

UN ICG WG S Workshop on GNSS Interference Detection and Mitigation
Hilton Waikiki Beach, Honolulu, HI
15th April 2024



Ambient-Aware PNT

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Workshop on GNSS Interference Detection and Mitigation

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Ambient-Aware PNT (R Filjar, Croatia)

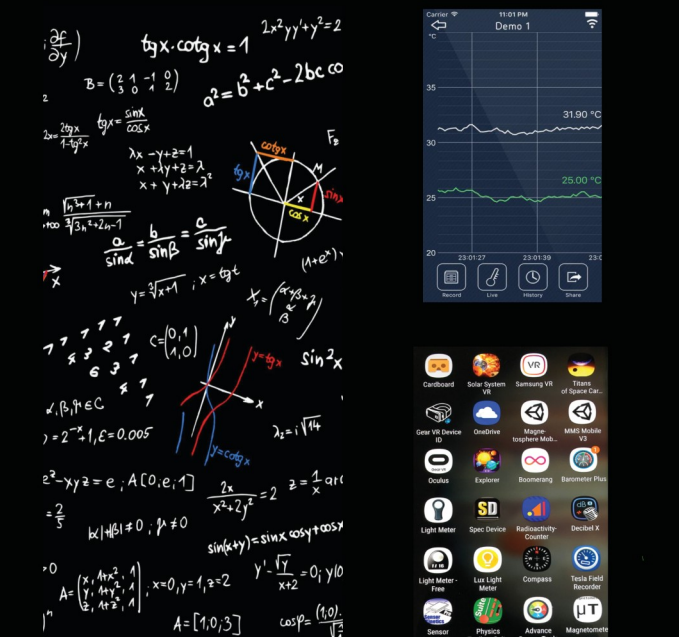

- Content of presentation

- Problem statement and motivation
- State-of-the-art
- Ambient-Aware (AA) GNSS-based PNT
- Implementation
- Validation
- Discussion

Source:

<https://spacemath.gsfc.nasa.gov/Sensor/SensorsBook.pdf>

National Aeronautics and Space Administration



A Guide to Smartphone Sensors

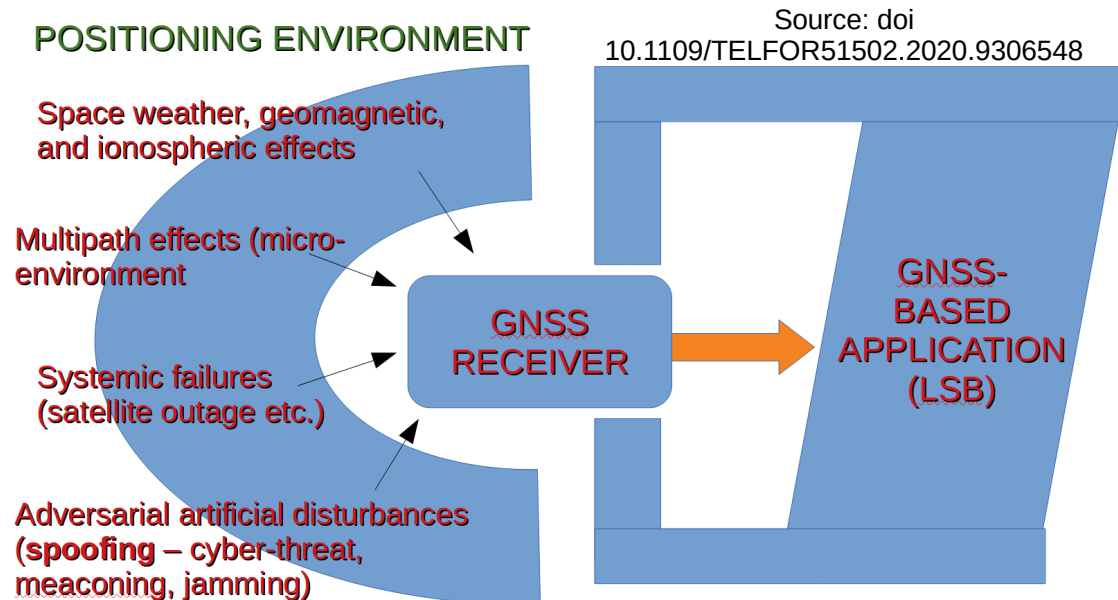
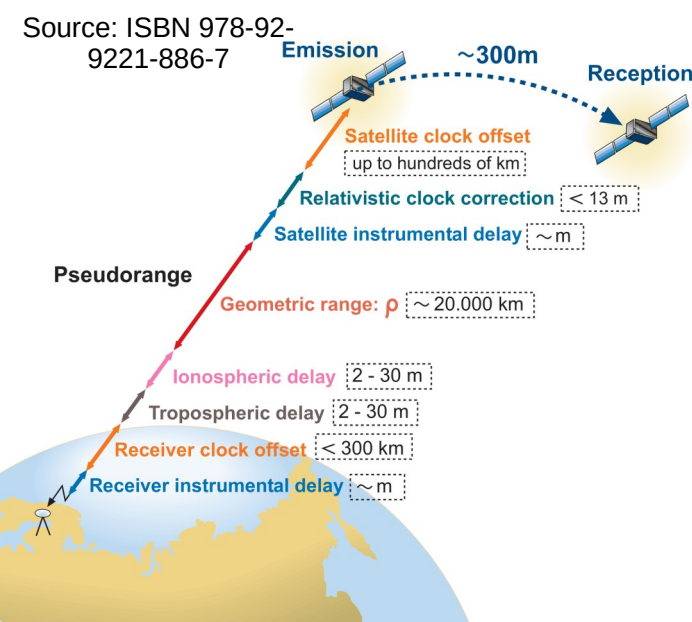
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Problem statement and motivation

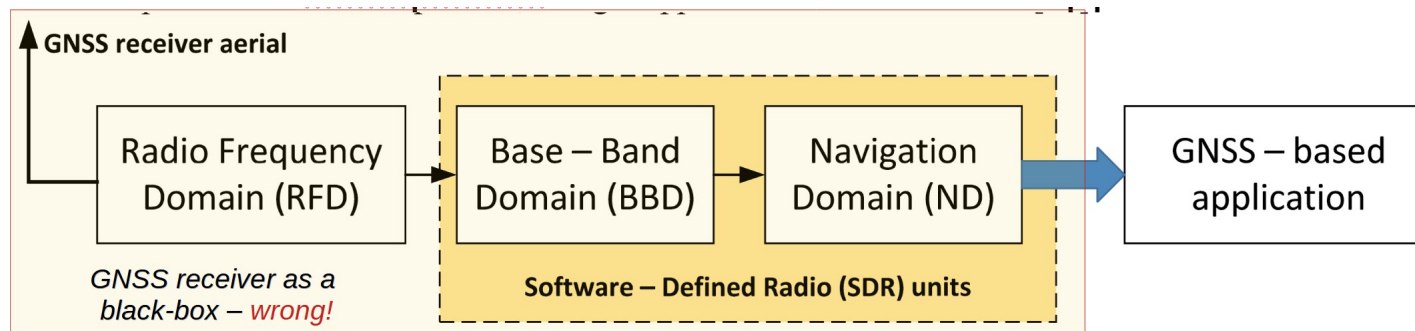
- Natural and artificial interference in the positioning environment (space weather/ionosphere, multipath, spoofing etc.)
- PNT process confined a black-box GNSS receiver
- GNSS PNT QoS guarantees required in the uncontrollable positioning environment
- GNSS PNT QoS and GNSS apps QoS requirements not aligned



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State-of-the-art

- GNSS PNT confined in a non-transparent GNSS receiver black-box, detached from GNSS application



- Numerous advancements are not exploited *in full*: (i) **Software-Defined Radio**, (ii) **statistical & machine learning, artificial intelligence**, (iii) **computational capacity of mobile devices**, (iv) **mobile platforms with SDR GNSS receivers & embedded sensors** (smartphones, connected vehicles, IoT devices, etc.), (v) **open access to position environment data in near-real time** (space weather, geomagnetic, and ionospheric indices, spatial databases etc.), (vi) **mobile internet and IoT**

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State-of-the-art – Ambient (space weather environment) awareness

Trusted third-parties

Source: <https://omniweb.gsfc.nasa.gov/form/dx1.html>

OMNIWeb
SPDF•Goddard Space Flight Center

About Browse FTP Input-Data News Feedback

Interface to produce plots, listings or output files from OMNI 2

[How to get data from command line](#)

For specification of Y scale ranges for data plots click [HERE](#)

☒ Plot data ☐ List data ☐ Create file ([file?](#))

Select resolution

☒ Hourly averaged ☐ Daily averaged ☐ 27-day averaged ☐ Yearly averaged

Click [HERE](#) to get time spans for individual parameters.

Enter start and stop dates (Use yyyyddd or yyyyymmdd)
Start Stop

Select variables

☐ Bartels Rotation Number
☐ IMF Spacecraft ID
☐ Plasma Spacecraft ID

Magnetic field

☒ IMF Magnitude Avg, nT
☐ Magnitude, Avg IMF Vr, nT
☐ Lat. of Avg. IMF, deg.
☐ Long. of Avg. IMF, deg.
☐ Bx, GSE/GSM, nT
☐ By, GSE, nT
☐ Bz, GSE, nT

☐ # Fine Scale Points in IMF Avgs
☐ # Fine Scale Points in Plasma Avgs

☐ By, GSM, nT
☐ Bz, GSM, nT
☐ Sigma in IMF Magnitude Avg.
☐ Sigma in IMF Vector Avg
☐ Sigma Bx, nT
☐ Sigma By, nT
☐ Sigma Bz, nT

Direct access to embedded sensors
(Motorola moto 30 edge, with AndroSensor application)

Source: <https://www.intermagnet.org/data-donnee/download-eng.php>

INTERMAGNET

Home > INTERMAGNET Data > Data Download

Conditions of Use
Data Download
Data Formats
Observatory Plots
Magnetic Field (XYZ)
Magnetic Field (HDZ)
Declination/Inclination
Rate of Change (dB/dt)
CD-ROM/DVD (Definitive data)
List of Available CDs/DVD
CD-ROM/DVD Production

Data Download

How to use the Data Download application

Sample Rate: minute
Data Type: best available of all types
Data Format: IAGA2002

Start Date (YYYY-MM-DD): 2022 07 23
End Date (YYYY-MM-DD): 2022 07 23

Filter by: Regions Latitudes

Search for data

AndroSensor

LOCATION:

Latitude:
Longitude:
Altitude: 504.65 ft
Altitude (google): unavailable
Accuracy: 17.80 ft
Provider: gps
Speed: 0.00 Kmh
Satellites in range: 17 (16)

ACCELEROMETER: (0.2mA)

x:-0.3547 m/s²
y:+1.9313 m/s²
z:+10.6041 m/s²
Σ:+10.7844 m/s²

GRAVITY: (0.5mA)

x:-0.3709 m/s²
y:+1.9901 m/s²
z:+9.5954 m/s²
Σ:+9.8066 m/s²

LINEAR ACCELERATION: (0.5mA)

x:-0.7849 m/s²
y:+0.1527 m/s²
z:+0.2529 m/s²
Σ:+0.8387 m/s²

GYROSCOPE: (0.6mA)

X:+0.0988 rad/s
Y:-0.0359 rad/s
Z:+0.0545 rad/s

LIGHT: (0.2mA)

53.0500 lux

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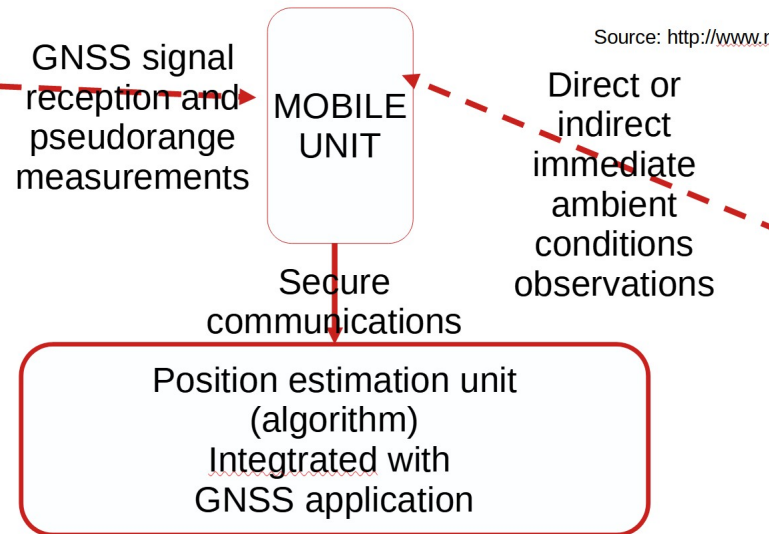
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Ambient-Aware (AA) GNSS PNT

- Mobile unit as pseudorange positioning conditions device and environment observations

- Self-adaptation of position estimation algorithm to immediate real-time ambient conditions



Source: http://www.nasa.gov/mission_pages/sunearth/news/M11-125-swef.html



RF signal processing

GNSS pseudorange measurement

software-defined

GNSS pseudorange correction

GNSS position estimation

GNSS-based application

closely integrated

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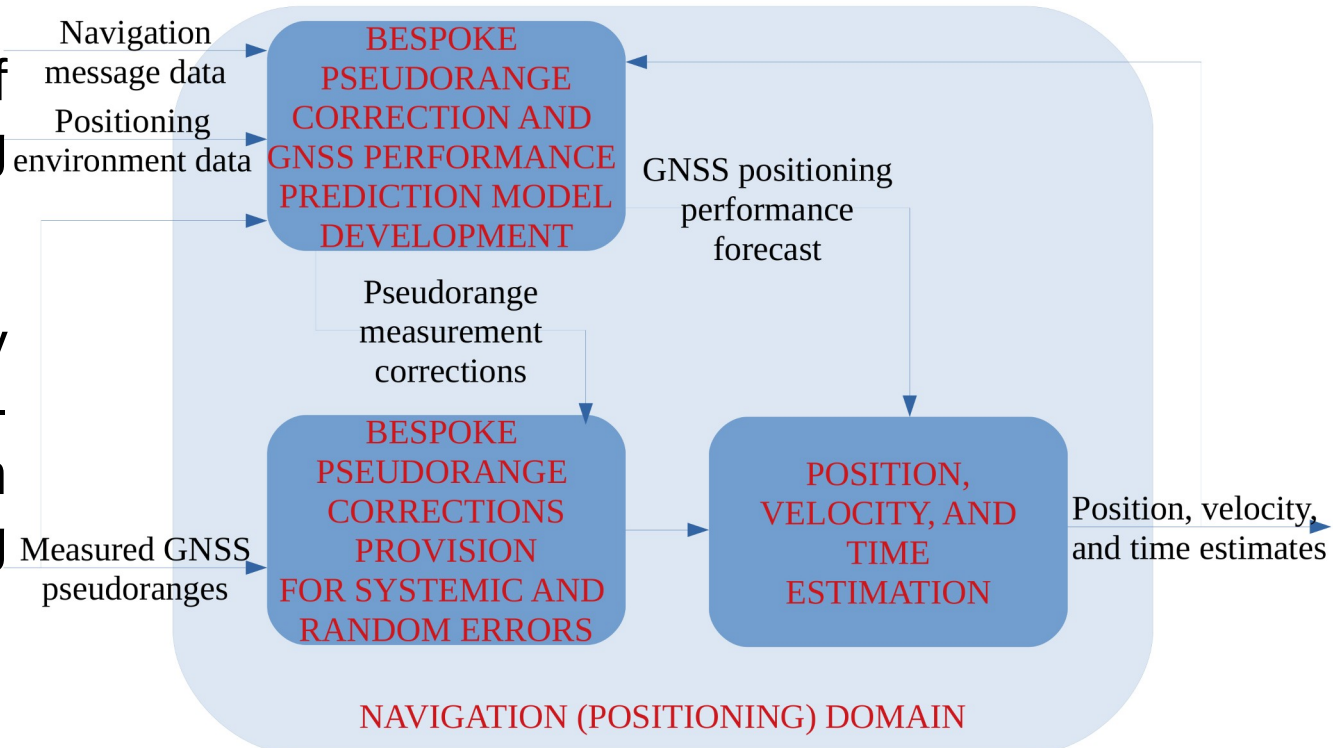
Ambient-Aware (AA) GNSS PNT

- Mitigation of space weather/ionospheric effects on GNSS PNT performance:

- direct observations of immediate positioning environment

- trusted third-party data (stream, server-application access), with optional processing (interpolation)

Sources: ISBN 978-613-9-90118-0,
doi:10.1088/1757-899X/1032/1/012001



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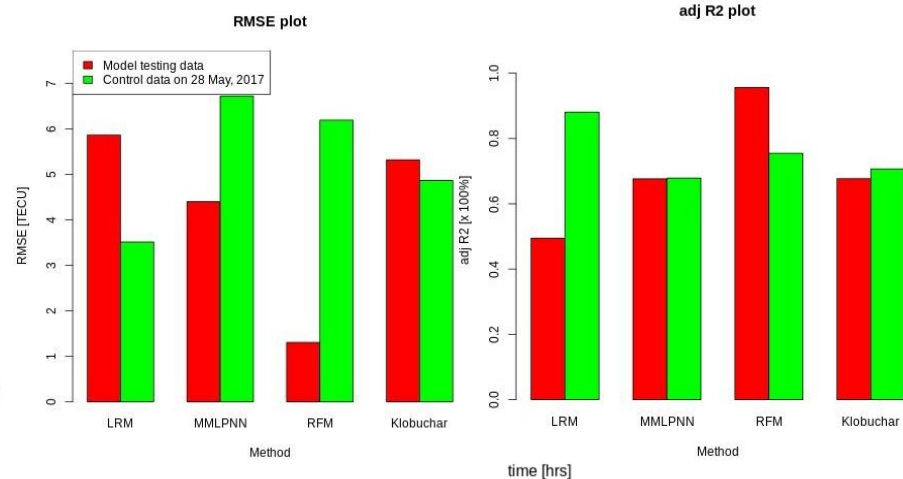
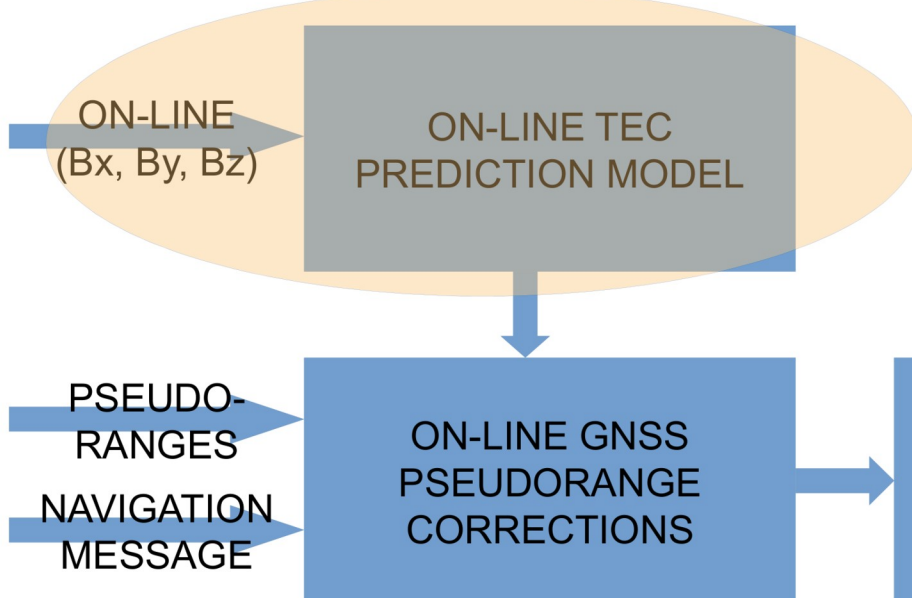
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Ambient-Aware PNT (R Filjar, Croatia)

Implementation & Demonstration

- Case-study of a short-term rapidly developing geomagnetic storm in sub-equatorial area (Darwin, NT)

LRM ... Linear Regression Model,
MMLPNN ... Monotone Multi-layer
Perceptron Neural Network Model, RFM ...
Random Forest Model, Klobuchar ...
standard Klobuchar Model



Reference model: global Klobuchar model

Tailored framework developed in the open-source **R** environment for statistical computing

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Validation (source: doi: 10.33012/2022.18247)

- Case-study of short-term rapidly developing geomagnetic storm in sub-equatorial area (Darwin, NT)
- Single-frequency GPS-based position estimation, no additional infrastructure utilised → GPS position estimation process self-adapted to the immediate environment conditions
- Ionospheric corrections: (i) Klobuchar model (reference/benchmark), (ii) **geomagnetic field density-based statistical learning Linear Regression Model (LRM)** (alternative)

in [m]	mean		standard deviation	
	Klobuchar corrections	self-adaptive corrections	Klobuchar corrections	self-adaptive corrections
<u>northing error</u>	-1.5368	-0.1098	2.24106	1.088705
<u>easting error</u>	0.72717	-0.02663	1.878769	0.9983062
<u>vertical error</u>	0.2225	-0.09773	1.29891	0.510632

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Discussion

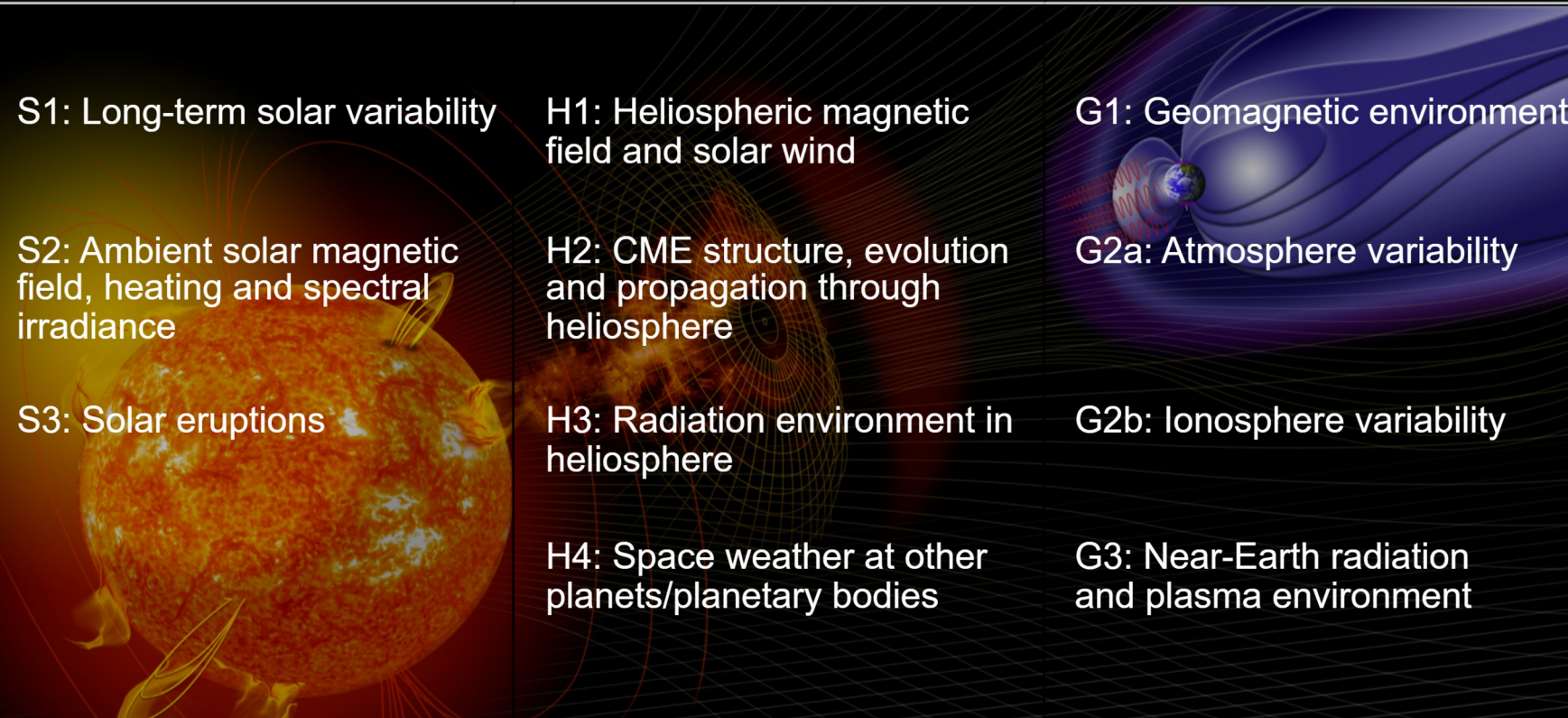
- Proposed utilisation of ambient awareness of immediate GNSS PNT environment conditions for Ambient-Adaptive (AA) PNT.
- Ambient-Adaptive GNSS PNT is inherently infrastructure-agnostic → no further investments in infrastructure is needed!
- GNSS positioning performance demonstrated in the case of short-term rapidly developing ionospheric disturbance.
- The need for space weather/geomagnetic/ionospheric observations and indices data standardisation (access, structure and format) and availability.
- Optimisation of ML/AI-based algorithms for ambient effects correction and PNT
- International activities, in collaboration with International Space Weather Action Teams (ISWAT, COSPAR)

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Source: <https://www.iswat-cospar.org/>

S: Space weather origins at the Sun	H: Heliosphere variability	G: Coupled geospace system	Impacts
 <p>S1: Long-term solar variability</p> <p>S2: Ambient solar magnetic field, heating and spectral irradiance</p> <p>S3: Solar eruptions</p> <p>Overarching Activities: Assessment Innovative Solutions</p>	<p>H1: Heliospheric magnetic field and solar wind</p> <p>H2: CME structure, evolution and propagation through heliosphere</p> <p>H3: Radiation environment in heliosphere</p> <p>H4: Space weather at other planets/planetary bodies</p>	<p>G1: Geomagnetic environment</p> <p>G2a: Atmosphere variability</p> <p>G2b: Ionosphere variability</p> <p>G3: Near-Earth radiation and plasma environment</p> <p>Information Architecture & Data Utilization Education & Outreach</p>	<p>Climate</p> <p>Electric power systems/GICs</p> <p>Satellite/debris drag</p> <p>Navigation/Communications</p> <p>(Aero)space assets functions</p> <p>Human Exploration</p>

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Recommendations

- 1. Ambient (SW/iono) conditions awareness to improve GNSS NT algorithm, as well as GNSS PNT performance and resilience against adverse SW/iono effects.
- 2. Ambient-Adaptive ML/AI-based GNSS ionospheric correction model to be developed based on SW/iono conditions awareness for every PNT process/receiver.
- 3. Ambient (SW/iono) conditions awareness to be obtained by: (i) direct SW/iono observations in the immediate vicinity of receiver, and/or (ii) link to trusted third-party sources.
- 4. International co-operation to be facilitated, established, and operated to:
 - 4.1 develop standards for ambient SW/iono data structure, formats, and protocols for internet-based data exchange;
 - 4.2 collect, assemble, aggregate, collate, and allow access to location-based real-time and archived ambient SW/iono observations;
 - 4.3 foster infrastructure-agnostic Ambient-Adaptive (AA) PNT correction model development, validation, and standardisation;
 - 4.4 develop inter-/multi-disciplinary expertise/capacity in support of transition to infrastructure-agnostic Ambient-Aware (AA) GNSS-based PNT.

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In appreciation of your attention, and
with invitation to participate to

Baška SIF (Spatial Information Fusion) Forum 2024
Baška, Krk Island, Croatia, 16th – 18th June, 2024

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