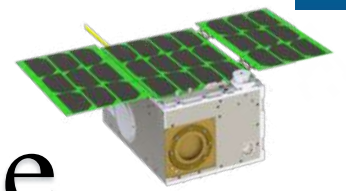
臺灣太空科技發展



The development of outer space technology in Taiwan

劉正彥 主任/講座教授

1. 國立中央大學 太空科學與科技研究中心
2. 國立中央大學 太空科學與工程學系
3. 國立中央大學 太空與遙測研究中心

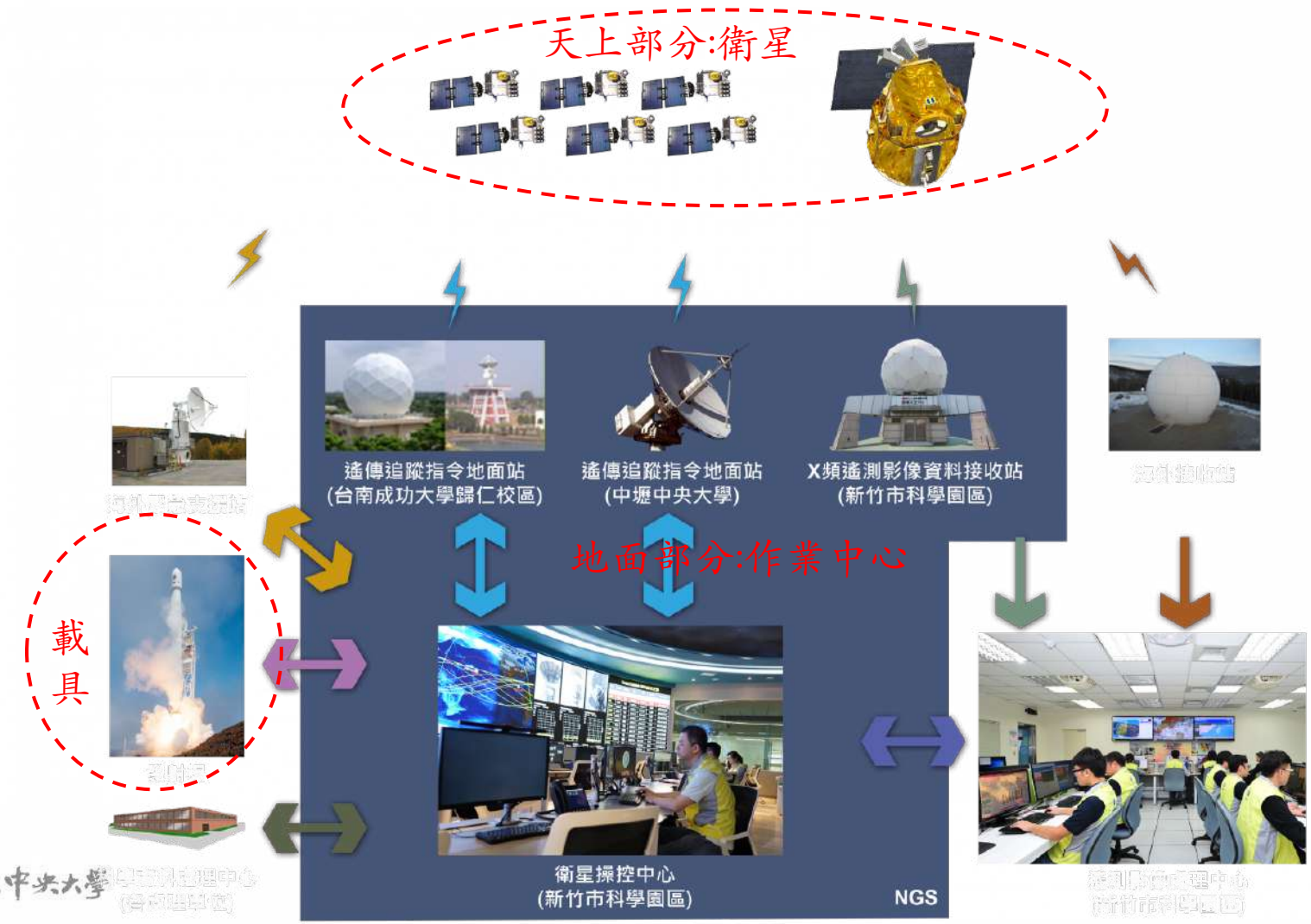
大綱

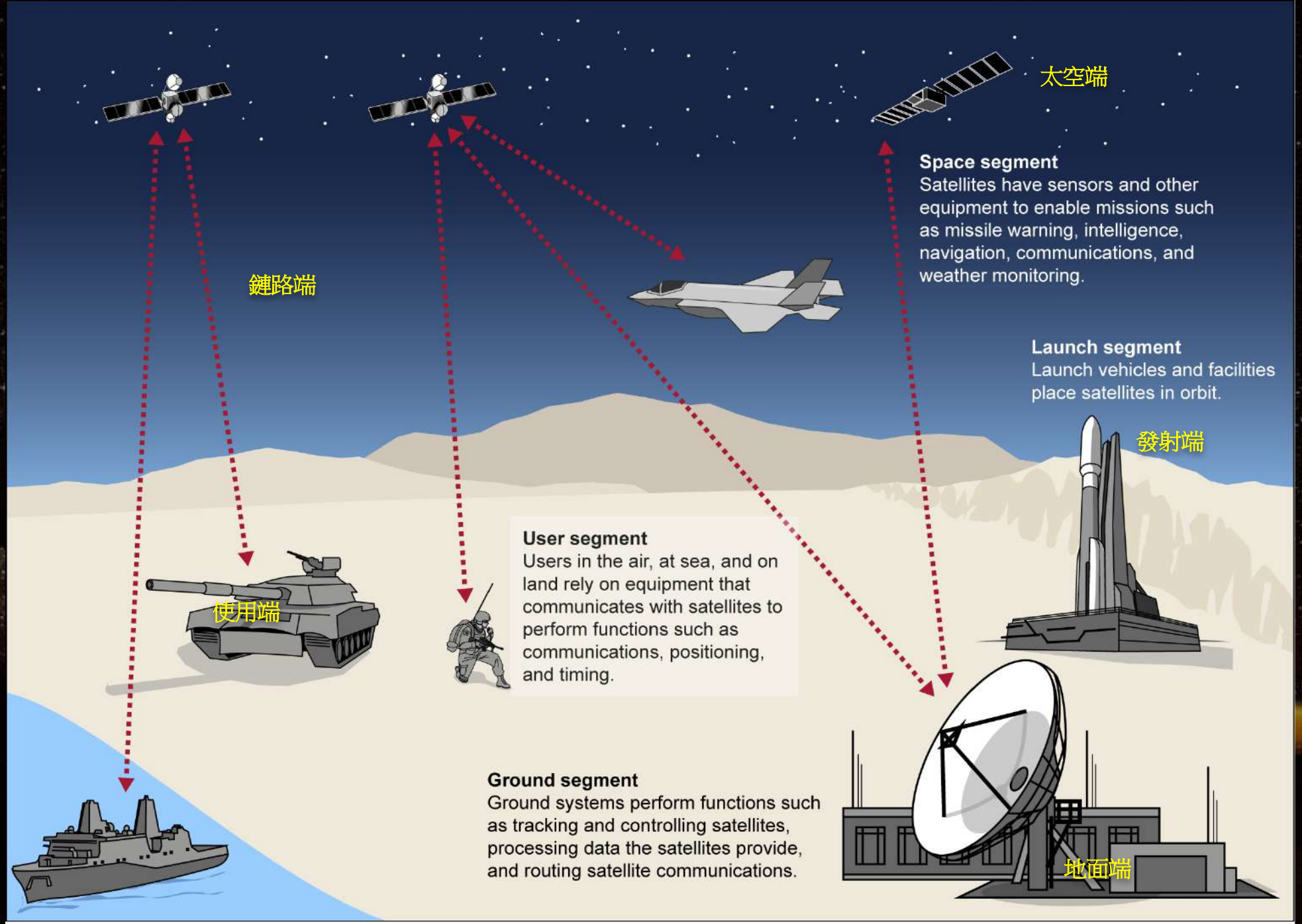
- 緒論
  - 太空計畫
  - 太空電離層環境
  - 低軌衛星無線通訊
  - 人造衛星
- 臺灣國家太空中心NSPO
- 臺灣完整大學級太空中心CAPE
- 結語

太空計畫

- 任務定義 (mission definition)
- 太空工程 Space Engineering
  - 衛星 space segment (satellite)
  - 載具 launcher (rocket)
  - 地面設施 ground segment

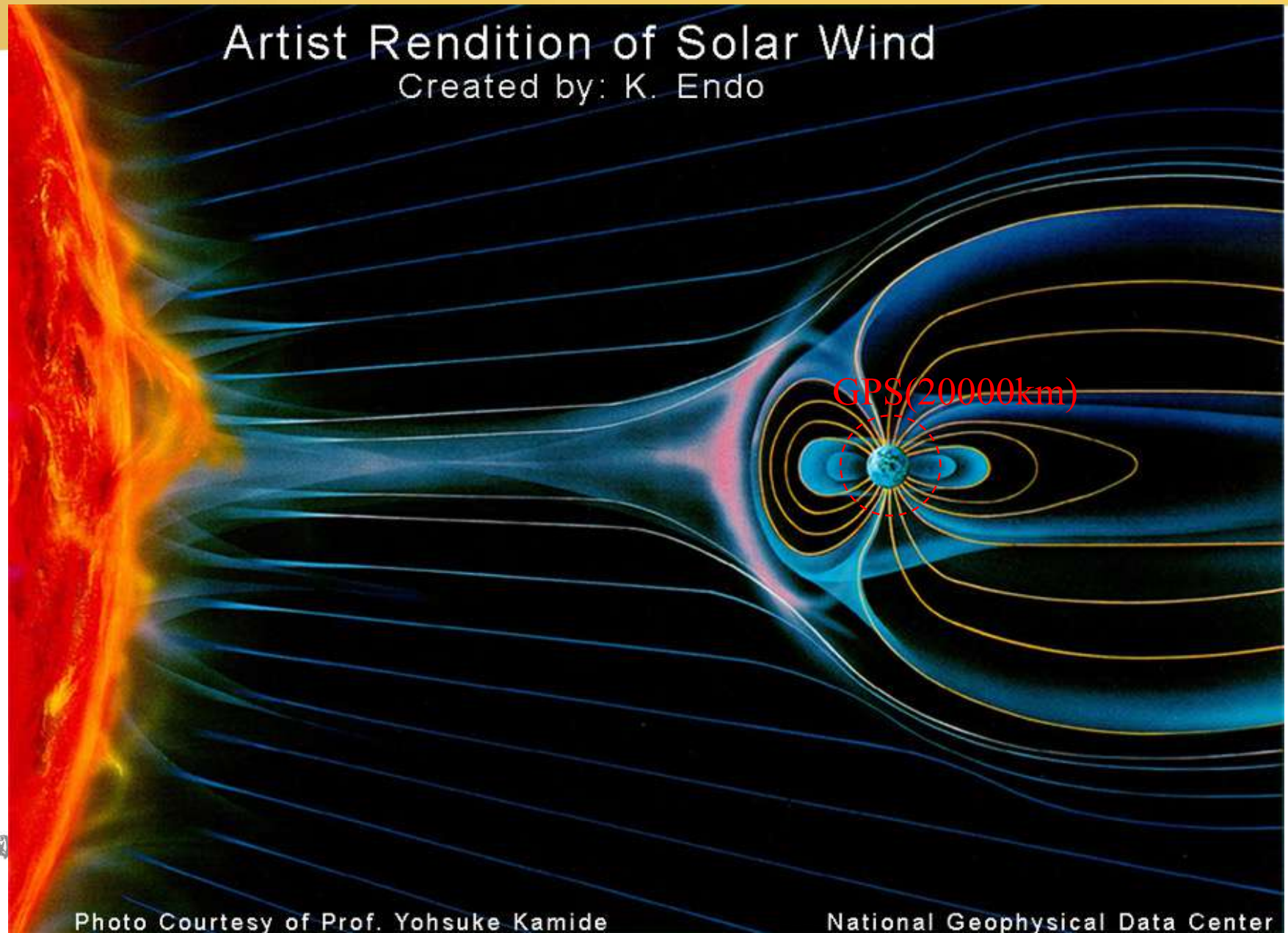
太空工程


天上部分:衛星
遙傳追蹤指令地面站
(台南成功大學歸仁校區)
遙傳追蹤指令地面站
(中壢中央大學)
X頻遙測影像資料接收站
(新竹市科學園區)
地面部分:作業中心
載具
衛星操控中心
(新竹市科學園區)
NGS

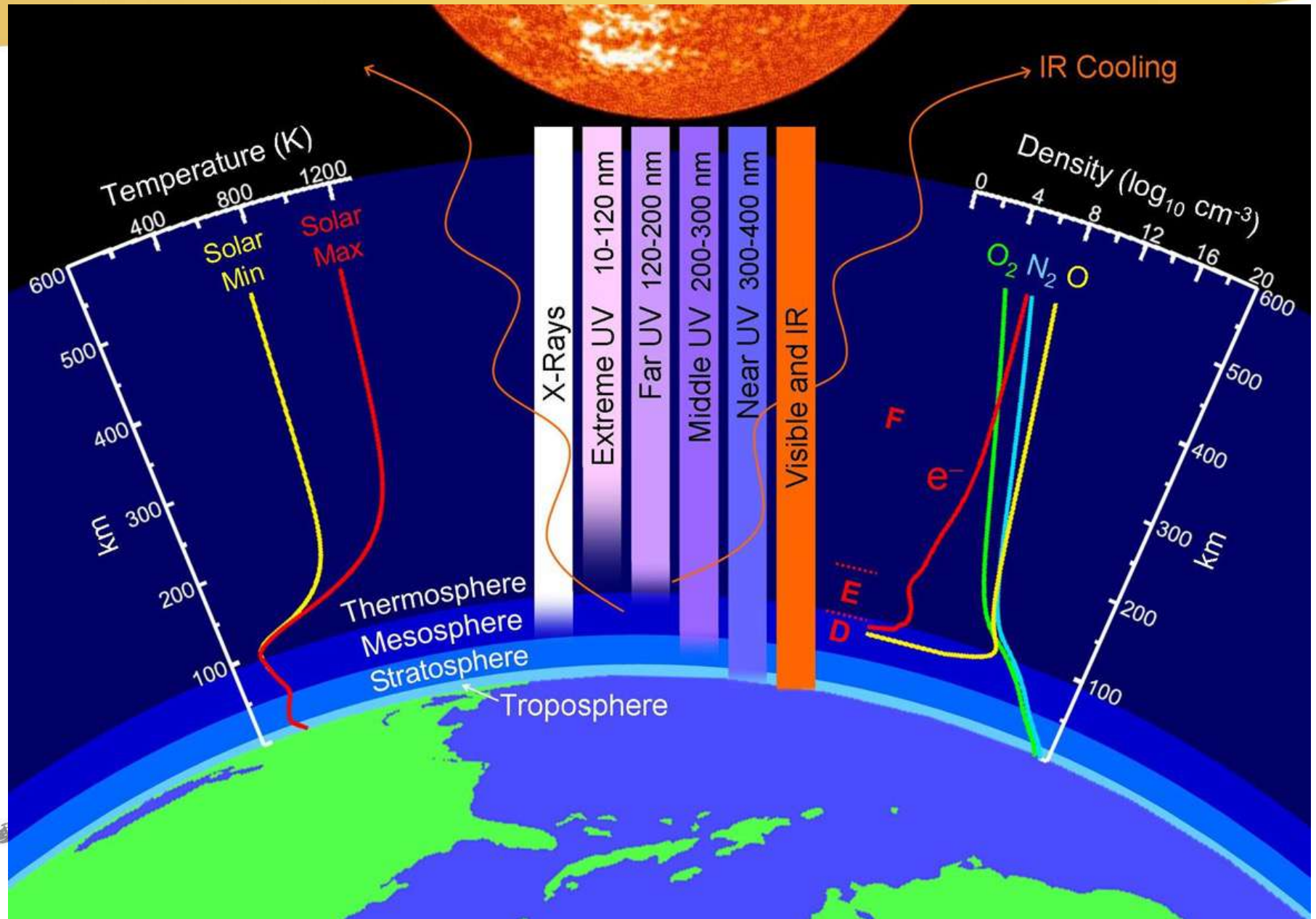


Source: GAO analysis of Department of Defense (DOD) documentation. | GAO-19-458T

日地環境

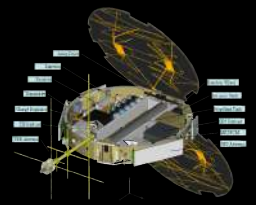

Artist Rendition of Solar Wind
Created by: K. Endo
GPS(20000km)
Photo Courtesy of Prof. Yohsuke Kamide
National Geophysical Data Center

近地太空: 電離層

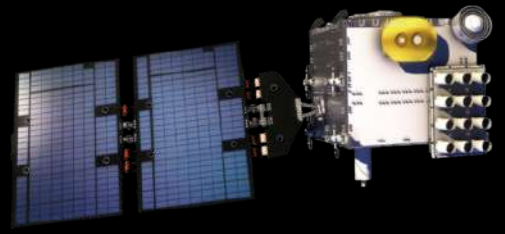

IR Cooling
Temperature (K)
400
800
1200
Solar Min
Solar Max
600
500
400
300
200
100
km
X-Rays
Extreme UV 10-120 nm
Far UV 120-200 nm
Middle UV 200-300 nm
Near UV 300-400 nm
Visible and IR
Thermosphere
Mesosphere
Stratosphere
Troposphere
Density (log_{10} cm^{-3})
0
4
8
12
16
20
O_2 N_2 O
F
e^-
E
D
600
500
400
300
200
100
km

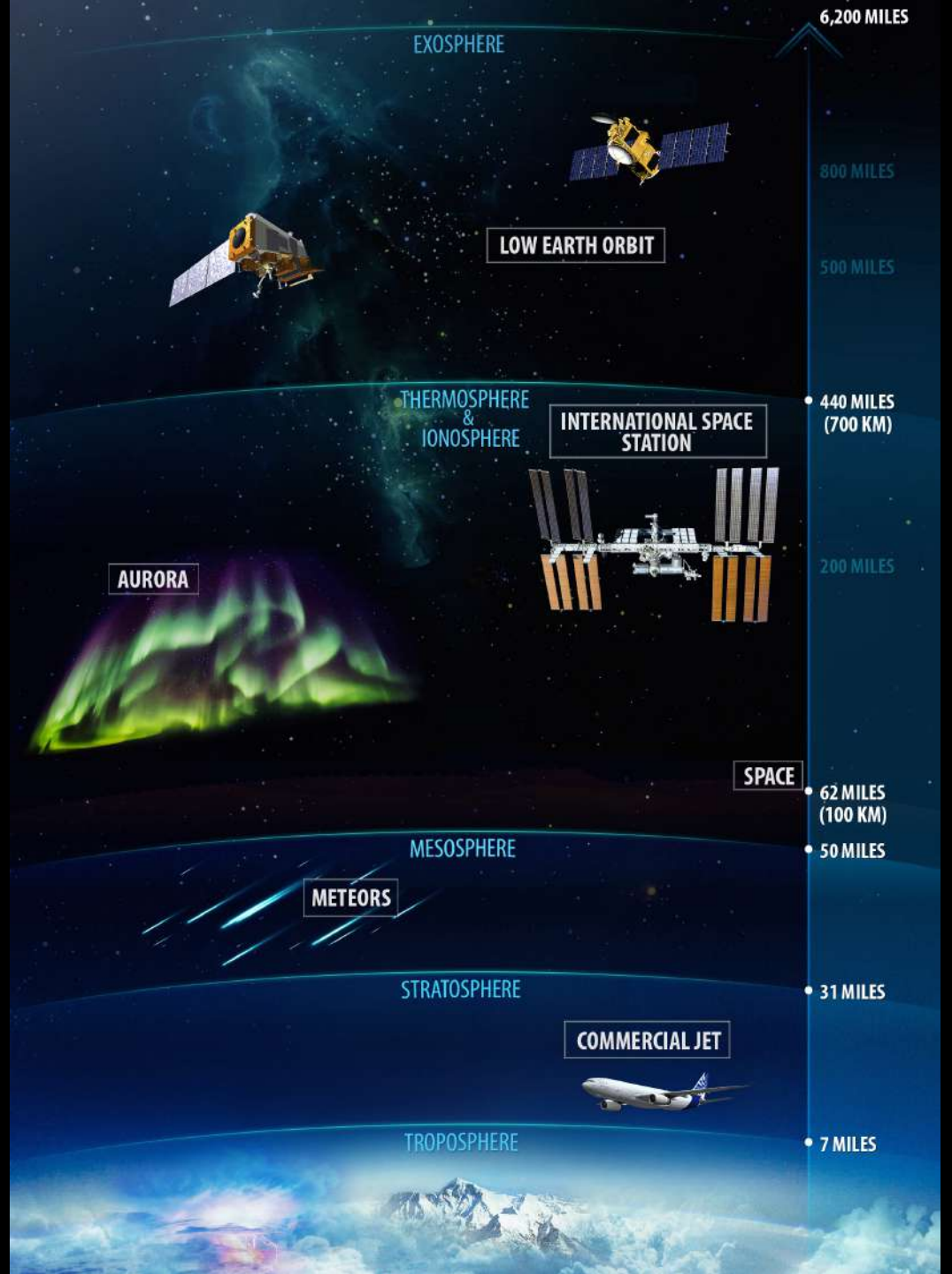
低軌道衛星高度

~800 km

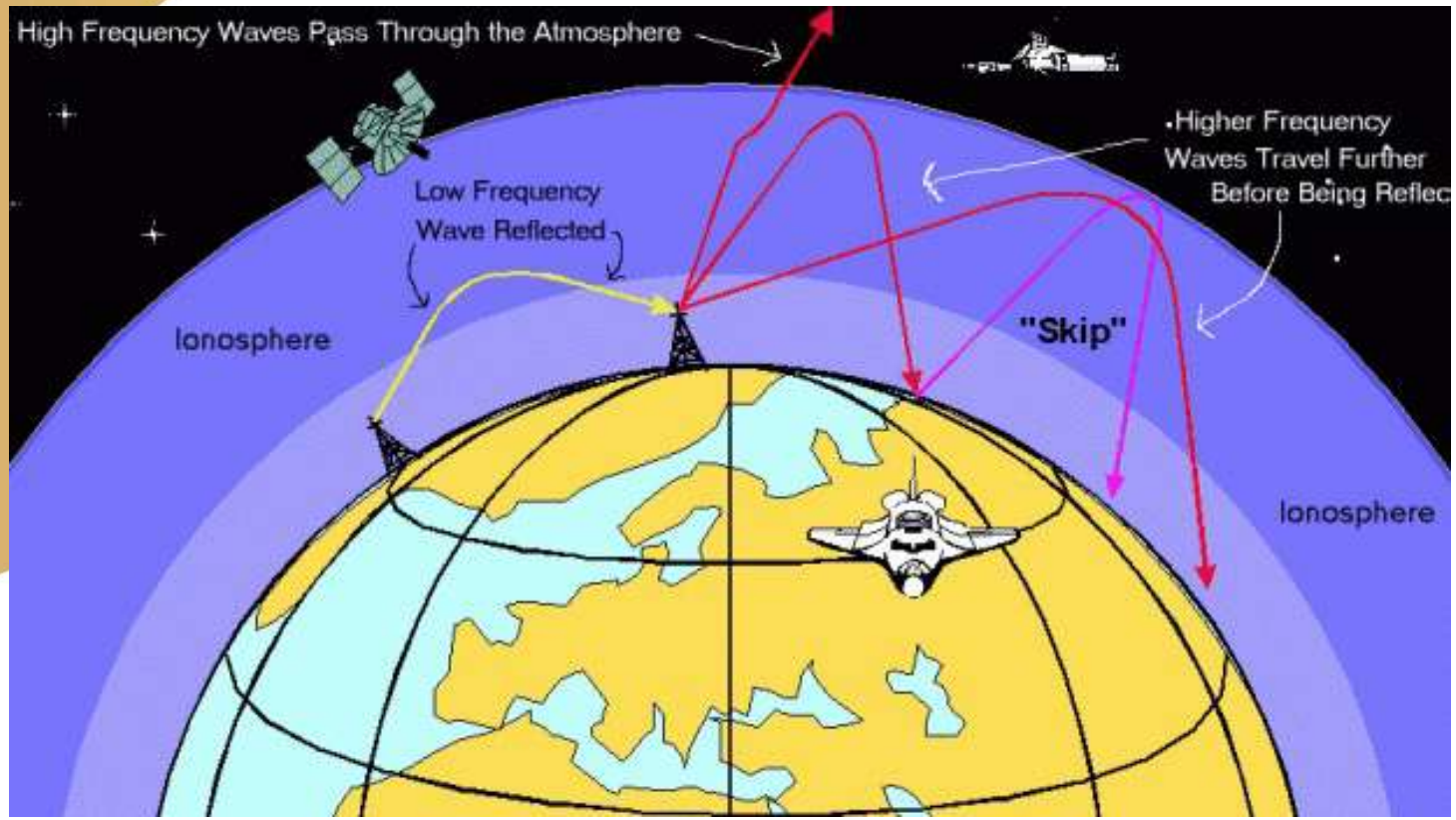


~500 km

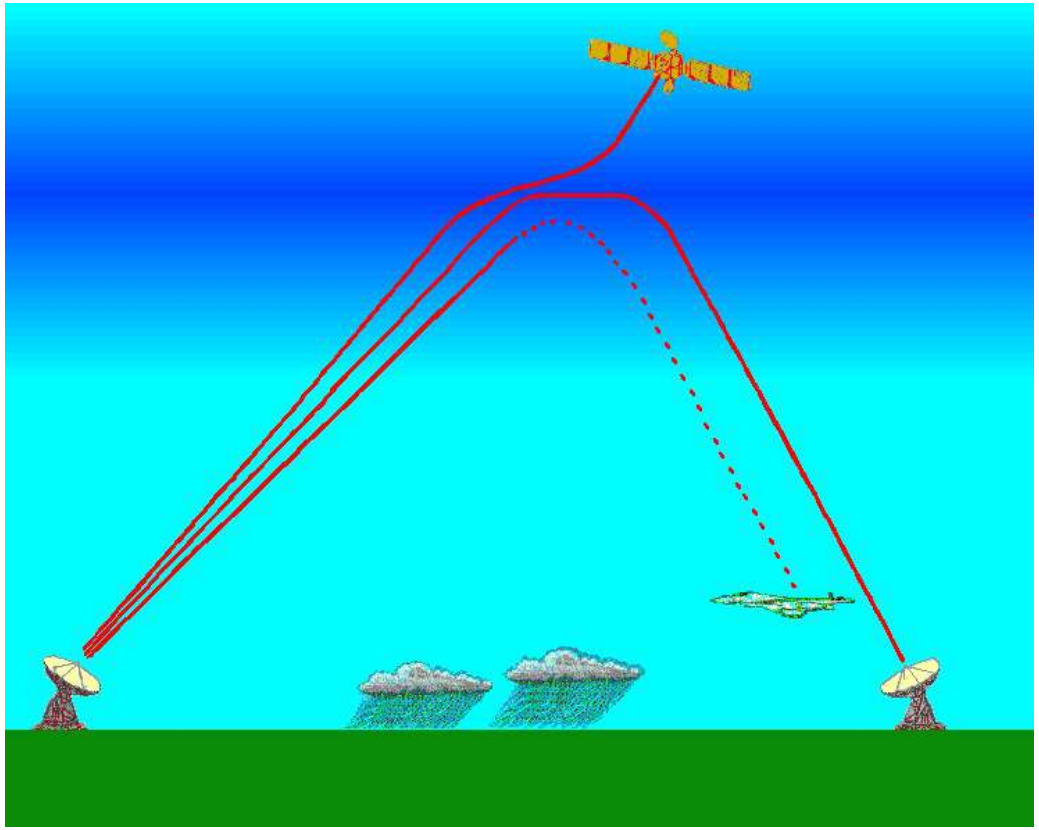




低軌衛星無線通訊與電離層

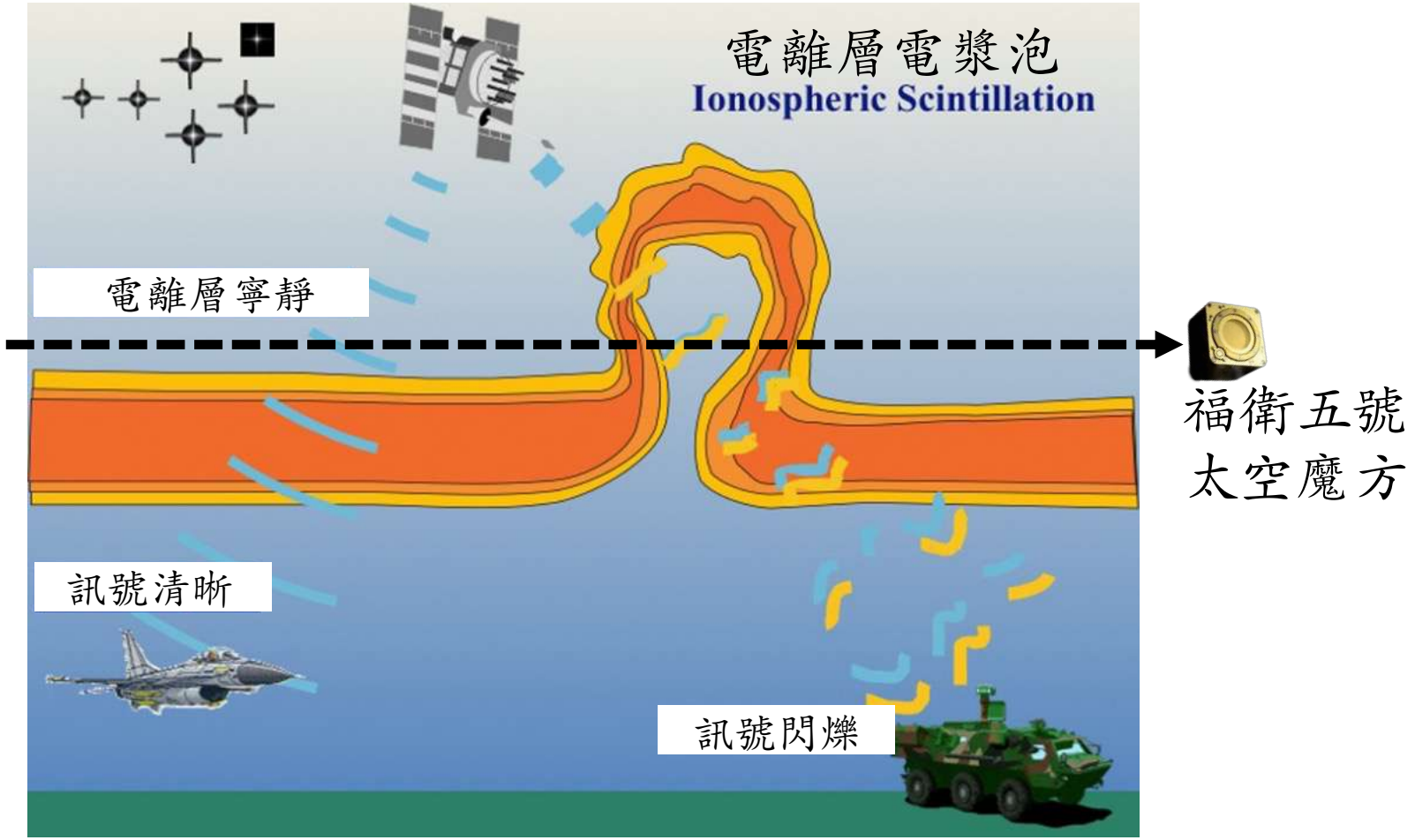


https://www.swpc.noaa.gov/phenomena/ionosphere



https://www.ngdc.noaa.gov/stp/iono/ionohome.html

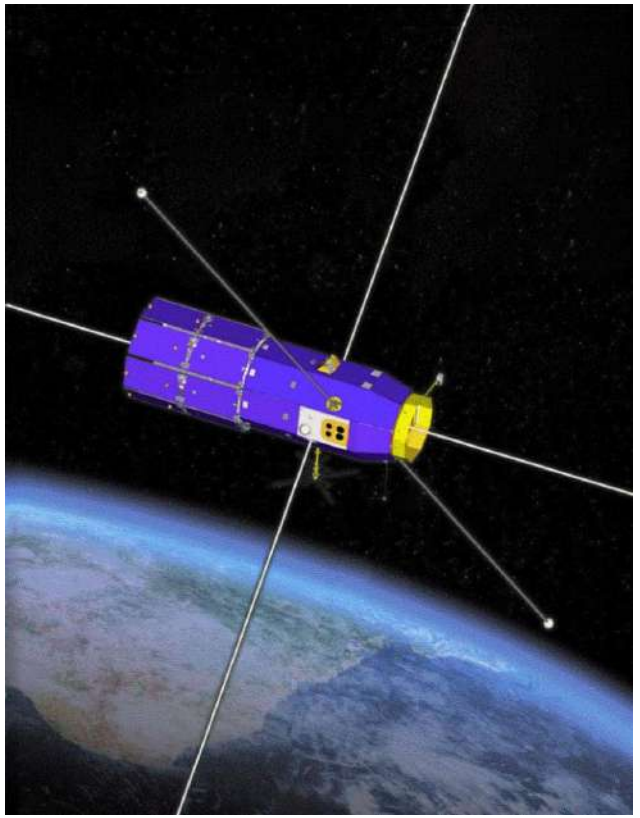
低緯度電漿泡和濃度不規則體



NASA

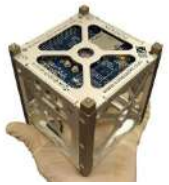
C/NOFS（通信/導航中斷預測系統）衛星

- C/NOFS(通信/導航中斷預測系統2008-2015)是美國空軍研究實驗室開發的衛星，用於低緯度電離層閃爍之監測和預測。
- C/NOFS搭載離子速度儀(IVM)、蘭摩爾探針(PLP)、中性風儀(NWM)、中性風儀(NWM)、GPS掩星接收機、電波信標、向量電場儀，並由Pegasus-XL火箭發射升空，進入13°低傾角，近地點400公里、遠地點850公里之橢圓軌道。主要任務由福七接手持續觀測。



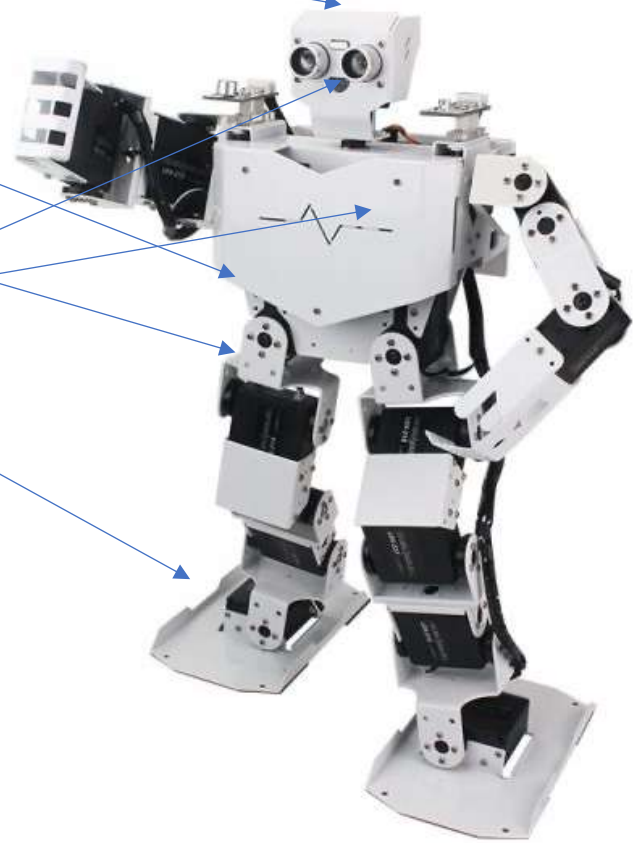
衛星的大小與重量

- 大型衛星：大於1000kg（1公噸）
- 中型衛星：界於500到1000kg（半公噸）
- 小型衛星：不到500kg的都叫小型衛星
  - 迷你型衛星：500到100kg
  - 微衛星：小於100kg
  - 奈米衛星：10kg或更低
  - 方塊衛星：按國際標準約1.3kg
  - 米粒衛星：僅以公克為單位

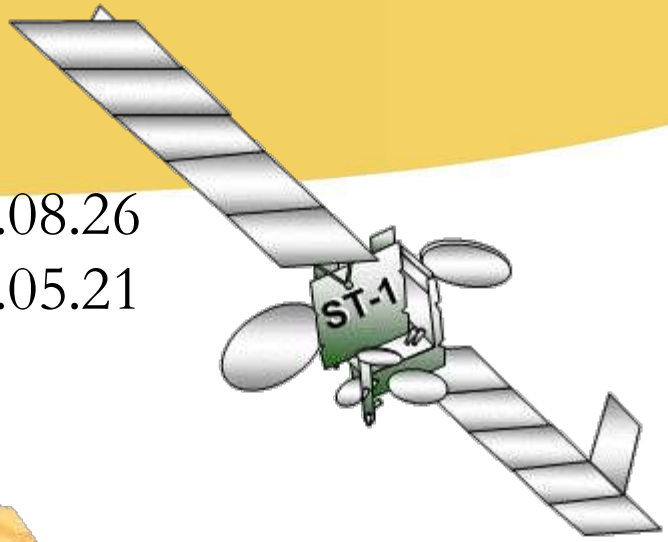


衛星次系統

- 電腦
- 結構
- 熱力
- 姿態
- 電力
- 通訊
- 酬載

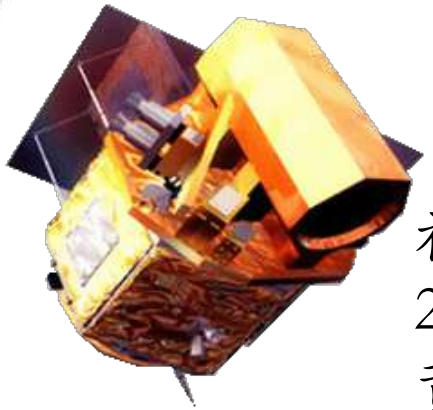


臺灣人造衛星

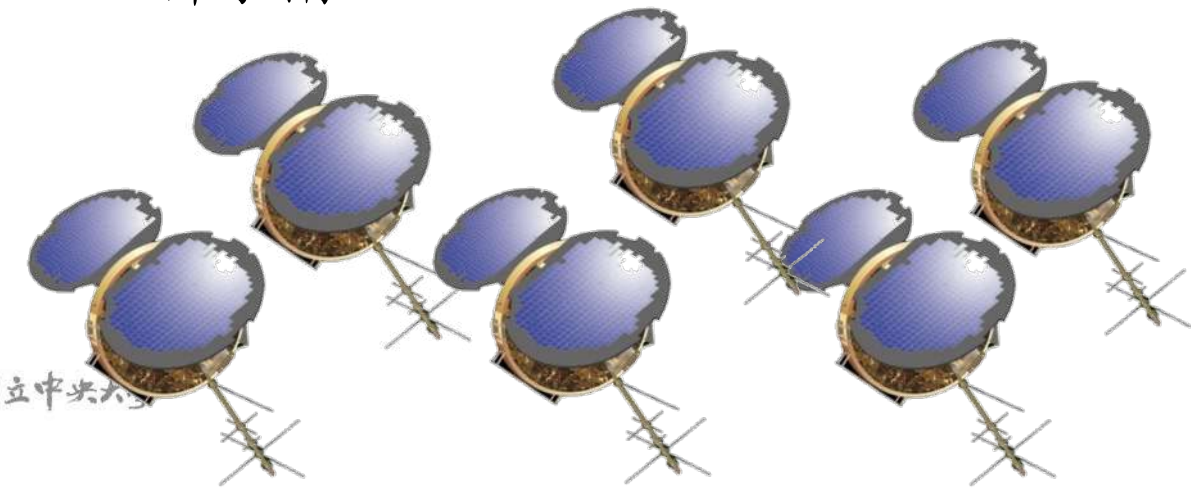


中新衛星
一號1998.08.26
二號2011.05.21
通訊衛星

福爾摩沙一號衛星
1999.01.27-2004.06.17
科學衛星

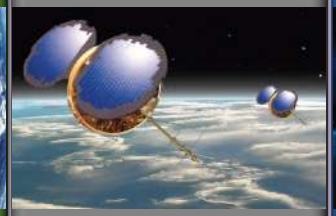
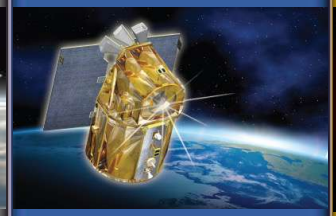
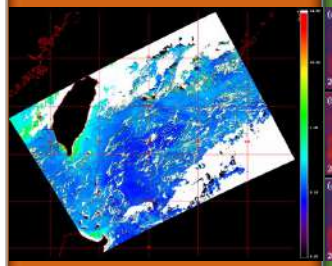
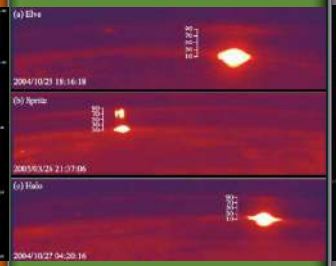
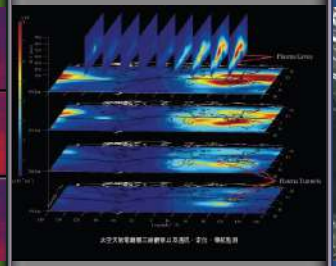


福爾摩沙二號衛星
2004.05.21
資源、科學衛星



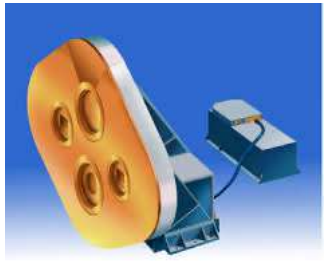
福爾摩沙三號衛星
2006.04.15
氣象、科學衛星

Taiwan Space Program
福衛承先啟後 開創傳奇紀元

福爾摩沙衛星1號 FORMOSAT-1	福爾摩沙衛2號 FORMOSAT-2	福爾摩沙衛星3號 FORMOSAT-3	福爾摩沙衛星5號 FORMOSAT-5	福爾摩沙衛星7號 FORMOSAT-7	獵風者號(TRITON) FORMOSAT-7R
					
科學任務	遙測與科學任務	氣象與科學任務	遙測與科學任務	氣象、太空天氣 與科學任務	氣象與科學任務
					
1999年01月27日 2004年06月17日	2004年05月20日 2016年08月20日	2006年04月15日 2020年05月01日	2017年08月25日 服役中	2019年06月25日 服役中	預計2021年 發射升空

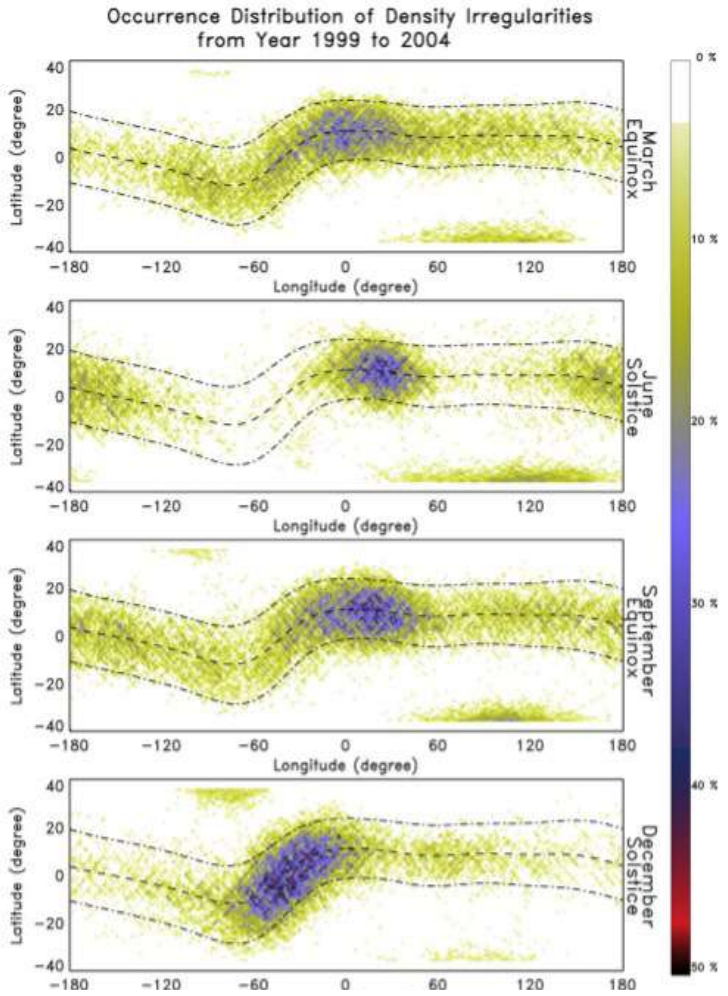
ROCSAT-1 (FORMOSAT-1)福衛一號

Ionospheric Plasma Electromagnetic Instrument (IPEI)



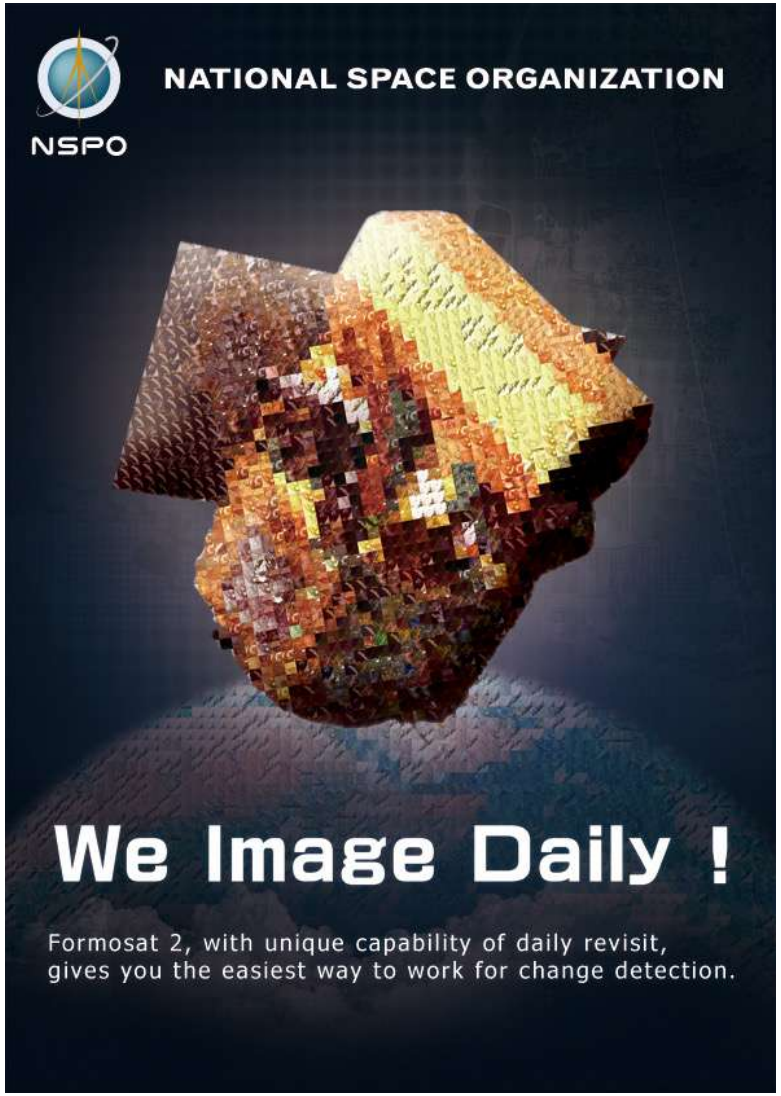
IPEI

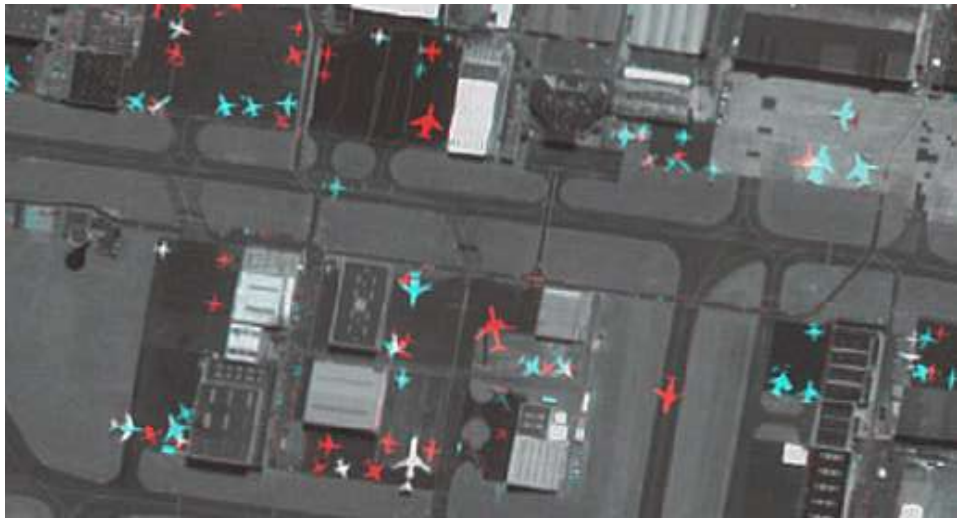
福衛一號電漿不規則體



Global distributions of density irregularities for four difference seasons from 1999 to 2004 shown in colorcoded scales to indicate the probability of irregularity occurrences. (Su et al., 2006)

FORMOSAT-2 福衛二號– Daily Revisit Capability



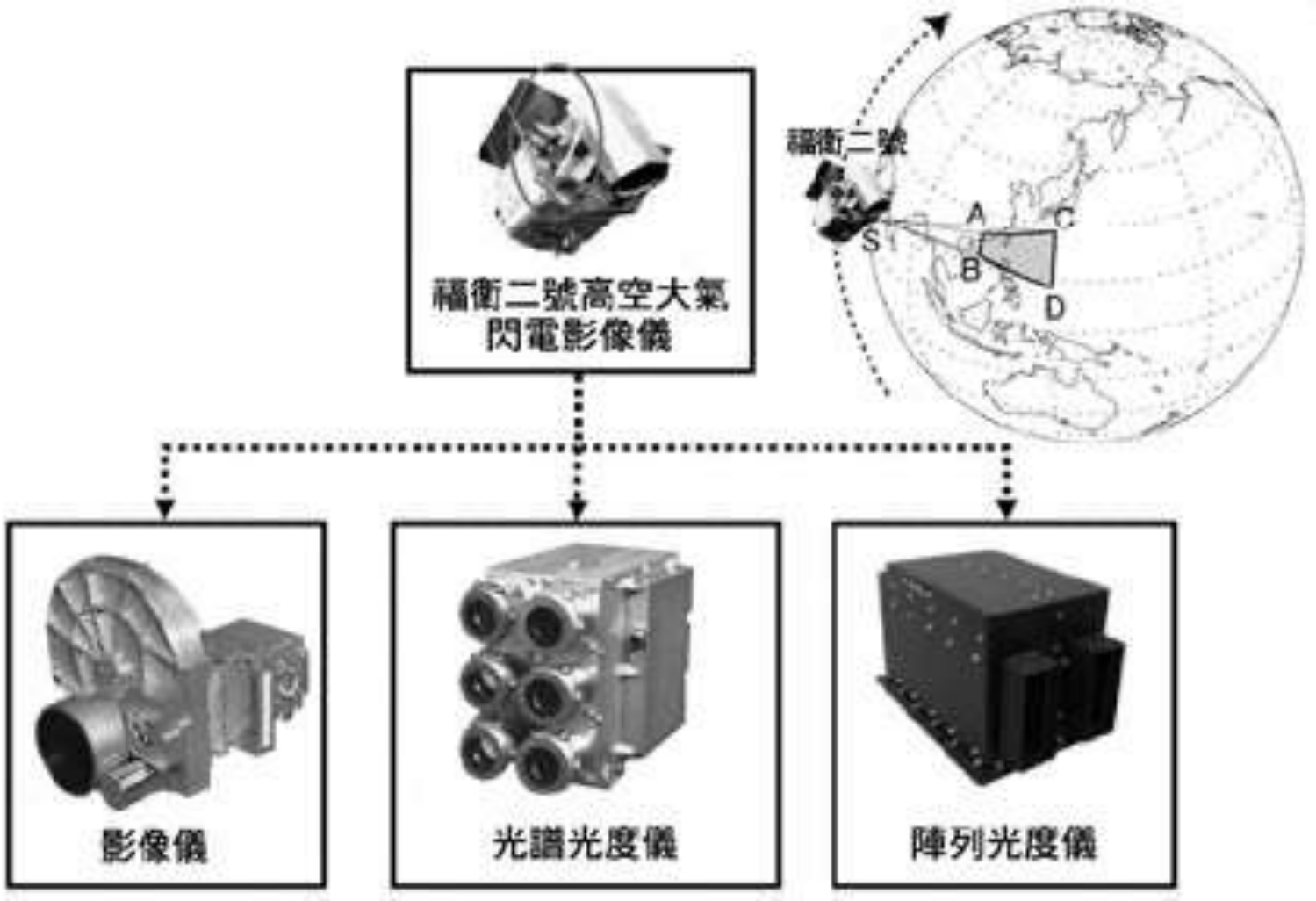


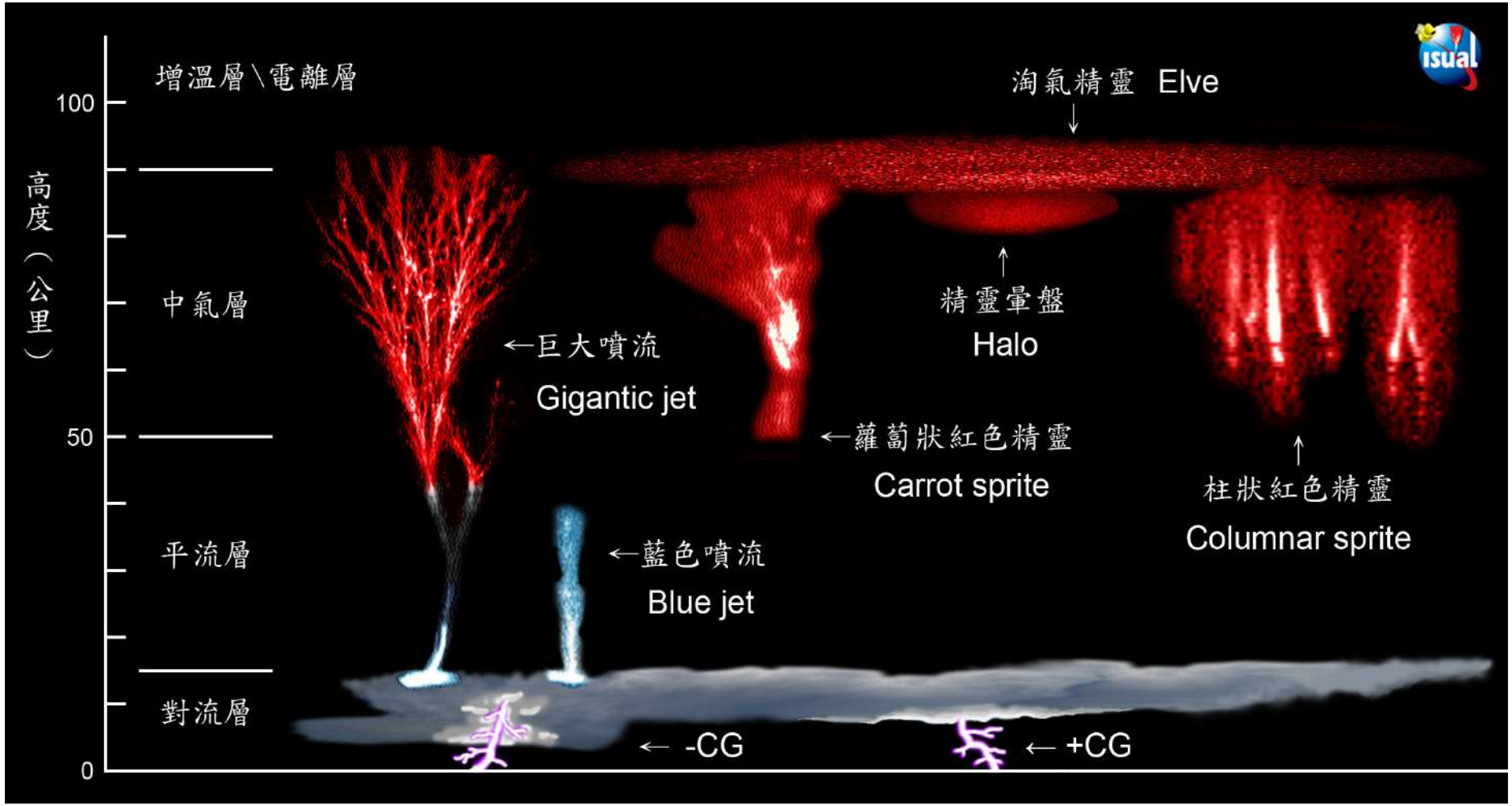
Support to Worldwide Nature Disaster Relief

2004 Southern Asia Tsunami
2008 Wilkins Ice Shelf Corruption
2008 Wenchuan Earthquake
2011 Eyjafjallajokull Volcano
Shinmoedake Volcano
2011 Japan Earthquake

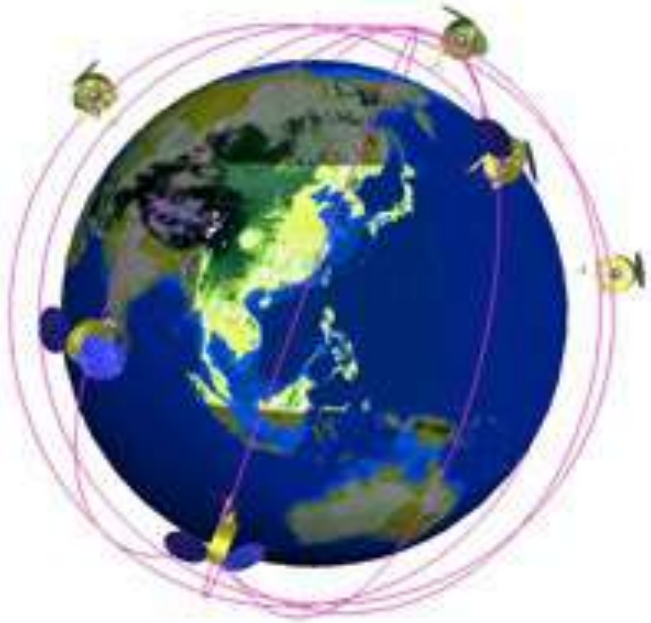
FORMOSAT-2 has supported more than 236 events across 57 countries since its launch.

FORMOSAT-2 – ISUAL (Science Payload)





高空大氣閃電影像儀（以下簡稱ISUAL）為福衛二號的科學酬載之一，主要的科學研究課題為大氣電學之新興領域-高空短暫發光現象（Transient Luminous Events, 以下簡稱TLEs）。這些現象包含了紅色精靈、淘氣精靈、精靈暈盤、藍色噴流與巨大噴流。



FORMOSAT-3/COSMIC

福衛三號

Global Real-time
Weather (Meteorology)
Space Weather (Ionosphere)
Observation and Prediction

The FORMOSAT-3/COSMIC program is an international collaboration between Taiwan and the United States that will use a constellation of six remote sensing microsatellites to collect atmospheric data for weather prediction and for ionosphere, climate and gravity research. Data from the satellites will be made freely available to the international scientific community in near real-time.

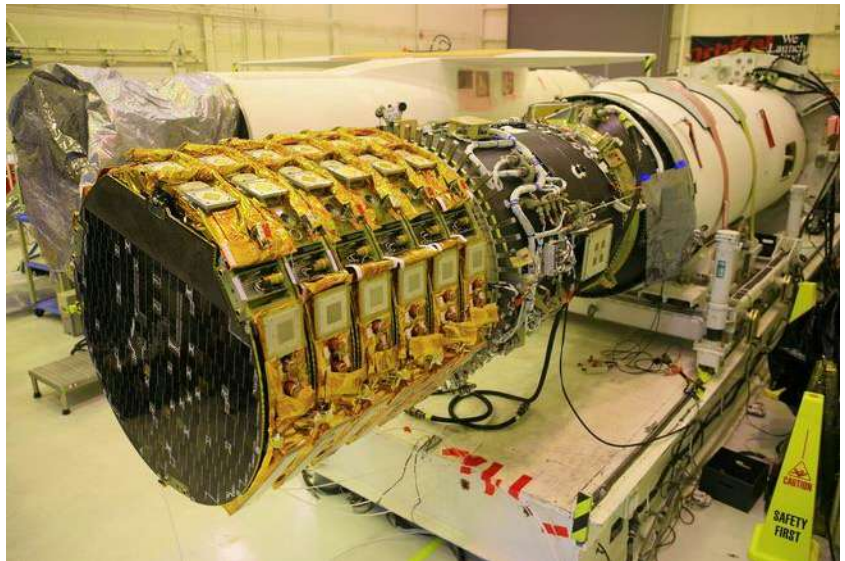
FORMOSAT-3/COSMIC

福衛三號

- ***FORMOSAT-3/COSMIC Constellation was launch at 01:40 UTC, April 14, 2006 (Taiwan Time: April 15 2006) at Vandenberg Air Force Base, CA.*** *Minotaur Launch*

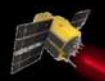
- ***Maneuvered into six different orbital planes (inclination ~72°) for optimal global coverage (at ~800 km altitude).***

- ***Five out of Six satellites are in good health and providing science data.***



GPS Radio Occultation 掩星觀測

Total sounding: 4,000,000+ profiles

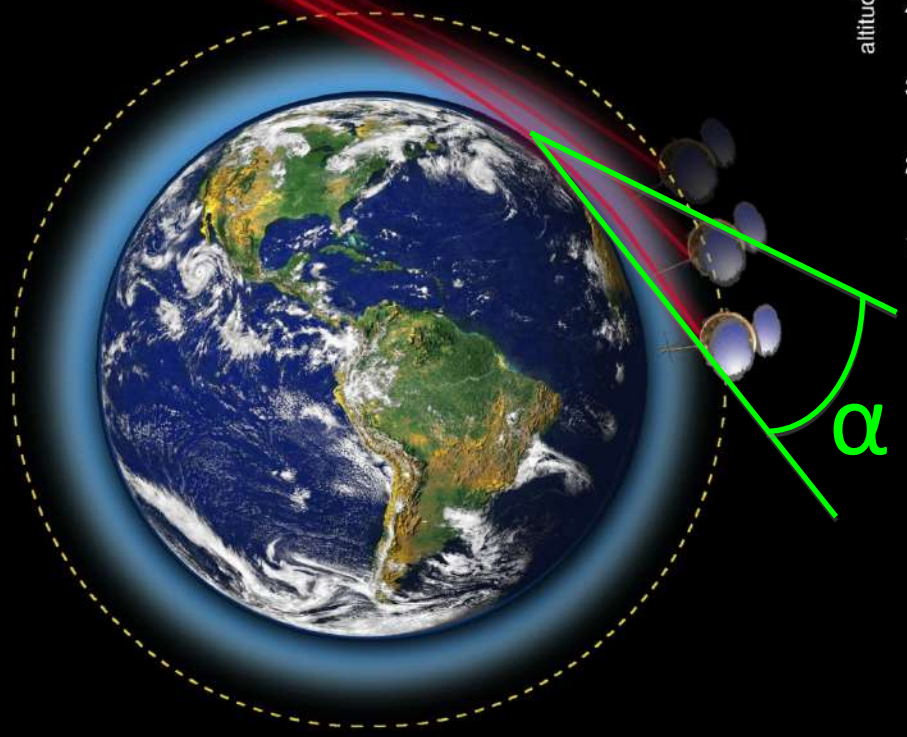


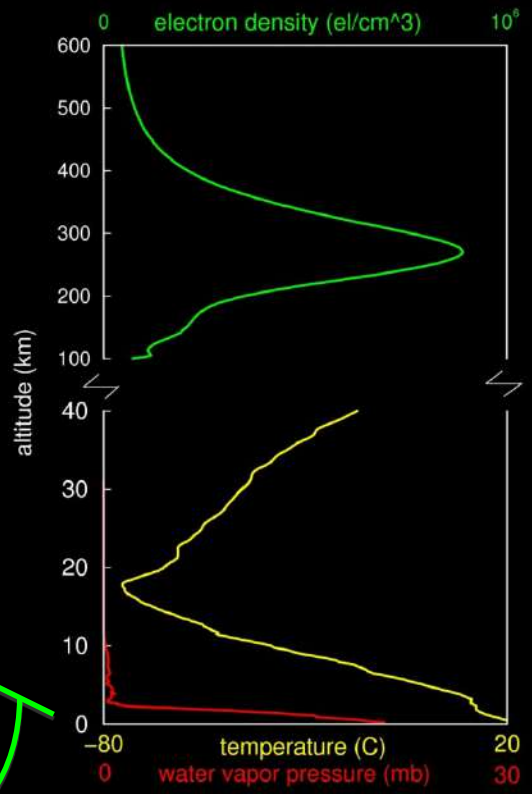
GPS

TECRO

Daily sounding:

2500-1500 profiles



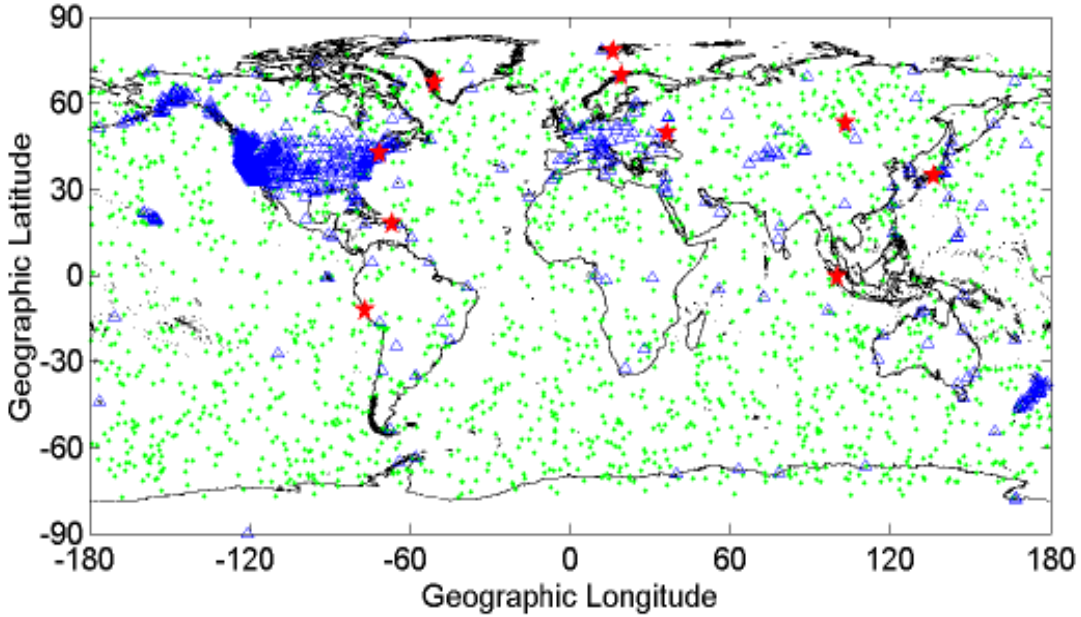


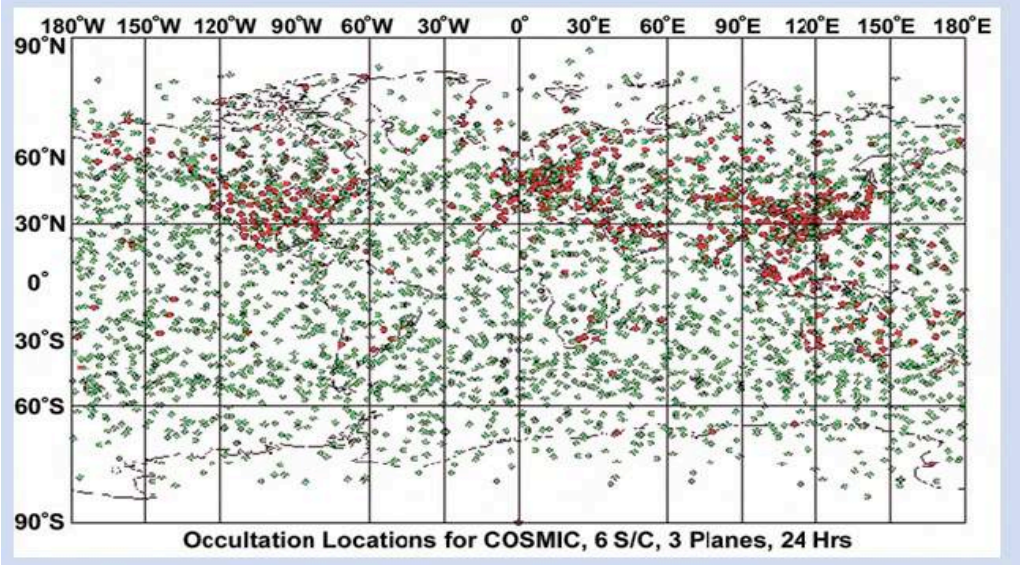
Wavelength and amplitude of in the vertical direction

Global 3D structure

Atmospheric and Ionospheric F3/C RO Sounding

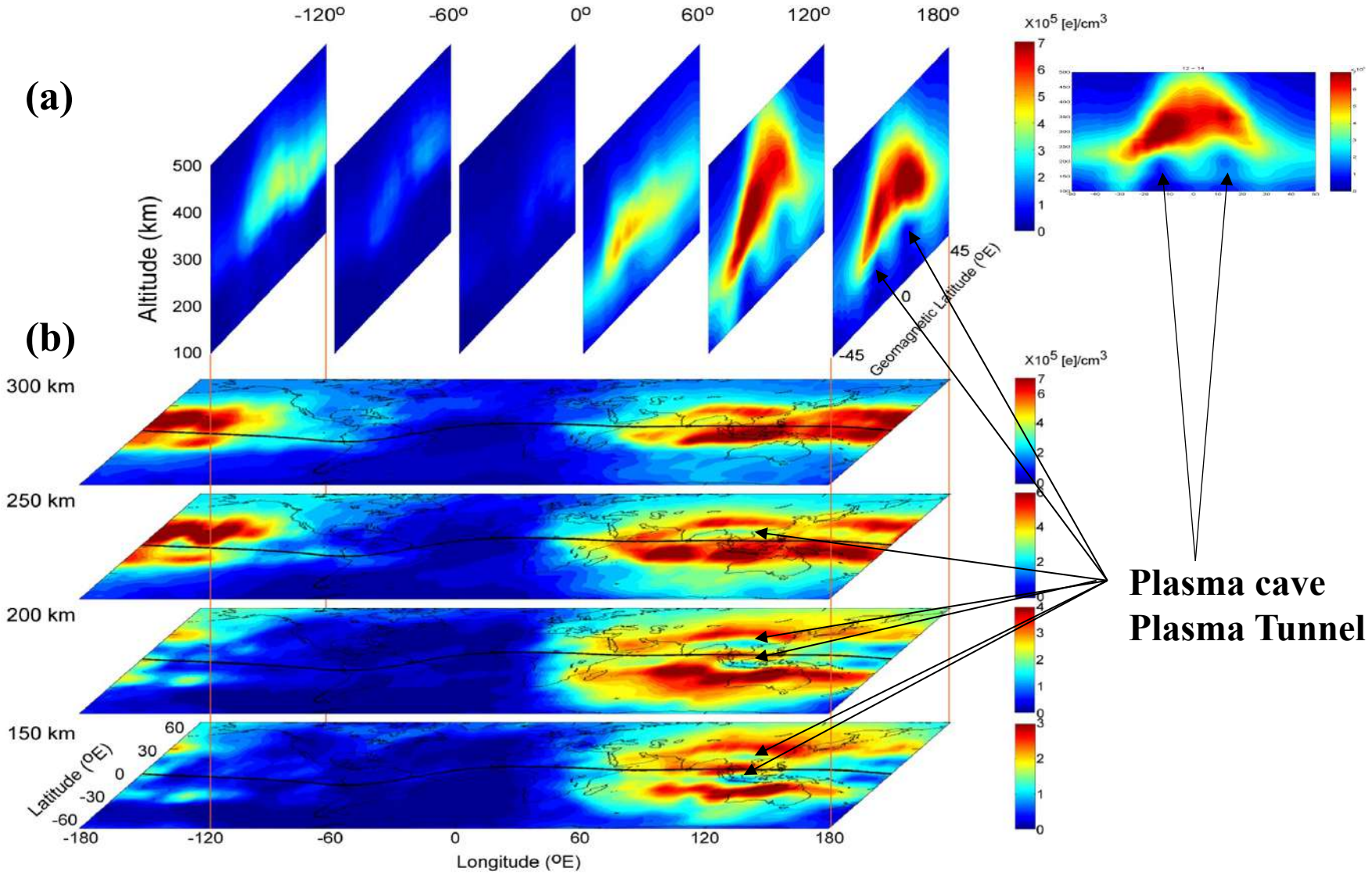
Ionospheric Sounding





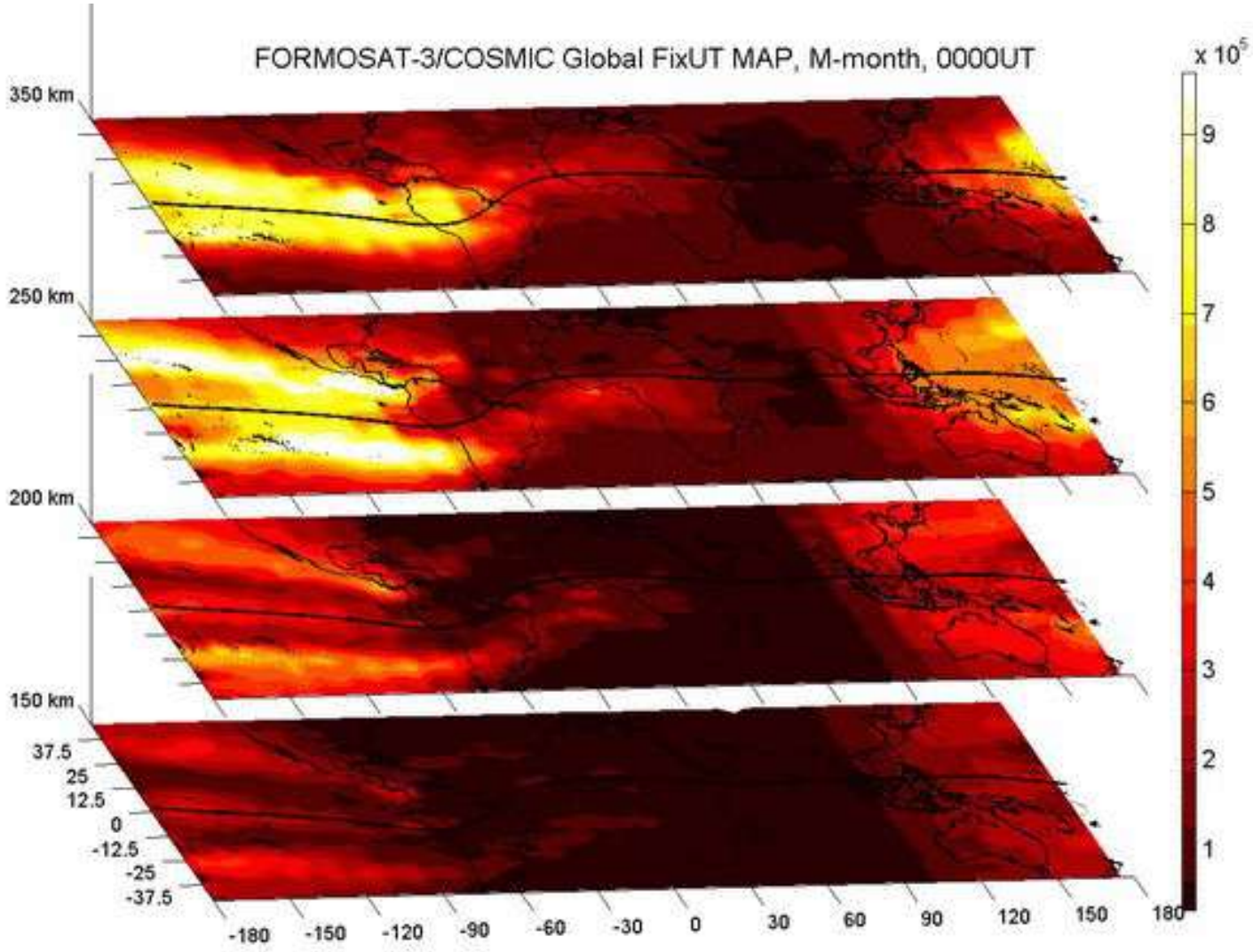
Atmospheric Sounding

3D Ionospheric plasma Structure

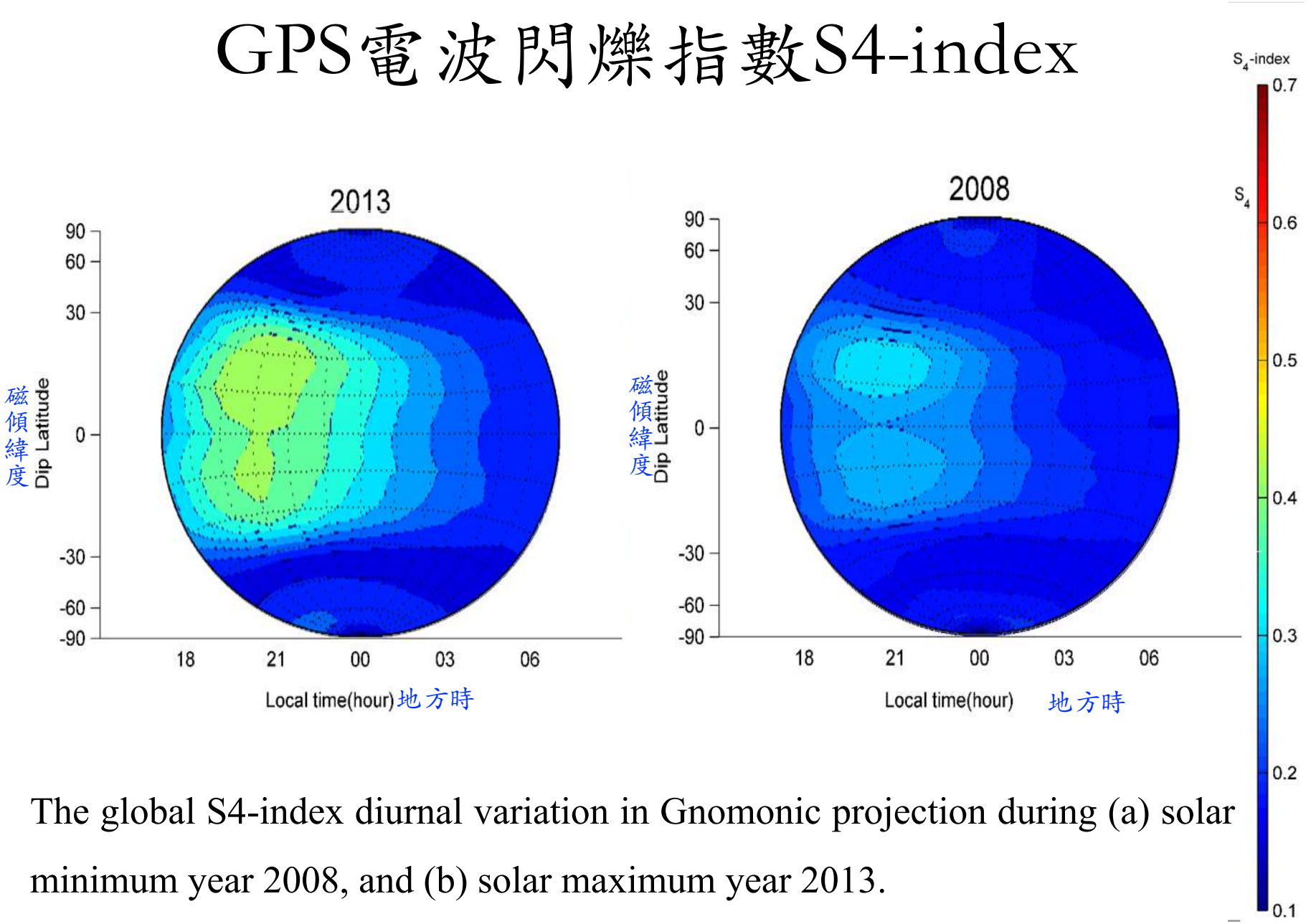


Liu et al. (JGR 2010)

EIA in M-month



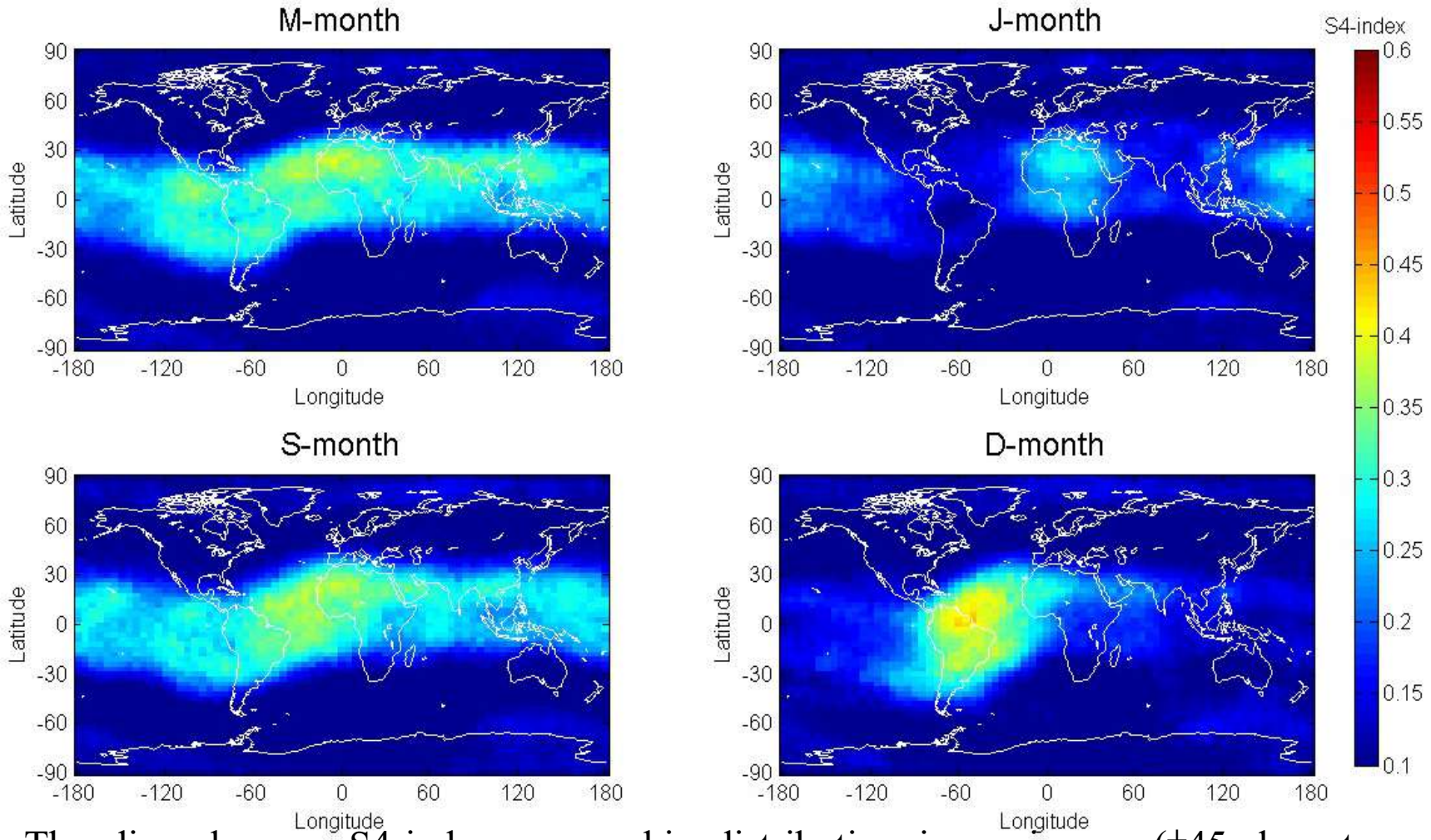
GPS電波閃爍指數S4-index



The global S4-index diurnal variation in Gnomonic projection during (a) solar minimum year 2008, and (b) solar maximum year 2013.

Liu et al. [SGP 2015]

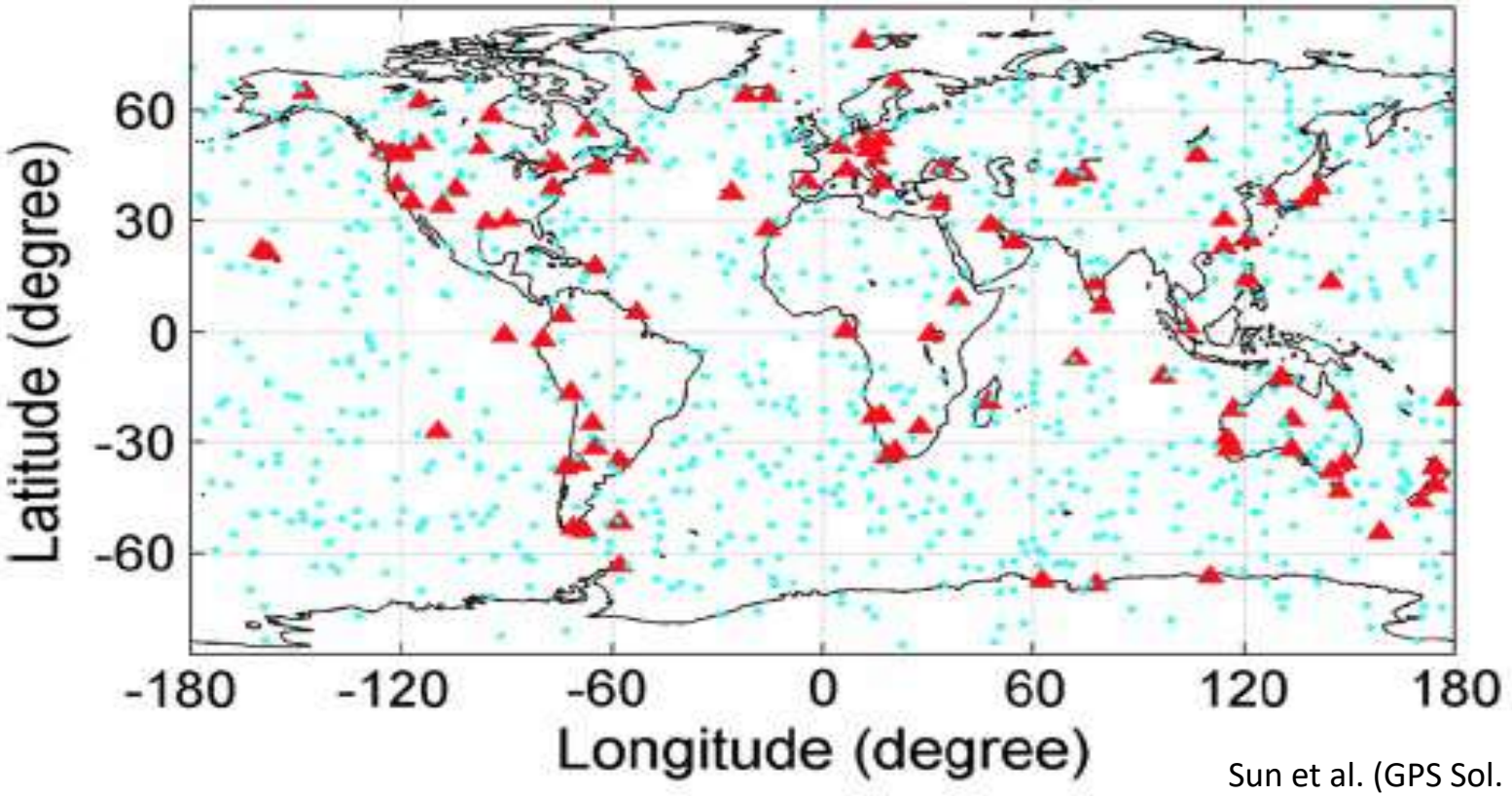
全球GPS電波閃爍指數季節變化



The diurnal mean S4-index geographic distribution in equinoxes (±45 days to March 22th and September 22th) and solstices (±45 days to June 22th and December 22th) during the F3/C operation period 2007-2014.

Liu et al. [SGP 2015]

全球導航衛星系統GNSS與福三電離層共同觀測

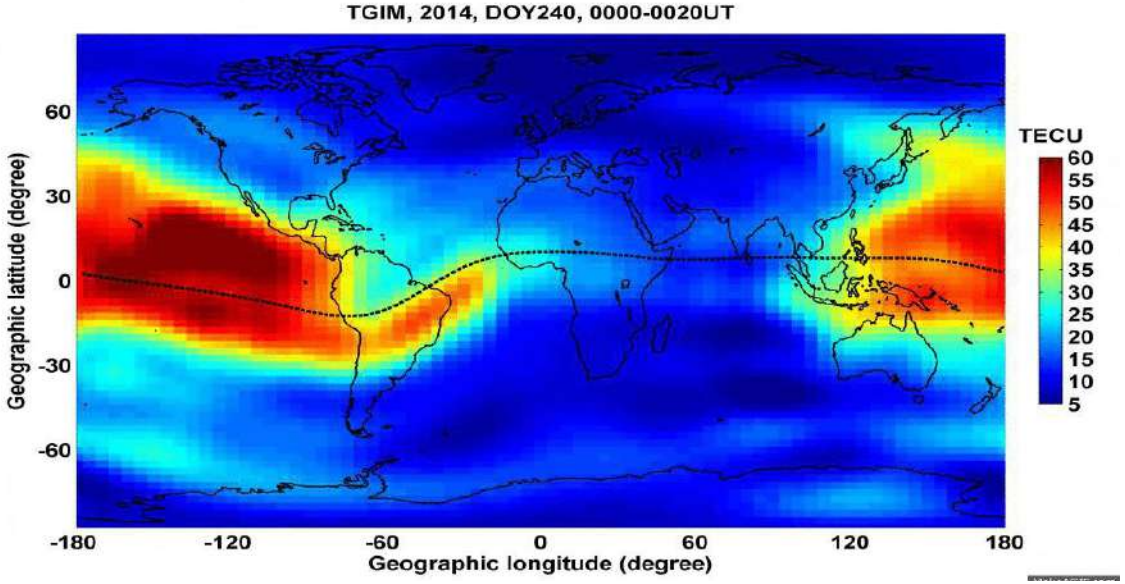


Sun et al. (GPS Sol. 2017)

Fig. 1 Global distributions of ground-based GNSS receivers (*red triangles*) from IGS and 1-day F3/C RO soundings (*cyan dots*) reveal that the GNSS receivers are mainly on continents and the F3/C soundings are distributed nearly uniformly around the globe. The *dots* stand for the distribution of daily F3/C observations, and *red triangles* refer to 123 ground-based GPS/GLONASS receivers

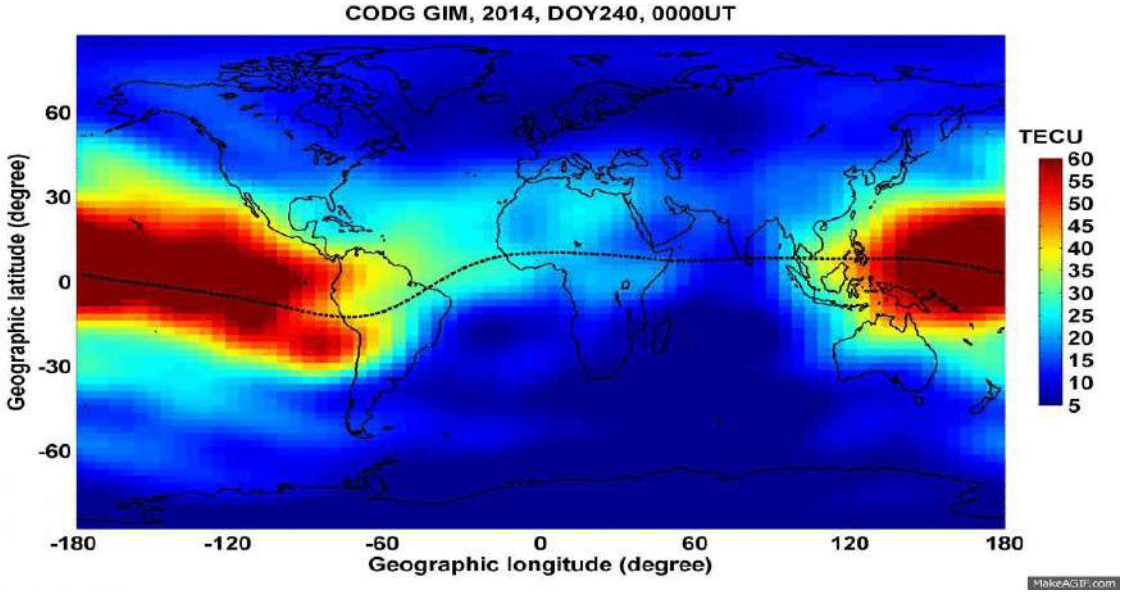
全球電離層圖Taiwan Global Ionosphere Map (TGIM)

（電波傳播與通訊、定位、導航即時校正）



Ground-based GNSS Receivers and FORMOSAT-3/COSMIC RO

4-hour delay, time resolution 10 minute



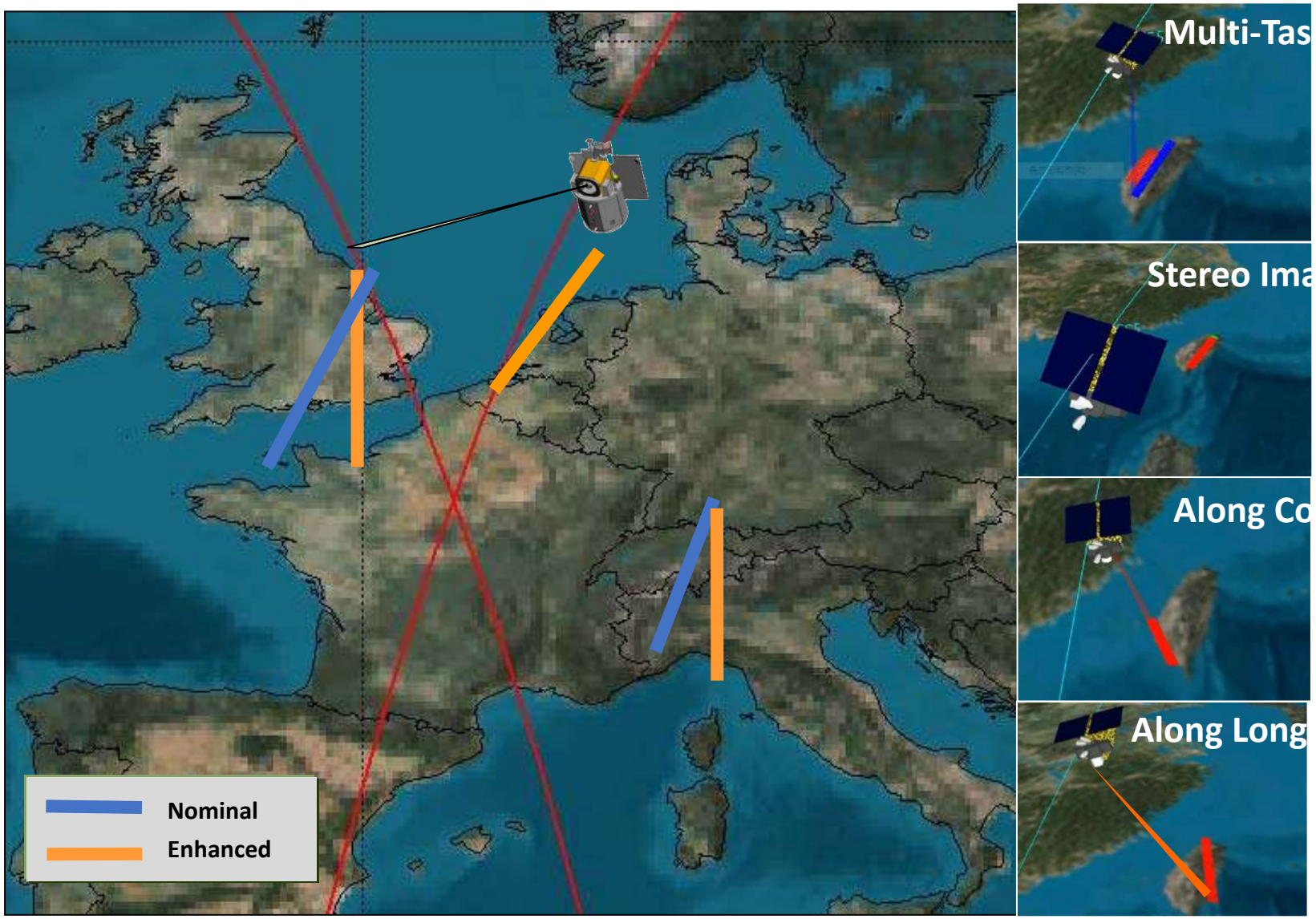
Sun et al. (GPS Sol 2017)

Ground-based GNSS Receivers 1-day delay, time resolution 1-hour

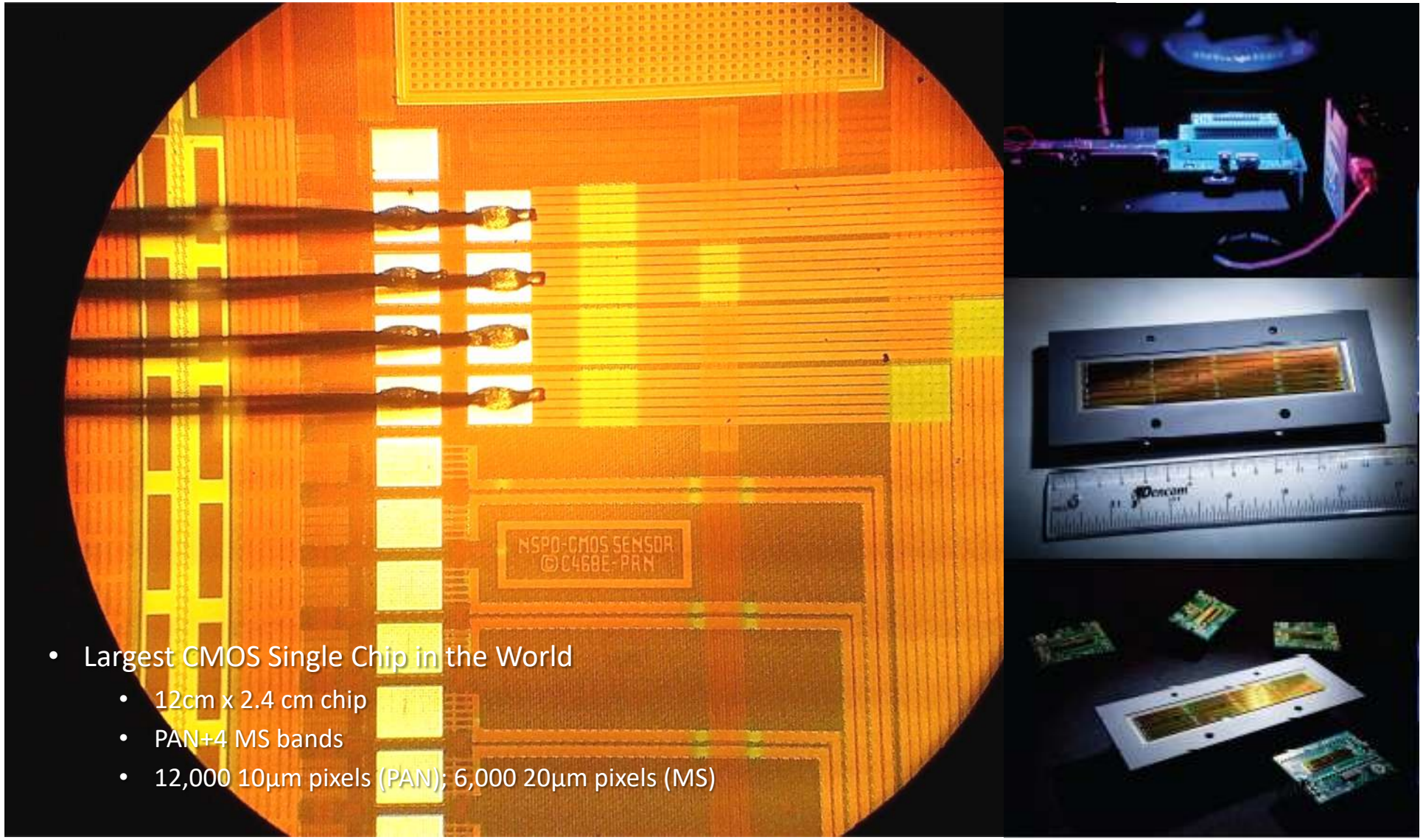
FORMOSAT-5 福衛五號

高度:720km 傾角:98.28° 重量:525 kg 感應器:CMOS 科學酬載:AIP

Smart Agility Capability



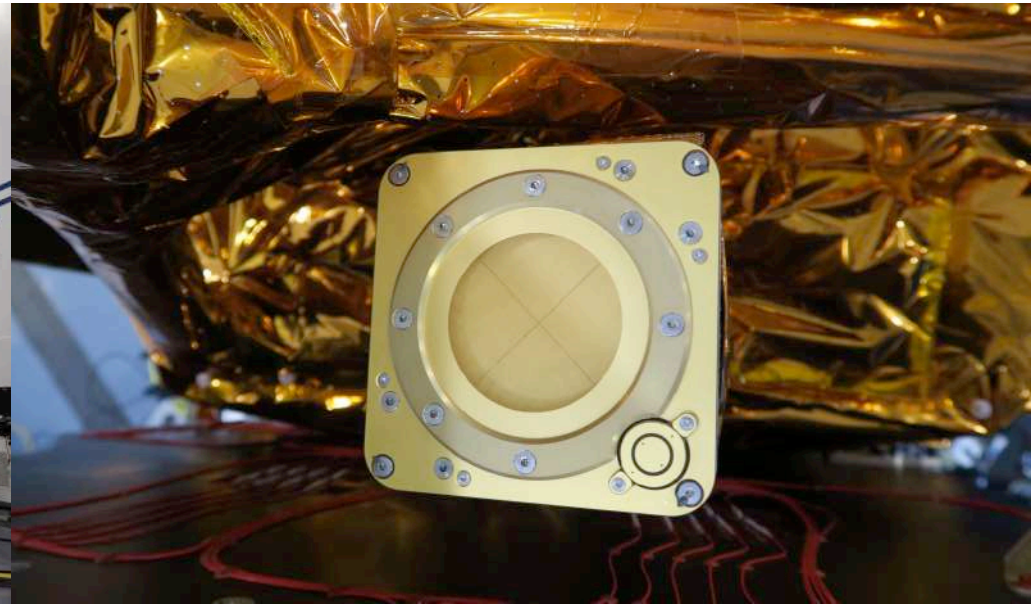
CMOS Image Sensor



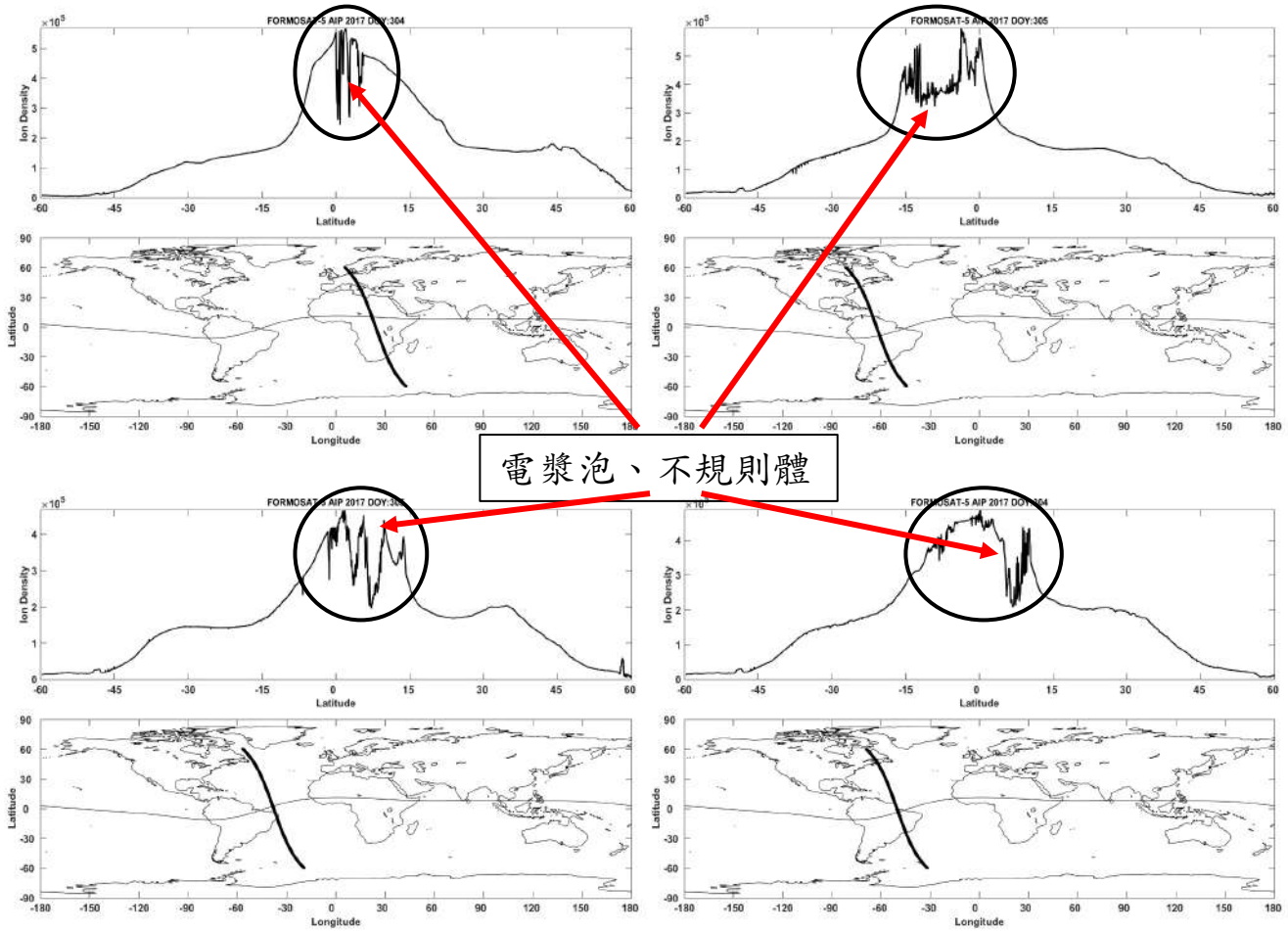
- Largest CMOS Single Chip in the World
  - 12cm x 2.4 cm chip
  - PAN+4 MS bands
  - 12,000 10µm pixels (PAN); 6,000 20µm pixels (MS)

福衛五號：先進電離層探測儀 AIP

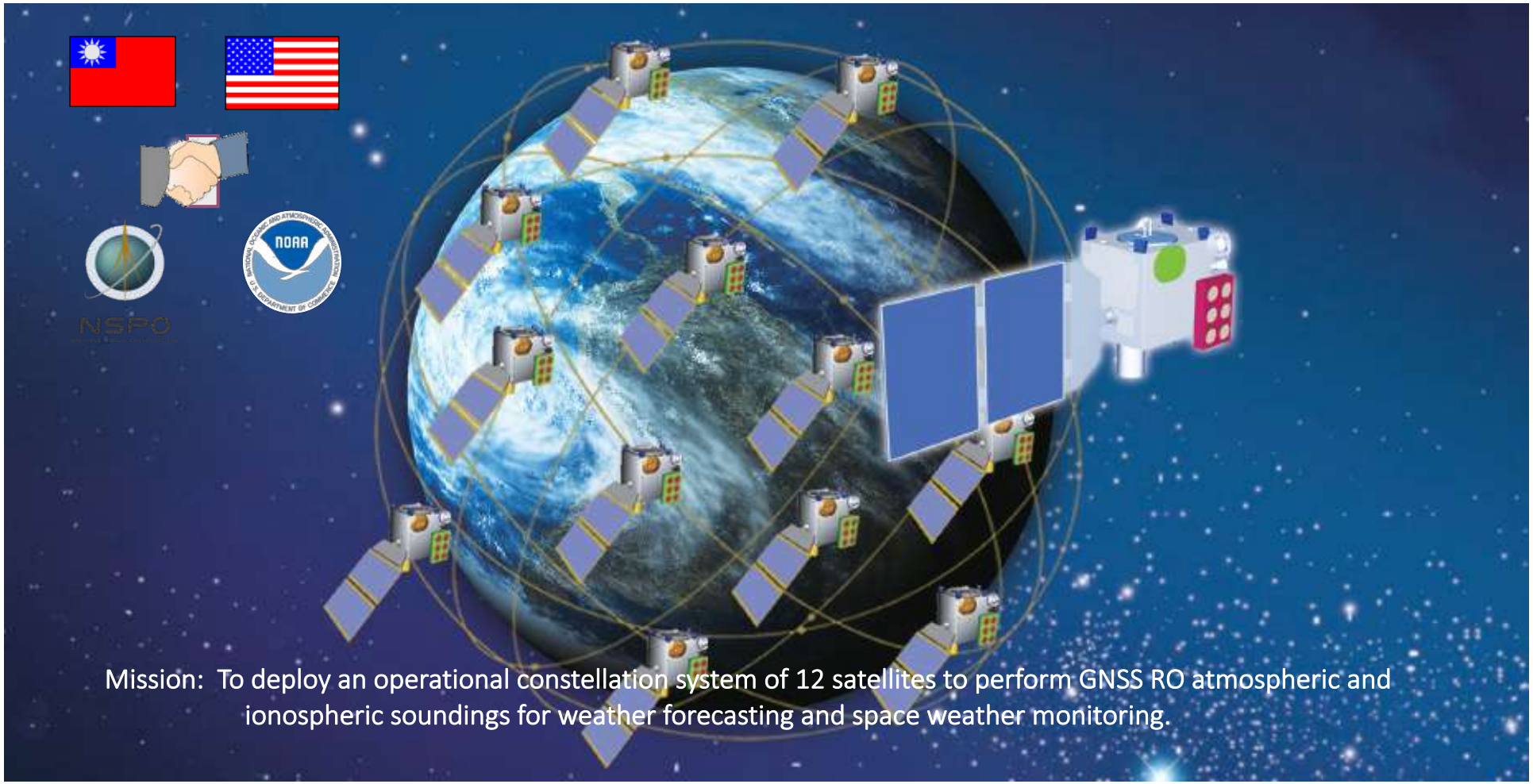
- 台灣第一顆自製人造衛星，任務酬載（光學遙測儀）與科學酬載（先進電離層探測儀）皆為國人自製。



離子濃度不規則體

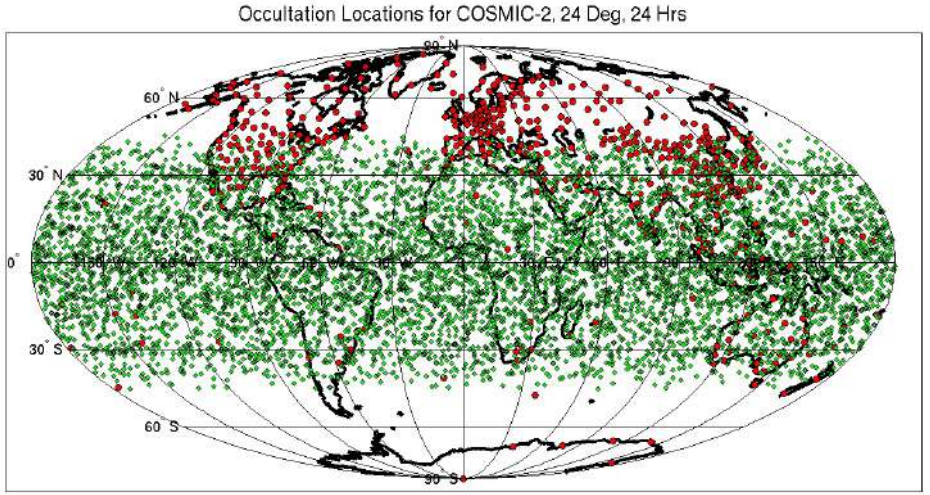


FORMOSAT-7/COSMIC-2 福衛七號



福衛七號 FORMOSAT-7/COSMIC-2

- In 2010, the Taipei Economic and Cultural Representative Office in the United States (TECRO) and the American Institute in Taiwan (AIT) signed an Agreement, the development, launch and operation of FORMOSAT-7/COSMIC-2.
- The FORMOSAT-7 constellation will deploy 6 satellites into the low inclination orbits to provide meteorology data at low and mid latitudes.
- The volume of data generated will be 3~4 times that of FORMOSAT-3/COSMIC, and will greatly increase the amount of atmospheric and ionospheric observation data available at low latitudes.

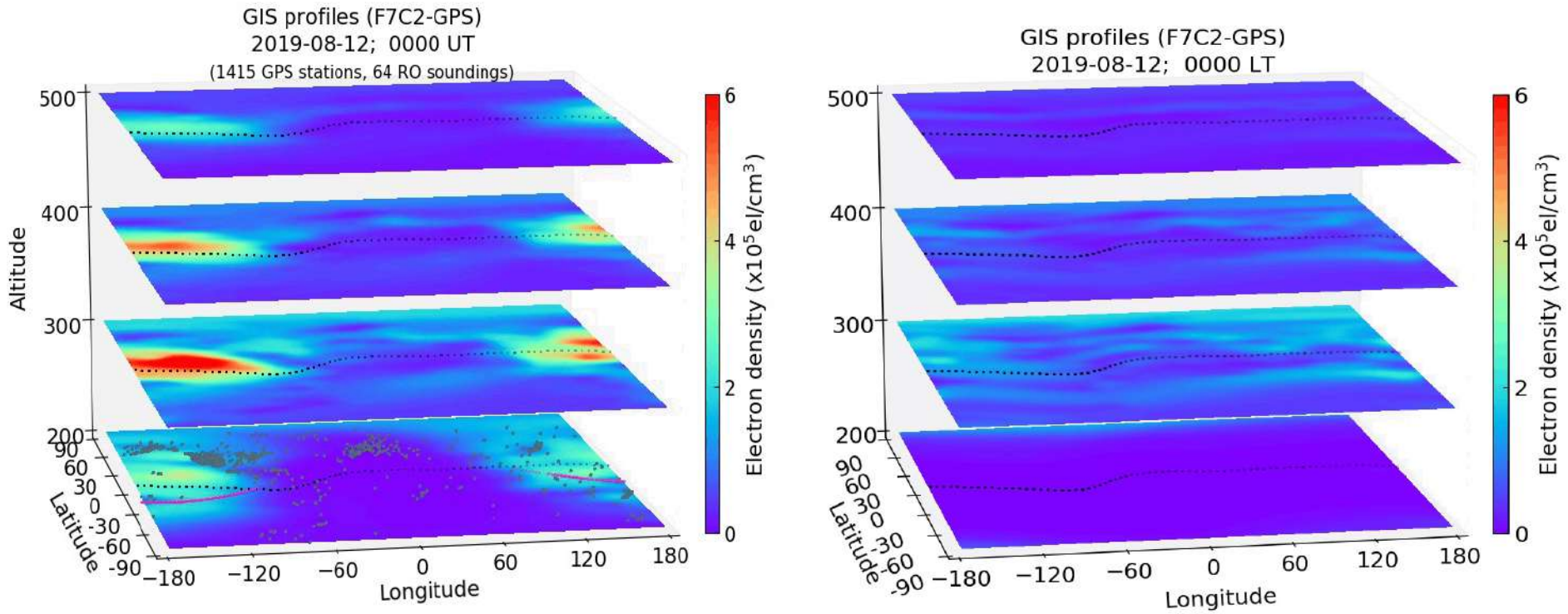


FORMOSAT-7/COSMIC-2

電離層現報模式

Global Ionospheric Specification(GIS)

(電波傳播與通訊、定位、導航即時校正)



國立中央大學

完備的大學級太空中心

太空科學與科技研究中心

CENTER FOR ASTRONAUTICAL PHYSICS AND ENGINEERING

主持人：劉正彥(主任)

共同主持人：趙吉光、陳彥宏、林唐煌、張起維、郭政靈

CAPE 實驗室介紹

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- 太空酬載實驗室(趙吉光老師)
- **衛星原型實驗室(張起維老師)**
- **太空光學實驗室(郭政靈老師)**
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- **太空通訊實驗室(太空科學與科技研究中心)**
- **積光陀螺儀組裝及地震旋轉量監測(太空科學與科技研究中心)**
- **無塵室(太空科學與科技研究中心)**
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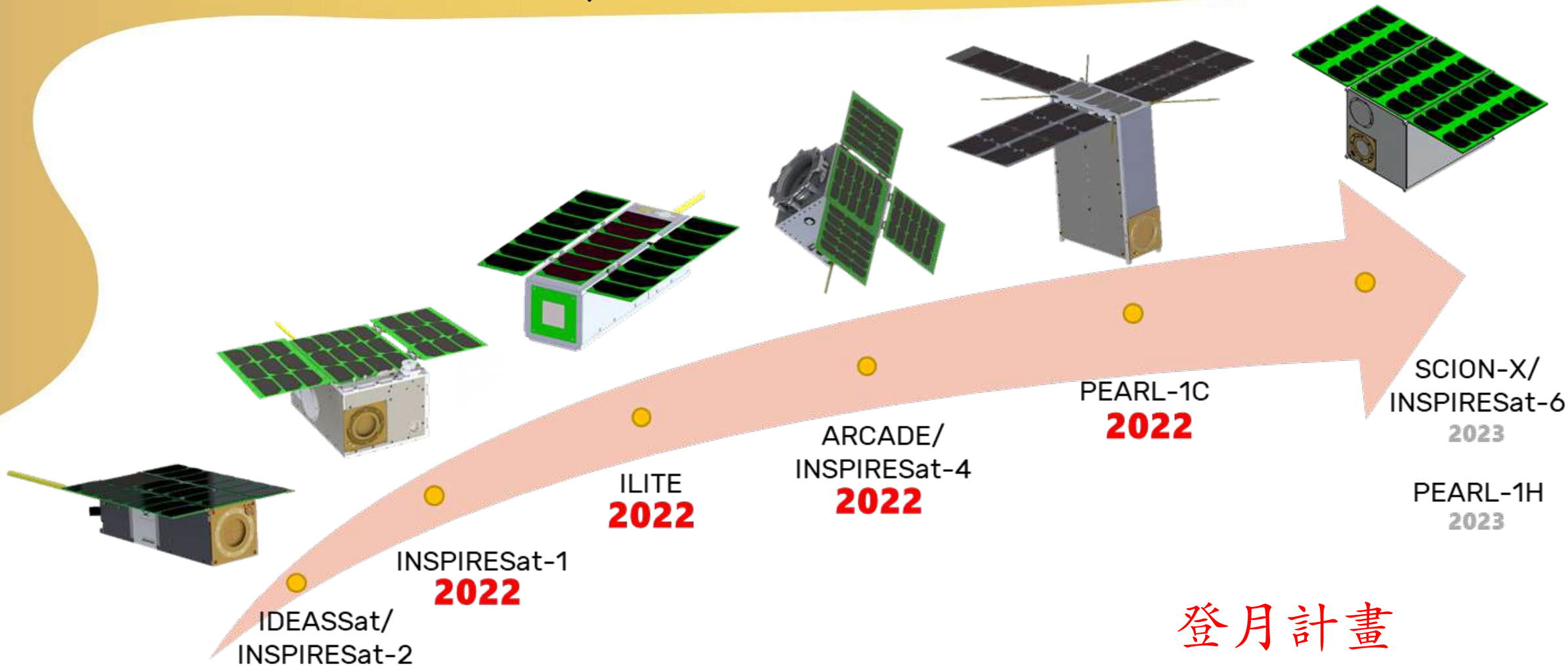
- **機械加工實習教室(太空科學與工程學系)**

CAPE 立方衛星



登月計畫

2023-2024

張起維

國立中央大學

任務作業操作中心

遙傳追蹤與指令站

衛星任務作業中心

結語

- 臺灣NSPO累積有30餘年小型衛星工程經驗。
- 電離層天氣主宰衛星定位、導航、通訊品質與精準，是衛星通訊之重要參考與校正。
- 福衛三、五、七號衛星，令我國電離層天氣監測、現報、預報執世界之牛耳。
- 國立中央大學CAPE承繼50餘年太空科學教學研究基礎，以及30餘年衛星元件與酬載工程經驗，自主建構立方衛星並進行前瞻科學與科技實驗研究。
- CAPE立方衛星可提供最佳低軌道衛星通訊先期實驗環境與機會。

國立中央大學

完備的大學級太空中心

NCU CAPE
國立中央大學 太空科學與科技研究中心
NCU Center for Astronautical Physics & Engineering
Taoyuan, Taiwan

We built satellites

謝謝聆聽！

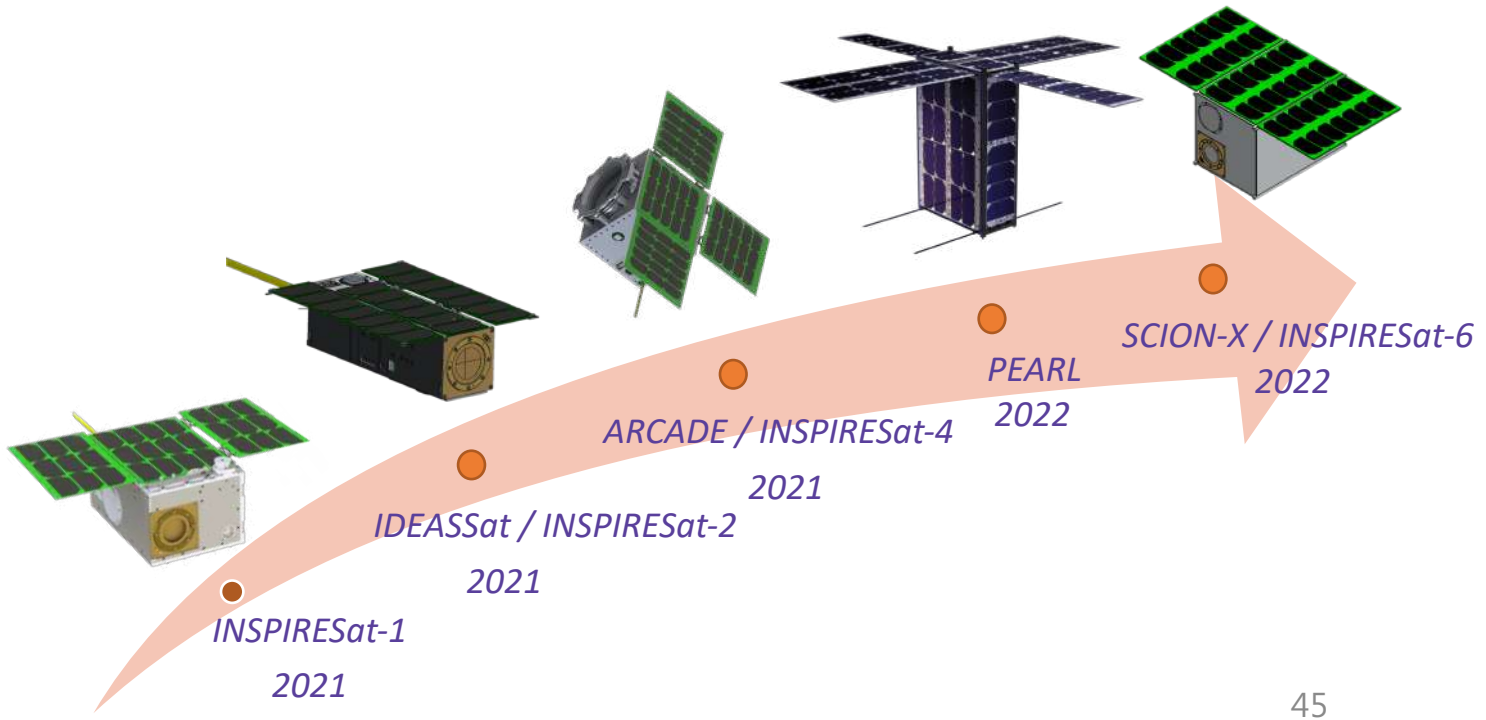
太空科學與科技研究中心

CENTER FOR ASTRONAUTICAL PHYSICS AND ENGINEERING

http://cape.ss.ncu.edu.tw/

劉正彥

趙吉光、陳彥宏、林唐煌、張起維、郭政靈



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