FORMOSAT-7/COSMIC-2 Mission Status & Future Operation

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Contributed by TASA, NOAA, UCAR & ARFL

ICEO 2024

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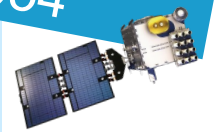
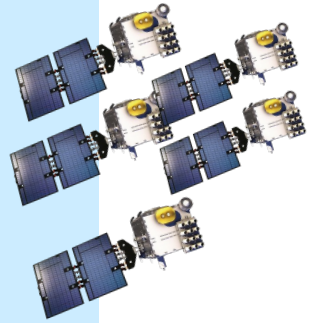
Program Overview

- Partnership: AIT-TECRO **NOAA:** AIT Designated Rep; **TASA:** TECRO Designated Rep
- 5 years mission, launched on 6/25/2019, SpaceX Falcon Heavy (USAF STP-2 Mission)
- 6-satellite constellation in six evenly-spaced orbit planes to provide uniform equatorial coverage
- 10 ground stations for downlink support
- Each satellite has 3 instruments provided by US Space Force (USSF)
  - Tri-GNSS Radio Occultation System (TGRS) –Primary Instrument
  - Ion Velocity Meter (IVM) – Secondary Instrument
  - Radio Frequency Beacon (RFB) – Secondary Instrument
- Providing > 5,500 daily radio occultation for weather forecasting
- Providing ~ 4,000 daily ionospheric total electron content tracks for space weather monitoring
- Providing ~ 30 min latency for ionosphere and neutral atmosphere data

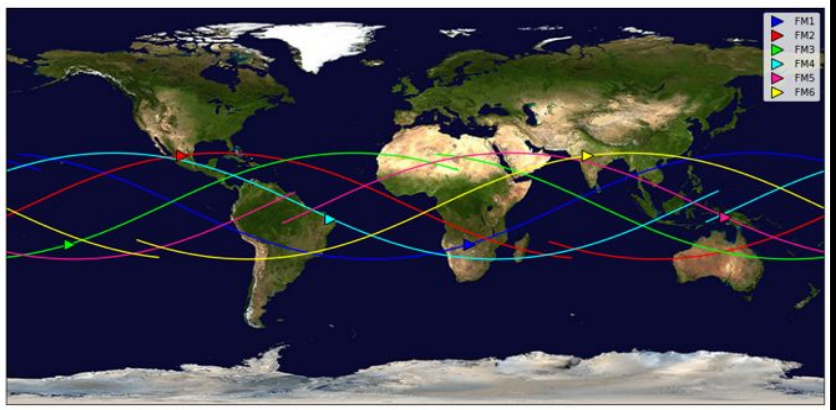
Working days:1,903
Atm. : 9,612,579
Ion. : 6,902,054



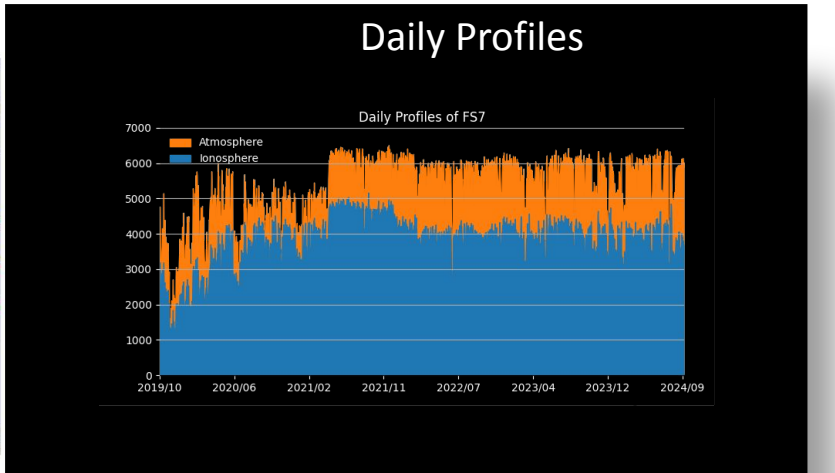


FORMOSAT-7/COSMIC-2 Ground Site Locations

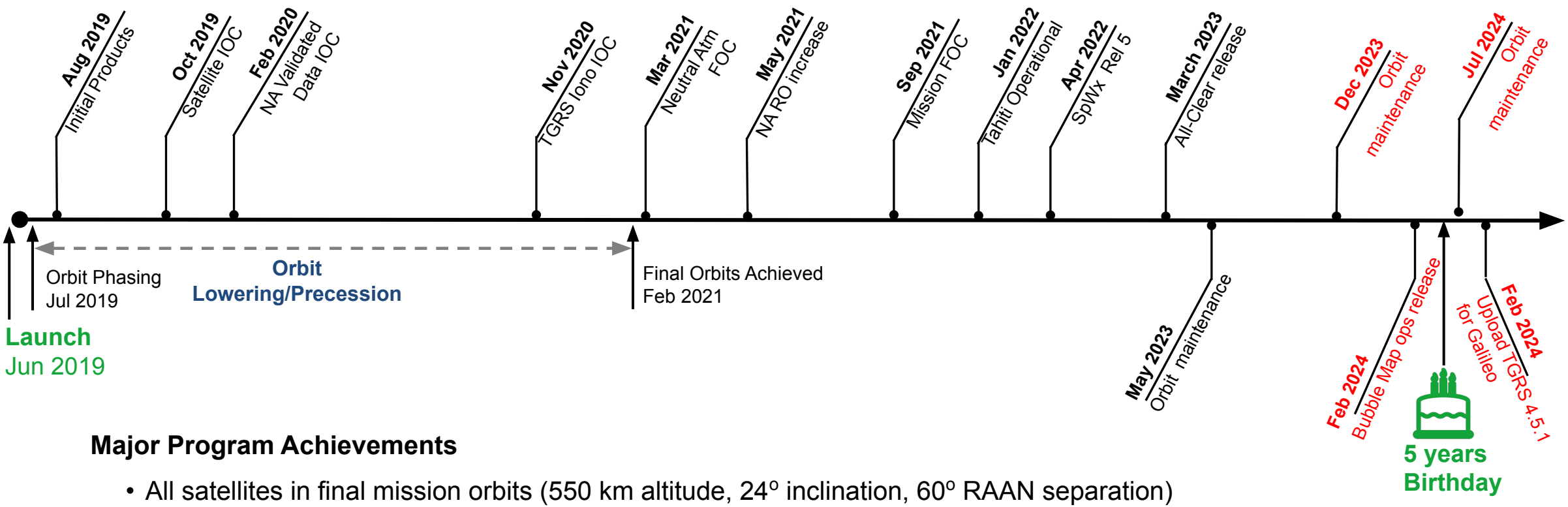
Mission Constellation Orbit



Daily Profiles



Major Post Launch Program Milestones



Major Program Achievements

- All satellites in final mission orbits (550 km altitude, 24° inclination, 60° RAAN separation)
- >5000 NA RO profiles/day with a precision better than 2 micro-radian from 60-80 km altitude
- Nearly 6,000/day Total Electron Content (TEC) occs and arcs with accuracy better than 3 TECU
- IVM density accuracy is at or below the 5% mission requirement
- Daily NA product and TEC latency from observation to product creation ~30 min median
- Data products delivered in Near Real Time (NRT) to multiple operational weather and space weather centers and openly available to the research community
- ~~New ionosphere products specifying the presence, absence, and location of scintillation (All-Clear and Bubble Map)~~ were released to operations in March 2023 (All-Clear) and Feb 2024 (Bubble Map)

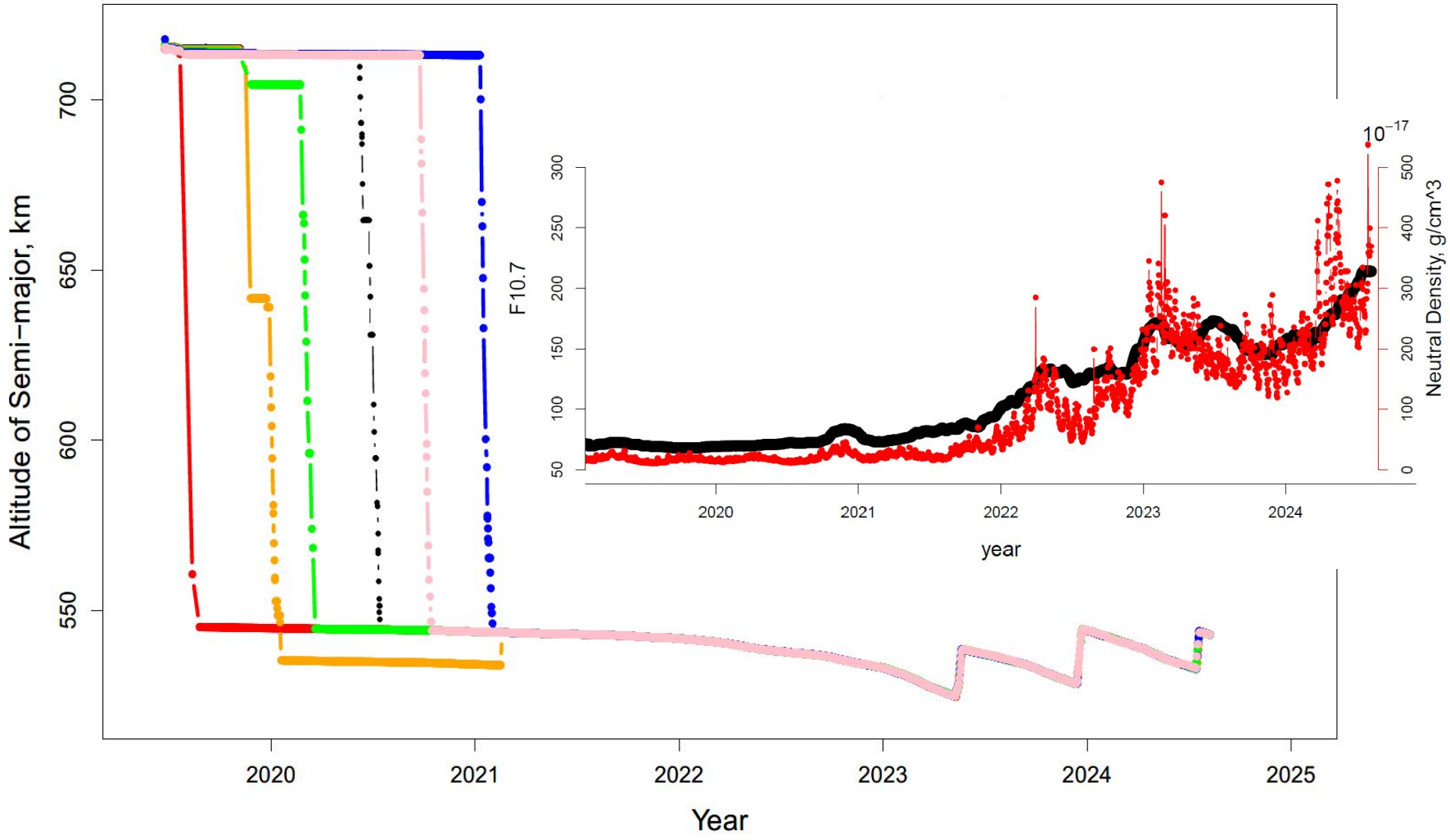
Satellite Orbit Altitudes (Jun 2019 – Feb 2024)

- Parking altitude : 720 km.
  Mission altitude : 520-550 km.

- June 2019 – Feb. 2021 :
  satellites deployment
  using diff precession rate between 550 km and 720 km, it is about ~ 0.55 deg/days

- The rate of orbital decay rate started increasing noticeably since 2022.

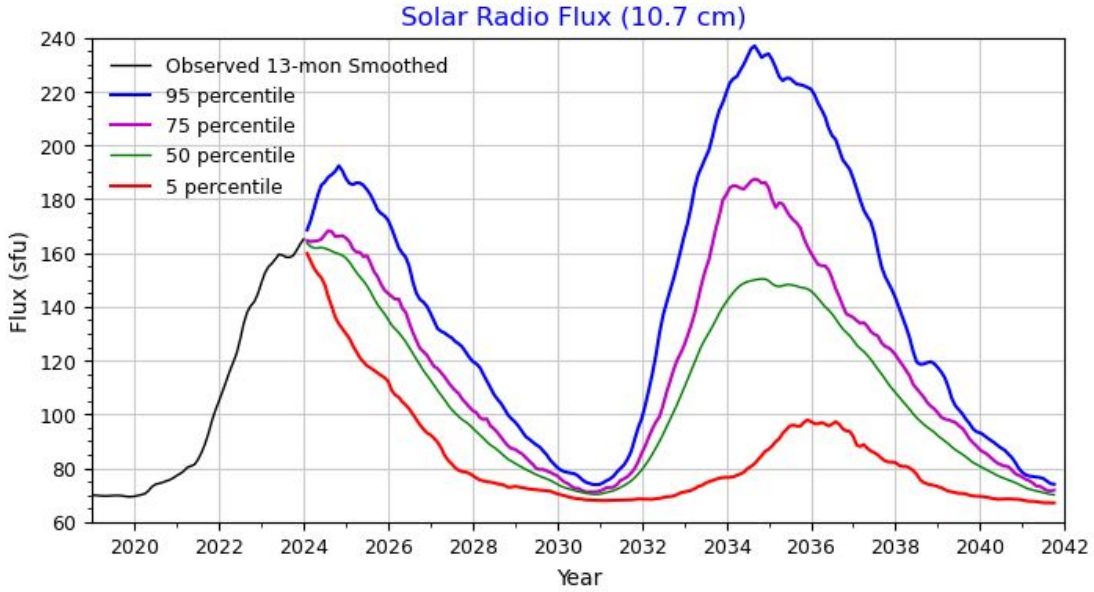
- May 2023 : raised satellite altitude ~15 km
- Dec. 2023 : raised satellite altitude ~15 km
- July. 2024 : raised satellite altitude ~10 km
- Next maneuver : Jan-Feb 2025, raise ~10 km

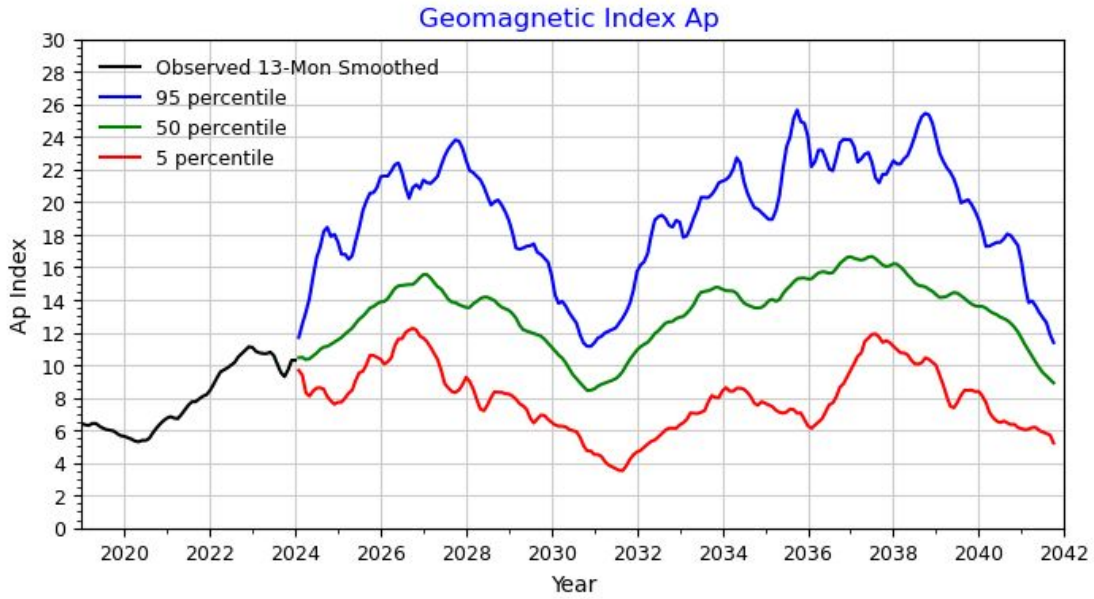


Satellite Operation Plan

Satellite Operation plan during 2024-01-01 to 2027-06-30

- TASA will maintain the altitude of satellites between 540-550 km, or at higher altitude.
- For current plan, 2-3 raisings will be required before Jun 2027, taking 2-3 kg propellant, the remaining propellant will be 3.5-5.0 kg.
- The remaining propellant is enough for satellite constellation adjustment and conjunction avoidance.
- The next raising may be scheduled in Jan-Feb 2025.

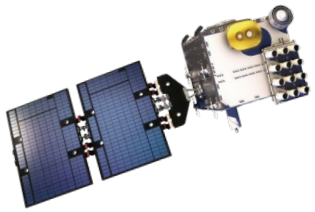


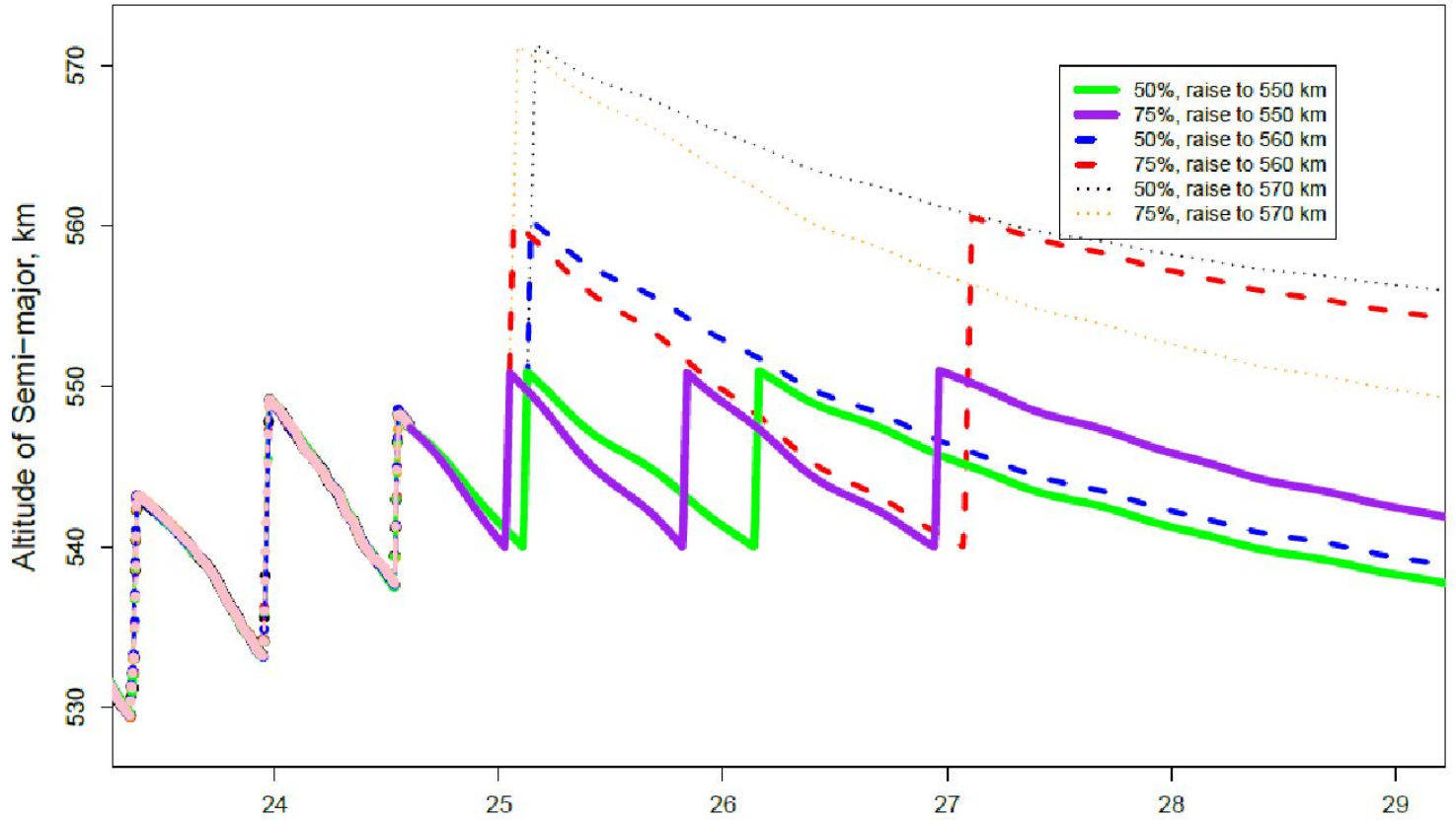


https://www.nasa.gov/solar-cycle-progression-and-forecast/

Satellite Operation Plan

For considering of satellite de-orbit after 5-years of satellite disfunction, we could not raise the satellite too high.





	50%	75%
540□550 Km	Feb, 2025 Mar, 2026	Jan, 2025 Sep, 2025 Nov, 2026
540□560 Km	Feb. 2025	Jan. 2025 Dec. 2026
540□570 Km	Feb. 2025	Jan. 2025

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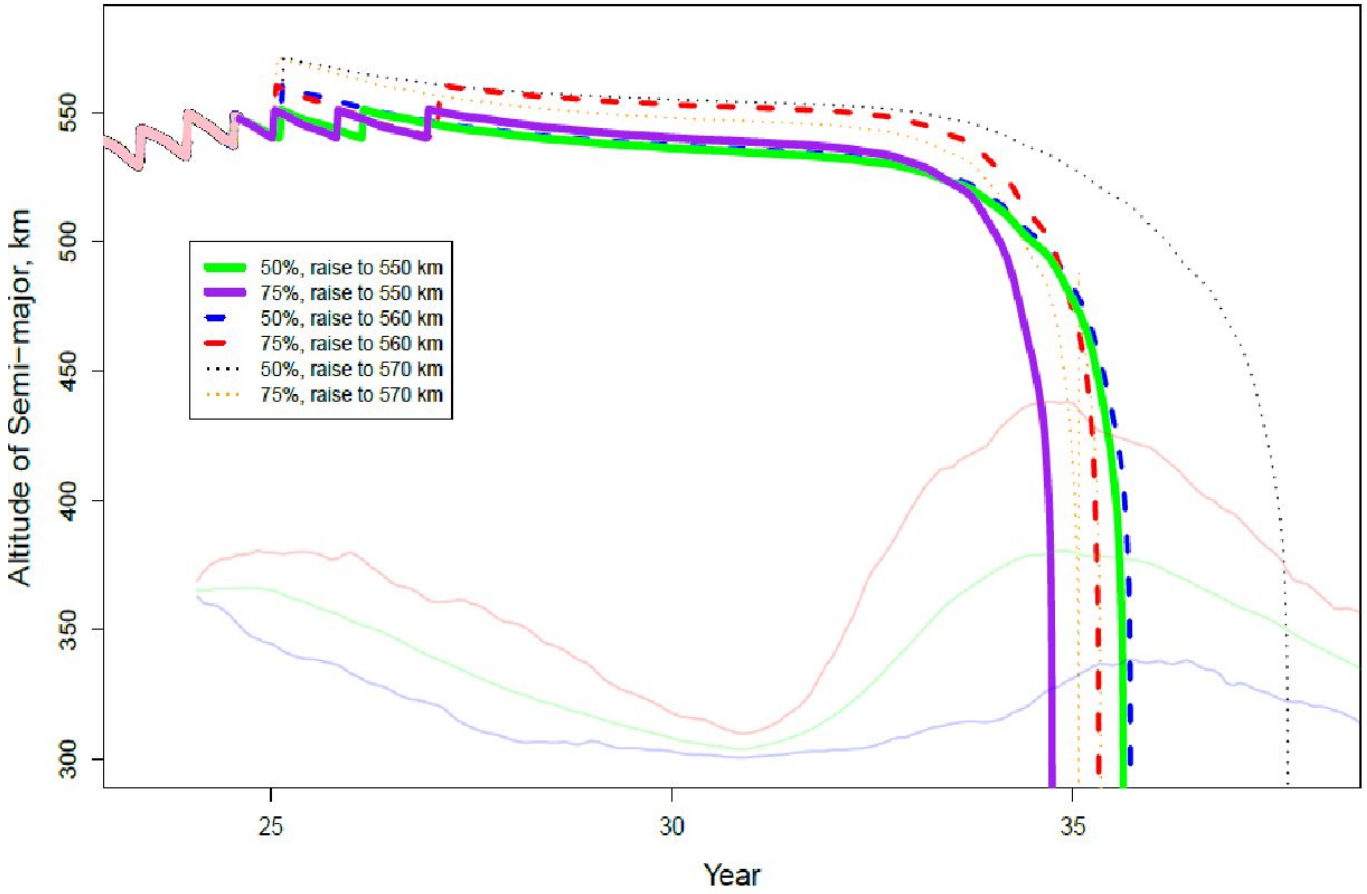
Remaining Propellant on 2023/11, 2023/12, 2024/07

FS-	Remaining Propellant Mass (kg)	Delta Propellant Mass (kg)
701	8.90/7.90/7.14	-1.0/-0.76
702	8.91/7.85/7.09	-1.06/-0.76
703	8.67/7.64/6.83	-1.03/-0.81
704	7.78/6.74/5.96	-1.04/-0.78
705	8.44/7.38/6.61	-1.06/-0.79
706	9.09/8.13/7.31	-0.96/-0.82



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FORMOSAT-7, FORMOSAT-3 & TRITON (2024.05.31)

https://tacc.cwa.gov.tw/

Provide atmospheric profiles 5500 #/daily, Ionospheric profiles 4,000#/daily.

FORMOSAT-7 data services

01 Near real time Products Monitoring

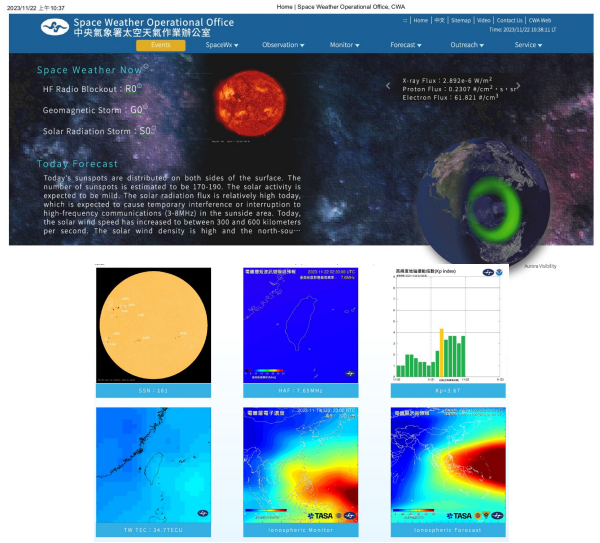
02 FS-7 Data download services

03 Joint Observation suporting

04 Space Weather monitoring

05 Space Weather monitoring, boracast and forecast

https://swoo.cwa.gov.tw/

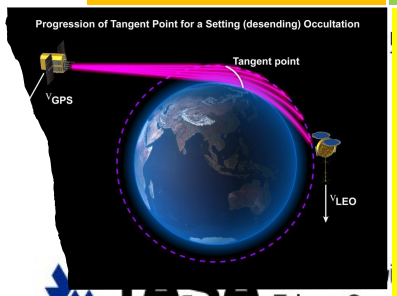


Raw Data

- High Rate GNSS observation
- Precise Orbit determination
- Satellite Attitude
- Raw S4 index

Atmosphere

- Atm. Phase Delay
- Bending angle
- Refraction
- Pressure
- Temperature
- Water Vapor
- WMO data



Ionosphere

- Ion. Phase Delay
- Total Electron Content
- Electron density
- Plasma drift velocity and composition
- S4 scintillation index
- GNSS radio frequency interference

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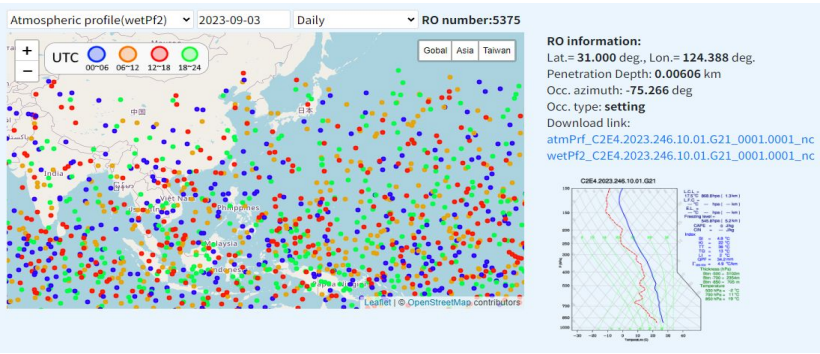
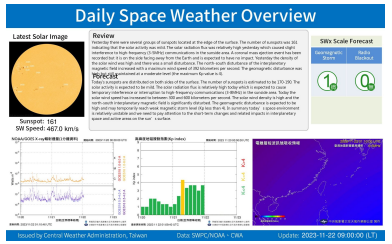
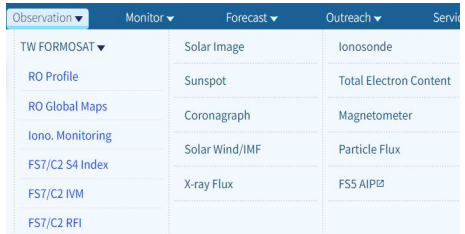


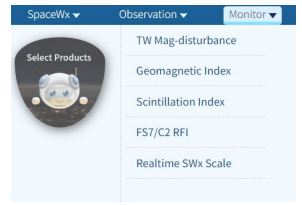
Real time distribution of Radio occultation & data validation with Radiosonde profiles
https://tacc.cwa.gov.tw/v2/occultation.html



Daily Space Weather Overview



Space Weather Observation

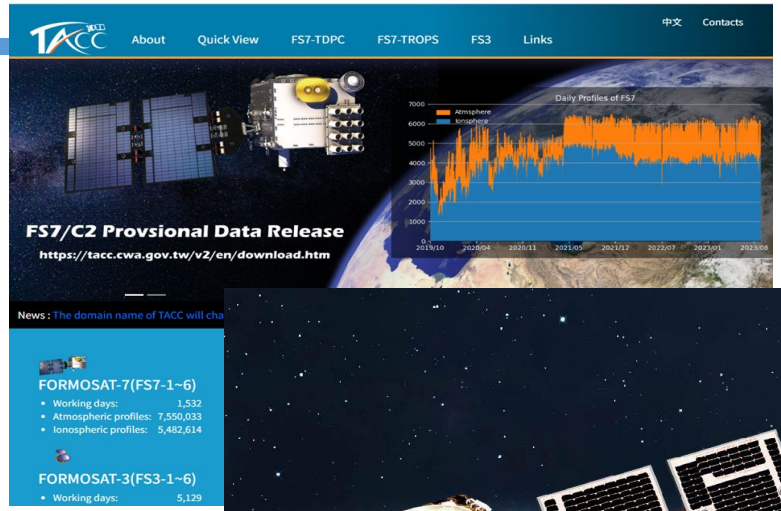


Space Weather Monitoring

Space Weather Forecasting

FORMOSAT-7, FORMOSAT-3 & TRITON (2024.05.31)

https://tacc.cwa.gov.tw/



Provide atmos
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FORMOSAT-7 data services

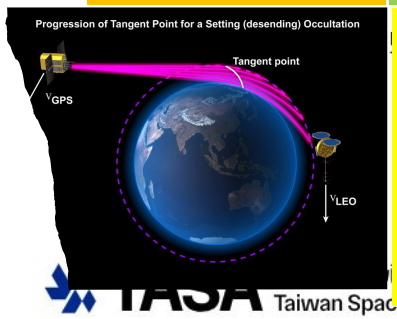
01 Near real time Products Monitoring

02 FS-7 Data download services

Joint Observation suporting

Raw Dat

- High Rat observati
- Precise O determina
- Satellite A
- Raw S4 ir



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Ionosphere

- Ion. Phase Delay
- Total Electron Content
- Electron density
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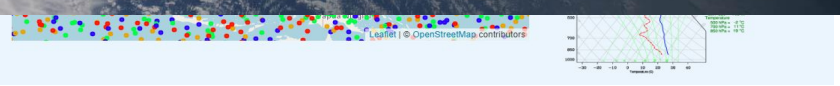

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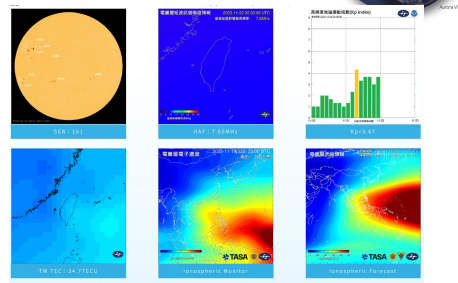
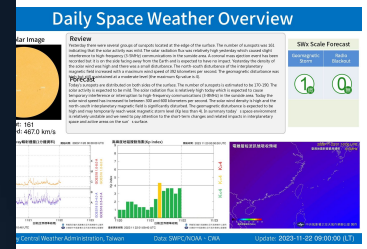
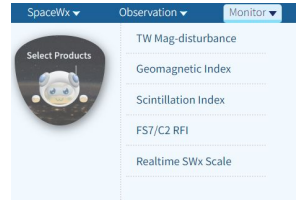




Daily Space Weather Overview

Space Weather Observation



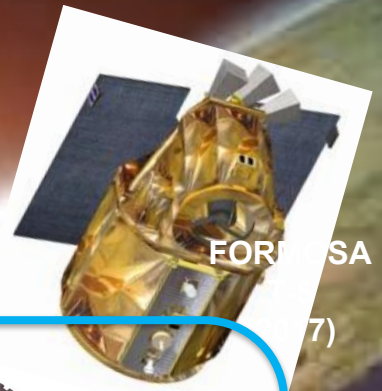
Space Weather Monitoring

Space Weather Forecasting

Taiwan Meterological Satellites

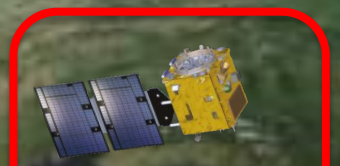
FORMOSAT-1
(1999)

FORMOSAT-2
(2004)



FORMOSA
7)

FORMOSAT-3/COSMIC
(2006)



Trito
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(2023
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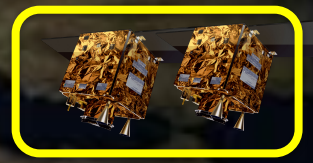
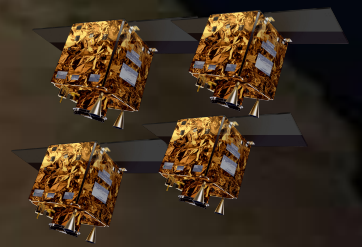
FORMOSAT-7/COS
MIC-2
(2019)

FORMOSA
T-9
(2027)





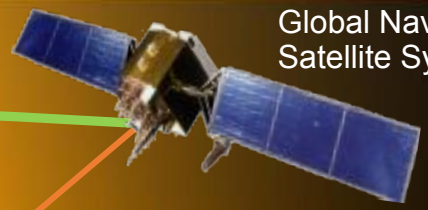
FORMOSA
T-8
(2025)

Integration and Application of Multi-Time and Multi-Source Data :

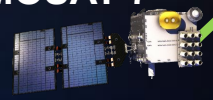
GNSS-RO/R Application

TASA Weather Satellites

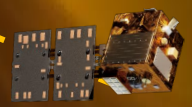
Global Navigation Satellite System,(GNSS)



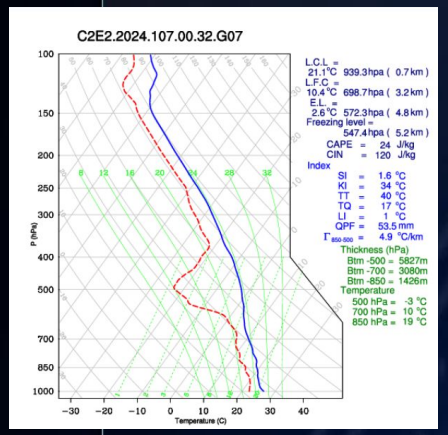
Radio occultation (RO)
FORMOSAT-7



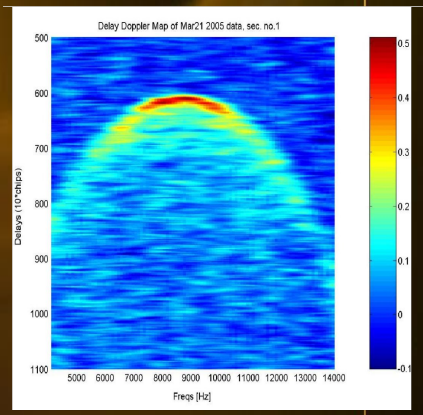
Signal reflected by ocean (R)
TRITON



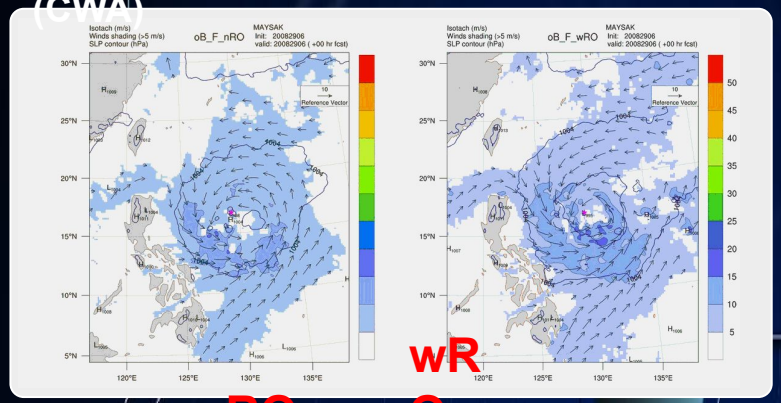
Atmospheric profiles (CWA)



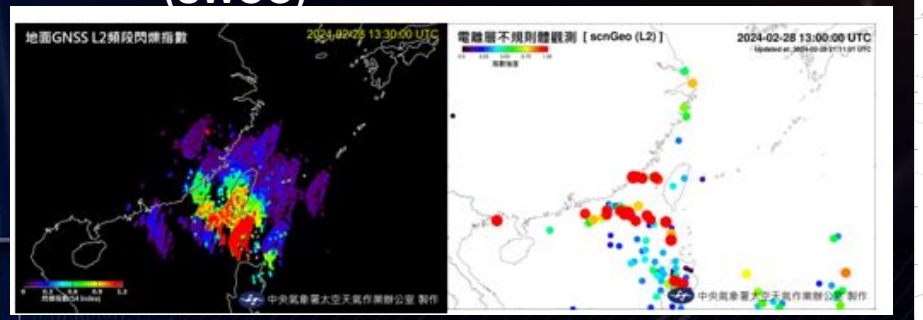
- **Ocean Wind**
- **Solid moisture**
- **Sea level**



Improve Typhoon prediction (CWA)

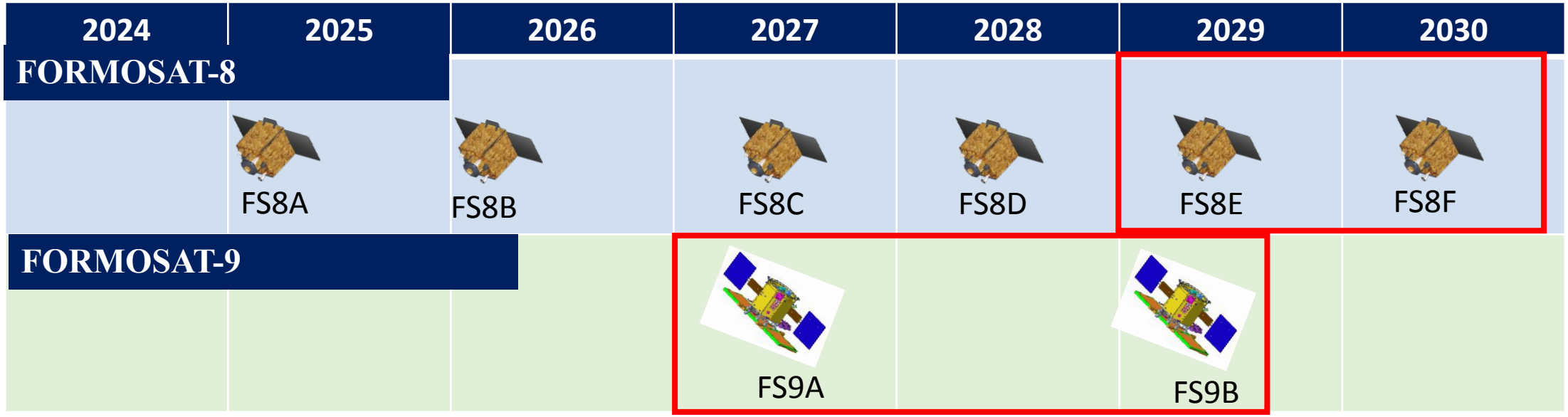


Space Weather monitor by Ground GNSS and FS-7/C-2 (SWOO)



GNSS Radio Frequency Interference (RFI) monitor (SWOO/CWA)

FS8 and FS9 Schedule

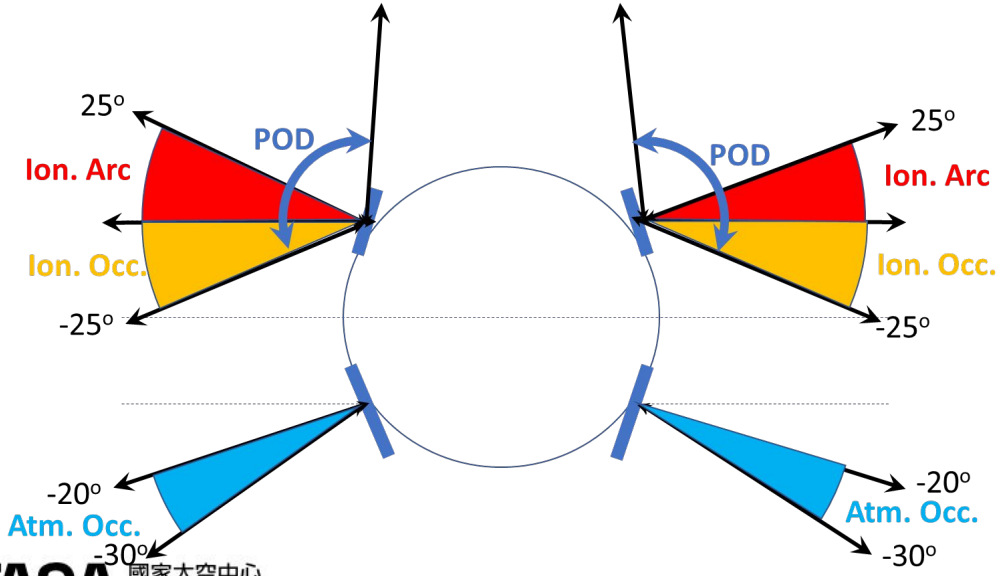


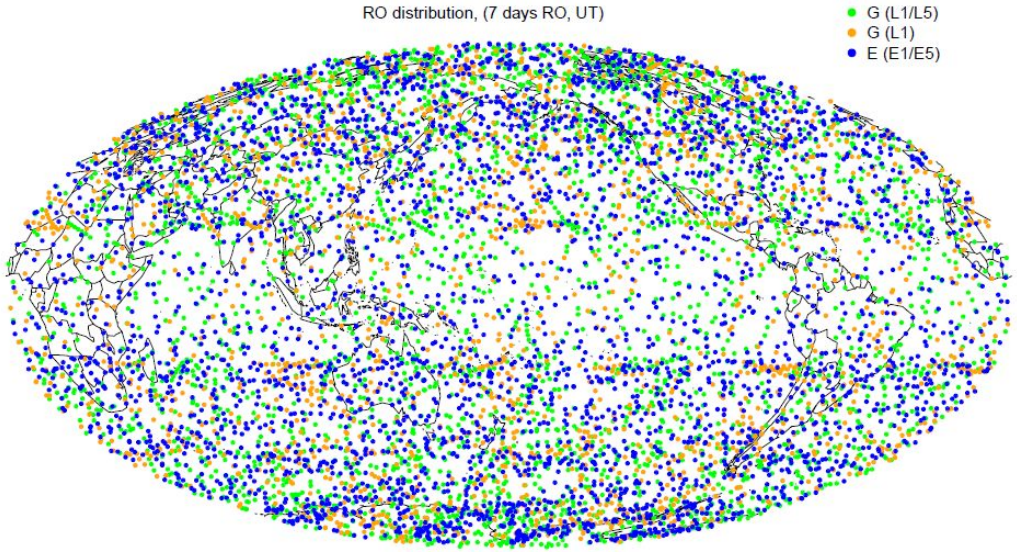
SAR (FORMOSAT-9A)		A	B
Mission life	5 Years		
Mission Orbit	514±5 km Sun Synchronous	LTDN 11:30 [TBD]	~LTDN 11:30 [TBD]
Attitude Accuracy	Pointing Knowledge: within 0.012 deg (3axis, 3σ); Pointing Accuracy: within 0.022 deg (3axis, 3σ)		
Launch Year		2027	2029
2nd PL		GNSS-RO/R	GNSS-RO/R

FS-9A R/RO

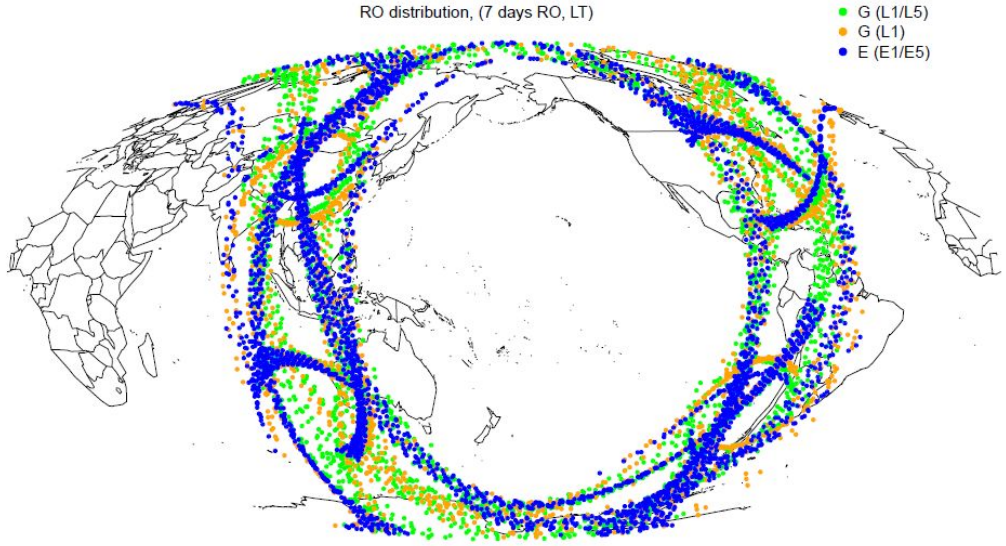
Per satellite provide (FS-9A):

- GPS L1/L5 & Galileo E1/E5
- Atmospheric RO : 300 – 600 (TBD) #/day
- Ionospheric RO : 300 – 600 (TBD) #/day
- Ionospheric S4 index
- Post high accuracy POD for SAR image





Global Distribution vs. Universal Time



Local Time ~ 11:30 am & 11:30 pm

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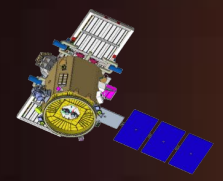
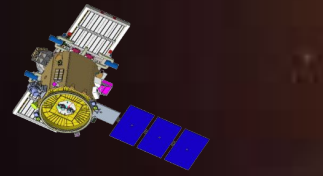
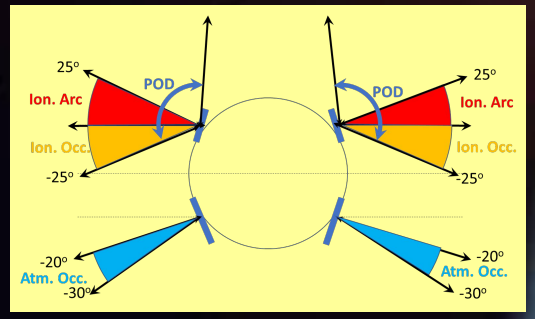
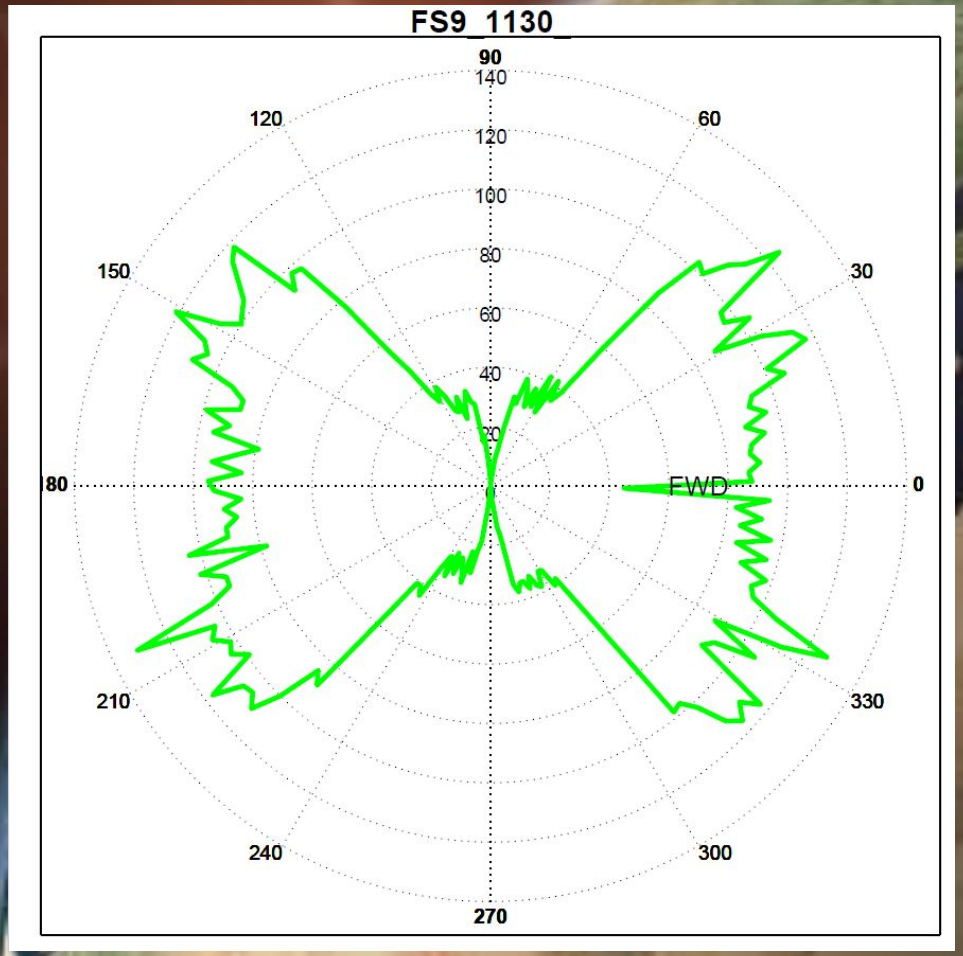
Configurations of FS9-A RO (Ideal)



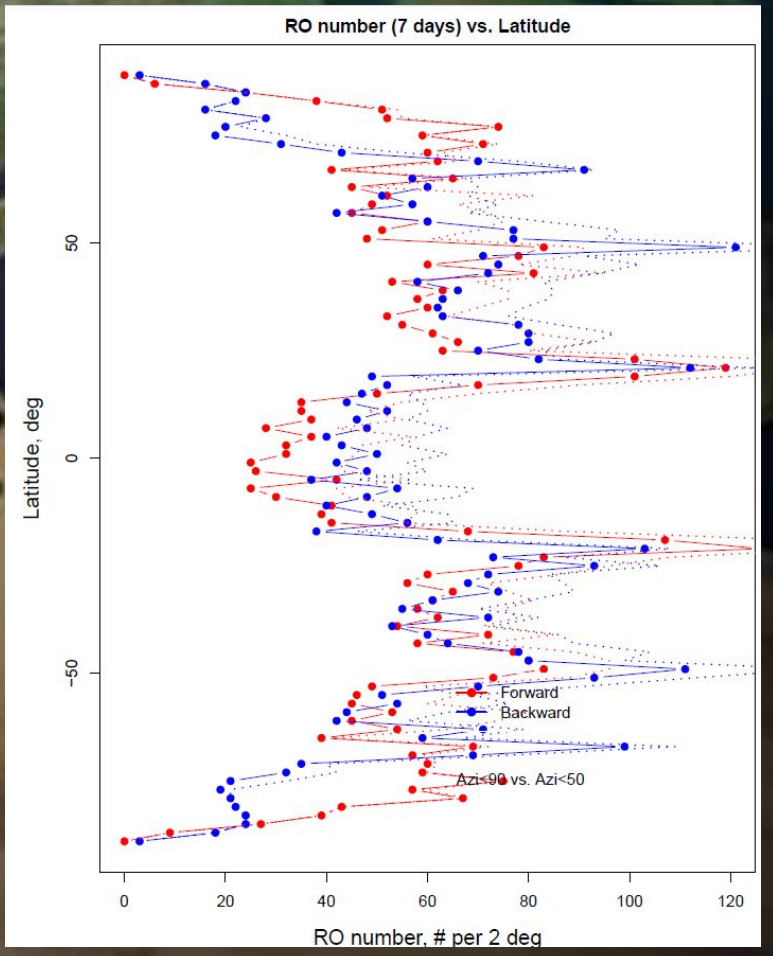




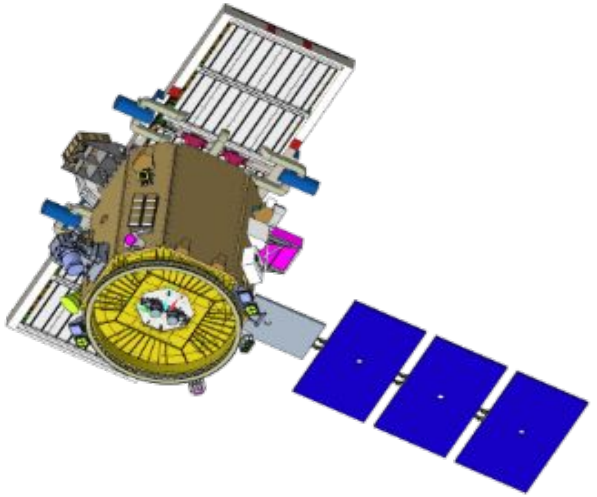
RO number vs. Azimuth (7 days)

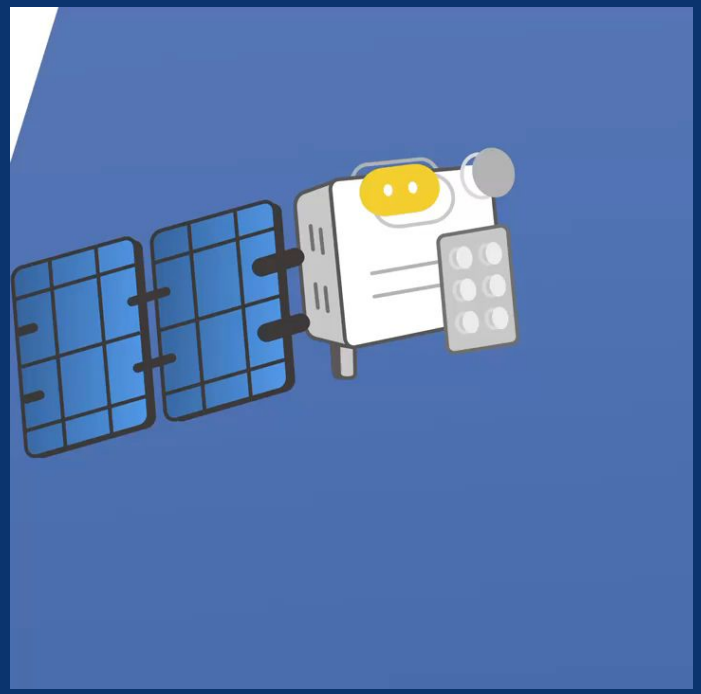


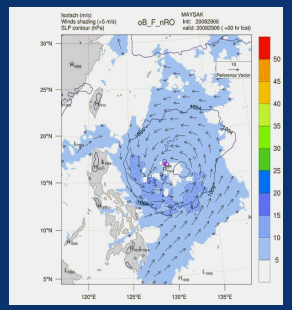
RO number vs. Latitude(7 days)



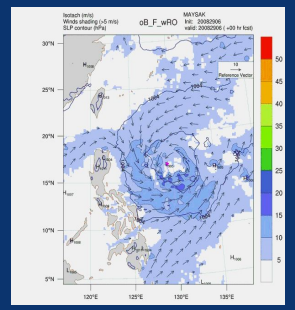
Conclusions





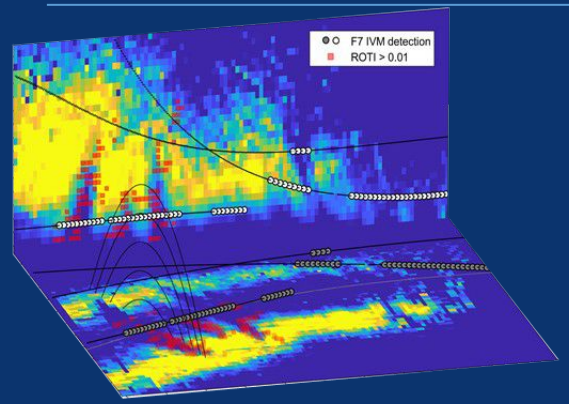


nRO



wRO

Ty Maysak (2020)



FORMOSAT-7/COSMIC-2 mission had completed the 5 years mission designed life on 2024.06.25, collect more than 9.6 /6.9 million profiles for atmosphere and ionosphere, have great achievement on weather/space weather forecast and scientific applications.

TASA will continue do our best to maintain the operation for FORMOSAT-7 to provide more data for atmosphere and ionosphere, and also outline the next vision on RO/R mission in future .