国立研究開発法人
情報通信研究機構

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Science and Technical Sub Committee
Committee on the Peaceful Uses of Outer Space (UN/COPUOS)

Update of Japanese Activities for Operational Space Weather Services

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Consideration of Space Weather Alert Criteria

https://www.soumu.go.jp/main_content/000809610.pdf (written in Japanese)

Background

- The importance of space weather forecasting for stable operation of social infrastructures is increasing, and outside of Japan, such as in the United States, there is a growing movement to prepare for social risks of space weather, such as evaluation of social impacts and announcement of national strategies.
- In Japan, as one of the activities of the Grant-in-Aid for Scientific Research on Innovative Areas "PSTEP*" (2015-2019), the scale of space weather phenomena and their social impact on Japan were examined and summarized.
  *PSTEP : Project for Solar-Terrestrial Environment Prediction (https://www.isee.nagoya-u.ac.jp/pstep/)
- Although **the current alert criteria focus on the magnitude of the phenomena**, a forecasting and alert based on the social impact is necessary for users of space weather forecasting to determine specific responses.
- **The Ministry of Internal affairs and Communication (MIC) established “Committee for the advancement of space weather forecast” in Jan. 2022 and publish a report on June 21.**
- **Under this committee, WG established for considering new alert types and criteria that also take into account the magnitude of social impact caused by space weather**.

Items for Consideration

- Forecasting and alert types and criteria in the following field:
  Communications and Broadcasting, Positioning, Satellite Operations, Electric Power, Aircraft Exposure.

Meetings

- Three plenary meetings and 2-6 subgroup meetings for each field were held from January to April 2022.

Members

- Twenty-seven experts from Japanese research institutes/universities, companies, government agencies, and general associations participated as WG members.

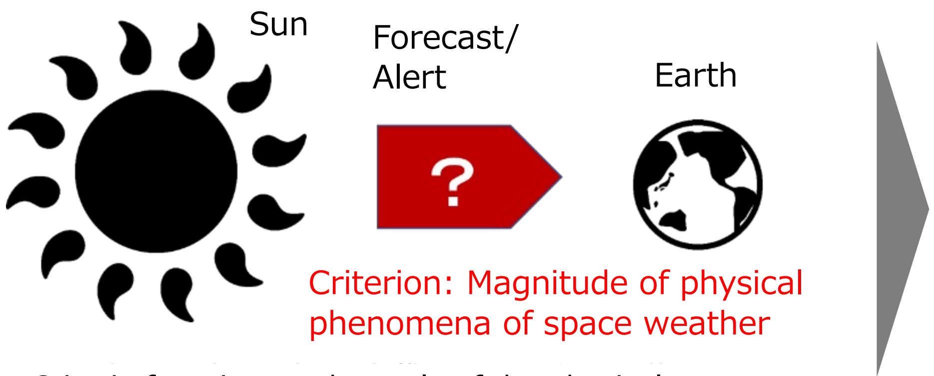
Introduction of new forecasting and alert criteria that take into account social impacts

○The purpose of space weather forecasting is to reduce the risks posed to social infrastructure by understanding and predicting hazards.

○Therefore, similar to the relationship between "magnitude" and "seismic intensity/tsunami warning" in earthquakes and tsunamis, forecasts and alerts should focus not only on the scale of physical phenomena of space weather, but also on the risk (damage) to social infrastructure.

○For this reason, new types and criteria of forecasts and alerts that take into account the social impact of space weather phenomena were considered. As a result, a total of 17 categories of forecasts and alerts were established in five fields, and criteria were developed for 12 of them.

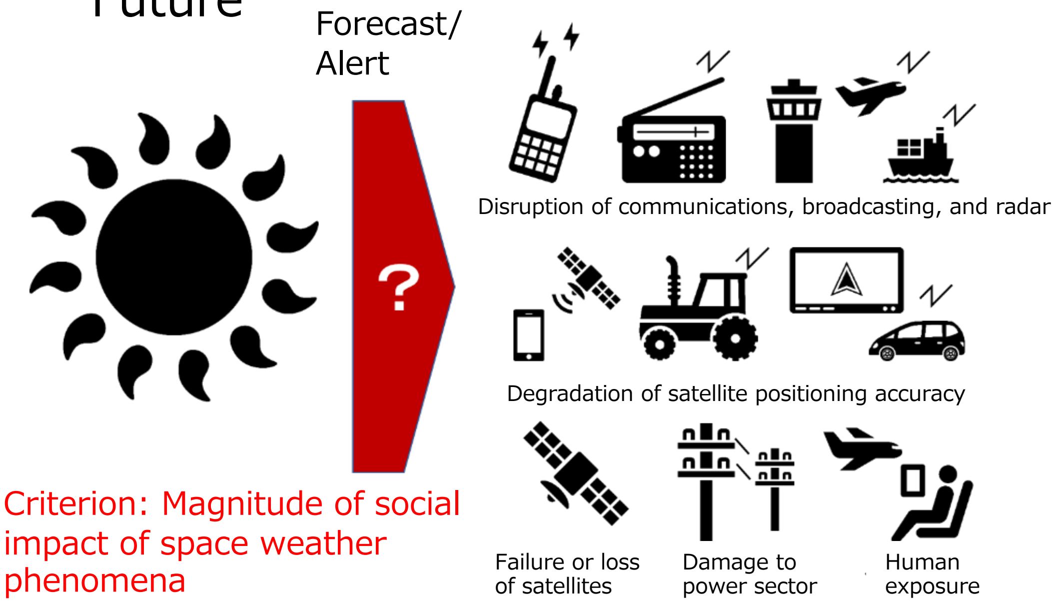
Now



Criterion: Magnitude of physical phenomena of space weather

- Criteria focusing on the scale of the physical phenomenon aspect of space weather (e.g., the amount of solar energetic particles, etc.)
- Difficult to intuitively understand the degree of danger of impacts on social infrastructure
- The presented information is academic in nature with technical terminology, making it difficult for the general public and media to immediately understand its meaning

Future



Criterion: Magnitude of social impact of space weather phenomena

- Easily understand the hazard posed by space weather phenomena
- Immediate understanding of the meaning of alerts by the general public and news media

Criteria for Communications and Broadcasting

- The PSTEP report classifies ionospheric or radio disturbance phenomena by type (ionospheric negative phase storms, radio blackouts, polar cap absorption, and plasma bubbles). Based on this, the types and thresholds of warnings and their social impacts were examined.
- In addition to the HF to VHF bands, the social impact of the UHF band (satellite communications) was added.
- Thresholds were established by considering international standards operated by ICAO, the U.S. NOAA, and the UKMO in the UK.
- Five alert criteria and thresholds were set for three of the criteria. Thresholds for the remaining two criteria were left for future study.

🟩 Negligible impact 🟨 Potential impact requiring appropriate action 🟥 Potentially serious impact that makes it difficult to continue operation

Impact and damage	Space weather phenomena / physical quantities that can cause damage	Social impacts and criteria		
		Lv 1	Lv 2	Lv 3
UHF band (satellite communication) **Radio intensity attenuation and scintillation**	**Plasma bubble**	🟩	**Threshold:** ROTI, S4, etc. (TBD) **Social Impact:** Scintillation beyond the fade margin of the L-band satellites may occur during nighttime in the low latitude.	**Threshold:** ROTI, S4, etc. (TBD) **Social Impact:** Scintillation beyond the fade margin of the L-band satellites frequently occurs during nighttime in the low-latitude and may also affect in the mid latitude.
VHF band **Communication quality degradation (radio intensity attenuation)**	**Sporadic E layer**	🟩	**Threshold:** foEs (TBD) **Social Impact:** Radio waves from outside the line-of-sight range may cause interference.	**Threshold:** foEs (TBD) **Social Impact:** Frequent radio interference from outside the line-of-sight range.
HF band **Radio intensity attenuation**	**Polar cap absorption**	🟩	**Threshold:** Proton (>10 MeV) 1,000 PFU or more **Social Impact:** Significant radio absorption occurs in high latitude areas (above 55 degrees) and continues for about two days.	**Threshold:** Proton (>10 MeV) 100,000 PFU or more **Social Impact:** Significant radio wave absorption occurs at high latitudes (above 52 degrees) and continues for about 3 days.
HF band **Radio intensity attenuation**	**Radio blackout**	🟩	**Threshold:** X1 flare **Social Impact:** Wide absorption of radio waves on the day side, making the low frequency band unusable.	**Threshold:** X10 flare **Social Impact:** The entire HF band is blacked out in a wide area on the daytime side.
HF band **Available frequency spectrum is reduced**	**Ionospheric storm (negative phase)**	🟩	**Threshold:** 30% reduction in MUF **Social Impact:** The frequency range for domestic and international communication is reduced by up to 30%.	**Threshold:** 50% reduction in MUF **Social Impact:** The frequency range for domestic and international communications will be reduced by up to 50-60%, and communications will not be possible during some time periods.

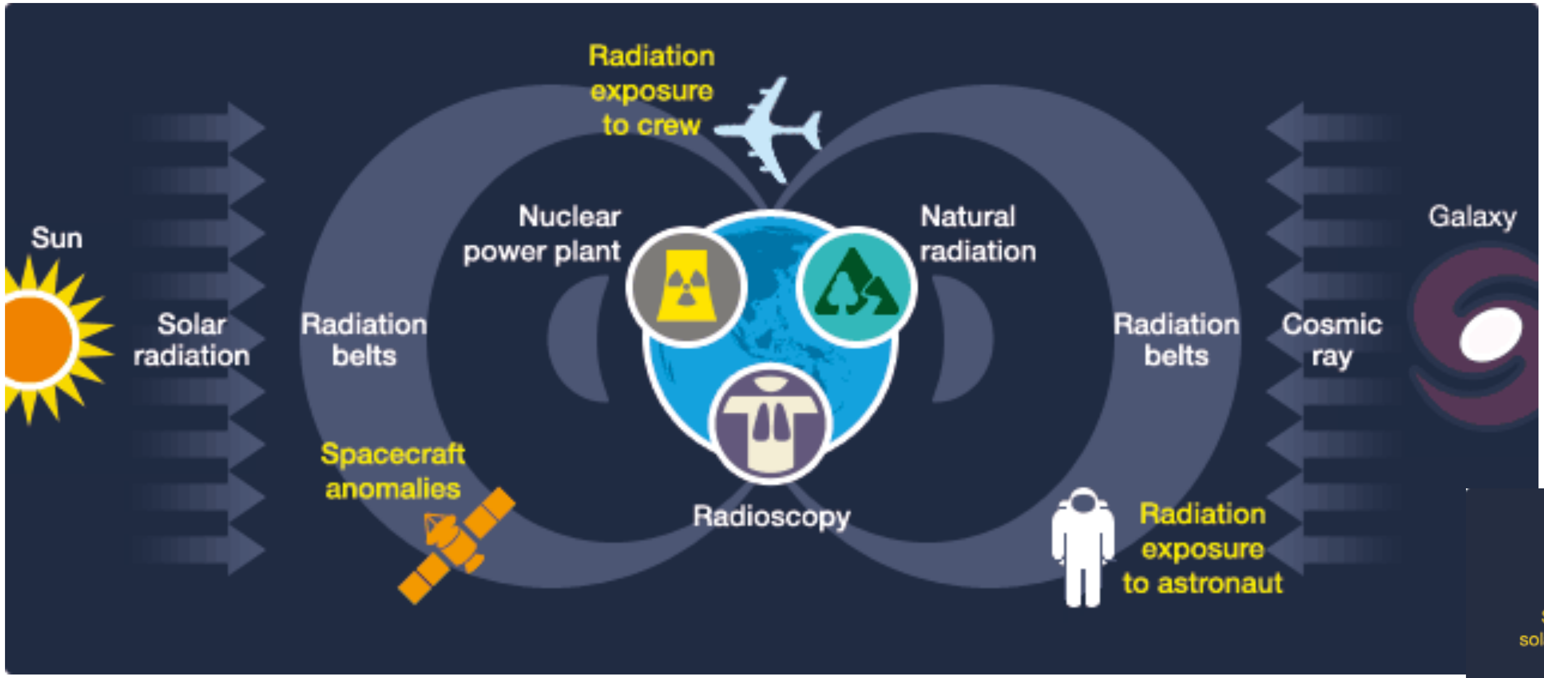
Report of the Council for Advancement of Space Weather Forecast (Summary)

https://www.soumu.go.jp/main_content/000813249.pdf (written in Japanese)

Worst-case scenario for extreme space weather events occurring once per 100 years or less (excerpts)

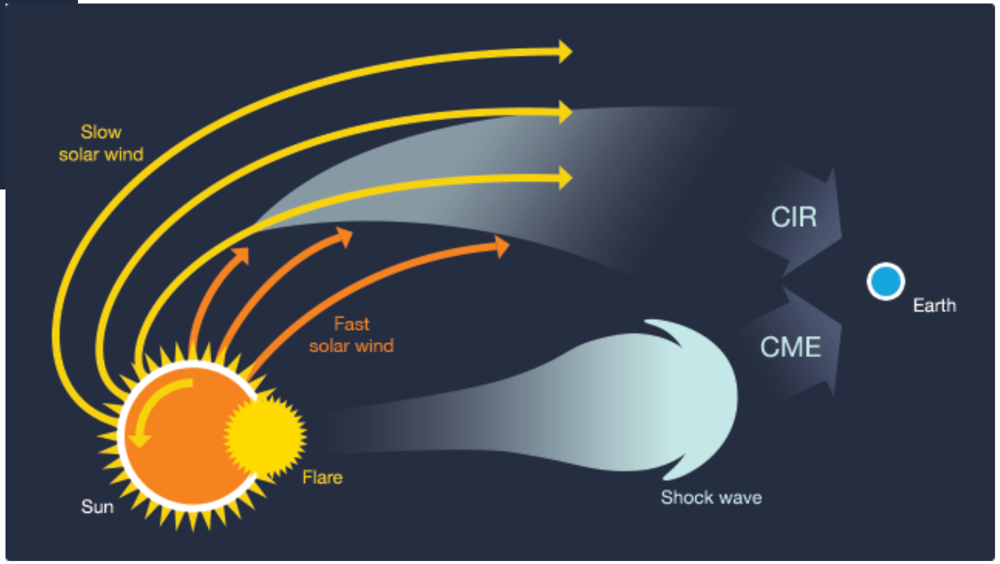
- Communications and broadcasting are intermittently disrupted, causing socioeconomic disruption. Cell phone service is also suspended in some areas.
- Satellite positioning accuracy deviates by up to several tens of meters. Collision accidents with drones and other vehicles occur.
- Many satellites are damaged. A significant number of satellites are lost. Satellite-based services are suspended.
- Aircraft and ship operations are suspended worldwide. Significant disruptions to schedules and plans.
- Widespread power outages in non-resilient power infrastructure

Distribution of hazardous space radiations near Earth

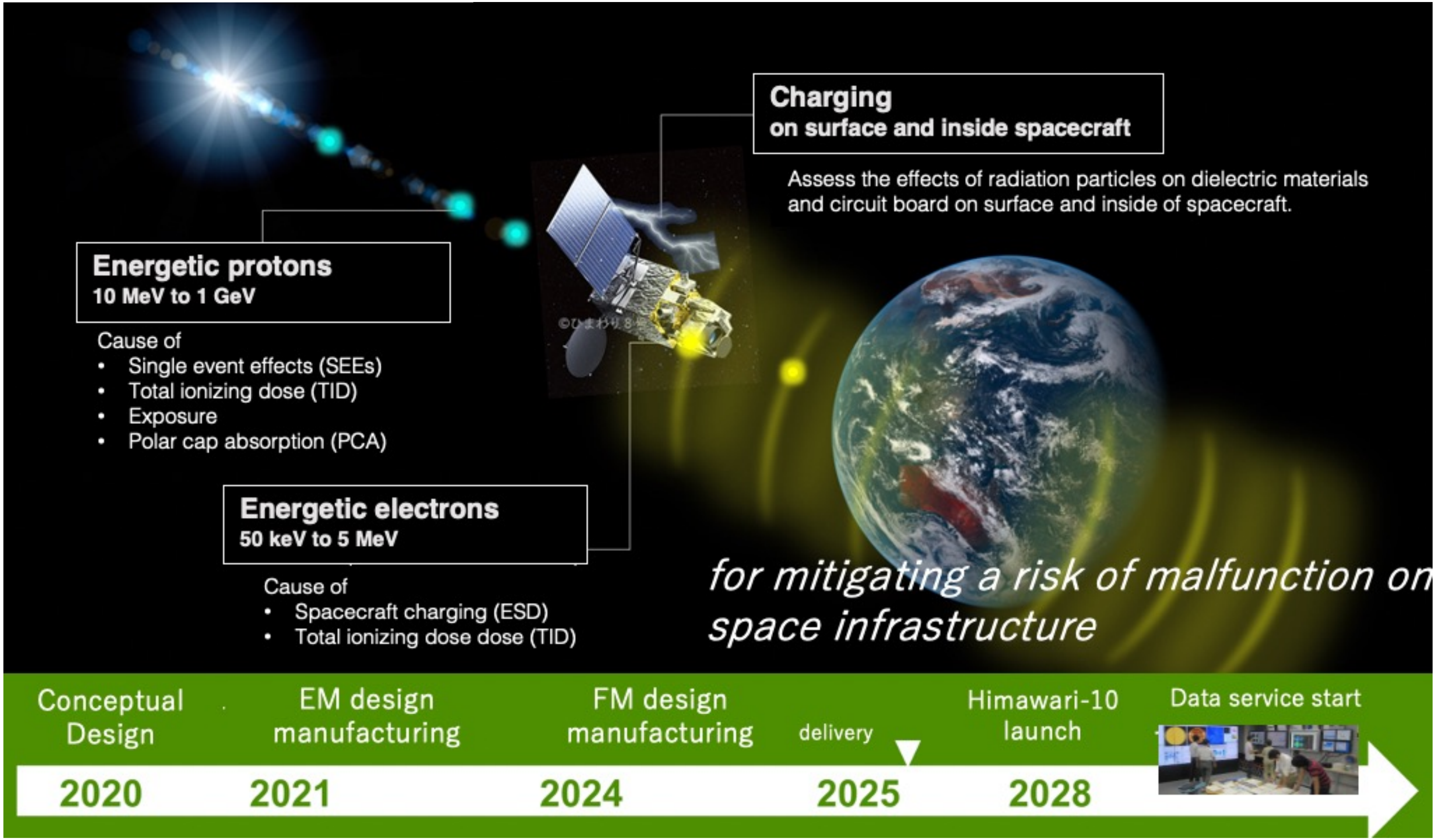


Radiation that comes from outside the Earth is called "space radiation" and includes high-energy particles originating from far-off galaxy and from explosive solar activities such as solar flares and coronal mass ejections. High-energy particles trapped in the geomagnetic field are another form of space radiation.

Space radiation cannot easily reach the surface of the Earth due to the Earth's geomagnetic field and the atmosphere. However, for astronauts working at altitudes of about 400 km, radiation exposure can be a health hazard. Even for spacecraft flying around the Earth, space radiation can cause damage and spacecraft failure. ESD and SEE, TID due to space radiation and plasma is major concern for mission life of any space system.



CHARMS Mission: *Simultaneous measurements of space radiation and spacecraft charging on Japanese geostationary meteorological satellite*



Energetic protons
10 MeV to 1 GeV

Cause of
- Single event effects (SEEs)
- Total ionizing dose (TID)
- Exposure
- Polar cap absorption (PCA)

Energetic electrons
50 keV to 5 MeV

Cause of
- Spacecraft charging (ESD)
- Total ionizing dose dose (TID)

Charging
on surface and inside spacecraft

Assess the effects of radiation particles on dielectric materials and circuit board on surface and inside of spacecraft.

for mitigating a risk of malfunction on space infrastructure

Conceptual Design	EM design manufacturing	FM design manufacturing	delivery	Himawari-10 launch	Data service start
2020	2021	2024	2025	2028	

Next Himawari/CHARMS-e & p

(performance requirement of electron & proton measuring sensors)

- Targets
  - Energetic electrons in the outer radiation belt (Van Allen belt)
  - Energetic protons in solar energetic particles and galactic cosmic ray
- Missions
  - High-energy particles that cause spacecraft malfunctions and degradations (ESD, SEEs, and TID), HF communication failure in the polar regions due to PCA, and space radiation exposure (polar aircraft and space activities) will be monitored, and are used space radiation nowcasting and forecasting, and issue warnings to space weather users.

	CHARMS-e(lo)	CHARMS-e(hi)	CHARMS-p(lo)	CHARMS-p(hi)
Particle	electron	electron	proton	proton
Energy range	50–1200 keV	0.8–4, >2, >4 MeV	10–250, >10, >100 MeV	250–1000 MeV
Energy resolution	< 20%	< 10%	< 20%	–
Energy channels	8 differential flux	6 differential flux 2 integral flux	6 differential flux 2 integral flux	8 differential flux
Field of view	± 20 degrees	± 20 degrees	± 20 degrees	± 20 degrees
Viewing direction *Reverse by yaw flip	1: East (*West) 2: South (*North)	1: East (*West) 2: South (*North)	1: East (*West)	1: East (*West)
G-factor	0.0005 cm^2 sr	0.1 cm^2 sr	0.2 cm^2 sr	1.5 cm^2 sr
Time resolution	1 s	1 s	10 s	10 s
Detector	SSD	SSD	SSD	Cherenkov

Status of Interntional Organizations related to SWx

National activities

Policy

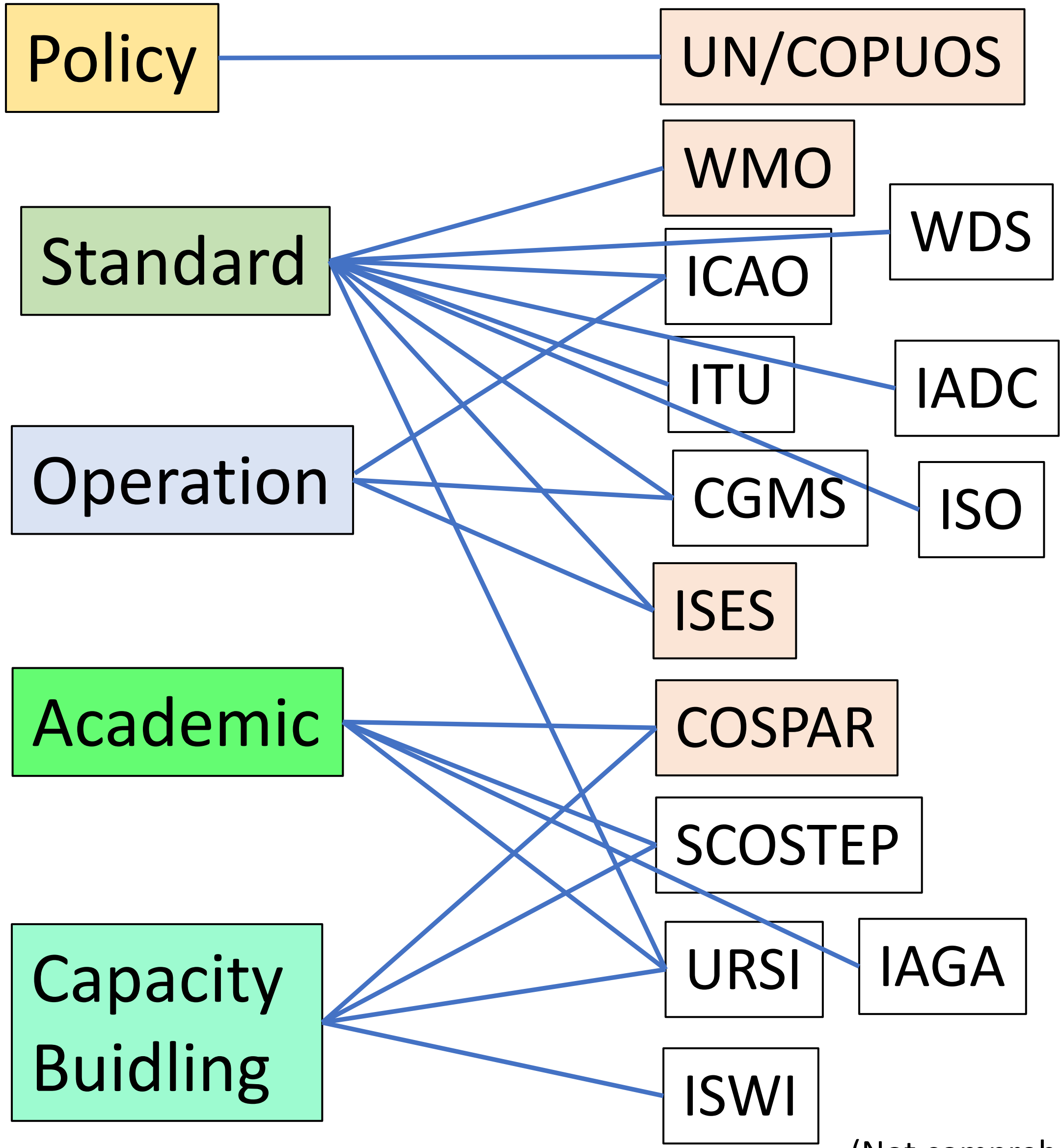
Operation

Standard

Capacity building

Academic

Overlapped Working Plans and Action Items



Policy

Standard

Operation

Academic

Capacity Buidling

UN/COPUOS

WMO

WDS

ICAO

ITU

IADC

CGMS

ISO

ISES

COSPAR

SCOSTEP

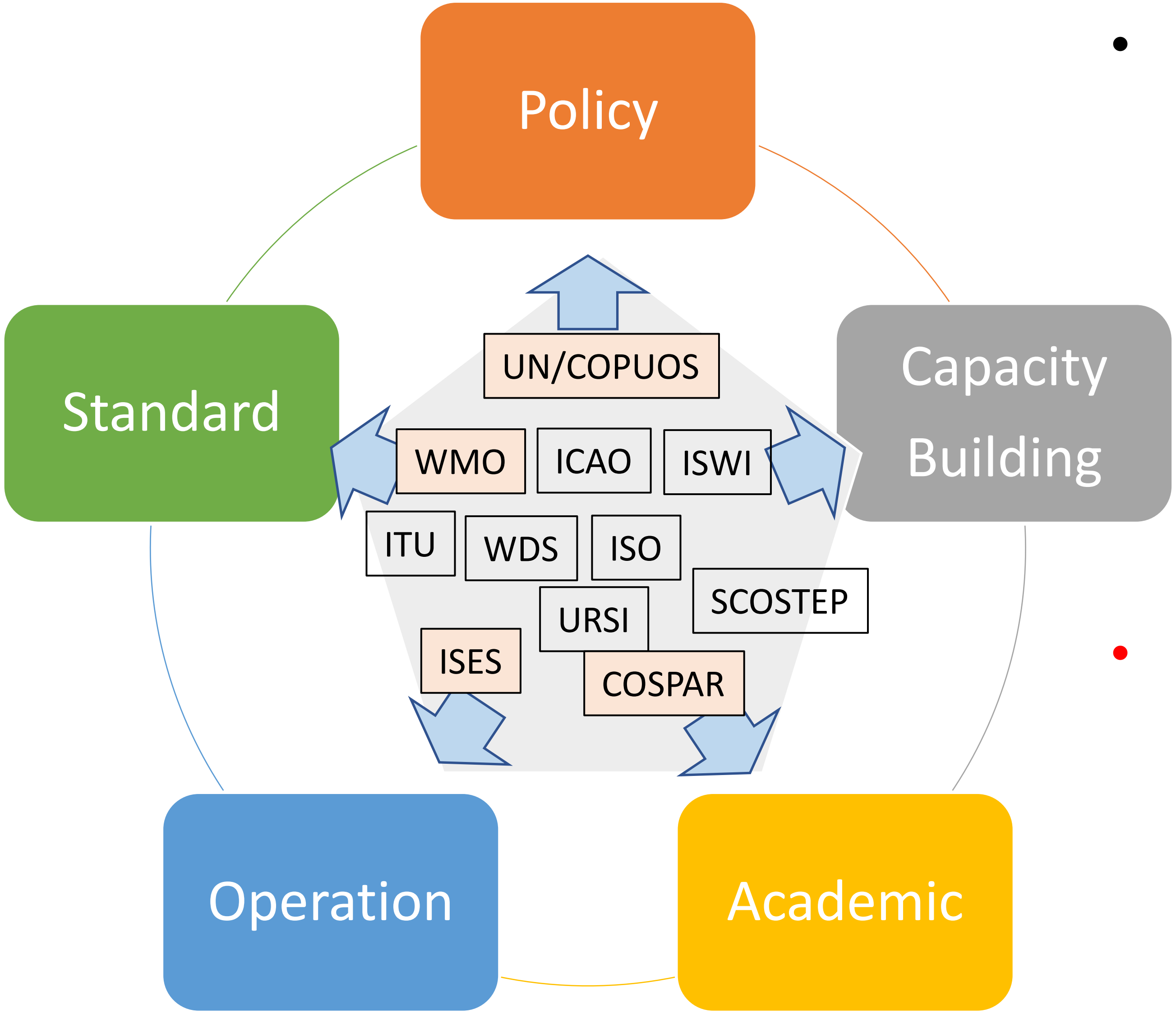
URSI

IAGA

ISWI

(Not comprehensive)

Recommendation: Establishing “Space Weather Summit”

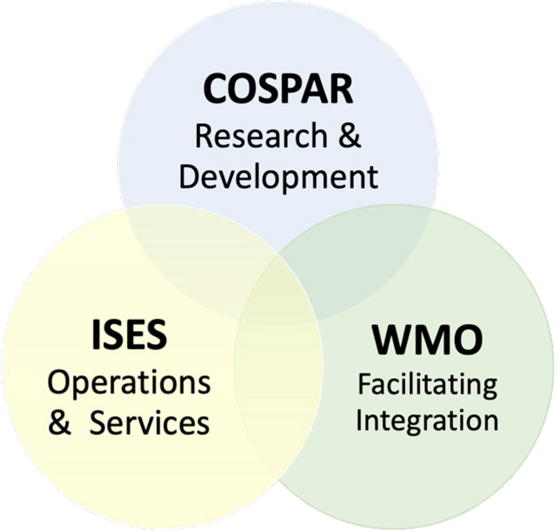


Independent Objectives and Goals

- How do we make a solution to have the most effective way for all players?
  - Each IO has original object and goal which should be respected.
  - Some of action plans can be collaborated among IOs, avoiding duplicate works.
  - Logistics: Meeting periods can be coordinated among IOs.
- “Space Weather Summit”
  - Coordinate IOs’ action plan and roadmap
  - Plan Joint projects among IOs
  - Host function is rotating
  - Arrange grand-conferences

WMO-ISES-COSPAR collaboration

- UN/COPUOS STSC to issue recommendations on space weather services in February 2022
- COSPAR-ISES-WMO is required to lead space weather related activities, and has begun to consider
- September 2022, two representatives from each institution participated in the study at the University of Coimbra, Portugal.
- A draft of the "Coimbra Declaration" has been prepared and is currently being discussed by various organizations.
  - Confirmation of the direction of the three institutions
  - Agree on framework, consider MoU
  - Pilot projects, regular meetings, round tables, etc.



COSPAR
Research & Development

ISES
Operations & Services

WMO
Facilitating Integration

Summary

- In Japan, “Committee for the advancement of space weather forecast” was established in the Ministry of Internal Affairs and Communications (MIC) and publish a report in June 2022.
- Based on this report, NICT will take necessary researches and actions, such as researches toward the actual operation of the new space weather alert criteria established by the WG.
- We now started a project to develop and deploy instrument for measuring space environment for safe and stable use of satellite operation, aviation and human activities in space. We plan to develop three kinds of sensors to measure energetic protons and electrons, and charging on surface and inside spacecraft.
- As an international activities, we contribute to the discussion of three bodies cooperation, ISES-WMO-COSPAR, and preparing the draft of "Coimbra Declaration“. We will continue and improve the cooperation among international organizations related to space weather.