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Cooperative Research and Development Agreement Final Report,

CRADA TC02367

December 11, 2023

Brian Giera, Automated Dimensional Metrology Tools for 4+ DOF Measurement Systems

Innovations and Partnerships Office

Prepared by LLNL under Contract DE-AC52-07NA27344.

Automated Dimensional Metrology Tools for 4+ DOF Measurement Systems

Cooperative Research and Development Agreement Final Report
CRADA No. TC02367
Date Technical Work Ended: October 2022

December 11, 2023

A. Parties

This project was a relationship between Lawrence Livermore National Security, LLC and Aerotech, Inc.

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This proposed CRADA project was sponsored by LLNL's LDRD Exploratory Research (ER) Project entitled "Autonomous Multimodal Manufacturing Optimization," Tracking Code LDRD 20-ERD-036. Funding for the project began in October 2020 and was expected to continue through September 30, 2022.

	FY21		FY22		Totals
Funding Type	Funds-in	*In-kind	Funds-in	*In-kind	
Aerotech, Inc.	0	$99,000	0	$99,000	$198,000
Dept. of Energy Tracking Code LDRD 20-ERD-036	$60,000		$60,000		$120,000
Totals	$159,000		$159,000		$318,000
**Federal Administrative Charge (FAC)	n/a		n/a		n/a

B. Project Scope

This was a collaborative effort between Lawrence Livermore National Security, LLC ("LLNS"), as manager and operator of Lawrence Livermore National Laboratory ("LLNL") and Aerotech, Inc. ("Aerotech or Participant"), to develop automated procedures for 4+ degree of freedom motion platforms.

The project was originally designated as a thirty (30) month project, and consisted of two (2) major tasks and the following three (3) major deliverables:

	TASK	DELIVERABLE	RESPONSIBILITY	DUE
1	Setup repository of modular source code	Modular and adaptable code base for automated inspection.	LLNL/Participant	Month 18
2	Demonstrate automated inspection	Two demonstration videos showing automated inspection on ES19286-1 platform that uses at least 4 degrees of freedom.	LLNL/Participant	Month 30
3	Final Report	Final Report	LLNL/Participant	Due at the completion or termination of the project

All of the deliverables for this project were successfully completed on time.

There were no amendments or no-cost time extensions associated with this project.

C. Technical Accomplishments

The specific technical accomplishments were development and demonstration of a modular and adaptable code base for automated inspection with greater than 3-axes of motion. The following milestone chart details the project delivery schedule. No major problems were encountered that resulted in departure from the planned methodology. Rather, a larger impact footprint was achieved from these results than anticipated. For instance, though we committed to demonstrating these capabilities on Aerotech's *ES19286-1* platform in the Advanced Manufacturing Laboratory, other Aerotech platforms (both 3- and 5-axis) machines benefited from the modernized code base developed as part of this work. Importantly, by taking the "object-oriented" approach defined in the proposal, we were able to change the paradigm in our coding approach from Aerotech control software with pythonic algorithmic calls, we created a python code base that executes Aerotech control sequences. In this way, we were able to incorporate additional inspection capabilities into this workflow, e.g. tool path adaptations, triggering different inspection/sensing capabilities, and databasing all associated data streams together.

The second deliverable – a demonstration of these capabilities – was presented in a publicly facing video on YouTube on this capability and how it enables digital twins at LLNL. The video has accumulated over 1400 views. (https://www.youtube.com/watch?v=_PtfxBuq6CE)

D. Expected Economic Impact

This effort enhanced U.S. competitiveness in advanced manufacturing by utilizing DOE-developed capabilities to provide automated metrology for higher order degree of freedom positioning systems.

D.1 Specific Benefits

Benefits to DOE
This work added to LLNL's Advanced Materials and Manufacturing core competency by automating manufacturing and inspection procedures.

Benefits to Industry

This CRADA used Aerotech's ES19286-1 system as a demonstrator system to develop automated procedures on platforms with 4+ degrees of freedom motion. While LLNL technically could execute this on a variety of motion platforms, this system's unique kinematic configuration was one of several factors that make it ideally suited to this effort. Firstly, this system is already on site in the Advanced Manufacturing Laboratory that was familiar to LLNL researchers. Since it is capable of 8-axis motion, LLNL was able to take a systematic approach to developing automated capabilities, for instance, by introducing additional degrees of motion, i.e. complexity, as needed. The CRADA's aim was to jointly develop automated metrology capabilities for higher order degree of freedom positioning systems, based on Aerotech's existing code for 2+D metrology and LLNL's efforts in autonomous generation of higher order motion profiles. Since 'plug-and-play' options are not available for all sensing modalities for this CRADA work, we had to create integration options that are not native to ES19286-1.

E. Participant Contribution

While this CRADA was no-cost-in by Aerotech, the work was performed on the *ES19286-1* positioning system, which was already on loan to LLNL in the Advanced Manufacturing Laboratory and is capable of 8-axis motion. Both parties contributed complementary expertise and capabilities for this CRADA. Aerotech's considerable experience in precision motion systems and developing motion profiles and toolpath codes for controlling these systems will be leveraged using *ES19286-1* as a demonstrator. No inventions were created during the CRADA project.

F. Documents/Reference List

Reports
No additional reports were created.

Copyright Activity
No externally released software was created by this project.

Subject Inventions
No subject inventions disclosed by either the industrial participant or LLNS.