Pilots´ View on Space Weather and Aviation

Klaus Sievers, German Airline Pilots´ Association

Pithia - NRF, virtual , 21 June 2022

Space Weather for Aviation

- Space Weather impacting Aviation - Examples
- Rules
- SWx information from the US Space Weather Prediction Center (SWPC)
- SWx information from ESA
- ICAO SWx advisories
- ICAO SWx advisories in flight operations

➢ Space Weather impacting Aviation: Examples

AIRCREW SAFETY & HEALTH

Cosmic Ionizing Radiation

Photo courtesy of Jure Noggerly (NCAR)

What you need to know

Aircrew and passengers are exposed to cosmic ionizing radiation on every flight. Here you can learn more about cosmic ionizing radiation, how you can be exposed, exposure levels, and possible health effects.

What is cosmic ionizing radiation?

Cosmic ionizing radiation (or cosmic radiation) is a form of ionizing radiation that comes from outer space. A very small amount of this radiation reaches the earth. At flight altitudes, passengers and crewmembers are exposed to higher levels of cosmic radiation.

Cosmic radiation exposures on aircraft include:

- galactic cosmic radiation, which is always present
- solar particle events, sometimes called "solar flares"

Are there any known health effects from cosmic ionizing radiation?

- The World Health Organization (WHO) International Agency for Research on Cancer (IARC) says that ionizing radiation causes cancer in humans. Ionizing radiation is also known to cause reproductive problems. We are looking more specifically at whether cosmic ionizing radiation is linked to cancer and reproductive problems.
- Most studies of radiation health effects have looked at groups with much higher radiation doses from different kinds of radiation (atomic bomb survivors, patients who received radiation therapy).

https://www.cdc.gov/niosh/topics/aircrew/cosmicionizingradiation.html

IFALPA
The Global Voice of Pilots

Human Performance
Briefing Leaflet

19HUPBL01 — 11 December 2019

Aircrews and Ionizing Radiation

https://www.ifalpa.org/media/3467/19hupbl01-aircrews-and-ionizing-radiation.pdf

AIRCREW SAFETY & HEALTH

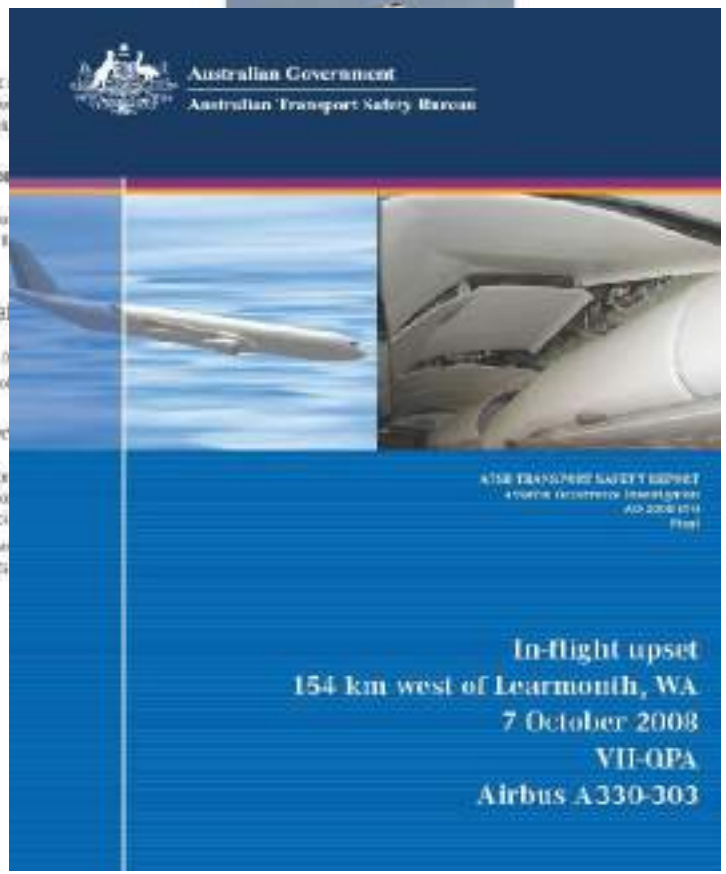
Cosmic Ionizing Radiation

What you need to know

What is cosmic ionizing radiation

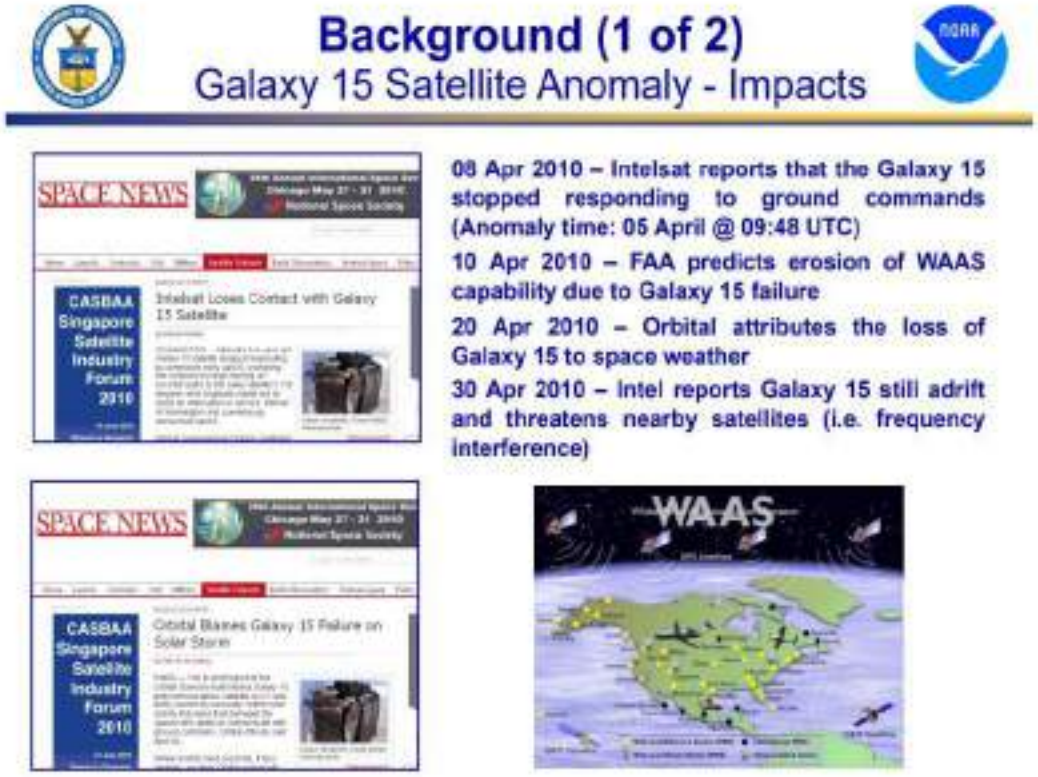
Cosmic radiation exposures on a

Are there any known health effe



https://www.atsb.gov.au/media/3532398/ao2008070.pdf

➢ Space Weather impacting Aviation: Examples



https://www.ngdc.noaa.gov/stp/satellite/anomaly/2010_sctc/docs/1-2_WDenig.pdf

➢ Space Weather impacting Aviation: Examples

AIRCREW SAFETY & HEALTH

Cosmic Ioniz

What you need

What is cosmic ion

Cosmic radiation e

- galactic cosmic
- solar particle events,

Are there any kno

- The World Health Org
- Most studies of radiat

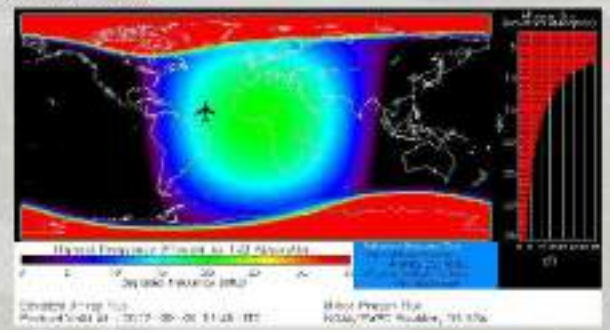
Background (1 of 2)
Galaxy 15 Satellite Anomaly - Impacts

08 Apr 2010 – Intelsat reports that the Galaxy 15 stopped responding to ground commands (Anomaly time: 05 April @ 09:48 UTC)

10 Apr 2010 – FAA predicts erosion of WAAS capability due to Galaxy 15 failure

French Civil Aviation Authority

"French Civil Aviation authorities reported that **HF radio contact was lost** with one non-Controller Pilot Data Link Communications (CPDLC) equipped aircraft off the coasts of Brazil and French Guyana **for approximately 90 minutes**, triggering an alert phase until a position report was received by New York radio"



➢ Space Weather impacting Aviation: Examples

AIRCREW SAFETY & HEA

Cosmic Ioniz

What you need

What is cosmic ion

Cosmic radiation e

Are there any know

Solar radio emission as a disturbance of aeronautical radionavigation

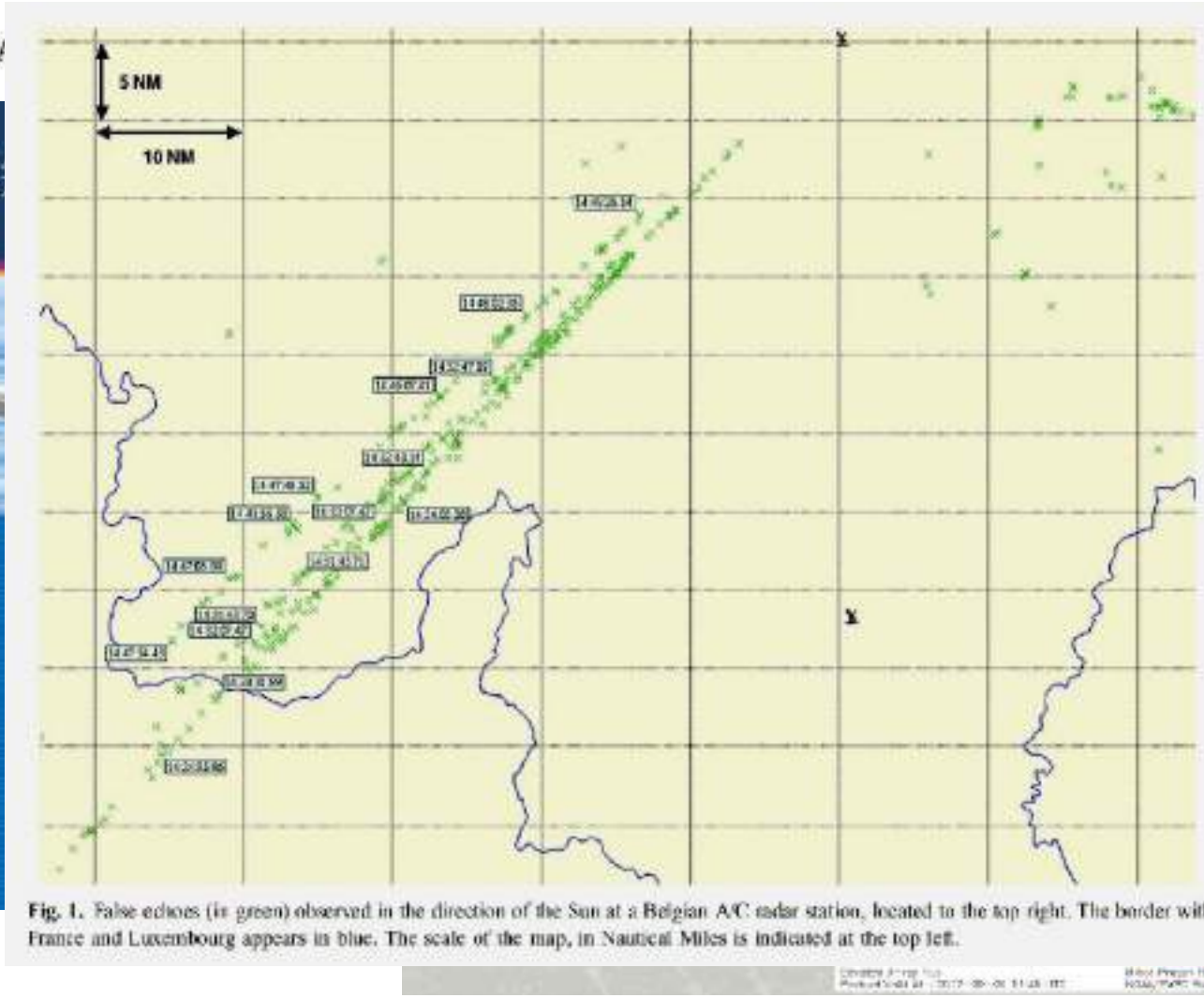
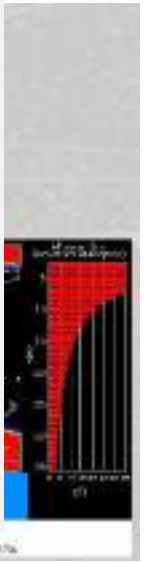
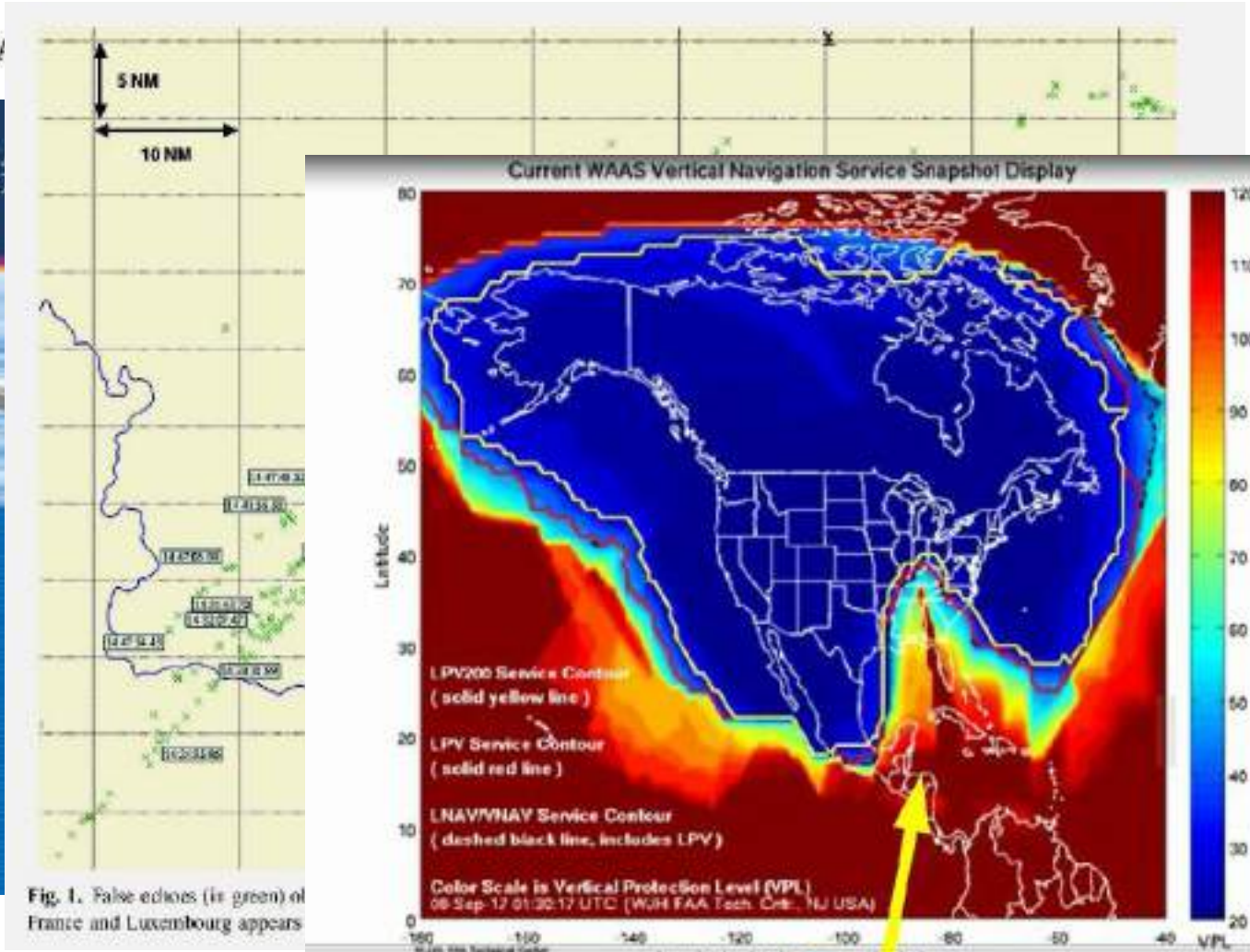


Fig. 1. False echoes (in green) observed in the direction of the Sun at a Belgian A/C radar station, located to the top right. The border with France and Luxembourg appears in blue. The scale of the map, in Nautical Miles is indicated at the top left.



https://tinyurl.com/yc9qpj24

➢ Space Weather impacting Aviation: Examples



https://www.nstb.tc.faa.gov/24Hr_WaasLPV200.htm

- Space Weather impacting Aviation - Examples : *Everything*
- During an active period in 2017, multiple impacts occurred at the same time. They affected aviation, too !

USAF survey for Sept 2017 found:

> 06 Sept. ....: Radar interference issues reported

> 10 Sept. ....: HF Comm issues in the Caribbean and SE Asia

> 10 Sept. ....: SATCOM issues noted over Florida

> 11-14 Sept.: High latitude communication issues / protons

> 04-11 Sept.: Sat anomalies in 4 NATO satellites,
1 USN Satcom, 2 HEO Sat

> 12-18 Sept.: 4 LEO, 1 HEO, 1 MEO and 3 GEO anomalies

((Total: 16 satellite anomalies))

USAF CPT B.Ross, NOAA Annual Meeting 2018

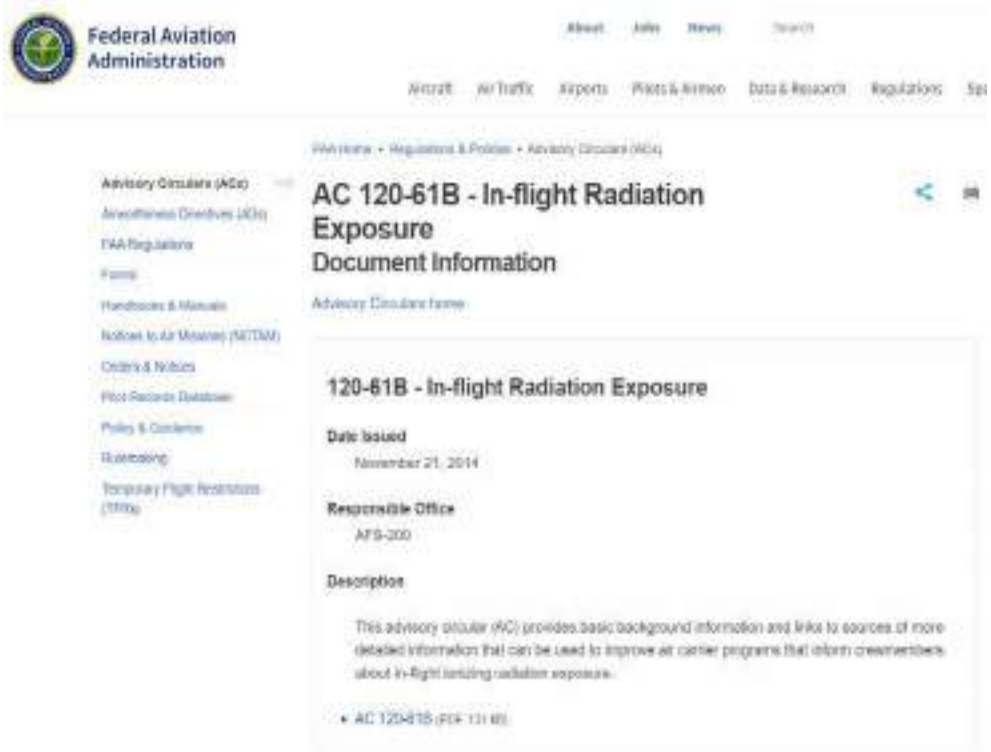
000
WOXX50 KWNP 101826
ALTPAV
Space Weather Message Code: ALTPAV
Serial Number: 7660
Issue Time: 2017 Sep 10 1821 UT
ALERT: Solar Radiation Alert at Flight Altitudes
Conditions Began: 2017 Sep 10 1805 UTC
Comments:
Satellite measurements indicate unusually high levels of ionizing radiation coming from the Sun. This may lead to excessive radiation doses to air travelers on trans-polar and other high-latitude flights. See map at
http://www.faa.gov/data_research/research/med_humanfac/aeromedical/radiobiology/solarradiation
The following dose, dose rate, and risk estimates do not include any shielding by the Earth's magnetic field.
Table 1. Effective dose rate estimates at selected altitudes based on the latest GOES solar proton flux measurements
Altitude Effective Dose Rate
(ft) (Microsieverts/hour)

30000 1.5
40000 5.8
50000 22
60000 50
70000 76

radiation exposure increased

➢ Rules

- ➢ US FAA requires information on radiation ,
- ➢ a plan for the mitigation of radiation for polar region flights
- ➢ and constant communication, which means HF might not be OK



(....) Section III.
Approvals for operations whose airplane routes are planned to traverse either the North Polar or South Polar Areas. (...)
(6) A training plan for operations in these areas.
(7) A plan for mitigating crew exposure to radiation during solar flare activity.
(8) A plan for providing at least two cold weather anti-exposure suits in the aircraft (...)

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1026386
https://www.govinfo.gov/content/pkg/CFR-2016-title14-vol3/pdf/CFR-2016-title14-vol3-part121-appP.pdf

➢ Rules

➢ Europe: Crew radiation protection requirements according to the general Euratom Basic Safety Standards

Council Directive 2013/59/Euratom (new BSS)

Official Journal

of the European Union

L 13

English edition | Legislation | Volume 57, 17 January 2014

Contents | II Non-legislative acts | page

DIRECTIVES

* Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom 1

https://eur-lex.europa.eu/legal-content/de/TXT/?uri=CELEX%3A32013L0059

Summary

Maximum radiation dose for exposed workers shall be 100 mSv / 5 years, and 50 mSv in any single year. For pregnant women there is a maximum dose of 1 mSv during the remainder of the pregnancy.

If more than 1 mSv / year is expected, dose assessment is required.

Workers have to be informed about the risk their work involves.

PLUS: national legislation, which may set occupational exposure limits at other values for crew, like 6 mSv/year.

- EASA: comprehensive but non-binding information bulletin on Space-Weather.
- Imminent or on-going Space-Wx: recommend delayed use of polar route, fly at lower altitude for atmospheric shielding.
- Detailed certification for electronics with regards to radiation

EASA

Safety Information Bulletin

Airworthiness – Operations – ATM/ANS

SIB No.: 2012-09R1

Issued: 28 April 2021

Subject: Effects of Space Weather on Aviation

Revision:
This SIB revises EASA SIB 2012-09 dated 23 May 2012.

Ref. Publications:
- Council Directive 2013/59/EURATOM dated 05 December 2013.
- EASA SIB 2012-09R1 dated 28 April 2021.
- Appendix 1 of this SIB contains a list of useful websites and identifies those that provide information on actual space weather.
- International Civil Aviation Organization (ICAO) Annex 3: Meteorological Service for International Air Navigation, 20th Edition 2018.
- ICAO Document 10100: Manual on Space Weather Information in Support of International Air Navigation, 1st Edition 2018.

Applicability:
All aircraft and their operations, all Air Traffic Management/Air Navigation Services (ATM/ANS) systems and their operations, all aerodromes and their operations.

Description:
This SIB informs aircraft operators and manufacturers, avionics systems designers, electronic equipment and component manufacturers, ATM/ANS service providers, aerodrome operators and competent authorities of the effects of space weather on electronic devices, communication, navigation and surveillance services and human beings, and should be read in conjunction with EASA SIB 2012-10R1 for on-board systems.

EASA

Certification Memorandum

Single Event Effects (SEE) Caused by Atmospheric Radiation

Certification Considerations and an Analysis Method to Demonstrate the Acceptability of Effects on Aircraft, Engine, APU and Propeller Systems and Equipment, caused by Atmospheric Radiation

EASA CM No.: CM-AS-004 Issue 01 Issued 08 January 2019

Regulatory requirement(s): CS-23, CS-25, CS-27, CS-29, CS-E, CS-P and CS-APU

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

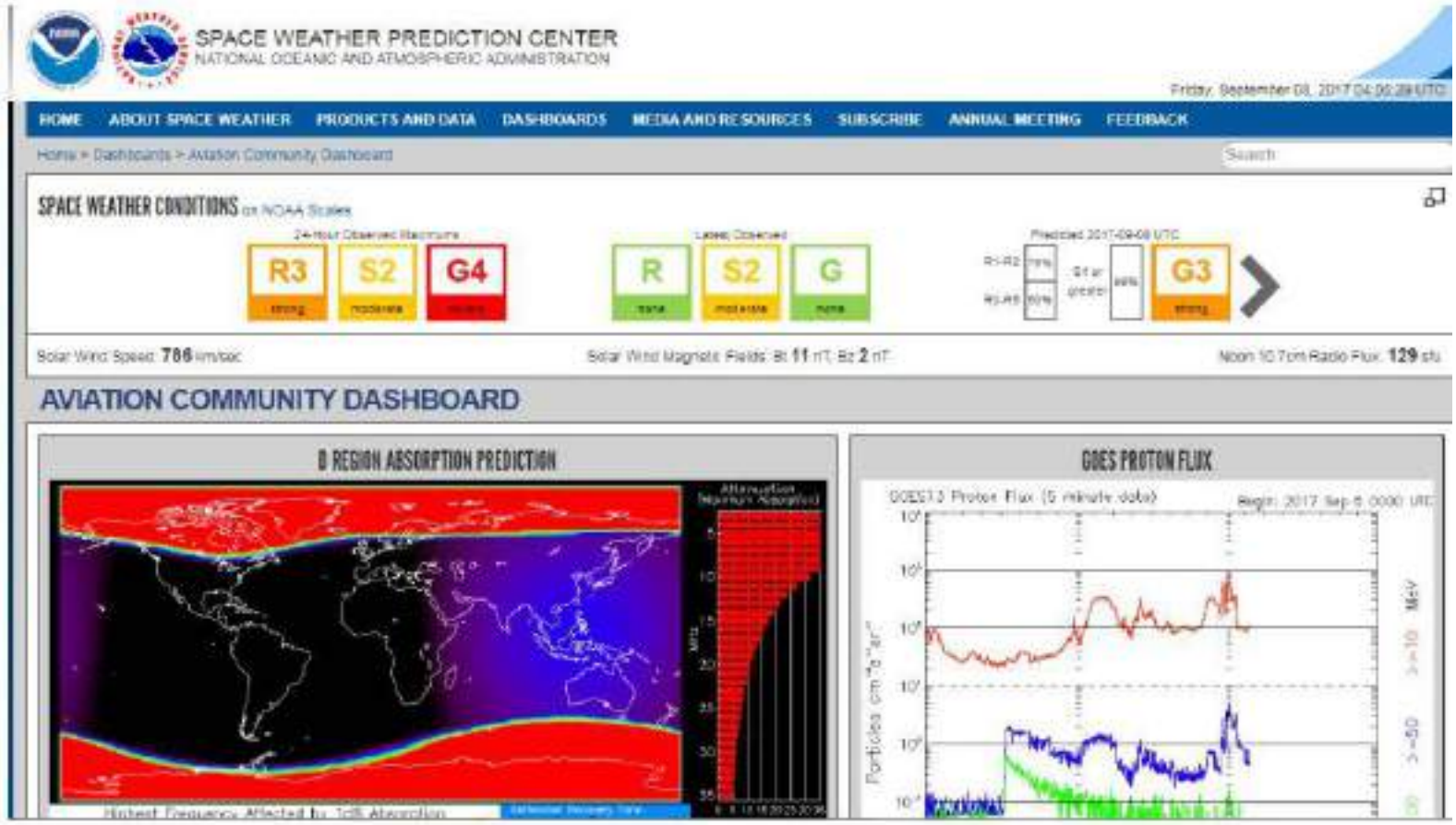
EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

https://ad.easa.europa.eu/blob/EASA_SIB_2012_09_R1.pdf/SIB_2012-09R1_1

- SWx information from the US Space Weather Prediction Center (SWPC)

- Traditional source of SWx for aviation - storm conditions, 08 Sep 17
- R: Radio Blackouts S: Radiation Storm G: Geomagnetic Storm

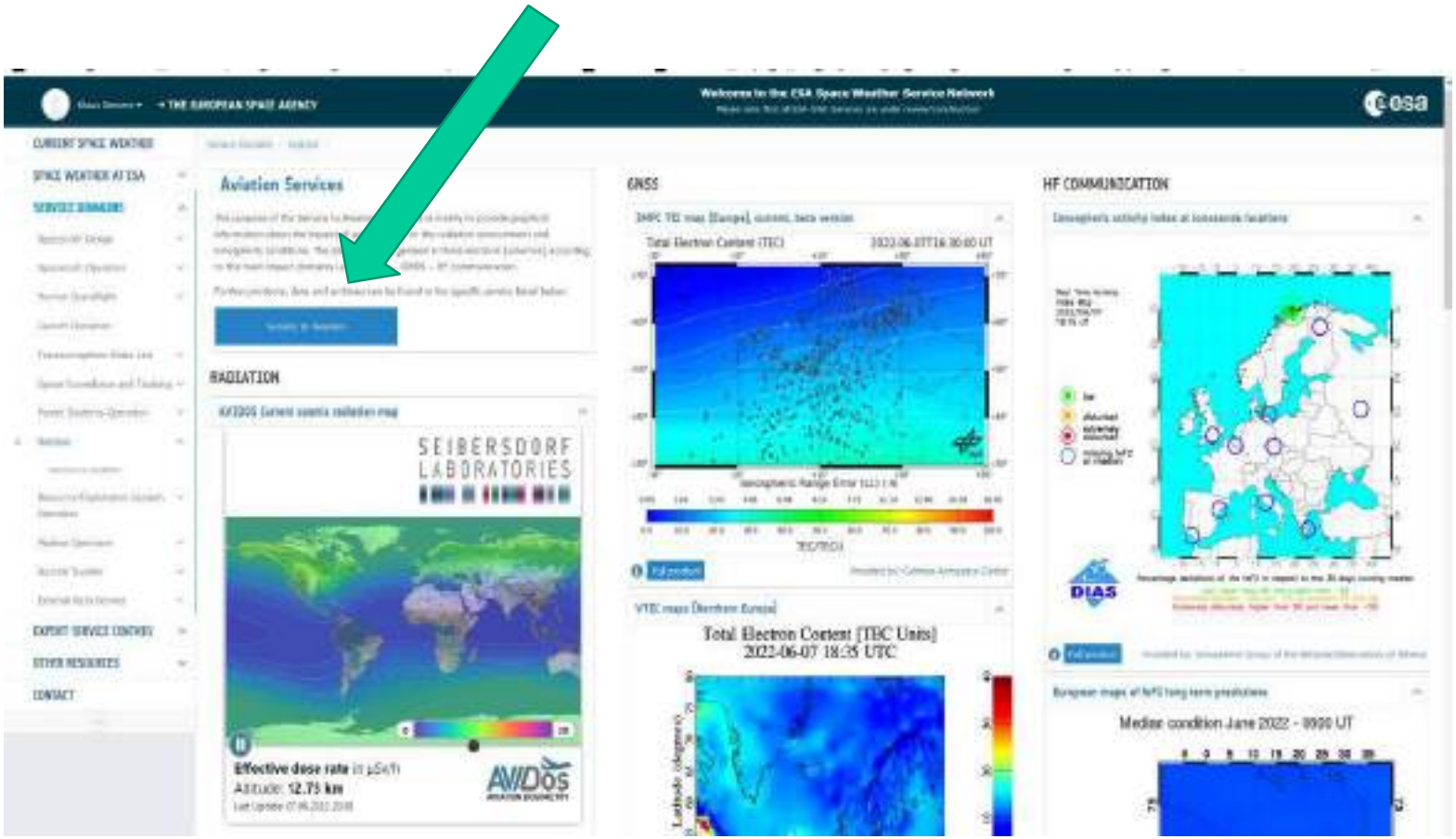
https://www.swpc.noaa.gov/noaa-scales-explanation



https://www.swpc.noaa.gov/communities/aviation-community-dashboard

- SWx information from ESA

- Comprehensive information - science oriented
- Registration required. Log-in available the next day
- Consult the Service to Aviation section for more information



https://swe.ssa.esa.int/nso_air_dashboard

➢ ICAO SWx advisories

- ➢ Basic rules, like message formats, organizational matters, to be found in ICAO Annex 3
- ➢ Threshold values , science description in the Manual

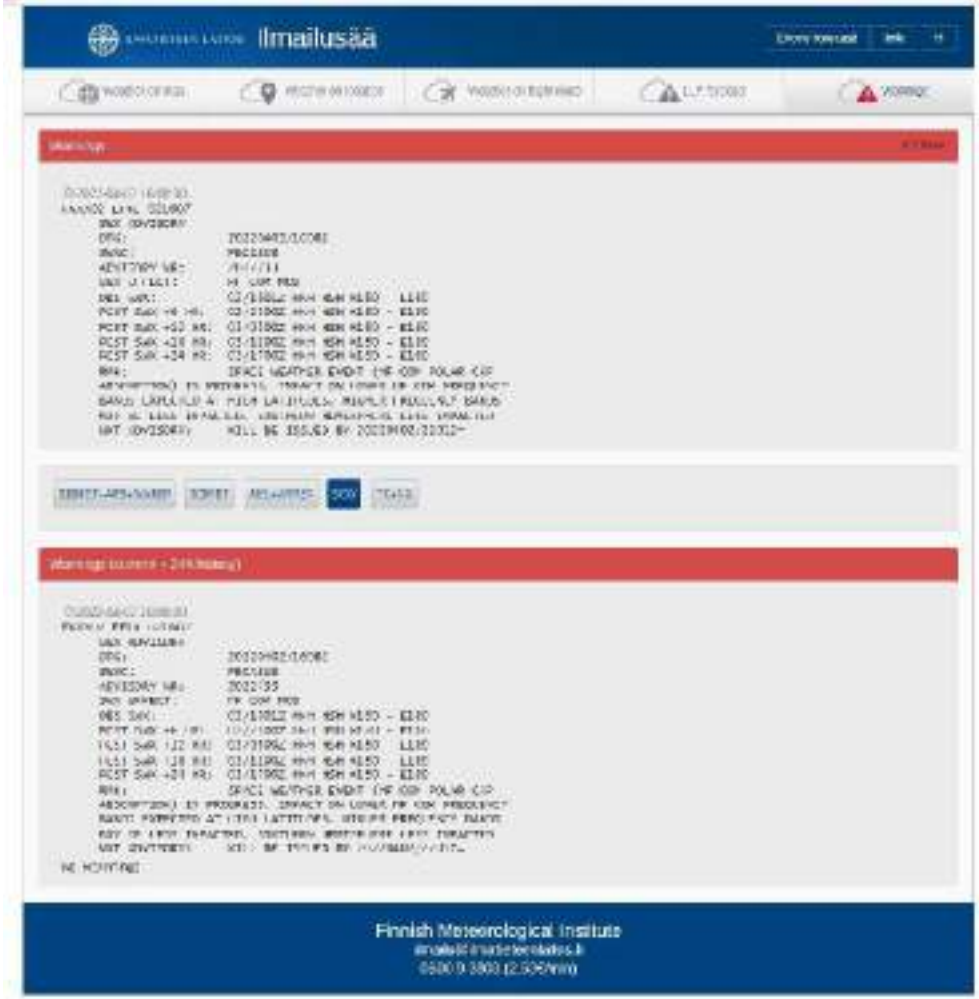
➢ ICAO SWx advisories

- ➢ SWx advisories are issued on a rotating schedule by the four global SWx Centres SWPC, PECASUS, CRC and ACFJ
- ➢ South Africa is associated with PECASUS for now

A.Naidu, BOM , https://www.icao.int/APAC/Meetings/2021%20METATM%20Seminar%20and%20METR%20WG10/SP11_AI.2_AUS_SpaceWeather.pdf

- ICAO SWx advisories

- Website of PECASUS, with link to real-time advisories



https://pecasus.eu/?page_id=319

https://www.ilmailusaa.fi/warnings.html#top=0#id=swx#FMILang=en#select-area=4

- ICAO SWx advisories

- Overview of affected systems covered.
- Advisories only provided when thresholds are reached

6. SPACE WEATHER CENTRES

6.1 Space weather advisory information

6.1.3 **Recommendation.**— *One or more of the following space weather effects should be included in the space weather advisory information, using their respective abbreviations as indicated below:*

HF communications (propagation, absorption)	*HF COM*
communications via satellite (propagation, absorption)	*SATCOM*
GNSS-based navigation and surveillance (degradation)	*GNSS*
radiation at flight levels (increased exposure)	*RADIATION*

6.1.4 **Recommendation.**— *The following intensities should be included in space weather advisory information, using their respective abbreviations as indicated below:*

moderate	*MOD*
severe	*SEV*

➢ ICAO SWx advisories

- ➢ Overview of affected systems covered.
- ➢ Advisories only provided when thresholds are reached

Annex 3 — Meteorological Service for International Air Navigation *Appendix 2*

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GNSS-based navigation and surveillance (degradation)	*GNSS*
radiation at flight levels (increased exposure)	*RADIATION*

- About SATCOM
  - ICAO has not given yet the thresholds for advisories
  - Data and voice drop out at frequencies < 2 GHz (L-band)
  - No big problems in S, C, Ku and Ka
  - SWx something to keep in mind when planning future automated ATM systems

PECASUS : https://presentations.copernicus.org/EGU2020/EGU2020-7650_presentation.pdf

- ICAO SWx advisories
- Thresholds for ICAO SWx advisory issuance

Table 3-1. Thresholds for space weather advisory

		Moderate	*Severe*
GNSS			
	Amplitude Scintillation (S4)(dimensionless)	0.5	0.8
	Phase Scintillation (Sigma-Phi)(radians)	0.4	0.7
	Vertical TEC (TEC Units)	125	175
RADIATION			
	Effective Dose (micro-Sieverts/hour)*	30	80
HF			
	Auroral Absorption (Kp)	8	9
	PCA (dB from 30MHz Riometer data)	2	5
	Solar X-rays (0.1 - 0.8 nm)($W\text{-}m^{-2}$)	$1X10^{-4}$ (X1)	$1X10^{-3}$ (X10)
	Post-Storm Depression (MUF)**	30%	50%

* *MOD advisories will only be issued when the MOD threshold is reached at FL460 and below. SEV advisories will be issued when the SEV threshold is reached at any FL.*

** *As compared to a 30-day running median of the critical frequency of the F2 layer (foF2).*

Note.— A more detailed description of how these values were determined can be found in Appendix 1.

Source: ICAO Doc 10100

- ICAO SWx advisories in flight operations
- Volcanic Ash Advisory < > SWx Advisory (ICAO Annex 3)

```
FVXX23 KNES 141138
VA ADVISORY
DTG: 20181014/1138Z

VAAC: WASHINGTON

VOLCANO: FUEGO 342090
PSN: N1428 W09052

AREA: GUATEMALA

SUMMIT ELEV: 12346 FT (3763 M)

ADVISORY NR: 2018/548

INFO SOURCE: GOES-EAST. NWP MODELS. CIMSS VOLCAT.

ERUPTION DETAILS: ONGOING VA EMS

OBS VA DTG: 14/1115Z

OBS VA CLD: SFC/FL170 N1429 W09053 - N1428 W09052
- N1412 W09119 - N1426 W09122 - N1429 W09053 MOV
SW 5-10KT

FCST VA CLD +6HR: 14/1730Z SFC/FL170 N1429 W09053
- N1428 W09052 - N1413 W09123 - N1428 W09126 -
N1429 W09053

FCST VA CLD +12HR: 14/2330Z SFC/FL170 N1429
W09053 - N1428 W09052 - N1412 W09123 - N1428
W09126 - N1429 W09053

FCST VA CLD +18HR: 15/0530Z SFC/FL170 NO ASH EXP

RMK: VA EMS CONT TO MOV WSW AND EXTD ROUGHLY 50
NM FM SUMMIT.  NWP MODEL GUIDANCE CONT TO SHOW A
W-LY MOV THRU T+12 HRS. ...KIBLER
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SWX ADVISORY
DTG: 20161108/0100Z

SWXC: DONLON*

ADVISORY NR: 2016/2

NR RPLC: 2016/1

SWX EFFECT: HF COM MOD AND GNSS MOD

OBS SWX: 08/0100Z HNH HSH E18000 – W18000

FCST SWX +6 HR: 08/0700Z HNH HSH E18000 – W18000

FCST SWX +12 HR: 08/1300Z HNH HSH E18000 – W18000

FCST SWX +18 HR: 08/1900Z HNH HSH E18000 – W18000

FCST SWX +24 HR 09/0100Z NO SWX EXP

RMK: LOW LVL GEOMAGNETIC STORMING CAUSING
INCREASED AURORAL ACT AND SUBSEQUENT MOD
 DEGRADATION OF GNSS AND HF COM AVBL IN THE
AURORAL ZONE. THIS STORMING EXP TO SUBSIDE IN
THE FCST PERIOD.
SEE WWW.SPACEWEATHERPROVIDER.WEB

NXT ADVISORY: NO FURTHER ADVISORIES
```

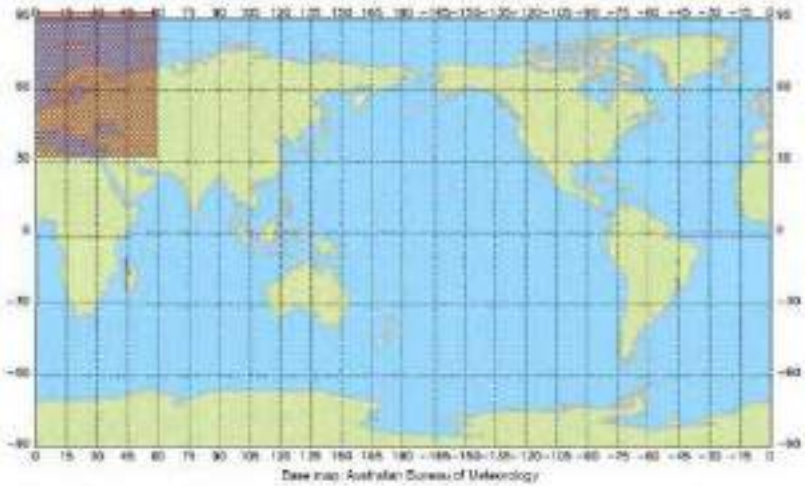
➢ ICAO SWx advisories in flight operations

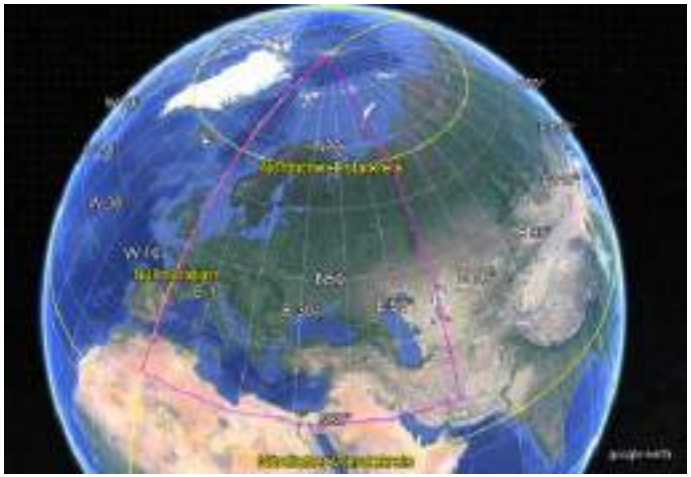
➢ **First** real SWx advisory ever issued. 28 September, 2020

```
2020-09-28 05:55:00
FNXX01 YMMC 280555
     SWX ADVISORY
     DTG:              20200928/0555Z
     SWXC:             ACFJ
     ADVISORY NR:      2020/26
     SWX EFFECT:       HF COM MOD
     OBS SWX:          28/0532Z HNH MNH E000 - E060
     FCST SWX +6 HR:   28/1200Z NO SWX EXP
     FCST SWX +12 HR:  28/1800Z NO SWX EXP
     FCST SWX +18 HR:  29/0000Z NO SWX EXP
     FCST SWX +24 HR:  29/0600Z NO SWX EXP
     RMK:              SPACE WEATHER EVENT (MAXIMUM USABLE FREQUENCY
     DEPRESSION) IN PROGRESS IMPACTING HIGHER HF COM
     FREQUENCY BAND. LOWER FREQUENCIES MAY BE LESS
     IMPACTED. ISOLATED AREAS OF SEV HF COM DEGRADATION
     POSSIBLE.
     NXT ADVISORY:     WILL BE ISSUED BY 20200928/1140Z=
No warnings
```

Decoding

Issued 2020 Sep 28, 0555 GMT,
by SWx Centre ACFJ
Impact: HF COM MOD
Observed SWx at 05:32 GMT:
affected area:
high latitudes N hemisphere
mid latitudes N hemisphere
00E - 060 E
Forecast SWx 28 / 12 GMT
no SWx expected
(...)





➢ ICAO SWx advisories in flight operations

- ➢ Flight operations are teamwork.
- ➢ All involved are on the same page - thanks to the ops manual

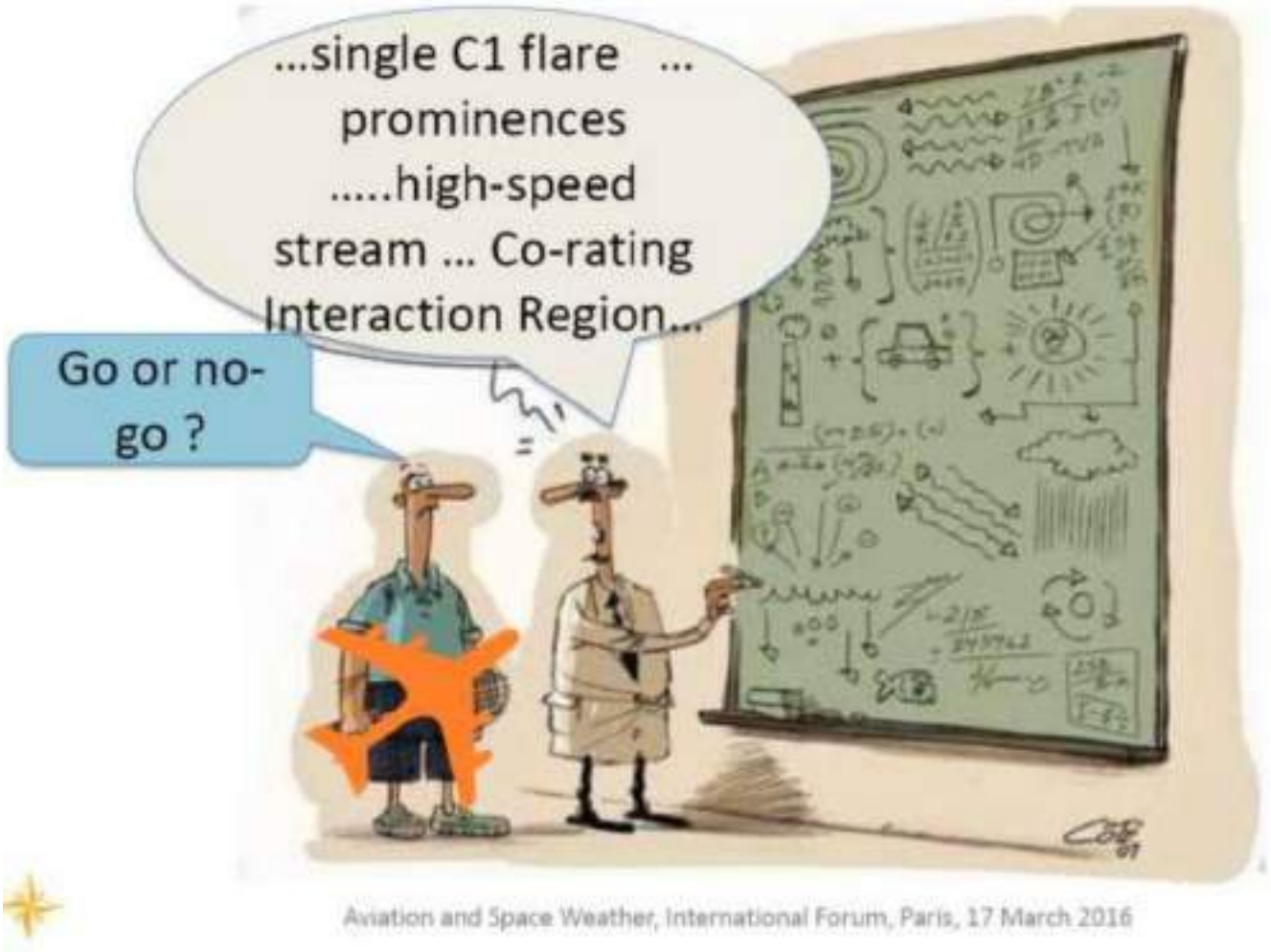
Besides assuring regulatory compliance, OPS- manuals: assuring that everyone is –actually- on the same page

The Airlines´ operation manuals specify
- general information, organizational structure and policies, safety management
- aircraft specific operating matters, normal and abnormal procedures
- regulations and information about routes, roles of personell, aerodromes
- training and evaluation of staff, health matters

https://blog.klm.com/taking-off-with-flight-dispatcher-nancy-put-serle/

- ICAO SWx advisories in flight operations

- ADVISORY: **GNSS SEV.** Go or no-go ? That´s the question !



Source: Presentation by J. Lafeuille, Aviation and Space-WX, Paris 2016

- ➢ Answer: ensure that they are not needed for the flight !
- ➢ Check, if navigation for the flight is not depending on GPS.
- ➢ Choose alternate airport with conventional approach

- ➢ All ok: decide that it is safe to fly.

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

MASTER MINIMUM EQUIPMENT LIST

AIRCRAFT: A330-200, A330-200F, A330-300	REVISION NO: 14 DATE: 05/31/2013	PAGE: 34-15

SYSTEM & SEQUENCE NUMBERS	ITEM	1.	2. NUMBER INSTALLED	3. NUMBER REQUIRED FOR DISPATCH	4. REMARKS OR EXCEPTIONS
34 NAVIGATION					
58-01 ***	Satellite Navigation				
	1) Global Positioning System (GPS)	C	2	0	(O)May be inoperative provided alternate procedures are established and used.
		D	2	0	May be inoperative provided procedures do not require its use.

https://fsims.faa.gov/wdocs/mmel/a-330_r14.htm

- ICAO SWx advisories in flight operations

- EUROCONTROL has looked into loss of GPS scenarios :
- very much reduced capacity
- need for conventional infrastructure as backup

Tabular Summary of Reversion Scenario 1

REVERSION INFRASTRUCTURE	
Available Navaid Infrastructure	~~GPS~~; ~~GBAS/GRAS~~; DME/DME; VOR/DME; ILS
Fleet Positioning Capability for PBN	~~GPS~~ + D/D > 90% + VOR/DME (10% can only do conventional); ILS; ~~GBAS/GRAS 20%~~
Surveillance Sensors Used	PSR; MULTIPLE SSR; with ~~ADS-B~~ or MLAT
Communication Service Used	Voice; ~~Data Link~~
Data Link Explanation: Whilst Data Link may not be lost immediately, it can be lost in the longer term if the outrage timing is extended	
Timing for On-Board Systems	Independent ~~- GPS synchronised~~
Timing for Ground Systems	Independent ~~- GPS synchronised~~
CONTINGENCY OPERATIONS (ENR & SID/STAR GNSS REVERSION)	
Applications which can continue in Airspace:	RNAV 5 (ATS Routes + FRA); ~~RNP 1~~ + RF (majority of SID/STAR); RNAV 1 (remaining SID/STAR); ~~RNP 0.3~~ (All Heli); Existing Conventional Procedures.
Applications Explanation: (i) For reversions of short duration, RNAV 1 with/without RF could substitute for 90% of the fleet and RNAV 1 for other routes; though 10% of the fleet would require vectoring or continue on conventional procedures. For reversion to DME/DME operations, special conditions may apply to the infrastructure (refer to PBN handbook No 4)	

https://www.eurocontrol.int/archive_download/all/node/12154

- ICAO SWx advisories in flight operations

- Detailed guidance on handling of SWx advisories in real life has not been published or mandated by FAA or EASA

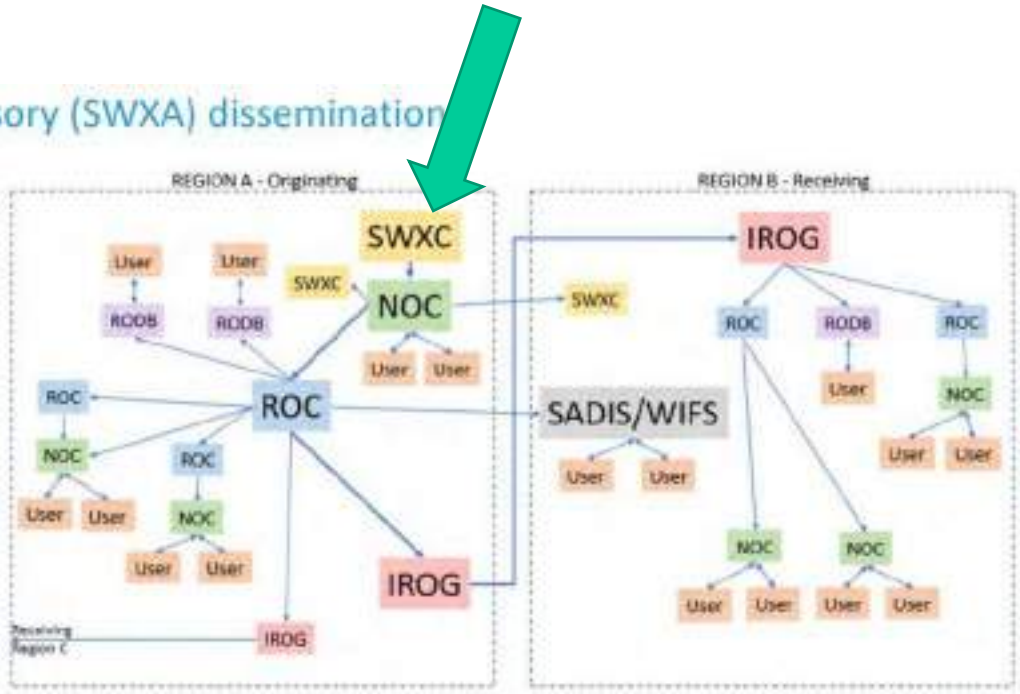
- The European Cockpit Association has a publication:

https://www.eurocockpit.be/news/icao-space-wx-advisories-instructions-be-included-ops-manual

Non-Distribution of SWx advisories - Safety Bulletin

Space Weather Advisory (SWXA) dissemination

Regular testing of the dissemination system (using SWXAs with STATUS: TEST) has been conducted since 2019 and will continue through 2021
(1 test advisory every 2 weeks)



ROC =
Rgional Opment Center

IROC =
Inter- Regional Opmet Center

NOC =
National Opmet Center

User = ?????

Grapic :
https://www.icao.int/APAC/Meetings/2021%20METATM%20Seminar%20and%20METR%20WG10/SP11_AI.2_AUS_SpaceWeather.pdf

➢ ICAO SWx advisories in flight operations

The Global Voice of Pilots

IFALPA

SAFETY BULLETIN

22SAB10
21 April 2022

Space Weather Advisories

ICAO Annex 3, Chapter 9 provides detailed Standards and Recommended Practices for Meteorological information to be supplied to operators and flight crew members for preflight planning, inflight replanning, use by flight crew members before departure, and aircraft in flight.

It has recently been discovered that some providers of the flight briefing packages do not include the ICAO – standard Space Weather Advisories as provided for in ICAO Annex 3 Chapter 9, 9.1.3 k. This means that many pilots do not receive the advisories.

Until such time as the distribution of Space Weather Advisories to flight crew members is implemented, they should be obtained from official sources by a query to the local Met Office or via the internet.

AUTHORITATIVE AND FREE WEBSITES

https://ifalpa.org/media/3755/22sab10-space-weather-advisories.pdf

Thank you for your attention !

Klaus Sievers
Klaus.Sievers@VCockpit.de