Interactive comment on "Space and ground segment performance of the FORMOSAT-3/COSMIC mission: four years in orbit" by C.-J. Fong et al.

Anonymous Referee #2

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General comments

The article provides a good and quite detailed overview of four years of the COSMIC mission, and could become a standard reference for this topic. Due to its overview nature, scientific advancements would not be expected. There is a certain amount of repetition which could be reduced (see also specific comments). The reader also has to remember a lot of acronyms. The emphasis on lessons learned and proposed improvements I consider valuable, and if still possible could even be reflected in the title of the paper.

Response:

- **Thanks for the reviewer's comments.**
- **For the reviewer's acronym comments. The authors here provide the acronym list and will put at the end of the paper. As follows: (page 619, line 11~)**

Appendix Acronyms and Abbreviations

ACE	**Attitude Control Electronics**
ADCS	**Attitude Determination and Control Subsystem**
AFWA	**Air Force Weather Agency**
Ant#	**Antenna No. #**
ATT	**Attitude**
BCR	**Battery Charge Regulator**
C&DH	**Command and Data Handling**
CDAAC	**COSMIC Data Analysis and Archive Center**
CHAMP	**Challenging Minisatellite Payload**
COSMIC	**Constellation Observing Systems for Meteorology, Ionosphere, and Climate**
Canada Met	**Canadian Meteorological Centre**
CLASS	**Comprehensive Large Array-Data Stewardship System**

CSSA	Coarse Sun Sensor Assembly
CSSA#	Coarse Sun Sensor Assembly no. #
CWB	Central Weather Bureau
DC	Direct Current
dMdC	Derivative of Battery Molecular to Charge
DPC	Data Processing Center
DPS	Data Processing System
ECMWF	European Centre for Medium-range Weather Forecast
EPS	Electrical Power Subsystem
ESPC	Environmental Satellite Processing Center
FB	Firmware Build
FC	Flight Computer
FCDAS	Fairbanks Command and Data Acquisition Station
FDC	Failure Detection Correction
FM	Flight Model
FM#	Flight Model no. #
FPGA	Field Programmable Gate Array
FS-3	FORMOSAT-3
FS-7/C-2	FORMOSA SATellite mission no.7/ Constellation Observing Systems for Meteorology, Ionosphere, and Climate mission no. 2
FSW	Flight Software
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GPS/MET	GPS/Meteorology
GOX	GPS Occultation Receiver
GPSR	GPS Receiver
GRACE	Gravity Recovery and Climate Experiment
GTS	Global Telecommunications System
I&T	Integration and Test
IV&V	Independent Verification and Validation
JMA	Japan Meteorological Agency
JPL	Jet Propulsion Laboratory
JSCDA	Joint Center for Satellite Data Assimilation
KSAT	Kongsberg Satellite Services Ground Station
LEO	Low-Earth-Orbit
LOS	Loss of Signal
LTS	Local Tracking Station

MAG	Magnetometer
Météo-France	French National Meteorological Service
MIU	Mission Interface Unit
NARL	National Applied Research Laboratories
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NSC	National Science Council
NSF	National Science Foundation
NSOF	NOAA's Satellite Operations Facility
NSPO	National Space Organization
NWP	Numerical Weather Prediction
OCC#	Occultation No. #
OSC	Orbital Sciences Corporation
PCM	Power Control Module
PL	Payload
POD	Precision Orbit Determination
POD#	Precision Orbit Determination No. #
RF	Radio Frequency
RF#	Radio Frequency No. #
RFI	Radio Frequency Interference
RO	Radio Occultation
RTS	Remote Tracking Station
RWA	Reaction Wheel Assembly
SAA	South Atlantic Anomaly
SAC-C	Satellite de Aplicaciones Cientificas-C
SADA	Solar Array Drive Assembly
S/C	Spacecraft
SFTP	Secure File Transfer Protocol
SNR	Signal-to-Noise Ratio
SOC	State-of-Charge
SOCC	Satellite Operations Control Center
SOH	State-of-Health
SSR	Solid State Recorder
TACC	Taiwan Analysis Center for COSMIC
TBB	Tri-Band Beacon

TBR	**To Be Reviewed**
TDRSS	**Tracking and Data Relay Satellite System**
TEC	**Total Electron Content**
TIP	**Tiny Ionospheric Photometer**
UCAR	**University Corporation for Atmospheric Research**
UKMO	**United Kingdom Meteorological Office**
USA	**United States of America**
USAF	**United States Air Force**
USN	**United Service Network**
VC#	**Virtual Channel No. #**
VIDI	**Velocity, Ion Density and Irregularities**
WCDAS	**Wallops Command and Data Acquisition Station**
ZTD	**Zenith Tropospheric Delay**

- **Based on the lessons learned comments, the authors would like to change the paper title name from "Space and ground segment performance of the FORMOSAT-3/COSMIC mission: four years in orbit" to "Space and ground segment performance and lessons learned of the FORMOSAT-3/COSMIC mission: four years in orbit"**

Specific comments

1. Section 3.1, page 604, line 5: "two-year experimental mission with a 5-year spacecraft design life". This is confusing. What exactly is meant? Is it 2 + 5 years, or are the 2 years included in the 5? In that case, what about the other 3?

Response:

- **The spacecraft mission life is 2 years and the spacecraft design life is 5 years. Two-year is included in the five-year. The additional 3-year is to make sure the spacecraft could complete the 2-year mission after launch.**
- **Modify this paragraph from "The constellation was intended to be a two-year experimental mission with a five-year spacecraft design life." to "The experimental constellation was defined to have a two-year spacecraft mission life, and the spacecraft design life is five years." (page 604, line 5)**

2. Section 3.1, page 604, line 20: second occurrence of the SADM failure and the reduced orbit altitude of FM3. This is the best place to describe this event.

Response:

- **Thanks for the suggestion.**

- **The authors decided to delete the paragraph of "One of the six satellites, designated as FM3, was not able to maneuver to the 800 km final orbit due to a solar array drive mechanism problem during the orbit raising phase that prohibited the continuous thrust firing of the FM3. Therefore, FM3 was maintained at an orbit altitude of 711 km. The other five FS-3/C satellites (all except FM3) reached their final mission orbit altitude of 800 km by the end of November 2007 (Fong et al., 2008b)." (page 604, line 18-24)**
- **Modify the paragraphs from "FM3 encountered the solar array drive mechanism failure at 711 km orbit that led to the inhibited propellant thrust firing for the continuous orbit raising and tracking the solar power at reduced duty cycle depending on the power status of the spacecraft." to**
  "FM3 encountered a solar array drive mechanism failure at 711 km orbit that prohibited the continuous thrust firing of the FM3. The other five FS-3/C satellites reached their final mission orbit altitude of 800 km by the end of November 2007 (Fong et al., 2008b). FM3 tracked the solar power at reduced duty cycle depending on the power status of the spacecraft." (page 604, line 19-22)

3. Section 3.1, page 605, line 17-18: I am left in doubt what really happened. Did the computer autonomously perform a master reset as a result of the SAA? Was it a coincidence, or was the reset triggered from the ground?

Response:

- **According to the observation and history, most of the satellite resets/reboots were caused from Single Event Effects (SEEs) and occurred in the South Atlantic Anomaly (SAA) region and polar regions. This particular reset event on FM6 was not triggered (or commanded) from the ground.**

4. Section 3.2, page 606, line 7: "occultating precision orbit determination (POD) antenna": does the antenna really have both purposes: occultation measurement and support of POD? Are the POD1 and POD2 antennas not used for occultation processing?

Response:

- **Although it is called POD antenna, in this mission the POD antenna has two functions (or purposes): one is to provide precision orbit determination, and the other is to perform ionospheric radio occultation processing function. The occultation antenna only performs atmospheric radio occultation processing function.**

5. Section 4.1, page 609, line 13-15: third explanation of the lower orbit of FM3, which probably does not belong in the section about ground systems. If this affected the operations scheduling, it would be worth mentioning that.

Response:

- **During the constellation orbit deployment phase, the NSPO mission operations team, including Spacecraft operations team and flight operations team, spent 19 months in the SOCC to perform all six satellite orbit transfers. As a result, only five out of six satellites reached the predefined mission orbit altitude of 800 km. FM3 is the only one did not make it. These mission operations activities did involve many operation scheduling issues.**
- **The sentence of explanation of the lower orbit of FM3 will be removed in this paragraph. Delete the sentence "As mentioned previously, FM3 stayed in a lower orbit altitude of 711 km, which is 89 km lower than the other five satellite orbits of 800 km." (page 609, line 13-15)**

Editorial

6. Section 3.1, p.605, line 4: "GOX duty cycle on" and line 7: "reduced duty-cycle GOX on operations". Both phrases are a bit awkward to read.

Response:

- **Duty-cycle is defined as the average percentage of payload power on during a day. For the GOX mission payload, it was required and expected to be all on (duty cycle = 100%) during the normal operation phase.**
- **Modify from "GOX duty cycle on" to "GOX payload duty cycle on" in page 605 line 4.**
- **Modify from "reduced duty-cycle GOX on operations" to "reduced GOX payload duty cycle on operations" in page 605 line 7.**

7. p.605, bottom line and ff.. Instead of GOX (stand-alone), better write GOX instruments.

Response:

- **In order to have better reading the authors will change "GOX" to "GOX payload" in many places of this article.**
- **Modify from "As the primary mission payload, four GOX are being operated at a duty cycle of 100% and two other GOX (onboard FM2 and FM3) are being operated based on the state of the power charge at various sun beta angles (due to the power shortages)." to "As the primary mission payload, four GOX payloads are being operated at a duty cycle of 100% and two other GOX**

payloads (onboard FM2 and FM3) are being operated based on the state of the power charge at various sun beta angles (due to the power shortages)." (page 605, line 27-28 & page 606, line 1)

8. Section 3.2, page 606, line 7: occulting instead of occultating

Response:

- **Modify from "occultating " to "occulting " in page 606 line 7.**

9. Section 3.2, page 606, line 11 and ff.: this sentence is not understood. How does the SNR affect the temperature? If the temperature is below the red high limit, this should be good, but it reduces the availability: : :

Response:

- **Signal-to-noise ratio (SNR) is a measure to quantify how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the noise power. Major noise contribution to the GOX payload SNR is the thermal noise in the GOX circuitry. Thermal noise is linearly proportional to the temperature.**
- **When SNR is very low, one operation solution by the mission operations team is to lower the operating temperature of GOX payload instrument by turning on the GOX payload power in a shorten period of time. In this way, the noise (N) (linearly proportional to temperature) will be lower than the normal value, so the SNR is still high enough to generate good RO data. If the GOX payload is power on for a longer time period, the N will be higher as the temperature is raised, so the SNR will be very low. The GOX payload could not process out good RO data.**

10. Section 4.1, page 609, line 23: the term 'Phoenix' was not introduced..

Response:

- **"Phoenix" is a dormant function of satellite, which is the off state of the satellite when satellite is out of battery power and is used to support satellite recovery when power condition is back to stable.**
- **In order to introduce the concept of 'Phoenix'. Modify the paragraph "… Phoenix resets. Each …" to "… Phoenix resets. Phoenix is an off state of the satellite when satellite is out of battery power and is used to support satellite recovery when power condition is back to stable. Each …". (page 609, line 23.)**

11. Section 6 (several places): I am not familiar with the word 'trades' as it is being

used here ('trades and improvements'). Please check if this is correct usage. I may be wrong, but I could also not find any other examples of this usage.

Response:

- **In systems engineering term, "trade" here means "trade off". Explanation from wiki, a trade-off (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. It implies a decision to be made with full comprehension of both the upside and downside of a particular choice.**
- **Here 'trade' is 'trade off'. It is a correct usage in space engineering field, even if we just use 'trade' in this paper.**