
* ISWI Newsletter - Vol. 17 No. 012 15 December 2025 *

* Editor: George Maeda, georgemaeda3[at]gmail.com

* Archive of back issues: ISWI Website <https://iswi-secretariat.org/>

* Send subscription request to: iswisupport@bc.edu

Dear ISWI Newsletter Subscriber:

Please be reminded that this newsletter has two versions:

- [1] Email version -- this gets distributed via email directly to you but does not have the attachments.
- [2] Web version -- this is the full version with attachments.

To view the Web version, go to this web page:

<https://iswi-secretariat.org/>

and click on "NEWSLETTERS".

If you have space-weather-related news or announcements, please send them to me and I will distribute your material through the ISWI NEWSLETTER.

Cordially,
George Maeda
Editor of the ISWI Newsletter, since 2009.

CONTENTS OF THIS ISSUE:

[01] End-of-Year Message from Dr. Nat Gopalswamy, Executive Director of ISWI
. ***** EVERYONE SHOULD READ IT *****

[02] New book from Sudan:
. TITLE:
. "Optimum deployment of ground magnetometers in challenging regions: Sudan"
. Paperback – July 18, 2025; by Magdi Yousif Suliman.

[03] REPORT ON THE UNITED NATIONS/NIGERIA WORKSHOP
. ON INTERNATIONAL SPACE WEATHER INITIATIVE ISWI,
. submitted by Prof. Babatunde Rabi

[04] Proceedings of the United Nations/Germany Workshop
. on the International Space Weather Initiative”;

. submitted by Dr. Nat Gopalswamy, *et al.*

[05] The world's first liquid-fueled rocket was launched on
. 16 March, 1926, in Auburn, Massachusetts. Preparations
. are underway for its centennial celebration in 2026;
. submitted by G. Maeda.

[06] Announcement for the initiative to compile a comprehensive record
. of ISWI instruments publications;
. submitted by Dr Shing Fung, ISWI DATA SUBCOMMITTEE

[07] URSI GASS 2026 call for abstracts
. -- SESSION G07: THE HIGH LATITUDE ATMOSPHERE;
. submitted by Dr Liliana Macotela (NORCE, Norway)

[08] Almost Everything About NASA's Latest Mission to Mars Is Unusual;
. The ESCAPE mission, which launched to space on a Blue Origin
. rocket on 13-NOV-2025, breaks the mold of how planetary science
. missions typically come together.
. THE NEW YORK TIMES, 14 Nov 2025.

[09] YouTube video about Prof. Syun-Ichi Akasofu and aurora borealis
. research in the arctic region. Released in 2023.

[01]-----

Please read **End-of-Year Message** from Dr. Nat Gopalswamy,
Executive Director of ISWI, with this PDF:

Dear Colleagues 2026.pdf

001

[02]-----

A new book about the deployment of ground magnetometers
is now available:

TITLE:

"Optimum deployment of ground magnetometers in challenging regions: Sudan"
Paperback – July 18, 2025; by Magdi Yousif Suliman (Author)

Space science is a recent field of knowledge which is a multidisciplinary field. And, it

has become attractive for worldwide scholars, including nationals from what so called developing, and least developed countries. There is an important new branch of space science, and it is what is known as space weather. The space weather is mostly those 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, and can affect human life or health. The space weather is then known to have an undecieved impact on our today's modern systems and technologies. For instance space weather can affect ground oil pipeline networks, electric power grids, and communication networks (Matthews, 2004); in particular space weather has effects on causing malfunctions or in severe cases damages on these systems. All technological systems mentioned formerly are vital in the development and economics for all nations. Therefore, the socio- economic impact of space weather overwhelms all nations to include even the so called developed nations.

This book can be purchased from three places:

Place 1:

<https://www.morebooks.de/shop-ui/shop/product/9786207996162>

Place 2:

https://www.adlibris.com/nb/bok/optimum-deployment-of-groundmagnetometers-in-challengingregions-9786207996162?utm_source=chatgpt.com

Place 3:

<https://www.amazon.com/Optimum-deployment-groundmagnetometers-challengingregions-Sudan/dp/620799616X>

[03]-----

**REPORT ON THE UNITED NATIONS/NIGERIA WORKSHOP
ON INTERNATIONAL SPACE WEATHER INITIATIVE ISWI**

FROM: Prof. Babatunde Rabi
TO: ISWI Newsletter
DATE: 14 Dec 2025

Dear Editor:

Compliments of the season!
Thanks for all you do for the space weather community!

Kindly include the report on the UN/Nigeria Workshop

on ISWI presented herein in the next edition of ISWI newsletter.

The United Nations/Nigeria Workshop on the International Space Weather Initiative: Space Weather During a Moderate Solar Cycle #25 was held between 6th and 10th October 2025 at Abuja, Nigeria.

The workshop was jointly organized by the United Nations Office for Outer Space Affairs (UNOOSA) and the National Space Research and Development Agency (NASRDA) on behalf of the Federal Government of Nigeria. It was supported by the International Committee on Global Navigation Satellite Systems (ICG) and the Defence Space Administration of the Federal Government of Nigeria.

A total of 46 expert participants from 22 countries participated in the Workshop. Detailed program of event and the United Nations final report are attached hereby attached for global circulation. The final United Nations report is also available in all the official languages of the UN on the workshop website at: <https://www.unoosa.org/oosa/en/ourwork/psa/schedule/2025/united-nations-nigeria-workshop-on-the-international-space-weather-initiative-2025.html> .

A group photograph taken after the opening session is attached to this mail. Meanwhile some pictures taken at the workshops are available for downloading at: - https://drive.google.com/drive/folders/1T92Wd8QJHkQsEe1egrnkSpurg6_8_cNK?usp=sharing

Sincerely,

Babatunde Rabi

National Focal Point & Chair Local Organising Committee,

United Nations/Nigeria Workshop on the International Space Weather Initiative

.....
Professor Babatunde Rabi, FAS

Research Director: National Space Research and Development Agency

Professor: Institute of Space Science & Engineering

African University of Science and Technology

Physical Address:

Obasanjo Space Centre, Km 17 Umaru Musa Yar'Adua Road; Abuja 900107, FCT, Nigeria

=====
Attached PDFs:

[1] ISWI2025_Programme of the Abuja Workshop.pdf

002

[2] A_AC.105_1370_E; final UN report

003

[3] 2025 ISWI workshop group photo

004

[04]-----

FROM: Nat Gopalswamy (671), Daniela Banys (DLR, Germany),
Sharafat Gadimova (UN, Austria), 2025:

**“Proceedings of the United Nations/Germany Workshop
on the International Space Weather Initiative”** ... has been published.

Springer Proceedings in Physics vol. 431, doi: 10.1007/978-981-95-1121-1, ISBN: 9789819511211, 9789819511204, 9789819511211. This open access book consists of refereed articles in Solar Physics; Solar Effects; Sun-Earth Connection; Space Weather Instrumentation; Global navigation satellite systems; Magnetosphere-Ionosphere-Thermosphere Coupling; Space weather programs.

The articles are based on the United Nations/Germany Workshop on the International Space Weather Initiative held in Neustrelitz, Germany during 10-24 June 2024. The publication was partly supported by NASA’s Living with a Star program.

[05]-----

Join us in honoring Dr. Robert and Esther Goddard's legendary first liquid-fueled rocket launch on March 16th, 1926. We will be celebrating where it happened, in Auburn, Massachusetts for the 100 year anniversary from March 13th-16th, 2026. Join our newsletter to be informed of events and activities leading up to and during the celebration.

We are a 501(c)(3) not for profit charitable organization as The Wellstorm, Inc. is our fiscal sponsor. -- All funds collected will be used for the Goddard centennial celebrations in Auburn with additional funds given to the town of Auburn MA.

<https://goddard100th.org/>

[06]-----

From: Shing Fung, ISWI DATA SUBCOMMITTEE
Date: 5 December 2025

To: ISWI Newsletter

=====
**Announcement for the initiative to compile
a comprehensive record of ISWI instruments publications**

We are excited to announce the initiative to create a comprehensive and centralized record of the scientific publications that have been supported by the data obtained by all the ISWI instruments. The primary goal of this initiative is to create a tool to demonstrate tangibly how ISWI has supported and contributed to space weather research. Although the different instrument teams are already maintaining the publication records for their instruments, the new centralized record will provide a global view of the breadth and depth of the science supported by ISWI.

We also hope that easy access to the research results from different instruments will also inspire cross-disciplinary research. A web-based form has now been created to capture publication metadata for web posting purposes. The ISWI community is now invited to use the form (<https://forms.office.com/r/7EEDvjYggB>) to submit your ISWI publication information, so we can start compiling the publication records by instruments.

We understand that the records will not be complete initially, but with continued community support and input in time, we hope to build eventually a comprehensive ISWI publication record (at least from now on) that is more accurately reflective of the success of ISWI.

With best wishes,
Shing Fung,
on behalf of the ISWI data subcommittee

[07]-----

RE: URSI GASS 2026 announcement
FROM: Liliana Macotela
DATE: 25 Nov 2025
TO: ISWI NEWSLETTER

Dear Professor Maeda,

Please, find below an advertisement or an URSI session.
Please, feel free to publish at your earliest convenience.

Kind regards,
Liliana Macotela

=====
Subject: URSI GASS 2026 call for abstracts
- SESSION G07: THE HIGH LATITUDE ATMOSPHERE
=====

Dear Colleagues,

The XXXVIth URSI General Assembly and Scientific Symposium (URSI GASS 2026) will be held in Krakow, Poland, from August 15 to 22, 2026.

We invite you to submit contributions to
Session G07 – The High Latitude Atmosphere.

Session Description
=====

A multidisciplinary and multi-instrument approach, supported by advanced modeling efforts, is essential to advancing our understanding of the high-latitude atmosphere, including the ionosphere, and the broader geospace environment. Addressing some of the most pressing scientific questions in atmospheric and space physics requires collaborative and integrative strategies. *Key questions include:*

- ① How are different atmospheric layers coupled in the polar regions?
- ② How does the upper polar atmosphere, comprising the mesosphere, thermosphere, and ionosphere, respond to increased geomagnetic activity and energy input from space?
- ③ How does the polar atmosphere influence short- and long-term climate variability?

Answering these questions will not only enhance our understanding of polar atmospheric processes but also significantly improve insights into global atmospheric dynamics. These research efforts contribute to **AGATA** (Antarctic Geospace and ATmosphere reseArch), a newly endorsed Scientific Research Programme by SCAR (Scientific Committee on Antarctic Research) and recognized by ICARP IV (Fourth International Conference on Arctic Research Planning) coordinated by the IASC (International Arctic Science Committee) as an open platform for collaboration among scientists and stakeholders.

We invite contributions that tackle key scientific challenges in atmospheric and space physics, including whole-atmosphere coupling, the impacts of space weather, and the response of the polar atmosphere to climate variability and change. We especially encourage submissions that present innovative tools, observational methodologies, and interdisciplinary approaches to upper atmosphere (including also ionosphere) and high-latitude research, ranging from advanced ground-based and space-borne instrumentation to emerging modeling techniques such as data assimilation and AI-

driven forecasting.

URSI also offers a rich program for students and young scientists, including awards and competitions.

Important Information and Useful Links

=====

Paper submission (deadline: January 25, 2026):

<https://www.eventure-online.com/eventure/login.form?A094859a9-5d82-40b2-8667-d3c6e7d18a9c>

Student Paper Competition: <https://www.ursi-gass2026.pl/studentpaper>

Young Scientist Award: <https://www.ursi-gass2026.pl/youngscientist>

Kind regards,

Liliana Macotela, on behalf of the convener team:

- Liliana Macotela (NORCE, Norway)
- Wojciech Jacek Miloch (UiO, Norway)
- Giorgiana De Franceschi (INGV, Italy)
- Ralph Latteck (IAP, Germany)
- Lucilla Alfonsi (INGV, Italy)

Liliana Macotela

Seniorforsker, Senior Researcher

Forskningsparken Tromsø, Sykehusvn 23, 9019 Tromsø

[08]-----

NASA's latest robotic mission to Mars, **ESCAPADE**, should perhaps have been named the Great Escape, given how many times it has eluded doom.

The data that the mission eventually collects will provide clues about why Mars, which once possessed a thick atmosphere and flowing water on its surface, is today cold, dry and almost airless.

The mission, which launched on Thursday, could also serve as a "trailblazer" for how NASA could get more bang for its buck from its science missions, said Rob Lillis, the mission's principal investigator.

NASA initially rejected Dr. Lillis' proposal several years ago. Later, ESCAPADE — a shortening of Escape and Plasma Acceleration and Dynamics Explorers — only got the go-ahead from NASA because

001



Dear Colleagues,

Season's Greetings!

It is almost the end of the year 2025! I hope you had a productive year in advancing space weather activities.

I am sure you all had a chance to read about the 3rd Interstellar comet (3I/ATLAS) that was first observed during the summer (July 1, 2025) by the ATLAS survey telescope in Rio Hurtado, Chile. 3I/ATLAS is expected pass Earth at the end of next week (December 19, 2025). ATLAS is part of NASA's planetary defense network that continually watches the skies to look for dangerous objects approaching Earth. While the Voyagers are venturing into the in stellar space, the solar system got to receive the visitor from the surroundings of another star.

The proceedings book of the UN/Germany workshop on ISWI held in Neustrelitz, Germany last year has been published as ***Springer Proceedings in Physics vol. 431***, ISBN: 9789819511211, 9789819511204, 9789819511211. This open access book consists of 33 refereed articles in 300+ pages on Solar Physics; Solar Effects; Sun-Earth Connection; Space Weather Instrumentation; Global navigation satellite systems; Magnetosphere-Ionosphere-Thermosphere Coupling; Space weather programs. The publication was sponsored by NASA's Living with a Star program. You can have your own copy of the entire book at <https://link.springer.com/book/10.1007/978-981-95-1121-1> for free.

The 2026 ISWI-SCOSTEP School on Space Weather is being organized by the Indian Institute of Geomagnetism, Mumbai, India during January 5-9, 2026. The lectures cover all aspects of space weather science from solar interior to Earth's surface. International experts will give lectures in the morning and conduct hands-on activities in the afternoons. About 80 participants (domestic and international combined) are expected to attend the school. In addition to ISWI and SCOSTEP, the school is co-sponsored by the Indian Institute of Geomagnetism, Indian Space Research Organization, Boston College, Japan's Core-to-Core program, and the Science and Engineering Research Board (SERB) in India. Details can be found in the workshop web site: <https://iigm.res.in/iswi/>.

The ISWI webinars continue to attract the community. Five excellent webinars were presented so far in 2025, bringing the total to 26. The recordings of the webinars are hosted by NASA/GSFC's CDAW Data Center. Please feel free to download them and spread them to the community: <https://cdaw.gsfc.nasa.gov/webinars/ISWI/>.

We had a very successful UN/Nigeria ISWI Workshop during 6 - 10 October 2025 at the Obasanjo Space Centre in Abuja, Nigeria. Details of the workshop can be found in: <https://www.unoosa.org/oosa/en/ourwork/psa/schedule/2025/united-nations-nigeria-workshop-on-the-international-space-weather-initiative-2025.html>. This workshop was

jointly organized by the United Nations Office for Outer Space Affairs (UNOOSA) and the National Space Research and Development Agency (NASRDA) of Nigeria. The workshop was supported by the International Committee on GNSS (ICG). The final United Nations report on this workshop is available in the above web site. A copy is also published in the current ISWI Newsletter.

We are excited that the next UN/ISWI workshop will be held in South Korea (2026). We expect to have more details soon.

I have been talking to many early career/mid-career members of the ISWI community regarding IHY+25, which will be in 2032. People have been very receptive to the idea and are willing to make use of the opportunity to promote space weather science in the AI/ML era. I have formed a committee of about a dozen people to explore ways to celebrate the 25th anniversary of IHY. This committee will come up with a plan that will enable the global space weather community to participate in IHY+25 in a meaningful way.

The Data Subcommittee has been working on developing a web form for capturing the publication records of ISWI, conference presentations, and other reports. The goal is to establish a central location (e.g., ISWI website). More details on this activity will be made available soon.

The next ISWI Steering Committee meeting will be held during February 4&5, 2026. This meeting provides an excellent opportunity for the national coordinators to advertise their space weather activities such as instrument hosting, national meetings, and research highlights. To ensure everyone gets sufficient time to present their activities, the duration has been extended for two days. The meeting agenda is provided in the annexure. Please feel free to suggest modifications.

Warm regards,

Nat Gopalswamy

2025 December 13.



Annexure I

ISWI Steering Committee Meeting: Tentative Agenda

February 4-5, 2026 10 am to 6 pm

Vienna International Center

Vienna, Austria

1. Introduction & Report (Nat Gopalswamy, Chair)
2. Secretariat Update (Nat Gopalswamy, Kathleen Kramer, George Maeda, Graciela Molina)
3. Steering Committee Update (Nat Gopalswamy)
4. SCOSTEP/PRESTO/COURSE (Kazuo Shiokawa)
5. UN/Nigeria ISWI Workshop report (Babatunde Rabiou)
6. ISWI/India School report (S. Tulasiram)
7. ISWI/NOAA Report (Jim Spann)
8. COSPAR Space Weather Roadmap and ISWAT activities (Mario Bisi)

9. UNOOSA Report (Sharafat Gadimova)
10. Reports from ISWI Regional & National Coordinators (lead: Christine Amory)
11. ISWI Instruments Update (Shing Fung and Instrument PIs); Data subcommittee report
12. AI/ML activities for Space Weather (M. Guhathakurta)
13. Discussion on IHY+25
14. Any other business



United Nations
Office for Outer Space Affairs

002



*United Nations/Nigeria Workshop on
the International Space Weather Initiative:
Space Weather During a Moderate Solar Cycle #25*

Co-Organised by

**The United Nations Office for Outer Space Affairs and
National Space Research and Development Agency
on behalf of the Federal Government of Nigeria**

Supported by

**the International Committee on Global Navigation Satellite Systems (ICG) and
Defence Space Administration of Nigeria**

6 – 10 October 2025

Abuja, Nigeria

PROGRAMME



The International Space Weather Initiative (ISWI) is a programme of international cooperation to advance space weather science by a combination of instrument deployment, analysis of space weather data from these instruments in conjunction with other data and the communication of such results.

Programme Committee

Babatunde Rabi	Co-chair, National Space Research and Development Agency, Nigeria
Sharafat Gadimova	Co-chair, United Nations Office for Outer Space Affairs, Austria
Natchimuthukonar Gopalswamy	Co-chair, National Aeronautics and Space Administration (NASA), United States of America
Christine Amory-Mazaudier	Sorbonne University, France
Daniella Banyś	German Aerospace Centre (DLR), Germany
Keith Groves	Boston College, USA
Shing F. Fung	NASA Goddard Space Flight Center, USA
Endawoke Yizengaw	The Aerospace Corporation, USA
Kazuo Shiokawa	SCOSTEP; Nagoya University, Japan
Olivier Obrou	Université Félix Houphouët-Boigny, Cote d'Ivoire
Zama Katamzi-Joseph	South African National Space Agency, South Africa
Daniel Okoh	National Space Research and Development Agency, Nigeria
Yenca Migoya Orué	The Abdus Salam International Centre for Theoretical Physics (ICTP), Italy
Ki Chang Yoon	Republic of Korea
Clezio Marcos De Nardin	Instituto Nacional de Pesquisas Espaciais, Brazil
Alphonse Sterling	NASA Marshall Space Flight Center, USA
Rami Vainio	University of Turku, Finland
Ashot Chilingarian	Alikhanyan National Science Laboratory, Armenia
Nikolai Ostgaard	University of Oslo, Norway
Ankush Bhasker	Vikram Sarabhai Space Centre, ISRO, India
Johan Muhamad	Indonesian National Institute of Aeronautics and Space, Indonesia

Local Organizing Committee

Babatunde Rabi	Chair, NASRDA, Nigeria
Bonaventure Okere	Member, NASRDA, Nigeria
Lami Ali Fadiora	Member, NASRDA, Nigeria
Ikpaya D. Ikpaya	Member, NASRDA, Nigeria
Idris Jega	Member, NASRDA, Nigeria
Henry Akoma	Member, NASRDA, Nigeria
Daniel Okoh	Member, NASRDA, Nigeria
Oluwatosin Ogedengbe	Member, NASRDA, Nigeria
Adedayo Adebowale	Member, NASRDA, Nigeria
Afolabi Olubiyi	Member, NASRDA, Nigeria
Olasehinde Adejoro	Member, NASRDA, Nigeria
Aderonke Akerele	Secretary, NASRDA, Nigeria

Monday, 6 October 2025

VENUE: OBASANJO SPACE CENTRE, Abuja

- 09:00 – 10:00 *Registration*
- 10:00 Opening Ceremony and Welcome Remarks**
Moderator: Babatunde RABIU, Nigeria
National Anthem
Chief Uche Geoffrey NNAJI, *The Honourable Minister, Federal Ministry of Innovation, Science and Technology, Nigeria*
Sharafat GADIMOVA, *United Nations Office for Outer Space Affairs, Austria*
Natchimuthukonar GOPALSWAMY, *National Aeronautics and Space Administration, United States of America*
Dr. Matthew ADEPOJU, *Director-General and Chief Executive, National Space Research and Development Agency, Abuja, Nigeria*
Air Vice Marshal Lanre Ibrahim OLUWATOYIN, *Chief of Defence Space Administration, Defence Space Administration, Abuja, Nigeria*
- 10:25 *Keynote address I: International Space Weather Initiative: A global cooperation, Natchimuthukonar GOPALSWAMY, United States of America*
- 10:55 – 11:00 *Goodwill messages*
Closing remark
- 11:00 – 11:30 *Tea Break (Group Photo)*
- 11:30 *Keynote address II: Space science, innovation, science & technology in sustainable development of a nation, Francisca OKEKE, Nigeria*
- 12:00 Session 1: Solar Physics (Solar eruptions – their sources at the Sun and impact on magnetosphere, ionosphere, atmosphere, ground)**
Chairperson: Kouadio Olivier OBROU, Côte d'Ivoire
Rapporteur: Esther HANSON, Nigeria
- 12:00 *(virtual, invited paper) Solar eruptions and space weather, Natchimuthukonar GOPALSWAMY, United States of America*
- 12:20 *Explore Solar Eruptions for Space Weather with MUSER Observations, Yihua YAN, China*
- 12:40 *Monitoring the effects of the Gamma ray burst 221009A on the ionosphere by multi-instruments, Amira SHIMEIS, Egypt*
- 13:00 – 14:00 *Lunch break*
- 14:00 Session 2: Space Weather Instrumentation and Data (ISWI Instruments and others)**
Chairperson: Filip ŠKLEBAR, Croatia
Rapporteur: Teshome DUGASSA, Ethiopia
- 14:00 *(virtual, invited paper) The Optical Mesosphere Thermosphere Imagers (OMTIs), SHIOKAWA Kazuo, Japan*
- 14:30 *(virtual, invited paper) ISWI Data Policy, Shing FUNG, United States of America*
- 15:00 *(virtual, invited paper) The International Meridian Circle Program (IMCP), Chi WANG, China*
- 15:30 – 15:50 *Tea Break*

**15:50 Session 2: Space Weather Instrumentation and Data (ISWI Instruments and others)
(continued)**

Chairperson: Amira SHIMEIS, Egypt

Rapporteur: Jean Claude UWAMAHARO, Czech Republic

15:50 Modulation of the TEC in the Midlatitude Region by ULF Waves: Preliminary
Conjunctive Observations between LFWR and GNSS in the Chinese Meridian Project,
Yong Cun ZHANG, China

16:10 *(virtual)* Improving the quality of CALLISTO images for solar burst identification, *David
WENZEL, Germany*

16:30 *(virtual)* International Meridian Circle Project – Europe-Africa-Pacific Sector,
Frédéric PITOUT, France

16:50 Discussions and wrap-up

17:00 *Adjourn*

Tuesday, 7 October 2025

VENUE: OBASANJO SPACE CENTRE, Abuja

09:00 Session 3: Space Weather Modelling and Artificial Intelligence

Chairperson: Saeed Abioye BELLO, Nigeria

Rapporteur: Patience MUCHINI, Zimbabwe

09:00 *(virtual invited paper)* Artificial Intelligence and Space Weather, *Daniel OKOH, Nigeria*

09:30 Study the effect of strong magnetic storm on the ionosphere over Algeria region using
ARIM model (Algerian Regional ionosphere model), *Omar HAMMOU ALI, Algeria*

09:50 Empirical modelling of ionospheric changes due to CME and CIR driven storms using
Feed Forward Neural Networks, *Jean Claude UWAMAHORO, Rwanda*

10:10 Comparative forecasting of geomagnetic kp index using ARIMA, LSTM, and GRU
models for space weather monitoring in equatorial regions, *Abimbola ATIJOSAN,
Nigeria*

10:30 Investigating the occurrence of regional ionospheric irregularities during solar cycle 24
as a forecasting tool for space weather hazards, *Patrick Azi Atsen IZANG, Nigeria*

10:50 Discussions

11:00 - 11:30 *Tea Break*

11:30 Session 4: Space Weather Extreme Events

Chairperson: Abimbola ATIJOSAN, Nigeria

Rapporteur: Daphine AYEBARE, Uganda

11:30 *(virtual, invited paper)* Introduction to space weather extreme events, *Wojciech Jacek
MILOCH, Norway*

12:00 Predictability of space weather extreme events, *Samuel OGUNJO, Nigeria*

12:20 Electrodynamics of the Earth's magnetosphere at high latitudes: geomagnetic superstorm
case of June 22/23, 2015, *Inza GNANOU, Burkina Faso*

12:40 Ionospheric storm effects in the equatorial ionisation anomaly region in the American
and Asian-Australian sectors during the storms of October 2016 and September 2017,
Adekoya BOLARINWA, Nigeria

13:00 Analysis of the temporal and spatial variations of ionospheric parameters during solar
flares events, *Racheal OLORUNTOLA, Nigeria*

13:20 – 14:20 *Lunch Break*

14:20 Session 5: Ionosphere, Magnetosphere, Thermosphere

Chairperson: Aderonke AKERELE, Nigeria

Rapporteur: Dadaso SHETTI, India

- 14:20 *(invited paper)* On the use of the ROTI and S4 indices for the study of plasma irregularities at low latitudes, *Christine AMORY, France*
- 14:40 Semi-annual variation of geomagnetic indices during solar cycles 21-24, *Abdullahi Kikelomo KAZEEM, Nigeria*
- 15:00 A Statistical Learning-based TEC predictive model improves GNSS ionospheric error correction during short-term rapidly developing geomagnetic storms, *Filip ŠKLEBAR, Croatia*
- 15:20 Dependence of total electron content (TEC) on the critical frequency $f_{o}f_2$: observations and modelling, *Vivian OTUGO, Nigeria*
- 15:40 – 16:00 *Tea Break*
- 16:00 Session 5: Ionosphere, Magnetosphere, Thermosphere (continued)**
- Chairperson: Faruk AFFERO, Indonesia*
Rapporteur: Omar HAMMOU ALI, Algeria
- 16:00 Characterization of the equatorial electrojet and its magnetic signatures deduced from Swarm observations, *Daphine AYEBAARE, Uganda*
- 16:20 Ionospheric parameters as precursors to earthquakes, *Afolabi KOTOYE, Nigeria*
- 16:40 Discussions and wrap-up
- 17:00 *Adjourn*

Wednesday, 8 October 2025

VENUE: OBASANJO SPACE CENTRE, Abuja

- 09:00 Session 6: Space weather effects**
- Chairperson: Christine AMORY, France*
Rapporteur: Kibrop Webber CHEMONGES, Kenya
- 09:00 Impact of the May 2024 Geomagnetic Storm and X-Class Flares on the Low-Latitude Ionosphere: Insights from IRNSS/NavIC, *Dadaso Jaypal SHETTI, India*
- 09:20 Impact of Ionospheric Disturbance on GNSS Receiver Position Measurement, *Faruk AFFERO, Indonesia*
- 09:40 The effects of space weather on LEO spacecraft dynamics and its implications for sustainable use of the space in the 25th solar cycle, *Victor Uchenna Jonathan NWANKWO, Germany*
- 10:00 – 10:30 *Tea Break*
- 10:30 Technical Tour (Nigerian National Space Research & Development Agency, including National Space Museum; Technical Art Village etc + *Lunch on the move*)
- 17:00 *Bus back to the hotel*

Thursday, 9 October 2025

VENUE: OBASANJO SPACE CENTRE, Abuja

- 09:00 Session 6: Space weather effects (continued)**
- Chairperson: Katarina PAVLOVIC, Serbia*
Rapporteur: Racheal Foluke OLORUNTOLA, Nigeria
- 09:00 Impact of high-intensity solar flares on the geomagnetic H-field at equatorial latitudes: A case study of Ilorin, Nigeria, *Saeed Abioye BELLO, Nigeria*
- 09:20 Space Weather for Civil Aviation: Extreme Space Weather Events and Solar Minimum, *Andrei KONDRATOV, Russian Federation*

9:40	Measurement and Characterization of Geomagnetically Induced Currents (GICs) in Zimbabwe's Power Grid During Adverse Space Weather Conditions, <i>Patience MUCHINI, Zimbabwe</i>
10:00	Discussions
10:30 - 11:00	<i>Tea Break</i>
11:00	Session 7: Space weather case studies, outreach and education
	<i>Chairperson: Babatunde RABIU, Nigeria</i>
	<i>Rapporteur: Adetoun Helen AKINLAMI, Nigeria</i>
11:00	Ionospheric disturbances in the African low-latitude region during the space weather event of September 2017, <i>Teshome DUGASSA, Ethiopia</i>
11:20	An investigation of solar flare effects on equatorial ionosphere using HF Doppler sounder measurements, <i>Aderonke AKERELE, Nigeria</i>
11:40	Assessment of the performance of the IRI's auroral oval boundary model as applied to the Mother's Day G5 storm during 10 - 13 May 2024, <i>Kibrop Webber CHEMONGES, Kenya</i>
12:00	On the response of the ionosphere over some African stations to the magnetic super storm of May 2024, <i>Babatunde RABIU, Nigeria</i>
12:20	Studying the ionospheric variation using Low cost and scientific grade GNSS receivers over Abidjan (Côte d'Ivoire), <i>Kouadio Olivier OBROU, Côte d'Ivoire</i>
12:40	Developing A Low - Cost Magnetometer for Real-Time Field Observations, <i>Joshua AKINSUSI, Nigeria</i>
13:00	Discussions
13:10 - 14:10	<i>Lunch Break</i>
14:10	Session 8: Space weather programmes
	<i>Chairperson: Inza GNANOU, Burkina Faso</i>
	<i>Rapporteur: Joshua AKINSUSI, Nigeria</i>
14:10	<i>(invited paper)</i> Space Weather Activities at SANSa and the Regional Space Warning Centre, <i>Zama KATAMZI-JOSEPH, South Africa</i>
14:40	From Global Data to Regional Action: A SERBSPACE Initiative for Space Weather Awareness and Application of Space Data Access in the Western Balkans, <i>Katarina PAVLOVIC, Serbia</i>
15:00	<i>(invited paper)</i> African Participation in ISWI and other International Space Weather Programs, <i>Babatunde RABIU, Nigeria</i>
15:30	Discussions
15:40 – 16:00	<i>Tea Break</i>
16:00 – 17:00	Discussion Session 1
	<i>Chairperson: Sharafat GADIMOVA, UNOOSA and Babatunde RABIU, Nigeria</i>
	<i>Rapporteur: Samuel OGUNJO, Nigeria</i>
	<ul style="list-style-type: none"> - Data Sharing - Regional cooperation - Deployment of instruments - Integration of new programs and capacity building programs
17:00	<i>Adjourn</i>

Friday, 10 October 2025

VENUE: OBASANJO SPACE CENTRE, Abuja

- 09:00** **Session 9: Applied space scientific research**
Chairperson: Esther HANSON, Nigeria
Rapporteur: Zama Thobeka KATAMZI-JOSEPH, South Africa
- 09:00 Influence of microgravity on the rotational directions and physicochemical characteristics of maize grains, *Adetoun AKINLAMI, Nigeria*
- 09:20 Assessment of groundwater-level changes in the subsurface along equatorial region using earth's gravity data from space. A case study of sub-saharan Africa, *Emmanuel JOEL, Nigeria*
- 09:40 Announcement of the ISWI Workshop in 2026, *Yoon KICHANG, Republic of South Korea*
- 10:00 - 10:30 *Coffee Break*
- 10:30** **Discussion Session 2**
Chairperson: Sharafat GADIMOVA, UNOOSA and Babatunde RABIU, Nigeria
Rapporteur: Samuel OGUNJO, Nigeria
- Round table to finalize the recommendations and observations
- 12:30** **Closing remarks**
Sharafat GADIMOVA, United Nations Office for Outer Space Affairs
Natchimuthukonar GOPALSWAMY, National Aeronautics and Space Administration, United States of America
Babatunde RABIU, Nigeria
- 13:00 – 14:00 *Lunch break*

**003****Committee on the Peaceful
Uses of Outer Space****Report on the United Nations/Nigeria workshop on the
International Space Weather Initiative: Space Weather
during a Moderate Solar Cycle****(Abuja, 6–10 October 2025)****I. Introduction**

1. The need for a better understanding of Sun-Earth relations emerged from the International Heliophysical Year, an internationally coordinated effort to promote and advance research into the Sun and its effects on the solar system and beyond. The goal of the International Space Weather Initiative, launched in 2009, was to develop the insight necessary to understand the science and to reconstruct and forecast near-Earth space weather. That included developing instrument networks, enabling data-sharing and delivering capacity-building (education, training and webinars) and public outreach. Information on all the achievements resulting from international cooperation and coordination under the Initiative is made available through its newsletter and website (www.iswi-secretariat.org).

2. The United Nations/Nigeria workshop on the International Space Weather Initiative: Space Weather during a Moderate Solar Cycle was organized jointly by the Office for Outer Space Affairs and the National Space Research and Development Agency, on behalf of the Government of Nigeria. The workshop was co-organized and co-sponsored by the International Committee on Global Navigation Satellite Systems. The workshop was hosted by the National Space Research and Development Agency in Abuja from 6 to 10 October 2025.

3. The present report sets out the background, objectives and programme of the workshop and provides a summary of the observations made and the conclusions reached by participants. It has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its sixty-ninth session and for consideration by the Scientific and Technical Subcommittee at its sixty-third session, both to be held in 2026.

A. Background and objectives

4. Globally, there is growing interest in better understanding solar-terrestrial interactions, in particular patterns and trends in space weather. This is not only for scientific reasons, but also because the reliable operation of ground-based and space-based assets and infrastructure is increasingly dependent on their robustness



against the detrimental effects of space weather. It is therefore important to enhance understanding of space weather physics, improve forecasting capabilities and develop strategies to mitigate its effects on technological infrastructure.

5. In line with the consideration by the Scientific and Technical Subcommittee of the agenda item entitled “Space weather”,¹ the objectives of the workshop were: (a) to focus on the deployment of new instruments, particularly in developing countries; (b) to discuss methods for analysing and interpreting data on space weather; (c) to focus on new research results and findings; and (d) to strengthen international coordination and cooperation on space weather products and services. The discussions at the workshop were also linked to the 2030 Agenda for Sustainable Development and to Sustainable Development Goals 4, 9 and 17.

B. Programme

6. At the opening of the workshop, welcoming remarks were made by representatives of the Federal Ministry of Innovation, Science and Technology of Nigeria, the National Space Research and Development Agency of Nigeria, the National Aeronautics and Space Administration (NASA) of the United States of America and the Office for Outer Space Affairs.

7. A keynote address on the results of the International Space Weather Initiative was delivered by an expert from NASA. The presentation covered the activities conducted under the Initiative, with a focus on the activities organized in Africa. The activities of the African Geophysical Society, formed in 2012 by scientists, were also highlighted.

8. A keynote presentation entitled “Space science, innovation, science and technology in sustainable development of a nation” was delivered by the representative of Nigeria. It was focused on the use of space science and technology for sustainable development and addressed regional and national challenges.

9. The workshop programme consisted of nine plenary sessions and two discussion sessions. Invited speakers, who came from both developed and developing countries, presented 43 papers describing their research achievements, education and outreach activities related to the International Space Weather Initiative and its instrument arrays. Discussion sessions provided participants with an opportunity to focus on specific problems and projects related to space weather, in particular instrument arrays and their status of operations and coordination and the operational use of space weather data.

10. The workshop was focused on the following topics: (a) solar physics; (b) space weather instrumentation and data; (c) space weather modelling and artificial intelligence; (d) space weather extreme events; (e) the ionosphere, the magnetosphere and the thermosphere; (f) space weather effects; (g) space weather case studies, outreach and education; (h) space weather programmes; and (i) applied space scientific research.

11. A tour of the facilities of the National Space Research and Development Agency, including the space museum and the planetarium, was organized for workshop participants.

12. In brief statements, the organizers of and participants in the workshop expressed their appreciation for the long-term, substantive contributions made to the development of the International Space Weather Initiative, in particular for the benefit of developing countries.

13. The programme of the workshop was developed by the Office for Outer Space Affairs and the National Space Research and Development Agency in cooperation with an international scientific organizing committee. The Chairs and rapporteurs

¹ [A/AC.105/1338](#), paras. 84–92.

assigned to the plenary and discussion sessions provided their comments and notes as input for the preparation of the present report.

14. Abstracts of the papers presented, the workshop's programme and background materials were made available on the website of the Office for Outer Space Affairs (www.unoosa.org). Copies of the presentations were also made available to the workshop participants.

C. Attendance

15. Scientists, engineers and educators from developing and developed countries in all regions were invited by the Office for Outer Space Affairs to participate in and contribute to the workshop. Participants were selected on the basis of their scientific, engineering and educational backgrounds and their experiences in implementing programmes and projects in which the International Space Weather Initiative played a leading role.

16. Funds provided by the United Nations and the International Committee on Global Navigation Satellite Systems were used to cover the travel, accommodation and other costs of 15 participants from 15 countries. A total of 46 experts, 14 of whom were women, attended the workshop.

17. The following 22 Member States were represented in person or online at the workshop: Algeria, Burkina Faso, China, Côte d'Ivoire, Croatia, Egypt, Ethiopia, France, Germany, India, Indonesia, Japan, Kenya, Nigeria, Norway, Russian Federation, Rwanda, Serbia, South Africa, Uganda, United States of America and Zimbabwe. The Office for Outer Space Affairs was also represented at the workshop.

II. Observations and conclusions

18. The workshop noted that solar eruptions generally referred to coronal mass ejections and flares. Both were sources of space weather. Solar flares created sudden changes in the ionization level in the ionosphere and coronal mass ejections were associated with solar energetic particle events and geomagnetic storms. A flare with unusually high intensity and/or a coronal mass ejection with extremely high energy could be thought of as examples of extreme events on the Sun.

19. Workshop participants recalled that a number of Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) spectrometers had been deployed worldwide in the framework of the International Heliophysical Year and the International Space Weather Initiative for monitoring solar radio bursts and solar flares and together constituted the e-CALLISTO network. It was noted that the German Aerospace Centre (DLR), at Neustrelitz, was operating several CALLISTO receivers (10–80 MHz, 100–800 MHz and 1,000–1,600 MHz), with antennas following the Sun's position for best measurements, and that the original receivers had been further developed to minimize noise and ease maintenance work so that the behaviour of different propagation paths could be observed. The results were compact receivers with a built-in screen and personal computer, forming the basis for a wide range of space weather event analysis.

20. The workshop participants discussed the problem of space weather forecasting using traditional approaches, as well as the advantages of using machine-learning techniques to identify and characterize phenomena that drove space weather.

21. The workshop participants observed that artificial intelligence techniques offered significant potential for improving the prediction of geomagnetic storms. By analysing vast amounts of historical and real-time data, artificial intelligence models could identify complex patterns and relationships that might not be apparent through traditional analysis. Machine-learning algorithms, such as linear regression and

support vector machines, could be used to predict the occurrence and intensity of geomagnetic storms based on solar wind parameters and other space weather data.

22. Moreover, the use of artificial intelligence in space weather forecasting had shown promising results. For instance, long- and short-term memory networks had been successfully applied to predict geomagnetic indices such as a quasi-logarithmic index, derived from ground-based magnetic field measurements (Kp index), which quantified geomagnetic activity. Those networks had demonstrated the ability to provide more accurate and timely predictions compared with traditional methods, potentially giving operators of critical infrastructure more time to implement protective measures.

23. The workshop participants took note of the Madrigal database, an upper-atmospheric science database (<http://cedar.openmadrigal.org/>) that integrated multi-decade observations from over 159 instruments, including global navigation satellite system (GNSS)-based vertical total electron content (VTEC). That unique dataset provided a resource for machine-learning applications in space weather research.

24. The workshop participants were informed about the advanced capabilities of global data services from the European Space Agency (ESA), NASA and the European Earth Observation Programme (Copernicus), which provided open access to Earth observation and space physics data. Those services included the ESA space situational awareness platform, the NASA heliophysics portals and the Copernicus Data Space Ecosystem, all of which were critical for monitoring Earth, the solar system and space weather.

25. The workshop participants noted that several space weather phenomena might create disturbances in the Earth's magnetosphere and ionosphere that degraded performance and satellite tracking ability for GNSS positioning receivers. Those phenomena included high-speed solar windstreams, coronal mass ejections, large solar flares and coronal holes, which were usually (but not always) related to the 11-year sunspot or solar cycle. Two indices, the amplitude scintillation index and the rate of total electron content index, had been established to study plasma irregularities based on their impact on the GNSS signal.

26. The workshop participants also noted that GNSS receivers, originally designed for positioning, were now being used to study ionospheric irregularities. The large number of GNSS receivers had enabled significant progress to be made in studying the ionosphere, and in particular plasma irregularities.

27. The workshop participants learned that dense networks of low-cost multi-frequency GNSS receivers could be used to retrieve ionospheric information with the same level of accuracy as geodetic and/or scientific-grade multi-frequency GNSS receivers and to demonstrate that such information could be used to generate maps of retrieved ionospheric parameters for scientific studies and radio system operations. That implied the possibility of achieving global scintillation monitoring using low-cost receivers in areas of poor coverage, thereby reducing costs and increasing the density of ground receivers for the local detection and characterization of ionospheric fluctuations produced by scintillation.

28. The workshop participants noted that the twenty-fifth solar cycle was currently at its peak and consequently driving the intensification of adverse environments for orbiting satellites in low Earth orbit. The current solar activity might exacerbate the problem of atmospheric drag for low Earth orbit objects, which could lead to accelerated orbital decay and thus affect existing space debris. A detailed analysis of long- and short-term drag impact on selected catalogued low Earth orbit objects provided information on how to improve space situational awareness in the current solar cycle. Those findings underscored the importance of continuously monitoring solar activity and improving atmospheric drag models to mitigate risks associated with accelerated orbital decay and the growing challenge of managing space debris in the low Earth orbit environment.

29. From an aviation operations perspective, space weather events were causing disruptions to communications, navigation and surveillance systems. In addition, radiation dose levels at flight altitudes were elevated, as space weather events might occur on short timescales, with the effects occurring from almost instantaneously to over a few days.

30. The South African National Space Agency operated a 24/7 regional space weather centre that had been established in November 2022 and designated as such by the International Civil Aviation Organization (ICAO). The role of a regional centre was to support the four ICAO global centres in the provision of space weather information to the aviation sector. As a designated regional centre, it was important to collaborate with the other ICAO designated global centres to ensure a consistent and reliable service that served the interests of Africa. The South African National Space Agency shared its experiences of establishing and running a 24/7 operational centre and of maintaining regional partnerships for ground-based instrumentation network expansion within the African region. With its functions as a 24/7 operational, regional space weather centre, the South African National Space Agency had positioned itself to effectively participate in global efforts to address the challenges of space weather.

31. The workshop discussions helped to identify: (a) significant gaps in instrument types and coverage in the African region; (b) problems in maintaining instruments and data flow in terms of the continuity, collection, analysis and modelling of data; and (c) ways of attracting early-career scientists and supporting other ongoing international initiatives on space weather.

32. The workshop participants recognized that fundamental aspects of the International Space Weather Initiative included education, training and public outreach activities. The concept was to encourage and support space science courses, workshops and curricula in university and graduate schools that provided instrument support. There had been much success in those areas, but there was a need to continue education and training and to develop public outreach materials that were unique to the Initiative, and coordinate their distribution. It was important to provide information on the Initiative instrument arrays and results to the media, especially local media.

33. The workshop participants agreed that data from the International Space Weather Initiative's instrument arrays should be combined with space-based and other ground-based data through modelling and measurements to advance space weather science, thus leading to robust research output and the publication of scientific papers in international journals.

34. To enable effective international coordination and collaboration in space weather research and services, there should not be any barriers to data flows and communications. To that end, an open data policy, complete with rules of operation and data standards, should be promoted at the national level.

35. The workshop participants expressed their appreciation to the United Nations, the Government of Nigeria, the National Space Research and Development Agency, the co-sponsors and the scientific organizing committee for the substance, excellent organization and successful conclusion of the workshop.



**The Official Group Photo of UN/Nigeria Workshop on the ISWI
October 2025; Abuja, Nigeria**

Almost Everything About NASA's Latest Mission to Mars Is Unusual

The ESCAPADE mission, which launched to space on a Blue Origin rocket on Thursday, breaks the mold of how planetary science missions typically come together.



Listen to this article · 9:31 min [Learn more](#)



By Kenneth Chang

Kenneth Chang went to California in 2024 to visit a Rocket Lab factory and interview the ESCAPADE scientists when he expected the mission to launch that year.

Nov. 14, 2025

NASA's latest robotic mission to Mars, ESCAPADE, should perhaps have been named the Great Escape, given how many times it has eluded doom.

The data that the mission eventually collects will provide clues about why Mars, which once possessed a thick atmosphere and flowing water on its surface, is today cold, dry and almost airless.

The mission, which launched on Thursday, could also serve as a “trailblazer” for how NASA could get more bang for its buck from its science missions, said Rob Lillis, the mission's principal investigator.

NASA initially rejected Dr. Lillis' proposal several years ago. Later, ESCAPADE — a shortening of Escape and Plasma Acceleration and Dynamics Explorers — only got the go-ahead from NASA because of a federal government shutdown in 2018.

And then it got kicked off its ride to space.

For all these troubles, the Space Sciences Laboratory at the University of California, Berkeley, which is leading the mission, and Rocket Lab of Long Beach, Calif., together delivered two identical spacecraft to Kennedy Space Center in Florida last year — on time and on budget.

But the rocket that would eventually launch it — a brand-new design called New Glenn from Blue Origin — was not ready.

So the two spacecraft were shipped back to California and put in storage, and mission planners had to figure out yet another path to Mars.

This mission has nine lives, Dr. Lillis said, referring to the mythical resilience of cats.

“It’s something we joke about on the team,” said Dr. Lillis, a planetary scientist at the Berkeley laboratory.

Just ahead of the launch, though, there were a couple more minor delays.

Bad weather — and a cruise ship entering the “keep out” zone near the launchpad — scuttled the first launch attempt on Sunday. Then, on Wednesday, a second launch attempt was called off because of worries that a huge solar storm could scramble the spacecraft’s computers.



A Blue Origin New Glenn rocket carrying the ESCAPE mission launching from Cape Canaveral, Fla., on Thursday. Steve Nesius/Reuters

The two spacecraft, named Blue and Gold after the Berkeley school colors, are each about the size of a mini fridge. They are to enter orbit around Mars in September 2027, but because the sun will be inconveniently located between Earth and Mars at that time, blocking communications, the science mission won't start until June 2028.

This is the first time that a mission to another planet has used multiple orbiters to make simultaneous measurements in different locations.

At the beginning of what will be a yearlong science campaign, the two will play follow-the-leader along an elliptical orbit, coming within 100 miles of the surface of Mars and swinging out as far as 4,300 miles. That will allow observations of changes in magnetic fields and the solar wind — a stream of charged particles from the sun — that occur over short periods of time.

Six months later, the two spacecraft will shift into different elliptical orbits, one swinging farther out, the other moving a bit closer. That will allow measurements of the long-distance effects from the buffeting of the solar wind. One of the spacecraft could be in front of Mars, measuring the incoming solar wind, while the other is behind Mars, observing how the planet's magnetic fields reverberate.

The magnetic field of Mars is unlike that of any other planet in the solar system. Unlike Earth, Mars does not today possess the same churning dynamo of molten iron that generates Earth's magnetic field. But early in its history, about four billion years ago, it did. As Mars cooled, its magnetic field was frozen into some of the planet's underground rocks, and a patchy magnetic field persists. This deflects some of the solar wind.

Over time, solar wind stripped away most of the Martian atmosphere.

The two spacecraft carry identical instruments: a magnetometer to measure the magnetic fields; a device called an electrostatic analyzer, which produces images showing the distribution of negatively charged electrons and positively charged protons and ions; and a probe that measures the temperature, density and voltage of the charged particles.

Each also carries a camera built by students at Northern Arizona University.

All of that came at a bargain-basement price tag of \$94.2 million, which includes developing and building the spacecraft, launching them and operating them for the next few years.

That may sound like a lot, but traveling to another planet is not cheap. The last orbiter that NASA sent to the red planet — the Mars Atmosphere and Volatile Evolution mission, or MAVEN, which launched in 2013 — cost nearly \$600 million.

Interplanetary spacecraft are typically bespoke machines carrying one-of-a-kind scientific instruments. They need to be sturdily built to survive not only the violent shaking of a rocket launch, but also the immense swings of temperature in the vacuum of space as well as years of radiation bombardment.

With the rise of entrepreneurial space companies and tiny spacecraft known as CubeSats, NASA officials have wondered whether “small” deep-space missions might be feasible. In 2018, the agency announced SIMPLEX, short for Small, Innovative Missions for Planetary Exploration.

The upper limit on cost for a SIMPLEX mission was set at just \$55 million, and to save money, the missions had to ride along on an upcoming launch of a larger spacecraft.

Dr. Lillis proposed that ESCAPADE could join Psyche, a NASA mission to explore a metal-rich asteroid, on its journey through the solar system.

It did not look like a winning proposal at first. Instead, it seemed that NASA would choose an orbiter that would travel to Venus, Dr. Lillis said.

The twin ESCAPADE spacecraft in a Florida clean room last month. Rocket Lab

Then the federal government shut down in 2018.

That delayed the SIMPLEX decisions by several months. Dr. Lillis said that by the time NASA finished its evaluations, there was not enough time for the proposed Venus orbiter to be ready for the launch it needed, and it was eliminated from consideration.

NASA chose ESCAPADE instead.

There were more twists. After NASA chose SpaceX's Falcon Heavy rocket to launch Psyche, it moved the launch date ahead by one year. That powerful rocket also meant that Psyche no longer needed to swing past Mars for a gravitational boost on the way to the asteroid, and ESCAPADE no longer had a direct ride to Mars.

The ESCAPADE team came up with an elaborate alternative. "In hindsight, it was kind of crazy," Dr. Lillis said. It failed a design review.

NASA did throw the team a lifeline: It gave them nine months and \$1.8 million to come up with another plan.

Instead of ESCAPADE hitching a ride with another spacecraft, NASA said it would now buy a separate launch for the mission. But it would not say which rocket, and now the ESCAPADE spacecraft would have to propel themselves out of Earth orbit to Mars. The design they had could not do that. The spacecraft had to be bigger.

Rocket Lab, best known for its small Electron rockets, proposed a variation of an in-space propulsion stage that it was already building to help push the CAPSTONE mission to the moon.

Although NASA said it would buy a rocket, it did not say which one, and that was a challenge for Christophe Mandy, the chief engineer for ESCAPADE at Rocket Lab. He said he chose 14 possible rockets.

But designing for 14 different rockets, many of which did not yet exist, “wasn’t fun,” Mr. Mandy said during a tour of the Rocket Lab factory in Long Beach last year. “Pretty insane and unpleasant.”

NASA eventually selected New Glenn, which is almost comically oversized for ESCAPADE. It’s like driving a tractor-trailer truck to deliver a couple of pizzas. Because this was to be the first launch of New Glenn, Blue Origin offered a deep discount to NASA, charging only \$20 million. (Blue Origin has not said what New Glenn will cost for other customers.)

The two ESCAPADE spacecraft were completed in about three-and-a-half years, almost a sprint in the aerospace world, and Dr. Lillis proudly noted that Berkeley and Rocket Lab delivered them at a cost of \$49 million.

That sprint was followed by another wait when New Glenn was not ready in time. And that created yet another challenge.

Earth and Mars come close to each other once every 26 months. ESCAPADE missed the window last year. One option would have been to wait until next year. But Jeffrey Parker, an orbital mechanics expert at Advanced Space in Westminster, Colo., looked into other options.

“We studied no fewer than a dozen ways to get to Mars during 2025,” Dr. Parker said.

The two spacecraft, after their successful Thursday launch on New Glenn, are now on a trajectory calculated by Dr. Parker. They will travel along a kidney-bean-shaped orbit that loops around L2, a point in space where the gravitational forces of the sun and Earth balance. A year from now, they will swing around Earth again and fire their engines to head toward Mars.

This trajectory offered a longer launch window that extended to March next year, and in the future, it could be useful for sending supplies to a future Mars colony, Dr. Lillis said.

“If humanity wants to settle Mars long term,” he added, “then we’re going to have to send hundreds or thousands of ships every window” that Mars and Earth pass by each other, but the window lasts just a few weeks.

It would be difficult to launch that many rockets in such a short period of time. “The trajectory that we’re pioneering actually gives an opportunity to launch over a year and sort of queue them all up to head off to Mars,” Dr. Lillis said.

***A correction was made on Nov. 14, 2025:** An earlier version of this article misstated the role played by a rocket company in a space mission. Rocket Lab built a propulsion stage that helped a spacecraft, CAPSTONE, get to the moon; it did not build CAPSTONE.*

When we learn of a mistake, we acknowledge it with a correction. If you spot an error, please let us know at nytnews@nytimes.com. Learn more

Kenneth Chang, a science reporter at The Times, covers NASA and the solar system, and research closer to Earth.