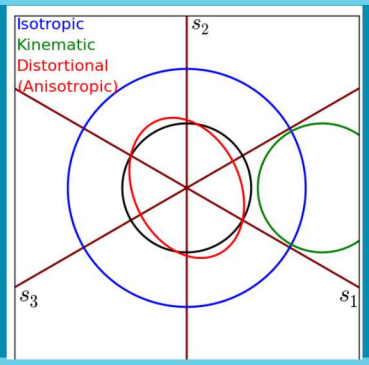
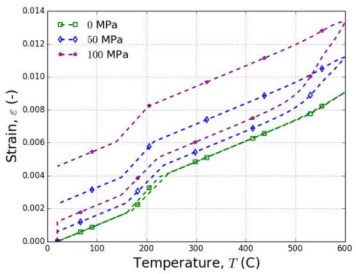
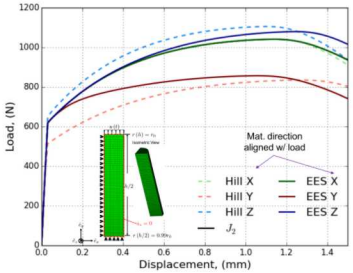
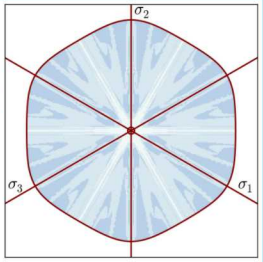
SAND2019-14750PE

Library of Advanced Materials for Engineering (LAMÉ): Introduction and Overview









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DRAFT

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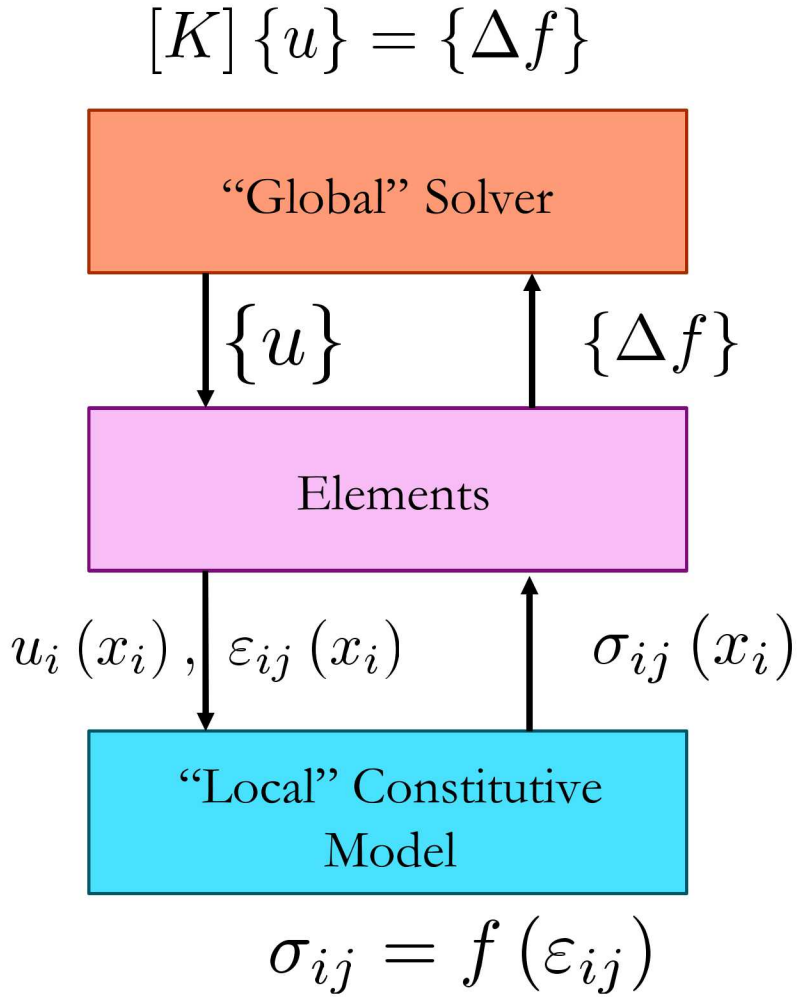
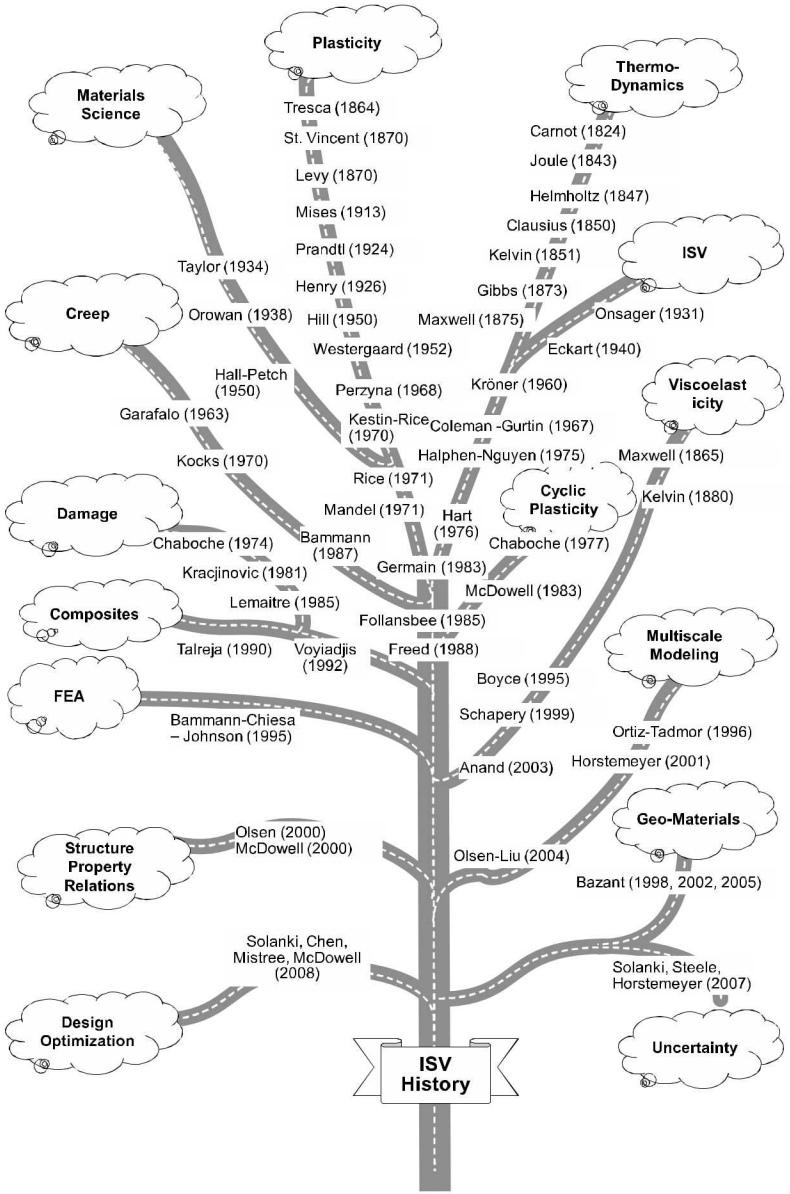
Constitutive Modeling

- "A constitutive equation demonstrates a relation between two physical quantities that is specific to a material or substance and does not follow directly from physical laws" (J. Fish, 2014, *Practical Multiscaling*, Wiley)

- Essential for the solution of structural boundary value problems
  - Provide mathematical closure
  - Introduce material physics



Constitutive Modeling Utilization

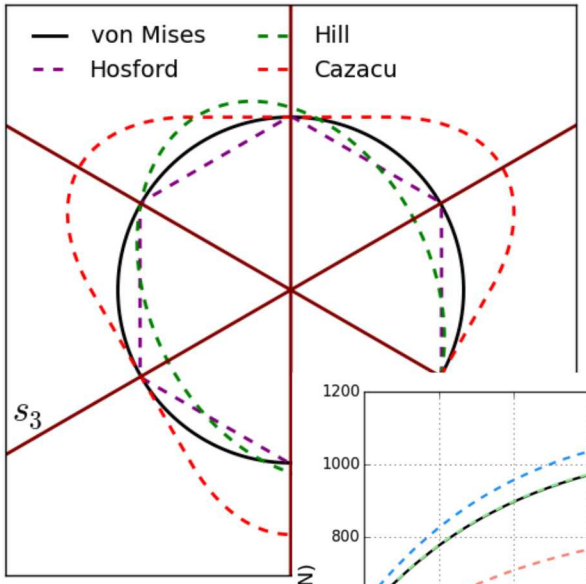


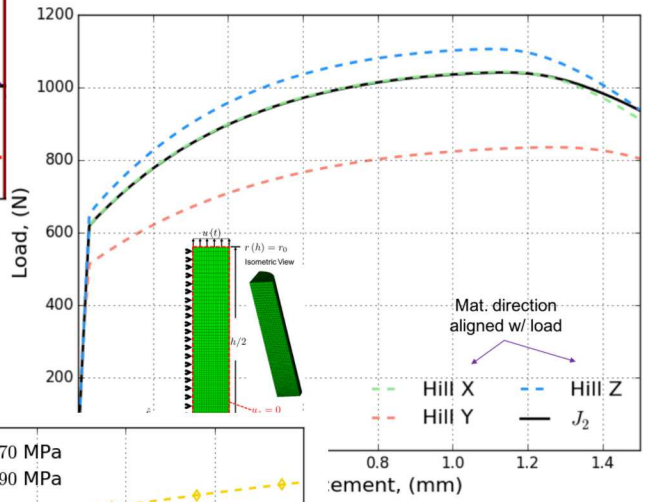
- Structural analyses require vastly different responses
  - Large range of deformation mechanisms
  - Dynamic and quasistatic
- Addressing needs requires
  - Flexible descriptions
  - Appropriate implementations
- "Library of Advanced Materials for Engineering" (LAMÉ)
  - Constitutive modeling library
  - Used w/ Sierra/SolidMechanics FE code

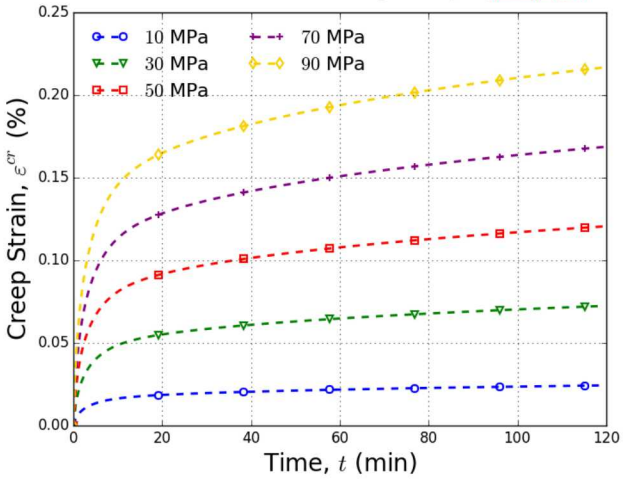
Horstmeyer and Bammann, 2010, *Int. Jrnl. Plas.*, 26: 1310--1334

Constitutive Models

- LAMÉ first started ~15 yrs ago
- Capabilities both for **production** and **research/development** models
- Support efforts span:
  - Creating
  - Coding
  - Verification
  - Documenting





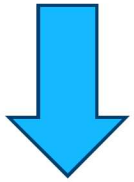


Model Creation

- Identify existing or create new models to address needs
  - Focus on continuum, phenomenological models
  - Span a variety of different descriptions

Free Energy Description

$$G\left(\sigma_{ij}, T, t, \xi, \varepsilon_{ij}^{\mathrm{t}}; \delta^{i}\right) = G^{\mathrm{te}}\left(\sigma_{ij}, T, \xi; \delta^{i}\right) + G^{\mathrm{in}}\left(\sigma_{ij}, T, t, \xi, \varepsilon_{ij}^{\mathrm{t}}\right)$$



Constitutive Expression

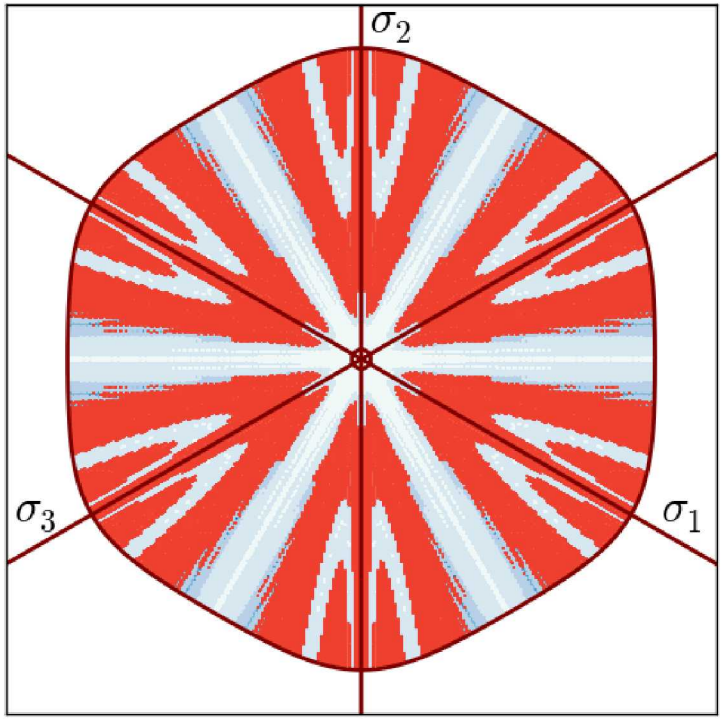
$$\varepsilon_{ij} = \frac{1}{2\bar{\mu}\left(\xi\right)}\sigma_{ij}' + \frac{1}{9\bar{K}\left(\xi\right)}\sigma_{kk}\delta_{ij} + g_{\varepsilon}\varepsilon_{ij}^{\mathrm{t}} + \bar{\alpha}\left(\xi\right)\left(T - T_{0}\right)\delta_{ij}$$

$$g_{v}\frac{\Delta\mu}{2\mu^{\mathrm{eq}}\mu^{\mathrm{g}}}H_{ij}^{2} - g_{v}\frac{\Delta K}{9K^{\mathrm{eq}}K^{\mathrm{g}}}H^{1}\delta_{ij} + g_{v}\Delta\alpha H^{3}\delta_{ij}$$

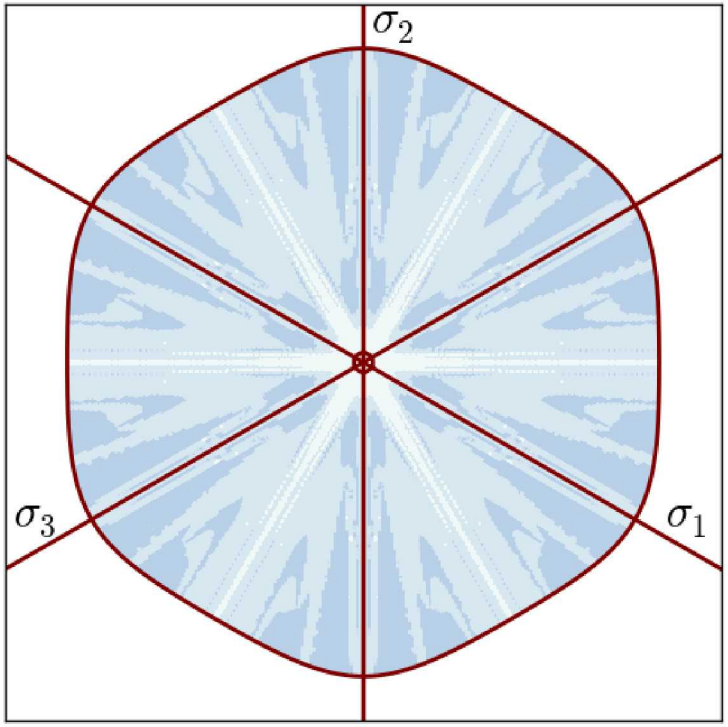
Model Coding

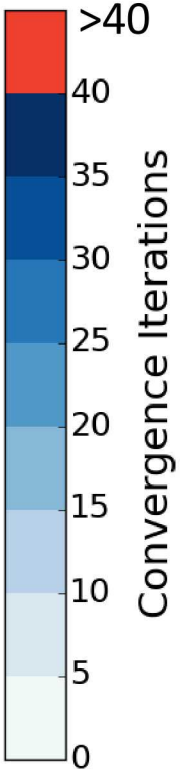
- Identify/come-up with novel integration schemes for different models
  - Robustness
  - Accuracy
  - Speed

Traditional Newton-Raphson



Trust-Region Based Approach

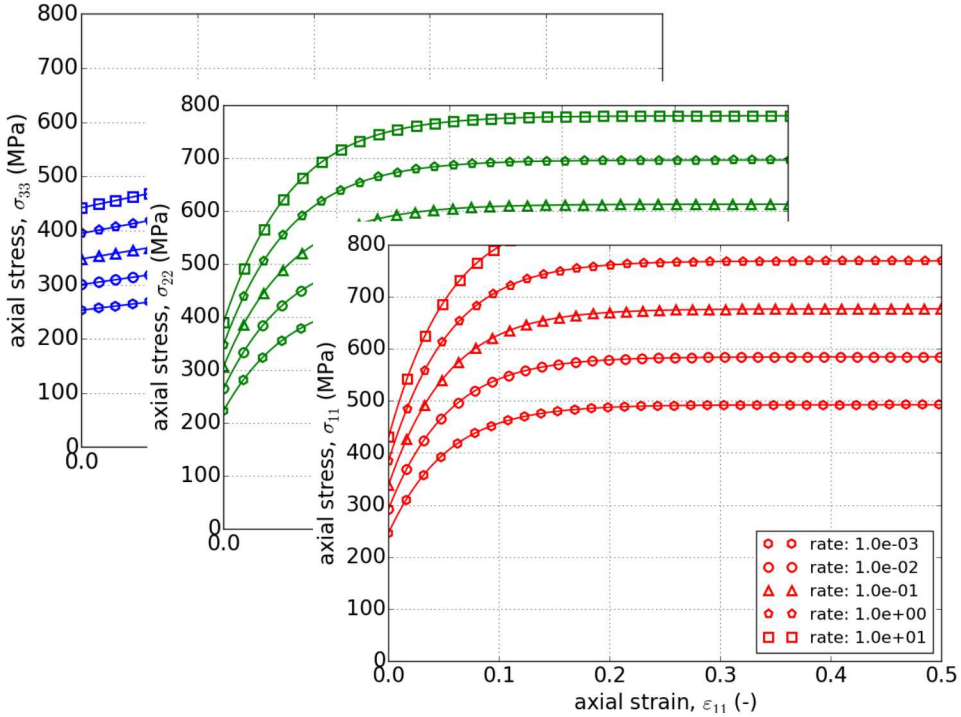




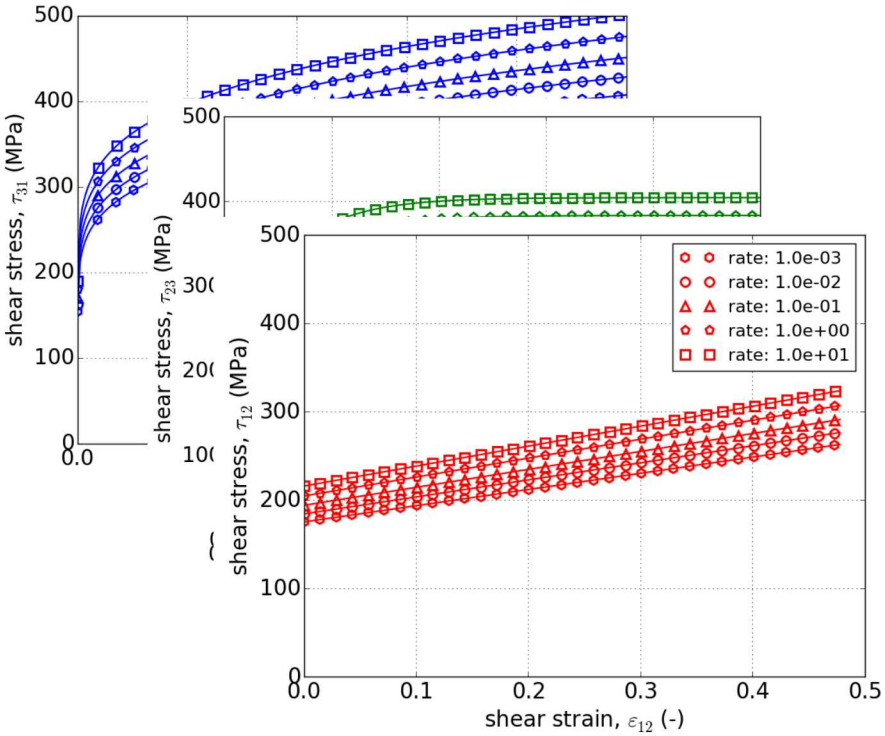
Model Testing

- LAMÉ Models subject to automated testing
  - Done regularly to ensure consistent, correct responses
  - Unit and regression testing
  - Preference for analytical tests

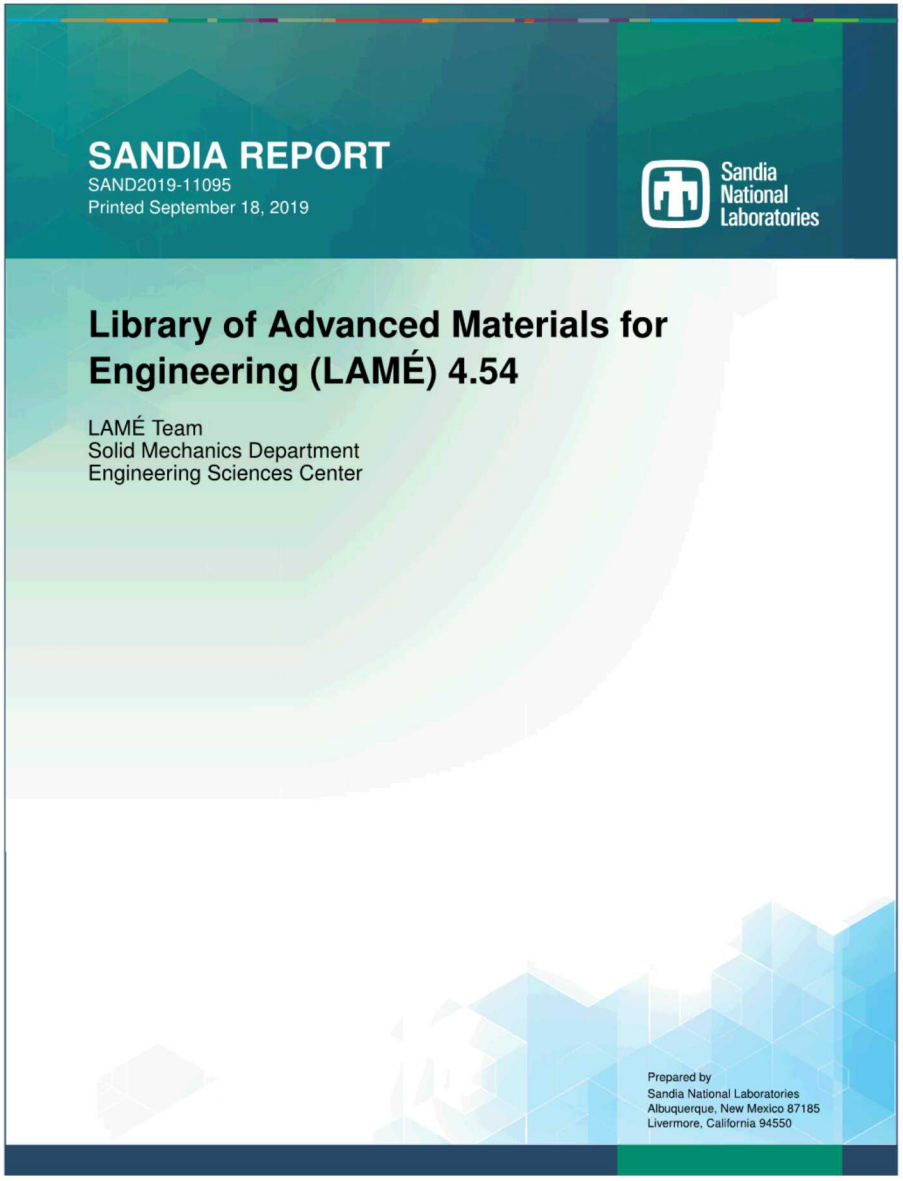
Uniaxial – Barlat (Yld2004-18p)



Pure Shear - Hill



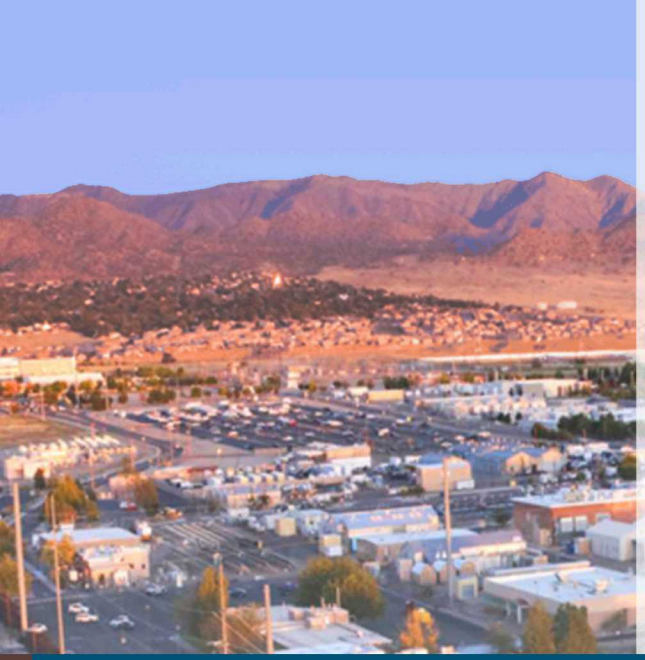
Model Documentation



- Documentation of models essential for adoption/utilization
- LAMÉ Manual provides details on model theory, implementation, and user guide
- Importantly LAMÉ Manual also documents series of verification tests for different models

Acknowledgements

- Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis. Any subjective views or opinions do not necessarily represent the views of the U.S. Department of Energy or the United States Government.



Questions?