ATA ENGINEERING, INC.

Webinar Series

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Webinar:

CFD Driven Conceptual Design of Giant Magellan Telescope Thermal Control System

Damien Vanderpool, ATA Engineering
October 30th 2018

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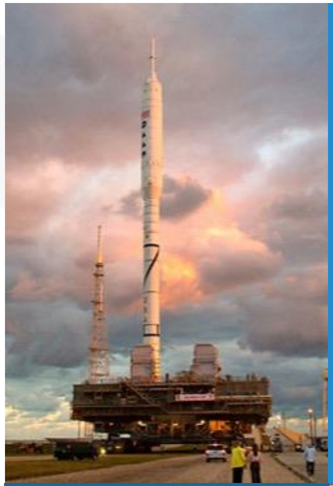
What We Do:

ATA Engineering’s **high-value engineering services** help solve the most challenging design challenges



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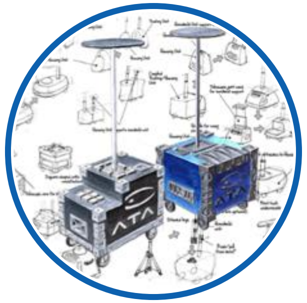
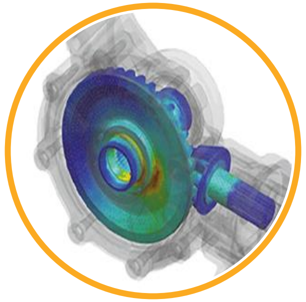
We provide our customers with **complete, integrated solutions**



Design

From initial concept development to detailed structural design



Analysis

Comprehensive structural, fluid, acoustic, and thermal analysis services

Test

Industry-leading structural test services for extreme loading environments

Our Software Services

ATA is a value-added reseller for **Siemens PLM Software**

- Siemens product lines we support include
  - STAR-CCM+
  - HEEDS
  - Femap
  - NX Nastran
  - Simcenter 3D
  - NX CAD & CAM
  - Teamcenter
  - Solid Edge
- Contact the hotline at 877-ATA-4CAE or http://ata-plmsoftware.com/support
- Developer of the official NX Nastran training materials
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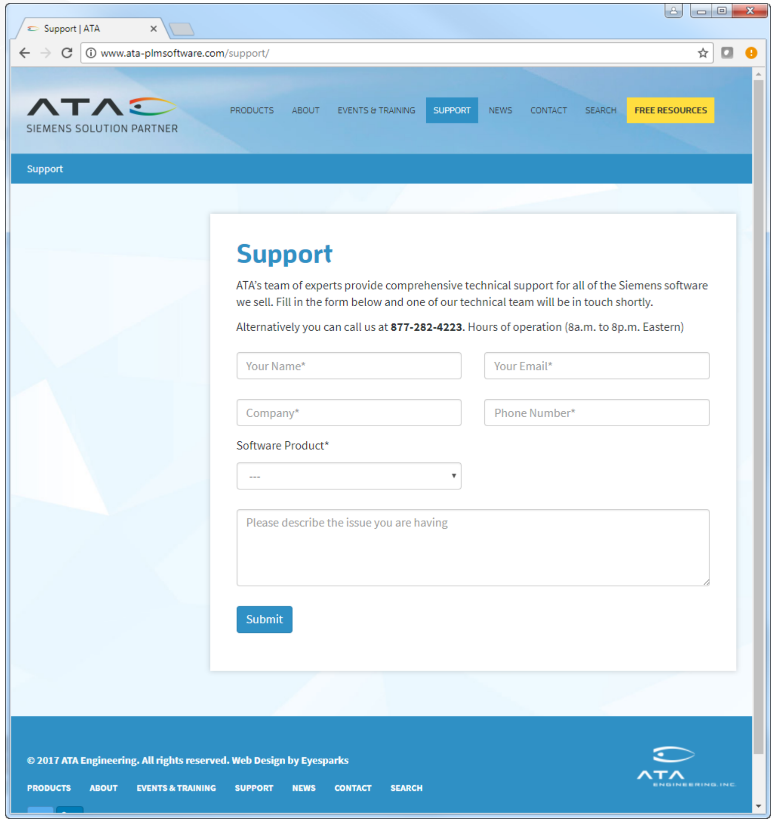
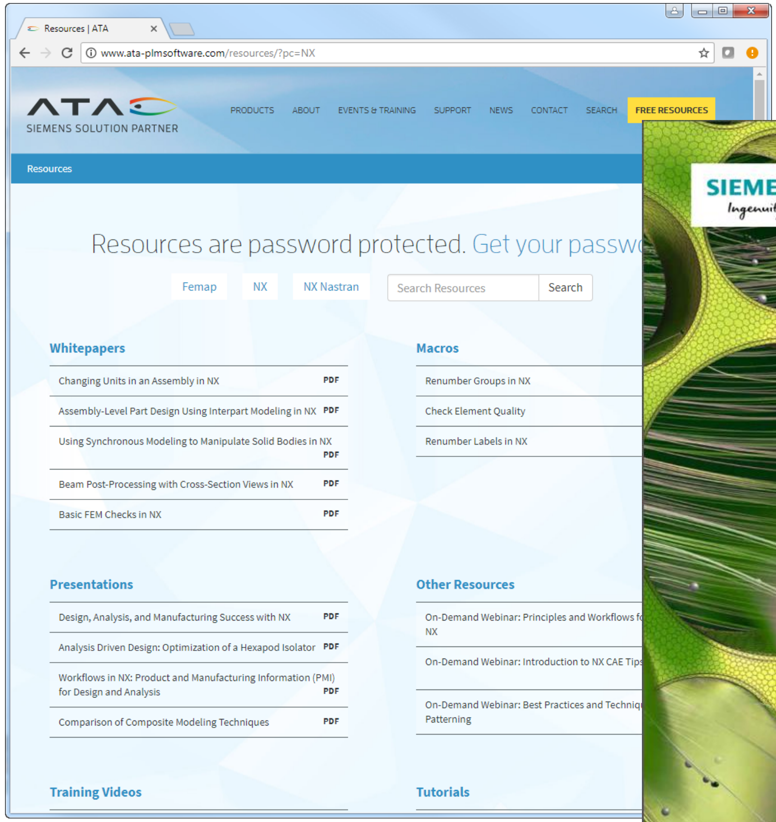
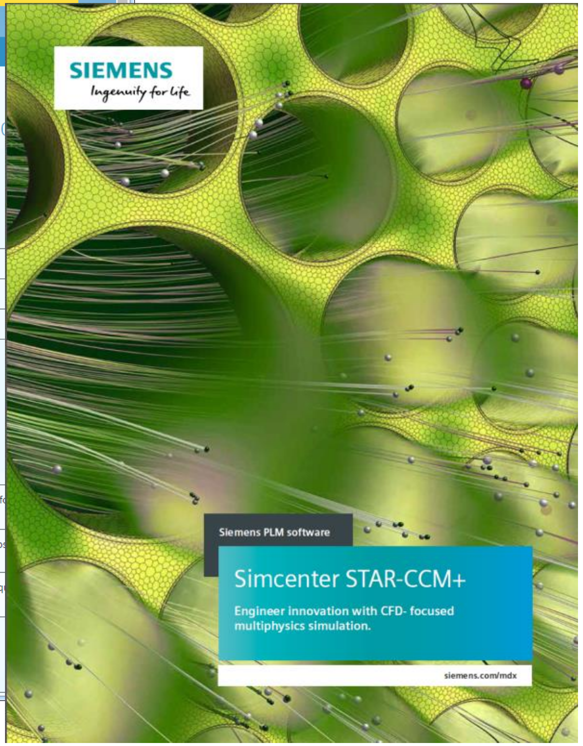
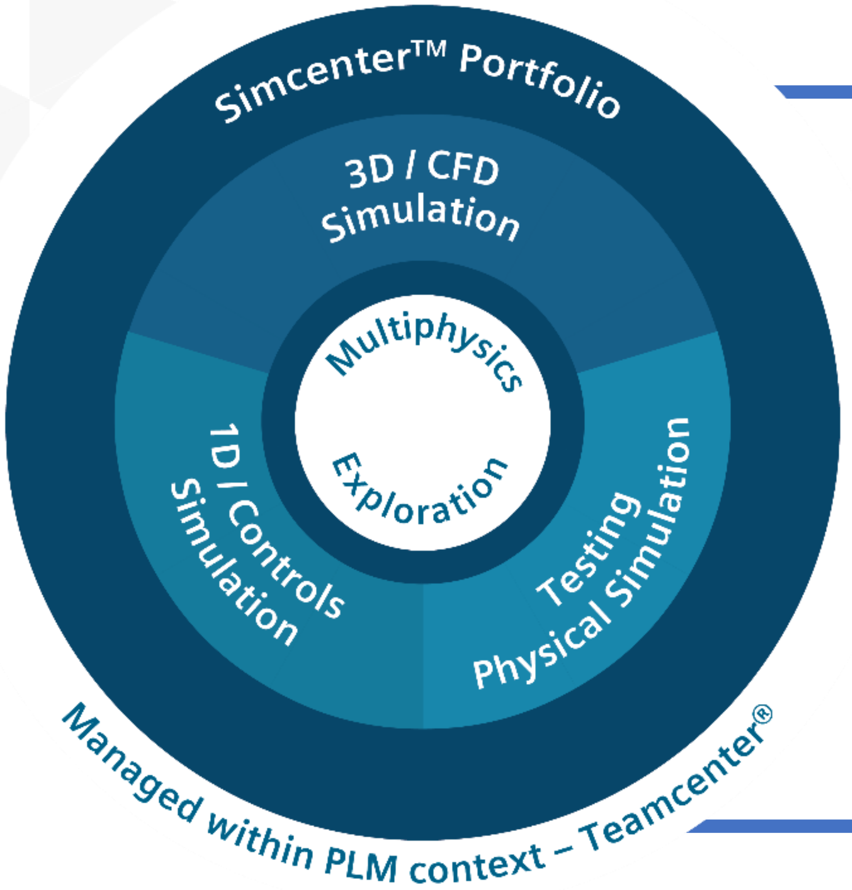






STAR-CCM+

Part of the Simcenter Portfolio for Predictive Engineering Analytics



- **Realism at each stage of development** by combining multiphysics, multi-disciplinary and systems simulation and test
- **Innovative designs** with multidisciplinary design exploration, and data analytics
- **Best practices, collaboration and long-term knowledge** with Teamcenter for simulation and data management in the context of the overall PLM system.

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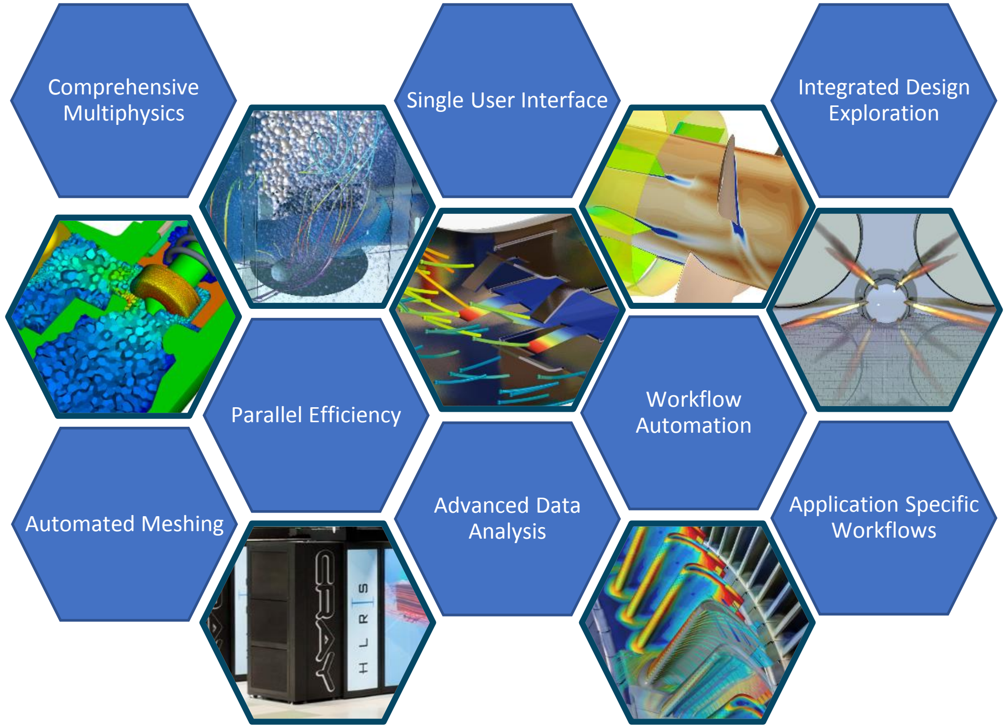
STAR-CCM+

An integrated multiphysics solution for the digital product

STAR-CCM+®

Engineer Innovation



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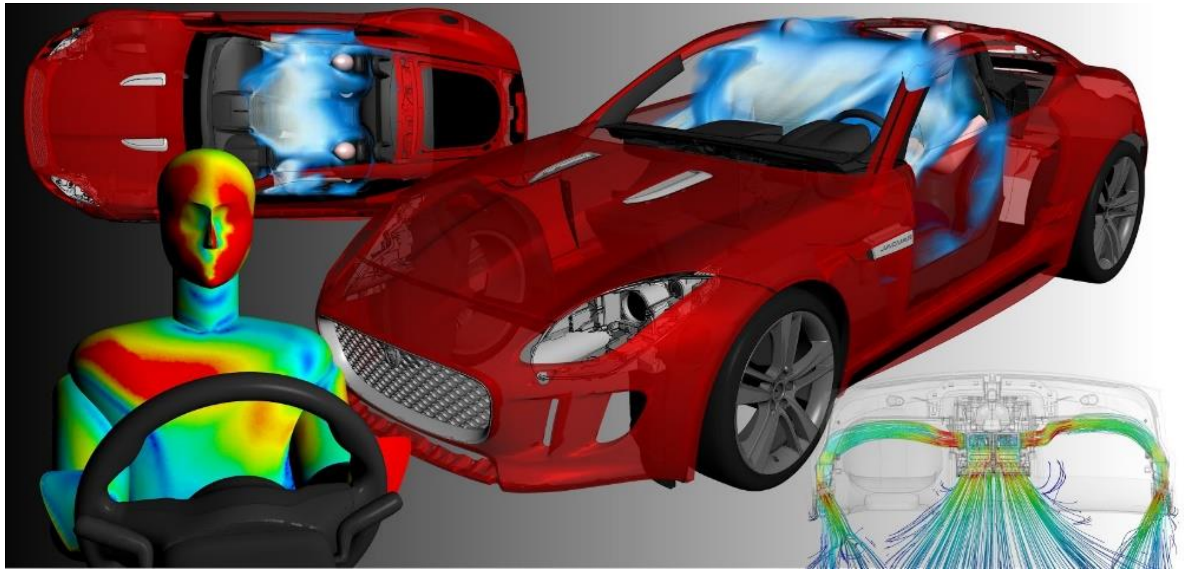

"Prototypes at JLR can be very expensive. If we can save a prototype, the software pays for itself. For systems such as the defrost system, we no longer build any prototypes apart from the final model. We rely totally on STAR-CCM+ to design the system"
Karamjit Sandhu, Jaguar Land Rover Limited

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STAR-CCM+

An integrated multiphysics solution for the digital product

Realism	Productivity	Efficiency	Innovation	Responsiveness	Success
with multiphysics	with streamlined workflows and automation	with HPC	with design exploration	with cutting-edge technologies	with customer support

Engineer Innovation

STAR-CCM+

An integrated multiphysics solution for the digital product

Realism with multiphysics

- Integrated multiphysics from a single user interface
  - Improved accuracy by taking into account a greater range of interconnected physical phenomena
  - Built on a backbone of state-of-the-art, industry leading CFD capabilities
- Both finite element and finite volume approaches
  - No need to compromise
  - Choose the scheme appropriate to the physics
- Integration with CAE tools to expand simulation scope
  - Flexibility to us the right tool for the job
  - Loose and fully coupled co-simulation with 1D & 3D software solutions

Image by Roush Industries

"We've been able to deepen our analysis and drive engine designs faster and more effectively with the same resources as before"
Jeff Schlautman, General Motors

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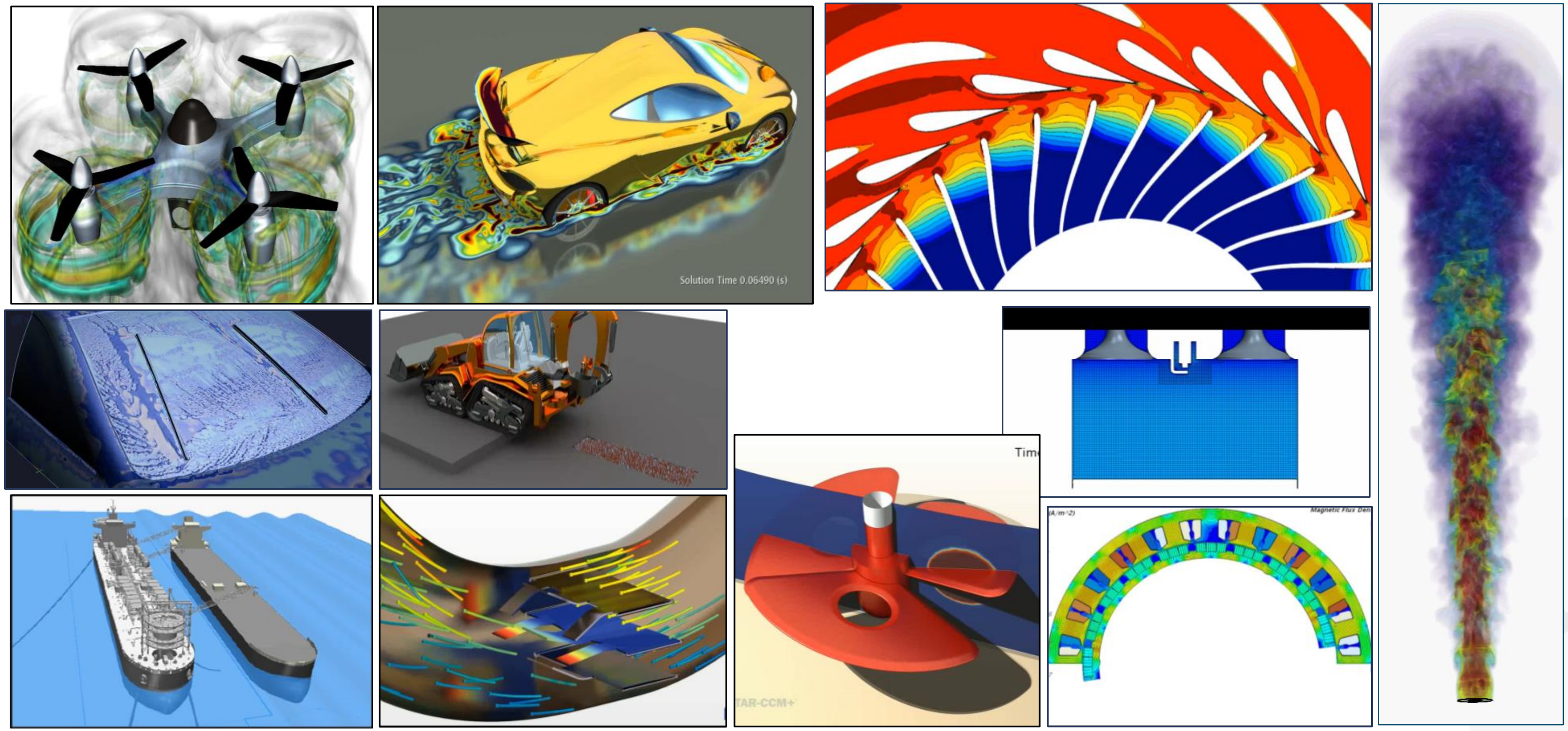
STAR-CCM+

An integrated multiphysics solution for the digital product

Realism with multiphysics

- Fluid dynamics
- Multiphase flows
- Reacting flows
- Solid mechanics
- Particle flows
- Rheology
- Electrochemistry
- Electromagnetics
- Aero-acoustics
- Fluid-structure interaction
- Conjugate heat transfer



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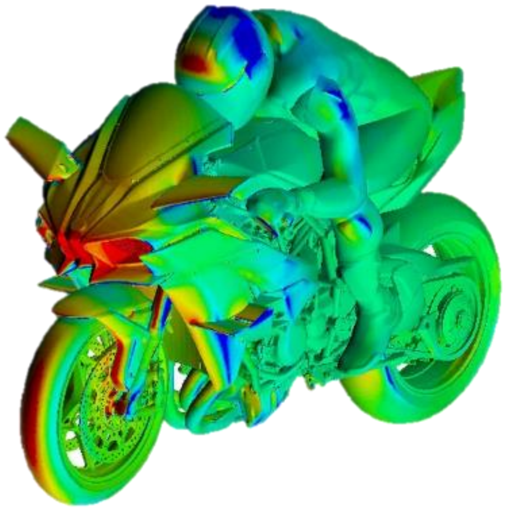
An integrated multiphysics solution for the digital product

Productivity with streamlined workflows and automation

- Designed with automation in mind
  - Seamless process from geometry to results
  - Consistent, robust and repeatable workflows
  - Ensuring best practice with simulation templates
- No compromise between usability and functionality
  - Easy to learn and use even for advanced configurations and physics
- Single, flexible yet powerful scripting language
  - Automate the complete workflow with Java
  - Customize your experience with user designed panels
  - Use Simulation assistants for step by step processes



"Compared to before, now we can simulate several dozen cases in a reduced time. Thanks to this, the number of actual prototypes being turned out has also been reduced, making an extremely valuable contribution to lowering cost and man-hours alike."
Eiji Ihara, Kawasaki Heavy Industries Ltd.

STAR-CCM+

An integrated multiphysics solution for the digital product

Efficiency with HPC

- STAR-CCM+ ensures computational resources are utilized with maximum efficiency
  - Solvers that scale to hundreds of thousands of cores
  - Parallel meshing reducing turnaround time and enabling mesh generation on clusters
- Unique licensing options to ensure software cost doesn't limit hardware utilization
  - Core count independent Power Sessions
  - Usage based Power-on-Demand for cloud deployment and burst capacity requirements
  - Flexible Power Tokens enabling design exploration

"Being able to use the POD licensing scheme and run simulations on a cloud has been a tremendous help for us in terms of productivity."
Mio Suzuki,Trek Bicycle Corporation

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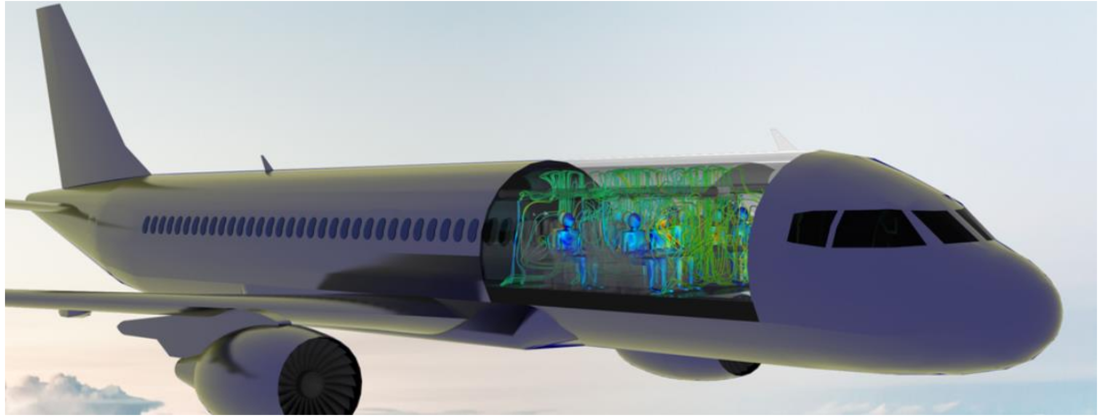
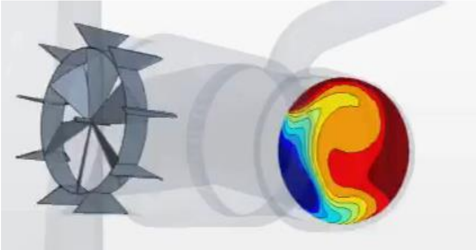
STAR-CCM+

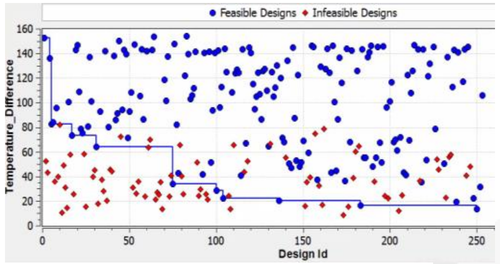
An integrated multiphysics solution for the digital product

Innovation with design exploration

- Built-in design exploration and optimization
  - Easy to use with a familiar experience
  - Comprehensive range of exploration options
  - Gain insight into product behaviour and parameter influence with unique post-processing options
- Design Manager
  - Facilitating parametric analysis
  - No additional license required to enable sweeps
- Design manager with STAR-Innovate add-on
  - Explore entire design space and find better designs
  - Automatic search using embedded HEEDS technology
- Flexible license scheme to deploy design exploration







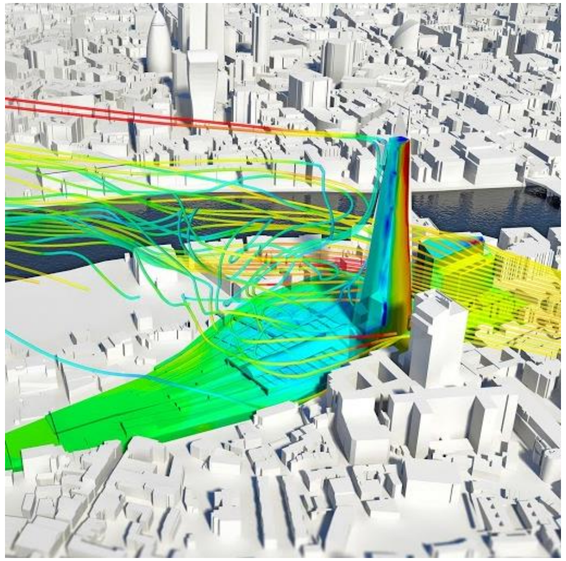
"With design exploration in STAR-CCM+ we learned what makes a good design and how to improve the performance of the system"
Andreas Ruch, ECS Analyst, Airbus

STAR-CCM+

An integrated multiphysics solution for the digital product

Responsiveness with cutting-edge technologies

- Three major releases a year:
  - Delivering state-of-the-art technologies
  - Includes over 100 new features and enhancements with each release
- Collaboration with customers to satisfy immediate simulation needs
  - IdeaStorm for collecting, voting, and commenting on new feature requests
- Partnering with our users to anticipate simulation trends allowing them to stay ahead of their competition
  - A proven track record of technological innovation since first release in 2006



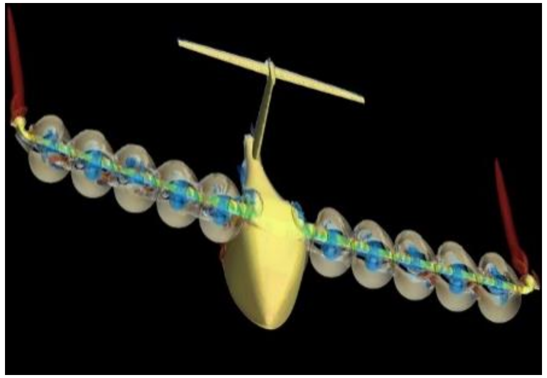
With regular releases, new features are always being introduced into the code, which enables us to produce more accurate simulations quicker. *James Bertwistle, WSP*

STAR-CCM+

An integrated multiphysics solution for the digital product

Success with customer support

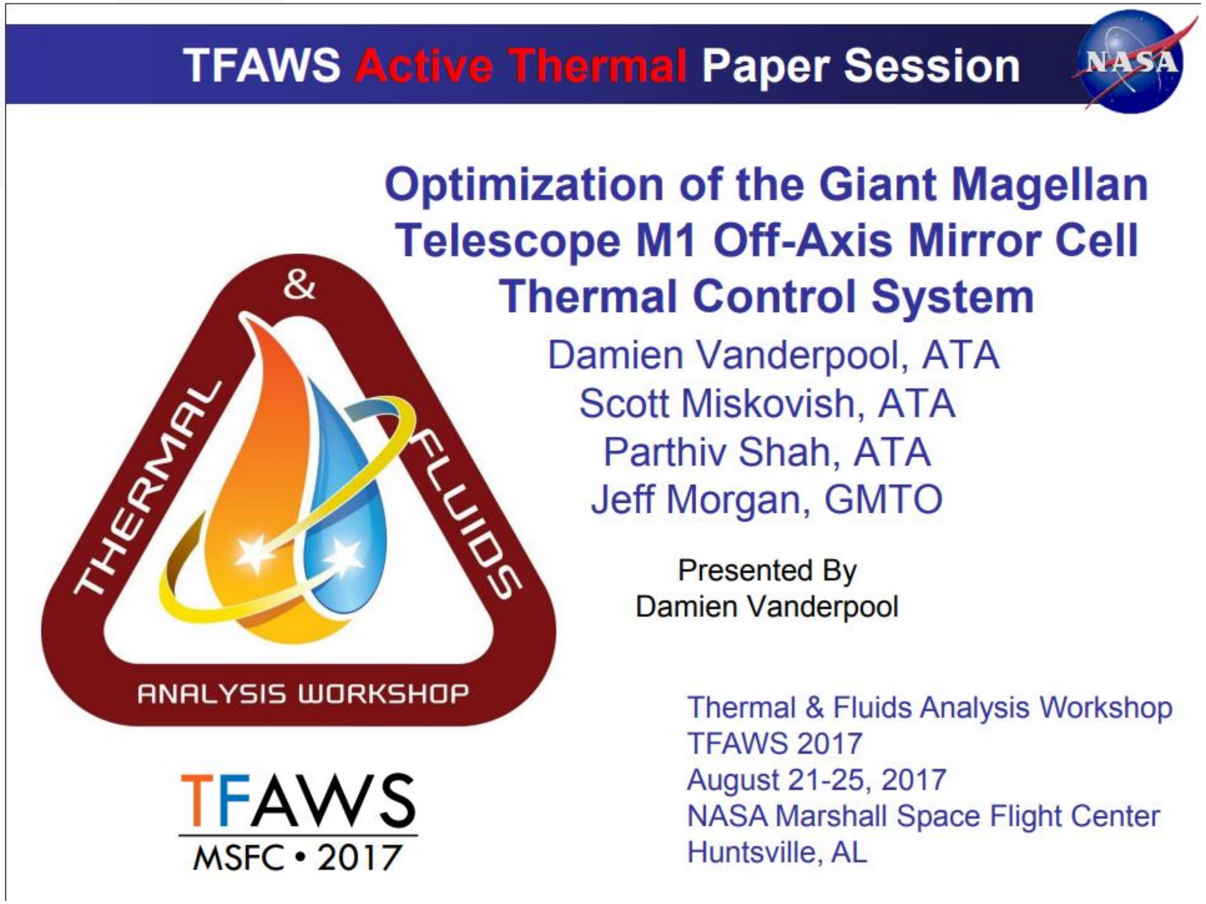
- A team of global experts to ensure our customer’s success
- Dedicated support to provide help every step of the way
  - Working closely with users to gain an in depth knowledge of their processes and requirements
  - Providing immediate solutions to your simulation challenges
- A customer portal, available 24/7
  - Access to a huge library of knowledge base articles
  - Track support queries and download software
  - Chat to support engineers and engage with the STAR-CCM+ user community

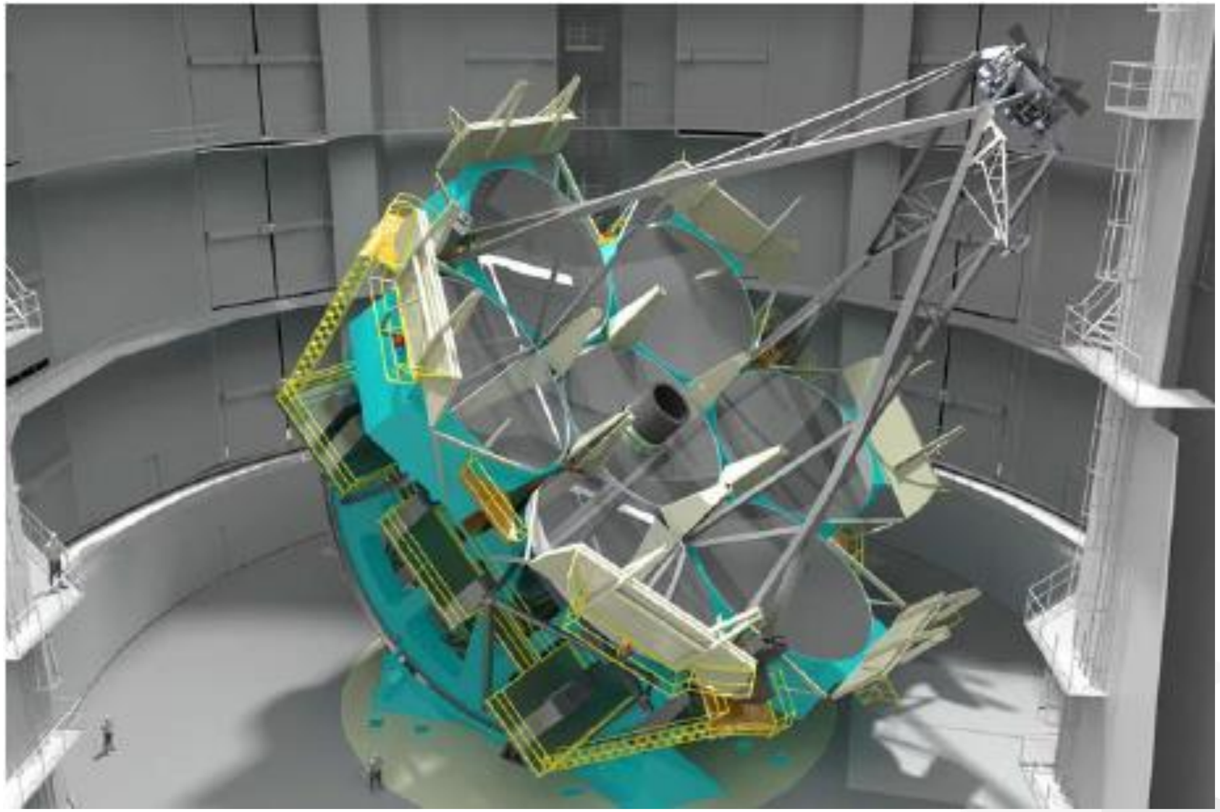


“Support from the engineers at Siemens PLM is great. It’s really nice to be able to call up an expert with a question, and they make you their first priority and help you be successful.”
Alex Stoll, Aeronautical Engineer, Joby Aviation

Today’s Presentation is Based on Material in the Public Domain

Paper and presentation approved for general release:
https://tfaws.nasa.gov/tfaws17/tfaws-2017-proceedings/

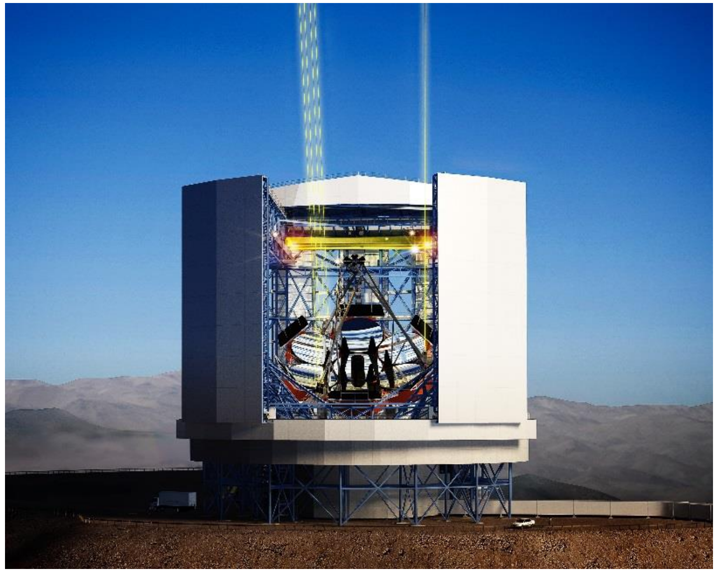


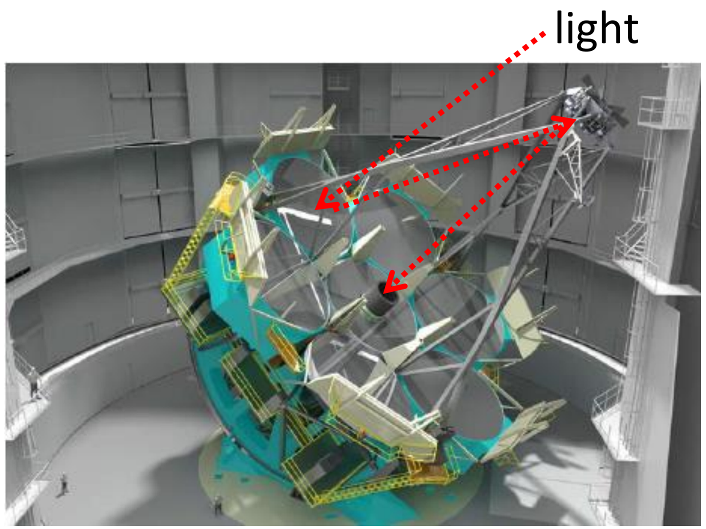


Introduction

- The GMT will have a resolving power 10x greater than the Hubble Space Telescope
  - Currently under construction in the mountains of Chile
- Light will reflect off mirrors and be concentrated on cameras for calculations
- Mirrors can adjust via actuators to be perfectly focused
- Each mirror is made of glass molded in a honeycomb patterned & polished to within a one-millionth of an inch
  - Mirrors' shape must be precise & predictable
  - To minimize thermal distortion, mirrors are temperature controlled via nozzles/fans
- This presentation describes how CFD was used to model the thermal control system and allowed us to explore alternate designs

Photo courtesy of GMTO website





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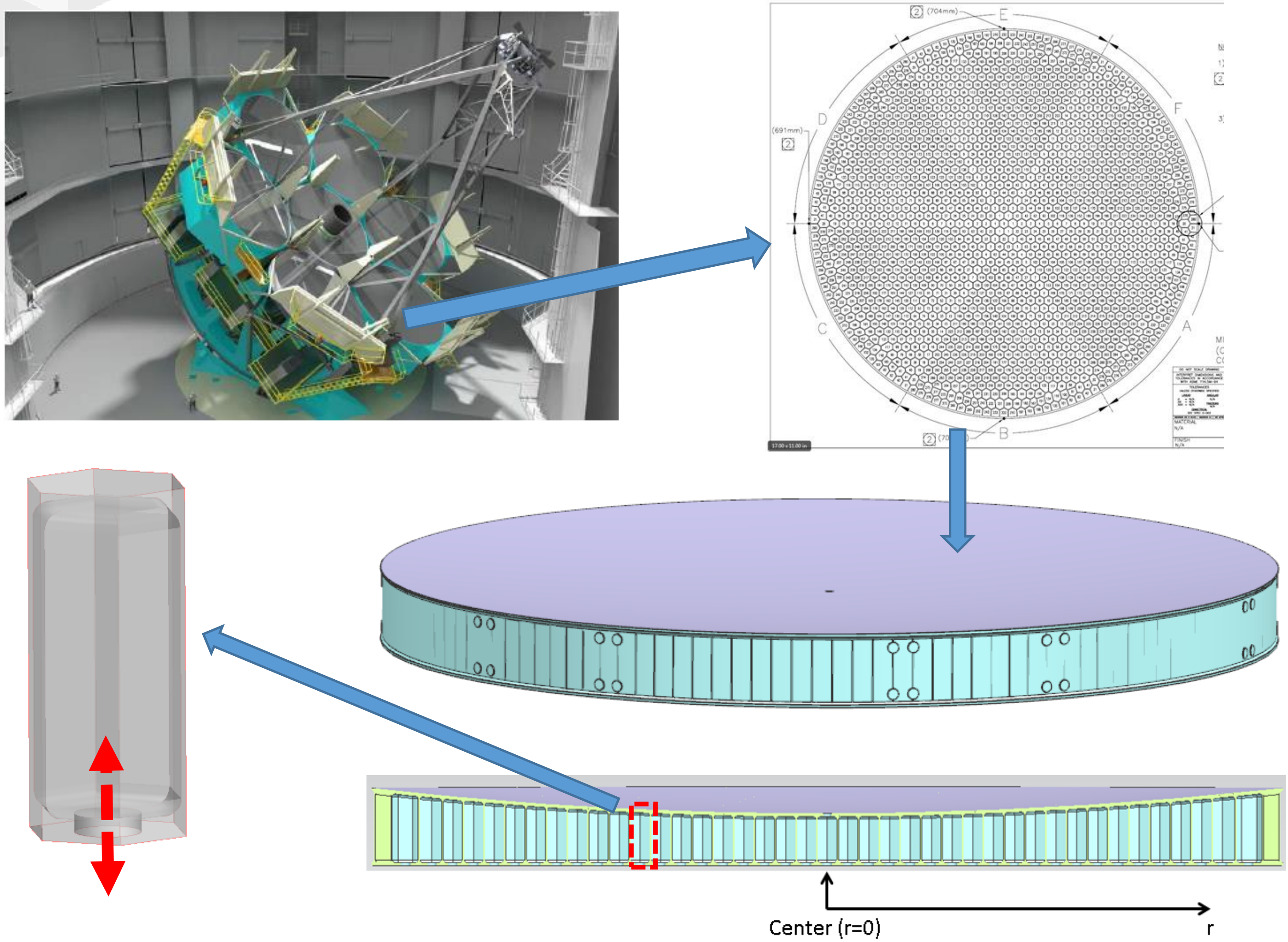
Mirror Overview



- Mirror has parabolic top surface & flat back surface
- Each mirror is comprised of 1681 honeycomb cores
- Cores, in general, have same cross-sectional area but varying height (as a function of mirror radius)
- Each core has a circular hole in bottom to allow air to enter/leave

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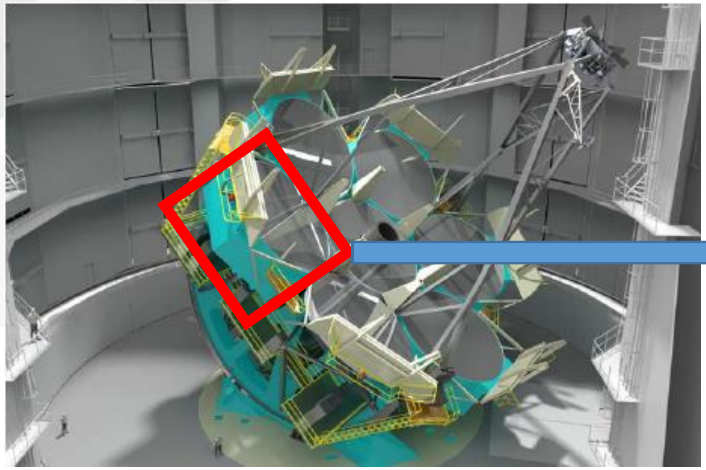
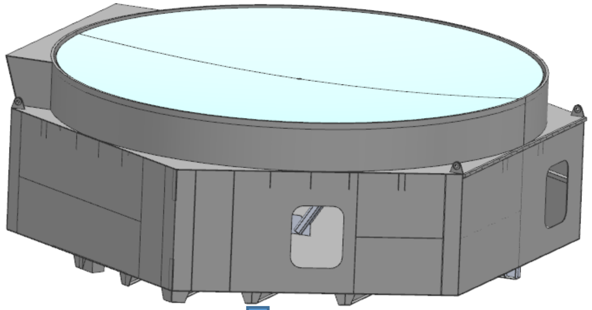
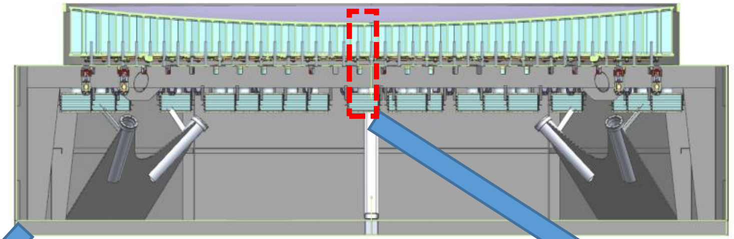
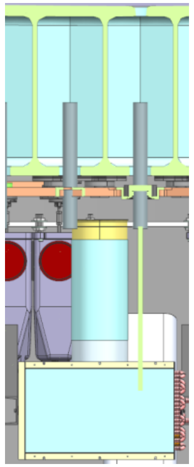
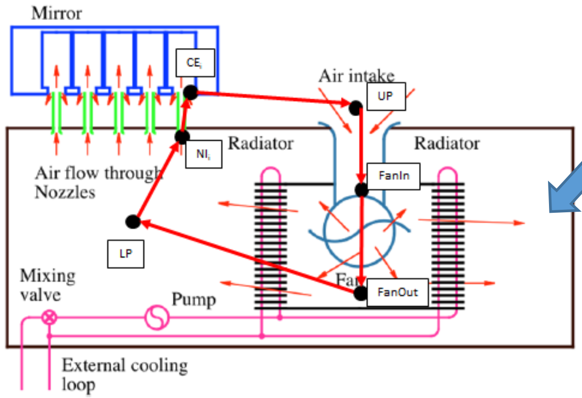
Mirror Assembly Overview











- Mirror assembly has: 1) mirror, 2) weldment, 3) fans/HEXs, 4) nozzles
- Mirror rests on actuators, above weldment, which creates a closed volume of air (Upper Plenum: UP)
- Fans draw in air from UP to Lower Plenum (LP)
- Fan blows air through HEXs to control temp
- LP is pressurized & air passes through nozzles and into mirror cores
- Air exits cores and enters back into UP

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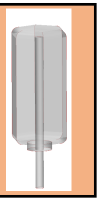
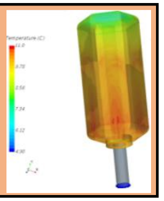
Methodology

CFD

Create Breakout Models to be used in CFD



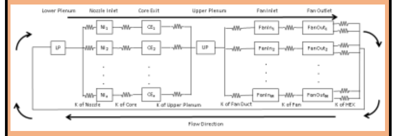
Perform CFD analysis for various design parameters



Post process CFD results to determine Nu correlations

$$Nu = ARe^{n}Pr^{m}$$

Determine flow network



Script that calculates ideal design parameters that result in uniform & minimize thermal time constants

Script parameter inputs:

- # of nozzle sizes
- # of fans
- Type of fans

Determine geometrical dimensions

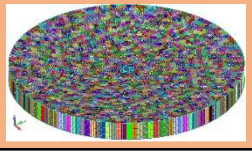
- Core heights
- Surface areas
- Volumes

HTCs on each surface of mirror

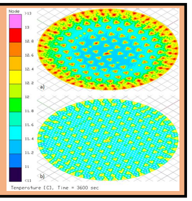
Thermal boundary conditions

- $T_{initial}$
- $T_{environment}$

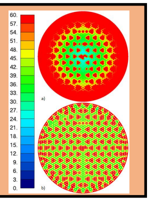
Thermal model



Temperature vs Time



Thermal Time Constants (tau)



End Goal (want a design that provides as uniform & small of a value as possible)

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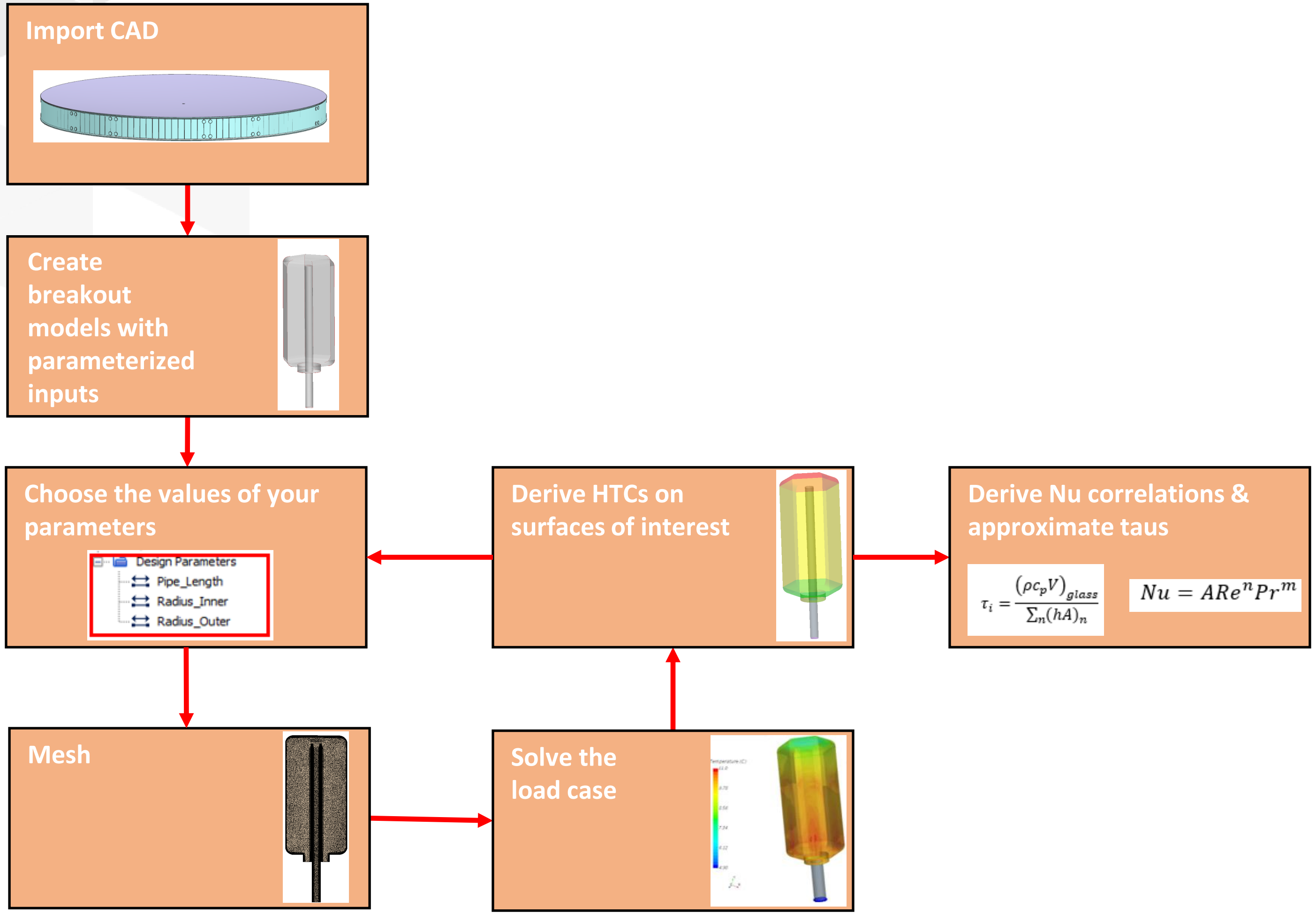
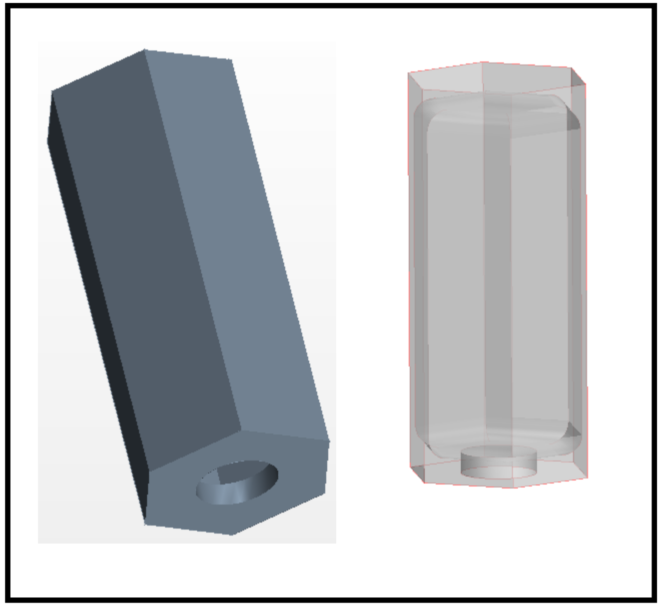
Siemens SimCenter/Star-CCM+ Work Flow



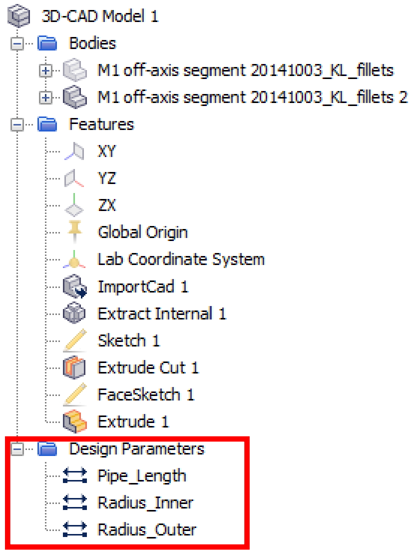
CAD Manipulation

Created parameterized CAD in Star to create multiple breakout model simulations

Original Solid CAD

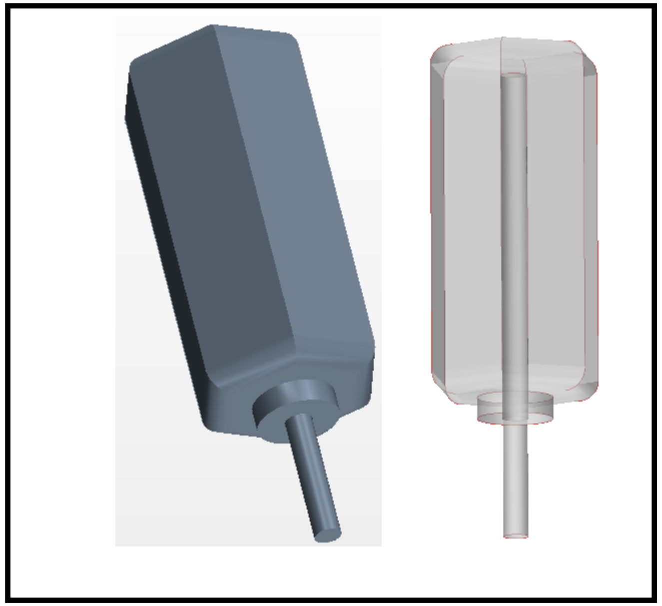


Edits to create Air Volume



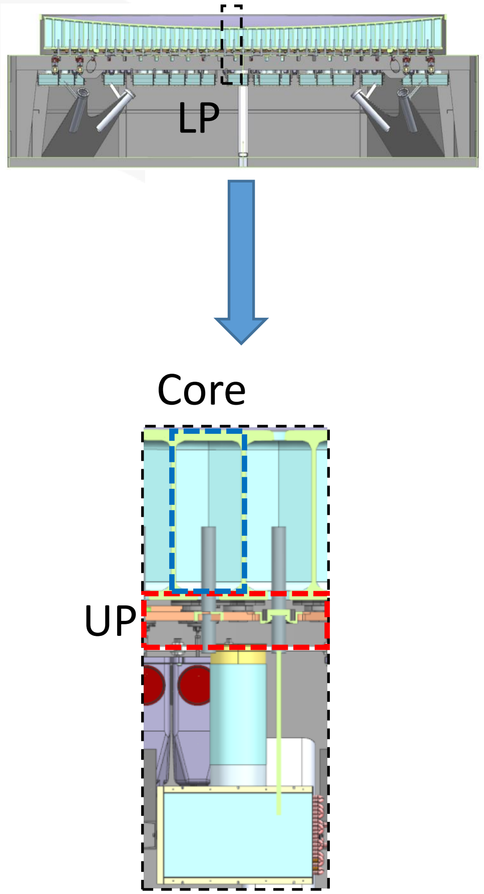
Exposed parameters so that CAD can be easily adjusted per case

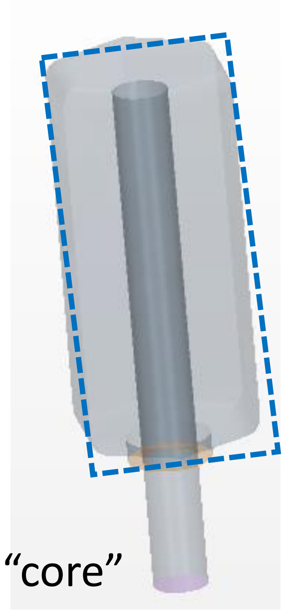
Final Air Volume CAD

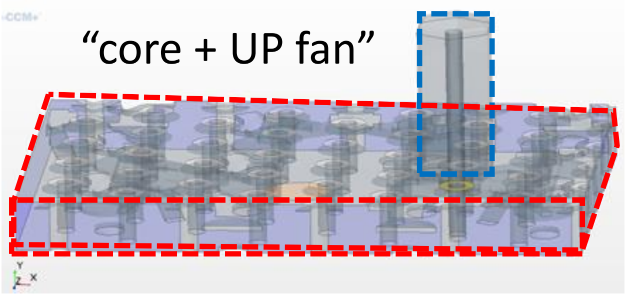


CFD Breakout Models

Analyzed two different CFD breakout models







- "core"
  - Aimed to solve for forced convection within the core (i.e. – all internal surfaces)
- "core + UP fan"
  - In order to account for convection on all surfaces of the mirror (including external back surface of mirror), UP centered around a fan was included

CFD Parameters

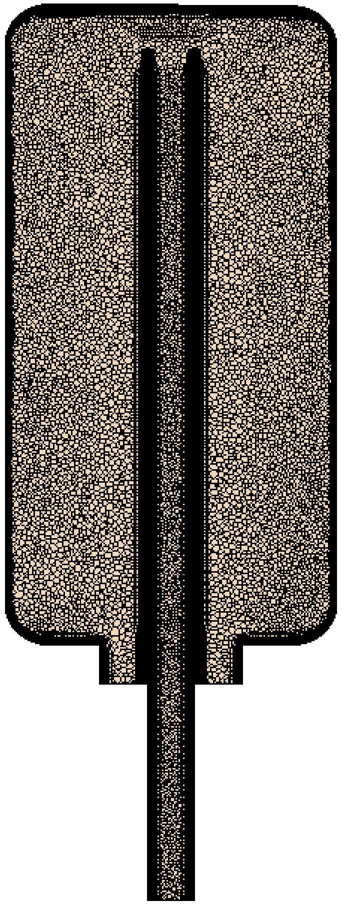
Star-CCM+ Details

- Physics Continua:
  - 3D, steady, single-phase gas, segregated flow, k-ε turbulence model, with ideal gas law
  - Gravity is ignored (no natural convection)

- Mesh Continua:
  - Surface remesher, polyhedral mesher, prism layer mesher
  - Boundary layers had y+ value between 1 & 10 for all surfaces of interest

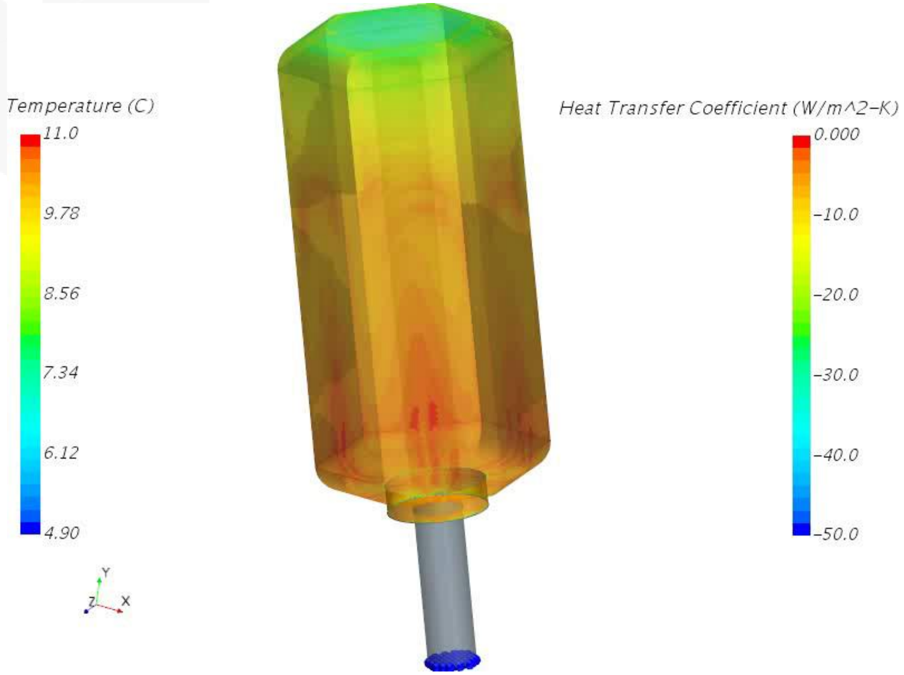
- Mesh count ranged from 0.5 to 13.5 million cells (depending on breakout model)

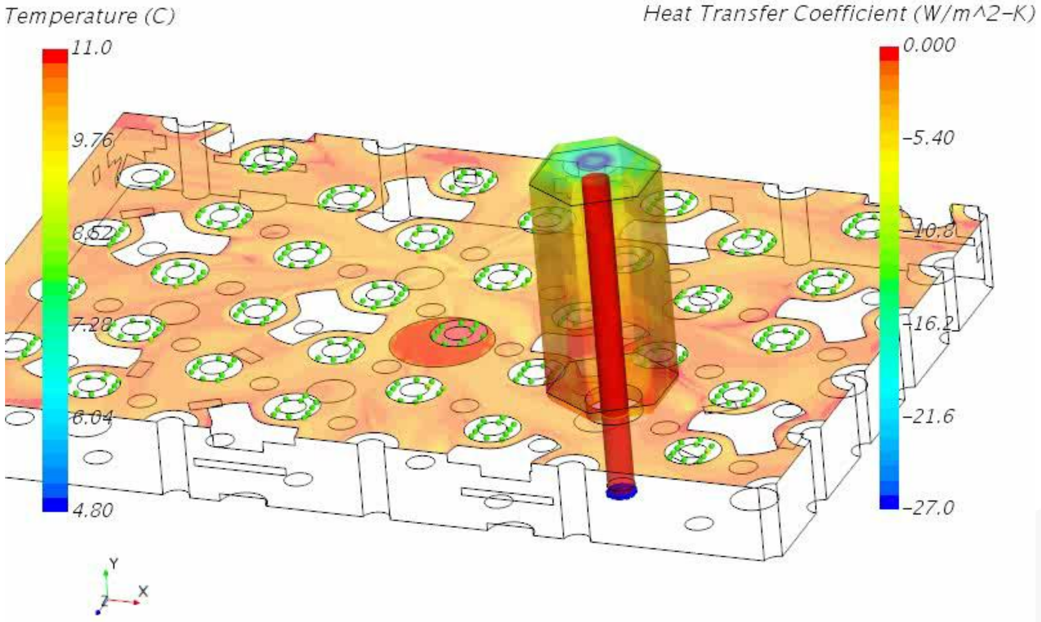
- Using 32 core, CPU time = ~52 core-hr (Wall clock ~1.6 hr)



CFD Results

Examples of animated streamlines with temperature contours and heat transfer coefficients on the surfaces





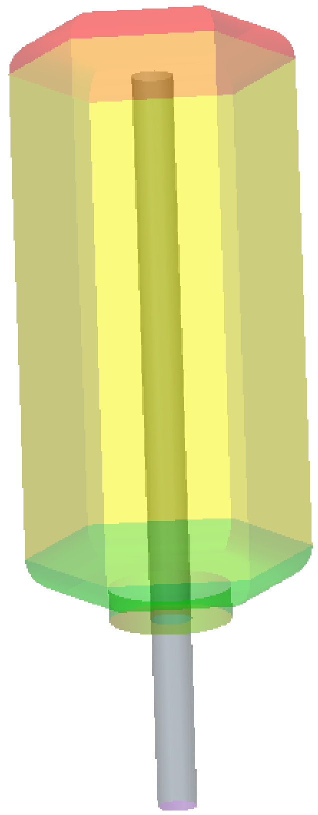
From CFD Derived HTC to Tau & Nu

Performed CFD parametric study to estimate thermal time constants

- Calculated surface area averaged HTCs on the different surfaces

- Goal = determine parameters needed so all cores had same thermal time constants

- From CFD HTCs, Nusselt Number (Nu) correlations were developed so that HTCs could be predicted for all cores/conditions

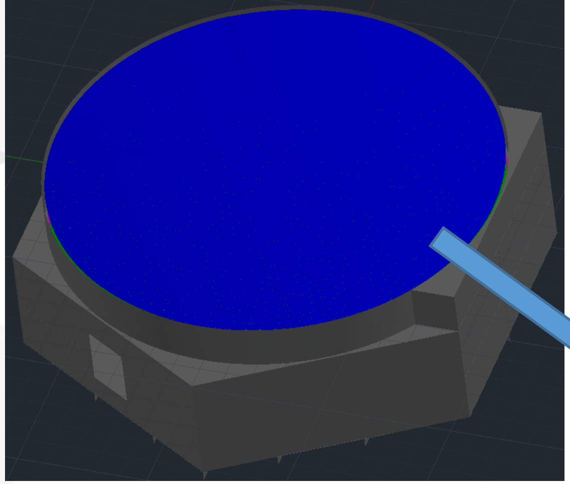


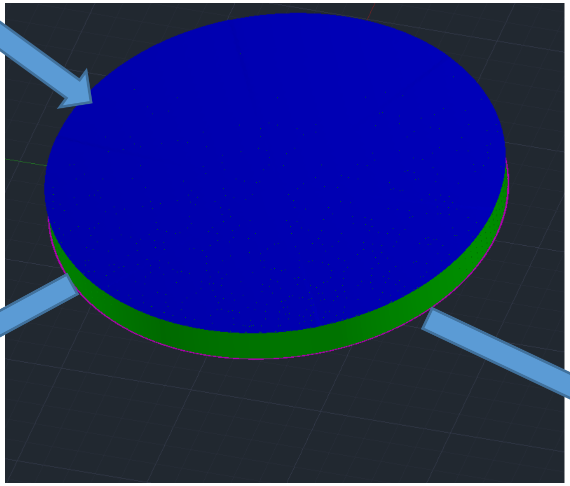
Thermal Time Constant Equation
(i = region, n = surface)

$$\tau_i = \frac{(\rho c_p V)_{glass}}{\Sigma_n (hA)_n}$$

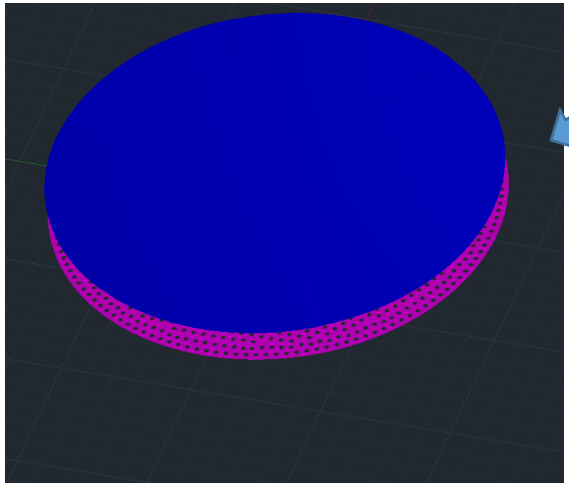
$$Nu = A Re^n Pr^m$$

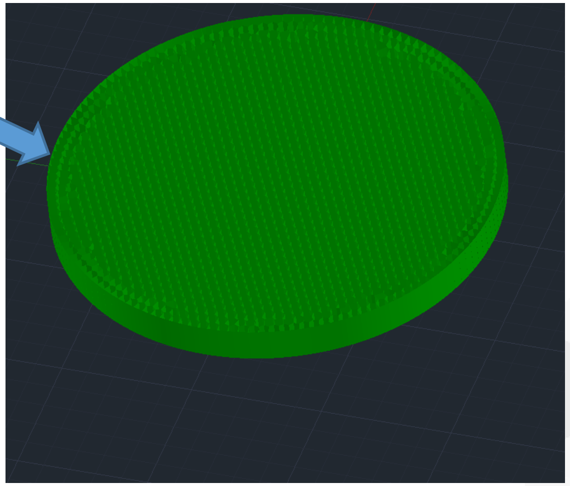
Thermal Model





Grey = weldment
Blue = top surface of mirror
Green = sides of mirror
Magenta = bottom surface of mirror





Note: Baseline design used a single nozzle length/diameter

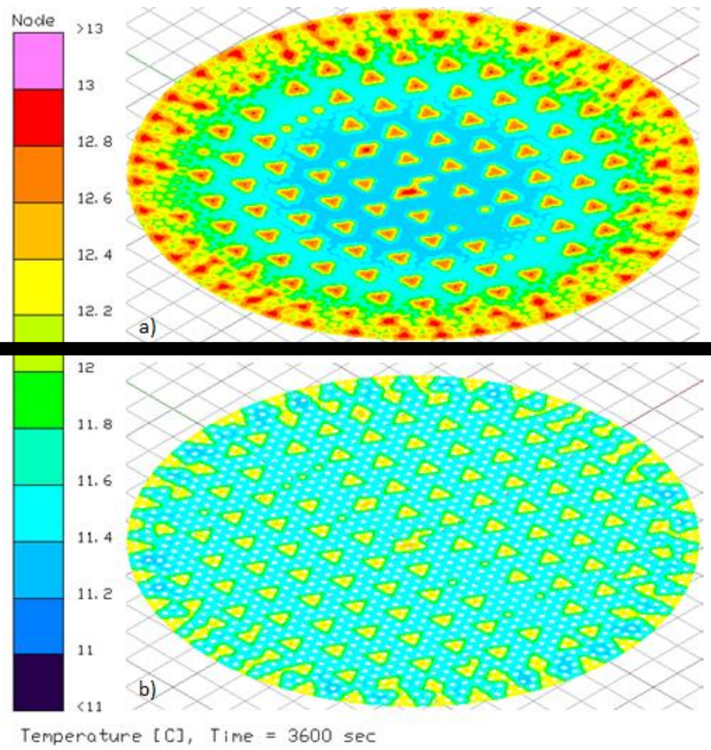
Results: Baseline

Baseline design showed non-uniform temperatures

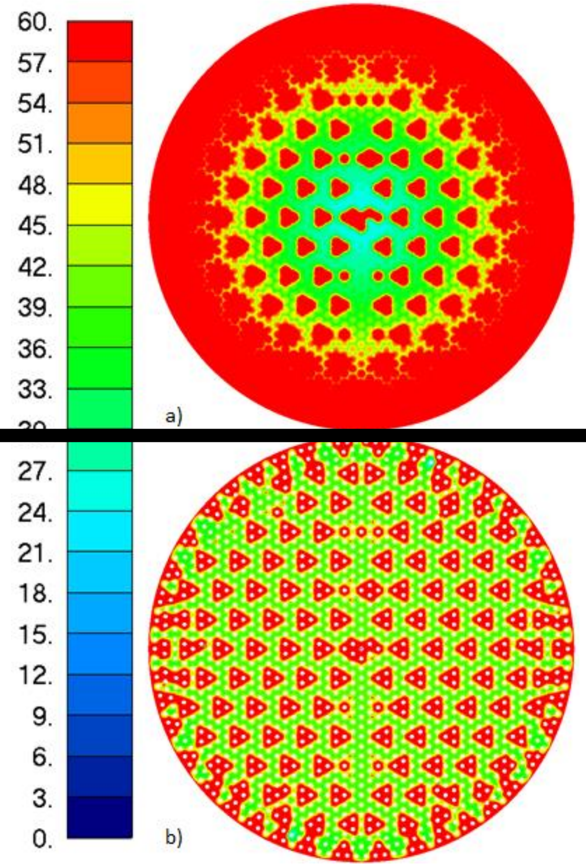
Temp contour of mirror after 1 hr

Top Surface

Bottom Surface



Local taus (in minutes)



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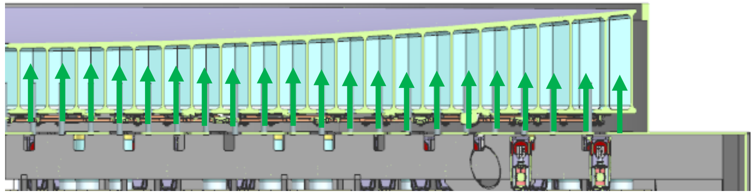
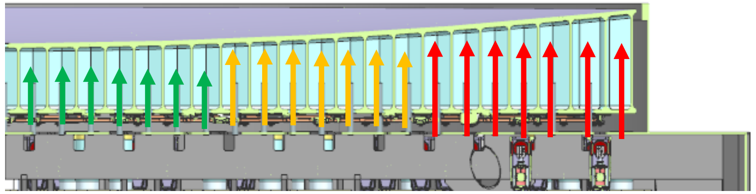
Need a New Design

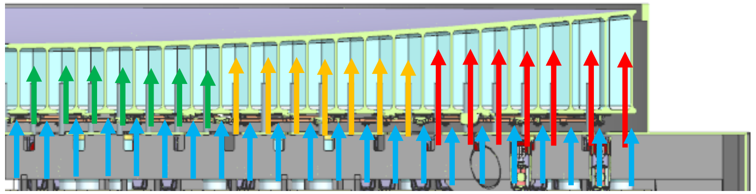
- Baseline design led to non-uniform temperatures & thermal time constants
  - Due to varying cell height with single nozzle size



- Attempted to optimize design by having a reasonable number of different nozzle lengths/diameters
  - Could not match thermal time constant on top & bottom surface of mirror for all cores
  - Needed to decouple HTCs on surfaces



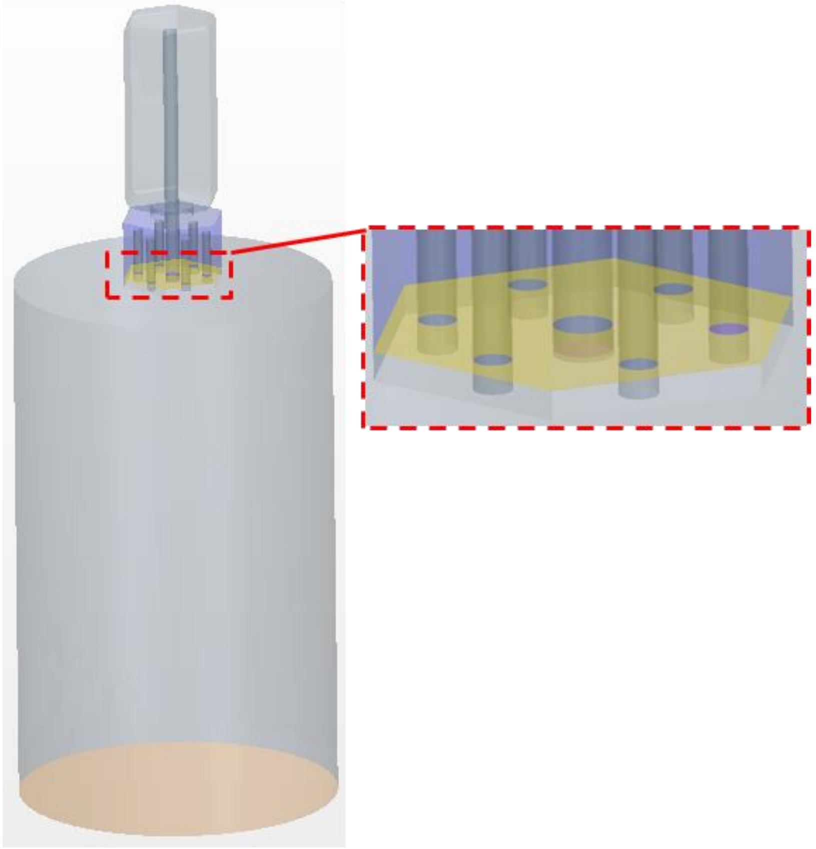
- New design proposed
  - Add "Upper Plenum Nozzles" that have impinge air on back surface while original nozzle ("Mirror Nozzle") can be optimized to impinge air on top surface



CFD Breakout Model

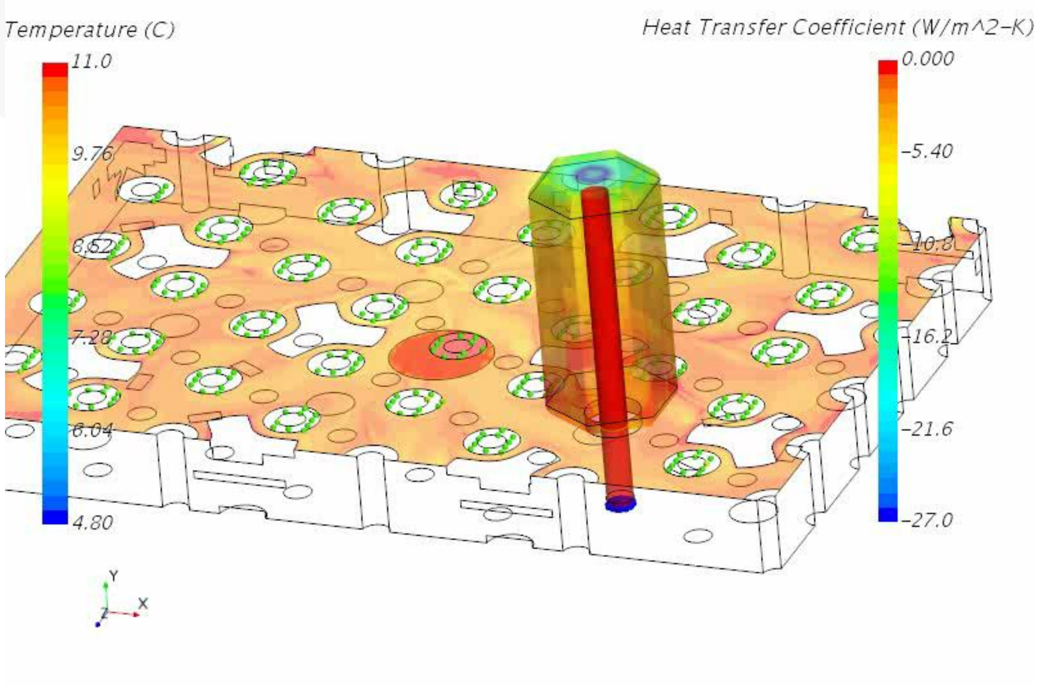
Analyzed a third CFD breakout model

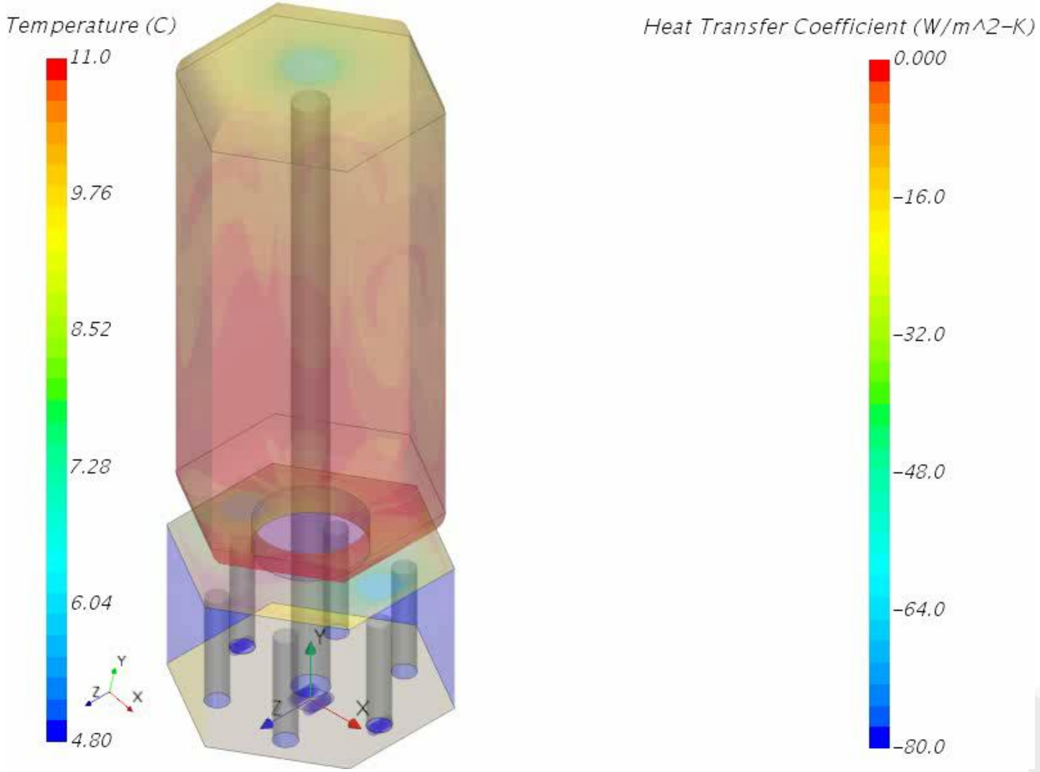
- "core + UP" breakout model was created for new design:



CFD Results

Example of animated streamlines with temperature contours and heat transfer coefficients on the surfaces





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Results: UPN Design

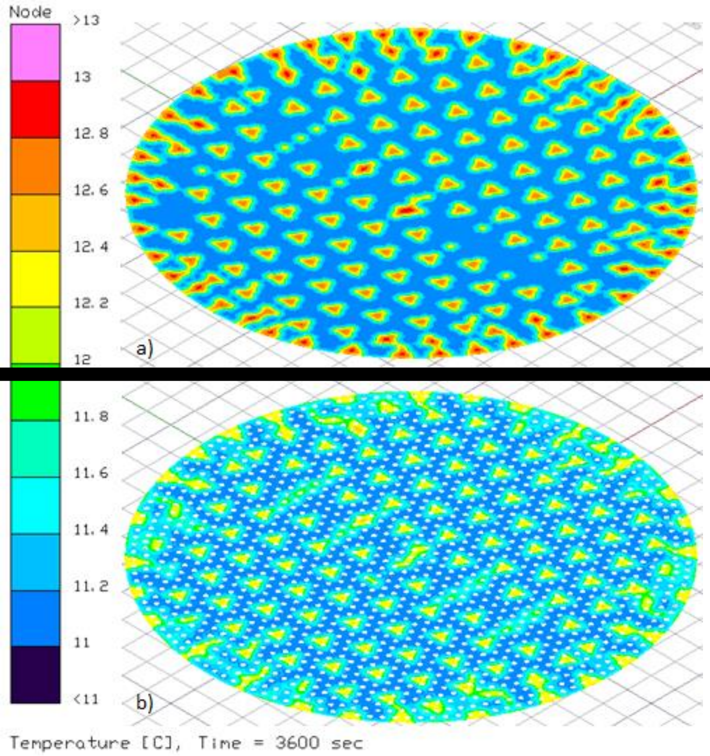
Optimized UPN design showed uniform temperatures

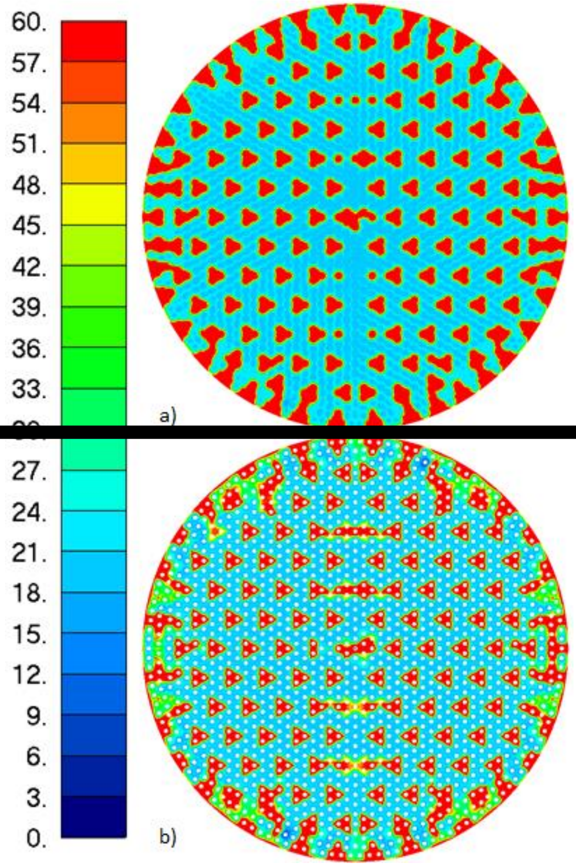
Temp contour of mirror after 1 hr

Local taus (in minutes)

Top Surface

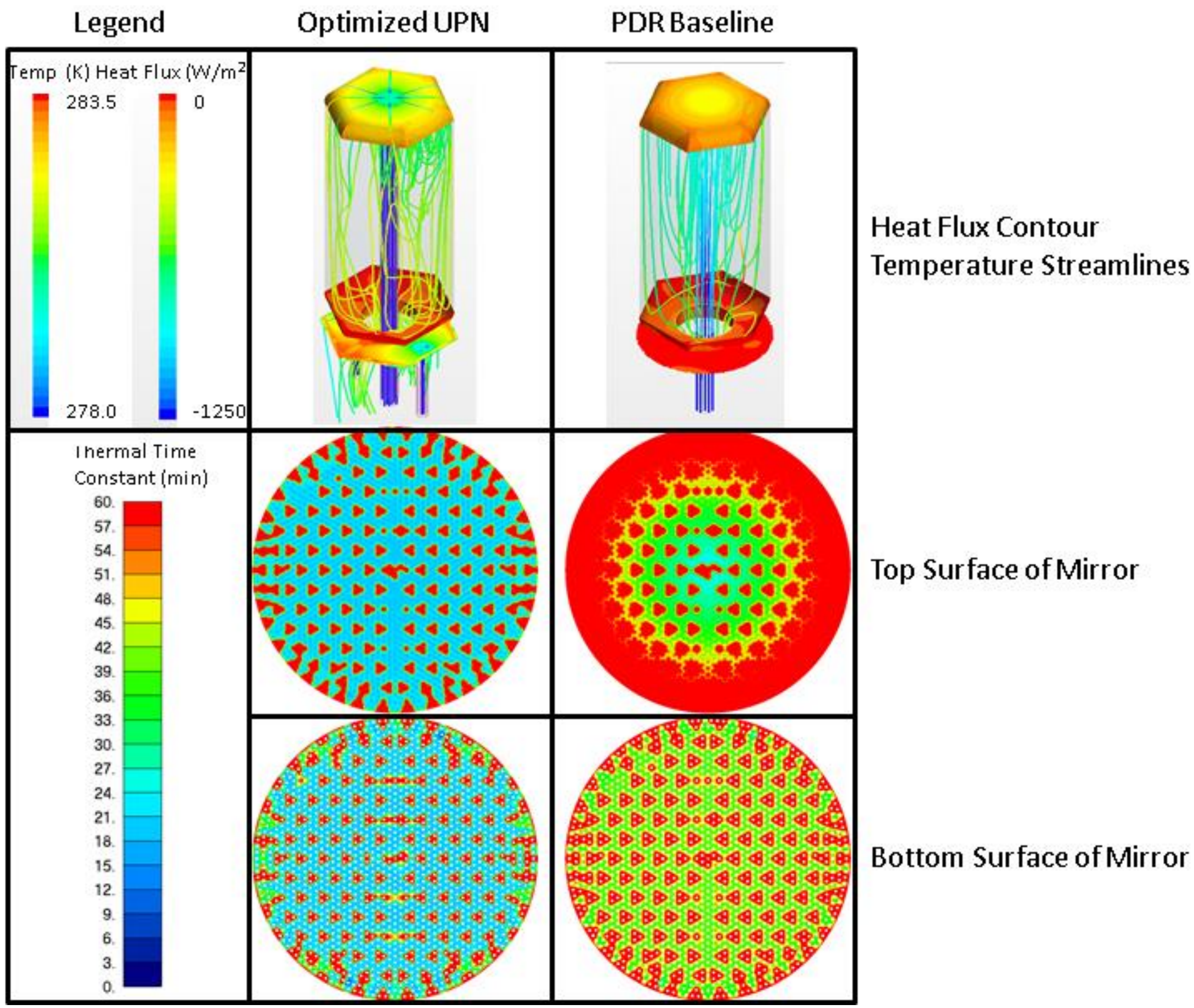
Bottom Surface





Results: Comparison

Comparisons show optimized UPN design outperforms baseline design dramatically



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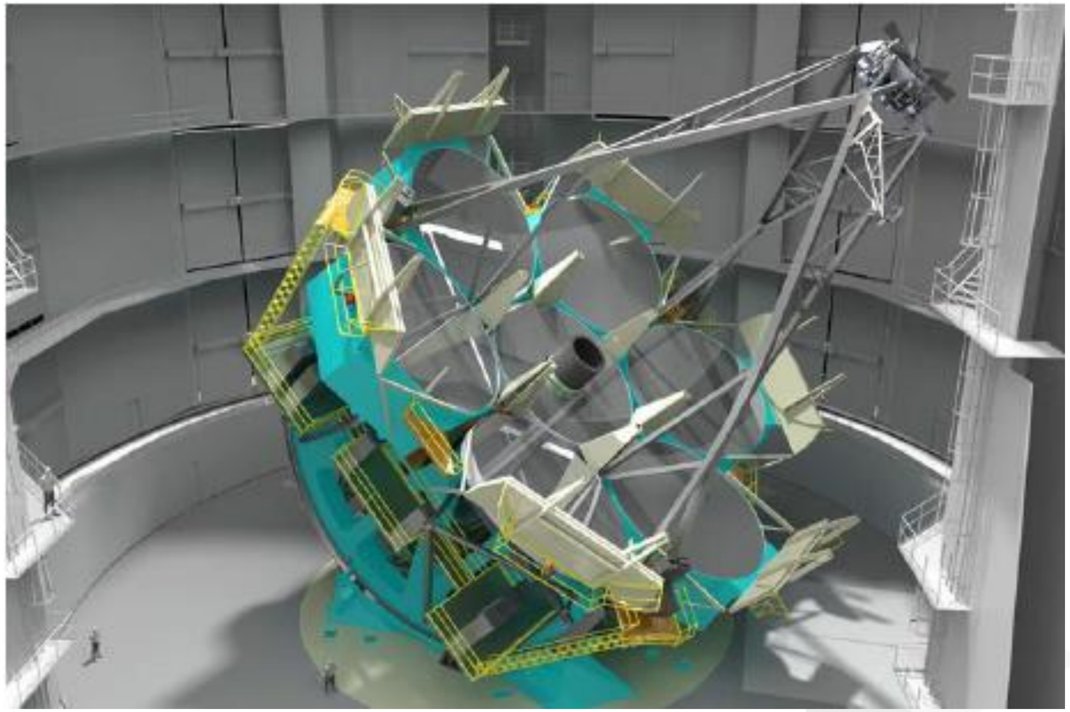
Conclusions

- Analyzed Baseline Design and found similar thermal time constants to what was seen in similar telescopes
- Proposed a new design which met all the goals/objectives
  - Design reduced the thermal time constant by a factor of two and improved uniform temperature distribution by a factor of 5
- Star-CCM+ was a great tool because it allowed the ATA team to manipulate the complex CAD data, quick solve times with use of cluster, and powerful postprocessing tools which allow for better and more complete understanding of the phenomena modeling



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