NESC Space Environment Activities

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Outline

- Introduction to the NASA Engineering and Safety Center (NESC) and NESC Space Environments
- Summary of Space Environments assessment and support activities
- Highlights from a selected set of activities
- Spacecraft Charging Materials Database

Introduction

- NASA Engineering and Safety Center's (NESC) mission is to
  - Perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success
  - Engage proactively to help NASA avoid future problems

- NESC discipline activities are led by a Technical Fellow supported by a Technical Discipline Team (TDT) composed of discipline experts from NASA, industry, academia, and other government agencies

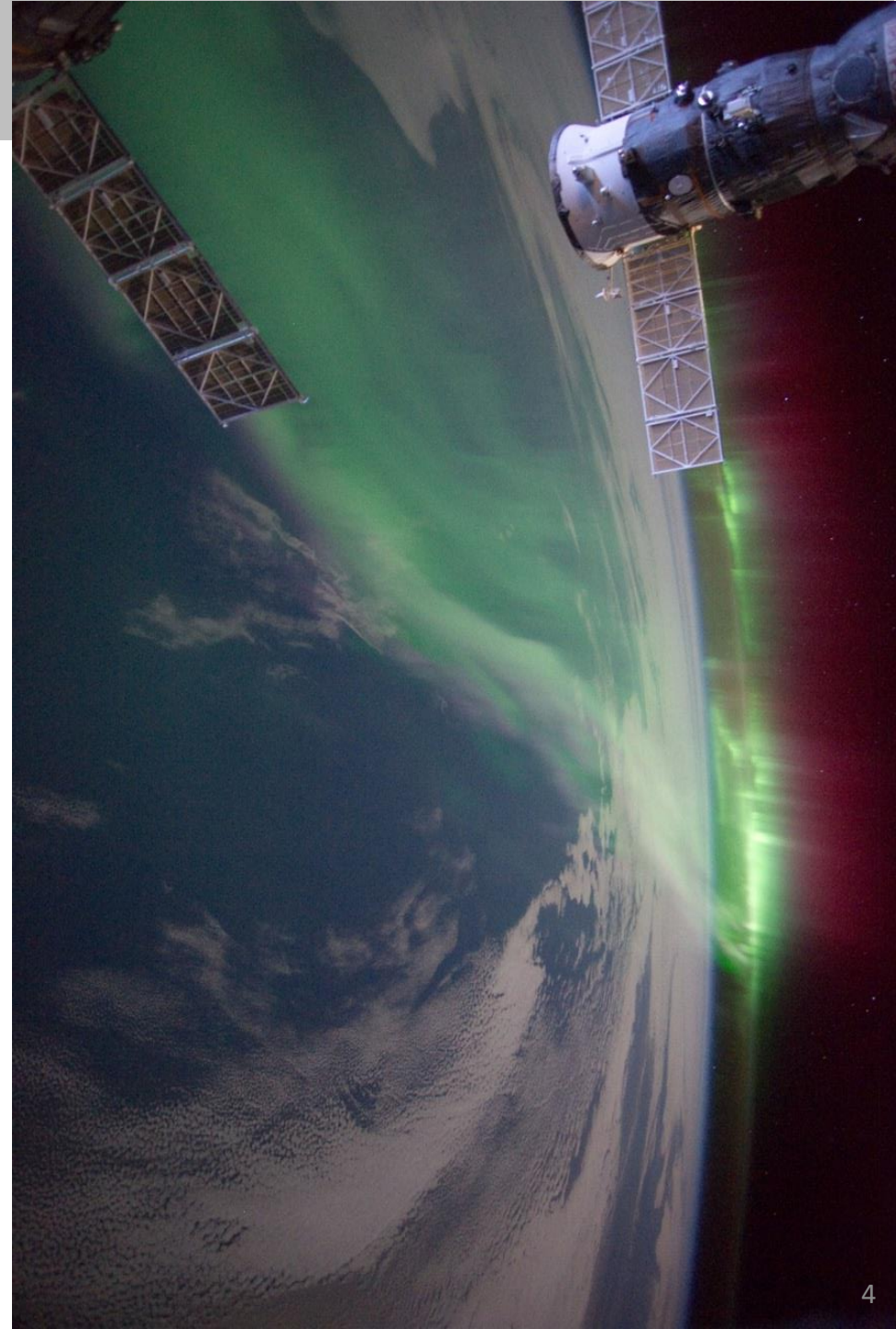
- Individual NESC assessment and support activities are staffed by NESC and TDT personnel, other technical experts from within NASA, and expertise external to the Agency using the "tiger team" model to address technical problems for NASA programs and projects or meet cross-Agency and discipline needs

Aerosciences	Mechanical Systems
Avionics	Nondestructive Evaluation
Cryogenics	Nuclear Power and Propulsion
Electrical Power	Passive Thermal
Environmental Control/Life Support	Propulsion
Flight Mechanics	Sensors/Instrumentation
Guidance, Navigation & Control	Space Environments
Human Factors	Software
Loads and Dynamics	Structures
Materials	Systems Engineering

NESC Space Environments TDT Scope

Space environments and their effects that impact the design, construction, and operation of NASA's human and robotic space systems and health of the crew

- Ionizing radiation, neutral energetic particles
- Meteoroids and orbital debris, hypervelocity impact
- Gravitational fields, microgravity
- Magnetic, electric fields and currents
- Space plasma, spacecraft charging
- Neutral atmosphere, vacuum, atomic oxygen
- Photons (IR, visible, UV/EUV, x-ray, gamma-ray)
- Applied space climate and space weather



Space Environments TDT Activities (Recent and Active)

ID	Title	Type*	Discipline	ECD**
15-01079	JWST Space Environment Launch Constraints	A	Spacecraft charging, radiation	06/2019
15-01107	Chandra X-Ray Observatory ACE Real-Time Data Support	S	Radiation environment	09/2019
16-01108	ISS Plasma Interaction Model Independent Review	A	Surface charging	02/2019
17-01204	Southern Hemisphere Meteoroid Environment Measurements	A	Meteoroid environment	09/2021
17-01215	Space Weather Architecture	A	Space weather prediction	03/2020
17-01281	Europa Lander Radiation Test Technical Support	S	Internal charging	04/2019
18-01322	Auroral Charging Threat Assessment	A	Surface charging	2023
18-01404	PAMELA Radiation Data Recovery Technical Support	S	LEO radiation environments	05/2021
18-01407	Technical Support for Revising NASA-HDBK-4002A	S	Surface, internal charging	05/2021
19-01428	NASCAP Integrated Spacecraft Charging Analysis	S	Surface charging	04/2020
19-01433	Badhwar-O'Neill Galactic Cosmic Ray Model Improvements Assessment	A	Radiation environment	12/2021
19-01434	FPMU Data Processing Algorithm Development and Analysis Assessment	A	Space plasma environment	12/2021
19-01435	Orion, NDSB2, and Gateway Material Electrical Properties Support	S	Surface, internal charging	06/2021
19-01468	CCP Post-flight Reference Radiation Environments	A	LEO radiation environments	12/2021
20-01576	Lunar Meteoroid Ejecta Model Review	A	Lunar ejecta environment	06/2021

* (A)ssessment or (S)upport

** Estimated completion date: completed active

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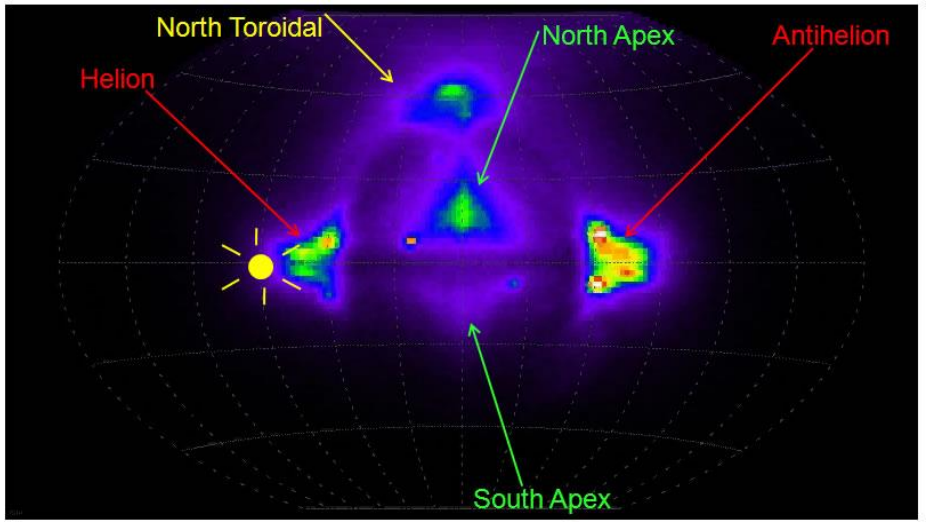
Southern Hemisphere Meteoroid Environment Measurements

- Knowledge of the meteoroid environment for particle in mass range of 1μg < mass < 10 g is relevant to both:
  - Science: planetary science, upper atmospheric chemistry, space weathering of airless bodies
  - Engineering: impact risk assessment

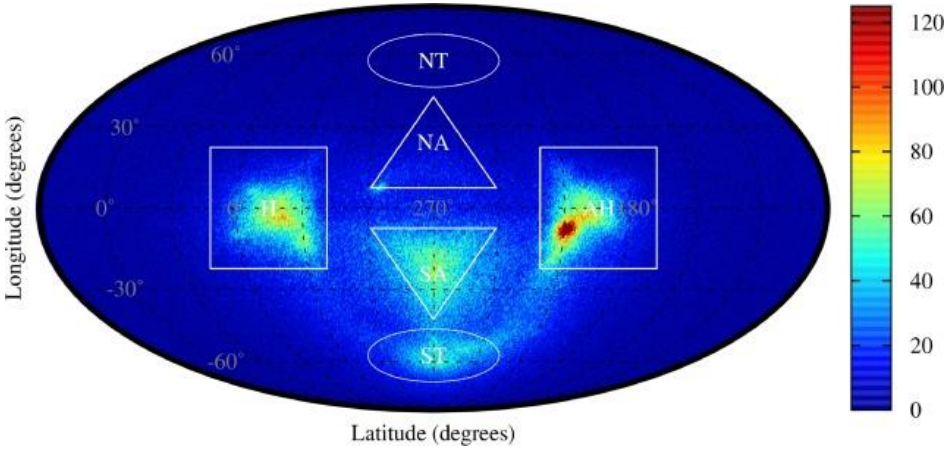
- Meteor radars provide continuous monitoring over most of the mass range. Unlike optical observations, radar observations are not limited to night hours and can observe in all weather conditions.

- NASA meteor monitoring for engineering threat assessments utilize data from the Canadian Meteor Orbit Radar (CMOR):
  - Funded by OSMA's Meteoroid Environment Office (MEO)
  - Meteors can come from all directions on the celestial sphere. CMOR, because of its high latitude, is limited to observing and characterizing sporadic meteors and meteor showers that are visible from the northern hemisphere
  - Sporadic meteors and meteor showers visible only from the southern hemisphere are not as well characterized

- Use the Southern Argentina Agile Meteor Radar (SAAMER) facility to obtain measurements of sporadic and shower meteors in the southern hemisphere



CMOR, University of Western Ontario



SAAMER, *Pokorny et al.*, 2017

Southern Hemisphere Meteoroid Environment Measurements

- NESC assessment activity
  - 3-year project 03/2018 – 09/2021
  - Tech Lead: Mark Matney/JSC
  - Tech Co-Lead: Diego Janches/GSFC

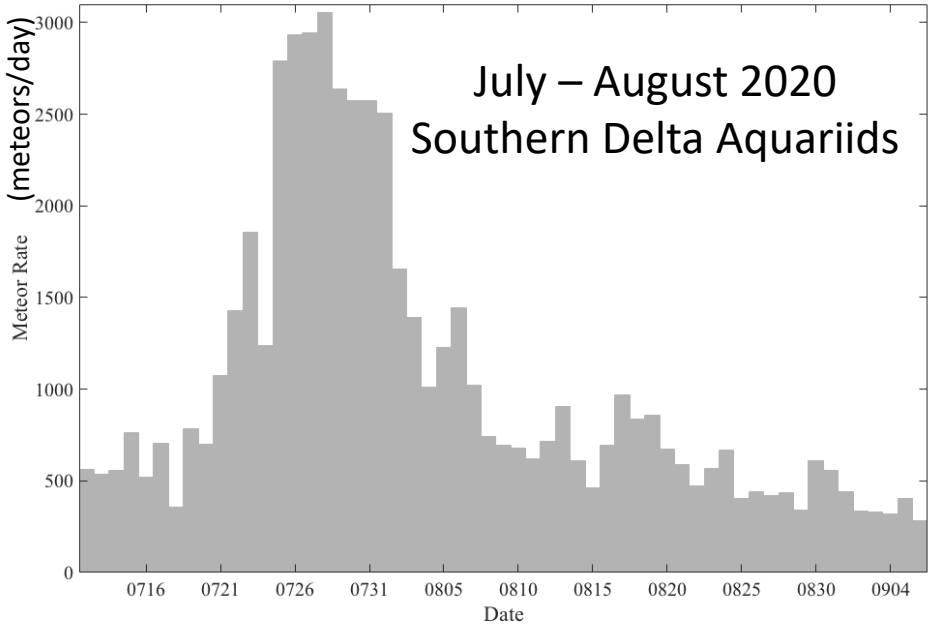
- Develop an accurate, calibrated, and statistically significant meteoroid environment data set from the Southern Hemisphere, including both the sporadic background and a comprehensive survey of meteor showers

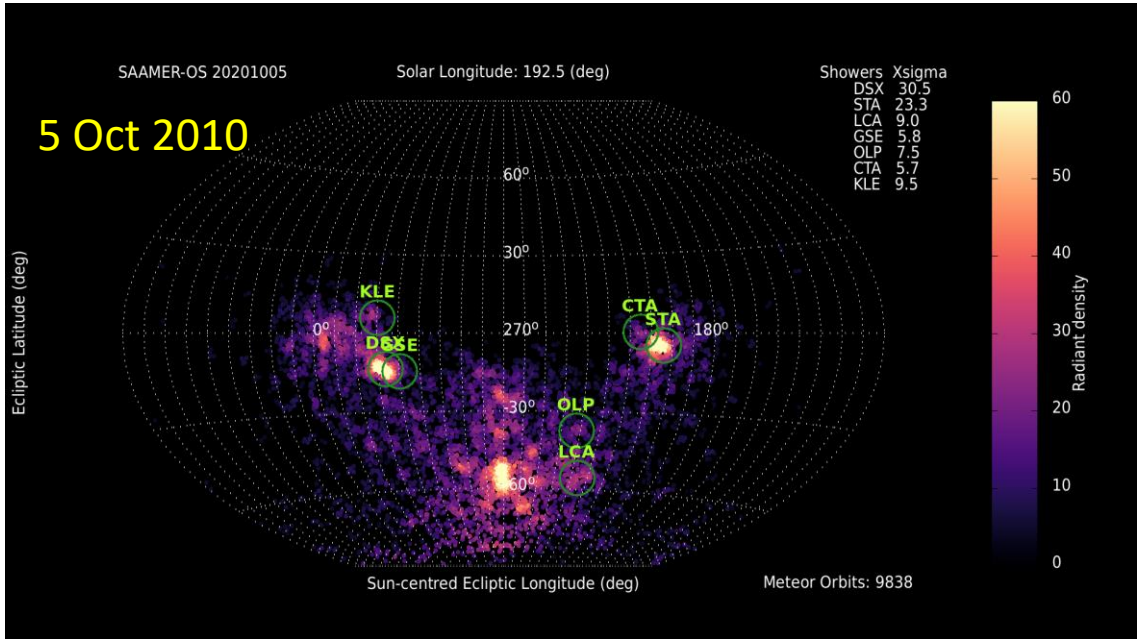
- Southern Argentina Agile Meteor Radar (SAAMER)
  - Central Tx (60 kW, 32.55 MHz) and Rx station
  - 4 remote Rx stations
  - Facility development funded by NASA SMD and NSF

- NESC improvements
  - Tx upgrade improves meteor recovery
  - Modify processing software to identify overdense echoes and determine orbits with all Rx sites simultaneously
  - Deploy optical cameras for simultaneous optical/radar measurements for meteor mass calibration

Meteor Shower Monitoring

- Orbital software using all remote sites simultaneously developed and operational, including underdense and overdense echoes.
- On average ~10-15K orbits recorded daily (5K by CMOR)
- Wavelet code and pipeline to provide daily report on shower activities developed and operational. Daily reports are being provided to MEO since 8/26/19.
- Deceleration correction being applied as of 10/04/2019.
- Daily orbital datasets files can be provided upon request.
- Automated daily summary results (test file, graphical output) distributed internally to assessment team using format developed to meet MEO engineering needs.
- Preliminary fluxes are being provided since 8/20/2020. Validation of flux is work on progress.
  - On-site calibration required, delayed due to covid





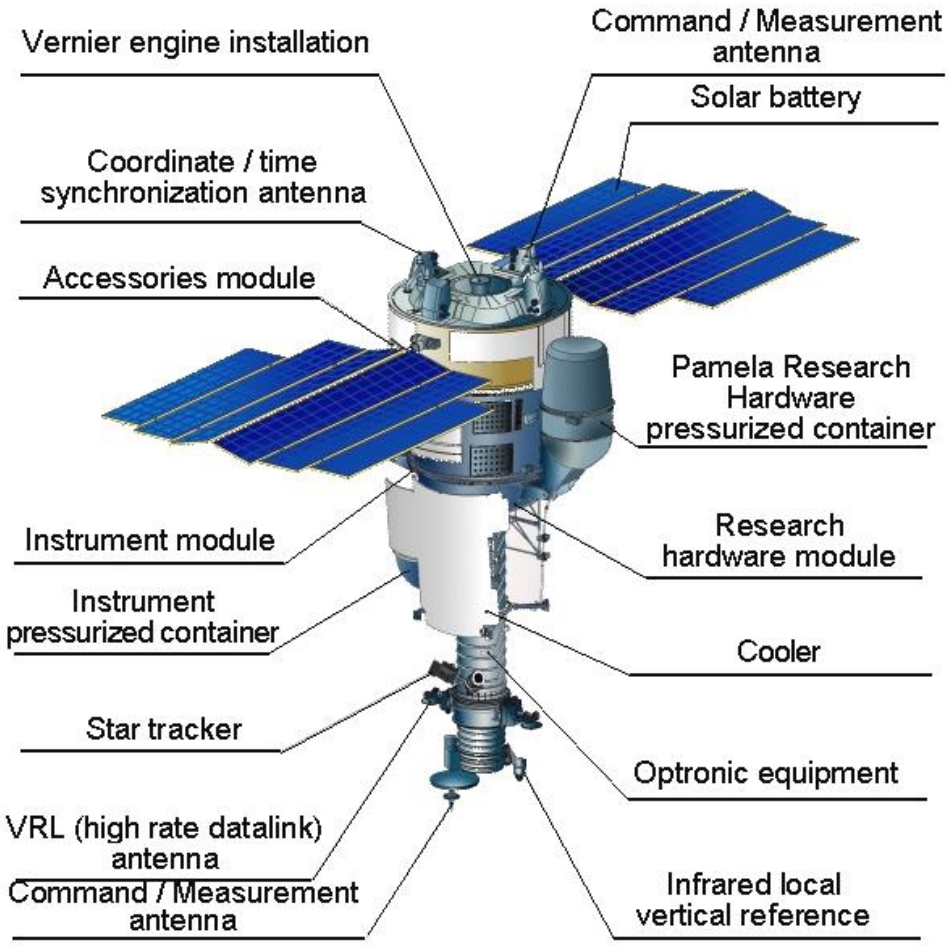
PAMELA Instrument

- Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) instrument was an international (Italy, Russia, Sweden, Germany) cosmic ray payload on the Resurs- DK1 satellite (Russia)

- Resurs DK1 satellite
  - Commercial Earth observation satellite, built in Russia by TsSKB-Progress for Roskosmos
  - Operational from 2006 to 2016
  - Initial orbit: 360 km x 604 km x 70° inclination
  - Orbit ~circularized to 567 km by 573 km x 70° in September 2010

Particle	Energy Range
Antiproton	80 MeV – 190 GeV
Positron	50 MeV – 270 GeV
Electron	up to 400 GeV
Proton	up to 700 GeV*
Electron/positron	up to 2 TeV
Light nuclei (≤Z = 6)	up to 200 GeV/n
Light isotopes (D, 3He)	up to 1 GeV/n

Resurs-DK1



*Proton energy range is 80 MeV – 4 GeV for this work

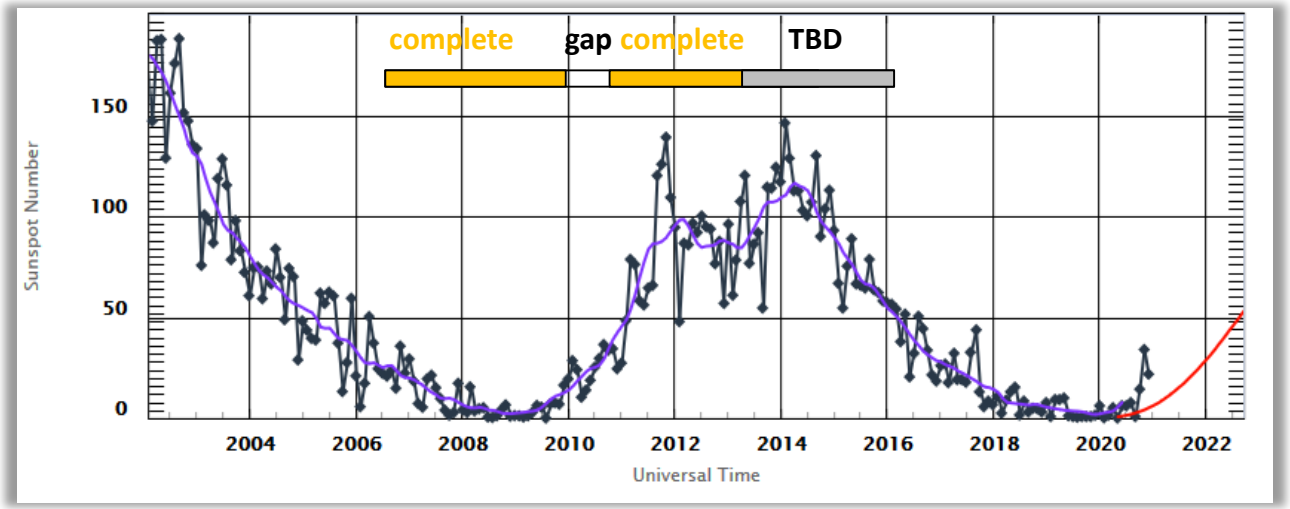
PAMELA Data for IRENE/AP9 LEO Proton Improvements

- NESC support activity
  - ~1 year project 04/2020 – 06/2021
  - NESC Lead: Joe Minow/NESC

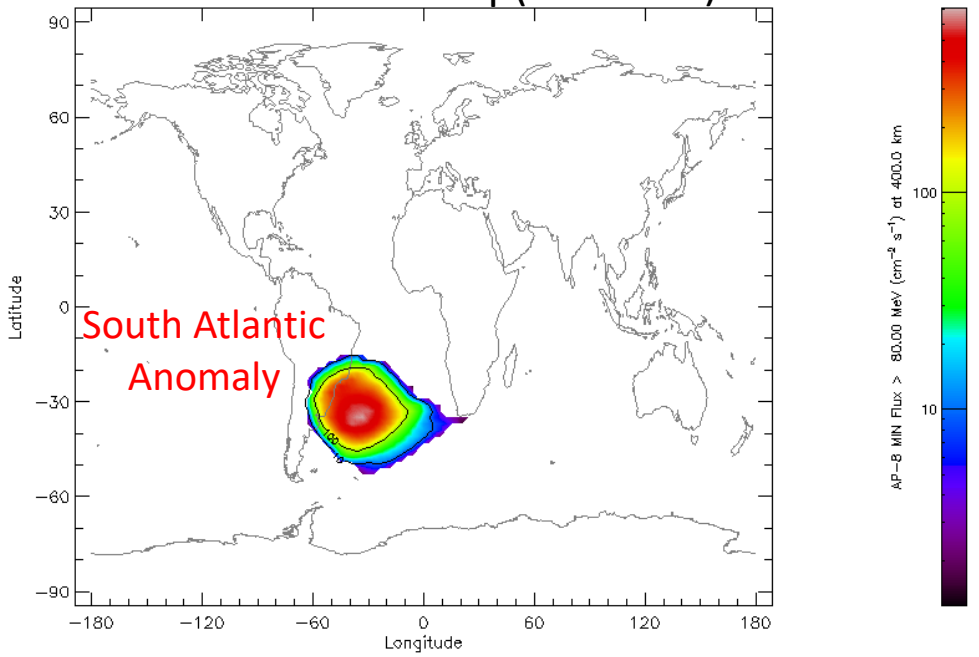
- Process PAMELA data into format for use in improving the low altitude proton component of the International Radiation Environment Near Earth (IRENE) model (AP9) at altitudes relevant to the International Space Station

- NASA, ESA, and US Air Force collaboration is implementing the PAMELA data processing and IRENE development work:
  - Goddard Space Flight Center (GSFC) personnel to process PAMELA data, Dr. Alessandro Bruno/GSFC/Catholic University of America (CUA) funded by this NESC support activity
  - National Institute of Nuclear Physics (INFN) personnel in Italy to process PAMELA data (funded by ESA)
  - Aerospace Corporation is the IRENE developer and will implement the updates with PAMELA data (funded by the Air Force)

- PAMELA data will contribute to IRENE/AP9 LEO proton environment improvements at energies of importance to total ionizing dose (crew, avionics) and single event effects (avionics)



SPENVIS AE8 MIN Jp(>80 MeV)

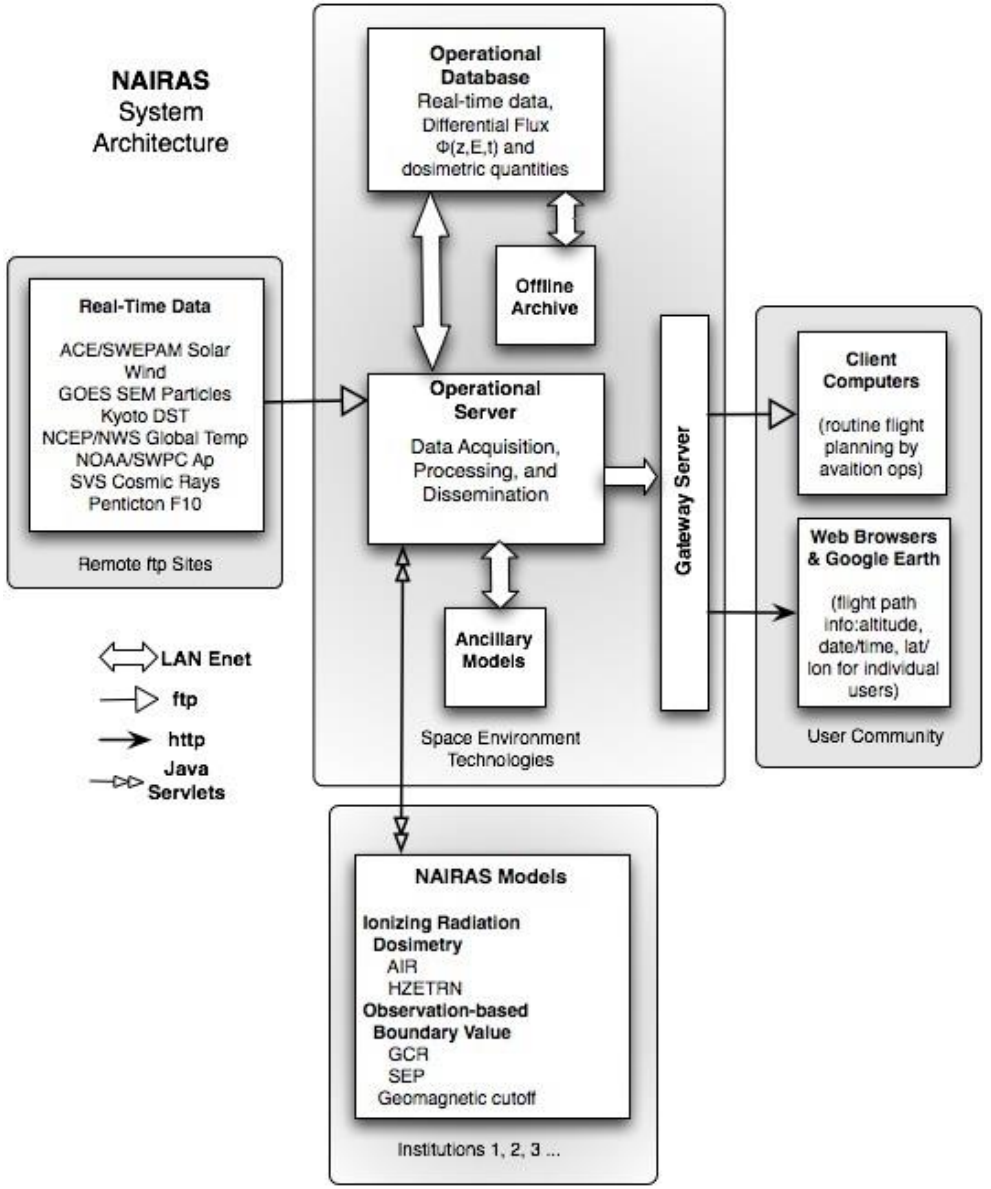


CCP Post-flight Reference Radiation Environments

- NESC assessment activity
  - ~15 month project 10/2020 – 11/2021
  - NESC Tech Lead: Insoo Jun/JPL

- Modify NASA's Nowcast of Atmospheric Ionizing Radiation System (NAIRAS) radiation environment model (originally developed for computing radiation dose for aviation flight crews) to provide best estimates of LEO radiation environments relevant to single event effects for use by NASA's Commercial Crew Program (CCP) and other programs

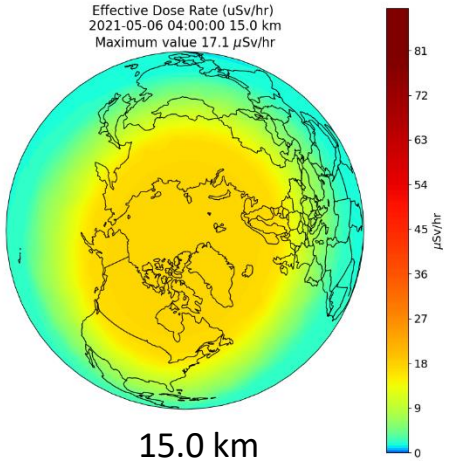
- The NAIRAS model uses real-time radiation data from satellites and other space and terrestrial environment data to constrain the GCR, SPE, and trapped proton environments at locations within the temporally and spatially dependent radiation shielding provided by the Earth's atmosphere and geomagnetic field
  - Original NAIRAS output is dose rate along flight trajectory for aeronautical crews
  - Updated model output to include proton and heavy ion flux as a function of energy and linear energy transfer (LET) along flight trajectories



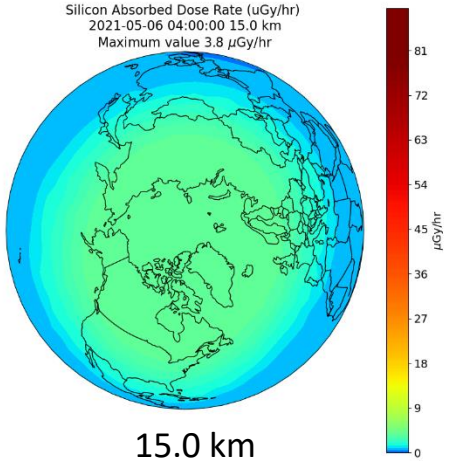
Source: https://sol.spacenvironment.net/nairas/

CCP Post-flight Reference Radiation Environments

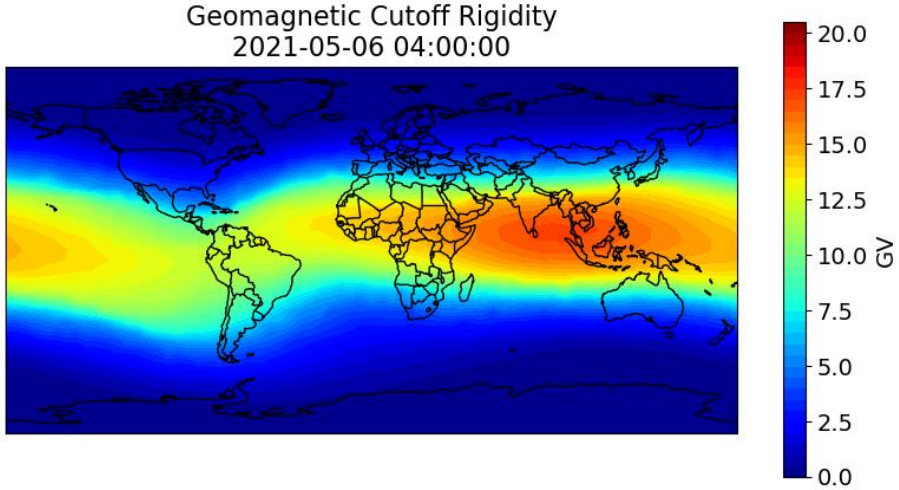
- The team is implementing NAIRAS in a stable, operational environment at GSFC's Community Coordinated Modeling Center (CCMC)
- Modification of the software to give tailored output in formats relevant to analysis of proton and heavy ion single event effects is in progress
- CCMC will provide two versions of NAIRAS:
  - Real-time space weather model running continuously, providing global output for a variety of dosimetric quantities
  - Runs-on-request version proving model output along user provided flight trajectories
- While the CCMC NAIRAS implementations are being developed for NASA's Commercial Crew Program, the software is running on a public server where the tools will be available to anyone with an interest in the model output
- Supports radiation assessments and anomaly investigations for systems operating in the Earth's atmosphere and low Earth orbit



15.0 km
Effective Dose Rate (μSv/hr)
2021-05-06 04:00:00 UTC



15.0 km
Si Absorbed Dose Rate (μGy/hr)
2021-05-06 04:00:00 UTC

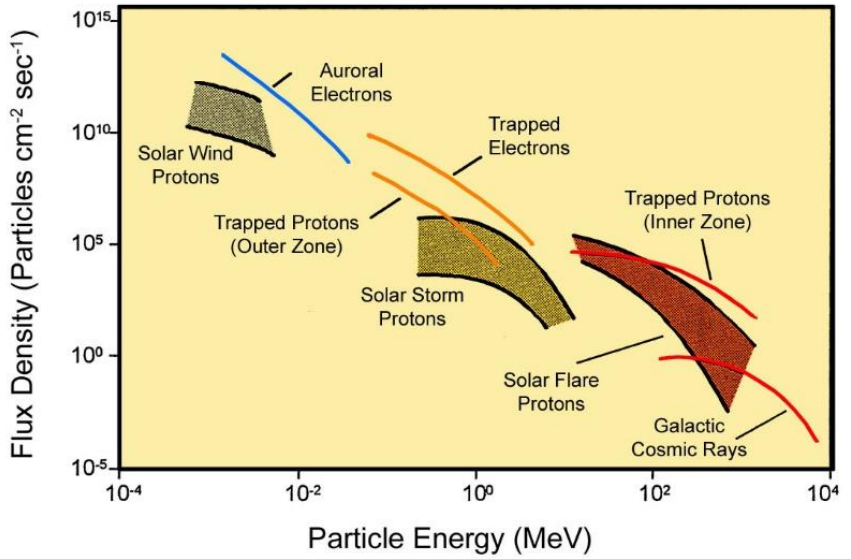


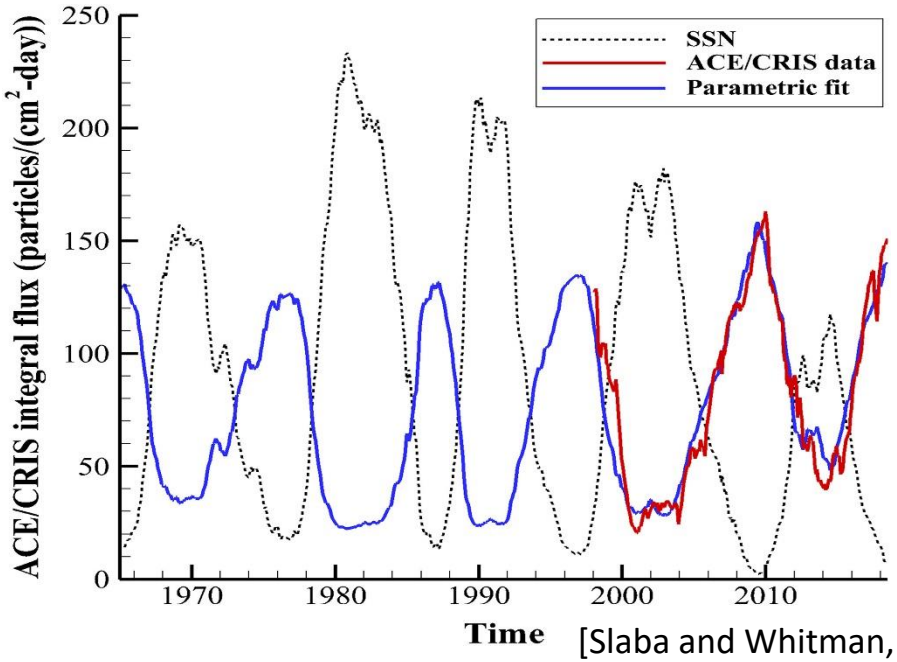
Badhwar-O'Neil (BON) Galactic Cosmic Ray (GCR) Model Improvements

- NESC support activity
  - ~15 month project 05/2021 – 08/2022
  - NESC Tech Lead: Insoo Jun/JPL

- Improve the BON2020 GCR model including
  - Use BON2020 as a starting point for development work
  - Calibrate extension to environments >1 AU
  - Improve local interstellar spectrum (LIS) for multiple ions using AMS and Voyager (and other) data
  - Updates to modulation potential algorithms
  - Estimates of model uncertainty

- Improved BON2020 GCR model functionality will provide
  - Better GCR dose estimates for designing human missions to Moon and Mars
  - Improvements in GCR environments of importance to single event effects in electronics





[Slaba and Whitman, 2020]

Spacecraft Charging Materials Database (SCMD)

Electrical Properties | New Record | NOTIFICATION 1 | home | help

The Spacecraft Charging Materials Database (SMDC) is a NASA sponsored repository for information on the electrical properties of materials relevant to surface charging and internal charging processes for materials exposed to charged particles and photons in the space environment. Contents of the archive are material properties obtained from laboratory testing (or space based experiments when appropriate) to support spacecraft charging modelling and analyses.

Materials exposed to the space environment will accumulate charge due to the differential collection of ion and electron currents from the space radiation and plasma environment. The magnitude of the electric fields, electric potentials, and electric potential gradients generated by an excess charge density on (or in) a material is an important consideration for space system design and operations. Accumulation of a significant localized charge density can lead to electric fields exceeding the electrostatic breakdown strengths of materials, resulting in electrostatic discharges which are responsible for a number of detrimental effects including material degradation, electromagnetic interference, and even catastrophic failure of sensitive electronic components in extreme cases.

This database contains parameters of importance to charging including volume and surface conductivity, dielectric constant, secondary electron and backscatter yields due to incident electrons and protons, photoelectric current density, material density, and radiation induced conductivity parameters. We hope the SCMD will provide a resource for the exchange of information on electrical properties of materials available to both contributors providing fundamental measurements of electrical properties of materials and the analysis community conducting quantitative modelling studies of spacecraft charging.

SCMD Template **NASA-HDBK-4002**

NASA-HDBK-4002A

Spacecraft Charging Materials Database (SCMD)

Electrical Properties

New Record

NOTIFICATION 1

home help

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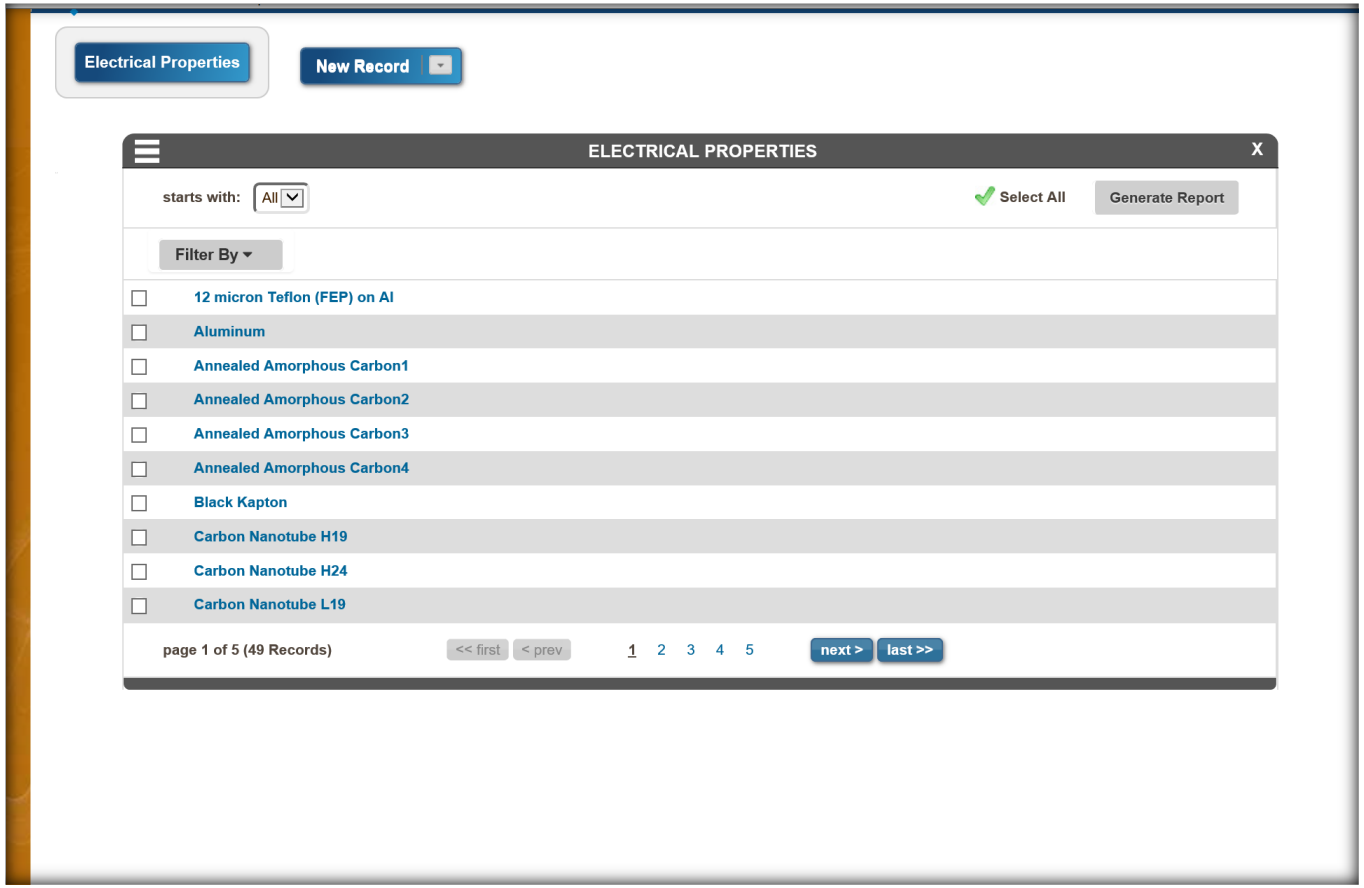
SCMD Template **NASA-HDBK-4002**

NASA-HDBK-4002A

SCMD – Electrical Properties of Materials

- Database currently holds information on 49 materials
  - NASCAP default materials
  - Utah State University test results



SCMD – Electrical Properties of Materials

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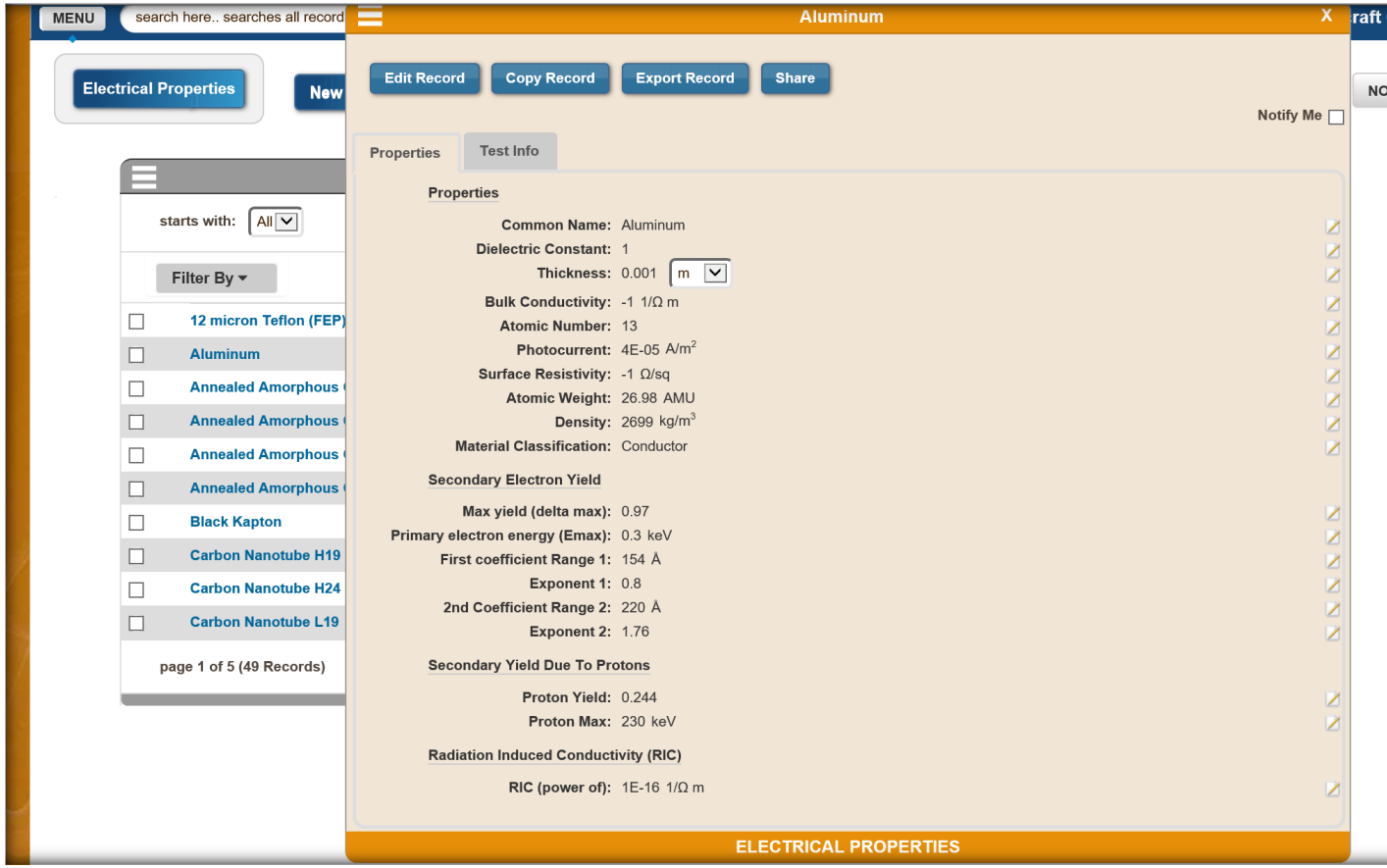
  - NASCAP default materials
  - Utah State University test results

- Electrical properties of materials



SCMD – Test Information

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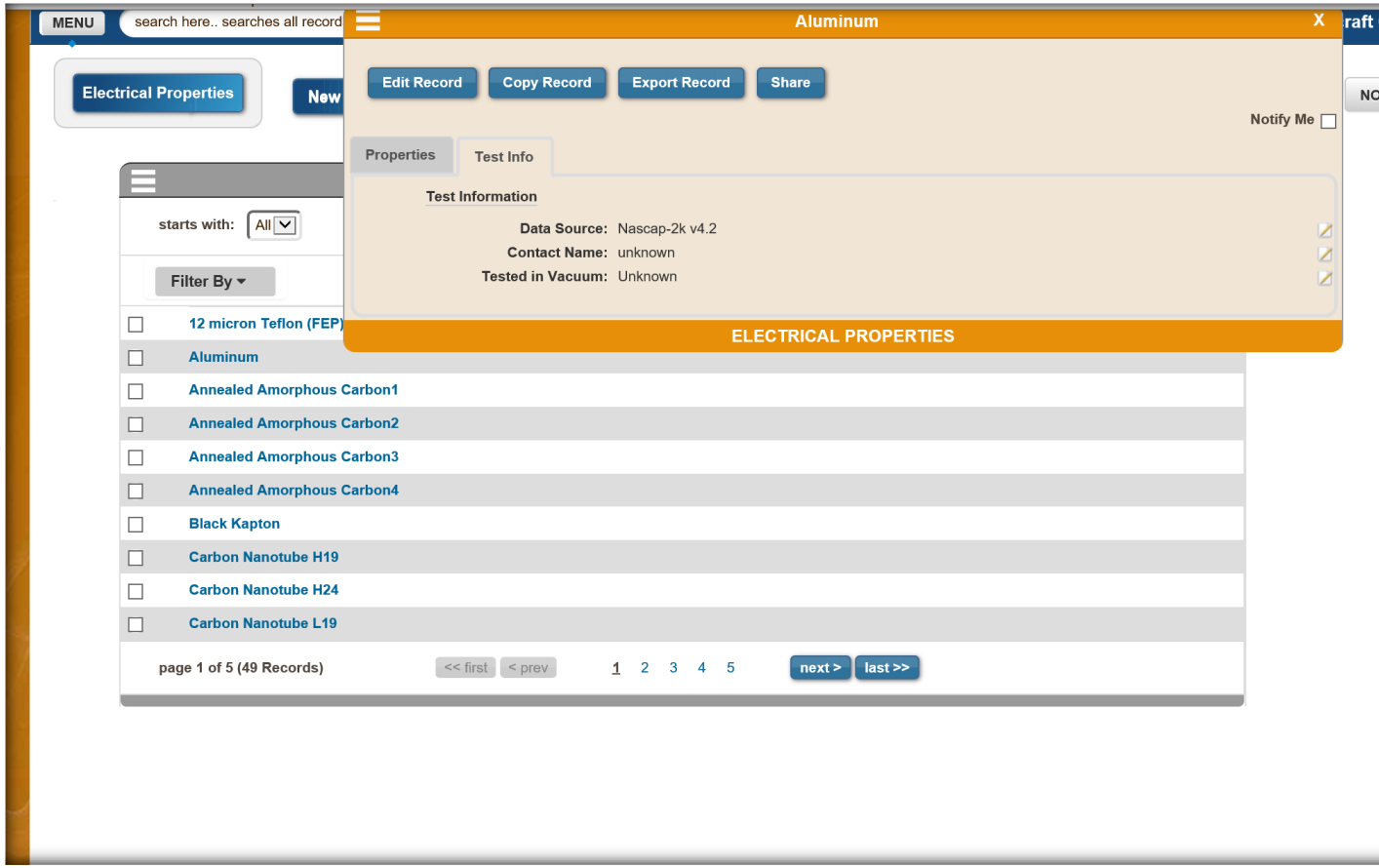
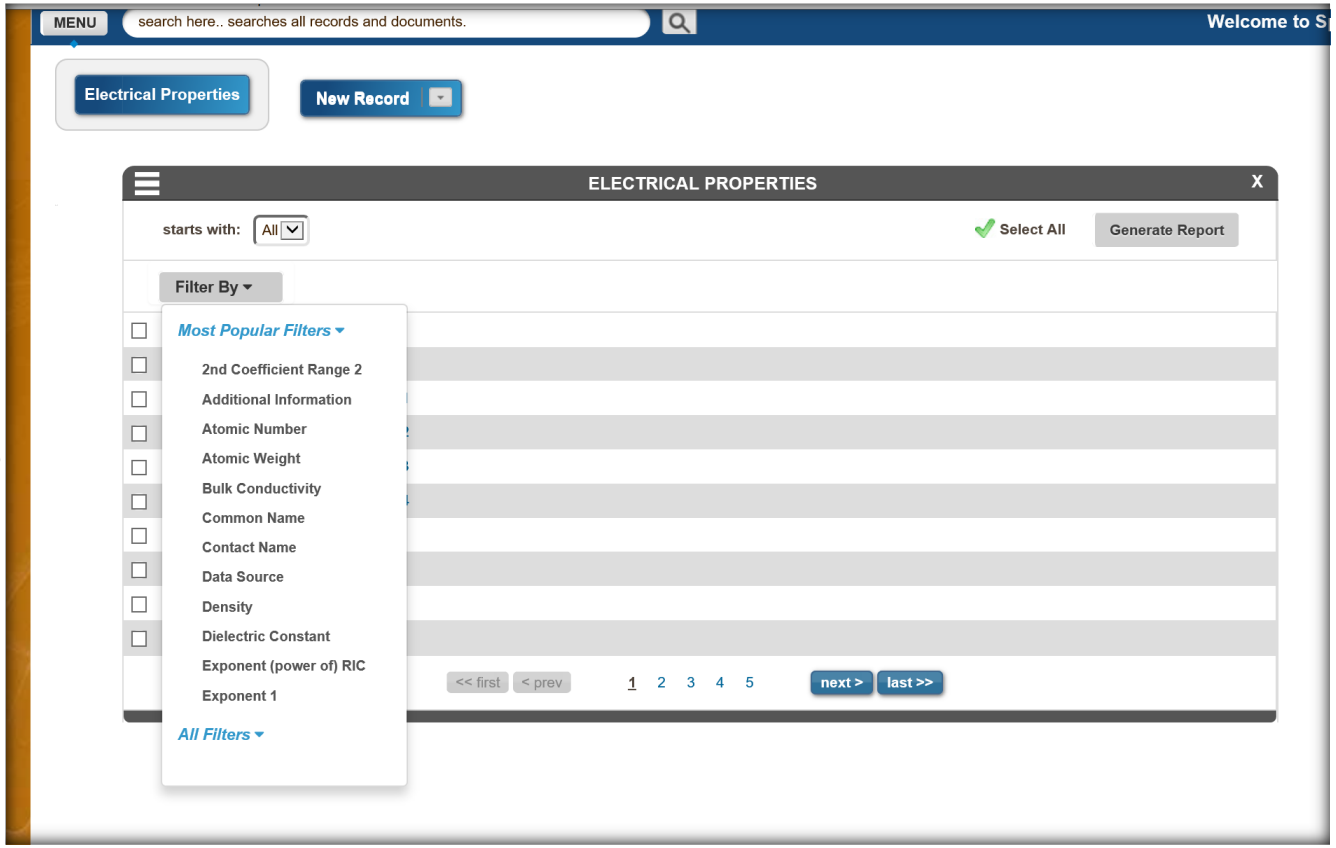
  - Utah State University test results
- Electrical properties of materials
- Information on test conditions and links to test reports



Information on test conditions and link to test reports (when available)

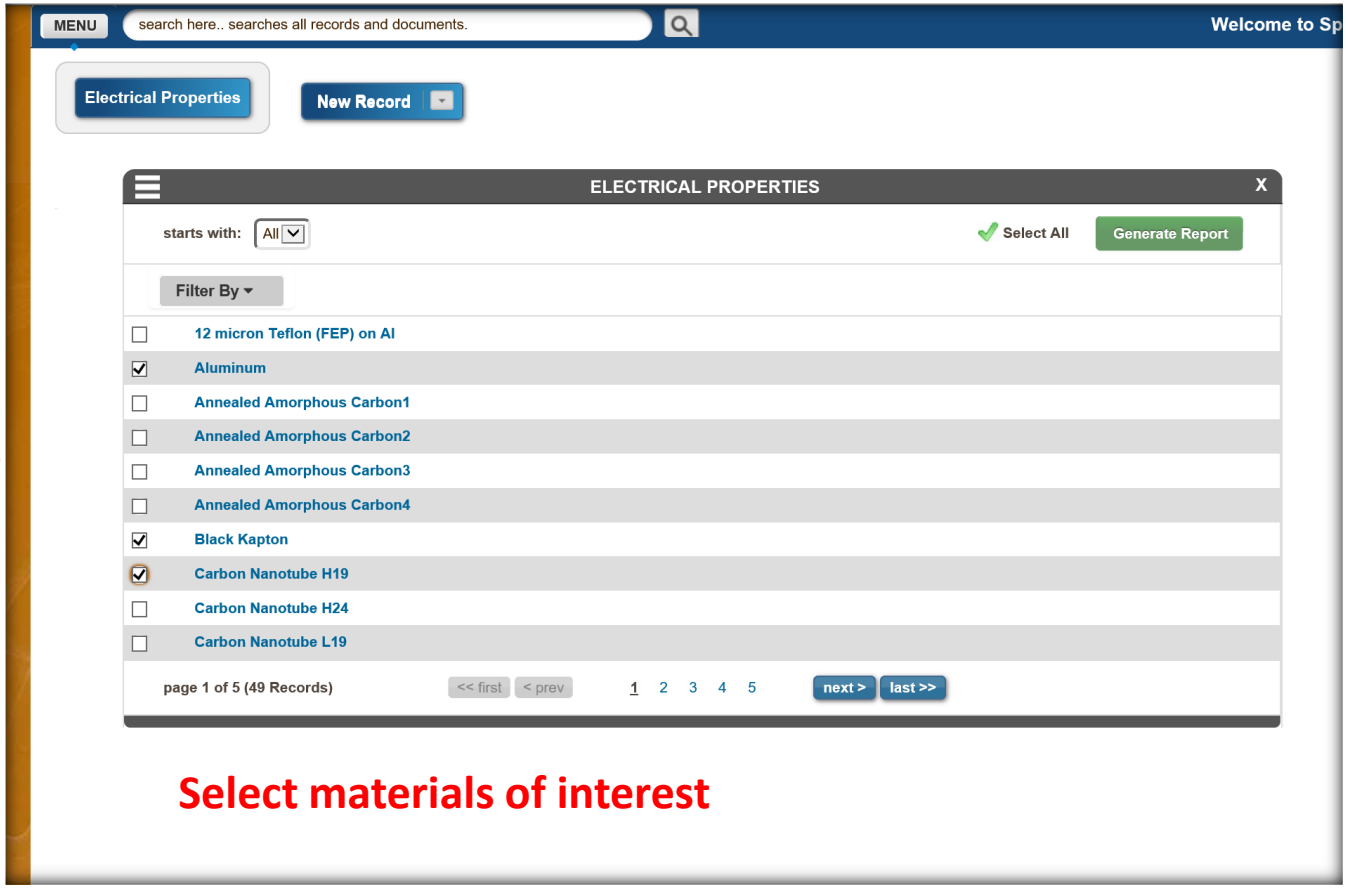
SCMD – Search Option

- Database currently holds information on 49 materials
  - NASCAP default materials
  - Utah State University test results
- Electrical properties of materials
- Information on test conditions and links to test reports
- Search options
  - Exact search match
  - Checking to see if can be “part” of word



SCMD – Other Features

- Database currently holds information on 49 materials
  - NASCAP default materials
  - Utah State University test results
- Electrical properties of materials
- Information on test conditions and links to test reports
- Search options
  - Exact search match
  - Checking to see if can be “part” of word
- Other features include
  - Export records of selected materials to a variety of external file formats
  - Generate reports on user selected material properties
  - Generate plots



SCMD Access

- Database is available on-line at the address https://maptis.ndc.nasa.gov/scmd

- SCMD is open to public use with free registration
  - Contact POCs for access request form (access is open, but we track the number of users)
  - No export controlled or proprietary information allowed in the database
  - Database contains fundamental properties of materials

- Adding new materials
  - Material property contributions from the community are welcome and requested!
  - Template required to add materials, request form POCs

- Point of contact (POC):

Linda Parker, SCMD administrator lparker@usra.edu

Joseph Minow joseph.minow@nasa.gov

- Goal of the SCMD project is to:
  - Facilitate sharing of material data required to conduct quantitative spacecraft charging modeling and analyses
  - Improve charging modeling used for space system design and anomaly investigations


Questions?