ADR Program Comparative Review

1. Project Identification
- Project Title: "Enabling Long Wavelength Streaking for Attosecond X-ray Science"
- Ryan N Coffee, Senior Scientist, LCLS+PULSE, coffee@slac.stanford.edu, 650-387-0981
- Peter Walter (L2SI) , James Cryan (LCLS/PULSE)
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2. Accomplishments:
- Major project goals
  - (Completed) Test 2μm streaking with attosecond pulses from LCLS-I using Axial VMI
  - (Completed) Design detector assemblies for array
  - (Completed) Purchase Digitizers
  - (Completed) Demonstrate ML-based pulse reconstruction
  - (75%) Use existing data to develop algorithms for streaming analysis.
  - (75%) Test waveform sampling versus pulse reconstruction accuracy.
  - (50%) Purchase all electronics supplies and chamber.
  - (50%) Design transfer learning implementation plan for LCLS-II.
  - (25%) Implement on-board FPGA processing and demonstrate calibration learning.
  - (25%) Optimize FPGA solution compared to larger ML-server solution.
  - (0%) Construct detector array prototype for benchmarking on the PULSE Institute euv laser system.
  - (0%) Install array on LCLS-II and benchmark resolution with XAFS using 3 μm laser dressing of N_2O.
  - Stretch goal, split the ML model into Digitizer FPGA + PCIe FPGA
- Schedule and budget
  - Design schedule 2 months behind desire, due to challenging L2SI resource coordination, but still consistent with FY20 delivery.
  - Advancing "known quantities" such as Detector assemblies, Flanges, and Digitizers into FY19 to accommodate long lead times
  - Digitizers consistent with compatible upgrade to L2SI came in above initial estimate but consistent with budget as received if removing the less desirable System-on-Chip option.
  - Data processing and machine learning based on simulated detector is few months ahead of schedule.

3. Publications, conference papers, patents: No publications to date

4. Collaborations:
- DESY/XFEL – very effective collaboration, provided new limitations on MCP choice and algorithm design to accommodate MCP depletion.
- PULSE – very effective collaboration, aided the flange assembly design and will host initial detector testing with EUV source.

- L2SI – effective integration effort to plan for an XIP project "MRCOFFEE" end-station for Hutch 1.1 user access. Engineering load of L2SI is very heavy and thus requires flexibility to accommodate existing LCLS-II needs with this engineering effort. This has put strain on the chamber and ToF desing though remains consistent with FY20 delivery.
- PCDS – This project has been chosen as an initial target for data handling at LCLS-II. Corbeil-Therrien serves also on the data management team for PCDS and Omar Quijano, is developing the FPGA development environments, is the principle IT engineer for LCLS/LCLS-II
- Stanford CS/EE – Kunle Olukotun is supporting Graduate Student Matt Feldman who has configured a Docker image/container that runs the spatial-lang high-level FPGA compiler.
- TID-AIR – Ryan Herbst and Matt Weaver are both soupporting our FPGA development.

5. IMPACT:
- This project exemplifies a co-design model whereby the detector geometry, sensor design, Digitizers, and EdgeML are co-optimized in order that limitations of one sub-system (Poisson noise in MCPs) are accommodated with capability in another component (Digitizer FPGA). Such a paradigm is foreseen for intelligent autonomous systems in general, e.g. Industry 4.0.
- Attosecond XFELs are uniquely capable of interrogating multi-electron correlations in molecular systems. This project enables the identification and data handling decisions by real-time recovery of the x-ray pulse shape for attosecond resolution for streaming pulse characterization.

6. CHANGES/PROBLEMS:
- MCP depletion at a hit rate of 50 electrons/shot. Mitigation plan is 1) smaller pore diameter MCPs, 2) upgraded Digitizer FPGA to accommodate under-sampling , and 3) neural network architectures robust to Poisson noise.

7. BUDGETARY INFORMATION:
- Total project budget received: 640K; Estimated total cost with updated quotes 639.5K
- Committed/spent 23K labor, 106.5 M&S
- SLAC LCLS/AD has contributed initial testing MCP assemblies
- PCDS has contributed an initial "base" digitizer model
- LCLS contribution: 30% FTE Coffee, 50% FTE Gatton, 50% FTE Driver, 20% FTE Quijano
- Banting fellowship: 50% FTE Corebeil-Therrien