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FORMOSAT-7/COSMIC-2 – An Advanced Small Satellite Constellation Platform for Numerical Weather Prediction

[1]Chen-Joe Fong*, Ming-Shong Chang, Nai-Chen Liu, Jer Ling, Vicky Chu
[2]Alex da Silva Curiel, Bernardo Martins, Ed Stevens, Mark Taylor

[1]National Space Organization, 8F, 9 Prosperity 1st Road, Science-Based Industrial Park, Hsinchu 30078, Taiwan
[2]Surrey Satellite Technology Ltd, Tycho House, Surrey Research Park, Guildford, GU27 YE, United Kingdom

*Email: cjfong@nspo.narl.org.tw

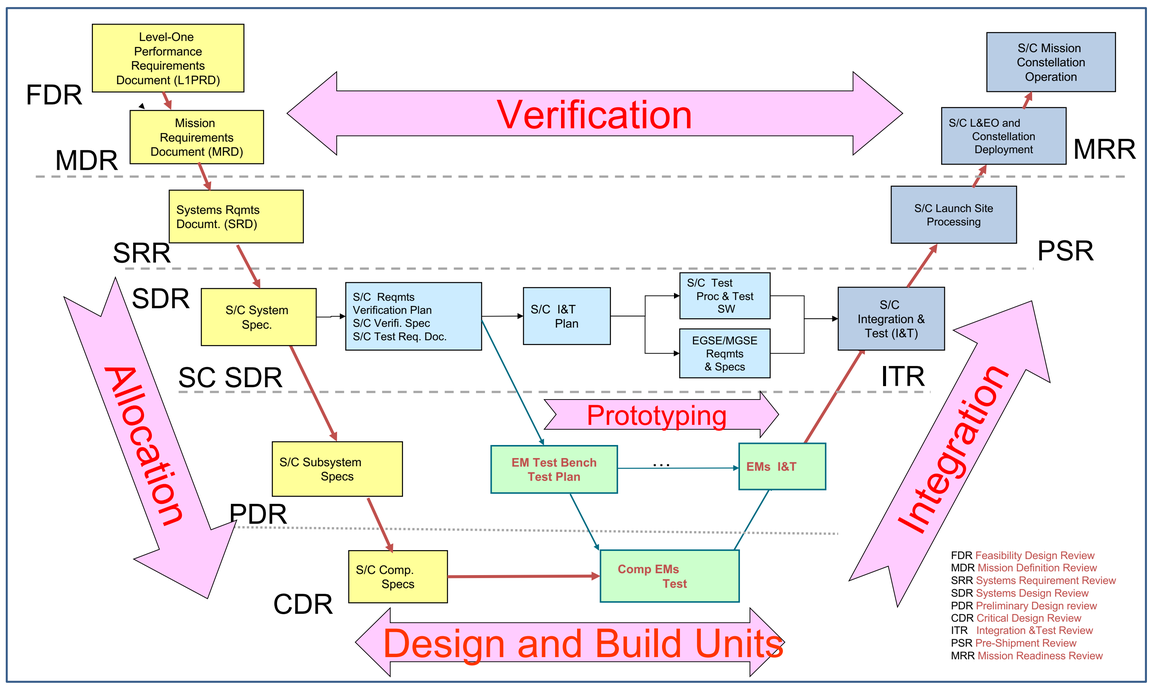
Introduction

The role of small satellite constellation in operational meteorology is being increasingly considered, and can potentially provide high impact on certain aspects of Numerical Weather Prediction and weather forecasting. Such systems can provide important additional information addressing specific geographic regions, or address some very specific applications at a suitable price point. This capability has become possible due to innovative payload and measurement techniques, technology miniaturization, and the availability of reliable small satellite technology used in constellations.

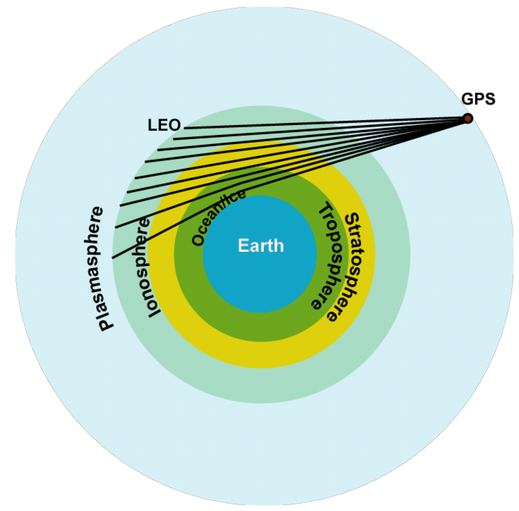
FORMOSAT-7/COSMIC-2 is a joint program between Taiwan and US to serve as the follow-on "Operational Mission" of FORMOSAT-3/COSMIC, which was a joint US-Taiwan 6-satellite constellation demonstration mission launched in April 2006, to continue the provision of next-generation Global Navigation Satellite System (GNSS) Radio Occultation (RO) data to the global users. The mission aims to collect atmospheric and ionospheric soundings globally through a constellation system of 12 satellites, providing high temporal resolution and high data quality.

The design, integration and test (I&T), and verification of the spacecraft heritage from the SSTL-100 bus are important drivers and selected in this joint system in order to obtain measurement data in time for the meteorological forecasting cycle to meet the challenging requirements. This paper provides an overview of the satellite constellation which were carried out to achieve the necessary system design and performance.

Keywords: FORMOSAT-7/COSMIC-2, GNSS, Radio Occultation, satellite, constellation, small satellite, Numerical Weather Prediction.



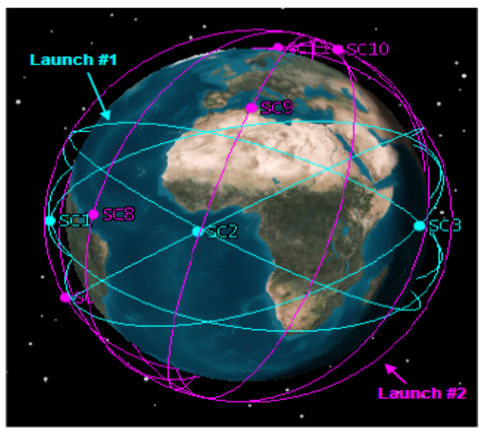
FORMOSAT-7/COSMIC-2 Systems Engineering Process (SEP)



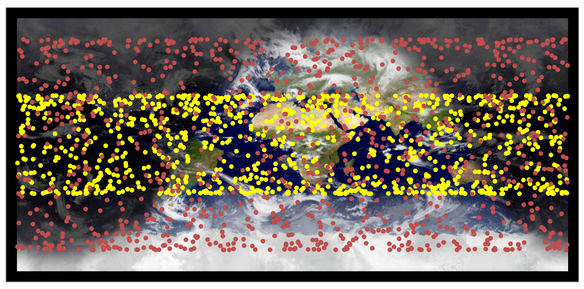
Radio Occultation Concept

FORMOST-7 Mission Baseline

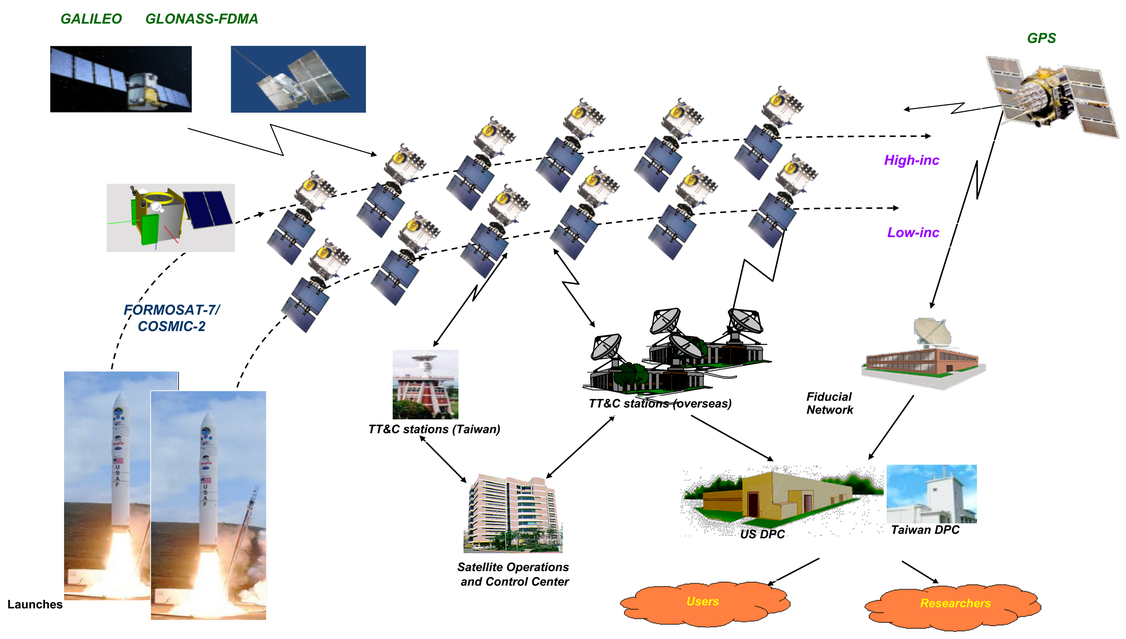
FORMOSAT-7	First Launch	Second Launch
Mission Objectives	To be achieved after Full Operational Capability: ■ Average 8,000 atmospheric sounding profiles per day ■ 45-min data latency for neutral atmosphere data ■ 30-min data latency for ionospheric data	
Constellation	6 Mission Spacecraft Mission altitude 520~550 km Low-inclination: 24 deg.	6 Mission Spacecraft + 1 NSPO-Build SC Mission altitude 720~750 km High-inclination: 72 deg
GNSS RO Payload	Tri-band GNSS Receiver System (TGRS)	Tri-band GNSS Receiver System (TGRS)
Scientific Payload	US Furnished Ion Velocity Meter (IVM) RF Beacon (RFB) Transmitter	Taiwan Furnished Scientific Payload
Mission Life	5 Years beyond the second launch	
Launch Vehicle	US furnished Falcon-Heavy (Rideshare)	US furnished EELV-like with a 5-m fairing
Launch Schedule	2Q Year 2017	[TBD]
Communication Architecture	Via ground station	



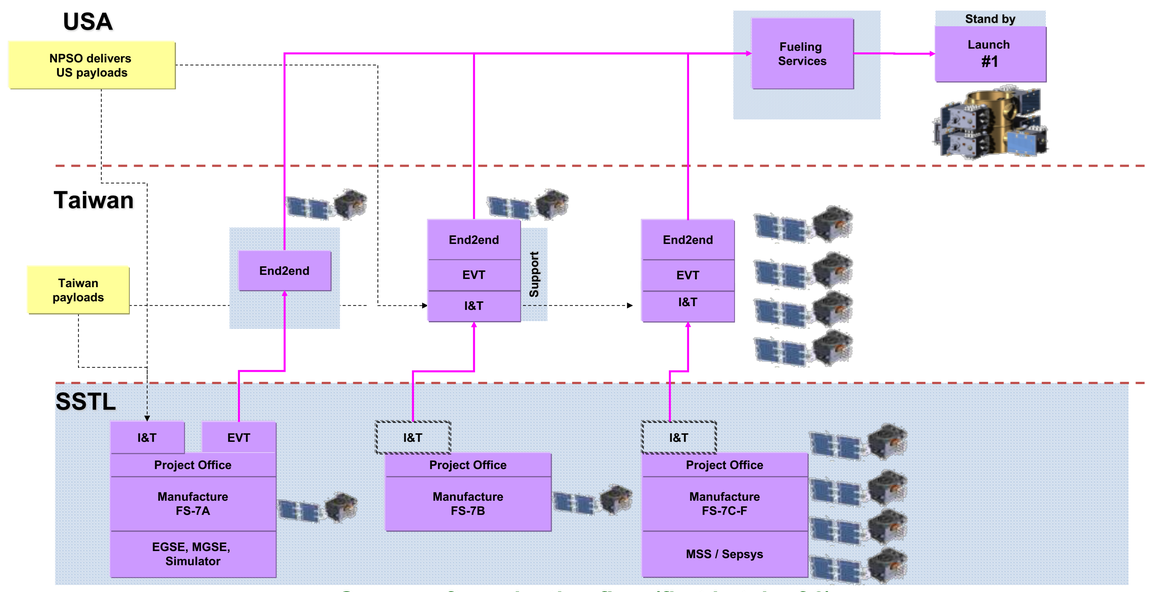
FORMOSAT-7 Constellation



Typical 12 hour global sampling pattern

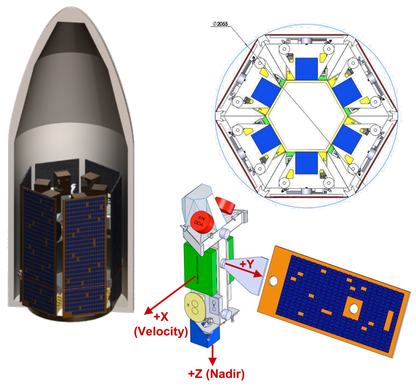


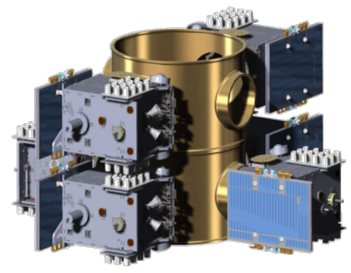
FORMOSAT-7/COSMIC-2 System Architecture



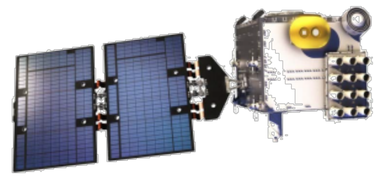
Spacecraft production flow (first batch of 6)

- Launch vehicle accommodation
- Payload accommodation and Field of View
- EMC compatibility
- Power and thermal for two orbits





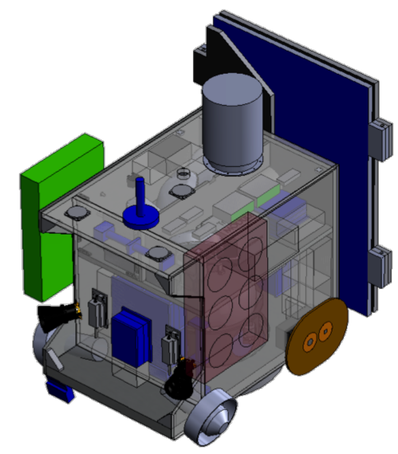
Stowed Launch configuration on the launcher



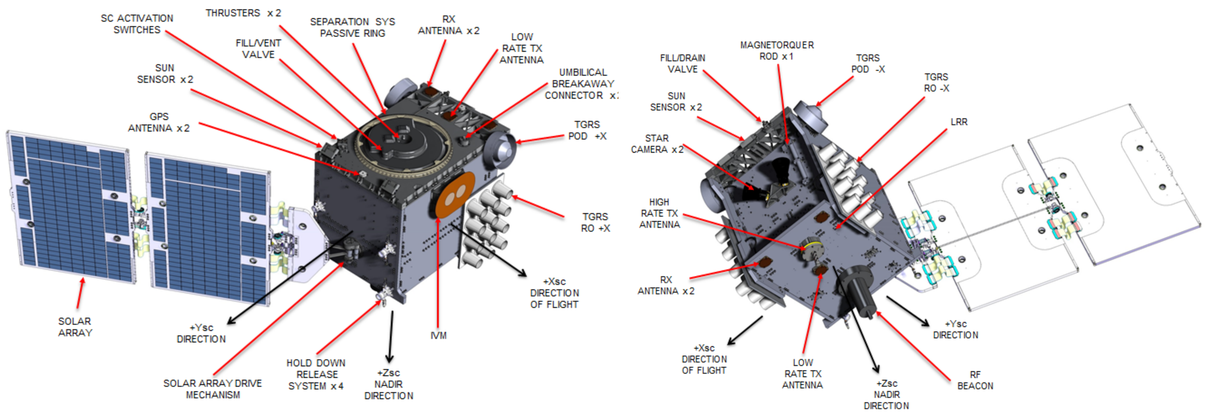
Design challenges

Satellite Specification

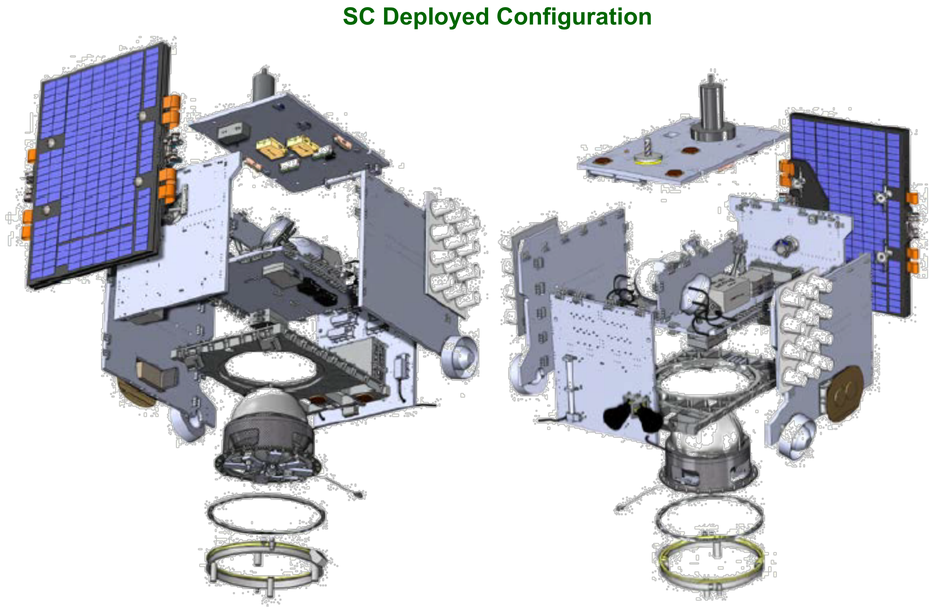
Dimensions (stowed)	1000 x 1250 x 1250 mm
Launch Mass (wet)	277.8 kg
Total Power Peak / OAP	229.8 (orbit average)
Battery Capacity	> 22.5A-hr
Attitude	3-axis Knowledge <0.07deg (3-sigma) Control <1deg (3-sigma)
Propulsion	Hydrazine monoprop ~141 m/s
Communications	S-band TM/TC, 32kbps uplink, up to 2Mbps 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	☑ dual redundant avionics ☑ Batch launch compatible ☑ Constellation compatible



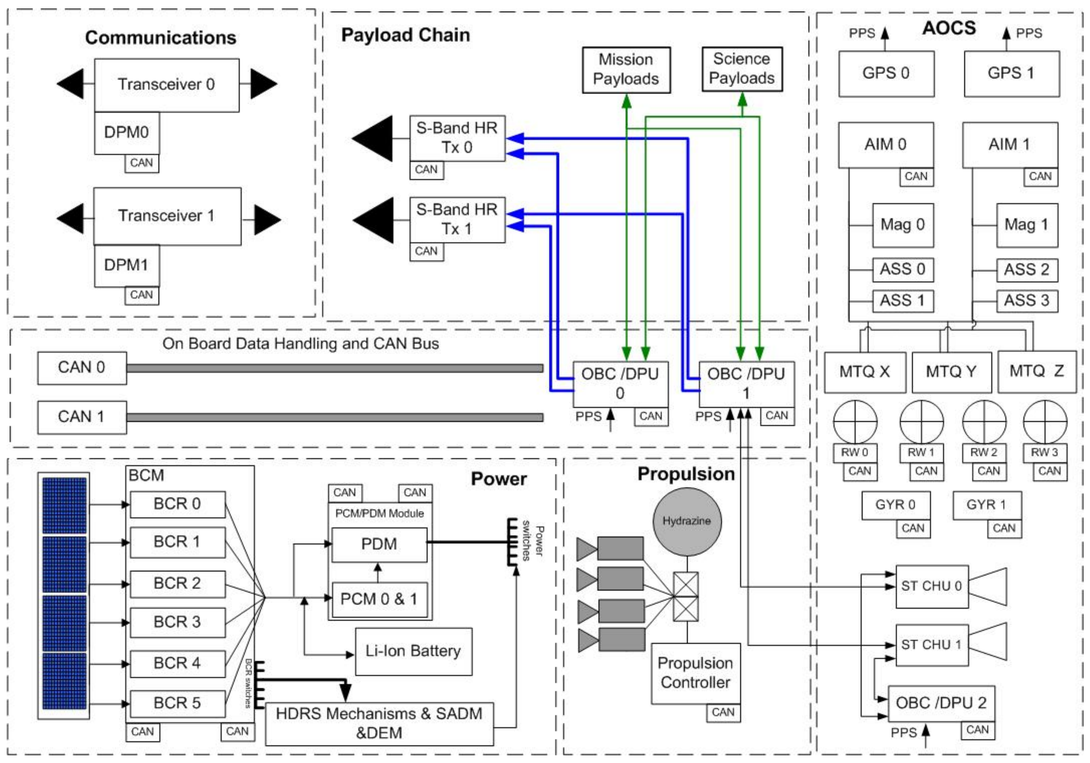
Spacecraft stowed configuration



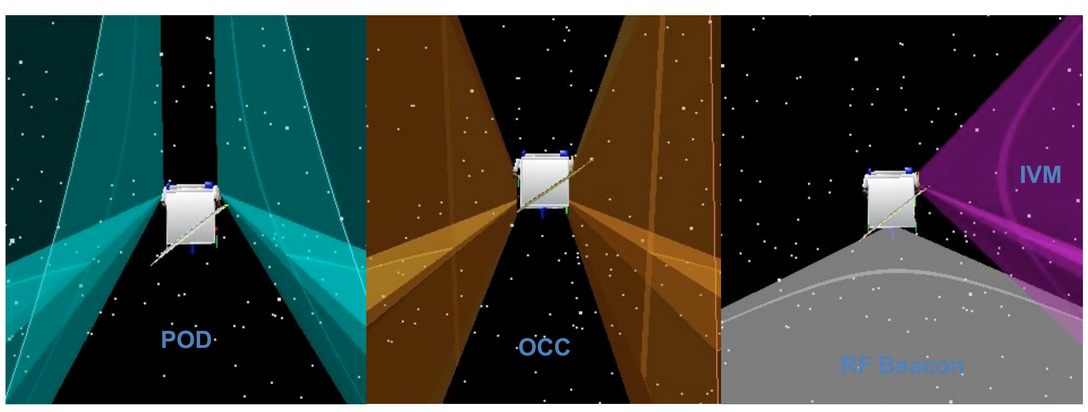
SC Deployed Configuration



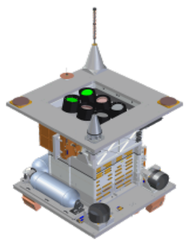
SC Exploded View



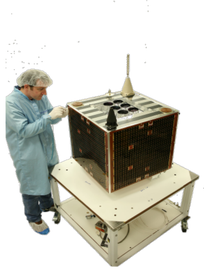
Satellite Electrical Configuration

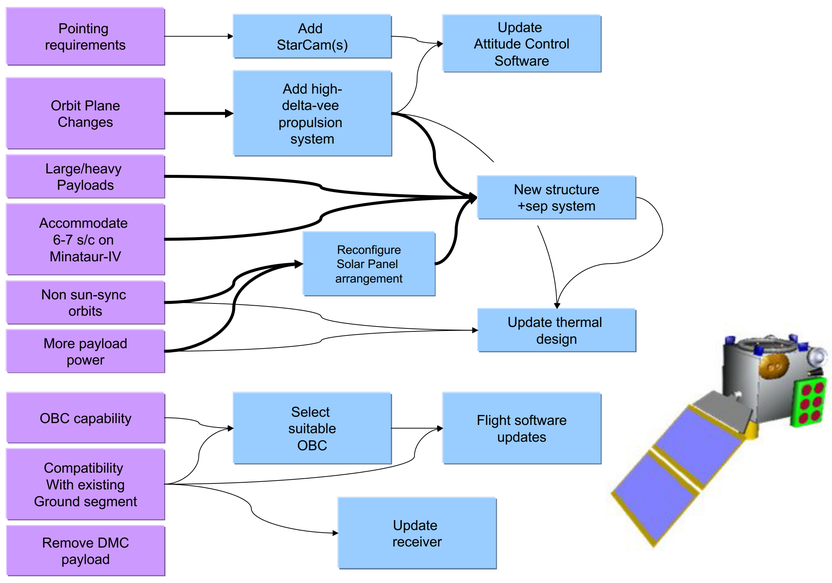


Payload FOVs Challenge

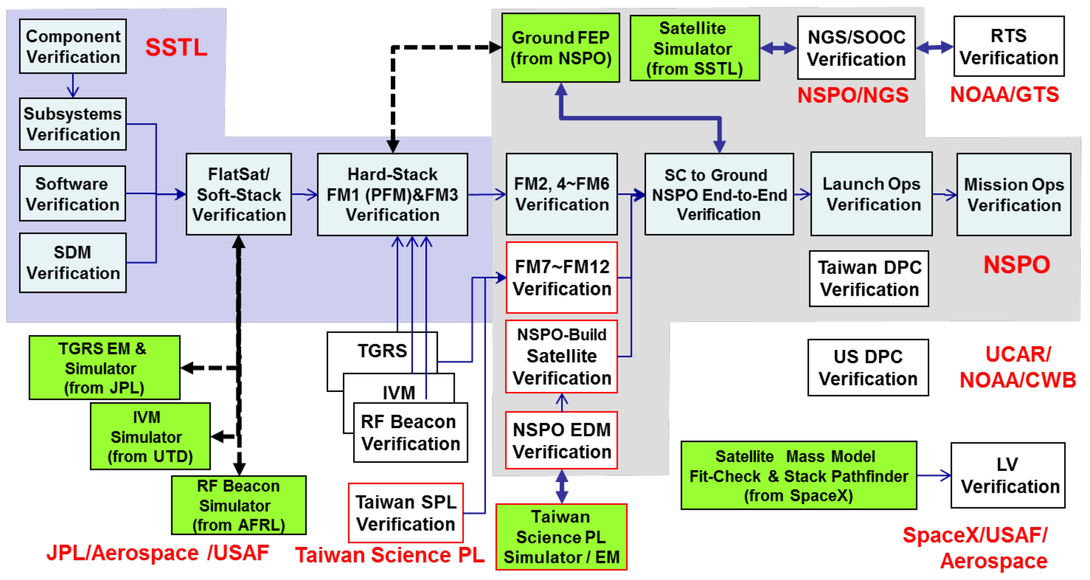


SSTL-100





Spacecraft Development Plan

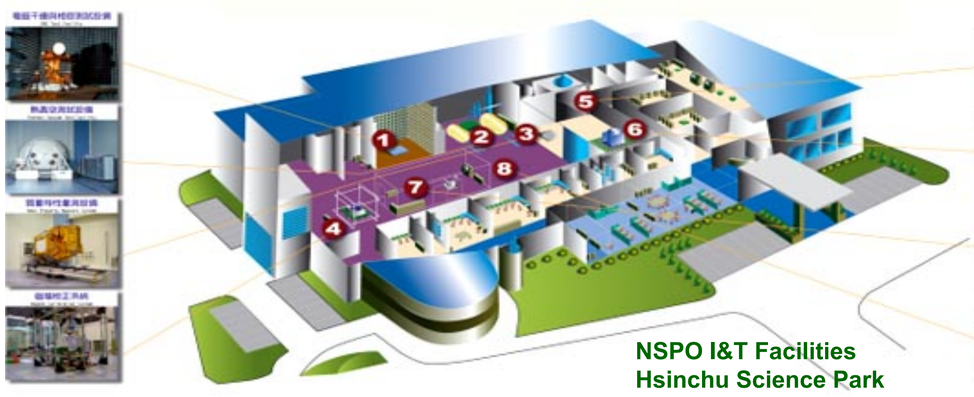


Satellite Verification Process

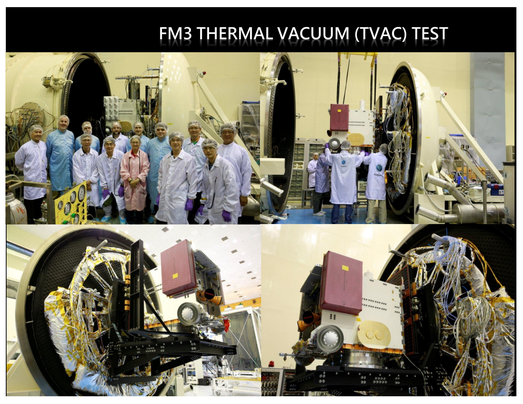
	PFM	FM2	FM3	FM4	FM5	FM6
ISFT (CPT)						
System End-to-End Test (SEET)						
Ground Segment Compatibility Test (NEET)						
EMC CE & CS		N/A	N/A	N/A	N/A	N/A
EMC RE & RS		N/A	N/A	N/A	N/A	N/A
Separation Shock		N/A	N/A	N/A	N/A	N/A
Acoustic	SDM (Q)	N/A	Proto-F	N/A	N/A	N/A
Quasi Static (Sine Vibe)	Proto –Q	N/A	N/A	N/A	N/A	N/A
Random Vibe	Proto –Q	Proto-F	Proto-F	Proto-F	Proto-F	Proto-F
Solar Deployment						
Leak						
TV – Thermal Vacuum						
TB – Thermal Balance		N/A	N/A	N/A	N/A	N/A
MOI		N/A	N/A	N/A	N/A	N/A
Mass/CoG						

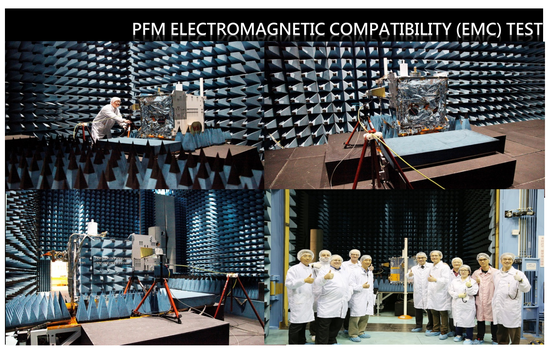
Verification Test Matrix

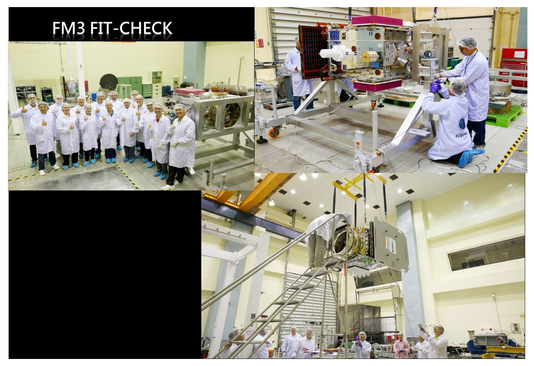
- Base area: 13,102 square meters
- Construction area: 6,162 square meters
- Building dimensions: 115 meters × 53 meters × 17 meters（height）
- Floor area: 12,676 square meters
- Floor level: 1 basement level and 2 above ground levels
- Building completion and open for use: in July 1997



NSPO I&T Facilities
Hsinchu Science Park







CONCLUSION

The FORMOSAT-7 missions demonstrate that small satellites can play a significant role in operational meteorology. The system also demonstrates the concept of a highly integrated distributed system, as the ground network and space system must be carefully designed in order to meet the tight operational constraints of the mission. The system also completely relies on the availability of another group of constellations of the Global Navigation Satellite Systems, in order to support the sensor. FORMOSAT-7 will only meet its objectives as a complete system, covering both planned orbit planes. Without the second batch in orbit in time there will be no high latitude coverage.

The FORMOSAT-7 spacecraft bus design is well suited for other constellations or single satellite missions, provides very high payload mass fraction, and exceptional power fractions for the size of the spacecraft.