To date, the commercial use of shape memory alloys (SMAs) has been mostly limited to binary NiTi alloys with transformation temperatures approximately in the -100 to 100 °C range. In an ongoing effort to develop high-temperature shape memory alloys (HTSMAs), ternary and quaternary additions are being made to binary NiTi to form NiTi-X (e.g., X: Pd, Pt, Au and Hf) alloys. Stability and repeatability can be further increased at these higher temperatures by limiting the stress, but the tradeoff is reduced work output and stroke. However, HTSMAs operating at decreased stresses can still be used effectively in actuator applications that require large strokes when used in the form of springs. The overall objective of this work is to facilitate the development of HTSMAs for use as high-force actuators in active/adaptive aerospace structures.

A modular test setup was assembled with the objective of acquiring stroke, stress, temperature, and moment data in real time during joule heating and forced convective cooling of Ni19.5Ti50.5Pd25Pt5 HTSMA springs. The spring actuators were evaluated under both monotonic axial loading and thermomechanical cycling. The role of rotational constraints (i.e., by restricting rotation or allowing for free rotation at the ends of the springs) on stroke performance was also assessed. Recognizing that evolution in the material microstructure results in changes in geometry and vice versa in HTSMA springs, the objective of the present study also included assessing the contributions from the material microstructural evolution, by eliminating contributions from changes in geometry, to overall HTSMA spring performance. The finite element method (FEM) was used to support the analytical analyses and provided further insight into the behavior and heterogeneous stress states that exist in these spring actuators.

Furthermore, with the goal of improving dimensional stability there is a need to better understand the microstructural evolution in HTSMAs that contributes to irrecoverable strains. Towards this goal, available Ni29.5Ti50.5Pd20 neutron diffraction data (from a comparable HTMSA alloy without the solid solution strengthening offered by the Pt addition) were analyzed. The data was obtained from in situ neutron diffraction experiments performed on Ni29.5Ti50.5Pd20 during compressive loading while heating/cooling, using the Spectrometer for Materials Research at Temperature and Stress (SMARTS) at Los Alamos National Laboratory. Specifically, in this work emphasis was placed on neutron diffraction data analysis via Rietveld refinement and capturing the texture evolution through inverse pole figures. Such analyses provided quantitative information on the evolution of lattice strain, phase volume fraction (including retained martensite that exists above the austenite finish temperature) and texture (martensite variant reorientation and detwinning) under temperature and stress.

Financial support for this work from NASA's Fundamental Aeronautics Program Supersonics Project (NNX08AB51A), Subsonic Fixed Wing Program (NNX11AI57A) and the Florida Center for Advanced Aero-Propulsion (FCAAP) is gratefully acknowledged. It benefited additionally from the use of the Lujan Neutron Scattering Center at Los Alamos National Laboratory, which is funded by the Office of Basic Energy Sciences (Department of Energy) and is operated by Los Alamos National Security LLC under DOE Contract DE-AC52-06NA25396.
The public is welcome to attend.