STELLAR TEAM NOBLE MISSION

Department of Defense and Heavy-Ion (HI) Single Event Effects (SEE) Facilities

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Current SEE Testing Landscape

- ~5,000 hour/year gap in meeting current and future U.S. HI SEE test demand
- Increasing HI SEE testing demand over next 10 years driven by
  - Overlapping Department of Defense (DoD) nuclear modernization efforts along with increased commercial space programs
  - Increased complexity of advanced electronics and systems (processors, application-specific integrated circuits [ASICs], field programmable gate arrays [FPGAs]) require more test hours
- Advanced electronics also require advanced capabilities such as higher ion energies >100 MeV/n
  - 3 dimensional (D) integrated circuits (ICs), flip-chip packages, system-on-a-chip, or system-in-a-package
- Only 3 HI test facilities in U.S.
    - Texas A&M (Texas A&M University) K500, LBNL (Lawrence Berkeley National Lab) 88 inch-cyclotron, NSRL (NASA Space Radiation Laboratory) as part of Brookhaven National Lab (BNL)
- 2 of 3 U.S. HI test facilities are DoE owned and operated with a primary science and research mission….not focused on meeting DoD mission objectives
    - Limited capacity, capability, and aging equipment for parts testing and DoD mission support

Historically, no single voice or funding stream existed to address capacity and capability gaps. Academia, industry and USG SEE test communities operated independently

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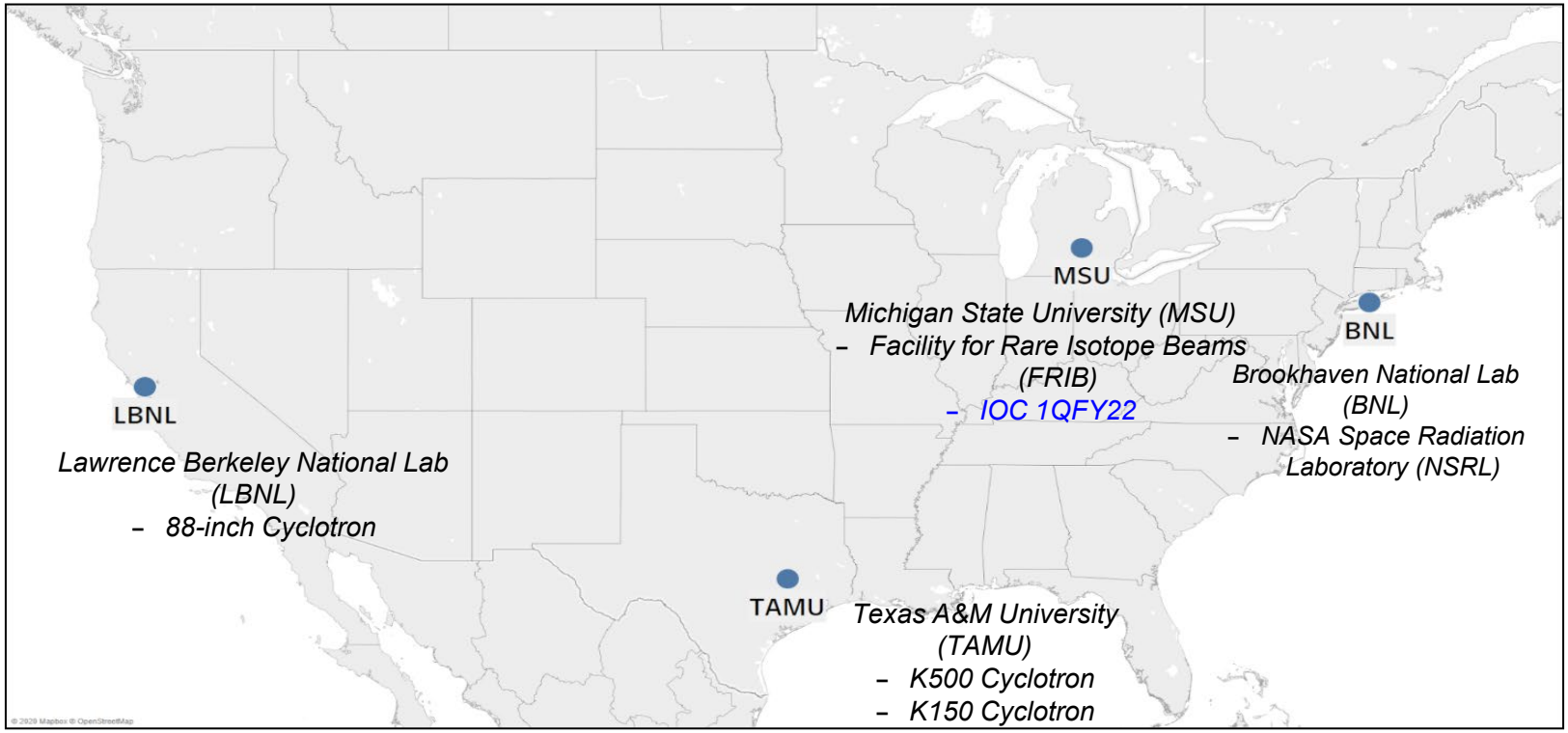
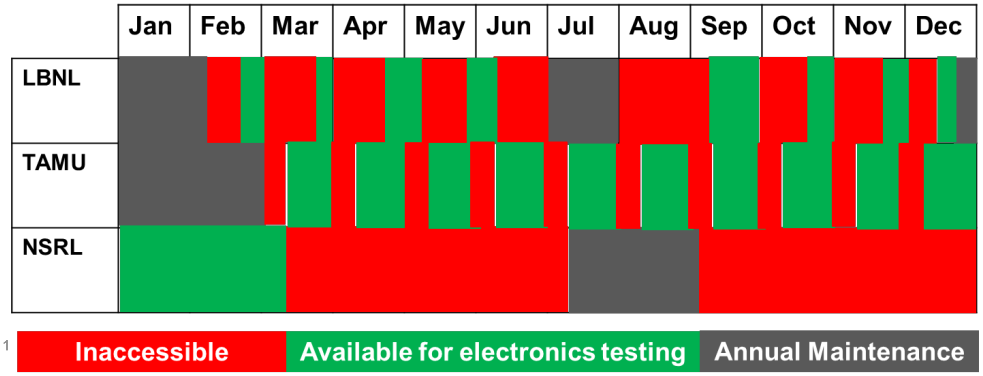
CONUS Heavy Ion Test Locations and Accessibility Calendar





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- The primary mission of heavy ion facilities is not microelectronic part testing but furthering nuclear physics, nuclear chemistry, and radiobiology

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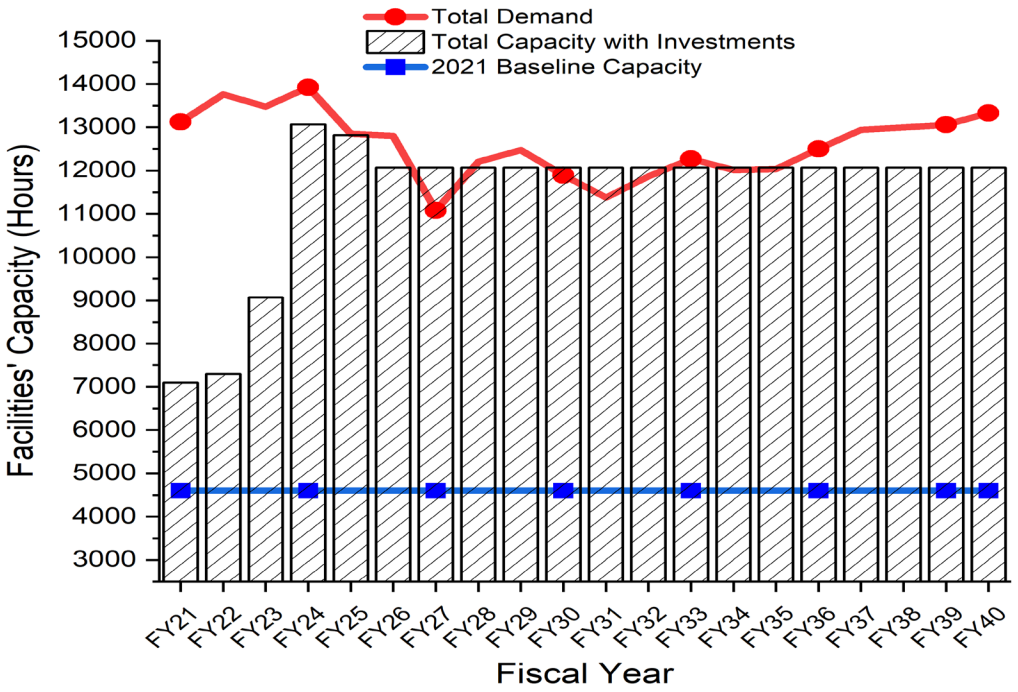
Collaborative Effort to Increase SEE Test Capacity

- **DoD created SRHEC, the Strategic Radiation Hardened Electronics Council, to address multiple aspects of Radiation Hardened Parts testing, development, standards, research, etc.**
  - **Includes National Aeronautics and Space Administration (NASA), other government agencies, research labs and technical subject matter experts (for example – Sandia National Laboratory, Johns Hopkins University Applied Research Laboratory [JHU APL], The Aerospace Corporation)**
- **SRHEC Test & Evaluation Working Group (TEWG) commissioned an Analysis of Alternatives to analyze the economic viability of *short-term and long-term solutions* to shortfalls in U.S. SEE facility capacity and capability**
  - **SEE test capacity gap of 5,000 to 6,000 hours/year by 2025**
  - **Expected increase in demand for higher-than-usual beam energy (>100 MeV/n)**
    - **Allows for testing larger, more complex components/boxes**
- **TEWG provided 9 key performance parameters (KPPs) for HI testing**
  - **Primary KPP is beam energy:**

	Threshold Near Term (0-5 yrs.)	Objective Long Term (>5<10 yrs.)
Low-Energy	5-25 MeV/n	25-100 MeV/n
Hi-Energy	25-100 MeV/n	>100 MeV/n

HI Facilities, Department of Energy (DOE) Science Missions, and Future Demand Signal

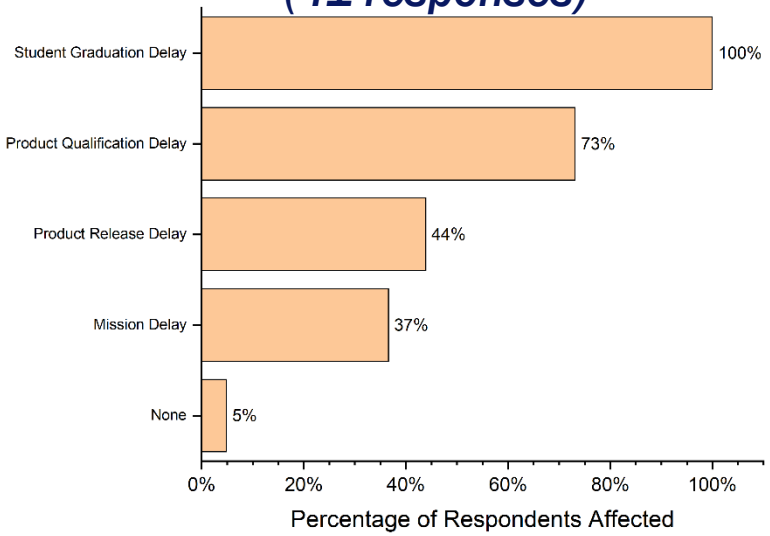
- **Current SEE Parts testing utilizes HI facility beam-time not used by Science or academic research**
  - Relationship has been mutually beneficial for nearly 50 years
  - SEE testing strengthens the financial model of each facility (generated revenue)
- **DOE strongly supports SEE testing as a critical service to nation on a non-interference basis**



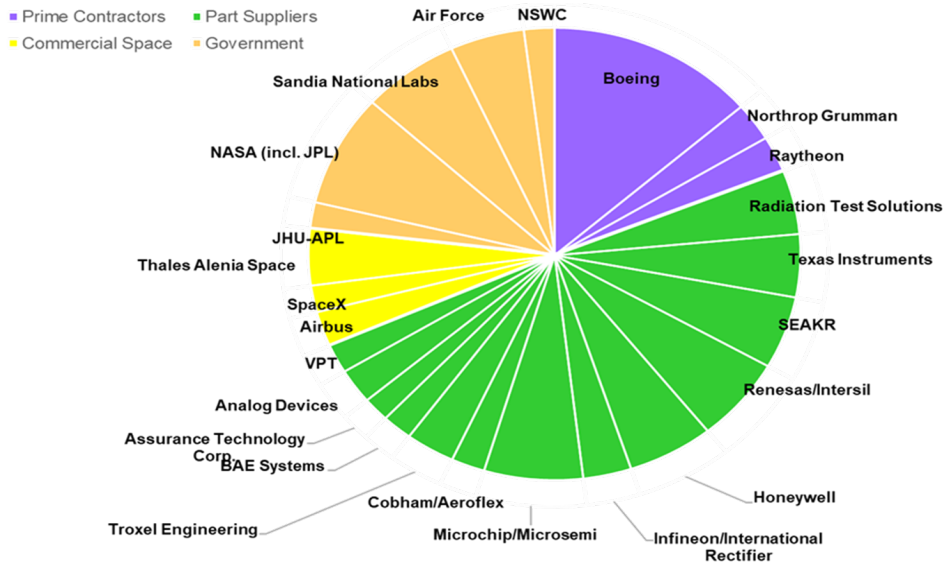
As HI SEE test growth exceeds capacity, the need for alternate sources is critical

SEE Facility Access Critical to US Industrial Base

What is / are the impact(s) of heavy ion beam time loss to your organization? (41 responses)



Texas A&M facility users for SEE testing in FY2019



amazon.com

- **Amazon's Public Response to Risks in the Semiconductor Manufacturing and Advanced Packaging Supply Chain, 86 Fed. Reg. 14308 (Dep't of Commerce March 15, 2021) (Notice of Request for Public Comments); RIN 0694-XC07; Docket # 210310-0052**
  - … "Resources are also limited in specialized areas, such as radiation testing for semiconductor products for aerospace applications… AWS's U.S. government and defense customers also rely on SEE testing in their development of leading-edge technologies. …

Wide user base from defense and commercial industry critically affected by shortfall in heavy-ion capacity

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Demand for High Ion Energy Testing is Growing

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

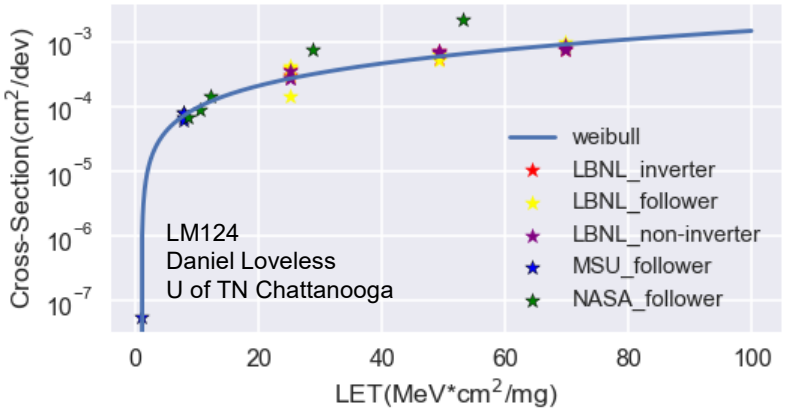
- 40% of SEE test is High Energy
  - New technology and CCA level testing will demand high energy
  - Economical for new technology
- Access assured by high energy investment
- 40% is ~4000 hours/yr
  - BNL AGS or MSU K1200 meets High Energy demand

Path Forward

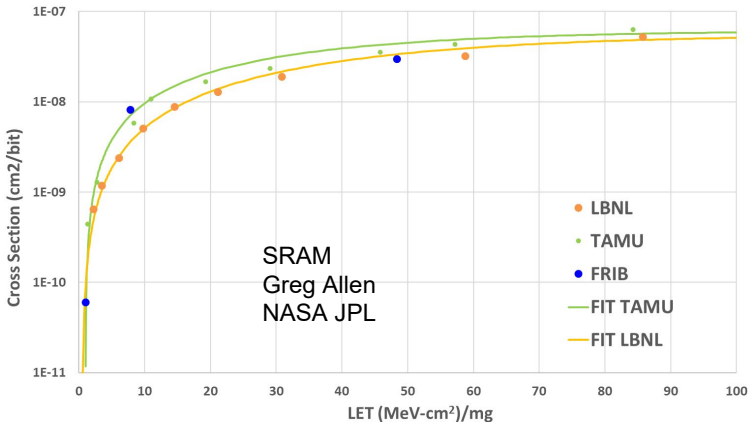
- **The DoD Test Resource Management Center (TRMC) providing funding to improve capabilities and capacities, and bring new facilities online, to address the 5,000+ hour/year gap and need for high energy capability**
- **TRMC tasked Missile Defense Agency (MDA) as the programmatic and technical lead for HI facility investments**
  1. **Prioritizing Low Energy capacity improvements to existing facilities in FY21-23**
     - **MSU:**
       - Leverage 1st segment of MSU's 3-segment LINAC Facility for Rare Isotope Beams (FRIB) to provide dedicated ions for part testing
       - K500 Refurbishment and repurposing
     - **LBNL Upgrades**
     - **TAMU K150 Upgrade (Vacuum and Ion Source Addition)**
  2. **Study High Energy capacity and demand; feasibility to upgrade existing facilities in FY23-27**
     - **Developing detailed KPPs for testing of ICs and assemblies**
       - Example: range of ion penetration based on evolving 3D technologies and notional assembly mechanical drawings; Deep dive evaluation of existing and emerging domestic high energy HI accelerators,

The DoD is investing in SEE test facilities to benefit the whole SEE community

FRIB Single Event Effects Beamline



- Addition of beamline and test station to existing Facility for Rare Isotope Beams (FRIB) LINAC at Michigan State University
- Acceptance testing and functional testing completed
- Anticipated to start accepting SEE test users in Spring of 2022
- Facility is new to SEE testing and still working through processes and efficiency improvements
- Expect: long cable runs (use of installed Ethernet cables recommended), reduced access to test tunnel, and initially a limited ion cocktail (O, Ar, Xe or Bi)
- FSEE user point of contact: BJ Abrams, abrams@frib.msu.edu



FRIB is a US Department of Energy Office of Science user facility.

FSEE creation was funded by the DoD Test Resource Management Center. The effort was managed by the Defense Threat Reduction Agency with oversight and support from the SRHEC T&E WG

LBNL, MSU, TAMU Upgrades (Planned)

- **LBNL**
  - Improve capabilities for the open air 20 MeV/n ion cocktail (higher Z, intensity) and improve overall reliability
- **TAMU**
  - Add a new ion source and improved vacuum system for the K150 cyclotron to improve 15 MeV/n selection of ions (higher Z) and intensities
- **MSU**
  - Refurbish, modernize and reutilize dormant K500 cyclotron for dedicated SEE community access
- **High Energy**
  - Develop appropriate KPPs and demand signal
  - Evaluate potential reuse of MSU K1200 cyclotron and BNL AGS

- Will add 4000+ hours/year of SEE-only Test Capacity

- Adds significant capacity at 15 MeV/n

Future Plans

- **Develop new Hi-Energy SEE Facility Capacity**
  - Between 100-1000 MeV/n
    - **Tradeoff study in-progress**
  - Supports Complex part testing
- **Investigate Block Buys to guarantee more access**
- **Develop at 200+ MeV Proton Test Facility**
  - Primary use would be SEE test

Summary

- DoD and TRMC are investing critical dollars into increasing Heavy Ion SEE test facility capacity, and capabilities, including bringing a new capability online at the FRIB to close the gap in upcoming testing needs
- MDA is leading a team from Defense Threat Reduction Agency (DTRA), NASA, Navy, Army, and others to oversee the programmatic and technical implementation of the TRMC investment dollars
  - Helps balance the current focus on DOE and science missions with direct programmatic needs
- Immediate increase in available test time by Summer 2022
  - Additional hours and new capabilities by mid-2023
- Continued collaboration across the SEE testing community is crucial as advanced technologies, high energy ions for testing, and larger test articles are needed to match the evolving testing environment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