Development of the Canadian Active Neutron Spectrometer for the ISS and Lunar Gateway

WRMISS
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PRESENTING FOR THE CSA CANS TEAM:

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Presentation Overview

Purpose:

Provide an update on CSA plans to develop a Canadian Active Neutron Spectrometer (**CANS**) for the Gateway-Habitation and Logistics Outpost (HALO) module as an internal science payload, including a prior Technology Demonstration on the ISS.

Topics:

- CANS Project – Introduction
- Scientific & Program Objectives
- Canadian Heritage in Neutron Spectrometry and Dosimetry in Space
- Mission Objectives
- CANS Concept & System Requirements
- ISS Technology Demonstration and Collaboration with ISS Partners
- Collaboration with Gateway Partners
- Data Sharing and Collaboration Plan

CANS Project - Introduction

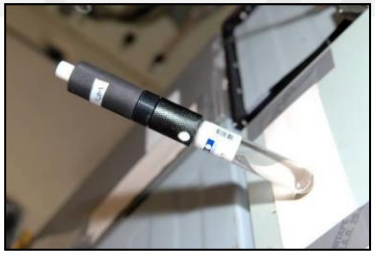
- Given Canada's significant expertise in neutron dosimetry and spectrometry, CSA has offered to build an active neutron spectrometer for the Artemis Program.
    - This was in response to NASA/Semones 2020 request for CSA to consider building an active neutron spectrometer for Gateway-HALO
- Canada received concurrence of Gateway Program Coordination Board in November 2023 to include the Canadian Active Neutron Spectrometer instrument as one of its primary science contributions for Gateway for 2027-2028 period (targeting Artemis IV launch).
- Development of CANS started with Phase A in 2023 by Canadian company Bubble Technology Industries (BTI). Contract for phase B and onward to be awarded by January 2026.
- Technology Demonstration on ISS will be performed within the Gateway unit development schedule, allowing the integration of lessons learned from it (to the extent practical).
- Even though CANS will **not** be built as an operational instrument, CANS data obtained can be used for operational purposes as well - to calculate contribution of neutrons to astronauts' total radiation dose.

Scientific & Program Objectives

- Neutrons are created in interactions of GCR and SEP with vehicle/habitat.
- Neutron spectrometry data is essential for a complete picture of the radiation environment for the Artemis missions, and will contribute to
  - ✓ Understanding the radiation risk in space from neutrons
  - ✓ Refining radiation risk assessment models and validating radiation transport codes
  - ✓ Studying the effects of space radiation on shielding materials, electronics and biological systems, etc.
- Neutron detection is difficult in the presence of energetic charged particles and gamma/x-rays necessitating bespoke instruments.
- CANS will monitor/measure the real-time neutron environment outside Earth's magnetosphere, inside Gateway-HALO, with data collected automatically, continuously and autonomously.
- For Gateway Program, CANS will fill one of the identified needs for "capabilities and facilities needed to enable the science" that the Gateway Program is not planning to provide.
  - ➢ Specifically, CANS will provide "additional radiation monitoring equipment to complement the IDA payload" (Internal Dosimeter Array) by providing neutron spectrometry capability (GPCB, Nov 2021: Gateway Utilization Planning Strategy and 15-Year Outlook).
- Data will be made available for the international science community as per Artemis Accords.

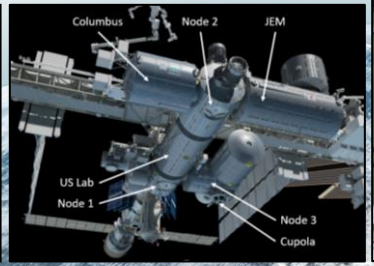
Canadian Heritage in Neutron Spectrometry and Dosimetry

- Canada has significant commercial and research expertise in neutron dosimetry and spectrometry, including in space.
  - Canadian made neutron detectors (bubble detectors) by Bubble Technology Industries (BTI) have been used to monitor neutrons inside space vehicles since 1989.
- Between 2009-2020, CSA supported a study, Radi-N2, aimed at measuring neutron radiation in multiple locations inside the ISS using Canadian made detectors and on-board reader.
  - Study used Space Bubble Detector Spectrometer (SBDS) by BTI, a set of six detectors, each with a different energy threshold, providing a coarse neutron energy spectrum.
- CSA supported the development of the Canadian High-Energy Neutron Spectrometry System (CHENSS) by BTI for Shuttle as a “Get Away Special” program payload
  - ❖ In the end, CHENSS was not deployed to space due to the cancellation of the program.
- In 2019, CSA awarded a contract to BTI to perform a technology concept study for a neutron spectrometer for deep space. The concept developed (CCNS) by BTI was used as basis for CANS.



BTI Canadian Compact Neutron Spectrometer (CCNS) Conceptual Design (2019)

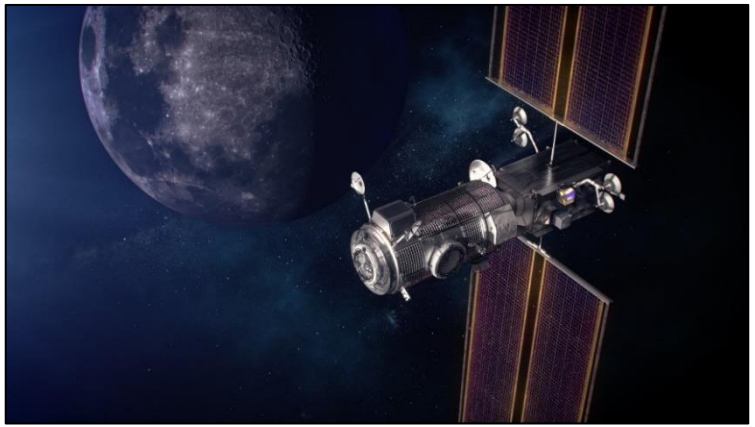
BTI Canadian High-Energy Neutron Spectrometry System (CHENSS)



Mission Objectives

- CANS as a Technology Demonstration on the ISS in late 2027.
  - Will be performed under CSA ISS Utilization allocation.
  - Validation and commissioning of CANS, with possibility of continued operation as a scientific mission.
  - Planning with NASA ISS Payload Integration Team has started (PIM: Tracey Lackey).
  - Proto-Flight Model PFM-1 (ISS) and PFM-2 (Gateway) units to be as similar as possible.

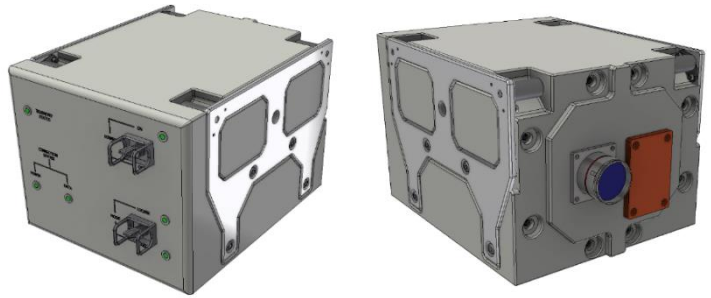
- CANS Gateway Unit is planned to provide data from Gateway-HALO starting with Artemis IV.
  - Planning with NASA GW Payload Integration Team has started (PIM: Amanda Rice).
  - CANS becomes a standard facility for neutron measurement on Gateway.

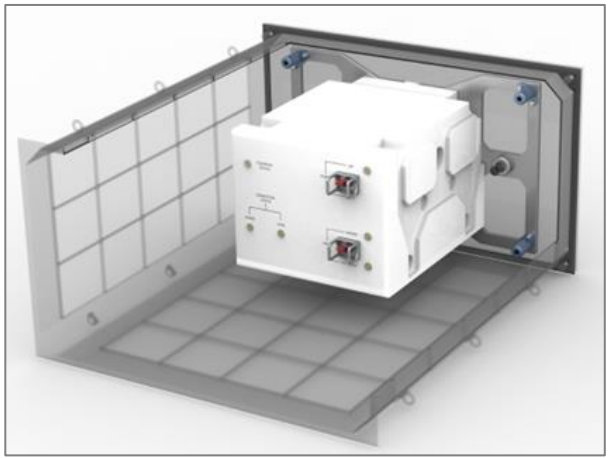


CANS Concept

Performance requirements

- Capability to monitor the neutron flux as a function of time and neutron energy, for energies between 1 MeV (or lower) and 30 MeV (or higher) - **Range predicted to be 0.5 MeV to 100 MeV.**
- Neutron signal discrimination from charged particles/gamma/x-rays.
- Capability to provide the measured time-stamped neutron flux versus energy to the Ground on-command and as part of scheduled autonomous operations.
- Current plan is for the CANS ISS unit to be aisle deployed, and the Gateway unit to be inside the Gateway-HALO Payload Bank.
- Mass: NTE 14 kg (excluding the single GFE Payload Enclosure for the Payload Bank)
- Power: NTE 15 W
- Approx. size after phase A is 27 [L] x 21 [W] x 18 [H] cm^3





CANS Phase A concept design for Payload Enclosure deployment on Gateway-HALO

CANS System Requirements

- No restrictions or special requirements for the launch vehicle; Soft stow;
- After de-stow and set-up, will operate autonomously, minimizing the amount of crew time required;
- The instrument shall continuously measure the neutron energy spectrum and store the data autonomously;
- Data transmitted to Earth with no user interaction (with ability to store data internally in case telemetry not available);
- Capability to present spectral, dosimetric and diagnostic information upon request;;
- Diagnosis and troubleshooting of issues remotely; software and firmware updates remotely;
- Movable - Velcro attachment for mounting (ISS).

ISS Technology Demonstration

- CANS unit will be tested and calibrated at ground-based accelerator facilities, prior to deployment to the ISS.
- CANS Technology Demonstration will consist of operating the first Flight unit on board the ISS for 6 months, concluding with its commissioning (i.e., a successful Commissioning Review).
- CANS to be tested in the space radiation environment, most comparable to the unique environment of the Artemis missions.
- Technology Demonstration will include a data comparison with other instruments on board the ISS, such as functionality testing to verify performance of the instrument platform against selected benchmark instruments.
- As soon as commissioning has been completed, the project can transition the CANS instrument to its operation phase (Phase E) and the unit can be utilized to collect scientific (and operational) data until planned decommissioning of the ISS in 2030.

Collaboration with ISS Partners

- The plan is to conduct the ISS Technology Demonstration in close collaboration with NASA SRAG and ISS Partners
- Cross-comparison with relevant radiation detectors on the ISS, for example:
  - ISS-Radiation Assessment Detector (ISS-RAD, NASA):
    - Fast Neutron Detector (FND): neutrons (~0.2-8 MeV)
    - Charged Particle Detector (CPD): charged particles, γ-rays and neutrons (~4-400 MeV)
  - Fast/Advanced Neutron Spectrometer (FNS/ANS, NASA): neutrons (~0.1-20 MeV)
    - ✓ Comparison with previously collected FNS data from same locations on ISS
  - Light Ion Detector for ALTEA (LIDAL, ASI): charged particles
    - ✓ CANS team has met with the representatives of ASI (Italian Space Agency) to discuss data sharing and possible collaboration on the cross-comparison of CANS and their LIDAL ISS payload data (CSA/ASI meetings: 28/05, 2024 and 05/11, 2024)
- After Tech Demo, plan to continue operating CANS on ISS and share data.
  - ➢ CSA is seeking to learn about international science community's interest to use CANS data from ISS.

Collaboration with Gateway Partners

- CANS is being developed in close collaboration with NASA RadWorks Project team and NASA Space Radiation Analysis Group (SRAG), including mission and systems requirements.
- CANS Team has initiated discussions with other Partners through GUCP (Gateway Utilization Control Panel and GW Discipline Working Groups (DWG) including:
  - Heliophysics DWG, which has prioritized two instruments for Artemis IV: JAXA's Lunar-RICheS (Ring Imaging Cherenkov Spectrometer) and CSA's Canadian Active Neutron Spectrometer.
  - Human Health DWG
- CANS team has initiated contacts with ESA-led Internal Dosimeter Array (IDA) payload developers – given data provided by CANS would complement the IDA charged particle focused measurements, by providing assessment of ***neutron contribution*** to the complete mixed-radiation field present in the spacecraft.
- **Next Steps:**
  - **Set up an international CANS Science team with other agency representatives.**
  - **Formalize exchange with IDA Team**
  - **Develop a partnership plan**

CANS Data Sharing and Collaboration Plan (ISS and Gateway)

- Data will be downlinked to CSA HQ and processed at the contractor's facility.
- CANS data will be released in a machine-readable format to the scientific community as soon as practical but no later than 6 months from its reception or creation. Priority will be given to Gateway Partners to access CANS data for operational purposes.
  - Achieved through Government of Canada repository (e.g. GoC Open Government Portal) and/or Gateway partners' repository (e.g. NASA RadLab, ESA database).
- Data parameters available for distribution to users will be discussed during Phase B of CANS development.
- Data compatibility/complementarity coordination with International Partner Payload developers through bi-lateral and multi-lateral meetings, e.g. with IDA PIs.
- **Next Step:**
  - **Develop a Data Sharing Plan with international partners (Gateway Utilization Arrangement Plan)**

THANK YOU FROM THE CANS TEAM

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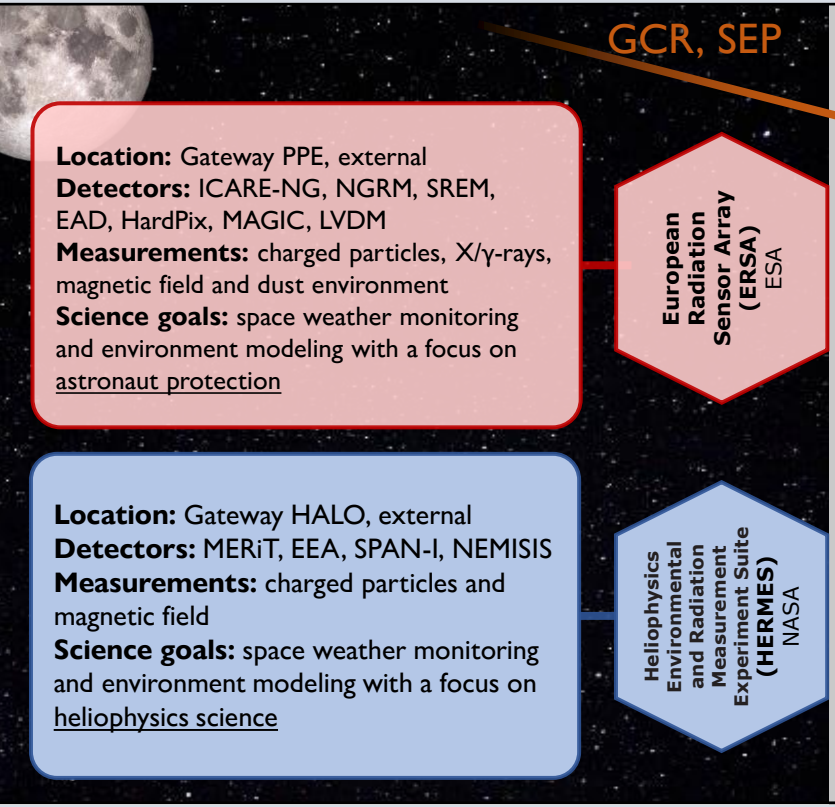
QUESTIONS ?

CANS Phase A Team

Back-Up Slides

GATEWAY RADIATION SCIENCE PAYLOADS



References:
- S. Petro, T. Null. HERMES Integration and Testing, IEEE, 2023, link
- J. Spann, L. Surdo. Artemis Program Heliophysics Science and Instruments on Gateway, 2021, link

- Internal and external radiation monitoring payloads are complementary by providing data that could improve radiation transport codes and environment models for shielding and health risk assessments.
- CANS will measure the neutron energy spectrum inside Gateway to meet the science objectives. Collected data could also be used for operational purposes.

CANS COMPLEMENTS IDA

CANS

CANS
Phase A concept

IDA

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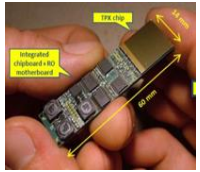
PADLES + D-SPACE



MediPix

CANS

Neutrons

- **Energy spectrum**
- Flux/fluence
- Dose rate
- Absorbed dose
- Dose equivalent

IDA

Charged particles, X/γ-rays

- Flux/fluence
- LET spectra
- Mean quality factors
- Dose rate
- Absorbed dose
- Dose equivalent

COMMON SCIENCE OBJECTIVES

1. Characterize the radiation environment inside Gateway
2. Assessment of shielding effects
3. Improve particles fluence rate predictions inside Gateway using existing particle transport codes
4. Compare measurements inside Gateway with those outside from the ERSA and HERMES instrument suites
5. Improve mission dose predictions and individual risk assessment
   - *On ISS, neutrons contribute to approximately 30% of the total dose equivalent*

CANS is the only instrument that will measure the neutron energy spectrum inside GW-HALO:

- The CANS will measure fast neutrons in the 0.5 – 100 MeV energy range, cleanly separated from photons and charged particles.
- While IDA EAD provides some information on thermal neutrons (a small portion of the total neutron dose) and IDA PADLES provides limited information on fast neutrons, both instruments report their dose information as a total for all particle types. Neither has the capability to separate the neutron information which is an added capability provided by the CANS.

References:
- ESA. Gateway Phase 1: IDA Payload (presentation to GPCB meeting), Jan. 21th 2021
- ESA. International Announcement of Opportunity for ERSA & IDA at Gateway, 2021, link

Agence spatiale canadienne

Canadian Space Agency