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National Applied Research Laboratories

FORMOSAT-7/COSMIC-2
Progress Update and its Launch Plan

Nick L. Yen

04-20-2015

Outlines

- Brief History of FORMOSAT-3 / COSMIC-1 Mission
- Formation of FORMOSAT-7 / COSMIC-2 Mission
- FORMOSAT-7 / COSMIC-2 Mission Requirement
- FORMOSAT-7 / COSMIC-2 Major Program Milestones
- Spacecraft Bus Developments
- TGRS Mission Payload Developments
- Launch System Developments
- FORMOSAT-7 / COSMIC-2 Current Satellite Production Status
- Satellite Constellation Deployment
- Ground System Developments
- Joint Program Master Schedule & Mission Data Policy
- Conclusion

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Brief History of FORMOSAT-3 / COSMIC-1 Mission

FORMOSAT-3 / COSMIC - Minotaur Launch Success

Launch Date: April 15, 2006 at UTC 01:40

Launch Site: Vandenberg AFB, CA, U.S.A.

Initial Orbit: Altitude ~515 km; Inclination ~72˚

Final Orbit: Altitude ~800 km; Inclination ~72˚

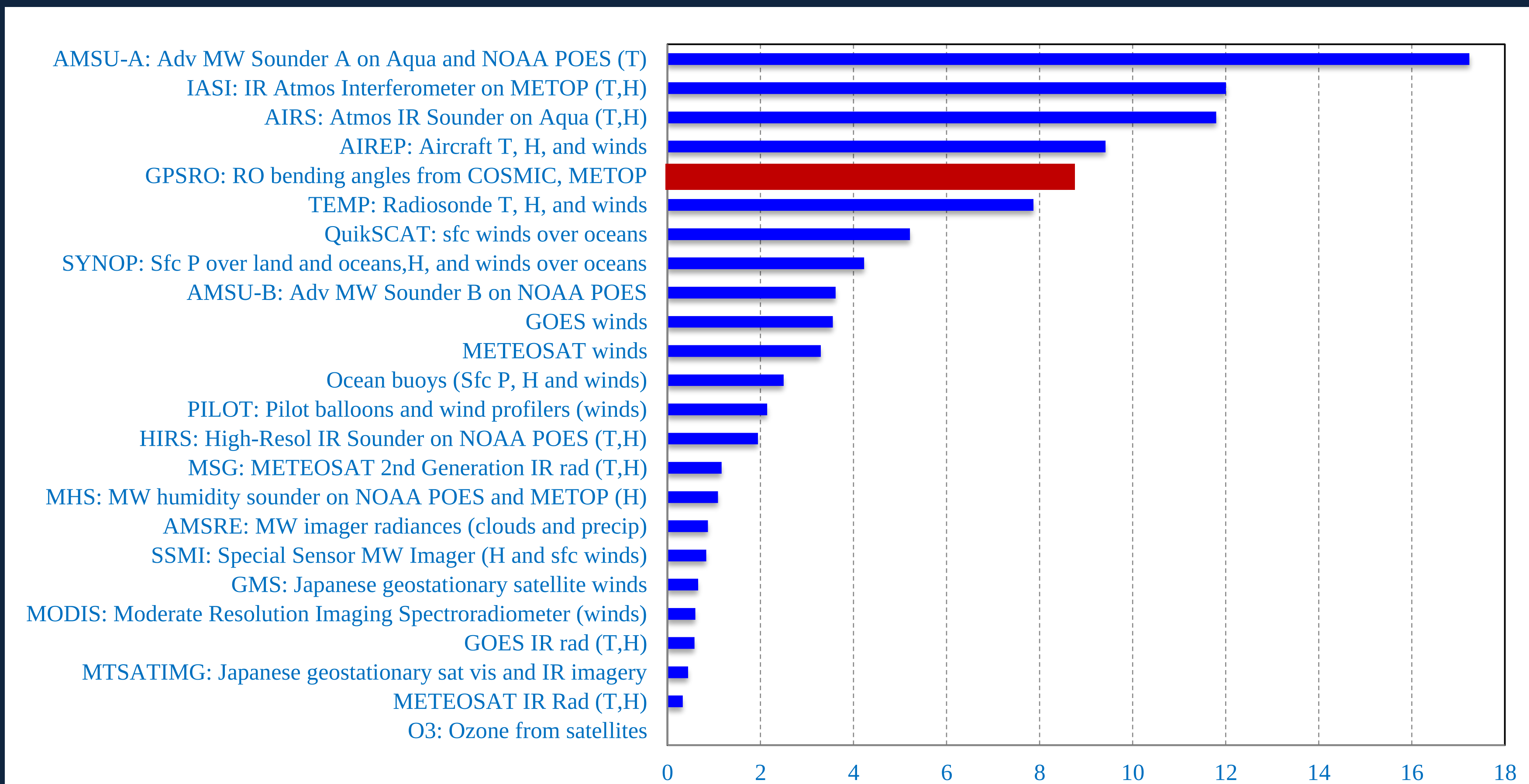
FORMOST-3 / COSMIC

Total Cost : ~ U.S. $ 100 M

- the first Radio Occultation Constellation that demonstrates the value of GPSRO in Weather, Climate and Space Weather -

GPSRO has Significant Impact:

Ranked #5 among all observing systems in reducing forecast errors, despite the small number of soundings.



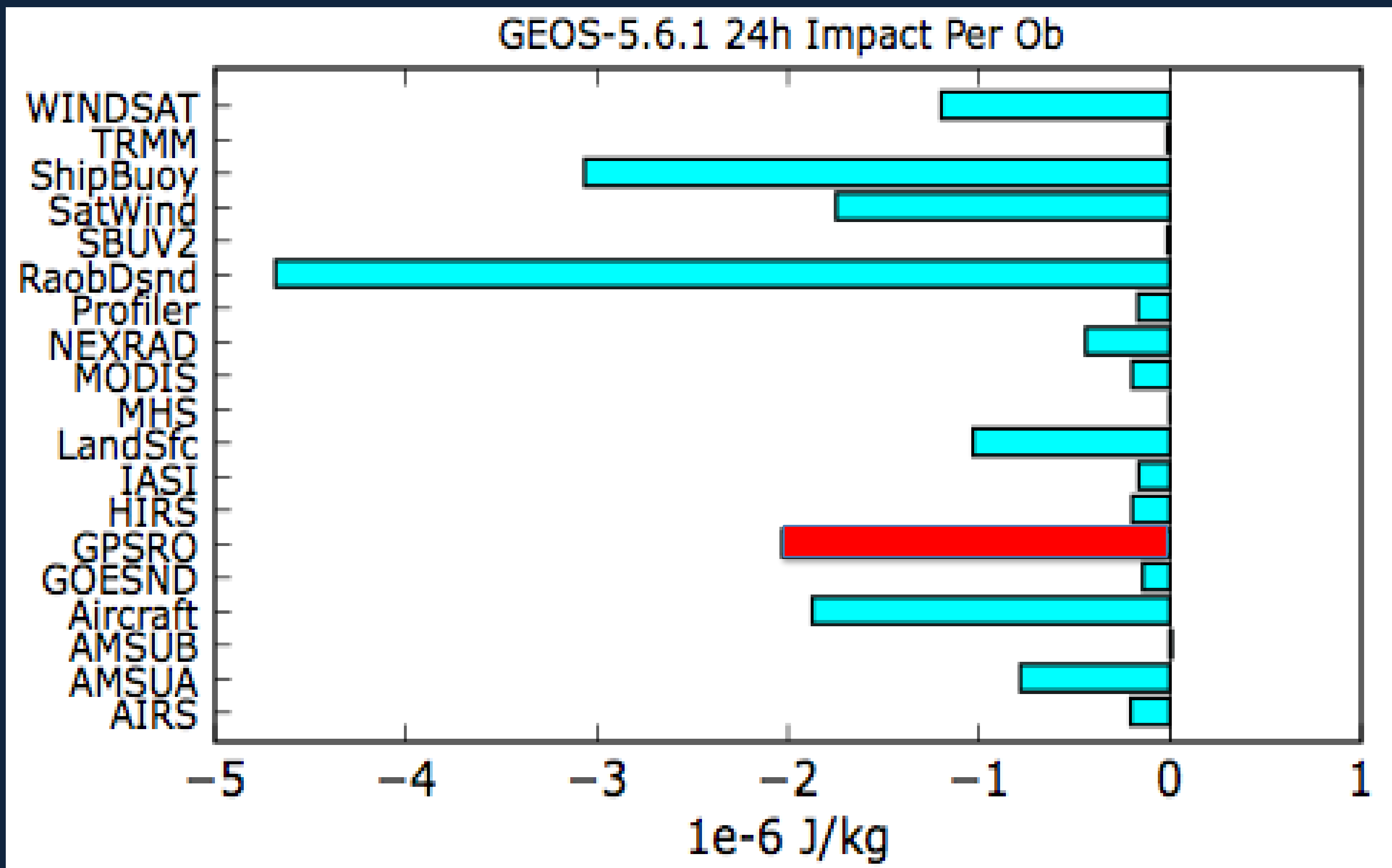
Forecast error contribution (%)

Published in the Quarterly Journal of the Royal Meteorological Society

Courtesy: Carla Cardinali and Sean Healy, ECMWF, 22 October, 2009

GPSRO Ranked #3 among other NOAA Instruments in Impact per Observation

美海洋大氣總署(NOAA)宣稱福衛三號資料對氣象預報誤差的改善與其他NOAA氣象衛星比較排行第三名



FORMOSAT-3/COSMIC GPSRO

Adjoint-based estimate of 24-hr global forecast error reduction in wind, temperature and surface pressure combined as energy (J/kg)

Impact of Various Observing Systems (NOAA Study)
GEOS-5.6.1 28 Jan – 05 March 2010 00z

From Ron Gelaro, NASA, GMAO

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FORMOSAT-3 / COSMIC Appears on Major Global Publications

國際知名期刊雜誌 爭相報導福三衛星星系

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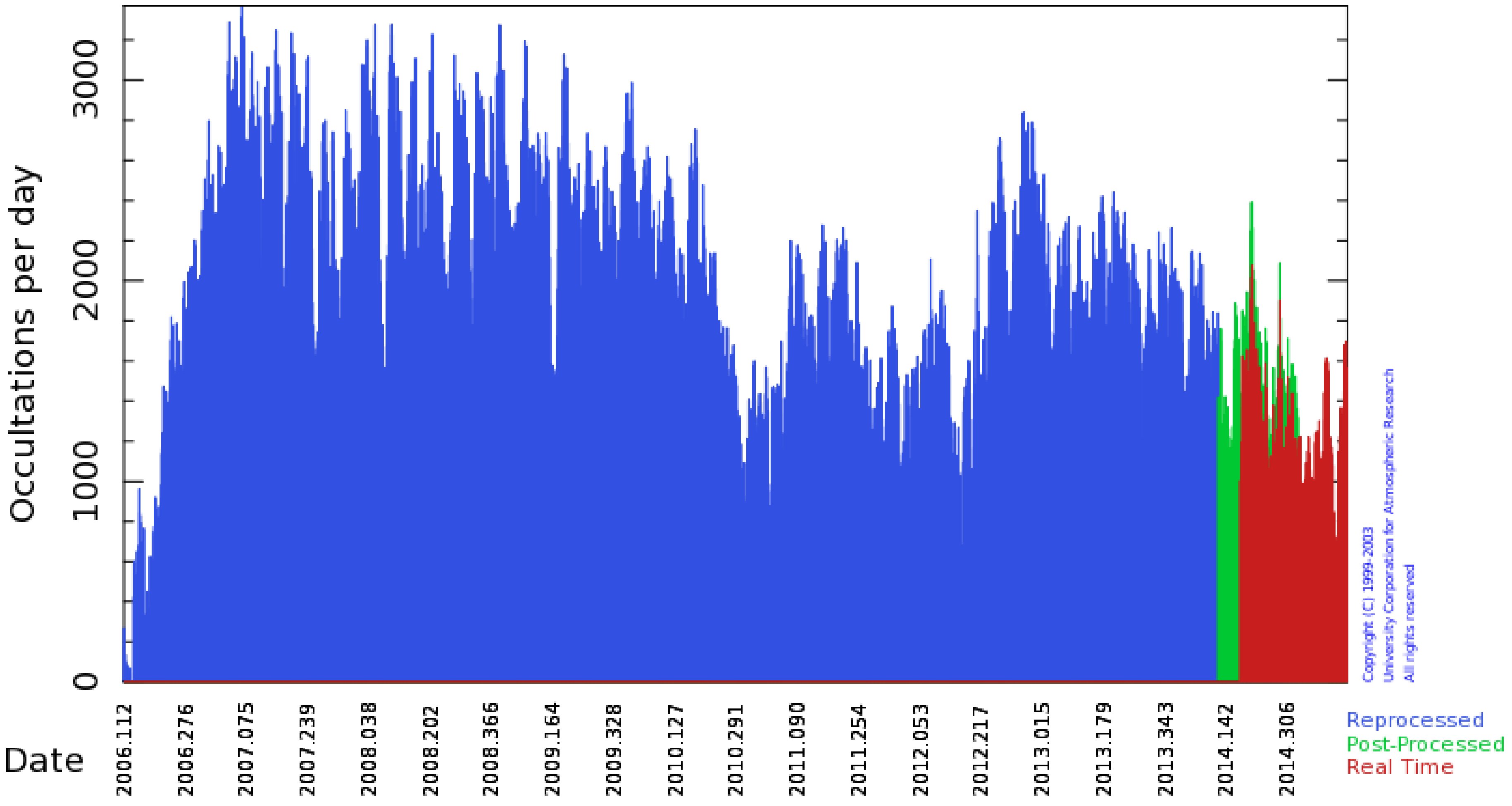
FORMOSAT-3/COSMIC RO Accumulated Atmospheric Profiles

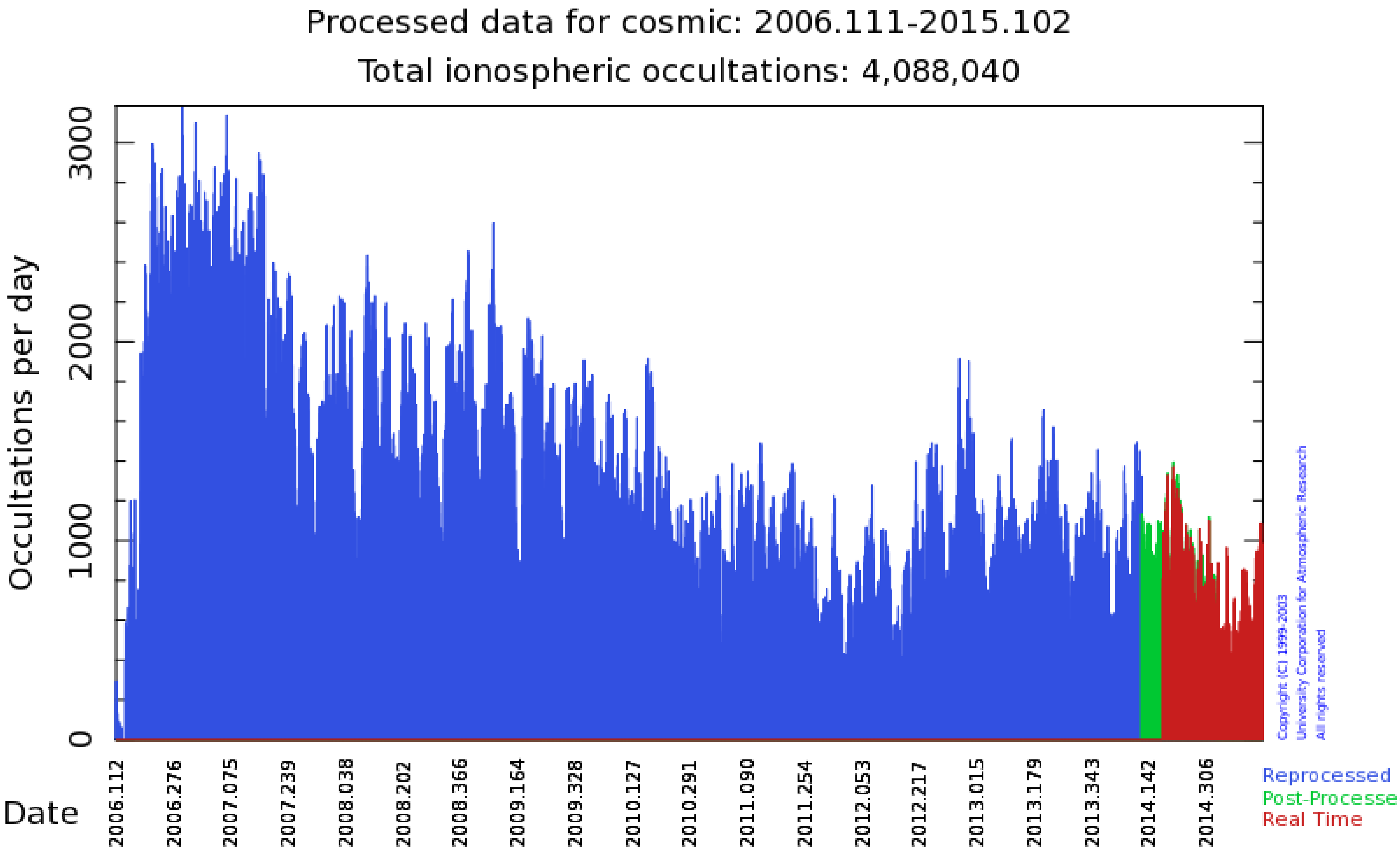
Processed data for cosmic: 2006.111-2015.102

Total atmospheric occultations: 5,961,187



Courtesy of UCAR CDAAC

FORMOSAT-3/COSMIC RO Accumulated Ionospheric Profiles



Courtesy of UCAR CDAAC

Global Data Users Status: 74 countries; 2693 users

As-of- 03/31/2015

U.S.A.	751	Iran	33	Finland	7	Puerto Rico	2	Costa Rica	2
Taiwan	447	Vietnam	20	Switzerland	7	Cuba	2	Macau	1
India	366	South Africa	20	Thailand	7	Colombia	2	Iraq	1
China	261	Argentina	19	Turkey	7	Sweden	2	Saudi Arabia	2
Japan	78	Austria	18	Ethiopia	7	Norway	3	Mongolia	1
U.K.	55	Spain	18	Ukraine	7	Cyprus	2	Lebanon	1
Germany	53	Singapore	16	Chile	6	Hungary	2	Vanuatu	1
Russia	53	Philippine	13	Czech	6	Egypt	2	Ecuador	1
Canada	47	Denmark	13	The Netherlands	4	Senegal	1	Trinidad and Tobago	1
Korea	45	Nigeria	12	United Arab Emirates	3	Bangladesh	1	Panama	1
Australia	41	Malaysia	10	Israel	3	Bhutan	1	Jamaica	2
Brazil	39	New Zealand	10	Peru	3	Tanzania	1	Mexico	1
France	37	Poland	9	Bulgaria	3	Ireland	1	Uganda	1
Indonesia	37	Portugal	8	Belgium	3	Kenya	1	Nepal	1
Italy	37	Kazakhstan	7	Pakistan	2	Cameroon	1		

福衛三號衛星星系目前提供全球2410使用者與71國家

Courtesy TACC, CWB

Campaign Slogan → Legendary Reality

"The Most Accurate and Stable Thermometer in Space"

was first used by Rick Anthes in the opening remarks of

Emeritus UCAR President

FORMOSAT-3/COSMIC Workshop 2006 < Early Results and IOP Campaigns >

Taipei, November 28 – December 1, 2006

Formation of FORMOSAT-7 / COSMIC-2 Mission

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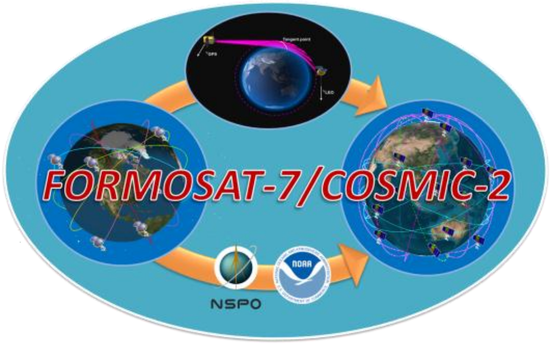
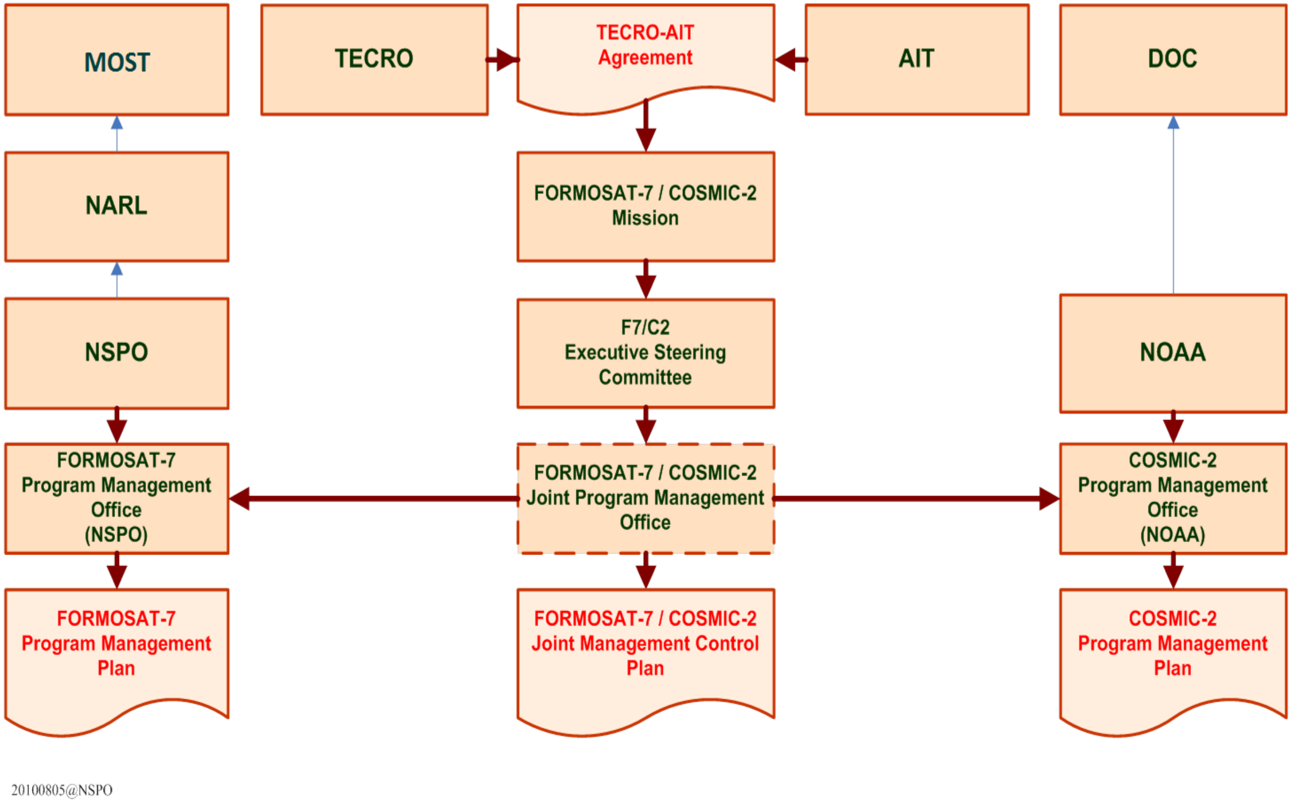
Advocacy of FORMOSAT-7/COSMIC-2 Mission

- The launch and the constellation deployment of the FORMOSAT-3/COSMIC-1 satellites and providing the RO profiles to the global user community, the usefulness and effectiveness of the RO data have been widely demonstrated and verified.
- The FORMOSAT-3/COSMIC-1 was originally designated as a 2-year experimental mission. Soon after the FORMOSAT-3/COSMIC-1 Workshop 2006 < Early Results & IOP Campaigns >, the advocacy for its follow-on mission began.
- Thanks to the following key individuals to promote/advocate the follow-on mission and incubate the establishment of the FORMOSAT-7/COSMIC-2 Mission:
  - ✓ UCAR: Rick Anthes, Jeff Reaves, Jack Fellows, Bill Kuo, Bill Schreiner, Dave Ector
  - ✓ NSF: Jay Fein, Eric DeWeaver
  - ✓ NOAA: Mary Kicza, Gary Davis, Mike Crison (deceased), Pete Wilczynski
  - ✓ JPL: Tony Mannucci
  - ✓ Taiwan: L-C Lee, C-H Liu, C-Y Tsay, G-S Chang, J.J. Miau, C-Y Huang, Tiger Liu
  - ✓ Many others not mentioned above
- A Taiwan-U.S. official TECRO / AIT collaboration agreement was signed in May 2010 for the execution of the FORMOSAT-7 / COSMIC-2 Joint Mission.

FORMOSAT-7/COSMIC-2 Agreement Implementation





MOST: Ministry of Science and Technology

NARL: National Applied Research Lab

NSPO: National Space Organization

TECRO: Taipei Economic and Cultural Representative Office

AIT: American Institute in Taiwan

DOC: Department of Commerce

NOAA: National Oceanic and Atmospheric Administration

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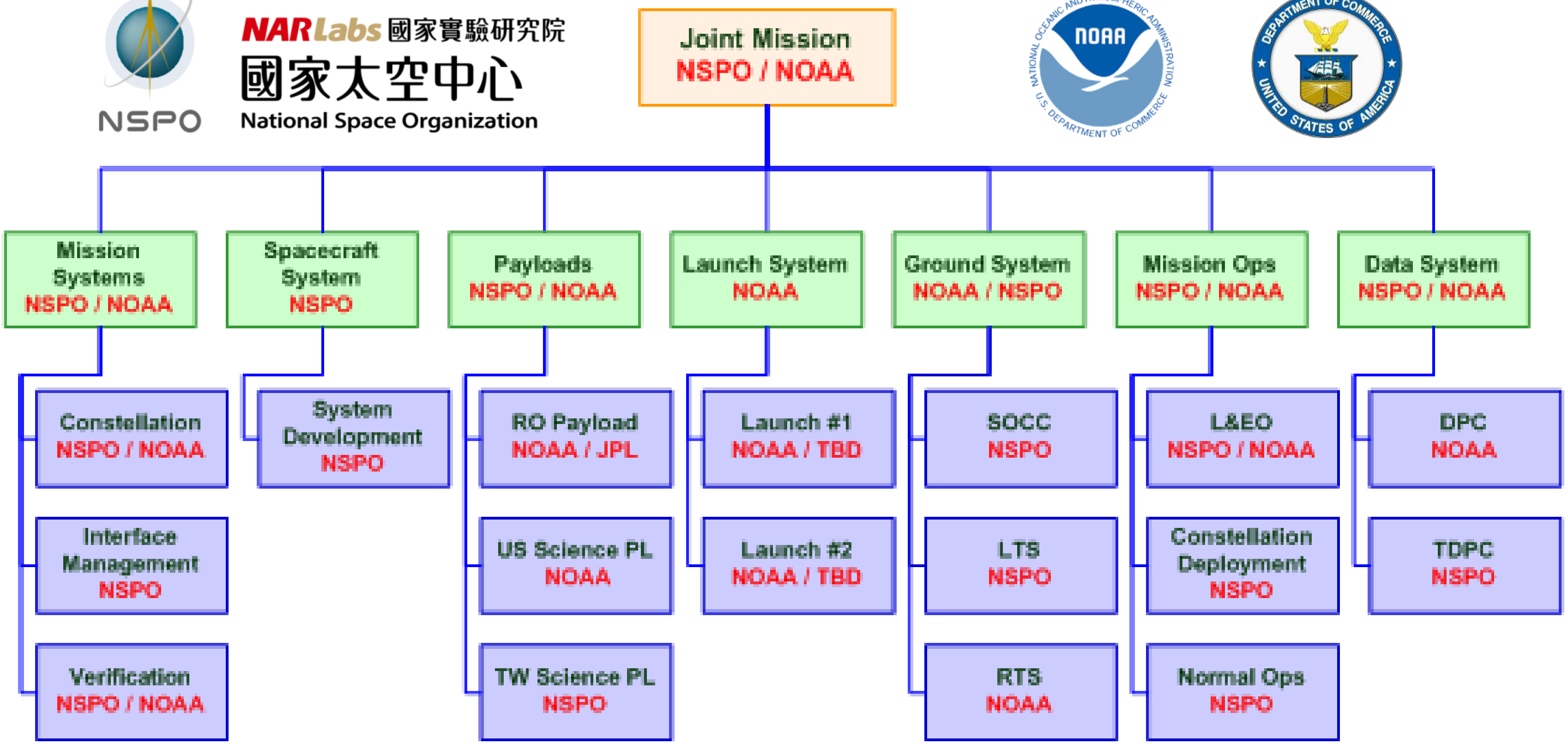
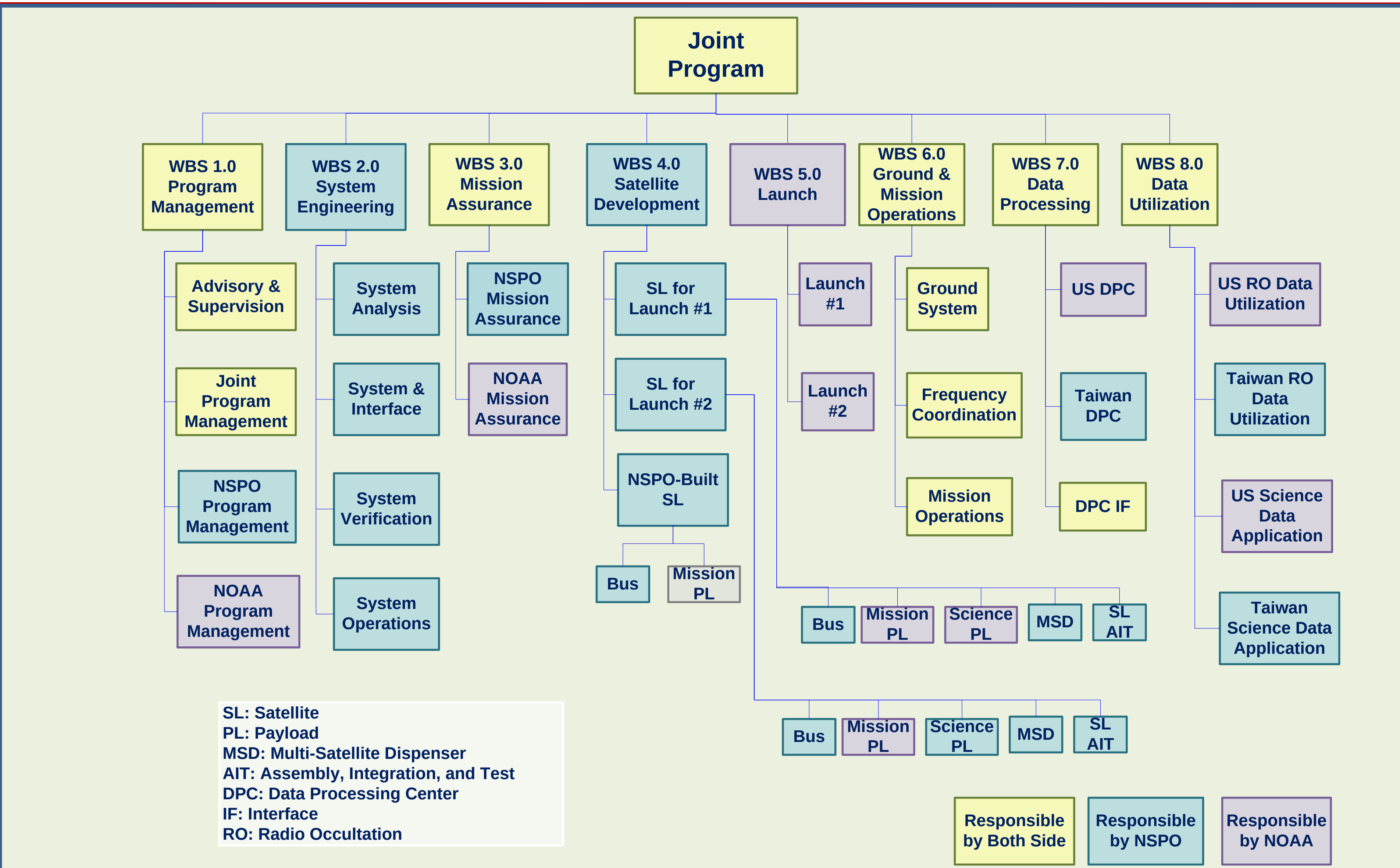
Joint Program Collaboration Framework

NSPO

NARLabs 國家實驗研究院
國家太空中心
National Space Organization

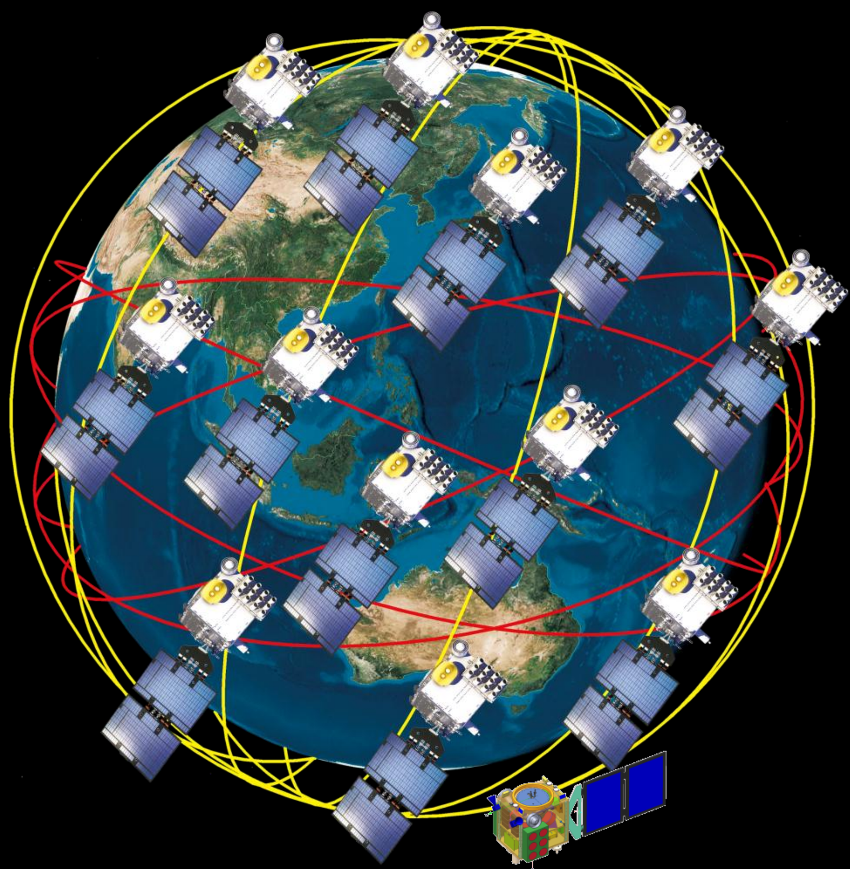


FORMOSAT-7/COSMIC-2 Joint Program WBS



FORMOSAT-7/COSMIC-2 Constellation

"Transition from Research to Operation"

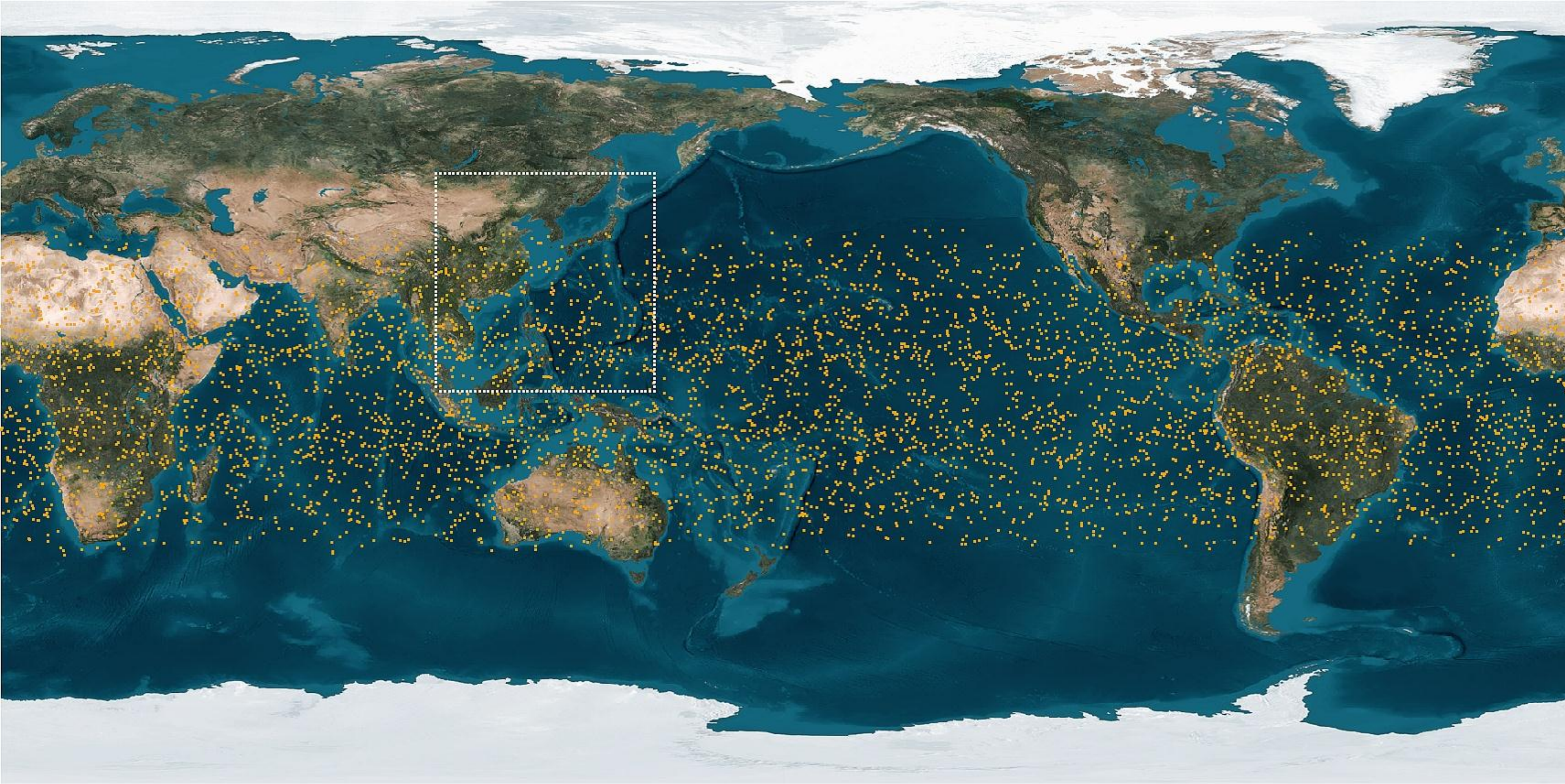


- **1st Launch**
  - 6 SC to a parking orbit with inclination angle of 24~28.5 deg.
  - Through constellation deployment, 6 SC will be separated to 6 orbital planes with 30-deg separation.
- **2nd Launch**
  - 6 SC to a parking orbit with inclination angle of 72 or 108 deg.
  - Through constellation deployment, 6 SC will be separated to 6 orbital planes with 30-deg separation.
  - NSPO-built satellite will be sent to the space by the 2nd launch (optional).

Total Estimate Budget: ~ U.S. $ 463 M

(Rick Anthes estimated @ U.S. $ 420 M

RO Data Distribution after the 1st Launch



5770 raw radio occultation profiles by 6 SC,
the data distribution is within a band of ± 50 deg latitude.

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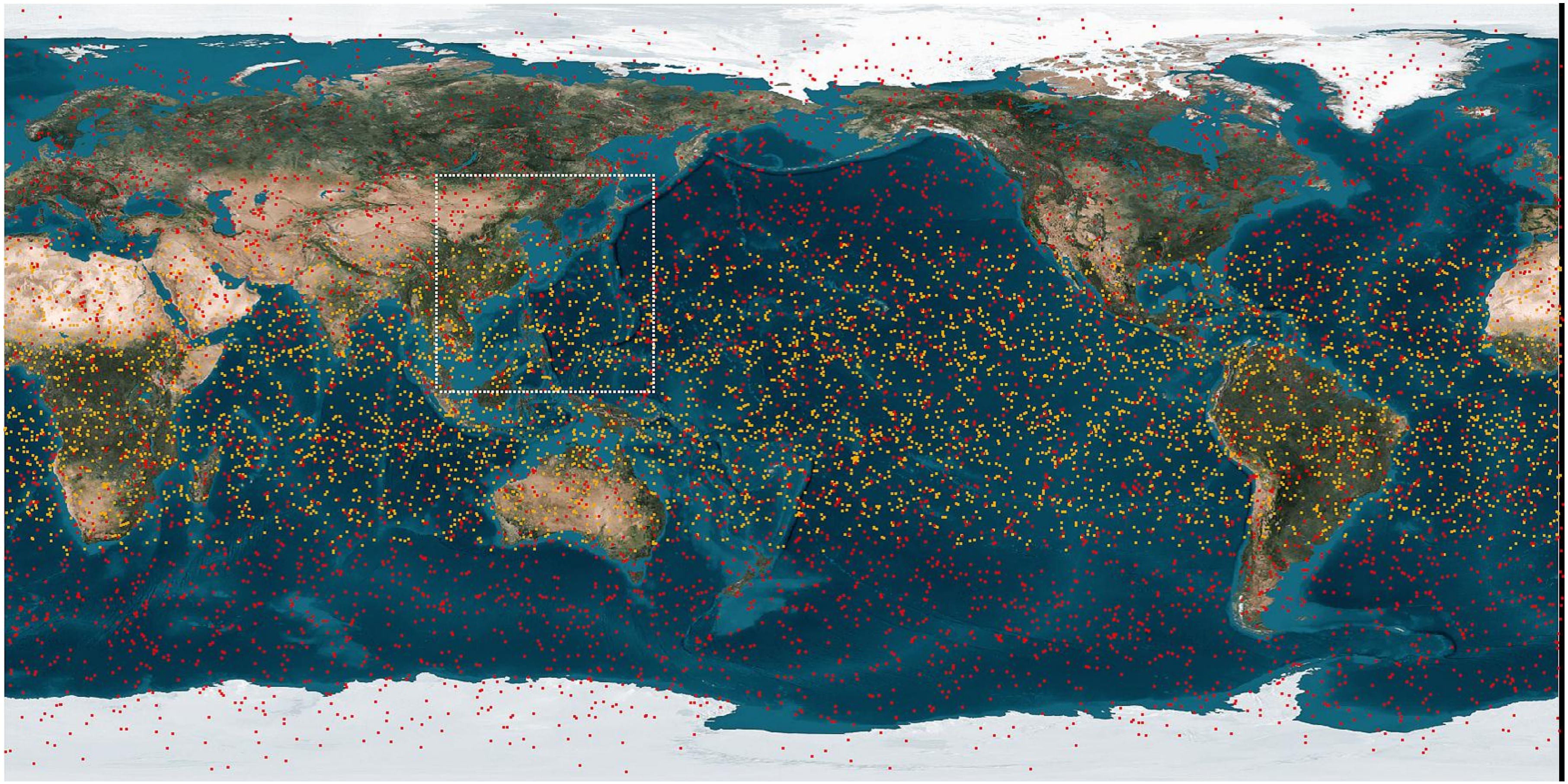
Total RO Data Distribution after the 1st and the 2nd Launch



11958 raw radio occultation profiles by 6 SC from the 1st launch (yellow dots) and 6 SC from the 2nd launch (red dots).

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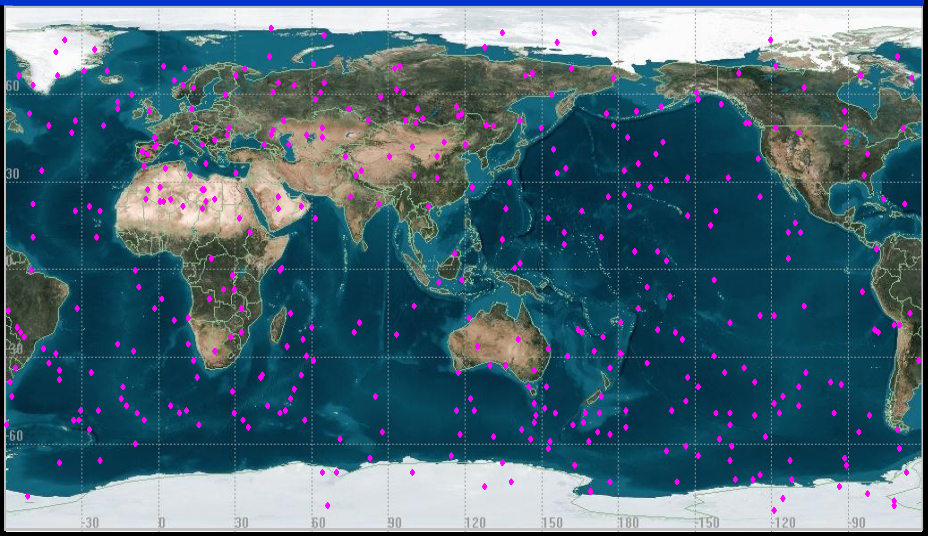
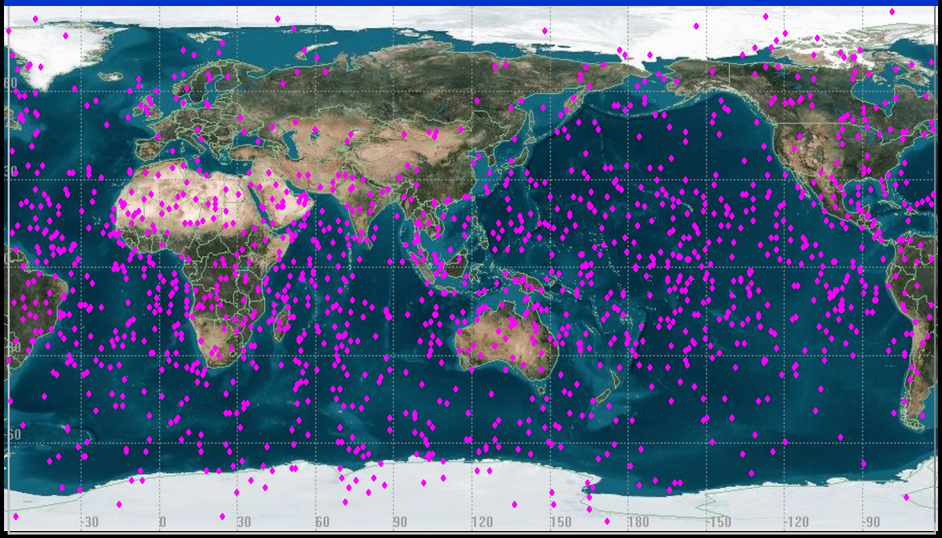
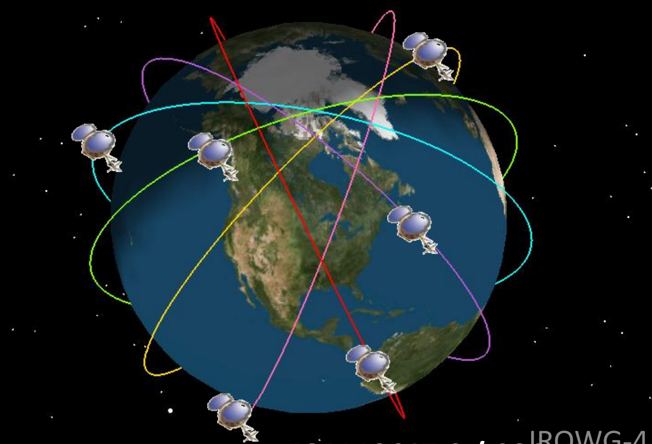
Greater FORMOSAT-7 v.s. FORMOSAT-3 Global GPSRO Coverage

FORMOSAT-3 Occultation – 3 Hrs Coverage

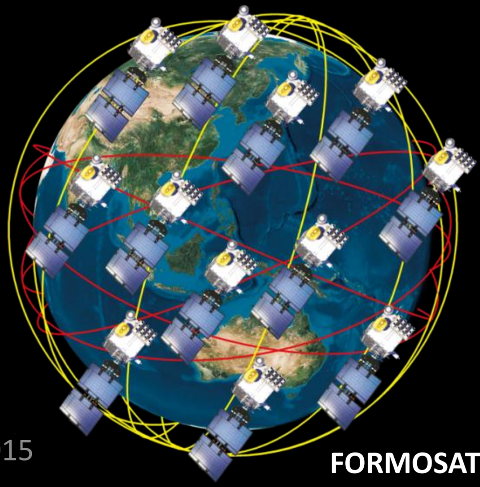


FORMOSAT-7 Occultation – 3 Hrs Coverage





FORMOSAT-3 / COSMIC



FORMOSAT-7 / COSMIC-2

FORMOSAT-7 / COSMIC-2 Mission Requirement

RO Data Products and Data Requirement

	Data Products	Data Requirement
Neutral Atmosphere	■ Bending angle profile ■ Refractivity profile ■ Temperature profile ■ Water vapor profile	■ Number of Profiles per day：8000 [Threshold] ■ Vertical Resolution： ● 0-25km：0.1 km ● 25-60km：1.0 km ■ Average Latency ：45 minutes [TBR]
Ionosphere and Space Weather	■ Total Electron Content (TEC) ■ Electron Density Profile (EDP) ■ Scintillation amplitude index(S_4) ■ Scintillation phase index (S_f)	■ Number of Profiles per day (TEC and EDP) ：12000 [Threshold] ■ Average Latency ：45 minutes
Metadata	■ GNSS & LEO satellite orbit location files ■ Excess phase files ■ Occultation tables ■ Records of major processing algorithm revisions	

System Implementation (1/2)

<table>
<tr><th>Satellite</th><th colspan="2">System</th></tr>
<tr><td>Spacecraft Bus</td><td colspan="2">Attitude Control, Power Control, Thermal Control, Propulsion, Command and Data Handling, Flight Software, Structure</td></tr>
<tr><td>Mission Payload</td><td colspan="2">TGRS (TriG GNSS Radio occultation System),</td></tr>
<tr><td rowspan="2">Science Payload</td><td>1st Launch (U.S. Contribute)</td><td>2nd Launch (Taiwan Contribute)</td></tr>
<tr><td>➢ IVM (Ion Velocity Meter)
➢ RF beacon (Radio Frequency Beacon scintillation instrument)
➢ LRR (Laser Retro-Reflector)</td><td>➢ Will be acquired from Taiwan domestic universities or research centers.
➢ Science payload interfaces shall be compatible with the ones of the 1st launch.
➢ A science mission compatible with 1st Launch is preferred.</td></tr>
</table>

System Implementation (2/2)

Constellation	System
First Launch (IOC)	◆ In Production: Mission Payload, Science Payload, Spacecraft Bus ◆ USAF Contract: SpaceX Falcon Heavy for STP-2 Mission ◆ In Development: U.S / Taiwan Data Processing Center ◆ In Planning: Ground Stations ◆ Target Launch Schedule: May 2016 (to be announced in May 2015)
Second Launch (FOC)	◆ Pending on the commitments of mission payload and launch vehicle ride to activate the spacecraft bus and science payload acquisition. ◆ Current Target Launch Schedule: 2018 (the earliest)

FORMOSAT-7 / COSMIC-2 Major Program Milestones

FORMOSAT-7 / COSMIC-2 Accomplished & Planned Major Milestones (1/2)

- **May-2010: Taiwan & U.S. signed the collaboration agreement for this Joint Mission**
- May-2010: Conducted Feasibility Design Review (FDR) Meeting in Taiwan
- Aug-2010: Joint Team Conducted Mission Definition Review (MDR) Meeting in Taiwan
- Jan-2011: JPL conducted TriG PDR (Preliminary Design Review)
- Apr-2011: Conducted the 1st ESC (Executive Steering Committee) Meeting in Taiwan
- Apr-2011: Conducted System Design Review (SDR) Meeting in Taiwan
- Nov-2011: NSPO ceased the 1st Spacecraft Bus procurement bid (< 3 bidders)
- Dec-2011: Conducted the 2nd ESC Meeting in Taiwan **(U.S Congress denied COSMIC-2 funding)**
- Feb-2012: Conducted the 3rd ESC Meeting in Taiwan
- Aug-2012: NSPO awarded the Spacecraft contract for the 1st Launch set to SSTL-U.K.
- Nov-2012: NSPO conducted the SSTL Spacecraft SDR (System Design Review) in Taiwan
- Dec-2012: USAF awarded an L/V contract to SpaceX Falcon Heavy for the 1st Launch
- Dec-2012: Taiwan & U.S. signed the IA#1 (Implementing Arrangement #1)

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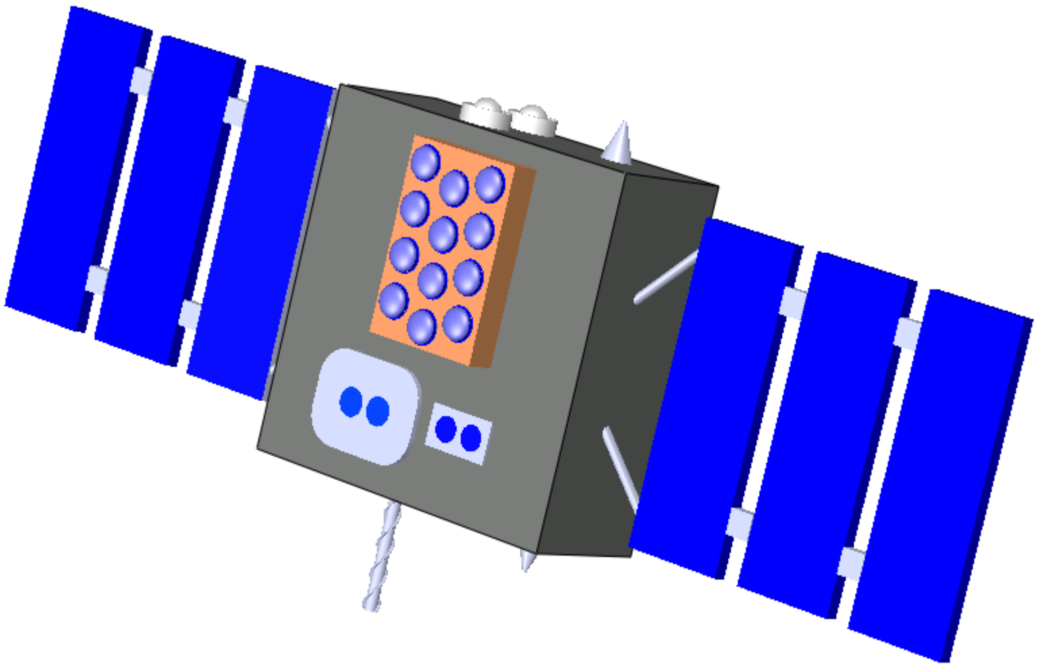
FORMOSAT-7 / COSMIC-2 Accomplished & Planned Major Milestones (2/2)

- Jan-2013: Conducted the 4th ESC Meeting in the U.S. **(Continuing Resolution Issue)**
- Jun-2013: NSPO conducted Spacecraft PDR (Preliminary Design Review) at SSTL U.K.
- Jun-2013: Conducted Joint Program PDR-A at SSTL U.K.
- Nov-2013: NSPO conducted Spacecraft CDR (Critical Design Review) at NSPO Taiwan
- Dec-2013: Joint Team Conducted Joint Program PDR-B at NSPO
- Jun-2014: NSPO conducted Spacecraft ITR (I&T Readiness) Review at SSTL U.K.
- Dec-2014: SSTL completed PFM I&T at SSTL U.K.
- **Mar-2015: FAR & SSTL delivers the PFM (Proto-Flight Model) and FM2 to NSPO**
- **Mar-2015: NSPO begins FM2~FM6 I&T at NSPO I&T Facility**
- **May-2015: SSTL delivers FM3~FM6 Kits to NSPO I&T Facility**
- **Mar-2016: NSPO delivers FM1~6 to Cap Canaveral and begins the launch campaign**
- **May-2016: Space-X conducts STP-2 Launch (FORMOSAT-7 / COSMIC-2 1st Launch)**
- **May-2016: NSPO conducts LEOP Check-Out and FM1~FM6 Constellation Deployments**

Spacecraft Bus Developments

NSPO Conceptual Design of the Spacecraft Bus Configuration

June 2012

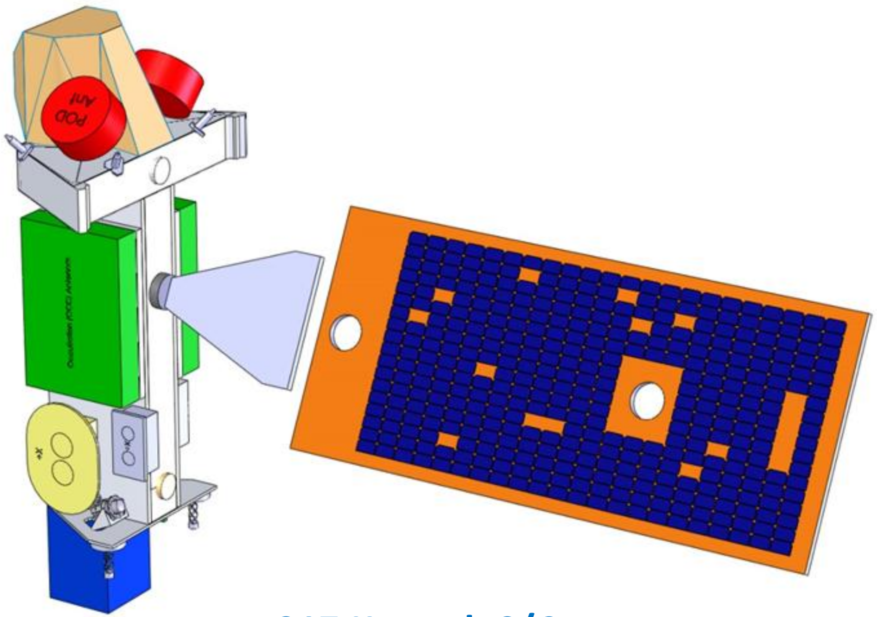


~ 223 Kg each S/C (including shared portion of the MSD*)

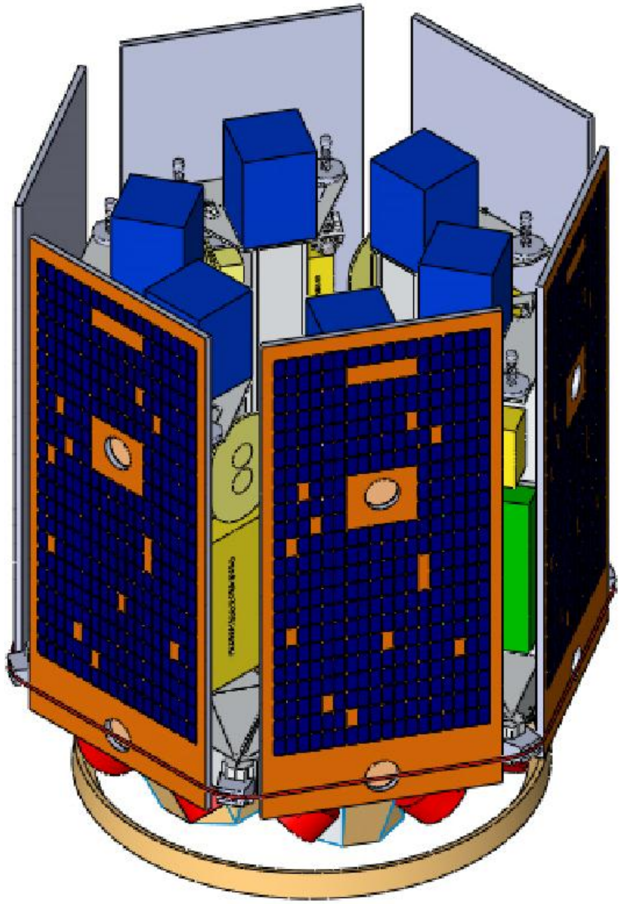
* Note: MSD - Multiple Satellites Dispenser

SSTL Original RFP Spacecraft Bus Configuration

August 2012



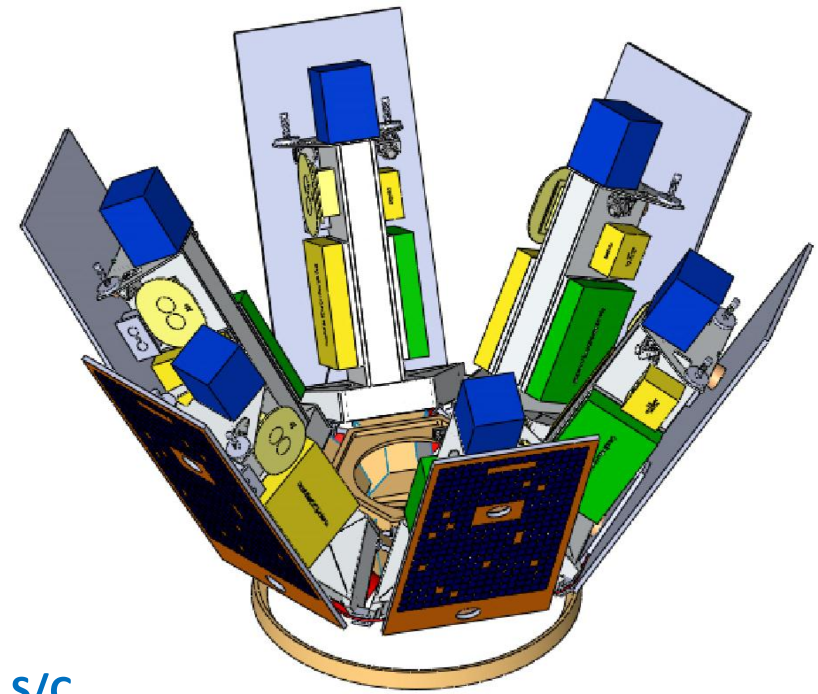
~217 Kg each S/C
~ 41.6 Kg one MSD



Courtesy of SSTL from Spacecraft Bus Proposal

SSTL Original RFP Spacecraft Bus fit inside MINOTAUR-IV L/V

August 2012



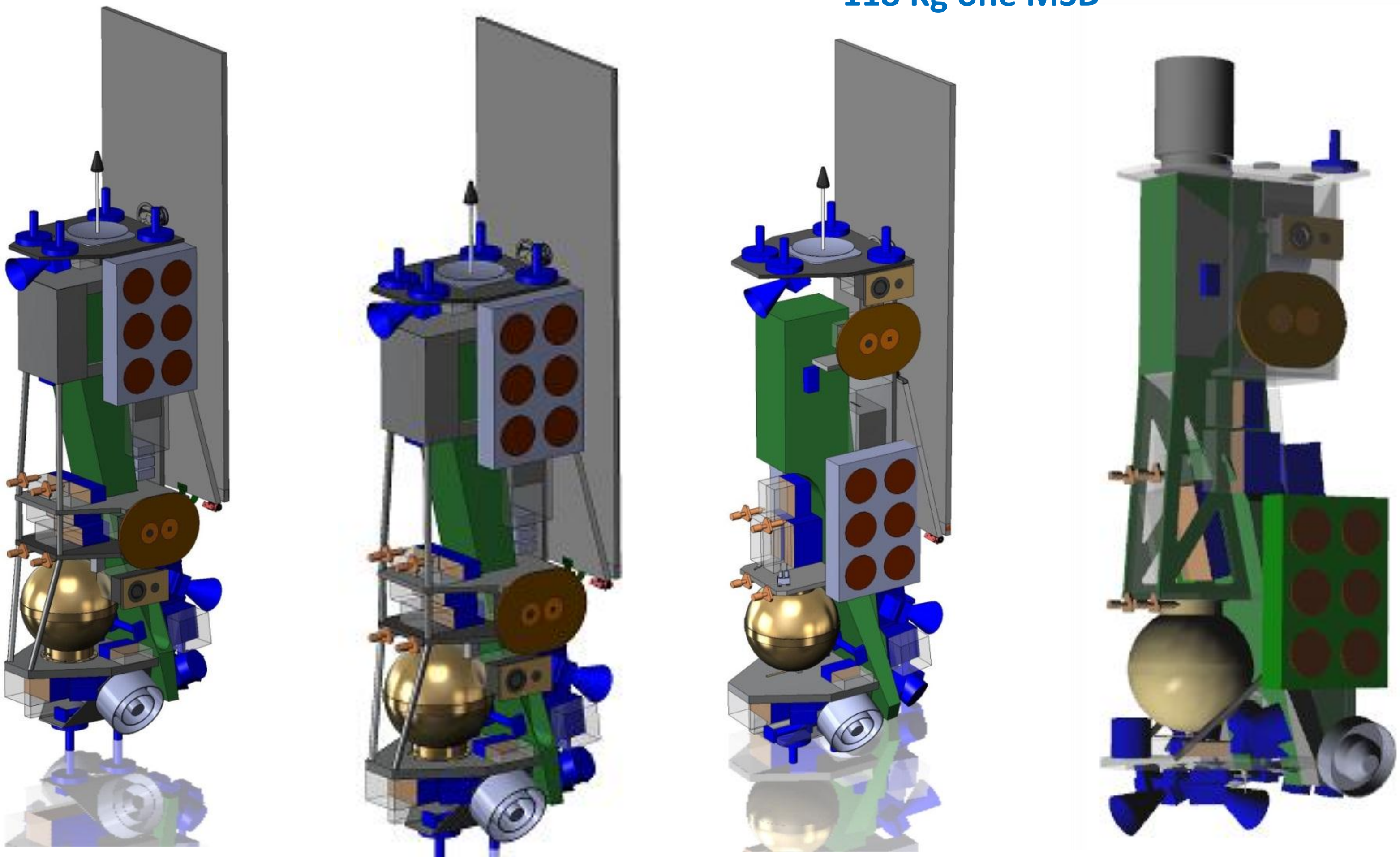
~217 Kg each S/C
~ 41.6 Kg one MSD

Courtesy of SSTL from Spacecraft Bus Proposal

SSTL Spacecraft Bus Configuration at System Design Review (1/2)

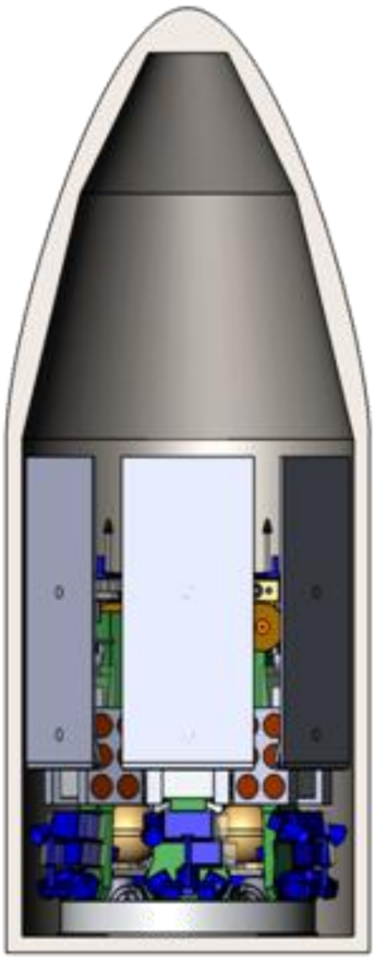
November 2012

~204 Kg each S/C
~ 118 Kg one MSD

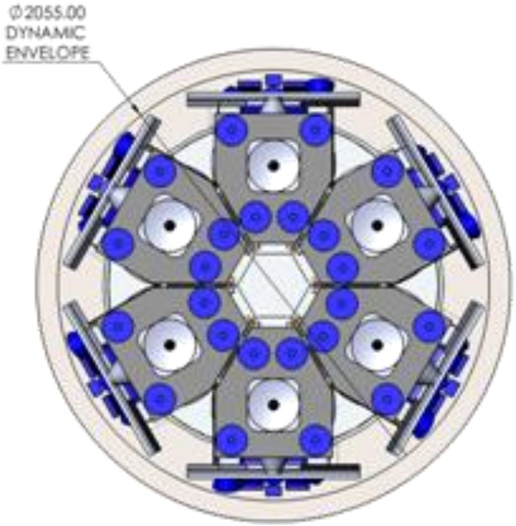


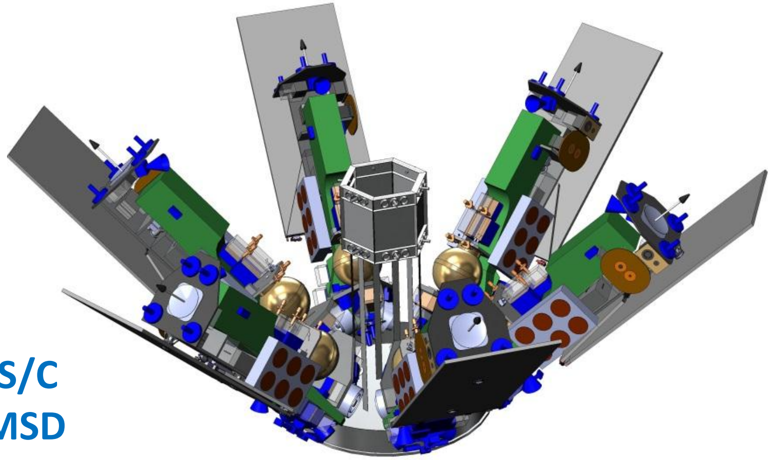
Courtesy of SSTL from Spacecraft Bus SDR

SSTL Spacecraft Bus Configuration at System Design Review



November 2012



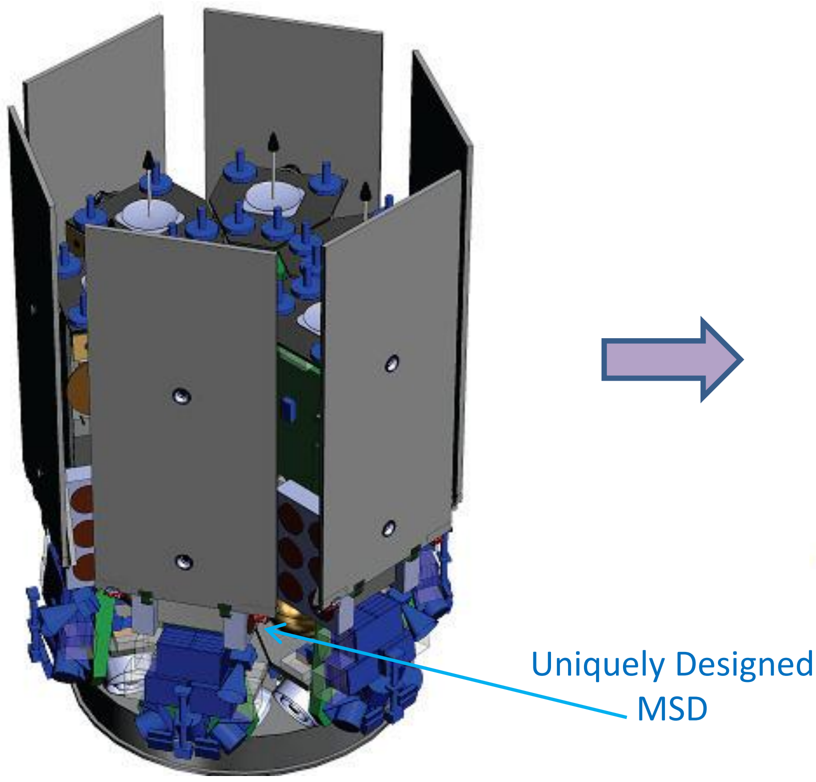


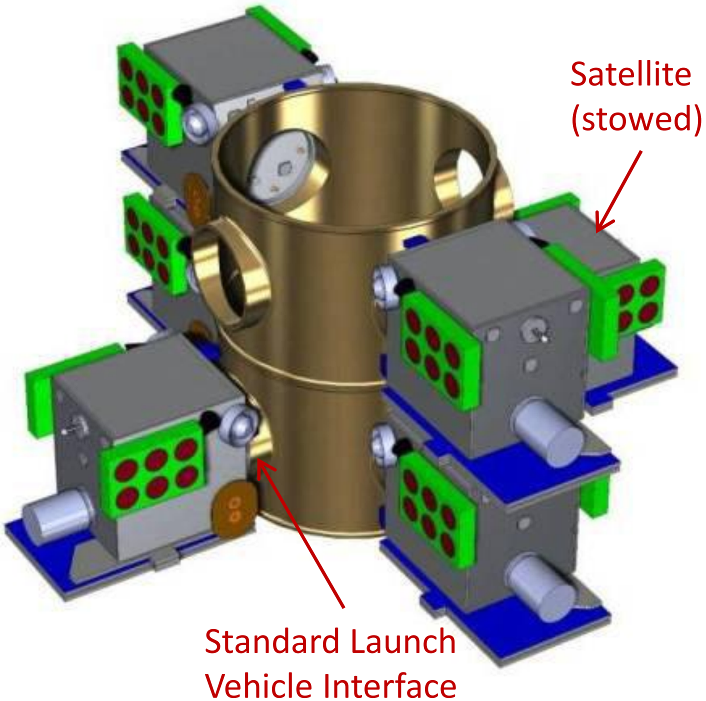
~204 Kg each S/C
~ 118 Kg one MSD
w/o margin

Courtesy of SSTL from Spacecraft Bus SDR

Stowed Configuration Change from MINOTAUR-IV → Falcon Heavy

The decision was jointly made in January 2013 to incorporate the MSD with ESPA Grande Ring for a better acquisition strategy for placing the launch vehicles for both Launches.





Courtesy of SSTL from Spacecraft Bus SDR

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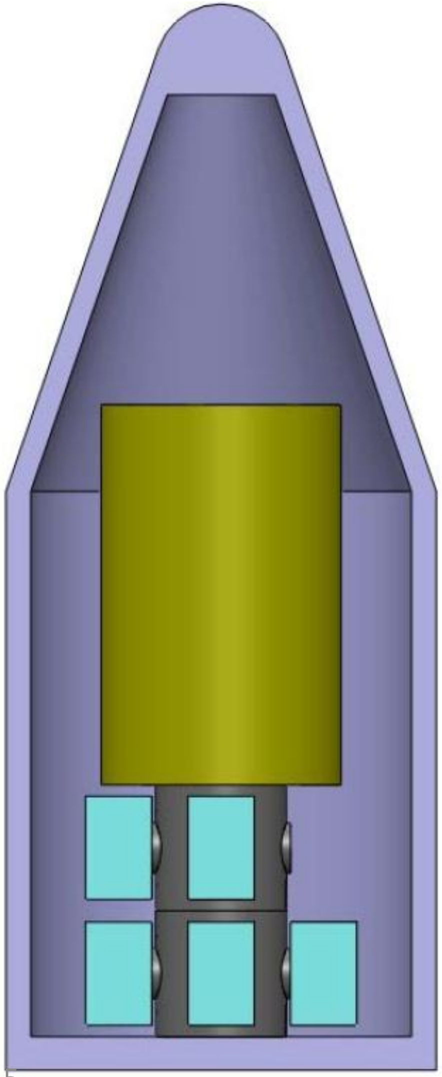
SSTL Spacecraft Bus Configuration to fit ESPA on Falcon Heavy L/V

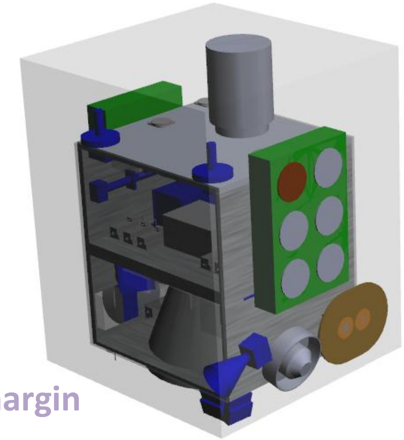
ESPA Grande Ring

January 2013



~285.4 Kg* each S/C
Using ESPA as MSD

* Note: 256.3 Kg w/o 5% margin

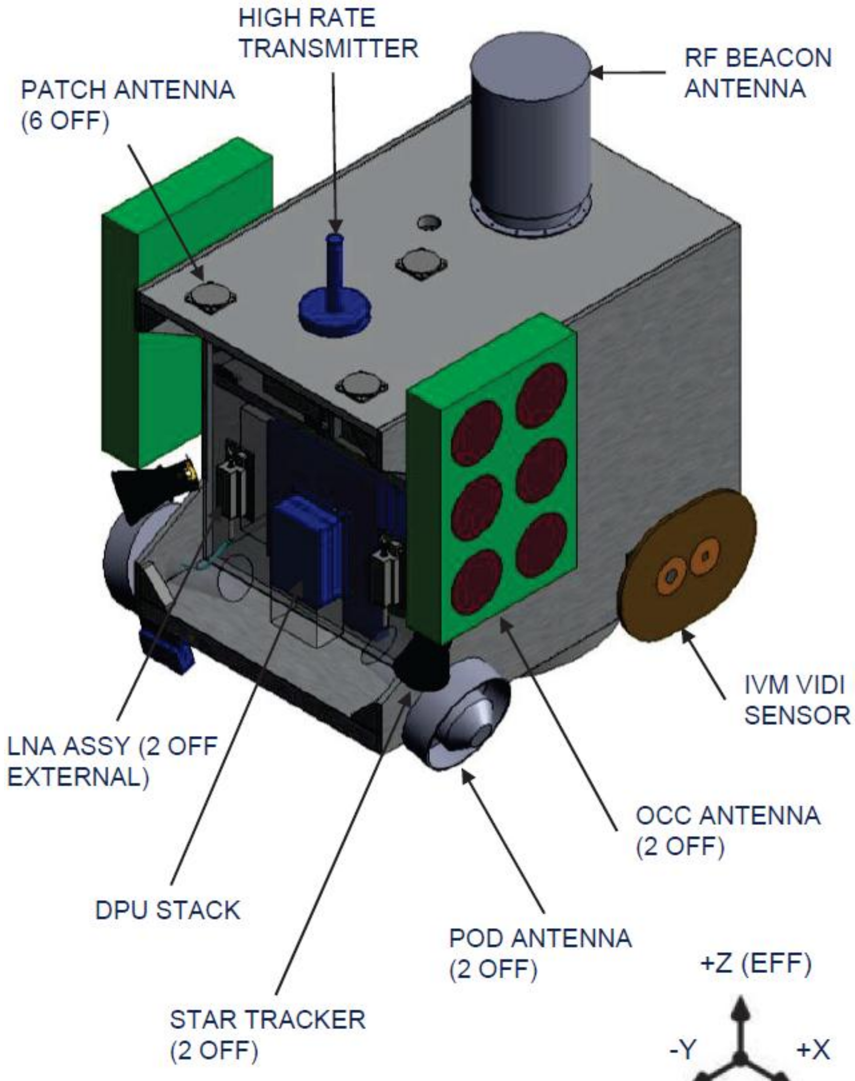


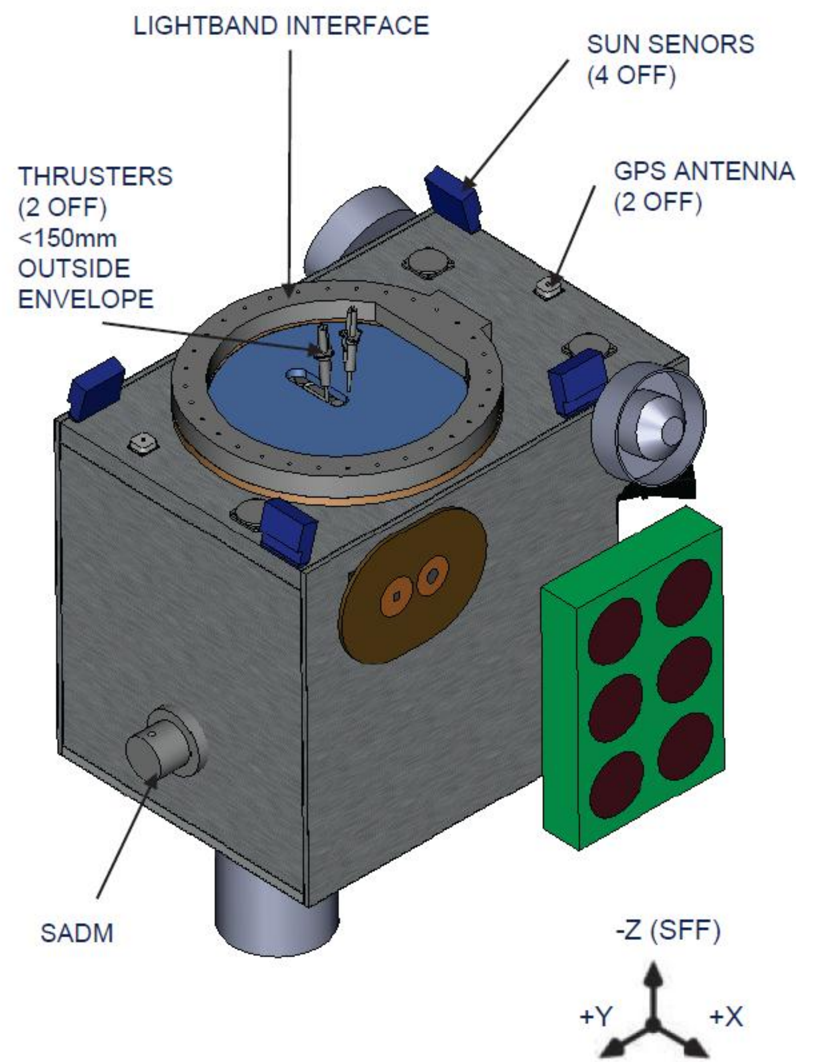
Conceptual Design of SSTL's Spacecraft

Spacecraft Bus Key Parameters and Requirements Overview

Parameters	Requirements
Dimensions (stowed)	1000 x 1250 x 1250 mm
Launch Mass (wet)	277.8 kg
Platform Power Required	229.8 W (orbit average)
Battery Capacity	> 22.5A-hr
Attitude	3-Axis; Knowledge < 0.07deg (3-sigma); Control < 1deg (3-sigma)
Propulsion	Hydrazine monoprop ~141 m/s
Communications	S-band TM/TC, 32kbps Uplink, up to 2Mbps Downlink
Navigation	GPS
Design Life	5 years, >66%
Availability	>95%
Launch Compatibility	EELV (ESPA Grande Adapter)
Payload support	> 2Gbits Data Storage; 39.4kg mass; 95W OAP

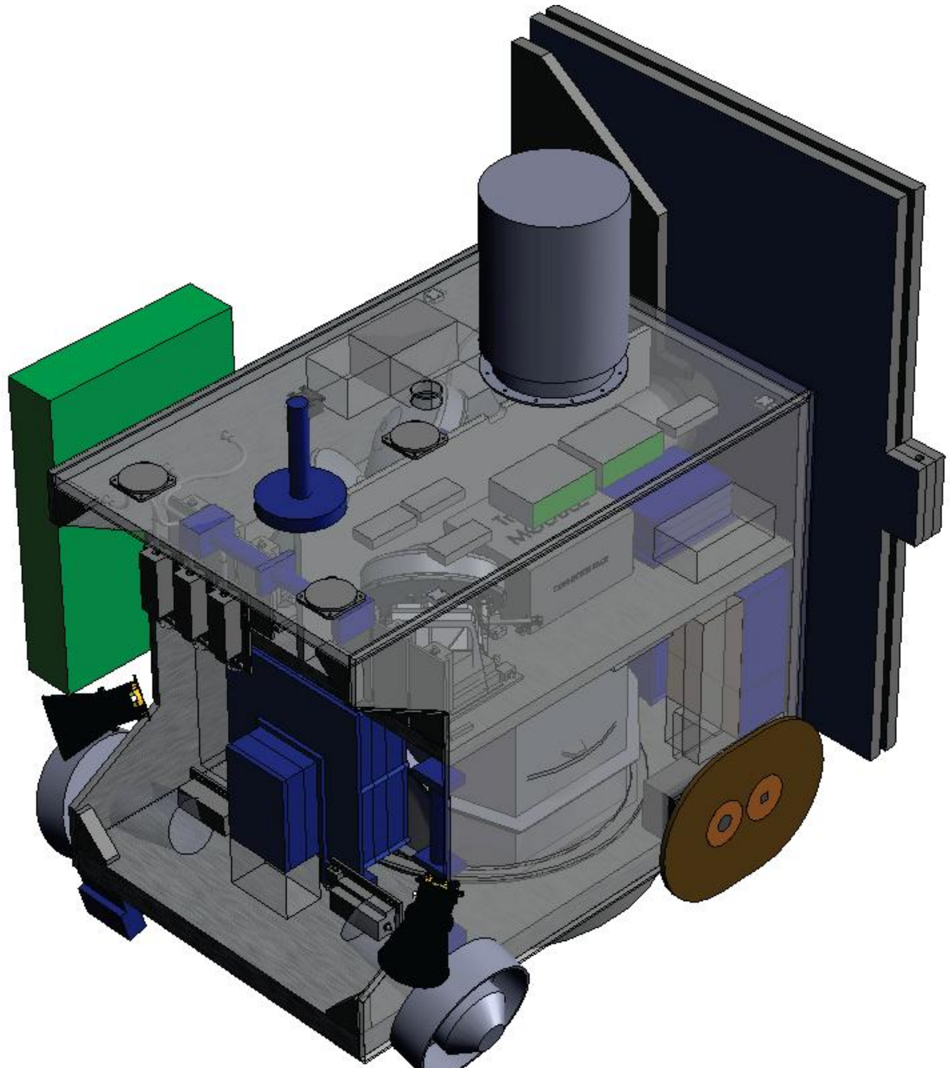
SSTL Spacecraft Bus Configuration at PDR / CDR (After June 2013)





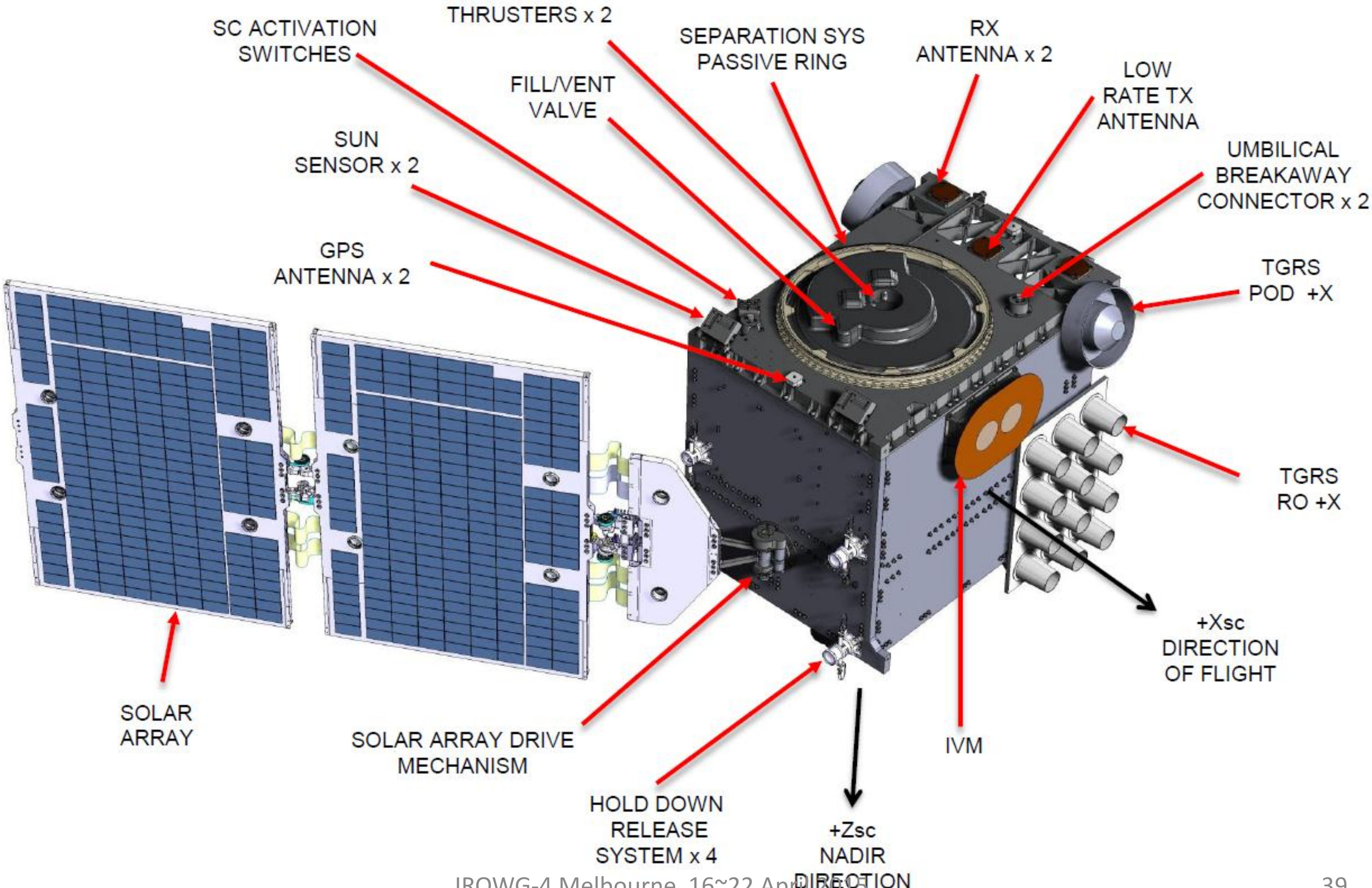
Courtesy of SSTL from Spacecraft Bus PDR/CDR

SSTL Spacecraft Bus Configuration as Designed (1/2)



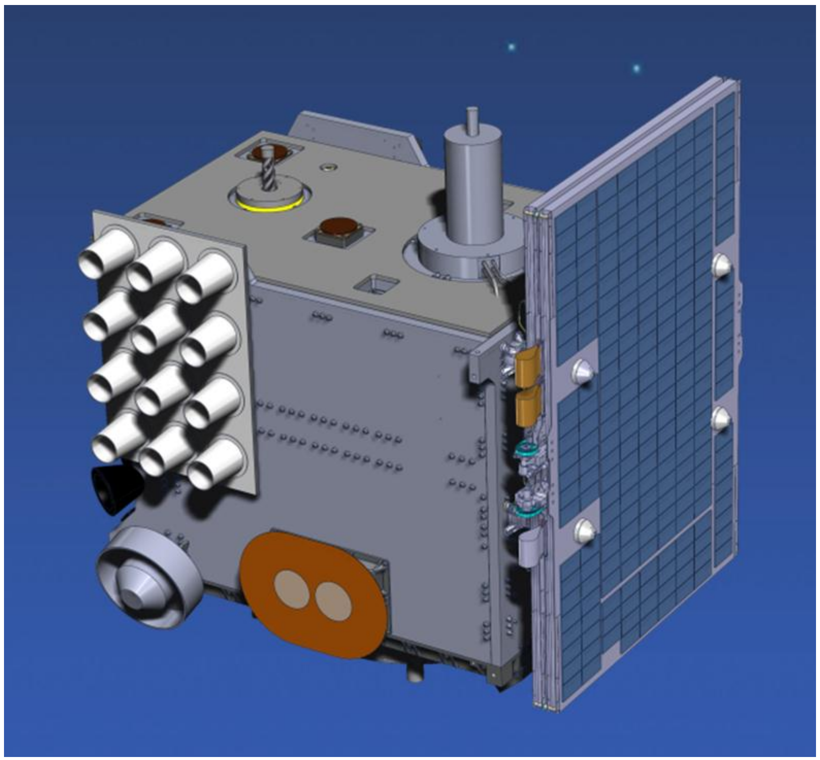
Courtesy of SSTL from Spacecraft Bus PDR/CDR

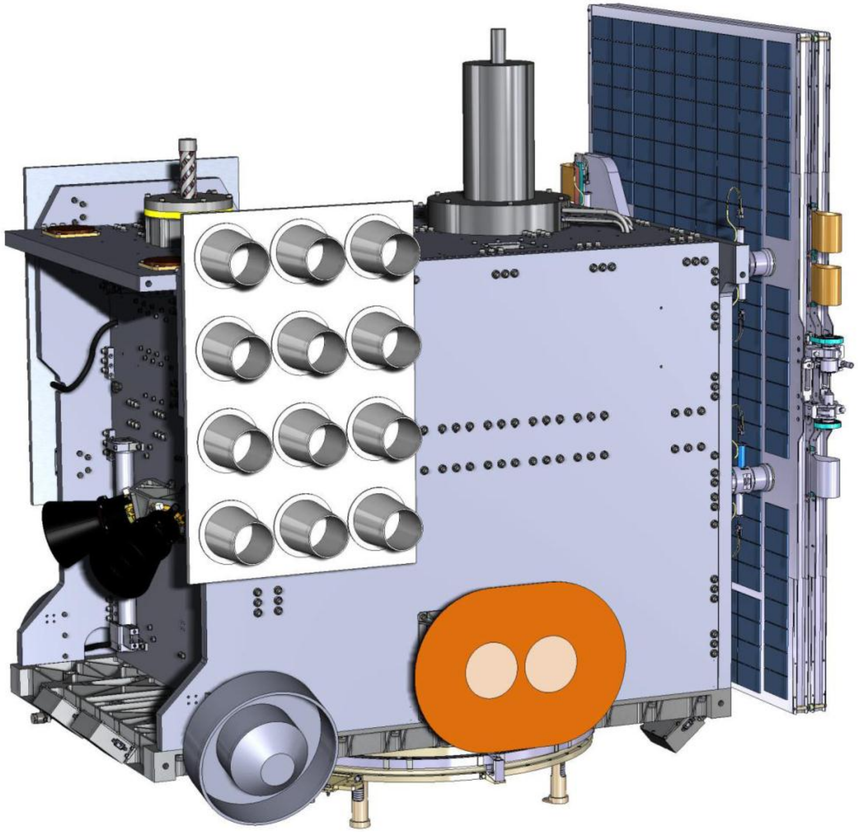
SSTL Spacecraft Bus Configuration as Designed (2/2)



Courtesy of SSTL from Spacecraft Bus PDR/CDR

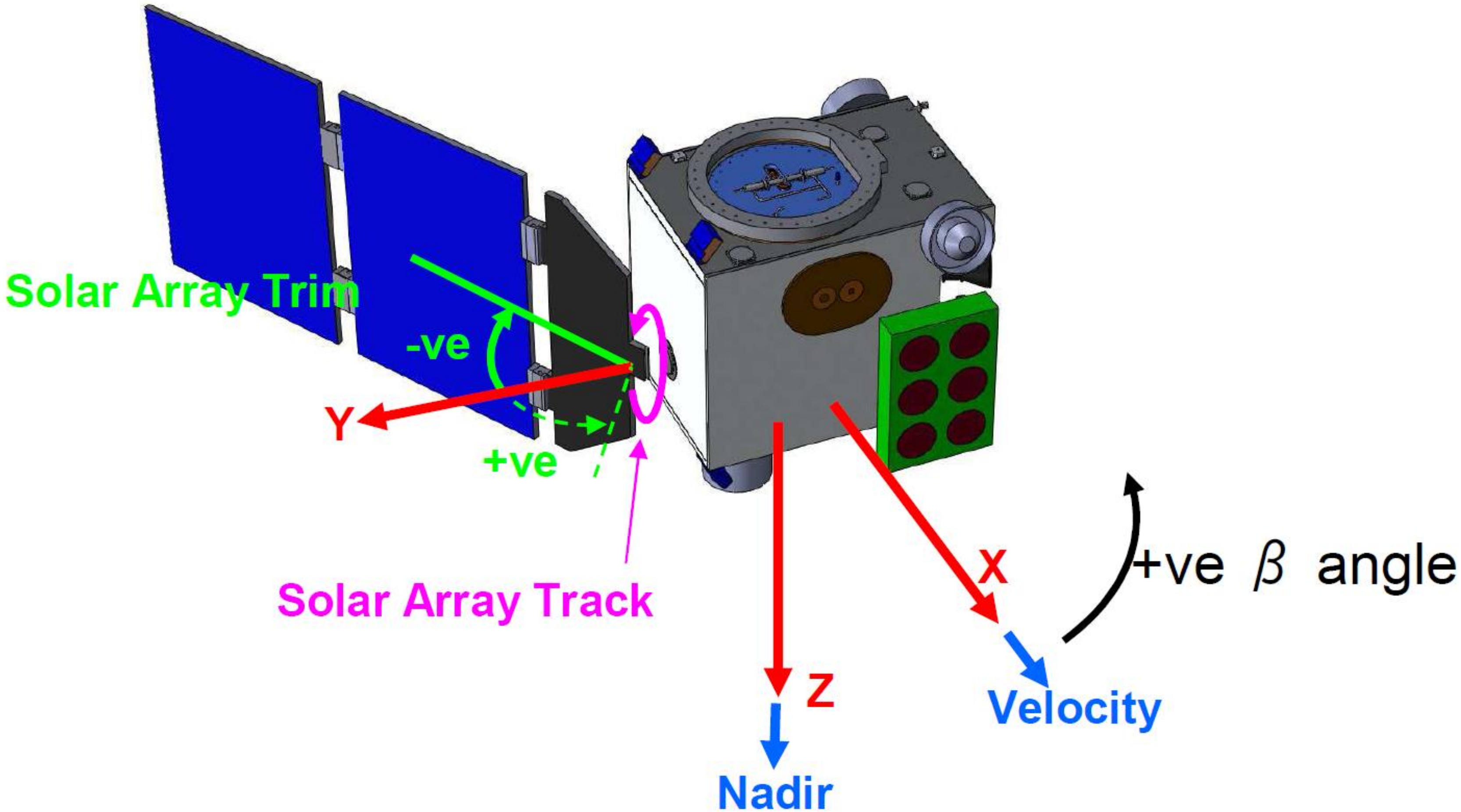
SSTL Spacecraft Bus Stowed Configuration





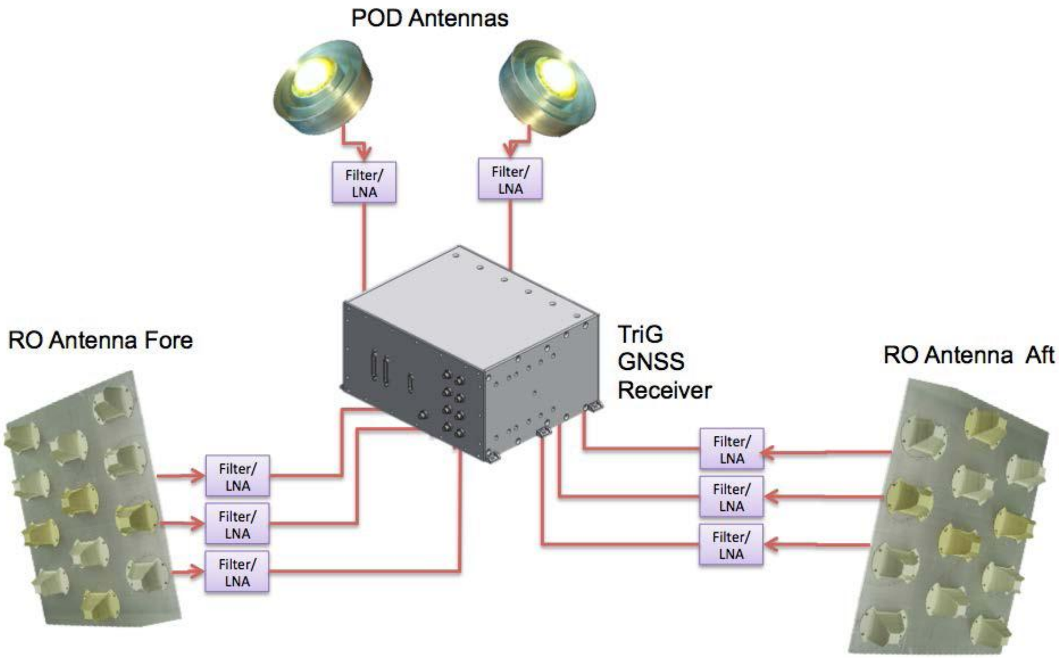
Courtesy of SSTL from Spacecraft Bus PDR/CDR

SSTL Spacecraft Bus Deployed Configuration



TGRS Mission Payload Developments

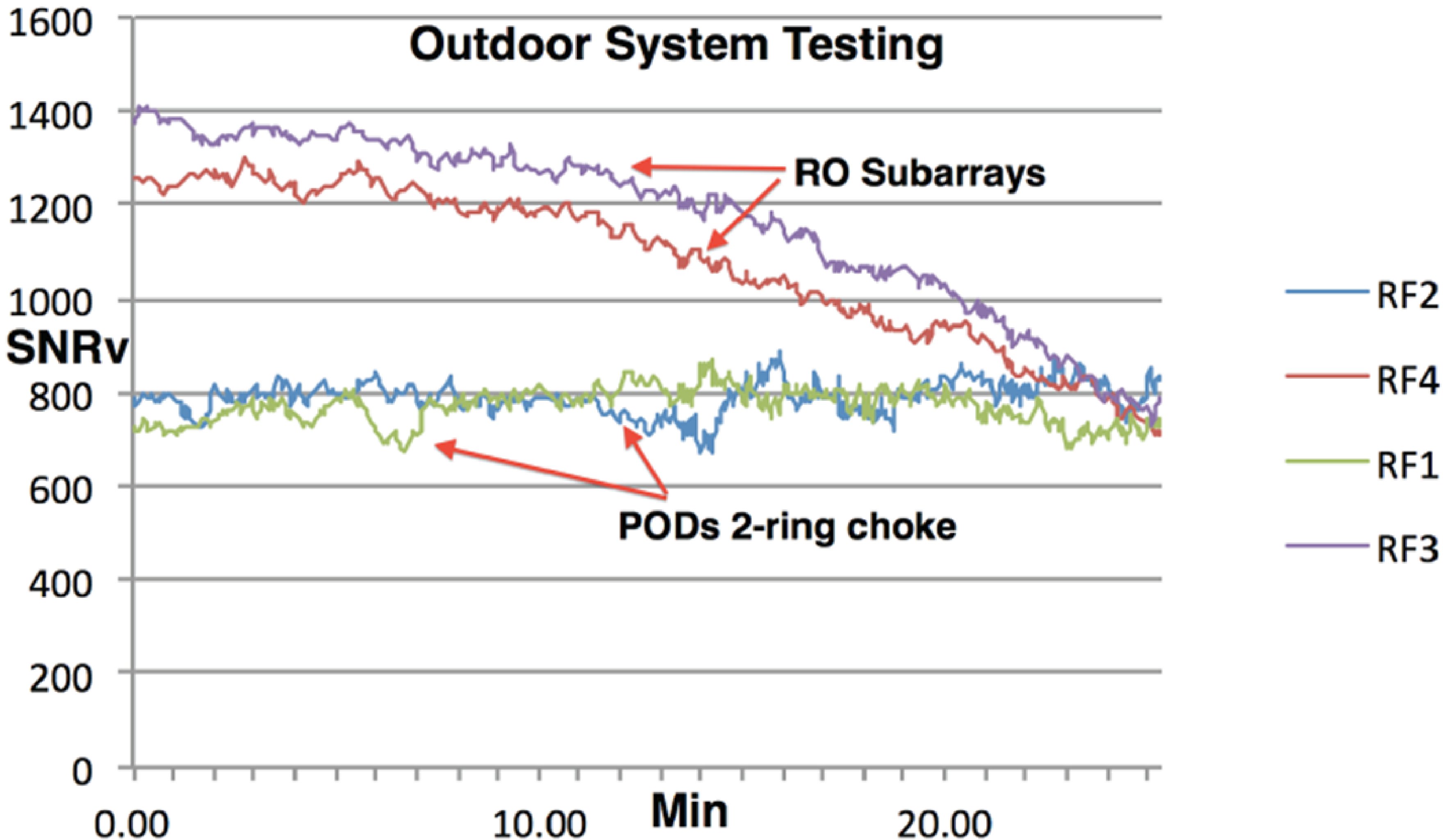
NASA-JPL TGRS Instrument



TGRS Block Diagram

The TGRS is a Global Navigation Satellite System (GNSS) science instrument for low Earth orbit. The TGRS consists of one FM TriG receiver, two Precise Orbit Determination (POD) antennas, two Radio Occultation (RO) antennas, eight Low Noise Amplifier (LNA)/Filter Assemblies for each antenna input and 16 RF cables. The TGRS is capable of tracking signals from GPS and GLONASS. It can measure the phase and group delay of the signals for orbit determination and radio occultation studies/application.

TGRS EM System Level Outdoor Testing



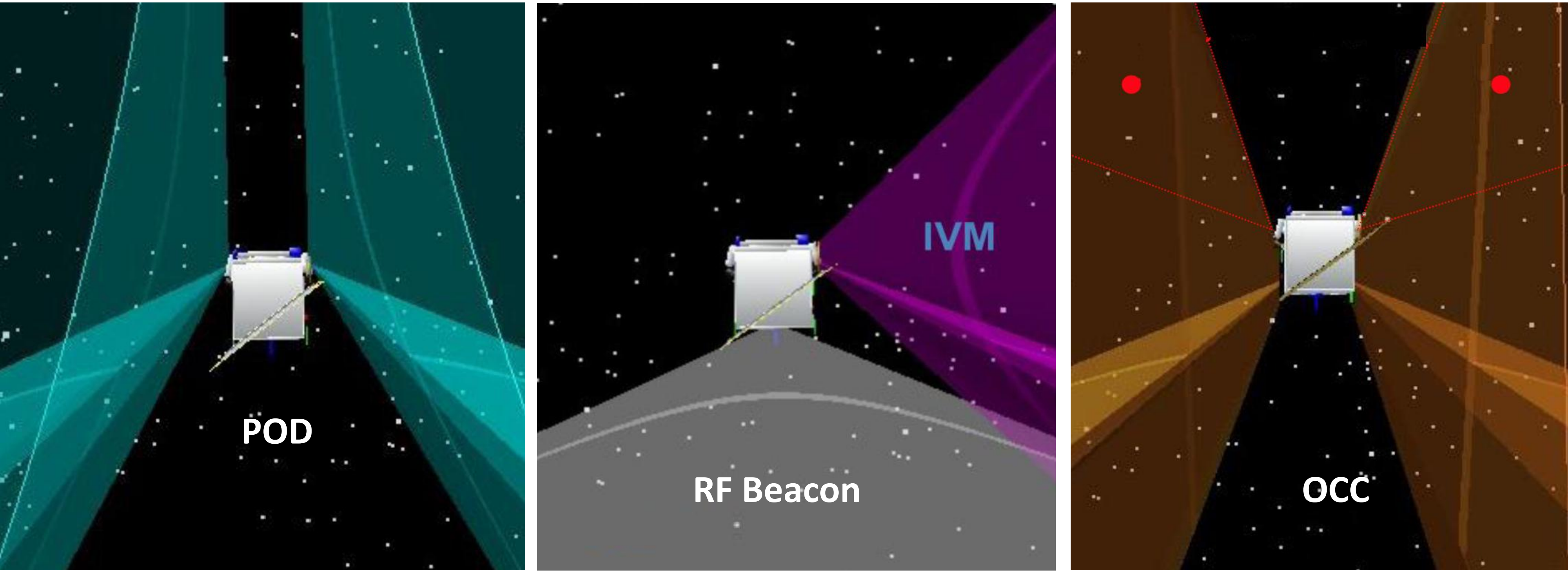
TGRS Neutral Atmosphere Product Requirements

	Data Type	Threshold	Objective
	Number of Profiles per day 1	1100	1100
	Vertical Data Resolution [km] a. Altitude Range 0 - 25 km MSL b. Altitude Range 25 - 60 km MSL	a. 0.1 b. 1.5	a. 0.1 b. 1.5
	Measurement Range a. Bending Angle [µrad] b. Refractivity [Refractivity-N units]	a. 0 - 120,000 b. 0 – 500	a. 0 - 150,000 b. 0 – 500
	RMS Measurement Uncertainty a. Bending Angle (0 – 10 km) [%] b. Bending Angle (10 – 20 km) [%] c. Bending Angle (20 - 60 km) [µrad] d. Refractivity (0 -10 km) [%] e. Refractivity (10 - 20 km) [%] f. Refractivity (20 - 30 km) [%]	a. 3 b. 0.7 c. 1.5 d. 0.4 e. 0.1 f. 0.3	a. 3 b. 0.7 c. 1.5 d. 0.4 e. 0.1 f. 0.3
	RMS Measurement Uncertainty a. Bending Angle (10 - 60 km) [µrad] b. Refractivity (30 km) [%] c. Bending Angle (10 - 60 km) [µrad] d. Refractivity (30 km) [%]	a. 0.36 b. 0.076 c. 0.78 d. 0.16	a. 0.18 b. 0.038 c. 0.39 d. 0.08
	Systematic Measurement Uncertainty a. Bending Angle (0 - 60 km) [µrad] b. Refractivity (30 km) [%]	a. 0.05 b. 0.04	a. 0.016 b. 0.013

TGRS Ionosphere Product Requirements

	Data Type	Threshold
	TEC Measurement Range [TECu] <TEC is measured in TEC units (TECu) = 1016 electrons/m2>	0 to 2,000
	Systematic Measurement Error a. Relative [TECu] b. Absolute [TECu]	 0.3 3
	Number of Limb TEC Profiles per day	1015
	Number of Zenith hemisphere TEC tracks/day (each TEC arc is expected to be in two tracks corresponding to the TGRS fore and aft POD antennas)	1015
	TEC sampling rate [seconds] a. Occulting satellites b. Zenith Hemisphere Satellites	 1 10
	Measurement Range a. S4 [dimensionless] b. σϕ [radians]	 0.1 to 1.5 0.1 to 3.14
	RMS Measurement Uncertainty a. S4 [dimensionless] b. σϕ [radians]	 0.1 0.1
	GNSS Frequencies for S4/σϕ Calculations	L1/L2
	S4/σϕ Underlying Minimum Sample Rate [Hz]	50
	S4/σϕ Calculation Time Interval [seconds]	10
	S4/σϕ Calculation Cadence [seconds]	10
	Tracks Analyzed for S4/σϕ Calculations	All
	Ionospheric Occultation High Rate Data Sent to Ground (60 km to S/C Altitude)2	Strongly scintillated profiles up to 10% of sensor data budget
	Ionospheric Tangent Altitude Range [km]	60 – S/C Altitude

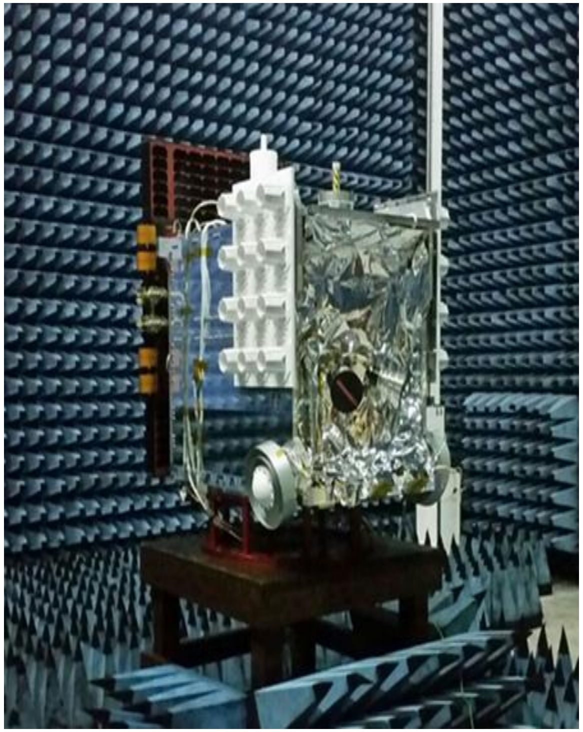
Payload Field of Views (FOV) for Analysis



Courtesy of SSTL

FORMOSAT-7 / COSMIC-2 Current Satellite Production Status

FORMOSAT-7/COSMIC-2 PFM Testing at British Aerospace in Stevenage, U.K.

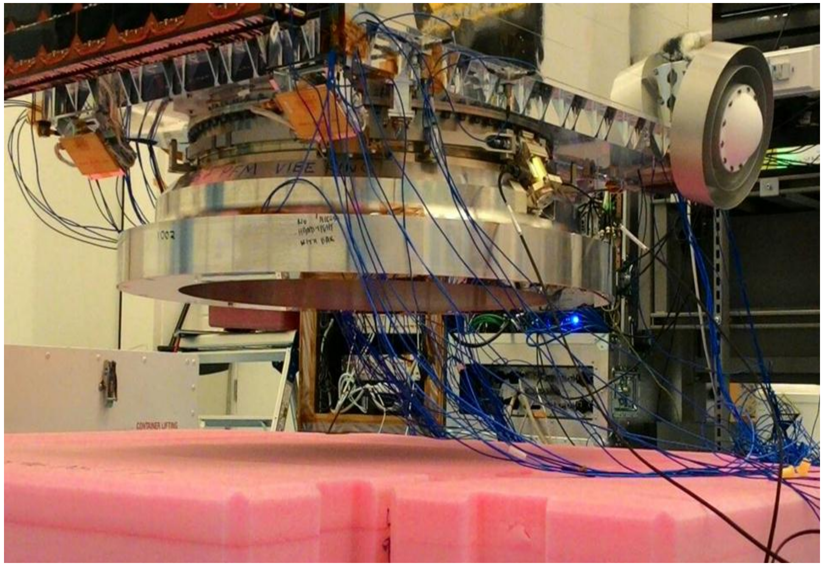


EMC / EMI Testing in Anechoic Chamber (Nov. 2014)

Dynamic Testing on Vibration Shaker (Dec. 2014)

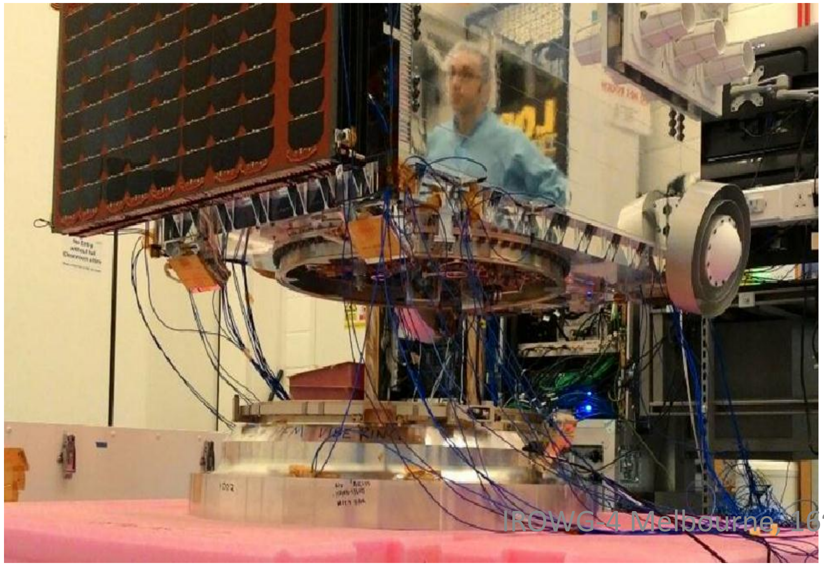
Courtesy of SSTL

FORMOSAT-7/COSMIC-2 PFM Testing
Separation System Test at SSTL U.K.



Before

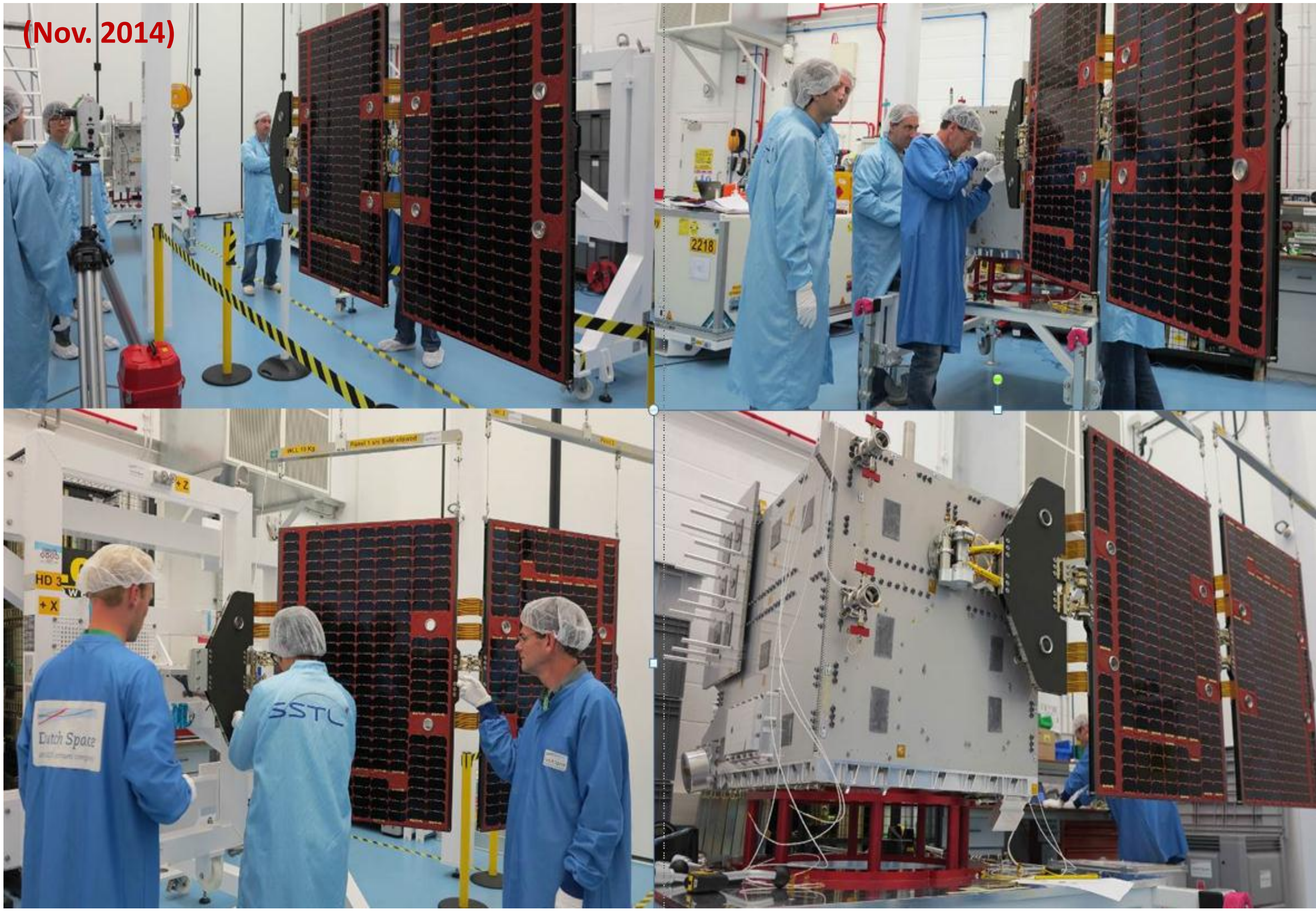
Satellite-to-Launch Vehicle Adaptor
Clampband Separation System Test (Dec. 2014)



After

Courtesy of SSTL

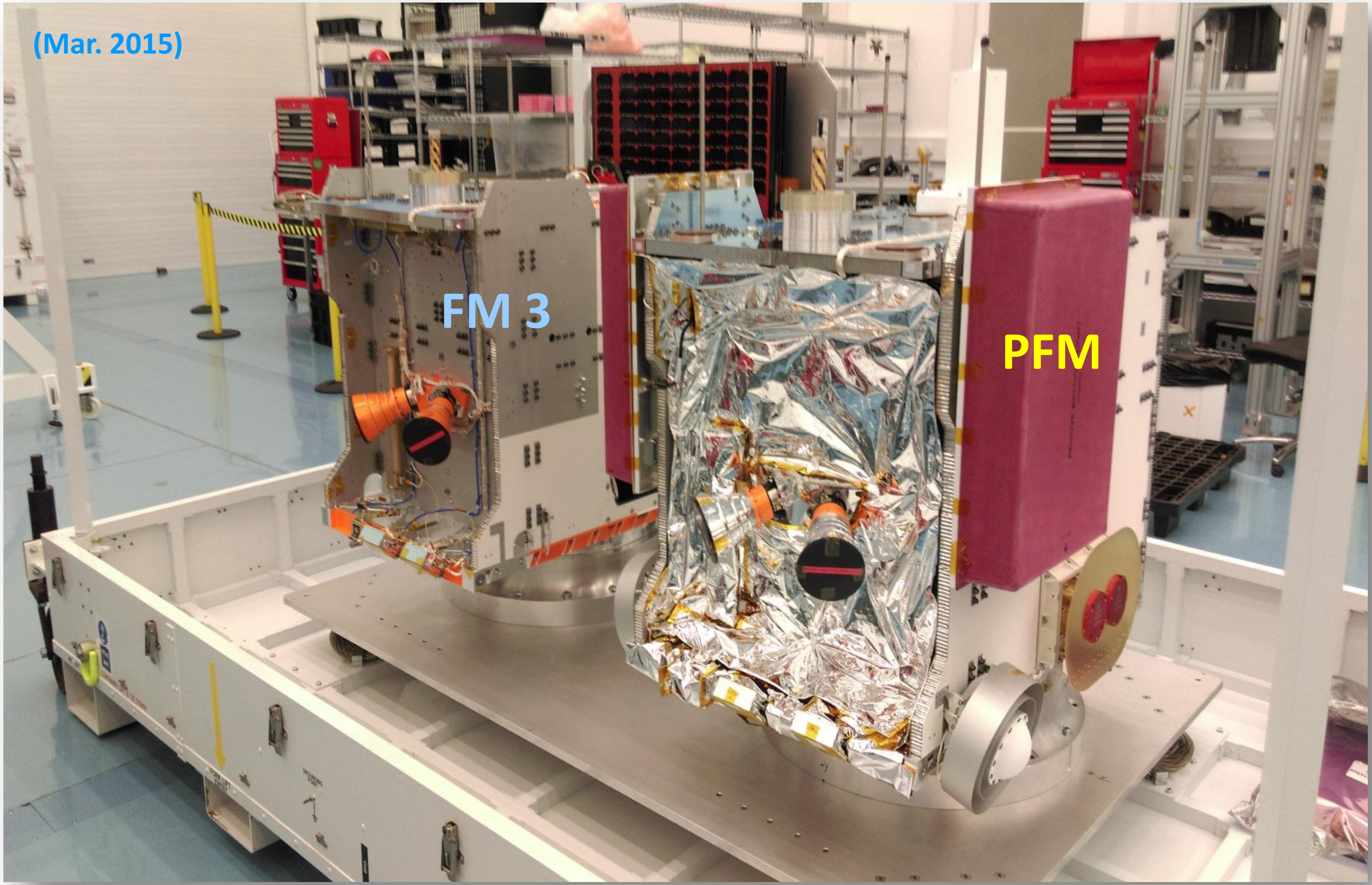
PFM Solar Array Undergoing Deployment Test at SSTL U.K.



Solar Panels Supplier: Dutch Space

Courtesy of SSTL

PFM and FM3 Ready for Packing to Ship in U.K. SSTL High-Bay



PFM / FM3 & GSE Arrival at NSPO I&T Facilities (March 26, 2015)

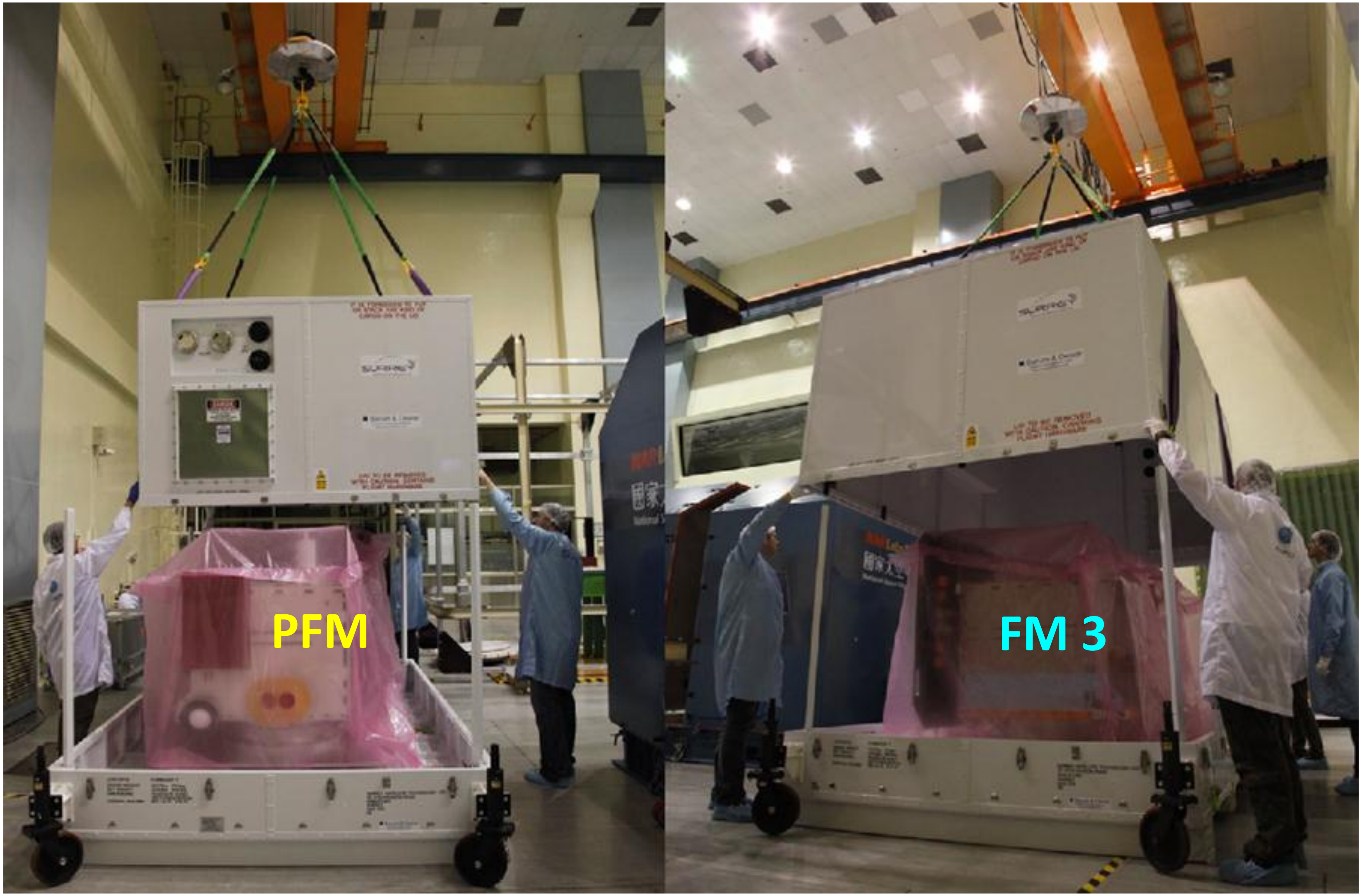

Arriving


Inspecting


Loading


Loading

PFM and FM3 Unpacking at NSPO I&T High-Bay



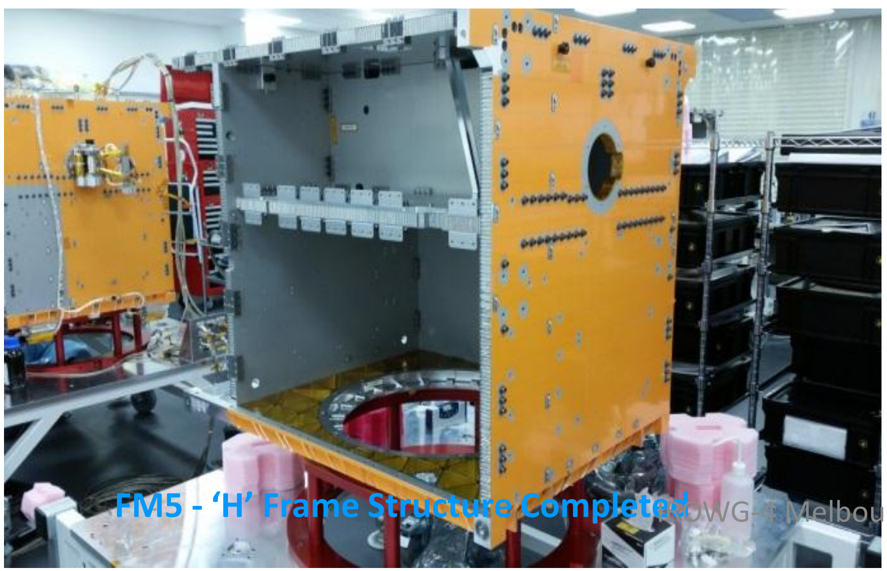
NSPO Director General Chang, et. al Thumb-Up to the PFM & FM3 Receiving

Setting Up GSE and SSTL / NSPO I&T On-Site Training

Status of the Remaining FM Production at SSTL U.K.

FM2 - Software and SKED Development Test Bed

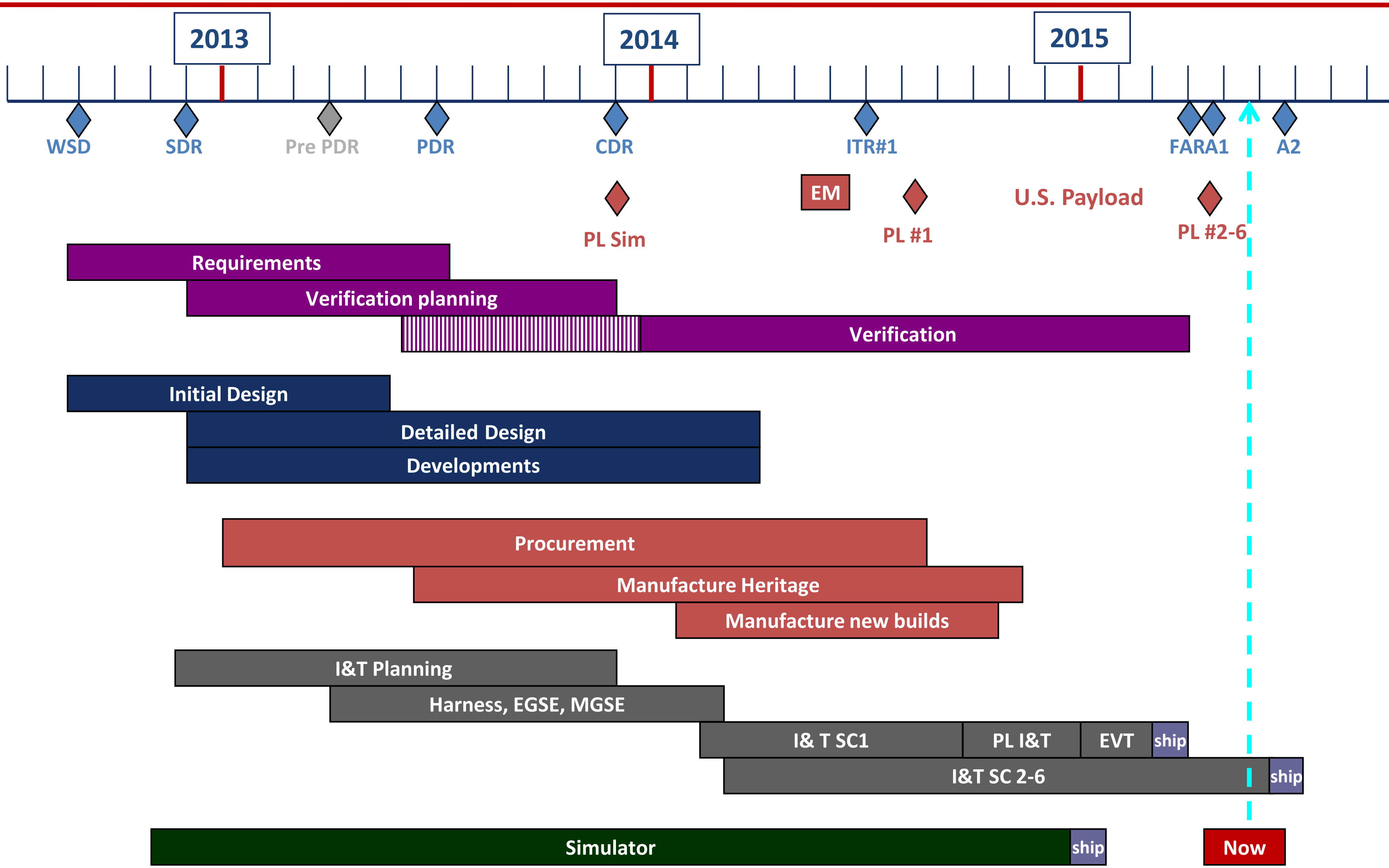
FM4 - Structure & Harness Checked-Out and Integrated



FM5 - 'H' Frame Structure Completed

FM6 – Just Received Structural Panels no Assembly Photo

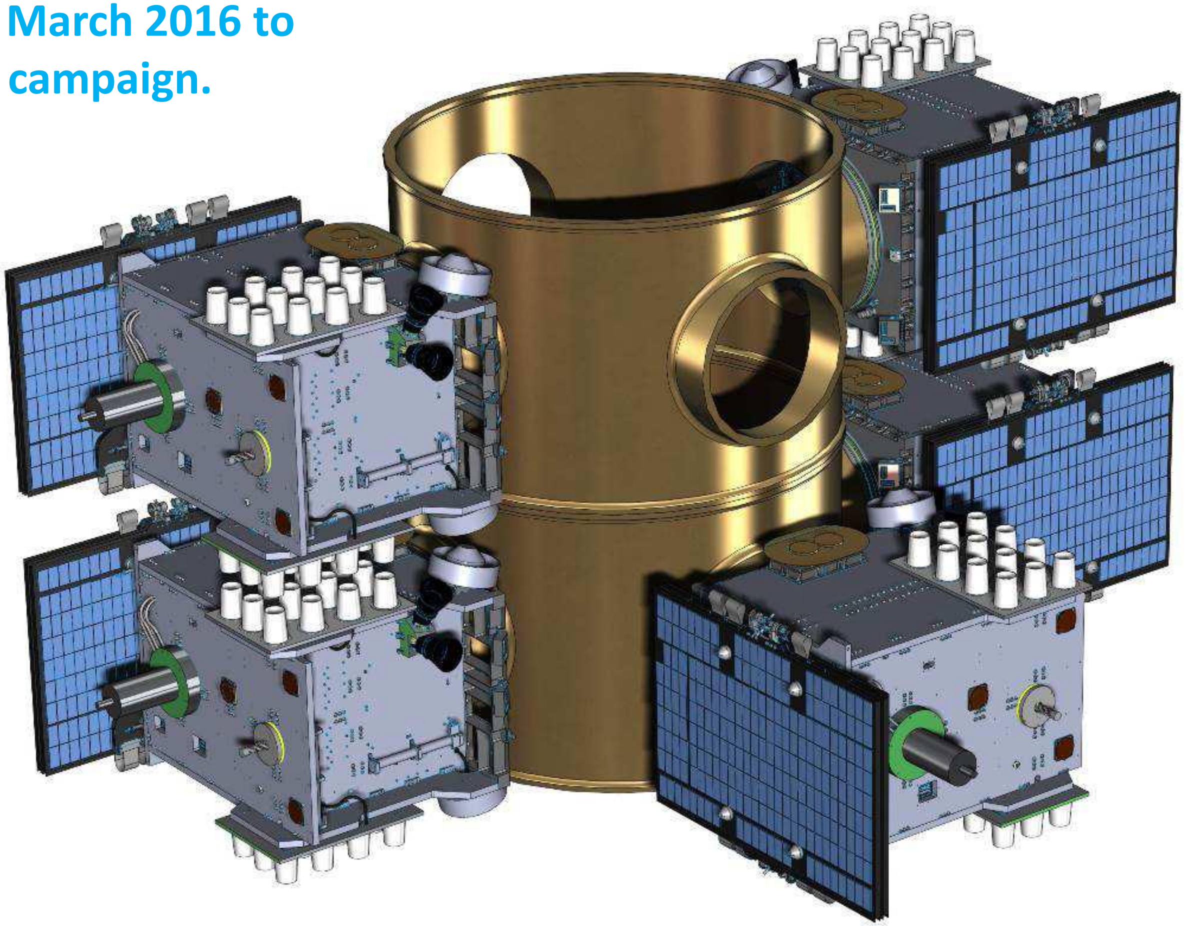
SSTL Spacecraft Bus Schedule Overview



Launch System Developments

FORMOSAT-7 / COSMIC-2 Satellite Preparation for Launch

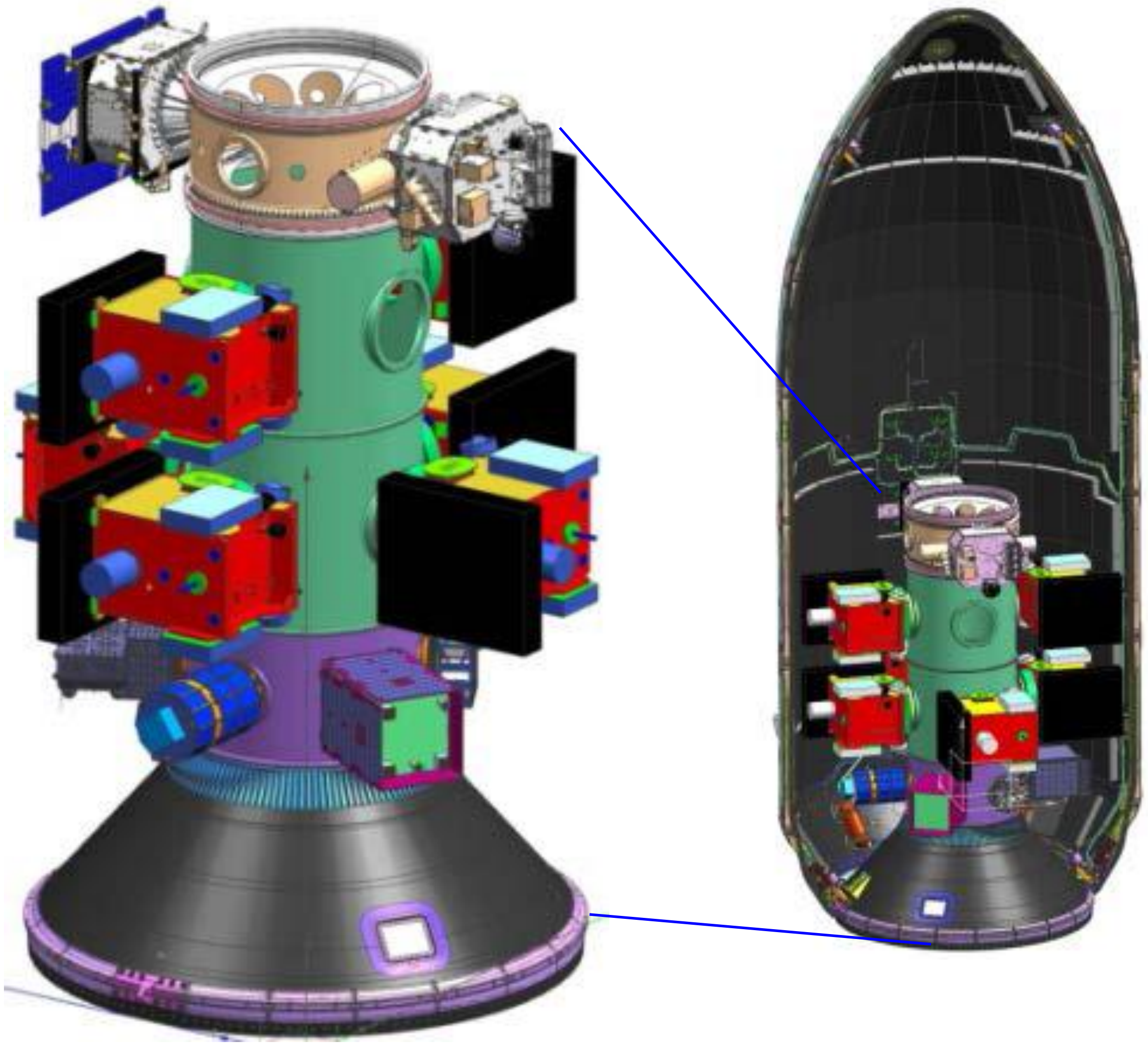
NSPO will ship all six satellites to Cap Canaveral in March 2016 to begin the launch campaign.



Curtsey of SSTL

All STP-2 Satellite Preparation for Launch

STP-2 Primary Passenger:
FORMOSAT-7 / COSMIC-2
STP-2 Co-Passengers:
DSX;
FalconSat-6;
GPIM;
OTB;
NPSAT-1;
Oculus;
Prox-1



Curtsey of SpaceX

Planned Launch Site: SpaceX Launch Pad LC-39A

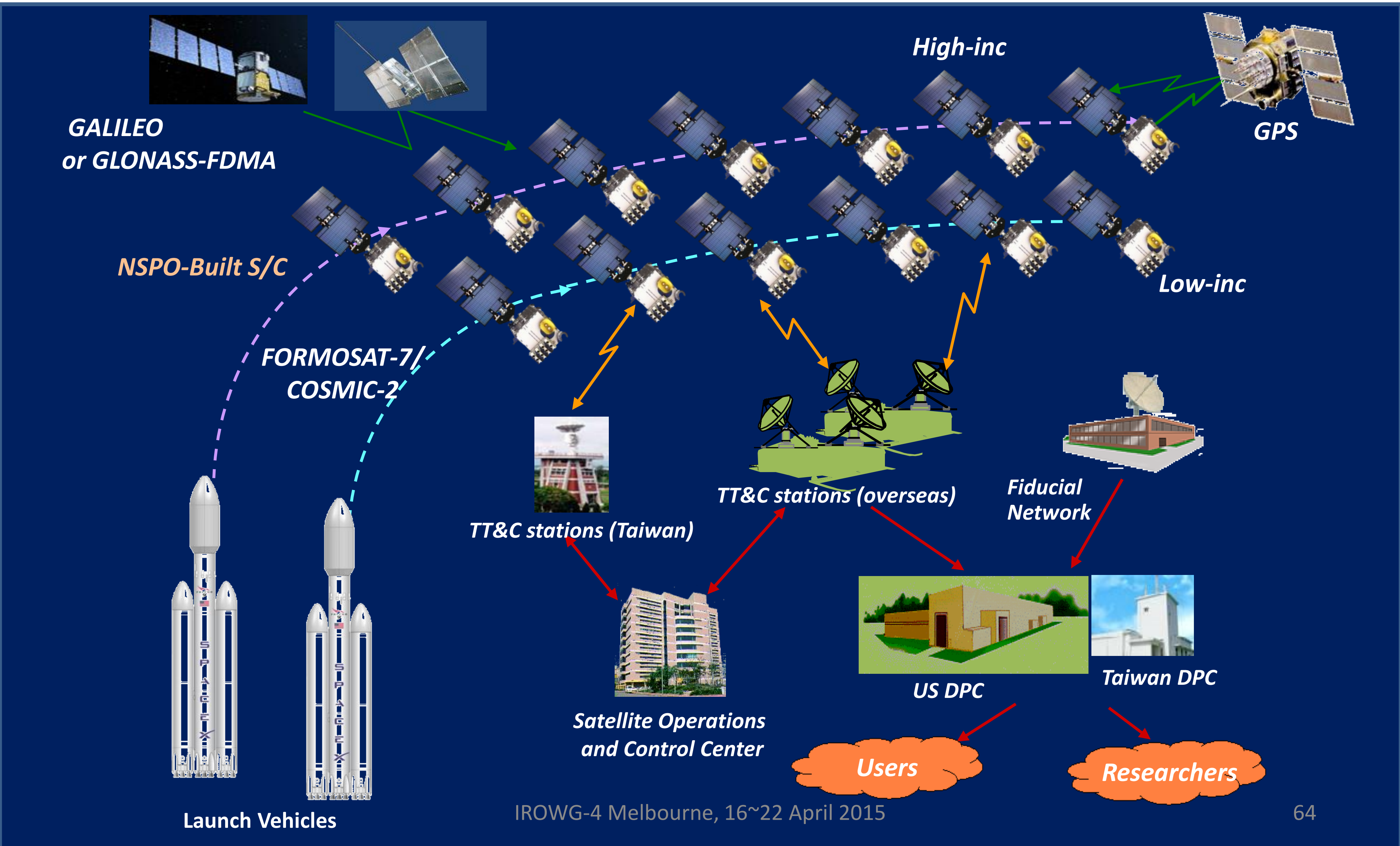
Falcon Heavy from LC-39A CCAFS

Source from http://www.astronautix.com/sites/caplc39a.htm
and https://www.google.com.tw/search?q=LC-39A+CCAFS

STP-2 Launch Vehicle: SpaceX Falcon Heavy

Satellite Constellation Deployment

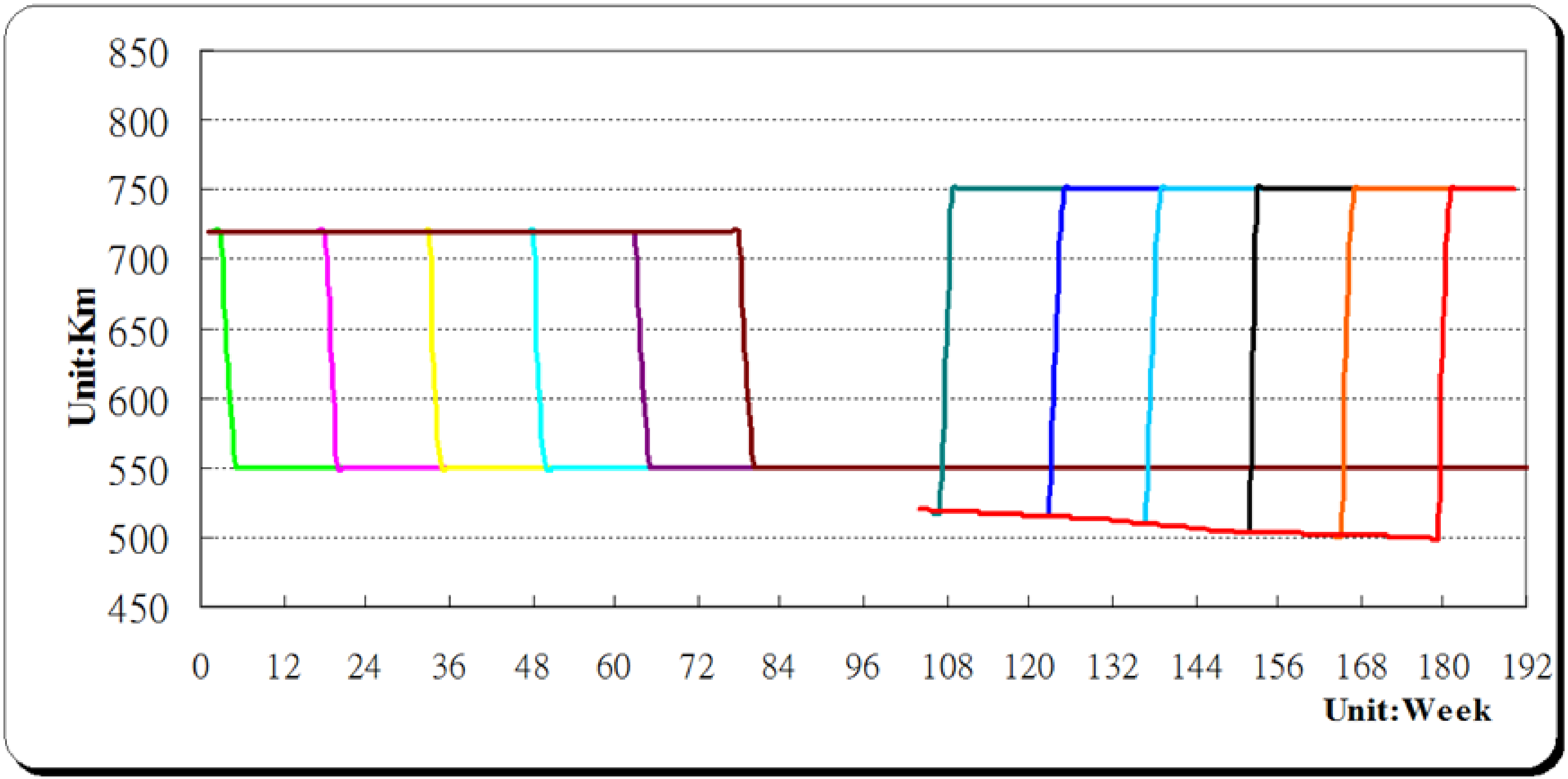
FORMOSAT-7 / COSMIC-2 Mission Architecture



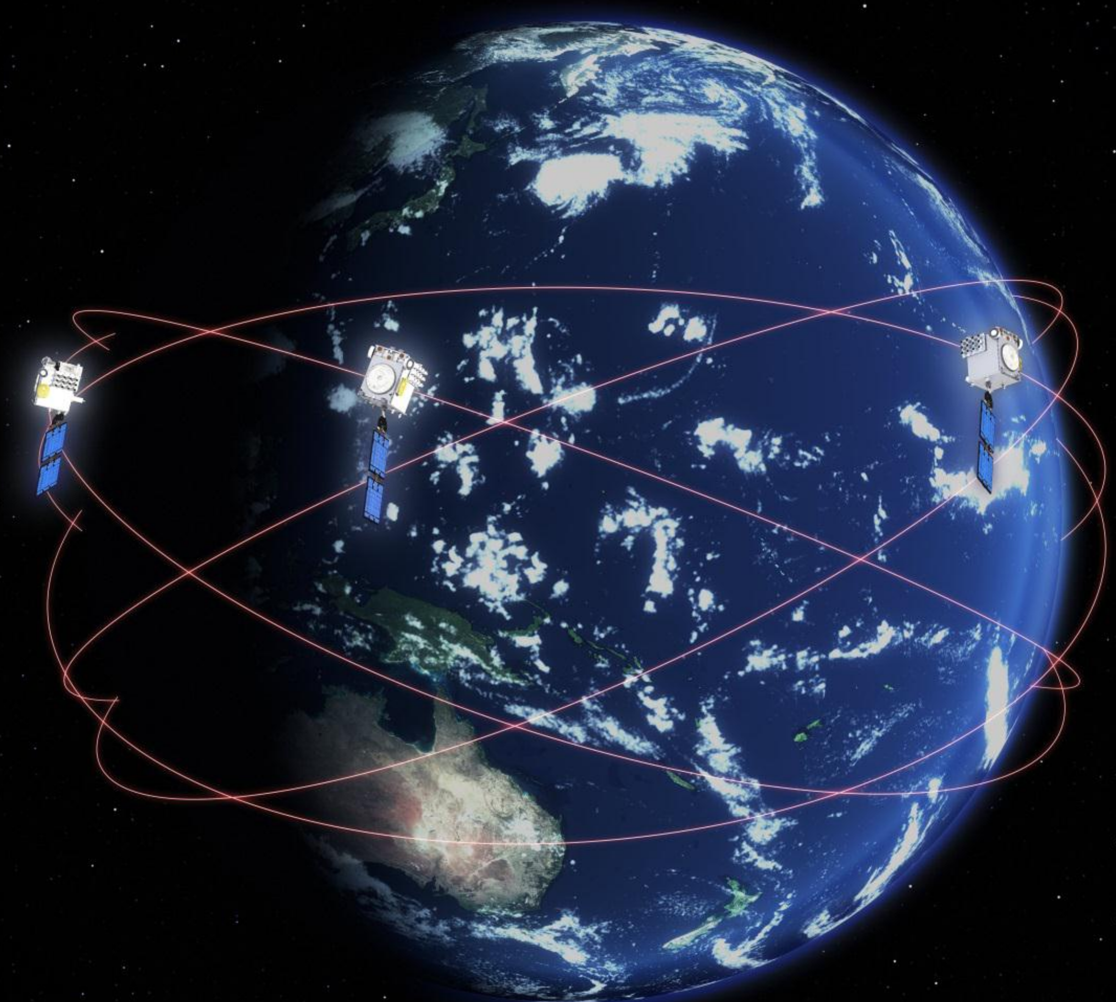
Artistic FORMOSAT-7 / COSMIC-2 Satellite Illustration in Orbit

Courtesy of SSTL

Constellation Deployment Maneuver Time



IOC Deployed Constellation for the 1st Launch



Courtesy of SSTL

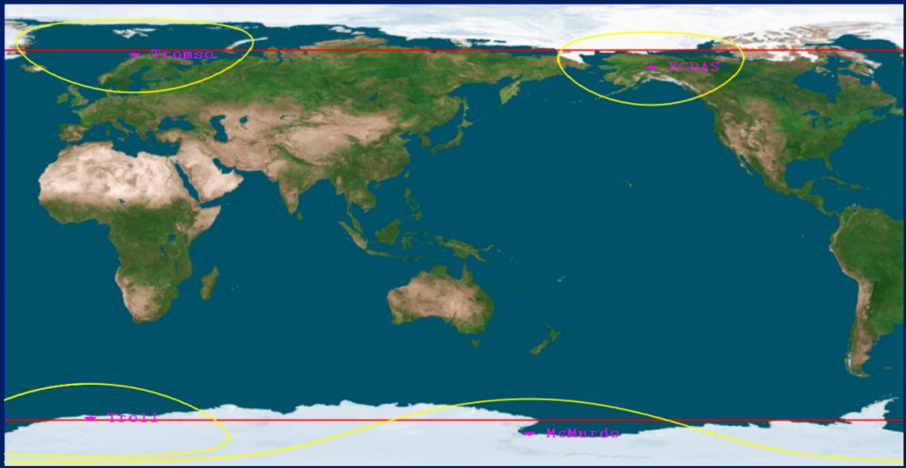
Ground System Developments

FORMOSAT-7 / COSMIC-2 Ground Communication Networks

- Achieving 45 Minutes Data Latency -

72° Orbit Data Recovery

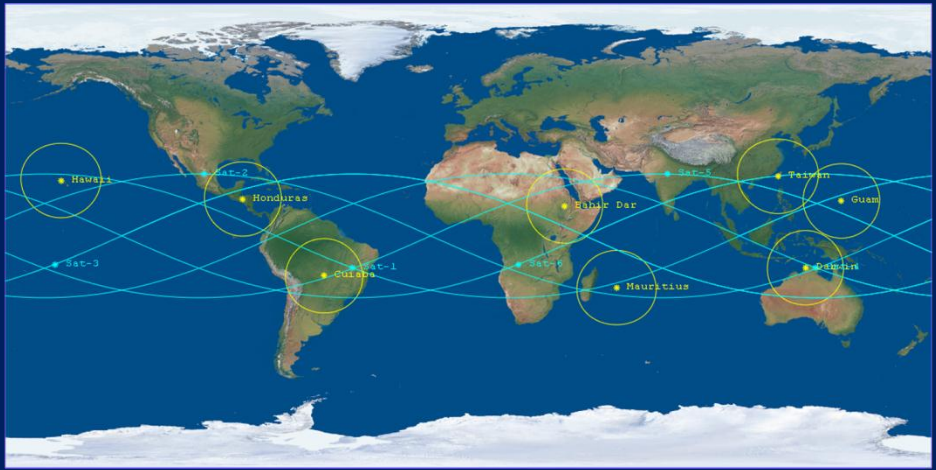
Current FORMOSAT-3 / COSMIC Network



- KSAT Tromso
- KSAT Troll (Back Up)
- NOAA FCDAS
- NASA McMurdo

24° Orbit Data Recovery

FORMOSAT-7/ COSMIC-2 Candidate Sites



Potential Low-Mid Latitude Candidate Sites:

Florida, Hawaii, Guam U.S.A.
Honduras
Singapore
Maritus
Bahir Dar, Ethiopia
Darwin (Bureau of Meteorology), Australia
Cuiabá (IPNE), Brazil
Taiwan

Courtesy of NOAA

FORMOSAT-7 / COSMIC-2 Equatorial Ground Stations Status

Ground Station Location	Partner / Sponsor	Level of Commitment	Notes
Taiwan	NSPO	100%	Uses existing Capability
Cuiaba, Brazil	INPE	100%	INPE awarded contract for GS in Jan 2014, MOU with NOAA in final Coordination
Mark IV-B – Hawaii	USAF	**100%**	Working with USAF to establish compatibility with COSMIC-2 downlink
Mark IV-B – Guam	USAF	**100%**	Working with USAF to establish compatibility with COSMIC-2 downlink
Mark IV-B – Honduras	USAF	**100%**	Working with USAF to establish compatibility with COSMIC-2 downlink
Darwin, Australia	BoM	**~90%**	BoM Australia discussing path forward to provide dedicated support
North Africa (TBD)	Commercial Service	0%	Subject of a FY15 solicitation for Data Services from commercial providers
Mauritius (TBD)	Commercial Service	0%	Subject of a FY15 solicitation for Data Services from commercial providers

Courtesy of NOAA

Data Latency vs. Potentially Planned RTS Network

LEO Inc. (deg)	RTS Network	Average Latency (min)
24	Taiwan, Darwin, Cuiaba, Mauritius, BahirDar	36.9
24	Taiwan, Darwin, Cuiaba, Mauritius, BahirDar, + Dedicated Guam, Hawaii, Honduras	26.9
24	Taiwan, Darwin, Cuiaba, Mauritius, BahirDar, + Shared Guam, Hawaii, Honduras	29.7
72	Fairbanks, Tromso, McMurdo, TrollSat	35.0
72	Fairbanks, Tromso, McMurdo, TrollSat + Taiwan, Darwin, Cuiaba, Mauritius, BahirDar	29.2

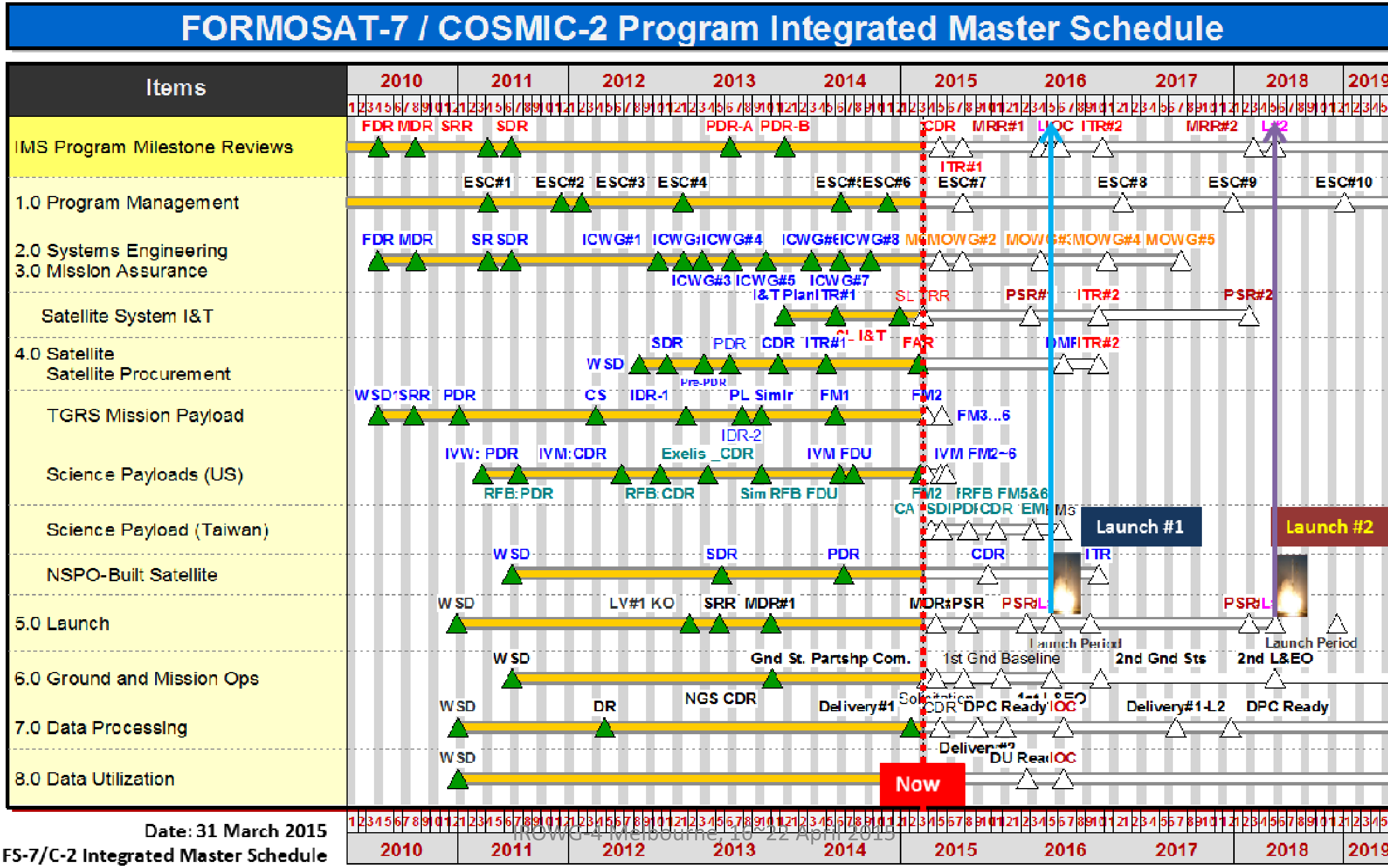
Courtesy of NOAA

Joint Program Master Schedule

&

Mission Data Policy

FORMOSAT-7 / COSMIC-2 Integrated Master Schedule



Quick Update on the 2nd Launch Implementation

- **May-2010:** Taiwan & U.S. signed the collaboration agreement for this Joint Mission
- **Dec-2011:** Conducted the 2nd ESC Meeting in Taiwan **(U.S Congress denied COSMIC-2 funding)**
- **Aug-2012:** NSPO awarded the Spacecraft contract for the 1st Launch set to SSTL-U.K.
- **Dec-2012:** USAF awarded an L/V contract to SpaceX Falcon Heavy for the 1st Launch
- **Dec-2012:** Taiwan & U.S. signed the IA#1 (Implementing Arrangement #1)
- **Jan-2013:** Conducted the 4th ESC Meeting in the U.S. **(Continuing Resolution Issue)**
- **Feb-2014:** U.S. Congress approved and allocated fund for COSMIC-2 as a new Program
- **Nov-2014:** Conducted the 6th ESC Meeting in Taiwan to conclude to move forward with the 2nd Launch
- **Feb-2015:** NOAA requested FY 2016 President Budget of U.S. $ 9.9 M for COSMIC-2 toward the 2nd Launch has been submitted
- **Mar-2015:** Amendment No.1 to the IA#1 through AIT/TECRO to update from 6-Satellite/1-Launch to 12-Satellite/2-Launch has been in work

FORMOSAT-7 / COSMIC-2 Major Collaboration Partners

U.S.A.

NOAA
UCAR
JPL Jet Propulsion Laboratory California Institute of Technology
NSF
NASA
SPACEX
SRI International
MOOG BROAD REACH
UTD
AEROSPACE
Ball

Taiwan

NSPO
NARLabs
ACADEMIA SINICA
科技部 Ministry of Science and Technology
凌群
NATIONAL CHENG KUNG UNIVERSITY 1931

Europe

SURREY SATELLITE TECHNOLOGY LTD

Australia

Australian Government Bureau of Meteorology

Adapting Free and Open Data Policy

- **Following FORMOSAT-3/COSMIC, FORMOSAT-7/COSMIC-2, another major Taiwan/U.S. Joint Mission, will adapt the free and open data policy to provide the global data users with the near real-time and the archived radio occultation data for weather, climate, ionosphere, geo-science researches and non-commercial weather forecast prediction.**

GPS / GLONOSS RO Data Distribution

- TDPC / USDPC will distribute the near-real-time GPS/GLONOSS RO neutral atmospheric data products (i.e. vertical profiles of bending angles, refractivity, electron density, temperature, pressure, and water vapor in the atmosphere) immediately after processing in WMO-approved BUFR (Binary Universal Form for the Representation) format to NOAA's NESDIS (National Environmental Satellite, Data, and Information Service), which will then distribute these products via the GTS (Global Telecommunication System) to the international weather centers.

- The distribution and the data format of the near-real-time GPS/GLONSS ionospheric data products from the TGRS Payload are under evaluation.

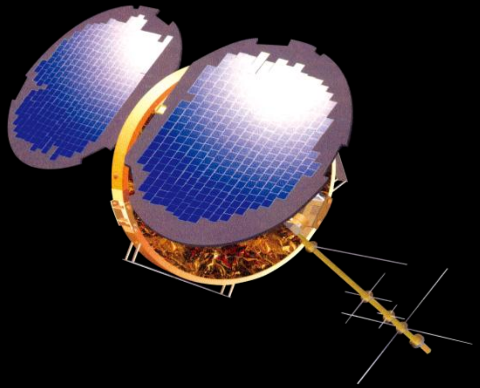
IVM / RF Beacon and Spacecraft Bus Data Distribution

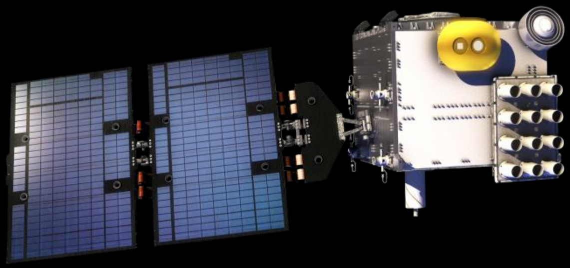
- **The IVM and RF Beacon Data and Data Products will be distributed by the U.S. Air Force by means of the FORMOSAT-7 / COSMIC-2 Science Data Use Agreement. < under discussion >**

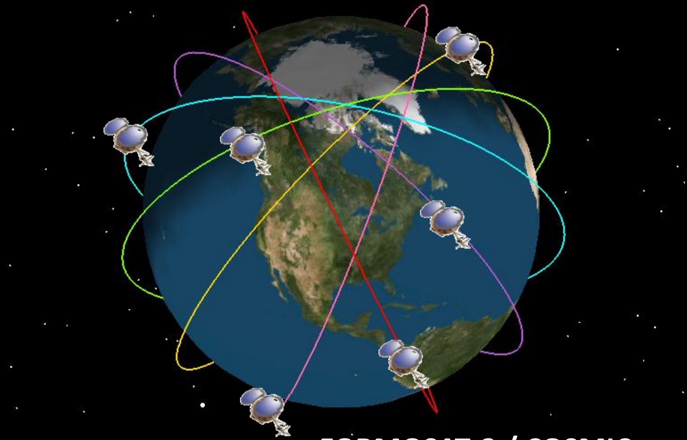
- **The related Satellite Bus telemetry data for the Data Users may be released at NSPO's discretion. < under discussion >**

- **Soliciting YOUR input for other beneficiary Data Distribution Policy !**

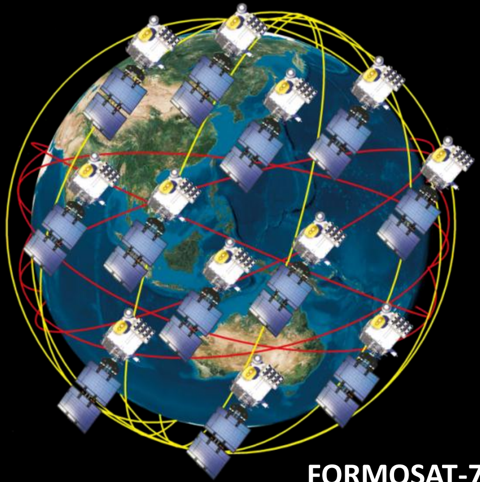
FORMOSAT-3 / COSMIC-1 → FORMOSAT-7 / COSMIC-2







FORMOSAT-3 / COSMIC



FORMOSAT-7 / COSMIC-2

3rd ICGPSRO 2016 Conference Announcement

The 3rd International Conference on GPS Radio Occultation (ICGPSRO 2016)

Time :

- **March 9 (Wednesday) ~ 11 (Friday) , 2016**

Venue:

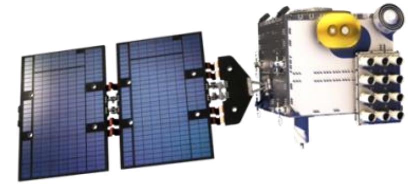
- **Howard International House, Taipei, Taiwan**

Conclusion

NAR Labs

Conclusion

- As the world's first GPSRO constellation, FORMOSAT-3/COSMIC has clearly demonstrated the advantages and utilities of a GPS RO constellation and has fulfilled all the promises and more.
- The contribution of FORMOSAT-3 / COSMIC GPSRO Constellation system to improve weather prediction and promote new ionospheric observations is "significant" and represents an immense benefit to worldwide forecasting capability.
- Constellation Radio Occultation Measurement has become a powerful Earth Observation System. NSPO and NOAA have recognized the need and the opportunity and jointly implemented a next generation GPSRO Constellation, i.e. FORMOSAT-7 / COSMIC-2 mission, with greater global coverage. The Initial Operational Capability (IOC) is targeted for 2016.
- It is certain that the implementation and realization of FORMOSAT-7 / COSMIC-2 GPSRO Constellation system will further increase weather forecast and monitoring capabilities in this unique Earth observation mission.



Thank You !