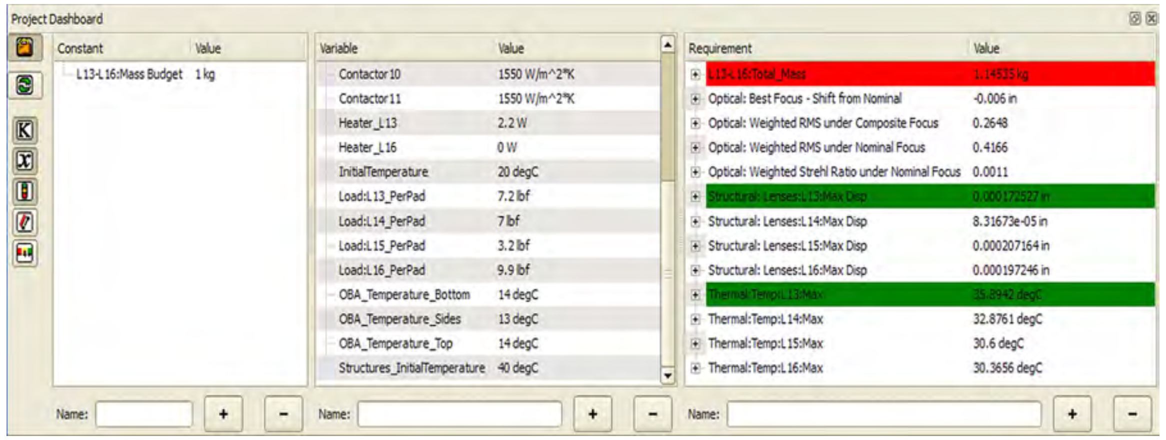

Comet's Project Dashboard provides a single, interactive view of the design's key performance data that automatically updates as the design evolves. System variables are changed directly from the dashboard and the STOP process repeated to conduct parametric studies and improve performance against requirements.

Comparison of Steady State Temperature Predictions with TVAC Test Data				
Steady State Case	3			
Lens 13 & 16 Heater Power	2.2 w			
Thermocouple	**Model**	**Test Data**	**ΔT**	**abs ΔT**
L13_F_S1	35.1	35.4	-0.3	0.3
L13_F_C	35.0	35.0	0.0	0.0
L13_F_S2	35.2	35.1	0.1	0.1
L13_B_S1	35.2	35.5	-0.3	0.3
L13_B_C	35.0	35.2	-0.2	0.2
L13_B_S2	35.2	35.7	-0.4	0.4
L14_F_C	32.2	36.6	-4.4	**4.4**
L14_F_S2	32.4	36.9	-4.5	**4.5**
L14_B_S1	32.2	36.8	-4.6	**4.6**
L14_B_C	32.1	36.6	-4.4	**4.4**
L14_B_S2	32.2	37.5	-5.4	**5.4**
L15_F_S2	30.4	34.9	-4.5	**4.5**
L16_B_S1	29.5	30.8	-1.3	1.3
L16_B_C	29.2	30.6	-1.4	1.4
L16_B_S2	29.5	29.7	-0.2	0.2
H_L13_R1	37.2	43.3	-6.0	**6.0**
H_L13_R2	36.8	37.2	-0.4	0.4
H_L13_R3	37.2	42.4	-5.2	**5.2**
H_SOH_R1	32.2	38.5	-6.3	**6.3**
H_SOH_R2	32.3	38.4	-6.1	**6.1**
H_SOH_R3	32.3	38.8	-6.5	**6.5**
H_L16_R1	30.4	34.3	-3.9	**3.9**
H_L16_R2	30.4	29.6	0.9	0.9

Comparisons between STOP model predictions and hardware measurements are readily implemented within Comet workspace. In the chart above, STOP model temperature predictions at thermistor monitoring points are compared to thermistor readings recorded during thermal vacuum testing for a thermal soak condition. Model comparisons to transient thermal test results are shown below right.

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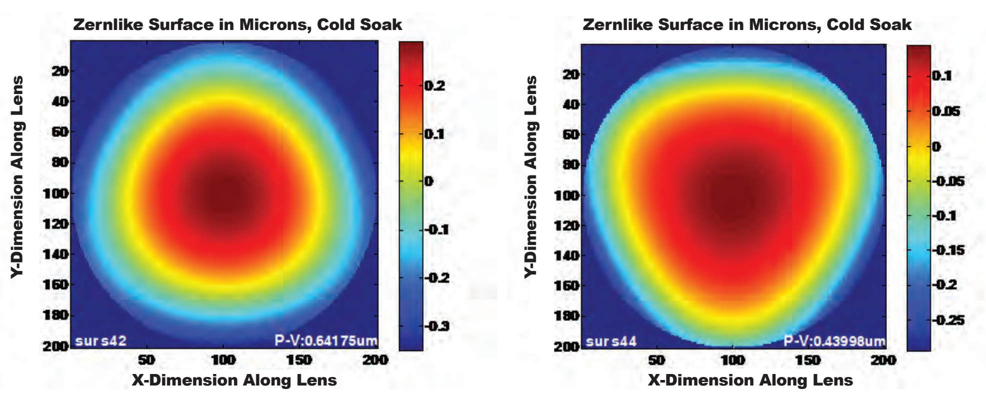
Thermally induced changes in design are readily visualized in the Comet environment. The figures (below) show the wavefront errors introduced by structural deformations to each surface on a single lens in the system and the best fit rigid body tilts and decenters of those surfaces when the system is exposed to a cold soak thermal environment.

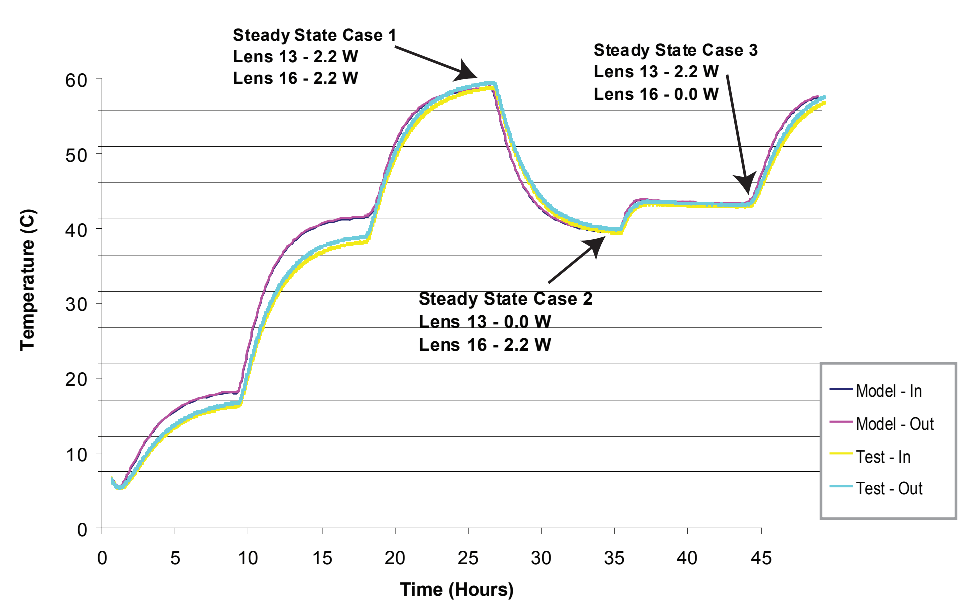


Best fit rigid body displacements of lens surfaces computed by SigFit.

x-decenter	S41	6.14E-05 in	x-decenter	S42	6.17E-05 in
y-decenter	S41	2.43E-05 in	y-decenter	S42	2.56E-05 in
z-decenter	S41	1.87E-04 in	z-decenter	S42	1.21E-04 in
a-tilt	S41	1.17E-04 °	a-tilt	S42	1.19E-04 °
b-tilt	S41	-2.91E-05 °	b-tilt	S42	-4.23E-05 °
c-tilt	S41	-5.79E-04 °	c-tilt	S42	-5.79E-04 °

About 2 waves of wavefronterror are introduced by changes in Lens 13 surface figure. A similar analysis was conducted for Lens 14 – its surface figure changes nearly cancel one another.

Lens 13 Center Temperature Comparison: Model vs. Thermal Transient Test Data



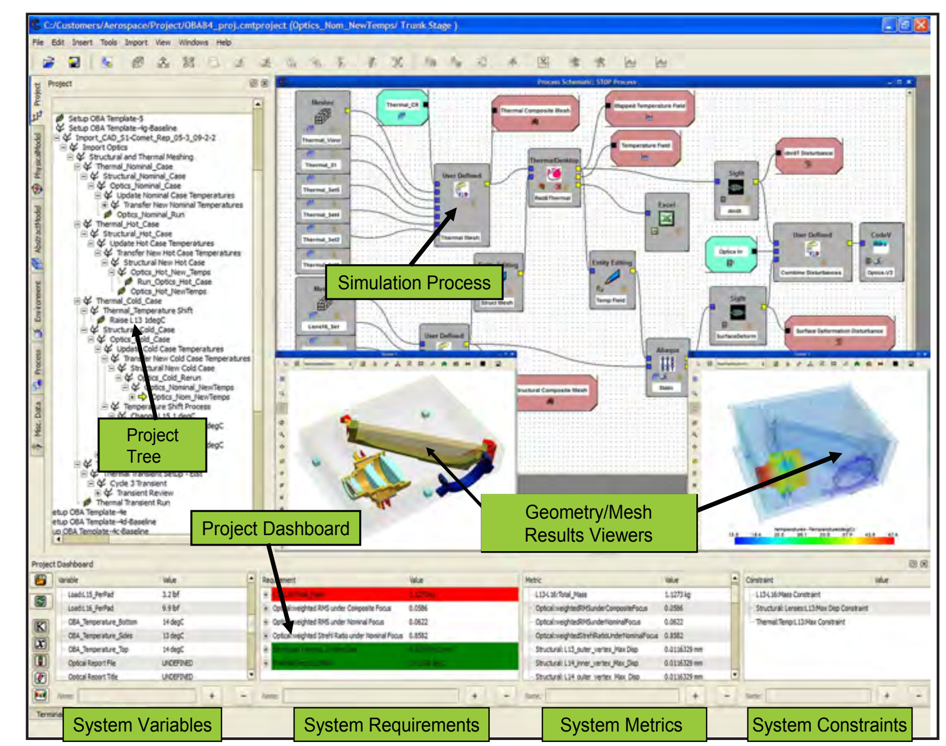
Collaborative Design and Analysis of Electro-Optical Sensors

The Aerospace Corporation has worked with Comet Solutions, Inc. to develop a Simulation Driven Engineering (SDE) software tool that enables Electro-Optical (EO) sensors to be designed and analyzed in an integrated and collaborative manner across engineering discipline boundaries. This brochure illustrates the use of the SDE environment for integrated Structural/Thermal/Optical Performance (STOP) analysis - the analysis of optical performance impacts arising from structural deformations to an opto-mechanical system that are caused by quasi-static changes in instrument thermal environment.

The STOP process described here is an example. Once developed by discipline experts, complex interdisciplinary analyses can be rerun for parametric studies or optimization purposes from Comet's Project Dashboard.

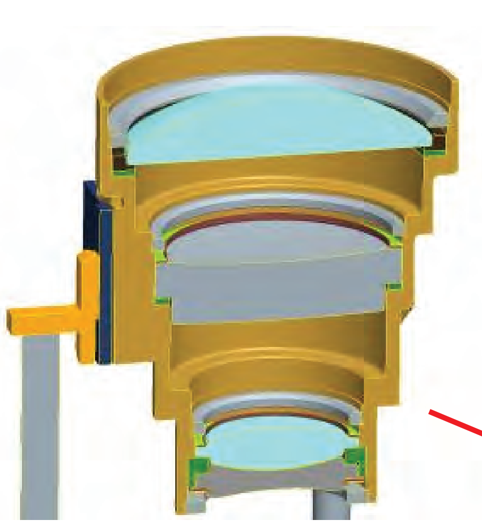
Features of the current SDE software-enabled EO sensor design environment:

- **The SDE software is configured to work with the CAD and CAE tools that discipline engineers already use to do their work:** PRO/Engineer® or SolidWorks® (mechanical CAD), Abaqus® or MSC NASTRAN™ (structures), Thermal Desktop® (thermal), SigFit (structural to optical conversion), CodeV® (optics), Excel®.
- **Design and analysis data for all disciplines is captured in a common data model that anyone can access through the SDE software interface.** This allows ready access to all analysis and key performance data.
- **Project data is efficiently captured and organized in the Comet™ project.** All analysis data and design variations are captured. Version control is enforced to ensure consistency of design between disciplines.
- **Interactive problem solving and design reviews are conducted within the Comet environment without the need for PowerPoint snapshots of design status.** Quantitative visualization of CAD/CAE results across discipline boundaries and in a single eye span facilitates discovery and troubleshooting of interdisciplinary design issues.
- **Model predictions can be easily compared to test results within Comet's SDE environment.**

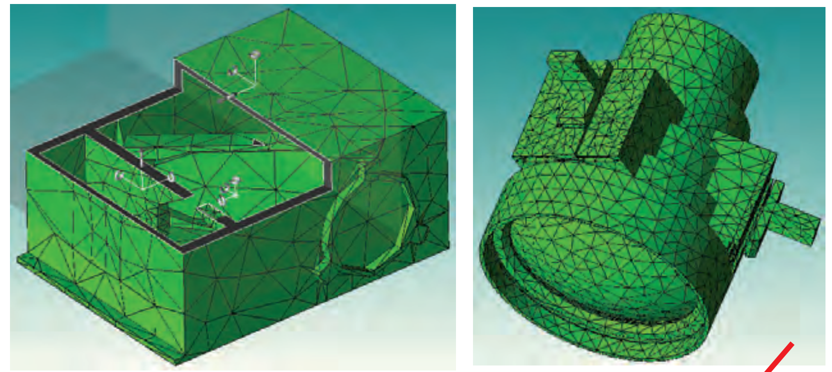


STOP analyses that typically take days to weeks can now be run in a single day.

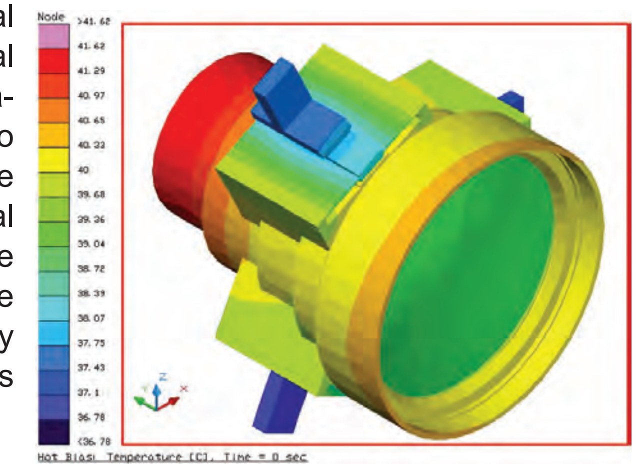
Design cycle time is reduced by factors of 2X or more and most data handoff errors are eliminated by capturing expertise in Comet simulation templates.



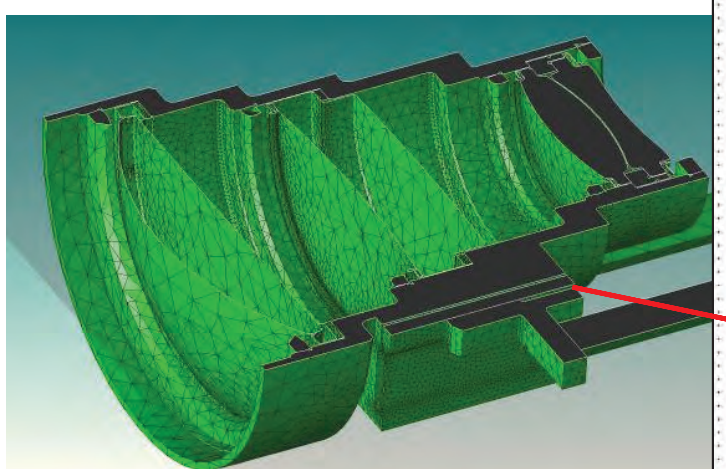
Step 1: Process starts with a single integrated CAD model for the optical system with tags applied by discipline engineers to parts and subassemblies that will be used by them for downstream analysis.



Step 2 (thermal): The parts of the CAD model of thermal interest are FEM meshed for subsequent analysis using rules that are iteratively developed by the thermal engineer and captured in the Comet environment.

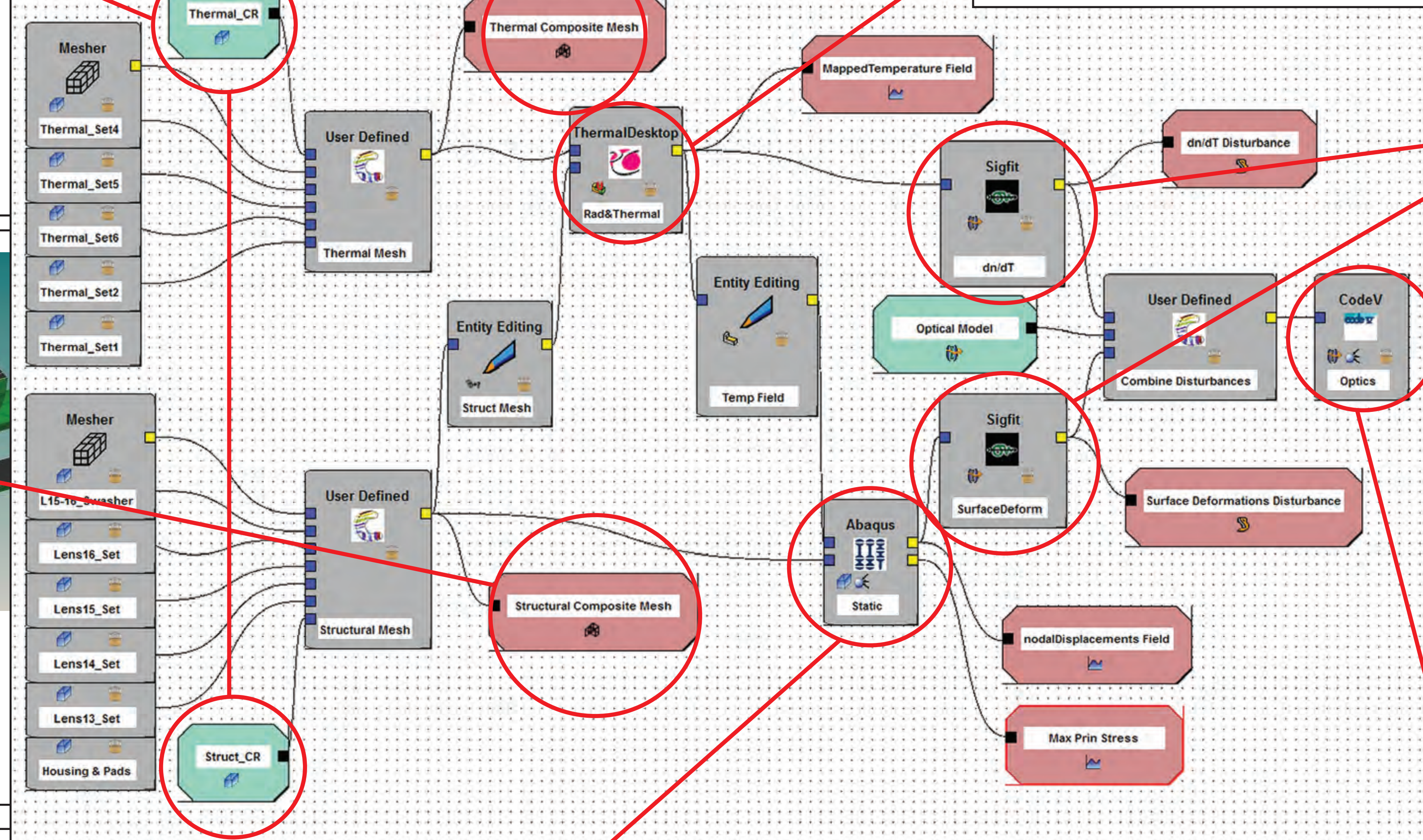


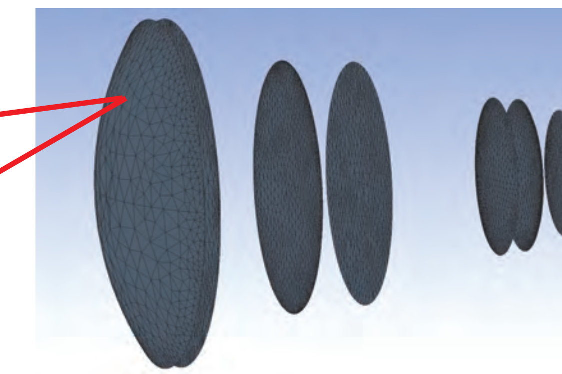
Step 3: The meshed thermal model is imported into Thermal Desktop for analysis of temperature distributions subject to boundary conditions and surface properties specified by the thermal engineer and captured in the Comet environment. The temperature field is automatically mapped to the fine structures mesh.



Step 2 (structures): The parts of the CAD model of structural interest are FEM meshed for subsequent analysis using rules that are iteratively developed by the structures engineer and captured in the Comet environment.

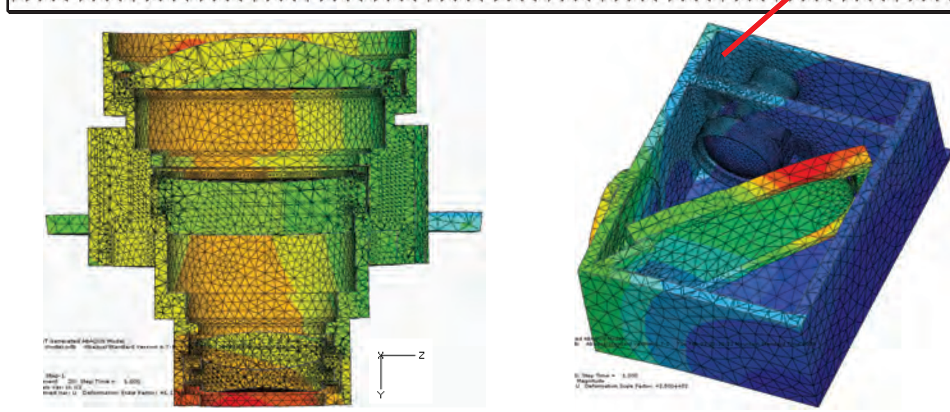
Integrated STOP Simulation Process

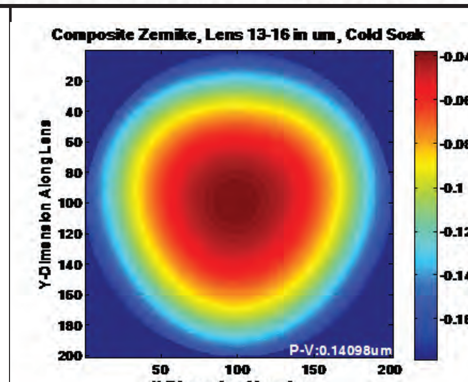




Step 5: Temperature fields from Thermal Desktop and structural deformations from Abaqus are imported into SigFit. Sigfit outputs a modified optical design model that represents structural deformations as rigid body component motions plus Zernike polynomial deformations to the optical surfaces. Zernike polynomials are also used to represent wavefront errors introduced by thermal gradients within the lenses.

Step 4: The meshed structures model and the temperature field produced by Thermal Desktop are imported into Abaqus for calculation of structural deformations subject to boundary conditions and material properties specified by the structures engineer and captured in the Comet. Lens mount contact stresses are modeled accurately, as shown to the right.





Step 6: Code V uses the modified optical model output by Sigfit to quantify impacts on optical performance produced by thermally-induced structural deformations and by changes in the refractive indices. An exit pupil wavefront error map is shown at left and a Modulation Transfer Function plot at right.