United Nations Committee on Peaceful Uses of Outer Space (COPOUS):

Space Weather Expert Group

Thematic Priority 4: Developing an International Framework for Space Weather Services (2018-30).

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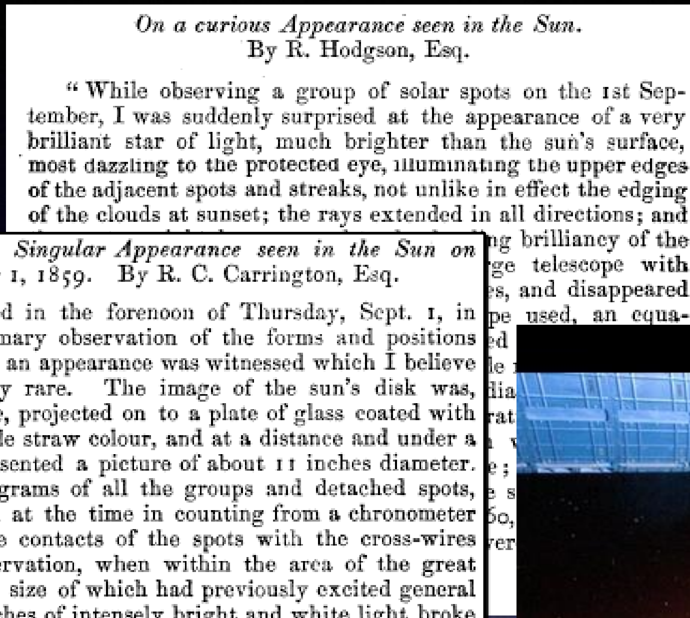
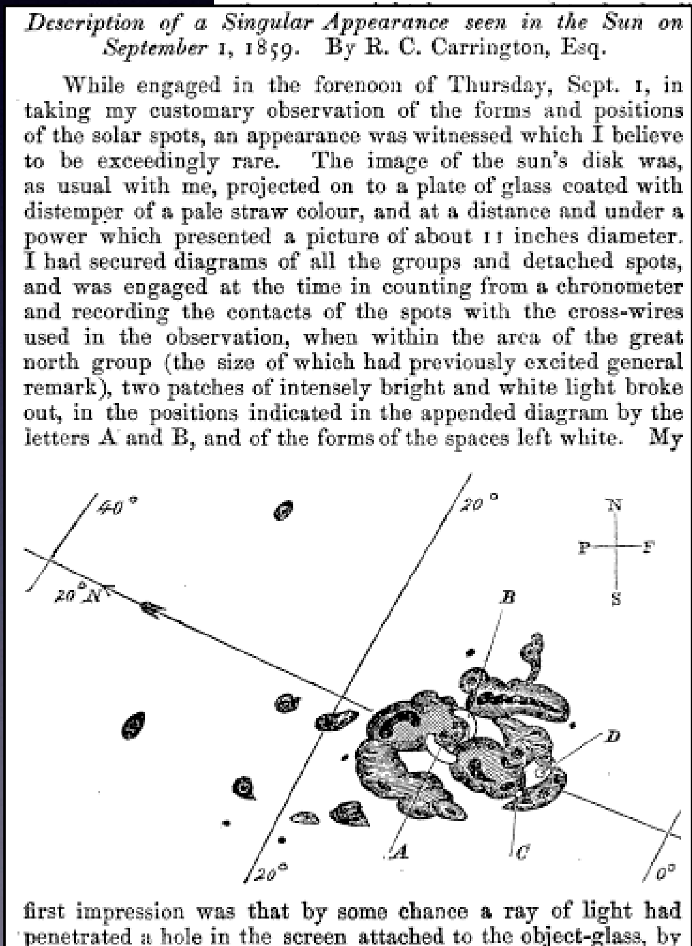
Thanks to Karel Schrijver, Chair of COSPAR-ILWS Space Weather Roadmap Team.

Solar flaring and the connection to geospace: discovered in 1859



On a curious Appearance seen in the Sun.
By R. Hodgson, Esq.

"While observing a group of solar spots on the 1st September, I was suddenly surprised at the appearance of a very brilliant star of light, much brighter than the sun's surface, most dazzling to the protected eye, illuminating the upper edges of the adjacent spots and streaks, not unlike in effect the edging of the clouds at sunset; the rays extended in all directions; and … ng brilliancy of the … ge telescope with … s, and disappeared … pe used, an equa- …



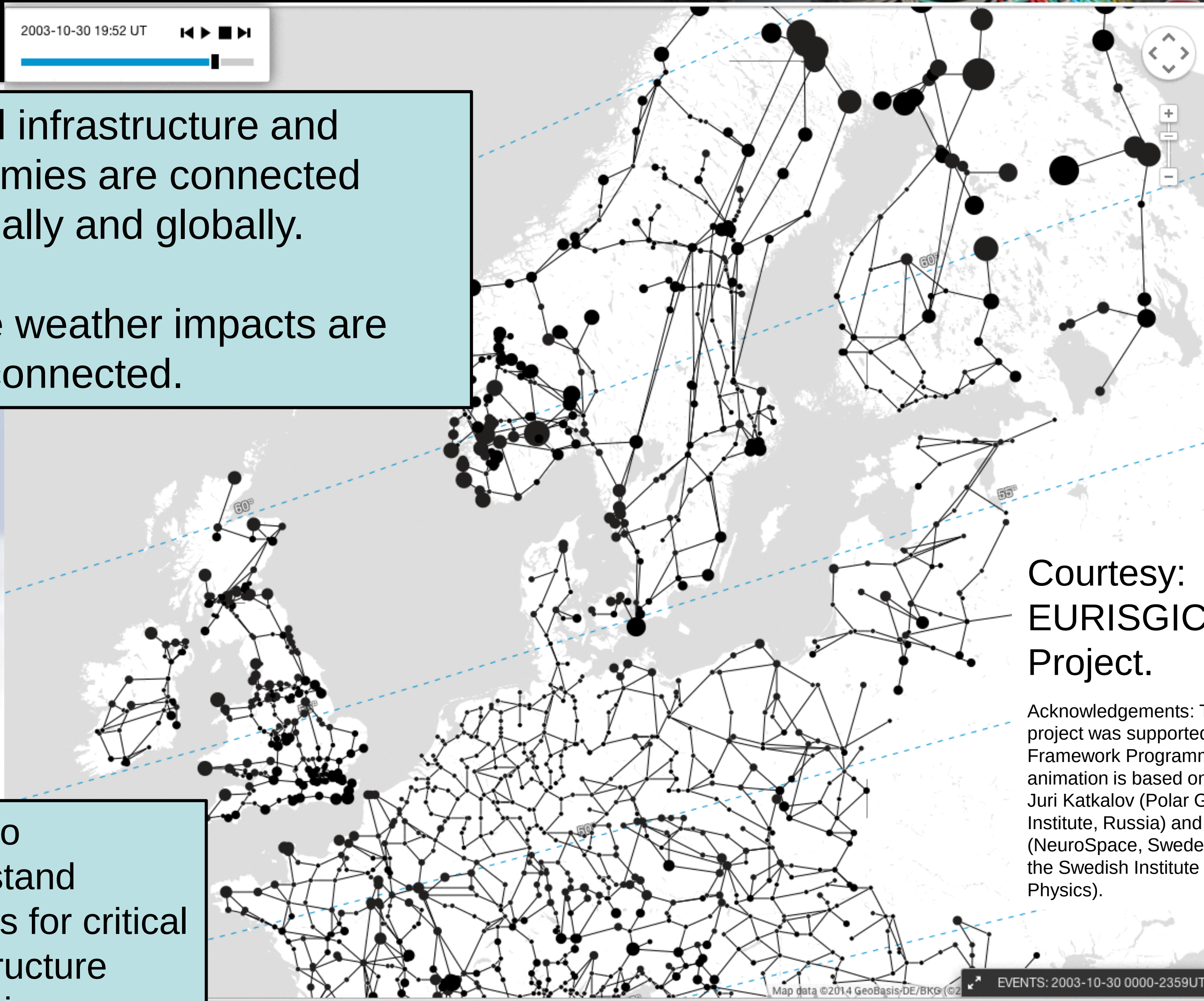
Description of a Singular Appearance seen in the Sun on September 1, 1859. By R. C. Carrington, Esq.

While engaged in the forenoon of Thursday, Sept. 1, in taking my customary observation of the forms and positions of the solar spots, an appearance was witnessed which I believe to be exceedingly rare. The image of the sun's disk was, as usual with me, projected on to a plate of glass coated with distemper of a pale straw colour, and at a distance and under a power which presented a picture of about 11 inches diameter. I had secured diagrams of all the groups and detached spots, and was engaged at the time in counting from a chronometer and recording the contacts of the spots with the cross-wires used in the observation, when within the area of the great north group (the size of which had previously excited general remark), two patches of intensely bright and white light broke out, in the positions indicated in the appended diagram by the letters A and B, and of the forms of the spaces left white. My

first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass, by

Global infrastructure and economies are connected regionally and globally.

Space weather impacts are inter-connected.



Need to understand impacts for critical infrastructure protection.

Courtesy: EURISGIC Project.

Acknowledgements: The EURISGIC project was supported by EU's 7th Framework Programme. The animation is based on the work by Juri Katkalov (Polar Geophysical Institute, Russia) and Magnus Wik (NeuroSpace, Sweden) (both now at the Swedish Institute of Space Physics).

United Nations COPUOS

- UN Committee on Peaceful Uses of Outer Space (COPUOS) formed in 1959, and was responsible for 5 space treaties, and was set up by and reports to UN General Assembly.

- COPUOS now has 84 member states with interests in space, and around 30 permanent observers (intergovernmental and non-governmental organizations including WMO, SCOSTEP, etc).

- Works on basis of consensus to:
  - Promote information sharing and international cooperation in peaceful uses and exploration of outer space under UN auspices
  - Study legal matters related to the use and exploration of outer space.

- COPOUS has two Subcommittees: Scientific and Technical Subcommittee (STSC) and the Legal Subcommittee.

- STSC approved regular Space Weather agenda item in 2013.

Heritage: Expert Group C LTS & New Space Weather Expert Group

- TP-4 can build on work of Expert Group C (Space Weather) in Long-Term Sustainability of Outer Space Activities (LTS) in UN Committee on Peaceful Uses of Outer Space (COPUOS). 2011- 2015.

- Leverages work of new Space Weather Expert Group with Rapporteur, reporting to UN COPUOS under permanent agenda item approved Feb. 2015 in Vienna.

UNISPACE+50 provides opportunity to define activities of an new UN Space Weather coordination group to meet strategic needs of international community.

UN Space Weather Expert Group

(UN COPUOS STSC)

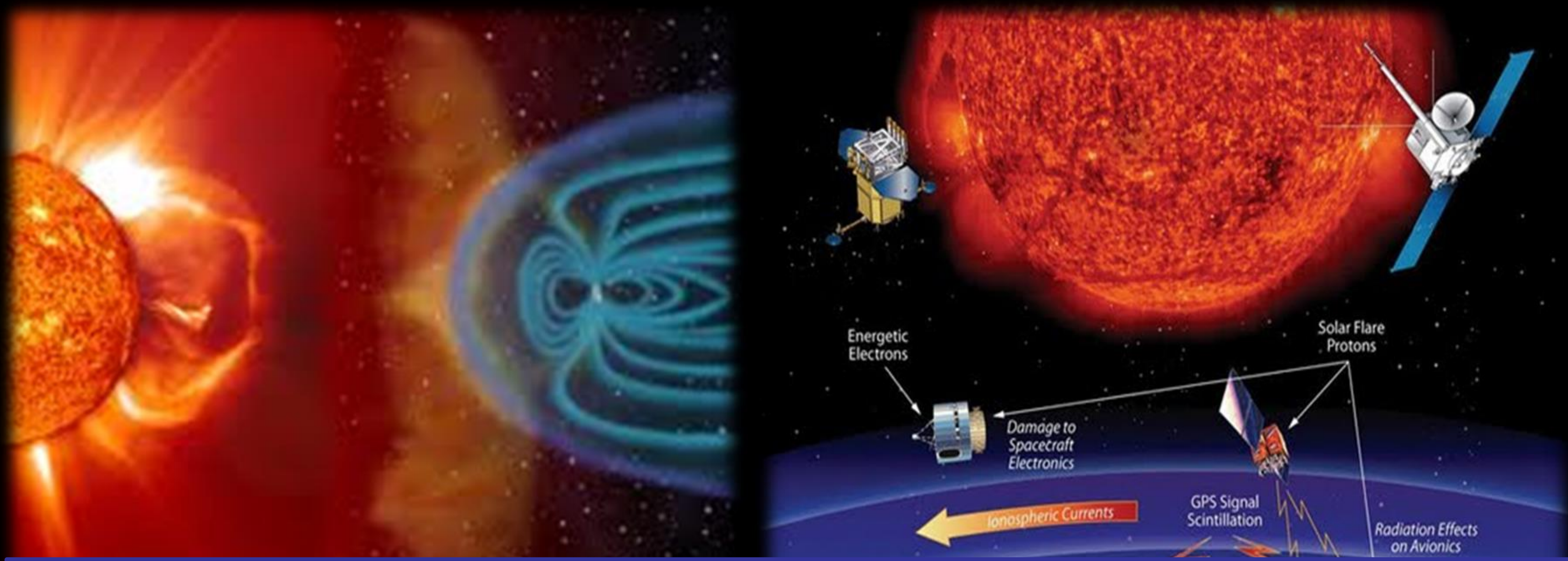
- Mandate: Promote awareness, provide guidance, and enable communication and cooperation in space weather related activities among Member States and related national and international organisations.

- Focus: To promote awareness, communication, and provide guidance and enable cooperation in space weather related activities.

- Specific actions and definite outcomes: Ensure that the work is complementary to other space weather coordination activities such as those within the WMO, ISES, COSPAR, ILWS, ICAO etc.

Space Weather has a wide range of impacts on terrestrial and space-based infrastructure.

International co-ordination and collaboration is critical to understand and quantify impacts and for ***future critical infrastructure protection.***



UN – Long-Term Sustainability of Outer Space Activities program resulted in approval of new space weather guidelines by General Assembly in 2016.

Courtesy NASA.

Recognised Space Weather Risks

- <u>High Impact:</u> Can have very high socio-economic impact on wide range of ground and space-based technological infrastructure (~$10s B to perhaps upto ~$1-2 Trillion; Baker et al., 2008).

- <u>High Likelihood of Extreme Event:</u> Comparatively high likelihood of extreme event (e.g., 23 July 2012 event – Baker et al., 2013). According to Riley (2012) probability of extreme event happening in the next decade might be as high as ~12%.

- <u>Impacts span all Space Weather Activity Levels:</u> Even modest space weather can have significant impacts (e.g., Schrijver et al., 2014; Schrijver and Mitchell, 2013).

- <u>Impacts are Regional:</u> Different geographical regions are vulnerable to different space weather; these need to be understood.

- <u>New Science and Applications Research</u>: Advances require both increased scientific understanding of the space weather processes as well as better applied research of impacts and mitigation.

Advancing space weather science to protect society's technological infrastructure: a COSPAR/ILWS roadmap

chaired by

Karel Schrijver and Kirsti Kauristie

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COSPAR site: http://tinyurl.com/swxrm

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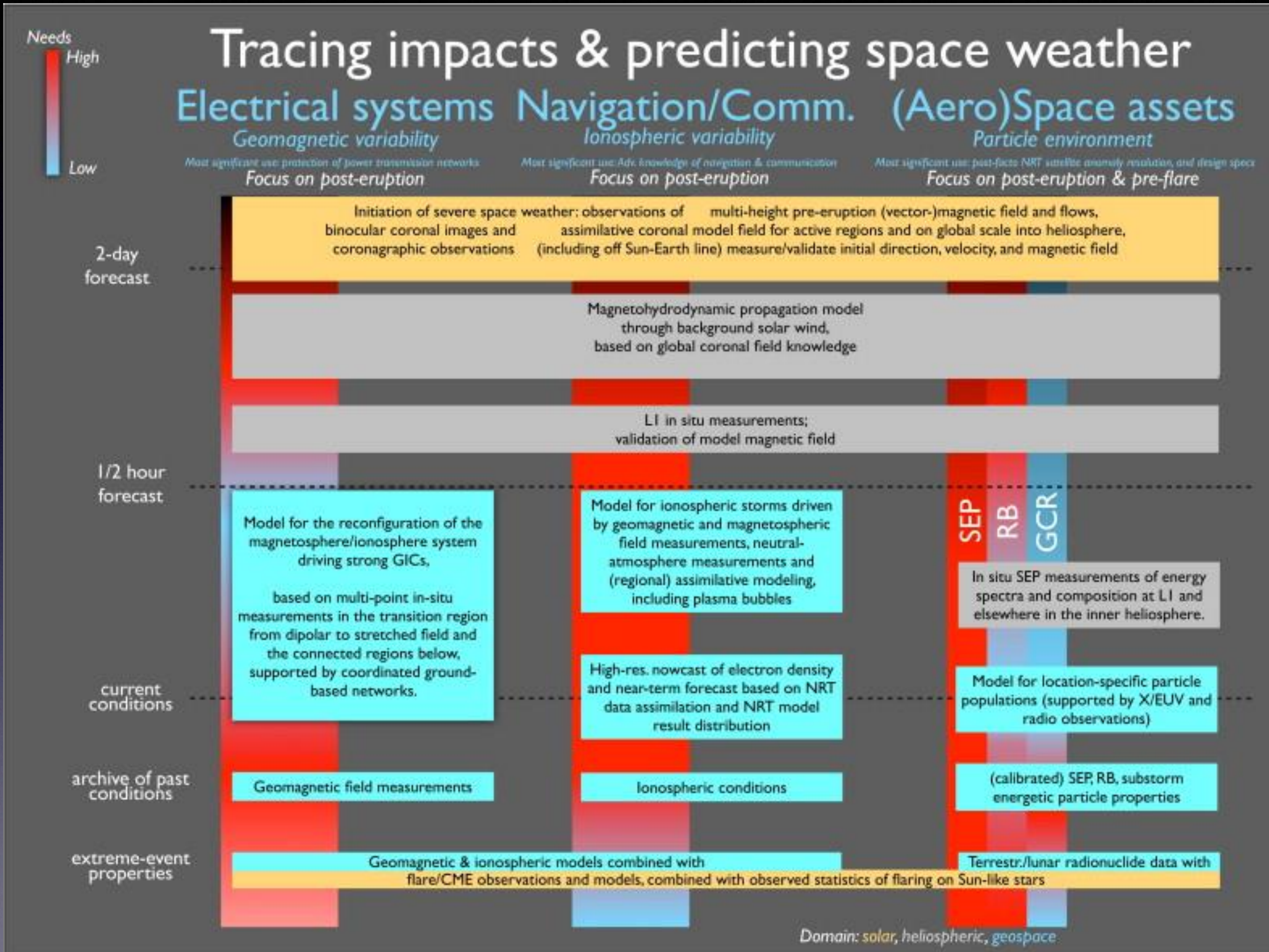
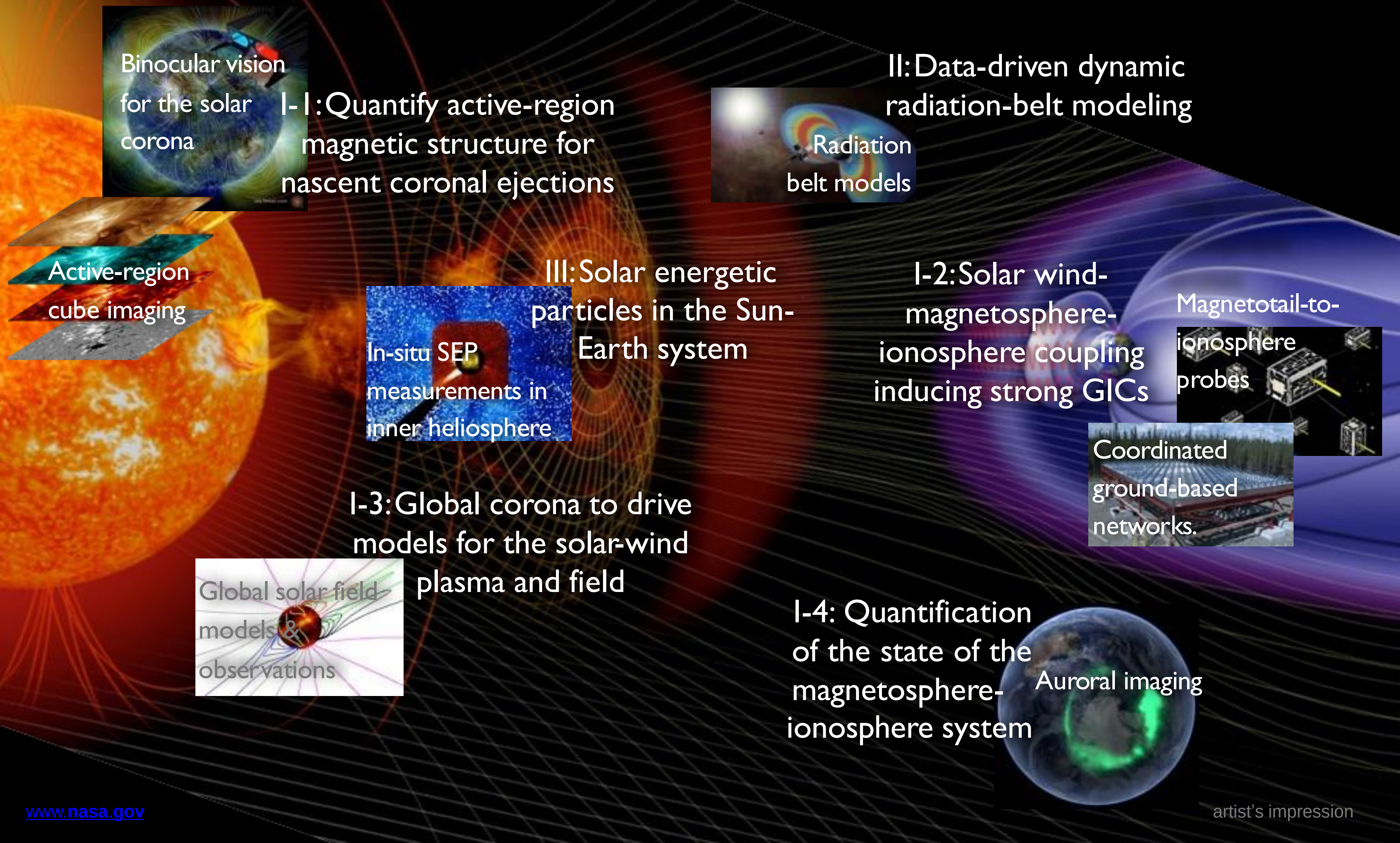

Tracing impacts & predicting space weather
Needs
High
Low
Electrical systems
Geomagnetic variability
Most significant use: protection of power transmission networks
Focus on post-eruption
Navigation/Comm.
Ionospheric variability
Most significant use: Adv. knowledge of navigation & communication
Focus on post-eruption
(Aero)Space assets
Particle environment
Most significant use: post-facto NRT satellite anomaly resolution, and design specs
Focus on post-eruption & pre-flare
2-day forecast
Initiation of severe space weather: observations of binocular coronal images and coronagraphic observations
multi-height pre-eruption (vector-)magnetic field and flows, assimilative coronal model field for active regions and on global scale into heliosphere, (including off Sun-Earth line) measure/validate initial direction, velocity, and magnetic field
Magnetohydrodynamic propagation model through background solar wind, based on global coronal field knowledge
L1 in situ measurements; validation of model magnetic field
1/2 hour forecast
Model for the reconfiguration of the magnetosphere/ionosphere system driving strong GICs,
based on multi-point in-situ measurements in the transition region from dipolar to stretched field and the connected regions below, supported by coordinated ground-based networks.
Model for ionospheric storms driven by geomagnetic and magnetospheric field measurements, neutral-atmosphere measurements and (regional) assimilative modeling, including plasma bubbles
SEP
RB
GCR
In situ SEP measurements of energy spectra and composition at L1 and elsewhere in the inner heliosphere.
current conditions
High-res. nowcast of electron density and near-term forecast based on NRT data assimilation and NRT model result distribution
Model for location-specific particle populations (supported by X/EUV and radio observations)
archive of past conditions
Geomagnetic field measurements
Ionospheric conditions
(calibrated) SEP, RB, substorm energetic particle properties
extreme-event properties
Geomagnetic & ionospheric models combined with
Terrestr./lunar radionuclide data with
flare/CME observations and models, combined with observed statistics of flaring on Sun-like stars
Domain: solar, heliospheric, geospace

Deployment of new/additional instrumentation, to add to existing observational resources and to modeling capabilities to be developed soon:



Active International Space Weather Efforts

UN has political role to promote and coordinate

Perhaps coordinate future COPUOS approach around approved LTS guidelines

UN COPUOS International Space Weather Coordination Group

↕

WMO | ICAO | ILWS | ISWI | COSPAR | National Efforts

Plus others….

With new understanding of both increased likelihood and impact of space weather, international coordination at strategic level is essential.

Potential COPUOS Foci (2018-30)

- <u>WHEN</u>: *Important to know when to act.*
  - ***International Space Weather Warning Network?*** Cf. UN International Asteroid Warning Network (IAWN)?
- <u>WHAT:</u> *Important to know what to do.*
  - Promote study of ***socio-economic and risk impact studies*** in member states.
  - Promote engagement of ***Critical Infrastructure Protection*** administrations in Member States.
  - Promote definition of ***actionable operational responses***.
  - Improve modeling and R2O – action teams under UN/COSPAR via CCMC SWAT.
- <u>HOW:</u> *Define appropriate mechanism/administration to meet space weather needs in UN context.*
  - Suggesting a potential ***International Coordination Meeting on Space Weather*** to kick-off of the post-2018 Space Weather actions?
  - Define future administration (eg could follow International Committee on GNSS (ICG) or other model…)
- <u>SCIENCE:</u> New science research needs to be prioritized at UN Member State and international agency level. How best to promote and achieve this?

UN COPUOS has political influence for communication and coordination with and between Member States; implementation expected to be delivered by other entities (WMO, ISES, national space weather plans etc).

Back-up Slides

Early UN COPUOS Space Weather Expert Group Recommendations:

- Make better use of existing data and models for space situational awareness, now-casting, and forecasting;

- New scientific research need for improved space weather forecasting: endorsed COSPAR-ILWS Space Weather Roadmap 2015-2025;

- For improved fidelity of severe space weather scales and indicators in forecast products, identified the need for regional forecast products, and (as appropriate) ongoing or increased access to real-time data;

- ***Promote increased collaboration between research and operational communities to transition new research findings into improved space weather products including situational awareness, now-casting, and forecast products.***

UN COPUOS: A/AC.105/C.1/2016/CRP.17.

15-17 February 2016 Space Weather Workshop and UN Expert Group findings.

UN COPUOS Space Weather Expert Group Work Plan

- Examine the report and conclusions of the ***LTS Expert Group C*** on space weather (A/AC.105/C.1/2014/CRP.15)) and other information related to space weather including the recent report from the ***COSPAR-ILWS Roadmap team*** "Understanding Space Weather to Shield Society". The group will examine the guidelines, recommendations and best practices to ***identify mechanisms to promote their implementation, including an assessment of prioritization.*** [year 1]

- ***Complete an inventory of relevant United Nations organisations***, including the World Meteorological Organisation (WMO) and International Civil Aviation Authority (ICAO) and others, ***and those within Member States and national and international organisations***. Identify and assess their role in the global space weather effort, ***promote coordination and communication between them***, and ensure that the efforts of STSC are complementary. [years 1-2]

- ***Promote increased and expanded member State involvement*** in providing ***space weather monitoring,*** from the ground and in space, and in ***developing, advancing, and sharing and delivering space weather services***. [years 2-4]

- ***Report yearly to the COPUOS STSC*** on its progress.

Tracing impacts & predicting space weather

1 Urgency/feasibility
O Opportunity for improved understanding & services.
C Scientific or technical challenge

Electrical systems
Geomagnetic variability
Most significant use: protection of power transmission networks
Focus on post-eruption

Navigation/Comm.
Ionospheric variability
Most significant use: Adv. knowledge of navigation & communication
Focus on post-eruption

(Aero)Space assets
Particle environment
Most significant use: post-facto NRT satellite anomaly resolution, and design specs
Focus on post-eruption & pre-flare

1 Initiation of severe space weather: observations of O multi-height pre-eruption (vector-)magnetic field and flows, O binocular coronal images and C assimilative coronal model field for active regions and on global scale into heliosphere, coronagraphic observations O (including off Sun-Earth line) measure/validate initial direction, velocity, and magnetic field 3

3 C Magnetohydrodynamic propagation model through background solar wind, based on global coronal field knowledge

Particle and shock background model to establish geospace linkage of potentially erupting regions

2 L1 in situ measurements; validation of model magnetic field

forecast

2 C Model for the reconfiguration of the magnetosphere/ionosphere system driving strong GICs,

2 O based on multi-point in-situ measurements in the transition region from dipolar to stretched field and the connected regions below, supported by coordinated ground-based networks.

2 C Model for ionospheric storms driven by geomagnetic and magnetospheric field measurements, neutral-atmosphere measurements and (regional) assimilative modeling, including plasma bubbles

1 O High-res. nowcast of electron density and near-term forecast based on NRT data assimilation and NRT model result distribution

1 O In situ SEP measurements of energy spectra and composition at L1 and elsewhere in the inner heliosphere.

2 C Model for location-specific particle populations (supported by X/EUV and radio observations)

archive of past conditions

Geomagnetic field measurements

3 Ionospheric conditions

1 O (calibrated) SEP, RB, substorm energetic particle properties

extreme-event properties

Geomagnetic & ionospheric models combined with

Terrestr./lunar radionuclide data with

flare/CME observations and models, combined with observed statistics of flaring on Sun-like stars

Domain: solar, heliospheric, geospace

Highest-priority recommendations in brief

In a collaborative international effort:

Research: observational, computational, and theoretical needs

1. "Augment the system observatory"
2. "Initial focus: Know what $\vec{B}$ is coming"
3. "Initial focus: Establish the GDM-GIC response"
4. "Quantify conditions to expect"

Teaming: coordinated collaborative research environment

I. "Uncover susceptibility"
II. "Focus resources"
III. "Ease access to data"
IV. "Grow coverage affordably"

Bridging communities: collaboration between agencies and communities

A. "Trust partners"
B. "Learn about SWx and its impacts"
C. "Evolve priorities and coordinate"
D. "Make use of advancing knowledge"
E. "Avoid duplication and mistakes"

Highest-priority recommendations

Teaming: coordinated collaborative research environment

In a collaborative international effort:

I) **"Uncover susceptibility": Quantify vulnerability** of humans and of society's infrastructure to space weather jointly with stakeholder groups.

II) **"Focus resources": Build test beds in which coordinated observing supports model development**: (a) state–of–the–art environments for numerical experimentation and (b) focus areas of comprehensive observational coverage, as tools to advance understanding of the Sun–Earth system, to validate forecast tools, and to guide requirements for operational forecasting.

III) **"Ease access to data": Standardize (meta–)data and product metrics, and harmonize access to data and model archives**: for observational and model data products, for data dissemination, for archive access, for intercalibration, for tests of models and forecasts.

IV) **"Grow coverage affordably": Optimize observational coverage of the Sun-society system**: Increase coverage of the Sun–Earth system by combining observations with data–driven models, by optimizing use of existing ground–based and space–based resources, by developing affordable new instrumentation and exploring alternative techniques, and through partnerships between scientific and industry sectors.

We live in the changing atmosphere of a powerful neighbor: space weather and its impacts are there all the time!

Domain volume, non-linearities, multi-process and cross-scale couplings, and hystereses require focused study before we can claim understanding and before we can expect to reliably forecast.

Major advances are possible with moderate investments in critical, state-of-the-art observations and models, through inter-agency, inter-national coordination, strengthening the existing Sun-Earth system observatory and the modeling capabilities that it enables.

ESA/NASA Solar and Heliospheric Observatory (SOHO)