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# Final Report

## Instrumentation to Characterize Smart Materials and Composites

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Instrumentation was purchased through this DURIP grant to carry out experiments on shape memory alloys and smart composite structures. The ultimate objective is to develop reliable constitutive models for these advanced materials. This will involve careful characterization of the individual constituents, for which there may be severe complicating factors, such as strong thermal-mechanical coupling, anisotropic behavior, complex failure mechanisms, and material instabilities. Once this is accomplished, we intend to design and manufacture novel composites that have useful and unique thermo-mechanical properties suitable for aerospace applications.

The equipment listed in Table 1 was purchased at a total cost of approximately \$441,000 (\$311,000 from AFOSR and \$130,000 from U of Michigan cost sharing). This equipment complements existing load frames (uniaxial electro-mechanical, custom-built planar multi-axial, and tension-torsion machines), an environmental chamber, a custom-built specimen bath, and state-of-the-art optical equipment. The instrumentation has facilitated three research projects, all of which have been supported to various extents by the DOD. The first project consists of ongoing research to characterize the very complex constitutive behavior of a shape memory alloy, Nickel-Titanium (or Nitinol) through accurate measurements of the mechanical behavior under various thermal conditions. The second project consists of ongoing work on the failure mechanisms and constitutive characterization of polymer matrix composites under compression and other multi-axial loadings. The third project is a new research program to manufacture and characterize smart composites with NiTi constituents. This will be done with an eye toward innovative applications, such as damage tolerant materials and smart structures.

The purchased equipment serves the needs of three general areas: thermal characterization, mechanical characterization, and high speed/high resolution deformation monitoring. The thermal equipment includes an infrared thermal imaging system (Inframetrics ThermaCam SC1000 infrared radiometer system) to measure nonuniform temperature fields, and a differential scanning calorimeter (Perkin Elmer Pyris I DSC) to measure latent heats, heat capacities and transformation temperatures of NiTi and polymeric materials. The mechanical equipment includes a dynamic mechanical analyzer (Perkin Elmer DMA 7e) to measure moduli and thermal expansion with temperature, a low-force fiber testing machine (constructed in-house) for

mechanical testing of fine wires, and a servo-pneumatic tension-torsion machine (EnduraTec Biaxial tester) for multiaxial stress state characterization. The imaging equipment includes a high resolution imaging camera (Princeton-Instruments 1.3M pixel digital imaging system), a high speed imaging camera (Kodak 1000HRC 1000 frame/sec video system), and a workstation computer (Hewlett-Packard C240 workstation) for image analysis and modeling. These camera systems are needed to monitor rapidly evolving deformation fields associated with the inherent material instabilities in these material systems. A speckle and moiré interferometry setup was also constructed in-house to enable full-field deformation monitoring of specimens under thermo-mechanical loading. Various data acquisition equipment and signal conditioning modules were purchased to allow real time monitoring of extensometers, load cells, thermocouples, etc. Labview software was installed on new Apple Macintosh G3 computers to enable the development of custom data acquisition software and post processing of experimental results. Overall, this equipment provides a natural complement to existing experimental facilities, especially in the form of new capabilities to measure thermal phenomena, dynamic events, and accurate data for the constitutive characterization of microstructures. This equipment is currently in active use by the investigators. The data acquisition equipment and the thermal imaging system has also been used by professors in other departments (Prof. A. Namaan in Civil/Environ. Engin. and Prof. Burns in Chemical Engin.) and at industrial sites for material characterization (Tenneco Automotive).

Item Description	Approx. Cost
Infrared Thermal Imaging System	\$80 K
Differential Scanning Calorimeter & Dynamic Mechanical Analyzer Systems	\$81 K
Low Force Biaxial & Fiber Mechanical Testing Machines	\$48 K
High-speed Video Camera System & High-Resolution Digital Camera System	\$103 K
Data Acquisition Equipment & Imaging Analysis Computer Systems	\$83 K
Moiré & Speckle Interferometry Measurement System	\$46 K
<b>Grand Total</b>	<b>\$441 K</b>

**Table 1: List of Purchased Equipment**