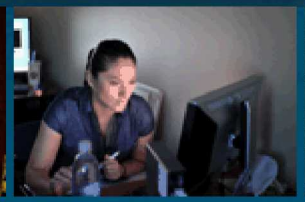
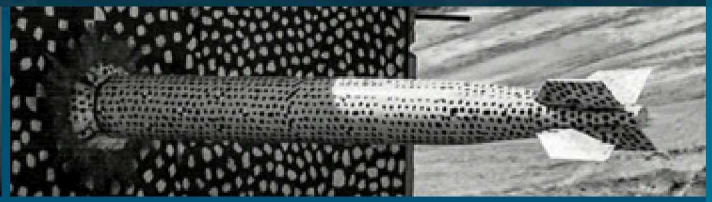
SAND2019-2381PE

Simplified and Reduced Order Models





PRESENTED BY

Adam R. Brink, PhD

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Introduction

Youngstown State University
- Bachelor in Mechanical Engi

North Carolina State University
- Master of Science, Major in Mechanical Engineeri

University of Akron
- PhD in Mechanical Engineering
- Advisor: D. Dane Quinn
- Dissertation: Modeling Complex Contact Phenomena with Nonlinear Beamshells

Introduction

Goodyear Tire and Rubber Company
- Manufacturing Engineer
- Facilities Manager
- Senior Mechanical Engineer – Engineering Me

Babcock and Wilcox Company, Nuclear Operations Group
- Senior Mechanical Engineer

Sandia National Laboratories
- Senior Mechanical Engineer

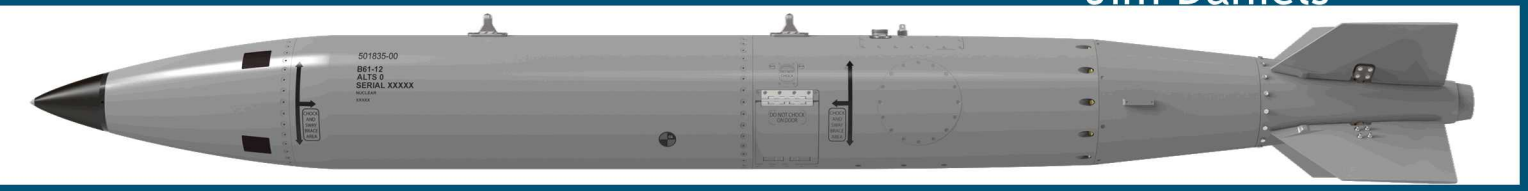
Sandia National Laboratories

https://www.youtube.com/watch?v=o1qAjLSEv0A

Engineering Sciences at Sandia National Labs

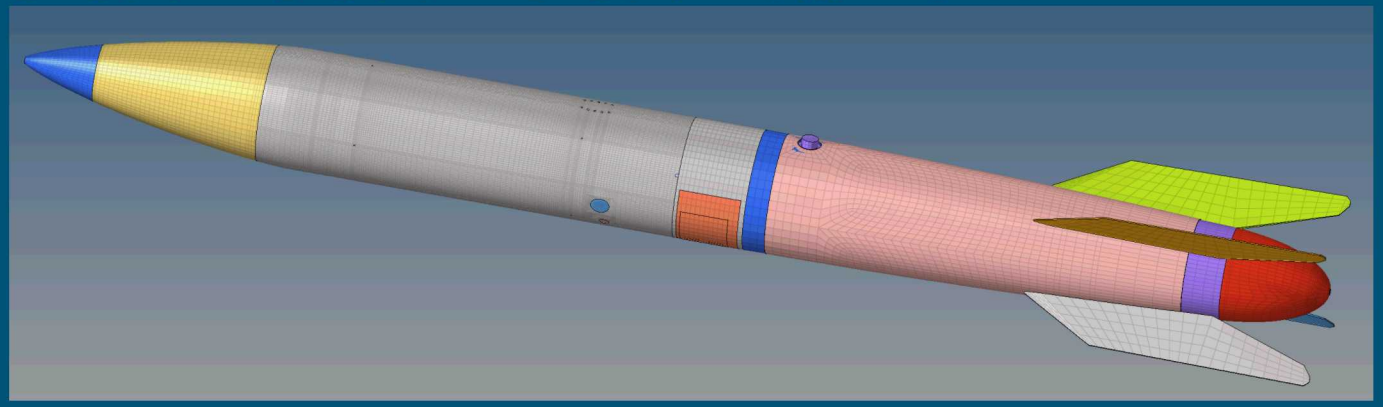
What is a model?

B61-12 CAD Rendering
Jim Daniels



CAD Model

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} + f_{nl} = f(t)$$



Numerical Model

B61 FE Model
Mike Ross

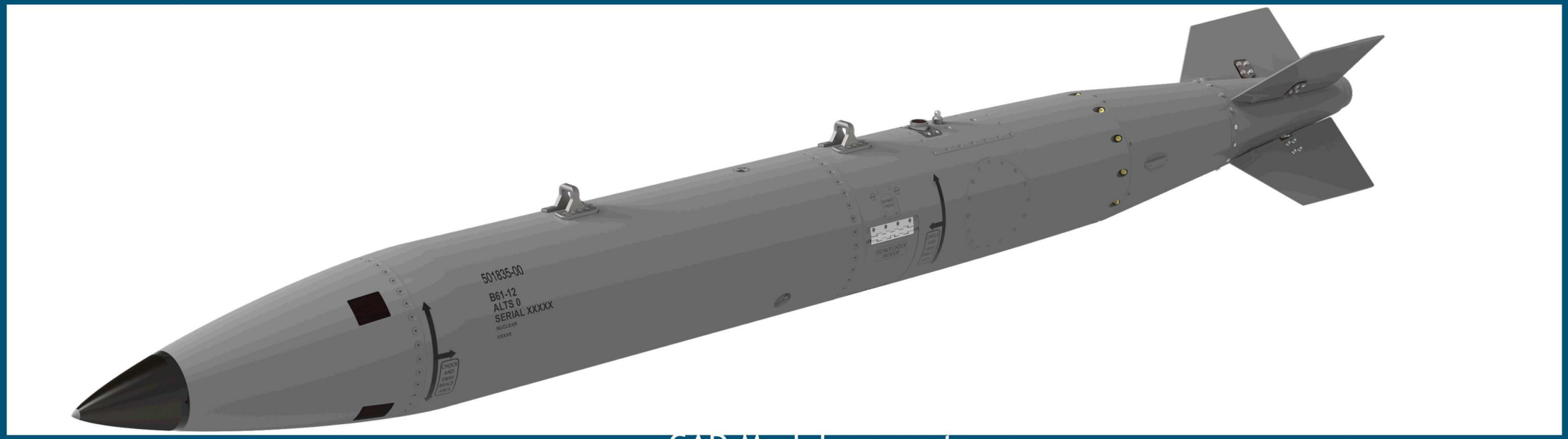
Male Model

Model Purpose – CAD Models

CAD Models can:

- Make designs visual.
-
-
-

B61-12 CAD Rendering
Jim Daniels



CAD Models cannot:

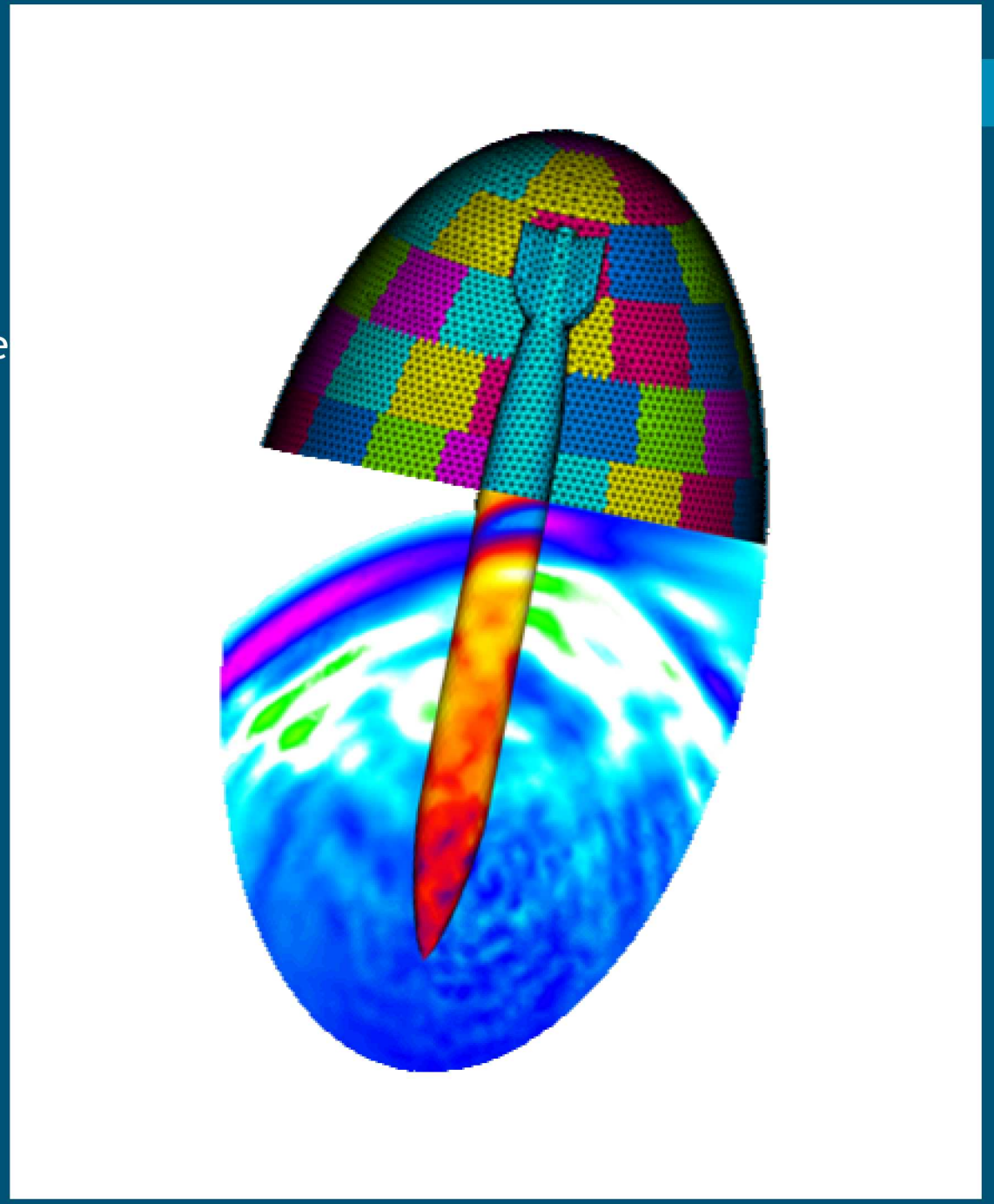
- Make predictions about response.
- Guarantee a good design.

Model Purpose – Numerical Models

Vibration and Dynamics models can:

- Derive loads and environments for components and syste
- Predict important frequency bands.
- Perform design trade studies.
- Qualify margins on existing designs.
- Noise, vibration and harshness predictions (comfort).
- Reduce cost and time of design cycles.

Through quantitative and qualitative analysis of the results, give a better understanding of the problem being studied!



Model Paradigms – High Fidelity

Typical Super Computer Cluster
80,784 compute cores
1.223 petaFLOP

High Fidelity Modeling:

- Extreme discretization of the geometry.
  - This captures the geometric features in fine detail.
- Precision Finite Element or Computational Fluid Dynamics code to solve Partial Differential Equations.

Advantages:

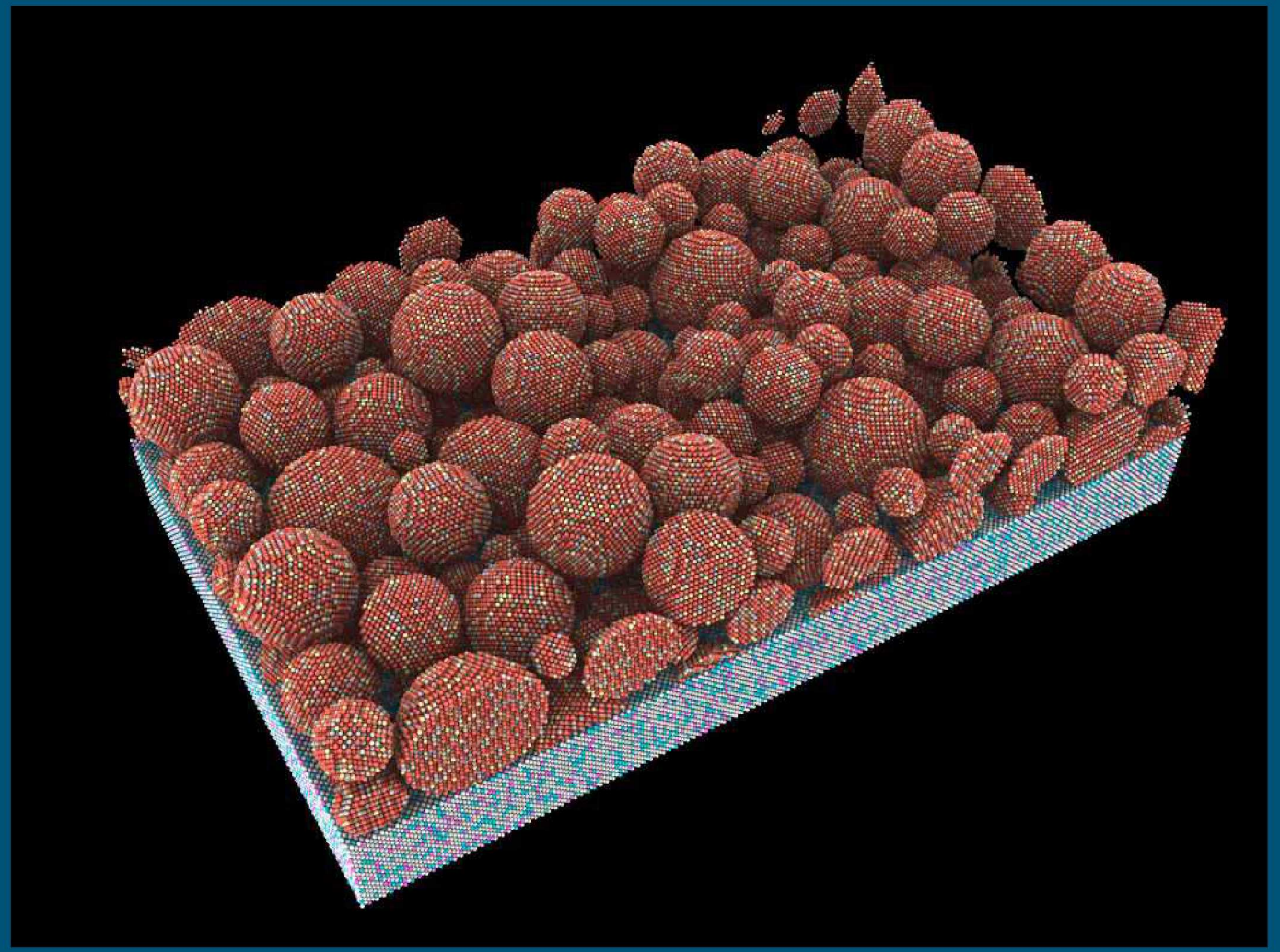
- Solver handles the physics.
- No thinking through geometric reductions.
- Can capture extremely complex physics.

Disadvantages:

- Requires huge computing resources.
- Problem size limits Uncertainty Quantification.
- Can take months to build models.
  - Limited flexibility.
- **Can be 100% absolutely dead wrong!**

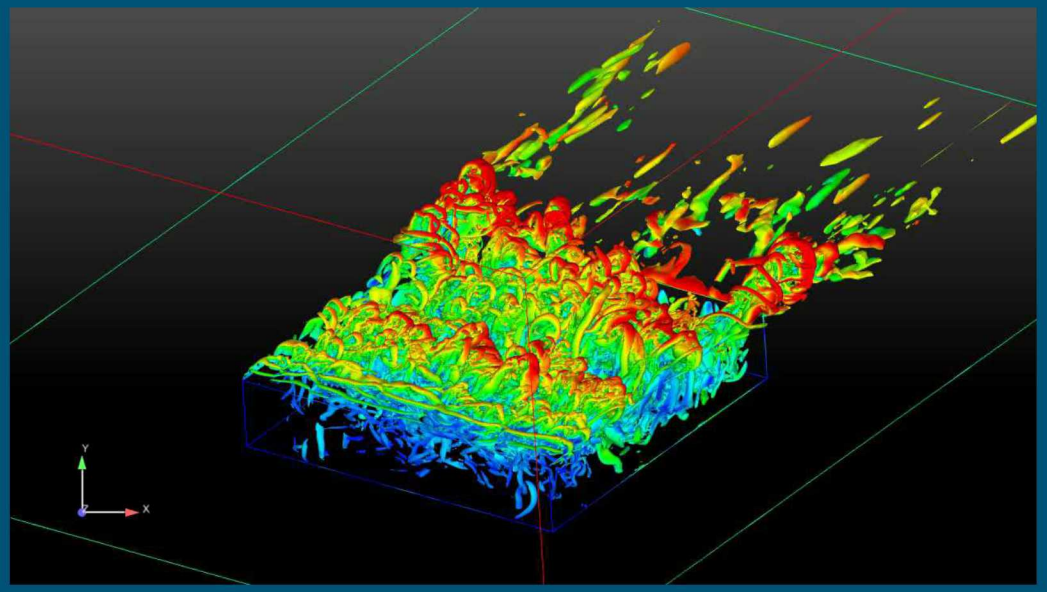
Model Paradigms – High Fidelity

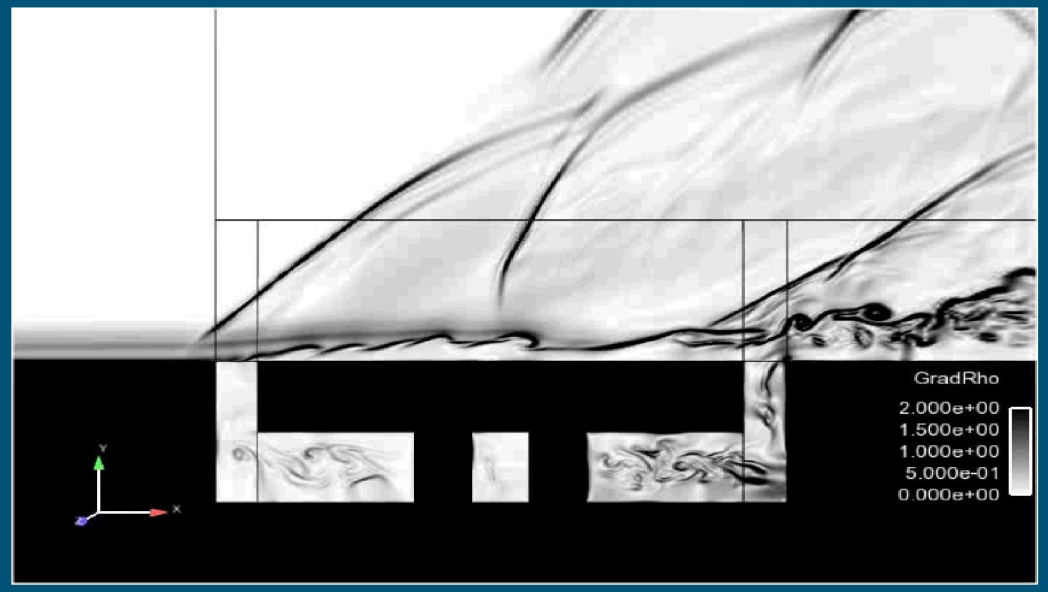
Fully atomistic representation of the additive manufacturing process of laser-powered-fusion in powderbed AM. The material is an approximation of 304L stainless steel (Fe,Cr,Ni). The laser is rastered across the nano-scale particles, melting them in the process. The movie shows the solidification after melting, along with the segregation of chromium (grey atoms) into localized regions.



Mark Wilson

Model Paradigms – High Fidelity





CFD visualization of vortices in a weapon storage bay.

Matt Barone, Srinivasan Arunajatesa, Mike Ross

Model Paradigm – Reduced Order Models

Mathematically reduces the order of the problem to make it less computationally expensive to solve.

ROMS can:

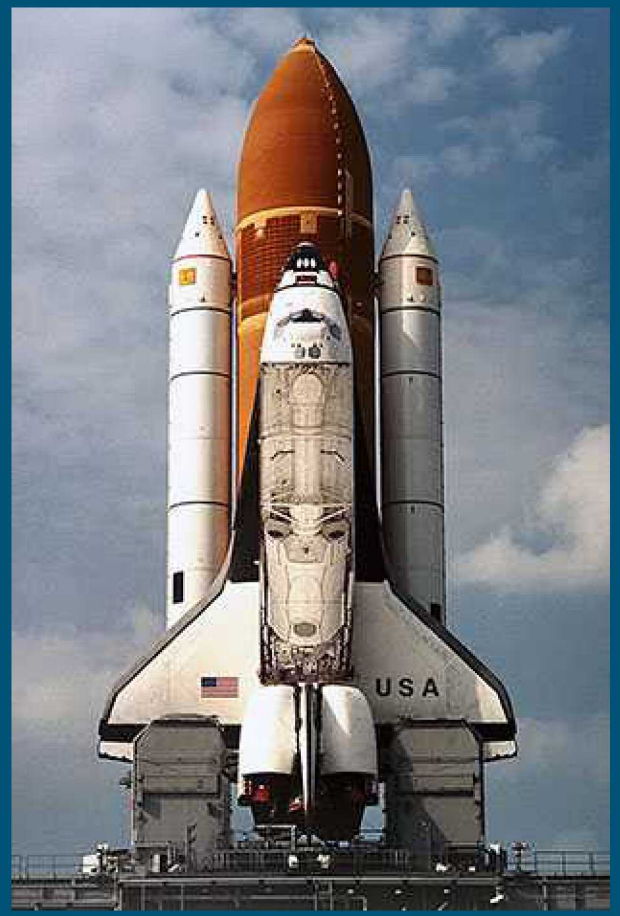
- Run with less computational power.
- Run more quickly.
- Preserve essential physics.
- Include nonlinearities.

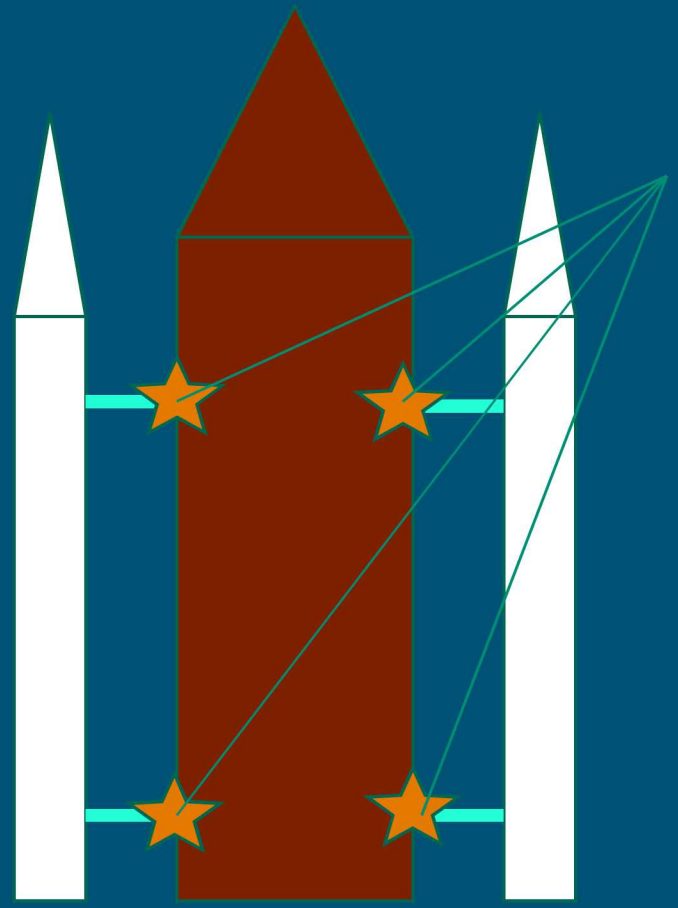
ROMS cannot:

- Be utilized without deeper knowledge of physics.
- Be used flexibly, kind of….

Model Paradigm – Reduced Order Models

Component Mode Synthesis (Hurty-Craig-Bampton)





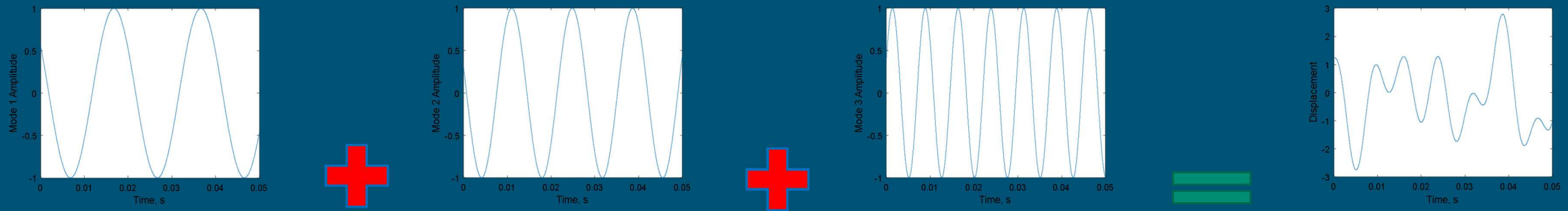
- Widely used since the 1970s.
- Reduces model down to its response at an interface.
- Static deflections supplemented by modal information.
- Great for model sharing as well.

Model Paradigm – Reduced Order Models

Linear Superposition

$$x(t) = \sum_{i=1}^{\hat{N}} \phi_i q_i(t)$$

- The most widely used model reduction technique for vibration analysis.
- Creates fast running models.
- Still expensive to calculate modes (only do it once though!)
- **Allows for a deeper understanding.**



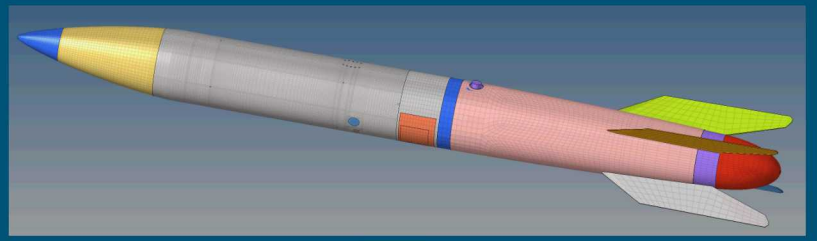
Model Paradigm – Simple Models

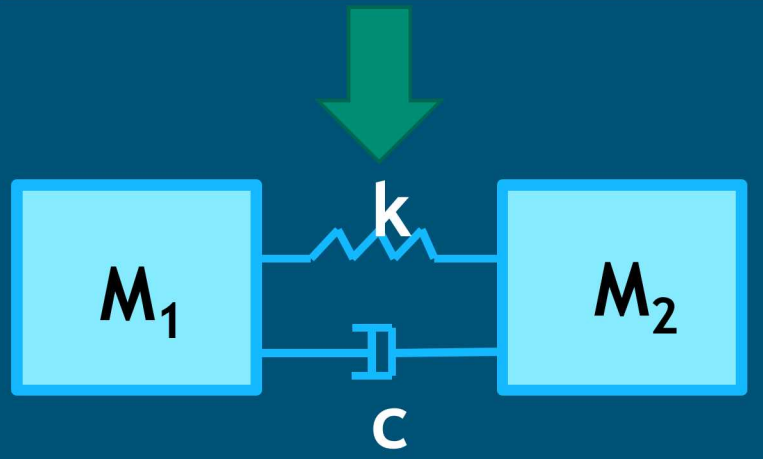
"Some of the most useful models I have worked with have consisted of several masses and springs"

-Adam R. Brink, PhD

Simple Models can:

- Run extremely fast.
- Include nonlinearities.
- Be analyzed with Python or Matlab.
- Give a better understanding of the problem.

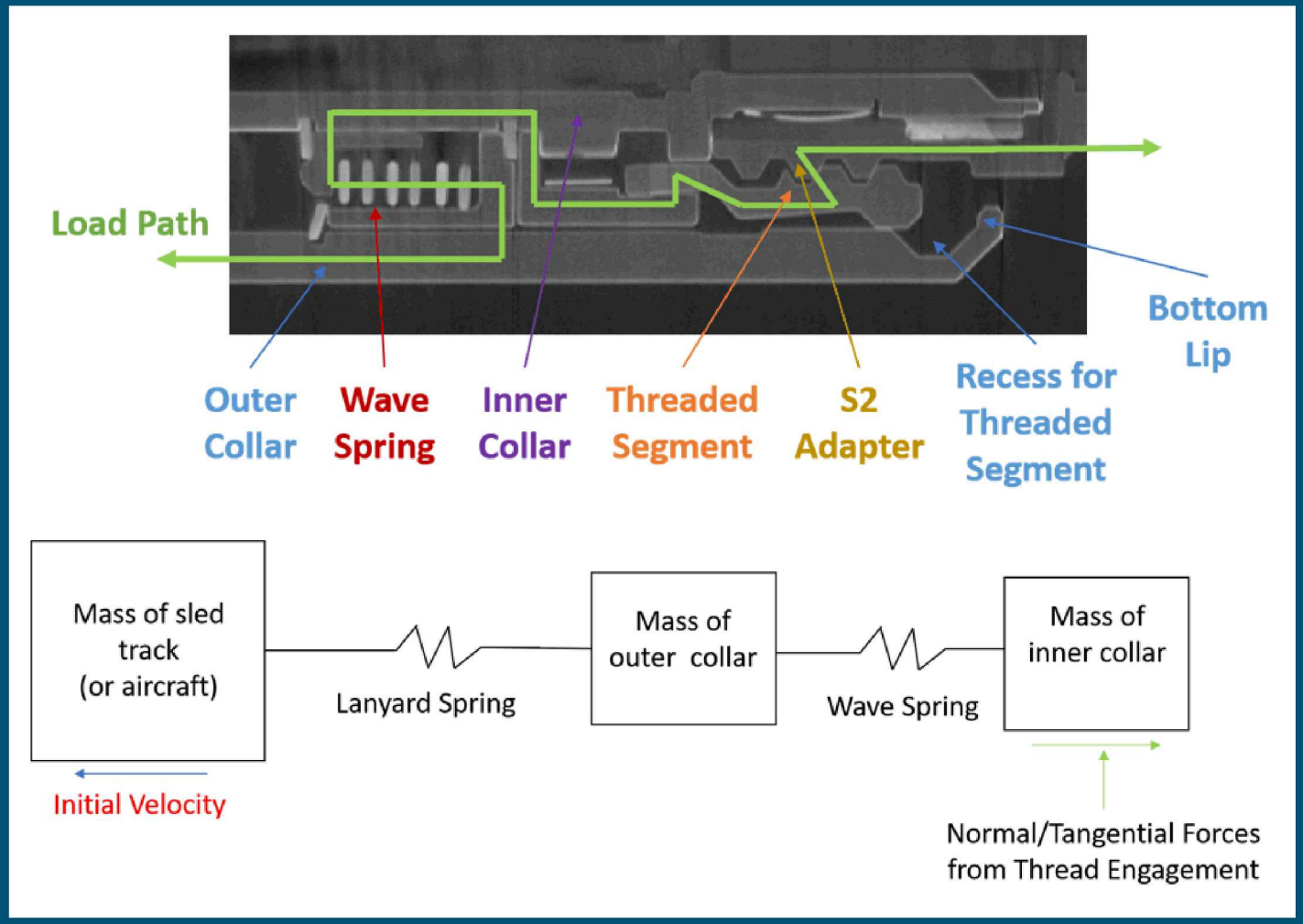


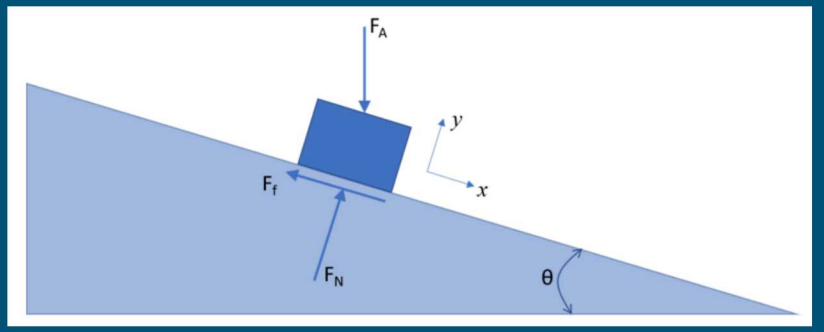


ROMS cannot:

- Give detailed stress information.
- Make awesome videos (sometimes).

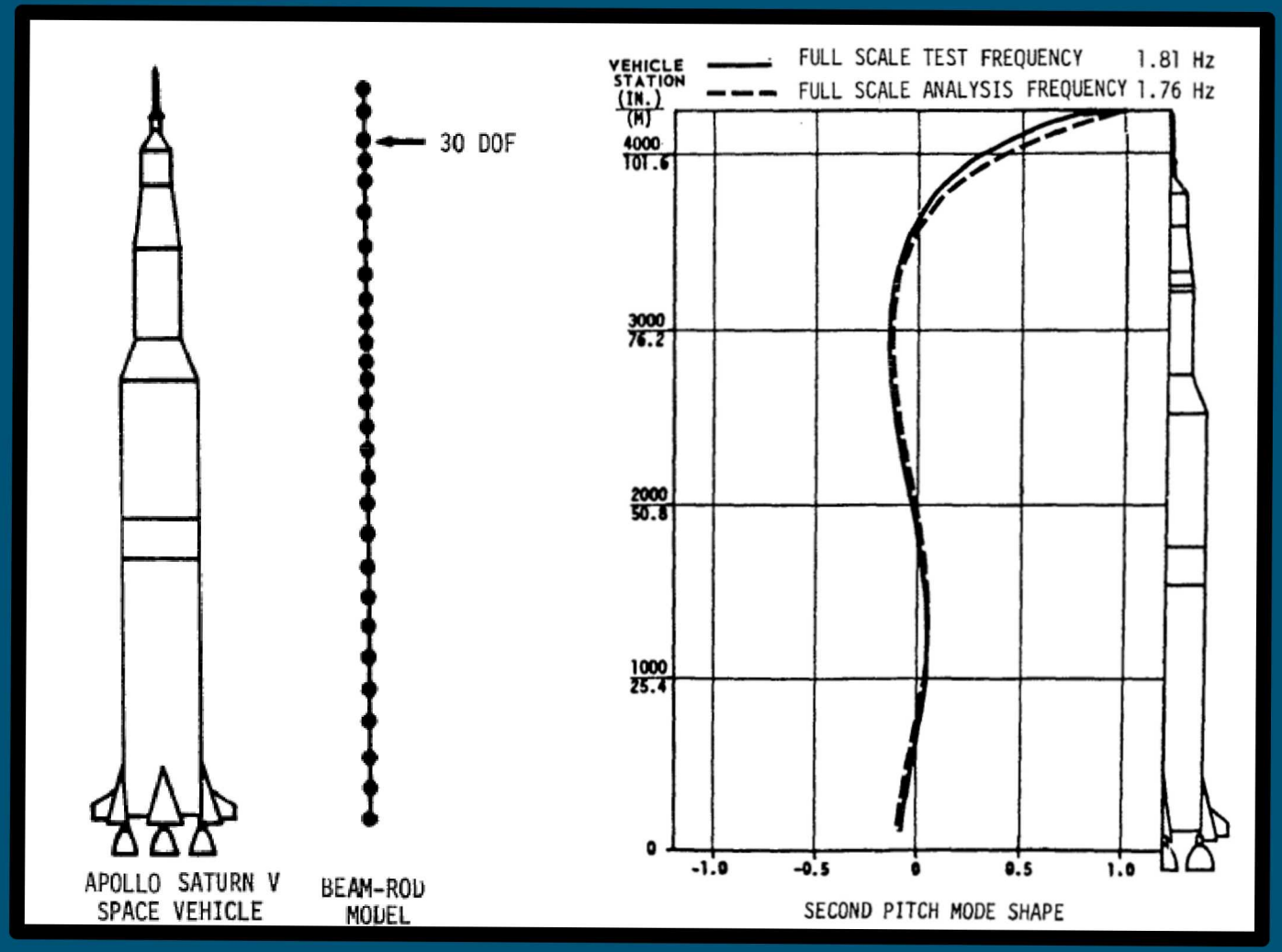
Model Paradigm – Simple Models





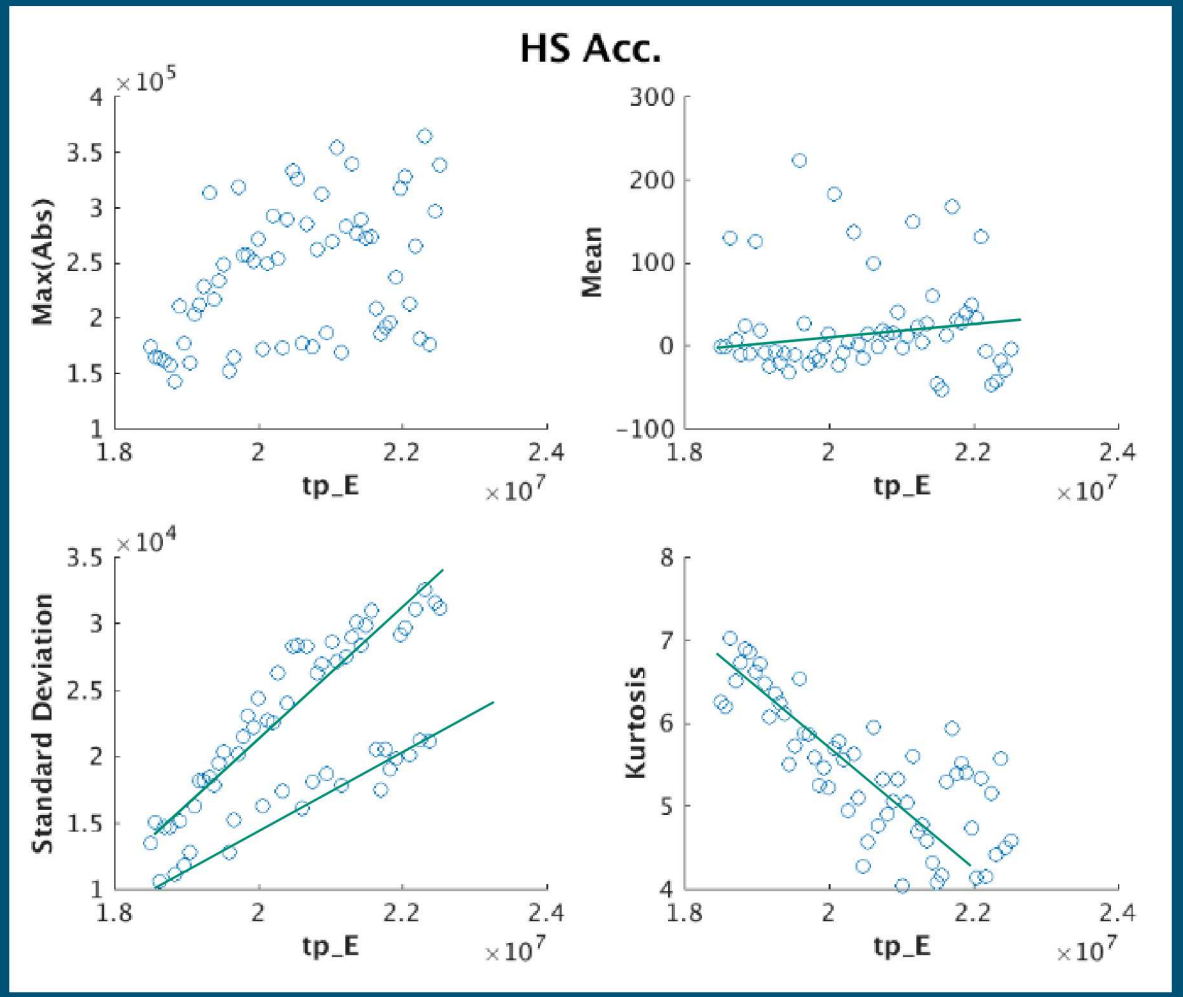
- A problem with a Commercial Off the Shelf connector for the B2 bomber was solved with 3 masses, two springs and an inclined plane.
- Simple model provided more insight than testing and high fidelity models.
- **Simple models solved the problem!**

Model Paradigm – Simple Models



Loads and dynamics model for the Saturn V rocket consisted of 30 Degrees of Freedom. This is the rocket used for the Apollo Missions.

Model Paradigm – Simple Models



UQ of system.
Adam R. Brink

- Extremely fast running models allow engineers to observe trends that wouldn't be apparent using high fidelity models.
- From a real life problem. Showed a bifurcated standard deviation trend, which could have been catastrophic.

Conclusions

Don’t forget the model’s main purpose is to gain understanding!

Highly detailed models are not always the best path and can be wrong!

Simple models, while difficult to create, often times uncover the most meaning.