African Solutions to Space Weather Threats

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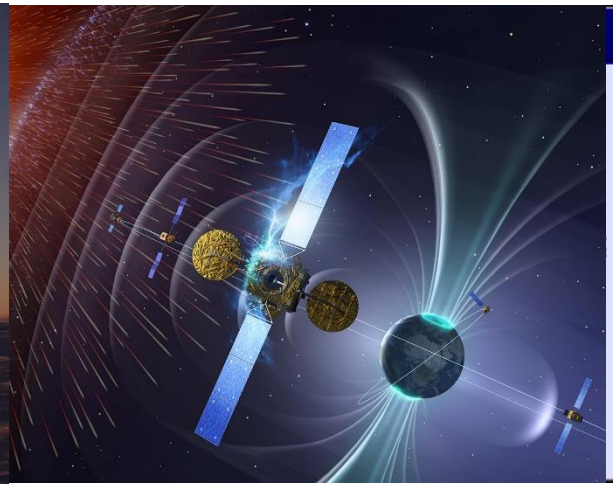
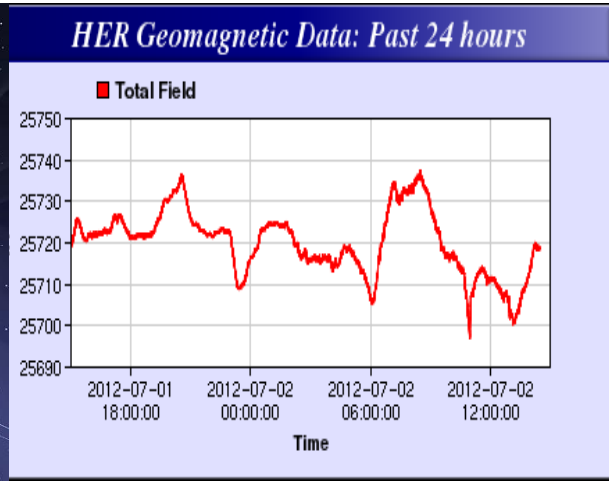
South African National Space Agency (SANSA)

OUTLINE OF KEYNOTE

- What is Space Weather?
- Why should we care?
- Providing a solution
- Regional Representation
- Conclusion





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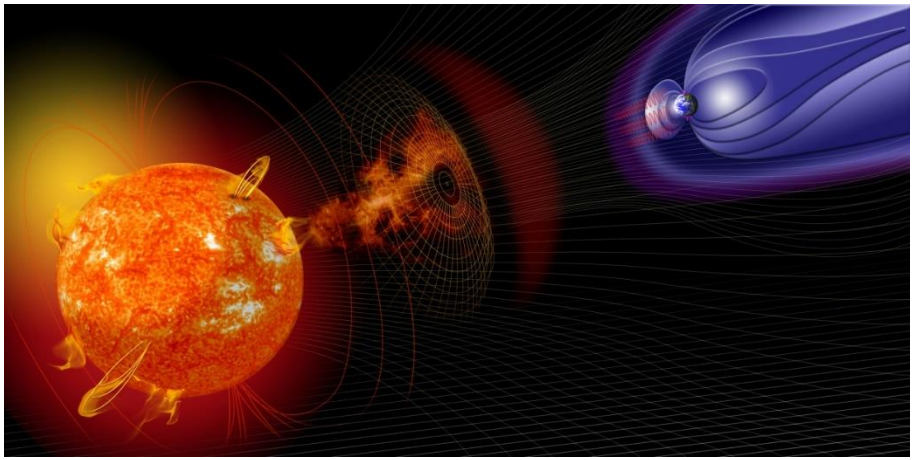
WHAT IS SPACE WEATHER?

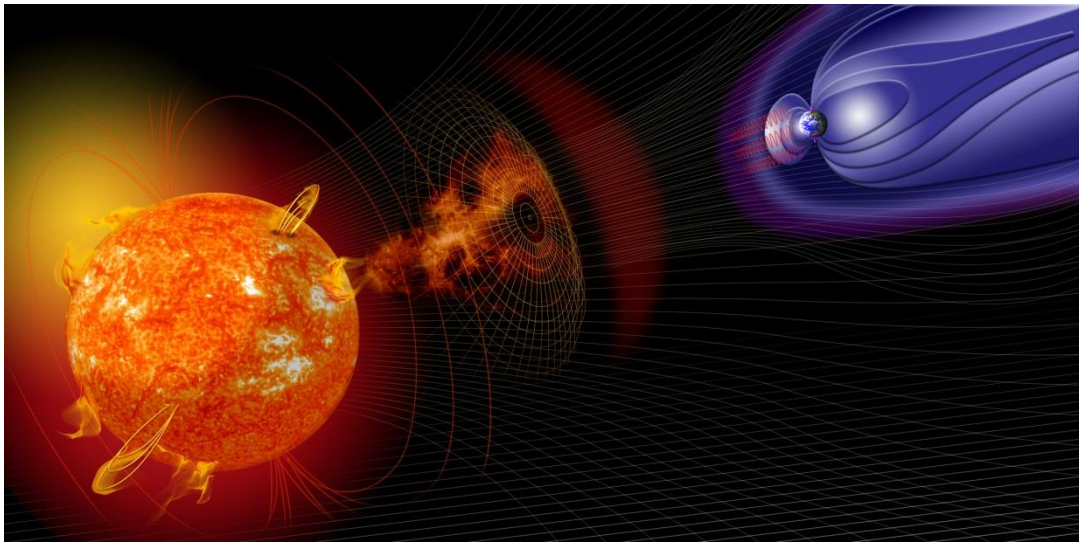


Protecting our technology for tomorrow

WHAT IS SPACE WEATHER?

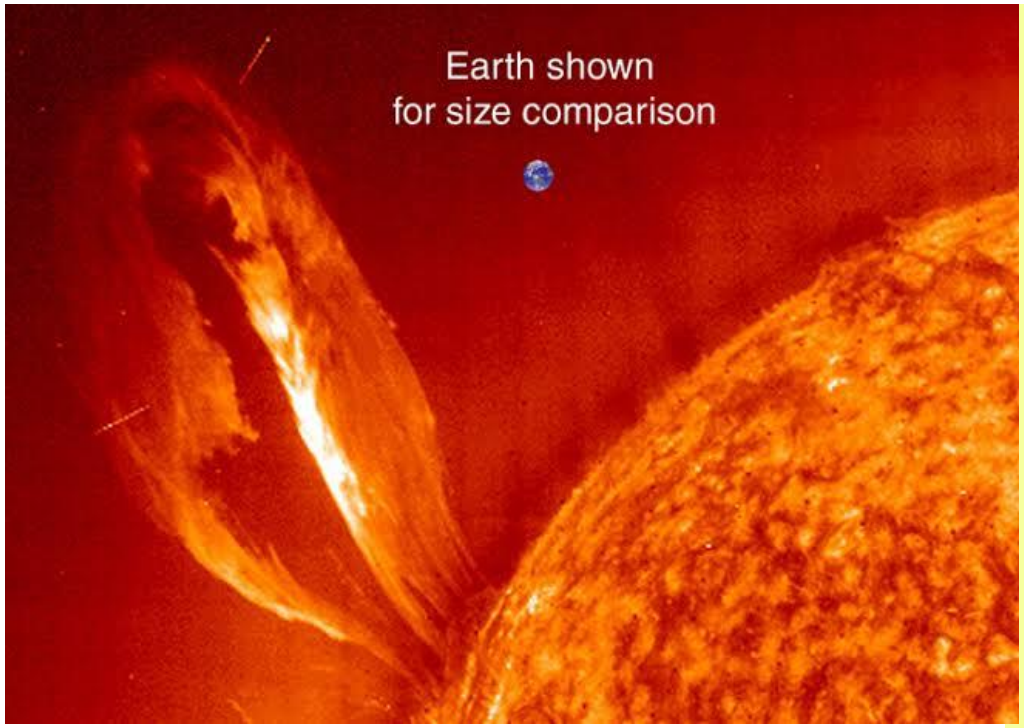
Space Weather refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems.

Space weather is a consequence of the behaviour of the sun, the nature of Earth's magnetic field and atmosphere, and our location in the solar system.

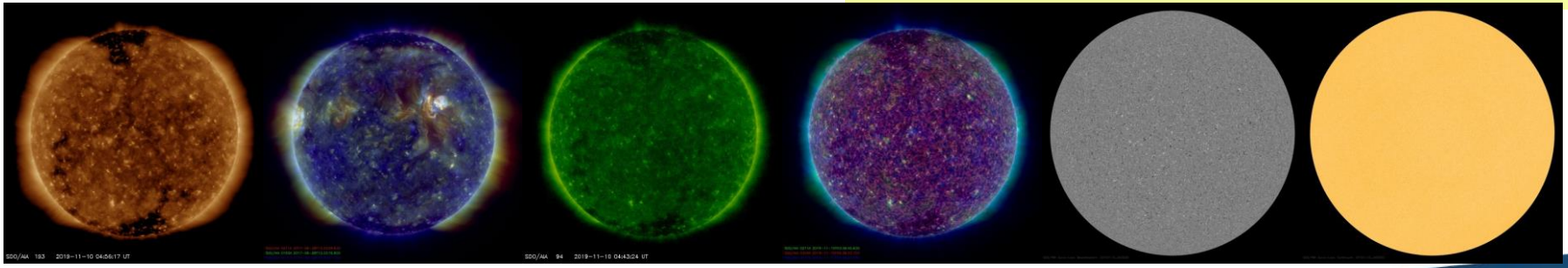


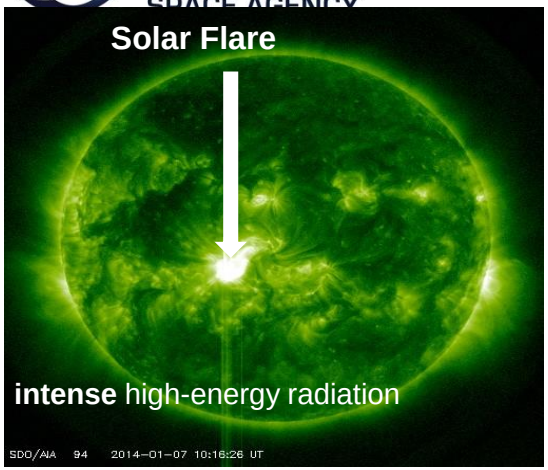
The Sun

Driver of Space Weather Events



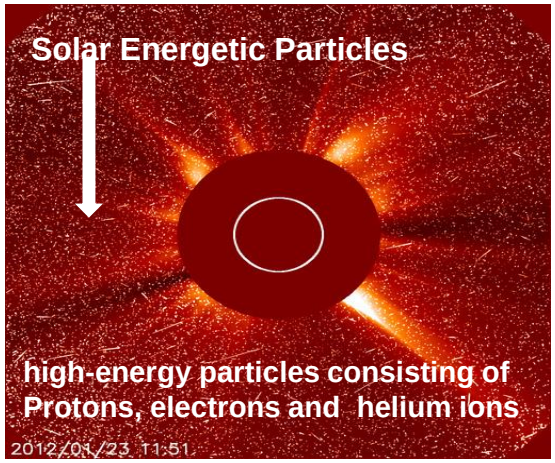
- The center of the solar system
- It is 4.6 billion years old
- ~93 million miles away from Earth (1AU)
- It holds 99.8% of the solar system's mass – with a diameter ~864,000 miles (109 times Earth's diameter)
- 8.3 light minutes from Earth
- It is a hot ball of glowing gases (mostly hydrogen, less helium)
- It would take 100 billion tons of dynamite every second to match the energy provided by the Sun





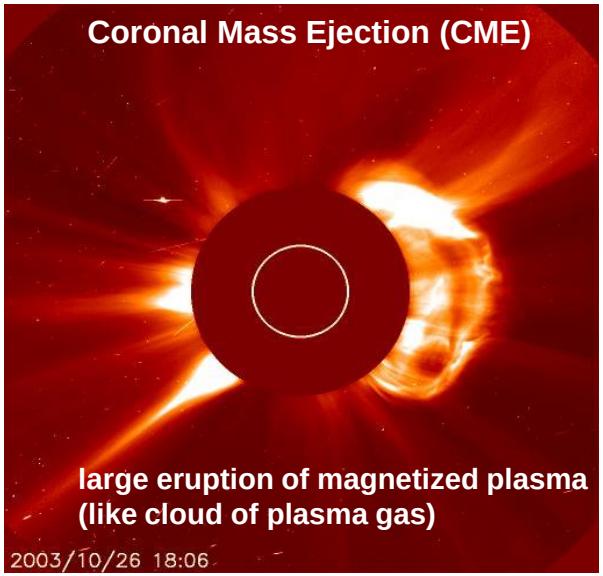
Solar Flares

- Arrive at Earth in 8 minutes
- Increase ionization in the ionosphere
- Disrupt HF radio communication
- Impacts:
  - Airline communication
  - HF radio operators
  - DoD Communications
  - Satellite Communications



Solar Energetic Particles

- Arrive at Earth in 15 minutes to few hours
- Increase ionization in the high latitude ionosphere
- Ionizing radiation penetrates into the atmosphere
- Disrupt HF radio communication
- Impacts:
  - Airline communication
  - HF radio operators
  - DoD Communications
  - Radiation exposure to pilots & crew
  - Astronauts (radiation)
  - Satellite failures



Coronal Mass Ejection (CME)

- Arrive at Earth in 1-4 days
- Accelerate particles within the magnetosphere and into the ionosphere
- Impacts:
  - HF radio communication
  - Radio Navigation (GPS)
  - Electric Power Grids and pipelines
  - Increased Satellite Drag
  - Aurora

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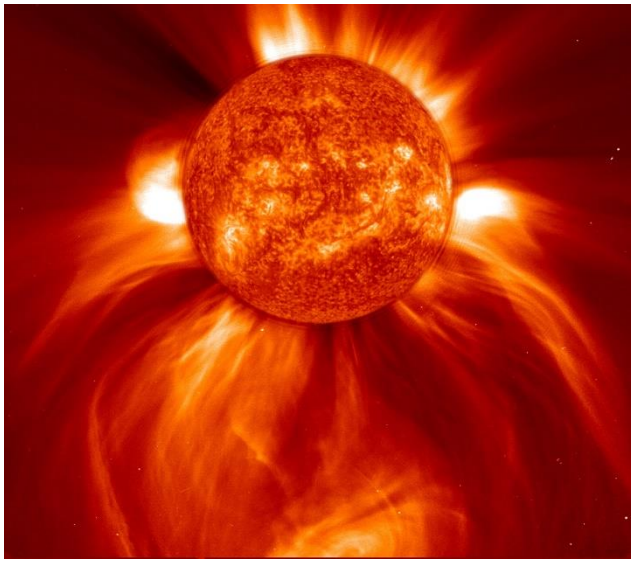
WHY SHOULD WE CARE?

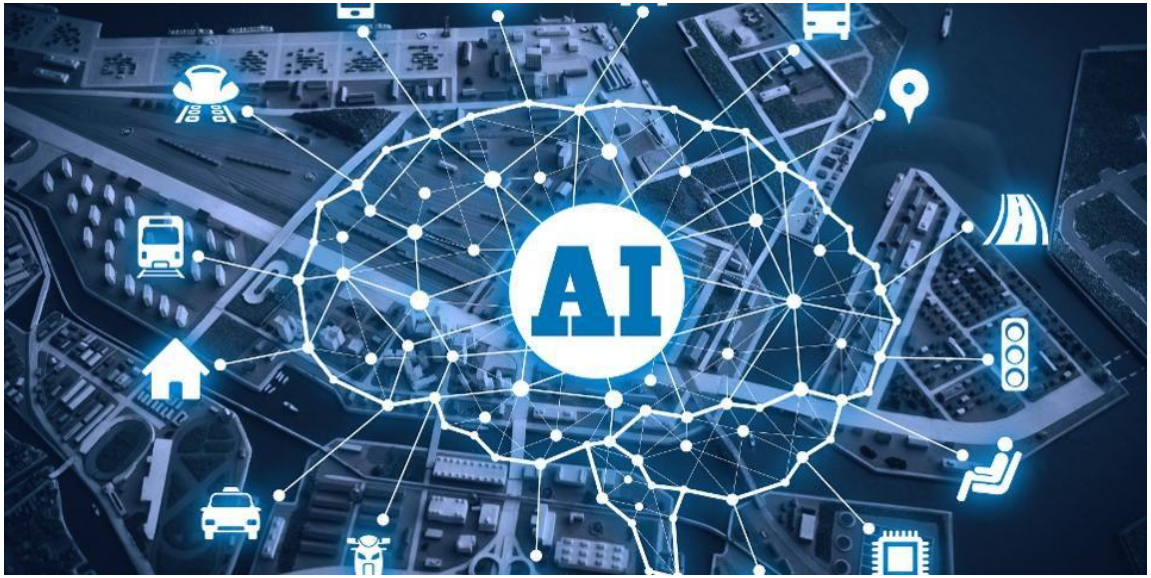


Protecting our technology for tomorrow

WHY SHOULD WE CARE?

- Technology continues to play an ever-increasing role in our society and the potential for space weather to impact our daily lives is also growing – especially as we move into the 4IR.

- Technological infrastructure, including the power grid, satellites used for communication and navigation, and the “Internet of Things” are vulnerable to space weather effects caused by the Sun's variability.

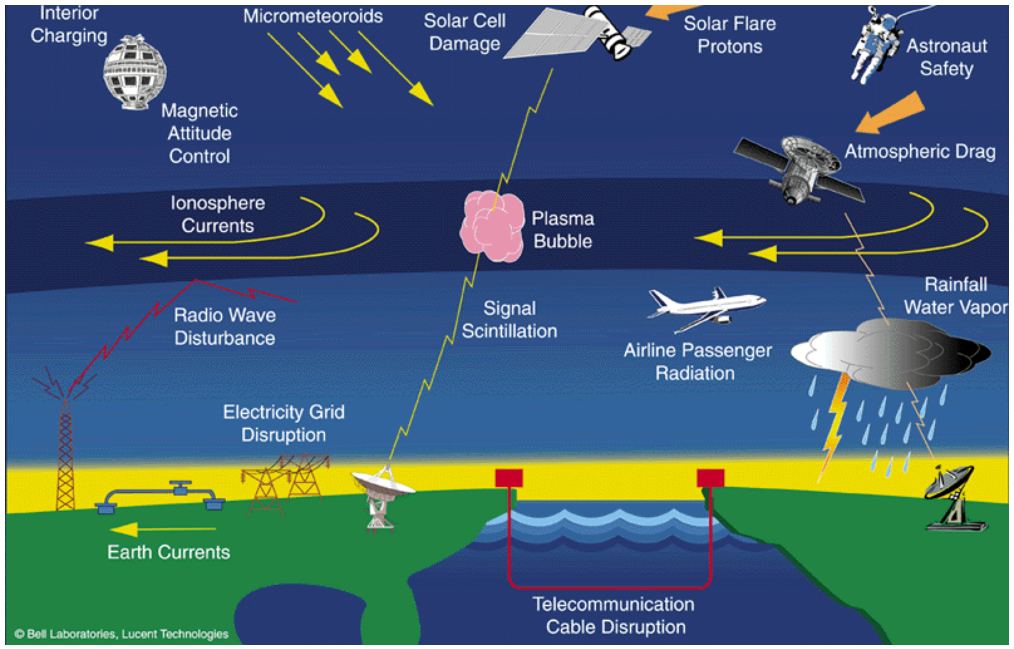


- **In the 4IR technology continues to play an ever-increasing role in our society and the potential for space weather storms from the Sun to impact our daily lives is also growing.**
- **Technological infrastructure, including the power grid, GPS and satellites used for communication and navigation, are vulnerable to space weather effects caused by the Sun.**

WHY IS SPACE WEATHER IMPORTANT?

- Space weather awareness is on the rise nationally and internationally.

- Space weather is a global phenomena with regional impact



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PROVIDING A SOLUTION

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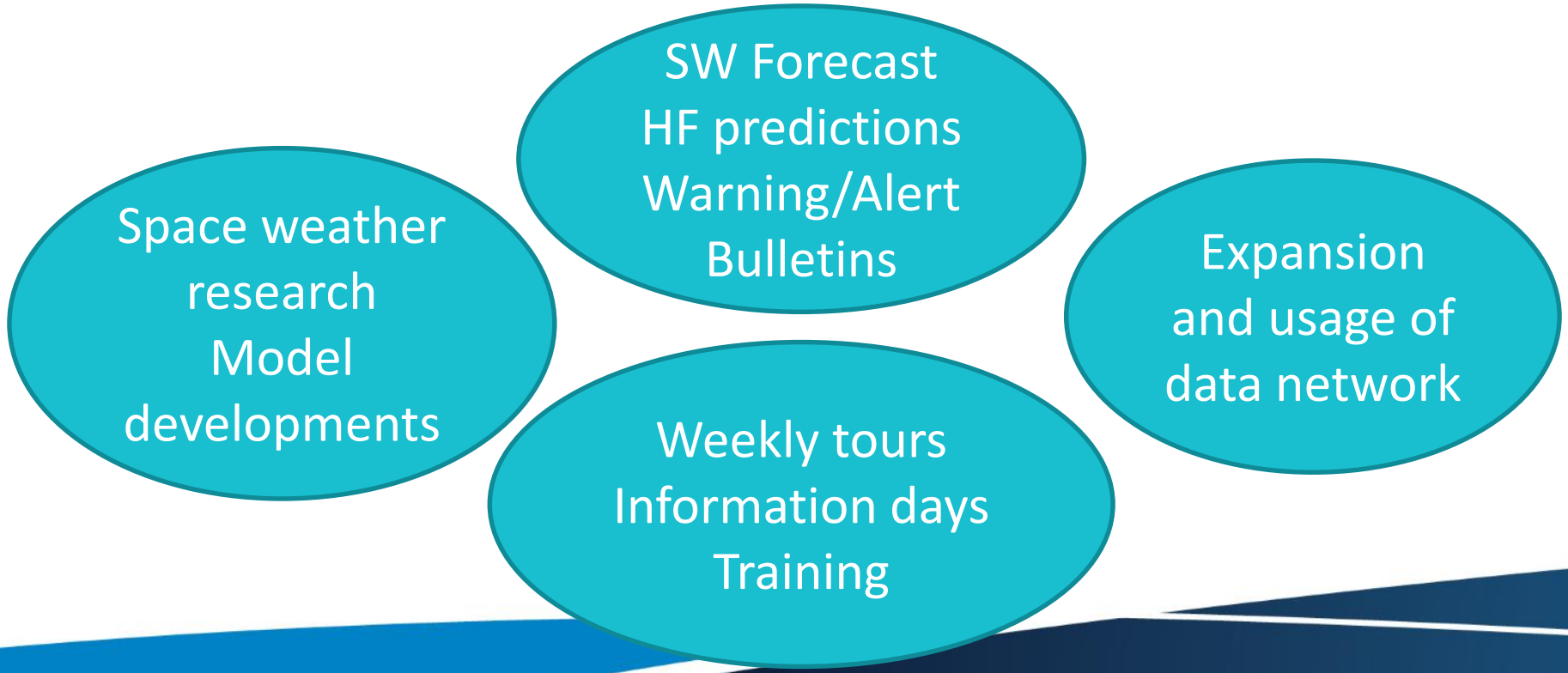
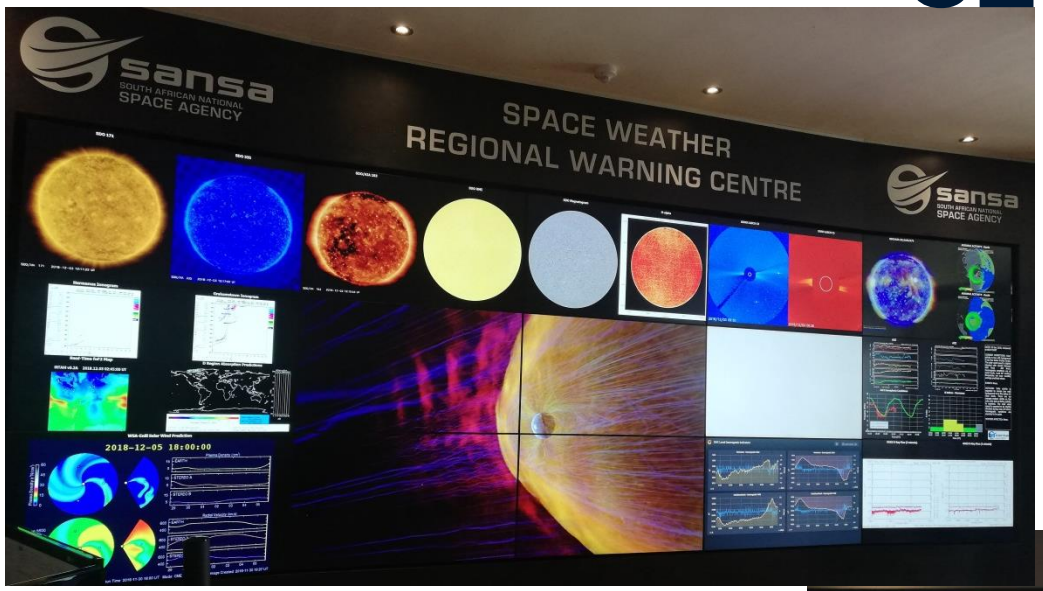
SPACE WEATHER REGIONAL WARNING CENTRE FOR AFRICA

SANSA observes, monitors, models, forecast and predicts the space environment and its impact on our technology



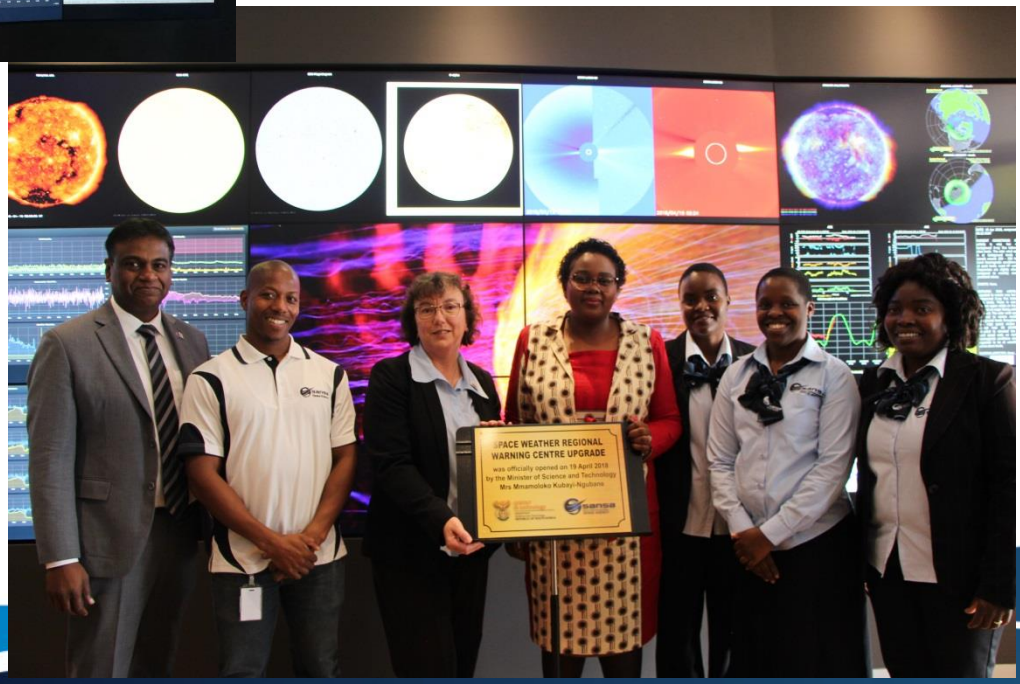
SANSA SPACE WEATHER CENTRE



Space Weather Centre launched in December 2010

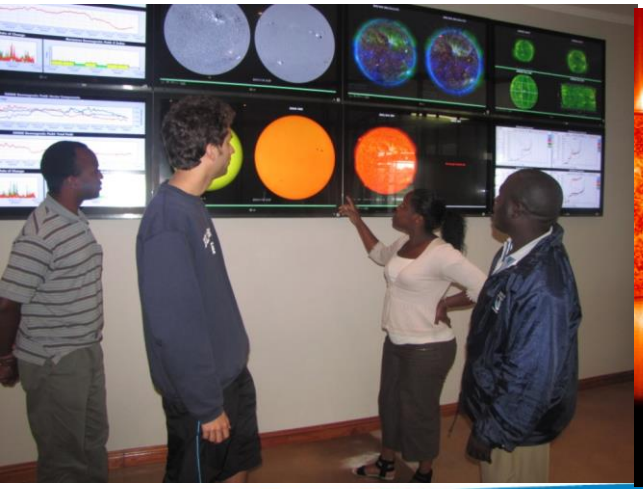
Re-launched after upgrade in April 2018

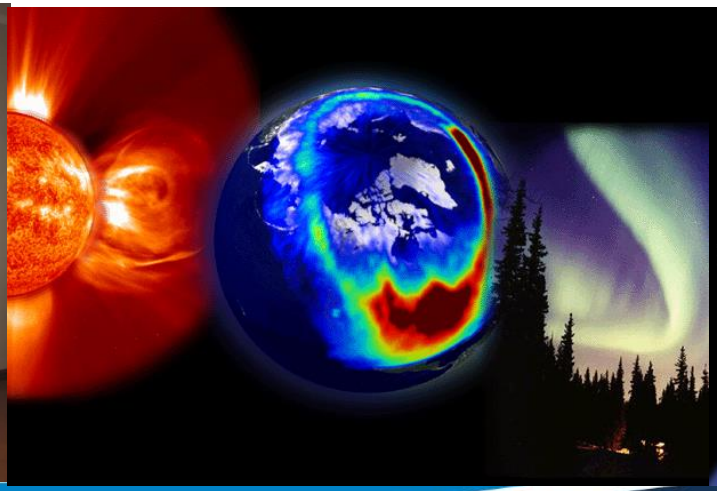
Provide the ***right*** information…
in the ***right*** format...
at the ***right*** time… to the *right* people…
to enable and facilitate the ***right*** decisions!

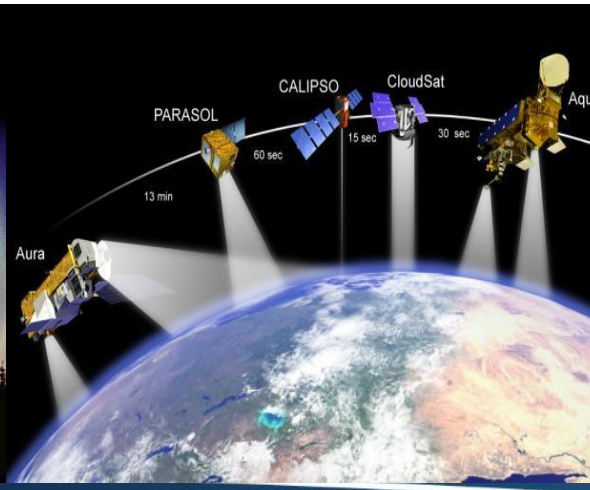


SPACE WEATHER OPERATIONS

- Monitoring the Earth-Space system, predictions and forecasts
- Distributing data and creating new knowledge on the system
- Providing space weather information to operations in the defence, energy and aviation sectors







Space Weather Information for Aviation

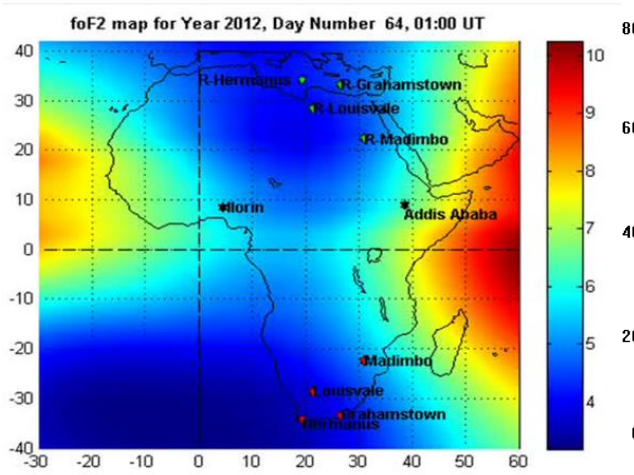
- Space weather phenomenon relevant to the whole flight route has been added to the information to be provided to operators and flight crew members.
- Space weather information shall be provided as part of the flight documentation.
- **SANSA has received designation as a Regional Centre for Space Weather Information Provision from the International Civil Aviation Organisation (ICAO)**
- Space weather advisory information will include one or more of the following effects:
  a) high frequency (HF) radio communications;
  b) Satellite communications
  c) GNSS-based navigation and surveillance; and
  d) radiation exposure at flight levels;

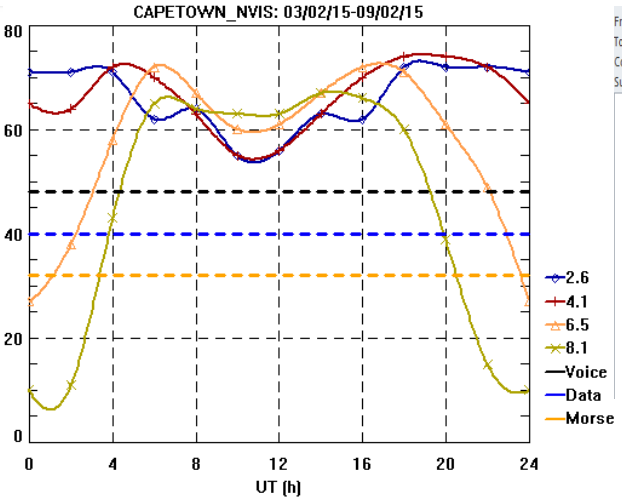
IMPLEMENTATION IS SET FOR BETWEEN NOV 2019 (Global) & Nov 2022 (Regional)



Space Solution to High-Frequency Communications

HF propagation path frequency predictions that allow users to prepare HF communication plans well in advance of operations. HF communications is dependent on the Earth's atmosphere which in turn is affected by space weather. Adverse space weather means a change in communication plan or paths – so applications have been developed to monitor for these changes and make suitable predictions.





From: SANSA Space Weather Centre Sent: Mon 2014/12/01 0
To: Mpho Tshisaphungo
Cc:
Subject: SANSA Space Weather Centre Information

Space Weather Bulletin

04 Nov 2014, composed at 10:35 SAST

WARNING/ALERT;

An M-class X-ray solar flare is in progress. Degraded frequency up to 16 MHz. Estimate recovery time is 20 minutes. Signal absorption is expected.

SYSTEMS THAT MAY BE AFFECTED;

HF communications.

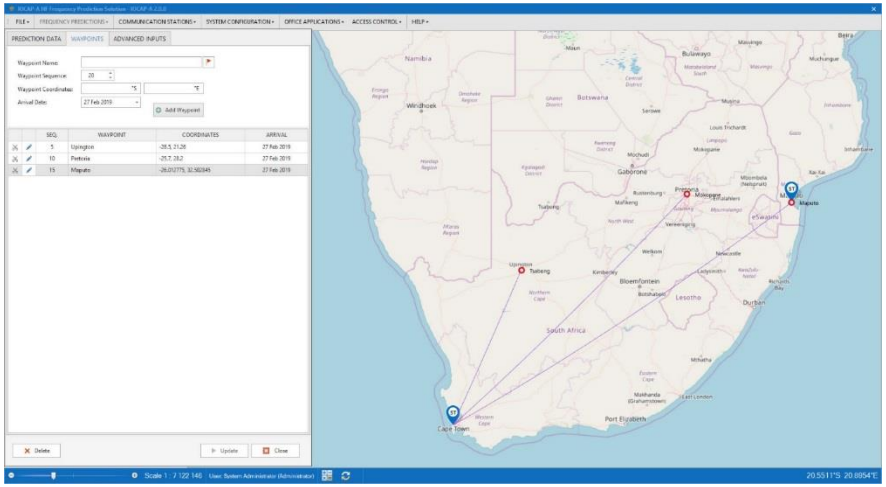
Prepared by M. Tshisaphungo

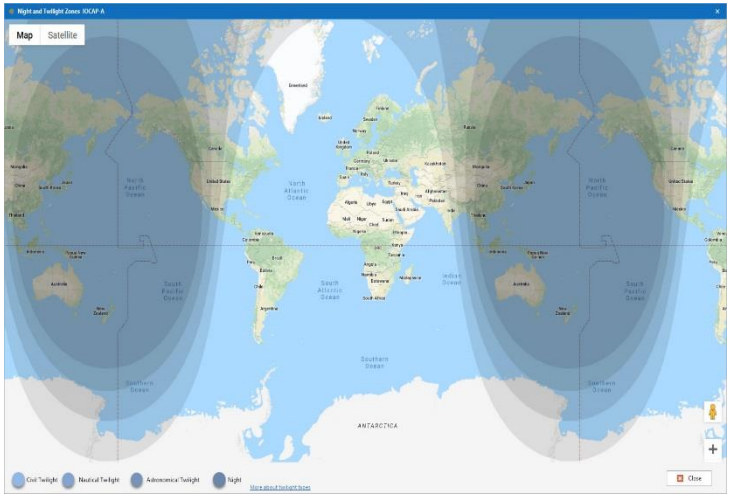
HF Communications

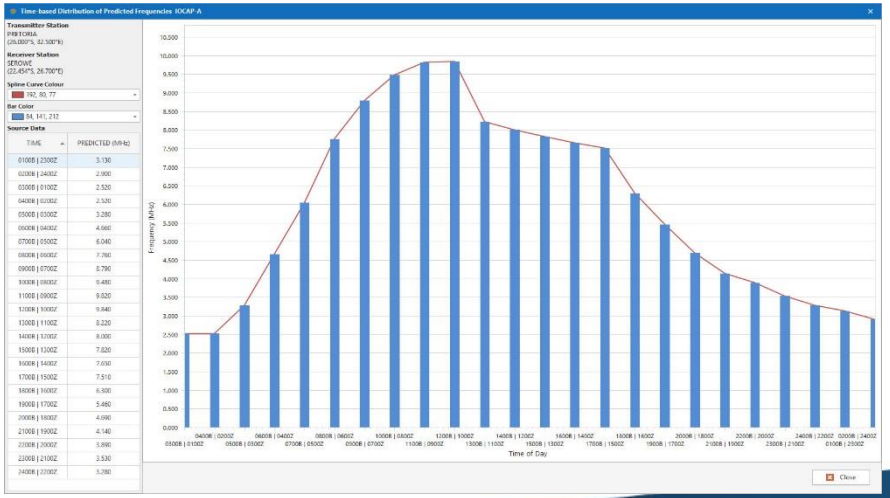
IOCAP = Ionospheric Characterisation, Analysis and Prediction

HF Communications Planning Tool

Frequency prediction results are shown in colourful charts and tables with specific emphasis on key prediction metrics, such as predicted frequencies, matches to available frequencies, signal-to-noise ratio and circuit reliability.







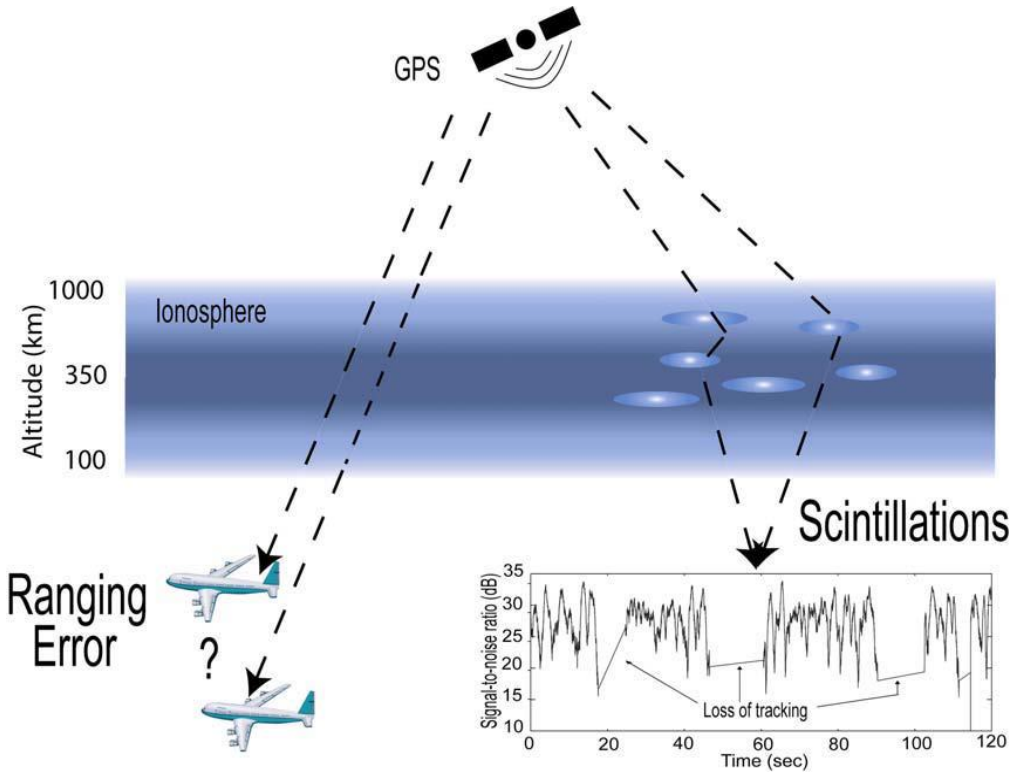
GNSS Navigation and Surveillance

Ionosphere: SW can induce perturbations in the ionosphere – inducing strong spatial gradients in TEC.

Scintillation: Attenuation of the GNSS-signal, lower C/N0 level

Solar Radio Noise: Results in background noise over GNSS frequencies and degrades signal

Solar flares, CMEs and the resulting magnetic storms can result in damaging effects on GNSS Signals.

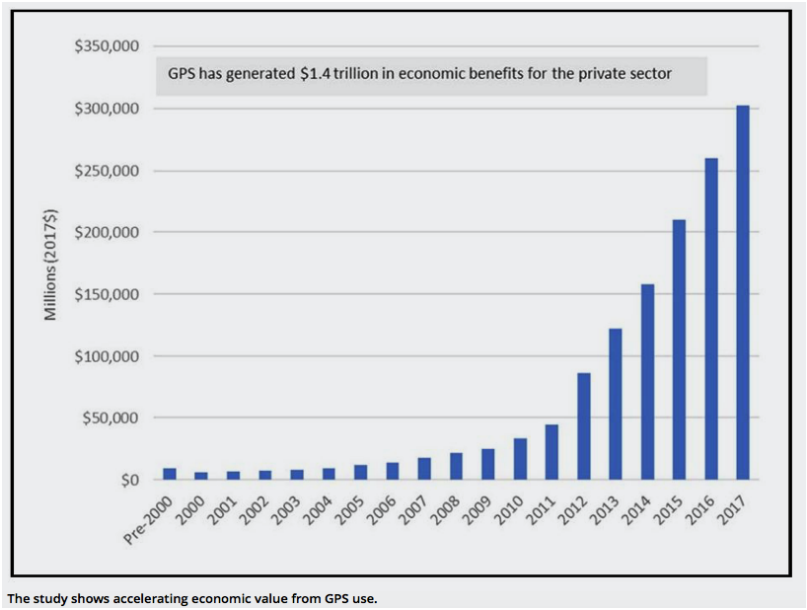


A Beginner's Guide to Space Weather and GPS
Professor Paul M. Kintner, Jr.

All result in poor positioning performance.

Space Weather and GNSS

New GPS3 satellite launched on SpaceX Falcon 9 in December 2018. 1st modernized satellite to broadcast all 4 signals. Signals are stronger to counter electronic jamming.



The study shows accelerating economic value from GPS use.

Recent NIST study estimates the economic benefit of GPS to be $1.4 Trillion since 1995 (mostly since 2010 as it is now used in so many technologies).

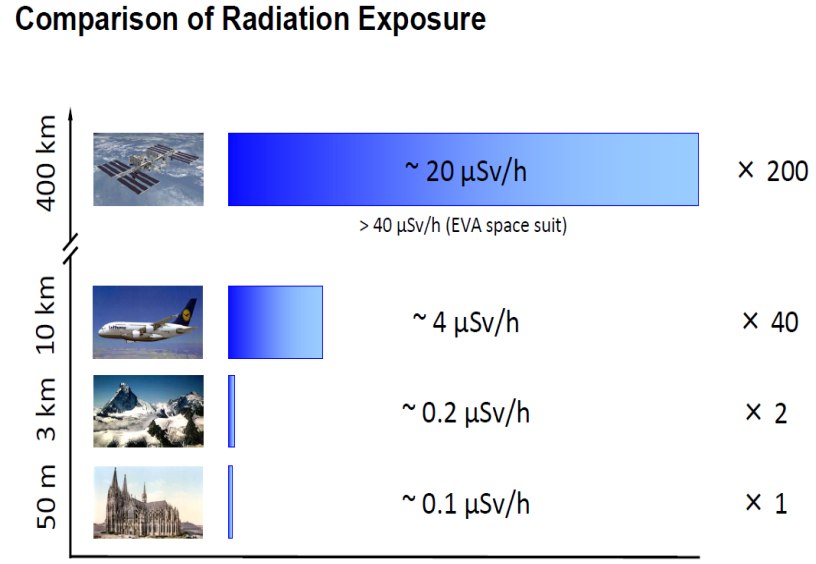
GPS —

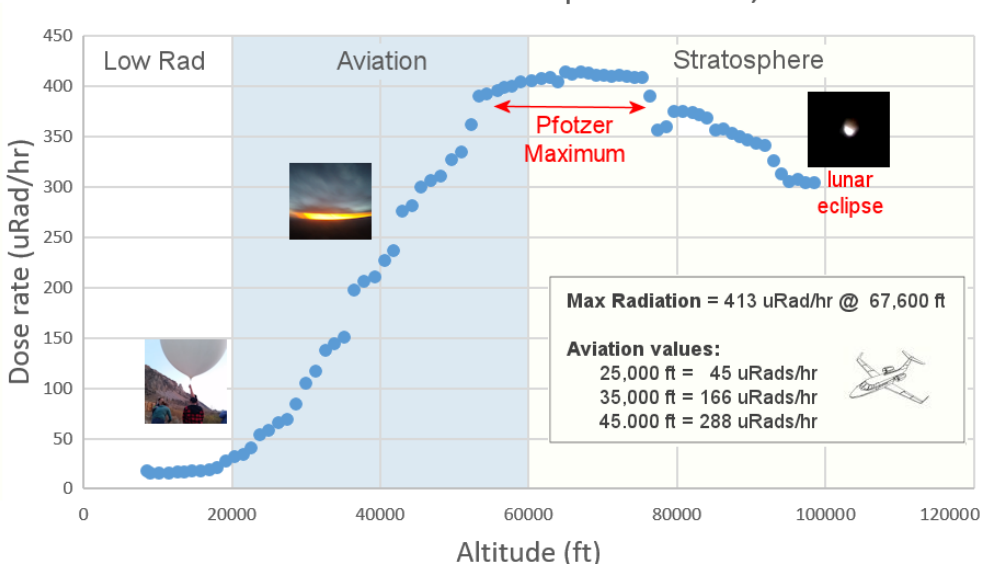
Study finds that a GPS outage would cost $1 billion per day

90 percent of the technology's financial impact has come since just 2010.

ERIC BERGER - 6/14/2019, 12:38 PM

Radiation Exposure

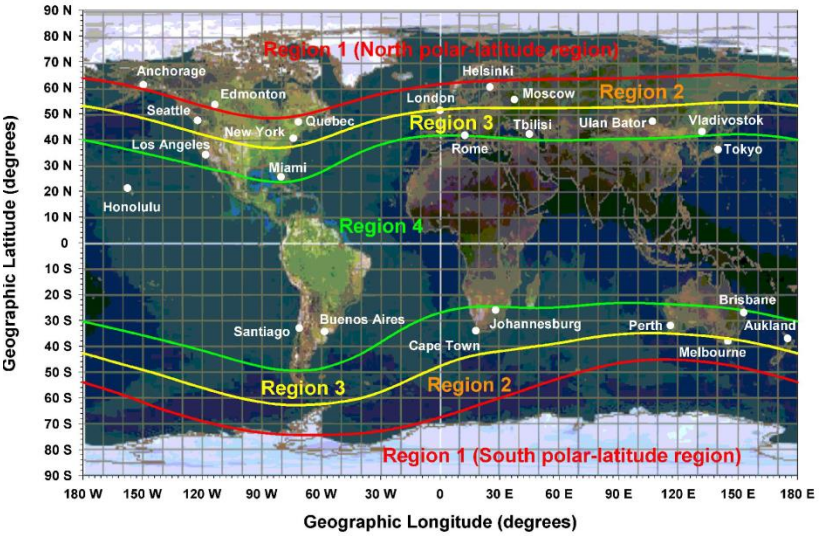




mSv: the average accumulated background radiation dose to an individual for 1 year.
1 mSv = **1000** µSv.
1 ft = 3.048×10^{-4} km
35000 ft = 10.6 km

Radiation dose	Source
0.01 millisievert (mSv)	Tooth X--ray
0.06 mSv (60µSv)	Flight(approx.9 hrs flight time)
0.1 mSv (100 µSv)	Chest X--ray
1 mSv	Annual dose limit for the public
2-5 mSv	Annual cosmic radiation dose for flying personnel
3.7 mSv	Average annual Finnish radiation dose (background radiation, indoor radon, medical radiation, etc.)
20 mSv	CT Scan, Limit on E_D for occupationally exposed workers averaged over defined periods of 5 years, with no single year exceeding 50 mSv
500-1000 mSv	Dose required for acute radiation illness
4000 mSv	Lethal dose when received at once

Radiation Exposure



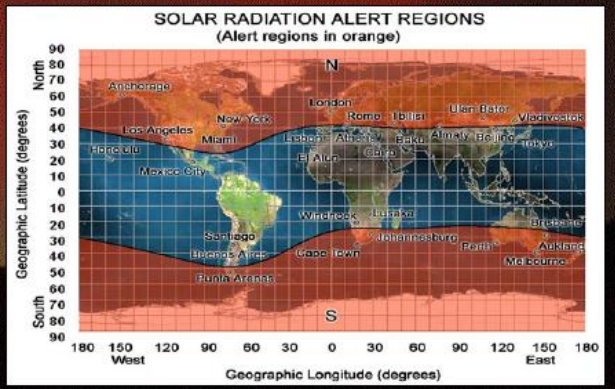
Airlines avoid polar routes during Radiation Storms due to both exposure and communications concerns

Low latitude concerns also exist:

***ALERT**: Solar Radiation Alert at Flight Altitudes Conditions Began: 2003 Oct 28 2113 UTC*

*Comment: **Satellite measurements indicate unusually high levels of ionizing radiation, coming from the sun. This may lead to excessive radiation doses to air travelers at Corrected Geomagnetic Latitudes above 35 degrees north, or south.***

(Federal Aviation Administration)

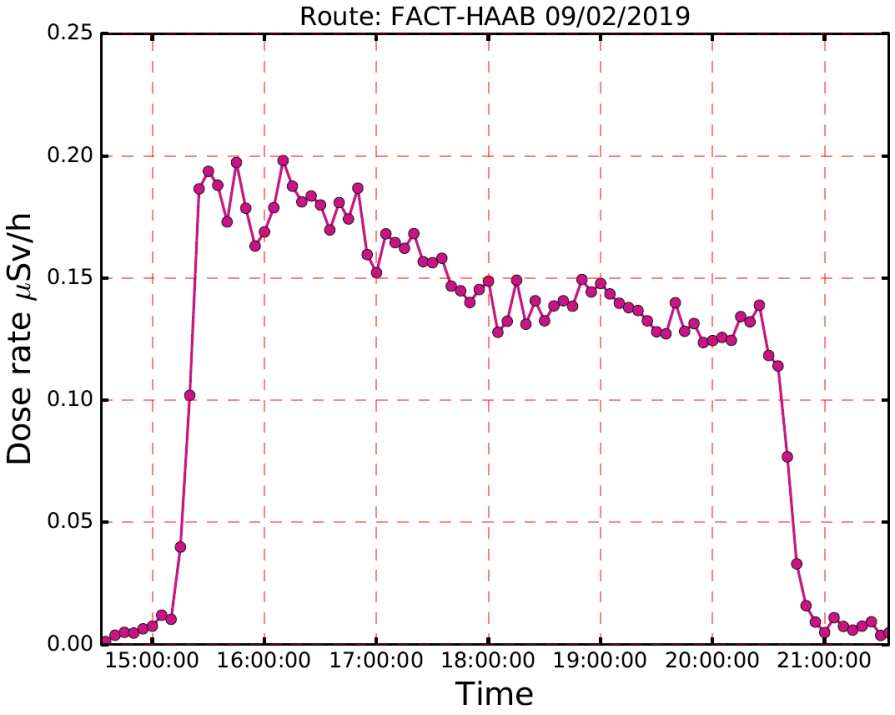


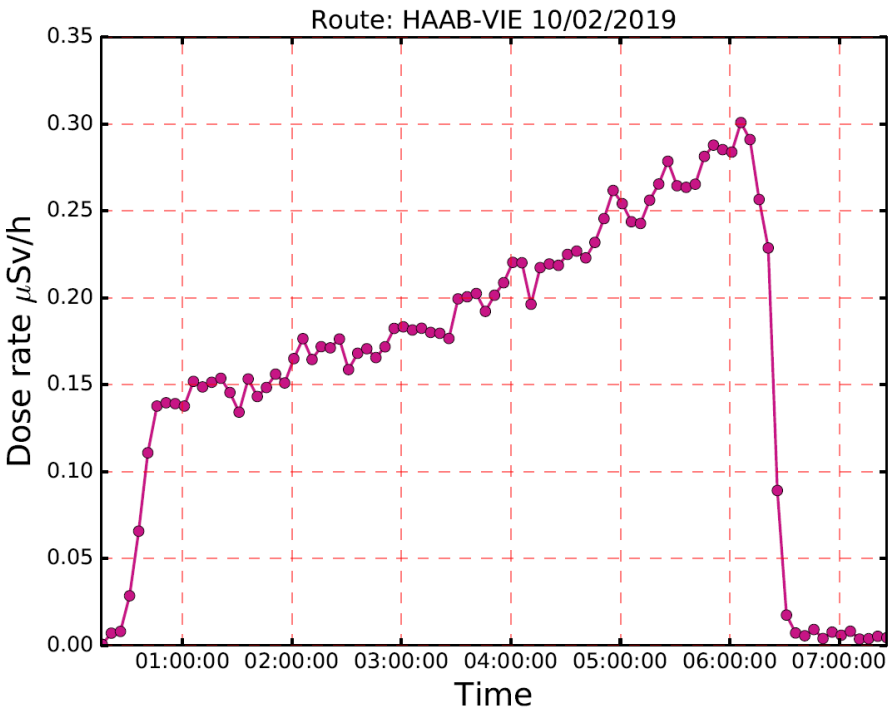
Left panel : under normal conditions: No space weather events

Right panel: Example of state of radiation on global scale. South Africa falls under Region 2 implying that the radiation risk alert has to be issued.

Radiation Exposure

Example of on-board flight measurements from: PM1610 dosimeter.





Example on-board results on flightd between Cape Town and Addis Ababa (left panel) and between Addis Ababa and Vienna (right panel). The area where the dose rate decreases is where the magnetic field shielding is the highest probably passing through the equator. The results show the dose rate which is the quantity of radiation absorbed per unit time during flight

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REGIONAL REPRESENTATION

Protecting our technology for tomorrow

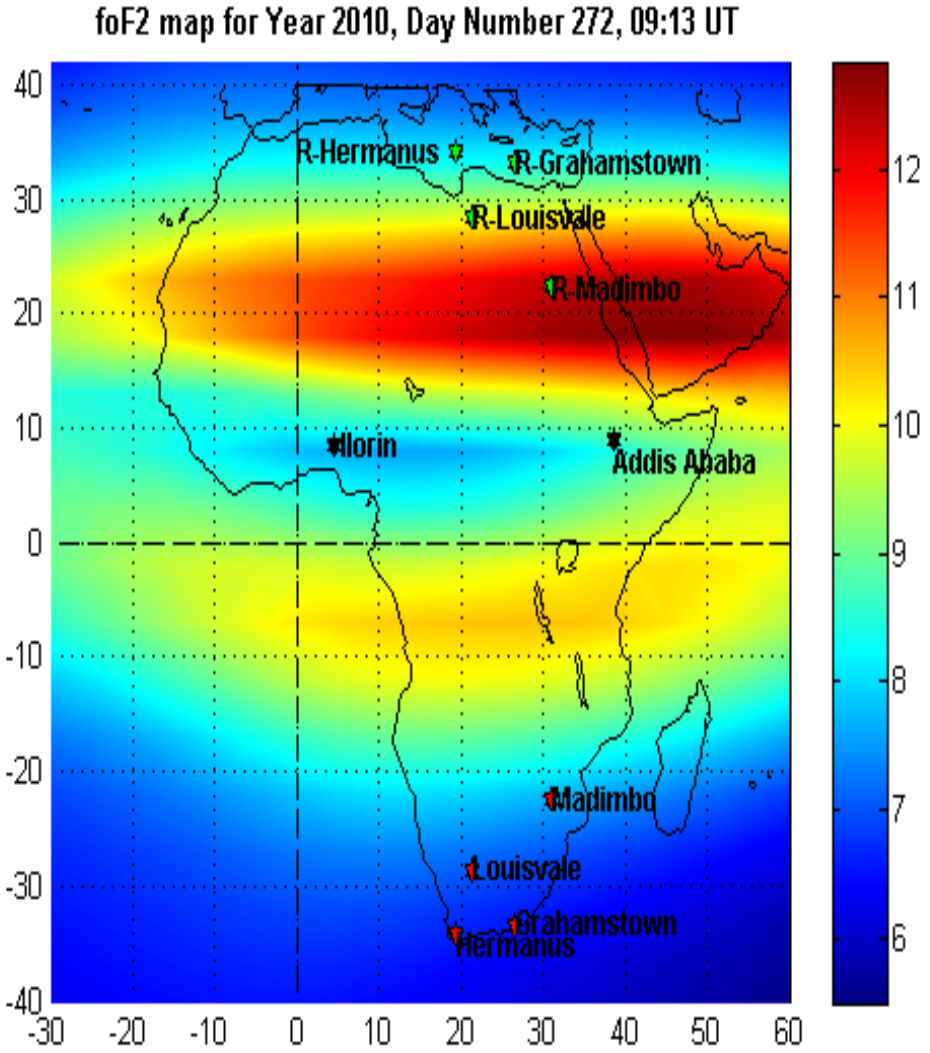
REGIONAL PERSPECTIVE

Africa's response to a global challenge

- Member of ISES (International Space Environment Service)
  One of 19 Regional Warning Centres for Space Weather
- Representation on WMO, UNCOPUOS and ICAO expert groups on Space Weather
- High quality regional data is benchmarked with international databases to deliver accurate well researched information
- Regional designation as Space Weather Information Provider for international air navigation

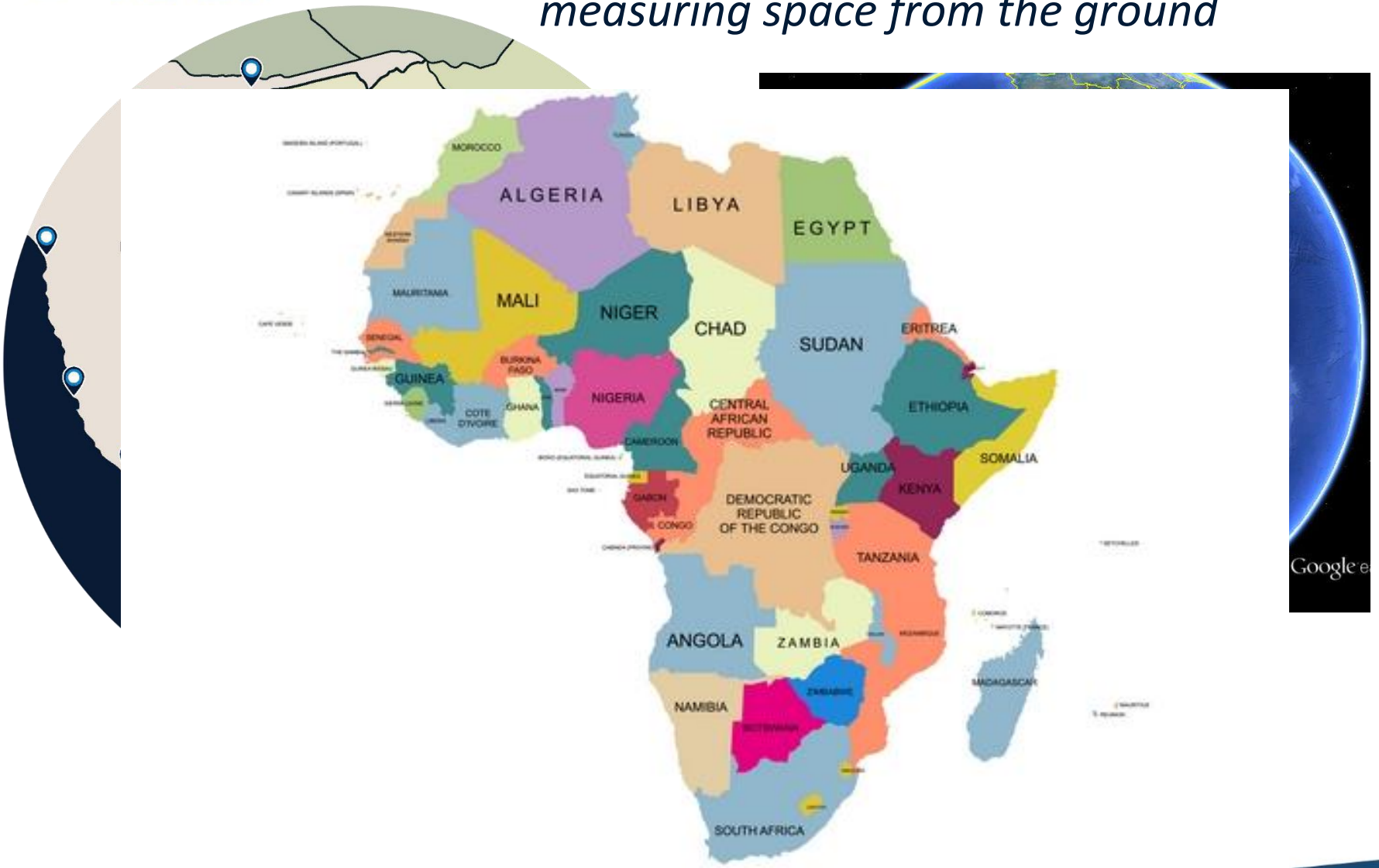
DEVELOPING AN AFRICAN IONOSPHERIC MAP

- → Utilising space science to develop solutions over Africa
- → Ionospheric map is utilised for monitoring the conditions under which communications are established
- → Applications in defence, maritime and transport sectors



INFRASTRUCTURE

measuring space from the ground



LEADING SPACE SCIENCE IN AFRICA

Through Space Weather SANSA is providing for the Development Agenda as follows:

→ Contributing to the growth and development of knowledge within the continent (research, training, students) – growing the knowledge economy and provision of a knowledge platform

→ Utilising space know-how to protect our technology and planet and ensure a sustainable future for all

→ Development of an African Instrumentation Network across the continent that forms the foundation for knowledge, applications, education

→ Providing unique solutions on the African continent to space and non-space sectors solving challenges in safety and security, maritime, energy, transport

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CONCLUSION

Policy Briefs

Executive Summary

This policy brief addresses the need to raise awareness of the impacts caused by space weather on the aviation sector. The main recommendation put forward is that South Africa should align itself with international standards for the provision and access to space weather information in order to meet the International Civil Aviation Organisation (ICAO) recommendations by 2017, and to protect the vulnerable areas within the aviation sector. An additional seven recommendations are included which would assist South Africa in developing capabilities, strategies and action plans around space weather and its impact on the aviation sector in South Africa.

Space weather refers to the conditions in space; on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems. Continuous monitoring of the space environment allows for early warning, forecasting and prediction of space weather events that could lead to technological and infrastructure failure. Due to the increasingly interconnected and interdependent technological systems of modern society space weather can negatively impact numerous sectors, leading to a cascade of operational failures. Research has shown that the defence, communications, navigation, aviation, and energy sectors are most vulnerable to space weather effects. The South African National Space Agency (SANSA) operates the Space Weather Regional Warning Centre for Africa, under the International Space Environment Service (ISES), which aims to coordinate global space weather activities. The SANSA Space Weather Centre was established in 2010 with the mandate to (i) develop space weather capabilities within South Africa, (ii) improve the understanding and awareness of space weather within Africa, and (iii) provide a space weather operational service to government, industry and the public. It is important to note that space weather is a global phenomenon with regional impact.

Ground based support and aircraft are vulnerable to space weather impacts, primarily in four key areas: communication, navigation, aircraft avionics and radiation exposure. ICAO has recognised the need for the adoption of procedures related to mitigating space weather impacts. During the 2014 Montreal Meeting of the ICAO Meteorology Division a recommendation was passed for

Executive Summary

This policy brief addresses the need to raise awareness of the economic impacts that can arise from space weather events and the national risk that space weather presents to South Africa. The main recommendation put forward is that South Africa should identify extreme space weather events as a potential risk to the economy and critical infrastructure, and therefore appropriate recognition, understanding and capability development is required in order to ensure adequate preparedness. Nine recommendations are included which would assist South Africa in developing capabilities, strategies, action and mitigation plans in order to manage the national risk presented by the space environment.

Due to the increasingly interconnected and interdependent technological systems of modern society space weather can negatively impact numerous sectors, leading to a cascade of operational failures. Research has shown that the defence, communications, navigation, aviation, and energy sectors are most vulnerable to space weather effects. Research has also shown that space weather is a global phenomenon with regional impact. The South African National Space Agency (SANSA) operates the Space Weather Regional Warning Centre for Africa, under the International Space Environment Service (ISES), which aims to coordinate global space weather activities. The SANSA Space Weather Centre was established in 2010 with the mandate to (i) develop space weather capabilities within South Africa, (ii) improve the understanding and awareness of space weather within Africa, and (iii) provide a space weather operational service to government, industry and the public.

The field of space weather is growing rapidly, with new discoveries and continuous developments in forecasting and prediction capabilities which improve almost daily. There are still many unknowns and a rigorous assessment of the economic impact resulting from a severe solar storm is a work in progress. Some analysis has been done on the impacts resulting from Geomagnetically Induced Currents (GICs), however, to a large extent the evidence is still anecdotal. This policy brief describes the possible economic impacts, and presents likely scenarios as well as discussion points around the risk that South Africa may be exposed to from space weather.

Available on www.sansa.org.za/publications

CONCLUSION

- → Space Weather events can create vulnerabilities within our technology dependencies, and is a risk to the 4IR
- → Space Weather affects safety of live principles for aviation operations, and compliance with ICAO is now a requirement
- → SANSA is addressing operational capability for Space Weather information provision as a service to the African region
- → SANSA will continue to utilize its existing capability and global networks to ensure that the most optimum solution for dealing with the threat of Space Weather is developed for the continent
- → SANSA will continue to partner with the various role players to ensure an adequate readiness level on both sides (provider & user) for space weather information

http://www.sansa.org.za
http://spaceweather.sansa.org.za
http://research.sansa.org.za