An Advanced Linear Accelerator Facility for Microelectronic Dose Rate Studies

P.E. Sokol and S.Y. Lee
Indiana University

3 December 2009

ALPHA Users Meeting
Outline

• Introduction
  – NSWC Crane
    • Radiation Effects Program
  • Crane Needs
• Advanced Accelerator Facility
  – Enhanced Capabilities
  – Improved Performance
• Summary
Strategic Systems

NSWC Crane is the leader in the Navy Strategic Systems community for failure and material analysis of space and high reliability electronics and the integration of Commercial Off-the-Shelf products.

NSWC Crane supports……..
• Guidance Systems
• Missile Systems
• Fire Control Systems
• Navigation Systems
• GPS Systems
• Radiation Tolerant Electronics

Thru……
• Design Modeling and Simulation
• Design of Radiation Tolerant Microelectronics
• Design of High-Reliability Microelectronics
• Application and Integration of Commercial Off-the-Shelf Technology
• Systems Engineering
• Inertial Sensor Expertise
• Satellite and Missile Electronics Radiation Testing
• Failure and Material Analysis
• Component Reliability and Quality Analysis
• Component Destructive Physical Analysis
• GPS Receiver Integration

NSWC Crane is assigned as the……
• Leader in Radiation Tolerant Electronics
• Leader in Commercial Off-the-Shelf Technology
• "911" Engineering Activity for Strategic Systems Program Office

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Radiation Effects

NSWC Crane’s Strategic Mission

support testing of electronics in various radiation environments – both manmade and natural.

Natural Environments

Solar Protons
Galactic Cosmic Rays (Neutrons)

Man Made Environments

Neutrons
Gamma Rays

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Current Crane Capabilities

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>1x10^{12}</th>
<th>10-50 nS</th>
<th>1-5 uS</th>
<th>40 mm</th>
<th>10 shots/sec</th>
<th>40-60 meV</th>
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</thead>
<tbody>
<tr>
<td>Dose Rate (Rad/s)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Pulse Width (narrow)</td>
<td></td>
<td></td>
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<tr>
<td>Pulse Width (wide)</td>
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<tr>
<td>Beam Spot Size</td>
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<tr>
<td>Pulse Rep Rate</td>
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<tr>
<td>Energy</td>
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</tbody>
</table>

Most powerful electron accelerator in the Department of Defense

Moore’s Law

1989 - 20 MHz 80386
2007 - 3.7 GHz Pentium

Linac – 1.3 GHz Klystrons
Primary Goals

• Crane
  – Eliminate RF Modulation
  – Provide higher dose rates for survivability testing.
  – Provide more uniform beam and more hospitable environment
Proposed Solution

Key Proposal Features:

Use Storage Ring to:
1. Accumulate and compress LINAC macropulses
2. Eliminate RF structure induced by LINAC
3. Non linear beam optics for uniform irradiation
Phase I/II Linac

Commissioning/Proof of Concept

Varian Medical Linac
“Clinac”
6 MeV – 120 mA
20 MeV – 30 mA

4 μS pulse width
400 Hz repetition Rate
Phase III Linac

Clinac Cavity

Accelerating Section
Cliniac Cavity at 10 MeV
70 mA
50 MeV – 5 accelerating Sections
~6 m Long

<table>
<thead>
<tr>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>Instantaneous Dose Rate</td>
<td>$0.4 \times 10^{10}$ Rad/s</td>
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<tr>
<td>Beam Size</td>
<td>$6.45$ cm$^2$</td>
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<tr>
<td>Pulse Length</td>
<td>$4$ $\mu$S</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>$10$ Hz</td>
</tr>
<tr>
<td>LINAC Current</td>
<td>$0.068$ A</td>
</tr>
</tbody>
</table>

5.5 MW Klystron

Working with Acceltronics on Design and Implementation

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5.1.2.1.3 Beam Ripple
Beam intensity ripple remaining from the Linac bunch structure upon extraction shall be less than ±10%.
High Dose Rate

1. For debunch operational mode, two 10 cm magnetic Kickers, located at 0.269 m from the dipole edge, can be used to bump orbit through the septum. These two kickers sit on ceramic vacuum chamber. *Similar to kicker developed by Lee and XXX*

2. For beam accumulation, we use additional 30 cm electrostatic kicker *System to be developed by commercial vendor (Danfysik, ..)*

### Requirement

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<tr>
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<tr>
<td>Beam Size</td>
<td>16 cm$^2$</td>
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<tr>
<td>Pulse Length</td>
<td>25 nS</td>
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<tr>
<td>Repetition Rate</td>
<td>0.0016 Hz (10 min period)</td>
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<tr>
<td>Stored Charge</td>
<td>1000 nC</td>
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</table>
Dose Rate

**Single Operation**

\[
\text{Dose Rate} = \left(3.73 \times 10^{11} \frac{\text{Rad}}{s} \frac{\text{cm}^2}{\text{amp}}\right) \frac{I}{A}
\]

**Pulsed Operation**

\[
\text{Dose Rate} = \left(3.73 \times 10^{11} \frac{\text{Rad}}{s} \frac{\text{cm}^2 \cdot \text{ns}}{\text{nC}}\right) \frac{Q}{A \cdot T}
\]

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The beam shall be able to be focused from 0.5 cm² to 4 cm² with a square profile. Beam uniformity intensity variation of ±10% will be maintained over this area.
Test Area - Physical

• Test Area Access
  – Access pathways allow passage of rectangular objects with dimensions less than
    • 36 inches wide
    • 36 inches deep
    • 72 inches tall.
  – Access for larger objects will be possible by removal of exterior shielding to the facility.
Test Area - Physical

• Sample Platform
  – Manipulating test devices
  – at least 3 ft × 3ft
  – accommodate a weight of 2000 pounds
  – x and y translations (transverse to the beam) ±1.5 ft in each direction ±0.25 mm.

• Cable Runs
  – Length of the cable run not to exceed 50 ft.
  – Experimenter signals shall be carried in 2 separate 4” conduits and one 12 inch open cable tray.
  Adhere to standard bend radius and threading.
<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Topic</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>9:45</td>
<td>10:15</td>
<td>Tour of Alpha</td>
<td>Gary East</td>
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<tr>
<td>10:15</td>
<td>10:30</td>
<td>Coffee Break</td>
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<td>10:30</td>
<td>10:45</td>
<td>Nonlinear Beam Spreading on LENS</td>
<td>Paul Sokol</td>
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<td>11:05</td>
<td>Background Simulations using GEANT-4</td>
<td>Patrick McChesney</td>
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<td>11:05</td>
<td>11:20</td>
<td>DUT Mounting and Access</td>
<td>Chandra Romel</td>
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<td>11:40</td>
<td>Air Ionization/Vacuum Environment</td>
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<td>Discussion</td>
<td>Moderator – Sokol</td>
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<td>12:00</td>
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<td>Lunch</td>
<td>Box lunches at IUCF</td>
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<td>13:20</td>
<td>User Space Design and Layout</td>
<td>Gary East</td>
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<tr>
<td>13:20</td>
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<td>Discussion</td>
<td>Moderator – Sokol</td>
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<td>13:40</td>
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<td>Beam Delivery Timing</td>
<td>Paul Sokol</td>
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<td>13:55</td>
<td>14:10</td>
<td>Control System Architecture and Commands</td>
<td>Max Ellis</td>
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<td>14:10</td>
<td>14:30</td>
<td>Discussion</td>
<td>Moderator – Sokol</td>
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<td>15:00</td>
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<tr>
<td>15:00</td>
<td>15:10</td>
<td>Bremsstrahlung Capabilities</td>
<td>Sokol</td>
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<tr>
<td>15:10</td>
<td>15:45</td>
<td>Discussion</td>
<td>Moderator – Sokol</td>
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<td>15:45</td>
<td>16:00</td>
<td>Closing Comments</td>
<td>Steve Clark</td>
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</tbody>
</table>
Secondary Goals - CRANE

X-ray Source
Bremmelstrung Radiation
Inverse Compton Scattering
Radiation Effects Studies
Inverse Compton Scattering
X-ray Source

A Conceptual Picture of the CLS
(The 30 cm ruler in the middle is shown for scale.)

Parameters of Source
Average flux: $10^{12}$ photons/sec
Source size: 100 microns

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