Current State of Domestic Heavy Ion Test Facilities

Author: Jonathan Pellish, NASA Goddard Space Flight Center (GSFC)
Co-Author: Kenneth LaBel, NASA GSFC / Science Systems and Applications, Inc.

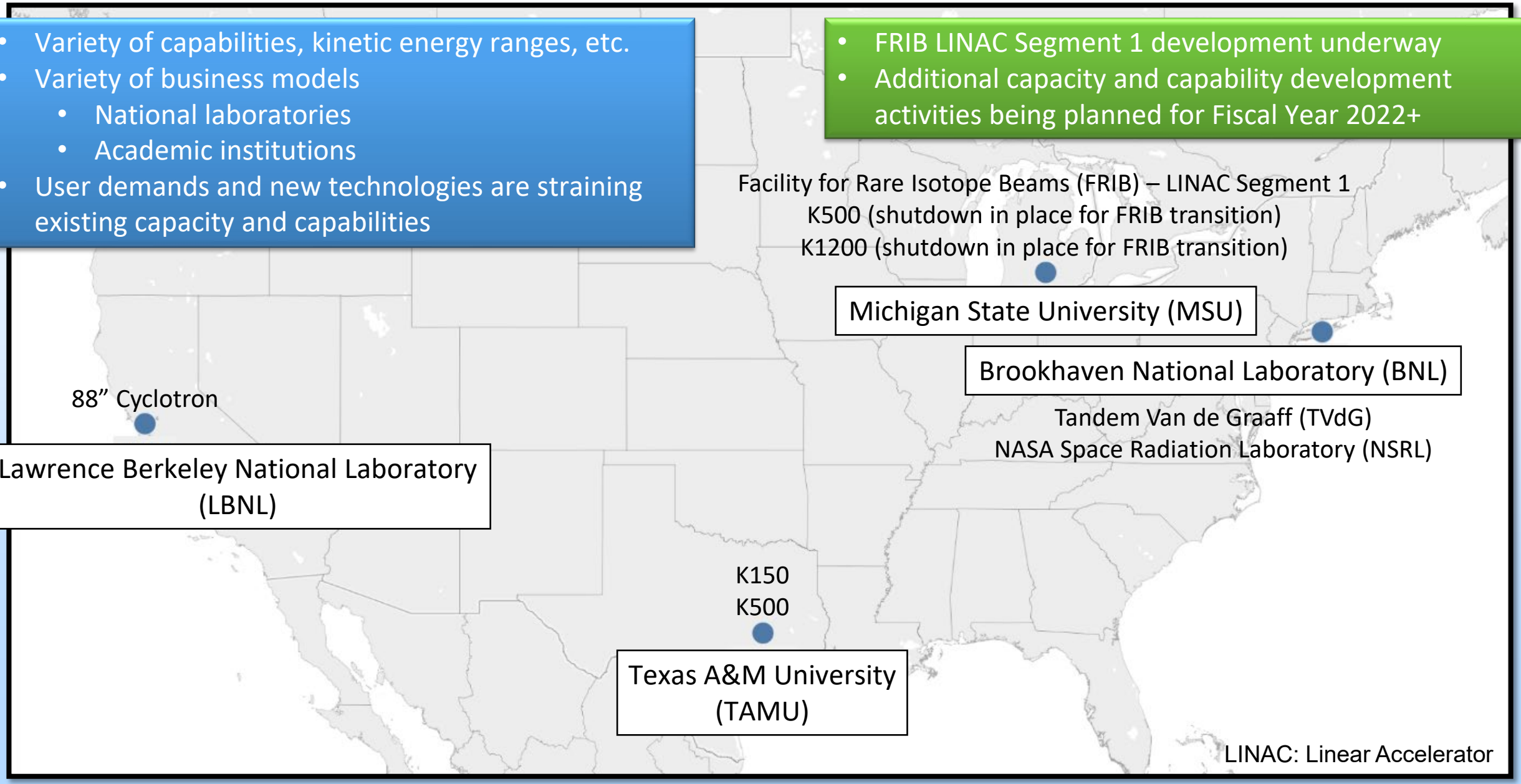
Abstract

We present the current status of United States domestic heavy ion single-event effects (SEE) radiation test facilities, including general perspectives on near- and mid-term needs for both capacity and capabilities.

Current United States Heavy Ion SEE Test Facilities

- Variety of capabilities, kinetic energy ranges, etc.
- Variety of business models
  - National laboratories
  - Academic institutions
- User demands and new technologies are straining existing capacity and capabilities

- FRIB LINAC Segment 1 development underway
- Additional capacity and capability development activities being planned for Fiscal Year 2022+



LINAC: Linear Accelerator

Breaking Down Radiation Effects Caused by the Natural Space Radiation Environment

Ionizing Radiation Effects

- Total Ionizing Dose (TID)
- Total Non-Ionizing Dose (TNID)
- Single-Event Effects (SEE)
  - Non-Destructive
  - Destructive

Primarily high-energy protons and **heavy ions**

Not including charging

NASA Engineering and Safety Center. 2021. Avionics Radiation Hardness Assurance (RHA) Guidelines. https://ntrs.nasa.gov/citations/20210018053.

Why Perform SEE Testing?

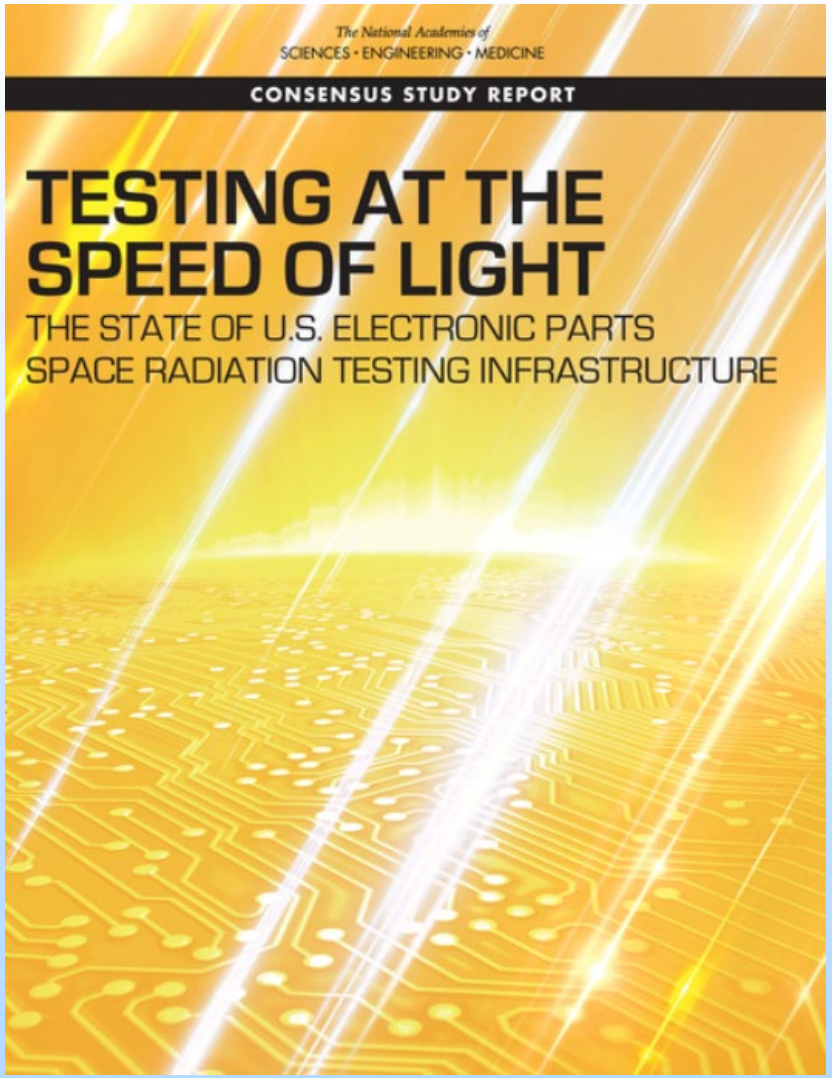
1. To determine the presence and characteristics of single events
   - Destructive or non-destructive?
   - Voltage- and/or temperature-dependent?
   - List goes on for a quite a while…
2. To calculate bounding SEE rates as part of availability and/or reliability assessments for a given mission, environment, application, and lifetime (MEAL) – this is what matters to designers, system engineers, etc.

- SEE testing is usually performed at particle accelerator facilities, which irradiate an electronic device target (or board or box) with high-energy ions.
- SEE test facilities are an essential part of the space industrial base.

Some content adapted from S. Buchner, 2011 School on the Effects of Radiation on Embedded Systems for Space Applications, Toulouse, France.

Recent Assessments – National Academies of Sciences, Engineering, and Medicine, 2018

- **Key findings**
  - Growing use and tightening supply
  - Infrastructure showing signs of strain
  - Aging workforce in a domain that requires specialized training and skills
  - Fast-moving technology
- **Points to / needs**
  - More organizational coordination
  - Test facility sustainment & new investments
    - Coupled with appropriate research & development
  - Workforce development
- **At least one detailed assessment pre-dated this work, Aerospace Corp. TOR-2015-00473.**



https://doi.org/10.17226/24993

Recent Assessments – Analysis of Alternatives, 2019

- **Key findings**
  - **Existing heavy ion SEE test facilities cannot meet current or future SEE test demand (~5000 hour/year gap)**
  - **Department of Defense efforts as well as U.S. Government and commercial space are driving significant increases in SEE testing demand**
  - **Current heavy ion accelerators for SEE testing at U.S. universities and Department of Energy labs have limited capacity and capability**
  - **More complex electronics require more test hours**
  - **More advanced electronics and packaging require higher ion energies, >100 MeV/amu**

Analysis of Alternatives Findings and Recommendations are Independent and Non-Binding

J. Franco & J. Ross, *Public Summary from Analysis of Alternatives for Domestic Single-Event Effects Test Facilities* (Meeting URL, Slides URL)

The AoA is a product of the SRHEC Test & Evaluation working group. Recommendations belong to the AoA team and do not necessarily represent the U.S. Government.

Recent Assessments – Analysis of Alternatives, 2019

- **Demand for high-energy SEE testing is growing (projections only)**

Low Energy SEE Test

2020

- 90% of SEE test is Low Energy
  - 10-50 MeV/n (Mega-Electron Volts /n)

2030

- 60% of SEE test is Low Energy
  - Economical test for monolithic integrated circuits
  - Issues for flip-chip, stacked die, 2.5/3D packaging, and assemblies
- Access assured with low energy investments
- TAMU K500 & K150, LBNL, FRIB Lin Seg 1, and MSU K500 meet Low Energy demand

High Energy SEE Test

2020

- 10% of SEE test is High Energy
  - >100 MeV/n

2030

- 40% of SEE test is High Energy
  - New technology and CCA level testing will demand high energy
  - Economical for new technology
- Access assured by high energy investment
- 40% is ~4000 hours/yr
  - BNL AGS or MSU K1200 meets High Energy demand

AGS: Alternating Gradient Synchrotron

J. Franco & J. Ross, *Public Summary from Analysis of Alternatives for Domestic Single-Event Effects Test Facilities* (Meeting URL, Slides URL)