Proton Cancer Therapy Facilities in the U.S. - Status on Evaluation for Electronics Radiation Testing

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Acronyms

Acronym	Definition
CNL	Crocker Nuclear Lab
GSFC	Goddard Space Flight Center
HUPTI	Hampton University Proton Therapy Institute
IAI	Integrity Applications Incorporated
ITAR	International Traffic in Arms Regulations
IUCF	Indiana University Cyclotron Facility
LBNL	Lawrence Berkeley National Laboratories (LBNL)
LLUMC	Loma Linda University Medical Center (LLUMC)
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts and Packaging
NSRL	NASA Space Radiation Laboratory
PTCOG	Particle Therapy Co-Operative Group
SCCA	Seattle Cancer Care Alliance
TRIUMF	Tri-University Meson Facility
UCD	University of California at Davis
UFHPTI	University of Florida Health Proton Therapy Institute

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" and limited "cycles" of availability**
    - ***TRIUMF is now "ITAR compliant"***
- **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.**

Team Members

(min. 1 site visit or significant consulting)

- NASA
  - Ken LaBel, Chuck Foster (consultant)
- The Aerospace Corporation
  - Tom Turflinger, Andy Kostic, Rich Haas, Jeff George, Steve Moss
- Integrity Applications Incorporated (IAI)
  - Brian Wie
- Vanderbilt University
  - Robert Reed
- Boeing
  - Jerry Wert, Sudhakar Shetty
- BAE Systems
  - Reed Lawrence, John Davis
- Jet Propulsion Laboratory
  - Steve Guertin

Ad Hoc "Team" Plan – 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
- 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.

Background: Proton Beam Delivery

- **There are two types of facilities being used for proton cancer therapy:**
  - **Cyclotrons, and,**
  - **Synchrotrons.**
- **In addition, there are three types of beam delivery methods used.**
  - **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.***

Basic Study Requirements

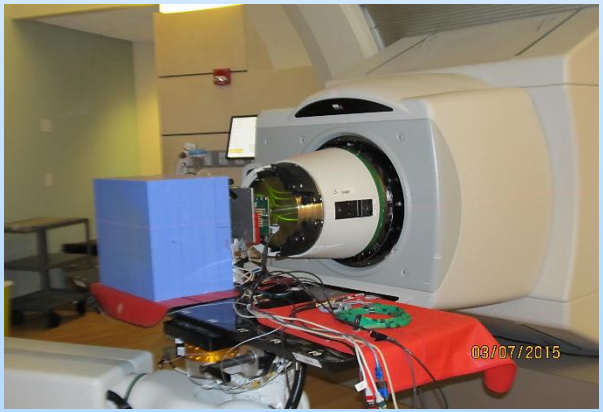
- **Energy range:**
  - **125 MeV to > 200 MeV**
- **Proton flux rates:**
  - **1e7 p/cm^2/sec to 1e9 p/cm^2/sec**
- **Test fluences:**
  - **1e9 p/cm^2 to 1e11 p/cm^2**
- **Irradiation area:**
  - **Small (IC ~ 1cm) to Large > 15cm x 15cm**
- **Beam uniformity:**
  - **>80%**
- **Beam structure:**
  - **Cyclotron preferred (random particle delivery over time)**
  - **Fixed spot or scatter (random particle delivery over area)**

Proton Facility Status (200 MeV – North America)

	Facility	Location	Hourly Rate	Type	Access/ Annual Hours	Expected Avail.	Shakeout Test
Future Facilities	Northwestern Medicine Chicago Proton Center	Warrenville, IL	TBD	Cyclotron	2 hrs – weeknights 8-16 hrs Saturdays	Now	Yes
	Scripps Proton Therapy Center	La Jolla, CA	TBD	Cyclotron	Up to 500 hrs	Now	Yes
	Seattle Cancer Care Alliance Proton Therapy - ProCure	Seattle, WA	TBD	Cyclotron	TBD	CY16?	Yes
	Hampton University Proton Therapy Institute (HUPTI)	Hampton, VA	TBD	Cyclotron	TBD weekends (up to 32 hrs?)	CY15	Planned
	OKC ProCure Proton Therapy Center	OKC, OK	$1000 + one-time $3000 setup fee	Cyclotron	Weekdays 6 hrs + possible shared time Saturdays 5-8 hrs	CY15	TBD
	University of Florida Health Proton Therapy Institute (UFHPTI)	Jacksonville, FL	TBD	Cyclotron	Weekend days (possibly shared with quality assurance)	CY15	TBD
	Provision Center for Proton Therapy	Knoxville, TN	TBD	Cyclotron	TBD	TBD	TBD
	Dallas Proton Treatment Center	Dallas, TX	TBD	Cyclotron	TBD	CY16?	TBD
	University of Maryland Proton Treatment Center	Baltimore, MD	TBD	Cyclotron	500	CY16?	TBD
Existing Facilities	Tri-University Meson Facility (TRIUMF)	Vancouver, CAN	$750	Cyclotron	4x/year	Yes	N/A
	Slater Proton Treatment and Research Center at Loma Linda University Medical Center (LLUMC)	Loma Linda, CA	$1,000	Synchrotron	~1000	Yes	N/A
	Mass General Francis H. Burr Proton Therapy (MGH)	Boston, MA	$650	Cyclotron	~800 hours 12hr weekend days, 2 of 3 weekends	Yes	N/A
	NASA Space Radiation Lab (NSRL)	Brookhaven, NY	$4,700	Synchrotron	~1000 hours	Yes	N/A
	Indiana University Cyclotron Facility	Bloomington, IN	$820	Cyclotron	2000 hours	No	N/A

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 dosage 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**



Shakeout testing at Cadence Health Proton Center, Warrenville, IL

Special Session Held at Single Event Effects (SEE) Symposium – May 20, 2015 in La Jolla, CA

- **Special Session: SEE Testing and Proton Therapy Centers: A New Paradigm**
  - **Co-chairs: Tom Turflinger, Brian Wie, Robert Reed**
  - **Proton Therapy "coordinators": Dr. Mark Pankuch (Cadence), Dr. Lei Dong (Scripps)**
- **Abstract:**
  - **With the closure of the most popular U.S.-based high energy proton SEE test facility (Indiana University Cyclotron Facility – IUCF), the community requires new locales for testing. This special session is focused on:**
  - **The investigation by an Ad Hoc Government Team that's been formed to explore the use of proton cancer therapy centers across the U.S. not currently used for SEE testing;**
  - **Status on existing North American proton facilities, and,**
  - **Discussion with some of the therapy centers for access options.**
- **We were fortuitous that a meeting was being held in parallel with SEE-MAPLD in San Diego:**
  - **Particle Therapy Co-Operative Group (PTCOG).**
- **Thanks also to Ethan Cascio for providing "guide" for new entrants from cancer therapy side.**
- **http://seemapld.org**

The Next Proton Steps

- **Shakeout test schedule**
  - **Tests completed**
    - **Seattle Cancer Care Alliance (SCCA)**
    - **Northwestern Medicine Chicago Proton Center (formerly Cadence Health)**
    - **Scripps Proton Therapy Center**
  - **Tests Planned**
    - **Hampton University Proton Therapy Institute (HUPTI) - June/July**
    - **TBD: Oklahoma City ProCure Proton Therapy Center, University of Florida Health Proton Therapy Institute (UFHPTI), ProNova/ProVision**
    - **CY16-17: University of Maryland Proton Treatment Center, Dallas Proton Treatment Center**
- **Contracts, consortia, and consolidator**
  - **Still working initial interactions and approaches.**
    - **Most facilities will take purchase orders, but may only want users who test on a regular basis**
  - **Consolidators and Consortia approaches were brought up in discussion with therapy centers.**
- **Long term - TBD**

Proton Thoughts

- Several facilities have stated wanting only those users who will utilize facility on regular basis.
  - Minimizes interference with medical priorities/contracts.
  - Impact to “occasional” user.
- Proton therapy sites might Consolidator in a manner somewhat similar to Berkeley Cyclotron and The Aerospace Corp in the “old days”
  - ISDE schedules access and provides an “expert” to interface between the users and the facility. I.e., train users how to use each facility.
    - This minimizes headaches for medical facilities not wanting the hassle of “newbies”.
  - TBD implications.
- Independent beam dosimetry needed
  - Team is evaluating options but leaning toward ion chamber and Gafchromic film in concert.
  - Copy needed at each therapy site.

Current Recommendations for Proton Testing*[1]

Type of Test	Cyclotron	Synchroton	Fixed or Scatter	Wobble/Uniform Scan	Pencil Beam Scan
Static test (Biased, non-clocked)	X	X	X	X	X
Destructive event test	X	X	X	X	X
Dynamic test (device with low proton sensitivity or slow operation) - example, commercial flash memory	X	X	X	X	X
Dynamic test (high proton sensitivity or fast operation) - example, Intel 14nm processor*[2]	X		X		
System test (board/box level) - example, commercial motherboard	X		X		

*1 - Assuming energy, flux, fluence, uniformity, etc… are met.

*2 - 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 for these kinds of tests.

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.**