

COSMIC-2: The Follow-on Mission to the Constellation Observing System for Meteorology, Ionosphere, and Climate

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Abstract – COSMIC/FORMOSAT-3 is a joint U.S.-Taiwan 6-microsatellite demonstration mission that was launched in April 2006. It is the world’s first operational GPS radio occultation (RO) mission for global Earth weather forecasting; climate monitoring; and atmospheric, ionospheric, and geodetic research. The GPS-RO data has been demonstrated to be valuable to the climate, meteorology, and space weather communities. COSMIC has proven to increase the accuracy of the predictions of hurricane/typhoon behavior, significantly improve long-range weather forecasts, and monitor climate change with unprecedented accuracy. COSMIC will reach the end of its design life in 2011, and the critical capability it provides has already begun to degrade as satellites reach their end of life. As a result, NOAA and NSPO intend to jointly develop and launch COSMIC-2, a high-reliability next generation follow-on system. COSMIC-2 will provide the next generation of global navigation satellite system (GNSS)-RO data to users who critically depend on it.

Key Words: climate, weather prediction, radio occultation, GPS-RO, forecasting

1. INTRODUCTION

COSMIC/FORMOSAT-3 (hereafter referred to as COSMIC) is a joint U.S.-Taiwan satellite constellation that was launched in April 2006 and is being operated by Taiwan’s National Space Organization (NSPO). Its mission is to demonstrate the value of near-real-time GPS Radio Occultation (GPS-RO) data to global users. It is the world’s first operational GPS-RO mission for global Earth weather forecasting; climate monitoring; and atmospheric, ionospheric, and geodetic research. The National Oceanic and Atmospheric Administration (NOAA) has been providing ground station services for the mission from two locations in the U.S. and one in Norway since April 2008. The satellite system is currently providing global data in near-real-time to over 1,400 users in more than 52 countries worldwide, including NOAA.

Table 1. Location and Number of Current Registered COSMIC Data Users (Courtesy of UCAR)

Armenia : 1	Indonesia : 25	Portugal : 4
Argentina : 12	Ireland : 1	Russia : 26
Austria : 13	Israel : 2	Senegal : 1
Australia : 23	India : 131	Singapore : 1
Bangladesh : 1	Iran : 3	South Africa : 6
Belgium : 1	Italy : 25	South Korea : 34
Bulgaria : 2	Japan : 53	Spain : 9
Brazil : 27	Malaysia : 2	Sweden : 1
Canada : 32	New Caledonia : 1	Switzerland : 5
Chile : 4	Nigeria : 5	Taiwan : 182

China : 94	Netherlands : 3	Thailand : 2
Costa Rica : 1	Norway : 1	Turkey : 4
Czech Republic : 1	New Zealand : 6	Ukraine : 4
Denmark : 5	Peru : 2	UAE : 2
Egypt : 1	French Polynesia : 1	United Kingdom : 32
Finland : 2	Philippines : 11	United States : 476
France : 19	Pakistan : 1	Vietnam : 17
Germany : 33	Poland : 3	
Hong Kong : 2	Puerto Rico : 2	

The GPS-RO data provided by COSMIC has proven to be valuable to the climate, meteorology, and space weather communities. These communities include both real-time forecasting users, as well as U.S. and international research communities. COSMIC has proven to increase the accuracy of the predictions of hurricane behavior, significantly improve long-range weather forecasts, and monitor climate change with unprecedented accuracy (Anthes et al., 2000; Anthes et al., 2008; Kuo et al., 2000, Kuo et al., 2004, Kuo et al., 2008).

Unfortunately, the COSMIC mission will reach the end of its design life in 2011, and the critical real-time satellite observing capability has already begun to degrade as satellites reach their end of life. In the FY10–FY14 Program Decision Memorandum (February 2008), NOAA’s Under Secretary of Commerce for Oceans and Atmosphere directed the NOAA Satellite Mission Sub-goal to “develop a follow-on plan for the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC).” As a result, NOAA intends to provide data continuity and improve sensing capability with the next-generation COSMIC-2/FORMOSAT-7 (hereafter referred to as COSMIC-2) (Chu et al., 2008; Cook, 2010; Fong et al., 2008; Fong et al., 2009a; Fong et al., 2009b).

2. COSMIC-2 OBJECTIVES

The objective of COSMIC-2 is similar to that of COSMIC: to collect a large amount of atmospheric data for weather forecasting and space weather monitoring as well as for meteorological, climatic, ionospheric, and geodetic research. Additionally the system will allow scientists to collect data over un-manned and remote regions (such as the poles and oceans) in support of research in these areas.

COSMIC-2 will meet its objectives by intercepting GPS, Galileo, and GLONASS signals with a satellite-based receiver and inferring the deviations in each signal’s straight-line path caused by temperature and moisture gradients (Fong, et al, 2010).

3. COSMIC-2 CONSTELLATION AND MISSION

COSMIC-2 is expected to be a much improved constellation system consisting of a new constellation of 12 satellites for an operational mission. The mission payload will be a TriG GNSS-RO receiver and will collect more data points per receiver by adding European GALILEO system and Russian's Global Navigation Satellite System (GLONASS) tracking capability, which will produce a significantly higher spatial and temporal density of profiles over tracking GPS signals alone. These will be much more useful for weather prediction models and for severe weather forecasting (including typhoons and hurricane forecasting), as well as for related research in the fields of meteorology, ionosphere and climate. In addition to the mission payload, discussions are underway regarding the feasibility of hosting several secondary science / technology payloads.

The constellation is planned to be comprised of 6 satellites at 72 degree inclination, and 6 satellites at 24 degree inclination, which will enhance observations in the equatorial region over what is currently being collected with COSMIC. This constellation configuration was chosen because it provides the most uniform global coverage out of the orbital inclinations that were considered (COSMIC-2/FORMOSAT-7 JMCP, 2010).

This constellation will produce more than 8,000 soundings per day, compared to the approximate 2,000 soundings per day currently produced by COSMIC due to COSMIC-2's ability to track three navigation systems' signals versus COSMIC's ability to track one.

The first COSMIC-2 launch is planned for the third quarter of FY14. Initial Operational Capability (IOC) of COSMIC-2 is expected to be in the fourth quarter of FY14, and Final Operational Capability (FOC) is targeted for early FY17. Similar to the current COSMIC satellites, the COSMIC-2 satellites are nominally expected to be around 100kg each, and therefore several can be launched on one rocket – in the class of Minotaur 4, Falcon 9, or Falcon 1E. The plan is to either launch 2 rockets with 6 satellites on each rocket, or 4 rockets with 3 satellites on each rocket. They will be launched and then positioned into their final orbits (nominally 800 km altitude for the 72 degree inclination orbit and 500 km altitude for the 24 degree inclination orbit) (COSMIC-2/FORMOSAT-7 JMCP, 2010).

The original COSMIC mission had an operational concept of allowing for one data downlink per orbit. The plan for COSMIC-2 is to allow for 2 data downlinks per orbit, which will considerably reduce the data latency. Consequently, COSMIC-2 will require more satellite ground stations for receiving the data. As with COSMIC, the data collected by COSMIC-2 will be downlinked to the tracking station, then transmitted to the COSMIC processing center (CDAAC in Boulder, CO) as well as to the Taiwan processing center (TACC) for processing. The processed products will then be provided to NOAA Global Transmission System (GTS) for distribution to the worldwide weather prediction centers. Command and Control for the COSMIC-2 constellation will continue to be provided by the NSPO Satellite Operations Control Center (SOCC). Payload operational configurations will continue to be managed by a joint effort between UCAR (University Corporation for Atmospheric Research) and JPL

(Jet Propulsion Laboratory) with NOAA and NSPO concurrence for updates and changes (COSMIC-2/FORMOSAT-7 JMCP, 2010).

COSMIC-2 is a joint mission, and as such, NOAA shall be responsible for:

- acquisition and management of the GNSS-RO mission payload;
- overall management of the data analysis, application, and distribution segment;
- acquisition and management of the launch vehicle system;
- acquisition and management of the ground receiving stations;
- acquisition and management of the data processing centers in the U.S.

NSPO shall be responsible for:

- acquisition, management, and deployment of satellites constellation;
- 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.

NOAA and NSPO shall be jointly responsible for:

- acquisition and management of the scientific payloads.

4. CURRENT STATUS OF COSMIC-2

The U.S.-Taiwan agreement that is the authorizing document for the COSMIC-2 program was signed by both parties in May 2010. The Joint Program Office held the Feasibility Design Review (FDR) in May 2010, and the Mission Definition Review (MDR) in August 2010. The System Requirements Review (SRR) is scheduled for April 2011, the Preliminary Design Review (PDR) for June 2011, and the Critical Design Review (CDR) for September 2011.

Several potential spacecraft vendors have submitted spacecraft designs to NSPO for COSMIC-2, and NSPO officially sent out a Spacecraft Request for Information (RFI) in July 2010. NSPO is anticipating releasing a Spacecraft Request for Proposal (RFP) in early 2011 and is planning on completing their spacecraft selection process by mid-2011.

The Level 1 Requirements Document is complete and has been approved, and the Joint Management Control Plan and Joint Performance Requirements Documents have been drafted and are in various stages of editing and approval.

5. CONCLUSION

COSMIC's contribution to weather prediction is considered to be "significant" by the National Weather Service (NWS) and represents an immense benefit to worldwide forecasting capability. This data is not available globally from other sources, and allowing this data to deteriorate due to the COSMIC satellites' end-of-life will result in a significant diminution of performance of the NOAA Numerical Weather Models. This will result in diminished weather prediction capability which may lead to increased costs and loss of life due to natural disasters. The realization of COSMIC-2 will

continue to fulfill this important mission and further increase weather forecast capabilities.

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