

A Next-Generation Computational Platform for High-Precision Thermal, Structural, and Optical System Synthesis

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Outline

- Introduction and motivation
- Solution approach and resulting code architecture
- A brief tour of selected analytical capabilities
- Summary and discussion

Introduction

Motivation:

- Design and analysis of precision deployable structures such as Space Interferometry Mission (SIM), Terrestrial Planet Finder (TPF), Single Aperture Far-Infrared Observatory (SAFIR)
- Millikelvin-, picometer-levels of controllability
- Full-up ground testing of such structures is unlikely

Goals:

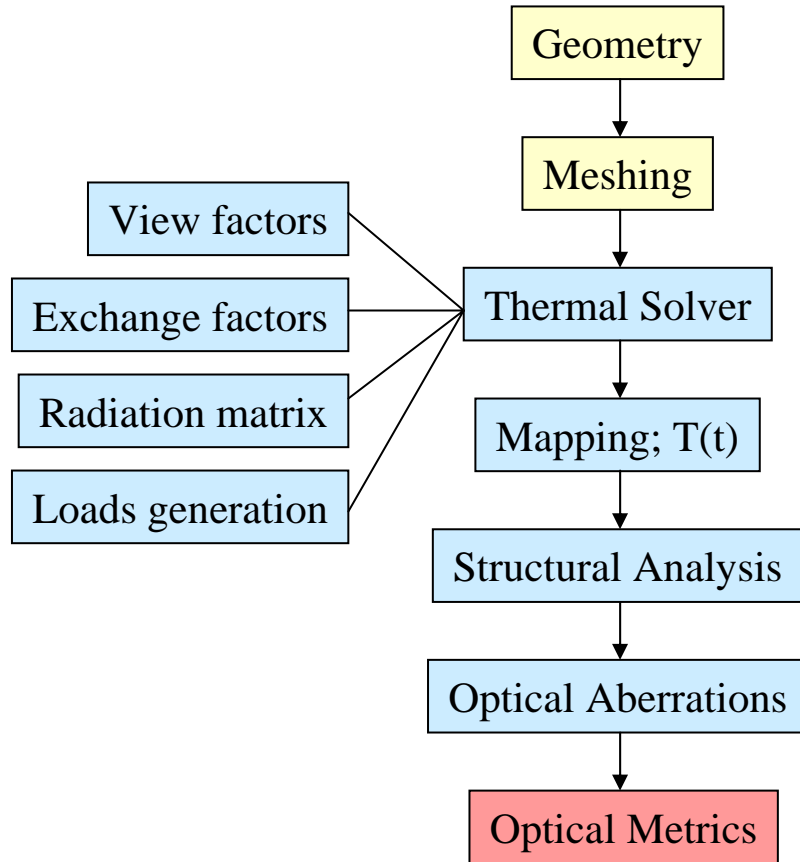
- Fundamentally integrated multidisciplinary analyses
- Extreme levels of fidelity, accuracy, precision
- High performance on serial machines, scalability to parallel architectures
- Ability to go beyond point designs; develop better understanding of design spaces

Additional Benefits:

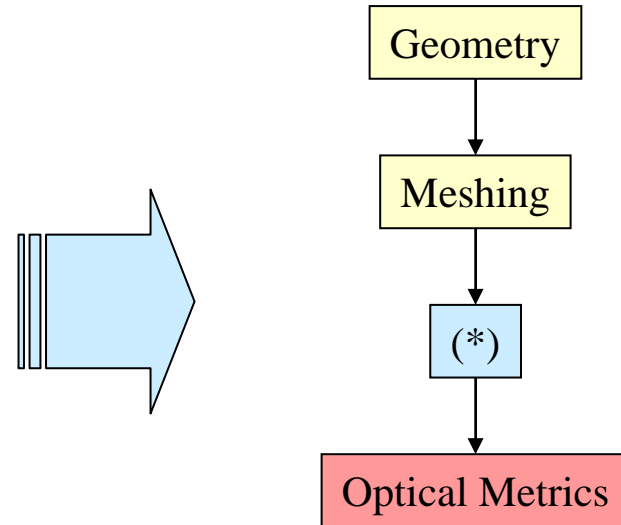
- Fully extensible by developers and analysts
- Fundamental integration with Matlab, Matlab toolboxes
- Process compatibility via Nastran input conventions

Solution Approach

“STOP” Analysis:



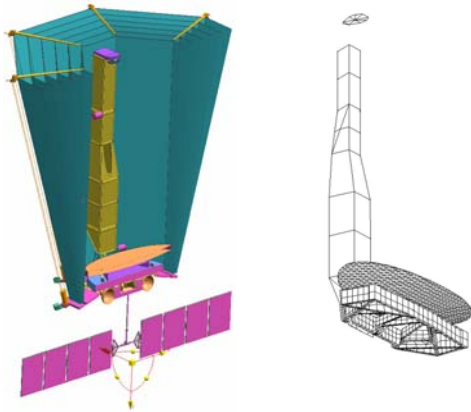
“Go” Analysis:



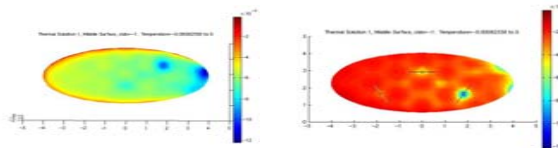
Systems Engineering Impact

Analysis-driven systems engineering and optimization design tool for precision deployable structures:

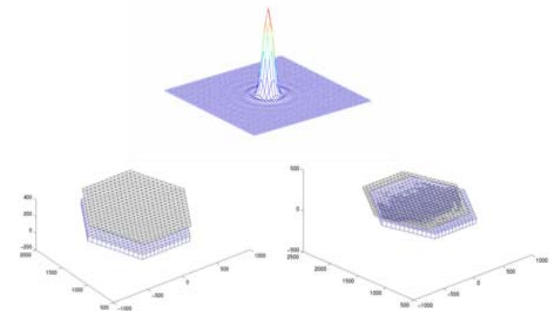
Integrated analysis capability facilitates development of detailed system-level model ...



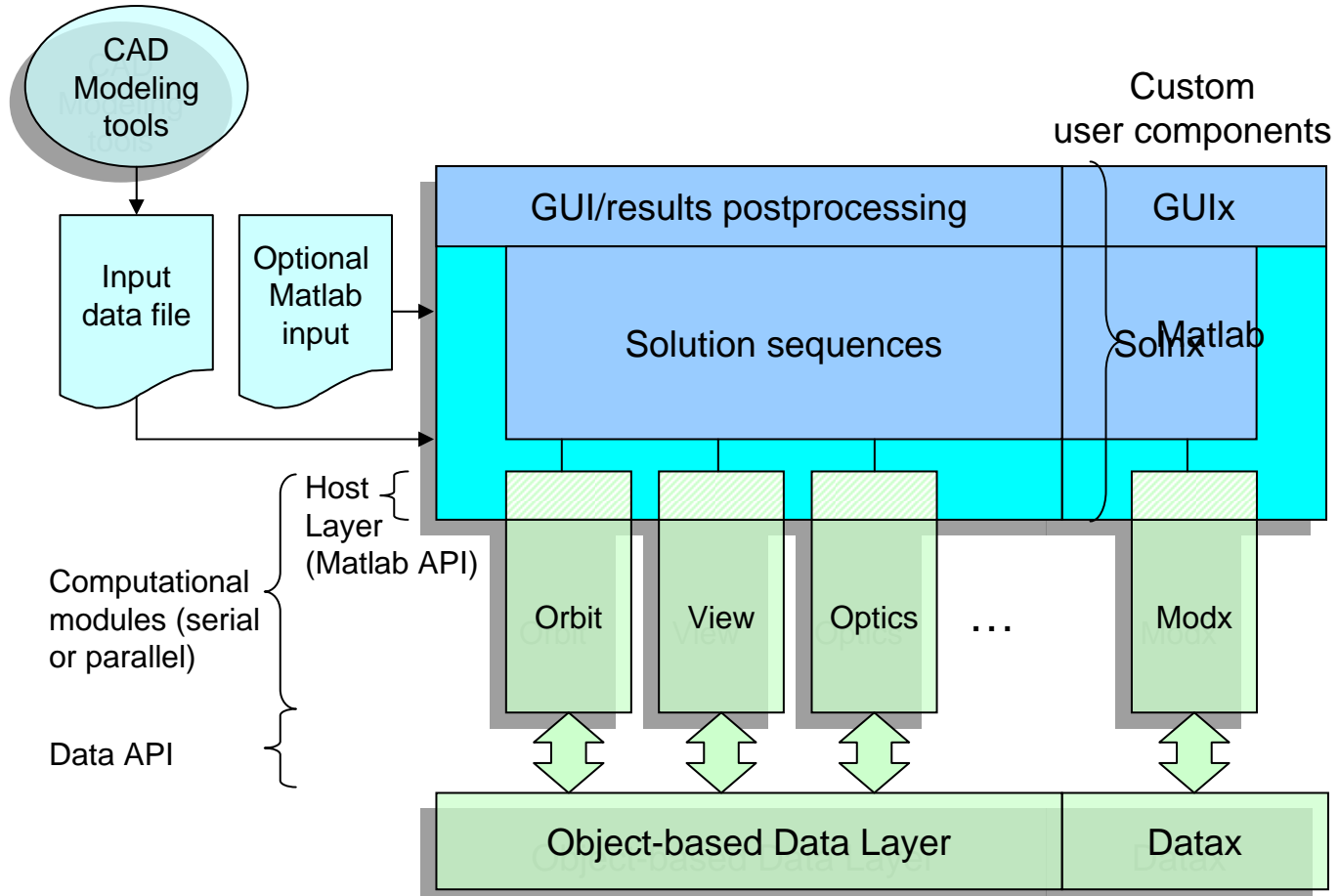
Propagates thermal, structural & dynamic effects down to optical elements and mounts ...



And computes aberrations from which optical merit functions & sensitivity matrices can be assessed and optimized...



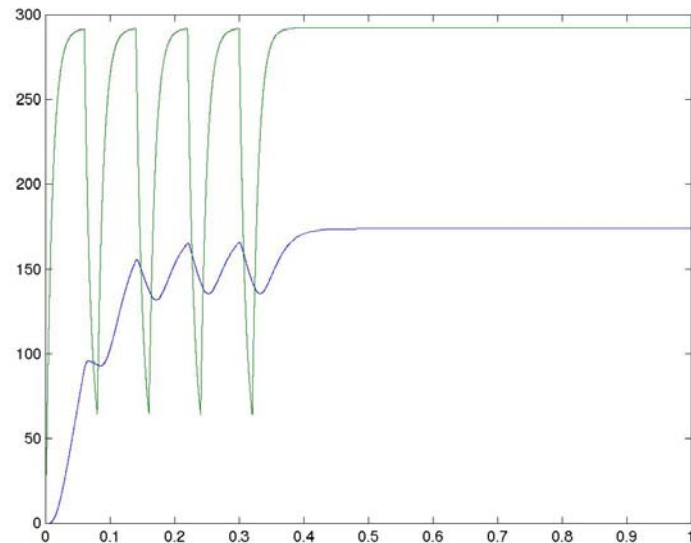
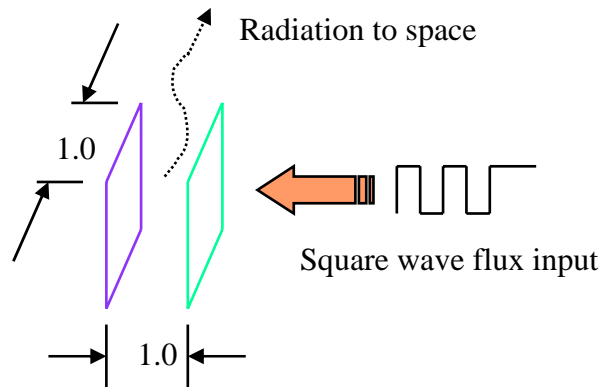
Code Architecture



Nonlinear Transient Heat Transfer

Matlab-hosted nonlinear heat transfer solutions feature:

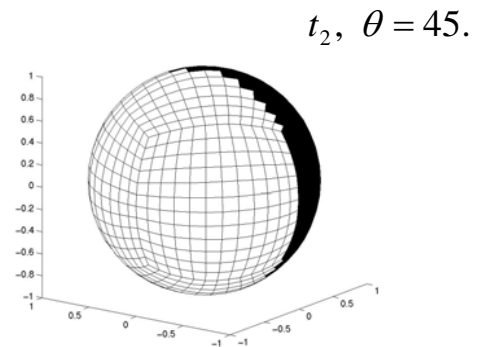
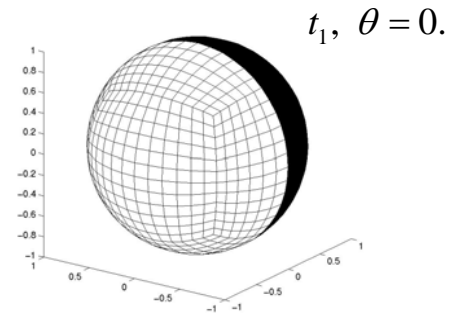
- Fixed/adaptive time stepping with bounds on time step, delta temperature
- Full/modified Newton, adaptive tangent matrix update strategies, implicit time integration
- Nonlinear iteration/convergence based on global behavior of temperature correction vector, residual, and heats of constraint / energy balance.



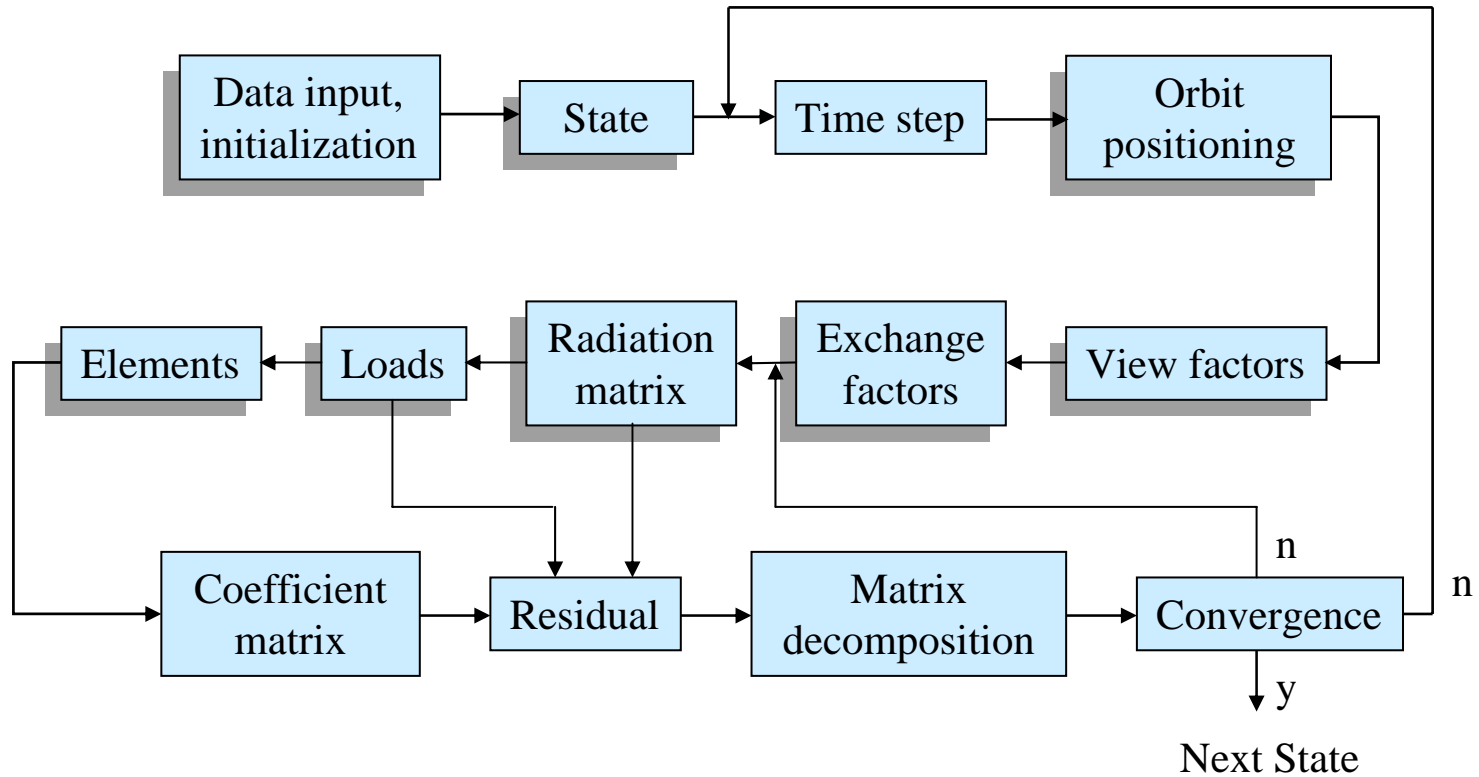


Nonlinear Transient Heat Transfer

- Vehicle orbit positioning
 - Implicitly-computed time-dependent loads from sun, planet(s) relative positions
- View factor calculation
 - Third-body shadowing, adaptive contour integration for highly-discretized models, very large number of exchange elements
 - Multicavity, with partial updates for time-dependent relative position changes
- Exchange Factors
 - Ray trace for specular surface character
 - Combines finite element model and analytic geometry when available
- Radiation matrix generation
 - Surface effects, exchange relationships expressed in finite element basis



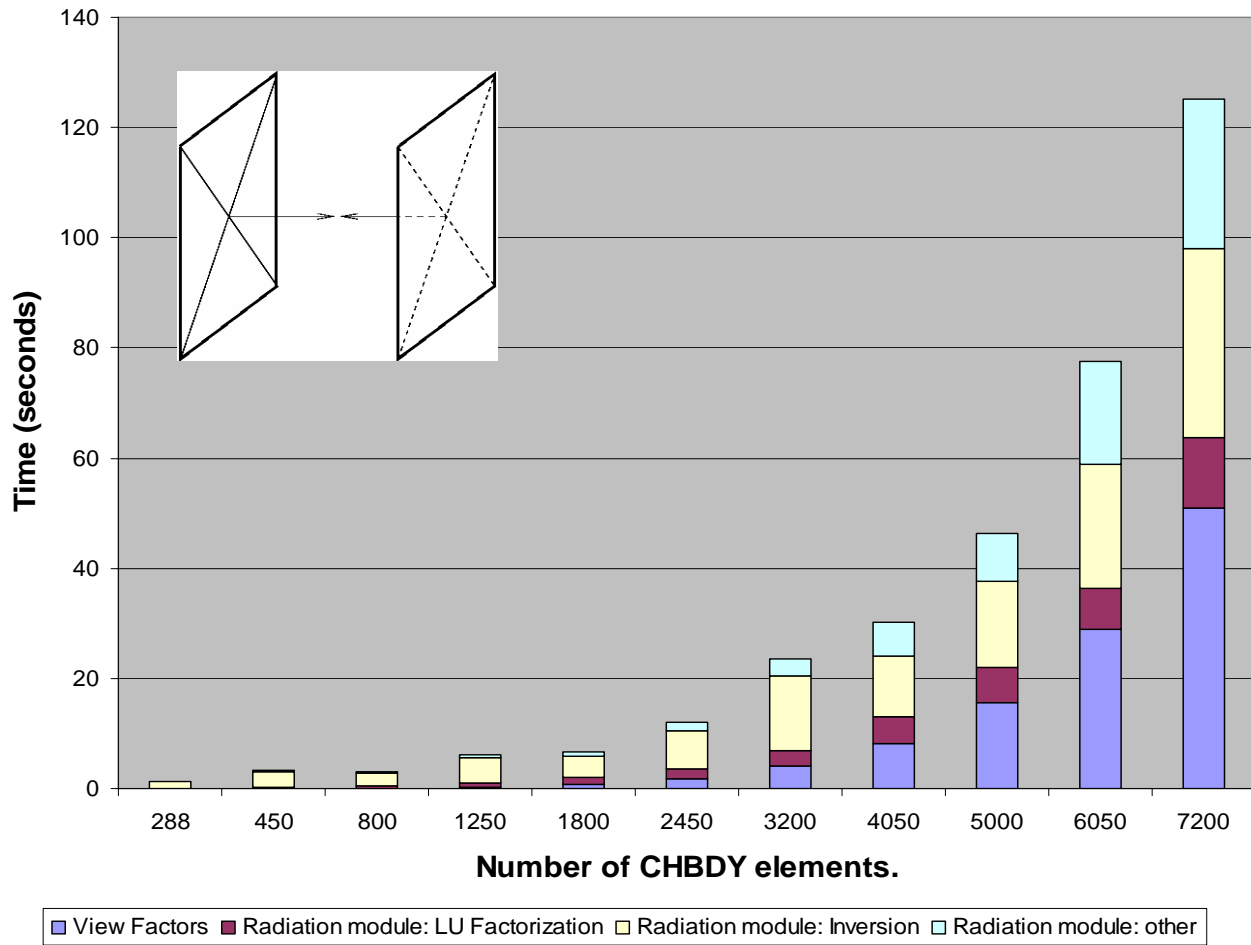
Thermal Solution Data Flow:



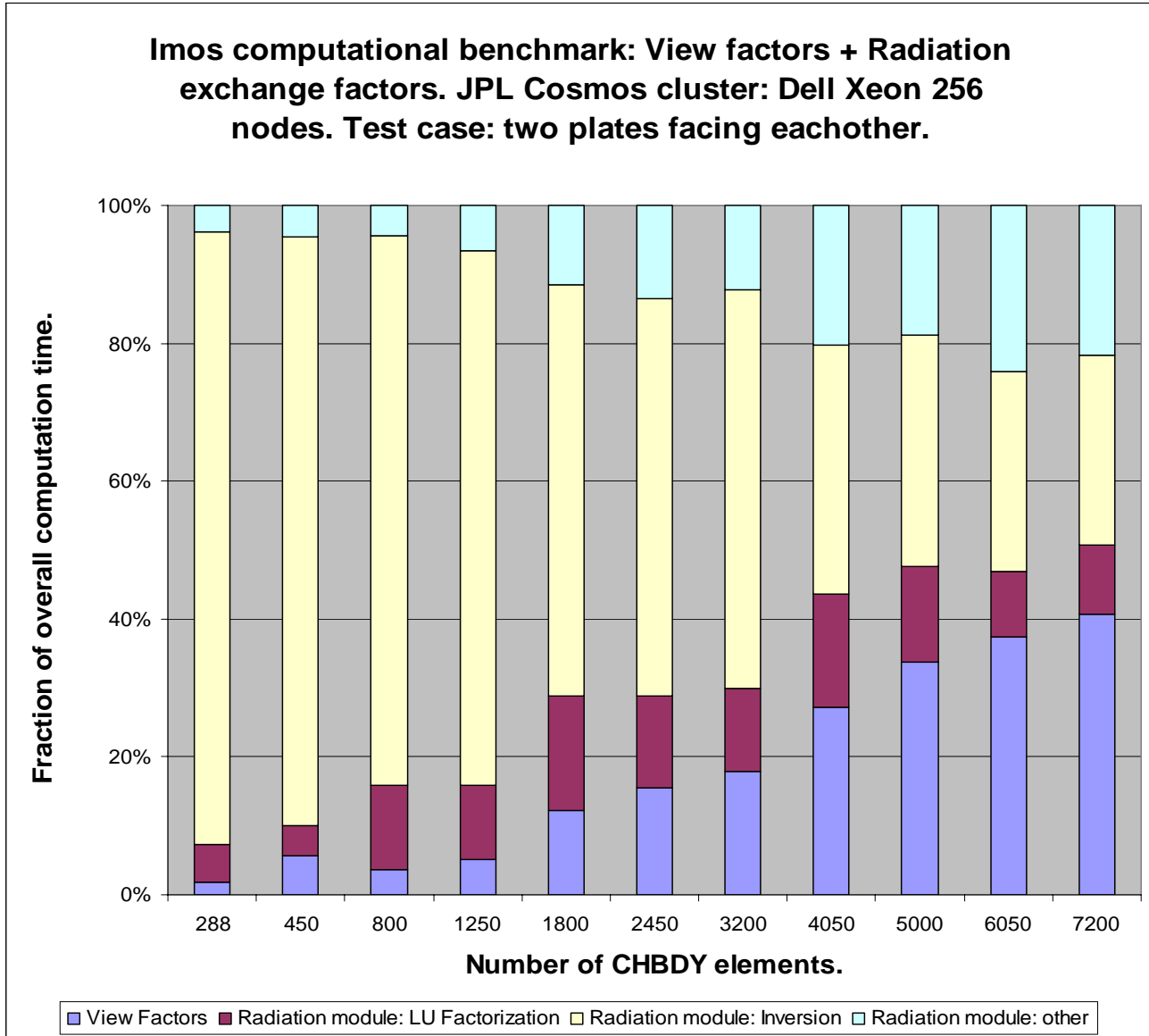
 = Module
  = Matlab script, utility

Parallel Benchmarking

Imos computational benchmark: View factors + Radiation exchange factors. JPL Cosmos cluster: Dell Xeon 256 nodes. Test case: two plates facing each other.



Parallel Benchmarking

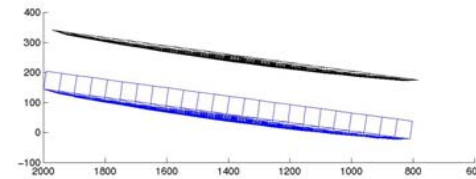
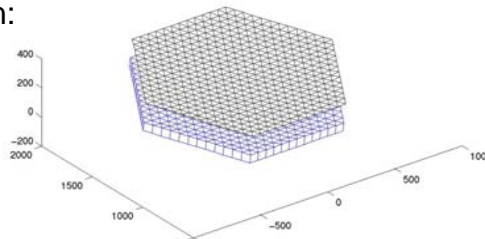


Optical Response Generation

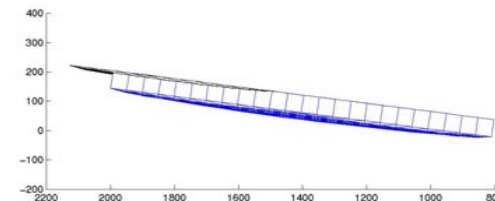
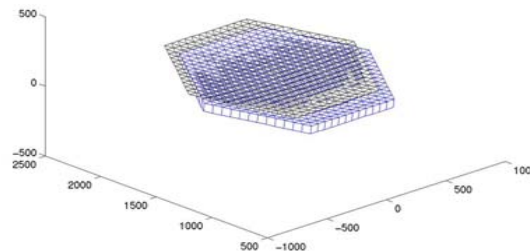
Optical Elements, Modes and Aberrations:

- “Optical elements” associatively defined in terms of the finite element model, with unique coordinate systems, and implemented as simple Nastran input file extensions
- Provides a basis for partitioning, projection and postprocessing of thermally-induced structural deformations
- Provides best-fit rigid body vector generation, and aberration (surface map) data recovery based on underlying finite element formulations

- Piston:



- Y-decenter:



Summary

- Code development efforts described here have been just one aspect of a comprehensive JPL Strategic Initiative in precision deployable structures.
- Current functionality includes:
 - Common-model finite element-based approach to integrated thermal, structural, optical analysis
 - Open, object-based, scalable architecture that fully exploits both serial and parallel compute facilities
 - Solution approach that complements existing engineering processes and targets aspects critical to improving analysis, design, and mission confidence
- Future development work will leverage data obtained from state-of-the-art deployable structures test facilities and precision optical testbeds, developed in connection with future NASA science missions.

