Topical Discussion Meeting report

Topic: Space Weather Collaborations for the Artemis Program of Lunar Exploration
Conveners: Nadine Boersma, Jamie Favors, John Manuel
Session: TDM-08
Room: Cassiopée Room
Date: Wednesday, November 22, 2023
Time: 11:45-12:45

Objective

The multi-national, multi-agency Artemis program of lunar exploration is providing new opportunities for space weather (including heliophysics) research. Artemis also presents challenges for operational monitoring and prediction of space weather as will be necessary to protect astronauts venturing beyond low Earth orbit. Consequently, multiple agencies are developing space weather capabilities specifically to support Artemis. These efforts include analysis and prediction centres as well as future payloads to study and monitor space radiation and space weather. All these efforts inform future international exploration plans such as NASA's Moon to Mars Architecture which will further enable scientific investigations in deep space and require Earth-independent space weather capabilities for human exploration. This Topical Discussion Meeting is offered with an intent of promoting gainful collaboration and coordination of projects.

Discussion Highlights

The session began with brief overviews of ESA, CSA, and NASA priorities and objectives for space weather and heliophysics research under the Artemis program. Several attendees including JAXA provided slides addressing potential collaborations:

- SWEPT (Sweeping Energetic Particle Telescope) is a Canadian instrument aiming to accurately characterize the Solar Energetic Particle energetic particle flux spectrum as a function of direction over a range of energies (3-300 MeV protons, 12-1200 MeV alphas, 0.3-2 MeV electrons). Further information is available in the Annex.
- Lunar RICheS (Lunar Ring Image Cherenkov Spectrometer) measuring energy spectra of solar proton and galactic cosmic ray spectra up to 2 GeV. Further information is available in the Annex.
- PS_TEPC LET (Position Sensitive Tissue Equivalent Proportional Chamber Linear Energy Transfer and dose monitor) has the ability to measure energy deposition but also trajectory of incident charged particles 0.2-1000 MeV/um. Further information is available in the Annex.
- LEXUS (Lunar Electron eXperiment for hUman activities on the lunar Surface) which is an energetic electrons detector (keV-MeV) providing energy and direction of incident electrons. This could also be embarked on Gateway. Further information is available in the Annex.

The convenors then elicited discussion on these potential collaborations and other topics.

1. Which kind of instrumentation is currently missing? For which scientific area is a gap in technology present which needs to be closed?

- There is a clear scientific interest to have HERMES operating during the Earth Raising Orbit Phase through the (Van Allen Belts). Collecting data during the lunar transit phase is equivalent to a science mission on its own. Real time data would be preferred here (specifically for operational space weather community), but also delayed data would be much needed.
- High energy part of SEP (GeV). No instruments are currently covering this. Also, more refined Science level energetic particle (1 - 100s MeV range) instruments. Plus instruments with large geometric factors capable of sampling higher Z ions which are less abundant. Some instruments or instrument ideas were suggested such as:
    - Alpha Magnetic Spectrometer on ISS (100s GeV) or a similar with more viability for more compact instrument concepts such as PAN or mini-PAN
    - Ulysses/COSPIN (Cosmic Ray and Solar Particle Investigation)
    - Cassini instrumentation
    - Solar Orbiter/EPD (energetic particle detector) and others – it was noted that there is a flight spare available
    - ACE/SIS for heavy ion detection
- The ERSA and HERMES instrument payloads are partially obstructed and likely to be affected by the induced space environment at Gateway. An option to mount future instrument payloads on the robotic arm would enable optimized measurements of the Gateway space environment.
- Platform charging environment monitoring (in particular during visiting vehicle docking) is not covered and is interesting for the science community.

2. How to engage new teams:
    - Agencies to organise and finance scientific gatherings where new teams can participate and engage.
    - The NASA SMD Bridge Program was mentioned as an opportunity and example for other agencies. This program's primary goals is the development of sustainable partnerships among institutions under-resourced by NASA with a focus on research and engineering opportunities.
3. How science teams can forward instruments and get involved into agency programs / hardware
    - The Facility Definition Teams are the correct place to start and to be in. There requirements are discussed and created as well as instruments discussion. The community is encouraged to participate in the calls for the Science Definition Teams. For ERSA and IDA next generations this call will likely be published 2024.

Conclusions

The Topical Discussion Meeting on Space Weather Collaboration for the Artemis Program of Lunar Exploration was a very good discussion which identified gaps in technology which need to be filled for future exploration (on the base of science needs) as well as offering candidate Instruments. This included

next generation dosimetry for inside Gateway and also multi-directional and higher energy coverage of the energetic particle distribution outside of Gateway.
In addition, possibilities were discussed on how to engage existing and new teams in the Exploration program.

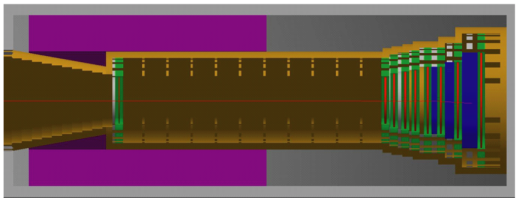
Annex – Contributed slides on potential collaborations

- SWEPT (Sweeping Energetic Particle Telescope)
- Lunar RICheS (Lunar Ring Image Cherenkov Spectrometer)
- PS_TEPC LET (Position Sensitive Tissue Equivalent Proportional Chamber Linear Energy Transfer and dose monitor)
- LEXUS (Lunar Electron eXperiment for hUman activities on the lunar Surface)

SWEPT (Sweeping Energetic Particle Telescope)

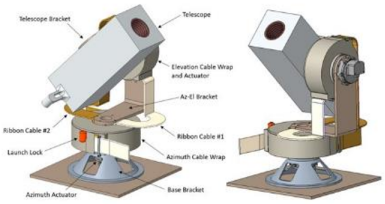
The slide below was excerpted from a presentation containing multiple slides.

SWEPT Telescope and Actuator Design



SWEPT cross section in GEANT

Red: Si Detector
Blue: W Degrader
Orange: Cu Degrader
Silver: Al Degrader
Purple: Electronics



2-axis gimbal, identical actuators
+/- 90° elevation, +/- 175° azimuth
Actuator max slew rate 1°/s
Cable wrap system, detector FOV 20°

Detectors	9		Total mass	4.88	kg
GF	0.1	str	PCB mass	0.49	kg
Width	10	cm	Length	26.9	cm
Side Shielding	60	MeV	Back Shielding	100	MeV

Particles	Energy Range
Protons	3 to 300 MeV
Alphas	12 to 1200 MeV
Electrons	0.3 to 2 MeV

High resolution, pulse height analysed, high speed, dE/dx spectroscopy, with telescopic coincidence and side shielding.

Lunar RICheS (Lunar Ring Image Cherenkov Spectrometer)

Lunar-RICheS
Lunar-Ring Image Cherenkov Spectrometer

Space radiation doses drastically change owing to the variation of the intensity and peak amplitude in solar energetic particle (SEP) events beyond the LEO.
RICheS measures energy spectra of high-energy solar proton events and energetic particles from 10 MeV/n to 2 GeV/n, where contribute to doses for crews and life-science material in the Artemis/ Gateway mission.
It is specifically engineered to provide wide dynamic measurement range capability and high accuracy for solar energetic particles (SEP) and energetic particles of Galactic Cosmic Ray (GCR), by combining semiconductor sensors and cherenkov radiator (See Fig.1).
RICheS features limited space and weight (less than 3U) to fit the Gateway Exposed area and Lunar surface missions.
Joint operation with JAXA PS-TEPC (Position Sensitive Tissue Equivalent Proportional Chamber: ISS LET and dose detector) and D-Space/PDS (Personal dosimeter: ERSA-IDA dosimeters), a cooperative system will be established to evaluate and predict radiation doses at desired location. Artemis/ Gateway mission, as shown in Fig.2.

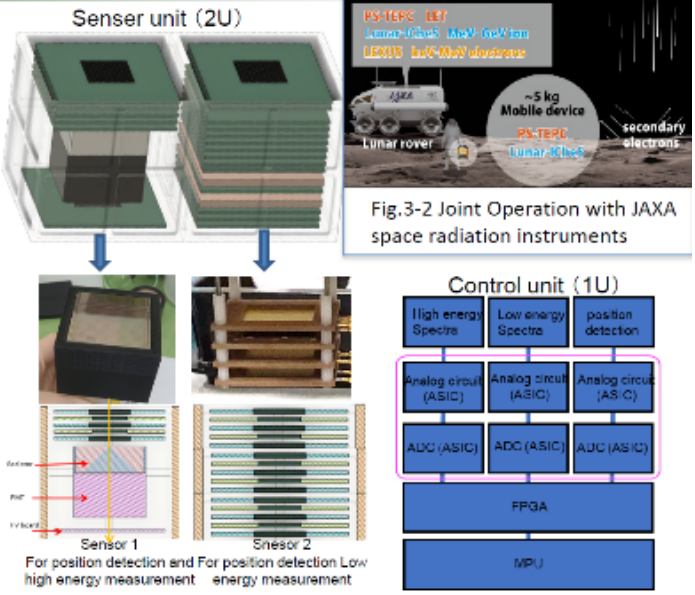


Fig.3-1 Lunar-RICheS spectrometer (3U)

Fig.3-2 Joint Operation with JAXA space radiation instruments

■Latest Status of Lunar-RICheS

・Lunar-RICheS is a R&D theme part of 'Development of high-quality and compact space radiation instruments for the expansion of lunar utilization' (Primary investigator Prof. Yoshizumi Miyoshi: Nagoya univ.), selected as JAXA feasibility study of science and technology mission on the moon on Nov. 2021.

・By incorporating AISC, we aim to develop the world's first ring image Cherenkov detector with significantly reduced power consumption and size.

PS_TEPC LET (Position Sensitive Tissue Equivalent Proportional Chamber Linear Energy Transfer and dose monitor)

PS-TEPC (LET and Dose monitor)

Position Sensitive Tissue Equivalent Proportional Chamber

Position-Sensitive Tissue-Equivalent Proportional Chamber (PS-TEPC) is a space dosimeter which jointly developed by KEK, JAXA, Keio Univ., Kobe Univ., Kyoto Univ., Waseda Univ.. PS-TEPC consists of a gas chamber with the detection volume of 2.6 × 2.6 × 5.0cm3 which has availability to measure not only the energy deposition but also the three-dimensional trajectory of an incident charged particle by using a time projection chamber method. By dividing the energy deposition by the path length of the trajectory, PS-TEPC can measure Linear Energy Transfer (LET) of the incident particle. Furthermore, PS-TEPC consists of tissue-equivalent materials, i.e. tissue-equivalent plastic A-150 and methane-based tissue-equivalent gas (CH4: 64.4%; CO2: 32.4%; N2: 3.2%), and consequently make it possible to emulate interactions of the incident radiations with soft tissues in human body. PS-TEPC can derive the dose equivalent strictly based on its definition with small uncertainties because any conversion and assumption coming from the difference between detector materials and soft tissues is not necessary.

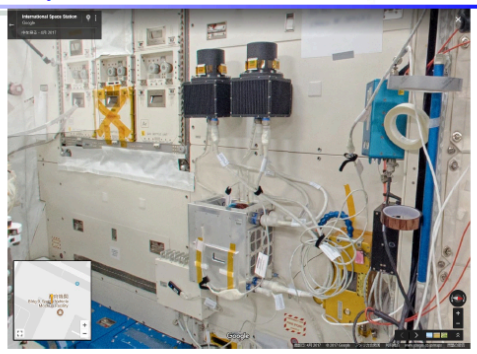


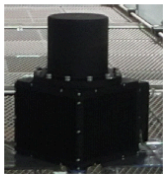
Fig.5-1 Installation on board the ISS KIBO 2016 4 Dec.

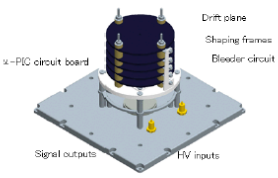
■Latest Flight onboard the ISS

PS-TEPC was launched by H2B rocket to the International Space Station on December 9th, 2016 and experiments were performed in the Japanese Experiment Module to demonstrate its operation and to investigate its actual performance in the spacecraft from December 28th, 2016 to April 2nd, 2018.

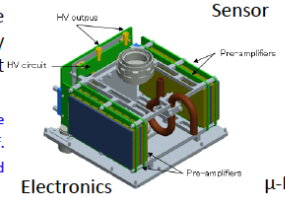
The detector units of PS-TEPC operated without any serious damage and problem for the experiment duration. It was successfully demonstrated that PS-TEPC could measure the LET of each incident charged particle with its range between 0.2 and 1000 keV/um.

•PS-TSPC is also a R&D theme part of 'Development of high-quality and compact space radiation instruments for the expansion of lunar utilization' (Primary investigator Prof. Yoshizumi Miyoshi: Nagoya univ.), selected as JAXA feasibility study of science and technology mission on the moon on Nov. 2021

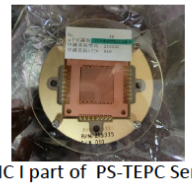




Sensor



Electronics



μ-PIC I part of PS-TEPC Sensor

LEXUS (Lunar Electron eXperiment for hUman activities on the lunar Surface)

LEXUS (Electron monitor)

Lunar Electron eXperiment for hUman activities on the lunar Surface

■Instrument overview

- Electron detections at keV – MeV
- Energy of each incoming electrons are measured by photo-diodes
- Direction of each incoming electrons are determined by a collimator

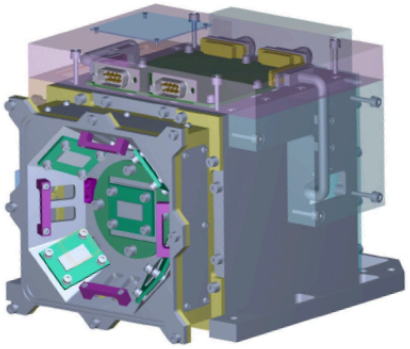
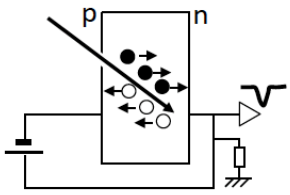


Fig.7-1 LEXUS Electron monitor

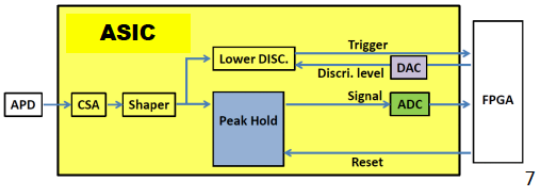
■Purpose of measurements

- Understanding of charging processes on lunar and artificial structure surfaces
- Possible monitoring as a proxy for surface charging



■Heritage

- MED onboard RockSat-XN (NASA)
  - Sugo+2021, JGR
- MEP-e and HEP onboard Arase (JAXA)
  - Kasahara+2018, EPS; Mitani+2018, EPS



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