



ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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ICAO SPACE WEATHER WORKSHOP

*ICAO Eastern and Southern African & ICAO
Western and Central African Offices*

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Space weather phenomena and their CNS/MET impacts

- Space weather phenomena and their CNS impacts
- Space weather phenomena and their MET impacts
- Q & A

Impact of Space Weather on CNS infrastructures

Space weather refers to natural perturbations coming from the sun or from space that can influence the performance and reliability of space-borne, ground-based or airborne systems and can endanger human life or health.

When a **space weather event occurs**, a **wide range of effects can result**. **Figure 1** presents the **probability of occurrence depending on the magnitude of the event**. Events have been separated into three different categories:

- **“Usual bad space weather”**: SWX events with the impact on earth infrastructures is very low
- **“Severe to Extreme event”**: SWX events occurring between one and five times per 11-year solar cycle with possible significant impact on infrastructure.
- **“Super-Extreme event”**: These events are very rare and may happen only once every 100 to 500 years. One such event was recorded in 1859.
- **Impacts of the “Severe to Extreme events” and “Super Extreme events” on CNS systems** are summarized in Slides 7 & 8

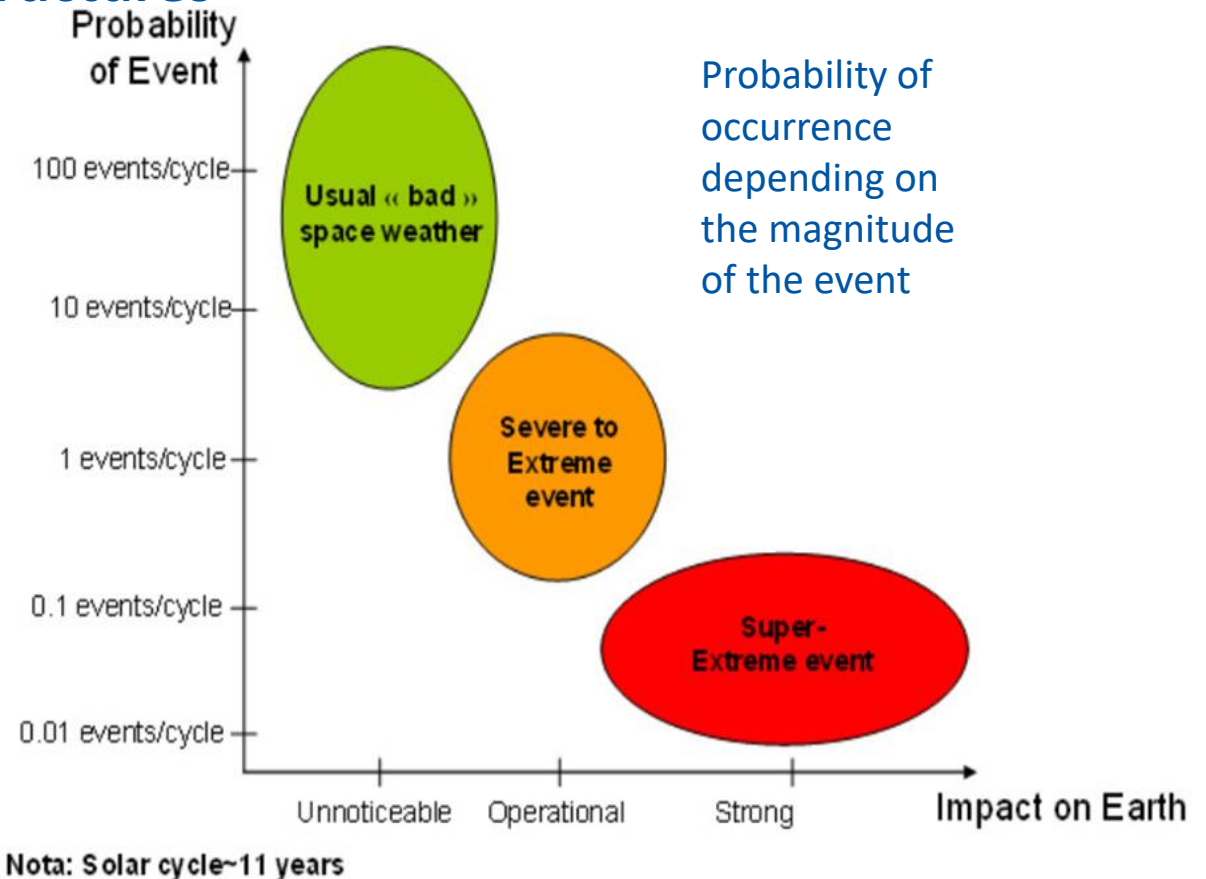
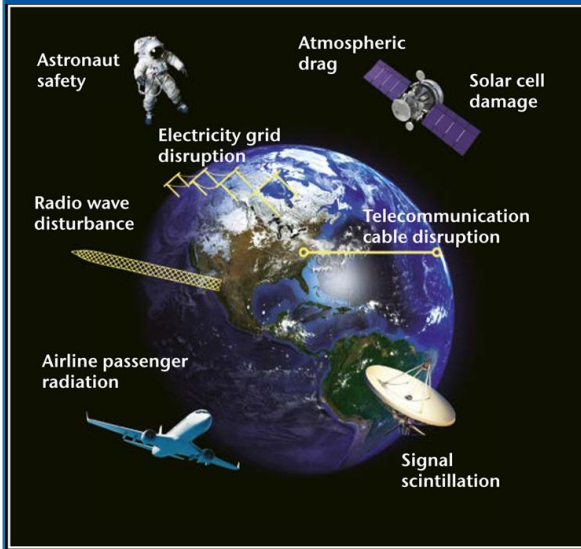


Figure 1: Probability of space weather events versus impact on Earth

Source: Impact of Space Weather on Aviation | SKYbrary Aviation Safety

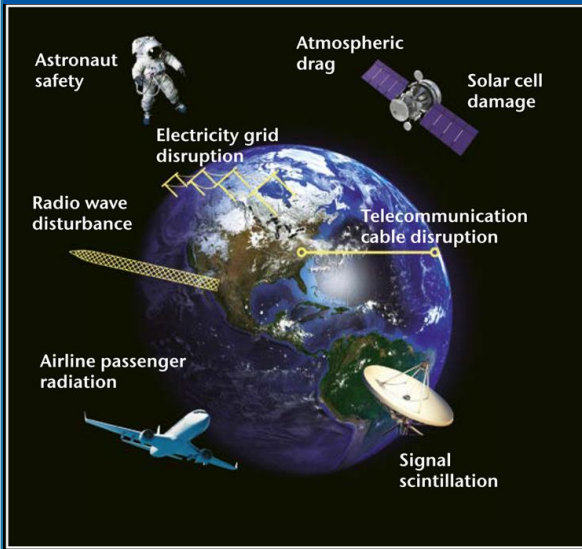
<https://www.skybrary.aero/articles/impact-space-weather-aviation>

Space Weather Phenomena and their CNS Impacts (1/2)



Category of SWX Events	Degradation of radio/satellite communication	Satellite failure	GNSS-based navigation	Surveillance Applications:	Power failure	Passengers and crew
Severe to extreme space weather event	During solar events, some disturbance may happen on HF and satellite communications , which would have side effects on CPDLC, ADS-C, ...	Potential loss of one or more satellites. Depending on which satellites are lost, the impact may vary significantly. Ex.: The March 1989 space weather event may have caused the loss of four US Navy satellites.	The GNSS radio signals , under severe disturbance, are strongly affected. As a result, unexpected position and timing errors can occur at the level of the user receiver. En-route GNSS-based navigation might be lost in a contained area for a limited duration. GNSS-based landing systems (SBAS, GBAS) may be unavailable for tens of hours. Ex.: In October 2003 the US SBAS system was unavailable for 9 and 15 hours.	GNSS receiver can lose reception of the satellite altogether and the position can no longer be computed. As a side-effect, GNSS-based surveillance applications may be degraded.	Potential power failure over part of a country for tens of hours. Ex.: At 2.45 a.m. on 13 March 1989 the entire Quebec power grid collapsed, and 6 million people suffered a power black-out for 9 hours.	Increase in the radiation level: Passenger and crew flying at high altitude and latitude may be exposed to a higher radiation level than usual. Increased level of radiation might also lead to onboard system failure.

Space Weather Phenomena and their CNS Impacts (2/2)

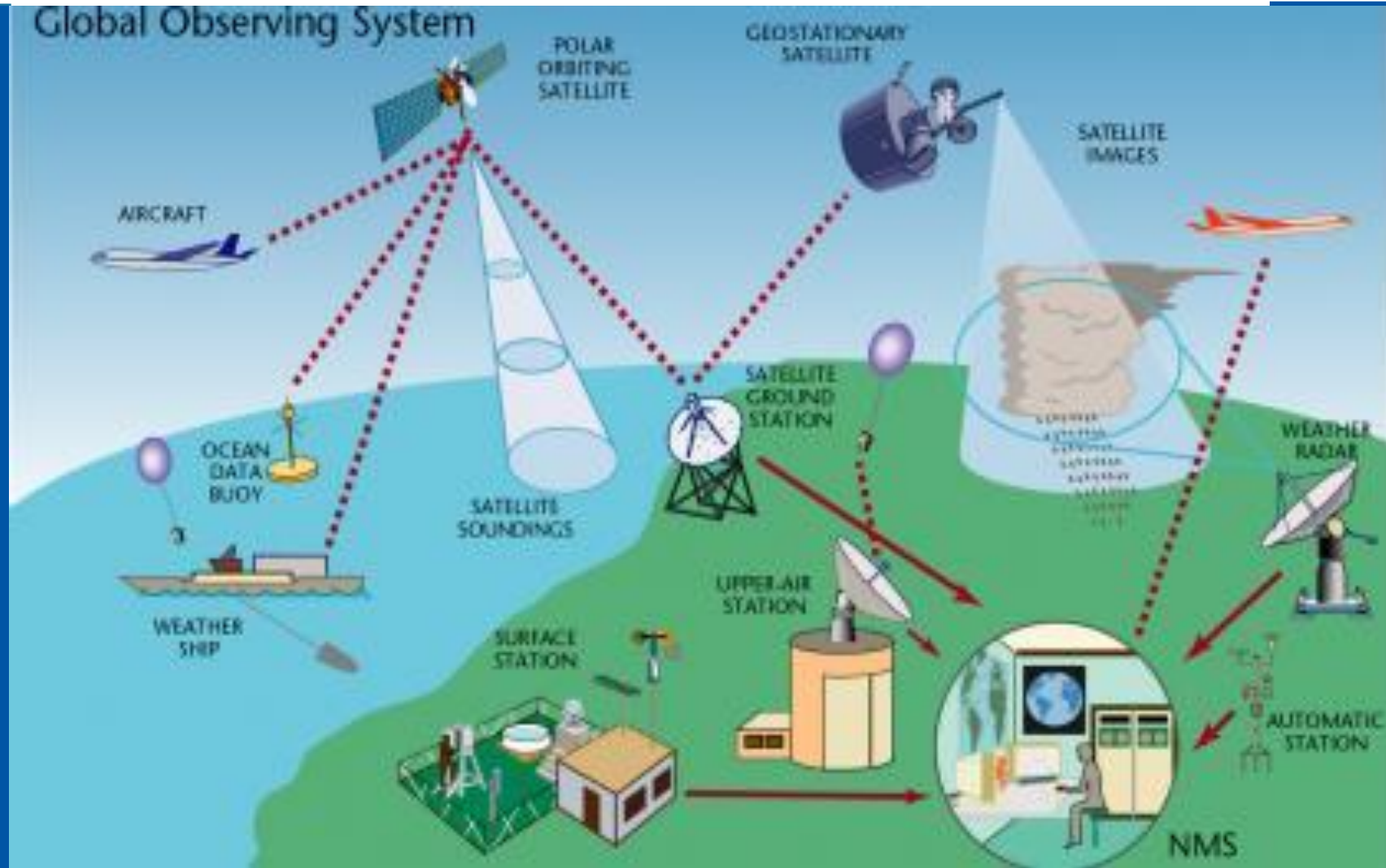


Category of SWX Events	Degradation of radio/satellite communication	Satellite failure	GNSS-based navigation	Surveillance:	Power failure	Passengers and crew
Super-extreme space weather event	During solar events, some disturbance may happen on HF and satellite communications , which would have side effects on CPDLC, ADS-C, AOC	From experts' assessment, up to 50% of the space vehicles may be lost. Depending on which space vehicles are lost, impact can vary significantly.	Space vehicle failure combined with ionosphere storms may lead to a partial or complete loss of GNSS services.	GNSS-based surveillance applications may be unavailable.	Simulations on the US power grid estimated that 50% of the US may be under a power black-out. Similar results may happen over Europe. The recovery time may vary between dozens of hours to months , depending on the system failure.	Increase in the radiation level: Passenger and crew flying at high altitude and latitude may be exposed to a higher than usual radiation level. Increased level of radiation may also lead to onboard system failure.

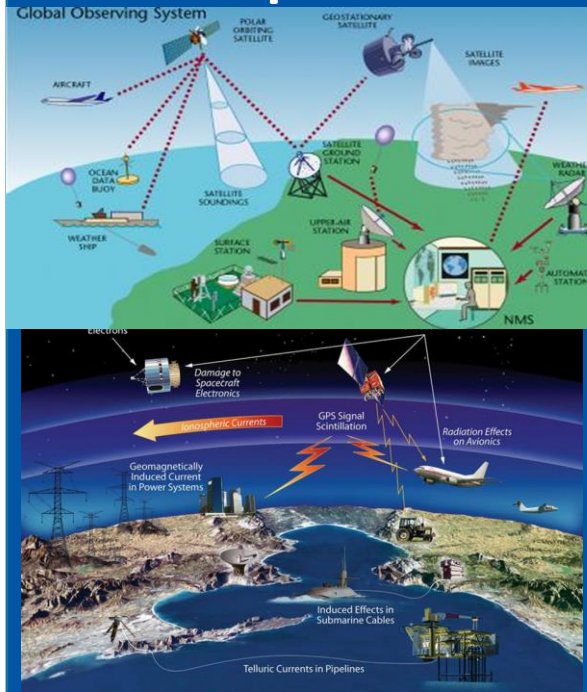
SWX & their MET Impacts

Global Observing System GOS

Offering operationally reliable, **surface-based & space-based subsystems** with observing facilities **on land, at sea, in the air** and in **outer space** in support of the World Weather Watch and climate applications.



Space weather phenomena and their MET impacts



Impact of SWX on meteorological infrastructure

- In June 2008, the WMO Executive Council (EC-LX) noted the considerable impact of Space Weather on meteorological infrastructure and important human activities.
- The study conducted by **Kaori Sakaguchi, Tsutomu Nagatsuma, April 2022** on the *Impact of Space Environment on Geostationary Meteorological Satellite Data Outage* provides an overview on the effects of SWX events on MET systems.
- Based on the results obtained, space weather effects on space systems can be ordered in number of classes, including:
 - **Radiation damage to spacecraft electronics** and other materials from radiation belt and solar energetic particles;
 - **Interference to spacecraft imaging and sensing systems** by particles passing through the detectors and causing noise;
 - **Electrostatic charging from hot plasma and energetic electrons.**

Figure 2 provides statistics of spacecraft anomalies on MET-7 and MET-8 operated by EUMETSAT : <https://uns.eumetsat.int> imagery observations that occurred in 2015–2017.

During three years from 2015 to 2017, Meteosat (MET-7 and MET-8) were operated at a longitude of 41.5° east as a part of the Indian Ocean Data Coverage Service (IODC).

A total of 190 service alert events were caused by anomalies on MET-7 and MET-8.

- 92 cases (320 hr) of “ground segment anomaly”:
- 84 cases (283 hr) of “spacecraft anomaly”
- 2 cases (2.5 hr) of “instrument anomaly”; and
- 12 cases (7.5 hr) of “other” reasons.

Consequences :

- The meteorological imagery service in 2015–2017 were affected by these anomalies for 613 hr in total.
- Impacts on user service by spacecraft anomalies were “data-degraded” (67 cases, 80%), “data-unavailable” (10 cases, 12%), and “data-interrupted” (7 cases, 8%).

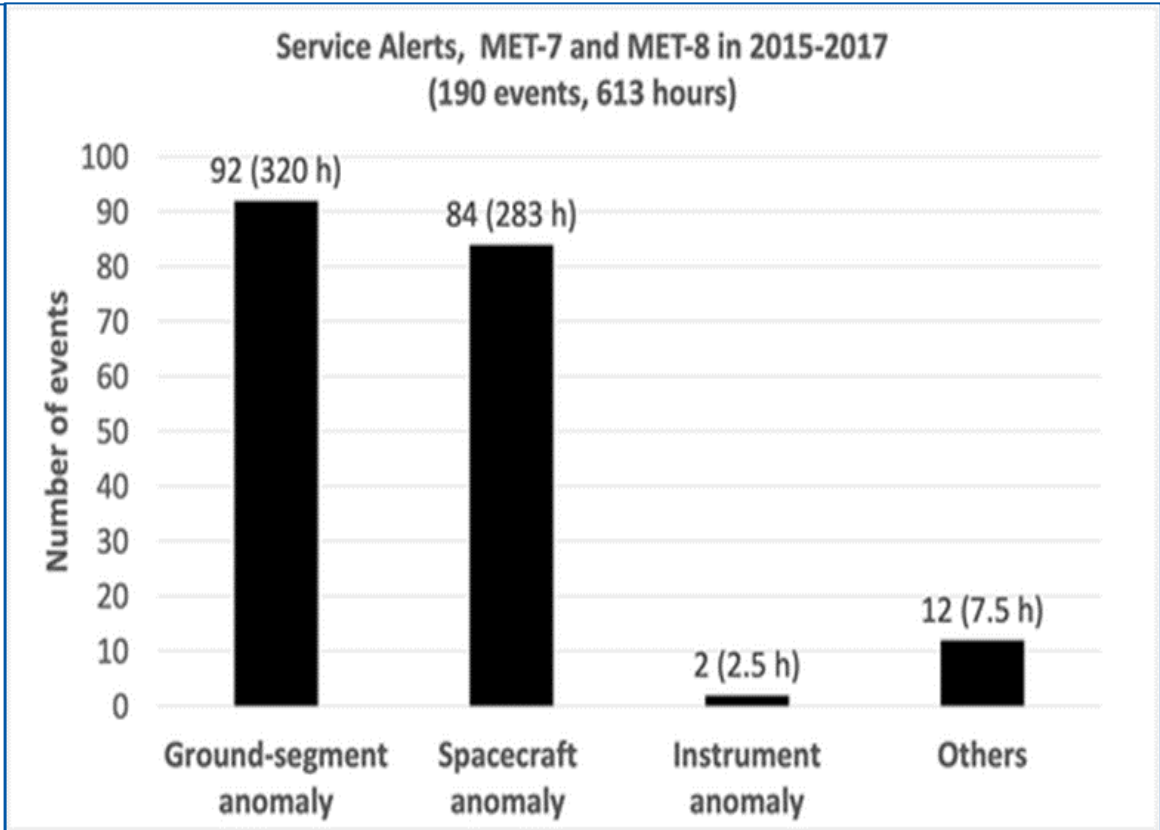


Figure 2 : Number of service alerts of MET-7 and MET-8 imagery observations that occurred in 2015–2017.

Among the 84 service alerts due to satellite anomalies, 79 cases occurred on MET-7 and five cases occurred on MET-8.

Conclusion

Space weather referring as to natural perturbations coming from the sun or from space that can influence in **different ways** the CNS infrastructures/systems and meteorological ground-based and air-based observing systems, affecting :

- The **performance of CNS systems**; and
- The **quality and reliability of meteorological data/information**.



Thank You!