EACCC23 Exercise Scenario

First draft

Introduction

This document contains the EACCC23 exercise scenario. It is not in its final state but it is sufficiently mature to be used to consider the list of questions at the end of the document.

The objective of the exercise is:

1. To determine the level of understanding with regard to space weather events, specifically:
    a. The impact on crew and passengers
    b. The impact on airborne electronics
    c. The impact on space-based electronics
    d. The impact on terrestrial electronics
2. To determine the level of preparedness of different stakeholders
    a. Are organisations aware of the potential risk?
    b. Are procedures in place and trained?
    c. Are mitigations implemented (or planned)
3. To determine the responses based on the current level of understanding.
    a. Flight restrictions
    b. Changing flight profiles
4. Based on the responses, the impact on the Network will be determined.

Other objectives may be included on request.

Scenario

Table 1 shows the scenario of a strong space weather storm for the EACCC23 tabletop exercise, prepared by the Finnish Meteorological Office and the University of Oulu. It is based on an extreme radiation event; the other elements are in the severe class. The event is limited to one X-ray flare and a Coronal Mass Ejection.

Table 1: Exercise scenario

Time	Event	Observation	Comment
T0-72 h	Space weather centers (SWXCs) follow evolution of an aggressive sunspot cluster	Solar disks observations in X-ray (SDO AIA instrument) & Synoptic maps of the solar disc Link to the data source URL01.	Sending any official ICAO advisories is still too early because it is unclear whether the cluster will generate any flares when it will be in the position corresponding to the Earth Sector (western part of solar disk)
T0	The sunspot cluster has progressed to the western part of the solar disk and it	X-ray flux data of GOES satellites show excess of the ICAO SEV threshold. The fluxes exceed the level	The ICAO On Duty SWX Center starts preparations for a Short Wave Fadeout advisory. On duty officers recognize that there is high probability also for a burst

	generates a strong X-ray flare.	of the highest X-class flare (10^{-4} W/m^2). link to the data source: URL02	of Solar Energetic Particles starting with a delay of ~2 hours.
T0+10-20 min	Airliners get an SWX Advisory on HF COM impacts on SEV level. Advisory HF COM 01.	Impacted area is the dayside of globe.	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves. According to the ICAO regulation the On-Duty SWXC shall give an update of the advisory within a delay of 6 hours from the time of the first advisory.
T0+10-20 min	Airliners get an SWX Advisory on GNSS impacts on SEV level. Advisory GNSS 01.	Impacted area is in the dayside of globe. Reference for more information: RD01	Solar bursts (X, EUV, & radio) increase the noise level of GNSS signals. Performance of SBAS systems get compromised. Availability maps of Localizer Performance with Vertical Guidance (LPV) show extensive regions with <90% availability.
T0+1 hr	Appearance of the Coronal Mass Ejection (CME) associated with the X-ray flare	Solar coronagraph images show a halo around the Sun. link to the data source: URL03	Interpretation of the coronagraph images is challenging. A halo can be interpreted either as a CME propagating towards the Earth or away from the Earth.
T0+1.45 hr	Airliners get an SWX Advisory on HF COM: Event over. Advisory HF COM 02, closes advisory HF COM 01.	X-ray flux data of GOES satellites return back to levels below ICAO Advisory thresholds	
T0+2 hr	Airliners get an SWX Advisory on GNSS: Event over. Advisory GNSS 02, closes advisory GNSS 01.	SBAS performance returns back to nominal level	
T0+2-6 hr	Solar Energetic Protons associated with the X-ray flare reach the Earth environment	Proton flux data of GOES satellites show increases in the high energy channels. link to the data source: URL 04	Proton flux enhancements give a signal for SWXCs to get prepared for ICAO RAD advisories. The duty officers notice that the probability of HF COM problems at cross-polar flights get enhanced.
T0+2	Geostationary communication satellite(s) experience problems in the	Breaks in the availability of the Controller Pilot Data Link Communications (CPDLC).	

	hardened radiation environment. Some of them are closed as precaution.	To be added: an estimate of the time period when the performance of CPDLC is compromised.	
T0+2.25 hr	Airliners get an SWX Advisory on HF COM impacts on SEV level Advisory HF COM 03	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+2.25 hr	Ground Level Enhancement signaling enhanced radiation levels at flight altitudes	Ground-based Neutron Monitors show enhanced flux rates at high latitudes	SWXC duty officer gets final confirmation about enhanced radiation levels at typical flight altitudes. Composition of the advisories starts. The task is not straightforward as MOD/SEV estimates needs to be composed for several FLs.
T0+2.50 hr	Airliners get an SWX Advisory on RAD impacts on SEV level Advisory RAD 01	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg). At longitudes near the magnetic poles the impacted areas extend more equatorward than at the other longitudes. The most widely used flight levels (around FL 400) are impacted. Figure 01: Impacted areas with accumulated dose rates according to modelling by Mishev et al.	According to the ICAO regulation the On-Duty SWXC shall give an update of the advisory within a delay of 6 hours from the time of the first advisory. In this case the updating advisory is expected to reach the airliners before T0+8.5
T0+ 4.5 hr	First estimates of the CME arrival times are available	In the case that the halo is associated with an earthward associated CME, the estimated arrival time is T0+23 h +/- 6 hours	The first estimate on the CME propagation speed can be derived from coronagraphic images. For the speed estimate the expansion rate of the halo needs to be followed for some hours. With speed estimate also the arrival time to Earth can be estimated. Airliners do not get information about these estimates in the framework of current ICAO advisories. It is still uncertain whether the CME will be able to generate a strong geomagnetic storm or not. Several space weather services give first warnings about

			forthcoming geomagnetic storm potentially causing problems in power transmission systems (Geomagnetically Induced Currents)
T0+5 hr	Airliners get an SWX Advisory on RAD impacts on MOD level Advisory RAD 02 replaces advisory RAD 01.	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg). At longitudes near the magnetic poles (Canadian sector) the impacted areas extend more equatorward than at the other longitudes. The most widely used flight levels (around FL 400) are impacted.	According to the ICAO regulation the On-Duty SWXC shall give an update of the advisory within a delay of 6 hours from the time of the previous advisory. In this case the updating advisory is expected to reach the airliners before T0+ 13 hr.
T0+7 hr	Airliners get an SWX Advisory on RAD. The event is over. Advisory RAD 03 closes RAD 02.		
T0+8 hr	Airliners get an SWX Advisory on HF COM impacts on MOD level Advisory HF COM 04 replaces advisory HF COM 03	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves. According to the ICAO regulation the On-Duty SWXC shall give an update of the advisory within a delay of 6 hours from the time of the previous advisory. In this case the updating advisory is expected to reach the airliners before T0+14 hr
T0+12 hr	Airliners get an SWX Advisory on HF COM. The event is over. Advisory HF COM 05 closes HF COM 04.		
T0+16 hr	The CME passes satellites at the L1 point	Satellite measurements of solar wind magnetic field, velocity and density reveal that the CME has high potential to generate a geomagnetic storm. CME's leading edge has a magnetic field component	SWXC duty officer gets further confirmation about forthcoming geomagnetic storm activity. However, it is still unclear whether the ICAO threshold of HF COM problems at auroral latitudes will be exceeded. The officer follows the situation

		anti-parallel with Earth's dipole field at the dayside magnetopause.	carefully for prompt reactions in the case threshold excess.
T0+16.5 hr	The CME hits the Earth	Dayside magnetometer data show the first signs of CME impacts in the near-Earth space, but the Kp index used in ICAO advisories as the threshold parameter stays still below 8. link to the Kp data source: URL 06 Some airports at high latitudes experience a transition from their default electric power feeding to back-up solutions. Rapid geomagnetic field variations induce harmful DC currents to power networks supporting airport and ATM activities.	The SWXC on-duty officer follows the storm evolution carefully. The official Kp index is available with 3-hour resolution. However, SWXCs have access to a proxy of Kp which is updated with one minute resolution. The recommendation is to follow the proxy time variations at least for 15 min before issuing any advisories.
T0+17 hr	Airliners get an SWX Advisory on HF COM impacts on MOD level Advisory HF COM 06	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+18	Airliners get an SWX Advisory on HF COM impacts on SEV level Advisory HF COM 07 replaces HF COM 06	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+18	Airliners get an SWX Advisory on GNSS impacts on SEV level Advisory GNSS 03	Impacted areas are the EQN and EQS bands (glats equatorward of +/-30 deg)	The quality of GNSS signal is low due to scintillation by ionospheric irregularities (equatorial plasma bubbles). Problems appear particularly at the longitudes of sun set.
T0+24	Airliners get an SWX Advisory on HF COM impacts on SEV level (update on activity staying at same level) Advisory HF COM 08 replaces HF COM 07	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg). Some airports at mid-latitudes (night side) experience a transition from their default electric	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves. Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.

		power feeding to back-up solutions. Rapid geomagnetic field variations induce harmful DC currents to power networks supporting airport and ATM activities.	
T0+25	Airliners get an SWX Advisory on GNSS impacts on MOD level Advisory GNSS 04 replaces GNSS 03	Impacted areas are the EQN and EQS bands (glats equatorward of +/-30 deg)	The quality of GNSS signal is low due to scintillation by ionospheric irregularities (equatorial plasma bubbles). Problems appear particularly at the longitudes of sun set.
T0+26	Airliners get an SWX Advisory on HF COM impacts on MOD level Advisory HF COM 09 replaces HF COM 10	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+27	Airliners get an SWX Advisory on GNSS. Activity is over. Advisory GNSS 05 closes GNSS 04		
T0+30	Airliners get an SWX Advisory on GNSS impacts on MOD level Advisory GNSS 06	Impacted areas are the EQN and EQS bands (glats equatorward of +/-30 deg)	The quality of GNSS signal is low due to scintillation by ionospheric irregularities (equatorial plasma bubbles). Problems appear particularly at the longitudes of sun set.
T0+32	Airliners get an SWX Advisory on HF COM impacts on MOD level (update on activity staying at same level) Advisory HF COM 11 replaces HF COM 10	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+35	Airliners get an SWX Advisory on HF COM impacts on SEV level (update on enhanced activity) Advisory HF COM 12 replaces HF COM 11	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+36	Airliners get an SWX Advisory on GNSS impacts on SEV level Advisory GNSS 07 replaces GNSS 06	Impacted areas are the EQN and EQS bands (glats equatorward of +/-30 deg)	The quality of GNSS signal is low due to scintillation by ionospheric irregularities (equatorial plasma bubbles). Problems appear particularly at the longitudes of sun set.

T0+37	Airliners get an SWX Advisory on HF COM impacts on MOD level (update on enhanced activity) Advisory HF COM 12 replaces HF COM 11	Impacted areas are the HNH and HSH bands (glats poleward of +/-60 deg).	Problems in the HF COM expected. Lower parts of the ionosphere absorb HF waves.
T0+41	Airliners get an SWX Advisory on HF COM. The event is over Advisory HF COM 13 closes HF COM 12		
T0+42	Airliners get an SWX Advisory on GNSS. The event is over Advisory GNSS 08 closes GNSS 07.		
T0+45	Airliners get an SWX Advisory on HF COM. Advisory HF COM 14	Impacted areas are mostly the MNH and MSH bands (glats between +/- 30 and +/-60 deg). Impacted longitudinal sectors vary during the event.	Problems in Over-the-Horizon communication. Maximum usable frequencies significantly lowered.
T0+117 hr	Airliners get an SWX Advisory on HF COM the event is over. Advisory HF COM 15 closes HF COM 14.		

URL01: SDO AIA 131 Angstrom | NASA

URL02: GOES X-ray Flux | NOAA / NWS Space Weather Prediction Center

URL03: LASCO Coronagraph | NOAA / NWS Space Weather Prediction Center

URL04: GOES Proton Flux | NOAA / NWS Space Weather Prediction Center

URL05: Real Time Solar Wind | NOAA / NWS Space Weather Prediction Center

URL06: Planetary K-index | NOAA / NWS Space Weather Prediction Center

RD01: Berdermann, J., Kriegel, M., Banys, D., Heymann, F., Hoque, M. M., Wilken, V., et al. (2018). Ionospheric response to the X9.3 Flare on 6 September 2017 and its implication for navigation services over Europe. Space Weather, 16, 1604–1615. https://doi.org/10.1029/2018SW001933

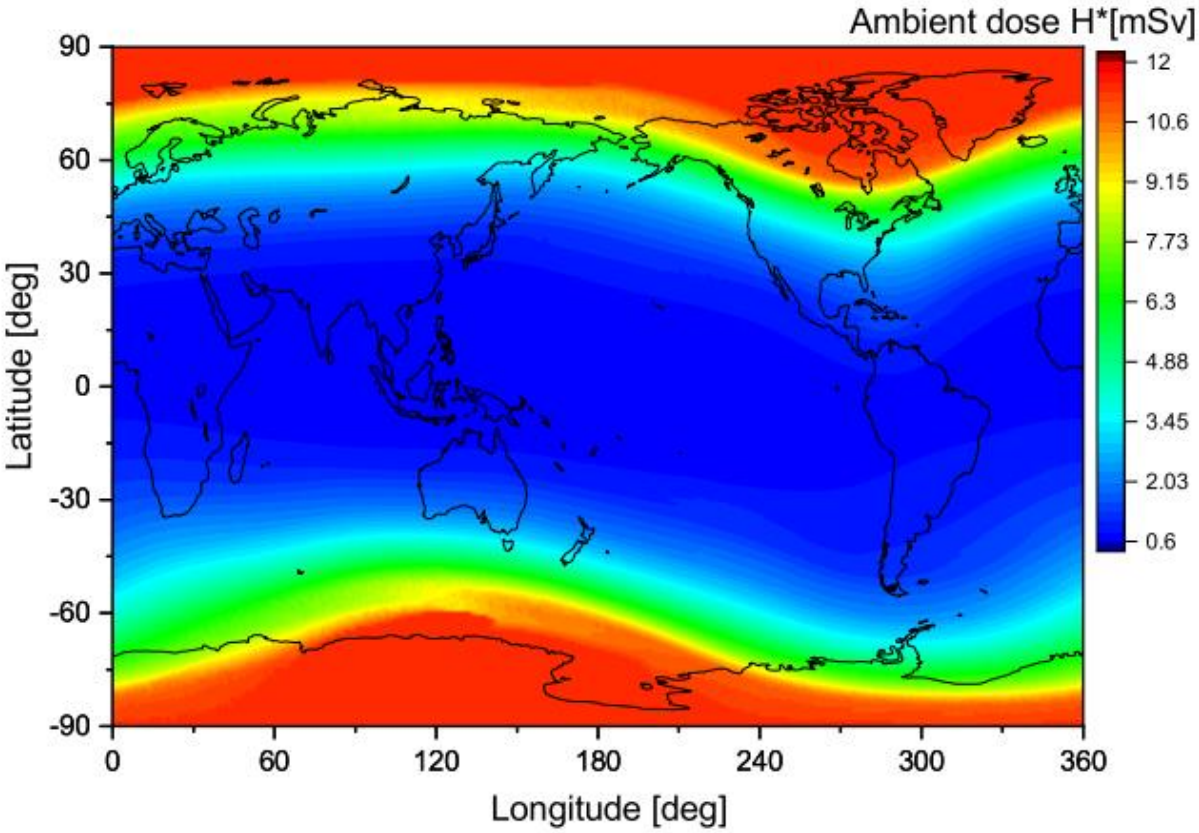

Figure 01: Model results by Mishev et al. for GLE #5, February 23 1956. Modelled Radiation dose during the first 4 hours of strongest Ground-Level-Enhancement event observed during the modern era.

Initial set of questions for stakeholders and states

Airlines

1. Is your company aware of the potential impact of severe space weather events?
    a. The effects on crew and passenger
    b. The effects on avionics and on-boards systems
    c. The effects on satellite navigation
    d. The effect on satellite communication
    e. The effect on HF communication
2. What are the classification criteria you are using for space weather events?
3. Does your company receive the space weather advisories?
    a. From the ICAO space weather advisory centres?
    b. From other sources?
4. Does your company have procedures to handle these advisories?
5. Does your company have procedures for flying during extreme space weather events?
    a. Is your staff trained on these procedures?
6. Does your company have radiation exposure limits for staff?
    a. What are these limits?
    b. Are these limits monitored?
    c. What happens if these limits are exceeded?
7. What would be the response to this scenario based on the current procedures?

Airports

1. Is your company aware of the potential impact of severe space weather events?
    a. Effects on airport systems
    b. Effect on power grid
    c. Effect on radio communications
2. Does your company receive the space weather advisories?
    a. From the ICAO space weather advisory centres?
    b. From other sources?
3. Does your company have procedures to handle these advisories?
4. Does your company have contingency procedures for extreme space weather events?
5. What would be the response to this scenario based on the current procedures?

CAAs

1. Does your state have legal limits for flying in extreme space weather conditions?
    a. What are these limits?
    b. How are they monitored?
    c. How are they enforced?
2. Would you consider (partial) airspace closure during extreme weather events?
    a. What would be your information source?
3. What would be the response to this scenario based on the current procedures?

EASA

1. Does EASA have regulatory requirements for radiation hardening of commercial aircraft?
2. Does EASA have regulatory requirements for radiation exposure limits for crew and passengers?
3. Given the unpredictability and fast development of an extreme space weather event, how fast could EASA publish a SIB?
4. How would EASA learn about the event?
4. What would be the response to this scenario based on the current procedures?

ANSPs

1. Is your company aware of the potential impact of severe space weather events?
    a. The effects on surveillance infrastructure
    b. The effects on performance of navaids
    c. The effects on satellite navigation
    d. The effect on satellite communication
    e. The effect on HF communication
2. What are the classification criteria you are using for space weather events?
3. Does your company receive the space weather advisories?
    a. From the ICAO space weather advisory centres?
    b. From other sources?
4. Does your company have procedures to handle these advisories?
5. What would be the response to this scenario based on the current procedures?