Terrestrial Planet Finder Mission

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Recent Advancements in Multidisciplinary Analysis and Design

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Problem Statement

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Development of high-precision, common-model, finite element-based multidisciplinary analysis and design capabilities for TPF classes of problems.

Systems are characterized by:

- Significant time-dependent thermal radiation loading, exchange
- Structural deformations having adverse effects on high-precision optics
- Actively-controlled optical systems
- Minimum weight, maximum rigidity, stability, and controllability objectives

In a manner that enhances JPL's technical infrastructure, advance the state of the art in the areas of multidisciplinary analysis and optimization, and provide an independent tool for technical oversight and verification purposes.

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Strategy

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What the current approach is not:

- High-level integration of closed-source (or limited access) commercial codes.
- Creation of a user interface that simply automates transfer of data from one code to the next ("glueware".)
- A toolset that is based on multiple input data formats and disparate discretization schemas.

What the current approach IS:

- Process improvement via fundamental integration at the data structure and methods level.
- An extensible platform for advanced computational methods development.
- Intended to address aspects not covered by existing commercial codes.
- Inspired by original NASA NASTRAN vision, though benefiting from advances in computer science since then.

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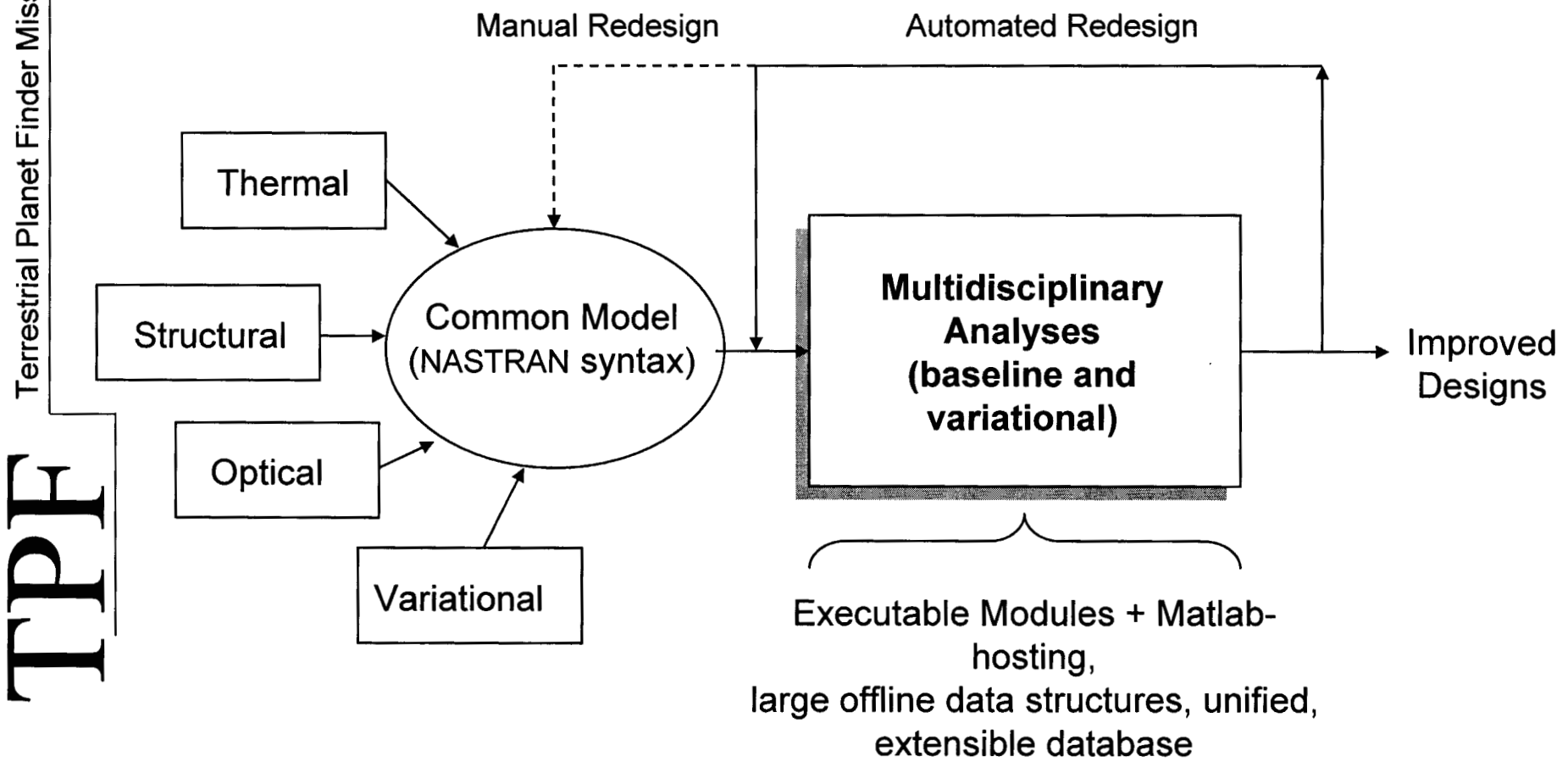
Proposed Analytical Process



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Groundwork

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- Task initiated 2+ years ago to extend IMOS (JPL's Integrated Modeling of Optical Systems) to large-model, multidisciplinary domain.

- Result is an entirely new code, architecture with:
  - Extensible, object-based, large model-capable data structures
    - "Tolerant" structures, coding principles easily allow new data and analysis types
    - Uniform behaviour via abstracted interfaces, data api's
    - No hard-coded program limits
  - Thin code layer to allow hosting from virtually any environment
    - Matlab, initially
    - Facilitates integration with third-party codes
  - Compiled program units (modules), called from the hosting environment
    - Designed along functional lines, allow high-level scripting ("DMAPing") in Matlab
  - Separation of model data and analysis description
    - NASTRAN input files, plus Matlab "solution sequences"

Highlights

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Over the past two years we've begun building new analytical capabilities that exploit this new program architecture for multidisciplinary analysis purposes.

Heat Transfer:

- View Module
  - Grey diffuse elemental view factors for 1, 3, & 4 grid point surface elements
  - General three dimensional capability
  - Error estimation and adaptive contour integration
  - Self-shadowing and third-body shadowing
  - Computes solar and planetary illumination given orbit module output
- ORBIT and LOAD Modules
  - Computes time dependent sun and planet positioning
  - Orbiting or stationary vehicle given fundamental parameters
  - Effects of large local rotations on vehicle orientation
  - Callable from the transient solution sequence integration scheme

Highlights

Heat Transfer (cont.):

- RMG and LOAD Module
  - Computes radiation exchange matrix for full model
  - Computes directed solar loads given view module output
  - Traces diffuse reflections of directed solar loads
  - Produces net solar and albedo load vector for full model
- Conduction and Capacitance Elements
  - Triangular elements
    - NASTRAN CTRIA3 and CTRIA6
    - CTRIA10 (full cubic)
  - Quadrilateral elements
    - NASTRAN CQUAD4 and CQUAD8
    - CQUAD9 (full quadratic) and CQUAD16 (full cubic)
  - 1-D elements
    - NASTRAN CROD and CBAR

New Features

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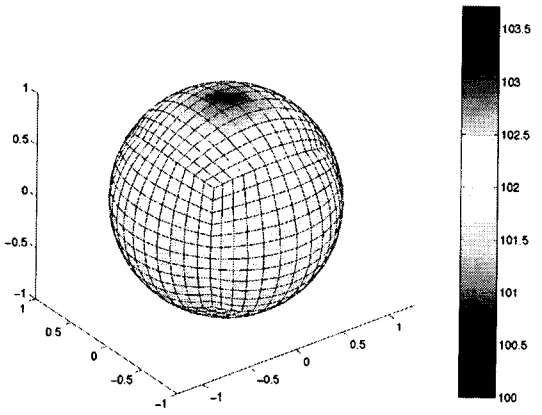
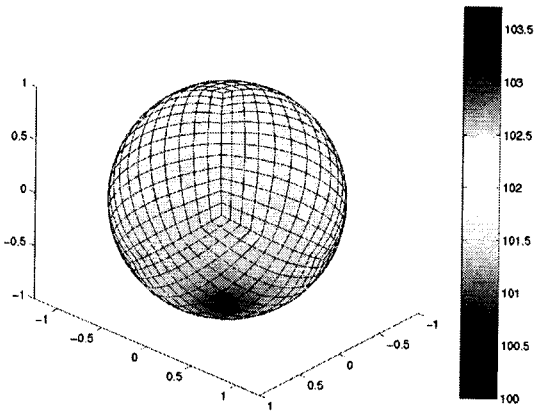
Loads and Constraints:

- Thermal Loads:
  - Face fluxes
  - Edge and node fluxes
  - Volumetric heat generation
- Thermal Constraints:
  - Face, edge and node temperatures





New Features

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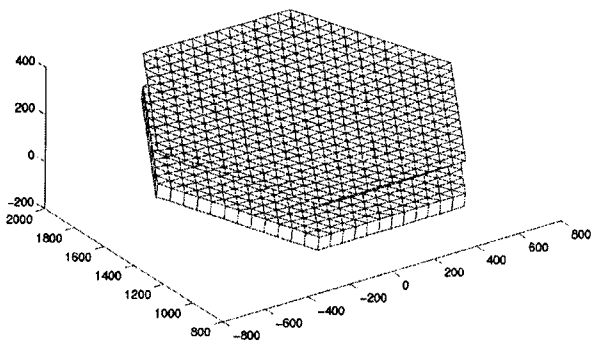
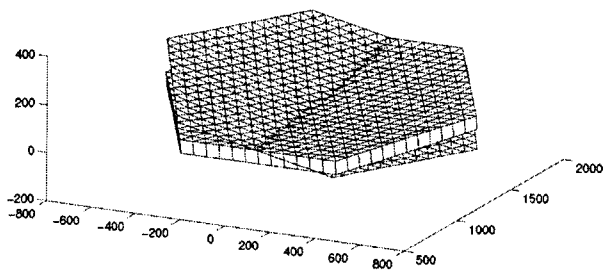
Optical Responses:

- Work in progress, but presently:
  - Automatic degree of freedom partitioning according to optical "element"
    - `COPTC, EID, CID, {GRID, ELEM, PROP}, SETID`
    - NASTRAN extension allows partitioning for all degrees of freedom for all grids connected to all elements for any particular material/property type.
    - Supports multiple optical elements, multiple local coordinate systems.
  - Automated calculation of rigid body modes, projection onto origin of optical element for "best fit" responses





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New Features

Structural Analysis, Matrix and Other Utilities:

- General
  - Interface via API to all of IMOS' existing capabilities
  - Native support for NASTRAN input files (incl. Case Control and Bulk Data)
  - Full implementation of NASTRAN's displacement degree of freedom sets
- Other NASTRAN conventions:
  - All coordinate systems supported
  - All single point constraints, static enforced displacements
- Matrix Utilities
  - In-place, partial, unsymmetric Crout factorization and inversion, with pivoting
  - Generalized class of sparse matrix utilities (dynamic construction, export in Matlab formats)

Summary

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By the end of pre-Phase A we will have:

- A new class of finite element-based, common-model thermal, structural, and optical capabilities
  - Targeted to TPF classes of problems.
  - Well-defined methods based on open code.
  - NASTRAN-based descriptions, allowing pre- and postprocessing support via commercial interfaces.
  - High level scripting capabilities, integration via Matlab.
  - Low-level extensibility allowing fundamental datatypes, physical attributes.
- Verification, validation via application to pre-Phase A scenarios
  - Internal JPL technical studies, oversight and verification.
  - Industry and university participation desired.
- Initial code "release" at end of pre-Phase A
  - Lots of work to do by then!