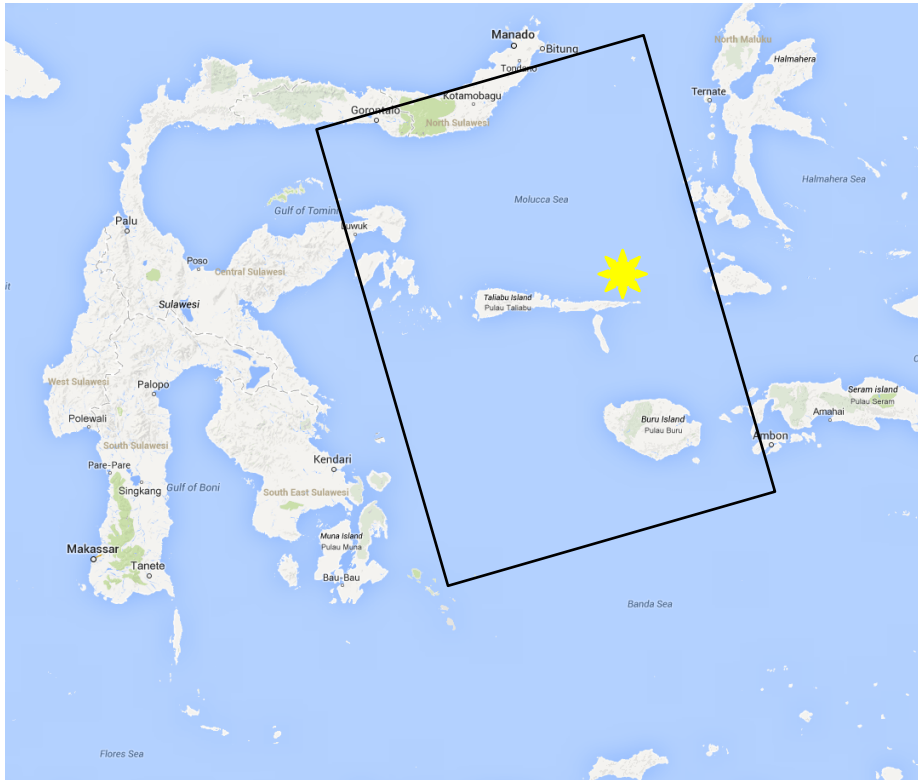
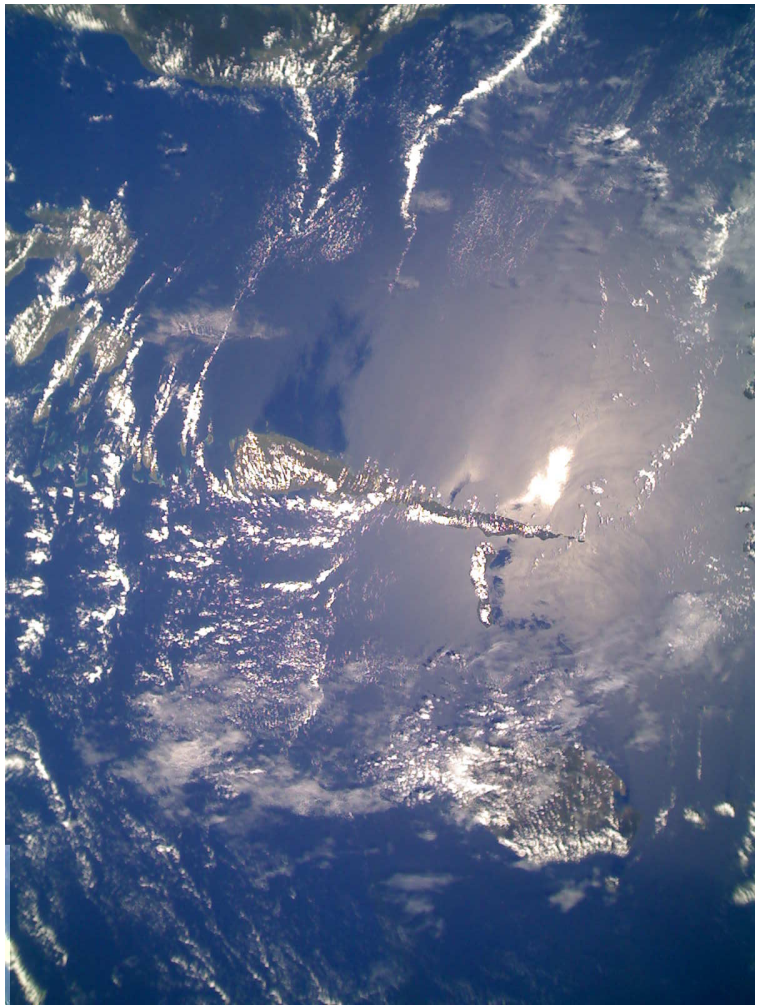
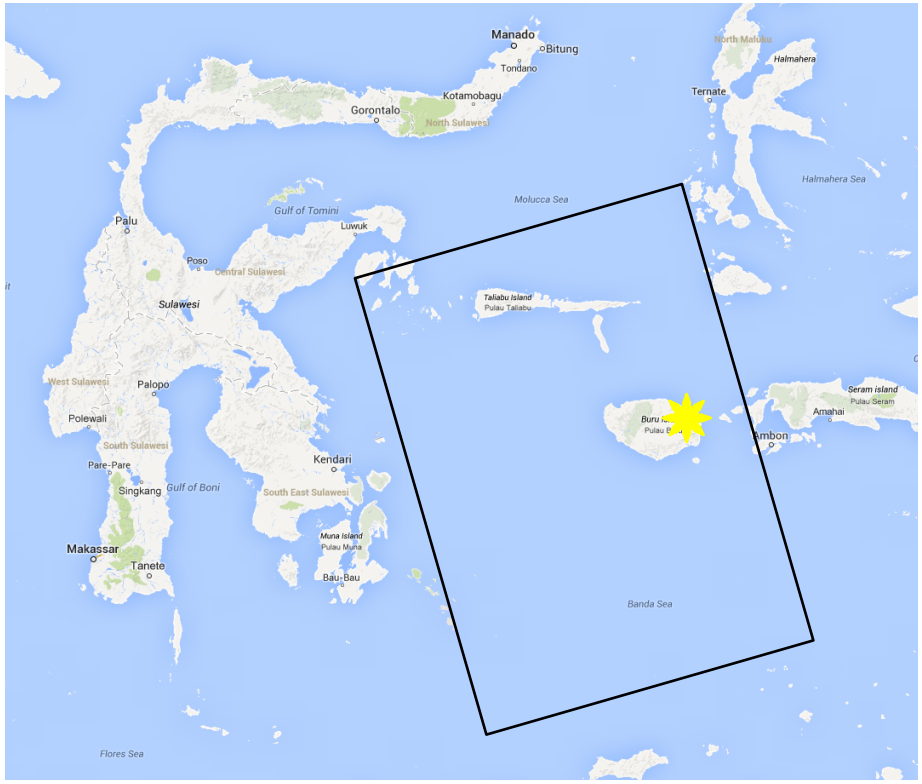
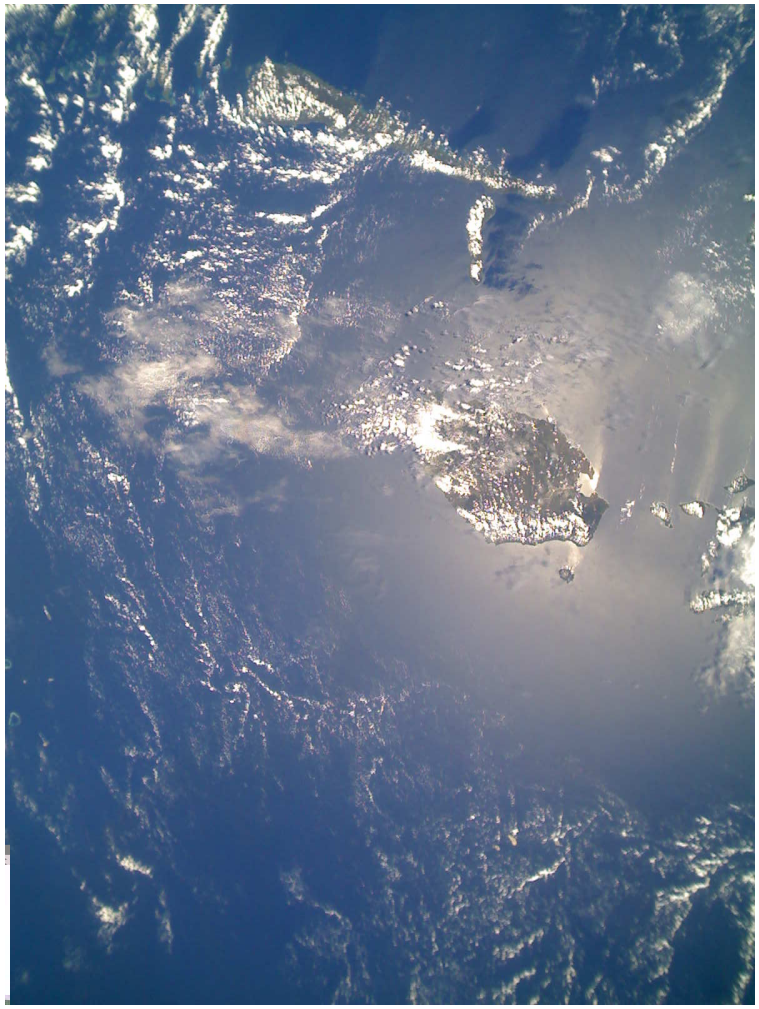
#5: Taliabu Island, 02:27 UTC



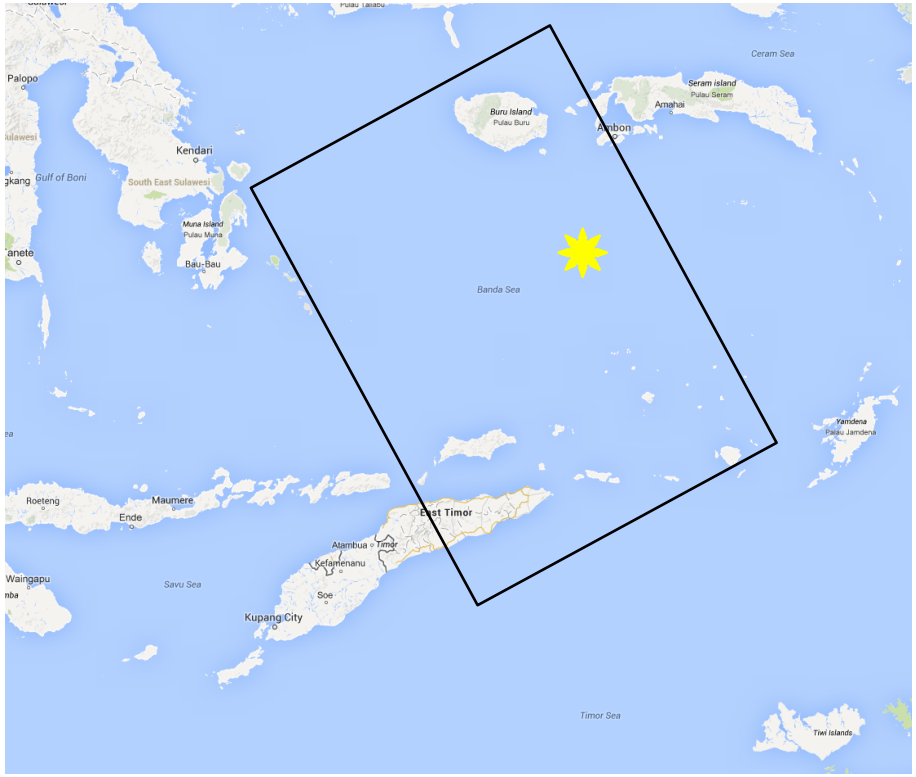


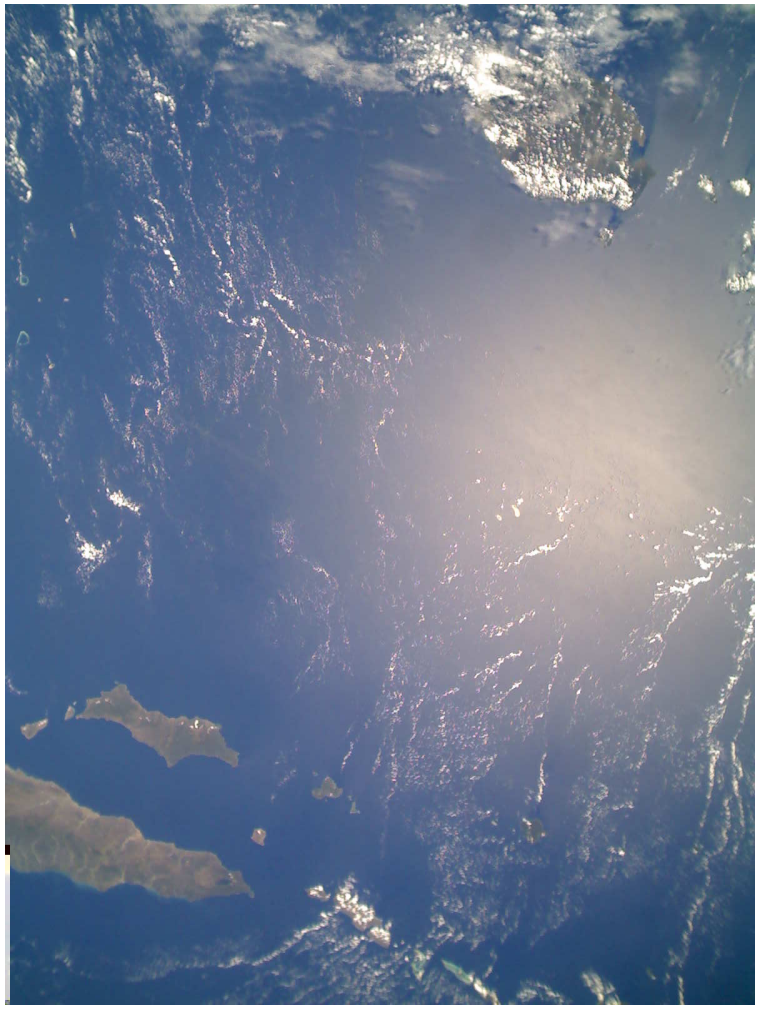
#6: Buru Island, 02:27 UTC



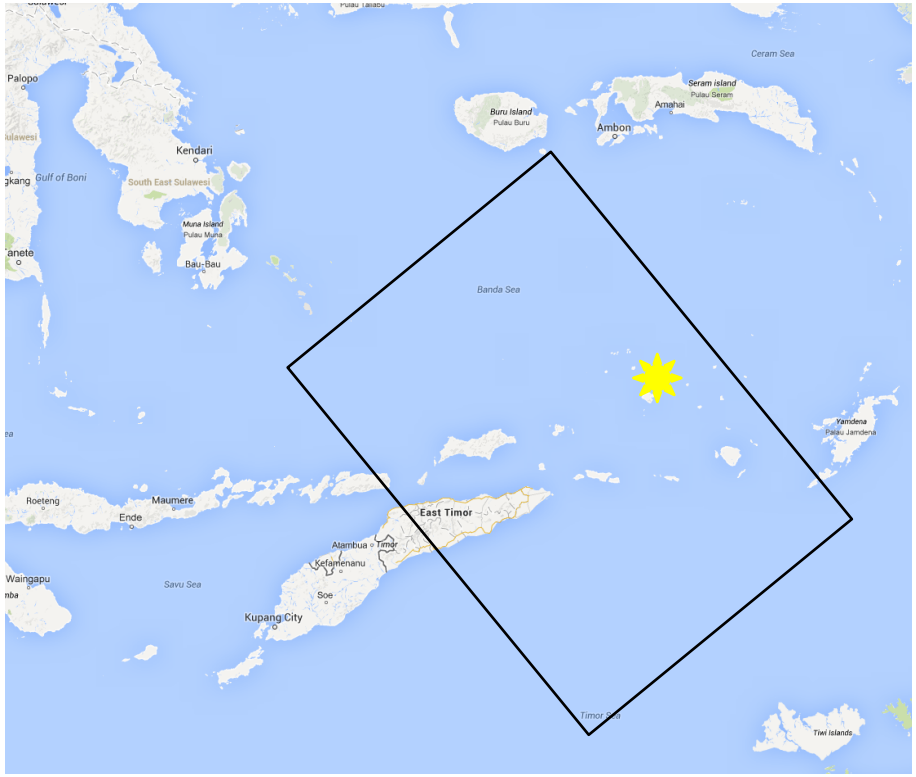


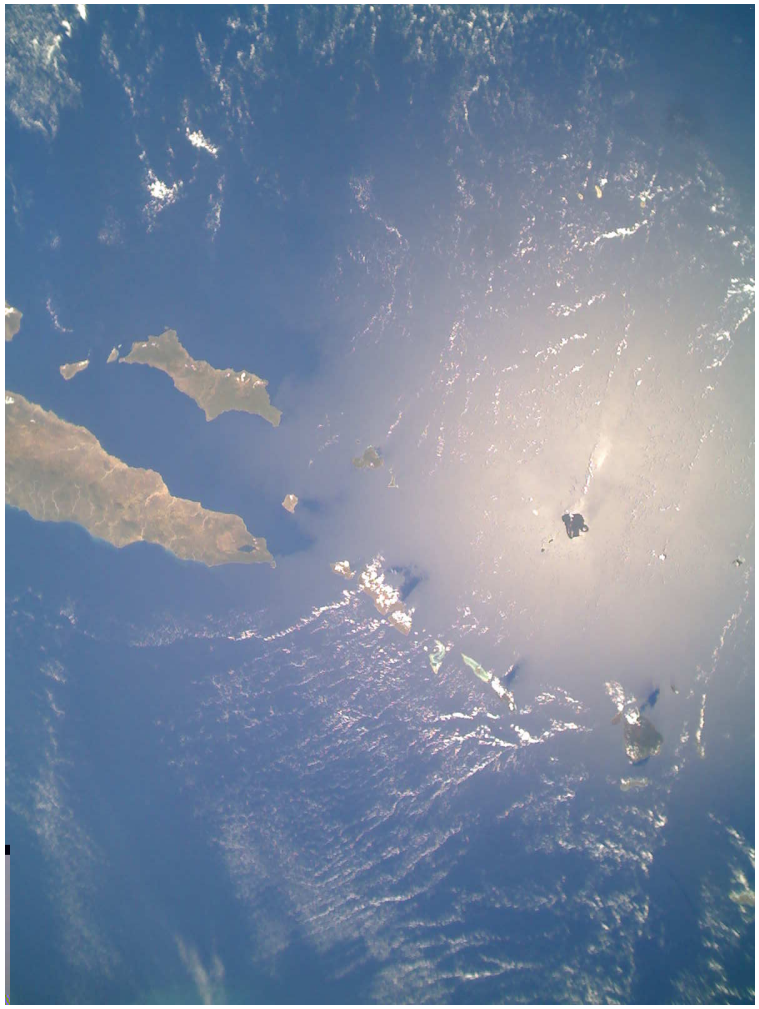
#7: Banda Sea, 02:28 UTC



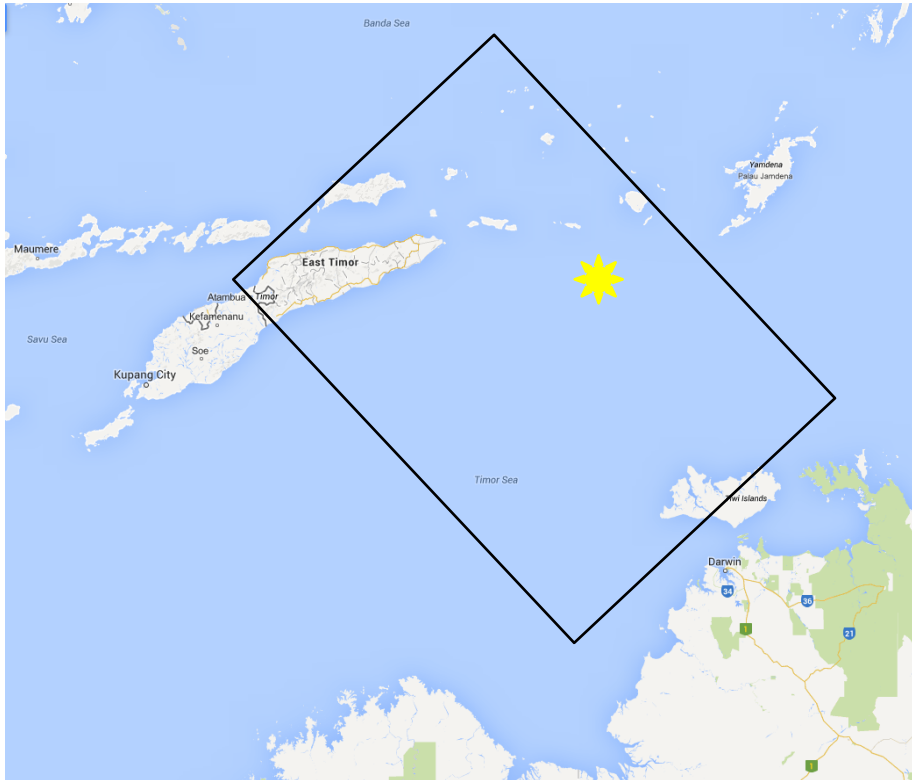


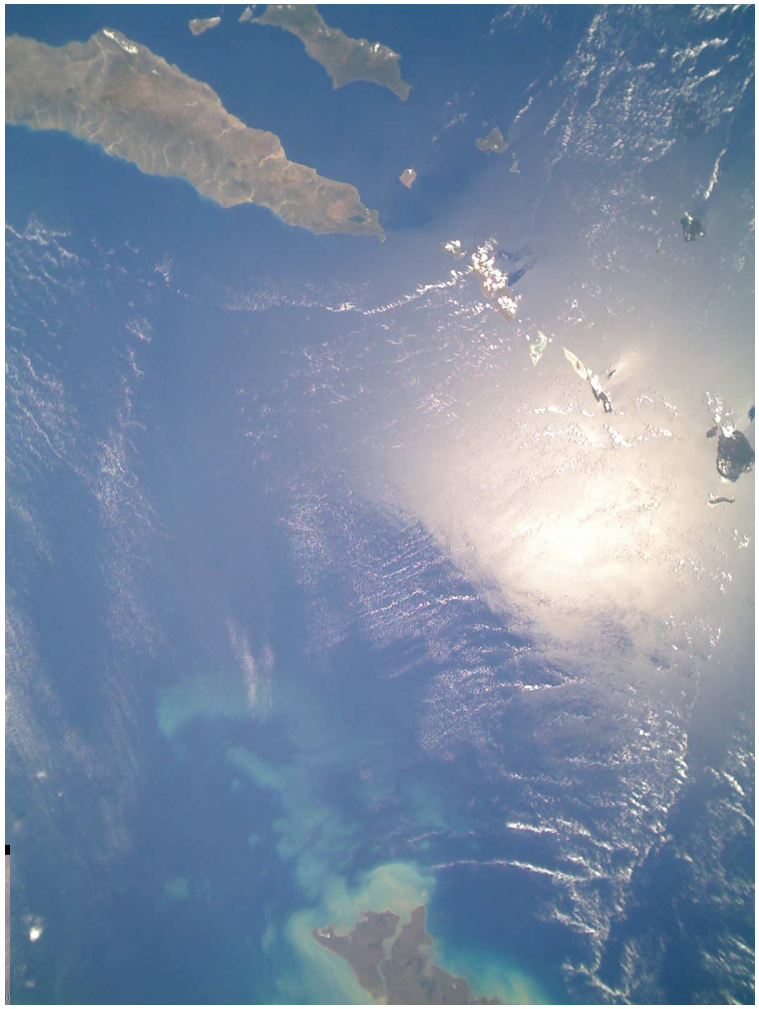
#8: Banda Sea and Babar Island, 02:28 UTC





#9: Timor Sea, 1 of 2, 02:29 UTC





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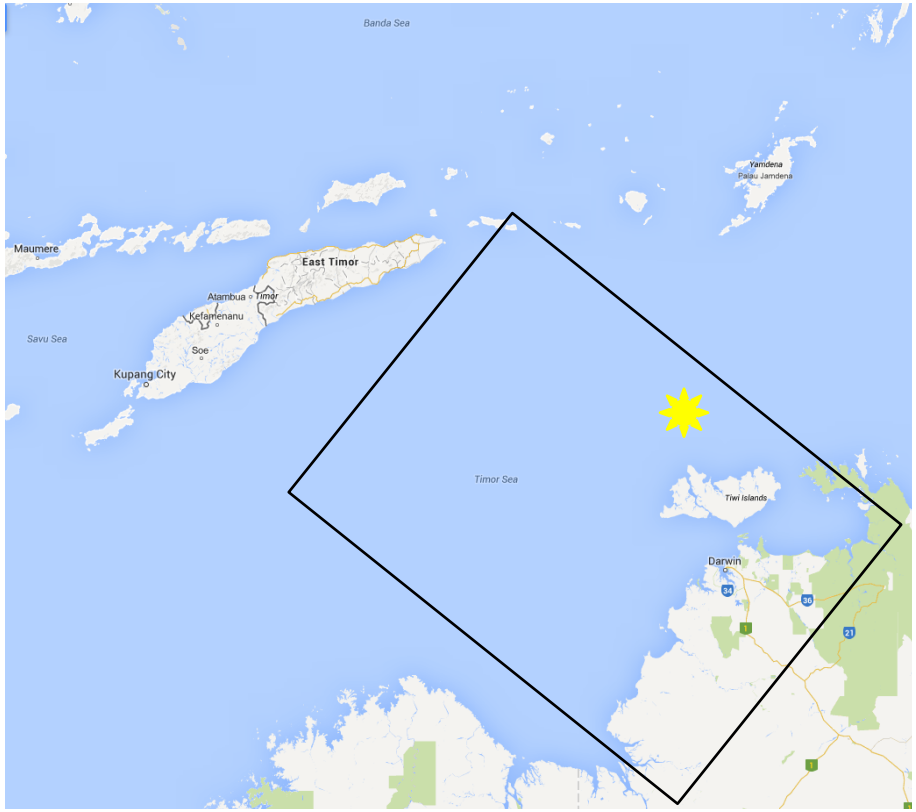
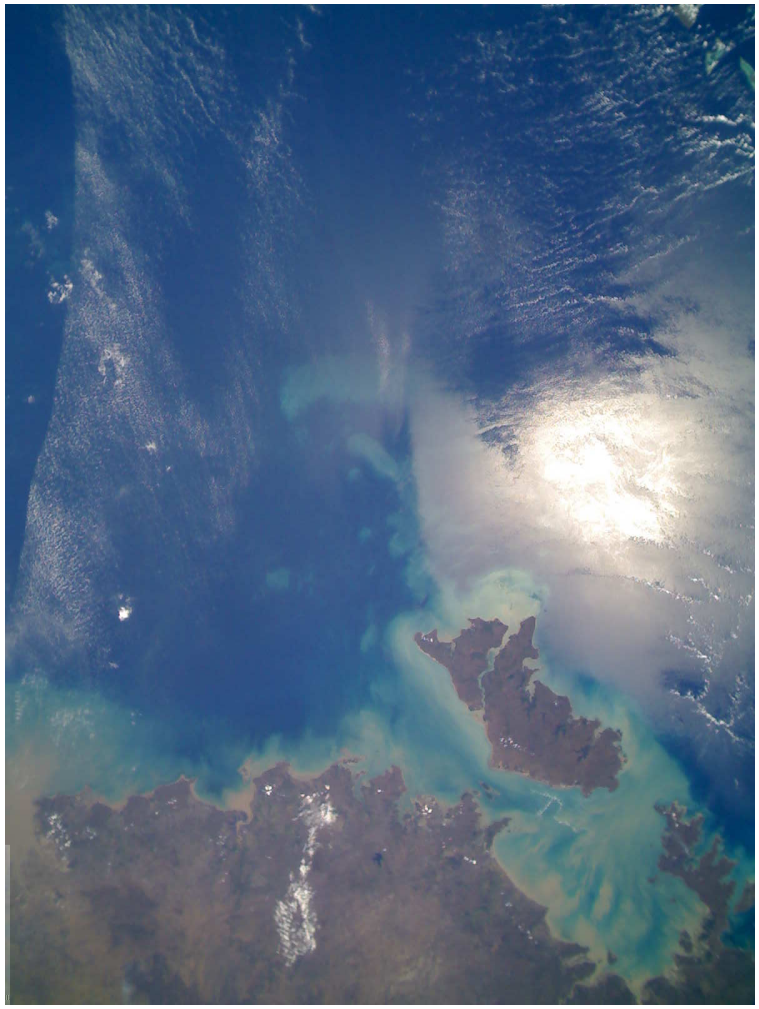
#10: Timor Sea, 2 of 2, 02:29 UTC





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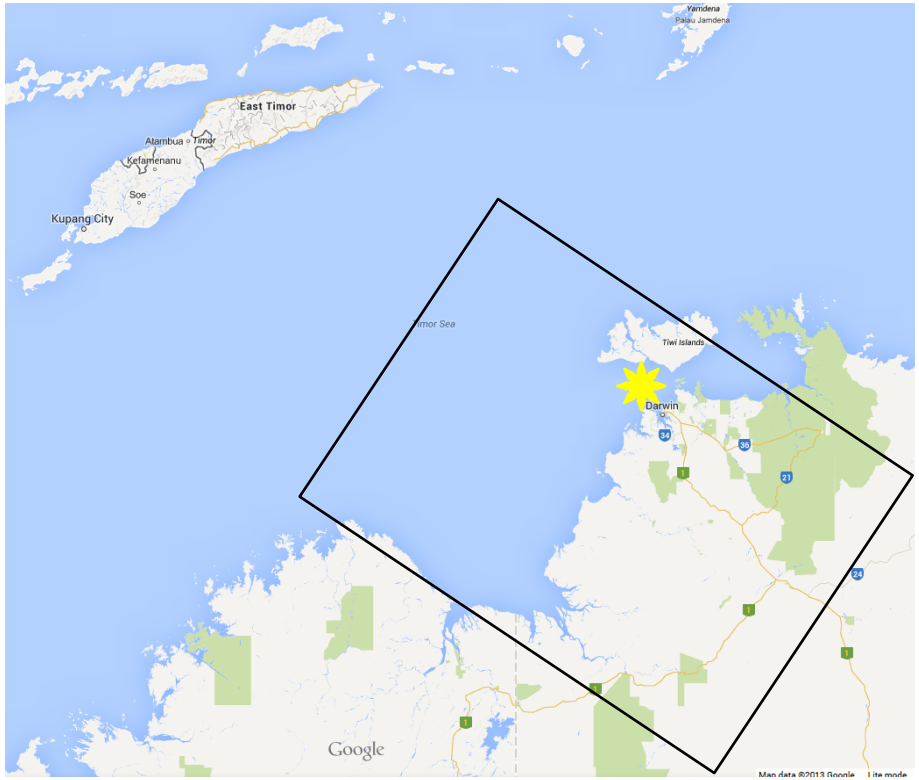
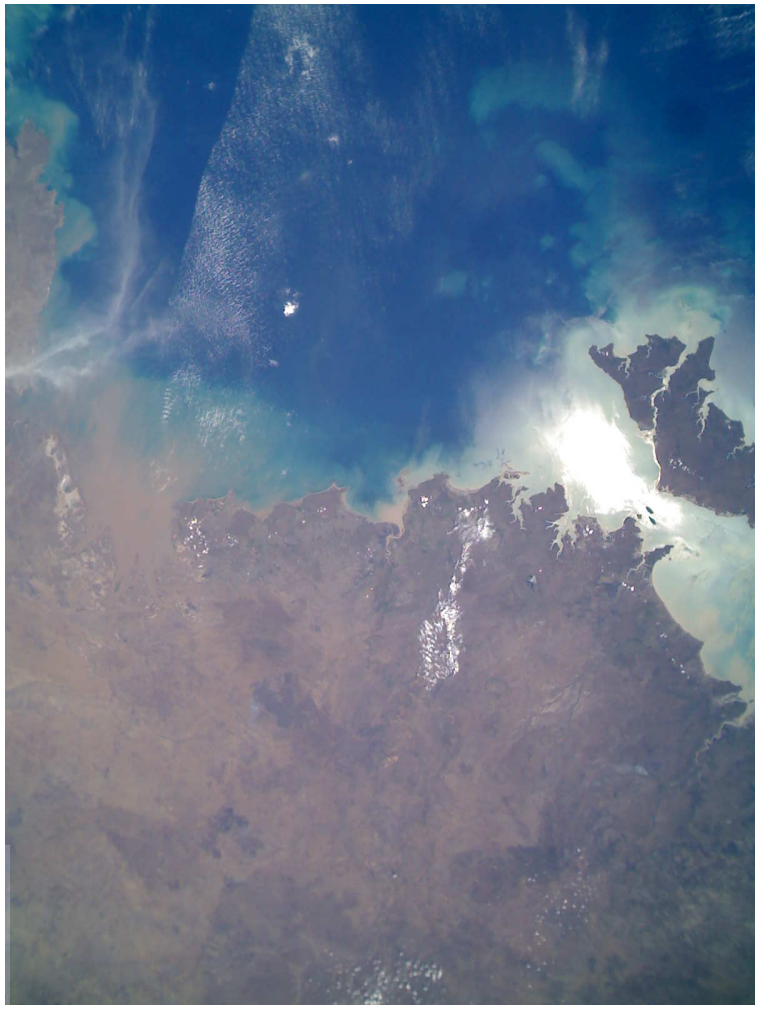
#11: Darwin, Australia, 02:30 UTC





AeroCube-4
Solar Eclipse, 3 Nov 2013

Predicted Path of the Eclipse

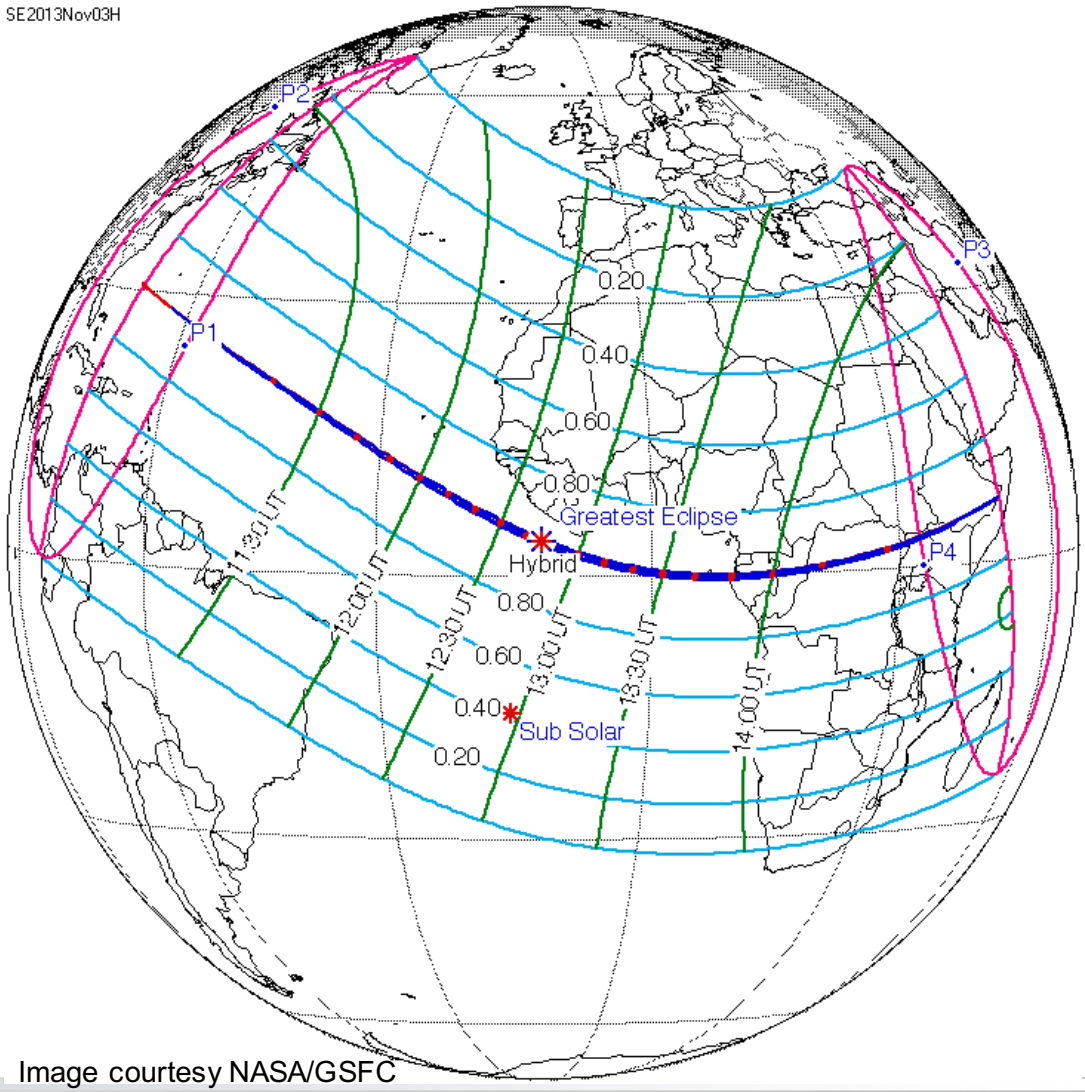


Image courtesy NASA/GSFC

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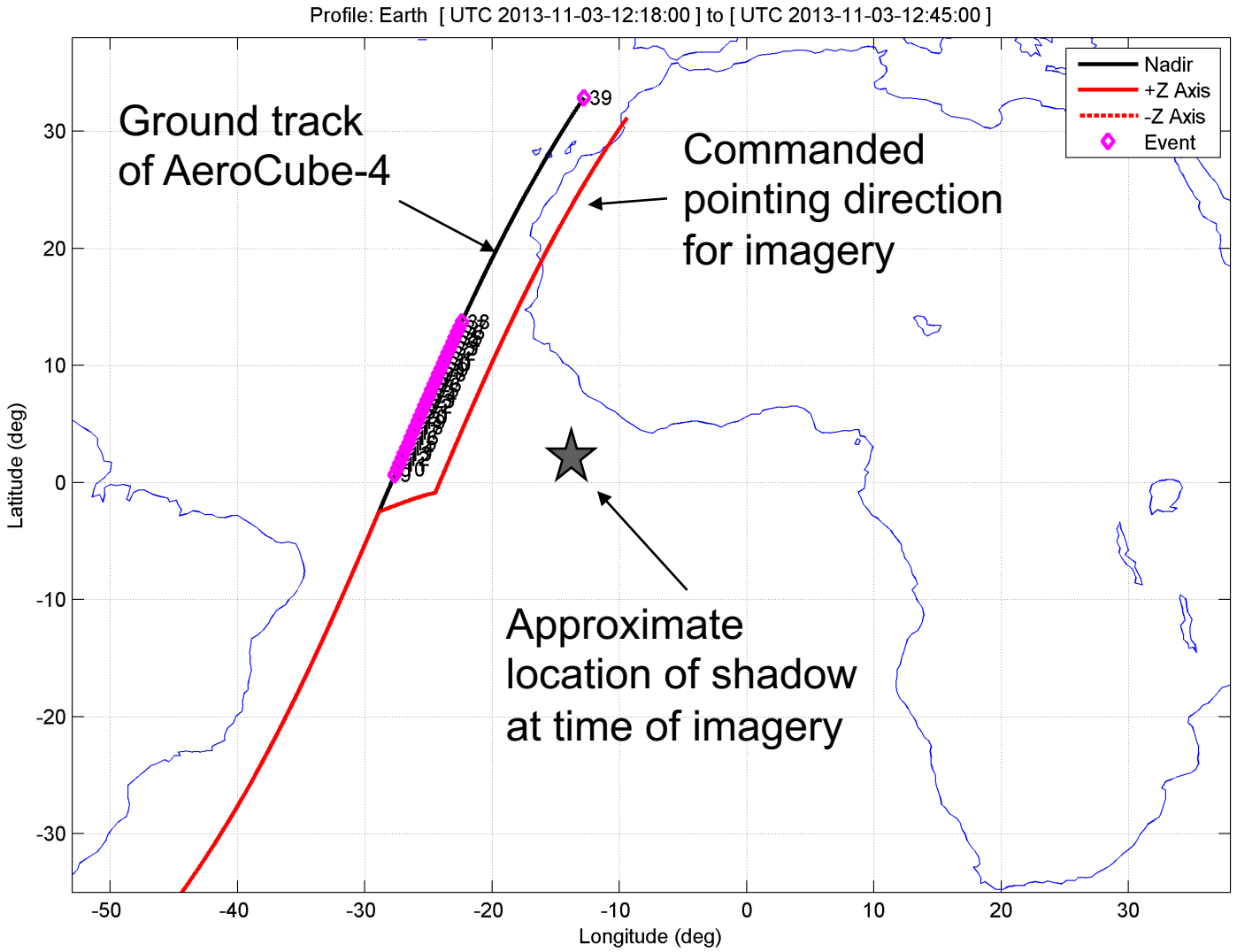
Operations Plan



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Summary

- AeroCube-4 has been on orbit for 18 months and still going strong.
- The 1U form factor still has great potential:
  - *11,000 images from 570 ops have been returned to Earth.*
  - *Reprogrammability is key to dealing with unexpected events on orbit.*
  - *A closely knit operations team enables rapid response to operations of opportunity.*
- A 1U CubeSat can provide responsive, targeted remote sensing data:
  - *Forest fire verification*
  - *Celestial events*
- A 1U CubeSat could provide science-quality remote sensing data:
  - *Sunglint image capture*
  - *AeroCube-4 imagery comparable to MODIS in resolution.*

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Questions?

Check out the AeroCube Flickr page!

http://www.flickr.com/photos/114622562@N02/

We acknowledge SMC/XR for their continued support and interest in the PICOSAT program.

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