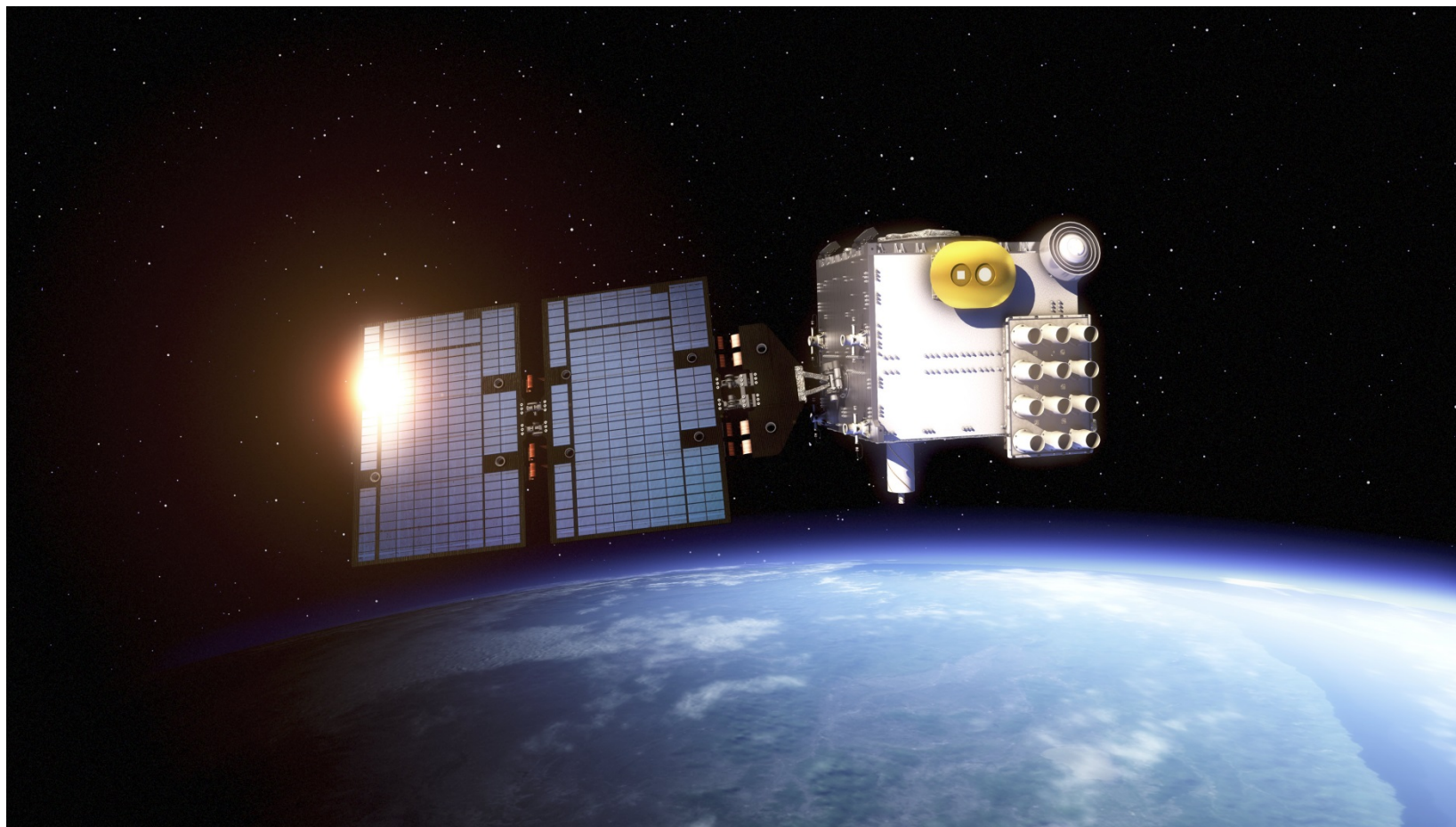




NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



COSMIC-2

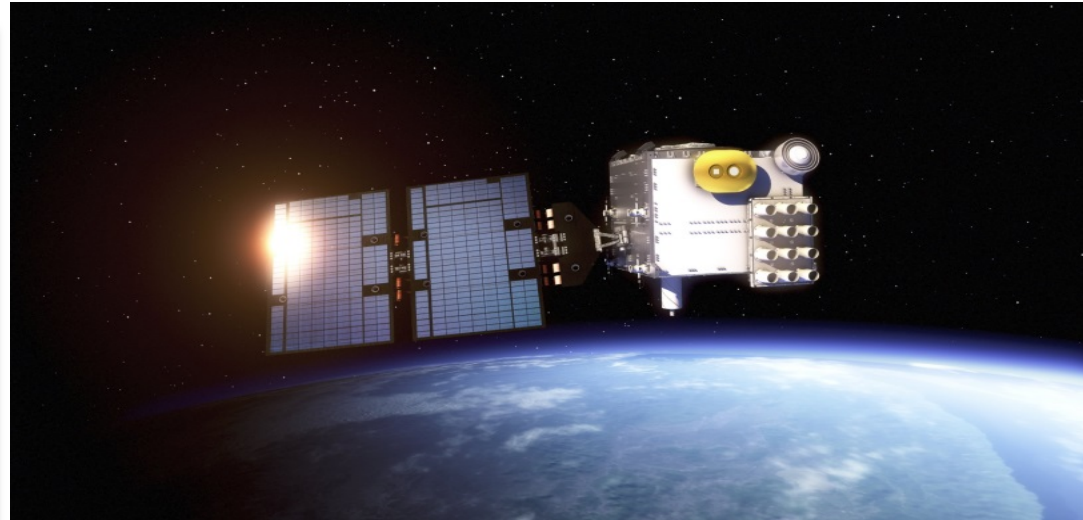


Pete Wilczynski
U.S. COSMIC-2 Program Manager - NOAA
April 2015

COSMIC-2 Mission Overview

Mission Objectives

- Follow-on to current COSMIC-1 satellite constellation
- Design concept meets L1RD requirements
 - System will provide 10,000+ worldwide soundings per day
 - All weather, uniform coverage over oceans and land with 30 min average latency
- 12 Satellite Constellation, 2 launches in different inclinations
 - 6 satellites to 24 degree orbit – carries USAF secondary payloads
 - 6 satellites (+ 1 optional spare) to 72 degree orbit – carries Taiwan secondary payloads (planned)



Mission Overview

- Launch Dates: 1st: May 15, 2016; 2nd: CY2018 (FY2019)
- Launch Vehicle: 1st: Falcon Heavy [STP-2 Mission]; 2nd – TBD (Falcon-9, Falcon Heavy, or EELV rideshare)
- Design Life: 5 years
- Mission: 5 years (on orbit)
- Orbits: 1st launch - 24 deg inclination, 2nd launch - 72 deg (or 108 deg) inclination

Instruments

- First Launch:
 - TriG GNSS-RO receiver (TGRS)
 - Ion Velocity Meter (IVM)
 - RF Beacon
- Second Launch:
 - TGRS
 - Taiwan-procured Scientific Payloads for second launch are TBD



COSMIC-2 Mission Roles



- **NOAA activities:**

- Manage all U.S. activities as Lead U.S. agency
- Arrangement for and oversight of the remote ground receiving stations
- Acquisition and management of the data processing center in the U.S.
- Overall management of the data analysis, application, and distribution segment
- Responsible for 6 primary payloads for the second launch [TBD]



- **U.S. Air Force activities:**

- Acquisition and management of the mission payload for the first 6 satellites
- Acquisition and management of the launch service for the first launch
- Acquisition and mission support of the scientific payloads for first six satellites
- Acquisition and management of the launch service for the second launch [TBD]



- **NSPO activities:**

- Acquisition and management of 12 spacecraft + 1 optional spare
- Acquisition, management, I&T, and deployment of satellite constellations
- Development and management of mission operation
- Modification and operations of Satellite Operations Command and Control (SOCC) station and Taiwan's TT&C station
- Acquisition and management of Taiwan data processing center
- Acquisition and management of the secondary scientific payloads for second six satellites

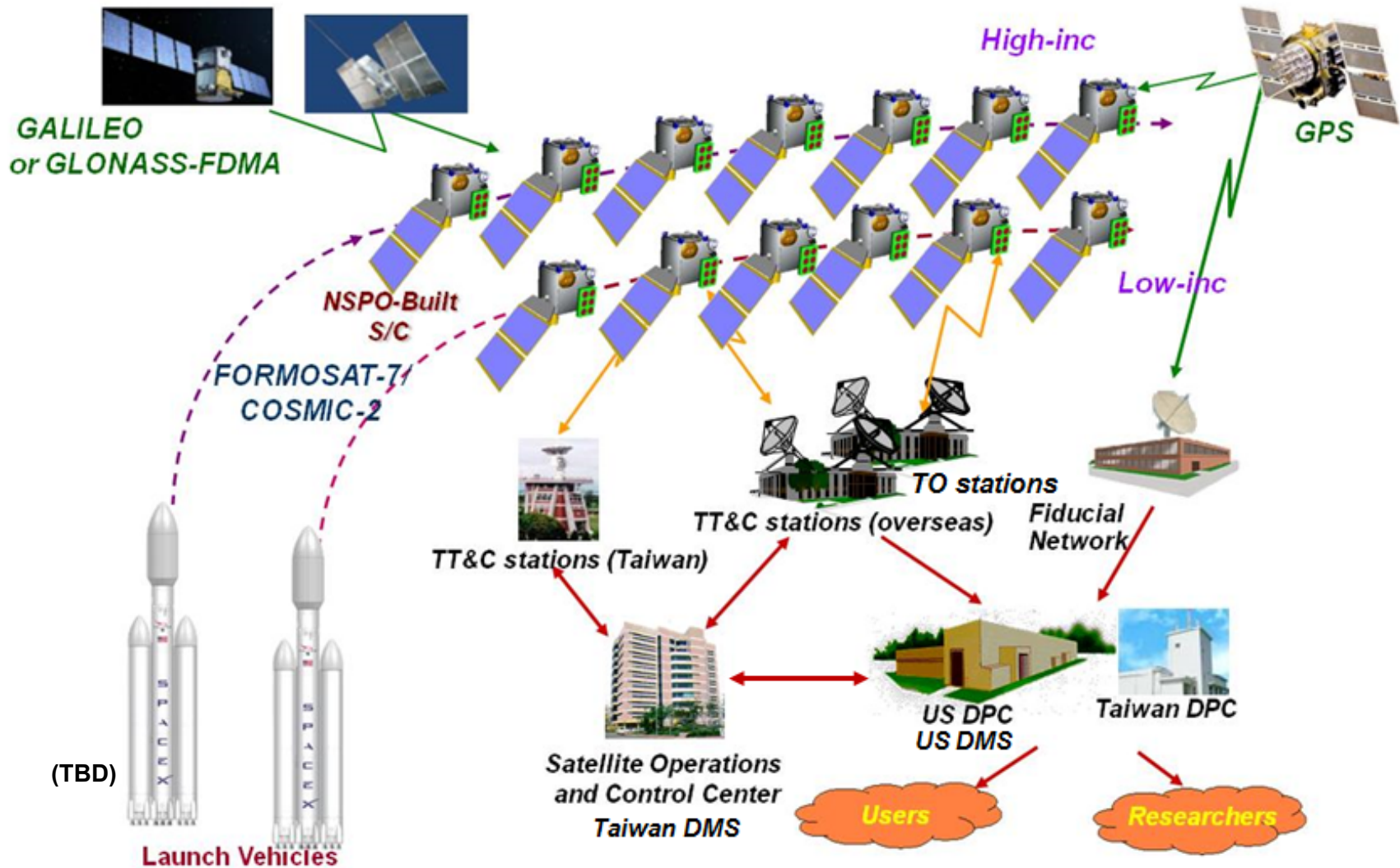


- **NASA/JPL activities:**

- Non Recurring Engineering (NRE) for new sensor design for TGRS
- Provide mission support for mission payload



CONOPS / COSMIC-2 System Architecture



Overall Program

Recent Events and Accomplishments

April 2015

- Still working with NOAA Contracts Office for the Data Processing Segment services procurement.
 - Need to determine which way we intend to proceed (sole source, grant, etc.)
- Initiated Ground Services solicitation documentation prep work
- Completed CDR-A (document-only milestone) March 31.
- The first shipment of satellites (FM1 and FM3) arrived at NSPO March 24, 2015.
- The USAF and JPL held the Pre-Ship Review (PSR) for the TGRS units #2-6 March 24, 2015. The PSR was successful and all sensors were shipped to Taiwan April 3, 2015.
- The USAF and SMI held the PSR for the RF Beacon unit #2 on April 2, 2015. The PSR was successful and the RF Beacon unit #2 was shipped to Taiwan on April 3, 2015 with the TGRS sensors.

C-2a Instrument Development Status

- All first flight units for TGRS, IVM, and RF Beacon were delivered to SSTL and successfully powered through the spacecraft
- **TGRS**
 - Software updates enabling loads through spacecraft
 - Units #2-4 completed and in storage
 - Completion of development, I&T, and software efforts for #2-6 through UCAR – JPL contract
 - Delivery of partial EIDP for Units #2-6 February 6th
 - TGRS Pre-Ship Review (PSR) for #2-6 March 24th
 - Near term focus is to complete flight software V2.0 (GPS only), and complete the test software update



TGRS Description

- Radio Occultation (RO) receiver that tracks GNSS signals across Earth's limb
- Weather prediction models, severe weather forecasting, and space weather monitoring
- Meteorological, ionosphere and climate research
- Provides global observations of refractivity, pressure, temperature, humidity, total electron content, ionospheric electron density, and ionospheric scintillation

C-2a Instrument Development Status

- **IVM (USAF)**

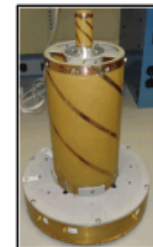
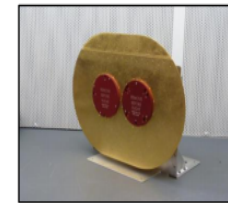
- Pre-Ship Review (PSR) for Units #2-6 completed January 27th
- JPL shipped units #2-6 to Taiwan April 3rd
- There is an issue of IVM contamination in the STP-2 stack that the USAF leadership (SMC/RS and SMC/AD are working to address)

- **RF Beacon (USAF)**

- Completion of development and I&T efforts for #2-6 will be through a UCAR - SMI contract
- All Antenna Units completed assembly
- BEU delivery schedule successfully optimized to meet S/C need date
- Delivery of RF Beacon Unit #2 occurred in March 2015

IVM Description

- Measures the in-situ plasma density, ion temperature and composition, and drift velocity
- Used for modeling the ionosphere to determine electric fields that could impact other systems (e.g. GPS radio signals)

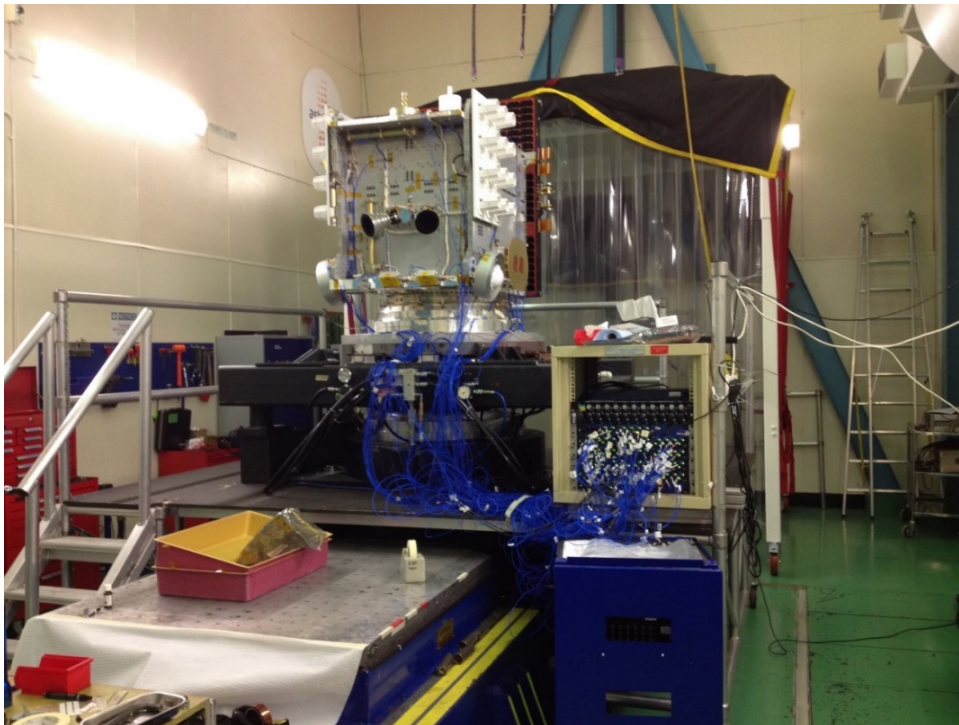


RF Beacon Description

- Transmitter that enables ground-based measurement of ionospheric scintillation and ionospheric total electron content (TEC)
- Critical to the understanding of the impacts of space weather on satellite communication systems and GPS

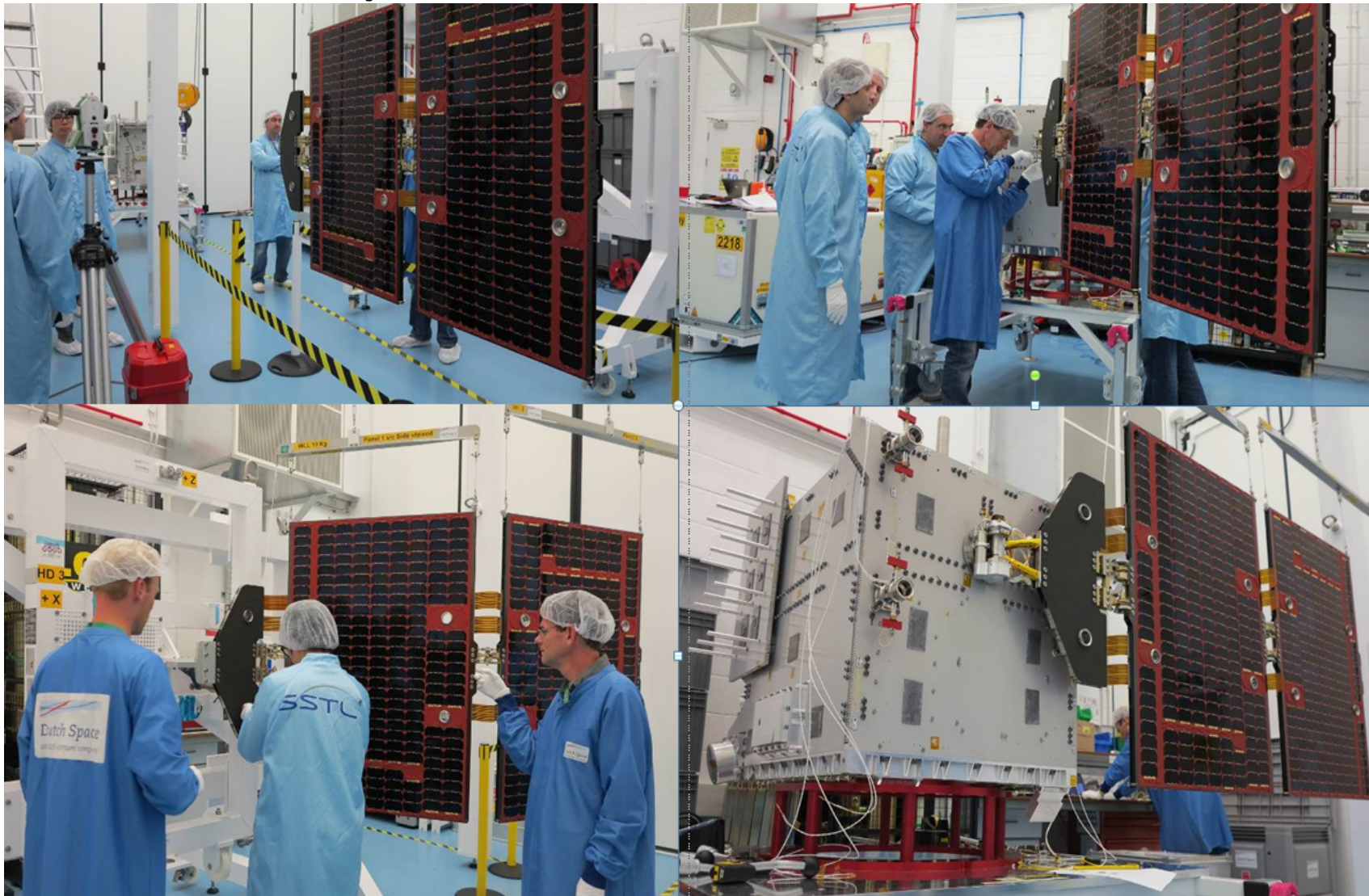
Satellite Development Status

- The first satellite has been assembled and has gone through testing in the UK.
- System End-to-End Test (SEET) occurred at the end of February, Flight Acceptance Review the was the first week of March, and the delivery of the first satellite to Taiwan occurred at the end of March
- The picture below was taken with the spacecraft on the table for Z axis testing in December 2014
 - Two star trackers are visible in front and the white square RO antennas on either side
 - The lower round white antennas are for positional determination (or POD)
 - The blue cables are the numerous connections to the accelerometers attached to the spacecraft that provided test data
- The top of the Flight Unit in this picture is the earth facing nadir side



Dimensions (stowed)	1000 x 1250 x 1250 mm
Launch Mass (wet)	277.8 kg
Total Power Peak / OAP	229.8 (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 Adaptor)
Payload support	>2Gbits data storage 39.4kg mass, 95W OAP
Design Features	<input checked="" type="checkbox"/> dual redundant avionics <input checked="" type="checkbox"/> Batch launch compatible <input checked="" type="checkbox"/> Constellation compatible

C-2 Flight Unit #1 Solar Panels are Undergoing Deployment Test and Fit Check on the Structure Demonstration Model Spacecraft Bus at SSTL in the UK



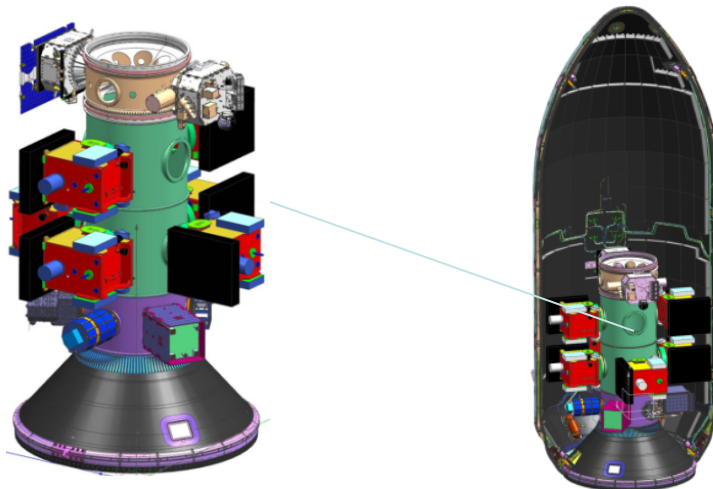
Spacecraft #1 in Taiwan at NSPO



C-2a Launch Status

- USAF awarded a launch vehicle contract to SpaceX in January 2013, to launch COSMIC-2 on the STP-2 Mission on a Falcon Heavy launch vehicle
 - Launch currently planned for May 2016
 - Scheduled to be a demonstration flight, not a certified launch
- Falcon Heavy in development

Demo mission to fly 4th quarter CY15





Ground Status Update

- Successfully completed NOAA-UCAR System Requirements Review (SRR) for the Data Processing Center (DPC) Segment on Oct 22, 2014
- INPE (Brazil's Space Agency) successfully conducted Factory Acceptance Testing (FAT), successfully ingested COSMIC-1 data. Antenna being shipped from the factory in France to the ground site in Brazil. Initial UCAR quality analysis indicates good performance in FAT.
- Active dialogue with Australia's Bureau of Meteorology (BoM) – they are willing to host a ground station at their site in Darwin
- The USAF Mark IVB support: On December 9, 2014, the USAF Acting Director of Weather sent NOAA a letter stating that the USAF, "decided to fund the upgrade and sustainment costs associated with this effort within our existing program."
 - Contract modifications pending, expect readiness by Nov/Dec 2015
 - Working on Pass Schedule coordination ConOp based upon GS ICD schedule definition
- Upcoming Activities
 - Meetings with Australia's BoM and Darwin Site Survey are planned for April 21-25
 - Ground and DPC Segment Critical Design Review (CDR) planned for summer/fall 2015 in Boulder, CO

Mark IV-B Ground Stations

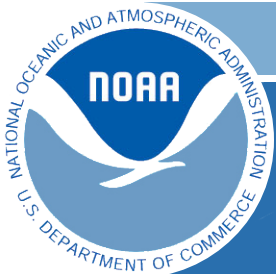


**3m Tracking
X/L/S-Band**



**Signal Processing
Racks**

- The USAF agreed to pay for the modifications and O&M costs associated with incorporating COSMIC-2 data collection and dissemination into the MARK IV-B baseline
- MARK IV-B capabilities
 - MARK IV-B utilizes S-band (e.g. 3m XLS-band polar antenna) in the current hardware architecture allowing it to capture COSMIC-2 data
 - MARK IV-B footprint at Guam, Hawaii and Honduras locations can help in the COSMIC-2 ground collection footprint
- Schedule
 - Work effort is in planned in CY 2015 to support COSMIC-2 launches planned in 2016 and 2018



COSMIC-2 Equatorial Ground Stations (Planned)

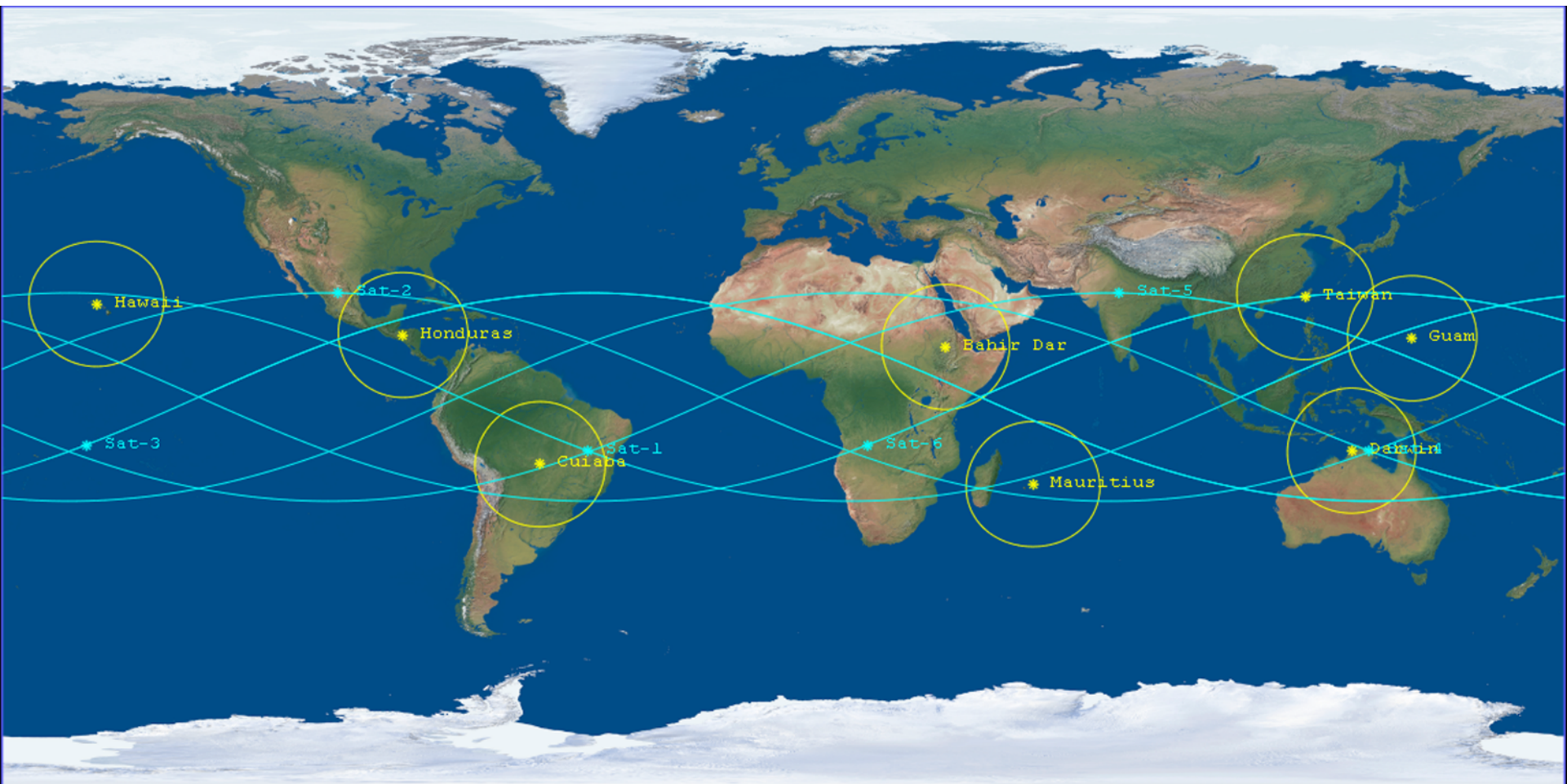
Ground Station Location	Partner / Sponsor	Level of Commitment	Notes
Taiwan	NSPO	100%	Uses existing Capability
Cuiaba, Brazil	INPE	100%	INPE awarded contract for GS in Jan 2014, MOU with NOAA in final Coordination
Mark IV-B – Hawaii	USAF	100%	Working with USAF to establish compatibility with COSMIC-2 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



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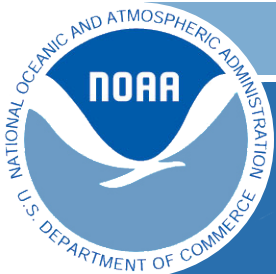
Ground Station Architecture (Planned First Phase)





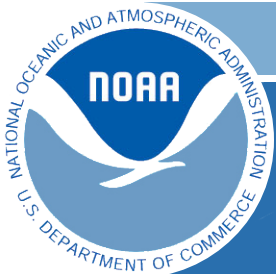
NOAA Ground Station Development Outline

Timeline	Activities
L-23 Months to L-21 Months (5/2014 to 8/2014)	<i>Firm-up ground station partnership commitments.</i>
L-20 Months to L-18 Months (9/2014 to 11/2014)	<i>Complete ground station partnership commitments. Prepare Commercial Services Solicitation.</i> <i>Informal ground station testing begins. (e.g., NSPO, INPE)</i>
L-17 Months to L-15 Months (12/2014 to 2/2015)	Informal ground station testing continues, (e.g., Mark IV-B). Issue Commercial Services Solicitation – Requires full FY15 appropriated funding.
L-14 Months to L-12 Months (3/2015 to 5/2015)	All agreements in place for ground station and communications operations. Establish Data Management System and Interfaces
L-11 Months to L-9 Months (6/2015 to 8/2015)	Ground station test procedures completed and ground station testing formally begins. Award Commercial Services Contract. Ground Station Architecture baselined for launch.
L-8 Months to L-6 Months (9/2015 to 11/2015)	Begin last phase of ground station pre-launch end-to-end testing.
L-5 Months to L-3 Months (12/2015 to 2/2016)	Ground station testing completed with SOCC, COSMIC-1 and UCAR participation. Results documented to MA IPT.
L-2 Months to Launch (3/2016 to 5/2016)	Support launch preparations and system-wide mission readiness. Commercial Services may not be ready to support launch, but will support by end of deployment.
Launch (5/2016)	Launch



DPC Status Update

- NOAA provided FY14 funds to UCAR in August 2014 to begin UCAR upgrades
- COSMIC-2 development hardware procured/installed and running beta COSMIC-2 SW at UCAR
- COSMIC-2 operational Ground-IO hardware purchased/installed and running
 - Receiving GNSS ground data streams and estimating GNSS clocks in near real-time
- UCAR delivered SW version #1 to Taiwan's data center Feb 5, 2015 (see next slide)
- UCAR and NSPO conducted successful initial connectivity and data flow tests
 - NSPO TT&C station transferred simulated COSMIC-2 VC2 data (using COSMIC-1 VC2 data) to USDMS
 - UCAR transferred VC2 data from simulated INPE TO station to the USDMS and then on to simulated TDMS
 - Tests used COSMIC-2 filenames and an upgraded FTPS transfer mechanism
- UCAR and NOAA working IT Security upgrades for COSMIC-2
- Summer/Fall 2015 – USDPC segment CDR
- May-Sept 2015 planned system I&T
- December 2015 planned UCAR Readiness Review



DPC SW Delivery #1

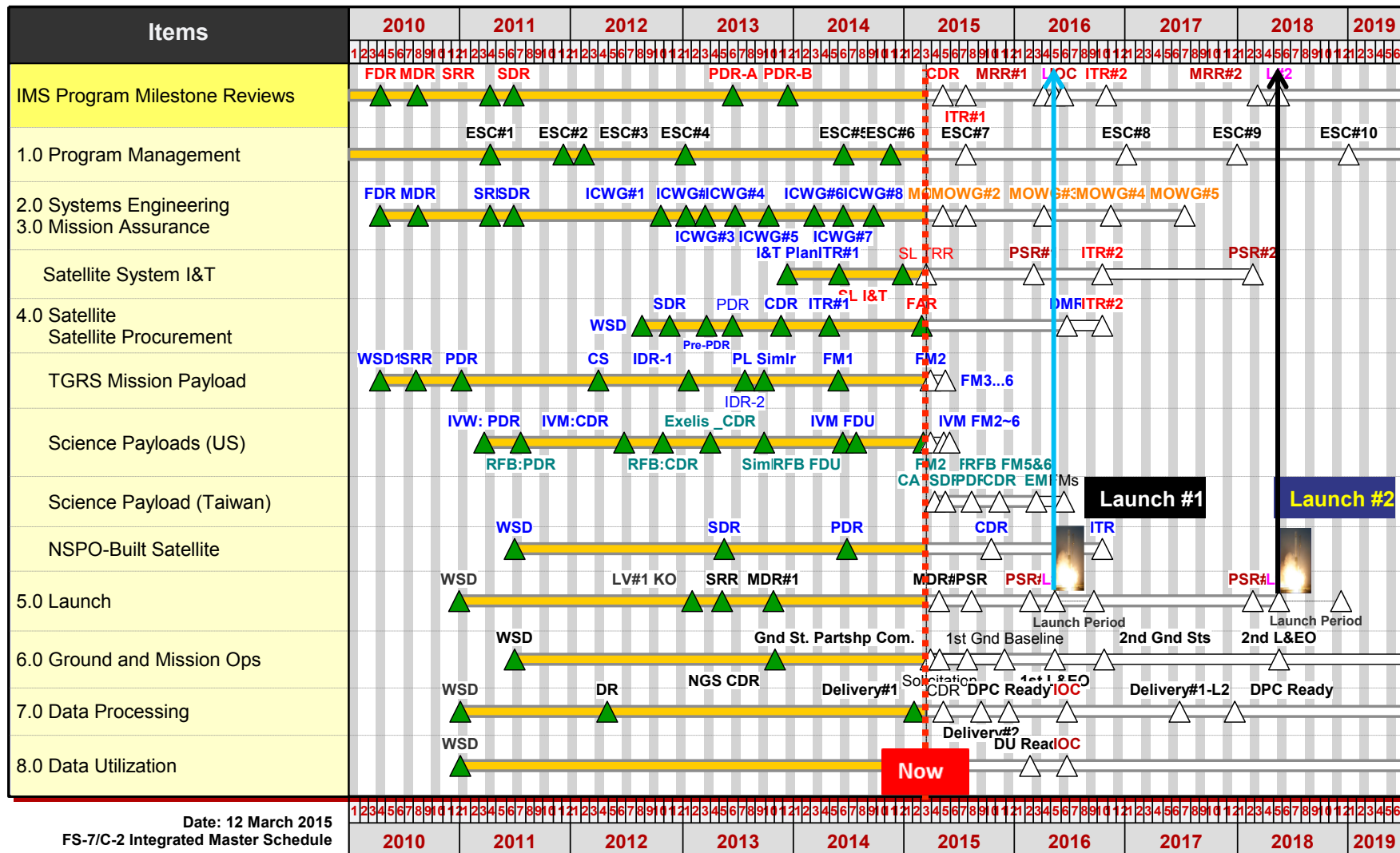
- UCAR delivered s/w version #1 to Taiwan's data center Feb 5, 2015
- Capability to acquire, manage, process, and monitor ground GNSS streaming data sources
- Capability to estimate low latency GNSS (GPS + GLONASS) clocks
- Initial TriG Level0-Level1 module
 - Reformats low rate GLONASS POD data
- Absolute TEC processing
 - Capability to estimate GLONASS absolute TEC data
 - Improved TEC arc monitoring and plotting
- Atmospheric excess phase processing
 - Capability to compute atmospheric excess phase with 100Hz data
 - GPS and GLONASS capability
- Neutral atmospheric retrieval (newroam) processing
 - Capability to process 100 Hz excess phase data
 - Capability to process GPS and GLONASS excess phase data
- Improved operator monitoring and monitoring database (MonDB)
- Have examined data latency of entire process – will meet 5 minute dump requirement

C-2a Ground and DPC Segment Schedule – April 2015

ID	Task Mode	Task Name	Duration	Start	Finish	3rd Quarter May	3rd Quarter Jul	3rd Quarter Sep	3rd Quarter Nov	1st Quarter Jan	1st Quarter Mar	1st Quarter May	3rd Quarter Jul	3rd Quarter Sep	3rd Quarter Nov	1st Quarter Jan	1st Quarter Mar	1st Quarter May	3rd Q
1		GROUND SEGMENT	490 days	Tue 7/1/14	Sun 5/15/16														
2		Firm Up Ground Station Partnership Commitments	240 days	Tue 7/1/14	Mon 6/1/15														
3		Complete Ground Station Partnership Commitments	0 days	Mon 6/1/15	Mon 6/1/15														
4		Prepare Commercial Services Solicitation	174 days	Wed 10/1/14	Mon 6/1/15														
9		Establish Data Management System and Interfaces	110 days	Mon 3/2/15	Fri 7/31/15														
17		DATA PROCESSING SEGMENT	221.38 days	Fri 2/6/15	Tue 12/15/15														
18		COSMIC-2 DPC SW Delivery #1 to TDPC	0 days	Fri 2/6/15	Fri 2/6/15														
19		Purchase Operational COSMIC-2 DPC RT HW (TriG Level0-Level1 Module, New FIDRT Architecture)	0 days	Fri 5/29/15	Fri 5/29/15														
20		COSMIC-2 DPC CDR	0 days	Wed 7/15/15	Wed 7/15/15														
21		System Integration and Test	120.25 days	Fri 5/15/15	Fri 10/30/15														
22		COSMIC-2 DPC SW Delivery #2 to TDPC (Remaining Software)	0 days	Tue 9/15/15	Tue 9/15/15														
23		Purchase COSMIC-2 DPC Post-Processing HW	0 days	Mon 11/16/15	Mon 11/16/15														
24		COSMIC-2 DPC Readiness Review	0 days	Tue 12/15/15	Tue 12/15/15														

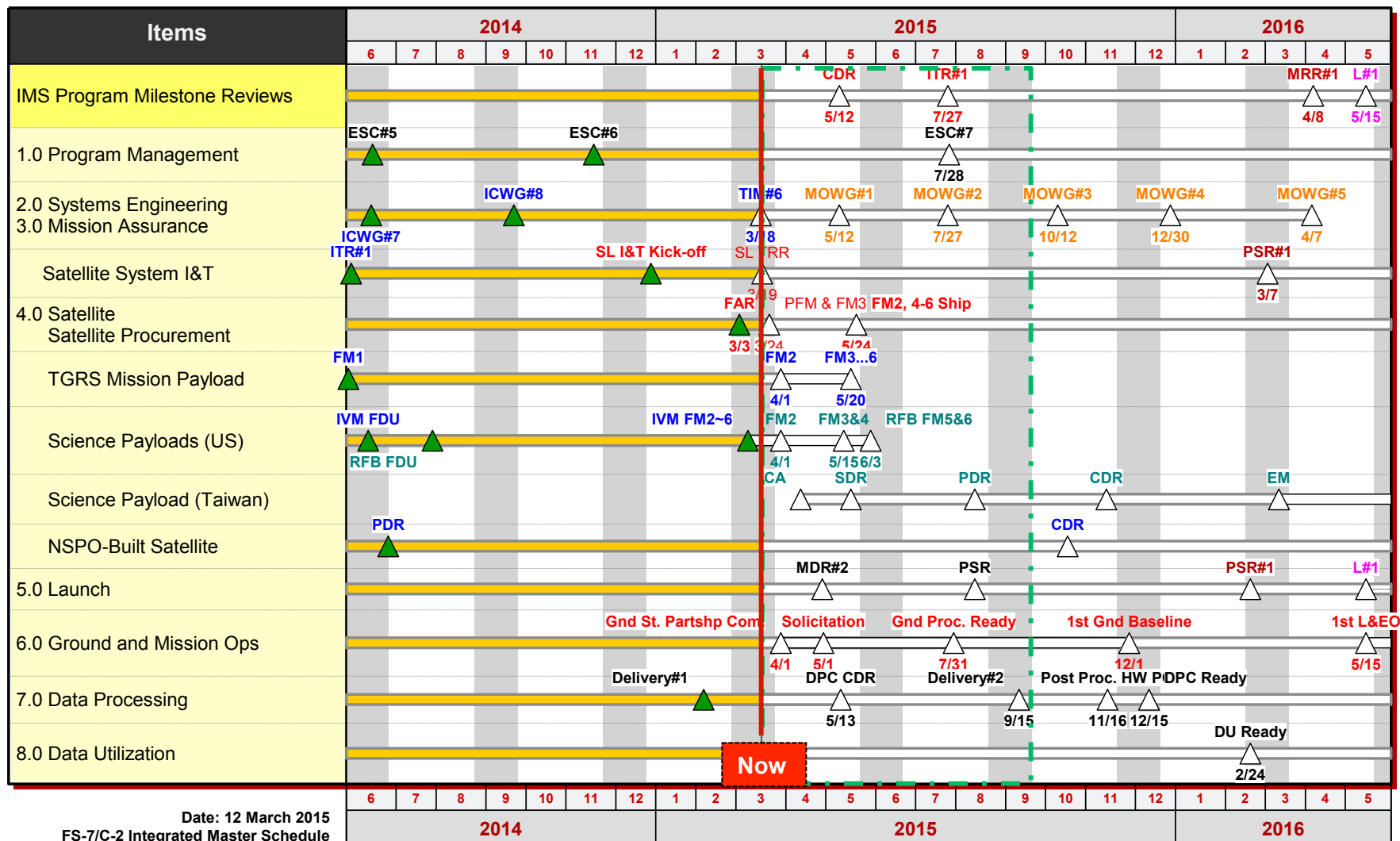
Joint Program Integrated Master Schedule

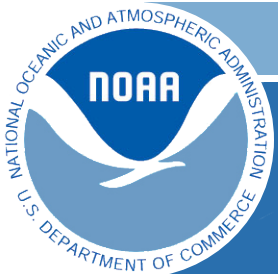
FORMOSAT-7 / COSMIC-2 Program Integrated Master Schedule



Joint Program Next 3-Quarters Schedule Planning

FORMOSAT-7 / COSMIC-2 Program Integrated Master Schedule





Summary

- Looking forward to an exciting 12 months ahead!!