RX15-15

1. **Research Title:** Full-Field Real Time Strain Measurement and Control using FPGA-based Image Correlation for Materials Behavior Characterization
2. **Individual Sponsor:** List the AFRL research topic sponsor's contact information

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3. **Academic Area/Field and Education Level**

Electrical Engineering/Computer Engineering /Computer Science, Mechanical Engineering, Materials Science and Engineering or equivalent (BA/BS, MS, PhD level)

4. **Objectives:** The objective of this effort is to develop a non-contacting full field real time strain measurement and control method to understand the cyclic fatigue behavior of materials for aerospace applications in realistic service environments. The critical portion of this work will be to identify a way to efficiently and accurately process the digital images in order to monitor the evolution of strain during the entire fatigue life of the material. Additionally, the ability to conduct experiments in strain control would identify differences in the material cyclic fatigue behavior based on loading modes. A more comprehensive understanding of how strain evolves during cyclic fatigue loading provides more insight and understanding of how materials will respond in actual service environments.
5. **Description:** In order to predict the behavior and life of a material one must first understand how it responds in its service environment. For most aerospace applications, cyclic fatigue loading is a critical factor in designing and lifing structural components [1]. Over the past several years, Digital Image Correlation (DIC) methods have been used to monitor damage accumulation due to cyclic fatigue loading in different materials [2]. DIC is a non-contact, full-field method that directly measures the displacement field by comparing an image of a deformed surface to the same surface in an un-deformed state [3]. Once the displacements are measured, the strain is calculated. Typically, the DIC displacement and strain analysis is obtained postmortem due to the fact that a large number of sub-images require a large computational effort. However, there have been recent advances in DIC methods to perform quasi real time strain measurements using sub-sampling principles to record images using a sampling period that is slightly larger than the period of the cyclic load signal [4] [5]. In this case, only a fraction of the cyclic fatigue response is being recorded. In order to capture the response from each fatigue cycle and conduct experiments in strain control, a true real time measurement capability is needed. Preliminary work has been conducted to determine the feasibility of field programmable gate arrays (FPGA) for real time image correlation [6]. DIC uses pattern matching optimization criteria such as cross-correlation which requires a large amount of multiply-accumulation operations with little control logic; FPGAs are well suited for this type of application. FPGAs have demonstrated a reduction in correlation computation time by more than two orders of magnitude with respect to a personal computer without a loss of accuracy [6]. However, there has been little work done to determine the FPGA architecture needed for real time cyclic fatigue

damage characterization. The optimization of the entire FPGA based DIC system will be critical to be able to conduct experiments in realistic service environments (ie. elevated temperatures).

References:

[1] T. H. Courtney, Mechanical Behavior of Materials, Boston: McGraw-Hill, 2000.

[2] J. Carroll, Relating Fatigue Crack Growth to Microstucture via Multiscale Digital Image Correlation, Urbana-Champaign: University of Illinois, 2011.

[3] M. A. Sutton, J.-J. Orteu and H. W. Schreier, Image Correlation for Shape, Motion and Deformation Measurements: Basic Concepts, Theory and Application, New York: Springer, 2009.

[4] S. Giancane, F. Panella, R. Nobile and V. Dattoma, "Fatigue Damage of Fiber Reinforced Composites with Digital Image Correlation Analysis," *Procedia Engineering,* vol. 2, pp. 1307-1315, 2010.

[5] S. Vanlanduit, J. Vanherzeele, R. Longo and Guillaume, "A Digital Image Correlation Method for Fatigue Test Experiments," *Optics and Lasers in Engineering,* vol. 47, pp. 371-378, 2009.

[6] A. Lindoso and L. Entrena, "High Performance FPGA-based Image Correlation," *Journal of Real-Time Image Processing,* vol. 2, pp. 223-233, 2007.

6. **Research Classification/Restrictions:** This research is unclassified.
7. **Eligible Research Institutions:** Indicate to what organizations this topic should be provided

[redacted] **DAGSI** (Wright State University, AFIT, Ohio State University, University of Dayton, Miami University, Ohio University, University of Cincinnati) NOTE: Topics submitted to DAGSI must be approved for public release. **Need PA Approval #**

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