Decline in radiation hardened microcircuit infrastructure

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Acronyms

Acronym	Definition
ASIC	Application Specific Integrated Circuit
CDH	Central DuPage Hospital Proton Facility, Chicago Illinois
CNL	Crocker Nuclear Lab
COTS	Commercial Off The Shelf
ESA	European Space Agency
FPGA	Field Programmable Gate Array
GSFC	Goddard Space Flight Center
HUPTI	Hampton University Proton Therapy Institute
IBM	International Business Machines
IEEE	Institute of Electrical and Electronics Engineers
IUCF	Indiana University Cyclotron Facility
ITAR	International Traffic in Arms Regulations
LBNL	Lawrence Berkeley National Laboratories
LLUMC	James M. Slater Proton Treatment and Research Center at Loma Linda University Medical Center
MGH	Massachusetts General Hospital
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts and Packaging
NSREC	Nuclear and Space Radiation Effects Conference
NSRL	NASA Space Radiation Laboratory
ProCure	ProCure Center, Warrenville, Illinois
SEE	Single Event Effect
SEU	Single Event Upset
TRIUMF	Tri-University Meson Facility
UCD	University of California at Davis

Abstract

- **Two areas of radiation hardened microcircuit infrastructure will be discussed:**
  - **The availability and performance of radiation hardened microcircuits, and,**
  - **The access to radiation test facilities primarily for proton single event effects (SEE) testing.**
- **Other areas not discussed, but are a concern include:**
  - **The challenge for maintaining radiation effects tool access for assurance purposes, and,**
  - **The access to radiation test facilities primarily for heavy ion single event effects (SEE) testing.**
- **Status and implications will be discussed for each area.**

U.S. RADIATION HARDENED MICROCIRCUITS

Radiation Hardened Microcircuits - Foundries

- **Well known decline in number of U.S. manufacturers of radiation hardened microcircuits:**
  - **From 20+ in 1990 to a handful in 2015.**
- **Many of the existing suppliers utilize a "foundryless" model where they are either:**
  - **A design house using a 3rd party fabrication facility, or,**
  - **Upscreen parts while adding radiation mitigation approaches (shielding, supervisory control, etc…)**
- **Changes to ITAR (U.S. State Department to Commerce) should ease access to these products for non-U.S. entities not on restricted list.**

Foundries - Current Concern

- **The cost of operating a dedicated state-of-the-art foundry is in the $Billions.**
  - **Using a commercial fabrication facility (like IBM) as front end for silicon die with radiation hardened library development (intellectual property, IP) and a Military/Aerospace vendor as the back end (packaging, test) has been the working plan.**
  - **This is similar to European Space Agency (ESA) approach with ST Microelectronics, for example.**
- **Many future radiation hardened standard product and Application Specific Integrated Circuit (ASIC) plans were based on the use of the former IBM foundry that is now GlobalFoundries (non-U.S. owned).**
  - **While the use of non-U.S. foundries/products is common for NASA missions, the U.S. government, in general, is concerned over access to a U.S. foundry.**
- **U.S. Government is reviewing options at this time.**
  - **NASA may be affected indirectly for future standard product access, but does not develop many ASICs requiring advanced technology nodes.**

Radiation Hardened Microelectronics – More COTS?

- **The underlying challenge:**
  - **Traditional radiation hardened electronics are multiple technology generations behind the commercial alternatives:**
    - **e.g., radiation hardened field programmable gate array (FPGA): 65nm feature size**
    - **Current state-of-the-art commercial FPGA: 20nm feature size. This is 3-4 generations more modern.**
  - **As technology has scaled, the power and volume versus performance metrics are improved – faster, smaller, more highly integrated, lower power.**
- **While NASA's been a user of commercial parts since the 1970's, these modern, very complex parts may require large amounts of additional mitigation for radiation sensitivities and evaluated for reliability challenges.**
  - **Modern system design mixes radiation hardened devices ("failsafe safing") with high-performing COTS devices.**

ALL ABOUT PROTONS

Indiana University Cyclotron Facility (IUCF) Closure

- **IUCF has been the most used higher energy proton test facility for most of the U.S. space industry (electronics).**
  - **It is primarily a medical facility that NASA and others have supported to develop a parallel capability for proton testing of electronics.**
    - ***~2000+ hours of use per year for electronics testing***
  - **IUCF closed to the Space Community Usage on Oct 31, 2014.**
  - **High energy Proton Test (>200 MeV) is Critical to Space Community.**
- **Ad hoc U.S. government team formed to investigate options.**
  - **Existing proton SEE test facilities (North America).**
  - **Explore access to newer proton cancer therapy sites.**
- **Study began in 2014-Oct.**

Existing North American Proton Facilities

- **Tri-University Meson Facility (TRIUMF) – Vancouver, Canada**
  - **Challenges with "border crossing," limited "cycles" of availability**
    - ***TRIUMF is working w/ US State Department for easier access and hardware transfer***
- **Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center (additional access limited beyond current beam amounts),**
- **University of California at Davis (UCD) Crocker Nuclear Lab (CNL),**
  - **Lower prime energy (63 MeV) does not meet all test requirements**
- **Lawrence Berkeley National Laboratories (LBNL) – (50 MeV) has similar technical challenges as CNL, and,**
- **Loma Linda University Medical Center (LLUMC) and NASA Space Radiation Laboratory (NSRL) – have pulsed beam structures and other technical considerations.**

Ad Hoc "Team" Plan/Status – Proton Therapy Sites

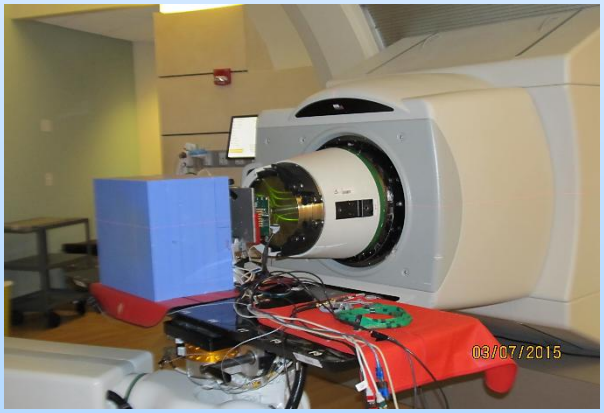
- ✓ Contact facilities (focus on cyclotrons)
- ✓ Site visit to determine interest
  - Technical
  - Access
  - Business case
- ❑ Beta/shakeout tests at interested sites to determine usability
  - ❑ Underway
- ❑ Work logistics of access
  - ❑ Underway
- Determine guidelines for usage of these sites
  - Goal is to discuss at IEEE Nuclear and Space Radiation Effects Conference in Boston, MA in July.
- Recommendations for modifications and longer term access.
  - TBD

Assumption: Facilities will have available 300-500 hours/year each (weekends).

Multiple facilities required to replace IUCF in the near term.

Challenges Identified with Using Proton Therapy Facilities

- **Technical**
  - **Beam structure and delivery are mostly different than we are used to. *This is the largest technical concern.***
  - **Independent dosimetry required for SEE testing – flux, fluence and uniformity.**
  - **Beam intensity control: translation between SEE test parameters and tumor delivery.**
  - **Beam stops required (therapy "stops" beam in patient).**
  - **Radiation dose limits may impact some higher fluence tests.**
  - **Remote-controlled movement of test article mounting stage may not exist at all sites – time hindrance.**
- **Logistics**
  - **Access**
  - **Scheduling**
  - **Cost**



Testing at Cadence Health Proton Center, Warrenville, IL USA

Background: Proton Beam Delivery

- **There are two types of facilities being used for proton therapy:**
  - **Cyclotrons, and,**
  - **Synchrotrons.**
- **In addition, there are three types of beam delivery methods.**
  - **Scatter,**
  - **Wobble/uniform scan, and,**
  - **Pencil beam scan.**
- ***IUCF was a cyclotron and utilized a scatter beam delivery system.***
  - ***Other options require thought and consideration for possible use.***

Proton Facility Status

	Facility	Location	Visit	Beam Attributes*	User friendly**	Hourly Rate	Invest. required	Annual Hours	Current Avail.	Short term Avail.	Long term Avail.	Beta Test
Future Facilities	Cadence Health (CDH) Proton Facility - ProCure	Warrenville, IL	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	Mar 7
	Hampton University Proton Therapy Institute (HUPTI)	Hampton, VA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	350	No	Maybe	Maybe	TBD
	Provision Center for Proton Therapy	Knoxville, TN	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
	Seattle Cancer Care Alliance Proton Therapy - ProCure	Seattle, WA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	Yes
	University of Florida Proton Therapy Institute	Jacksonville, FL	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
	University of Maryland Proton Treatment Center	Baltimore, MD	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
	Scripps Proton Therapy Center	La Jolla, CA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	May 1-2
	OKC ProCure Proton Therapy Center	OKC, OK	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	May-June
	Mayo Foundation	Rochester, MN Phoenix, AZ	N	TBD (synchrotron)	TBD	TBD	TBD	TBD	No	No	TBD	TBD
Existing Facilities	Tri-University Meson Facility (TRIUMF)	Vancouver, CAN	N	Acceptable (cyclotron)	Yes	$750	No	4x/year	Yes	Yes	Yes	N/A
	Slater Proton Treatment and Research Center at Loma Linda University Medical Center (LLUMC)	Loma Linda, CA	Y	Acceptable (synchrotron)	Yes	$1,000	No	1000	Yes	Yes	Yes	N/A
	Mass General Francis H. Burr Proton Therapy	Boston, MA	N	Acceptable (cyclotron)	Yes	$1,000	No	< 800 hours, at capacity	Yes	Yes	Yes	N/A
	NASA Space Radiation Lab (NSRL)	Brookhaven, NY	Y	Acceptable (synchrotron)	Yes	$4,700	No	> 1000 hours	Yes	Yes	Yes	N/A
	Indiana University Cyclotron Facility	Bloomington, IN	N/A	Reference	Yes	$820	N/A	2000 hours	No	No	No	N/A

*Beam size, dosimetry, flux, fluence, uniformity; **location, safety training, regulations, scheduling, payment, hazardous material handling, shipping, contracts, ITAR, etc...

Proton Takeaway Chart

- **Rules of thumb**
  - **All proton cancer therapy sites are usable for static tests, parts that are fairly proton-SEU tolerant, and destructive tests.**
    - **Cyclotron, synchrotron**
    - **Any of the beam delivery modes (scatter or scan)**
  - **Timing dependent tests (dynamic operations) especially on very proton sensitive devices require careful thought for using other than an IUCF-like beam (a cyclotron with a scatter mode).**
    - **Further work is needed to evaluate useful nature of scan beam delivery.**
  - **Guideline development will be a critical deliverable by this team.**
    - **Expect to have a version available at IEEE Nuclear and Space Radiation Effects Conference**
      - **Boston, MA. USA – July 13-17, 2015.**

Protons – The Future

- **Access/contracts/technical logistic "headaches" for cancer centers must be minimized to allow widest use for radiation effects research.**
  - **We are NOT their prime customer.**
  - **Long-term access hinges on three items:**
    - **Minimum invasiveness of our community on cancer therapy sites (technical, logistics),**
    - **Business model (for cancer therapy sites), and,**
    - **Medical usage not expanding to use "spare time" – insurance and doctor access are current limits, but may be changing.**

QUESTIONS?