Committee on Space Radiation Effects Testing Infrastructure for the Space Program

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Co-Chair

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Aeronautics and Space Engineering Board Meeting

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Goddard Space Flight Center

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

Statement of Task (1/2)

- Assess the existing infrastructure for verifying the ability of existing and emerging microelectronic, optoelectronic, and photonic components to operate properly in the space radiation environment. A full definition of Infrastructure shall include, but not necessarily be limited to the following five bulleted items–
  - Facilities and related resources necessary to characterize radiation stress induced failure modes of electronic components;
  - Simulation capabilities and related theory and modeling;
  - Facilities and related resources available for undertaking those simulations;
  - The workforce available to conduct such simulation and characterization; and
  - The training and research experience programs in place to prepare a workforce for these activities.

Statement of Task (2/2)

- Characterize the infrastructure that will be needed in FY 18 and beyond (nominally thru 2030 particularly in the case of particle accelerators) to adequately provide the required capabilities for new and emerging electronic technologies, and identify the principal gaps that exist between existing and needed infrastructure.

- Recommend steps needed to establish within the United States an effective infrastructure that eliminates, or reasonably minimizes, any identified gaps.

- Recommend steps required to provide effective stewardship of the necessary radiation test infrastructure for the foreseeable future.

Committee

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Study Director

Meetings

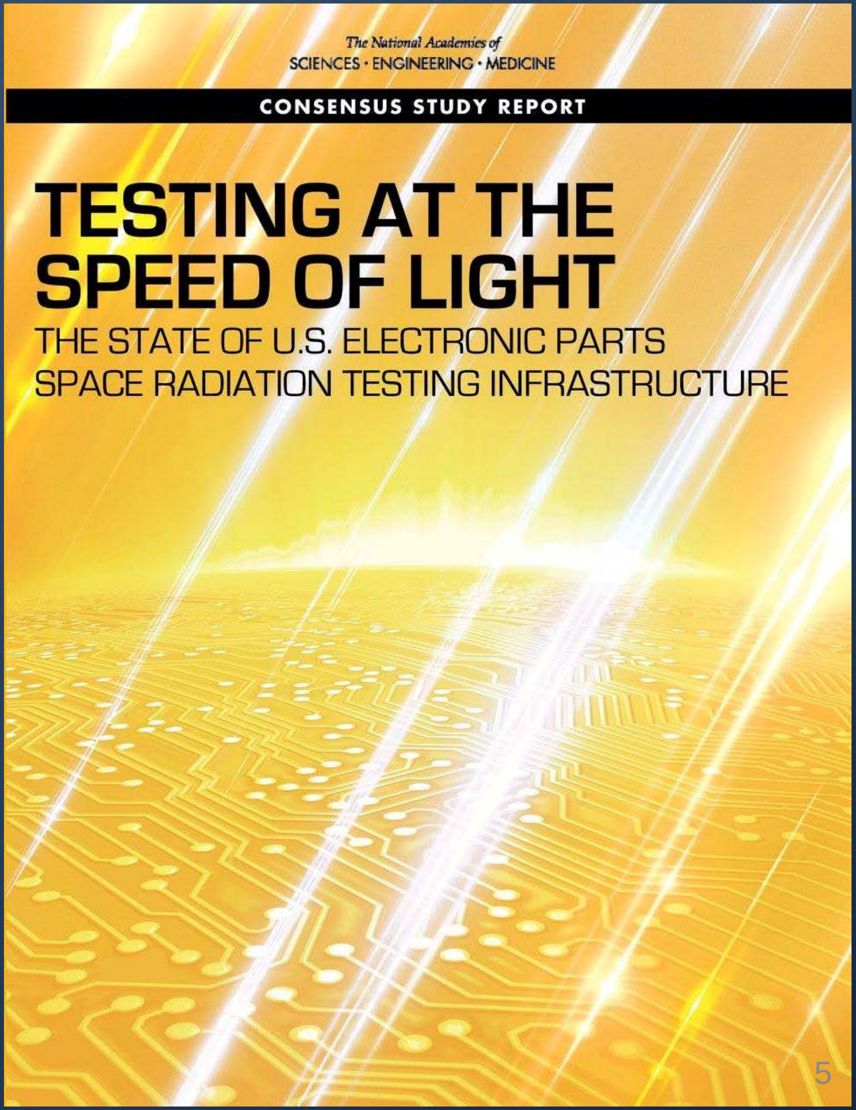
Meeting #1: March 29-31, 2017, Washington

Meeting #2: May 31-June 2, Irvine

Meeting #3: Aug 31-Sept 1, Woods Hole

Meeting #4: Oct 23-24, Washington

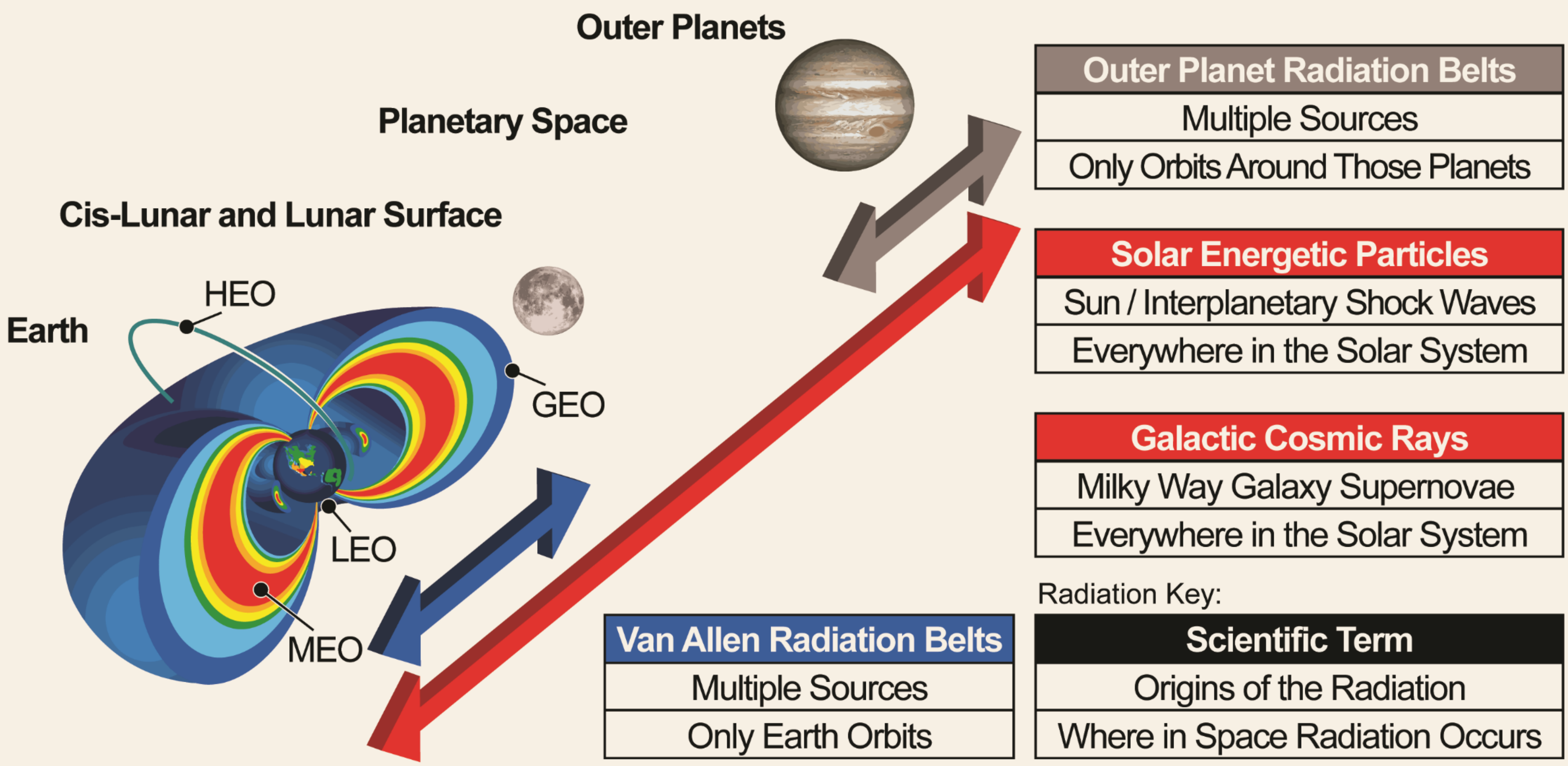
DELIVERED: January 2018



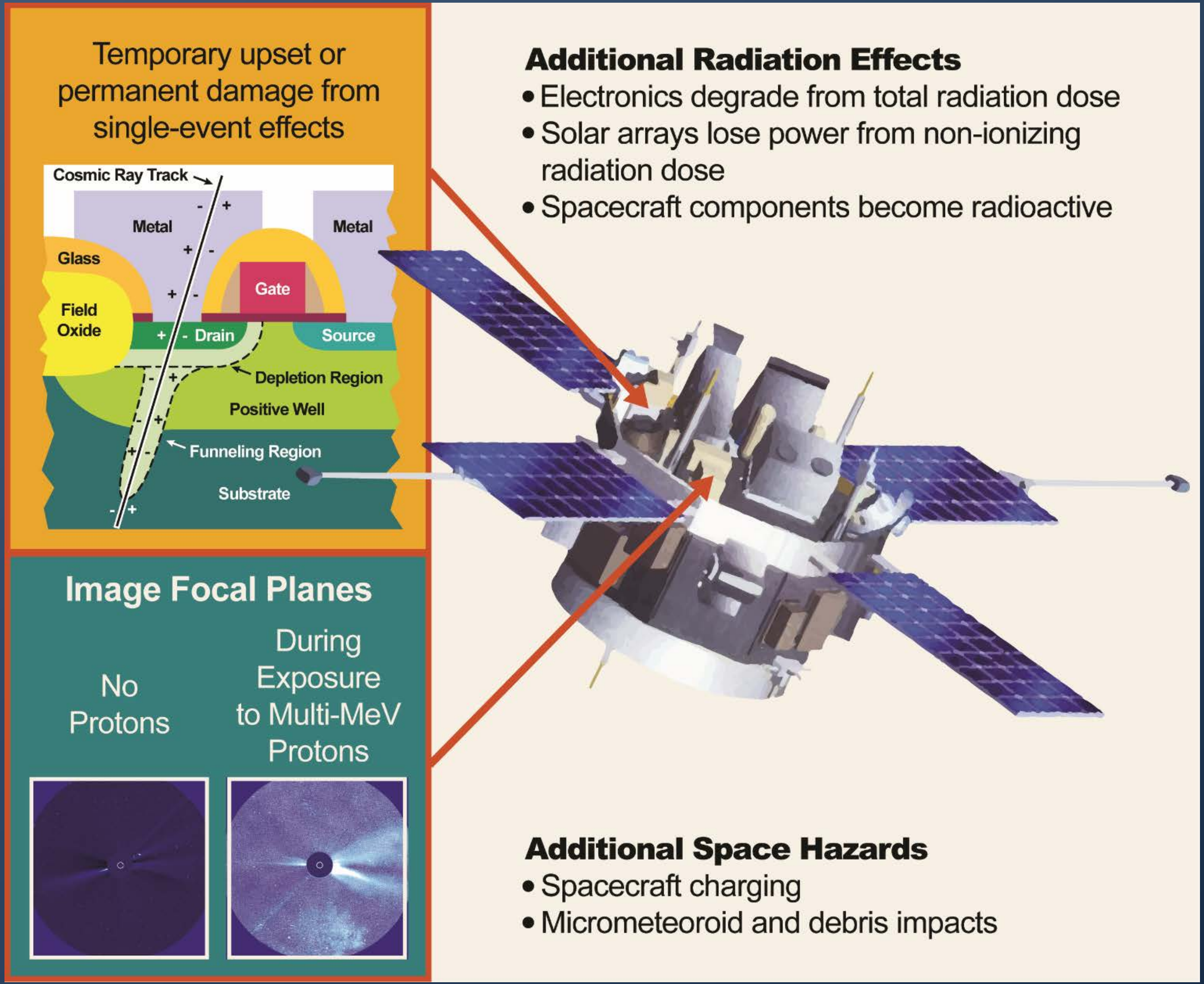
Report Structure

- Background
  - Radiation
  - Radiation effects in electronics
- Review of current infrastructure
  - Testing methodology
  - Facilities
  - Databases
  - Workforce
- Future infrastructure needs and challenges
  - Technology changes
  - Growing demand

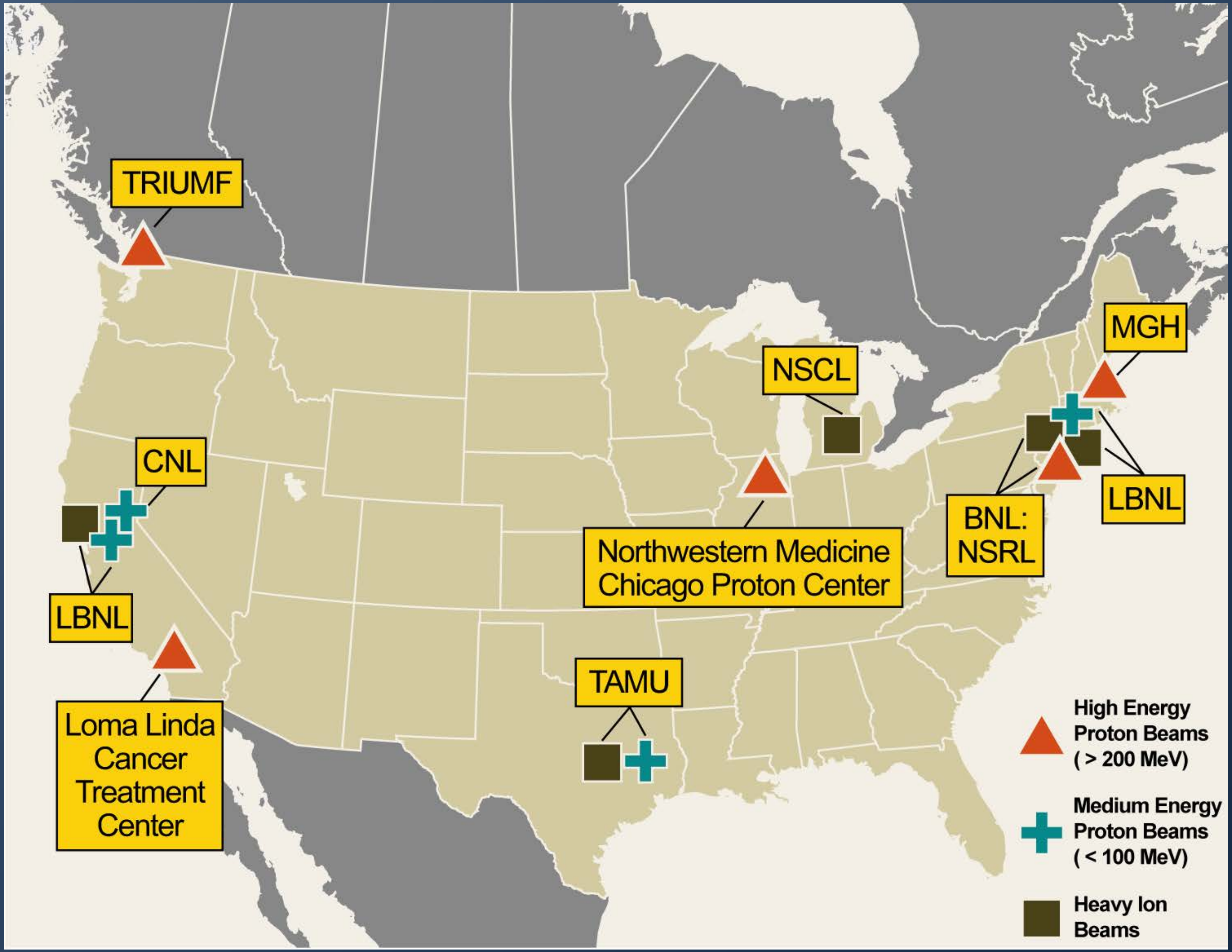
The Where of Space Radiation



The Impacts of Space Radiation



Facilities


TRIUMF
CNL
LBNL
Loma Linda Cancer Treatment Center
TAMU
NSCL
Northwestern Medicine Chicago Proton Center
MGH
BNL: NSRL
LBNL
High Energy Proton Beams (> 200 MeV)
Medium Energy Proton Beams (< 100 MeV)
Heavy Ion Beams

Key Finding 1: Growing Use and Tightening Supply

- Growing number of spacecraft; commercial users are booking a lot of test time
- Existing facilities are booked to capacity, there are long waiting times up to 6-9 months (getting quick access in event of on-orbit anomalies requiring emergency testing is difficult)
- High cost – some facilities are charging $6000+ per hour

Key Finding 2: Infrastructure Showing Signs of Strain

- Major facilities (e.g., Indiana University Cyclotron, Scripps bankruptcy, financial turmoil at LBNL) closed down in recent years

- Facilities are aging, getting past design life, failure of critical systems likely

- Many facilities are primarily used for medical treatment and space electronics testers have to share time.

- Not at a crisis yet, but there is no margin in the testing infrastructure.

Key Finding 3: Aging Workforce in a Domain that Requires Specialized Training and Skills

- An apparent bimodal distribution in the radiation testing workforce exposes the risk that critical knowledge may not be transferring at a sufficient rate from mid-career to early-career radiation engineers.
- Informal learning on the job/apprenticeship model; however, summer schools and short courses have been a valuable resource for education of past generations of radiation engineers

Key Finding 4: Fast Moving Technology

- Commercial CMOS/Flash devices will stretch out Moore's Law for at least three to four more generations. However, rad hard devices will likely reach their scaling limit sooner because of increasing uncertainties in predicting and mitigating SEE rates.

- The complicated packaging and high level of integration of many COTS parts will make it increasingly difficult to test at conventional heavy-ion accelerators.

- The rapid development of semiconductor devices means that the body of knowledge for the field advances more rapidly than it can be accommodated in test standards.

Other Findings

- No clear roadmap on what is required and who will provide it
- There are some new(ish) testing approaches with promise
- DoE budget for supporting testing facilities has been targeted for major cuts (committee is not addressing this recent budget development, but things could get much worse)

Summary of Findings

- Demand side
  - Expected larger number of spacecraft both in near-Earth and deep space, increasing the load on the radiation hardness testing infrastructure
  - Need for greater reliance on electronics on these spacecraft as they must begin to be more autonomous
  - Fundamental changes in electronics technology which will create the need for new or different kinds of testing environment.

- Supply side
  - More options for M&S and *in situ* testing, likely not adequate to address the demand.
  - Aging and growing costs of the current facilities will further shrink opportunities for testing

- Mismatch between demand for both more and different kinds of testing, and shrinking supply

Recommendation 1

- The Department of Energy, in collaboration with the Department of Defense and NASA, should establish a joint coordination body to define the usage needs for parts radiation testing and assure the adequacy and viability of radiation test facilities out to 2030. The joint coordination body should be inclusive and recognize the needs of the broader space community.

Recommendation 2

- The joint coordination body or an equivalently empowered entity should accomplish the following:
  - A review of testing under way at facilities across the country and internationally; • An assessment of survey test equipment availability and needs at participating institutions to facilitate sharing and to avoid needless duplication of hardware critical to testing state-of-the-art electronics;
  - A strategic forecast of both government and commercial satellite launches that will require radiation-hardened microelectronic and optoelectronic (M&O) components to include reliability and lifetime requirements;
  - A joint roadmap developed by representatives from commercial (M&O) device suppliers and the radiation-hardening testing community to ensure test procedures and facilities are capable of testing the latest electronics technologies;
  - A facilities plan, updated periodically, which includes the following:
    - A projection of testing time availability of current radiation testing facilities, planned upgrades, and new facilities, including cost-effective strategies for increasing testing capacity and technical support;
    - A review of reliability issues for critical systems at accelerators under current use, which identifies potential threats to sustained operation and the means to mitigate these threats; and
    - An assessment of the business models and financial stability of critical accelerator facilities, which can affect total testing capacity and costs, including the possibility of a dedicated facility for electronics testing; and
    - Mechanisms for incentivizing modeling and simulation capabilities, data sharing, and collaborations that can reduce total testing burden.

Recommendation 3

- The Department of Energy (DOE), NASA, the U.S. Air Force, and other interested parties should stabilize funding for proton and heavy-ion accelerator facilities in order to restore resilience in national testing capabilities.
  - At the Lawrence Berkeley National Laboratory (LBNL) cyclotron, NASA, DOE, and the U.S. Air Force should determine a method to increase beam time availability to the community to meet projected needs and to provide resiliency. The prior joint-stewardship program at LBNL was a model for how to exploit this existing U.S. capacity for heavy-ion testing.
  - At Texas A&M University, support efforts to bring the K150 accelerator online for proton and heavy-ion testing.
  - Facilitate advanced purchases to guarantee minimum beam time to both the proton and the heavy-ion-testing community. This will provide greater financial stability to LBNL and proton test facilities in the near term while ensuring access to electronics testers over the coming years. Without such advance purchases, LBNL in particular may need to make staffing and development decisions that harm the interests of the electronics testing community.

Recommendation 4

- The Department of Energy, NASA, and the U.S. Air Force should cooperate with professional organizations (e.g., the Institute of Electrical and Electronics Engineers) and other interested parties to accelerate career development of the younger testing and modeling scientists and engineers through summer schools, short courses, university certificate programs, and internal mentoring to enable them to more rapidly achieve mid-career proficiency levels.

Recommendation 5

- The joint coordination body should assess and support university capabilities for improving space electronics testing and development infrastructure, including the following: the development of advanced accelerator concepts, improved testing strategies, improved radiation hardening solutions designs, and radiation mitigation techniques.

Recommendation 6

- The joint coordinating body should engage with the commercial space sector to ensure testing norms meet the needs of this sector as well as the conventional satellite design and radiation testing communities.

Recommendation 7

- The joint coordination body, in combination with existing working groups, should establish a mechanism to (1) assure the preservation and maintenance of existing modeling and simulation codes for the analysis of space radiation effects on microelectronic and optoelectronic components and (2) support basic research for the development of new codes.

Summary

- Coordination of radiation testing requirements could help rationalize infrastructure needs
- More stable funding for proton and heavy ion facilities could restore capacity and resilience
- Recruitment, training and development of the next generation of S&Es is important
- Universities have a critical role in training and in research--requires consistent federal funding
- “New space” needs must be represented
- Modeling and simulation will continue to play an significant role in understanding radiation effects