**What is SMA Constitutive Model Calibration?**

SMA Constitutive Model Calibration, or Parameter Identification, describes the process of finding the set of model parameters (Martensite Start Temperature, Maximum transformation strain, etc.) that best fit material experimental data in the mode of operation relevant for the engineering component of interest (e.g., tension, compression, torsion, or a combination thereof). Mathematically, calibration is the process of minimizing error between constitutive model predictions and experimental data subject to physical constraints (conservation laws, known bounds for material properties, etc.) by varying model parameters.

**Why is model calibration important?**

An appropriately calibrated constitutive model is essential for design of complex systems with SMAs. The inherent thermomechanical coupling present in SMAs makes it important to understand how the SMA component will behave when installed in the system and subject to relevant loading conditions. Understanding the strain recovery behavior of SMAs, especially in the presence of minor loops, is crucial to designing the entirety of the engineering component. The inherent complexity of Shape Memory Alloys is an opportunity to design more space- and weight-efficient assemblies, but a challenge to accurately design these systems to perform as intended. Furthermore, even though not addressed in this work, the fatigue life and cyclic behavior (including the possibility of transformation-induced plasticity) must be designed with the component lifecycle in mind. For many applications, selecting a particular SMA component based on transformation temperature and maximum transformation strain is insufficient; the transformation temperatures and actuation strain *in the operating stress regime* must be well characterized and predictable. Constitutive model calibration is a vital link for designing and validating SMA performance.

**How have people performed model calibration in the past?**

Historically, SMA model calibration has been performed analytically, based on analysts’ best-guesses of appropriate properties, and via numerical optimization. Closed-form analytical results/expressions can be derived for simple models (e.g., cite cite cite) when a deterministic amount of data is available. However, when the operating range of the SMA spans many stress regions and requires many (>3) experimental tests, these analytical methods become overdetermined. Commonly, an appropriate calibrated model is determined based on rules of thumb and guess-and-check methods that rely on analysts’ intuition and many manual iterations. More recently, many groups have adopted numerical optimization to find the combination of model parameters that best fit experimental data. These approaches help to speed the process, but exist as purpose-built codes and are themselves steeped in institutitional knowledge that is difficult to transfer from analyst to analyst.

**What are the drawbacks of these methods?**

Most existing calibration methods, while sufficient to produce an adequate fit, have limited applicability outside the authors’ specific application or research group. The rules of thumb and tribal knowledge required to produce a consistent and accurate calibration lead to difficulties reproducing similar calibrations on different material systems, and the required effort for new analysts to learn the “tricks of the trade” limits the effectiveness and transferability of these methods.

**What are the trends in SMA design?**

Recently, significant momentum towards standardizing SMA test methods and exploring the full composition – processing – property space has collected/been undertaken/can be seen. There exist robust tools to graphically interpret the relationship between composition, processing, and material properties, developed and maintained by NASA Glenn. Automated extraction of ASTM standard properties can be performed via an open source GUI. However, despite many tools for model calibration of standard and even superelastic SMA constitutive models available in open-source and commercial software, no such analog exists for SMA actuation models.

**Thesis statement**

In this work, we describe a new open-source GUI for constitutive model calibration of SMA actuators. We hope to provide a vital link between materials scientists and SMA design engineers via an accessible software, written in python but requiring no programming experience. We focus on the temperature-driven Lagoudas 1-D constitutive model, but the methods and accompanying software described herein can be easily extended to consider other constitutive models, higher dimensional models (e.g., 3D models with anisotropic effects), and different loading modes (e.g., superelasticity).