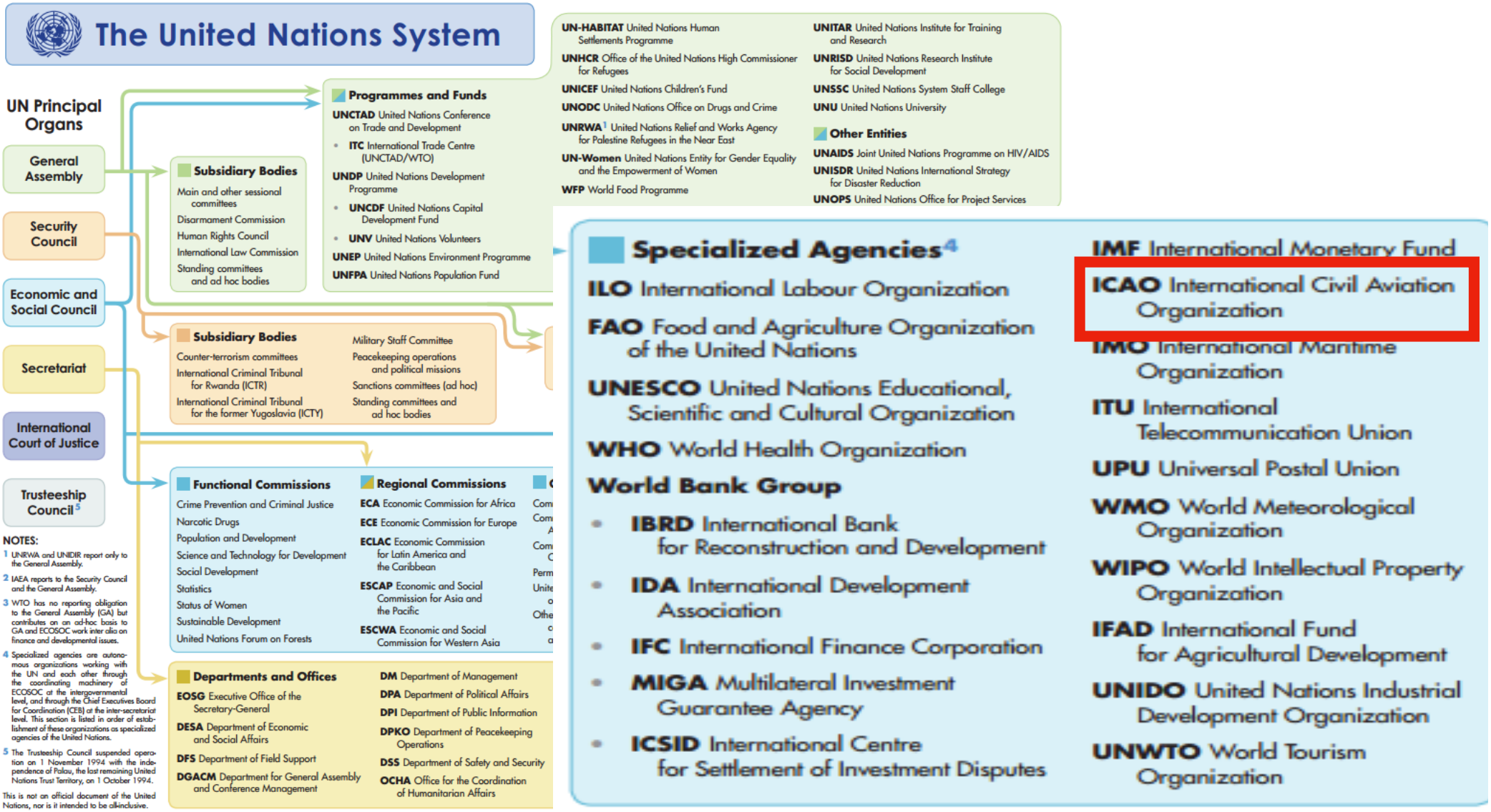
The PECASUS constellation

D. Berghmans, E. De Donder, J. Andries


The United Nations System
UN Principal Organs
General Assembly
Security Council
Economic and Social Council
Secretariat
International Court of Justice
Trusteeship Council[5]
Programmes and Funds
UNCTAD United Nations Conference on Trade and Development
ITC International Trade Centre (UNCTAD/WTO)
UNDP United Nations Development Programme
UNCDF United Nations Capital Development Fund
UNV United Nations Volunteers
UNEP United Nations Environment Programme
UNFPA United Nations Population Fund
UN-HABITAT United Nations Human Settlements Programme
UNHCR Office of the United Nations High Commissioner for Refugees
UNICEF United Nations Children's Fund
UNODC United Nations Office on Drugs and Crime
UNRWA[1] United Nations Relief and Works Agency for Palestine Refugees in the Near East
UN-Women United Nations Entity for Gender Equality and the Empowerment of Women
WFP World Food Programme
UNITAR United Nations Institute for Training and Research
UNRISD United Nations Research Institute for Social Development
UNSSC United Nations System Staff College
UNU United Nations University
Other Entities
UNAIDS Joint United Nations Programme on HIV/AIDS
UNISDR United Nations International Strategy for Disaster Reduction
UNOPS United Nations Office for Project Services
Subsidiary Bodies
Main and other sessional committees
Disarmament Commission
Human Rights Council
International Law Commission
Standing committees and ad hoc bodies
Subsidiary Bodies
Counter-terrorism committees
International Criminal Tribunal for Rwanda (ICTR)
International Criminal Tribunal for the former Yugoslavia (ICTY)
Military Staff Committee
Peacekeeping operations and political missions
Sanctions committees (ad hoc)
Standing committees and ad hoc bodies
Functional Commissions
Crime Prevention and Criminal Justice
Narcotic Drugs
Population and Development
Science and Technology for Development
Social Development
Statistics
Status of Women
Sustainable Development
United Nations Forum on Forests
Regional Commissions
ECA Economic Commission for Africa
ECE Economic Commission for Europe
ECLAC Economic Commission for Latin America and the Caribbean
ESCAP Economic and Social Commission for Asia and the Pacific
ESCWA Economic and Social Commission for Western Asia
Departments and Offices
EOSG Executive Office of the Secretary-General
DESA Department of Economic and Social Affairs
DFS Department of Field Support
DGACM Department for General Assembly and Conference Management
DM Department of Management
DPA Department of Political Affairs
DPI Department of Public Information
DPKO Department of Peacekeeping Operations
DSS Department of Safety and Security
OCHA Office for the Coordination of Humanitarian Affairs
Specialized Agencies[4]
ILO International Labour Organization
FAO Food and Agriculture Organization of the United Nations
UNESCO United Nations Educational, Scientific and Cultural Organization
WHO World Health Organization
World Bank Group
IBRD International Bank for Reconstruction and Development
IDA International Development Association
IFC International Finance Corporation
MIGA Multilateral Investment Guarantee Agency
ICSID International Centre for Settlement of Investment Disputes
IMF International Monetary Fund
ICAO International Civil Aviation Organization
IMO International Maritime Organization
ITU International Telecommunication Union
UPU Universal Postal Union
WMO World Meteorological Organization
WIPO World Intellectual Property Organization
IFAD International Fund for Agricultural Development
UNIDO United Nations Industrial Development Organization
UNWTO World Tourism Organization
NOTES:
1 UNRWA and UNIDIR report only to the General Assembly.
2 IAEA reports to the Security Council and the General Assembly.
3 WTO has no reporting obligation to the General Assembly (GA) but contributes on an ad-hoc basis to GA and ECOSOC work inter alia on finance and developmental issues.
4 Specialized agencies are autonomous organizations working with the UN and each other through the coordinating machinery of ECOSOC at the intergovernmental level, and through the Chief Executives Board for Coordination (CEB) at the inter-secretariat level. This section is listed in order of establishment of these organizations as specialized agencies of the United Nations.
5 The Trusteeship Council suspended operation on 1 November 1994 with the independence of Palau, the last remaining United Nations Trust Territory, on 1 October 1994.
This is not an official document of the United Nations, nor is it intended to be all-inclusive.

International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

Tel.: +1 514-954-8219 ext. 6717

Ref.: AN 10/1-IND/17/11

9 June 2017

Subject: Request for interest in providing a space weather information service

Action required: Comments to reach Montréal by 8 September 2017

Sir/Madam,

3. To assist ICAO in the designation of space weather information providers, the World Meteorological Organization (WMO) has been invited to assess each potential candidate State through site visits and audits. It is important to note that each potential candidate State must cover the expenses related to the site visits and audits.

4. It is also important to note that the Air Navigation Commission highlighted the need for a Provider State and its associated space weather centre(s) (SWXC) to arrange for the provision of a contingency service to ensure the continuity of service in the event of a service interruption. In this regard, a space weather information provider in one State with one SWXC could designate its backup centre within its own political boundaries, or in another State. Backup centres must also be audited and the expenses related to the site visits and audits must also be covered by the potential candidate State.

5. It should also be noted that the Guidance on Criteria for Space Weather Information Providers (see attachment), and consequentially applications to be considered as a service provider, may be met by a single entity or a consortium of multiple space weather information providers with appropriate arrangements for coordination and harmonization.

6. May I request that, if your State is interested in providing a space weather information service (as described in SL AN 10/1-17/41, Attachment B, Initial Proposal 1) in any of the ways described in paragraph 5, a formal expression of interest be dispatched to reach me at your earliest convenience and, in any case, not later than **8 September 2017**. The Air Navigation Commission has asked me to specifically indicate that, in view of the established timeline for the process outlined in the Schedule for Establishing Space Weather Information Capability (see attachment), expressions of interest in the provision of the service received after the due date may not be considered by the Commission and the Council. After reception of the expressions of interest, the subsequent work of the Air Navigation Commission and the Council would be in accordance with the schedule.

Accept, Sir/Madam, the assurances of my highest consideration.

Fang Liu
Secretary General

ICAO calls for a global space weather service

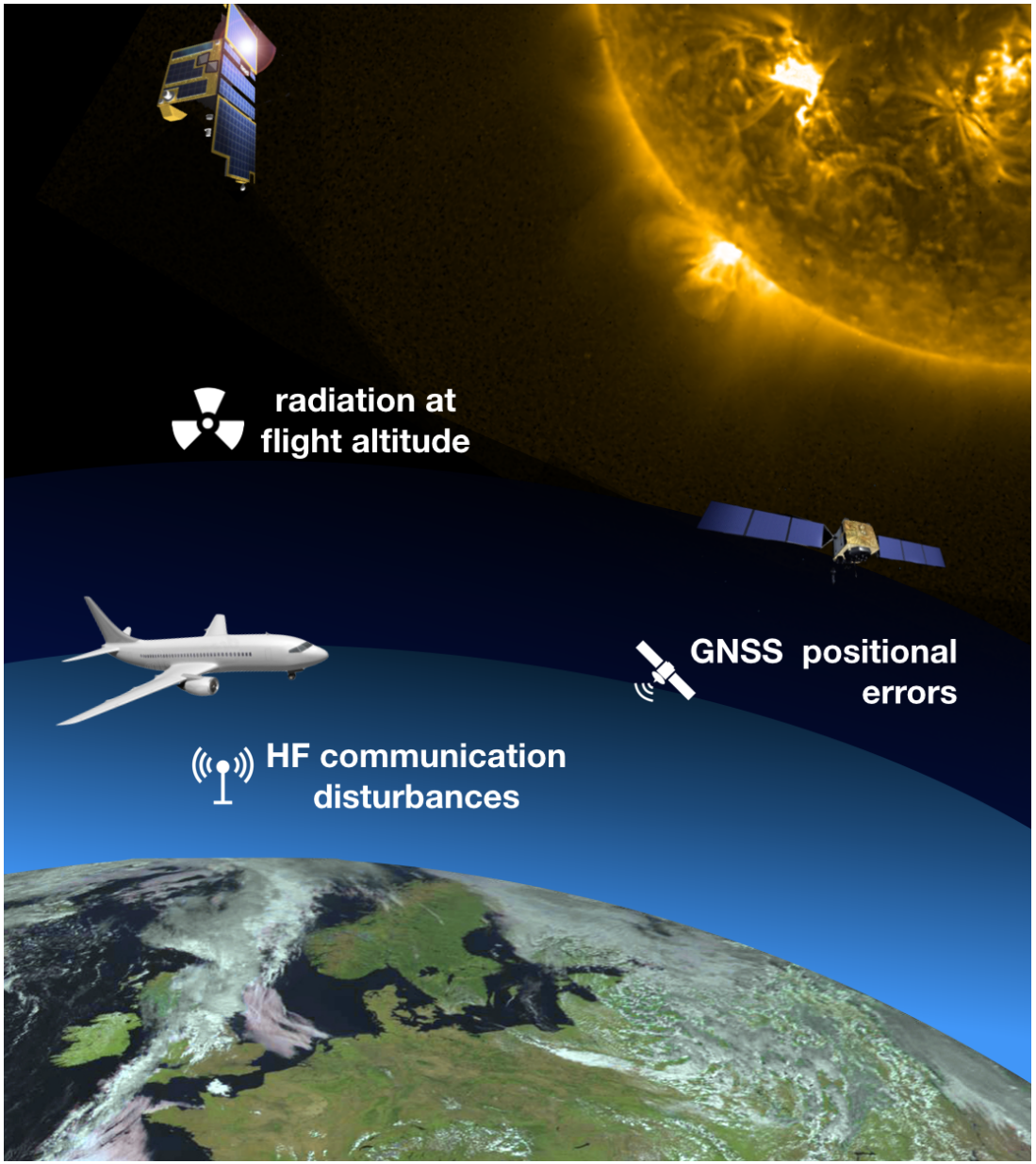
proposers will be audited by WMO

contingencies and back-ups

single entities or consortium

a space weather information service

deadline Sept 8 2017



International Civil Aviation Organisation

SWX ADVISORY		
DTG:	20170818/020304Z	*time of generation*
SWXC:	PECASUS	*space weather center*
ADVISORY NR:	2017/314	*sequence nr*
SWX EFFECT	HF COM SEV	*impact MOD or SEV*
OBS SWX	20170818/015520Z	*observed time of flare*
	DAYLIGHT SIDE	*affected area*
FCST SWX +6HR:	NO SWX EXP	*forecast*
FCST SWX +12HR:	NO SWX EXP	*forecast*
FCST SWX +18HR:	NO SWX EXP	*forecast*
FCST SWX +24HR:	NO SWX EXP	*forecast*
RMK:	Solar flare occurred. Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.	
NXT ADVISORY:	NO FURTHER ADVISORIES	

An STCE response

- None of our institutes can do it alone: ROB: Solar & GNSS, BIRA: radiation, KMI: 24h operations & Dourbes
- STCE executive committee (2017 June 15):
  “If we don’t do this, then why does the STCE exist?”
- STCE steering committee
  “Agreed that is a first priority for STCE”
- RMI/Daniel Gellens
  “24h operations can be supported by RMI weather room”

Partners?

Belgocontrol

DG Luchtvaart

NOAA

belspo

Solar-Terrestrial Centre of Excellence

ISES International Space Environment Service

European Commission

EASA European Aviation Safety Agency

EUROCONTROL

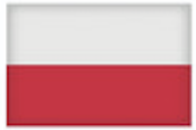
esa space situational awareness


Italy


Netherlands


United Kingdom


Austria


Poland

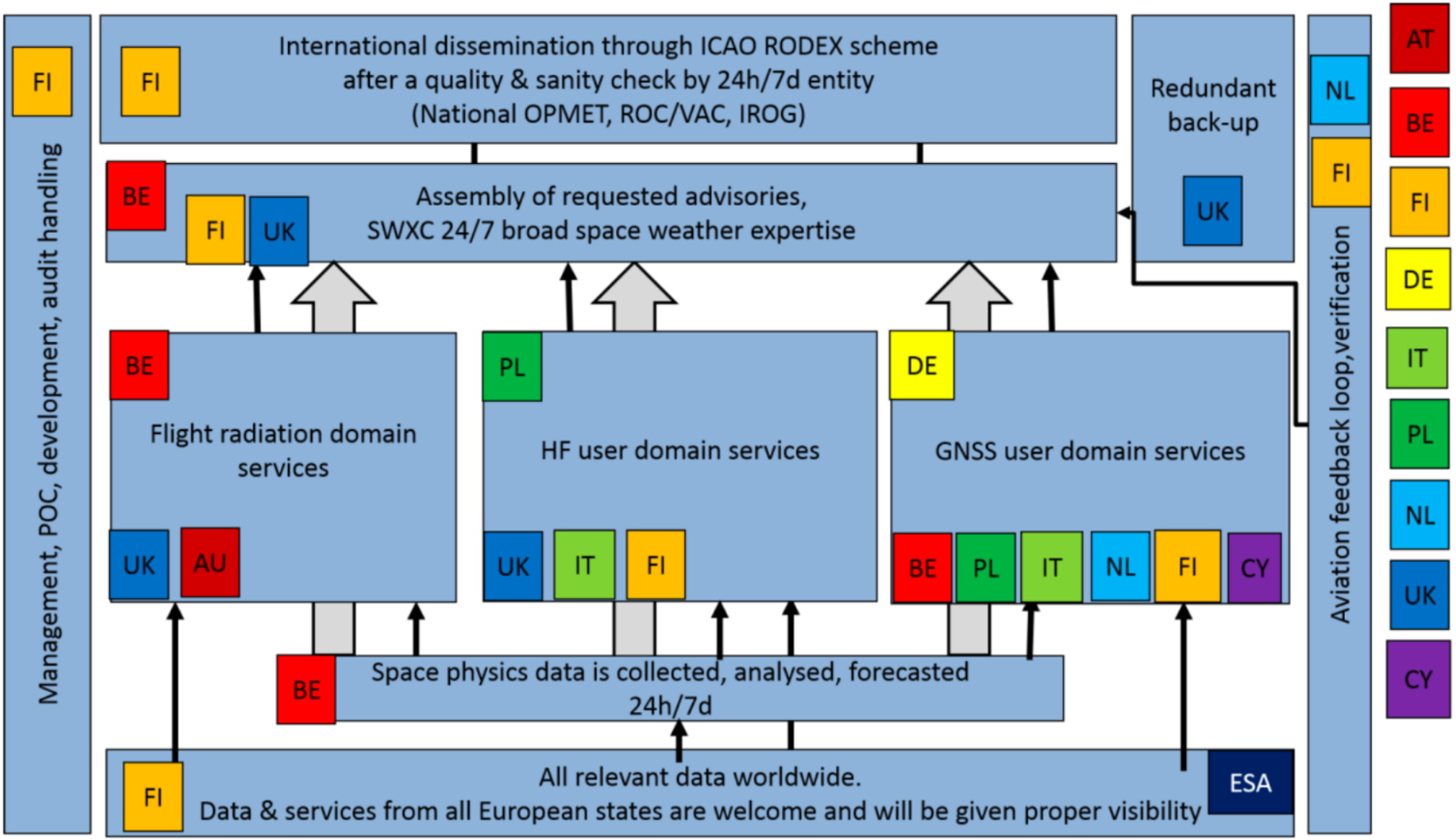

Germany

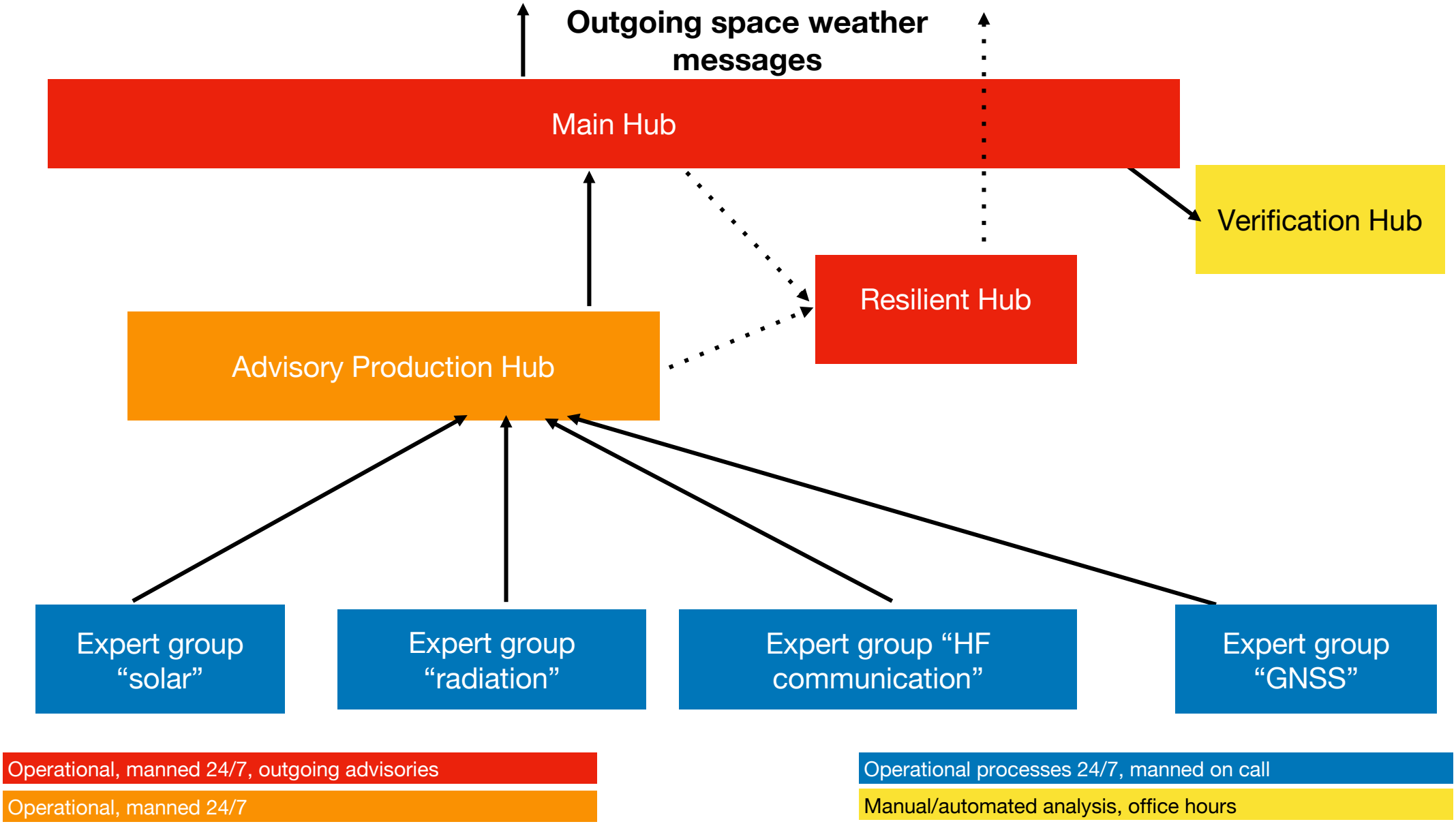

Finland

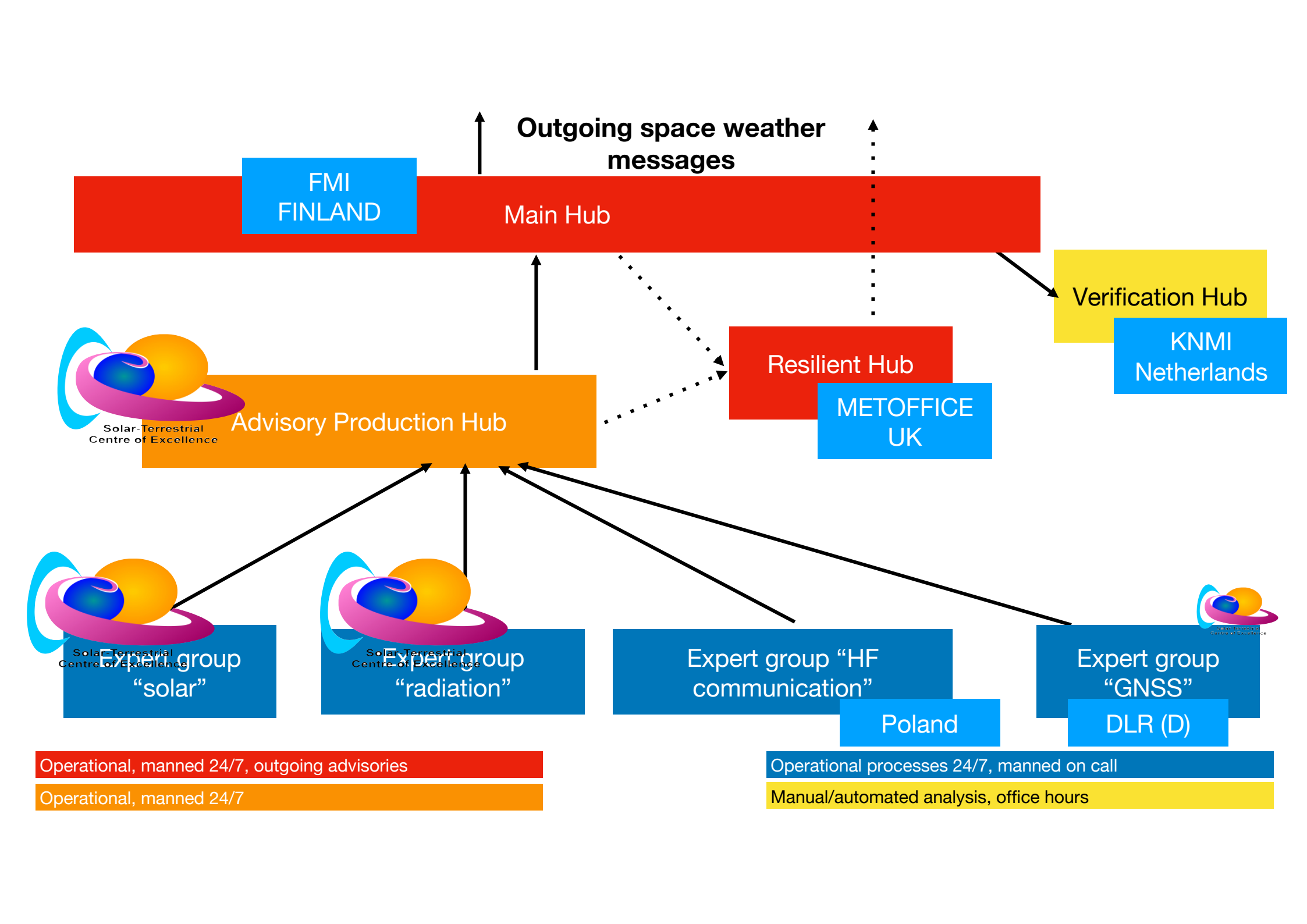

France

Partners?


Belgocontrol
DG Luchtvaart
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
belspo
Solar-Terrestrial
Centre of
Excellence
ISES
International Space
Environment Service
European
Commission
EASA
European Aviation Safety Agency
EUROCONTROL
esa
space situational awareness
Italy
Netherlands
United
Kingdom
Austria
Poland
Germany
Finland
France


FI
Management, POC, development, audit handling
FI
International dissemination through ICAO RODEX scheme
after a quality & sanity check by 24h/7d entity
(National OPMET, ROC/VAC, IROG)
Redundant
back-up
UK
NL
FI
Aviation feedback loop,verification
BE
FI
UK
Assembly of requested advisories,
SWXC 24/7 broad space weather expertise
BE
Flight radiation domain
services
UK
AU
PL
HF user domain services
UK
IT
FI
DE
GNSS user domain services
BE
PL
IT
NL
FI
CY
BE
Space physics data is collected, analysed, forecasted
24h/7d
FI
All relevant data worldwide.
Data & services from all European states are welcome and will be given proper visibility
ESA
AT
BE
FI
DE
IT
PL
NL
UK
CY


Outgoing space weather messages
Main Hub
Verification Hub
Resilient Hub
Advisory Production Hub
Expert group "solar"
Expert group "radiation"
Expert group "HF communication"
Expert group "GNSS"
Operational, manned 24/7, outgoing advisories
Operational, manned 24/7
Operational processes 24/7, manned on call
Manual/automated analysis, office hours


Outgoing space weather messages
FMI FINLAND
Main Hub
Verification Hub
KNMI Netherlands
Resilient Hub
METOFFICE UK
Solar-Terrestrial Centre of Excellence
Advisory Production Hub
Solar-Terrestrial Centre of Excellence
Expert group "solar"
Solar-Terrestrial Centre of Excellence
Expert group "radiation"
Expert group "HF communication"
Poland
Expert group "GNSS"
DLR (D)
Operational, manned 24/7, outgoing advisories
Operational, manned 24/7
Operational processes 24/7, manned on call
Manual/automated analysis, office hours

Successful audit

WORLD METEOROLOGICAL ORGANIZATION

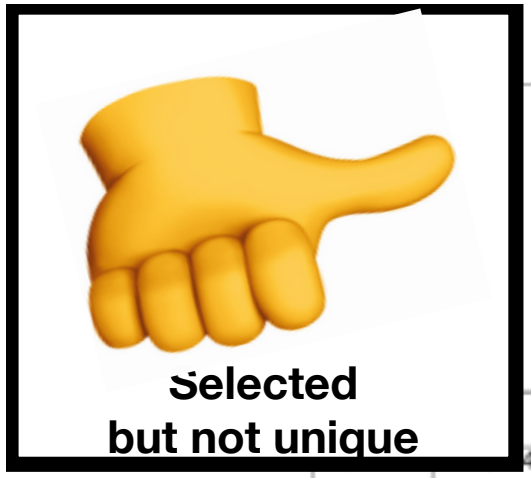
OSPECTIVE SPACE WEATHER INFORMATION PROVIDER

POST-AUDIT REPORT – PECASUS

e weather provider:	Pan-European Consortium for Aviation Space Weather User Services (PECASUS)
Prospective space weather centre (primary):	Finnish Meteorological Institute (FMI)
Prospective space weather centre (backup): (where applicable)	United Kingdom Met Office Space Weather Operational Centre (MOSWOC)
Date and location of site assessment(s) and audit(s):	12 - 14 February 2018, Helsinki, Finland and 16 February 2018, Exeter, United Kingdom

The PECASUS consortium has found to be compliant in all respects by the audit team. The consortium produced sufficient evidence to satisfy the auditors that the global service they propose to offer will comply with the requirement laid out by ICAO.

Of particular note, FMI, the UK Met Office and the STCE are already very experienced providers of space weather services, nationally and within Europe, and have strong relationships with operational centres such as SWPC (USA) and the research and academic communities to ensure they remain at the forefront of the science.



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4-954-8219 ext. 7079

Ref.: AN 10/1 – IND/18/9

21 December 2018

Subject: Designation of provider States of space weather information

Action required: a) to note the information provided; and b) reply by 15 January 2019

Sir/Madam,

1. I have the honour to inform you that the Council, at the seventh meeting of its 215th Session held on 13 November 2018, reviewed a proposal presented by the Air Navigation Commission for the establishment of a global space weather information service in accordance with the relevant Standards and Recommended Practices (SARPs) of Annex 3 — *Meteorological Service for International Air Navigation*, which became applicable on 8 November 2018.

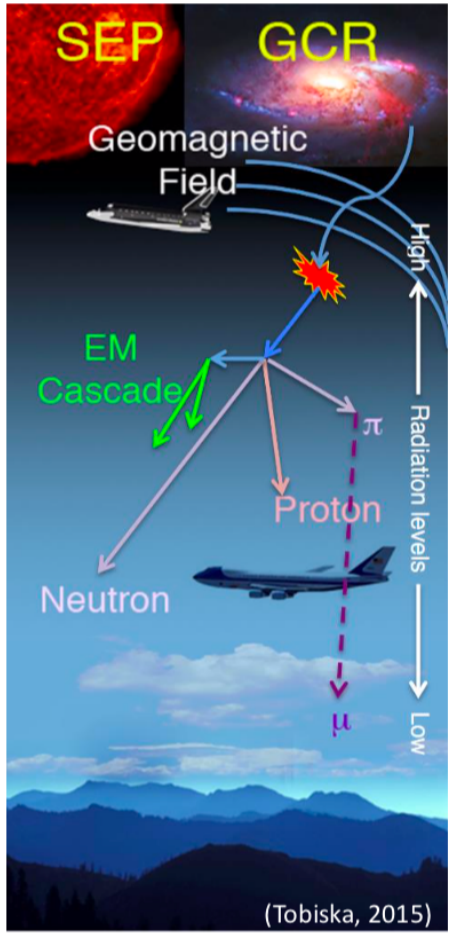
2. In this regard, I am pleased to inform you that the Council decided that the ACFJ consortium (formed by Australia, Canada, France and Japan), the PECASUS consortium (formed by Austria, Belgium, Cyprus, Finland, Germany, Italy, Poland, Netherlands and United Kingdom), and the United States will serve as global space weather information service providers on the understanding that the space weather information services would be provided at no cost to the aviation user community for the first three years of operation. It also agreed that two regional centres, comprising the China/Russian Federation consortium and South Africa, be established no later than November 2022. An extract from C-DEC 215/7 is provided in the attachment.

Radiation Group

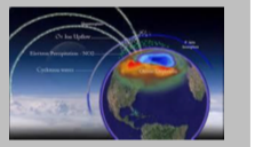
(E. De Donder – M. Dierxcksens – S. Calders)

(M. Latocha, P. Beck)

Aviation radiation sources - impacts



- GCRs (global)
- **Extended major SEP events** (**p^+, high latitude**)
- Short-term minor events precipitating outer radiation belt (e^-, high latitude)

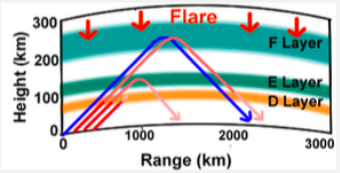


- Instantaneous minor events terrestrial gamma-ray flashes (TGFs)

↑Radiation dose

Communication

HF disruption



Avionics

SEUs, EMI

Main tasks of the EG RADIATION

Delivery of products (in quasi real-time) for the production of "Radiation Advisories" and alerting on-duty operator

- SEP/GLE event forecasts
- Dose rate nowcasts at flight level

→ Operational (24/7) on basis of automated process
→ On call system support and (scientific) expert support

+ maintenance product manual, coordination, contribution to training, …

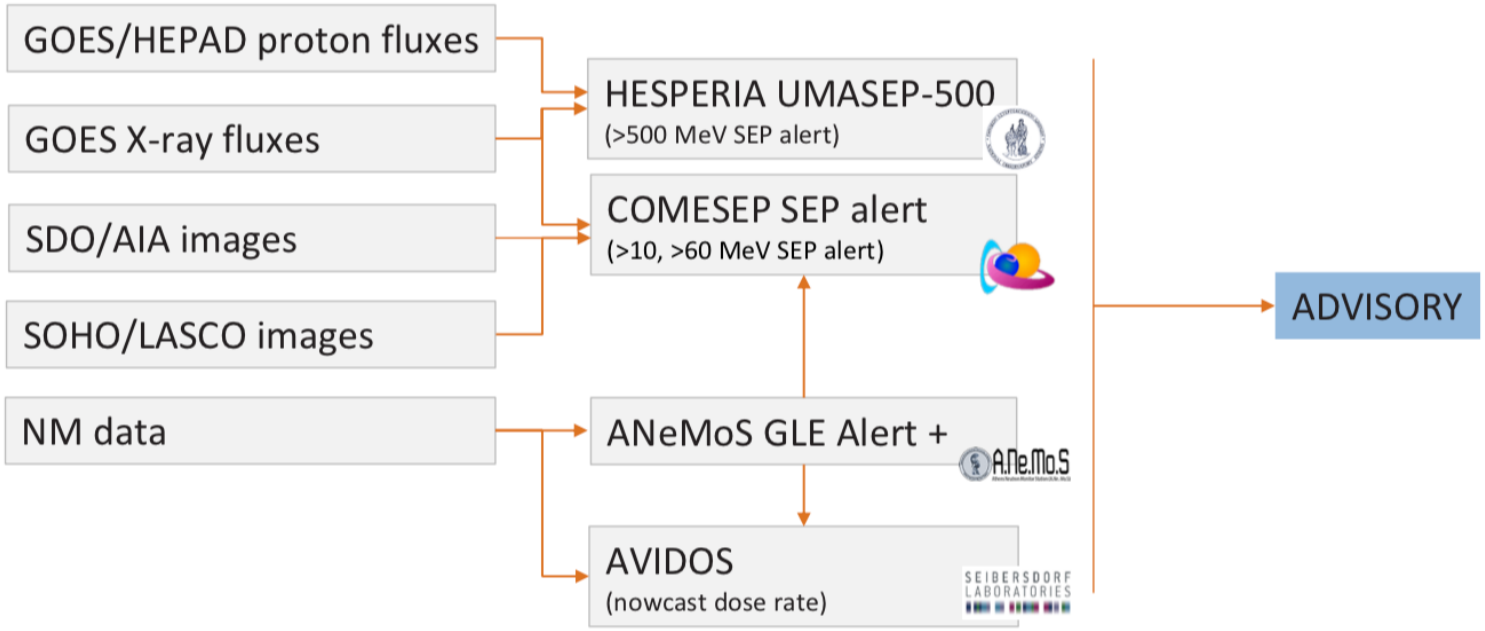
Why us?

- Expertise in space particle radiation environments & effects (COMESEP, SEPEM, HESPERIA, SPENVIS, …)

- ESA SSA Space Weather Service Network
  - Expert Service Centre for Space Radiation *(R-ESC)*
    - ✈Service to Airlines
    - ✈SEIBERSDORF = EG for dose rate (AVIDOS)
  - SSA Space weather Coordination Centre *(SSCC)*
    - ✈ Aviation User support test campaign

Advisory workflow

(observations – statistics – models)



Radiation thresholds - advisories

Communication header	
SWX ADVISORY	
DTG:	20120517/0300Z
SWXC:	PECASUS
SWX EFFECT:	RADIATION MOD
ADVISORY NR:	2012/2
OBS/FCST SWX:	20120517/0300Z HNH HSH E18000-W18000 ABV FL350
FCST SWX + 6 HR:	20120517/0900Z HNH HSH E18000-W18000 ABV FL350
FCST SWX + 12 HR:	20120517/1500Z HNH HSH E18000-W18000 ABV FL350
FCST SWX + 18 HR:	20120517/2100Z NO SWX EXP
FCST SWX + 24 HR:	
RMK:	RADIATION AT AIRCRAFT ALTITUDES ELEVATED BY SMALL ENHANCEMENT JUST ABOVE PRESECRIBED THRESHHOLD. DURATION TO BE SHORT-LIVED. SEE WWW.PECASUS.EU.
NXT ADVISORY:	NO FURTHER ADVISORIES

MOD	SEV
30-80 (µSv/hr)	>80 (µSv/hr)

year, month, day, time in UTC

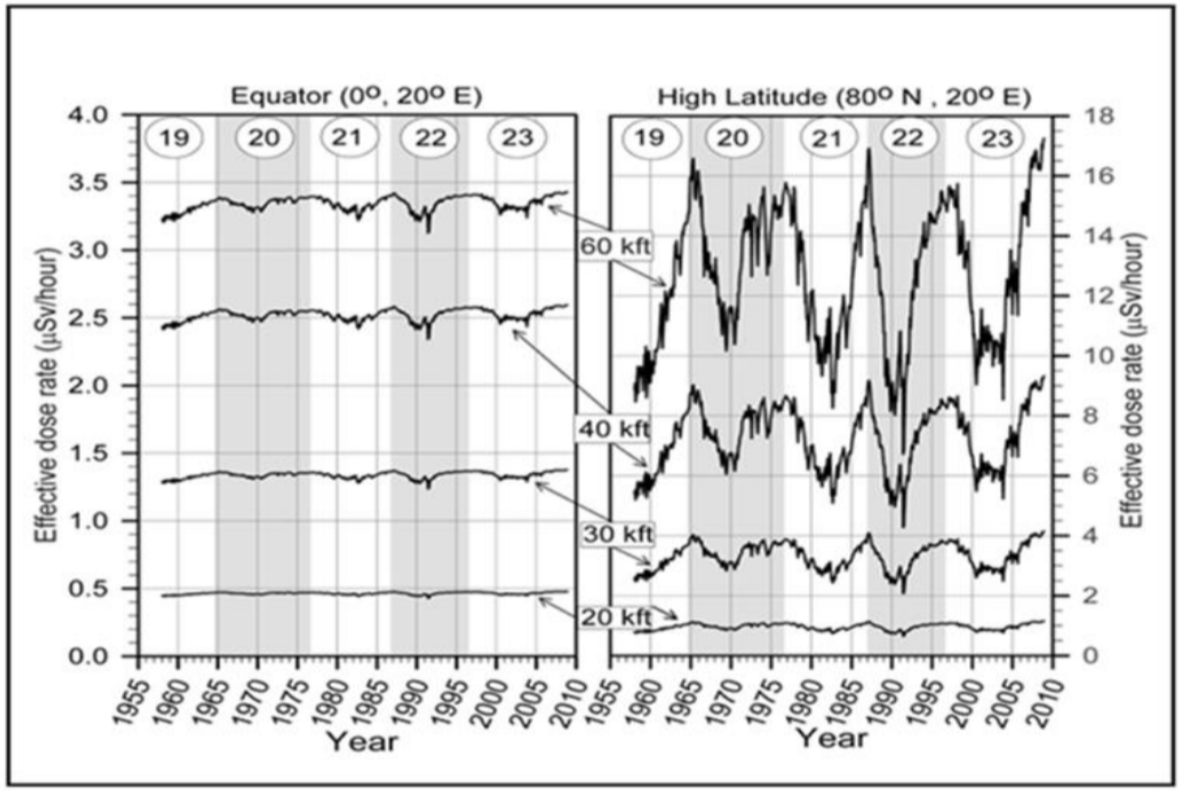
region: lat-lon bands

altitude in flight level

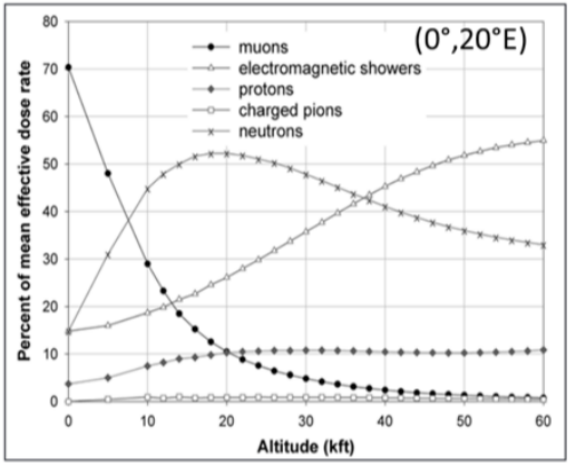
(FL350 = 35,000 feet above mean sea level when the pressure at sea level is 1013.2 mb
~ 11 km)

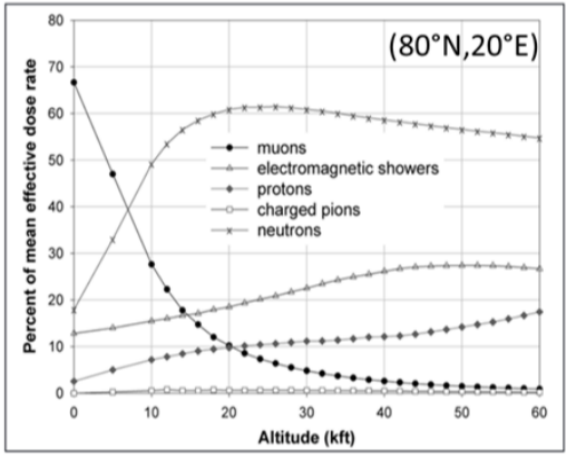
"Apparently, flying no higher than 1,000 feet saves air travelers from the perceived ravages of cosmic radiation."

Effective dose rate calculations



(Friedberg&Copeland, 2011)





Effective dose rate calculations

GLE	Date	Max. E [μSv h^{-1}]	E_{GCR} [μSv h^{-1}]
5	23.02 1956	2977	6.9
8	04.05 1960	57.3	5.0
10	12.11 1960	12.1	5.2
11	15.11 1960	140.5	5.2
13	18.07 1961	13.7	5.4
16	28.01 1967	15.8	6.4
19	18.11 1968	11.4	5.3
22	14.01 1971	25.1	6.2
25	07.08 1972	7.8	6.4
29	24.09 1977	8.8	7.3
30	22.11 1977	15.5	7.7
31	07.05 1978	35.4	6.4
32	23.09 1978	8.1	7.2
38	08.12 1982	22.4	4.7
39	16.02 1984	13.5	6.1
41	16.08 1989	10.8	5.0
42	29.09 1989	92.7	4.8
43	19.10 1989	41.9	4.5
44	22.10 1989	92.5	4.5
45	24.10 1989	61.0	4.5
47	21.05 1990	12.0	4.3
48	24.05 1990	17.0	4.3
51	11.06 1991	6.0	3.5
52	15.06 1991	11.2	3.5
55	06.11 1997	19.9	7.5
59	14.07 2000	48.1	4.9
60	15.04 2001	51.3	5.3
61	18.04 2001	9.0	5.3
65	28.10 2003	12.4	5.4
67	02.11 2003	15.6	4.6
69	20.01 2005	3592	5.9
70	13.12 2006	78.2	7.4
71	17.05 2012	32.9	7.2

(Tuohino et al., 2018) - 35 kft

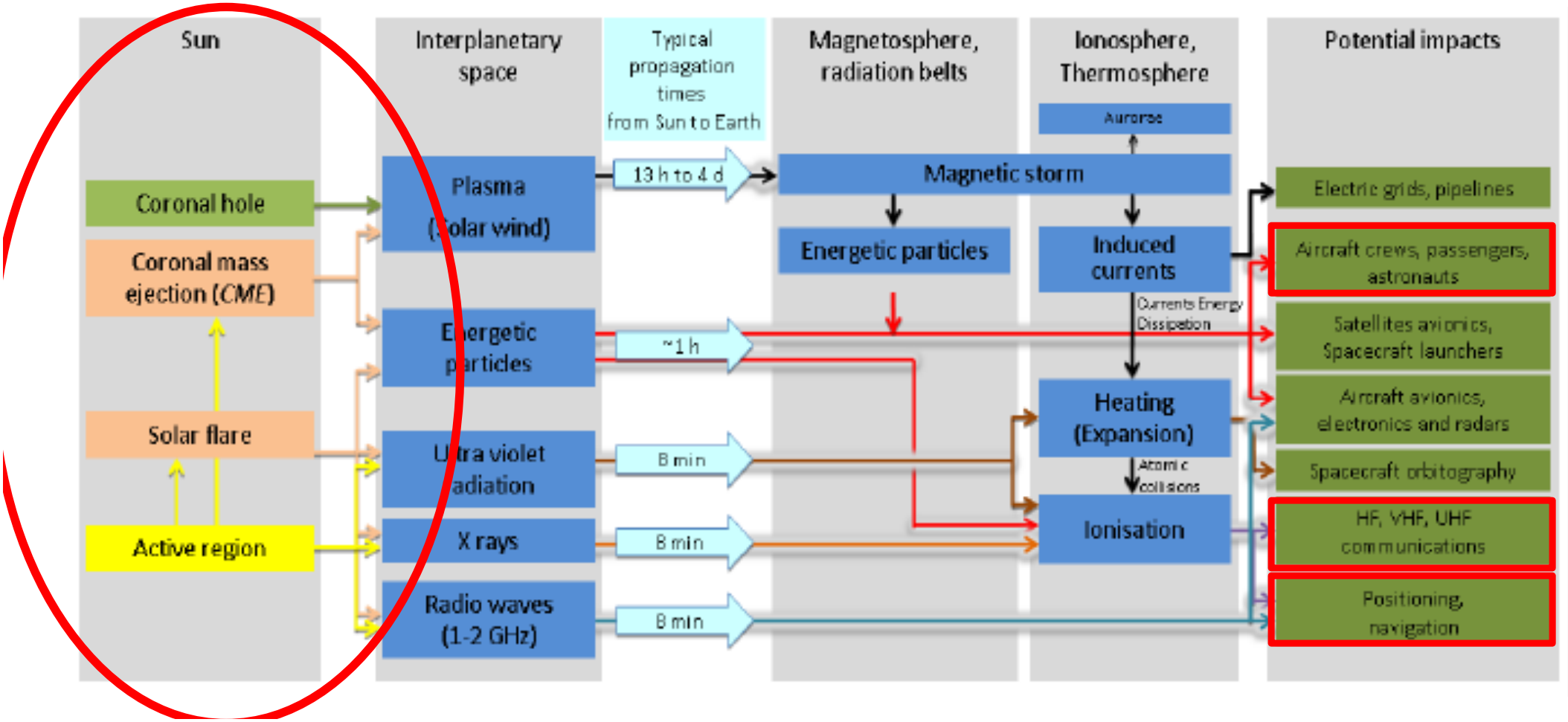
Average Effective Dose Rates From Galactic and Solar Cosmic Rays During GLE 72 on 10–12 September 2017, as Calculated by MIRA and PANDOCA

Vertical cutoff rigidity (GV)	Altitude (km [ft × 1,000])	MIRA (μSv/hr)		PANDOCA (μSv/hr)		GCR percent difference[a] (%)
		GCR	SEP	GCR	SEP	
0.01	10.7 (35)	6.32	0.79	5.39	0.47	−14.79
	12.2 (40)	8.25	1.25	7.21	0.94	−12.58
	15.2 (50)	12.72	3.75	10.60	3.04	−16.54
	21.3 (70)	24.01	18.16	—	16.80	
1	10.7 (35)	6.24	0.22	5.38	0.18	−13.80
	12.2 (40)	8.15	0.33	7.20	0.32	−11.64
	15.2 (50)	12.54	0.77	10.56	0.94	−15.52
	21.3 (70)	23.50	2.69	—	3.23	
2	10.7 (35)	5.88	0.06	5.13	0.02	−12.76
	12.2 (40)	7.61	0.09	6.75	0.04	−11.26
	15.2 (50)	11.45	0.15	9.50	0.06	−17.38
	21.3 (70)	20.54	0.24	—	0.08	
3	10.7 (35)	5.29	0.02	4.57	0.00	−13.69
	12.2 (40)	6.78	0.02	5.91	0.01	−12.86
	15.2 (50)	9.85	0.04	8.03	0.01	−18.48
	21.3 (70)	16.35	0.05	—	0.01	
4	10.7 (35)	4.72	0.01	3.99	0.00	−15.40
	12.2 (40)	5.98	0.01	5.10	0.00	−14.77
	15.2 (50)	8.43	0.01	6.75	0.00	−19.95
	21.3 (70)	13.17	0.02	—	0.00	

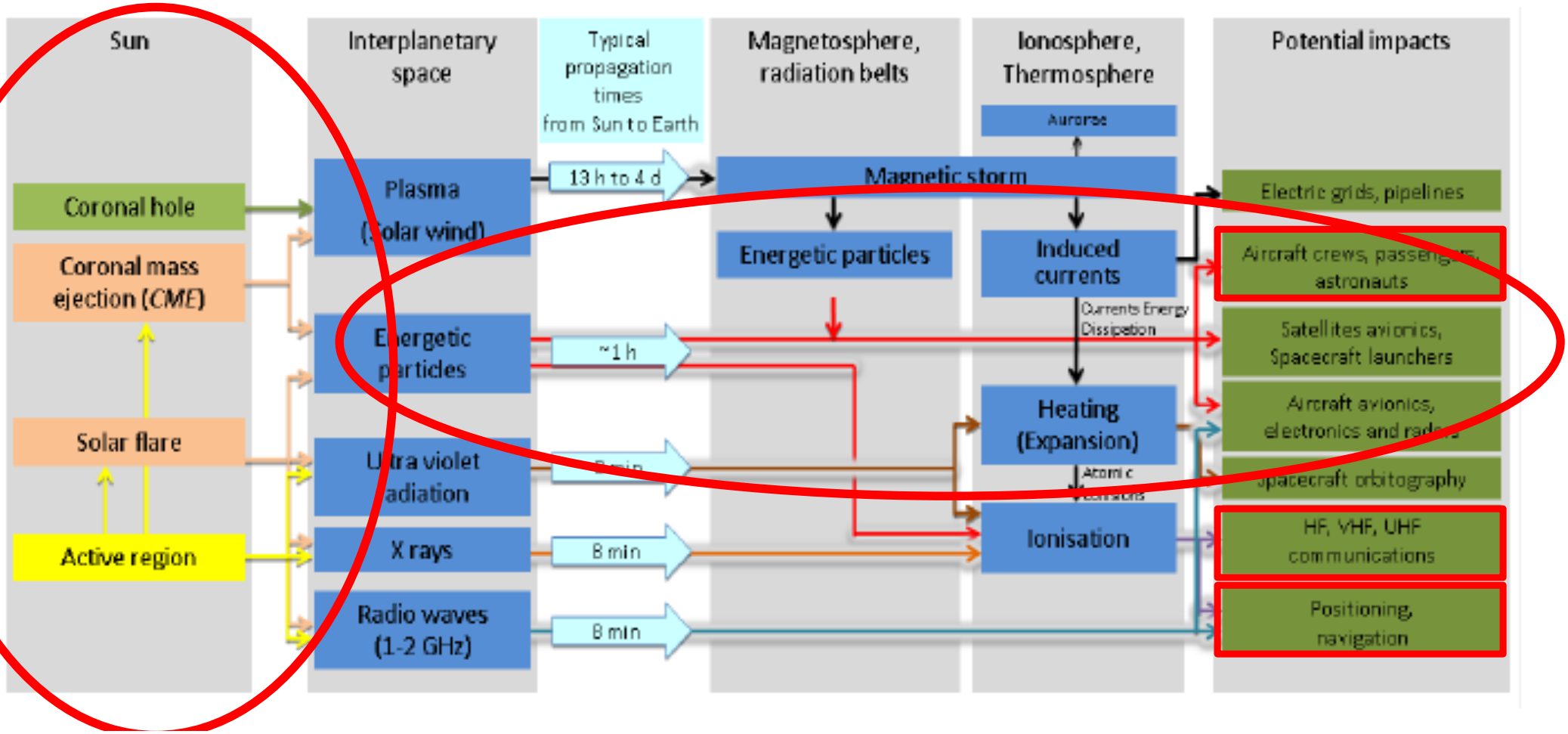
(Copeland et al., 2018)

Advisory hub and Solar Weather

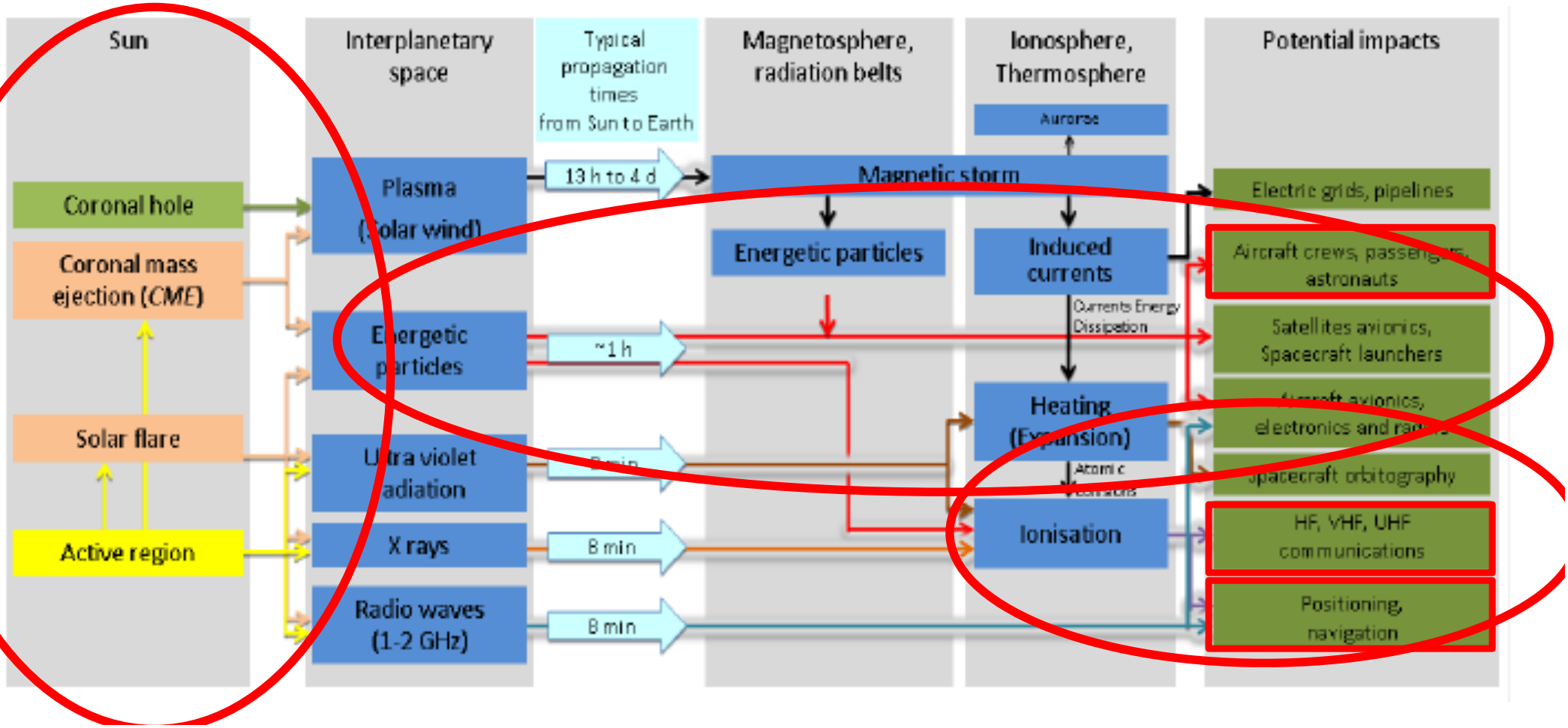
Causal event chains



Causal event chains



Causal event chains



Advisory Production = extension of existing Regional Warning Centre

ISES International Space environment Services
- ROB = Belgian RWC since 2000
- RWC > Solar Weather

Current RWC staffing:
- 8 forecasters in weekly shifts (not full time occupation when on duty). All are contractual collaborators who already have a full time job in their respective projects
- 1FTE on STCE envelope + 1FTE statutory (but 1.5FTE of these effectively also manage and deliver most of the ESA-SWE ESCSOLAR project of 500kEUR/y -> effective 270 kEUR for ROB)

→ STCE decision to participate in PECASUS implies
- Extension of tasks
- Increase in operational capability
- Transition to 24/7 operations (support from RMI was decided under STCE)

ICAO METP SWXCWG

- Ad-hoc group within the ICAO METPanel Space Weather workstream to coordinate the setup of the three global centres
- F2F meeting in Melbourne 2/2019 → overall implementation timeline
- (bi)-weekly meetings to follow-up implementation

Highlights

- Advisory cookbook (due 3/2019, draft ready 5/2019)
- Test runs to test output consistency across 3 SWXC (due 5/2019, ….)
- Dry-run operation (due to start 8/2019)
- Fully operational: 8/11/2019

Advisory Production Hub status

Advisory editor with automated submission to FMI (=PECASUS dissemination hub)

- In development (dependencies on cookbook)

Data gathering repository

- Several essential data feeds missing due to slow reaction by PECASUS members and lack of ROB staff devoted to manage this and chase them up

Procedures for RWC forecaster

- In development (dependencies on cookbook; data repository, interaction with RMI for 24/7, dashboards)

Dashboards

- In development (dependencies on cookbook; data repository)

Procedures for interaction with RMI on 24/7

- To be developed

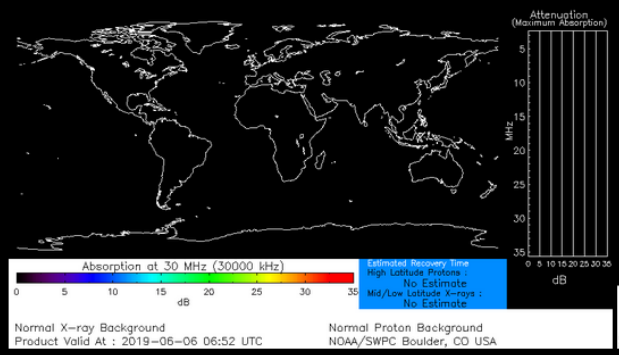
Jun 6, 2019
06:55:36 UTC

- MAIN
- GNSS
- RADIATION
- HF
- SATCOM
- ARCHIVE
- RWC

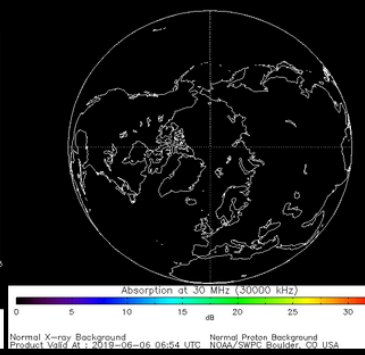
HF Space weather advisory	Moderate	Severe	Current Values	Current Status
Auroral Absorption (Kp)	8	9	2	QUIET
PCA (dB from 30MHz Riometer data)	2	5	????	Not operational
Solar X-rays (0.1 - 0.8 nm)(W/mÂ²)	X1.0	X10.0	Quiet	QUIET
Post-Storm Depression (MUF)	30%	50%	????	Not operational

Kp-index (Potsdam)	Kp-index (NOAA)	K-index (Dourbes)
0.7	1	3

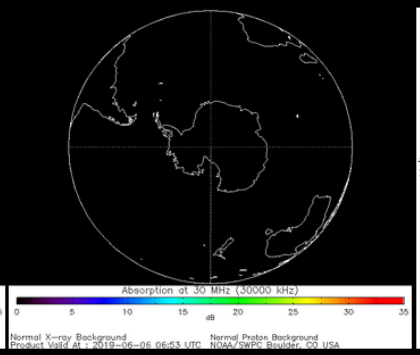
D-RAP (NOAA) Global 30 MHz



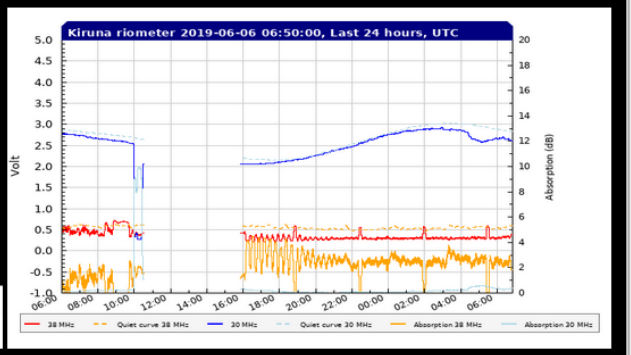
D-RAP (NOAA) North Polar 30 MHz



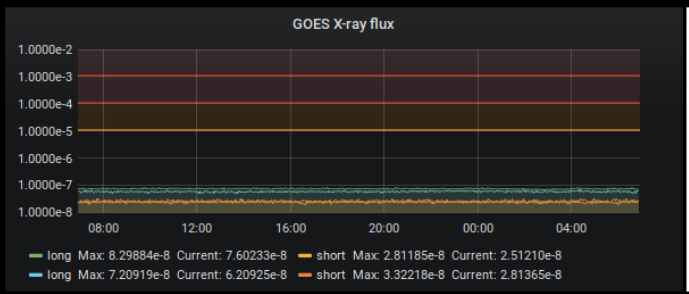
D-RAP (NOAA) South Polar 30 MHz



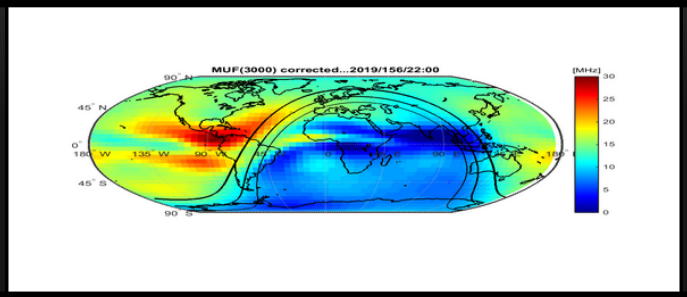
PCA (dB from 30MHz Riometer data) !!! Not working !!!



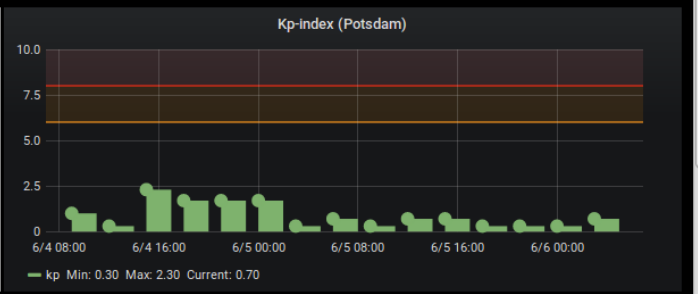
Solar X-rays (0.1 - 0.8 nm)(W/m2)



Post-Storm Depression (MUF) !!! Not working !!!



Auroral Absorption (Kp)



Other products

Kp-index (NOAA)	K-index (Doubes)