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# Abstract Modeling Enables Aerospace Corporation Project to Reap Benefits of Concurrent Engineering

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# Presentation Agenda

- Space flight Electro-Optical (EO) sensor programs are experiencing large (100%) cost and schedule overruns.
- Simulation Driven Engineering software enables a more effective process – Concurrent Engineering.
- Abstract Modeling – What is it? What are the benefits?
- Aerospace Corporation Project
  - The complex environment and tools we need to use
  - Overview of the Integrated STOP Workspace
  - Overview of the stages of the project
  - How Abstract Modeling and an integrated environment improved our process
  - Project Results
- Q&A

# The Aerospace Corporation

- Provides federally funded R&D to U.S. Air Force and technical services to national-security, civil, and commercial space customers.
- Services include:
  - Systems engineering
  - Testing/Analysis/Validation
  - Launch readiness/certification
  - Application of new technologies for existing and next-generation space systems

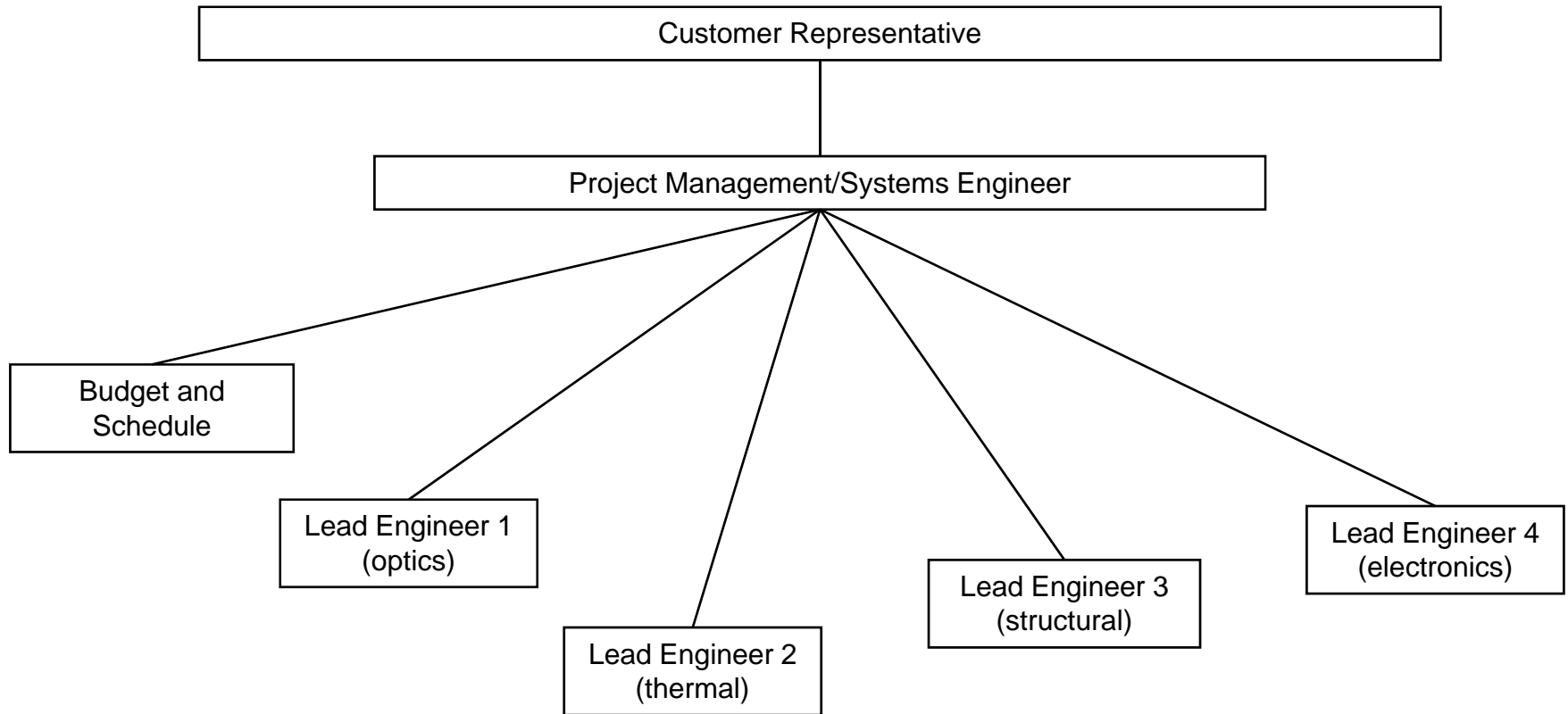




# Statement of the Problem

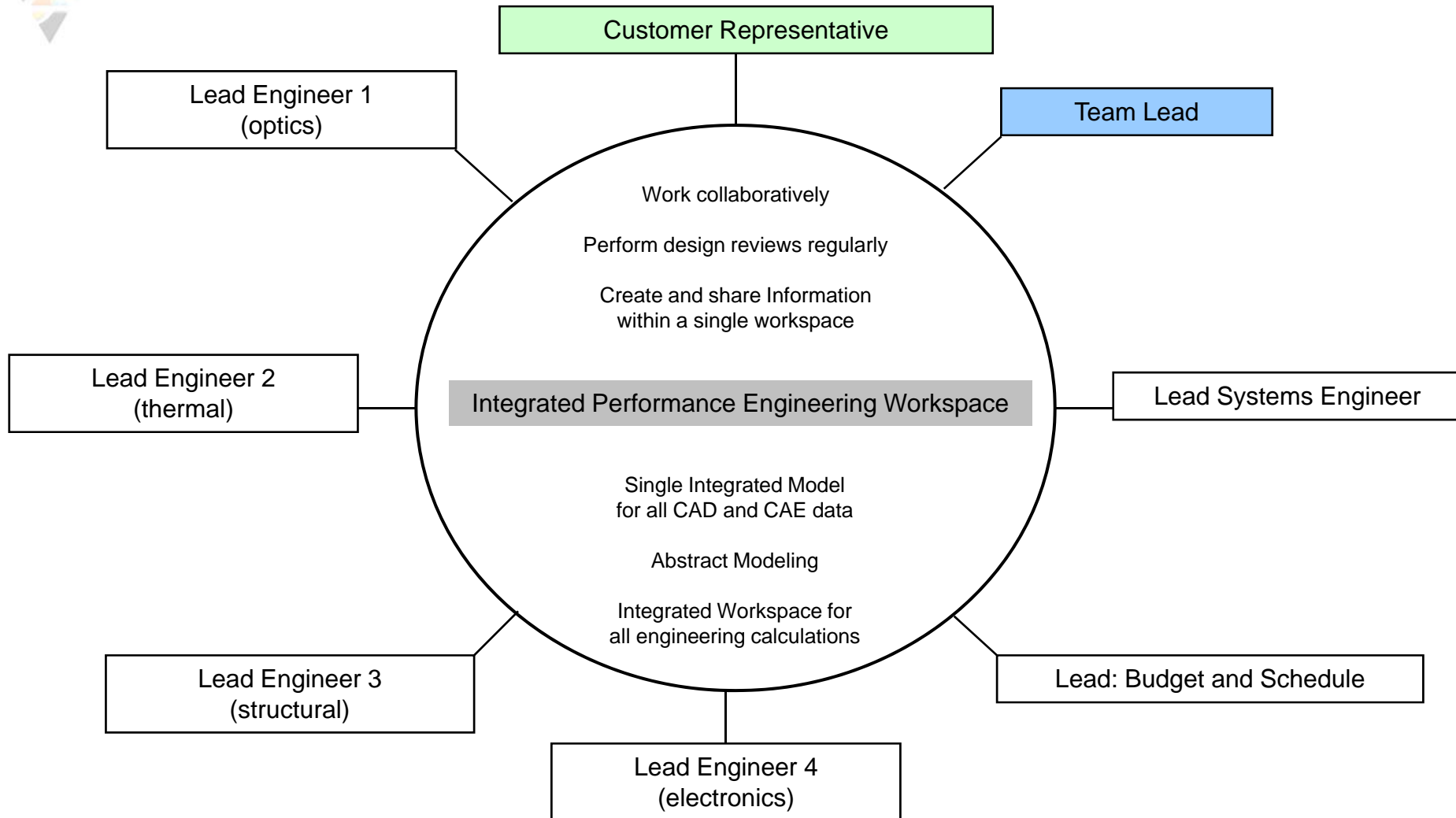
- About 25% of all space-borne EO sensor programs are overrunning budget & schedule allocations by 100% or more.
- Standard program reserves are closer to 20%.
- A 5 times improvement in process cycle time is not likely to result from iterative improvements to existing processes.
- A Concurrent Engineering approach addresses the delays, errors, and late discovery of design problems that underlie our current fragmented process.

# Classic Flight Program Organization



Requirements are handed down to stove-piped engineering functions from a central systems engineering function. Inter-disciplinary interactions are infrequent and often indirect.

# Concurrent Engineering Organization



**Note:** Each lead may in turn be supported by a small team of support engineers or specialists

# The Aerospace Corp. STOP Project

- Goal  
Higher fidelity STOP analysis of space flight EO sensors in shorter cycle time.
- Pain  
Current fragmented approach is slow, inefficient, error-prone.
- Project Team  
Team Lead plus optical, mechanical, structural, and thermal engineers.





# Requirements to Meet Team's Goals

- Effective and efficient communication and management of *all* project data with *all* team members including managers.
- Single, integrated view of all the model data (*CAD, structural, thermal, optical.*)
- Earlier evaluation of more concepts, and more iterations of a concept at multiple levels of model fidelity.
- “No-wait design reviews” including requirements checking (*no simulation tool expertise needed.*)
- Use of COTS CAD and CAE tools (extensible environment for commercial and in-house tools.)



# Performance Engineering Workspace

C:/Documents and Settings/Matt/My Documents/Projects/Welded\_Beam/Welded Beam 01.cmtproject (Iteration 1.2/ Leaf Stage )

The interface is divided into several main sections:

- Project Stages:** A tree view on the left showing the project hierarchy, including Root, Abstract Model, and multiple iterations of HF and LF models.
- Project Dashboard:** A central 3D view of the welded beam model.
- Simulation Process:** A process schematic titled 'FEA Process' showing the workflow from 'Imported Asse...' through 'User Defined' and 'Update Geo' to 'Meshing' and 'Simulation'.
- Geometry/Mesh Results Viewers:** A collection of result viewers on the right, including 'Max Stress', 'Field-Viz', and 'Nodal Di'.

Terminal System Console SolarPanel\_EnergyGenerated\_Constraint

SystemConstant	Value	SystemVariable	Value	SystemRequirement	Value
AppliedOrbitCelestialBodyName	EARTH	OrbitParameter.maximumAltitude	500 km	HeatingRates.directError-albedo	4.13051
AppliedOrbitfacingObject	planet	OrbitParameter.minimumAltitude	500 km	HeatingRates.directError-solar	4.47212
Launch_Cost_Budget	1e+07	SolarEnergyPerArea	50 J*m <sup>-2</sup>	HeatingRates.totalAbsorbed-albedo	101.993 m <sup>2</sup> *kg*s <sup>-3</sup>
Launch_Cost_Per_kg	12000	SolarPanel.Length	2	HeatingRates.totalAbsorbed-solar	369.294 m <sup>2</sup> *kg*s <sup>-3</sup>
Launch_Mass_Budget	1000 kg	SolarPanel.Material	AluminumAlloy,6061T6	Launch_Cost	1.33647e+07
		SolarPanel.Surface_Treatment	KaptonFilm,0.5milAlum	Launch_Mass	1113.73 kg
		SolarPanel.Width	1	SolarPanel_EnergyGenerated	200 m <sup>2</sup> *kg*s <sup>-2</sup>

System Constants

System Variables

System Requirements



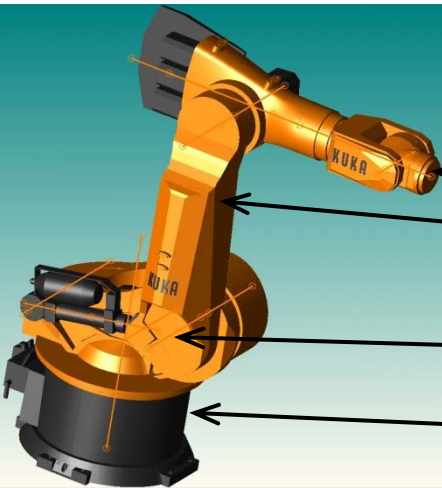


# What is an Abstract Model?

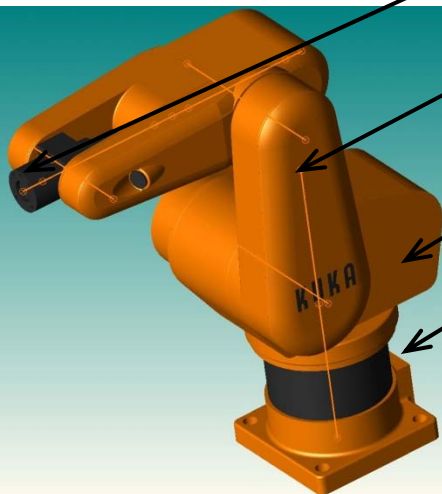
- Models for Performance Simulation – the *Status Quo*
  - Models for simulation are typically geometry-centric – the engineering data is directly attached to the CAD geometry.
  - Changes to the CAD design require large amounts of manual rework to run simulations on the new design.
  - Systems Engineering models are independent of detailed CAD.
- An Abstract Model

“A functional model of a product containing all the engineering data (performance requirements/metrics, materials, environments...) and simulation processes, independent of the CAD geometry or shape characteristics of the product.”

# The Status Quo: Geometry-Centric Modeling in Silos



Geometry



**Rework**  
**Wasted Time**  
**Manual Errors**  
**Data Silos**

- Mesher 1
- Mesher 2
- Abaqus
- ANSYS
- Nastran
- Excel
- MATLAB
- Adams
- Thermal-Desktop
- CODE V
- SigFit
- In-House Codes

## Engineering Data Silos

- Materials
- Surface Treatments
- Environments (Loads/BCs/...)
- Joints
- Contact and other Interactions
- Springs/dashpots/bushings/...
- Meshing rules
- Analysis rules
- Subsets of the assembly

Processes

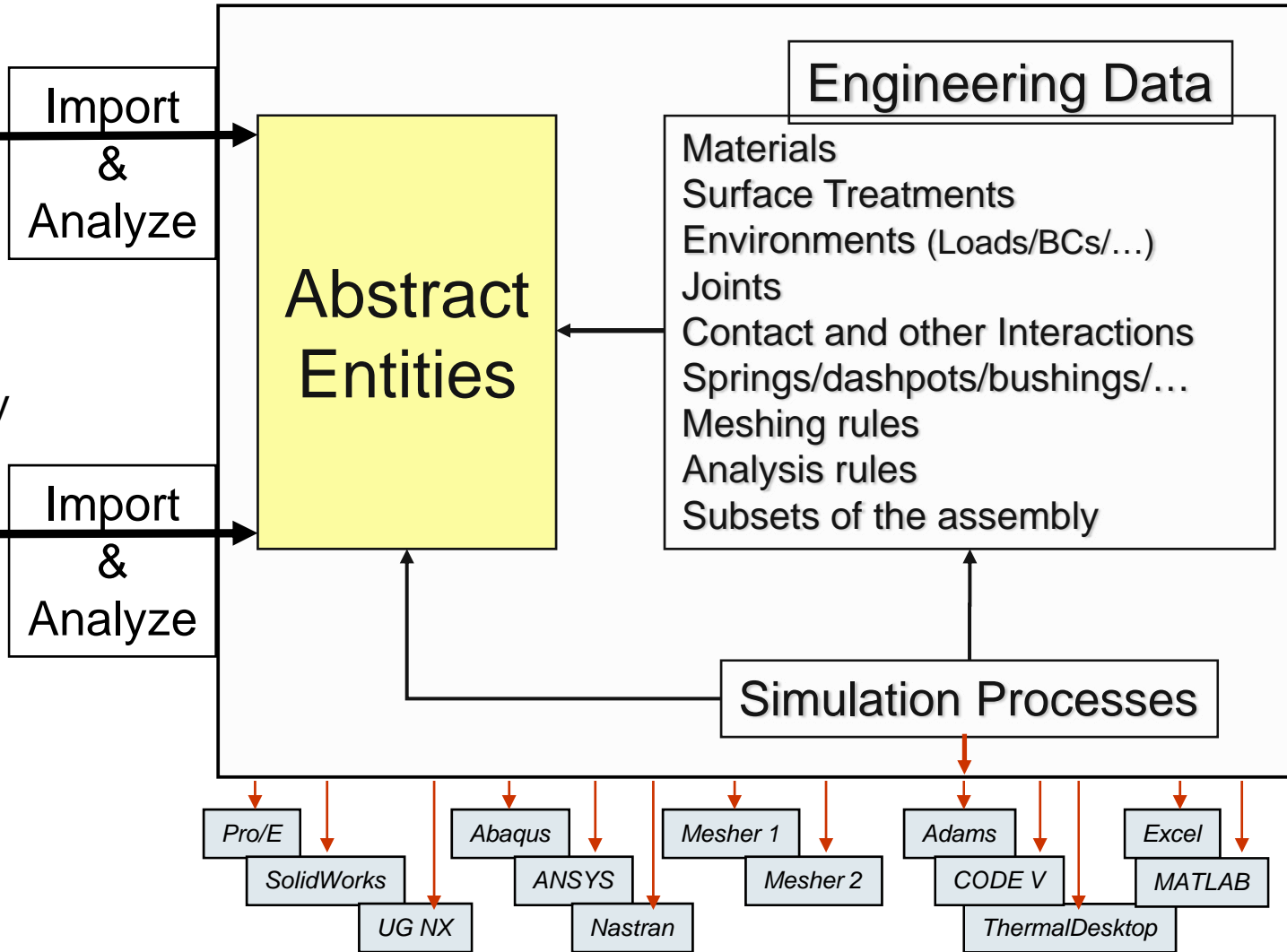
# The Future: Integrated Abstract Modeling



Tagged Geometry



## Abstract Model





# Why Abstract Modeling?

- Automatically generate the analysis model across multiple disciplines – minimize/eliminate data reentry and manual errors.
- Capture engineering “best practice” workflows abstractly, independent of the *design geometry*.
- Set up performance requirements abstractly, independent of the *design geometry*.

***Bottom Line:* High-fidelity, accurate simulations in a fraction of the time.**

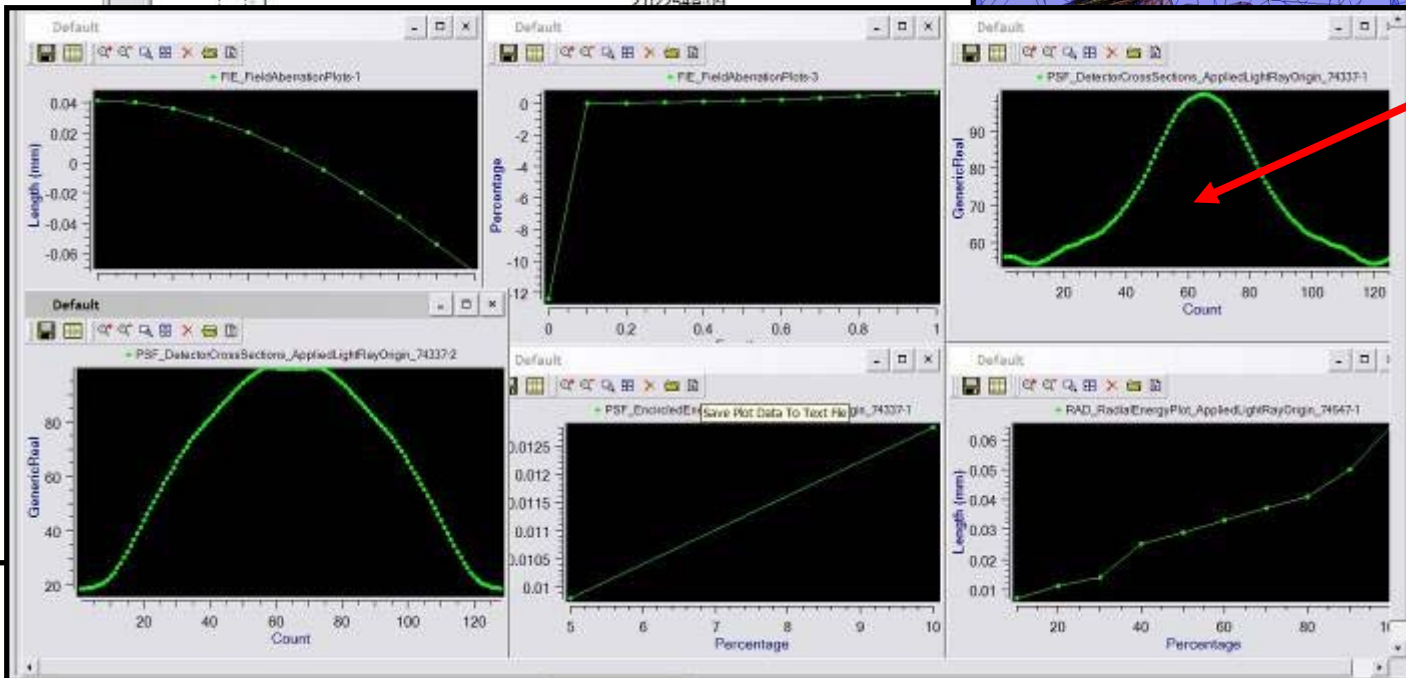
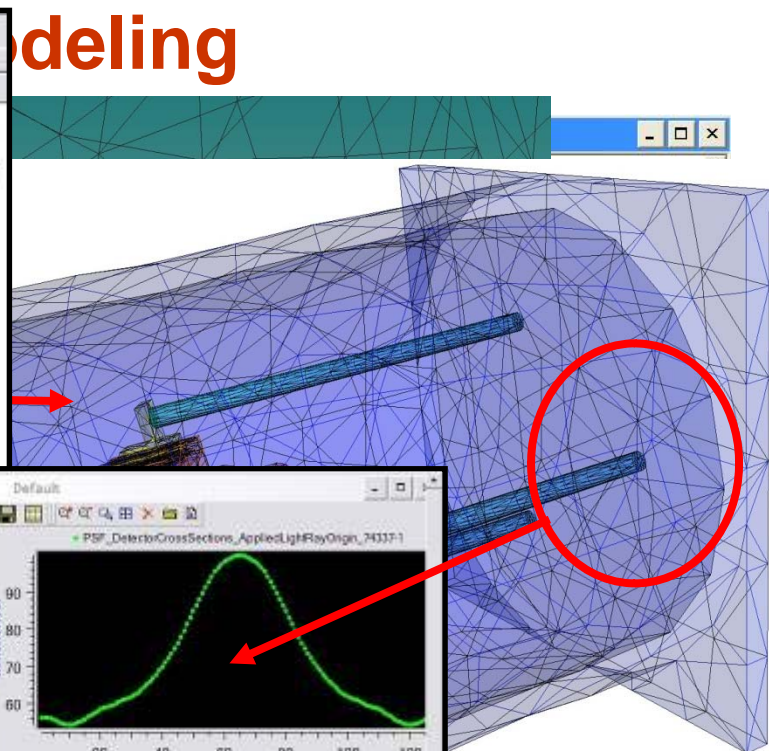
# Structural/Thermal/Optical Performance Modeling

System Console [CompositeOpticalEntityDisturbance 280522 6]

CompositeOpticalEntityDisturbance  
MirrorDisturbance 281500 6  
R07: PrimaryMirror

MirrorDisturbance Properties

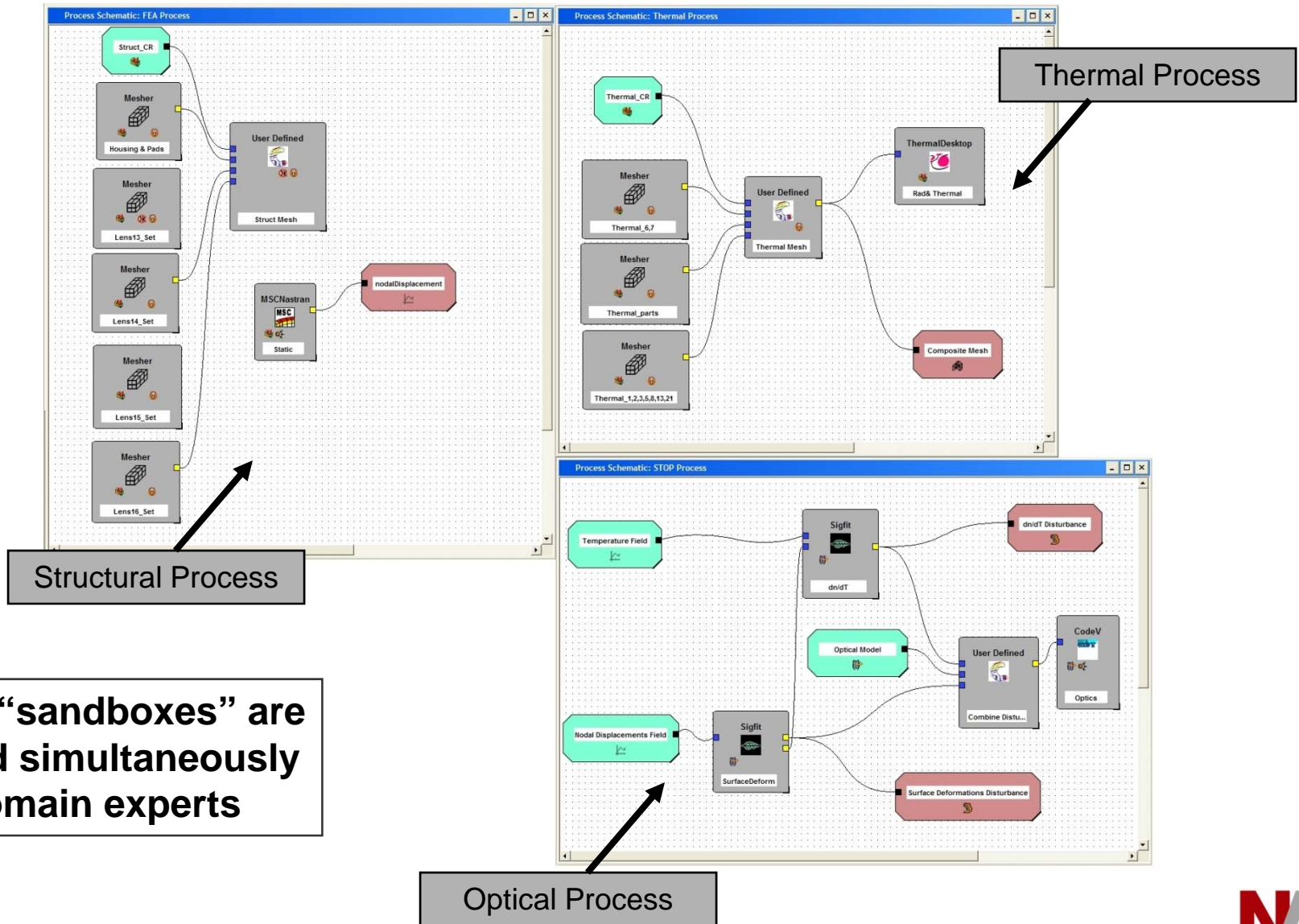
Key	Value
surfaceDisturbanceSpecification	OpticalSurfaceDisturbanceSpecification
Optional Member(s)	
<input checked="" type="checkbox"/> surfaceDisplacementSpecification	OpticalSurfaceDisplacementSpecification
-x	1.60672e-08 m
-y	1.65955e-08 m
-z	-3.35259e-07 m
<input checked="" type="checkbox"/> surfaceTiltSpecification	OpticalSurfaceTiltSpecification
alpha	-7.74712e-06 degree
beta	-2.6697e-06 degree
gamma	-2.54115e-06 degree
zernikePolynomialSpecification	ZernikePolynomialSpecification
coefficients	List(Coefficient)
-0	-1.88836e-09
1	2.02254e-09



OBA\_Tempe

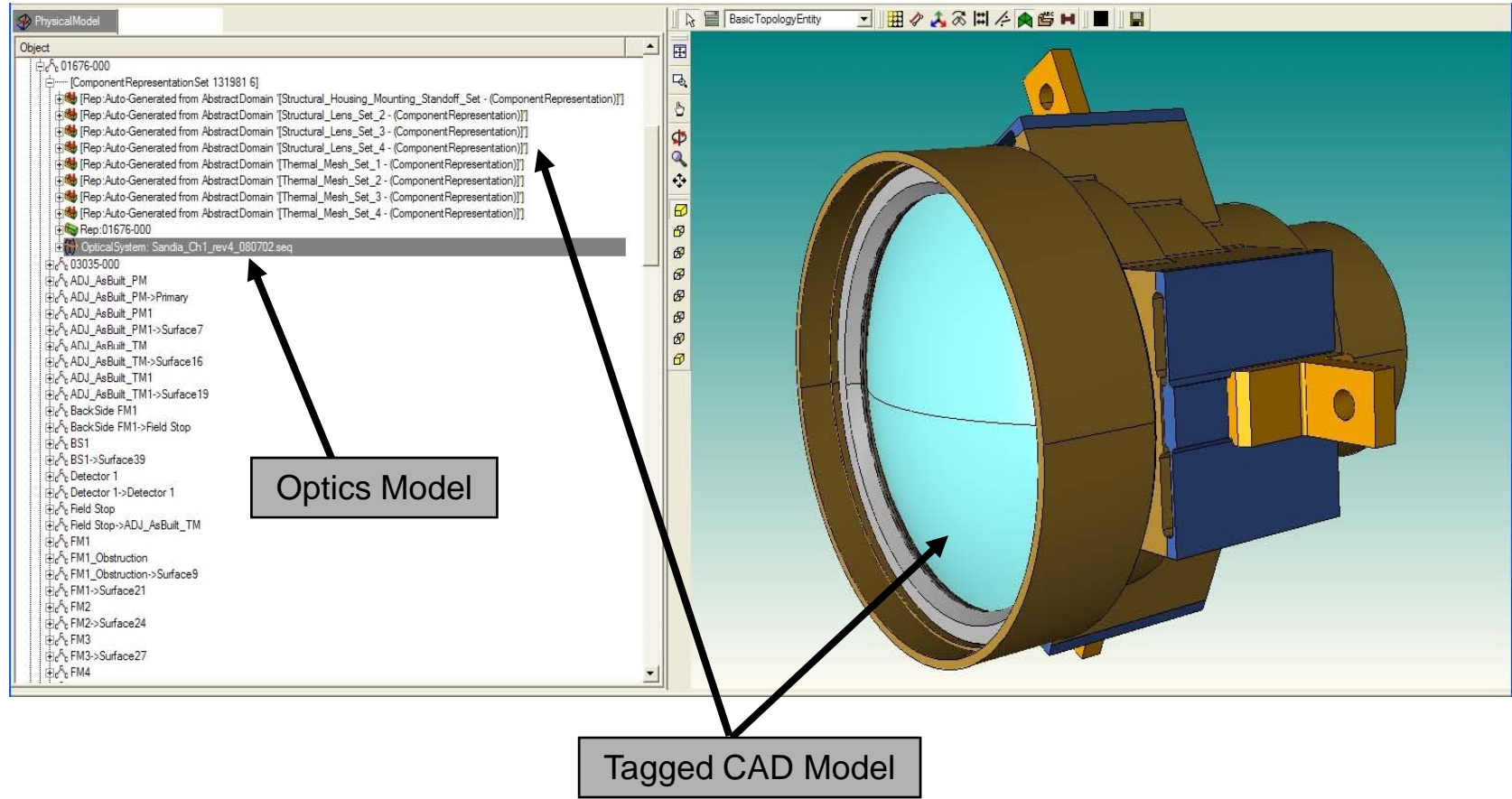
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# Reusable Simulation Templates: Capture/Reuse Multi-Disciplinary Processes



Process “sandboxes” are executed simultaneously by domain experts

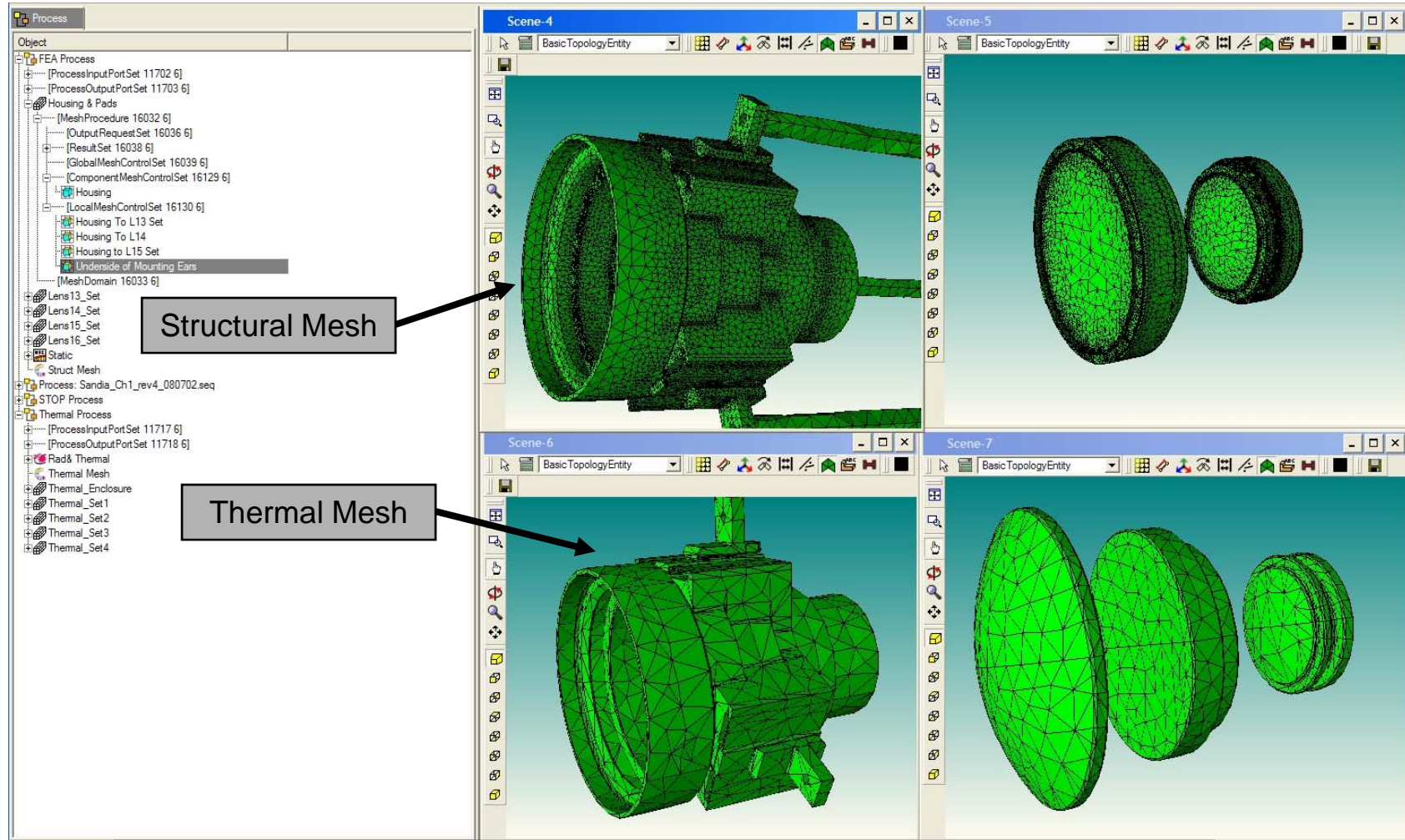
# Import initial CAD and Optics Models



**Optics and CAD models are “synchronized” when imported**

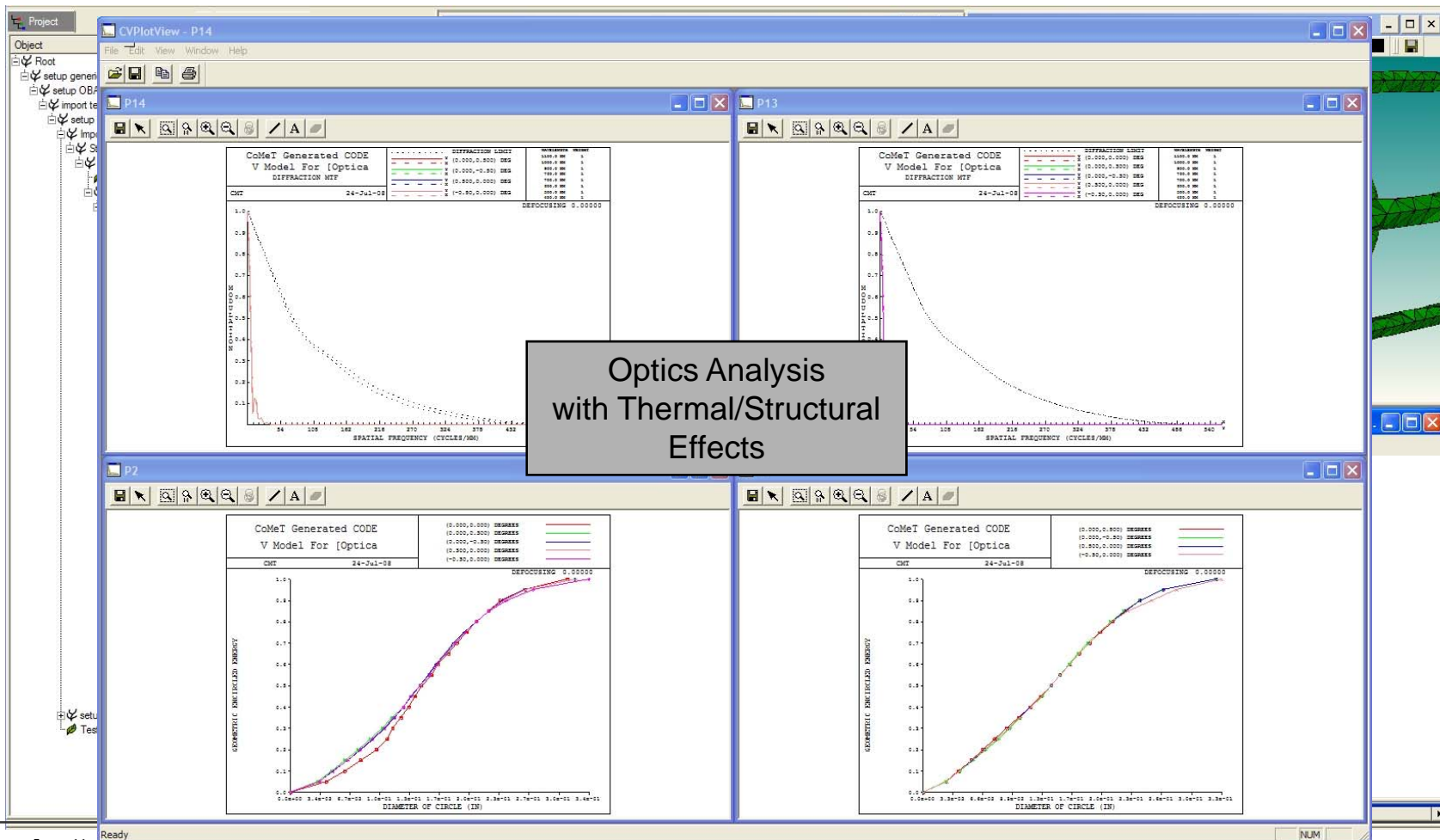


# Mesh the CAD Model



**Automatic meshing “rules” set up in the Abstract Model resulted in significant efficiency gains during iterations**

# Get Optics Performance Results



Analysis “rules” (BC’s, analysis controls, environments...) for each engineering domain are captured in the template

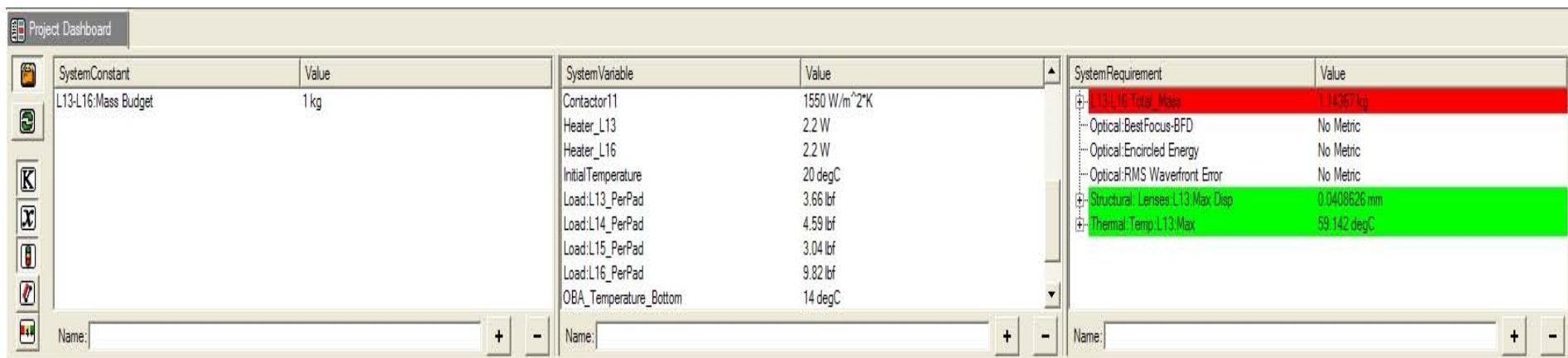
Analysis “rules” for SigFit and CODE V are captured in the template

Results are immediately available for review and downstream inputs



# Use Project Dashboard for Reviews: A Single Summary View of Product Performance

- Change system variables.
- Run simulation processes.
- Immediately review key performance data regardless of the underlying CAD and CAE tools used.
- Facilitate the concurrent engineering process and customer briefings.



The screenshot displays the Project Dashboard interface with three data tables. The first table, SystemConstant, shows a mass budget of 1 kg. The second table, SystemVariable, lists various parameters such as contactor power, heater power, initial temperature, and loads. The third table, SystemRequirement, lists performance metrics like total mass, optical focus, energy, wavefront error, lens displacement, and temperature.

SystemConstant	Value
L13-L16:Mass Budget	1 kg

SystemVariable	Value
Contactor11	1550 W/m <sup>2</sup> K
Heater_L13	2.2 W
Heater_L16	2.2 W
InitialTemperature	20 degC
Load:L13_PerPad	3.66 lbf
Load:L14_PerPad	4.59 lbf
Load:L15_PerPad	3.04 lbf
Load:L16_PerPad	9.82 lbf
OBA_Temperature_Bottom	14 degC

SystemRequirement	Value
L13-L16:Total_Mass	1.14367 kg
Optical:BestFocus-BFD	No Metric
Optical:Encircled Energy	No Metric
Optical:RMS Waverfront Error	No Metric
Structural:Lenses:L13:Max Disp	0.0408626 mm
Thermal:Temp:L13:Max	59.142 degC



# STOP Project Results and Conclusions

- Performance Engineering Workspace with Abstract Modeling is enabling our team to meet its goals:
  - We developed a higher fidelity STOP model *in less than half the time compared to standard processes.*
  - The abstract modeling technique allowed us to *perform more simulations effectively*, reducing manual data entry and errors.
  - Quantitative visualization of CAD/CAE results across discipline boundaries and in one view is key to *identifying and troubleshooting interdisciplinary design issues.*
  - The integrated project environment allowed us to *capture and track all analysis data and design variations.*
  - We conducted *effective and efficient design reviews* with customers from within the software environment with no need for PP slides!



## Q&A

- Any Questions?
- A detailed white paper is available on this subject.
- Please see me or a Comet representative following this presentation or during the conference to request a copy.



# Webinar Q&A

- Any Questions?
- A detailed white paper is available on this subject.
- Please visit [www.cometsolutions.com](http://www.cometsolutions.com) for more information about our performance engineering workspace and abstract modeling. Or email – [malcolm.panthaki@cometsolutions.com](mailto:malcolm.panthaki@cometsolutions.com).

# Managing Multiple CAD/CAE Representations

The screenshot displays a CAD/CAE software interface with a spacecraft model. The interface includes a menu bar (File, Insert, Tools, Import, View, Window, Help), a toolbar, and a project tree on the left. The main view shows a 3D model of a spacecraft with various components highlighted in different colors (green, yellow, grey). Several callout boxes are overlaid on the image, pointing to specific parts of the model and the software interface. The callouts include: 'Thermal Analysis of Spacecraft', 'Component-Centric Model, not geometry-centric', 'Single Master CAD Representation per Stage in the Project', 'Optical System', 'Multiple Component Representations per Component', 'Modal Analysis of Gimbal Yoke', 'Deformation of Optical Element', 'Working with Subsets of the CAD Model', and 'Working with Relevant Subsets of the Model'. The bottom of the interface shows a system console and a terminal window.

**Thermal Analysis of Spacecraft**

**Component-Centric Model, not geometry-centric**

**Single Master CAD Representation per Stage in the Project**

**Optical System**

**Multiple Component Representations per Component**

**Modal Analysis of Gimbal Yoke**

**Deformation of Optical Element**

**Working with Subsets of the CAD Model**

**Working with Relevant Subsets of the Model**

**Work with multiple, closely associated, automatically created, CAD/CAE models and meshes**

# Space Borne Sensor Design: Tools Environment



Structural FEA



Optical Disturbances



Thermal/Radiation Simulation



CAD



Optics Simulation



General Calculations



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Comet Solutions, Inc.





# Software Approaches were Limited

- Current Choices
  - Single-vendor, integrated suites of CAE tools
  - CAE point tools with bi-directional connection to CAD models
  - CAD-embedded “light” tools
- Limitations
  - Lack of integrated environment with access to all data & tools from multiple vendors
  - Lack of ready access to data for decision-making
  - Highly inefficient process when dealing with design changes