



Jet Propulsion Laboratory
California Institute of Technology

RapidScat

A New Measure of Ocean Winds

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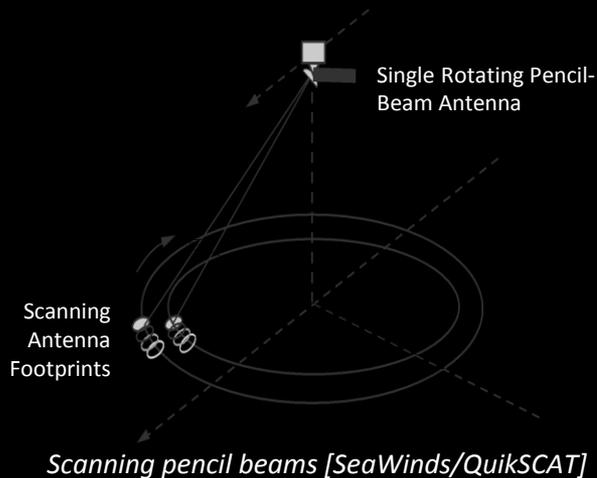
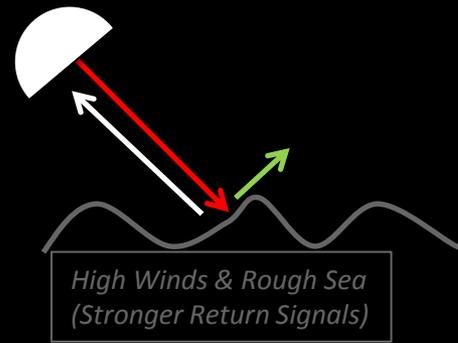
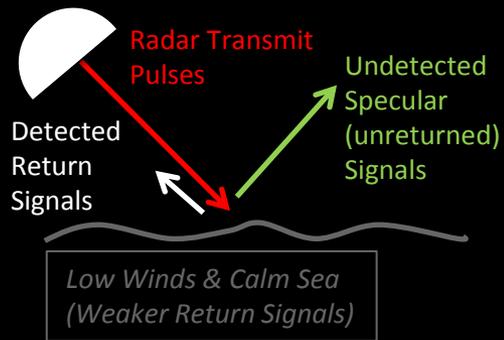
Instrument Manager

Glen Havens

Mission Manager



What is RapidScat?



Well-established empirical geophysical model function at Ku-band to retrieve winds

Science Objectives

1. Provide ocean vector winds to improve weather forecasting

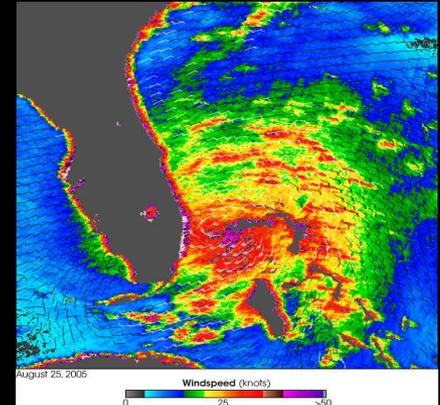
The mid and low latitude coverage will provide additional observations of storms that may develop into hurricanes or other tropical cyclones, essential with recent loss of OSCAT.

2. Provide direct cross-calibration for the international constellation

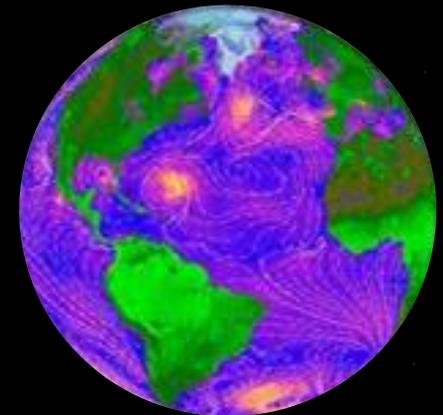
The ISS orbit will enable coincident measurements in space and time with other ocean vector winds satellites (ASCAT, QuikSCAT, future ISRO scatterometer)

3. Improve estimates of the diurnal ocean vector wind cycle and determine the semi-diurnal cycle

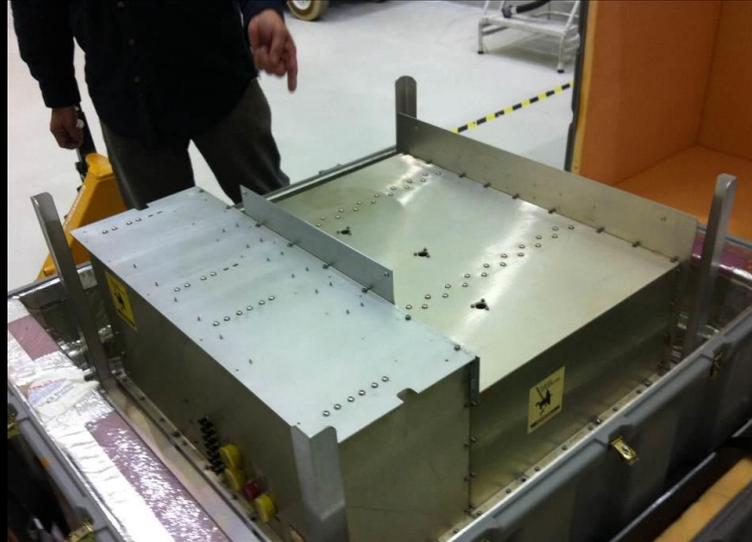
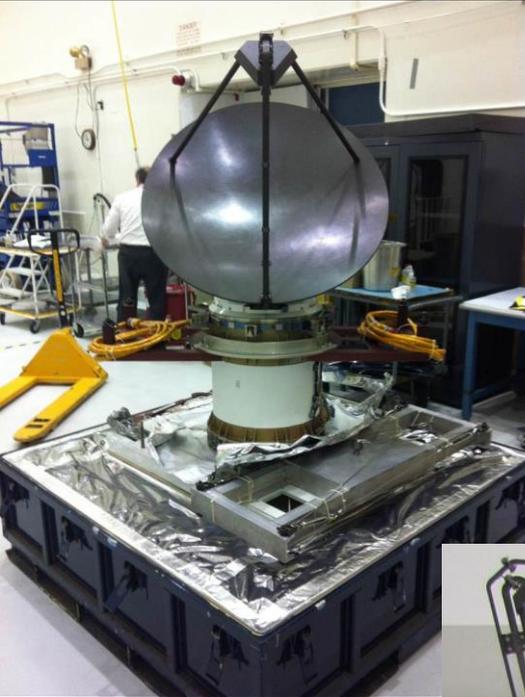
Subdiurnal variability cannot be resolved with the other satellites that are in sun-synchronous orbits.



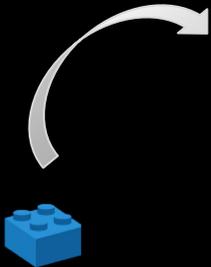
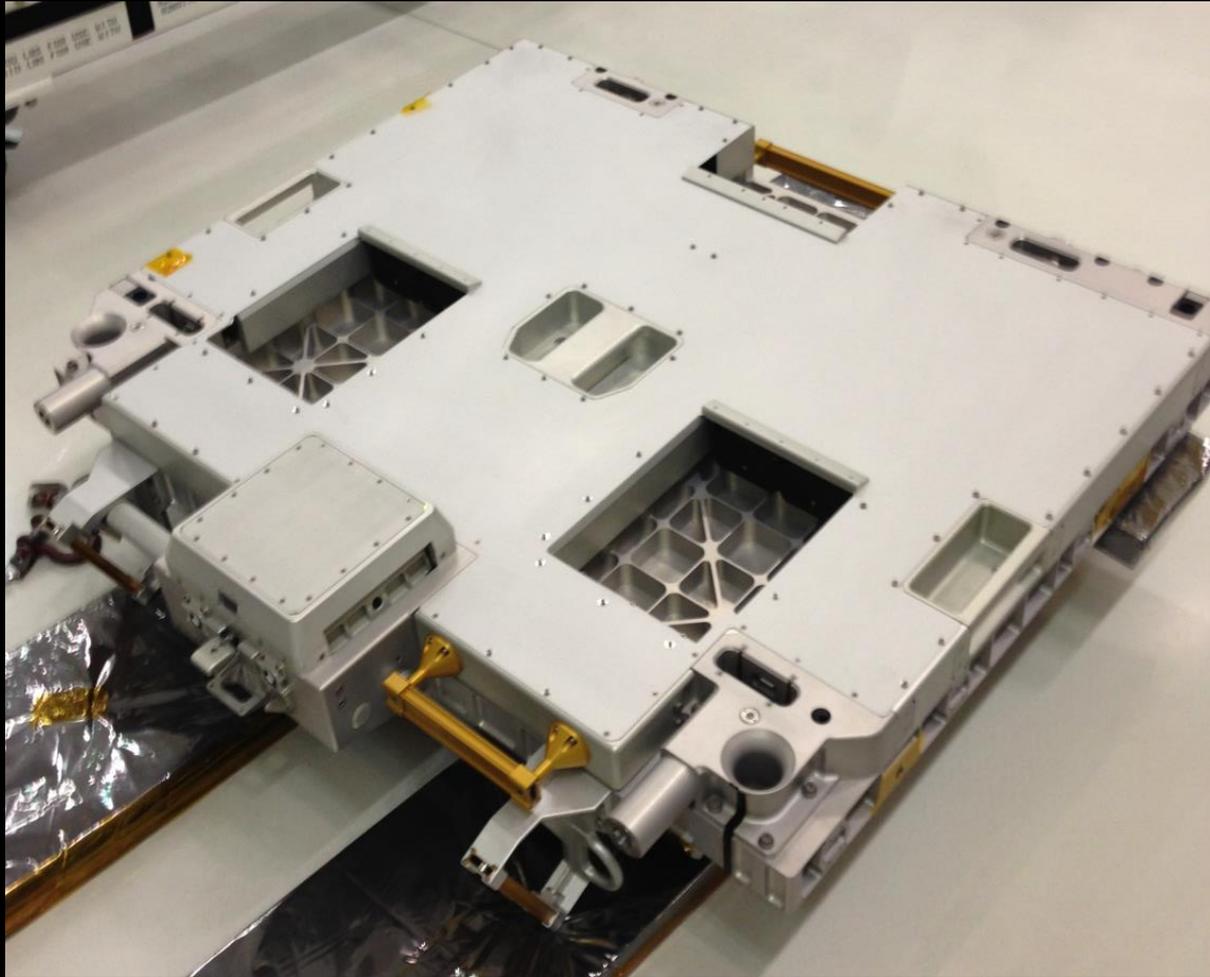
*QuikSCAT Sees
Hurricane Katrina*



*Global Winds as
Viewed by QuikSCAT*



In theory, there is no difference between theory and practice. But, in practice, there is.



It takes a few villages...



Data Archive and Science Analysis



NASA JPL



NASA KSC



NASA JSC



NASA MSFC

Project Office

- Instrument Development
- Operations
- Science Data Processing

Launch Site

- ISS Compatibility Testing
- Source of integration knowledge
- Assembly equip

Program Office

- Funding
- Interface/Requirements Mgmt
- Safety
- Robotic Installation

Payload Operations

- Command forwarding
- Safety Critical Commanding
- Payload and ISS data flow



Columbus Module

- Provides power and commands and data
- Primary mechanical interface



ISS Engineering

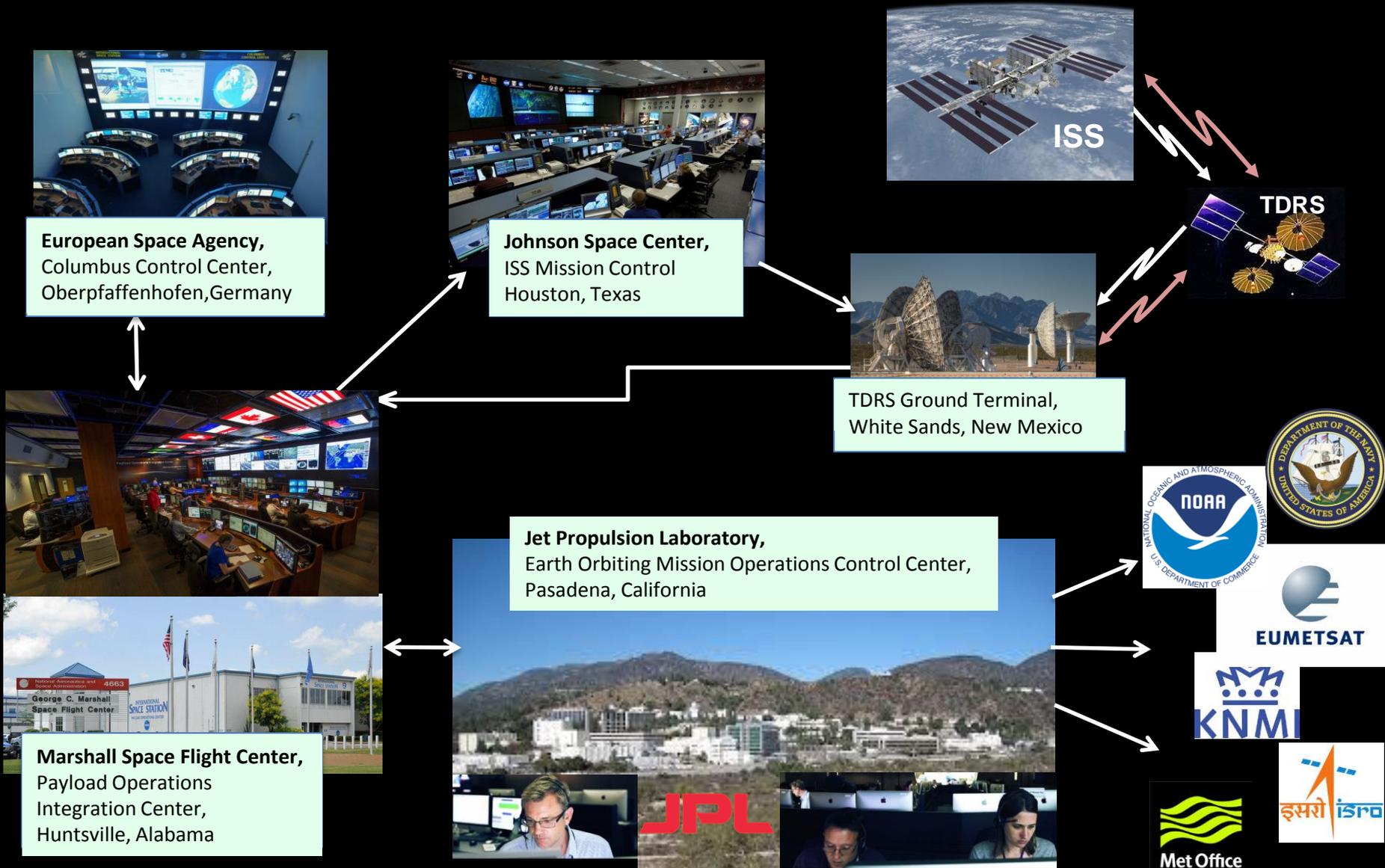
- Maintains technical design of ISS
- Provides Furnished Equipment



Launch Service

- Contracted to ISS/JSC
- Pre-conditioning before transfer to ISS
- Provides Furnished Equipment

Mission Operations



European Space Agency,
Columbus Control Center,
Oberpfaffenhofen, Germany



Johnson Space Center,
ISS Mission Control
Houston, Texas



ISS



TDRS



TDRS Ground Terminal,
White Sands, New Mexico

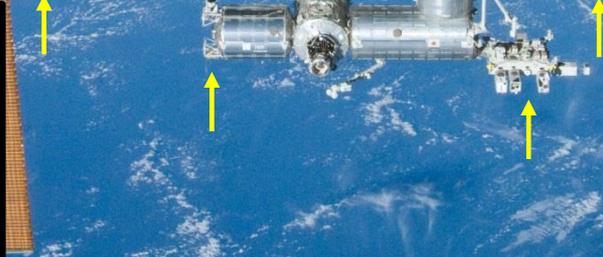
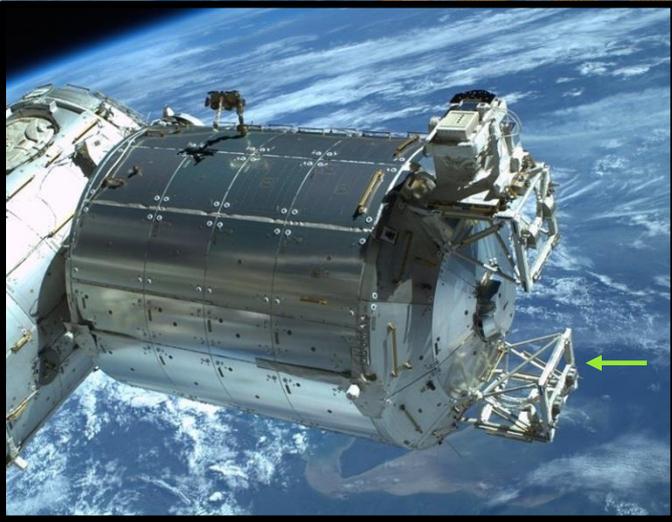
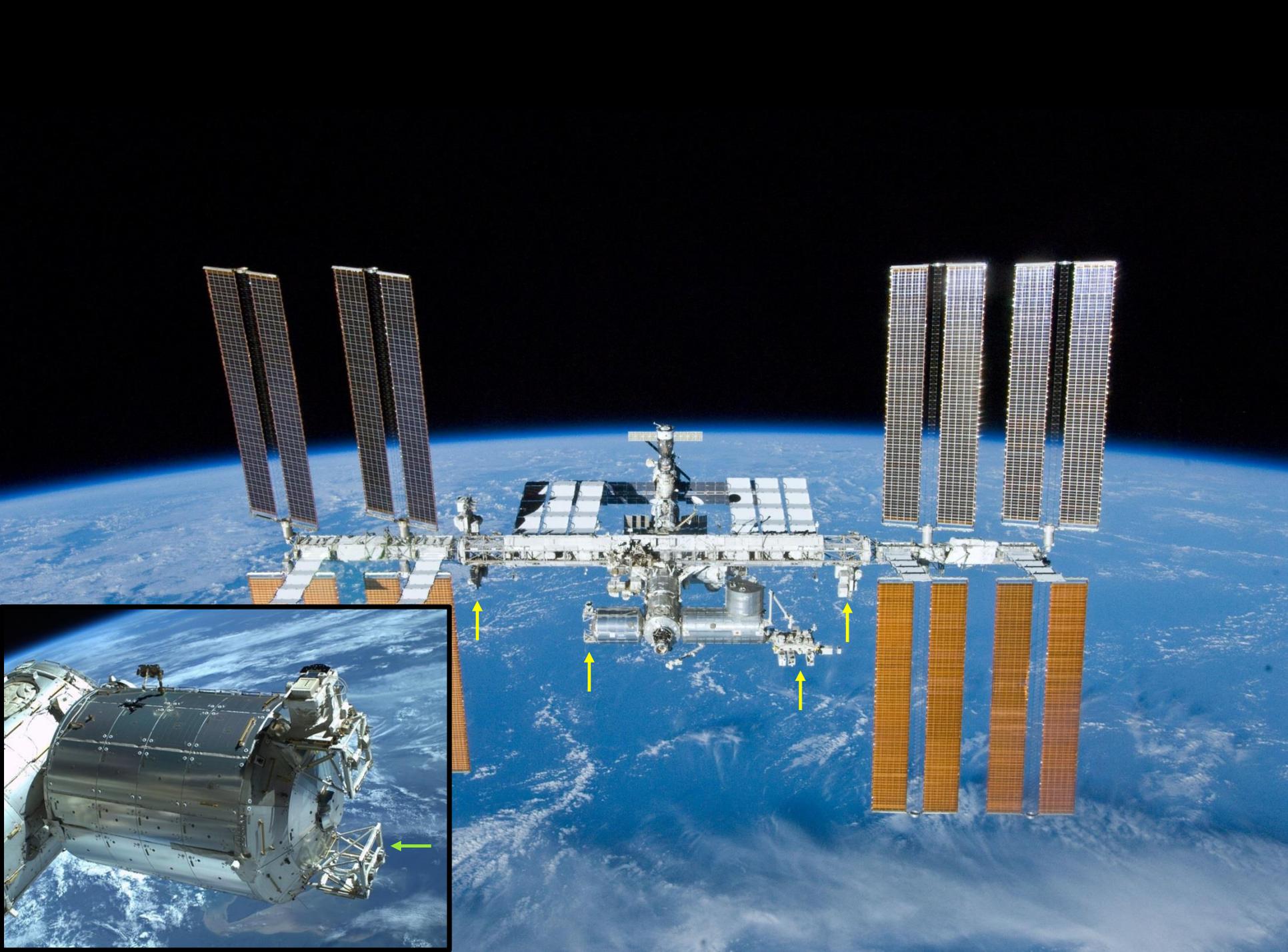


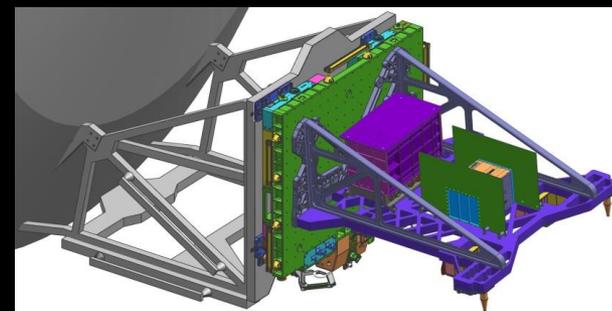
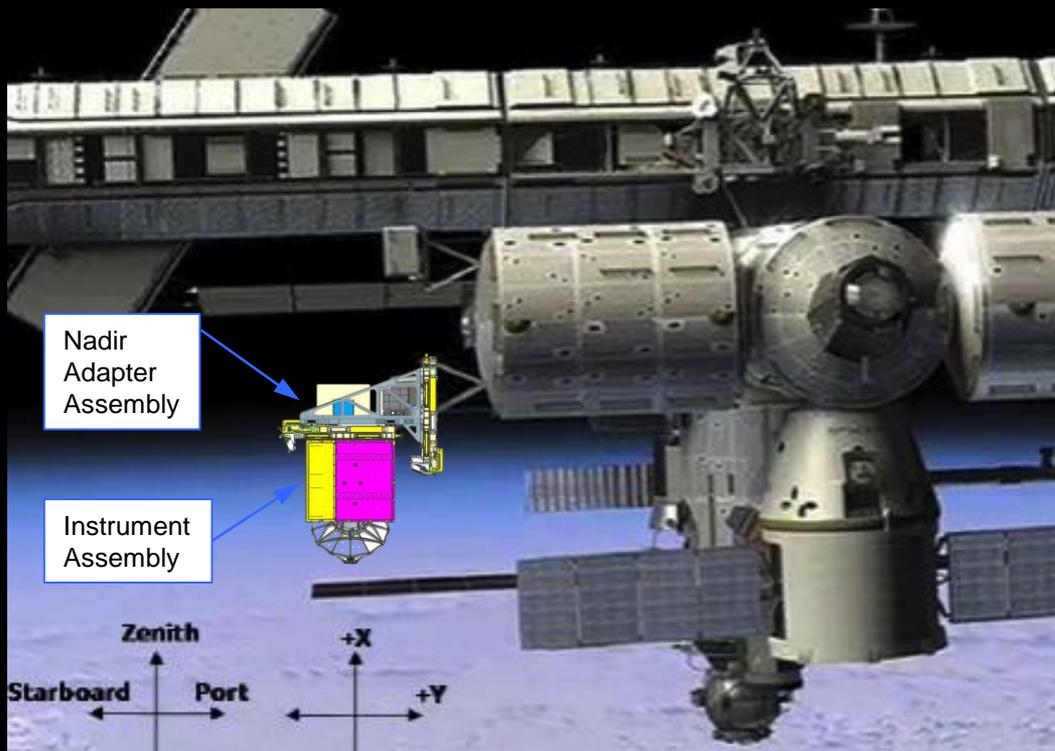
Marshall Space Flight Center,
Payload Operations
Integration Center,
Huntsville, Alabama



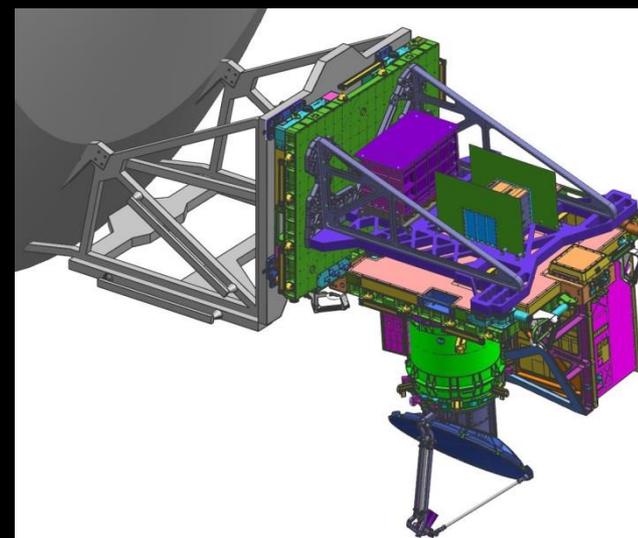
Jet Propulsion Laboratory,
Earth Orbiting Mission Operations Control Center,
Pasadena, California



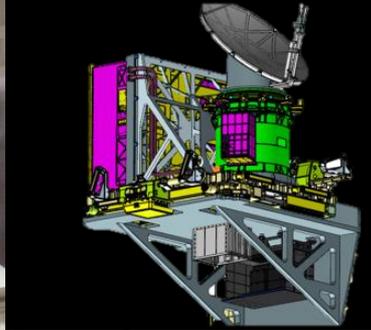
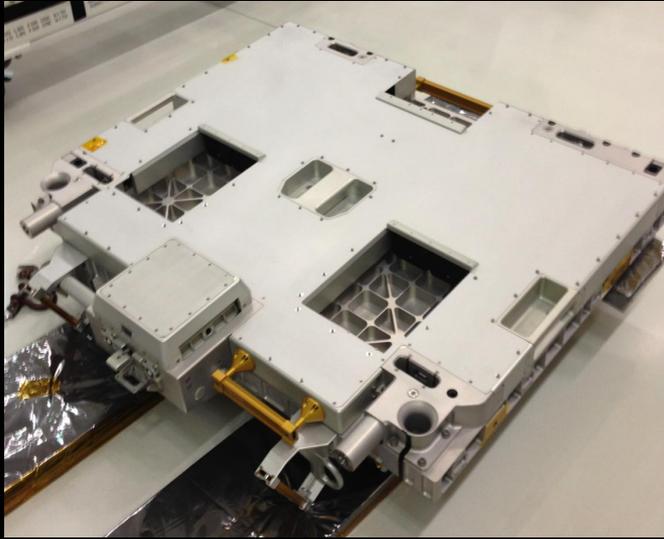




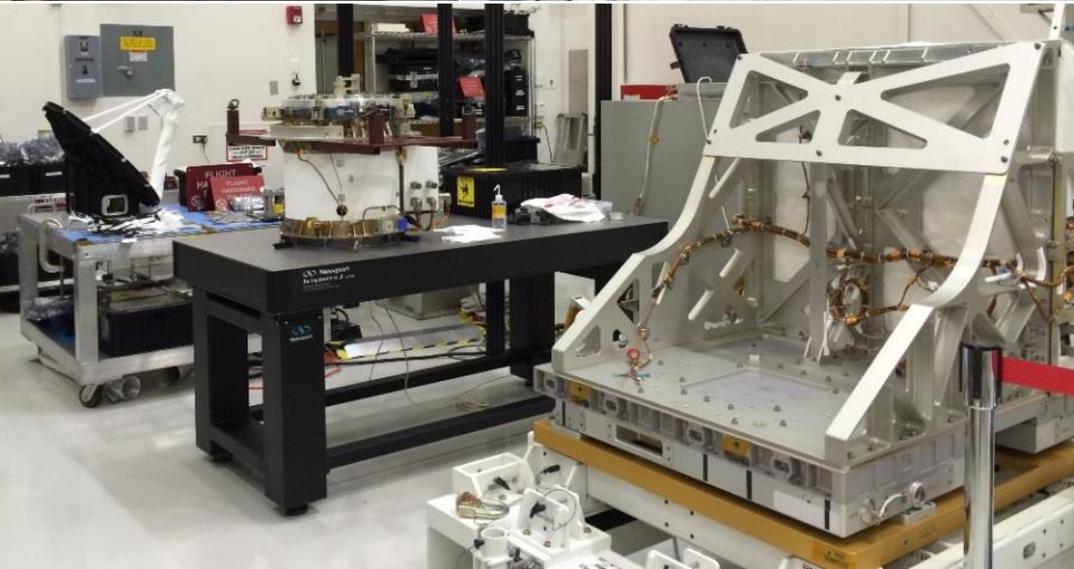
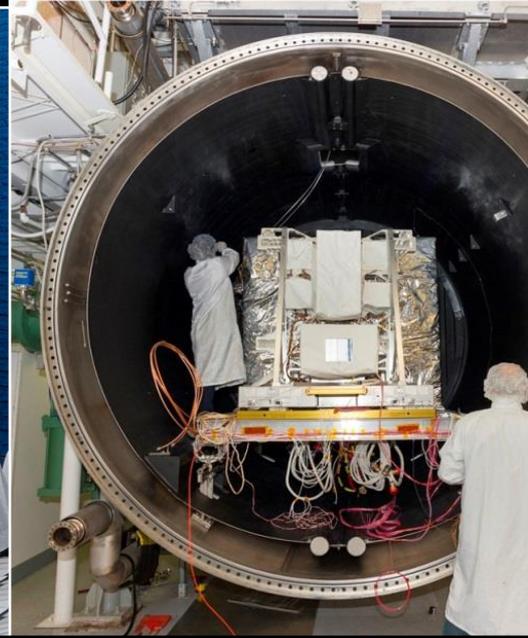
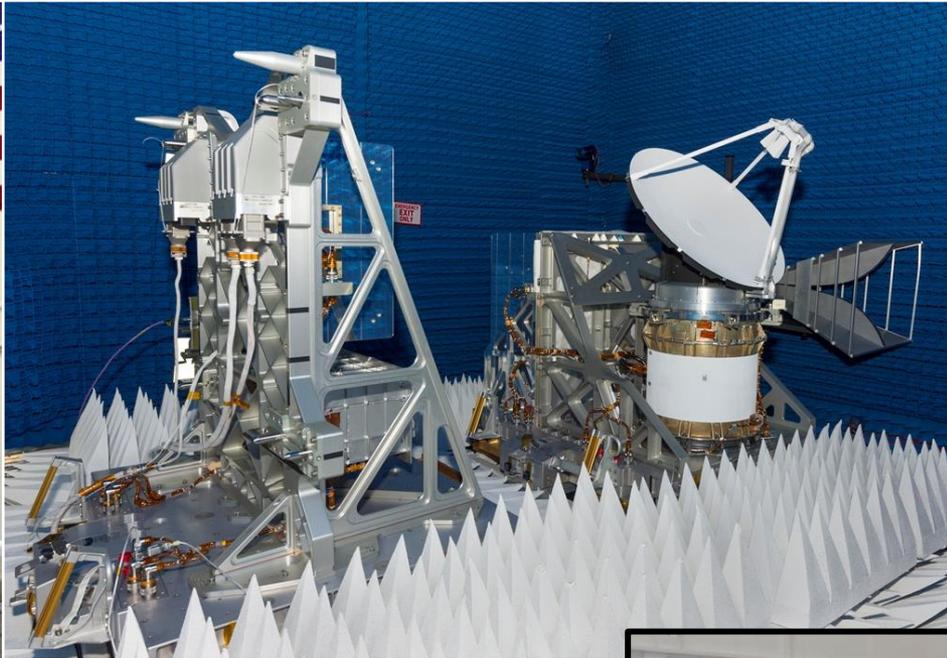
(1st) Nadir Adapter installation onto Columbus SDX



(2nd) Instrument installation onto Nadir Adapter



Test, Test, Test, Fix, Test

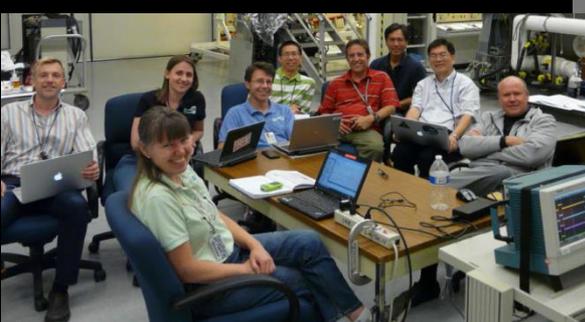




ISS-RAPIDSCAT DEVELOPMENT TEAM
FEBRUARY, 2014



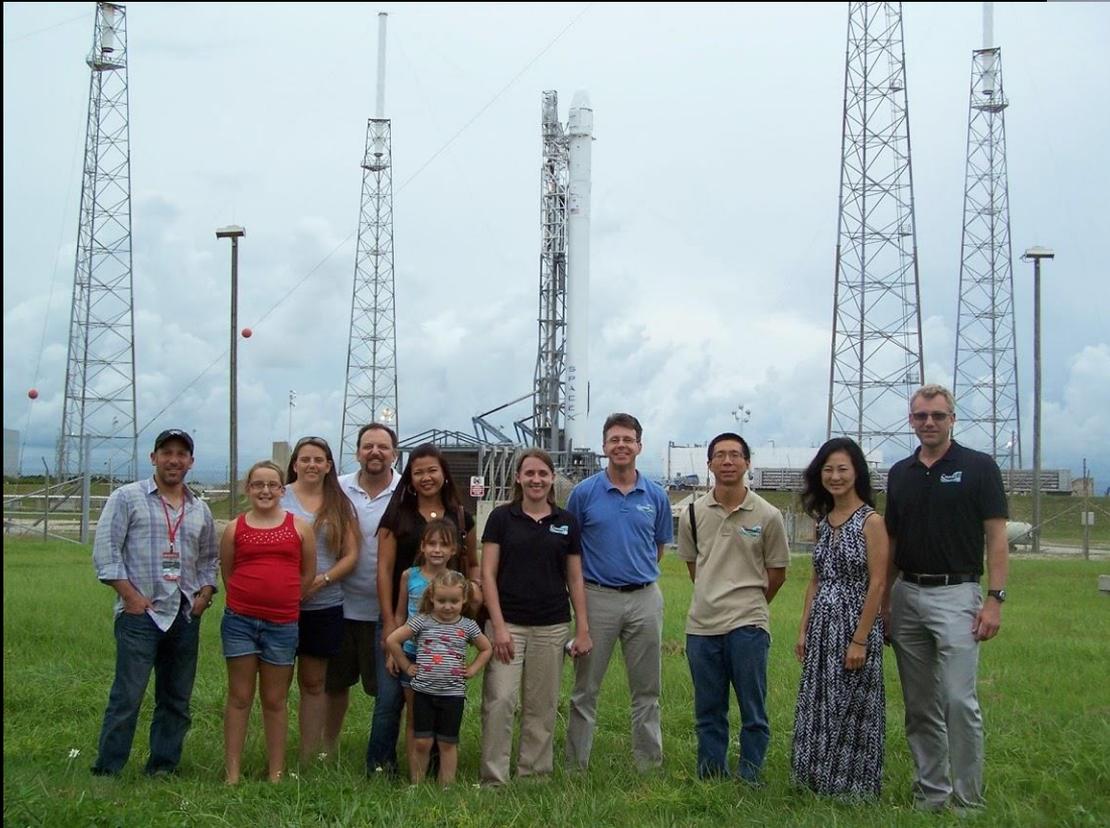
PAYLOAD MATE VERIFICATION TEAM
06 MARCH, 2014



Integration



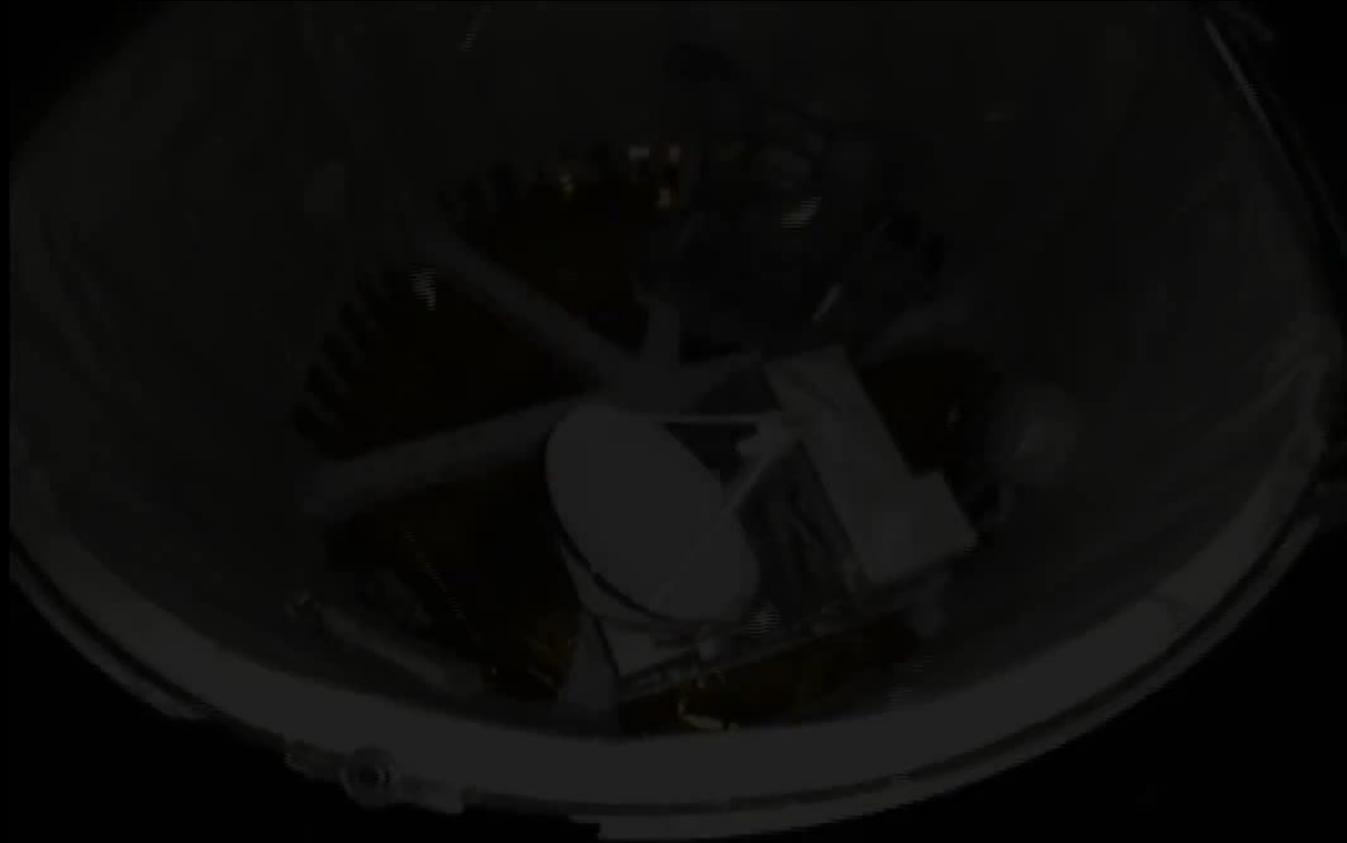
Ready for Launch!



Launch!



On our Way!



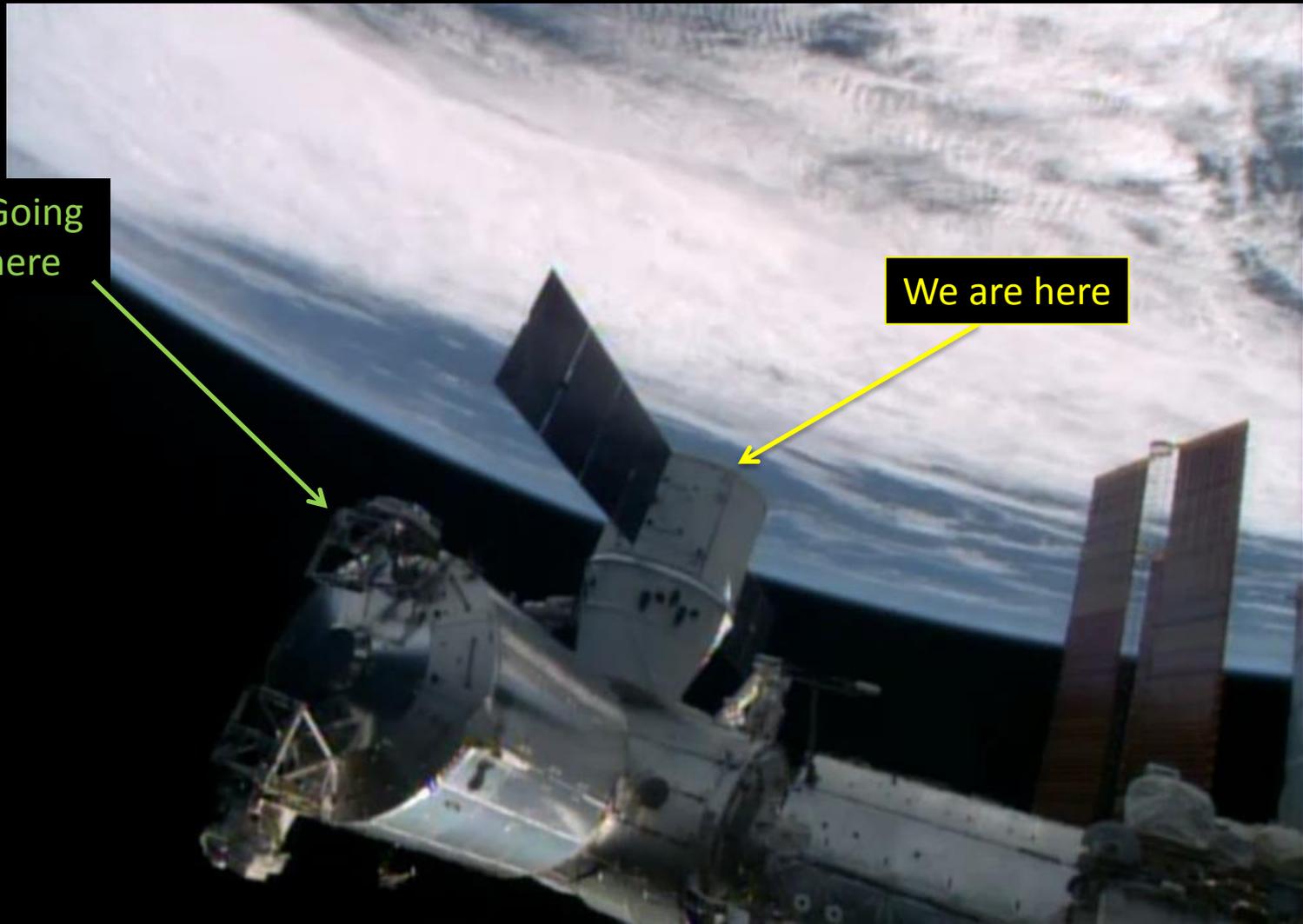
06:02:21.30

Berthed!

Going here



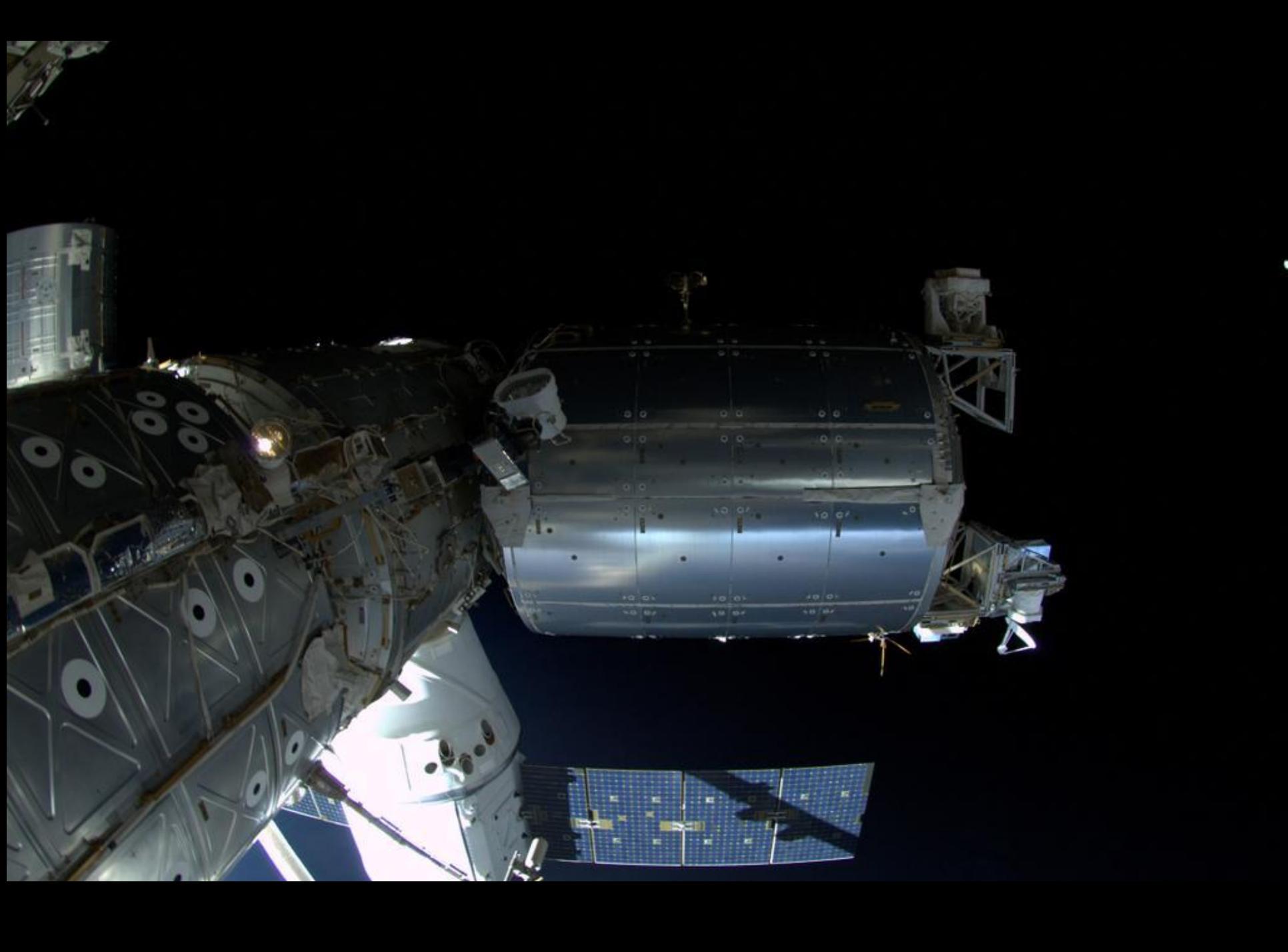
We are here



Installation

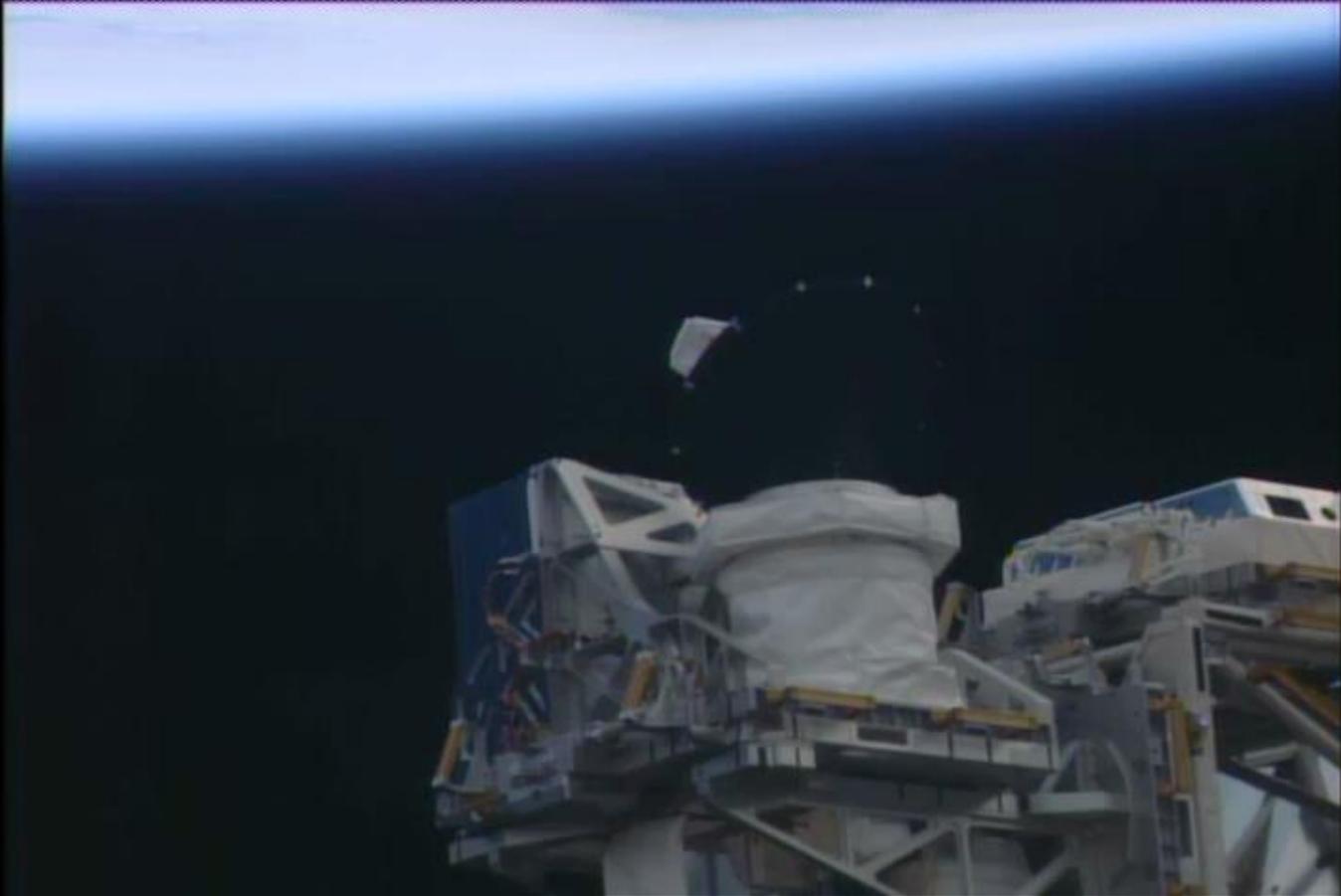




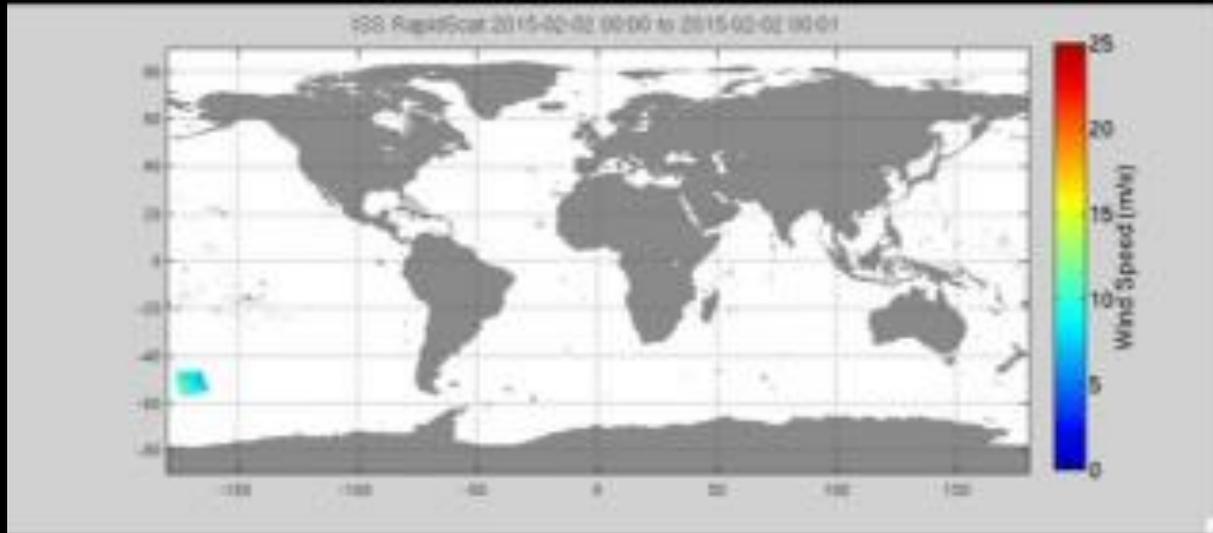




October 1, 2014

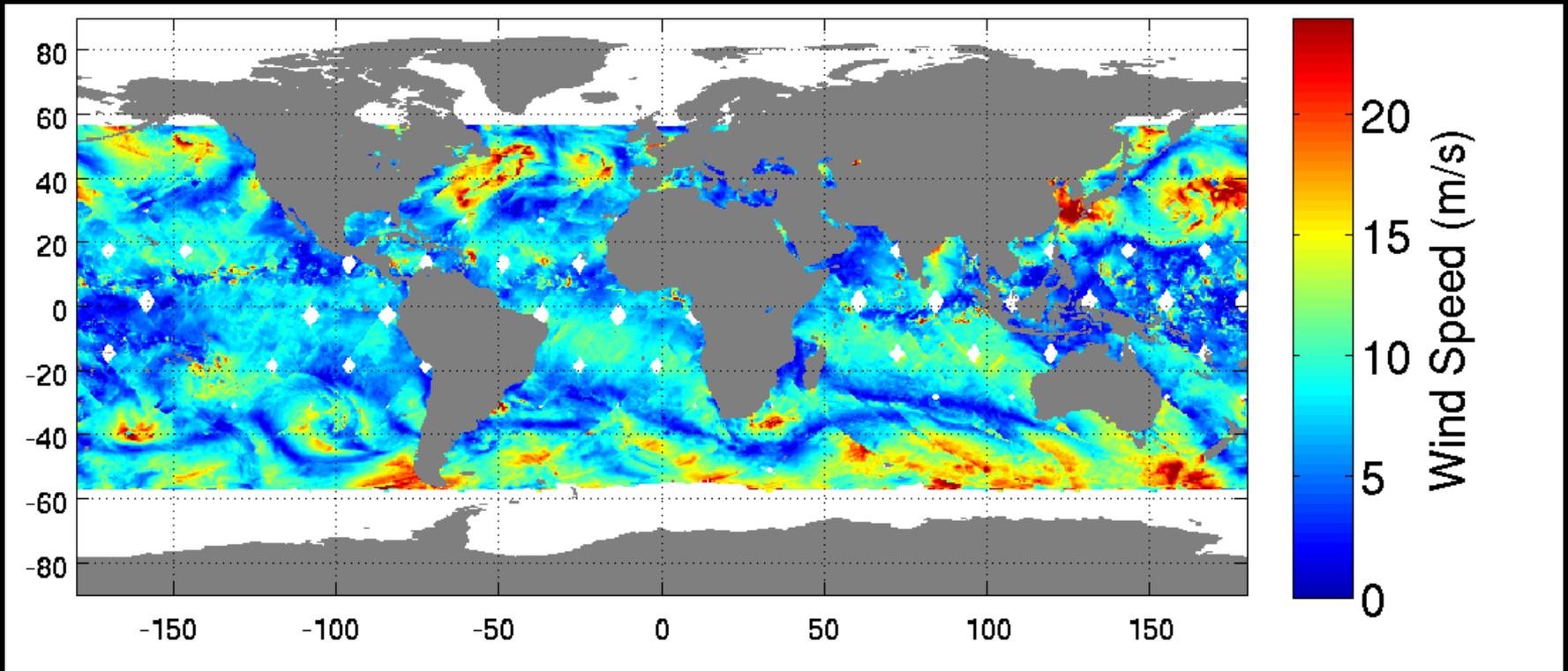


Near-global coverage (48 hrs)



<http://winds.jpl.nasa.gov/>

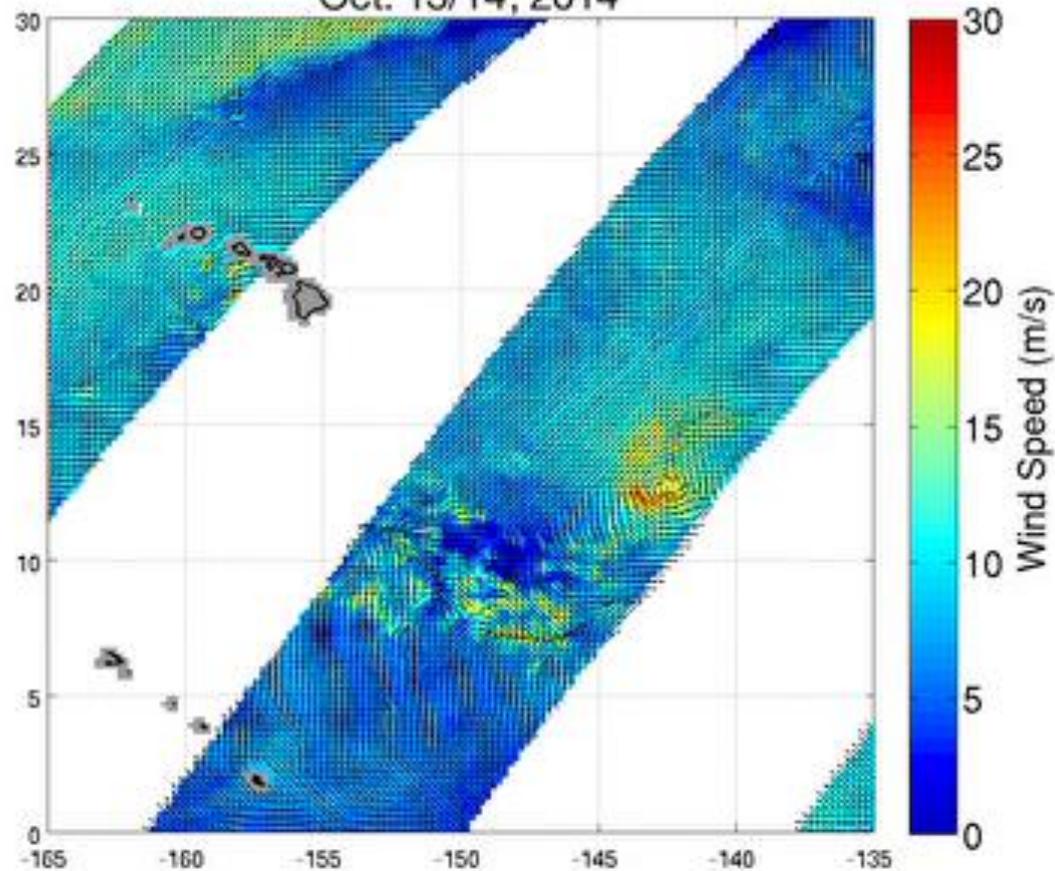
Near-global coverage (48 hrs)



<http://winds.jpl.nasa.gov/>

Tracking a Storm

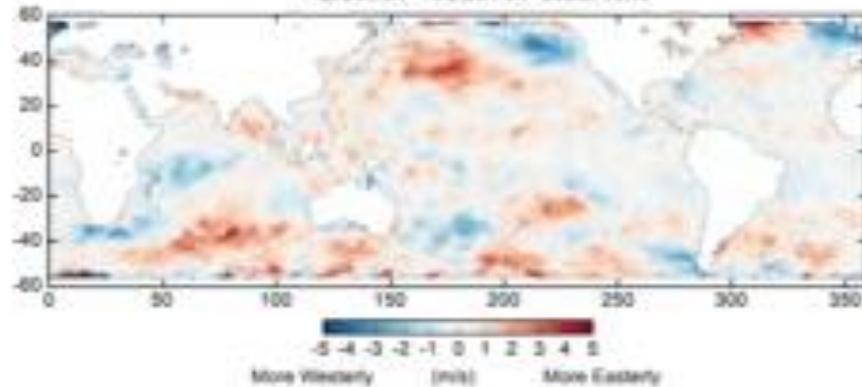
ISS-RapidScat 12.5-km Uncalibrated Wind Data
for Hurricane Ana, Hawaiian Islands
Oct. 13/14, 2014



Daily variation in zonal winds

RapidScat Daily Variation in Zonal (East-West) Winds

12:00 AM – 06:00 AM Local Time

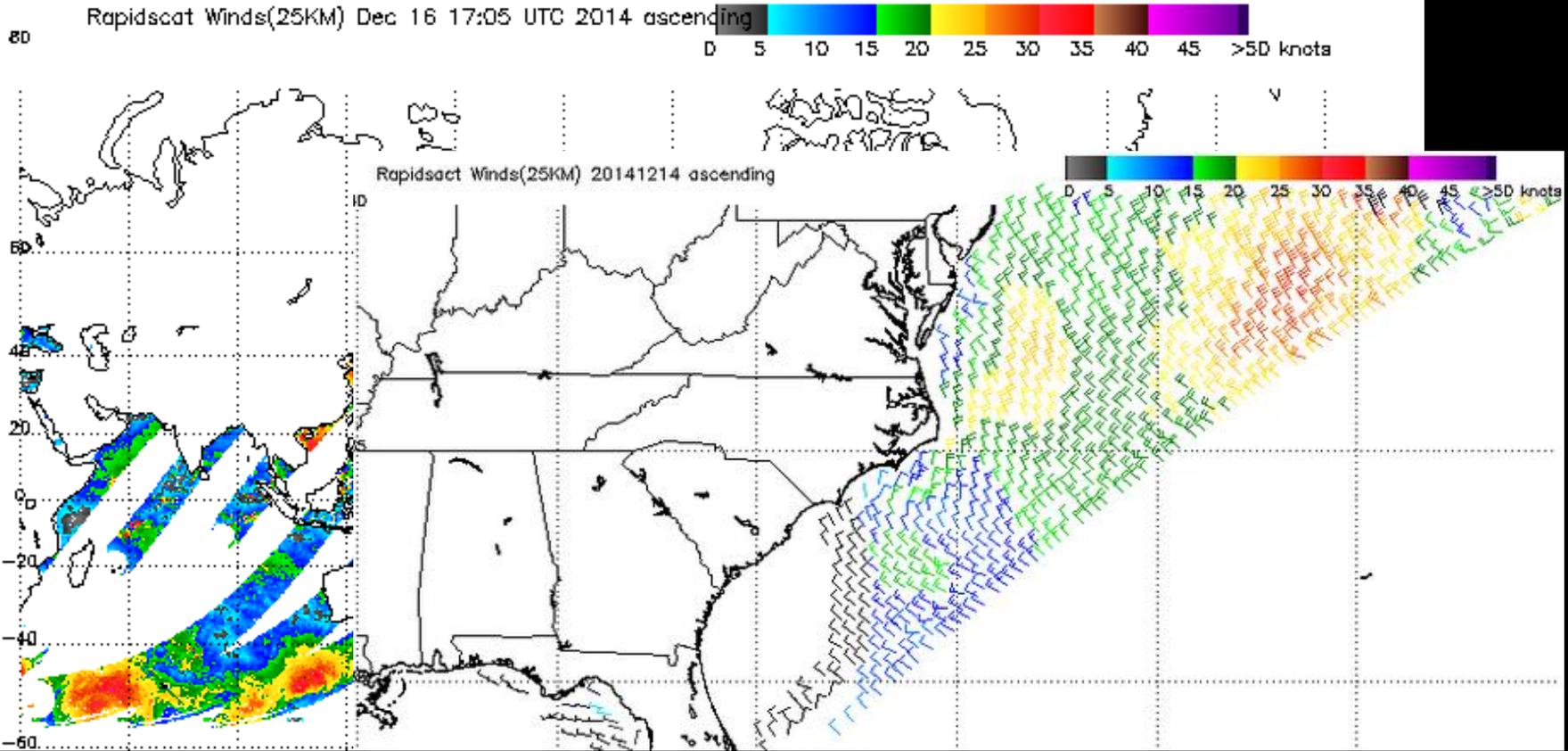


Data from Satellite/Instruments: [RapidSCAT](#)

Additional Products: Wind Vectors 20x30 (25KM) | Year: 2014 | Month: 12 | Day: 16 | Global(80N80S-180E180W) | Get Images

RapidScat Scheduled Outages

Ascending Pass



Example NOAA National Hurricane Center Forecast using RapidScat data

000

AXPZ20 KNHC 191538

TWDEP

TROPICAL WEATHER DISCUSSION

NWS NATIONAL HURRICANE CENTER MIAMI FL

1605 UTC MON JAN 19 2015

TROPICAL WEATHER DISCUSSION FOR THE EASTERN PACIFIC OCEAN FROM THE EQUATOR TO 32N...EAST OF 140W. THE FOLLOWING INFORMATION IS BASED ON SATELLITE IMAGERY...WEATHER OBSERVATIONS...RADAR...AND METEOROLOGICAL ANALYSIS.

BASED ON 1200 UTC SURFACE ANALYSIS AND SATELLITE IMAGERY THROUGH
1500 UTC.

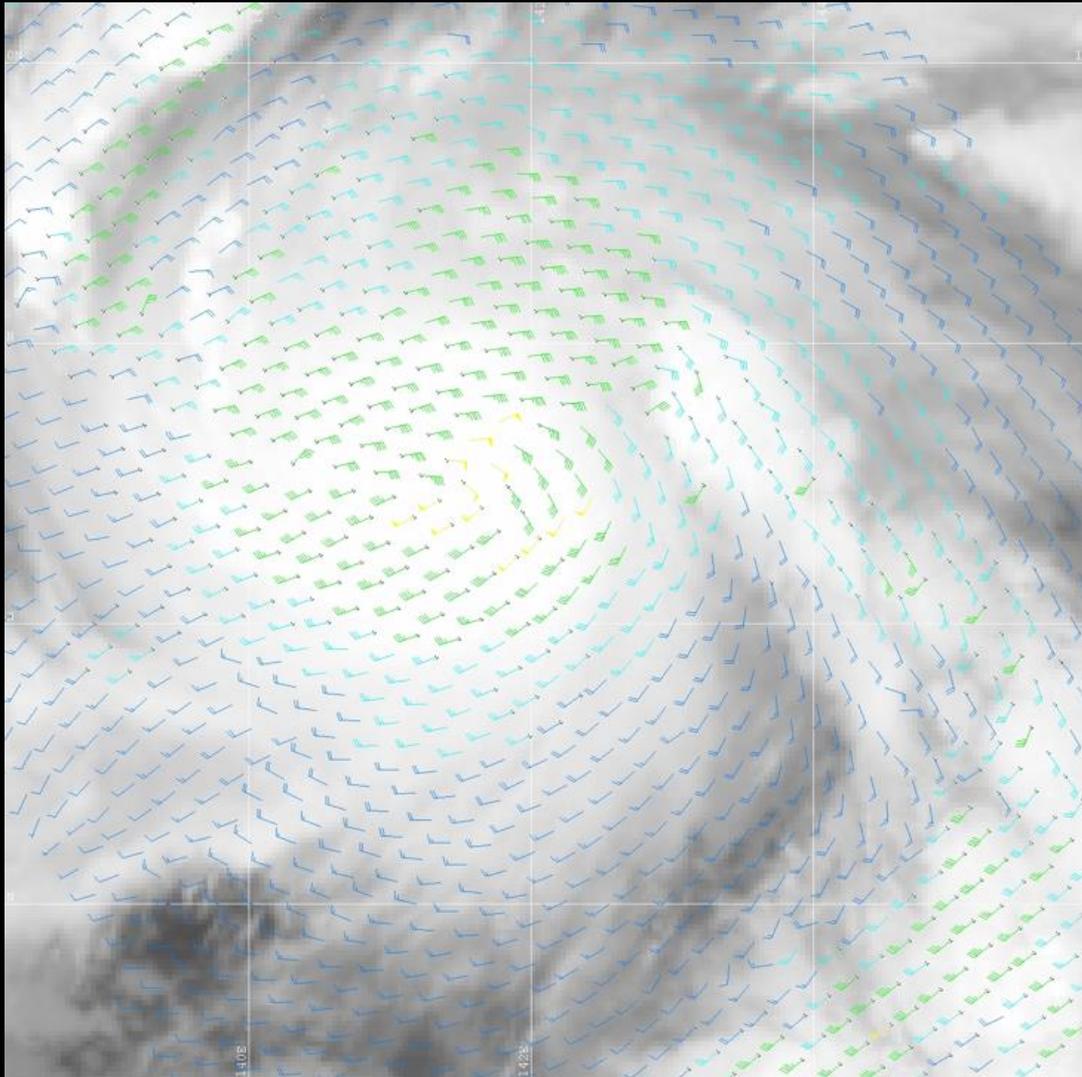
...INTERTROPICAL CONVERGENCE ZONE/MONSOON TROUGH...

MONSOON TROUGH EXTENDS FROM 08N78W TO 09N85W TO 05N96W. ITCZ IS FROM 05N96W TO 09N115W TO 07N130W TO 06N140W. SCATTERED MODERATE ISOLATED STRONG CONVECTION WITHIN 90 NM N AND 30 NM S OF AXIS BETWEEN 103W AND 109W.

...DISCUSSION...

GULF OF TEHUANTEPEC...SURFACE OBSERVATIONS FROM SALINA CRUZ ALONG THE TEHUANTEPEC COAST HAVE BEEN BELOW 20 KT THIS MORNING WHICH INDICATES THE NORTHERLY WINDS FUNNELING THROUGH CHIVELA PASS INTO THE GULF OF TEHUANTEPEC ARE NOT NEARLY AS STRONG AS 12 -15 HOURS AGO WHEN GUSTS WERE 25-30 KT. **RAPIDSCAT SCATTEROMETER PASS AT 0600 UTC INDICATED PEAK WINDS 30-35 KT IN THE GULF...**AND MODEL GUIDANCE SHOWED WINDS WOULD FALL BELOW GALE FORCE SHORTLY AFTER 1200 UTC. BASED ON THIS INFORMATION A GALE WARNING IS NO LONGER IN EFFECT. EXPECT THE ASCAT PASS LATER TODAY TO SHOW MAX WINDS 30-32 KT...BUT ANYTHING IS POSSIBLE. WINDS AND SEAS WILL RAPIDLY DIMINISH THROUGH TUE MORNING. GLOBAL MODELS SHOW GALE FORCE WINDS MAY BE POSSIBLE AGAIN IN THE REGION SAT MORNING.

RapidScat Winds used by Navy to monitor Typhoon Hagupit



12/02/14	1800Z	32W	HAGUPIT
12/02/14	2019Z	ISS	RSCAT
12/02/14	2032Z	MTSAT-2	IR

Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
ISS RSCAT (RSCAT) Vectors (knots)

5 10 15 20 25 30 35 40 45 50 55 60 65

NASA Hurricane Page

NASA's Hurricane Web Page is on Facebook.

To connect with NASA's Hurricane Web Page, sign up for Facebook today.

[Sign Up](#) [Log In](#)

NASA's Hurricane Web Page ✓
Government Organization

Timeline About Photos Likes Videos

PEOPLE

111,118 likes

ABOUT

NASA's Hurricane Web Page covers tropical cyclones all around the world, every day of the year! www.nasa.gov/hurricane. It is managed out of NASA's...

READ MORE

<http://www.nasa.gov/hurricane>

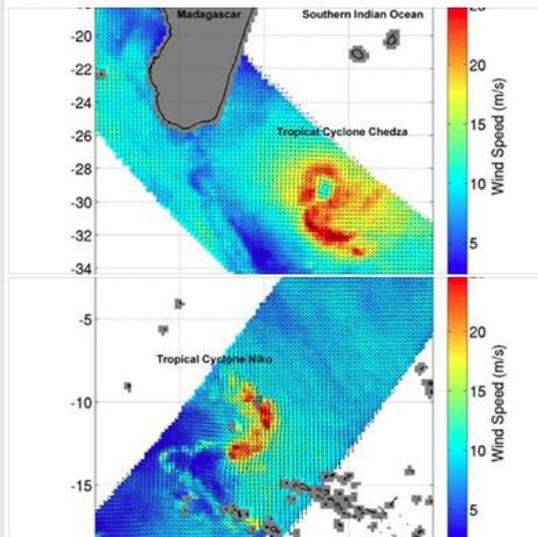
PHOTOS

VIDEOS

Like · Comment · [27](#) [6](#)

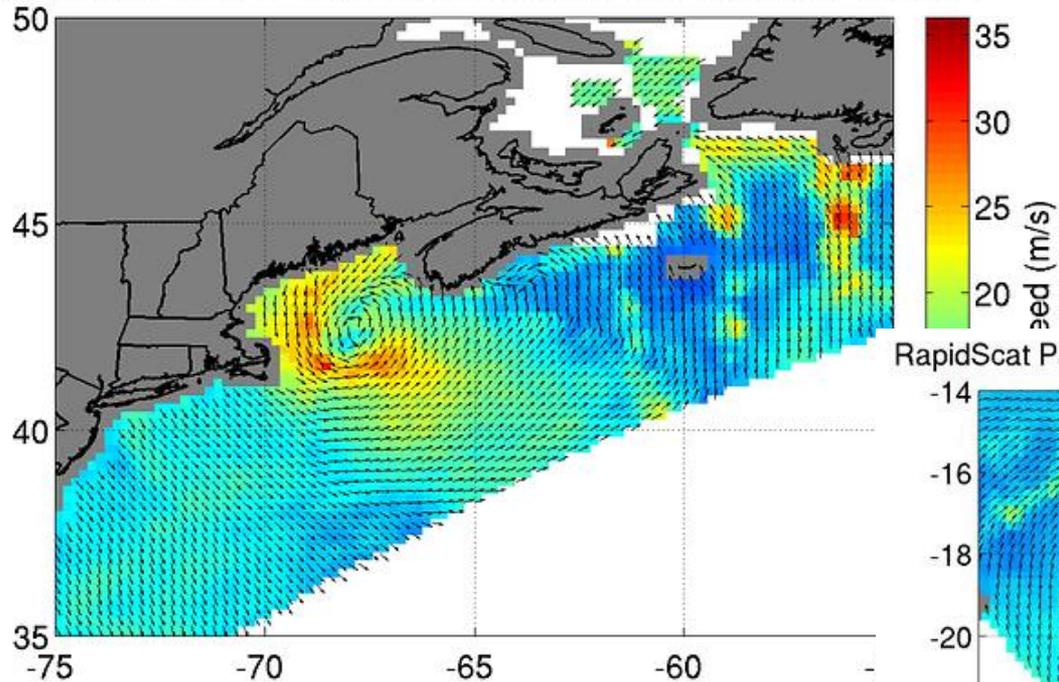
NASA maintains a hurricane page that features RapidSCAT imagery of tropical cyclones from all over the world.

Shown here are cyclones Chedza and Niko near Madagascar as seen on Jan 19 and 20, 2015.

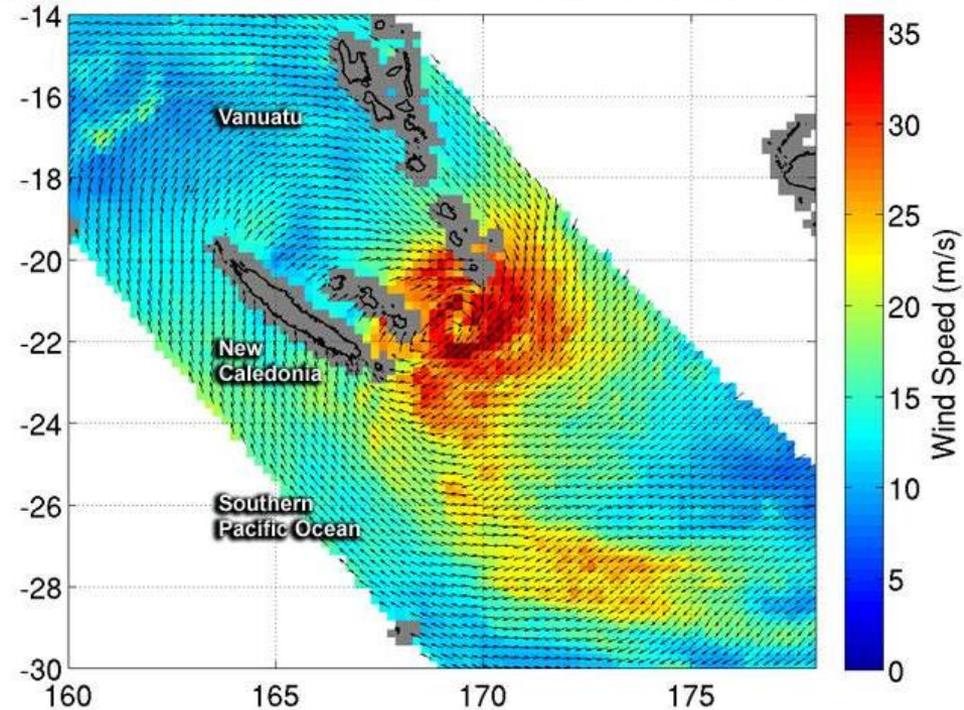


A Nor'easter & Tropical Cyclone

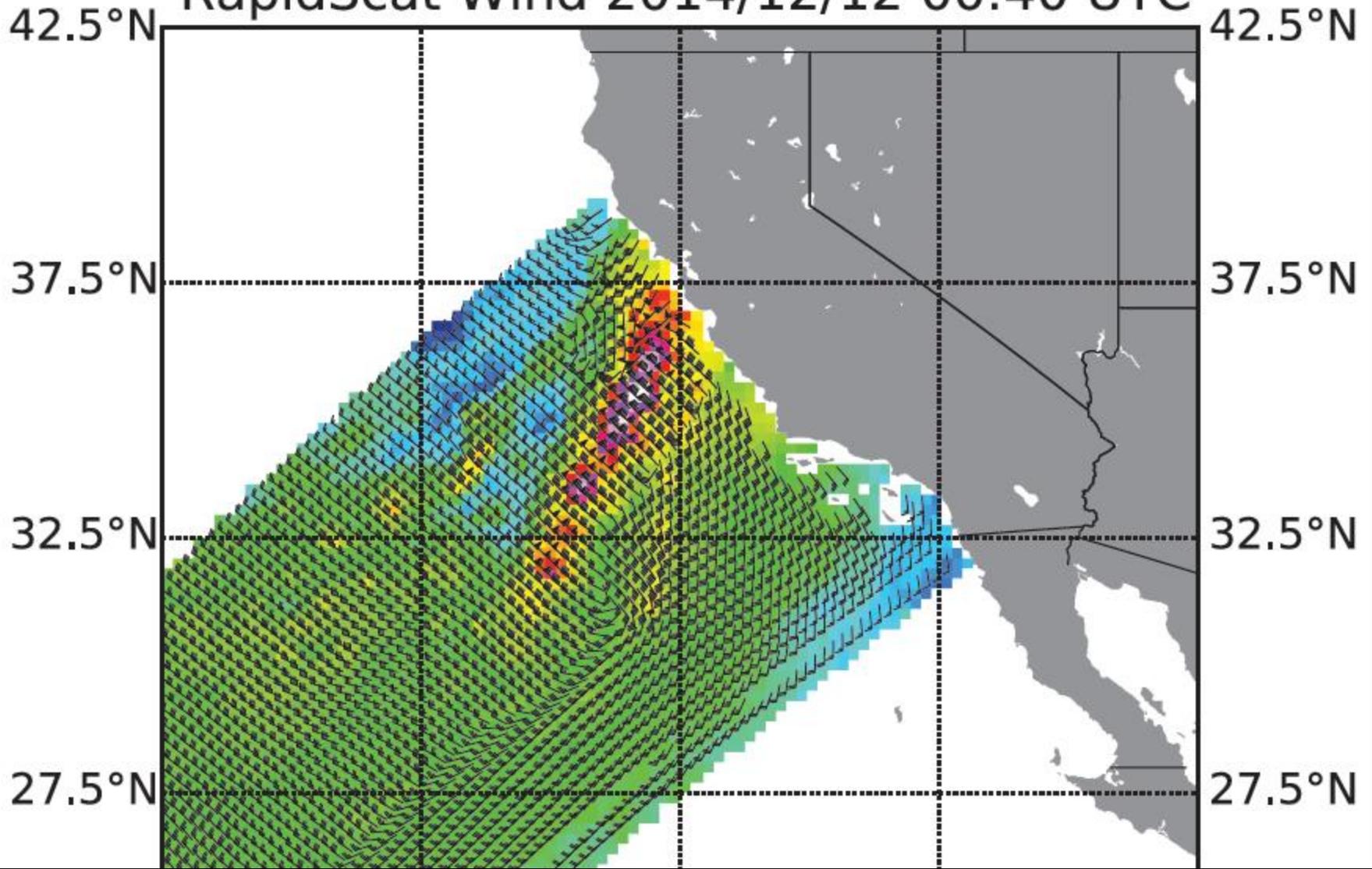
RapidScat Juno UTC 28-Jan-2015 02:41:26 to 28-Jan-2015 04:14:04



RapidScat PamUncorr UTC 14-Mar-2015 02:32 to 14-Mar-2015 04:04



RapidScat Wind 2014/12/12 00:40 UTC



RAPIDSCAT SCHEDULED OUTAGES

UPDATED

Fri 2015_03_16 Z06:00

RapidScat (RS) observes ocean winds from the International Space Station (ISS).
 ISS activities sometimes require that RS stop observing winds or cause outages or poor RS data.
 When such activities are known in advance they are recorded here.

This schedule can be found at www.knmi.nl/scatterometer/rscat_del_25_prod/RapidScat_Scheduled_Outages.txt
 and at http://manati.star.nesdis.noaa.gov/rscat_images/monitor/RapidScat_Scheduled_Outages.txt
 Each site is automated and picks up updates to this schedule within a few hours.

START	END	DESCRIPTION
2015-09-10		Undocking of Soyuz 42S
2015-09-01		Docking of Soyuz 44S
2015-08-28		Relocation of Soyuz 42S
2015-08-26		Undocking of Progress 58P
2015-08-24		Relocation of HTV 5
2015-08-23		Berthing of HTV 5
2015-08-06		Docking of Progress 60P
2015-08-04		Undocking of Progress 59P
2015-07-15		Release of SpaceX SpX-7
2015-07-07		US EVA construction work on IDA
2015-06-24		Russian EVA 41
2015-06-15		Berthing of SpaceX SpX-7
Wed 2015-05-27		Docking of Soyuz 43S
Sun 2015-05-17		Unberthing of SpaceX SpX-6
Wed 2015-05-13		Undocking of Soyuz 41S
Tue 2015-04-28	2015-04-28	RS will not observe winds during the arrival of Progress 59P
Sat 2015-04-25	2015-04-25	RS will not observe winds while Progress 59P undocks
Fri 2015-04-10	2015-04-10	RS will not observe winds during the arrival of SpaceX SpX-6 (which will be empty)
Fri 2015-03-27 Z14:10 24 hours	Sat 2015-03-28 Z14:52	ISS yaw will change 180 degrees for arrival of Soyuz crew transport 42S. RS will not observe winds
Wed 2015-03-18 Z22:10	Thu 2015-03-19 Z00:30	ISS altitude reboost using Progress 58P. RS data will be marginal until attitude stabilizes again



Operations On-Time Log

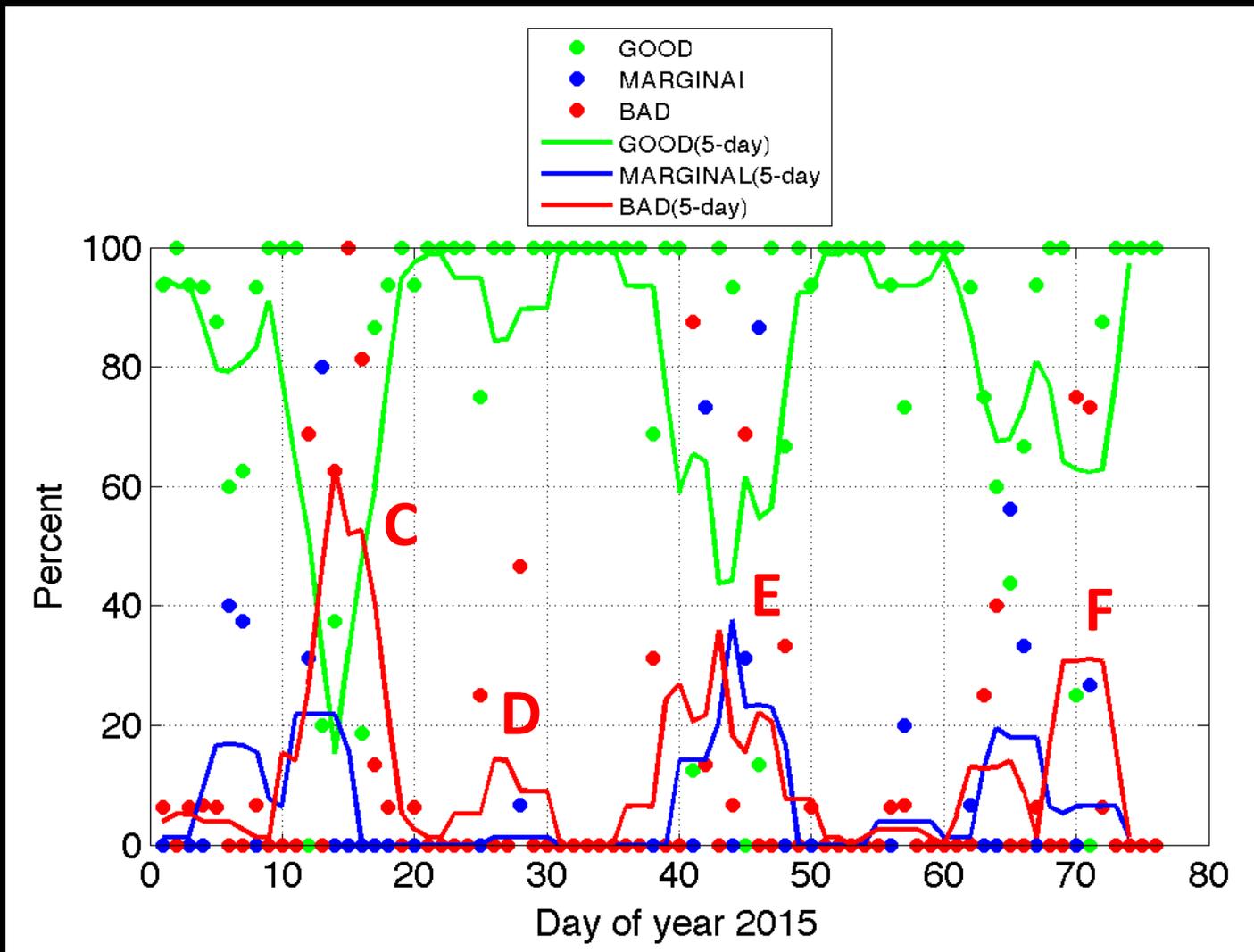
3 Added by Fannie Chen, last edited by Fannie Chen on Jan 12, 2015 (view change)

Last Update: 03/12/2015 16:51:00 GMT

Total Operation Time:	3881.1 hrs.	161.7 days
Total On Time:	3550.3 hrs.	147.9 days
Total On Time %:	91.48%	91.48%

Activation Time (WIND_OBS_MODE)	De-Activation Time (non WIND_OBS_MODE)	On-Time hrs.	On-Time %	Mode Status	ISS/Rapidscat Event
03/12/2015 16:12:02 GMT		0.6 hrs.	91.5%	Wind Obs	
02/17/2015 21:43:43 GMT	03/11/2015 19:31:04 GMT	525.8 hrs.	91.5%	Wind Obs --> Standby	40S undocking
02/14/2015 16:34:53 GMT	02/17/2015 14:48:24 GMT	70.2 hrs.	77.9%	Wind Obs --> Standby	58P docking
02/11/2015 01:10:26 GMT	02/14/2015 00:36:20 GMT	71.4 hrs.	76.1%	Wind Obs --> Standby	ATV-5 undocking
01/12/2015 17:33:15 GMT	02/10/2015 04:12:52 GMT	682.7 hrs.	91.5%	Wind Obs --> Standby	Spx-5 unberth & release
11/27/2014 18:01:55 GMT	01/12/2015 00:35:41 GMT	1086.6 hrs.	89.8%	Wind Obs --> Standby	Spx-5 capture & berth
11/24/2014 17:48:20 GMT	11/27/2014 00:26:00 GMT	54.6 hrs.	82.8%	Wind Obs --> Standby	ESA/Russian crew act.
11/10/2014 17:27:27 GMT	11/23/2014 23:09:51 GMT	317.7 hrs.	83.2%	Wind Obs --> Standby	41S docking
10/29/2014 15:47:36 GMT	11/09/2014 20:06:07 GMT	268.3 hrs.	79.4%	Wind Obs --> Standby	39S undocking
10/27/2014 14:59:13 GMT	10/28/2014 00:01:11 GMT	33.0 hrs.	72.8%	DIB only --> Standby	57P launch and dock

2-hour delay data quality vs. time



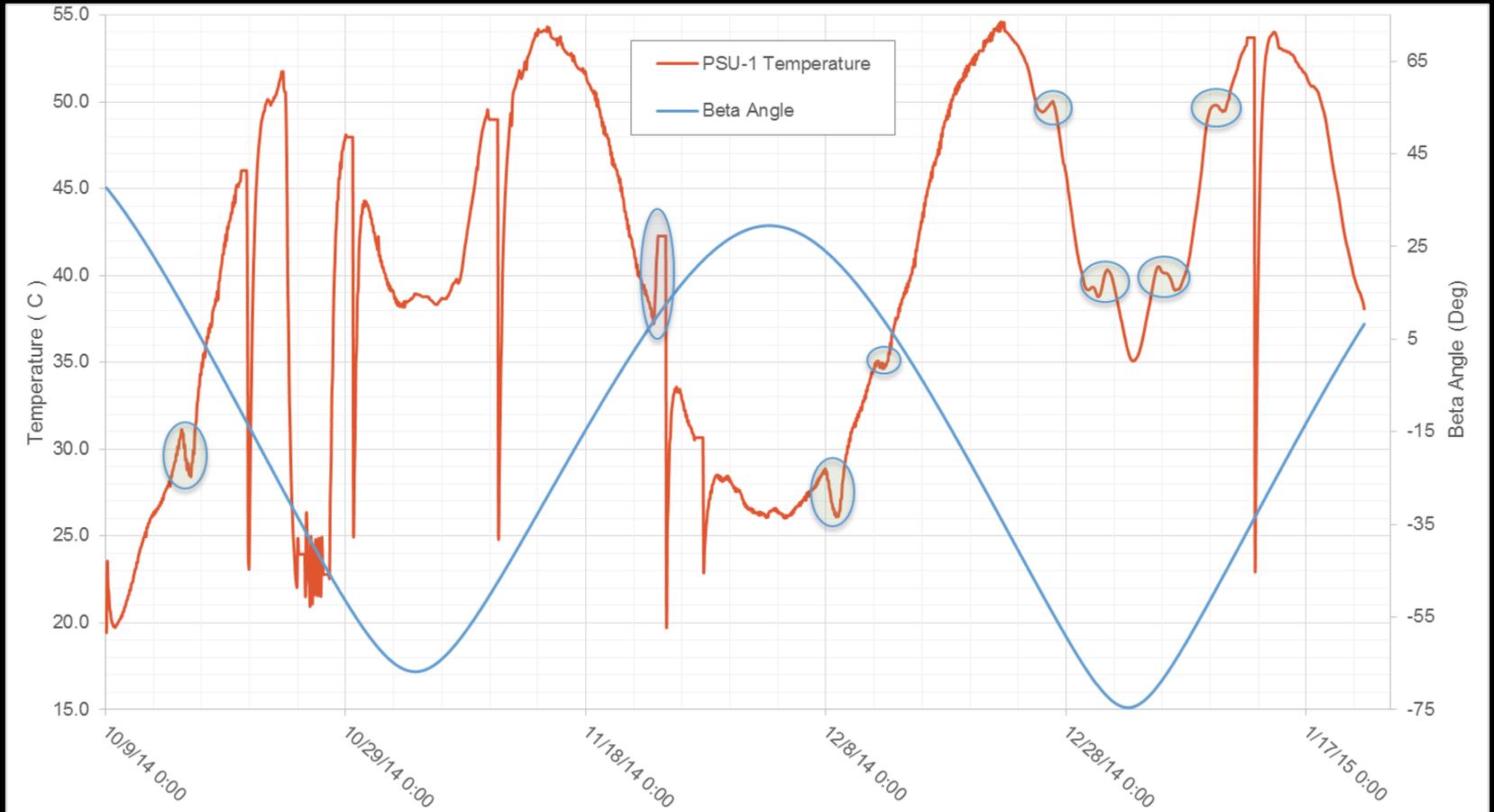
C Ammonia leak false alarm, data loss due to PEYG turn off.

D Large number of Gaps in downlinked data caused processing failure.

E Several deactivations in succession and Doppler tables inconsistent with attitude

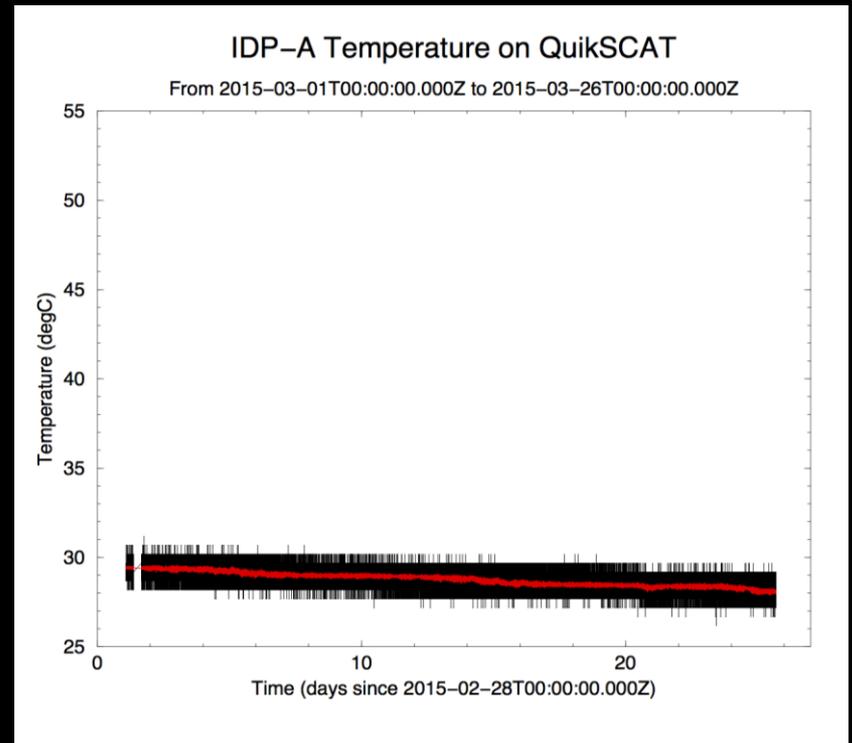
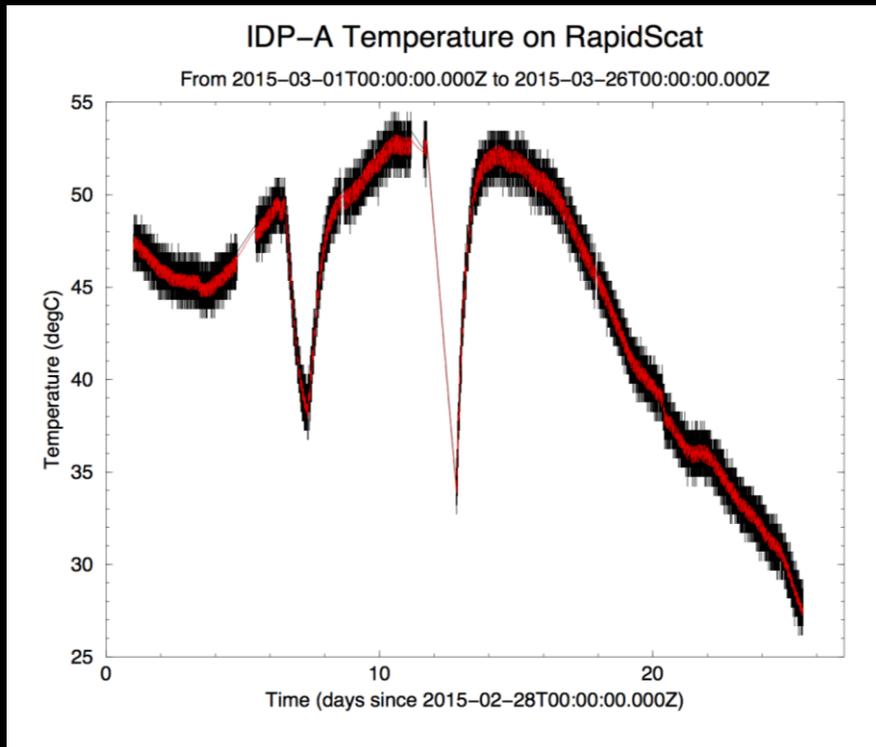
F Numerous Deactivations, HOSC software failures, and JPL connectivity failures

CDS Subsystem Temperature (& Beta Angle) vs. Time



Courtesy: D. Perkovic, JPL

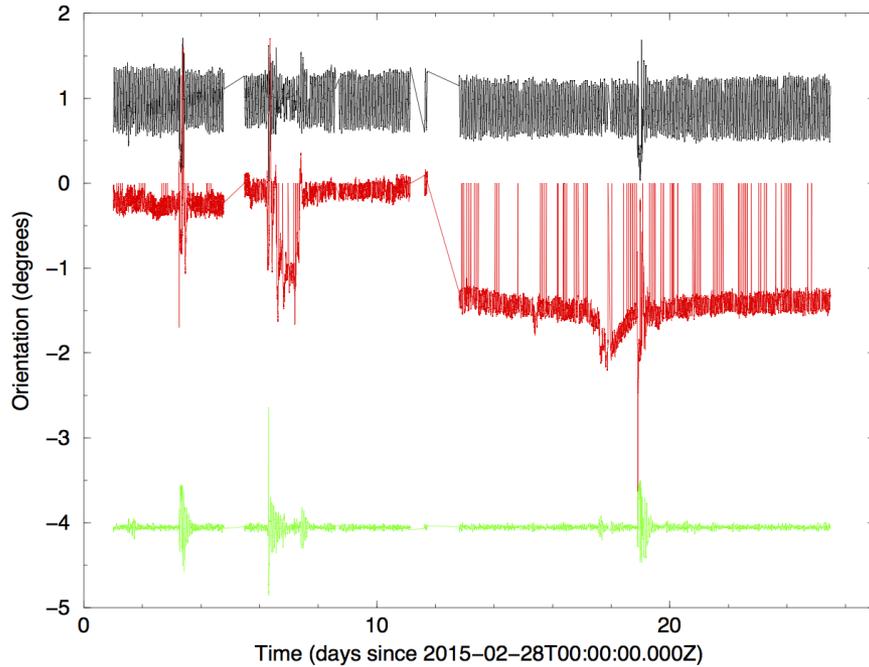
Temperature Variations: RapidScat vs. QuikSCAT



Roll, Pitch, Yaw: RapidScat vs. QuikSCAT

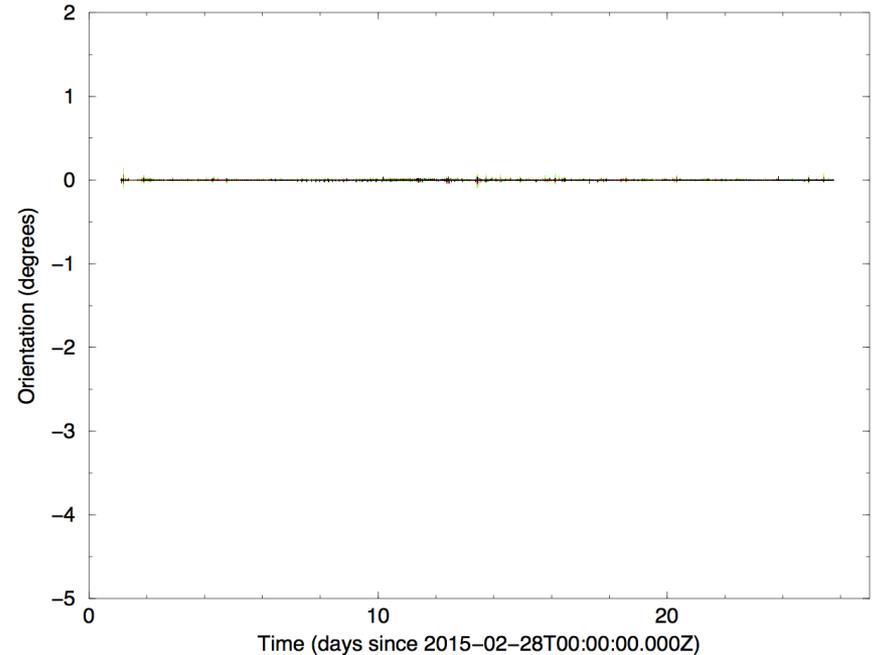
S/C Roll, S/C Pitch, S/C Yaw on RapidScat

From 2015-03-01T00:00:00.000Z to 2015-03-26T00:00:00.000Z

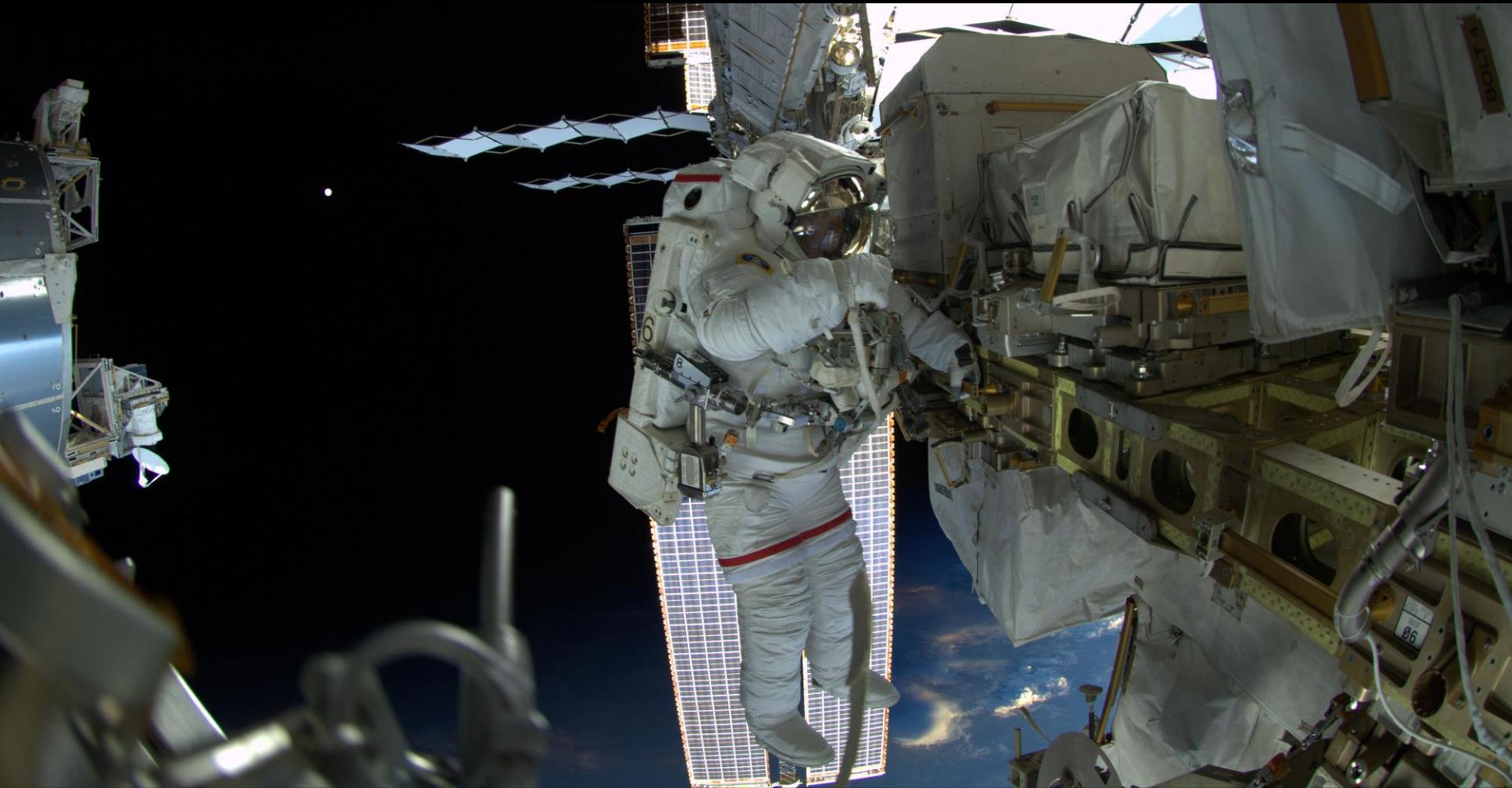


S/C Roll, S/C Pitch, S/C Yaw on QuikSCAT

From 2015-03-01T00:00:00.000Z to 2015-03-26T00:00:00.000Z









RapidScat is a participating mission in
the Earth Right Now campaign, celebrating
the many flying missions and the five launches of 2014-2015.

EARTH *RIGHT* NOW

Your planet is changing. We're on it.



www.nasa.gov/earthrightnow
#earthrightnow

Backup

NASA's Radar Scatterometry

Fixed Fan Beams Scatterometers

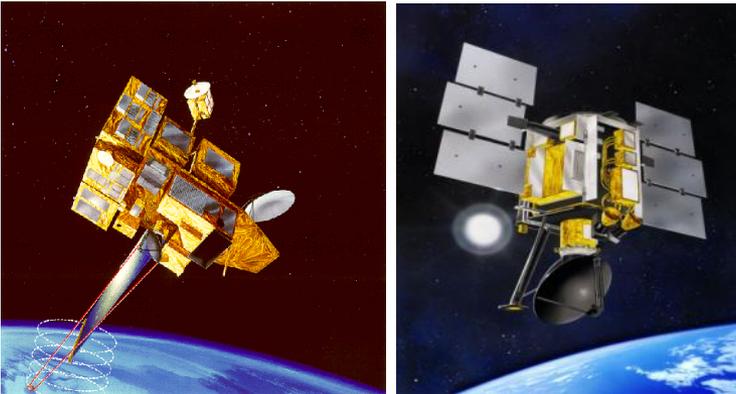


*SASS-A on SeaSAT
(1978) – Concept Demo*

*NSCAT on ADEOS
(1996-1997*)*

- NASA pioneered and established modern radar scatterometry for the measurement of sea surface wind speed and direction measurements (ocean vector winds)
- For more than a decade, QuikSCAT provided dynamic views of air-sea parameters that enabled improved understanding of the process and generated many applications

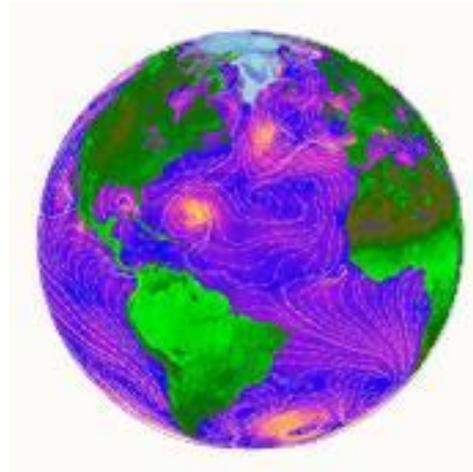
Scanning Pencil Beam Scatterometers



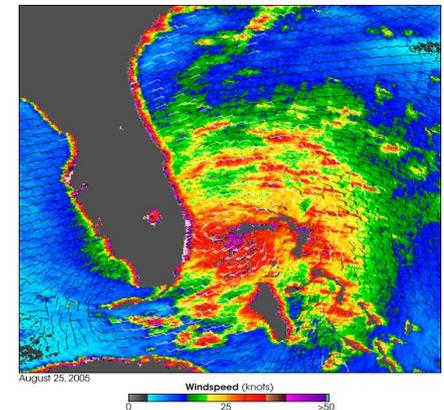
*SeaWinds on
ADEOS-II (2002-
2003*)*

** Terminated due to
solar panel failure*

*SeaWinds on QuikSCAT
(1999-Present)
[Stopped Rotating]*



*Global Winds as Viewed by
QuikSCAT*



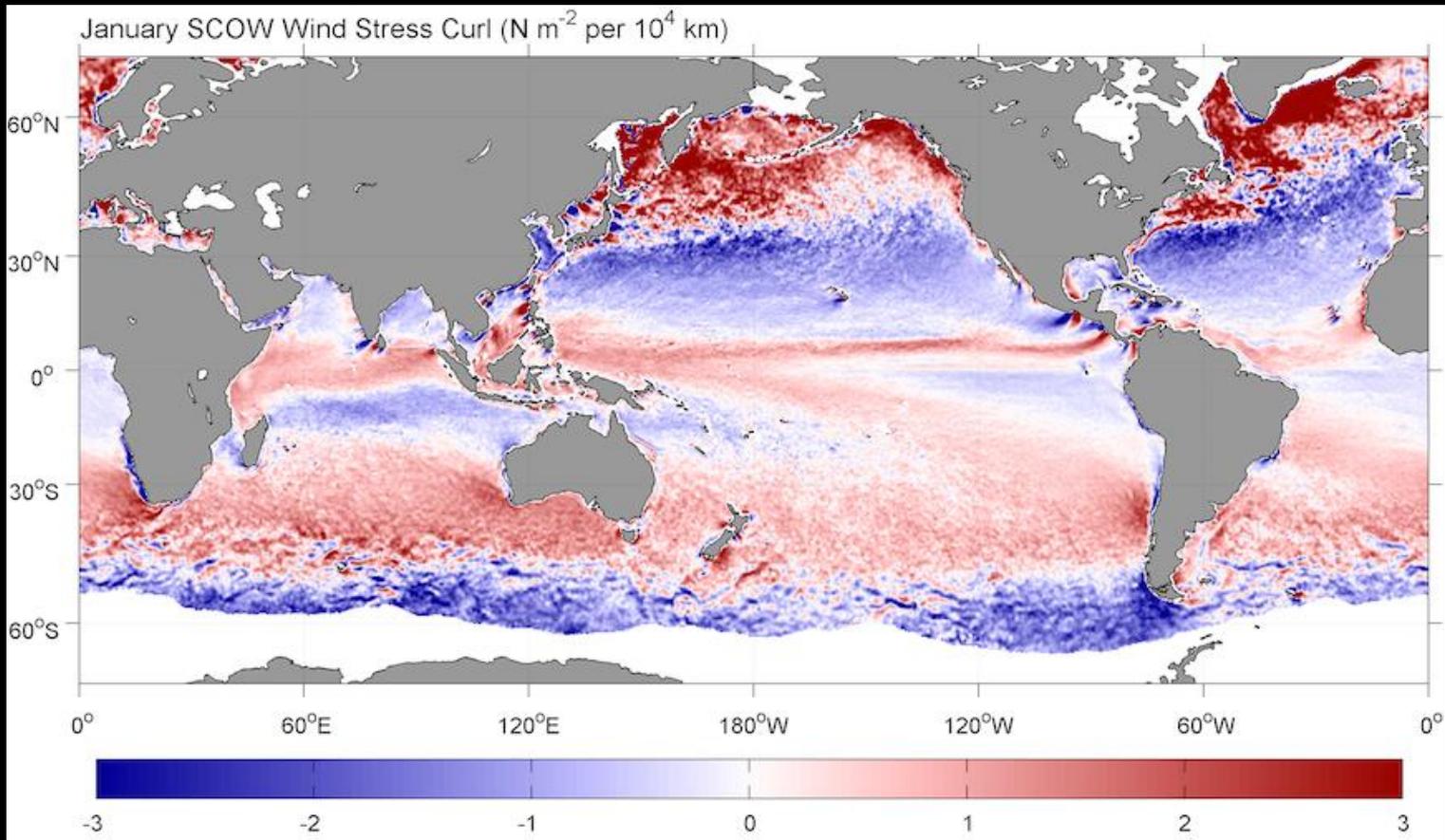
*QuikSCAT Sees Hurricane
Katrina*

Mate Verification



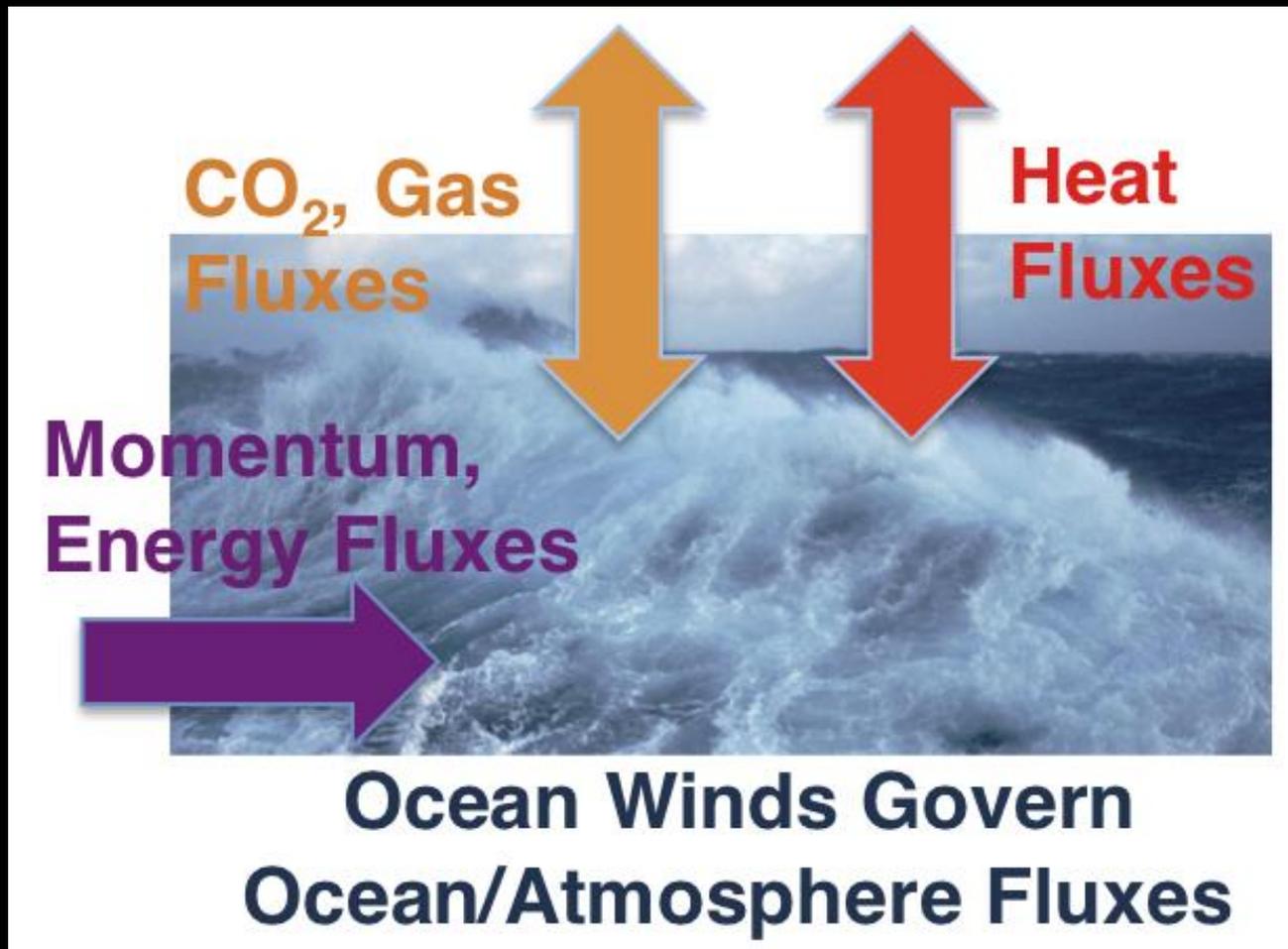


Ocean Winds Drive Ocean Currents

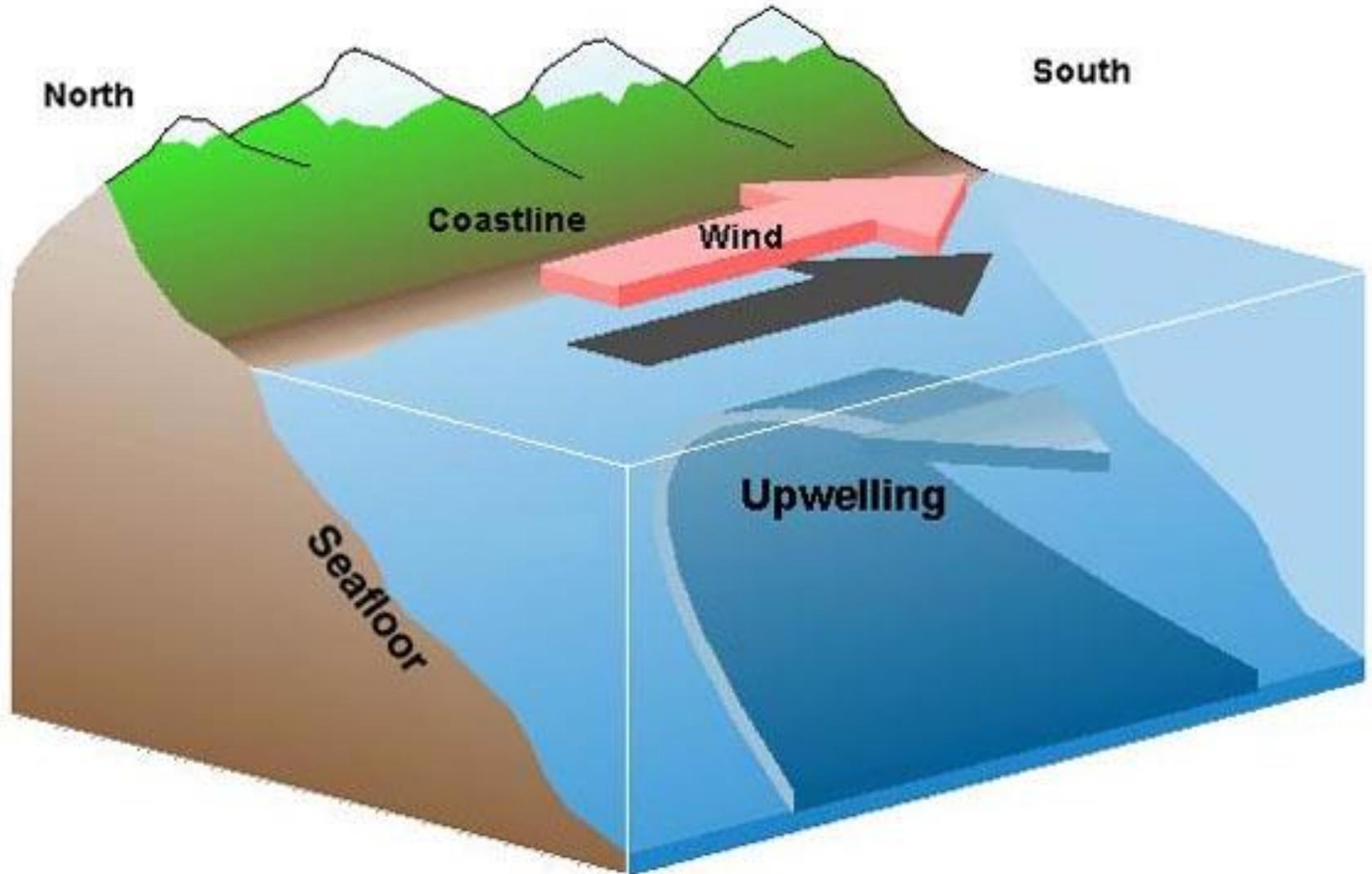


- Wind stress and wind stress curl drive the horizontal and vertical circulation of the ocean, the Earth's principal repository for heat and CO_2
- The small features are not appropriately resolved by models
- Scatterometer data essential for understanding key climate processes

Winds drive exchanges between the atmosphere and the ocean

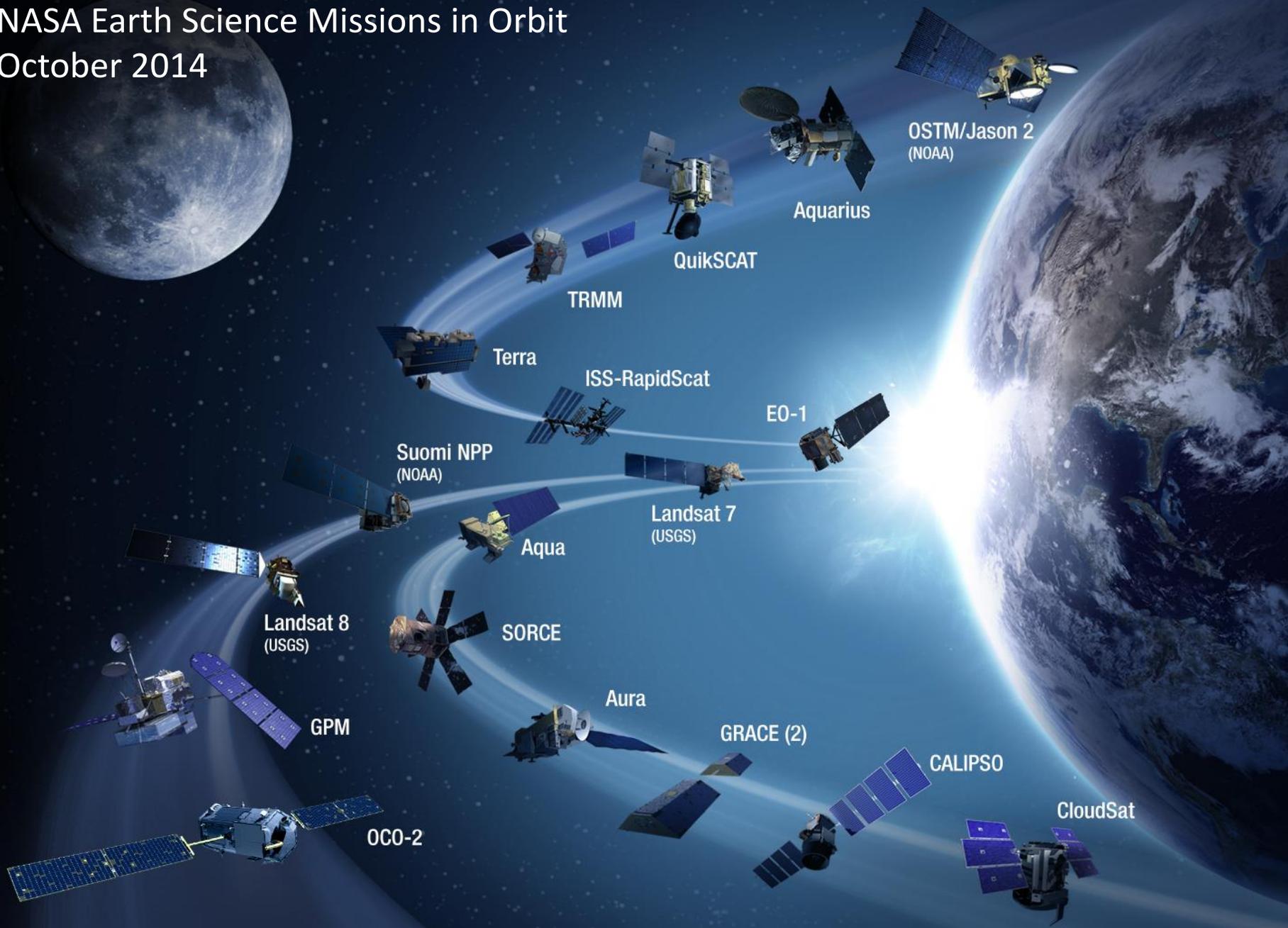


Winds Drive Ocean Productivity

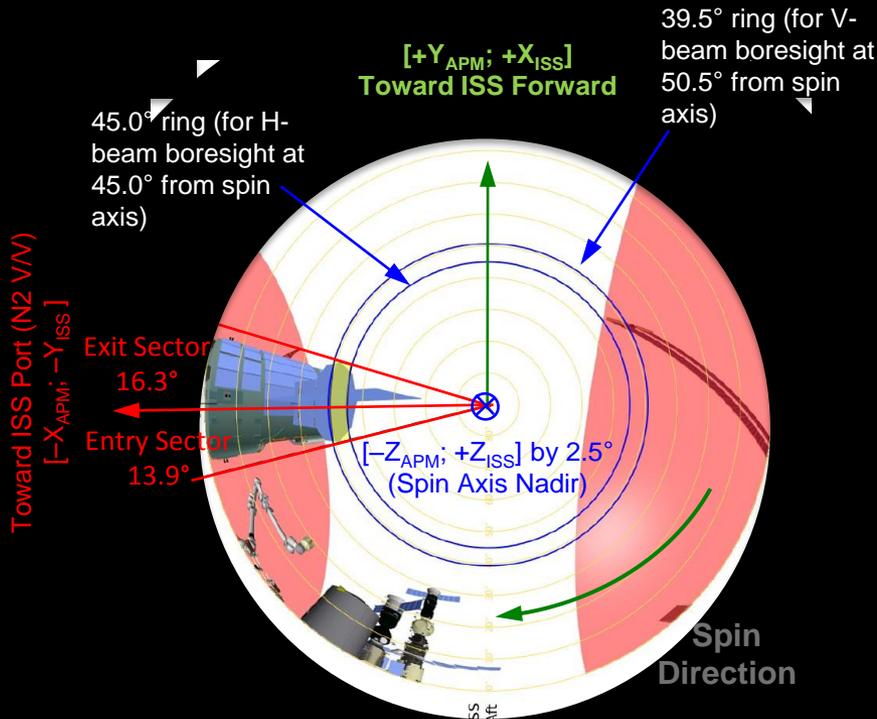


NASA Earth Science Missions in Orbit

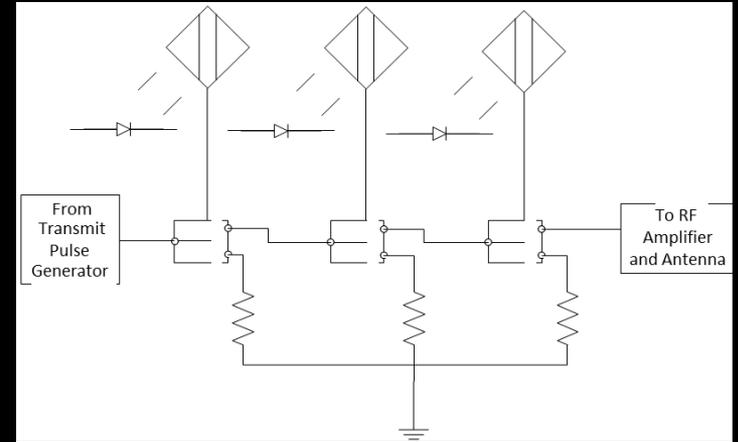
October 2014



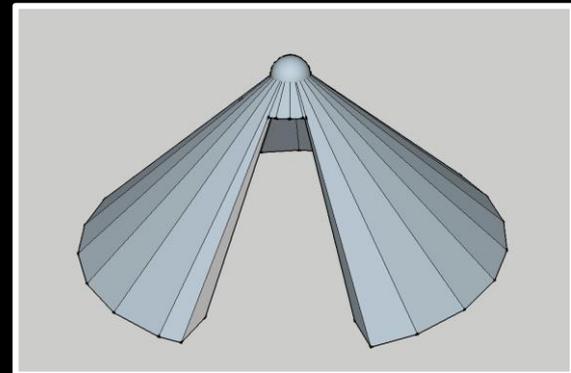
Don't Fry Anything!



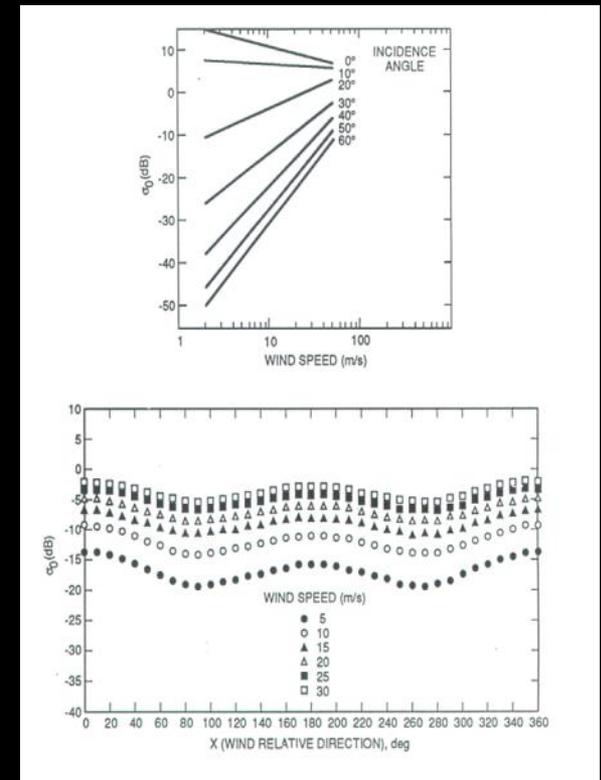
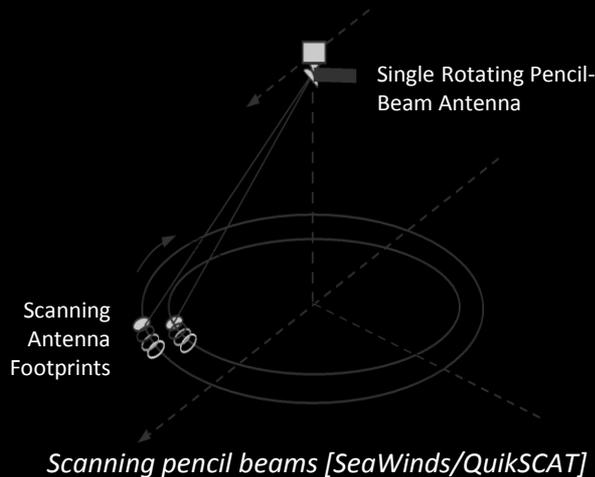
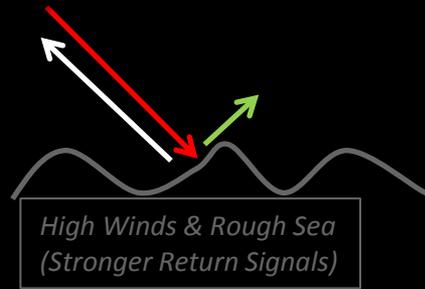
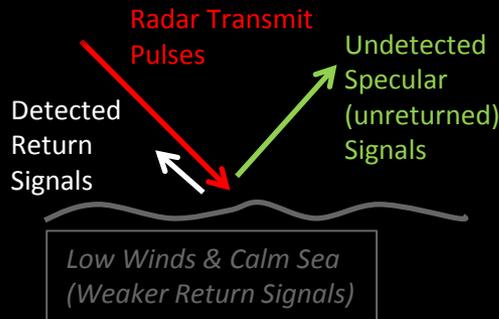
Line of site interference shown. RF needs to be augmented with antenna pattern



Keep Out Zone Applies to EVA/EVR and transitioning Visiting Vehicles



Measure Wave Reflections to Infer Winds

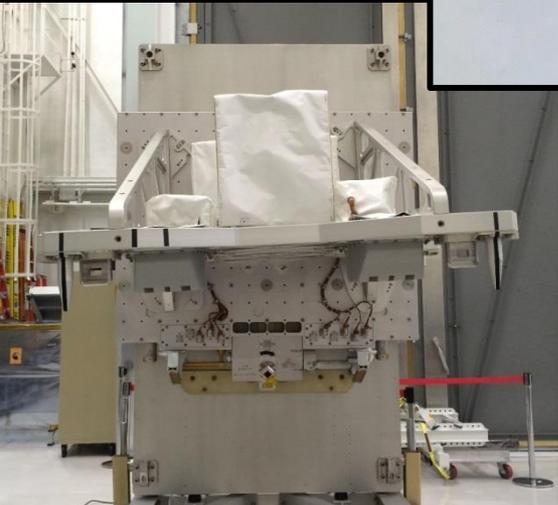


*Well-established empirical geophysical model function at Ku-band to retrieve winds
 (top): radar cross-section as a function of wind speed and incidence angle
 (bottom): radar cross-section as a function of wind direction and speed*

Astronaut Compatible



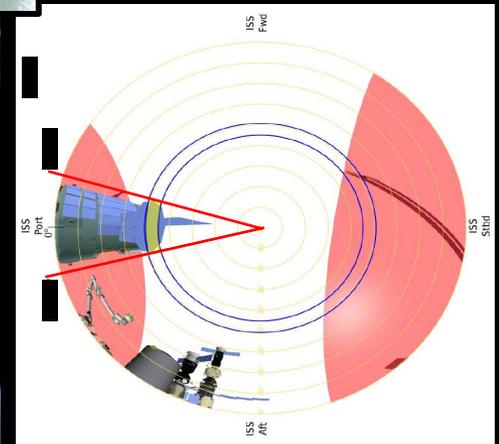
Match Our View to ISS Attitude



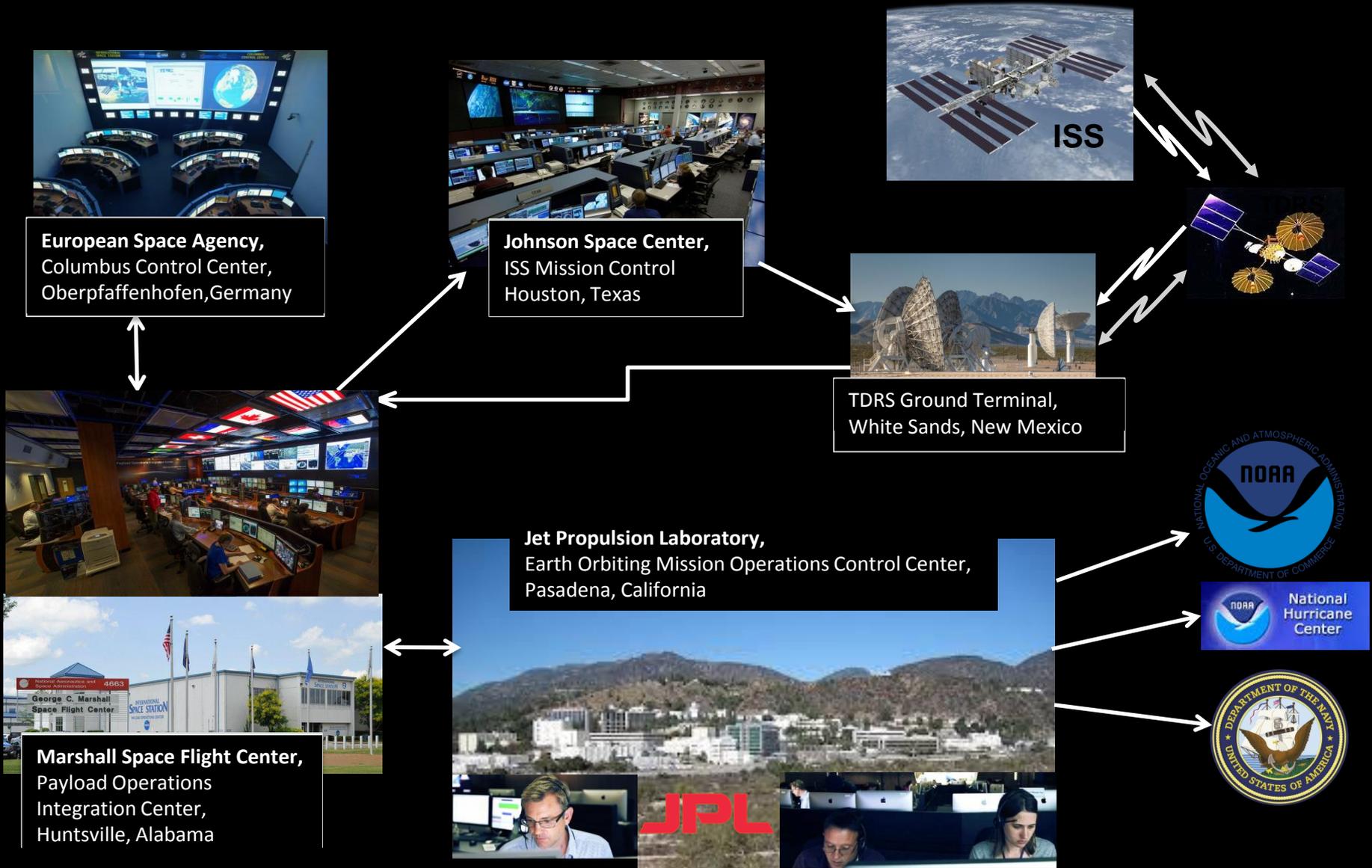
Robotic Assembly on Orbit



Don't Zap the Visiting Vehicles!



Mission Operations



Status Summary

- Data has been calibrated using non-spinning QuikSCAT backscatter
- Science quality data now being released to public via PODAAC
 - http://podaac.jpl.nasa.gov/dataset/RSCAT_LEVEL_2B_OWV_COMP_12_V1
- Data now being used by NOAA and U. S. Navy with imagery published on the web
 - <http://manati.star.nesdis.noaa.gov/datasets/RSCATData.php> (NOAA)
 - Imagery is used operationally to make forecasts, see example on next slide
 - <http://www.nrlmry.navy.mil/tcdat> (U. S. Navy)
 - To navigate to images choose year (tc14) then basin, storm name
 - RapidScat data is in the ssmi/scat/windbarbs directory e.g.
 - http://www.nrlmry.navy.mil/tcdat/tc14/WPAC/22W.HAGUPIT/ssmi/scat/wind_barbs/20141202.2019.iss.RSCAT_IR.wind.22WHAGUPIT.1193_095pc_85kts-959mb_66N_1421E_sft20141202_1800.jpg
- Data now being used operationally by European forecasters
 - http://www.knmi.nl/scatterometer/rscat_nrt_25_prod/rscat_app.cgi
- RapidScat has quickly acquired much of the user community that followed QuikSCAT. For example, RapidScat winds are used to help surfers find good waves.
 - http://www.surflines.com/surf-news/forecast/rapidscat-wind-instrument-producing-ahead-of-schedule_120508/