Expansion of Radiation Hardness Assurance Tool Suite

NASA NEPP Electronics Technology Workshop, June 2022

Brian Sierawski

Vanderbilt University

This work supported by NASA NEPP Grant #80NSSC20K0424 and the U.S. Department of Defense under prime contract no. W52P1J2093009.

Expansion of RHA Tool Suite FY22

Vanderbilt Engineering

Objective

This effort proposes to evaluate assessments of single event functional interrupts and expand online capabilities through integrating environment and effects models developed post-CREME96 for radiation hardness assurance.

PI: Brian Sierawski

Vanderbilt University

Approach

- Investigate application of SEE rate prediction methods for functional interrupts in complex devices
- Expand upon existing on-orbit prediction tools through implementation of probabilistic radiation environments and effects, inclusion of displacement damage, …
- Provide on-line guidance to designers for electronics part selection and SEE rate prediction
- Improve user access to tools and pursue interoperability with model-based, system level modeling approaches.

Milestones

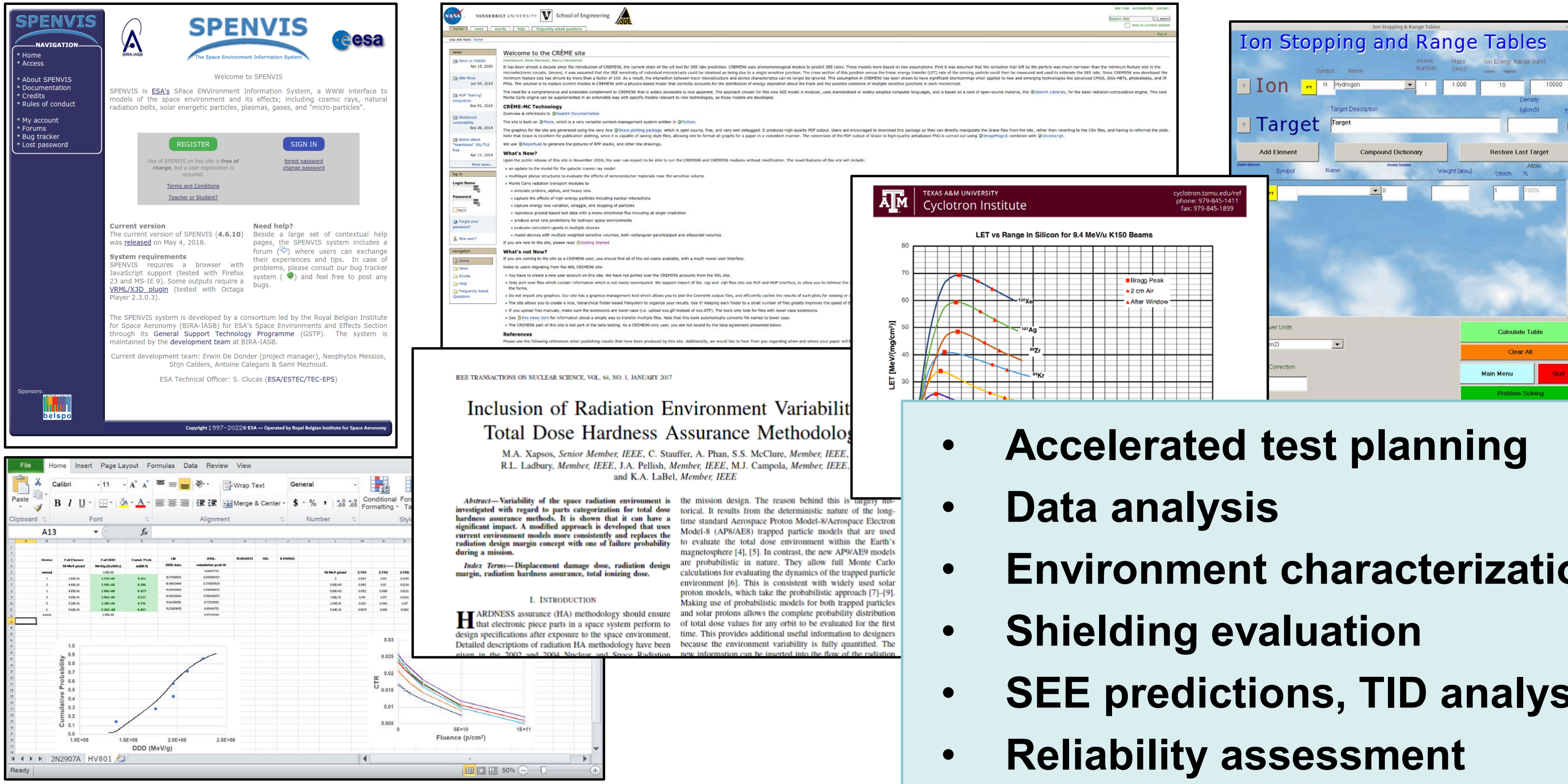
- Defined online platform for releasing additional RHA tools
- Implemented effective flux model for complex device SEE rate predictions
- Implemented ESP/PSYCHIC models for solar environment
- Proposed a probabilistic method for TID dose failure for multiple components, ETW 2021

Tech Transfer

- "Evaluating SEE Rate Prediction Methods for Complex Devices," ETW 2021
- "Extending A Probabilistic Method for Total Ionizing Dose Failure to Multi-Component Systems," ETW, 2021.
- "Evaluating SEE Rate Prediction Methods for Complex Devices," SEE/MAPLD 2021.

The Radiation Effects Engineer's Toolbox

Vanderbilt Engineering



- Accelerated test planning
- Data analysis
- Environment characterization
- Shielding evaluation
- SEE predictions, TID analysis
- Reliability assessment

RADHUB Concept

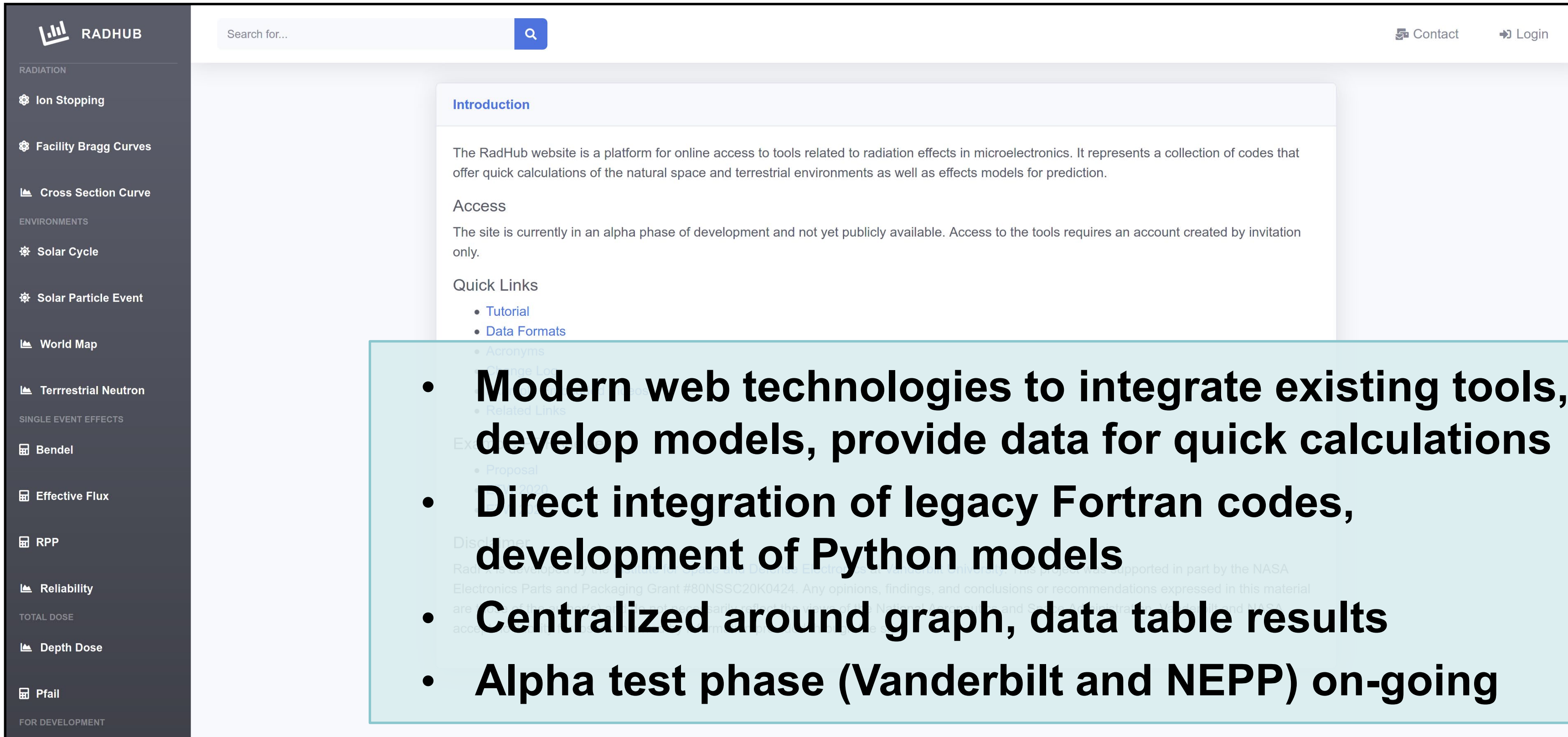
Vanderbilt Engineering

- **Goal – companion platform to complement CRÈME and serve as host for rapid dissemination of analytical models in a common, accessible, and referenced location**
  - Open-access, maintain path for licensing / distribution, closed programs
  - Split from CRÈME, enable bleeding edge tools
  - Home for published analyses to disseminate to community
  - Improved links between test planning, data collection, and effects prediction
- **CRÈME Status**
  - Supports over 3000 users, still adding 37 users / month
  - Considered stable, legacy codes
  - Cursory treatment of proton dose, ignores electron contribution
  - CREME96 was never designed to include electron environments
  - Heavy ion analysis limited to RPP-based models for SEU
  - Storage bloat – 50GB+ user data
  - Performance, extendibility, maintainability issues hinder expansion

RADHUB Platform

Vanderbilt Engineering

http://

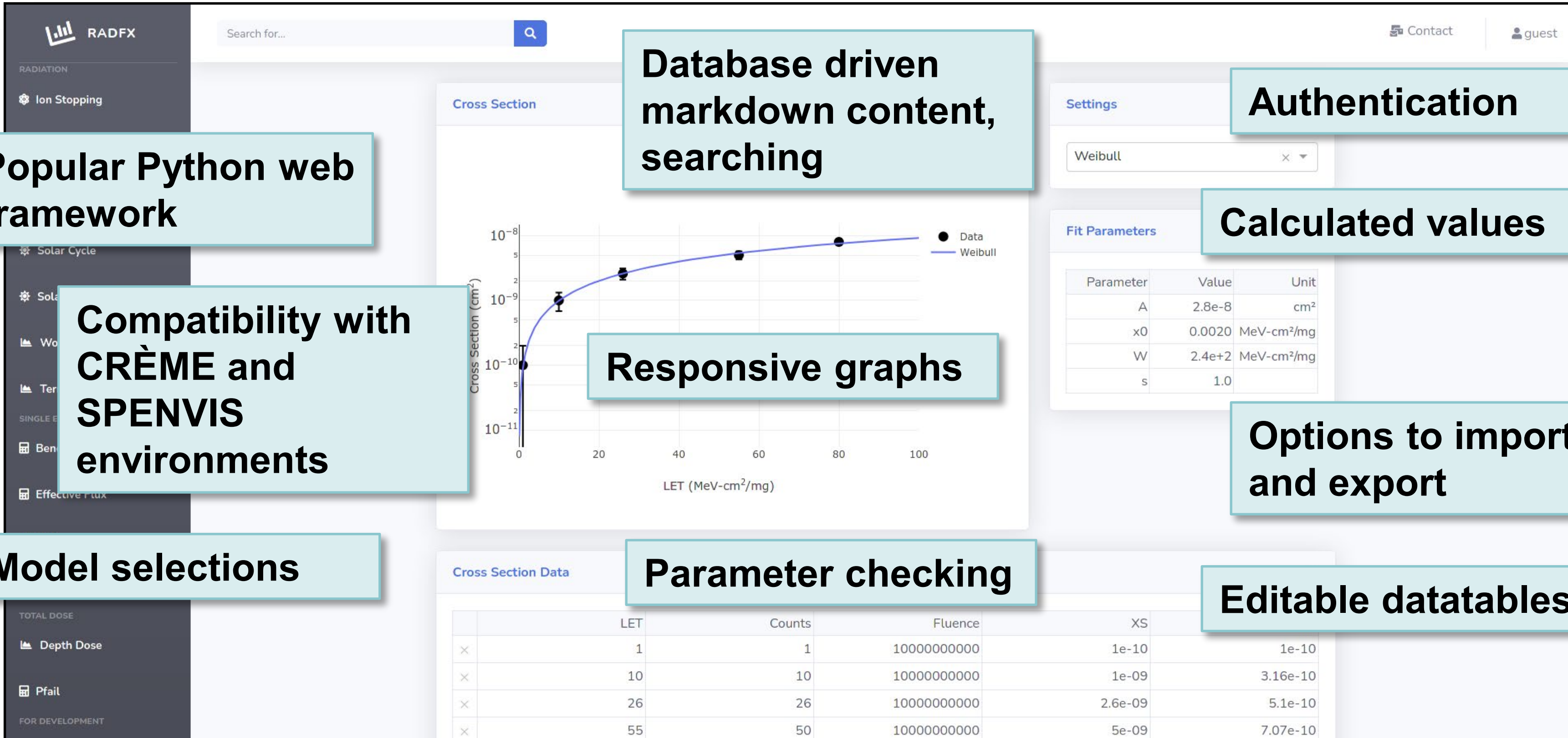


- Modern web technologies to integrate existing tools, develop models, provide data for quick calculations
- Direct integration of legacy Fortran codes, development of Python models
- Centralized around graph, data table results
- Alpha test phase (Vanderbilt and NEPP) on-going

RADHUB Developments

Vanderbilt Engineering

http://

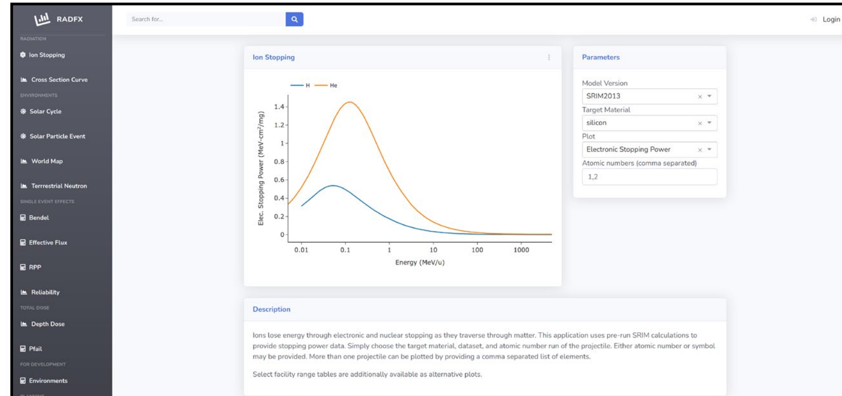


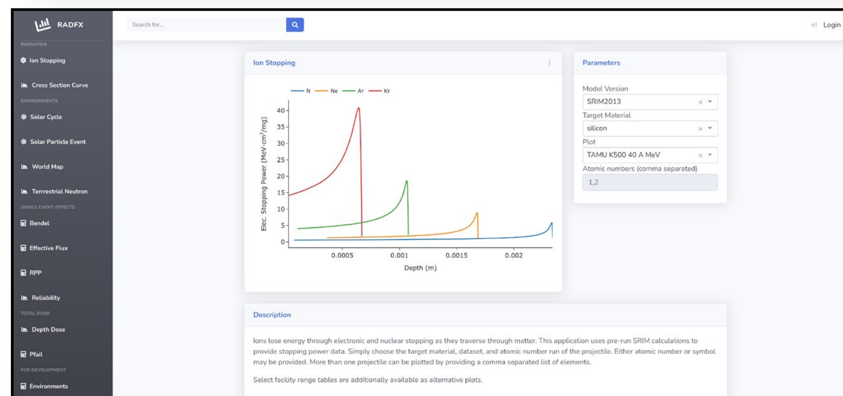
- Database driven markdown content, searching
- Authentication
- Popular Python web framework
- Calculated values
- Compatibility with CRÈME and SPENVIS environments
- Responsive graphs
- Options to import and export
- Model selections
- Parameter checking
- Editable datatables

RADHUB for Accelerated Test Planning

Vanderbilt Engineering

- **Proton and ion stopping**
  - Used to investigate LET, range
  - Stopping power and range for ions in silicon and aluminum targets
  - Based on SRIM data (currently)
- **Facility Bragg curves**
  - Used to select ions with sufficient range, appropriate LET
  - Elec. stopping power vs depth (Si)
  - LBNL 88", TAMU K150 & K500
- **Responsive graphs adjust to user selections and parameters, easily export json, csv, xlsx, pdf**

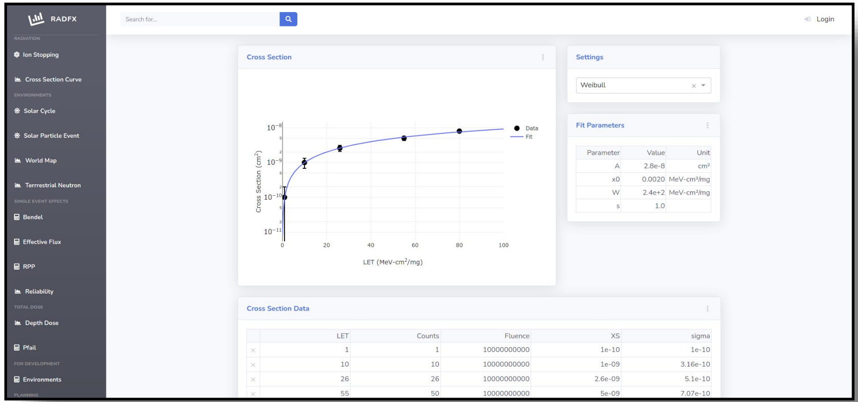


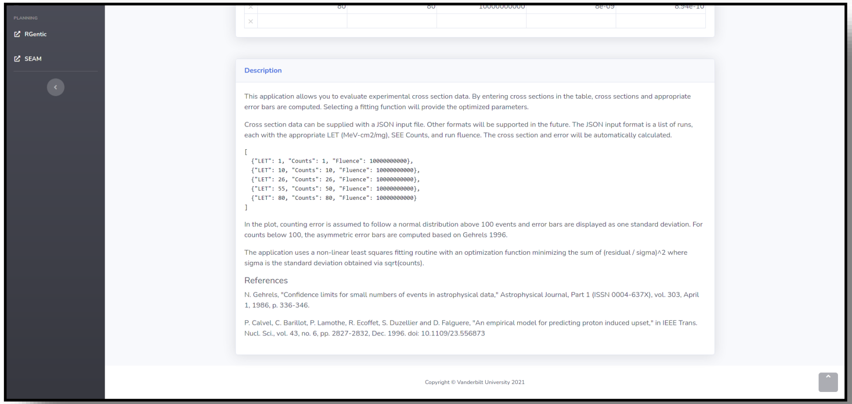


RADHUB for SEE Analysis

Vanderbilt Engineering

- **Cross section data fitting**
  - Provides consistent parameter fits
  - Performs MLE fits to Weibull, Bendel cross sections, suggests parameters
  - Accounts for statistical error in data
  - Calculates Petersen figure of merit
- **Editable data table allows entry of event data, calculates error bars**
  - 1σ, 90% CI, asymmetric low counts
- **Data and graphs export for reports and journals (eg. *IEEE TNS*)**

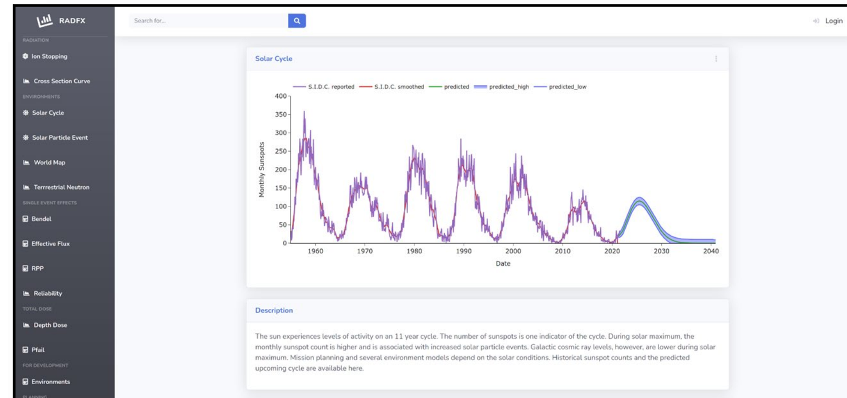




RADHUB for Solar Environments

Vanderbilt Engineering

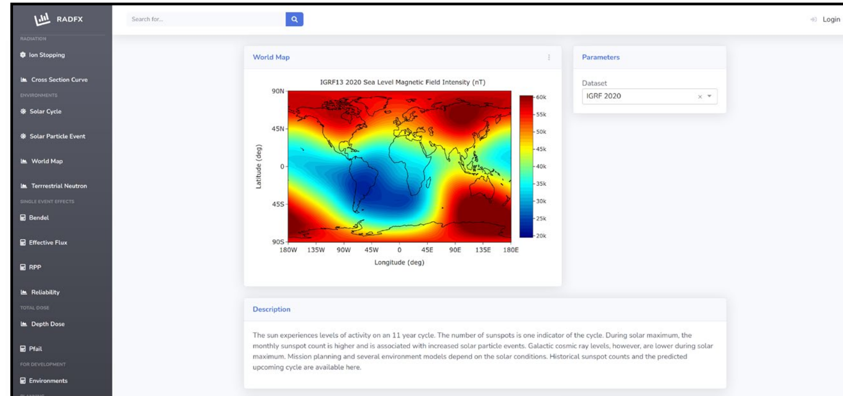
- **Solar cycles and sunspots**
  - Used for mission planning, parameterizing particle environment models
  - Historical and predicted sunspot counts from SIDC
  - Reporting changed in 2015, providing adjusted Wolf numbers based on input from Royal Observatory
- **Solar protons and heavy ions**
  - Used for worst case CI calculations
  - Implemented ESP/PSYCHIC, integrated SOLPRO

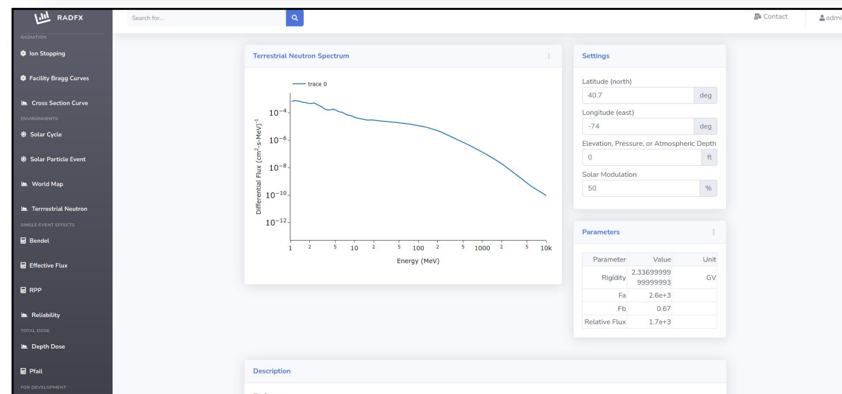


RADHUB for Terrestrial Environments

Vanderbilt Engineering

- **IGRF13 world magnetic intensity maps – 1995-2030**
  - Used to explore impact of mission profile on near-Earth environment
- **Terrestrial neutron spectrum**
  - Used to scale neutron flux with lat. long. and altitude
  - Based on JESD89B and seutest.com

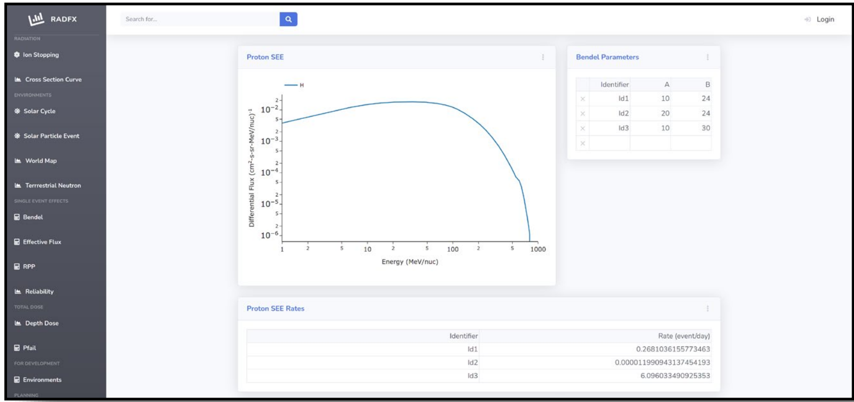




RADHUB for On-Orbit SEE Predictions

Vanderbilt Engineering

- **Bendel model**
  - Used for proton SEE rates
  - Imports proton spectra in CRÈME, SPENVIS formats
  - Accepts parameters for multiple parts
  - Rate predictions export to json, csv, xlsx
- **RPP and effective flux models**
  - Used for heavy ion SEE rates
  - Imports LET spectrum in CRÈME, SPENVIS formats
- **Reliability calculations for single bit, multiple bit errors**



RADHUB for On-Orbit TID Predictions

Vanderbilt Engineering

- **Depth dose**
  - Used as first pass evaluation of shielding effectiveness
  - Evaluates proton, electron, brem dose rates
  - Implemented with SHIELDOSE-2
- **TID failure probability**
  - Used to evaluate part-to-part and environment variability
  - Implemented Xapsos TNS 2017
  - Built in environment definitions
  - Research into probabilistic analyses on-going

RADHUB Modules Currently Developed

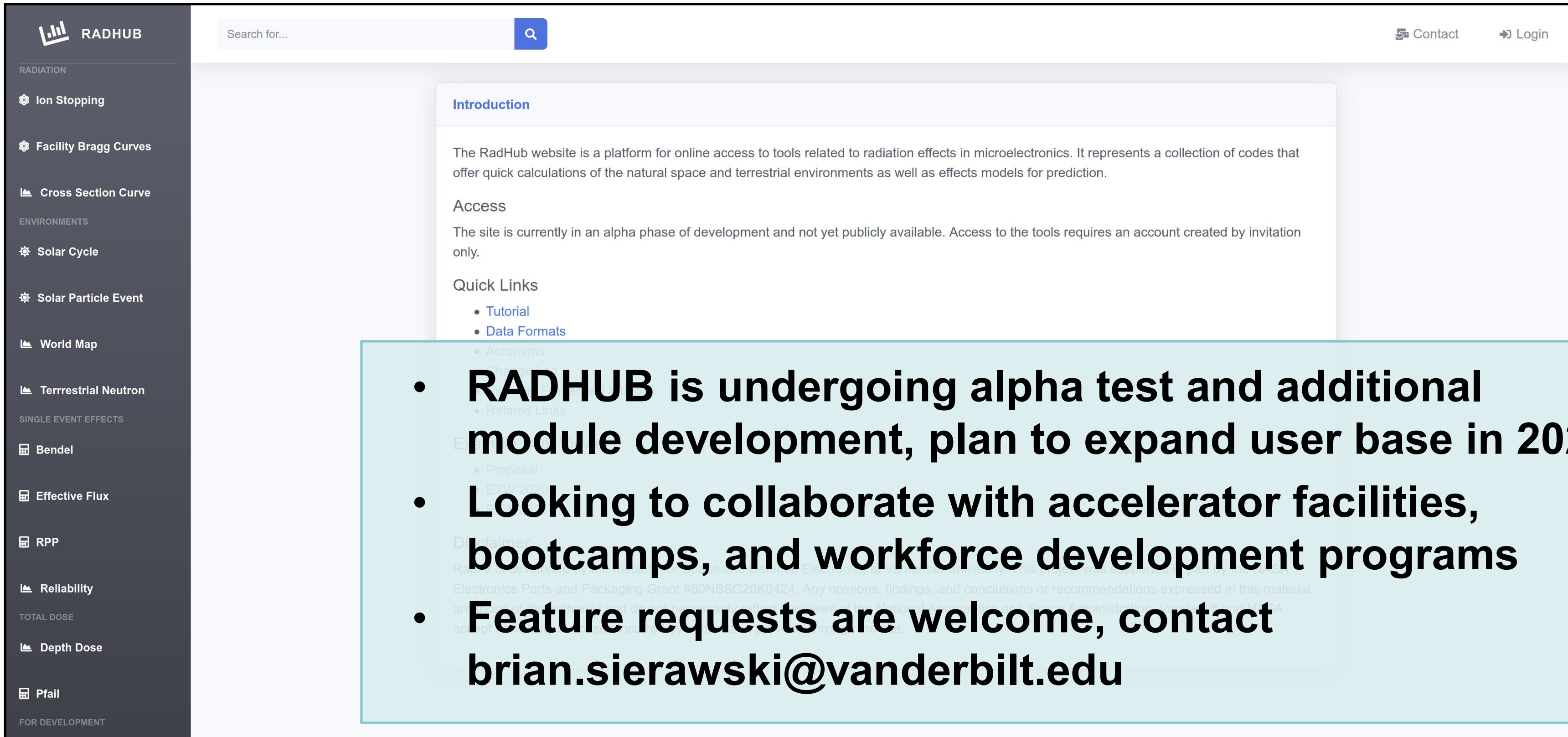
Vanderbilt Engineering

- Ion stopping based on SRIM – stopping power and range for ions in silicon and aluminum
- Range plots – LBNL 88”, TAMU K150 & K500
- Weibull fitting to heavy ion cross sections
- Solar cycle data – historical and predicted from on S.I.D.C
- ESP, PSYCHIC, SOLPRO – solar protons and heavy ions
- IGRF13 world magnetic intensity maps – 1995-2030
- Terrestrial neutron spectrum – JESD89B
- CREME96 and SPENVIS environment parsers
- Bendel predictions for on-orbit proton SEE rates
- RPP predictions for on-orbit heavy-ion SEE rates
- Peterson Figure of Merit for on-orbit heavy-ion SEE rates
- Effective flux predictions for on-orbit heavy-ion SEE rates
- Reliability calculations for single bit, multiple bit errors
- Depth dose based on SHIELDOSE2
- TID failure probability for part and environment variability – Xapsos

Summary

Vanderbilt Engineering

http://



- **RADHUB is undergoing alpha test and additional module development, plan to expand user base in 2023**
- **Looking to collaborate with accelerator facilities, bootcamps, and workforce development programs**
- **Feature requests are welcome, contact brian.sierawski@vanderbilt.edu**

Acknowledgments

Vanderbilt Engineering

The SCALE (Scalable Asymmetric Lifecycle Engagement) program for workforce development through Purdue University has enabled the following undergraduate students to make direct contributions to this program

- **Nicholas Hopwood**
- **Chloe Champagne**
- **Thomas Wu**
- **Alexander Fullerton**
- **Kensington Huber**
- **Jack Evans**