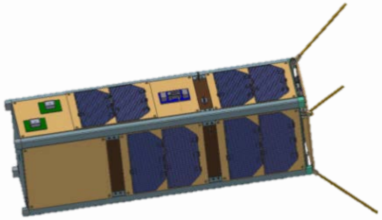
30th Annual AIAA/USU Conference on Small Satellite



SSC16-III-09

The STU-2 CubeSat Mission and In-Orbit Test Results

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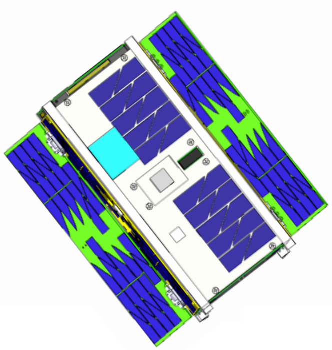
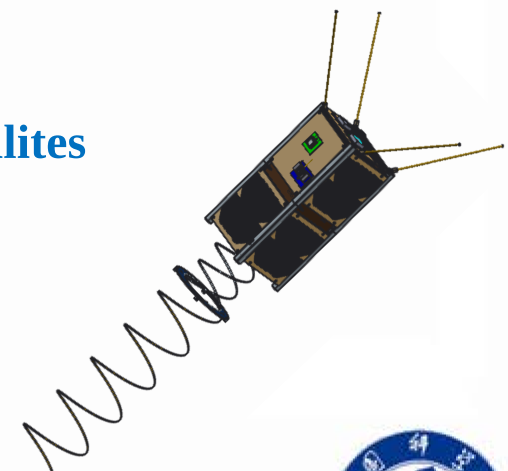




Contents

- SECM Introduction
- Mission Requirement & System Configuration
- Project Schedule
- Satellite Design
- In-Orbit Data Analysis & Results
- Lessons Learned
- Summary

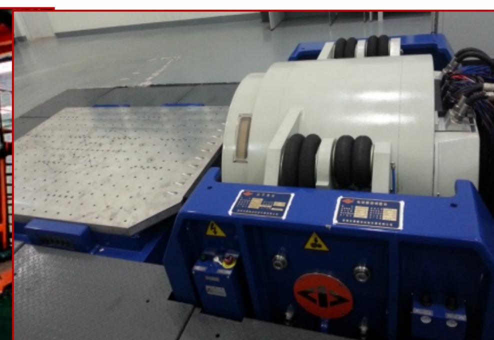
SECM: Shanghai Engi Centre for MicroSat

- **SECM was founded on Sep.15, 2003**
  - Founded by Chinese Academy of Sciences (CAS) and Shanghai City Government
  - To build a technical platform and innovation base for micro/small satellites

- **Located in Pudong of Shanghai**
  - ✓ Offices: ~ 15,000 m^2
  - ✓ AIT area: ~12,000 m^2
- **Able to manufacture 20+ satellites simultaneously**

AIT Area

KM3



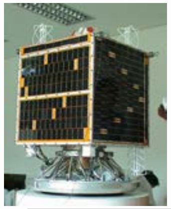
20T Vibration table

10T Vibration table

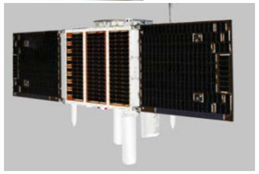
SECM: Mission Accomplished

Commni-cationu

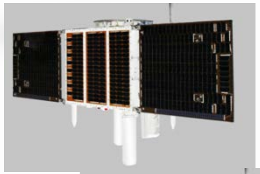
2003 · CX-1(01)



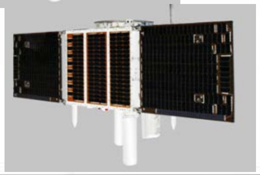
2008 · CX-1(02)



2011 · CX-1(03)

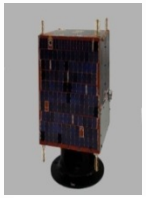


2014 · CX-1(04)

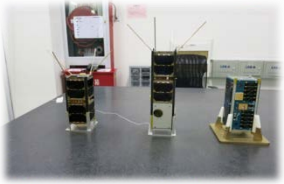


Micro/Nano Satellite

2008 · BX-1



2015 · STU-2
(TW-1) 3 CubeSats



Navigation & Science

2015 · Nav-1
2016 Nav-2
2016 DarkEnerge
2016 Quantum

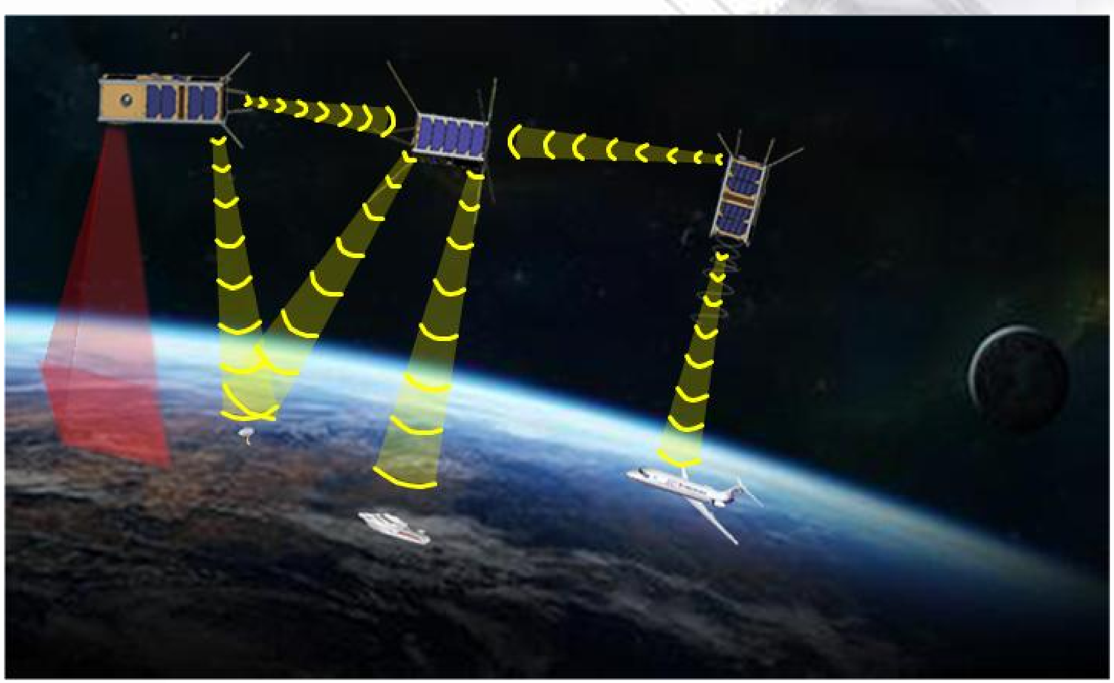
Over past 12+ years, SECM has launched into orbit 12+ micro/small satellites (2-1800kg), accumulated 30+ orbit-year of satellite operation.

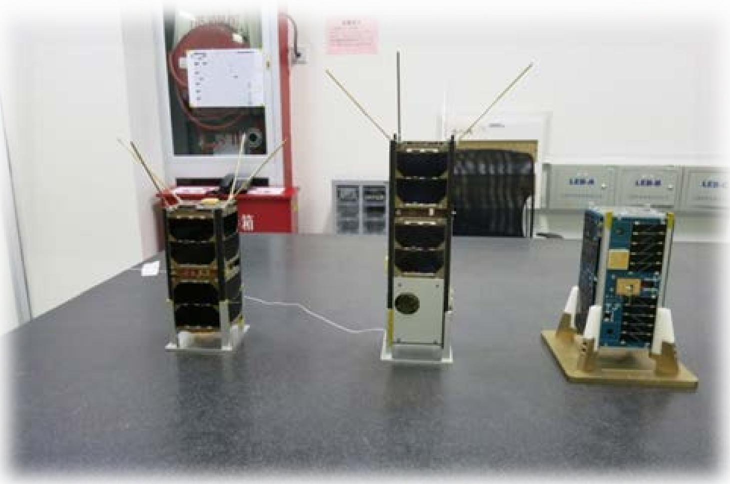
STU-2 Mission Requirements

- Monitoring sea ice status in polar regions
- Gaining the maritime traffic information via AIS receiver
- Monitor civil aircraft traffic information via ADS-B receiver
- New technology demonstration & validation of Micro-propulsion, dual-band GPS-BD receiver, and Gamalink
- Demonstration of autonomous rendezvous (RVD) flight

STU-2 Mission Configuration

- 3 Cube Satellites to carry different payloads
- 2 Ground Stations (UHF band) in Shanghai and Nanjing of China
- 1 Data Receiving Station (S-band) in Shanghai
- Orbit: SSO, 480km, 8:00am
- Launch: Sept 25th 2015
  Jiuquan, China

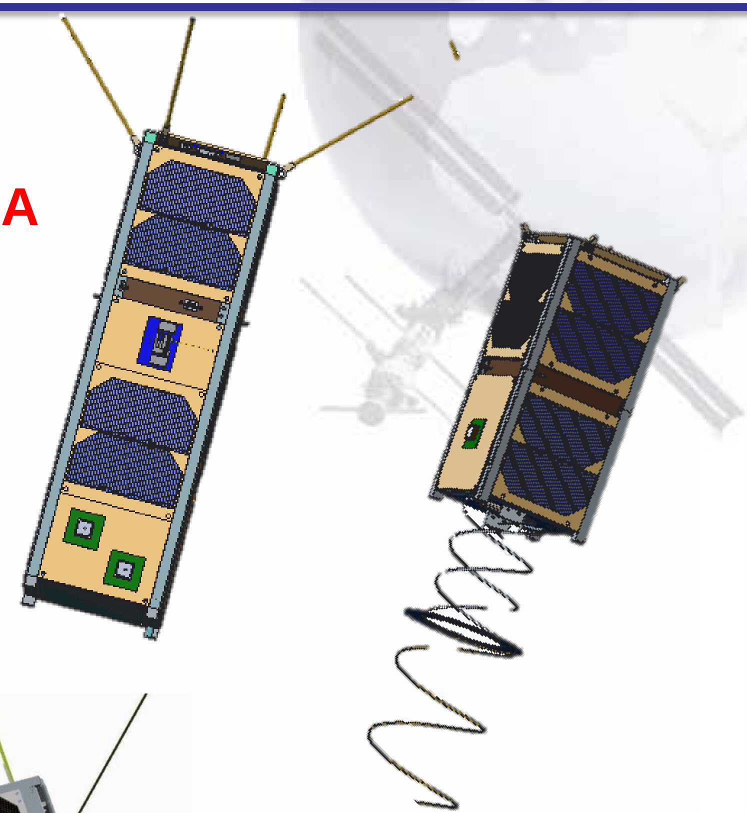




Satellites Configuration

- STU-2A: 3U CubeSat
  - ✓ Gamalink
  - ✓ Camera
  - ✓ GPS/BD Receiver
  - ✓ Micropropulsion
  - ✓ S-band transmitter
- STU-2B: 2U CubeSat
  - ✓ Gamalink
  - ✓ AIS receiver
  - ✓ GPS/BD receiver
- STU-2C: 2U CubeSat
  - ✓ ADS-B Receiver
  - ✓ GPS/BD receiver

STU-2A



STU-2B

STU-2C

Project Schedule

Phase A/B

1.Mission Analysis & Design

2.System design

3.SRR, PDR

Phase B/C

1. Procurements
2. Subsystem testing
3. Ground electrical testing
4. … …

AIT & Launch

1.AIT,

2.Testing

3.Launch campaign

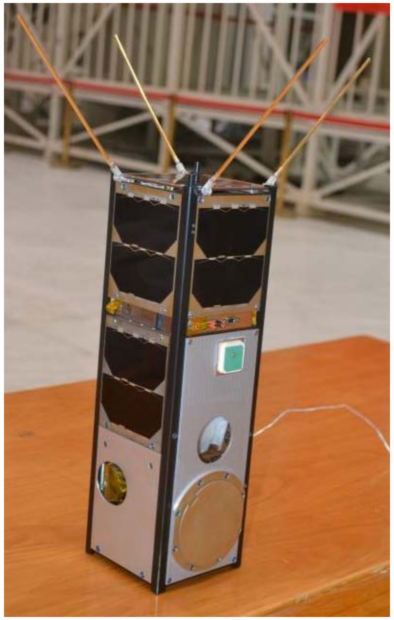
4.LEOP & operation

Mar Apr May June July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July Aug Sept

2014 2015

STU-2A CubeSat

Body mounting solar panel, 3-axis attitude stabilization and control based on momentum wheels and star tracker, UHF TT&C, and S-band transmitter. ………



STU-2A

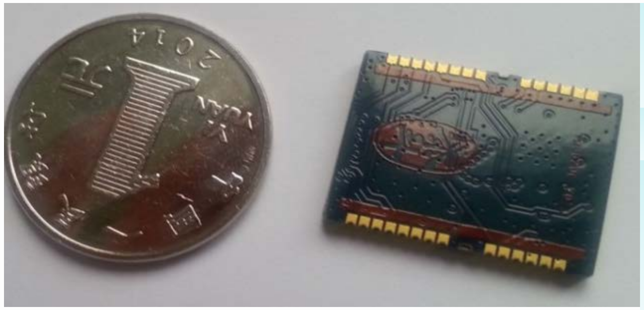
Subsystem	Item	Specification
Structure	Dimension [mm]	340.5x100x100
ADCS	Attitude Knowledge	1° (3σ)
	Pointing Accuracy	2° (3σ)
	Pointing Stability	0.1° /s
Thermal	Internal temperature	-10℃～+35℃
EPS	Bus voltage	13.2 V～16.8V
	Battery properties	2.6 Ah，1 Year
TT&C	Frequency	UHF(435-438 MHz）
	Modulation	2-FSK
	Uplink	4.8 kbps
	Downlink	4.8 kbps
S-band transmitter	Date rate	125kbps
	Frequency	2.425GHz
	Modulation	QPSK
	BER	$<10^{-6}$
OBC	Process capacity	20 MIPS
	Process storage	RAM >2 M, Flash>256 K

STU-2A Cubesat-Payload

Optical Camera

Structure	Mass	466g
	Dimension	90×90×72mm^3
Electrics	Power	< 8.2 W (ave) < 8.75W (peak,<10ms)
Observation	Resolution	94.4m
	Swatch	222x160km^3

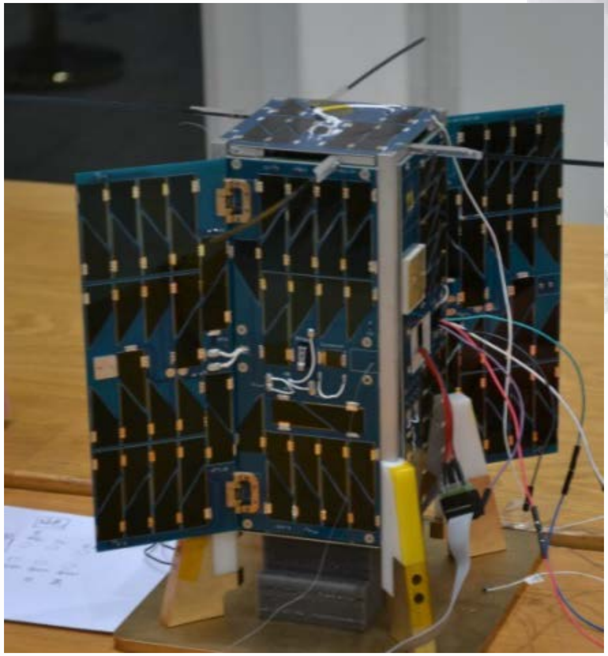
BD/GPS Receiver

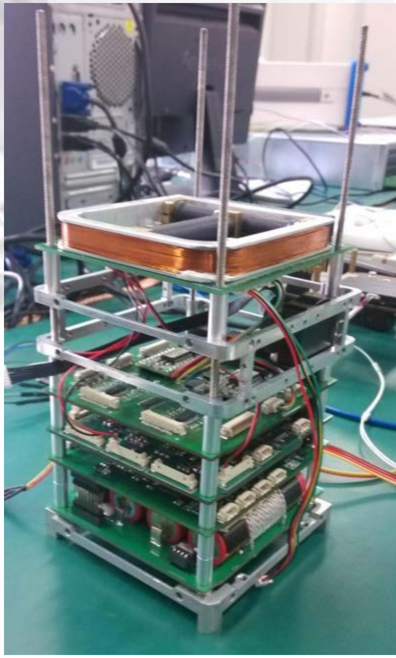


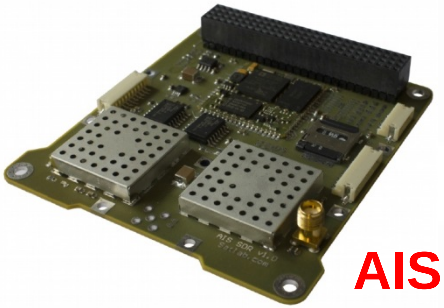
Structure	Mass	4g
	Dimension	22.4×17×2.2mm^3
Electrics	Power	0.5 W
Position	Horizontal	93m
	Altitude	217.8km
	Velocity	1 m/s

STU-2B CubeSat

Subsystem	Item	Specification
Structure	Dimension envelope	239 x 100 x 100 mm3
ADCS	Attitude Knowledge	5° (1σ)
	Pointing Accuracy	10° (1σ)
	Pointing Stability	0.5° /s
Thermal	Internal temperature	-10℃～+35℃
EPS	Bus voltage	6.4V～8.4 V
	Battery properties	5.2 Ah，1 Year
TT&C	Frequency	UHF（435-438 MHz）
	Modulation	2-FSK
	Uplink	4.8 kbps
	Downlink	4.8 kbps
OBC	Process capacity	20 MIPS
	Process storage	RAM >2 M, Flash>256 K





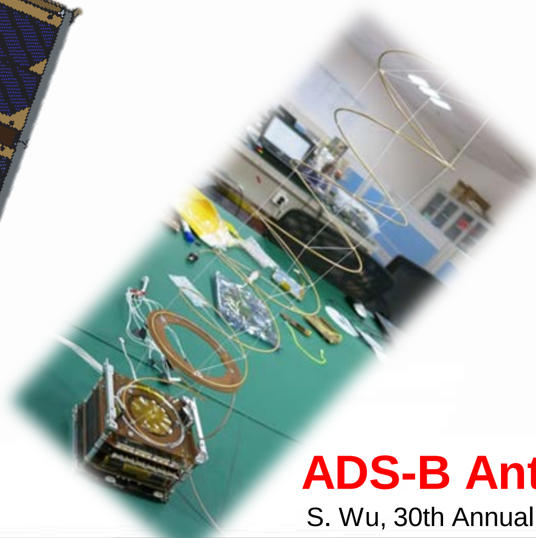


AIS Receiver

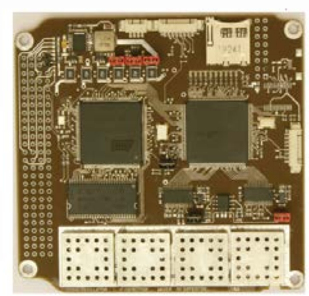
南京理工大学 Nanjing University of Science and Technology

STU-2C CubeSat

Subsystem	Item	Specification
Structure	Dimension envelope	239 x 100 x 100 mm^3
ADCS	Attitude Knowledge	5° (1σ)
	Pointing Accuracy	10° (1σ)
	Pointing Stability	0.5° /s
Thermal	Internal temperature	-10℃～+35℃
EPS	Bus voltage	12.0V～16.8V
	Battery properties	2.6 Ah，1 Year
TT&C	Frequency	UHF（435-438 MHz）
	Modulation	2-FSK
	Uplink	4.8 kbps
	Downlink	4.8 kbps
OBC	Process capacity	20 MIPS
	Process storage	RAM >2 M,Flash>256 K



ADS-B Antenna



ADS-B Receiver

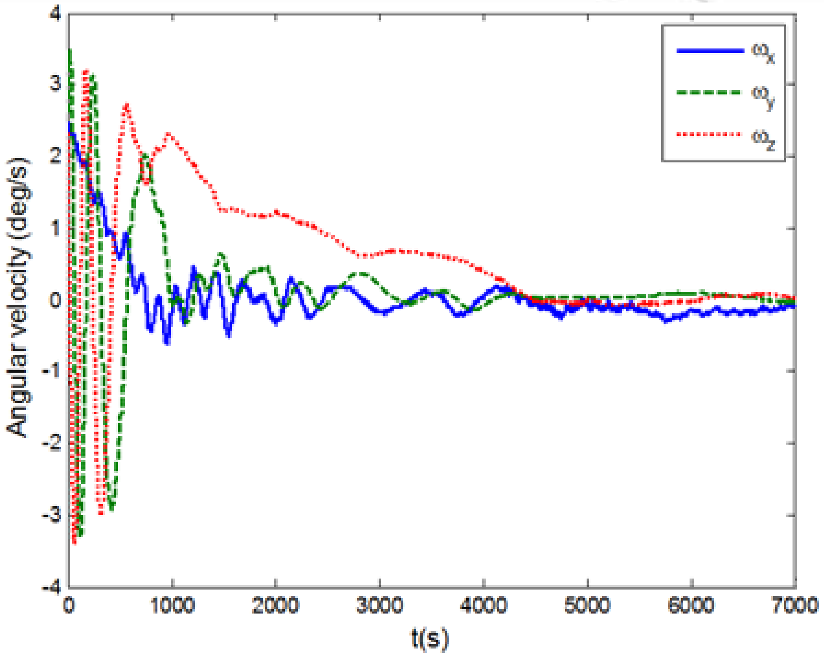
S. Wu, 30th Annual AIAA/USU Conference,

In-Orbit Data Analysis

●Detumbling Phase

94 minutes after launch, the first received signals showed that the satellite had completed rate damping (three axis angular velocity have been reduce within 0.3º/s) within one orbit period time and entered Sun Pointing Mode automatically.

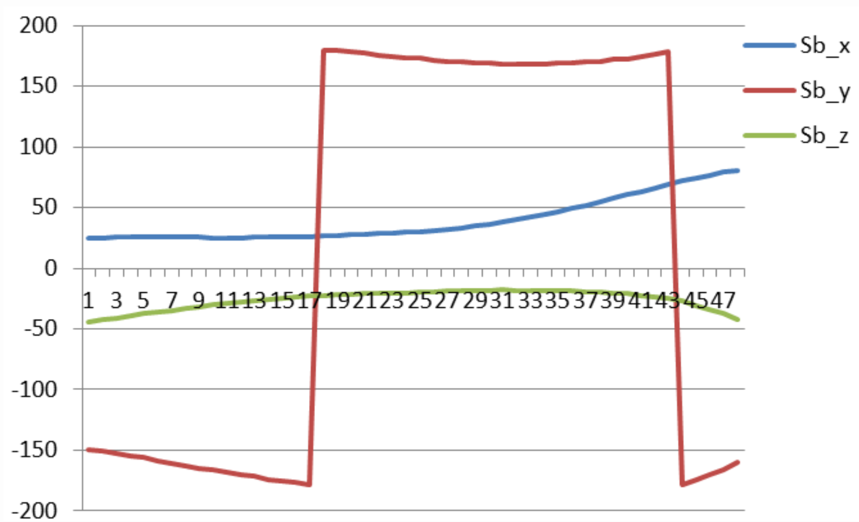
The in-orbit result was in conformity with simulation.



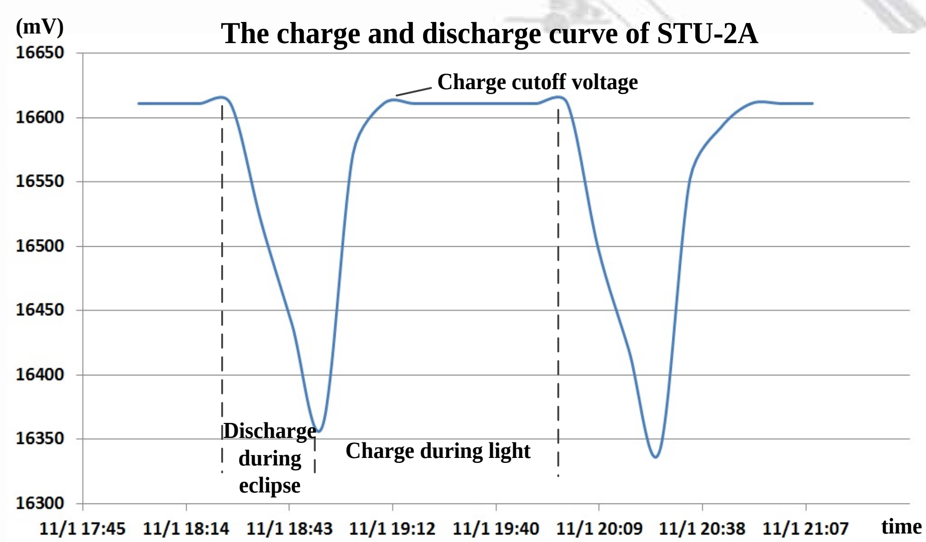
In-Orbit Data Analysis

●Sun Pointing / Sun Acquisition

Sun vector in body coordinate system



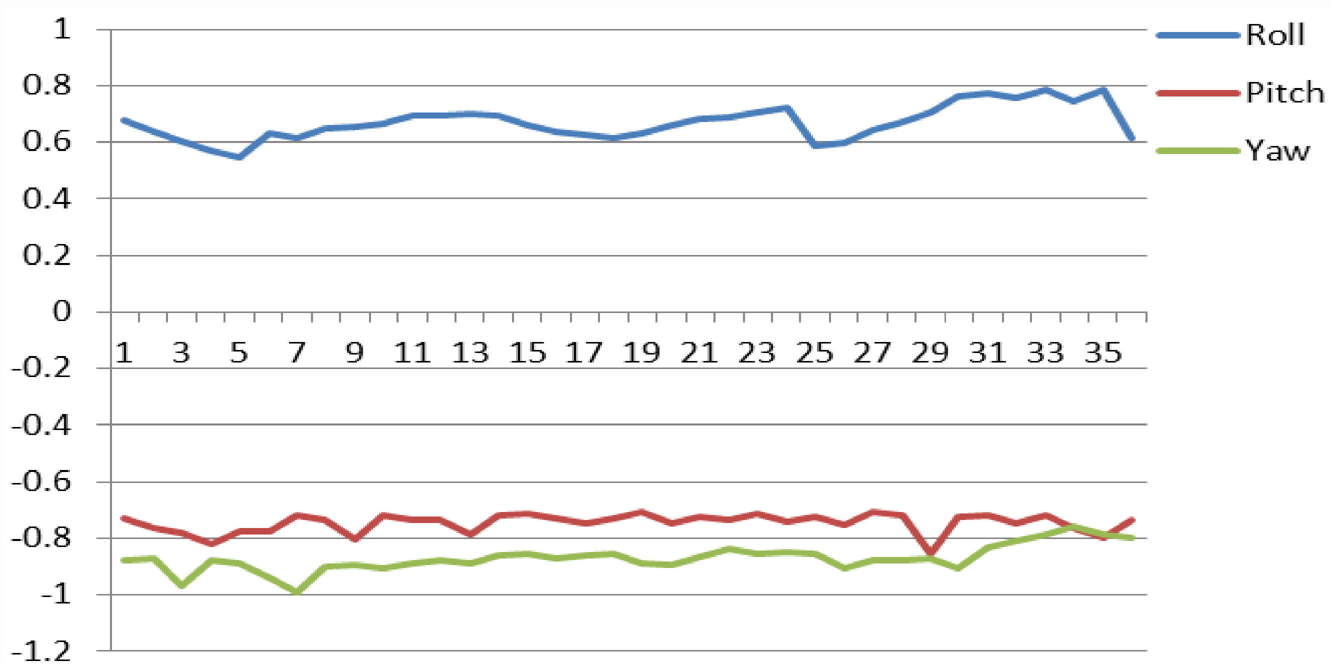
EPS Charge-discharge curve



In-Orbit Data Analysis

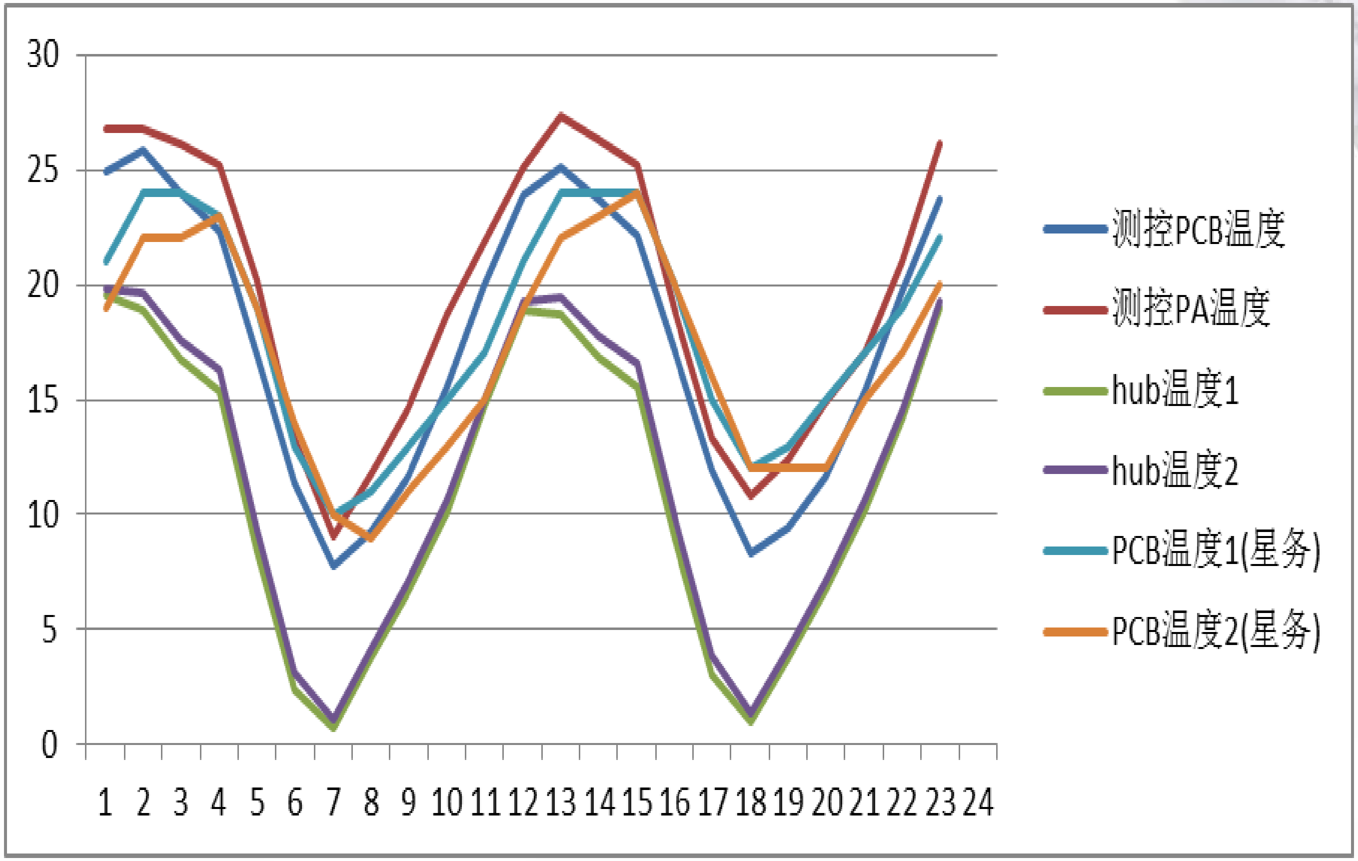
●Nadir Pointing Mode

Three attitude angles were constrained within 1º.
The time period is from 08:20 to 08:26, 30th Sep, 2015.



In-Orbit Data Analysis

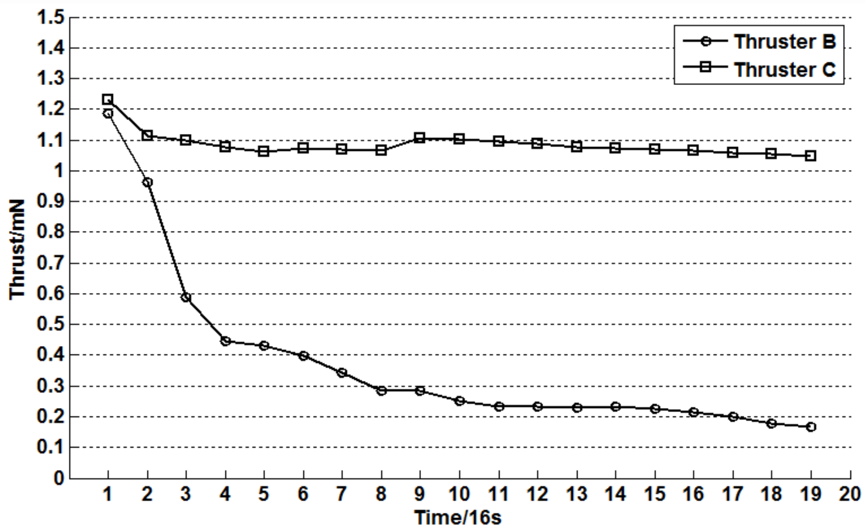
● **Thermal Behavior (STU-2A)**

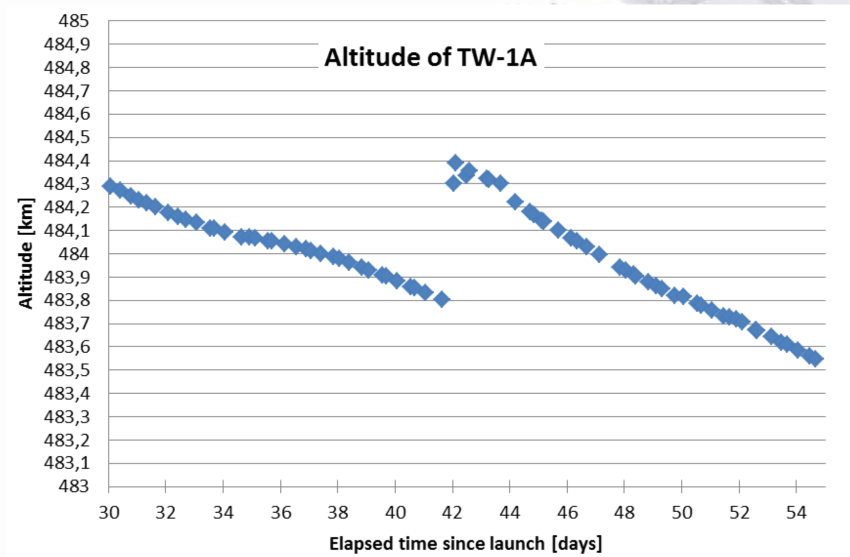


In-orbit Test – Thruster Firing

Micro-Propulsion In-Orbit Firing

On Nov 5th 2015, 10:09(UTC), thruster B and C are commanded for 5 min firing @ 1mN, aiming to raise the orbit





Firing Results

- Thruster B falls into problem rapidly
- Unbalanced thrust level leads high rate spinning
- Spinning rate upto ca 65 deg/s (measured by redundant MEMS gyro on Nano-Hub)
- The resulted orbit change becomes very limited – ca 0.6km

In-orbit Test – Oscillation Spin

- **Local Oscillation work-point at ca 65 deg/s**
  - Initial tests try to reduce spin rate by counter-firing the thrusters
  - Reduced 5 deg/s by firing in one pass, resumed back at ca 65 deg/s in next pass
  - Reduced 10 deg/s by firing in one pass, back to 65 deg/s again in next pass

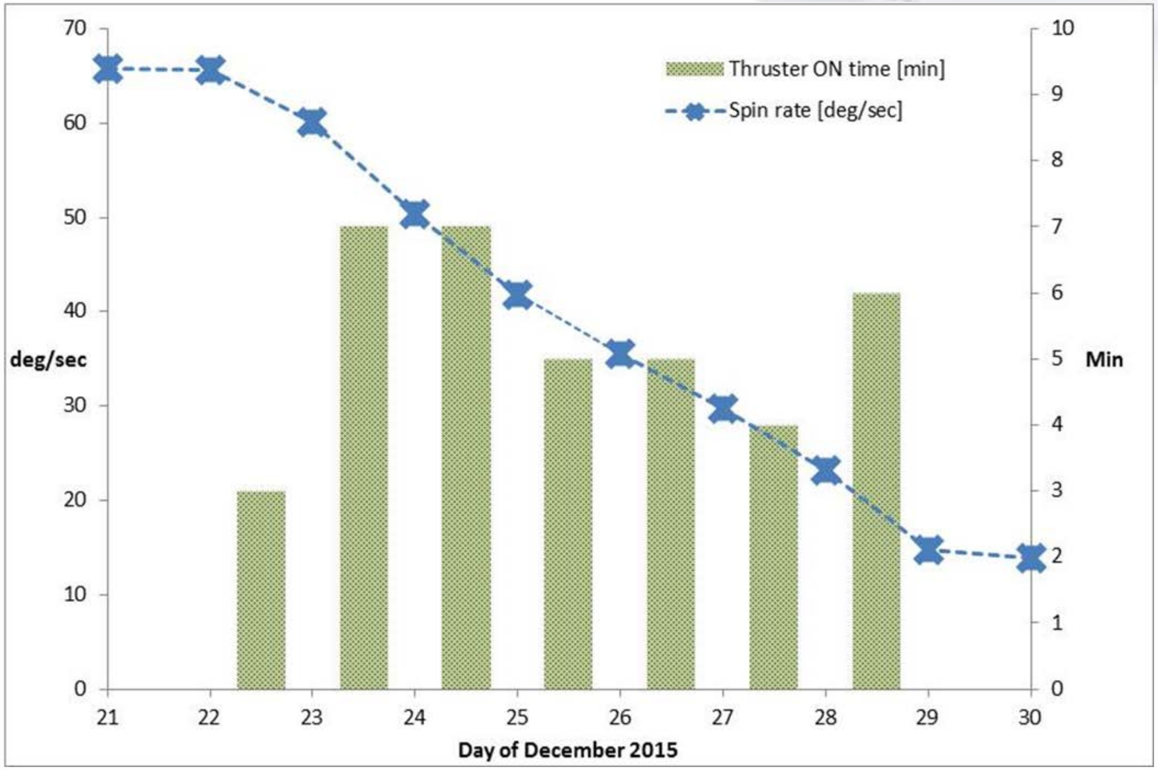
- **Simulation analysis on local Oscillation work-point at ca 65 deg/s**
  - Ts= 1 sec delay in the magnetic control loop (take the measurement before sending out the magnetic control, to separate disturbance)
  - This delay in the control loop results in a steady oscillation work-point
  - Simulation results revealed the oscillation work-point at ca 65 deg/s
  - If remove the delay in simulation, the oscillation disappear

- **Condition back to 0 work-point**
  - Simulation shows, the initial rate needs to be below 20 deg/s
  - Then, magnetic control can reduce the rate down to zero

In-orbit Test – Attitude Rescue

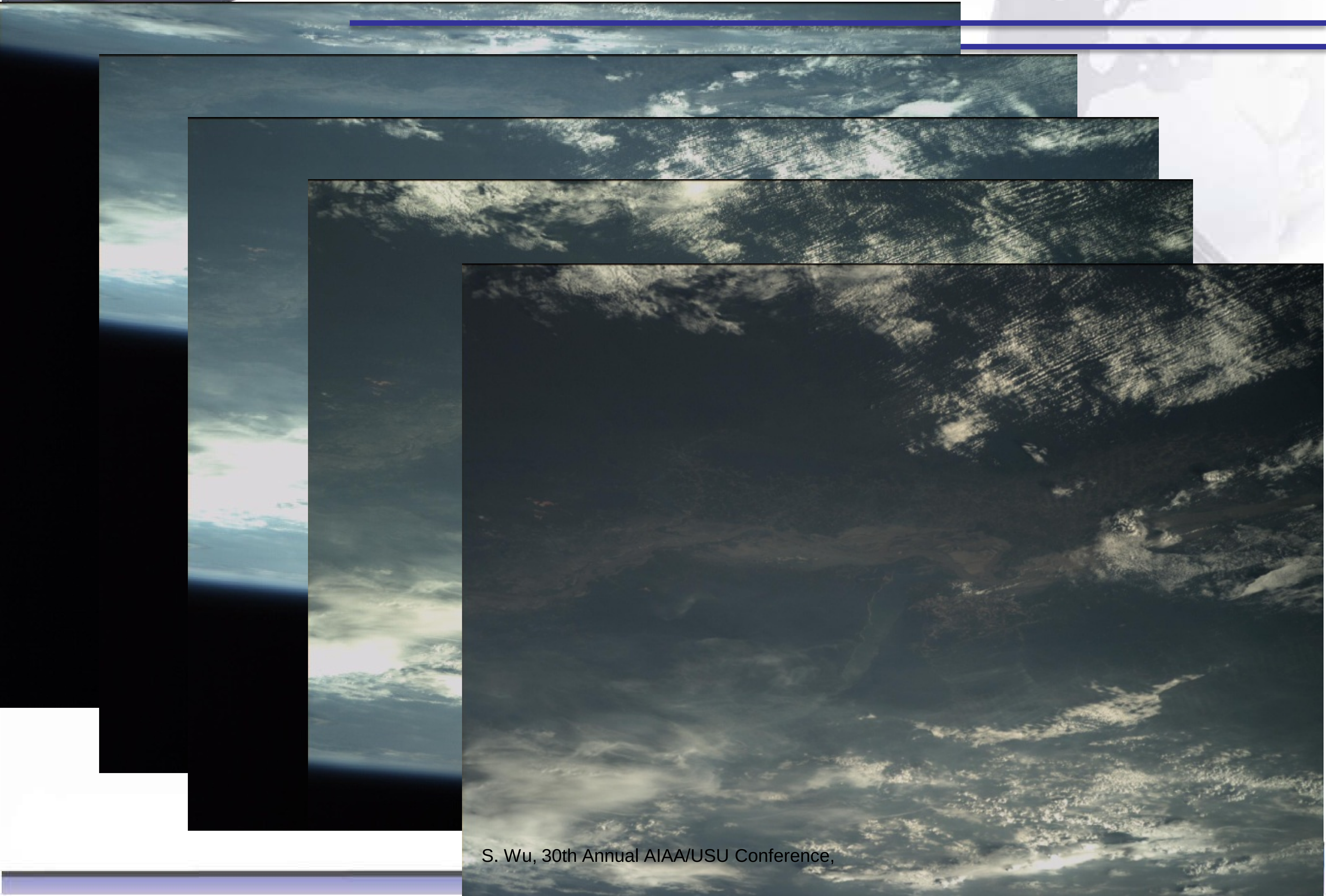
- **Rescue Process**
  - Switch off ADCS loop
  - 7 days successive firing to reduce the rate
  - Rate down to ca 14 deg/s
  - Switch on the ADCS
  - Magnetic control bring the spin rate down to zero
- **Thanks to:**
  - CSP allows direct access to subsystem
  - redundant MEMS gyro and magnetometer
  - Open-loop control

Successfull l Rescue around the 2015 Xmas week



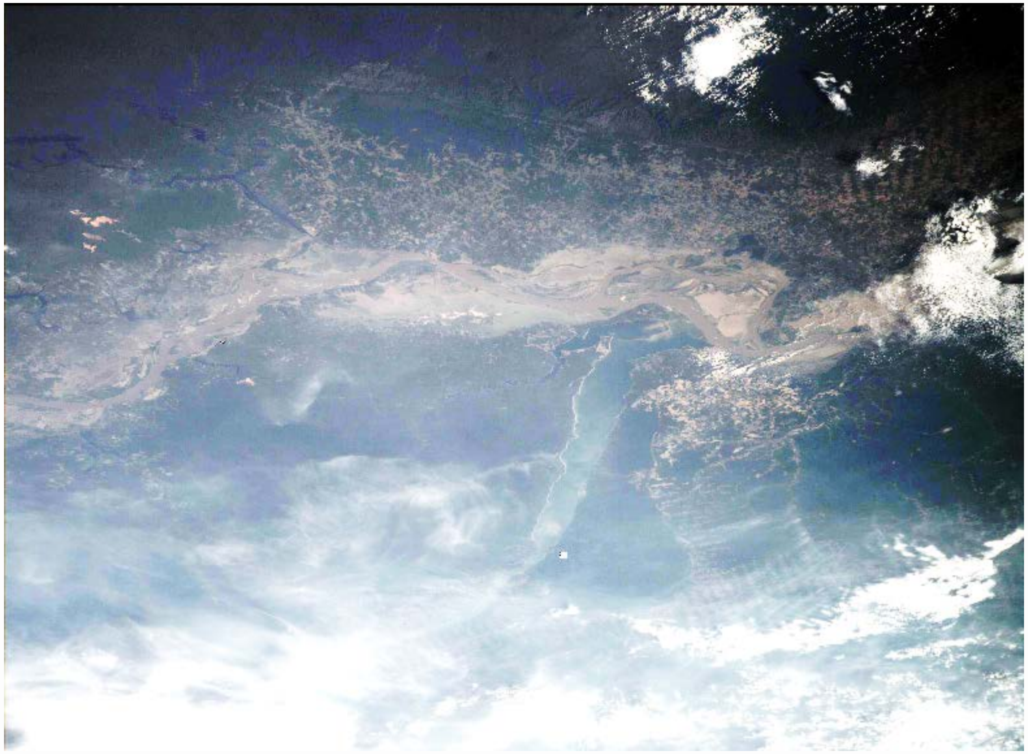
Sequence of thrust firings to de-spin the STU-2A

In-Orbit Results

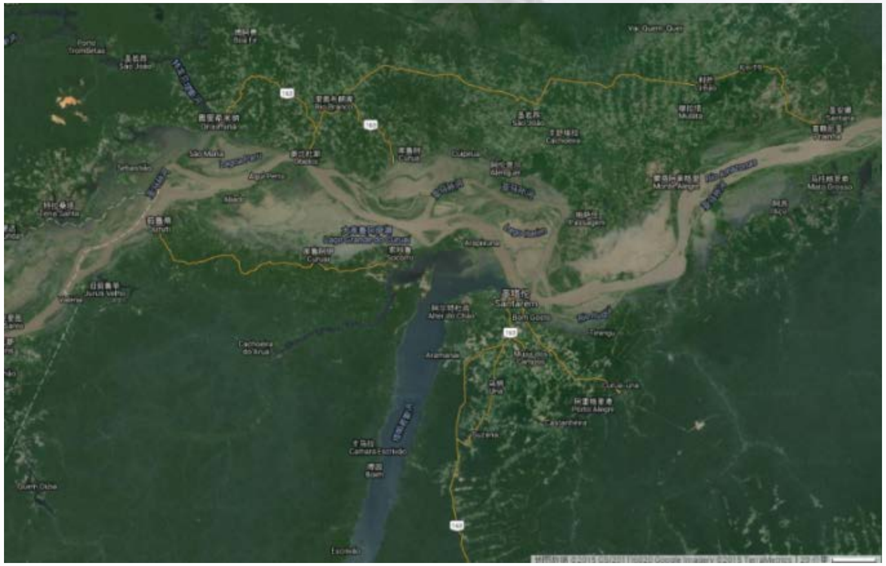


Earth Observation: Nov 2015

STU-2A Imagine



Google Map

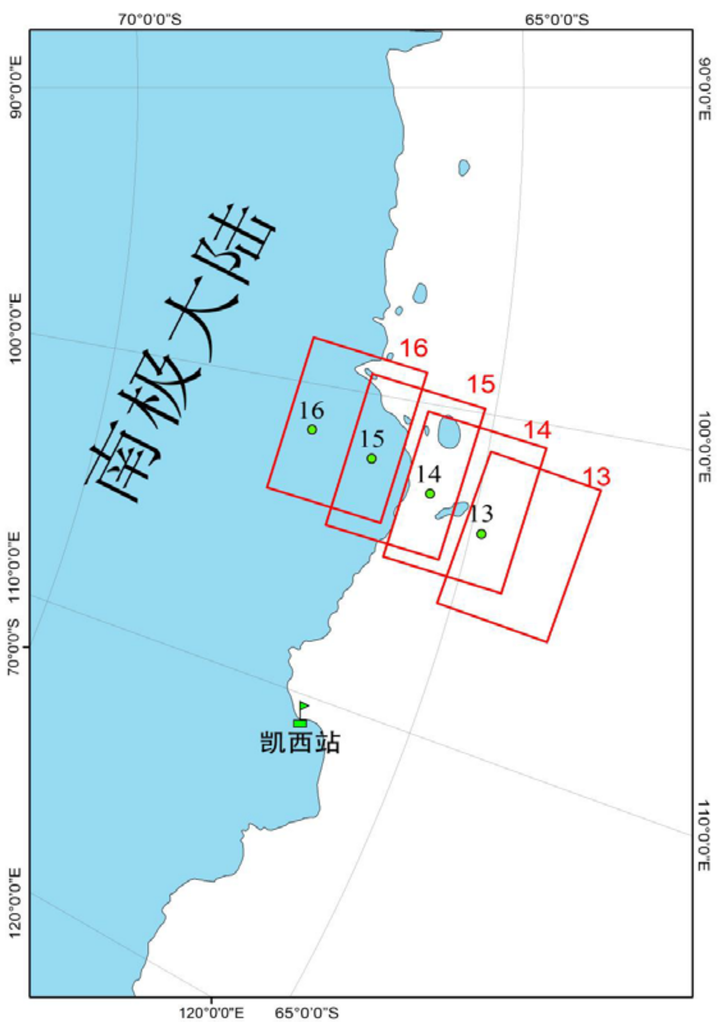


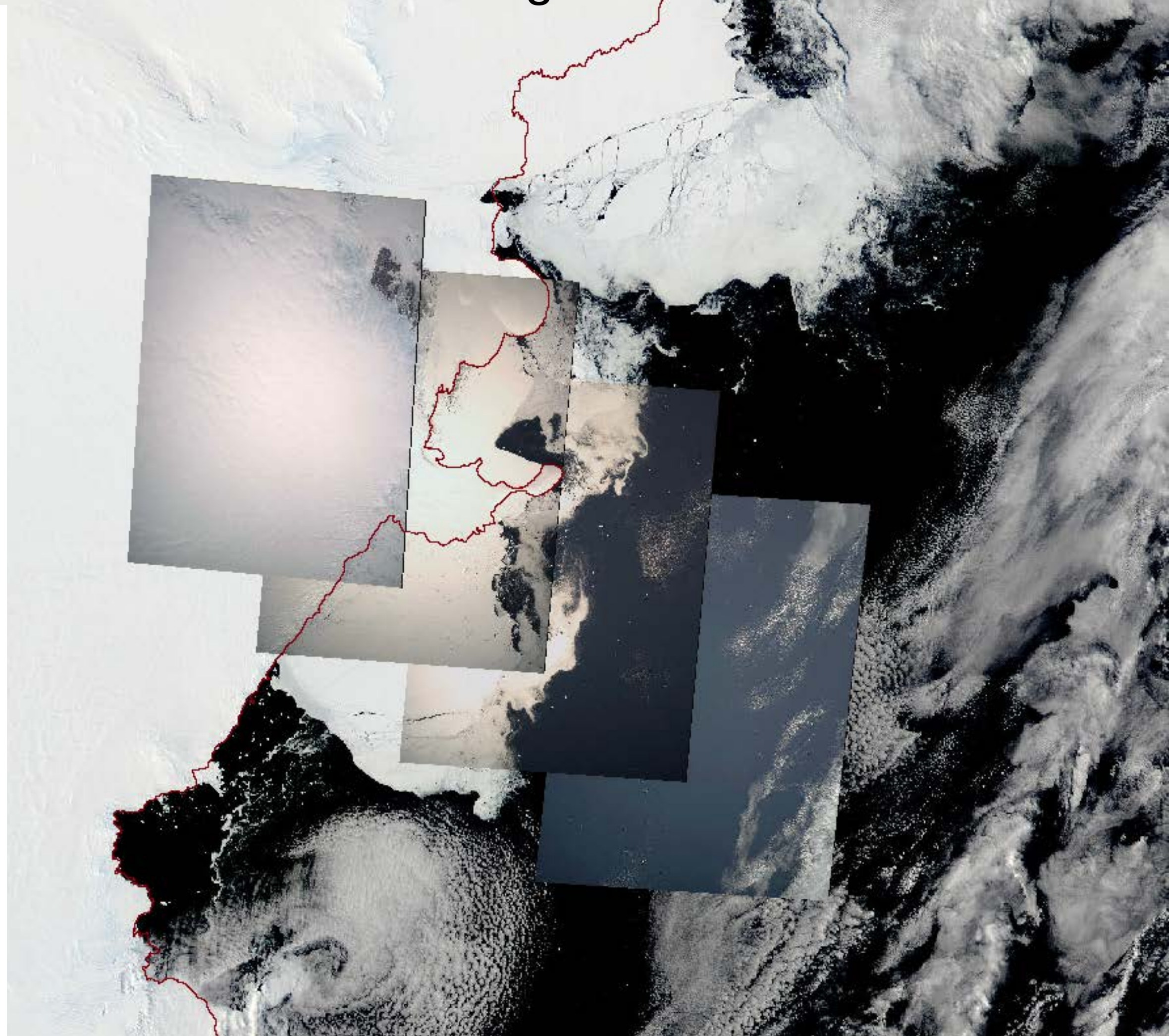
STU-2A Orbit & Location

Location: North Brasil, crossing region of the Tapajos river joining the Amazon river

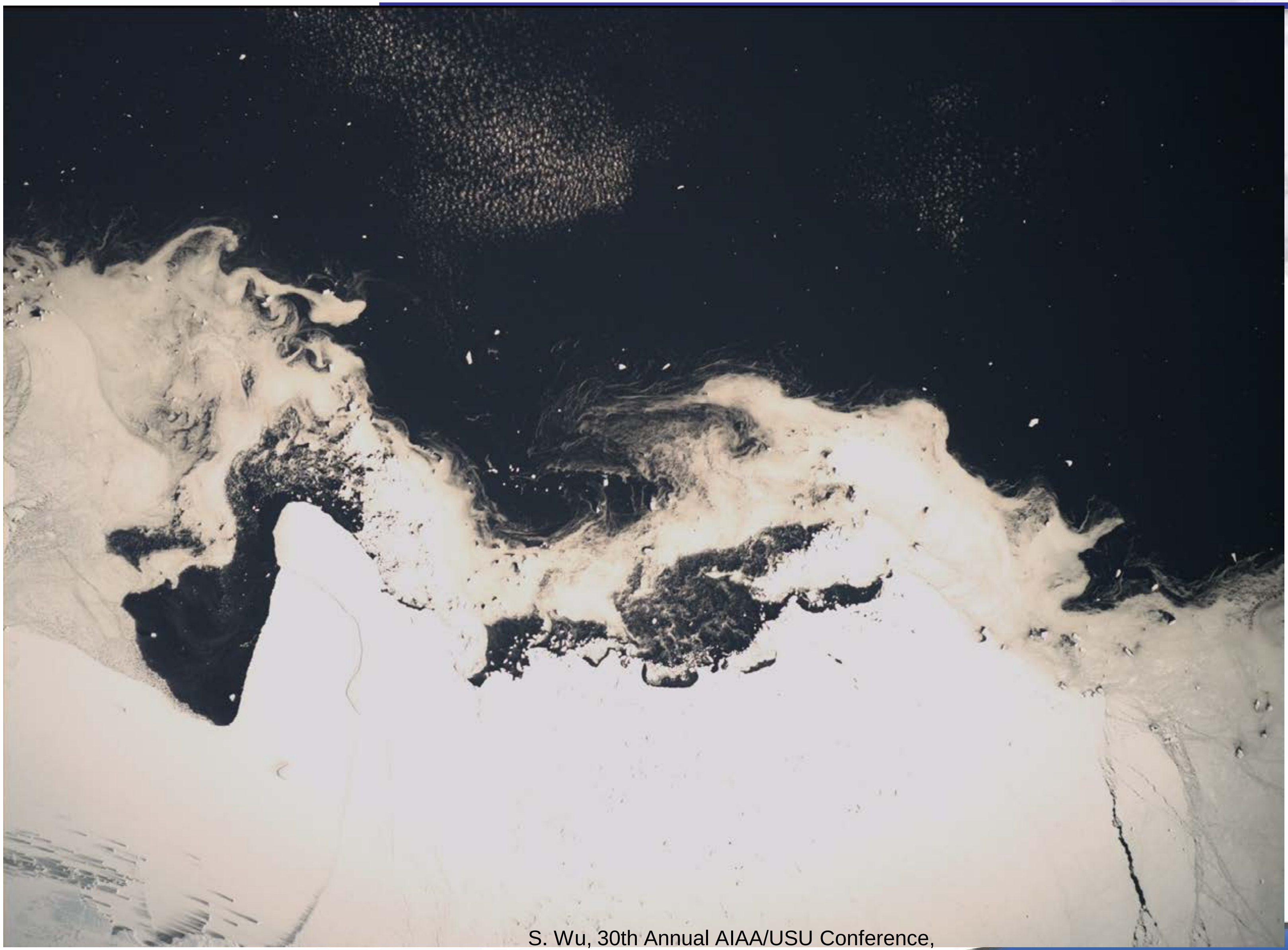
Antarctic Observation: Feb 20 2016

STU-2A pictures as placed into Modis250 data background

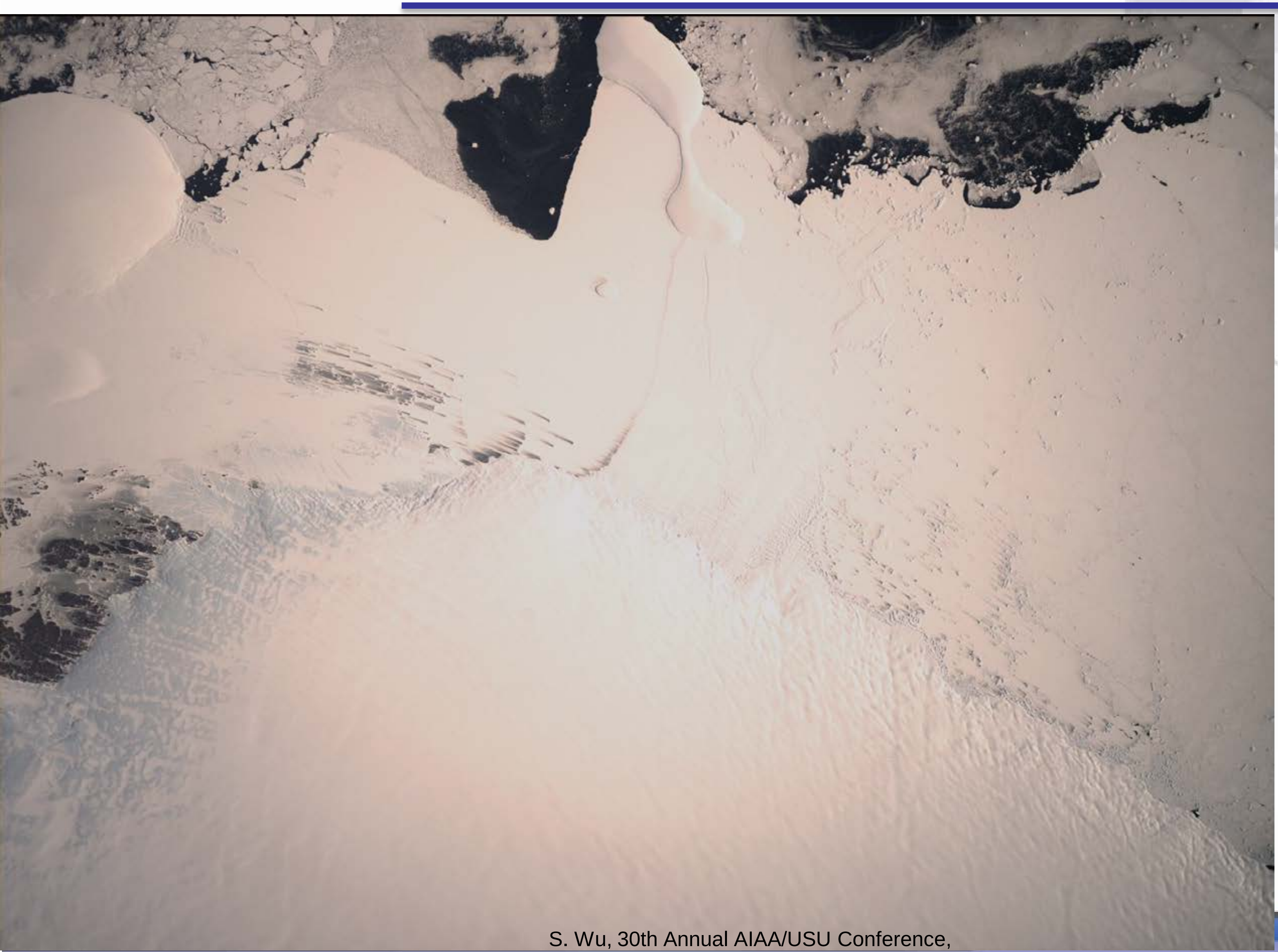




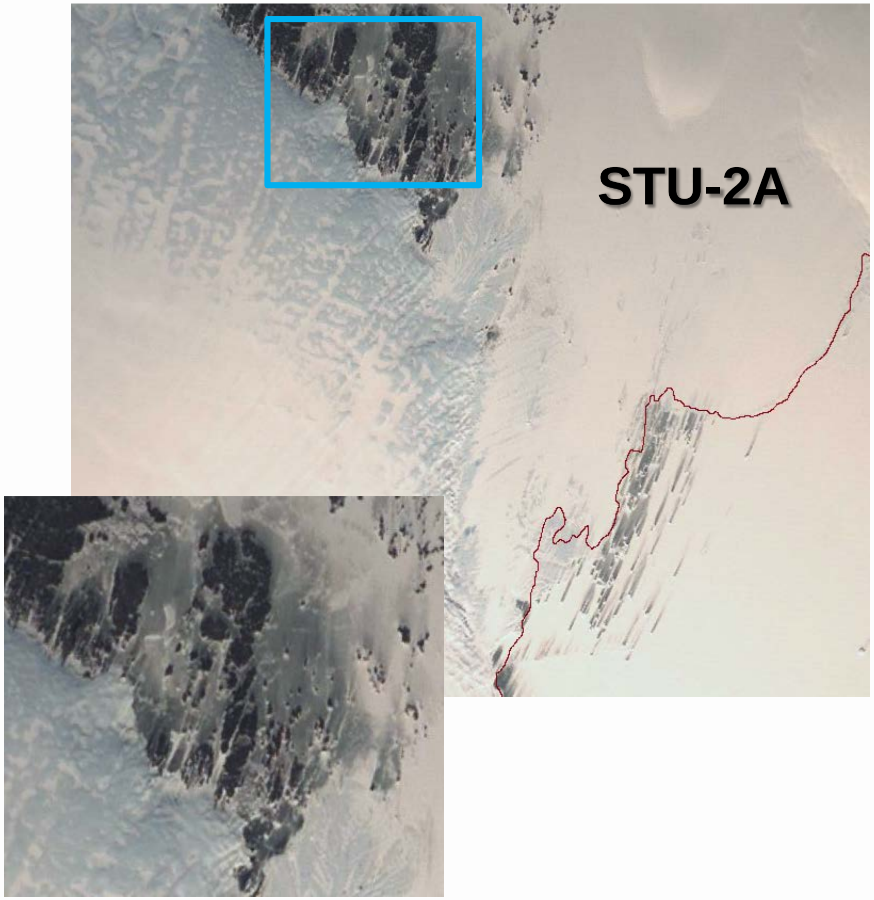
Imagine No 15, Feb 20 2016

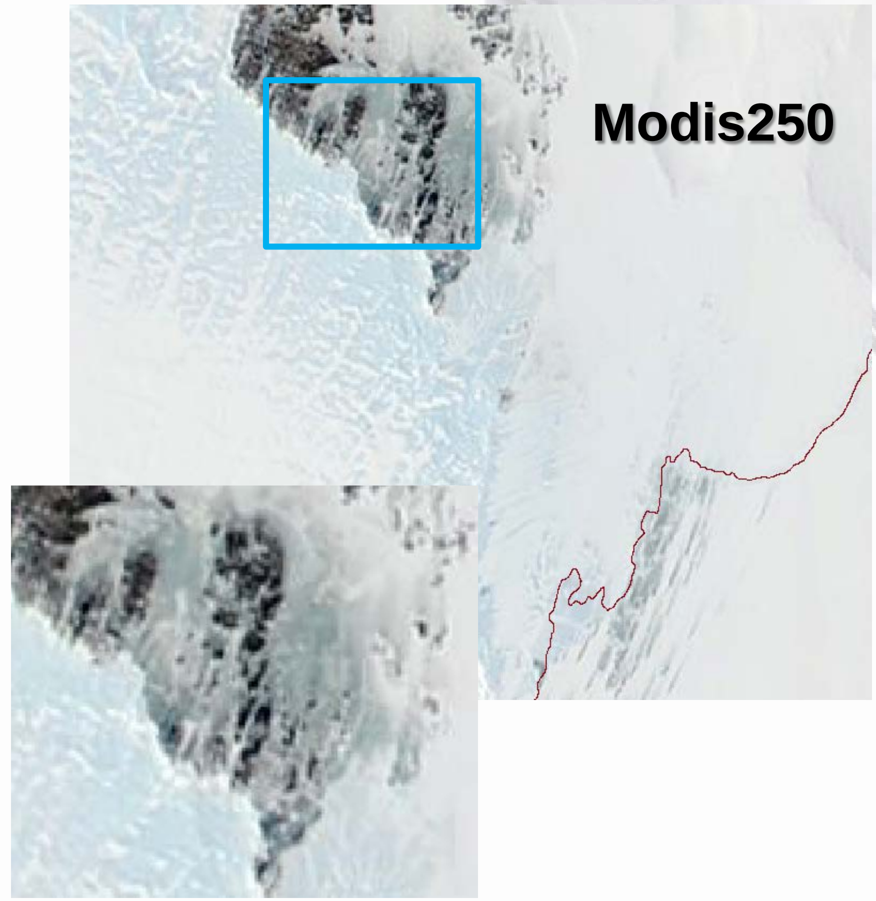


Imagine No 14, Feb 20 2016



Comparison of STU-2A with Modis250 image

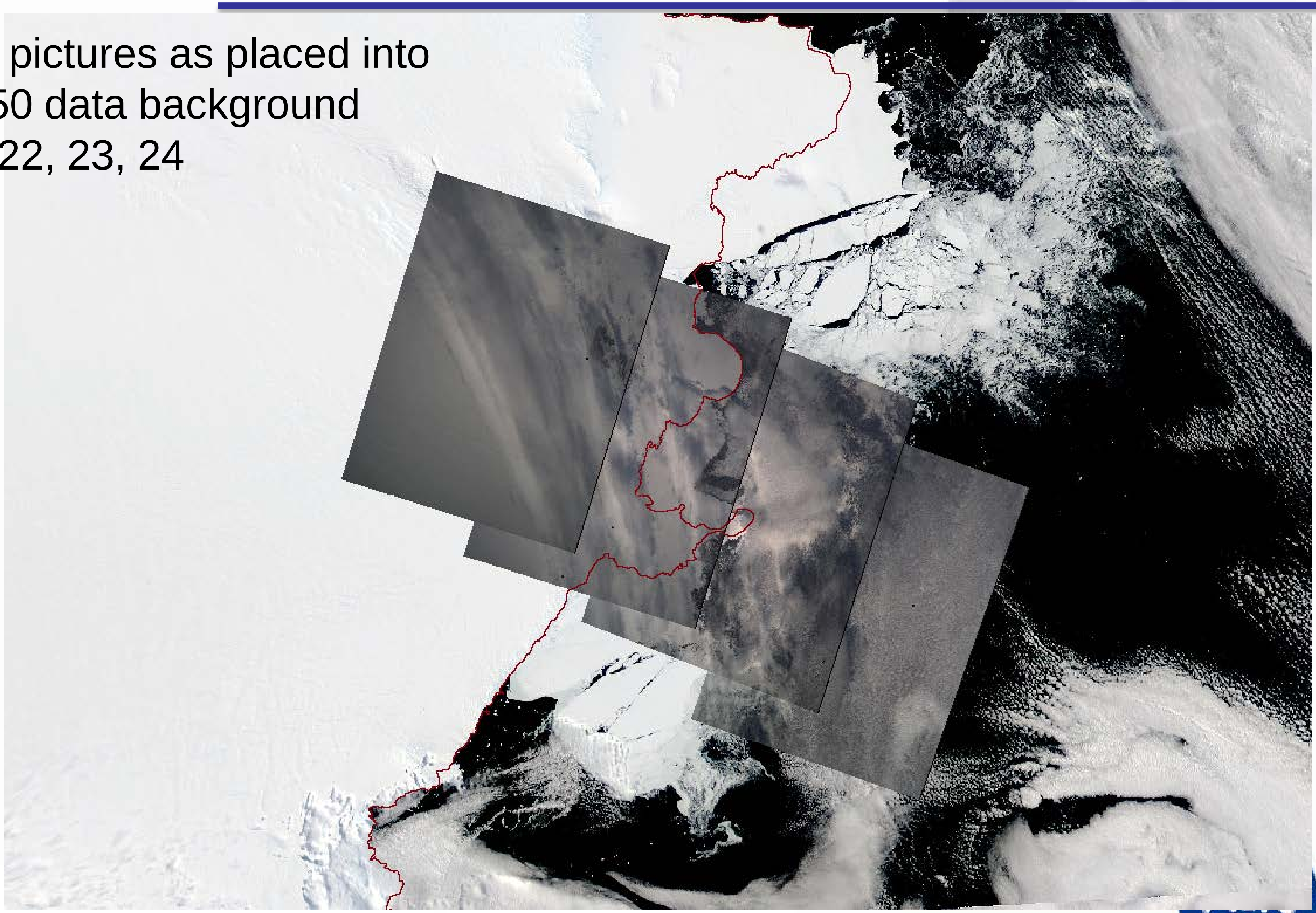




STU-2A's image has a resolution at 100m, much better than the resolution of 250m of the Modis250 imagines

Antarctic Observation: Feb 23 2016

STU-2A pictures as placed into
Modis250 data background
No. 21, 22, 23, 24

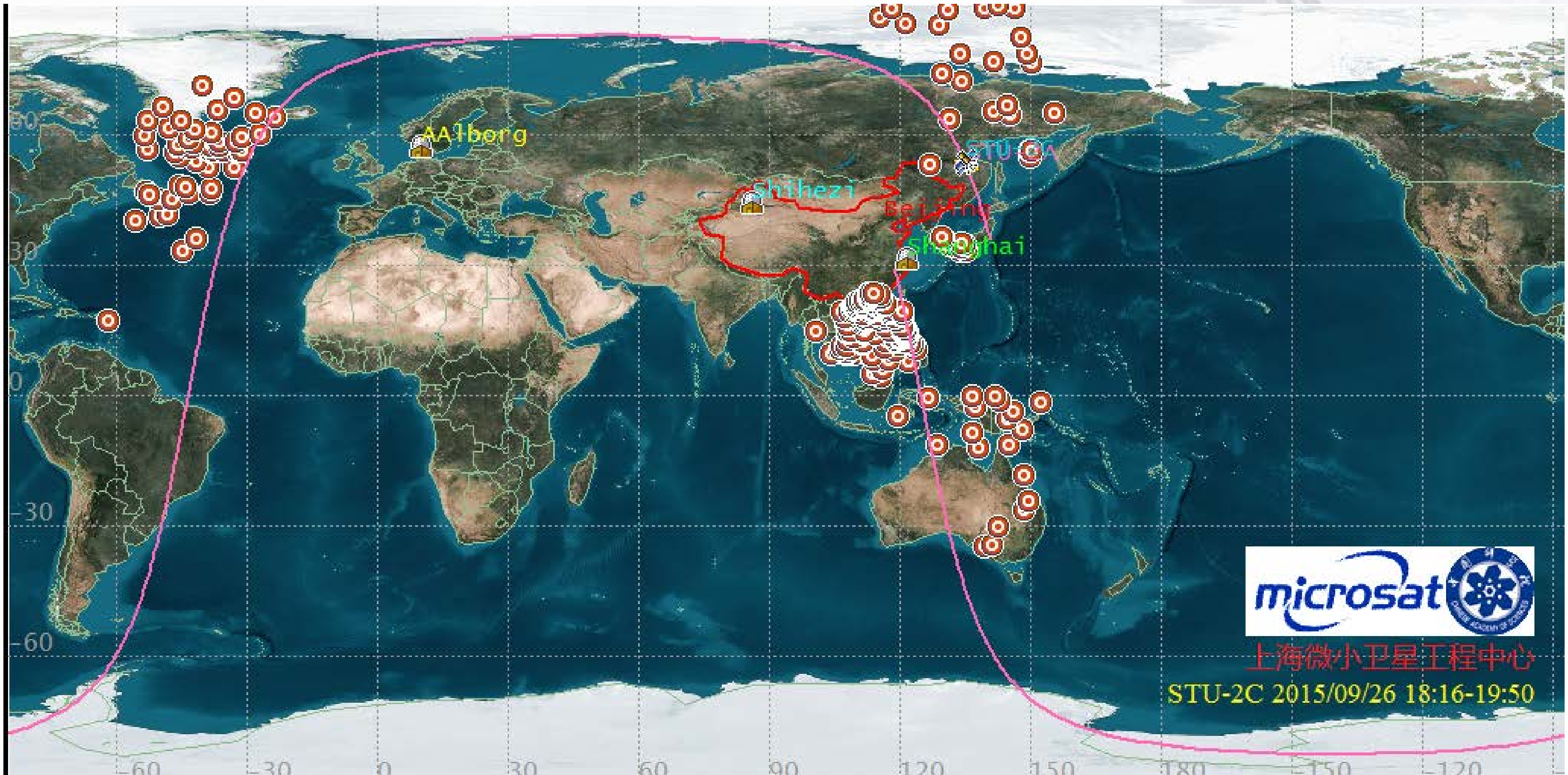


Imagine No 22, Feb 23 2016

Imagine No 23, Feb 23 2016

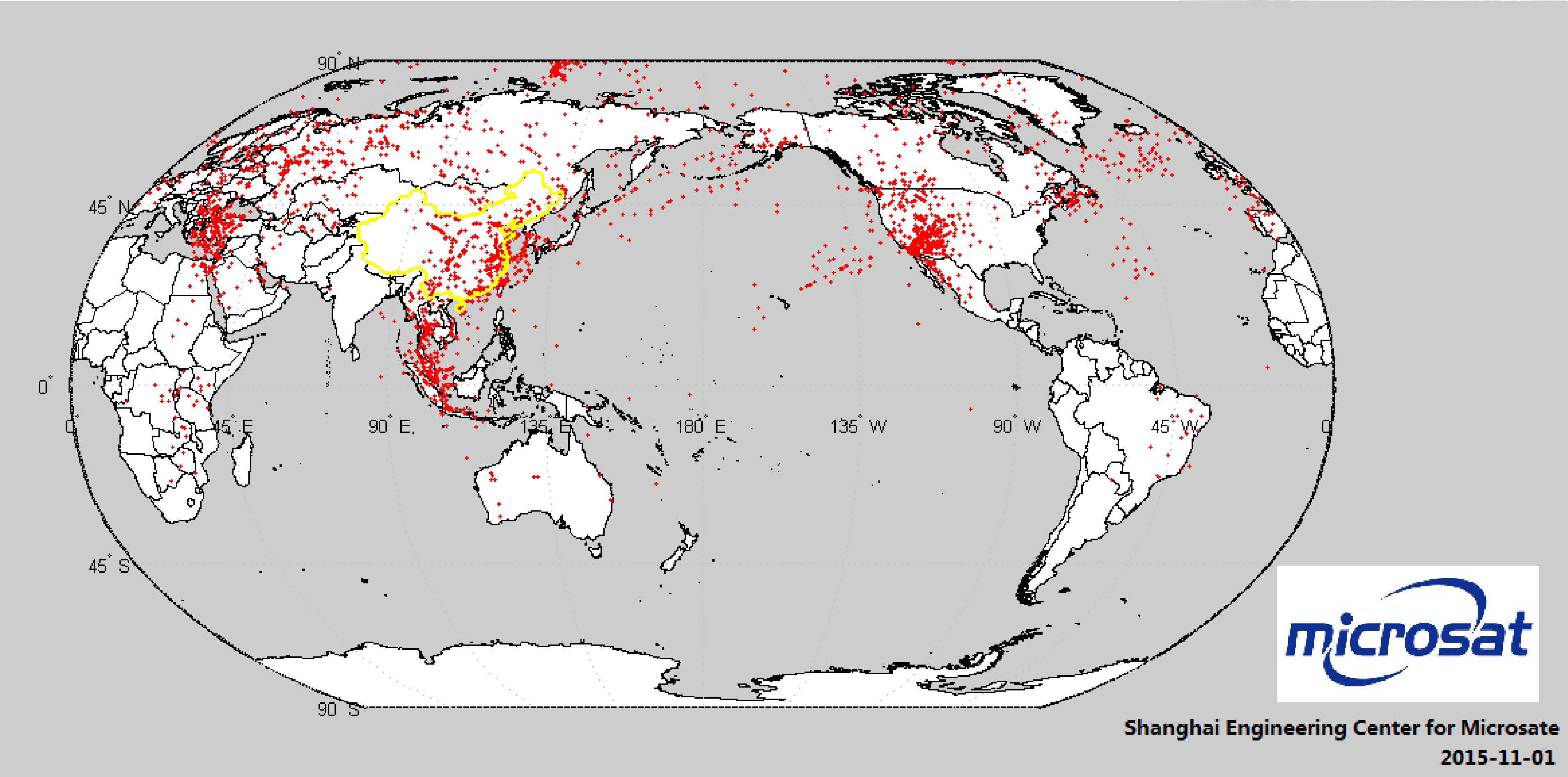
ADS-B In-Orbit Results – One Orbit

ADS-B Received Data from Sept 26, when switched on



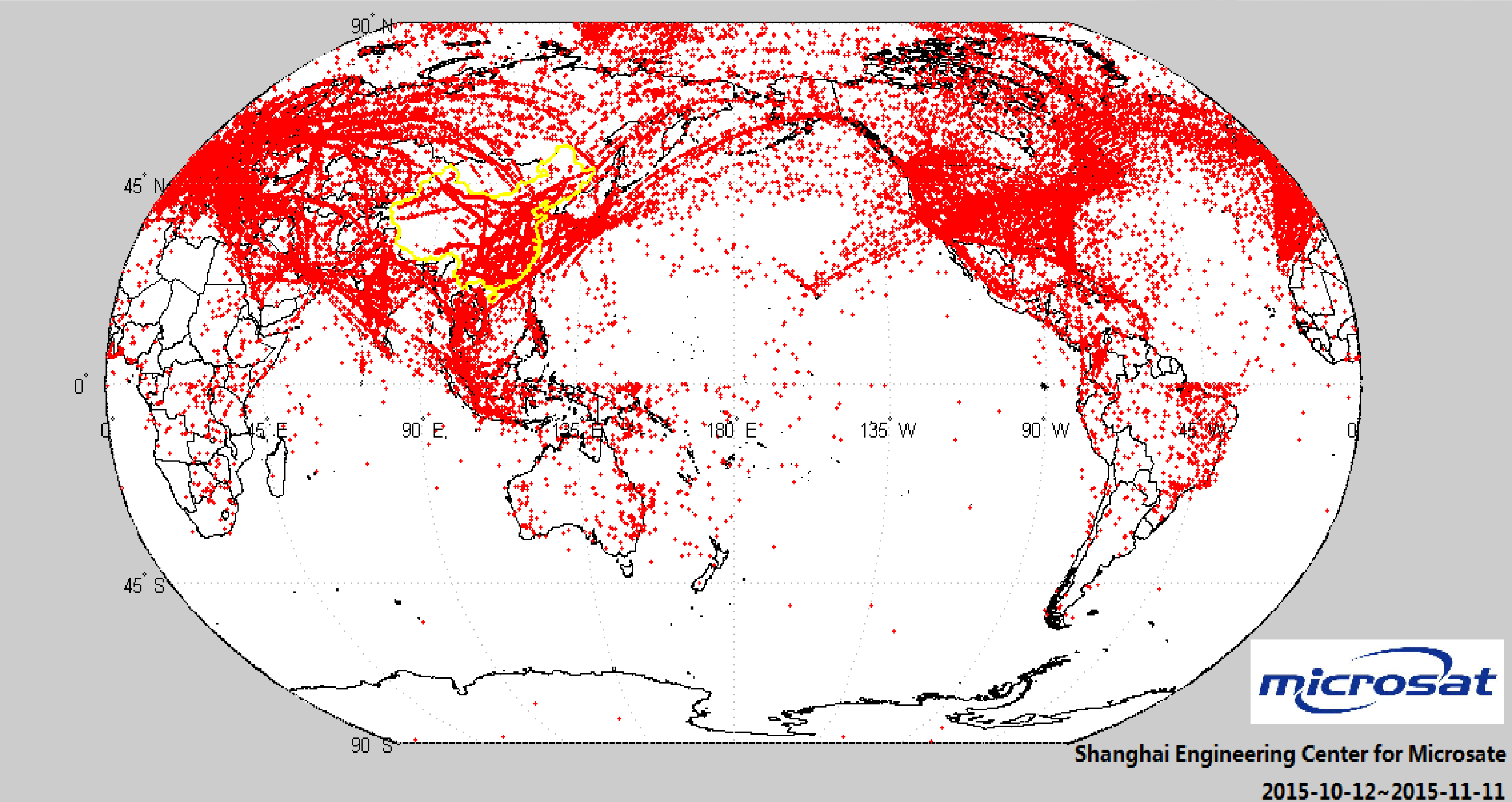
ADS-B In-Orbit Results – One Day

ADS-B Received Data On Nov 1st 2015

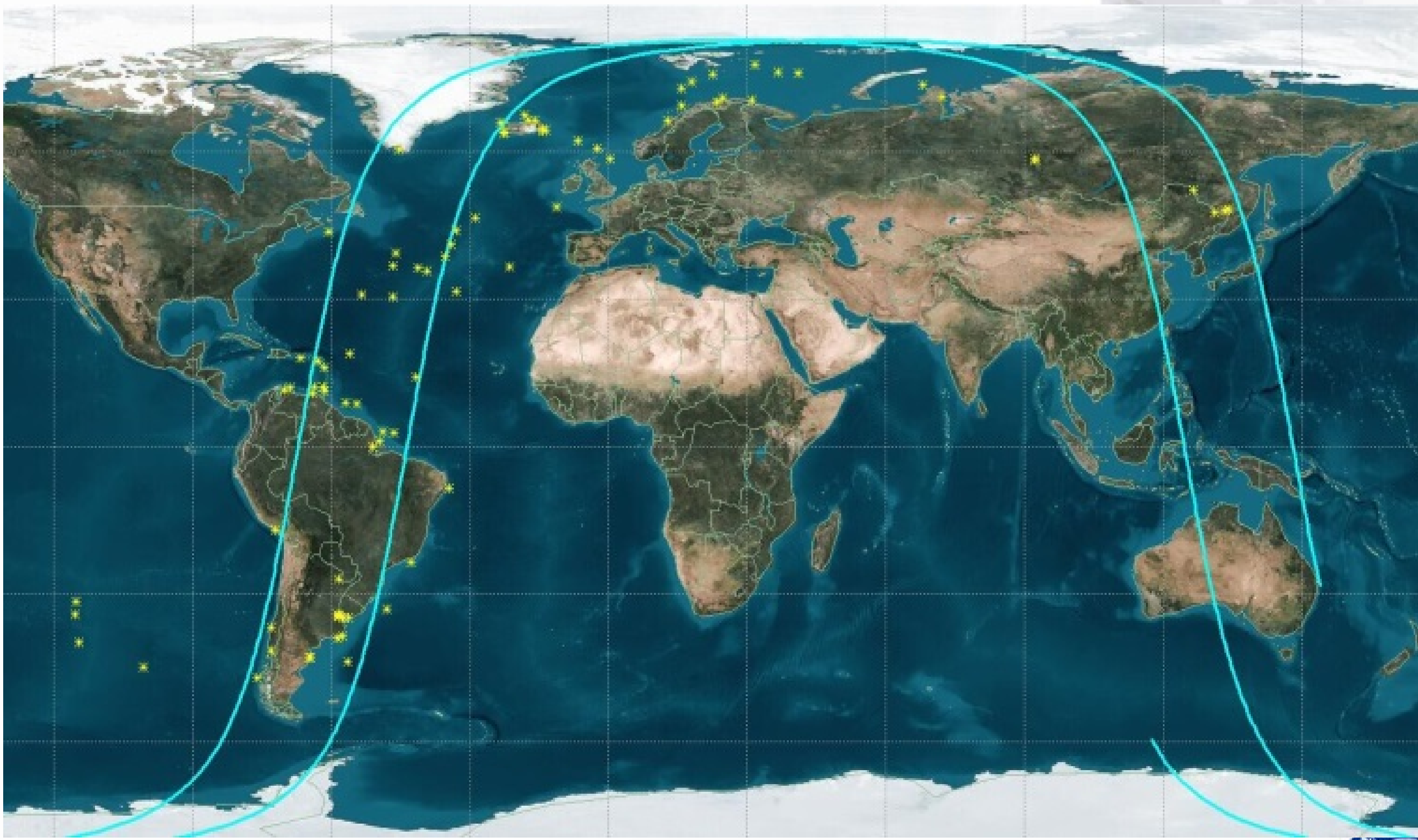


ADS-B In-Orbit Results over One Month

ADS-B Received Data from Oct 12th till Non 11th 2015,

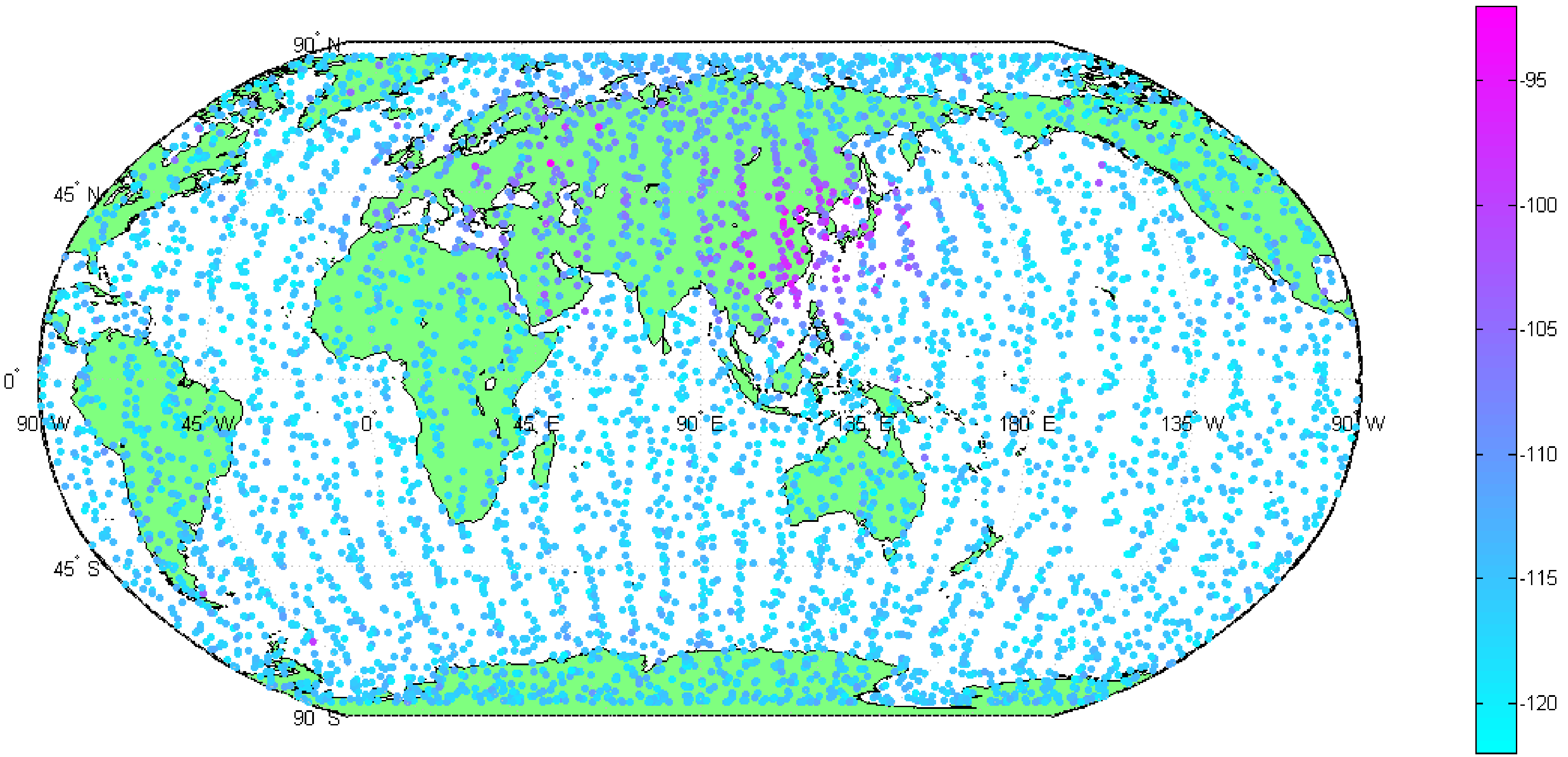


STU-2B (AIS) In-Orbit Results along one orbit



In-Orbit Results

Global UHF background noise level measurements [dB]



Lessons Learned

- EMC is a critical issue in system design and final testing

- Redundant key sensors/actuators could greatly improve the reliability, providing more measures to tackle iregular cases

- In-orbit injection of control parameters & software patches

- The impact of magnetic residual remains to be very critical.
  it can affect attitude stability

- The 18650 lithiump-ion batteries have a significant magnetic dipole which needs to be compensated

- Magnetometer should be placed as far as possible from large current devices, e.g. PC-104 socket, batteries, etc.

microsat

Summary & Acknowledgement

1. CubeSat used for AIS, and ADS-B receivers in China
2. CubeSat used for polar region observation
3. CubeSat networking experiment (CSP/Ad hoc)
4. IOD of a few new technology/products
5. … …

上海科技大学
ShanghaiTech University

microsat

GOMSPACE

tekever SPACE

NANO SPACE

南京理工大学
Nanjing University of Science and Technology

Astro- und Feinwerktechnik Adlershof GmbH

SATLAB

Thanks!

Prof Dr Shufan Wu

Chinese Academy of Science(CAS)

Shanghai Engineering Centre for Microsatellite

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