GHOST - Green House gas Observations of the Stratosphere and Troposphere

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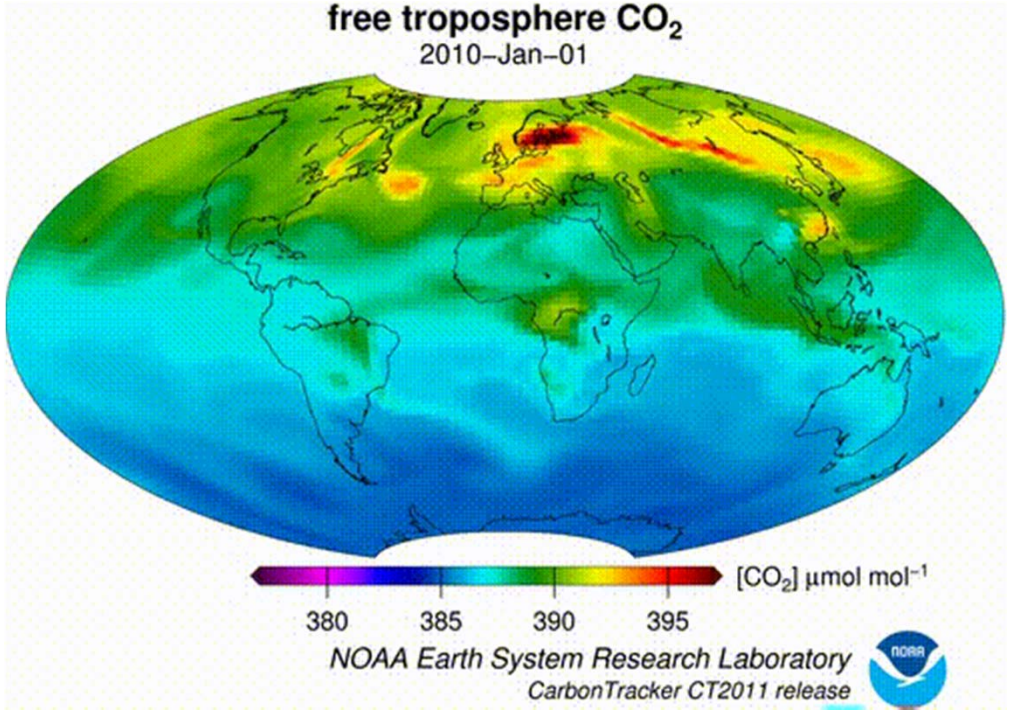
Motivation

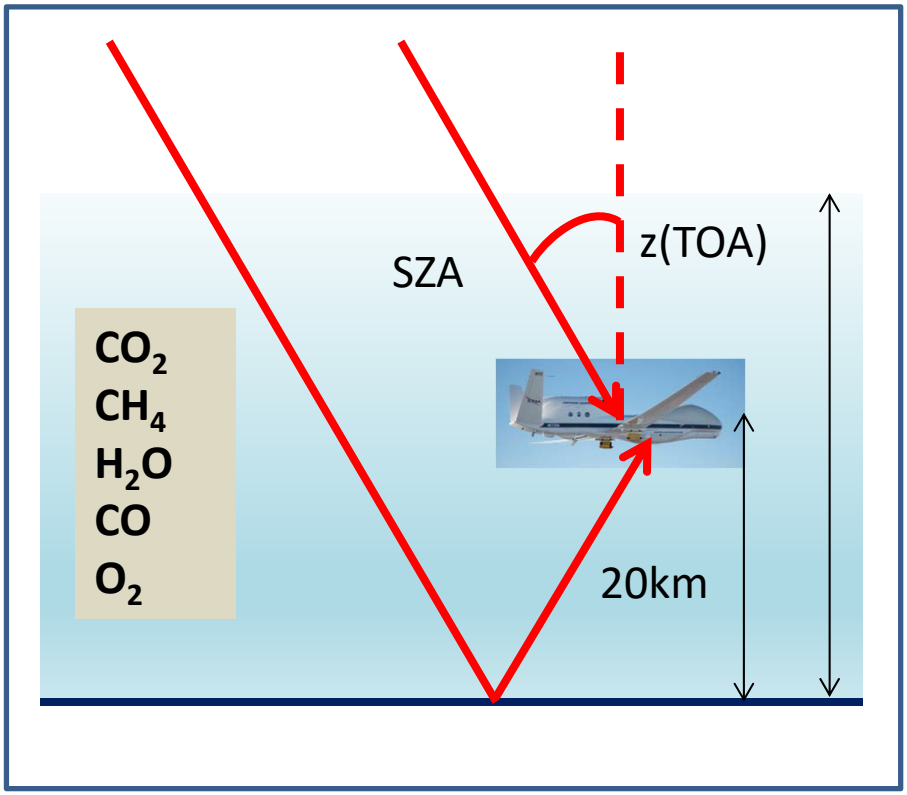
Improved understanding of sources and sinks (natural and anthropogenic)

- Surface fluxes inferred from GHG observations coupled with an inverse model
- Uncharacterised transport model errors can lead to significant biases in surface flux estimates
- Particular challenge for CO_2, CH_4: relatively small perturbations on large background concentrations



Observation concept

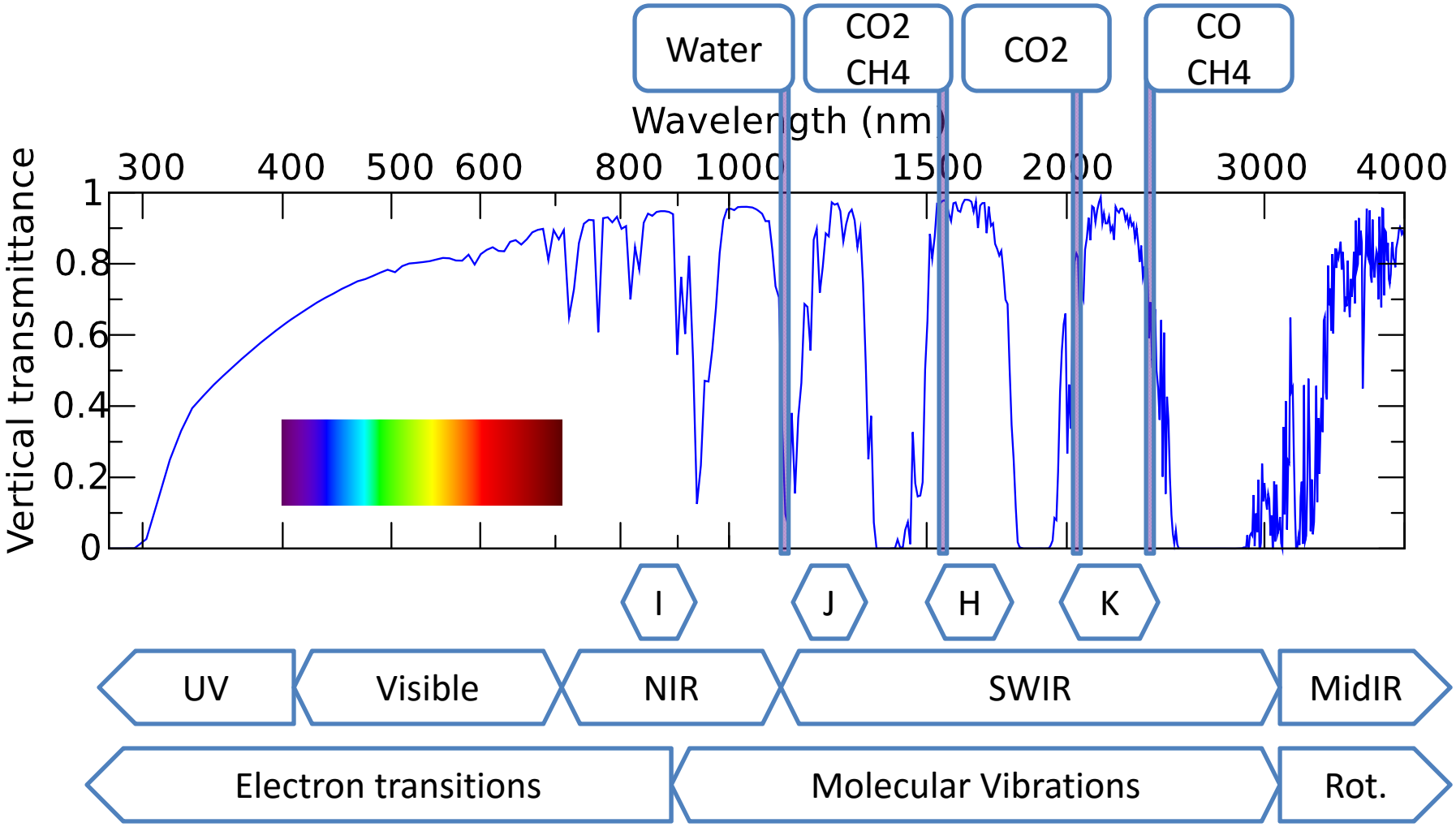
- Observe shortwave infrared spectral radiances (1.2 to 2.4 µm) at high spectral resolution
- Gases of interest absorb solar radiation at specific wavelengths – absorption related to concentration averaged over the total atmospheric column
- Scattering in the atmosphere lengthens the atmospheric path → measure O_2 absorption lines to estimate optical path length
- Tracking mode: when over ocean observe direct solar reflection to maximise signal



Instrument Requirements

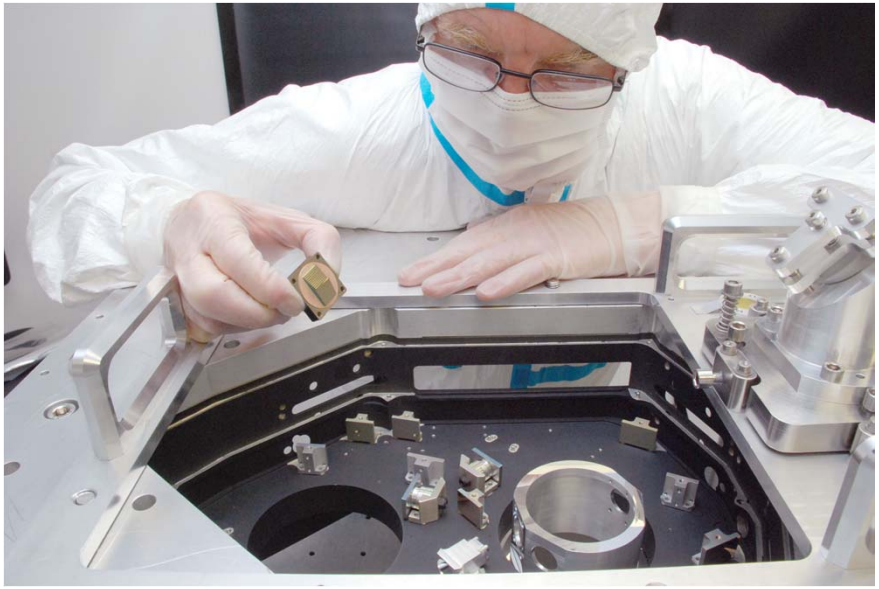
	Band 1	Band 2	Band 3	Band 4
Function	Cloud/aerosol surface pressure	CH_4 and CO_2 columns	Cloud/aerosol, CO_2 columns	CO, CH_4, H_2O, HDO columns
Spectral Band (µm)	1.25 – 1.29 1.235 – 1.305	1.59 – 1.68 1.584 – 1.676	2.04 – 2.09 1.980 – 2.095	2.31 – 2.39 2.254 – 2.385
Spectral resolution (nm, FWHM)	<0.1 0.1	<0.25 0.13	<0.15 0.17	<0.25 0.19
SNR (at Lref)	150 389	80 204	100 181	80 137

Instrument Requirements



GHOST: GreenHouse Observations of the Stratosphere & Troposphere

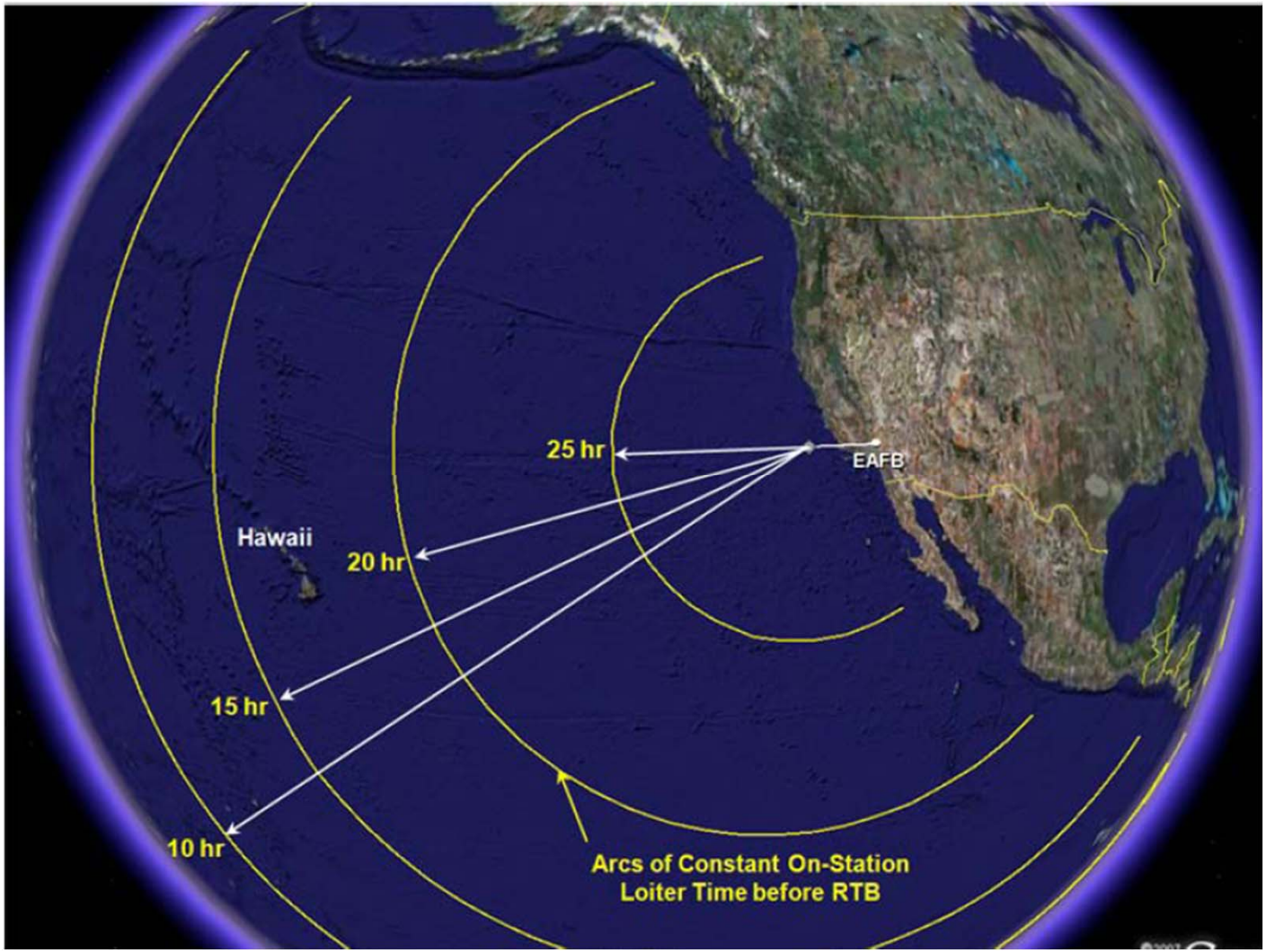
- Part of the NERC/STFC funded CAST consortium project
- Technologies developed for the JWST-MIRI instrument
- Designs based on studies of a low mass OCO-2 equivalent
- Fly on a NASA Global Hawk from California (NASA Armstrong)

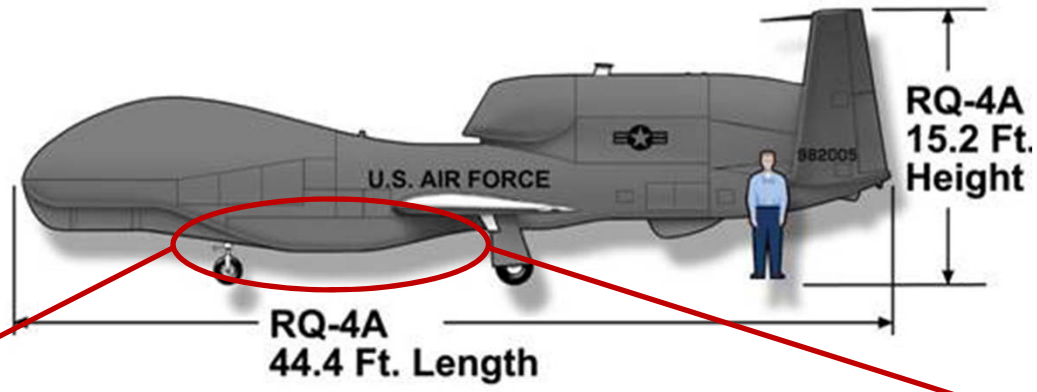


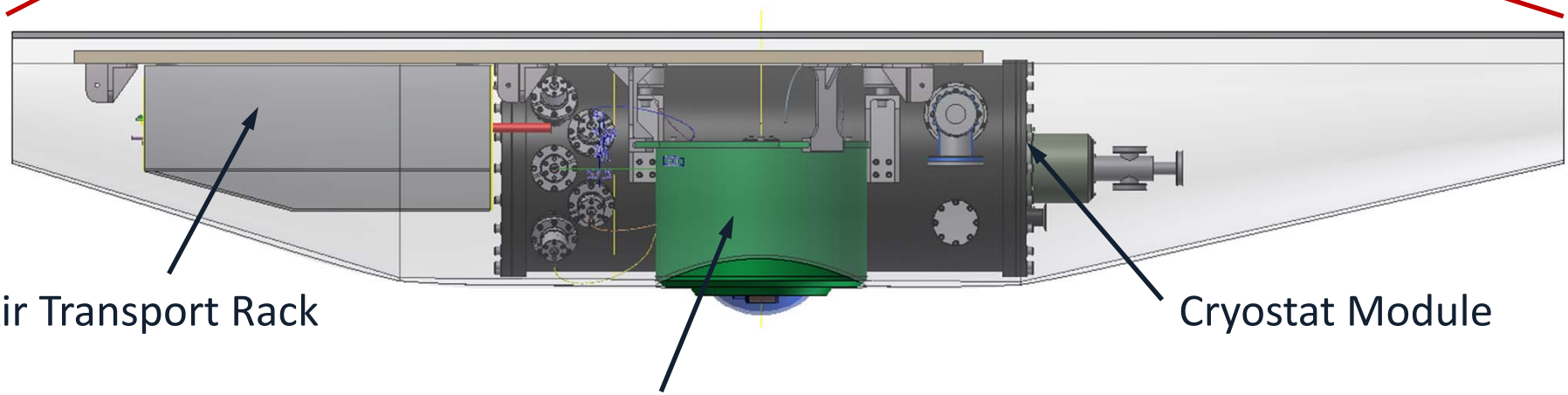
Global Hawk

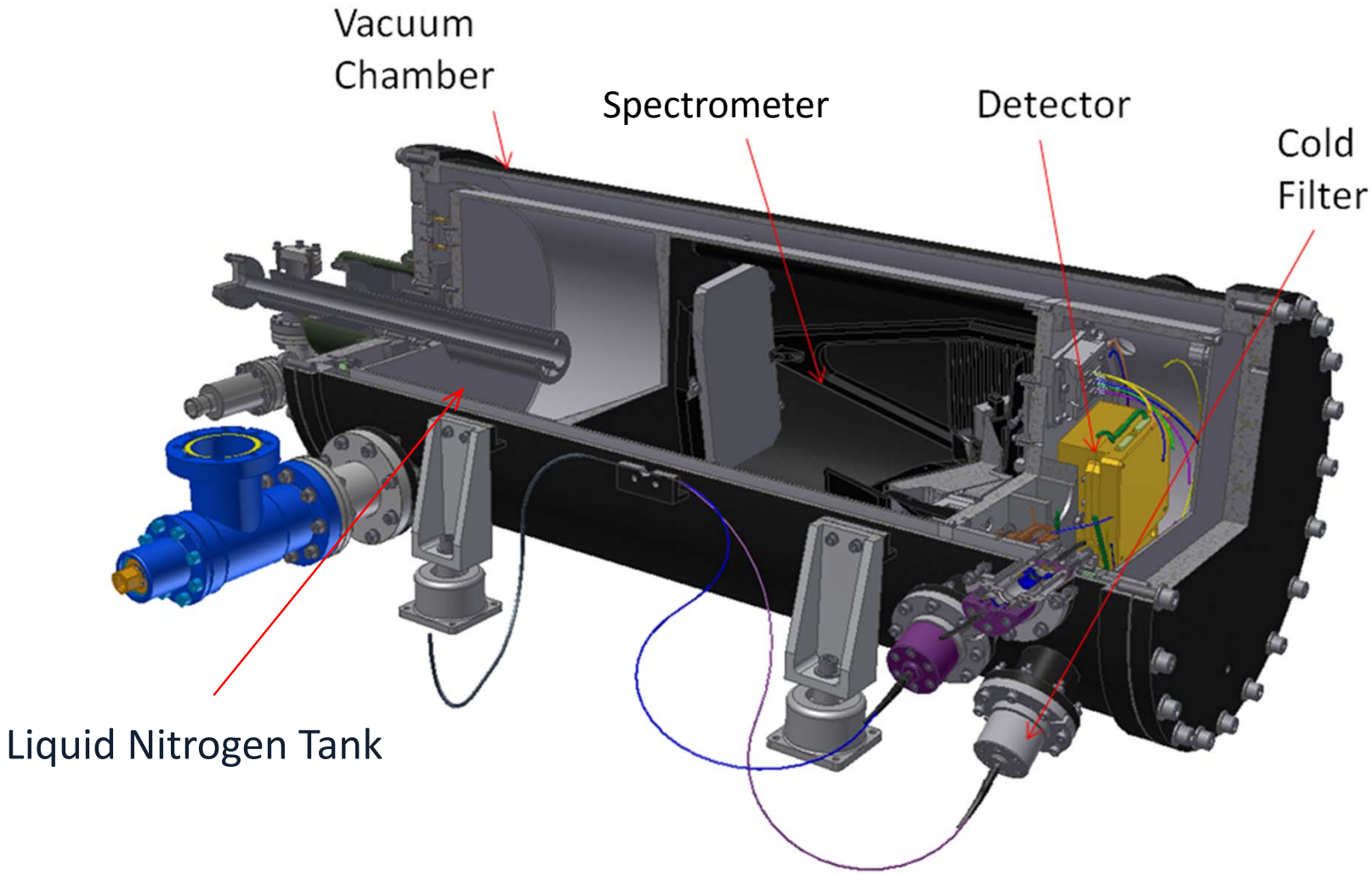
Good for Scientists...	...tricky for Engineers
Can straddle Stratosphere and Troposphere → Interesting dynamic processes	65,000ft ➔ $0.05\ p_0$ $0.07 \rho_0$ $T_a = -65°\ C$
Long duration flights → Up to 30hrs	Defines amount of cryogen Large data storage
Very stable platform → Enables high pointing accuracy	High pointing spec
Extreme flexibility in measurement location → Can travel up to 14,000 km	Unmanned operation
	$$$$$ Only two flights to shake down

Range and Loiter from AFRC



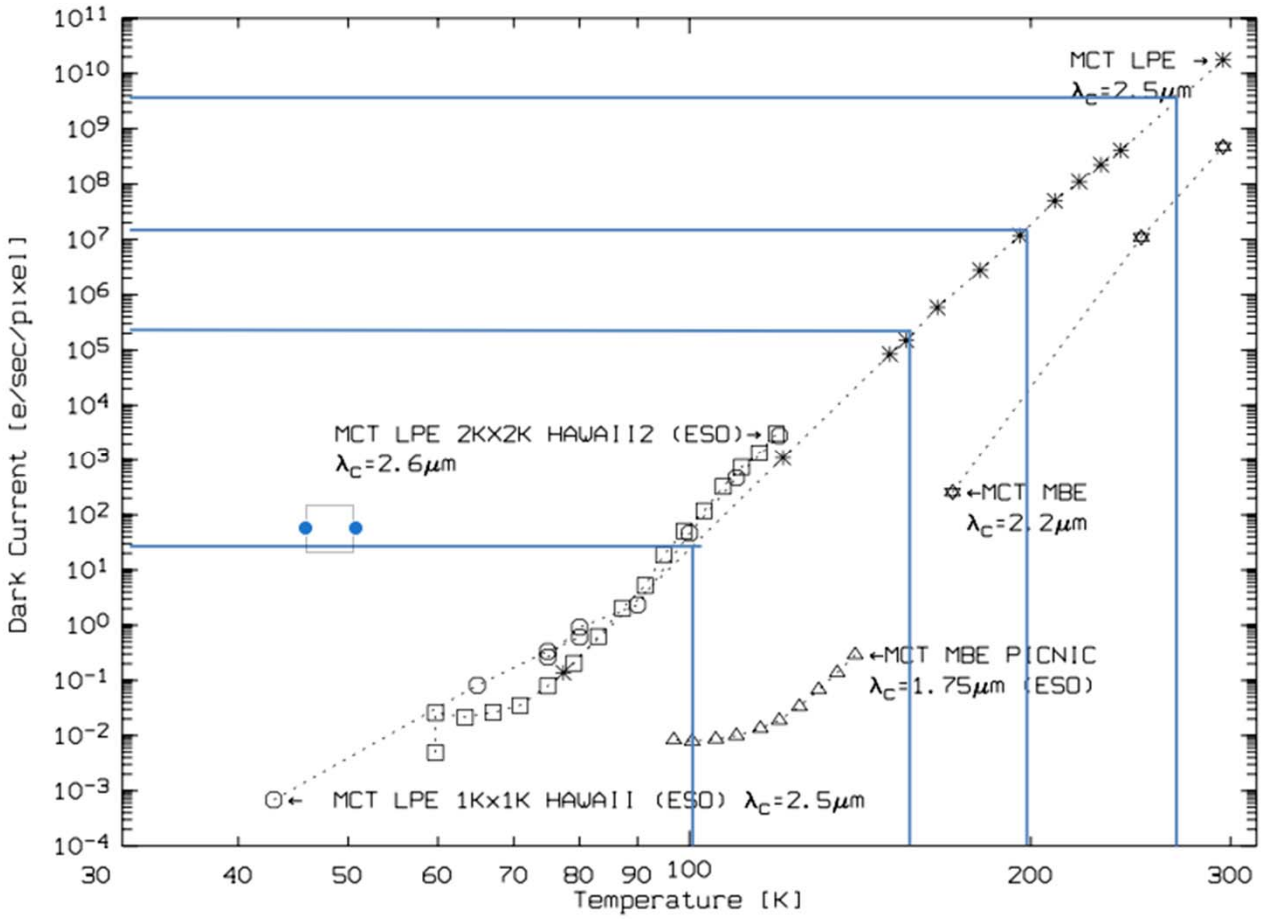

U.S. AIR FORCE
RQ-4A
15.2 Ft.
Height
RQ-4A
44.4 Ft. Length


Air Transport Rack
Target Acquisition Module
Cryostat Module

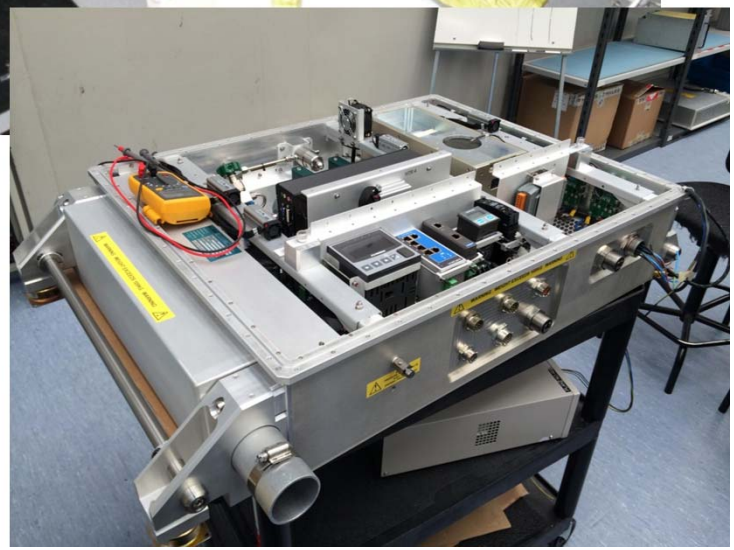

Vacuum Chamber
Spectrometer
Detector
Cold Filter
Liquid Nitrogen Tank

Why such a large instrument

Noise and cost
The SNR requirements of the objective are quite extreme so we have to cool to reduce the thermal noises, the worst of which is the detector dark current.
A closed cycle cooled design would have been smaller but more expensive.



Build for Global Hawk



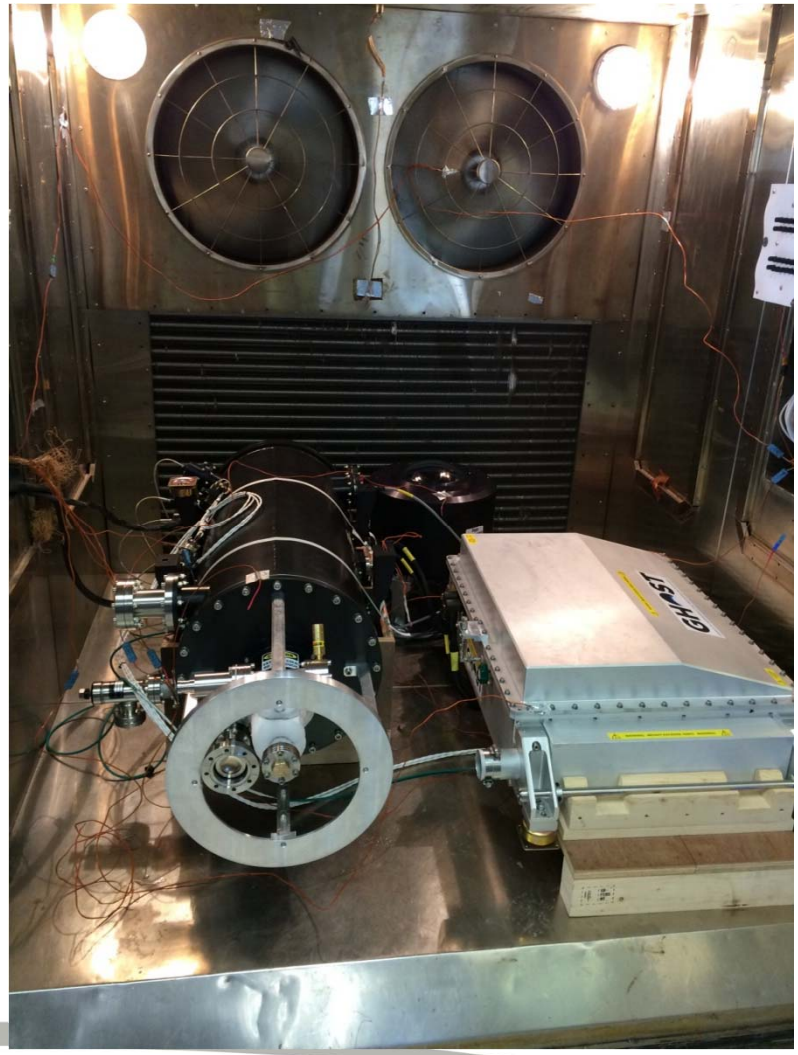
65,000ft ➔ $0.05\ \rho_0$
$0.07\rho_0$
$T_a = -65^\circ\ C$

- Flight Duration (>20hrs) consumables & data
- Global Hawk – Unmanned aircraft (automation) & ITAR restrictions
- Load Tests
- Vacuum tests, ATR pressure tests
- Cryogenic tests


U.S. AIR FORCE


EXIT

TVAC Testing



-65ºC 0,05 bar & 40ºC atmospheric pressure (operational)

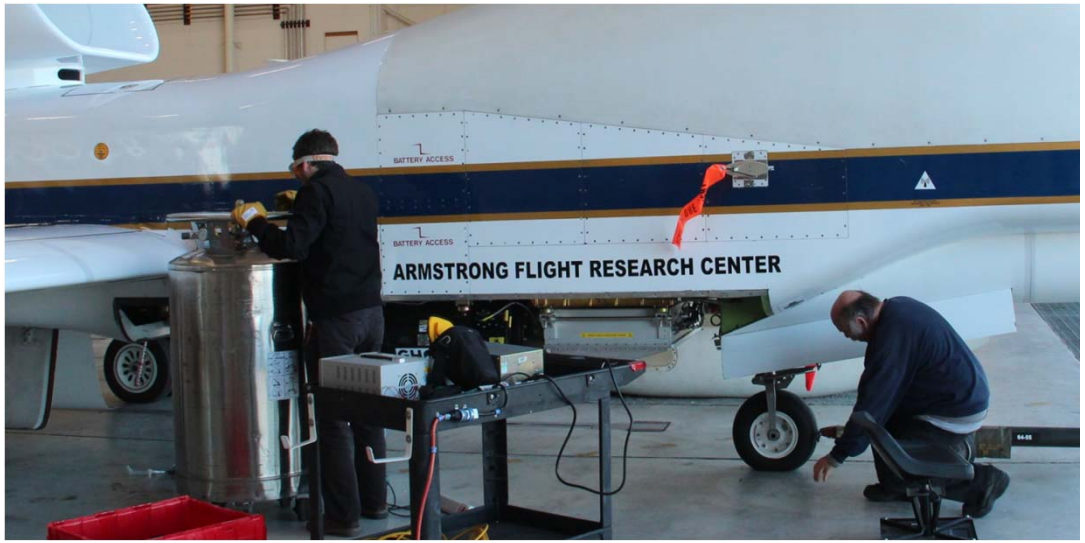
Vibration testing

Each module, each axis, operational to 3g

Communications and operations testing

Installation

Operations


BATTERY ACCESS
BATTERY ACCESS
ARMSTRONG FLIGHT RESEARCH CENTER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GHOST

GHOST range flight test, 02/26/15.

Science & Technology Facilities Council
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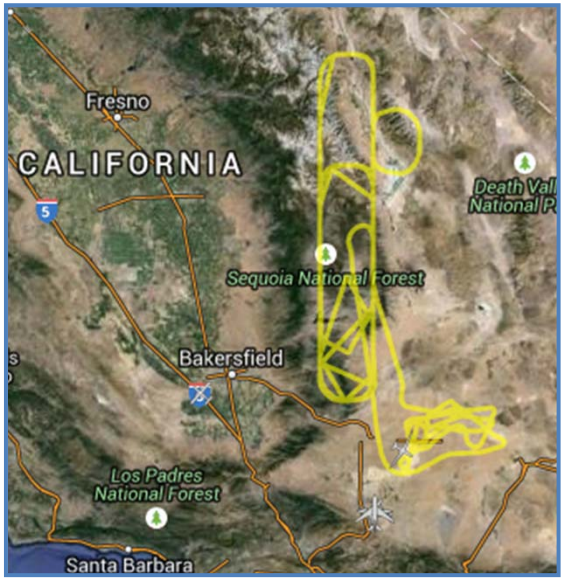
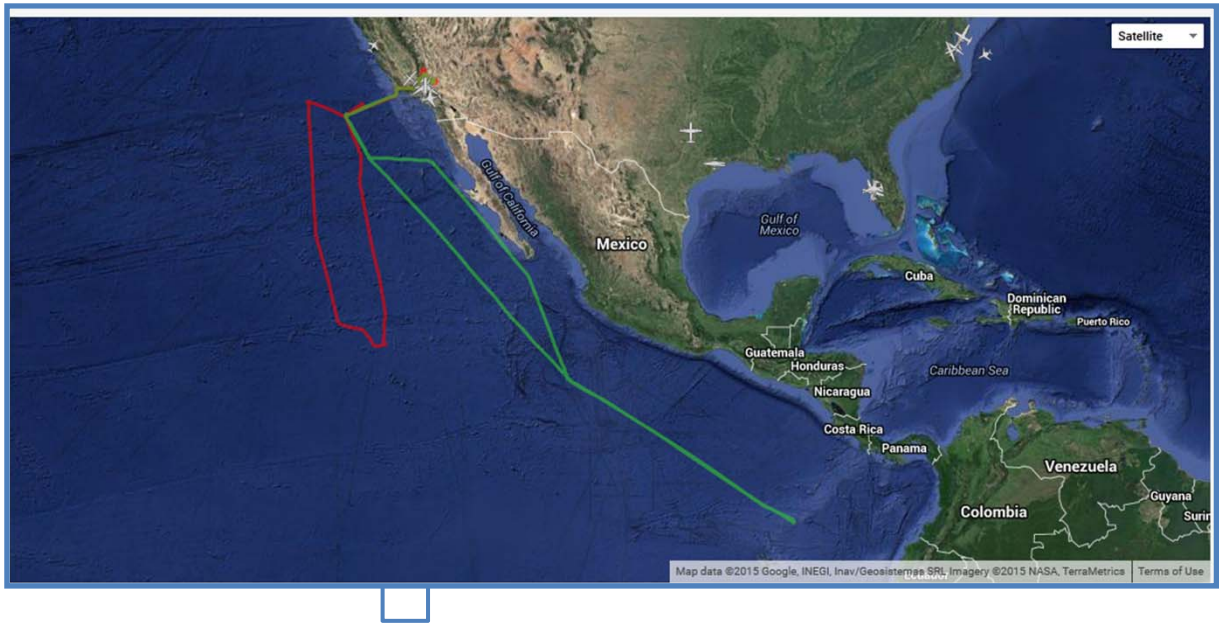
Control Centre

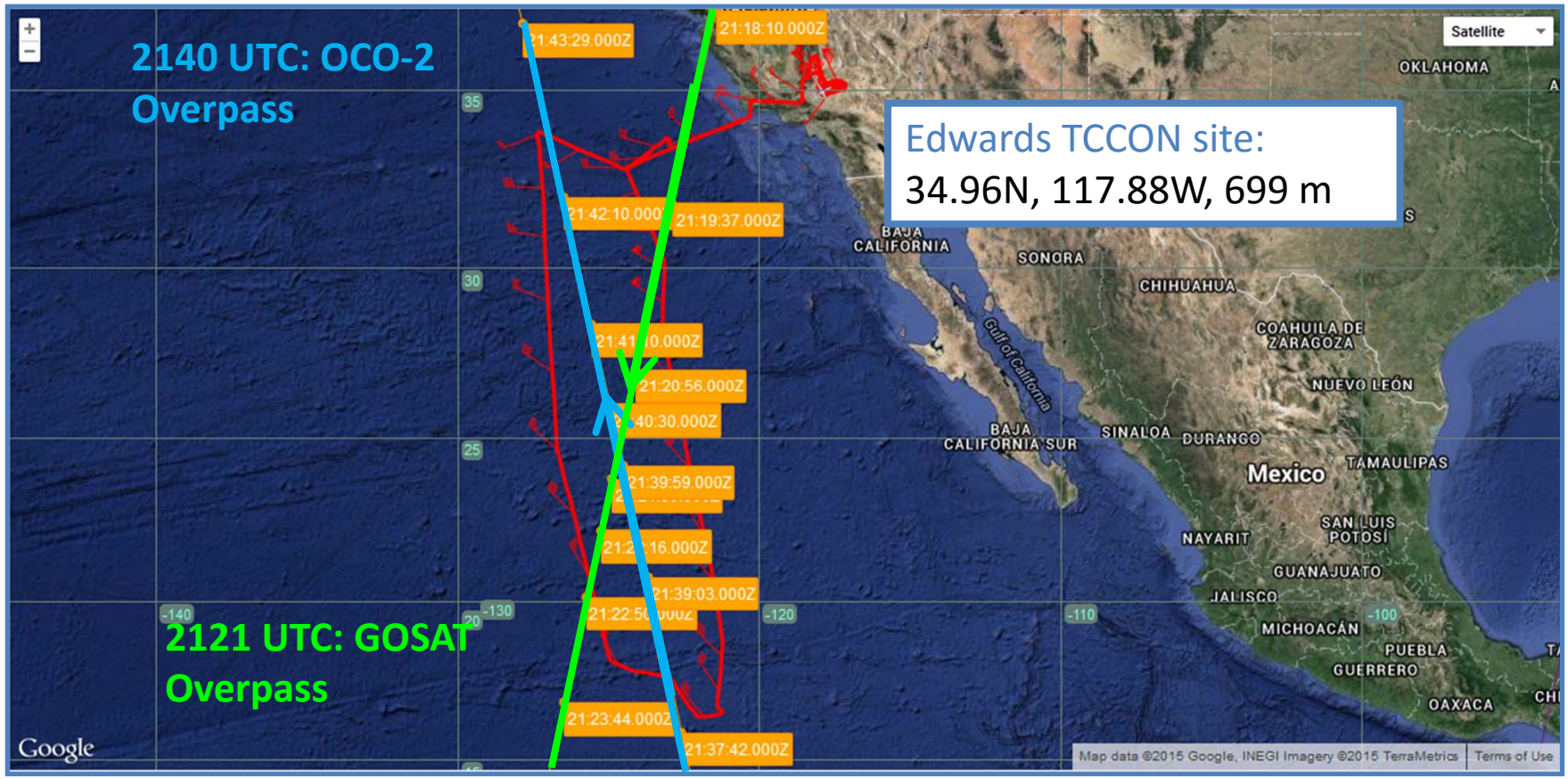
Global Hawk range and science flights



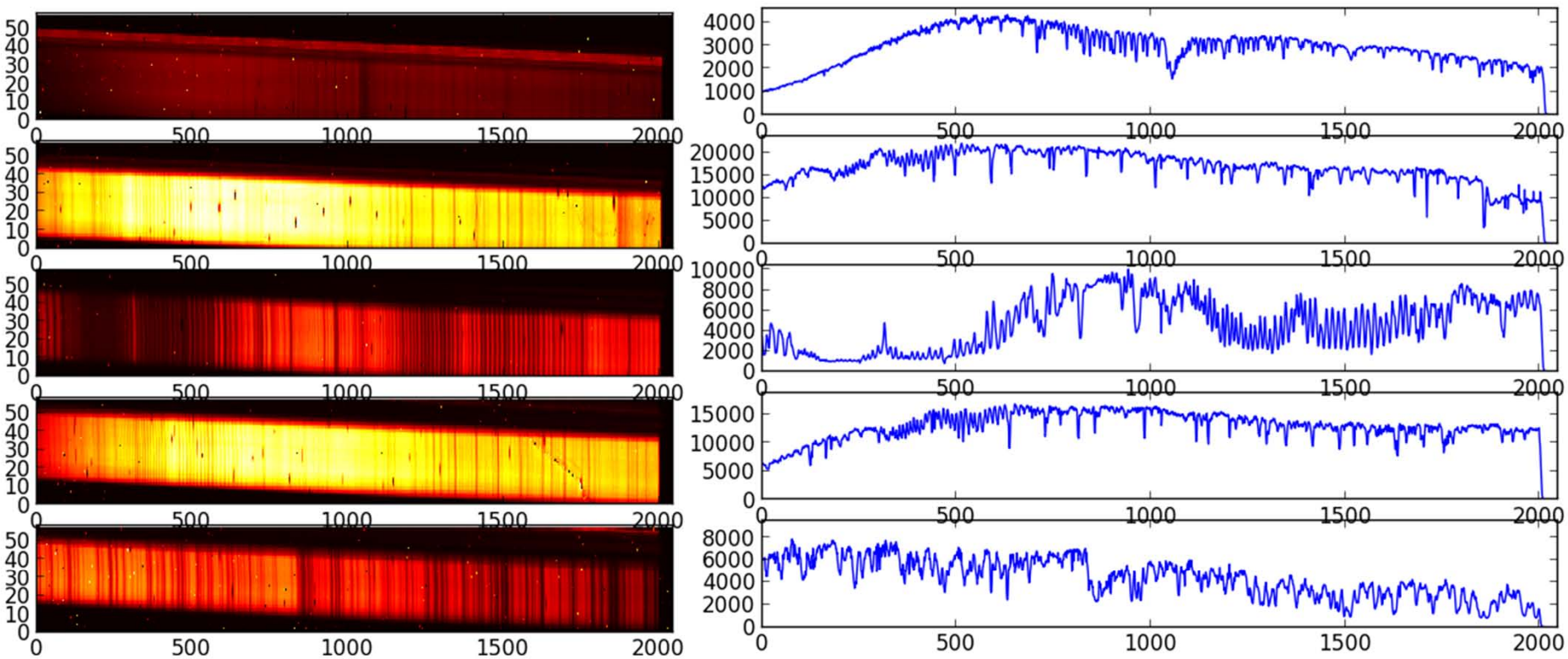


- 26th February 2015 (0700 local, 6.5hr duration)
- 5th March 2015 (2000 local, 21hr duration)
- 10th March 2015 (0900 local, 11.5hr duration)

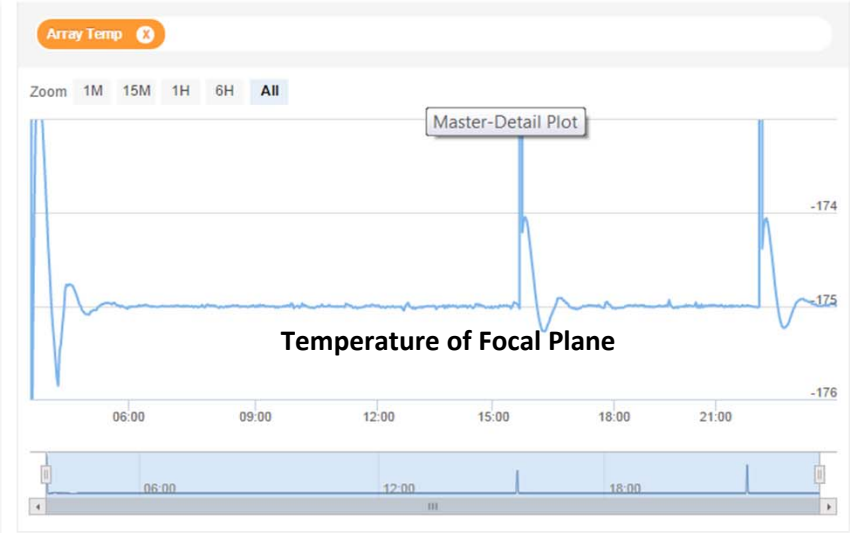
2nd science flight: satellite overpasses

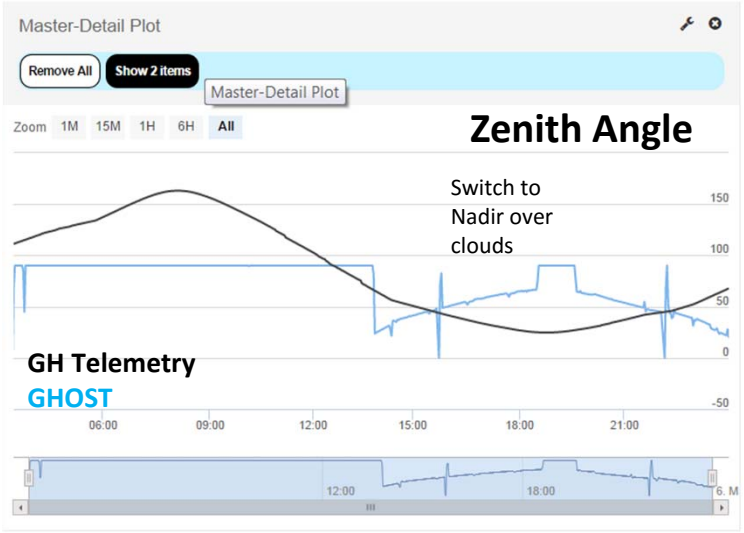


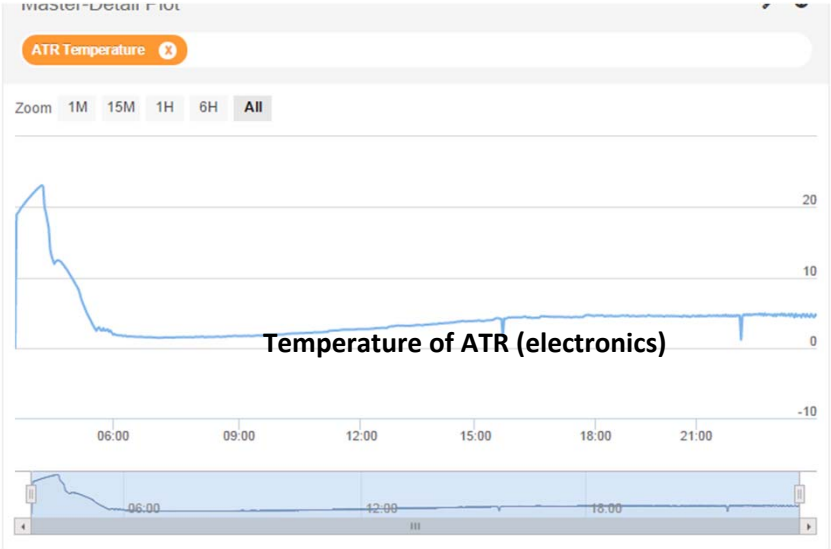
GHOST science data
03/05/15, Tropical Eastern Pacific

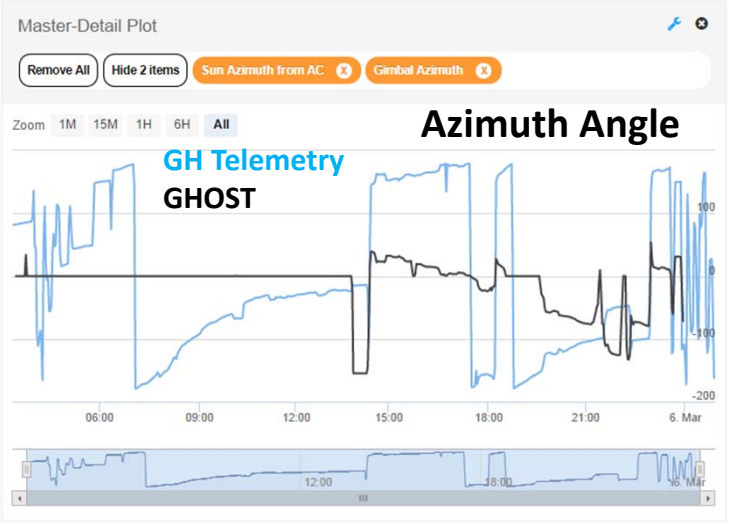


Real time instrument data









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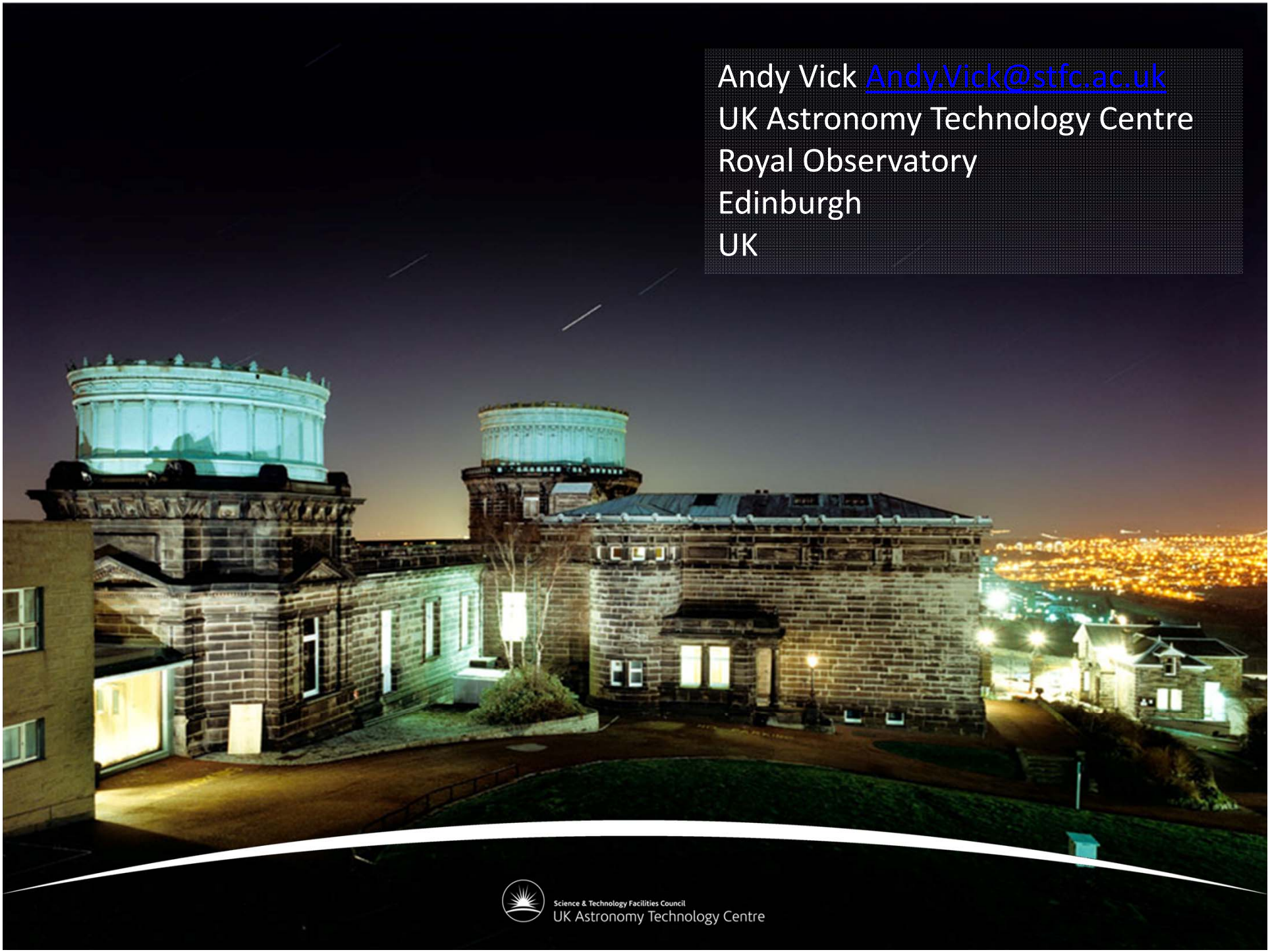
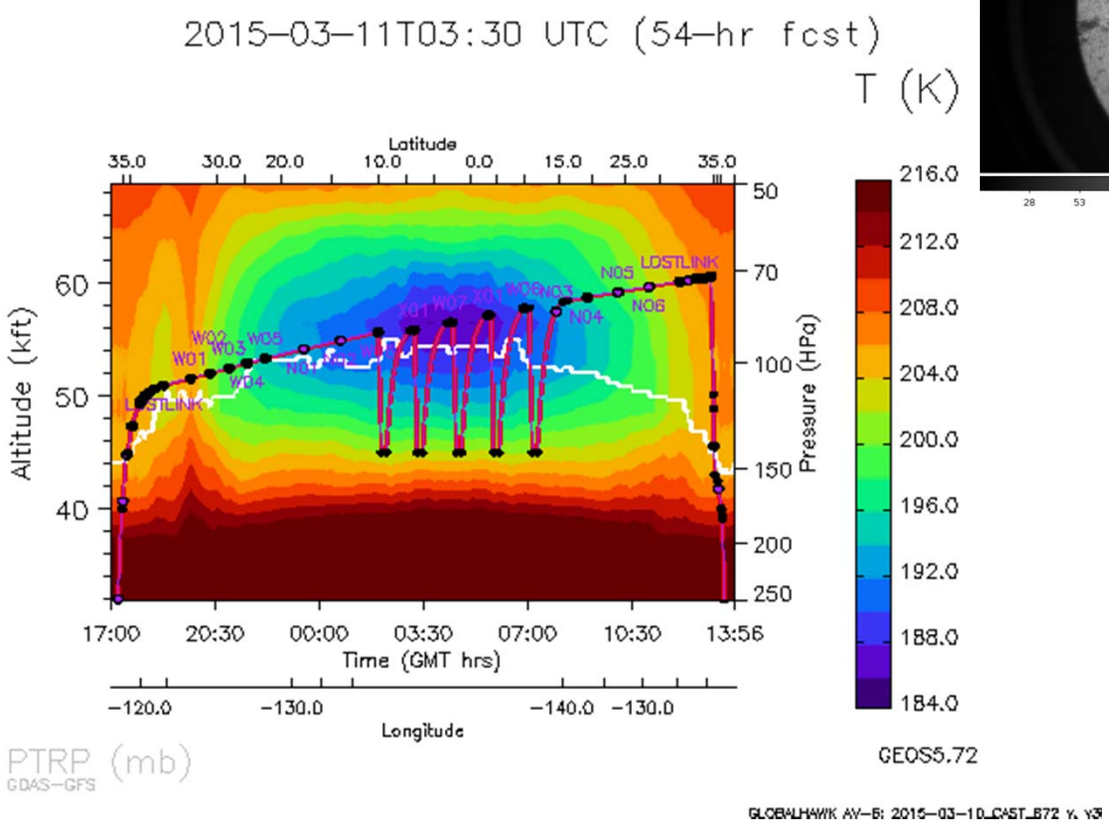
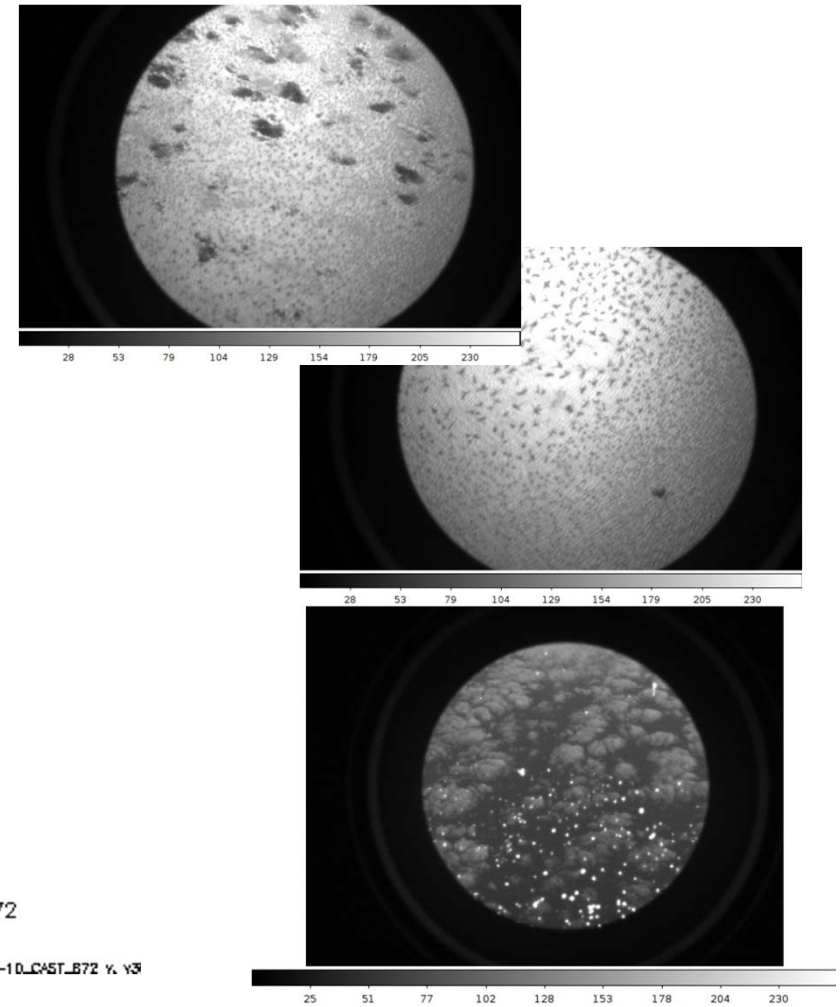


Lessons learned

Icing on TAM dome





Typical flight profile

Lessons learned

Satellite communication

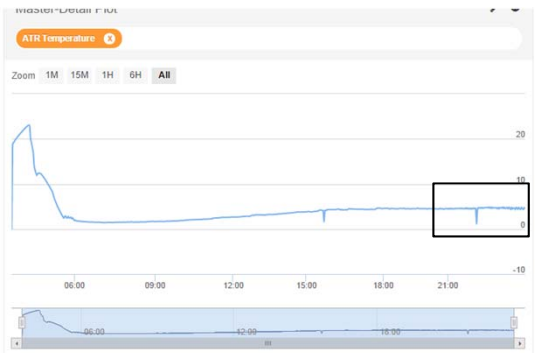
There were 2 satellite bands available:
Iridium – low bandwidth
KU band – high bandwidth

Lessons learned

Don’t use epoxy

Cryostal electrical feedthrough

ATR vessel near heat exchanger



Successes

- Cryostat hold time – much longer than expected (> 30 hours)
- Cryostat (instrument) stability
- Automation, with intermittent comms.
- Environmental stability of equipment
- Pointing and tracking
- Flights
- Data ?

Problems

- Cryostat external fixings (leaks)
- Bad communications
- Dome icing (visibility)
- Lengthy process
- Operations