TECHNICAL SCOPE OF WORK
FOR THE 2015 FERMILAB MTA DETECTOR IRRADIATION PROGRAM

T-1050
CDRD High Rate Data Links Program

March 20, 2014

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Picture should be 800 x 600 pixels,
also known as Document Small size.
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INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of University of Minnesota, Fermilab, Argonne National Laboratory (ANL), Ohio State University (OSU) and Southern Methodist University (SMU) who have committed to participate in beam tests to be carried out during the 2013 - 2014 Fermilab Test Beam Facility program.

The TSW is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to modify this scope of work to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

This TSW fulfills Article 1 (facilities and scope of work) of the User Agreements signed (or still to be signed) by an authorized representative of each institution collaborating on this experiment.

Description of Detector and Tests:

Irradiation of components for high bandwidth optical communication systems. The experimenters plan to conduct radiation tolerance testing on several different components of ultra-high bandwidth data links. All components are small with surface densities less than 1 gm/cm$^2$. The following category of tests are foreseen:

1) Measurement of the effect of total ionizing dose (TID) with hadrons at levels up to 1 MGy for ASICs made with silicon and standard semiconductor impurities.
2) Measurement of the effect of TID of thin films of Barium Strontium Titanate deposited on fused silica substrates to levels of 1 MGy and total fluxes of up to $10^{15}$ protons/cm$^2$.
4) Measurements of darkening effects (i.e. loss of transparency) in optical components

Category 1) tests are done with an in situ readout of the components. This will be accomplished by having the component under study attached to a simple, and usually disposable, driver board that is placed approximately 1 m from the beam. This driver board is connected with copper cables and fiber optics to a readout and control system that is to be located in an accessible room for continuous monitoring of the component under test.

Category 2) tests are performed where it is sufficient to place the material in the beam and remove it once the irradiation is complete.

Category 3) tests require a beam with a flux as low as 100 Gy/hr. This corresponds approximately to a proton flux of $10^{11}$ protons/hour or $10^7$ protons per second. Ideally the flux should be continuous.
I. **PERSONNEL AND INSTITUTIONS:**

Spokesperson: Roger Rusack  
Fermilab Experiment Liaison Officer: Aria Soha

The group members at present are:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Collaborator</th>
<th>Rank/Position</th>
<th>Other Commitments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The University of Minnesota</td>
<td>USA</td>
<td>Roger Rusack</td>
<td>Professor</td>
<td>CMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A. Finkel</td>
<td>Grad Student</td>
<td>CMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T. Norbert</td>
<td>Grad Student</td>
<td>CMS</td>
</tr>
<tr>
<td>Fermilab</td>
<td>USA</td>
<td>Alan Prosser</td>
<td>Engineer</td>
<td>CMS</td>
</tr>
<tr>
<td>OSU</td>
<td>USA</td>
<td>K.K. Gan</td>
<td>Professor</td>
<td>ATLAS</td>
</tr>
<tr>
<td>SMU</td>
<td>USA</td>
<td>Jingbo Ye</td>
<td>Professor</td>
<td>ATLAS</td>
</tr>
<tr>
<td>Argonne</td>
<td>USA</td>
<td>David Underwood</td>
<td>Scientist</td>
<td></td>
</tr>
</tbody>
</table>
II. **EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:**

2.1 **LOCATION**
2.1.1 The beam test(s) will take place in the experimental hall of the MTA.

2.2 **BEAM**
2.2.1 **BEAM TYPES AND INTENSITIES**
   - Energy of beam: 400 MeV
   - Particles: H- ions
   - Beam spot size: 1 cm²
   - Required Fluences: From $10^{13}$ to $10^{15}$ particles/cm²

   The purpose of this test is to irradiate components to evaluate their use in a high radiation environment. The flux of particles needs to be known with a precision of 1%.

2.2.2 **BEAM SHARING**
   Beam sharing is feasible. If the material is downstream then it is only a question of access. Upstream the experimenters would be affected if the material was significant.

   **Radiation Length of all material in the beam**

2.2.3 **RUNNING TIME**
   Access will be required to change out materials. See section 3.3.3 for total run time and long-term schedule.

2.3 **EXPERIMENTAL CONDITIONS**
2.3.1 **AREA INFRASTRUCTURE**
   The experimenters will need radiation monitoring and after irradiation storage of radioactive material as it cools down.
   The experimenters will also need beam flux measurements by material activation methods.

2.3.2 **ELECTRONICS AND COMPUTING NEEDS**
   The electronics are all custom (for example, consisting of micro-TCA crates) and small custom cards to be placed close to the beam. Experimenters will submit electrical diagrams of these custom electronics to the OCR Chair two weeks prior to the ORC inspection.
   All components and readout systems are provided by the experiment.
   No PREP Electronics are requested.
2.3.3 DESCRIPTION OF TESTS

The experimenters will conduct radiation qualification measurements on several different components to evaluate the effect of radiation on device. In particular, the experimenters are interested in single event upsets and lattice damage in silicon. More details on the tests to be carried out for individual groups are listed here:

**University of Minnesota:**
Tests: TID and Displacement damage. Tests will be carried out with devices operating and monitored.
Material (Item 1): Commercial lithium niobate optical modulator
Dimensions (Item 1): ~65 mm x 7 mm x 5 mm (estimated from Thor Labs modulator data sheet)
Material (Item 2): Barium Strontium Titanate waveguides
Dimensions (Item 2): 20 mm x 10 mm x 0.1 mm
Required fluences: $1 \times 10^{13}$ protons/cm$^2$ to $1 \times 10^{15}$ protons/cm$^2$
Material (Item 3) Silicon Carbide Avalanche photodiodes and Shottky diodes.
Required fluences: $1 \times 10^{13}$ protons/cm$^2$ to $1 \times 10^{15}$ protons/cm$^2$
Material (Item 4) Nano crystalline amorphous silicon wafers mounted on glass substrates.

**Argonne National Laboratory:**
Tests: TID, Displacement Damage, Single Event Effects (SEE). All tests are to be carried out with devices operating and monitored.
Material: Silicon photonics optical modulator
Dimensions: 5 mm x 5 mm
Other factors: Dose rate to be limited to $10$ kRad/hr.

**Southern Methodist University and Fermilab:**
Tests: TID, SEU (electronics), Displacement damage (optics)
Materials: Optical transmitter assemblies, laser driver ASICs, and passive optical components. Electronics components and assemblies will be operated and monitored.
Largest dimensions: ~20 mm x 20 mm (transmitter assemblies)
Required fluences: $>1 \times 10^{13}$ protons/cm$^2$

**Ohio State University:**
Tests: TID, Displacement damage, SEE. Tests will be carried out with devices operating and monitored.
Material: Laser Driver ASICs.
Dimensions: 5 mm x 5 mm
Required fluences: From $8.6 \times 10^{13}$ protons/cm$^2$ to $2.5 \times 10^{15}$ protons/cm$^2$
2.4 **SCHEDULE**

The experimenters will be ready to begin tests in 2013 when beam is available. Different components can be irradiated over the course of about 1 year. The exact timetable will be determined by the availability of the components. The time required for irradiation is expected to be minimal (< 1 hour).
III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

This is a collaboration of several institutions who are working on the development of a new generation of high speed data links. Each institution will bring their own items for testing and remove them as soon as transportation is permitted. They will be each responsible for the individual components for testing and the data collection and storage.

<table>
<thead>
<tr>
<th>Source of Funds [SK]</th>
<th>Materials &amp; Services</th>
<th>Labor (person-weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argonne (experimenter)</td>
<td></td>
<td>???</td>
</tr>
<tr>
<td>Minnesota (experimenter)</td>
<td></td>
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<tr>
<td>Ohio State (experimenter)</td>
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<td>???</td>
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<tr>
<td>Southern Methodist</td>
<td></td>
<td>???</td>
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<tr>
<td>(experimenter)</td>
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<td></td>
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</tbody>
</table>
IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 FERMILAB ACCELERATOR DIVISION:

4.1.1 Use of MTA beamline as outlined in Section II.
4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.
4.1.3 Scalers and beam counter readouts will be made available via ACNET in the MTA control room.
4.1.4 Reasonable access to the equipment in the MTA beamline.
4.1.5 Connection to beams console and remote logging (ACNET) should be made available.
4.1.6 Conduct a NEPA review of the experiment.
4.1.7 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.1.8 Provide safety training as necessary, with assistance from the ESH&Q Section.

4.2 ACCELERATOR PHYSICS CENTER

4.2.1 Position and focus of the beam on the experimental devices under test will be under control of the MTA group within the APC.

4.3 FERMILAB PARTICLE PHYSICS DIVISION:

4.3.1 Update/create ITNA’s for users on the experiment.
4.3.2 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews. [0.2 person-weeks]

4.4 FERMILAB SCIENTIFIC COMPUTING DIVISION

4.4.1 Internet access should be continuously available in the MTA control room.
4.4.2 See Appendix II for summary of PREP equipment pool needs.

4.5 FERMILAB ESH&Q SECTION

4.5.1 Assistance with safety reviews.
4.5.2 Provide safety training, with assistance from AD, as necessary for experimenters. [0.2 person weeks]
4.5.3 The ESH&Q section will cooperate with the Accelerator Division radiation safety group to monitor activity of irradiated samples and will be responsible for allowing irradiated samples off site.

4.6 FERMILAB COLLABORATORS
V. **Summary of Costs**

<table>
<thead>
<tr>
<th>Source of Funds [$K]</th>
<th>Materials &amp; Services</th>
<th>Labor (person-weeks)</th>
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<td>Accelerator Physics Center</td>
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<td>1.0</td>
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<tr>
<td>Particle Physics Division</td>
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<tr>
<td>Scientific Computing Division</td>
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<td>0</td>
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<tr>
<td>ESH&amp;Q Section</td>
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<tr>
<td>Fermilab Collaborators</td>
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<tr>
<td><strong>Totals Fermilab</strong></td>
<td><strong>$0.0K</strong></td>
<td><strong>1.7</strong></td>
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<tr>
<td>Totals Non-Fermilab</td>
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VI. **GENERAL CONSIDERATIONS**

6.1 The responsibilities of the Spokesperson and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Researchers": [http://www.fnal.gov/directorate/PFX/PFX.pdf](http://www.fnal.gov/directorate/PFX/PFX.pdf). The Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ESH&Q) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the Division’s Safety Officer.

6.3 The Spokesperson will ensure at least one person from the experiment is present during all irradiation and cool-off periods and that this person is knowledgeable about the experiment’s hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ESH&Q section.


6.6 The Spokesperson will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Scientific Computing Division management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector management.

6.7 The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

*At the completion of the experiment:*

6.8 The Spokesperson is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.9 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ESH&Q requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.

6.10 The experimenters will assist Fermilab with the disposition of any articles left in the offices they occupied.

6.11 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters’ Meeting.
SIGNATURES:

_______________________________ / / 2014
Roger Rusack, Experiment Spokesperson, University of Minnesota

_______________________________ / / 2014
Mark Palmer, MAP Director
APPENDIX I: MTA AREA LAYOUT

[Describe where you would like to put your apparatus, or how you would like to arrange it. Including a diagram is a good idea. You may draw on the picture below, or use the power-point file on the website to create your own. See examples for ideas.]

MTA AREAS
APPENDIX II: HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need should be checked. See next page for detailed descriptions of categories. (There is NO need to list existing Facility infrastructure you might be using)

<table>
<thead>
<tr>
<th>Flammable Gases or Liquids</th>
<th>Other Gas Emissions</th>
<th>Hazardous Chemicals</th>
<th>Other Hazardous /Toxic Materials</th>
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</thead>
<tbody>
<tr>
<td>Type:</td>
<td>Type:</td>
<td>Cyanide plating materials</td>
<td>List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:</td>
</tr>
<tr>
<td>Flow rate:</td>
<td>Flow rate:</td>
<td>Hydrofluoric Acid</td>
<td></td>
</tr>
<tr>
<td>Capacity:</td>
<td>Capacity:</td>
<td>Methane</td>
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<table>
<thead>
<tr>
<th>Radioactive Sources</th>
<th>Target Materials</th>
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<tbody>
<tr>
<td>Permanent Installation</td>
<td>Beryllium (Be)</td>
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<tr>
<td>Temporary Use</td>
<td>Lithium (Li)</td>
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<tr>
<td>Type:</td>
<td>Mercury (Hg)</td>
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<tr>
<td>Strength:</td>
<td>Lead (Pb)</td>
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<table>
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<tr>
<th>Lasers</th>
<th>Target Materials</th>
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<tbody>
<tr>
<td>Permanent Installation</td>
<td>Tungsten (W)</td>
</tr>
<tr>
<td>Temporary installation</td>
<td>Other:</td>
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<table>
<thead>
<tr>
<th>Calibration</th>
<th>Electrical Equipment</th>
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<tbody>
<tr>
<td>Alignment</td>
<td>Cryo/Electrical devices</td>
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<table>
<thead>
<tr>
<th>Type:</th>
<th>Capacitor Banks</th>
<th>Mechanical Structures</th>
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<tbody>
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<td>Wattage:</td>
<td>High Voltage (50V)</td>
<td>Lifting Devices</td>
</tr>
<tr>
<td>MFR Class:</td>
<td>Exposed Equipment over 50 V</td>
<td>Motion Controllers</td>
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<tr>
<td></td>
<td>Non-commercial/Non-PREP</td>
<td>Scaffolding/ Elevated Platforms</td>
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<tr>
<td></td>
<td>Modified Commercial/PREP</td>
<td>Other:</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Vacuum Vessels</th>
<th>Pressure Vessels</th>
<th>Cryogenics</th>
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<tbody>
<tr>
<td>Inside Diameter:</td>
<td>Inside Diameter:</td>
<td>Beam line magnets</td>
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<tr>
<td>Operating Pressure:</td>
<td>Operating Pressure:</td>
<td>Analysis magnets</td>
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<td>Window Material:</td>
<td>Window Material:</td>
<td>Target</td>
</tr>
<tr>
<td>Window Thickness:</td>
<td>Window Thickness:</td>
<td>Bubble chamber</td>
</tr>
</tbody>
</table>
The following people have read this TSW:

_______________________________ / / 2014
Michael Lindgren, Particle Physics Division, Fermilab

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Sergei Nagaitsev, Accelerator Division, Fermilab

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Vladimir Sheltsiv, Accelerator Physics Center, Fermilab

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Robert Roser, Scientific Computing Division, Fermilab

_______________________________ / / 2014
Martha Michels, ESH&Q Section, Fermilab

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Greg Bock, Associate Director for Research, Fermilab

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Stuart Henderson, Associate Director for Accelerators, Fermilab