

Appendix V
FORMOSAT-3/COSMIC Mission Support Plan
for NOAA Ground Stations

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1 Introduction

1.1 Purpose

The Mission Support Plan (MSP) serving as the Statement of Work provides an overview of the COSMIC mission, categorizes the NOAA RTS/RTS-R and COSMIC operations and interfaces, highlights NOAA RTS/RTS-R testing activities and end-to-end data paths, and presents the NOAA RTS/RTS-R operations support plan for real-time flight operations. This document is provided as the SOW requirements to support the existing FORMOSAT-3/COSMIC mission.

1.2 Scope

The scope of the MSP, as described in this document, entails all system elements required to support telemetry, tracking, command and data transport functions for the FORMOSAT-3/COSMIC mission during ground interfaces build-up phase and normal on orbit operations.

2 Related Documents

2.1 Applicable Documents

1. RS3-ICD-0003 FORMOSAT-3/COSMIC Ground Network ICD for NOAA Ground Stations
2. RS3-ICD-0004 FORMOSAT-3/COSMIC NOAA to SOCC IT Configuration Document
3. FORMOSAT-3/COSMIC NOAA Link Budget
4. NOAA/NASA SR

2.2 Reference Documents

N/A

3 List of Terms

SOCC: In this document, SOCC is the satellite operations control center of NSPO located in Taiwan.

NOAA RTS/RTS-R: RTS are the ground stations of NOAA supporting FORMOSAT-3/COSMIC mission with commanding, real-time telemetry and post pass file transfer, while RTS-R is an RTS without real-time connectivity to the SOCC, and it provides a S-band downlink service and a post pass file transfer service.

FORMOSAT-3/COSMIC: Reference to the spacecraft bus (FORMOSAT-3) and payload (COSMIC).

VPN: A VPN is one or more WAN links over a shared public network, typically over the

Internet or an IP backbone from a Network Service Provider (NSP), that simulates the behavior of dedicated WAN links over leased lines.

4 Mission and Spacecraft Overview

4.1 General

The FORMOSAT-3/COSMIC mission is a joint U.S. – Taiwan venture whose goal is to gain inexpensive profiles of temperature and moisture across the globe by intercepting GPS signals with a satellite-based receiver and inferring the deviations in each signal's straight-line path caused by

temperature and moisture gradients.

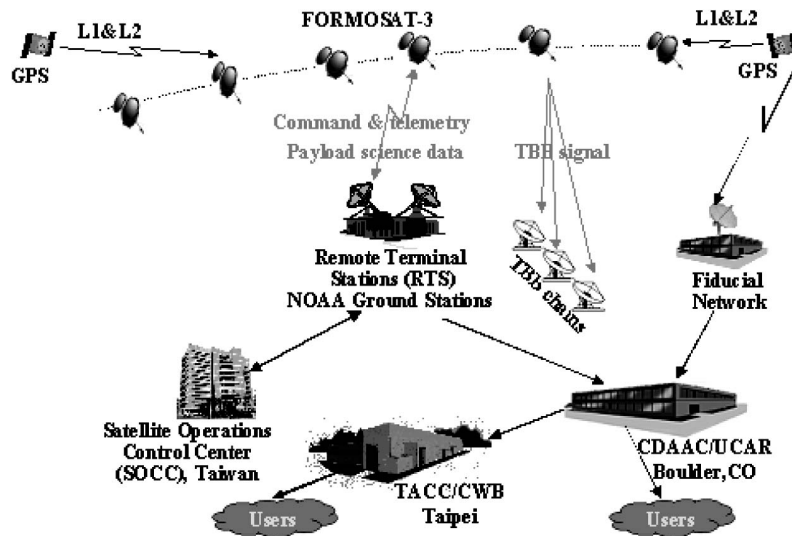


Figure 4-1 System Architecture

As depicted in Figure 4-1, the FORMOSAT-3/COSMIC mission consists of six spacecraft each with three instruments, a Satellite Operation and Control Center (SOCC) in Hsin-Chu, Taiwan, and a COSMIC Data Analysis and Archive Center (CDAAC) at the University Corporation for Atmospheric Research (UCAR) site in Boulder, Colorado. Operations consist of both real-time TT&C and non real-time data delivery. The mission is conducted from the RTS/RTS-R (Fairbanks in Alaska, or KSAT Tromso in Norway, or Wallops CDA). The real-time interfaces occur between the RTS and the SOCC. The non real-time telemetry files are delivered automatically in post-pass from the RTS/RTS-R to the CDAAC and SOCC.

4.2 Science Segment

The primary instrumentation aboard FORMOSAT-3 is an advanced GPS receiver. The receiver can autonomously track all GPS satellites in view simultaneously. The instrument reports phase changes within the frequencies of the carrier within sub millimeter accuracy for high resolution profiling.

Two additional instruments, a photometer (TIP) and a beacon transmitter (TBB), will measure electron density and relay this to ground receivers. TBB data is not in VC2 file.

4.3 Spacecraft Communications

The FORMOSAT-3/COSMIC mission is an S-Band CCSDS downlink mission with S-Band High-level Data Link Control (HDLC) telecommanding uplink. The spacecraft has RHCP downlink frequency of 2215 MHz and receives the RHCP uplink at 2039.5 MHz. The downlink data rate is selectable between 32 Kbps and 2 Mbps while the uplink is only 32 Kbps. NRZ-M format and BPSK modulation techniques are used on both the uplink and downlink.

4.4 Mission Duration

The FORMOSAT-3 constellation was launched on April 15, 2006, and is expected to last for five years.

4.5 Orbit

There are 6 satellites to form a constellation to fulfill the FORMOSAT-3/COSMIC mission. Each satellite is in one of six orbit planes at the same altitude of 800 km and 72° inclination, and the orbit plans and satellites are phased about 30° apart in ascending node and 52.5° apart in argument of latitude, respectively.

5 RTS/RTS-R Overview

5.1 Remote Tracking Station

The FORMOSAT-3/COSMIC mission requires a string of RTS/RTS-R hardware at Fairbanks in Alaska and Tromso in Norway. The string of hardware is required to support 24/7 operations of the FORMOSAT-3/COSMIC mission. The Wallops RTS is provided as a backup station.

The Front-End-Processor in RTS/RTS-R is the Cortex. The operations controller in SOCC connects directly to the RTS Cortex in real-time to monitor SOH telemetry and Cortex status and issues Telecommands via Cortex during the pass contact. This real-time connection to the Cortex is not provided at the RTS-R site. The post-pass data delivery is handled by RTS/RTS-R. The data files are pushed to the CDAAC site and SOCC.

5.2 Ground Station Coverage

Figure 5-1 FORMOSAT-3/COSMIC Ground Coverage is an illustration that depicts FORMOSAT-3/COSMIC to NOAA RTS/RTS-Rs access. The simulation is based on the nominal orbit parameters of 800 kilometers, with a desired inclination of 72°. The FORMOSAT-3/COSMIC mission will schedule approximately 42 passes per day for each RTS/RTS-R site (Fairbanks and Tromso). It is about one pass scheduled every 30 minutes. A pass is defined as from ground antenna elevation angle 10 deg to 10 deg.

2Mbps is the nominal COSMIC downlink rate; the downlink data contains science and telemetry data. Each pass will have two science data dumps for one file. The data rate may autonomously change in mid-pass which requires the RTS/RTS-R CORTEX to automatically change to lower rate of 32kbps. The 32kbps data includes real-time state of health data; it does not include science data.

NSPO schedules 2 commanding passes per day for each satellite for nominal operations. Fairbanks is the nominal primary station for uplink. Fairbanks and Wallops will keep the carrier up for all the scheduled passes.

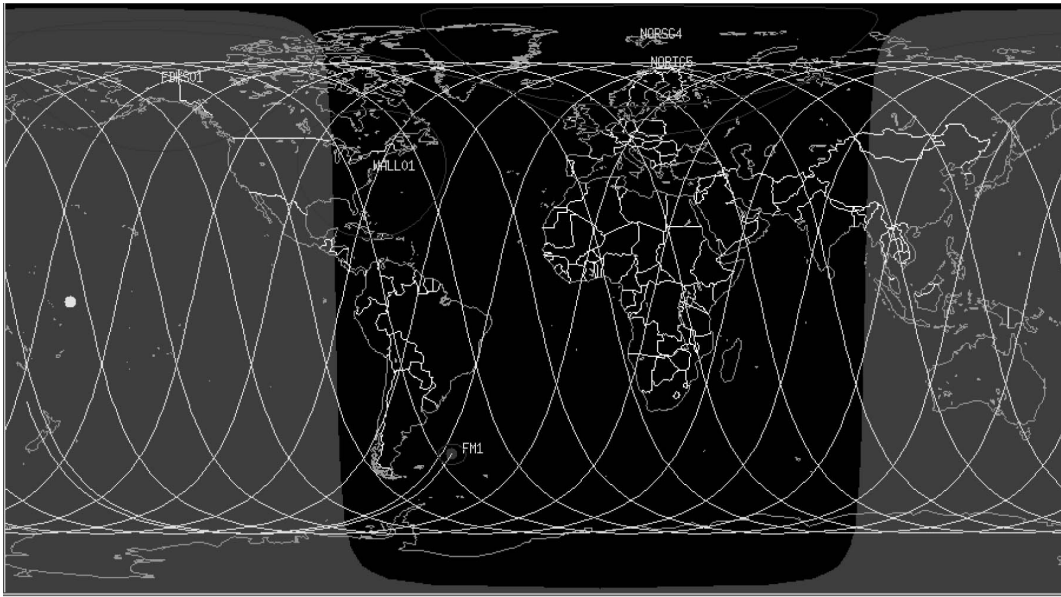


Figure 5-1 FORMOSAT-3/COSMIC Ground Coverage

6 Interface Descriptions

The spacecraft will transmit real-time telemetry, stored SOH, and stored science data to the ground station during a RTS/RTS-R pass. During a pass the RTS will send real-time telemetry and RTS cortex status to SOCC for monitoring. At the end of a pass, the RTS/RTS-R will first push SOH data (VC0 and VC1) to SOCC, then science data (VC2) and SOH data (VC1) to CDAAC through the open internet to a firewall protected FTP server. After the science and SOH data have been transmitted to CDAAC, the RTS/RTS-R will push science data (VC2) to SOCC. The data transfer between the RTS/RTS-R and the SOCC is through a VPN.

For off-line operations, SOCC will provide request for pass scheduling files and will update the ephemeris so that RTS/RTS-R can pull these files from the ftp site.

Fairbanks is a primary ground station for uplink and downlink. Wallops is a backup commanding station for the Fairbanks station and it can also be a backup to Tromso if necessary. Tromso, is a primary ground station for receiving telemetry, but has no capability to do commanding, and does not provide real-time telemetry / status to the SOCC it is called RTS-R (Receive only). Svalbard, as the backup station of Tromso, has uplink and downlink capability, this site is expected to be available only until June 2008. FORMOSAT-3 can use it to do the uplink when there is an emergency.

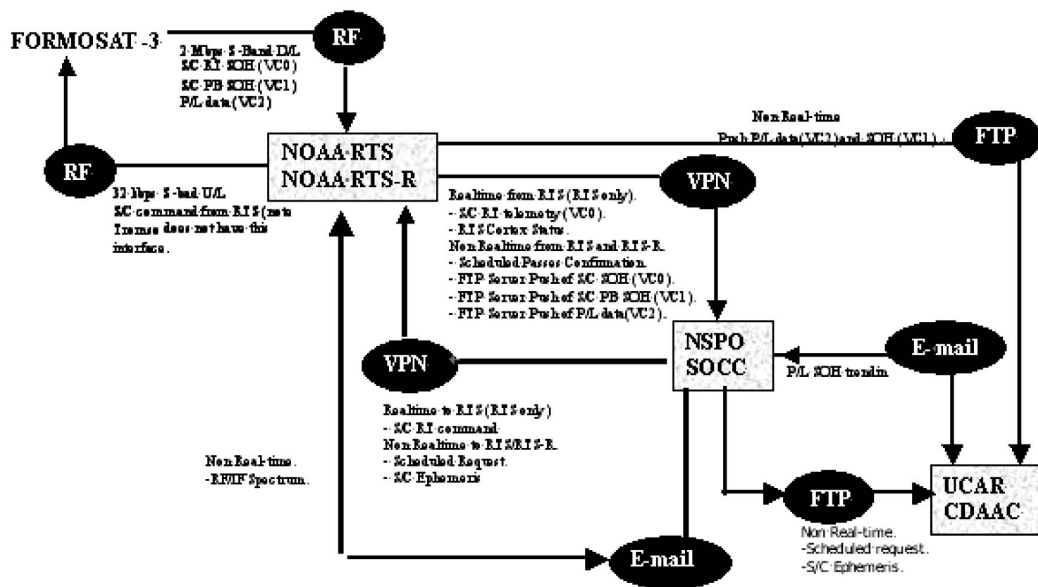


Figure 6-1 FORMOSAT-3/COSMIC Connectivity Network

6.1 Satellite Ephemeris Update

SOCC shall provide the IP address of an FTP server, directory path specification, and name of a file containing the two-line orbital element (TLE) information used by the NOAA RTS/RTS-Rs. This FTP Server information is documented in the FORMOSAT-3/COSMIC IT/Network Connectivity Document. All TLE data are placed on the SOCC FTP site for download by the RTS/RTS-R by 09:00 UTC on Monday and 22:00 UTC on Thursday of every week. The TLE at each RTS/RTS-R is updated daily with the most current information available to RTS/RTS-R operations personnel. The RTS/RTS-R sites will FTP-pull files from the SOCC FTP Server.

If the SOCC is unable to provide a Two Line Element set (TLE), then the TLE will be obtained from the publicly accessible site listed in the FORMOSAT-3/COSMIC IT/Network Connectivity Document. The ephemeris data updates will be done as TLE data. The TLE file naming convention is detailed in the document of FORMOSAT-3/COSMIC Ground Network Interface Control Document for NOAA Ground Stations.

6.2 Support Scheduling

There are four types of contact scheduling supported on the FORMOSAT-3/COSMIC mission – routine supports, backup supports, emergency supports that require immediate contact with the spacecraft, and proficiency supports. For any contact, the SOCC is responsible for providing RTS/RTS-R with a contact schedule in the format as described in the document of FORMOSAT-3/COSMIC Ground Network Interface Control Document for NOAA Ground Stations.

6.2.1 Routine Supports

Antennas for support of the FORMOSAT-3/COSMIC mission are scheduled via weekly pass schedule request files from the SOCC in Taiwan. The schedule request files include all satellite support requests for a single site, and are for a one-week period starting with Thursday of the current week. All scheduling requests are placed on a SOCC FTP site for download by the RTS/RTS-R by 09:00 UTC on Monday of every week. All scheduling requests will be reviewed and processed

within 24 hours of receipt or by the end of the next business day. If a support is needed that was not included in the weekly scheduling cycle, then verbal notification to the RTS/RTS-R will be required, in addition to an e-mail notification of the schedule request the contacts for these requests are identified in section 7.5.

Once the request(s) is/are received, processed, and accepted into the Contact Schedule, a confirmation message shall be sent via FTP to the SOCC by 22:00 UTC on Tuesday of every week. This shall serve as notification that the RTS/RTS-R Contact Schedule has been updated. The RTS/RTS-R shall be responsible for scheduling the resources to support SOCC operations for the mission. The RTS/RTS-R shall ensure that the resources are operational and properly configured for each support.

6.2.2 Backup Supports

If Fairbanks or Tromso is unavailable (for maintenance reasons for example), the Wallops CDA shall be coordinated as an additional resource available for the support. If the resource has not been committed to support another mission, the equipment is scheduled. Svalbard is also available as an interim emergency commanding site until June 2008.

6.2.3 Emergency Supports

If the SOCC determines that a spacecraft emergency exists, the SOCC should immediately notify the RTS operations personnel for additional ground station support for uplink (therefore, Tromso is not under consideration in this case). The RTS/RTS-R Controller will work with the SOCC to determine availability of RTS resources to provide the emergency support.

The spacecraft emergency requester and all those affected are notified of the RTS/RTS-R Controller final decision via verbal communications. If the RTS/RTS-R Controller has approved a change, an email with the updated schedule will be sent to all project schedulers.

6.2.4 Proficiency Supports

Wallops pass will be scheduled once per week for maintaining proficiency.

6.3 Data Management

Post pass processing of non-real time telemetry begins within the three minutes following the conclusion of each contact. The spacecraft downlink telemetry data is sorted into Virtual Channel files at the RTS/RTS-R sites. Table 6-1 identifies the Virtual Channels used on the FORMOSAT-3/COSMIC mission

The retention period and data transfer sequence/priority for files are defined in FORMOSAT-3/COSMIC Ground Network ICD for NOAA Ground Stations.

Table 6-1 Virtual Channel Archive Files

Virtual Channel Number	Description
VCID 0	Spacecraft Real-time SOH
VCID 1	Spacecraft Bus Stored SOH
VCID 2	Payload Science/SOH
VCID 7	Fill Frames – Not Archived

6.4 Pass support Reporting

RTS/RTS-R Controller initiate written and oral problem reports for any anomalous condition. If a problem has impacted the FORMOSAT-3/COSMIC pass support, the RTS/RTS-R Controller notifies the SOCC Controller via SOCC operators' e-mail and phone call. When the problem would impact the pass support, a problem report is required.

6.5 Spectrum Request

For spacecraft RF anomalies the SOCC may request the RTS/RTS-R to generate RF/IF spectrum plots. The request will be sent verbally and by e-mail and the spectrum data will also be transmitted from the RTS/RTS-R to the SOCC via e-mail.

7 Procedures and Contact Information

7.1 RTS/RTS-R-to-SOCC Connectivity Testing

SOCC performs connectivity testing between the RTS/RTS-Rs and the SOCC using the IP addresses listed in the FORMOSAT-3/COSMIC NOAA to SOCC IT Configuration Document. During this procedure, SOCC exercises all communication data rates between RTS/RTS-R and SOCC.

7.2 RTS/RTS-R-to-SOCC Data Flow Testing

SOCC performs data flow compatibility testing between the RTS/RTS-Rs, SOCC and CDAAC using a data flow test plan based on the FORMOSAT-3/COSMIC Ground Network Interface Control Document. During this procedure, SOCC exercises all required communications interfaces including voice, real-time and playback telemetry, and commanding.

7.3 End-to-End Test

SOCC supports both real-time and non real-time End-To-End tests with the on-orbit FORMOSAT-3 satellite to confirm RTS/RTS-Rs readiness to support the FORMOSAT-3/COSMIC mission.

7.4 Routine Mission Support

For pass operations, NSPO will comply with the operations requirements described in the NOAA/ NASA SR in an effort to limit the radio frequency interference with NASA missions.

During routine mission support, Fairbanks contacts will be used for real-time command and telemetry, and the downlink of stored housekeeping and science data. Tromso contacts will be used to receive telemetry and science data. Science data collection continues during contact with the ground, but there is no "real-time" science downlink; all science data is recorded and stored on the RTS/RTS-R FTP server.

Operations personnel at the RTS/RTS-R configure supports according to the most recently updated contact schedule. The ground station equipment is configured and the antenna is loaded with the most current TLE available to RTS/RTS-R. Prior to the start of each scheduled contact, monitoring and control software perform pre-check verification of the ground station equipment and the Data Router socket connections.

The operational system is configured to alert the RTS/RTS-R operation personnel of any anomalous condition. The RTS/RTS-R operation personnel take corrective action whenever needed to support the mission objectives. If the objectives are impacted, the RTS/RTS-R operation personnel notify the SOCC personnel via telephone the extent of any problems and the resolution.

Following the conclusion of each contact, the automated data management system software completes post pass processing of the non-real time data.

7.5 Contact Information

Table 7-1 Points of Contact for FORMOSAT-3/COSMIC Mission Operation

POC	Org./Div.	Phone #	Fax #	Email Add.
SOCC 24 hr (operators)	NSPO/ SOCC	886-3-578-4208 Ext. 1683	886-3-578-7930	ngs_oc@nspo.org.tw
SOCC scheduler	NSPO/ SOCC	886-3-578-4208 Ext. 1682	886-3-578-7930	mcc@nspo.org.tw
Bo Chen (SOCC technical point of contact)	NSPO/ SOCC	886-3-578-4208 Ext. 1592	886-3-577-9058	bochen@nspo.org.tw
Raymond Yang (SOCC backup technical point of contact)	NSPO/ SOCC	886-3-578-4208 Ext. 9492	886-3-577-9058	rmyang@nspo.org.tw
Tie-Yue Liu (science)	NSPO/ SRD	886-3-578-4208 Ext. 9381		tie@nspo.org.tw
CDAAC Operator	UCAR/ CDAAC	303 579 3776	303 497 2610	cosmicops@mail.cosmic. ucar.edu
Shift Leader	Fairbanks	907-451-1222	907-451-1209	fcda leaders@noaa.gov
Shift Leader	W a l l o p s CDA	757-824-7304	757-824-7300	wcdaopsmgr@noaa.gov
Stig E. Kræmer	K S A T Tromso	(47) 77661313	(47)7600299	stigk@ksat.no
Roger Lind (TNOC Operations manager)	K S A T Tromso	(47) 77600285	(47)7600299	Roger.lind@ksat.no
TNOC 24/7 operators	K S A T Tromso	(47) 77600268 (47) 77600269	(47)7600298	tnoc-operator@ksat.no
NORTG5 and NORSG4 scheduling	K S A T Tromso	(47) 77600268	(47)7600269	scheduling@ksat.no

Appendix A Acronyms

ACU Antenna Control Unit
BPSK Binary Phase Shift Keying
CCSDS Consultative Committee for Space Data Systems
CDAAC COSMIC Data Analysis and Archive Center
COSMIC Constellation Observing System for Meteorology Ionosphere, and Climate Program
DOY Day of Year
FTP File Transfer Protocol
HDLC High-Level Data Link Control
ICD Interface Control Document
KSAT Kongsberg SATellite Services AS
LAN Local Area Network
MSP Mission Support Plan
NOAA National Oceanic and Atmospheric Administration
NSPO National Space Organization
RTS-R Remote Terminal Services –Receive only
SOCC Satellite Operation and Control Center
SOH State of Health
SOW Statement Of Work
TBB Tri-Band Beacon
TBD To Be Determined
TCP/IP Transmission Control Protocol/Internet Protocol
TIP Tiny Ionospheric Photometer
TLE Two Line Element
TNOC Tromso Network Operation Control
UCAR University Corporation for Atmospheric Research
USN Universal Space Network
VPN Virtual Private Network
WAN Wide Area Network
VCID Virtual Channel Identifier