Object-Based FEA Modeling in IMOS
(A progress report)

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Outline

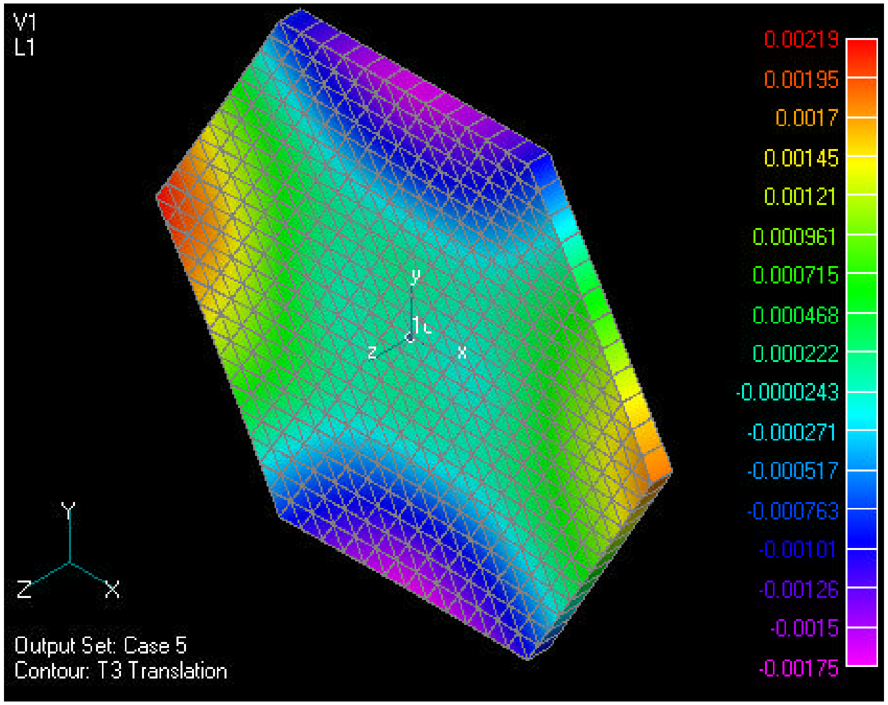
- IMOS (Integrated Modeling of Optical Systems) one year ago
- Development goals
- Some notes on object-based design and large-scale FEA
- Implementation in IMOS
- Future development

What is IMOS?

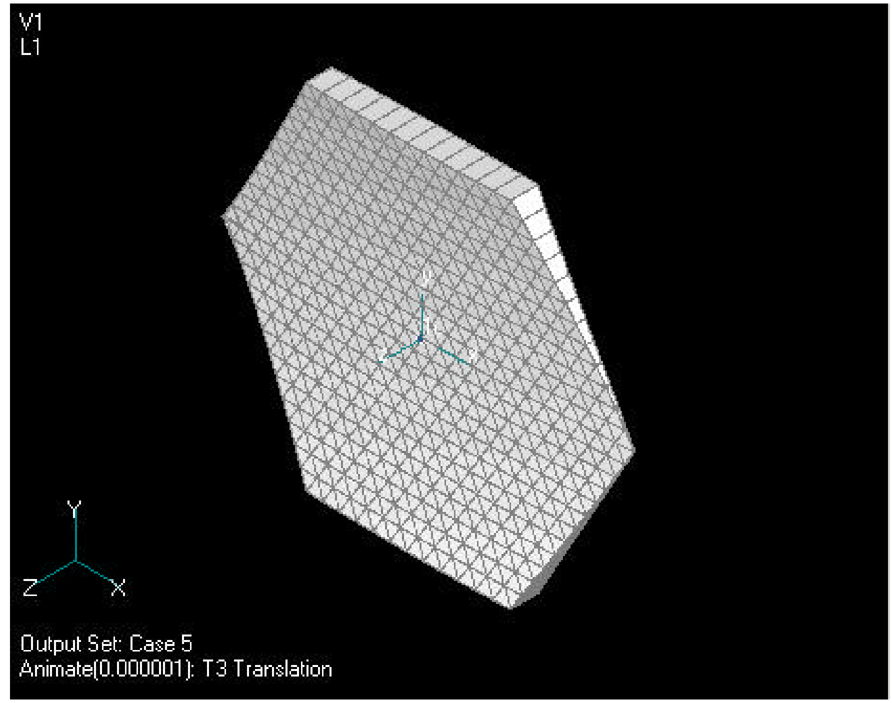
- Toolbox of Matlab script and executable files (*.m, *.mex) for finite element structural and thermal analysis, optical ray-tracing, statistical energy analysis, limited pre/postprocessing.

- Much of IMOS' flexibility is due to Matlab-hosted environment
  - matrix utilities, numerics, controls, visualisation
  - other tools running within Matlab environment (e.g. MACOS)

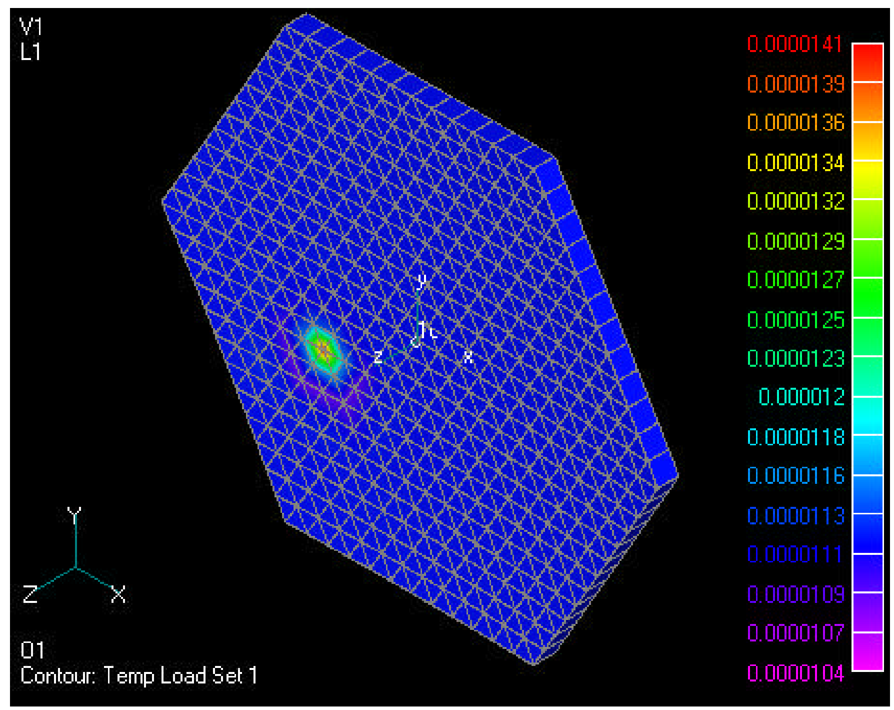
- Next slide example courtesy of Andy Kissil, JPL...



Temperature Profile Computed in IMOS to Produce Astigmatism (Zernike N=2,M=2) on Mirror Surface Using a Least Squares Approach



Animation of Axial Displacements of Mirror Surface for Computed Temperature Profile (double click to activate)



Identification of CTE Changes from Nominal Based on Simulated Displacement and Temperature Measurements

IMOS status, one year ago

- At FEMCI 2001 we outlined some of IMOS' shortcomings, and motivation behind proposed major code overhaul:
  - lack of large problem scalability (~50k dof has been practical limit)
  - flexibility, ease-of-use in conflict (powerful, though for expert users)
  - little support for higher-level analysis and design concepts
  - minimal data recovery, postprocessing

Motivation for recent, and future work

Previous shortcomings, especially:

- large problem scalability and performance
- support for NASTRAN models without data translation (native NASTRAN interface)
- Support for higher-level concepts (e.g. case, or state, control, substructures, multiple configurations (boundary conditions)
- Enhanced multidisciplinary analysis capabilities
  - integration with MACOS
- End-to-end design sensitivities and optimization

Some technical considerations in code redesign

- Efficient use of computing resources
  - compute space to span local memory, disk, and remote machines
  - indirect addressing (elimination of namespace collision)

```
for every substructure {
   for every boundary condition {
      compute reduced stiffness, mass matrix
   }
}
```

  - static, vs. dynamic, objects
- computational efficiency
  - maximum code reusability, minimal code overhead
  - NASTRAN model description compatibility, data structure and functional compatibility

Technical considerations, cont.:

- scripts-data-code:
  - user convenience != programmer convenience
  - how much functionality goes in Matlab, how much in executable code?
  - Where should data reside, and in what form?

Some Definitions:

- Object-based, vs. object-oriented code:

Object-oriented:

Object-based:

abstraction	Creation of a well-defined object interface
encapsulation	Keeping abstraction details hidden
hierarchy	Ability to reuse abstractions

polymorphism	Methods transparency for derived objects

Thinking about FEM objects:

- Is the finite element model:
  - The set of mathematical operations and approximations
  - The collection of grid points, elements, discretized loads etc.?
  - The resulting matrices?

- Answer:

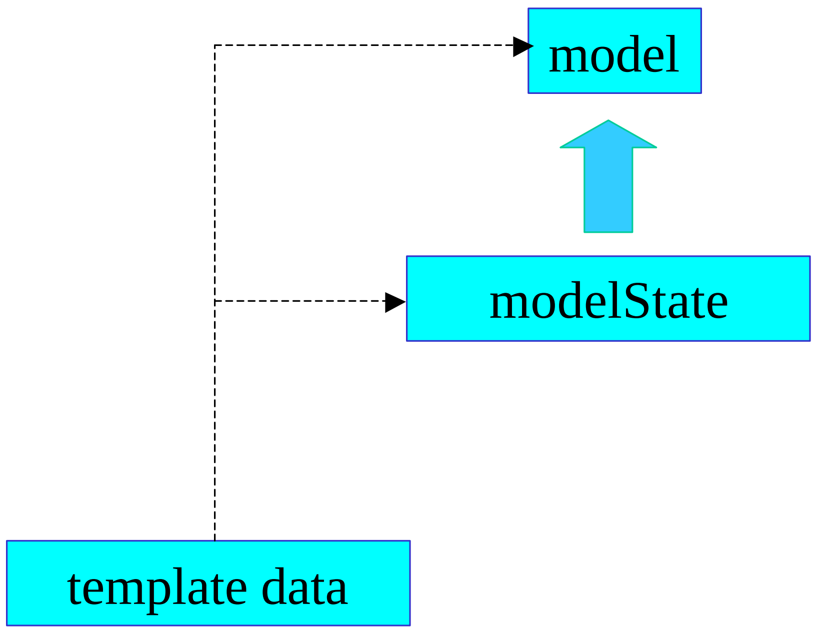
  YES

Thinking about FEM objects, cont.:

Object-based approach must also accommodate:

- Substructures/assemblies
- Multiple boundary conditions
- Modeling conventions
  - (autospc, dynamic reduction, inertia relief, etc.)
- Design states (model parameterization)

IMOS model containers:

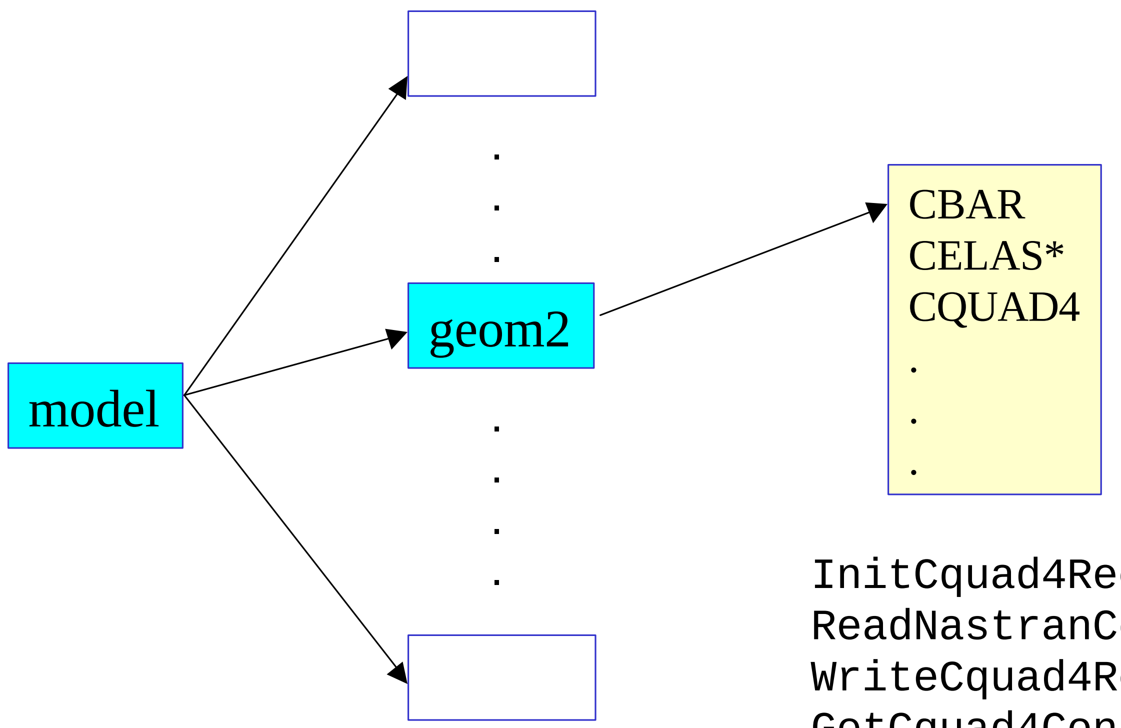


Basic, invariant data

Model configurations

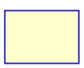
User-modifiable in Matlab

Container classes:




```
InitCquad4Record();
ReadNastranCquad4Record();
WriteCquad4Record();
GetCquad4Connectivity();
```

Matlab-resident data



Compact (bytestream) data,
location depends on template

Benefits:

- Container classes provide top-down, hierarchical framework for complex model data
- Matlab-based template information provides user modifiability
- Namespace collision avoided
- Abstraction/encapsulation ensures dataset, individual data element integrity
- Open source provides unlimited customization

Selected new functionality:

FEA model reader:

```
[arrayOfModels, arrayOfModelStates] = . . .
               IMReadInputFile(infile,nullfile);
```

- Matlab executable (*.mex) for speed
- Native NASTRAN input (STEP extensible)
- Small, large, and free-field support
- Unlimited model sizes, continuations
- Case control (states), substructures, in progress

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Selected new functionality, cont.:

Data extraction:

```
[data_to_workspace] = . . .
                Imdb('verb object from dataset where clause');
```

Example:

```
[ni] = IMdb('select ni from geom2 where name=cquad4);
```

- Matlab executable
- Data either in memory or on disk (could be remote, too)
- Based on data structure api's
- Performance is excellent

Example:

```
                          < M A T L A B >
              Copyright 1984-1999 The MathWorks, Inc.
                    Version 5.3.1.29215a (R11.1)
                            Oct  6 1999
  To get started, type one of these: helpwin, helpdesk, or demo.
  For product information, type tour or visit www.mathworks.com.

>> IMDataStruct;
>> infile = 'ngst_concept.dat';
>> nullfile = 'ngst_concept.null'
>> [ept,geom1,geom2,ifs,mpt] = IMReadInputFile(infile,nullfile);
   Input file summary:
   bulk data entry count:
    cbar           : 3065
    cord*          : 100   (includes all cordx*-type records)
    cquad4         : 76228
    crod           : 5296
    ctria3         : 32116
    grid           : 81342
```

```
    mat*            : 71   (  71 mat1's  )
    pbar            : 31
    prod            : 2
    pshell          : 97

created data sets
registered data sets
wrote data sets

>> [xyz] = IMdb('select xyz from geom1');

>> whos
  Name                         Size           Bytes  Class

  IMOSDataPath                 1x3             1972  struct array (global)
  IMOSDataStruct               1x12            4922  struct array (global)
  IMOSDefaultLocation          1x10            2054  struct array (global)
  ept                          1x1              534  struct array
  geom1                        1x1              538  struct array
  geom2                        1x1              538  struct array
  ifs                          1x1              534  struct array
  mpt                          1x1              534  struct array
  xyz                      81342x4          2602944  double array

Grand total is 325899 elements using 2614570 bytes
```

Current/Future work:

- Driven by design modeling considerations, e.g.:

$$? \, P(x,t) \, ? \quad ? \, u(x,t) \, ? \quad ? \, u^{S}(x,t) \, ? \quad ? \, PSF(x,t)$$

- MACOS interface
- NASTRAN element set migration
- FEA-based conductive and radiative heat transfer