



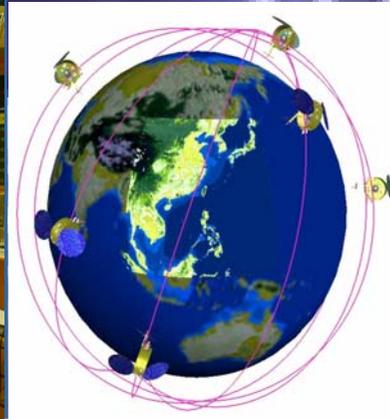
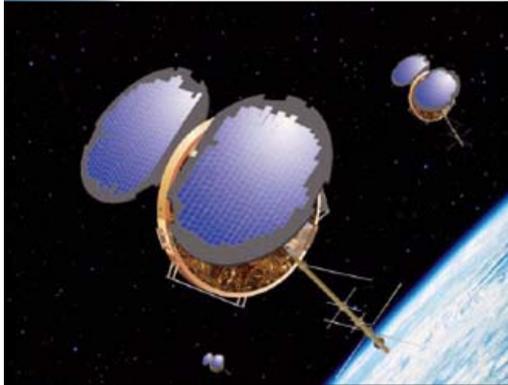
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OPAC-4, GRAS-SAF & IROW-1 Graz, Austria, September 6~11, 2010



Space & Ground Segment Performance of the FORMOSAT-3 / COSMIC Mission: Four Years in Orbit

Chen-Joe Fong, Doug Whiteley, Eddy Yang, Kendra Cook, Vicky Chu, Bill Schreiner, Dave Ector, Pete Wilczynski, Tie Yue Liu, & Nick L. Yen



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Outline

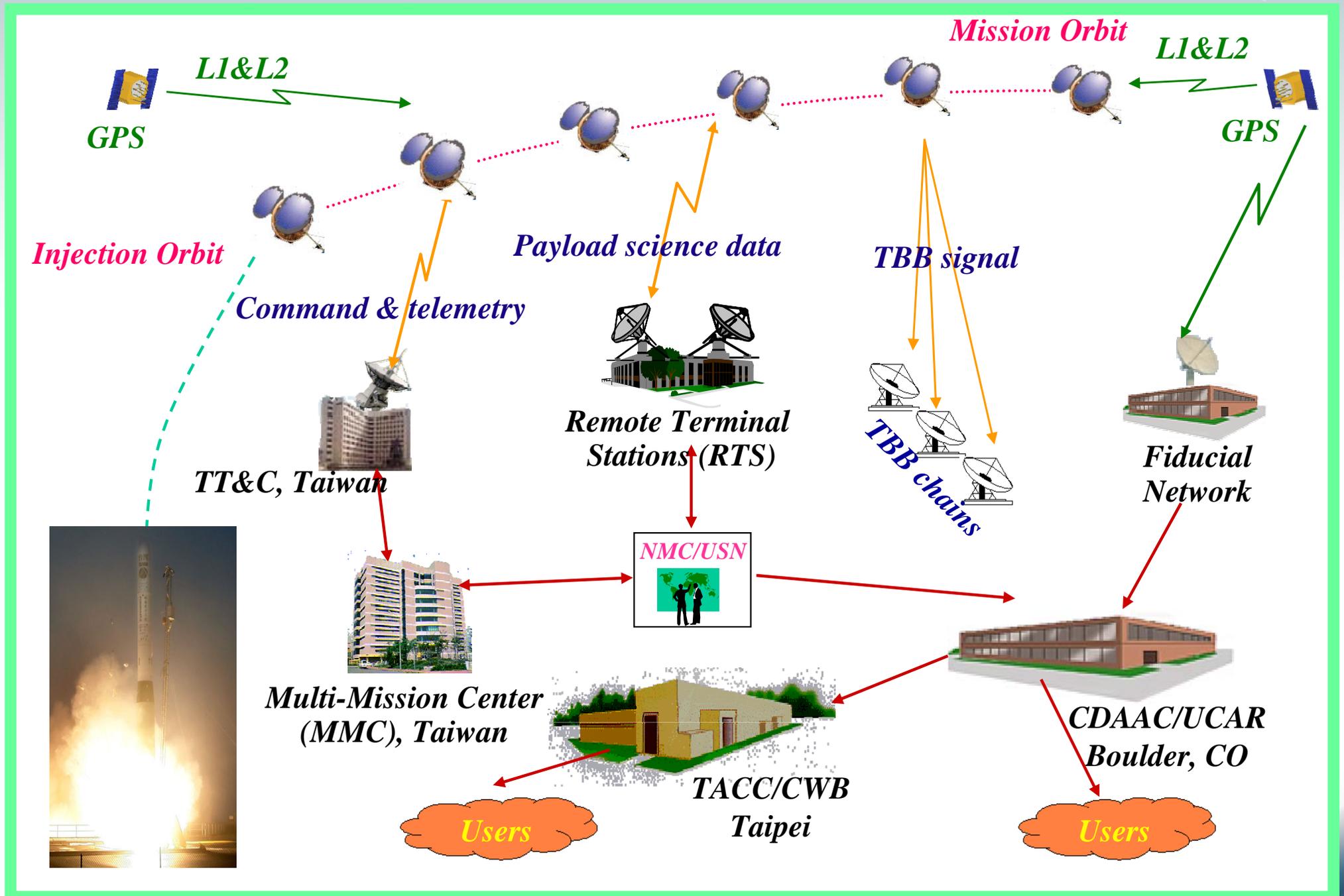
- *Mission Overview*
- *Spacecraft System Performance*
- *Ground System Performance*
- *Lessons Learned*
- *Design Improvements*
- *Conclusion*



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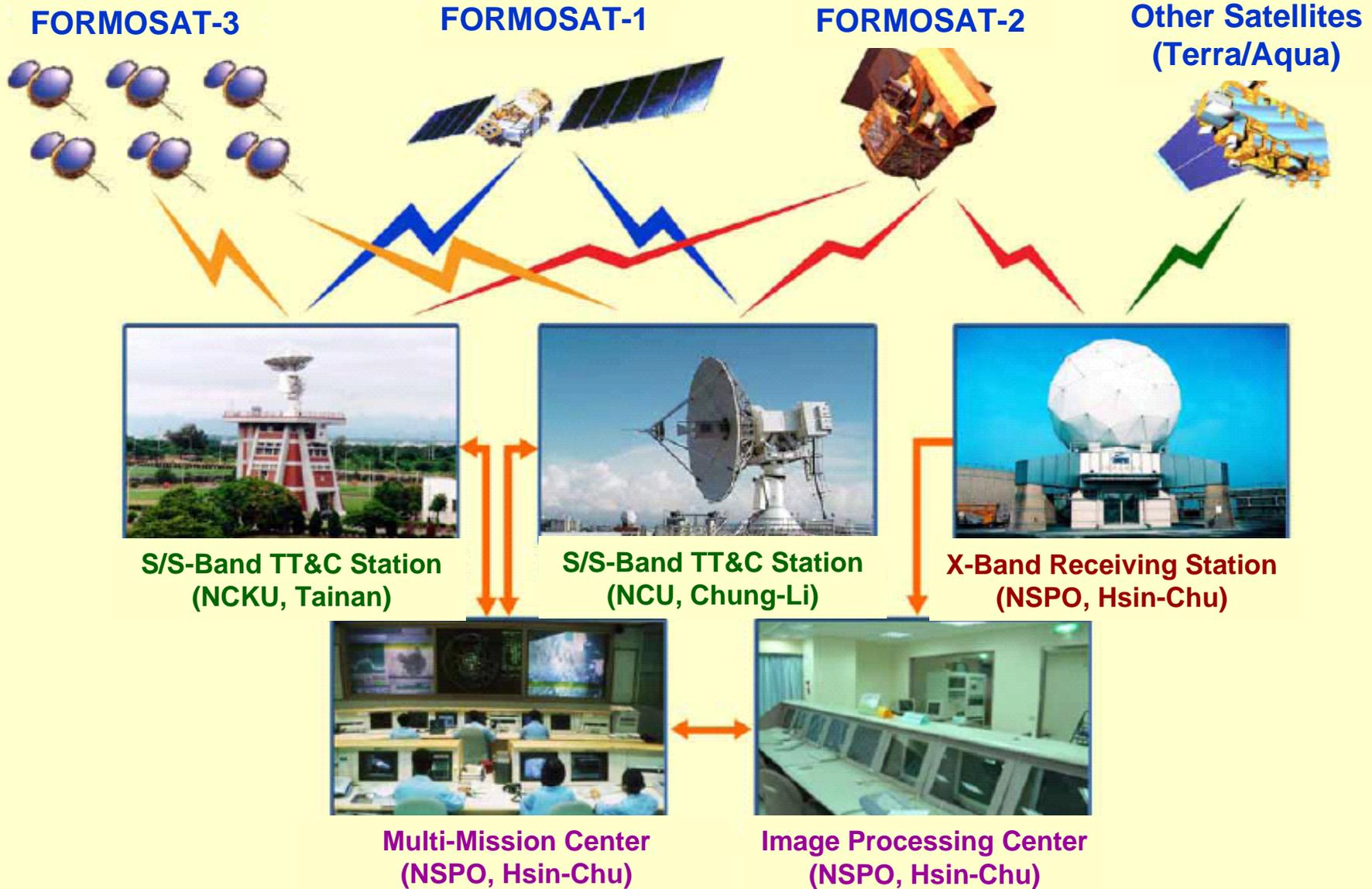
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FS-3/C System Architecture

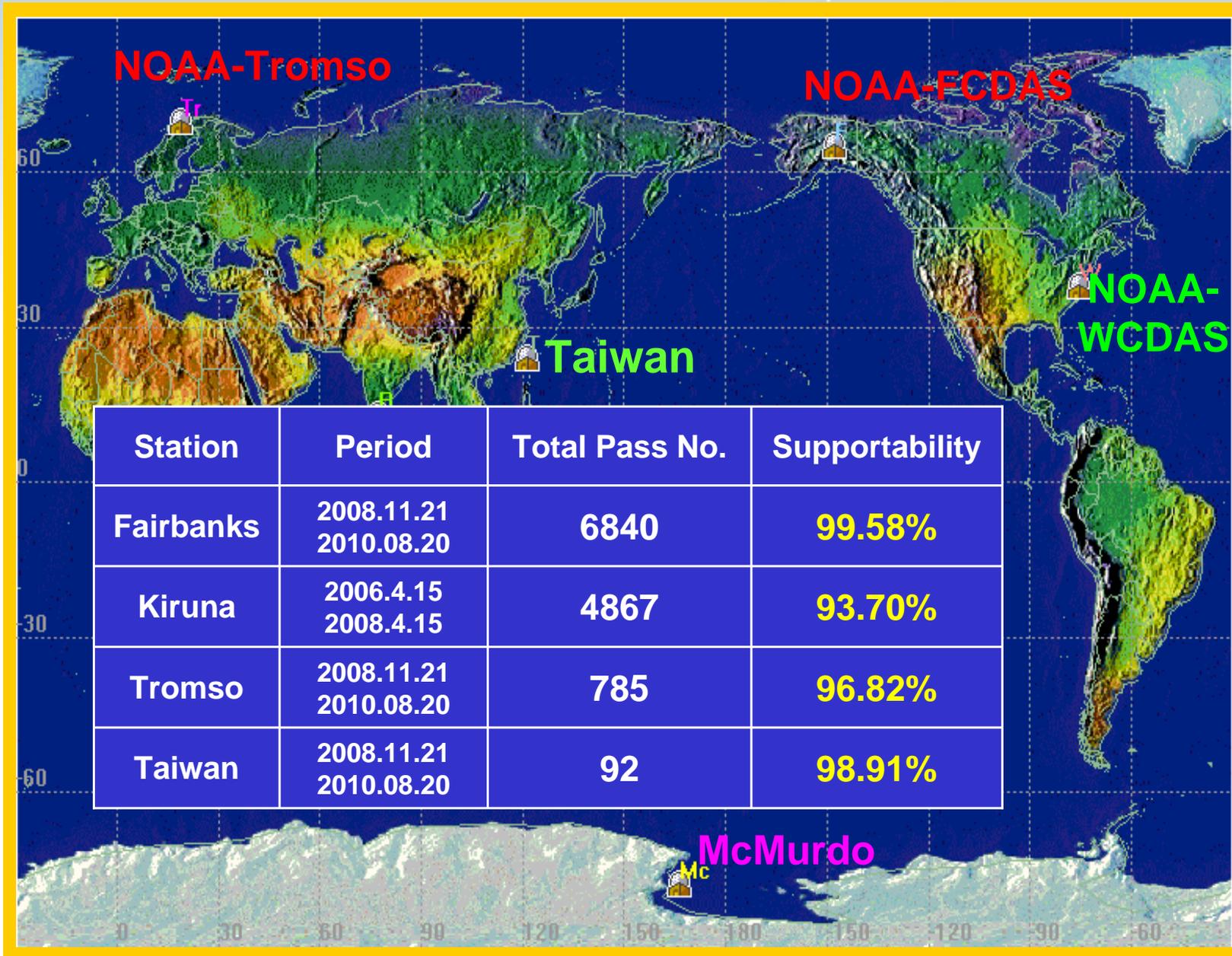


FORMOSAT Ground Segment

This facility is capable of operating multiple missions simultaneously



FS-3/C Ground Stations Networks

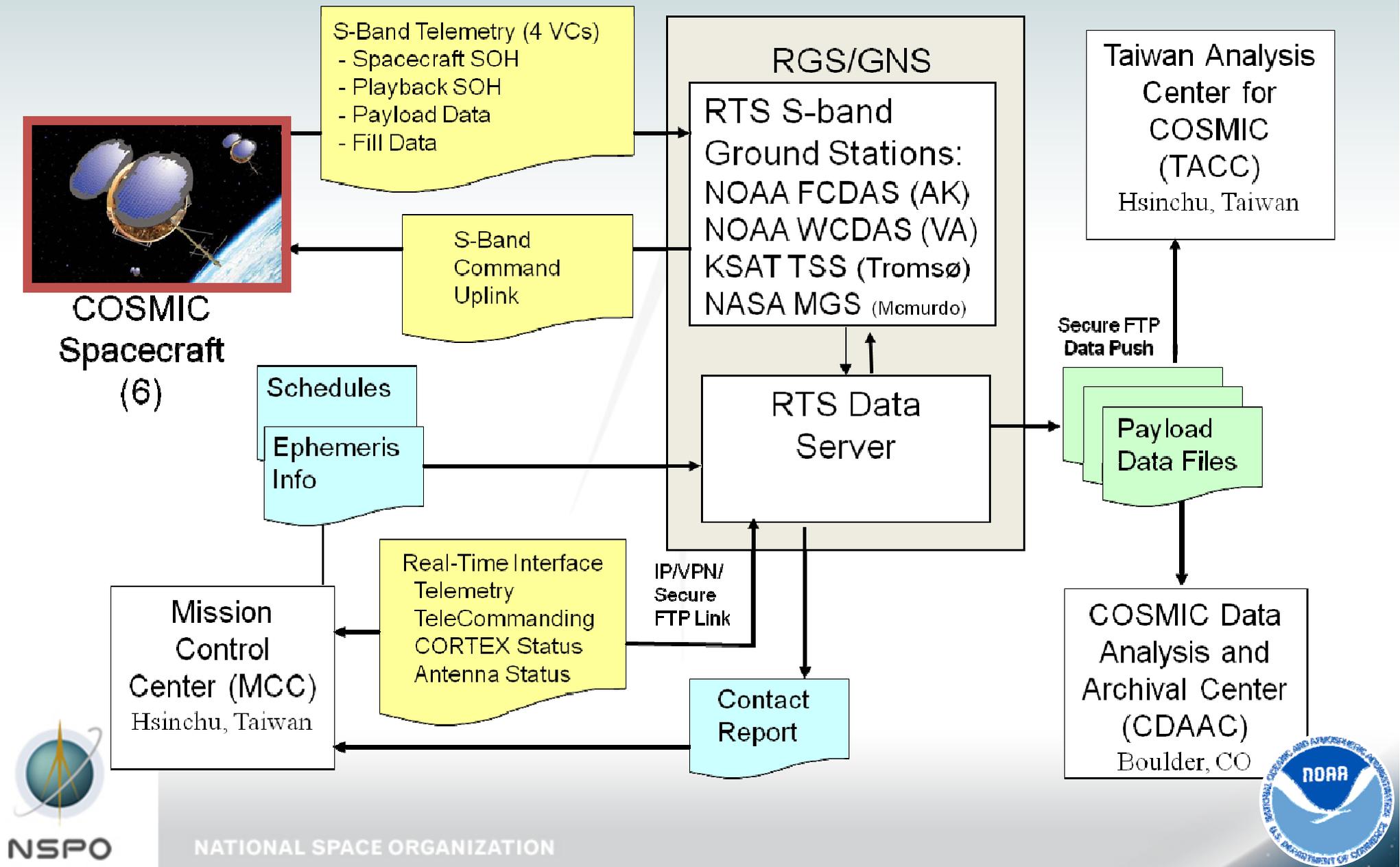


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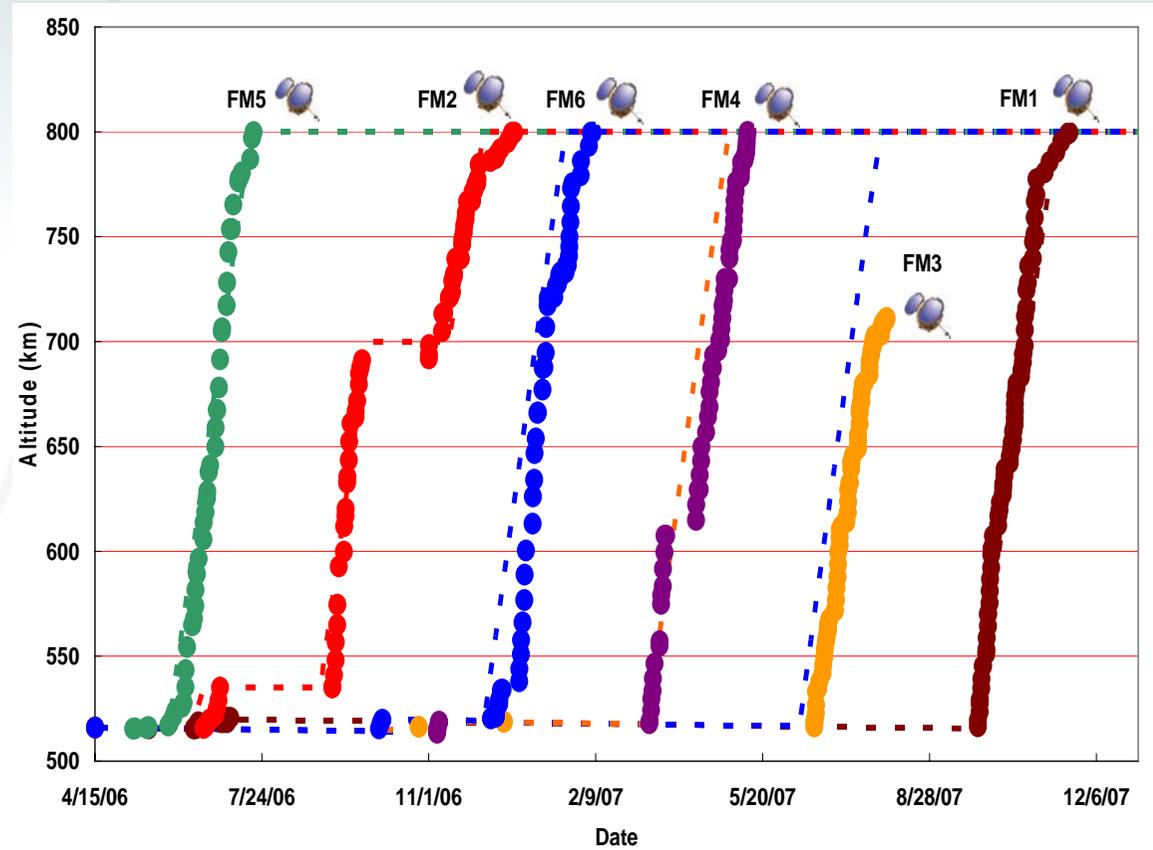
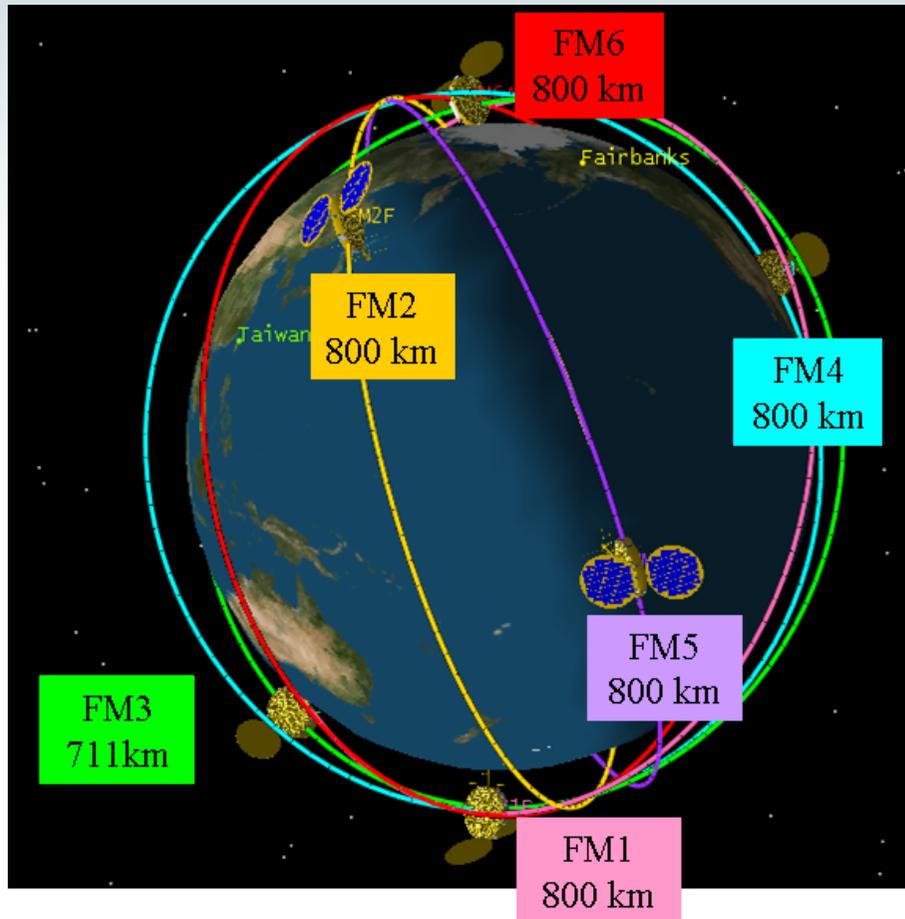
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FS-3/C Ground System Data Flow



Current FS-3/C Constellation



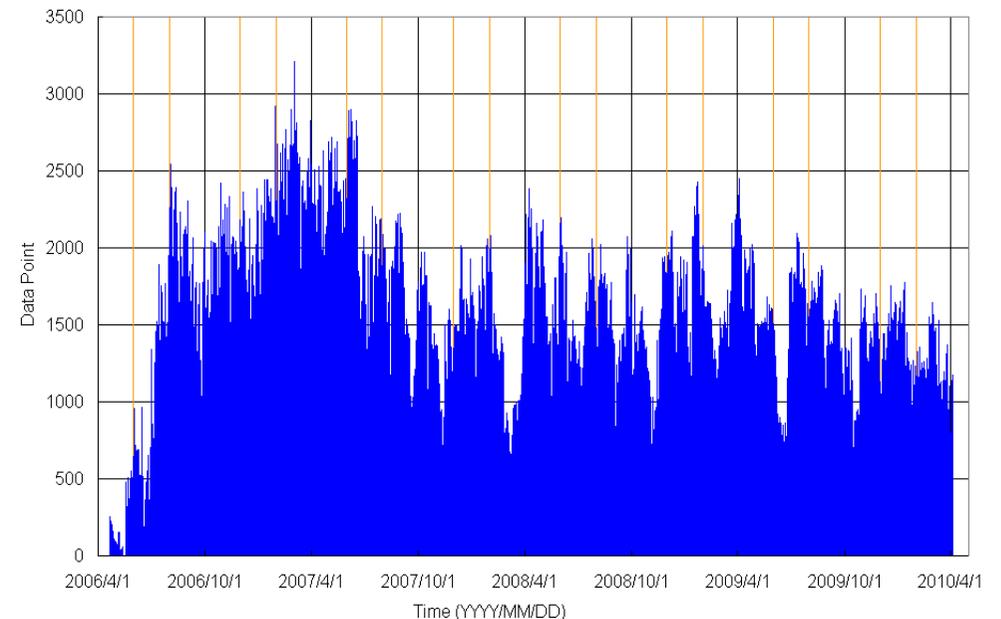
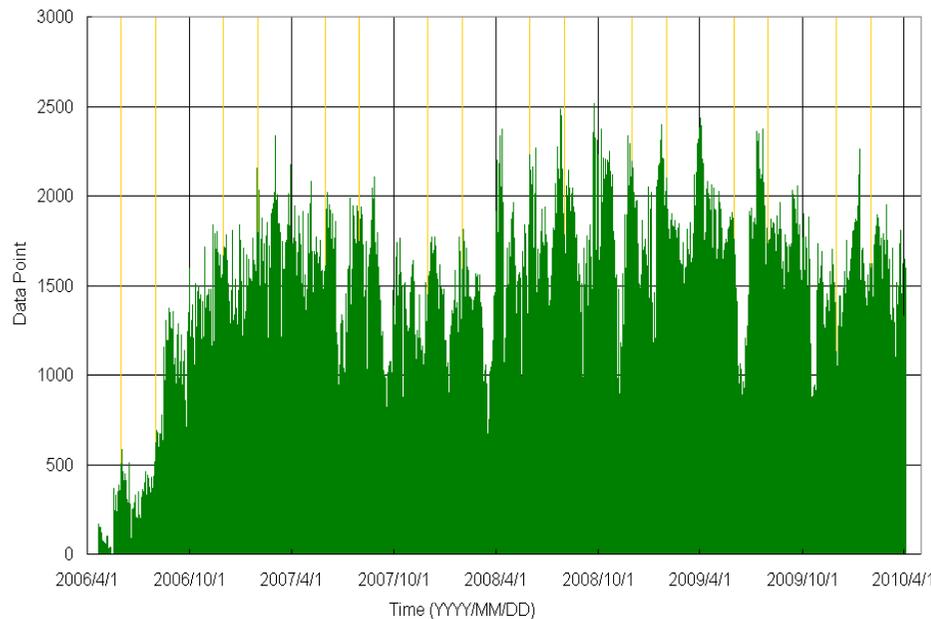
FS-3/C Radio Occultation Profiles (as is of 4-5-2010)

Atmospheric

Total 2,116,936 since launch

Ionospheric

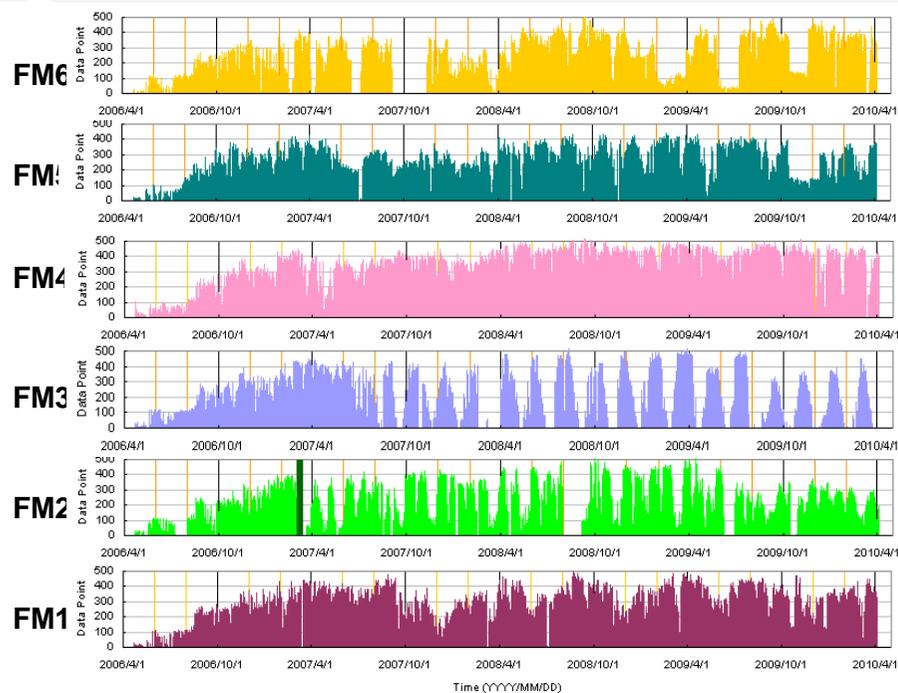
Total 2,265,964 since launch



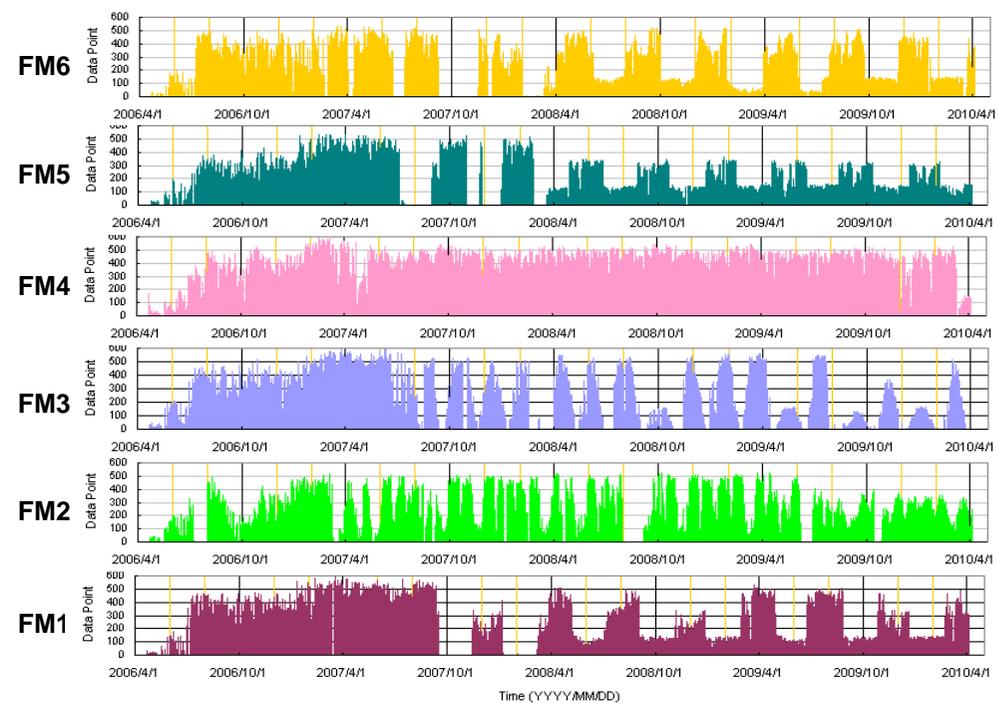
	FM1	FM2	FM3	FM4	FM5	FM6	Total
Atmosphere	398,245	294,198	284,970	474,713	348,475	316,335	2,116,936
Ionosphere	368,049	354,054	343,353	561,426	309,966	329,116	2,265,964

FORMOSAT-3 / COSMIC Radio Occultation Profiles (as is of 4-5-2010)

Atmospheric



Ionospheric



Spacecraft Mission Operation Status

- 1,400~1,800 sets of data profiles are generated per day on average
- FM3 have been an abnormal condition since July.

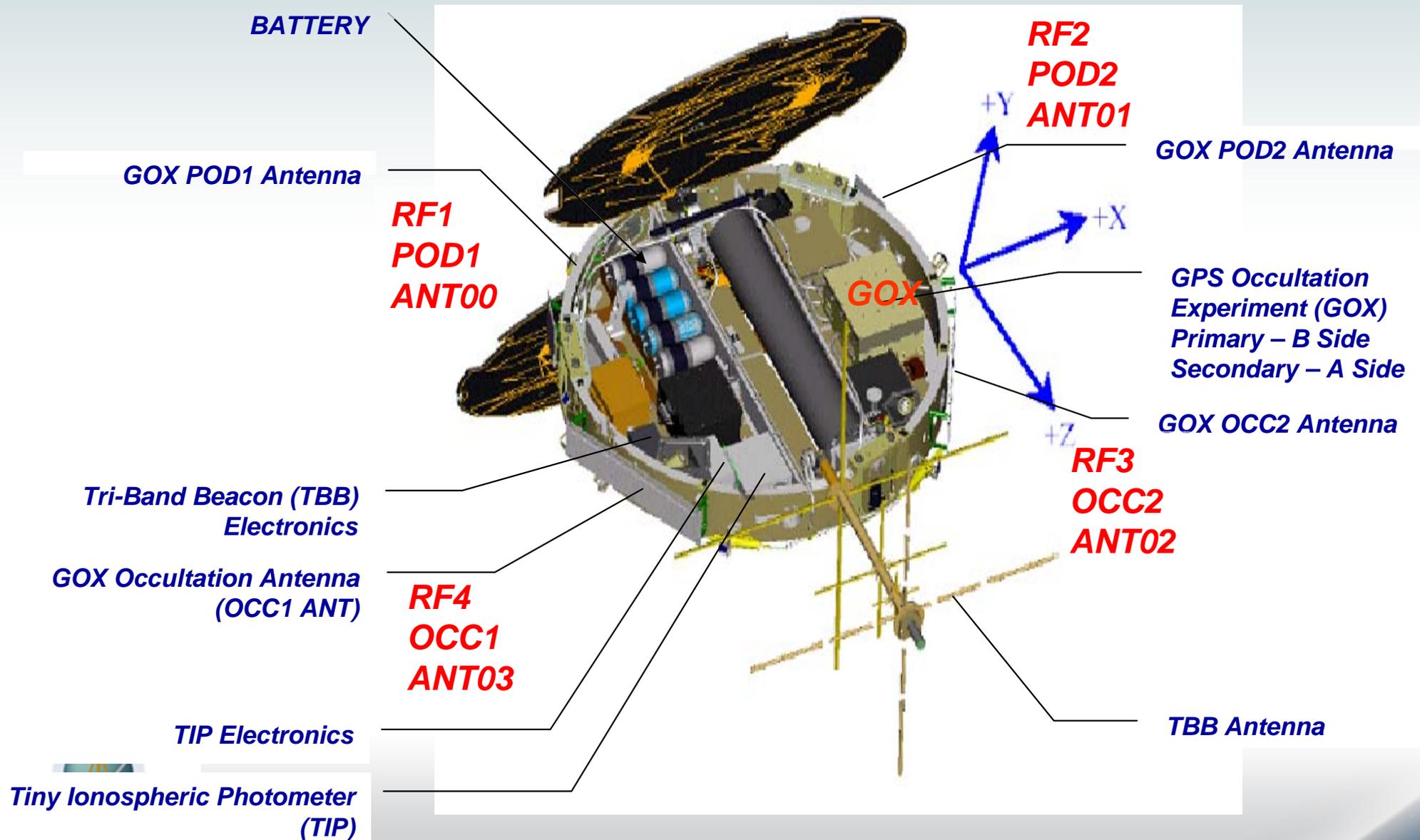
SC No.	Operational Mode	Spacecraft State	ACS Mode	EPS Mode	C&DH Mode	GOX	TIP	TBB
FM1	Normal	Normal	Fixed-Yaw	Normal	High Rate	Operating	Low Beta Operating	Low Beta Operating
FM2	Normal	Power Shortage	Fixed-Yaw	Normal	High Rate	Reduced Duty-Cycle Operating	Off (Note 1)	Off (Note 1)
FM3	Normal @711 km (Note 3)	SADE Stuck Battery Degradation (Note 2)	Fixed-Yaw	Normal	High Rate	Reduced Duty-Cycle Operating	Off (Note 1)	Off (Note 1)
FM4	Normal	Battery Degradation (Note 2)	Fixed-Yaw	Normal	High Rate	Operating	Low Beta Operating	Low Beta Operating
FM5	Normal	Normal	Fixed-Yaw	Normal	High Rate	Operating (Low SNR)	Low Beta Operating	Low Beta Operating
FM6	Normal	Battery Degradation (Note 2)	Fixed-Yaw	Normal	High Rate	Operating (Low SNR)	Low Beta Operating	Low Beta Operating

Note: 1. Secondary payloads are power off due to power shortage.

2: Significant FM4 & FM6 battery degradations causes payload power off at high battery state-of-charge.

3: FM3 was kept at 711 km orbit due to stuck solar array drive.

Spacecraft & Payload Configuration



GOX Payload Performance Summary

SC No.	GOX Duty Cycle	POD1 RF1 ANT00	POD2 RF2 ANT01	OCC2 RF3 ANT02	OCC1 RF4 ANT03	60 day Average Data Profile (Mean/Peak)	Remark
FM1	100 %	Low SNR				290/350	
FM2	80% -> 60%					200/320	Power Charging Issue
FM3	60% -> 36%	Low SNR				150/300	
FM4	100 %					300/420	
FM5	100 %	Low SNR	Low SNR		Low SNR	160/310	
FM6	100 %	Low SNR			Low SNR	130/300	

4 Year Spacecraft Summary

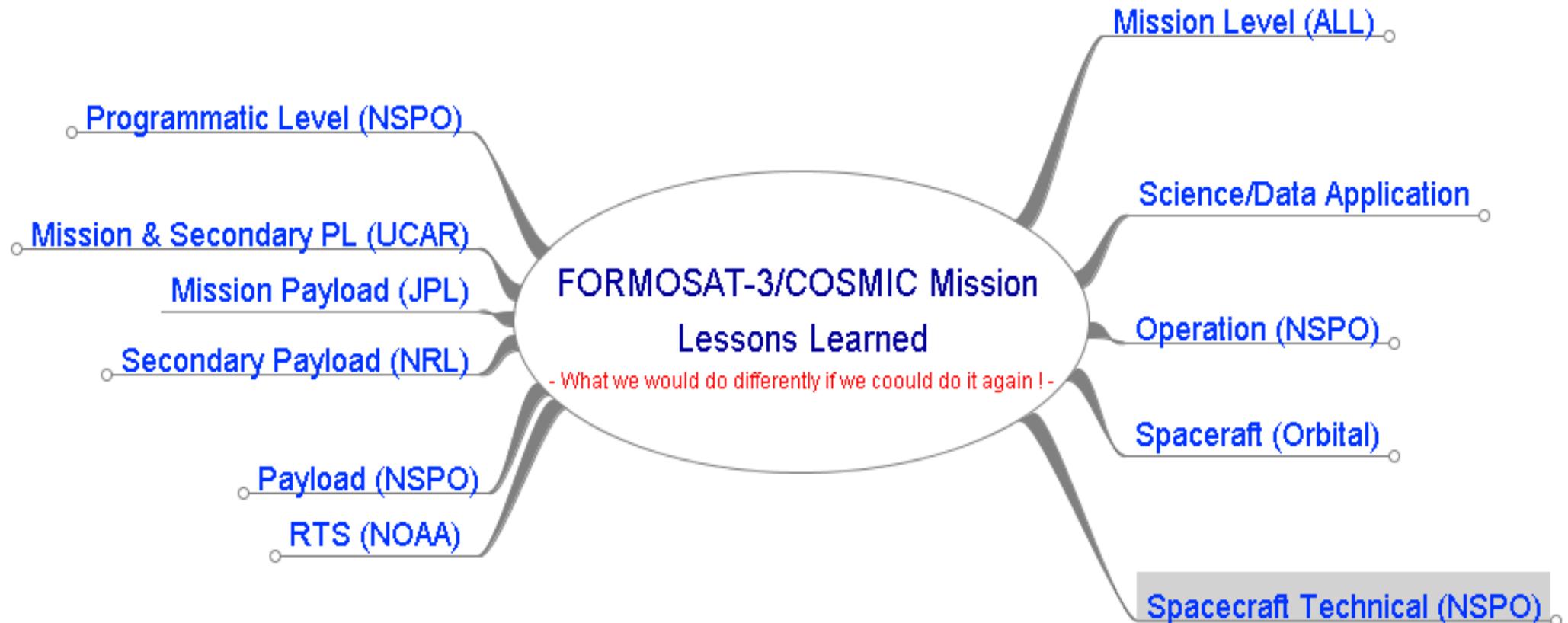
S/C ID	Summary
FM1	<ul style="list-style-type: none"> <input type="checkbox"/> Bus GPSR GPS Non-Fixed -> Operation Solution <input type="checkbox"/> GOX RF1 (POD1/ANT0) Lower SNR -> GOX Reboot Loop -> GOX FB 4.4 Update <input type="checkbox"/> Battery Degradation -> Payload Unexpected Off <input type="checkbox"/> Bad Attitude
FM2	<ul style="list-style-type: none"> <input type="checkbox"/> BCR dMdC Charge Algorithm Issue -> FSW Update <input type="checkbox"/> Solar Array Power Shortage -> Reduced GOX Operation <input type="checkbox"/> GOX Reboot Loop -> GOX FB 4.4 Update <input type="checkbox"/> Battery Pressure Difference Anomaly -> FSW Update <input type="checkbox"/> PCM DC Converter Abnormally Off -> TBB & TIP Off <input type="checkbox"/> Lost of Communication -> Auto Recovery
FM3	<ul style="list-style-type: none"> <input type="checkbox"/> Lost of Communication -> Auto Recovery <input type="checkbox"/> Solar Array Driver Lockout -> Reduced GOX Operation <input type="checkbox"/> Bus GPSR GPS Non-Fixed -> Operation Solution <input type="checkbox"/> GOX RF1 (POD1/ANT0) Lower SNR -> GOX Reboot Loop -> GOX FB 4.4 Update <input type="checkbox"/> Battery Degradation -> Payload Unexpected Off
FM4	<ul style="list-style-type: none"> <input type="checkbox"/> Bus GPSR GPS Non-Fixed (since Launch)-> Operation Solution <input type="checkbox"/> GOX RF1 (POD1/ANT0) Lower SNR -> GOX Reboot Loop -> GOX FB 4.4 Update <input type="checkbox"/> Battery Degradation -> Payload Unexpected Off -> On-Orbit Discharge to Phoenix Mode
FM5	<ul style="list-style-type: none"> <input type="checkbox"/> GOX RF1 (POD1/ANT0) Lower SNR -> GOX Reboot Loop -> GOX FB 4.4 Update <input type="checkbox"/> GOX RF4 (OCC1/ANT3) SNR Decreasing-> Operation Solution <input type="checkbox"/> Battery Degradation -> Payload Unexpected Off
FM6	<ul style="list-style-type: none"> <input type="checkbox"/> Lost of Communication -> -> Auto Recovery <input type="checkbox"/> GPSR GPS Non-Fixed -> Operation Solution <input type="checkbox"/> GOX RF1 (POD1/ANT0) Lower SNR -> GOX Reboot Loop -> GOX FB 4.4 Update Bus <input type="checkbox"/> GOX SNR decreasing at High Temp. -> Auto Recovery <input type="checkbox"/> Battery Degradation -> Payload Unexpected Off <input type="checkbox"/> Orbit Raise-Up -> Under Investigation

Average SC Battery Variation Rate Per Year

S/C ID	Batt V Mean [V]	Batt V Min [V]	Batt SOC Max [Ah]	Batt SOC Min [Ah]	PL Off SOC	Remarks
FM1	-0.034	-0.104	1.169	-0.657	~ 1.95	Unexpected payload off since 2008/4 Battery over pressure
FM2	-0.031	-0.159	-0.236	-0.036	~1	Unexpected payload off since 2008/10 Battery charging efficiency decreased
FM3	-0.094	-0.080	0.769	0.127	~0.45	Unexpected payload off since 2008/10
FM4	-0.060	-0.319	0.453	0.628	~2.5	Unexpected payload off since 2007/12 Battery over pressure
FM5	-0.026	-0.122	0.617	0.596	~1.95	Unexpected payload off since 2008/1
FM6	-0.042	-0.249	1.213	1.184	~2.5	Unexpected payload off since 2007/12 Battery over pressure

FS-3/C Mission Lessons Learned

- What we would do differently if we could do it again ! -



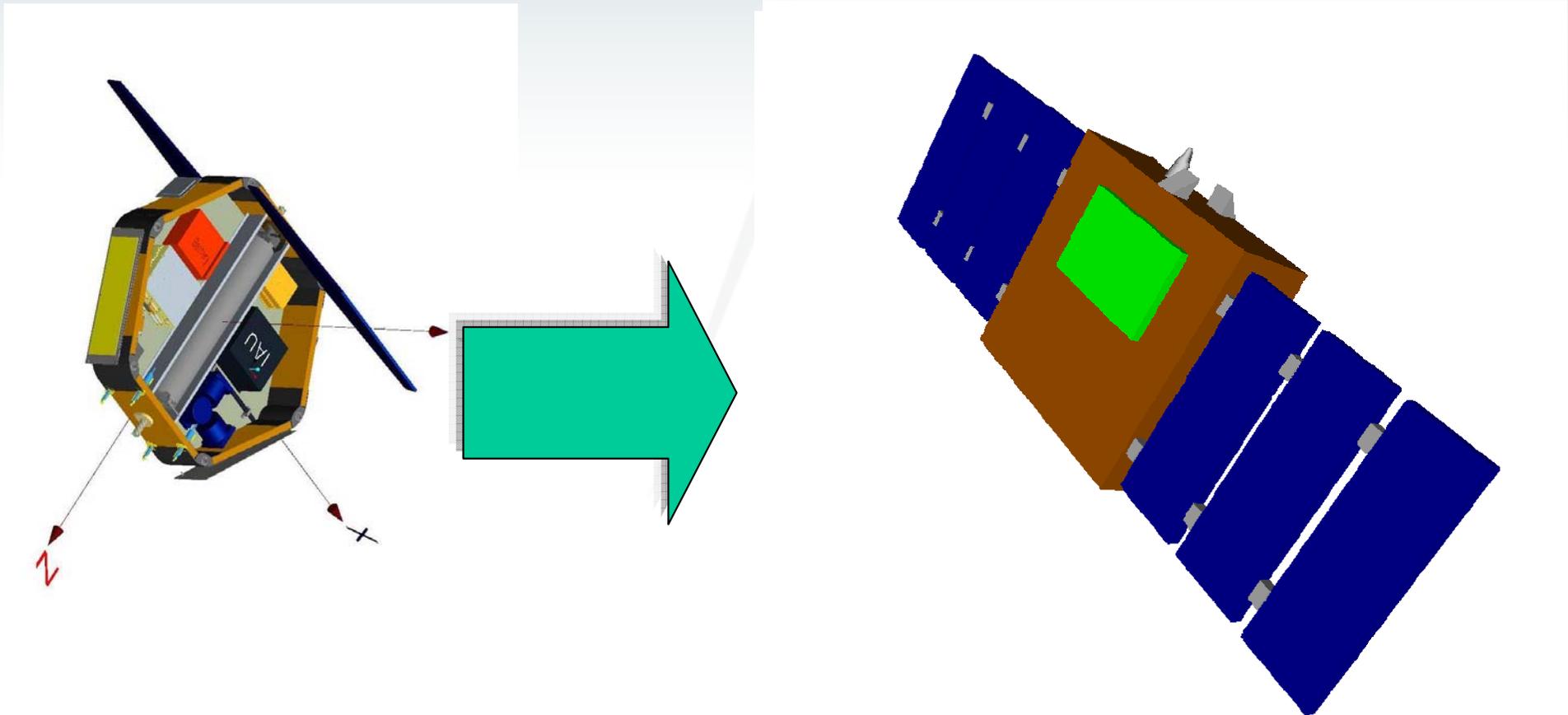
Collision Avoidance

- **Observation/Major Finding**
 - **Increased debris in space (Chinese ASAT test, Iridium/Cosmos collision)**
- **Improvement/Correction**
 - *NSPO/SOCC monitors the close approach events based on the data post on public domain.*
- **Evidence of improvement**
 - *N/A*
- **Recommendation for future/follow-on program**
 - **Maneuver capability for collision avoidance**
 - **An adequate orbit altitude for Follow-On mission**

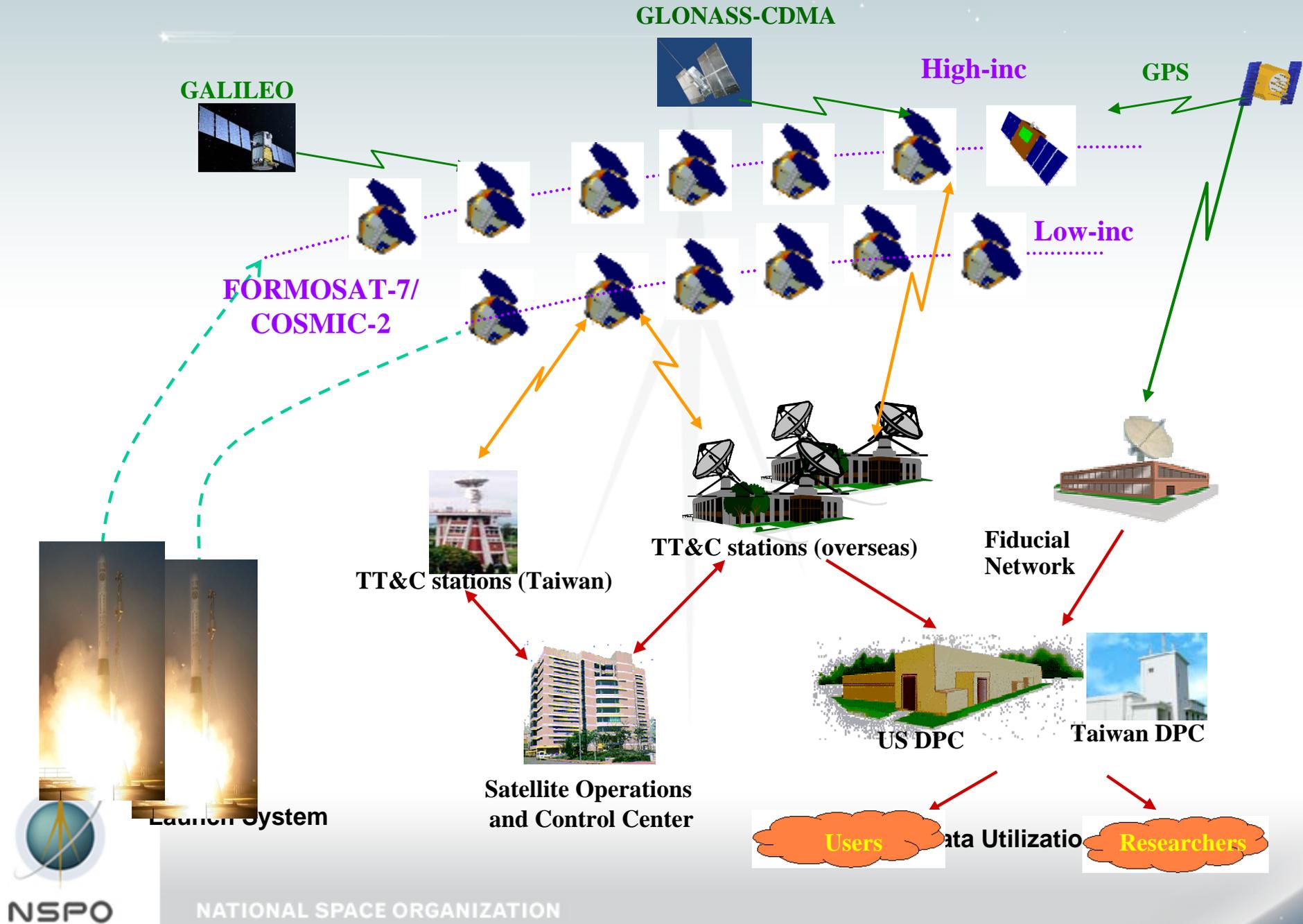
Spacecraft Configuration

- Payload to Spacecraft Interface -

- *Payload locations and view directions schematic diagram*



System Architecture for COSMIC-2



Existing Radio Occultation Mission and Outlooks

Mission	Launch Time	Mission Life	RO Profiles per Day	Note
GPS/MET	1995/4	2	125	Proof of Concept
CHAMP	2000/11	5	250	Improved receiver, tracking
SAC-C	2000/11	3	300	Improved receiver, open loop tracking test
GRACE	2002/5	5	500	RO data publicly not available
FORMOSAT-3/COSMIC	2006/4	5	2000	World Only Near-real-time Operational Constellation
MetOp-A	2006/10	5	500	Near-real-time operations
TerraSAR-X	2007/6	5	400	IGOR RX & Antennas
OceanSat-2	2009/9	5	500	ROSA RX
TanDEM-X	2010/6	5	400	FORMOSAT-3 RX
KOMPSAT-5	2010	5	300	IGOR+ RX & Antennas
EQUARS	2012 On-hold	3	400	IGOR RX & CHAMP Antennas
MetOp-B	2012	5	600	GRAS RX & Real-time operations
PAZ	2012	5	500	IGOR+ RX
Megha-Tropiques	TBD	5	500	ROSA RX
SAC-D	TBD	5	500	ROSA RX
CICERO	TBD	5	>10,000	Pyxis/TriG RX and Real-Time Ops for GPS-RO & GPS-SR
FORMOSAT-7/COSMIC-2	2014 2016	5	>8,000	Real-Time Ops with TriG RX

Conclusion

- *The FORMOSAT-3 / COSMIC satellites have performed successfully for over 4 years now. It's not a perfect constellation for the operational system, but it has achieved more than satisfactory expectation for an experimental system in an semi-operational usage.*
- *The FORMOSAT-3 / COSMIC satellites are degrading as anticipated; however, NSPO assesses these satellite will continue to operate into the next few years.*
- *While NSPO and NOAA are proceeding to the FORMOSAT-7 / COSMIC -2 joint mission implementation, NSPO is committed to continue the FORMOSAT-3 / COSMIC satellite constellation operation to collect the RO data to minimize the data gap duration.*



Acknowledgments

It takes a great team to do a great job

