Title: RFQ water system activities for FERMILAB

Sponsor: Fermi National Accelerator Laboratory (FNAL)

Sponsor Points of Contact: Brian Chase (chase@fnal.gov) and James Steimel (steimel@fnal.gov)

Principal Investigator: Sandra G. Biedron (biedron@engr.colostate.edu)

Institution: Colorado State University, Department of Electrical and Computer Engineering (Administrative point of contact - jennifer.strange@colostate.edu)

Period of Performance: 12 January 2015 – 11 February 2016

Introduction:
The Department of Electrical and Computer Engineering (ECE) at Colorado State University (CSU) granted its first bachelor degree in electrical engineering over 100 years ago and has since then grown in prestige and reputation in a broad range of disciplines. The present major research areas of the department are biomedical engineering, communications and signal processing, computer engineering, controls and robotics, electromagnetics and remote sensing, lasers optics and applications, systems engineering, and of course accelerator and FEL technologies. These technologies intersect the activities of FNAL. The department has a strong tradition with working on industry-funded and government-funded programs. In addition, the CSU ECE department boasts two NSF funded engineering research centers, one focused on Extreme Ultraviolet Science and Technology and the other on Collaborative Adaptive Sensing of the Atmosphere. The Department has won several technology transfer awards for their work with industry.

Since 2011, CSU ECE and FNAL have been working together on several accelerator endeavors including advanced controls, developing proposals for diagnostics and other systems for the Department of Defense (DOD) and the Department of Homeland Security (DHS), as well as working together on several reports for the Department of Energy (DOE) related to the Accelerators for America's Future endeavor. Further, they have a Memorandum of Understanding (MOU) in place since 2013. Finally, CSU and FNAL collaborate on several high-energy physics programs, including the Long-Baseline Neutrino Facility (LBNF) and a Professor at CSU, Robert Wilson, serves as the LBNF co-director.

Statement of Work – Specific Tasks:

1. Assist with the formulation of the commissioning, test, and verification strategies for the RFQ. (2 weeks Edelen, 2 Weeks Morin, 1 week Biedron)

2. Based on the existing LBNL (Lawrence Berkeley National Laboratory) and FNAL design of a significant portion of the cooling system, including the local RFQ water instrumentation, simulate the system and design the local water

temperature control loop, including flow rate and temperature. (2 months Edelen, 1 week Milton)

3. Work with the LLRF group on interfacing of the water temperature control with the LLRF systems necessary to control and maintain RFQ resonant frequency. (3 months Morin, 1 week Milton)

4. After development of the necessary algorithms, work with the controls, LLRF, and water engineers to implement and verify (5 months Morin, 1 month Edelen, 3 weeks Biedron):

    - The cooling water temperature effect on RFQ resonant frequency.
    - The RFQ power effect on cooling water temperature.
    - The RFQ power effect on RFQ resonant frequency.

5. Develop the necessary operators interfaces, including automated start-up, exception, and shut-down procedures (2 months Morin, 1 week Biedron)

6. Prepare reports, assist engineers in documentation related to the above systems, and assist said engineers in preparing for internal and DOE reviews. (2 weeks Morin, 1 week Biedron, 1 week Milton)

Deliverables:

1. At least two publications (one archival and one conference proceedings) to document the research. Suggested venues might include the archival IEEE (Transactions on Nuclear Science) – Special 50th Anniversary Issue for the Particle Accelerator Conference (PAC), Proceedings from the 2015 IBIC conference, or Proceedings from the 15th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS).

2. Simulation tool for the resonant control system.

Biographies:

Sandra G. Biedron is an Associate Professor of Electrical and Computer Engineering at Colorado State University and holds a Ph.D. in Physics from the Lund University in Sweden. Formerly she was the Department of Defense project office director and a physicist at Argonne National Laboratory and was an associate director of the Argonne Accelerator Institute. Dr. Biedron served as a technical and management consultant on the successful FERMI free-electron laser project at Sincrotrone Trieste (Italy). She recently served as a co-leader of the security and defense portion of the Accelerators for America's Future publication sponsored by the Department of Energy, the follow-on support information for a report requested by the Senate, and a subsequent DOE report on high power lasers. She also has served on a National Academies committee and report. Dr. Biedron is an active member of several professional societies. She is a Fellow of the

American Physical Society (APS), a Senior Member of the Optical Society of America (OSA), a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of the SPIE, and a member of the Italian Optical Society (SIOF). She has served on a variety of international program and organizing committees and has organized a number of conferences, workshops, and plenary sessions. She serves as a reviewer for several journals, including as an Associate Editor of IEEE Photonics, and as a technical reviewer on projects worldwide. Dr. Biedron has a myriad of archival and conference papers and technical documents and holds a U.S. patent. Further, she serves on a NATO panel for sensors and electronics. In 2010 she was presented a Letter of Commendation by the Chief of Naval Research for her technical efforts and in 2013 she was honored with the George T. Abell Outstanding Mid-Career Faculty Award for the College of Engineering at Colorado State University.

Stephen V. Milton's recent interest includes making accelerator and beam systems more efficient and more compact. Milton received a bachelor's degree in physics from the University of California-Davis and a Ph.D. in physics from Cornell University. Prior to joining Colorado State, Milton was the director of the 155M Euro FERMI@Elettra Free-Electron Laser project in Italy, during which time he concurrently served as a senior scientist at Argonne National Laboratory. Before taking on the FERMI director role, Milton led the design, engineering, and construction of the $55 million magnetic device undulator line for the Linac Coherent Light Source, the world's first x-ray FEL, at SLAC National Accelerator Laboratory. Milton also led the Argonne FEL, also known as the Low Energy Undulator Test Line, the world's first Self-Amplified Spontaneous Emission FEL to achieve saturation at visible through ultraviolet wavelengths. He is a Fellow of the American Physics Society, a Senior member of the IEEE, and the Particle Accelerator and Technology Prize winner of the IEEE (2003).

Jonathan Edelen completed his B.Sc. degree in Electrical Engineering at Rensselaer Polytechnic Institute, and is now working to complete his Ph.D. at Colorado State University. Jonathan's work at CSU focuses mainly on electron injection systems for free electron lasers. Jonathan is also working on modeling and simulation of the LINAC being built at CSU and the design and simulation of novel techniques for thermionic cathode electron guns. He is also investigating the theory and simulation of virtual cathode oscillator beam instabilities. In addition to his research, Jonathan is refurbishing the high power RF system for the CSU LINAC. Jonathan has worked with SUPERFISH, PARMELA, and SPIFFE particle accelerator codes. From Aug 2009 - Aug 2012 he worked as an Electrical Engineer in the Underwater Electromagnetic Signatures and Technology Division at the Naval Surface Warfare Center, Carderock Division. His primary role in this position was technology development lead for signature reduction systems on submarine platforms. In this capacity, he has served as principal investigator for a Large Scale Missile Compartment model test, participated in a closed loop degaussing, physical scale model test in the United Kingdom in collaboration with the UK government, and has served as a magnetic signatures analyst in support of technology development, as well as fleet support for full scale trials.

Auralee Morin earned her B.Sc. in Physics from Rensselaer Polytechnic Institute with magna cum laude honors. While at RPI, she also earned minors in Philosophy of Science and Mathematics, Psychology, and Science Technology and Society. Auralee also

conducted part-time graduate work at Johns Hopkins University while working full-time as an engineering researcher in Washington, D.C. Auralee also completed several research internships during her undergraduate education, including two National Science Foundation Research Experience for Undergraduates internships (NSF REUs) and one DOE Science Undergraduate Laboratory Internship (SULI) at Los Alamos National Lab. These gave her a breadth of hands-on research experience in various sub-fields of Physics, most notably including Astronomy/Astrophysics, Fluid Dynamics, Magnetohydrodynamics, Optics, Particle Physics, and Detector Physics. After graduating from RPI, Auralee worked as a researcher based in the Theory, Modeling, and Analysis Branch of the Naval Surface Warfare Center, Carderock Division (where she operated as an on-site contractor). While there, she spearheaded an effort to develop and validate boundary element modeling methods for use in UEM signatures applications. This included the design and analysis of numerical models, the design and analysis of experimental tests and test results for model validation, and participation in large-scale physical model tests with the Naval Research Laboratory and international collaborators. Auralee joined the CSU accelerator group in the summer of 2012 and is working on applying neural network based techniques to control and optimization problems encountered in accelerator systems. She is also working on the design and setup of an initial laser wakefield experiment at CSU and is involved in the commissioning and upgrading of the CSU accelerator control system.

Cost breakdown:
Total effort breakdown in the duration of one year and one month – Biedron 1.5 months, Milton 0.75 months, Morin 11 months, Edelen 3.5 months

Effort:		$ 74,925
Fringe:	$ 10,852	
Domestic Travel:		$ 15,720
Total Direct Costs:		**$ 101,497**
Facilities and Administrative Charges (48.7%)		$ 49,429
TOTAL:		**$ 150,926**

Travel breakdown –
Airfare DIA/ORD round trip, 8 @$400: $3200
Rental car: $3000
Per diem for 4 months in Batavia (71 USD/day): $5520
Housing: $3000 (25 USD per day in on-site FNAL housing)
Ground Transportation/CO: $1000