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Space Weather Impact on Satellite Operations

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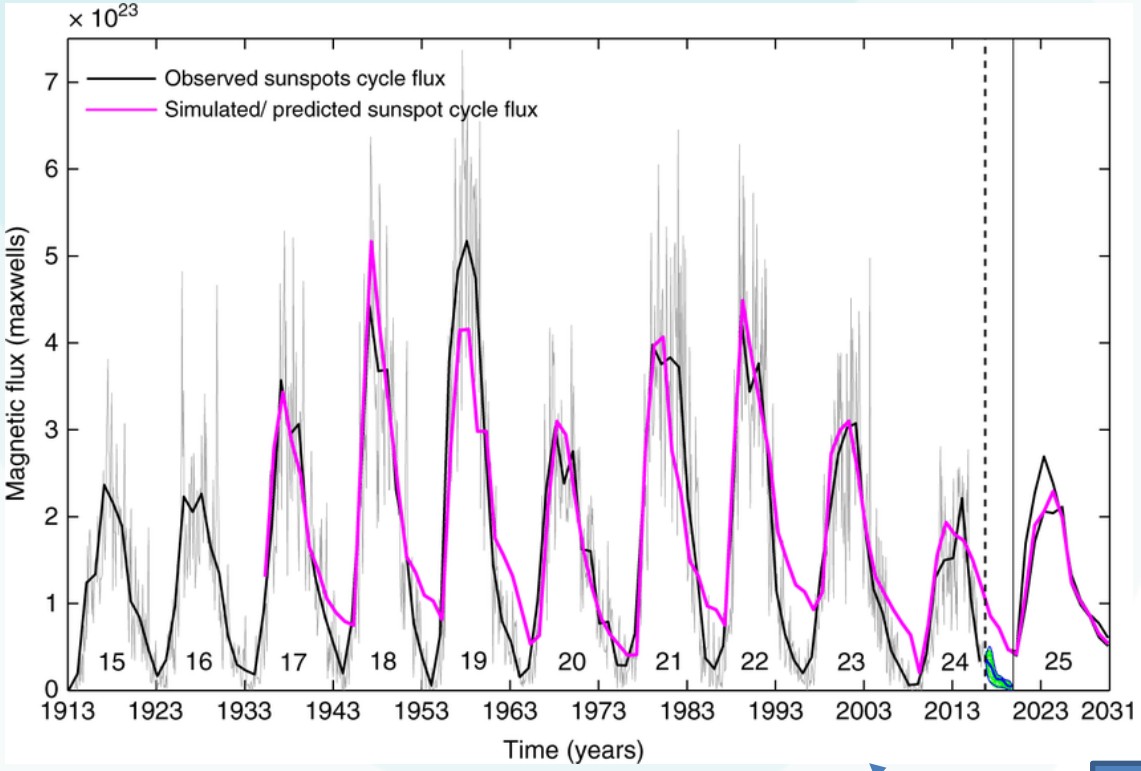
Agenda

- Space weather sources
- Types of damages
- SWPS parameters
- Take home messages

Major Interactions

- Outputs from the Sun
- Propagation of disturbances from the near earth space
- Galactic cosmic rays

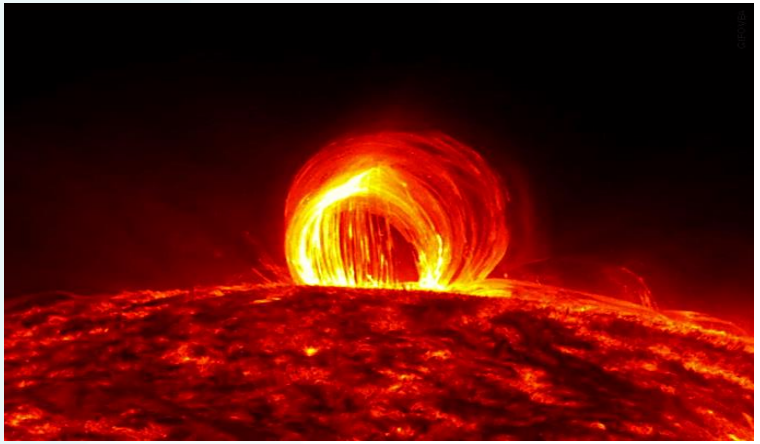
SUN is a magnetic Star.



Cycle number 23
23 October - 6 November 2003
Halloween storm
Total lost of 47 satellites

Solar Wind

CME



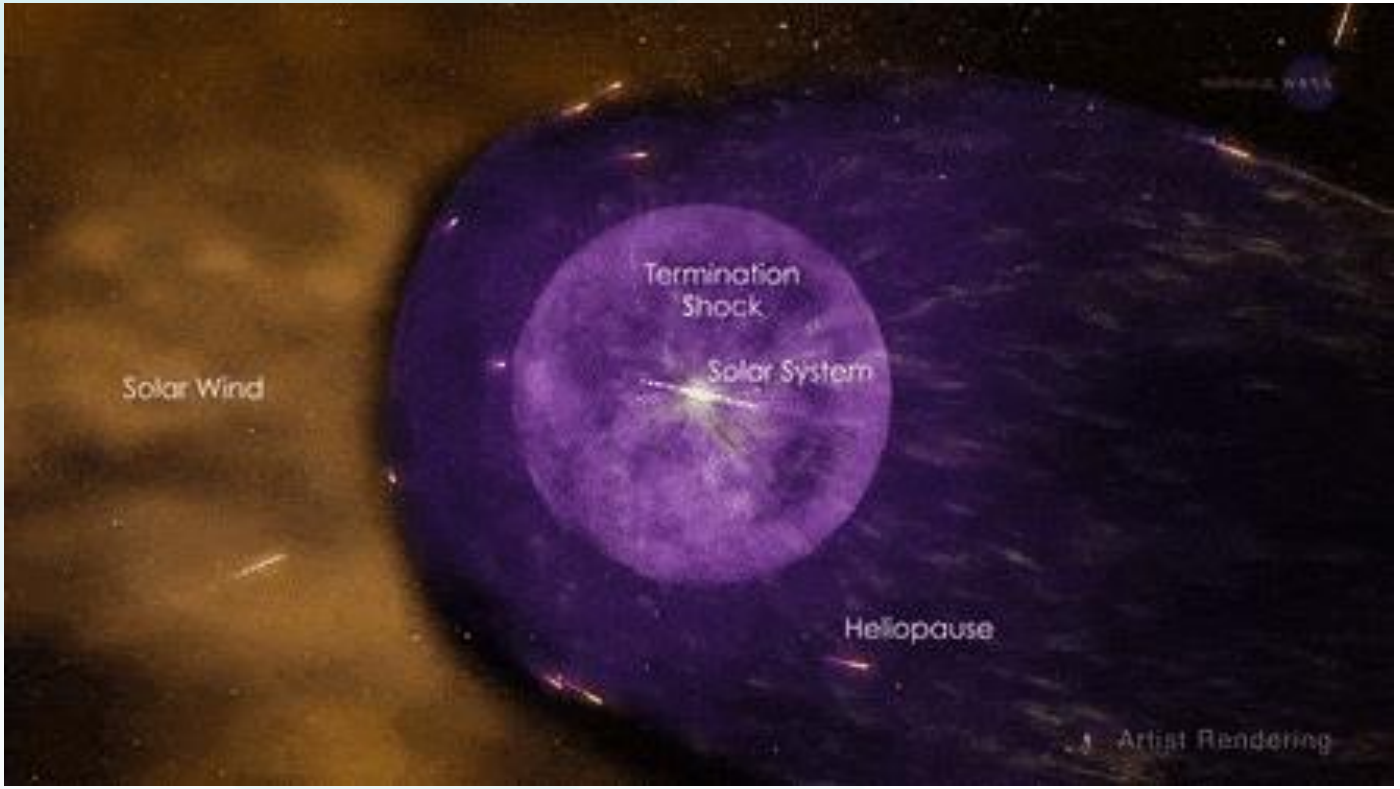
Flares

SpaceX, Starlink Project

- Starlink Megaconstalation Internet project
- 42 000 satellites
- 49 satellites launched by Falcon 9 on 3th of February
- 40 out of 49 satellites fell and burned in atmosphere due to strong geomagnetic storm (Kp Index 5)

A SpaceX Falcon 9 rocket launches 49 Starlink internet satellites into orbit from Pad 39A of NASA's Kennedy Space Center in Cape Canaveral, Florida on Feb. 3, 2022

Galactic Cosmic Ray



Basically consist of :oxygen, helium, hydrogen and Heavy elements such as Fe

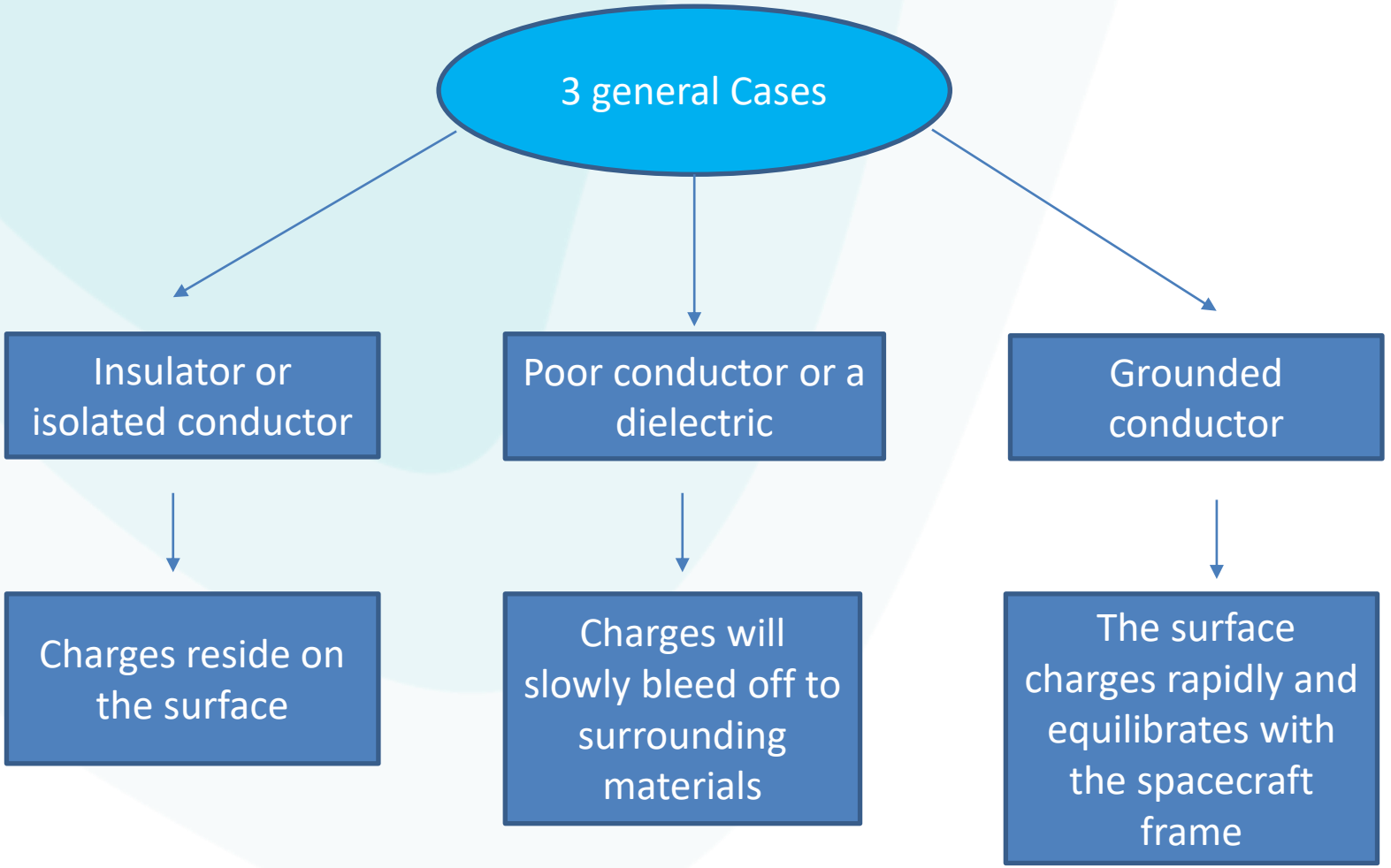
IMPACTS

- Surface Charging
- Internal Charging
- Single Event Upsets
- Total Radiation Dose

Surface Charging

- Electrons and protons collect on the surface
- Charging it up to high differential voltages
- Can lead to a damaging arc or electric discharges
- Can then create an electromagnetic pulse
- Put electronics into unusual state
- Leading cause of spacecraft mission failures

Surface Charging



Internal Charging

- Caused by higher energy electrons
- Can pass right into the satellite
- Internal charge can built to the point of a breakdown and cause a discharge
- make a pulse that couple into the satellite and puts it into some unusual state
- Internal charging shows a peak near noon

Single Event Upsets

- Caused by very energetic ions
- Can pass right through the satellite
- Can cause a latchup or complete device failure
- May be self-correcting

Single Event Latchups

- Latch-up caused by a single event upset
- The free charges created by the ion interact with the parasitic transistors
- Causing a short across the device

Total Radiation Dose

- Total Radiation Dose refers to the slow degradation from the constant radiation dose throughout the mission or from a stepwise increase in that radiation dose.
- Have longer accumulation period than surface charging and SEU
- LEO satellites faces less radiation dose than MEO and GEO satellites

Solutions

- Radiation resistant materials

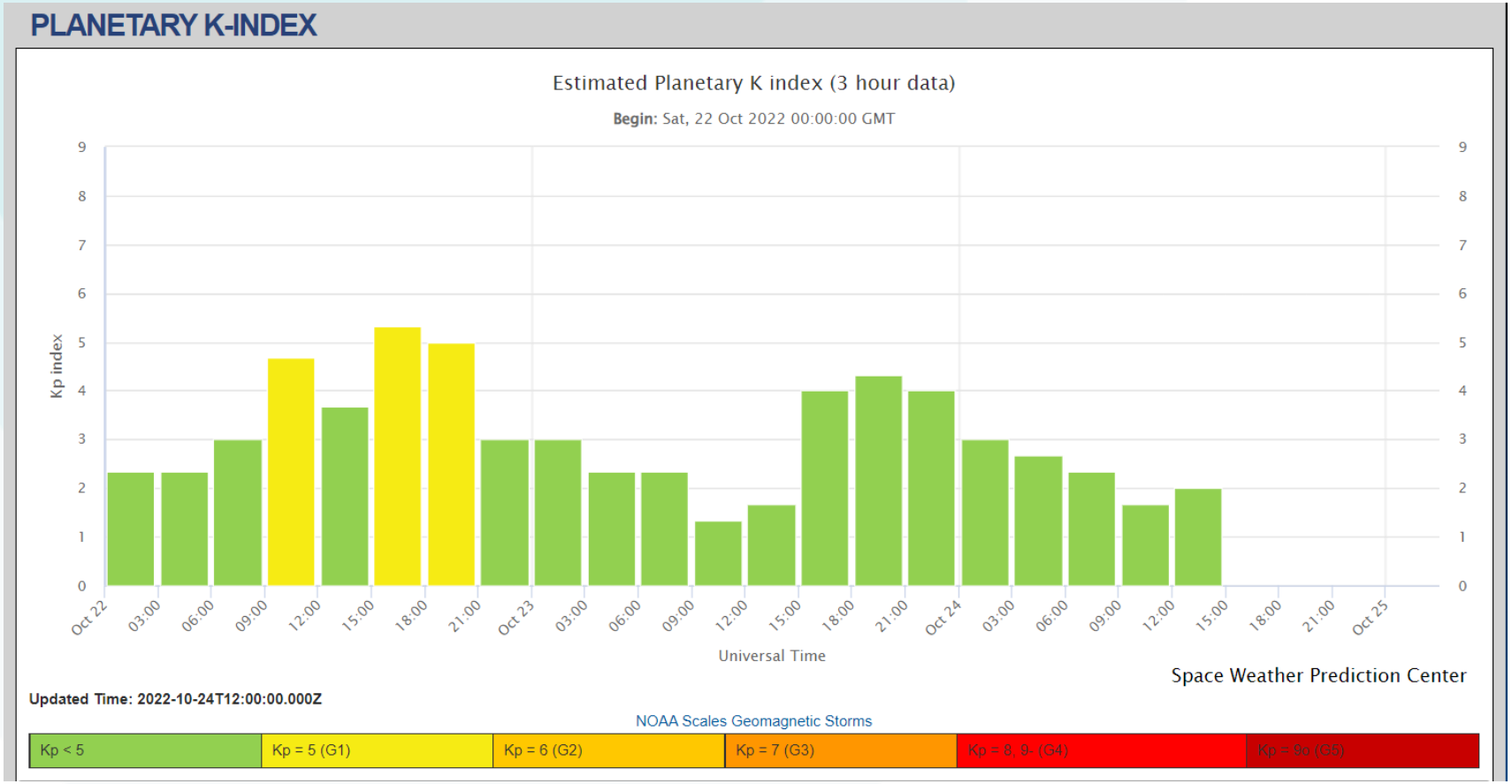
Typical damages and failures on satellites

- Solar Arrays (AF , 6%per year)
- Microwave transmission lost (DMSP)
- RAM hits by SEU (TDRS-A, TDRS-C, TDRS-D, Pioneer Venus)
- Pitch glitches (INTELSAT-6)
- Attitude control loss (Insat 1 B)
- Communication circuit anomaly (GOES-7)
- Permanent loss on half of dual redundant command circuit (Japanese CS-3B)
- Severe scintillation, data transmission lost (Japanese GMS-3)
- Orbital attitude anomalies
- Switching events (Maracs-1)
- GPS radio signal lost

Satellite Operations and SWPC

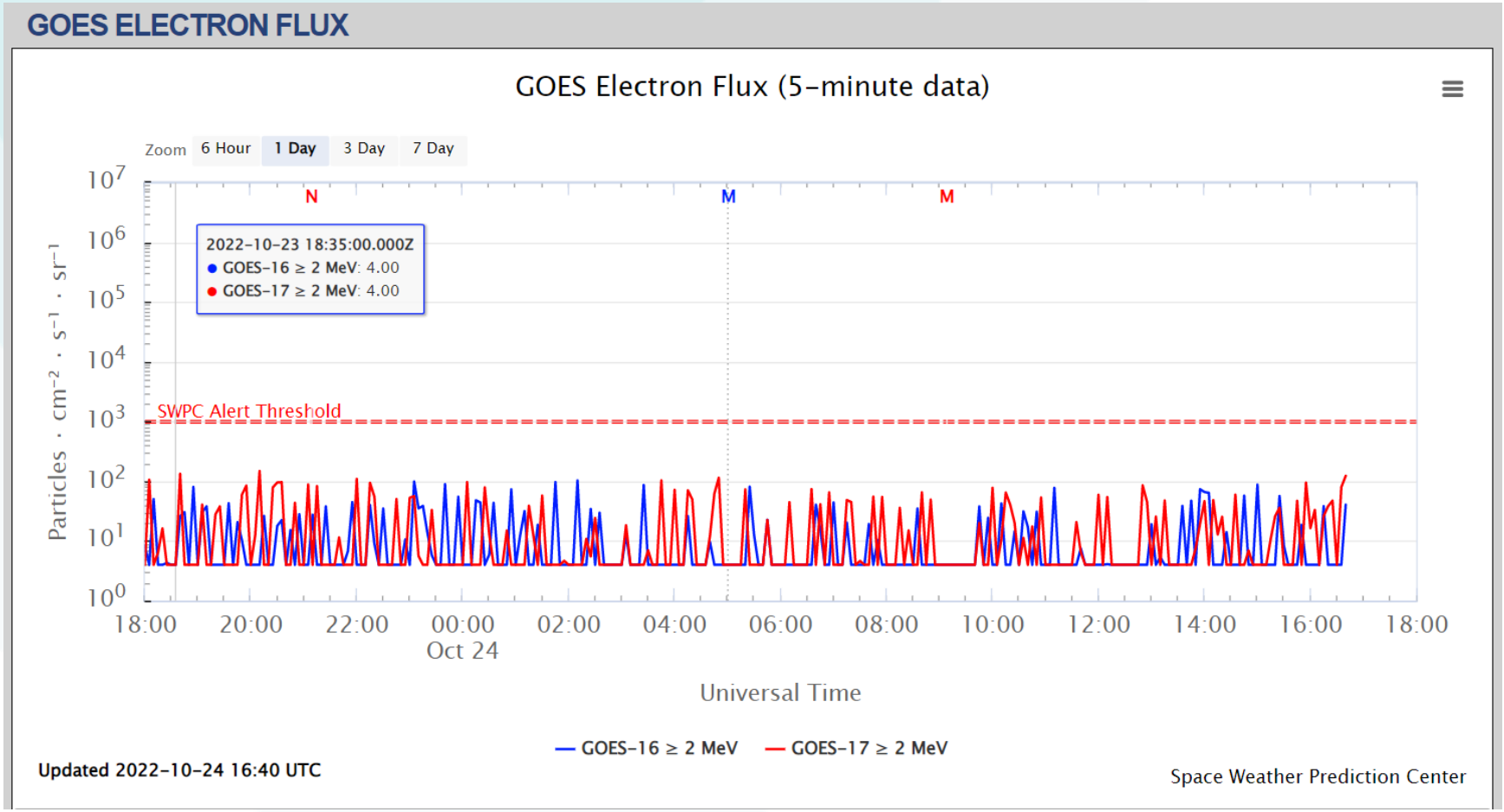
- Goals
  - maintain the safeness of the satellite
  - avoid critical hazardous space conditions
  - keep the communication uninterrupted
- SWPC parameters
  - KP index
  - Electron flux
  - Proton flux
  - X-ray Flux

Kp Index

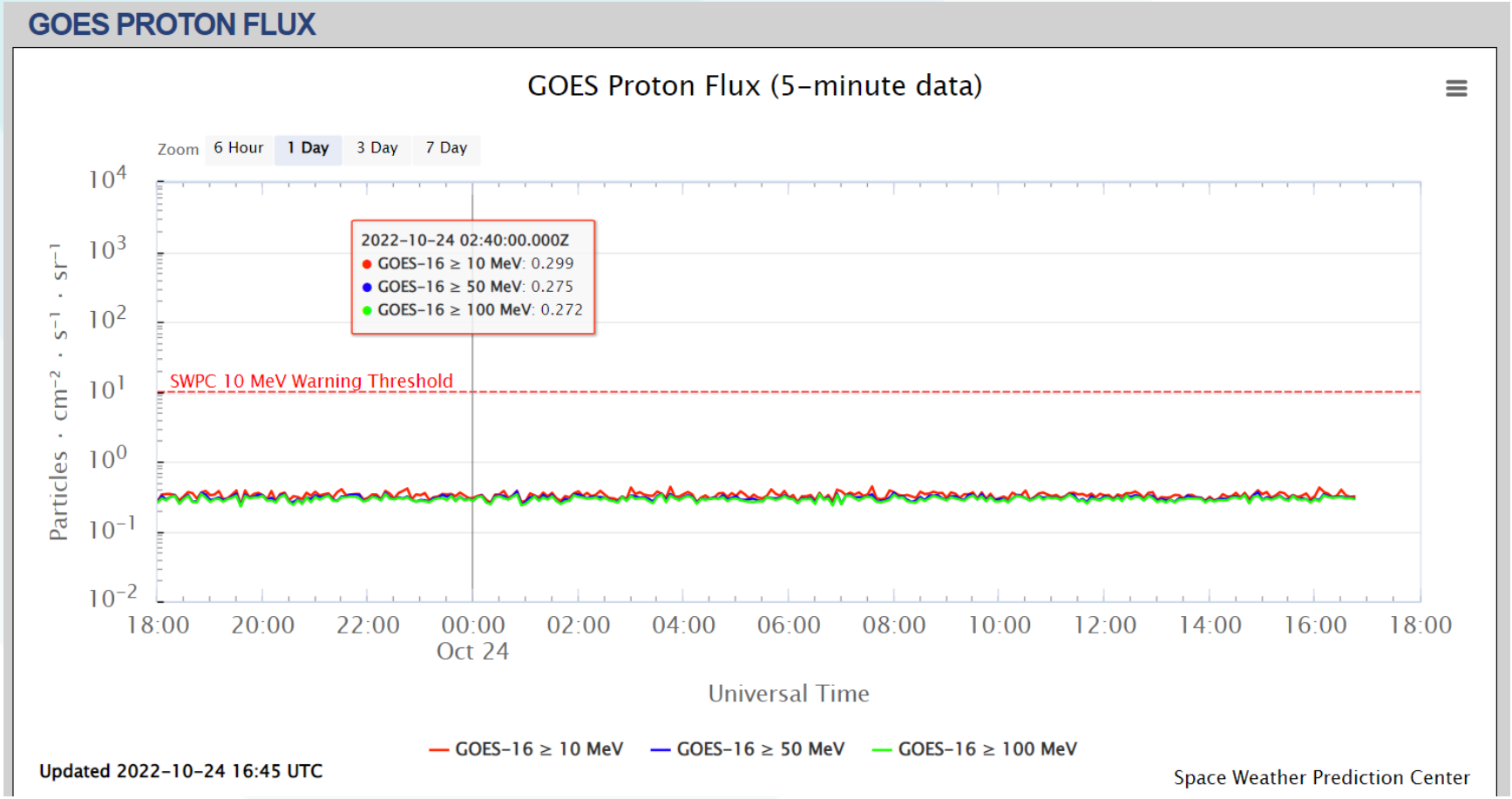


13 ground-based magnetometers in: Sitka, Alaska; Meanook, Canada; Ottawa, Canada; Fredericksburg, Virginia; Hartland, UK; Wingst, Germany; Niemegk, Germany; and Canberra, Australia.

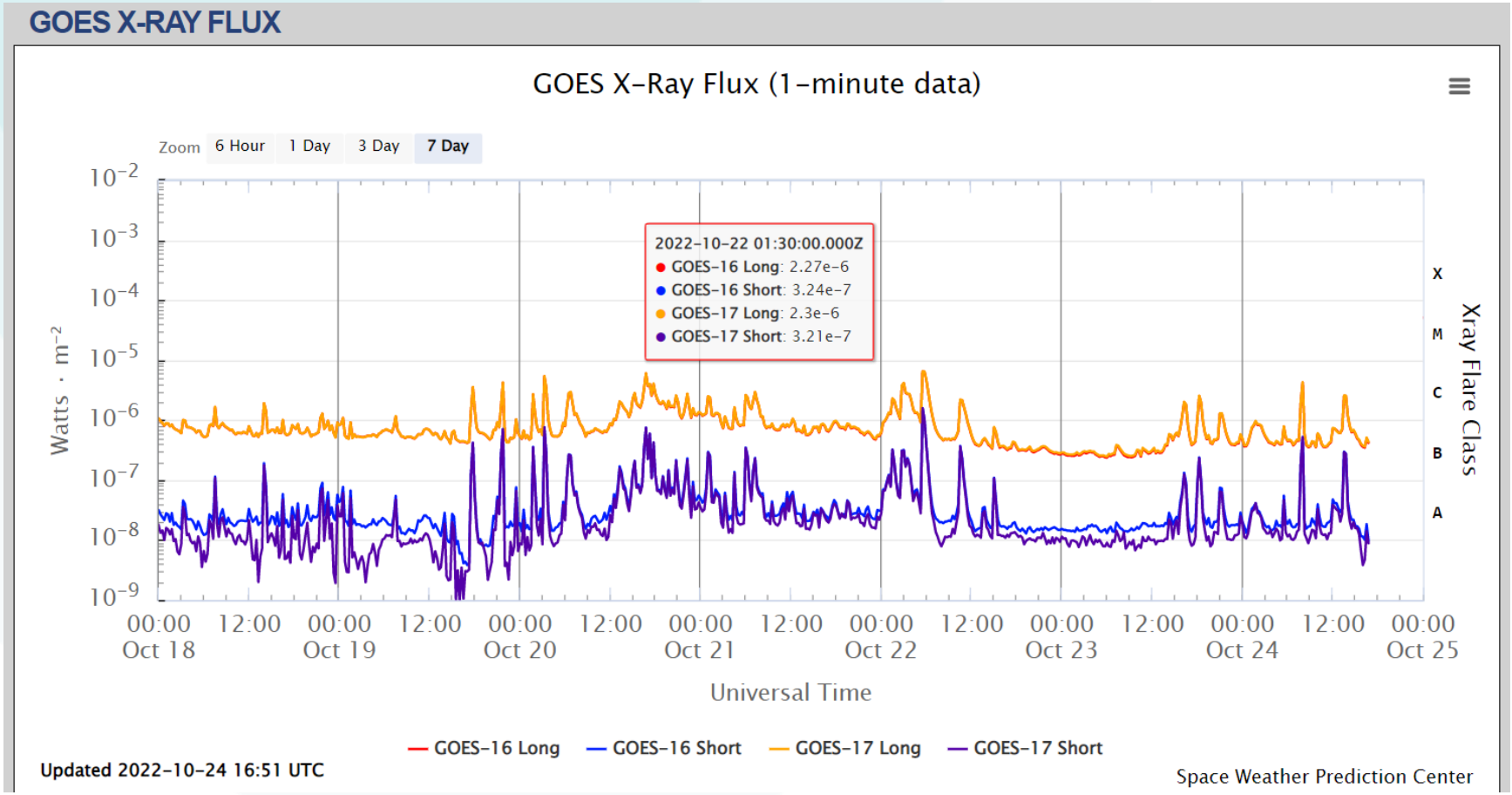
Electron flux



Photon Flux


GOES PROTON FLUX
GOES Proton Flux (5-minute data)
Zoom 6 Hour 1 Day 3 Day 7 Day
2022-10-24 02:40:00.000Z
GOES-16 ≥ 10 MeV: 0.299
GOES-16 ≥ 50 MeV: 0.275
GOES-16 ≥ 100 MeV: 0.272
SWPC 10 MeV Warning Threshold
Particles · cm⁻² · s⁻¹ · sr⁻¹
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁻²
18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00
Oct 24
Universal Time
GOES-16 ≥ 10 MeV
GOES-16 ≥ 50 MeV
GOES-16 ≥ 100 MeV
Updated 2022-10-24 16:45 UTC
Space Weather Prediction Center

X-ray


GOES X-RAY FLUX
GOES X-Ray Flux (1-minute data)
Zoom 6 Hour 1 Day 3 Day 7 Day
2022-10-22 01:30:00.000Z
GOES-16 Long: 2.27e-6
GOES-16 Short: 3.24e-7
GOES-17 Long: 2.3e-6
GOES-17 Short: 3.21e-7
Watts · m⁻²
Xray Flare Class
X
M
C
B
A
00:00 Oct 18
12:00
00:00 Oct 19
12:00
00:00 Oct 20
12:00
00:00 Oct 21
12:00
00:00 Oct 22
12:00
00:00 Oct 23
12:00
00:00 Oct 24
12:00
00:00 Oct 25
Universal Time
GOES-16 Long
GOES-16 Short
GOES-17 Long
GOES-17 Short
Updated 2022-10-24 16:51 UTC
Space Weather Prediction Center

Conclusion , take home messages

- Once your satellite in orbit there is not much you can do to prevent anomalies
- Space Weather is jus one of the various reasons of satellite anomalies
- While better design can help protect satellites, reliable space weather services provides:
  - help identify the cause of an anomaly
  - provides situation awareness that can be used to raise the alertness level of operators on the ground
  - enables satellite operators to take action to mitigate the risk of service interruptions

Thank you for attention

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