



CFE Services

Integrating S/W Tools for Opto-Mechanical Design

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NASA Mirror Technology Days - 2014

Long, Rich Heritage in Integrated Modeling

Integrated Modeling Applied to the Terrestrial Planet Finder Mission

Andrew Kissil^a, Eug Kwack^a, Timothy Ho^a, Philip Dumont^a, Sandra Irish^b, Ichung Weng^c
^aBall Aerospace & Technologies Corp., 1600 Commerce St., Boulder, CO, 80501
^b4800 Oak Grove Drive, Pasadena, CA 91109
^cUSA 20705

IMOS 2005

Integrated Structural and Optical Modeling of the Orbiting Stellar Interferometer

S. Shaklan, J. Yu, and H.C. Graber
 Jet Propulsion Laboratory
 California Institute of Technology
 4800 Oak Grove Drive
 M/S T1701
 Pasadena, CA 91109

Next generation lightweight mirror modeling software

William R. Arnold, Sr^{*a}, Matthew Fitzgerald^b, Rubin Jaca Rosa^b, H. Philip Stahl^c
^aDefense Acquisition, Inc., Jacobs ESSSA Group, Huntsville, AL, USA 35806-
^bNASA Intern, MSFC, Huntsville, AL, USA 35812;
^cNASA ZP10, MSFC, Huntsville, AL, USA 35812

2013

IMOS 199

Development of a validated end-to-end model for space-based lidar systems

Mike Lieber[#], Carl Weimer, Michelle Stephens, and Ray Ball
 Ball Aerospace & Technologies Corp, 1600 Commerce St, Boulder, CO, 80501

EOSyM 2007

Advancements in Integrated Structural/Thermal/Optical (STO) Analysis of Optical Systems.

Gerhard Stoeckel, David Crompton, Gerard Perrin

Optical modeling activities for NASA's James Webb Space Telescope (JWST): VI. Secondary Mirror Figure and Tertiary Mirror Segment Motions

Lee D. Feinberg

2009

Automated Design Tools for Biophotonic Systems

Giacomo Vacca^a, Hannu Lehtimäki^b, Tapio Karras^c, Sean Murphy^d
^aKinetic River Corp., 661 S. Baywood Ave., San Jose, CA 95128
^bHietalahdenranta 5 c A 6, FI-00120 Helsinki, Finland; ^cDesign Partners, Inc., 1000
 #106, San Jose, CA 95129, USA; ^dSKMurphy Inc., 494 Chinaberry

BeamWise 2014

Integrated

telescope

R.W. Besuner¹, M.J. Sholl², M.D. Lieber³, M.L. Kaplan³,

¹Lawrence Berkeley National Laboratory
²University of California, Berkeley
³Ball Aerospace & Technologies Corporation

EOSyM

Victor Genberg, Gregory Michels
 Sigmadyne, Inc. Rochester, NY

Keith Doyle
 Optical Research Associates, Westborough, MA

SigFit 2002

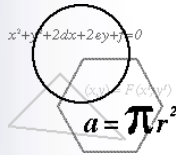
With All These Tools...What is Left?

- Most Tools are Internal
 - IMOS, EOSyM, MACOS, et al.
- Notable Exceptions
 - SigFit, BeamWise, and some primitive tools
- Necessity is the Mother of Invention
 - Several SBIR's Drove Creation of Tools to Help the Engineering Process
 - Avoid Errors (and Tedious Work)
- Started Working with API's... Here's What I Found

Case Studies

- Matlab Design to Optical Design
 - Matlab / Zemax / FRED
- Linking Optical Design with Strain Analysis
 - Nastran / Matlab / Zemax
- CGH Design with SolidWorks
 - C# / Java / SolidWorks

Matlab Driven Design



- Architectural Trade Space
- Analytical Expressions

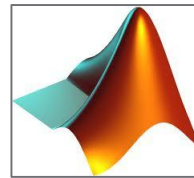
Conceptual Design

- Render Layout
- Optimize Architecture
- Transfer to Ray Trace

Optimize Concept

- Establish Merit Fn
- Create Performance Metric
- Optimize Sub-Space

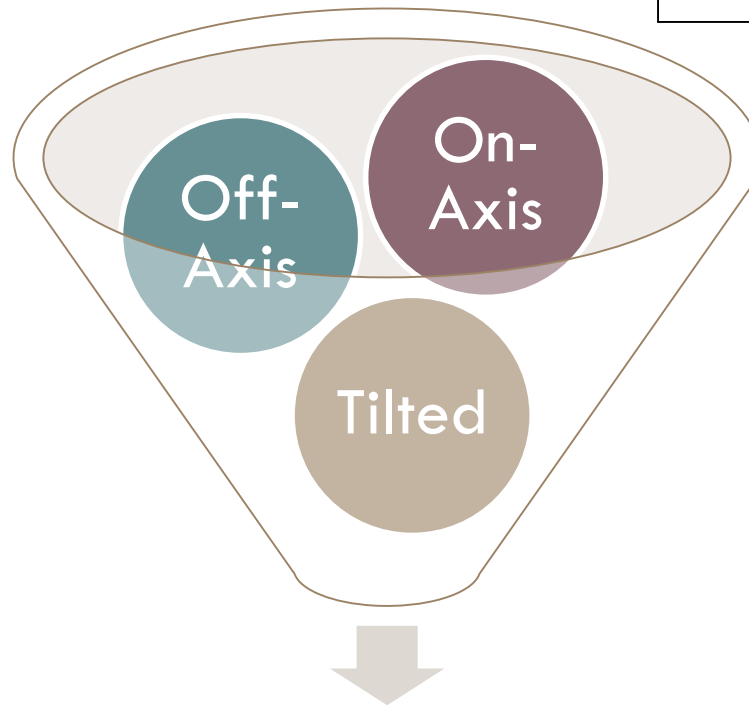
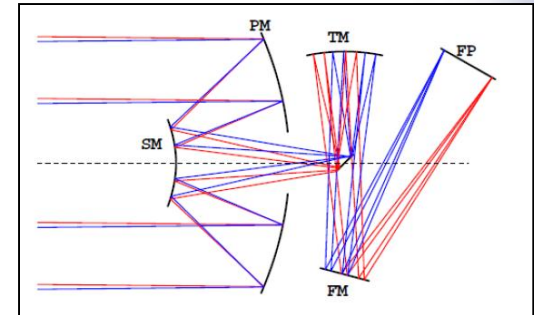
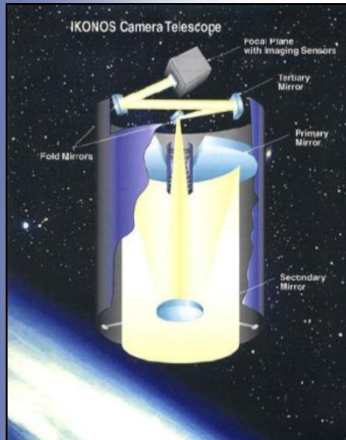
Optimize Performance



Zemax

Photon ENGINEERING
Illuminating Ideas

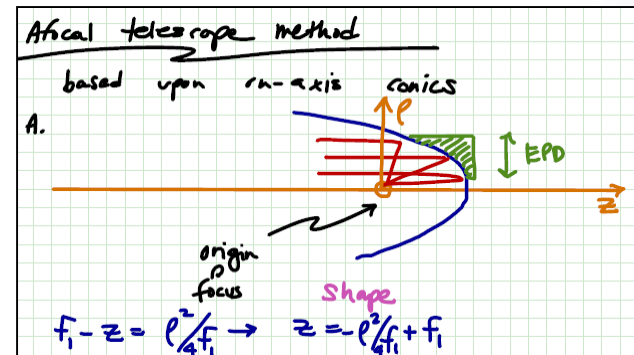
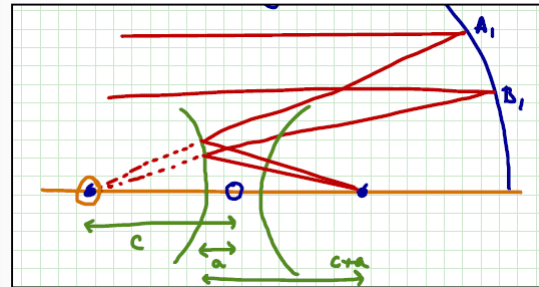
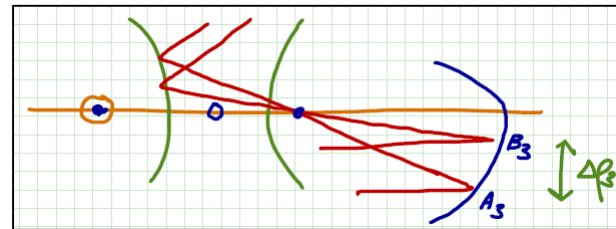
Case Study: TMA



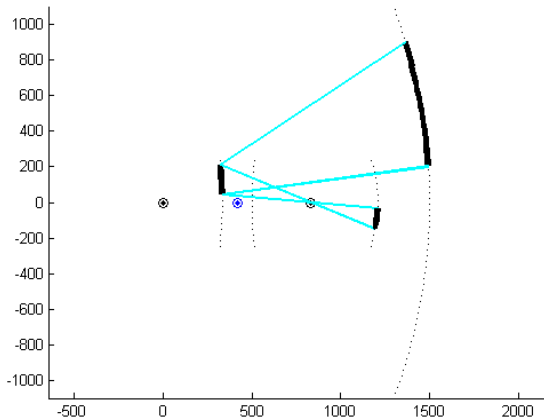
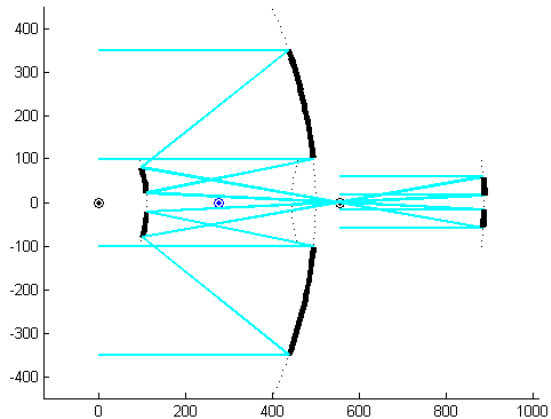
Trade Study: Compare and Down Select

Create Analytical Relationships

- Model: Basic Conic Surfaces
- System Level Parameters
 - Off-Axis Distance, Tilt Angles, Distances, Magnification

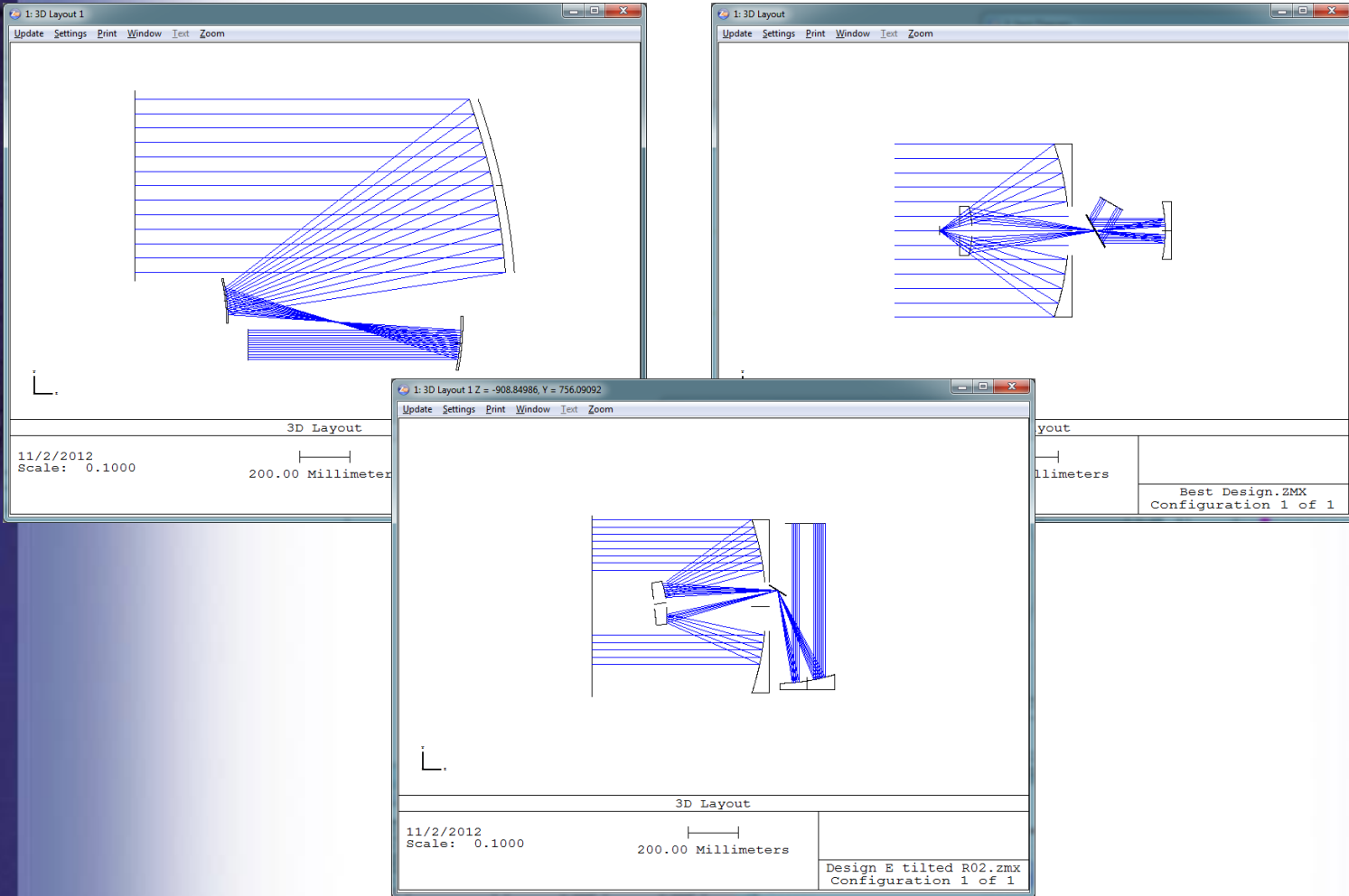


Exercise Model in Matlab

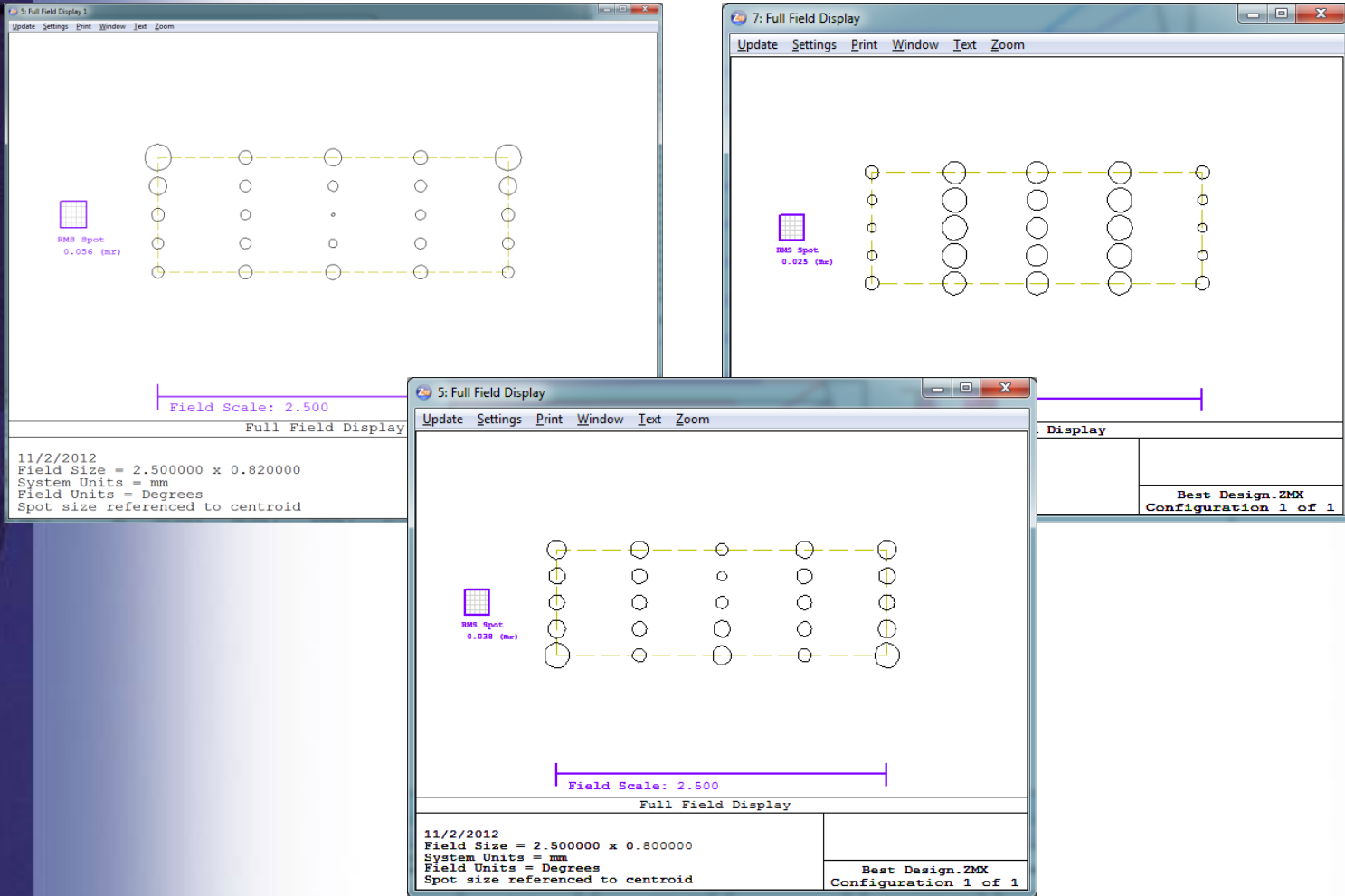


- Object Oriented Programming
 - Classes w/ Methods + Properties
 - Encapsulation + Polymorphism
- Render Surfaces
 - Foci, Marginal Rays, Common Axis, Origin, Vertex
- Inspect Obscuration
- Export to Zemax
 - Push to Zemax
 - Radius of Curve, Conic Constant, Distances, Aperture Size

Optical TMA Models



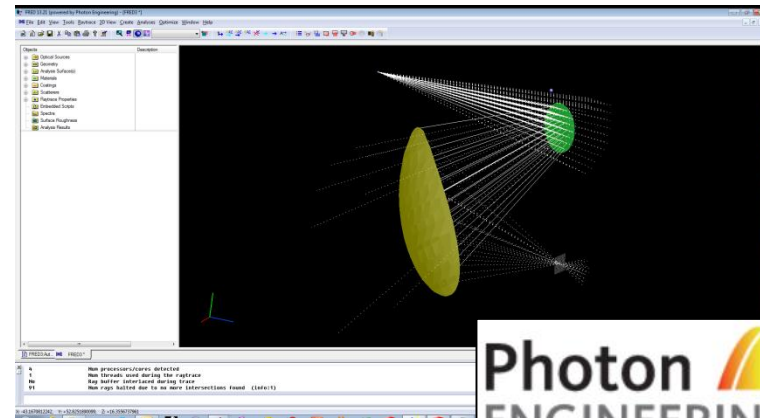
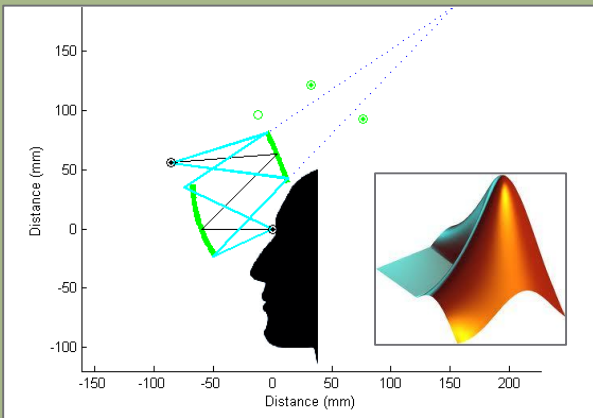
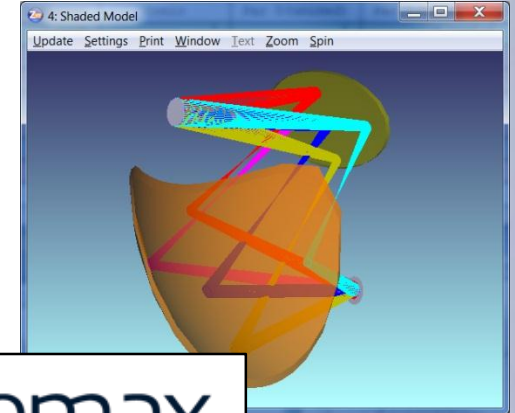
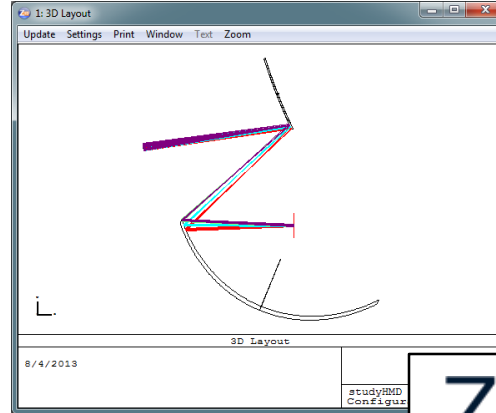
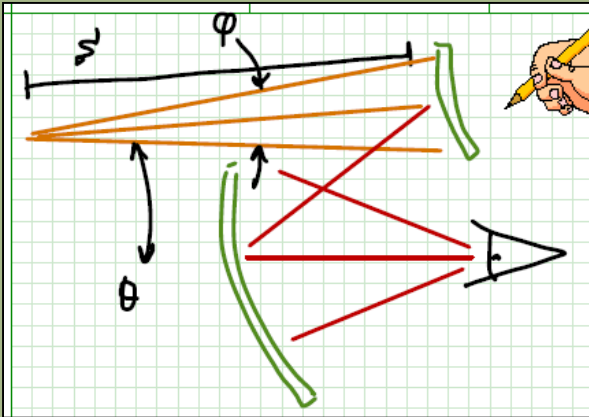
Performance / Full Field Display*



*Custom Zemax Extension DLL

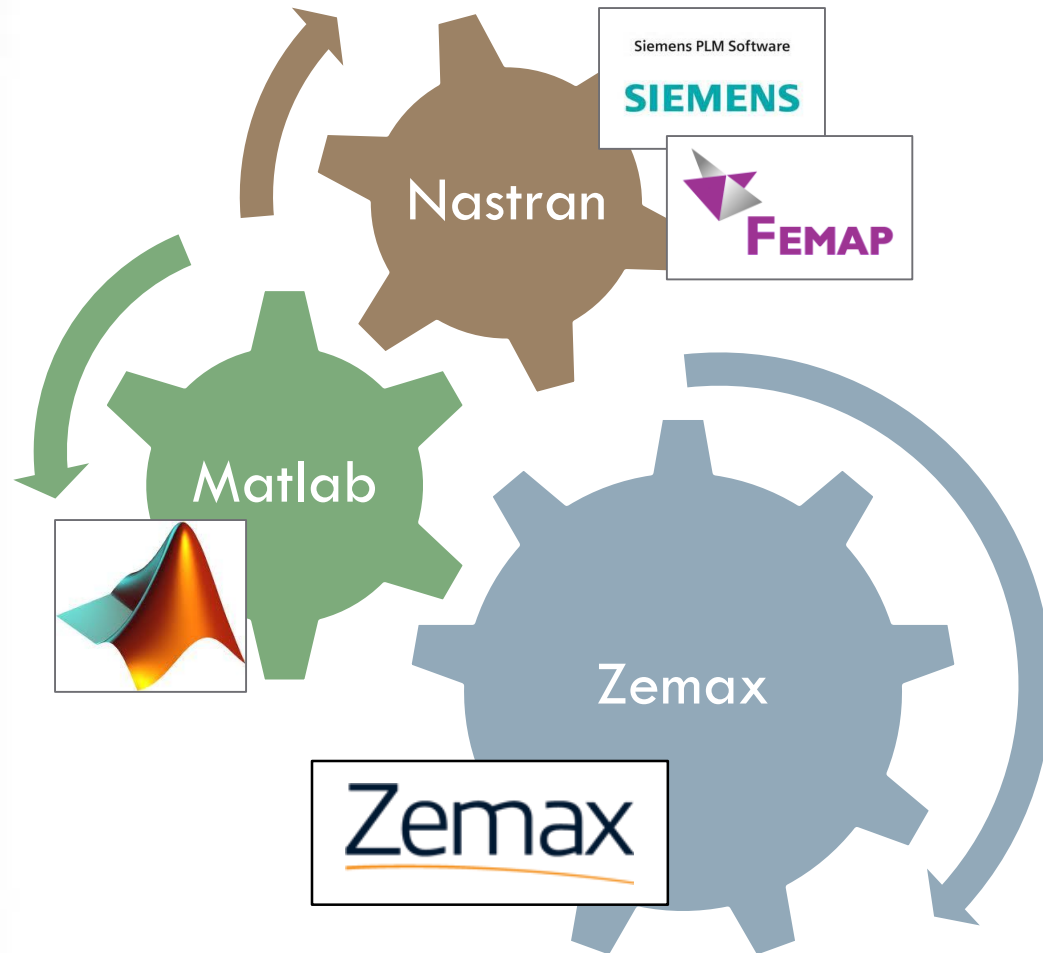
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Case Study: Two Off-Axis Mirrors

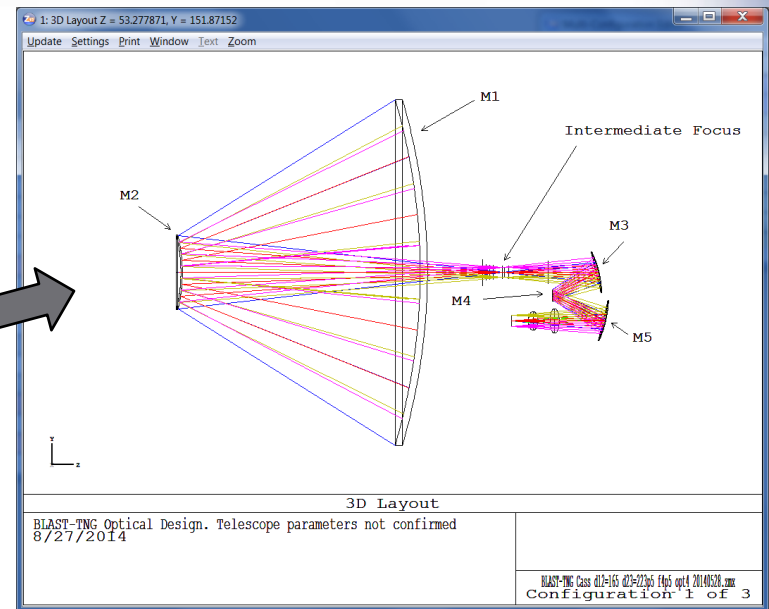
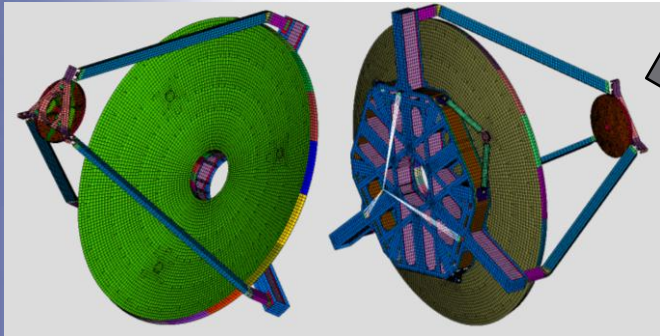


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Case Study: Linking Zemax and Nastran



BLAST Goals

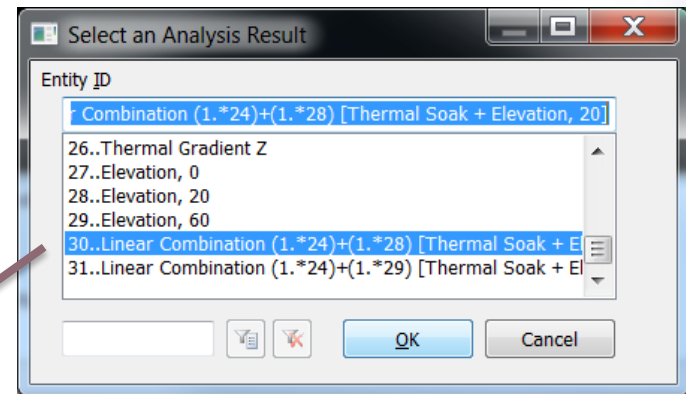
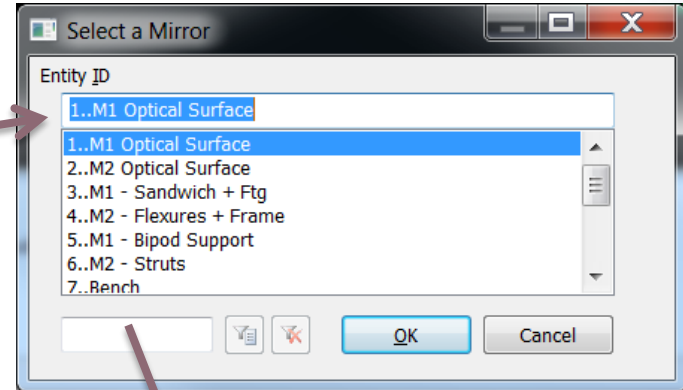
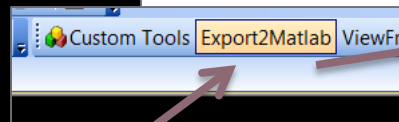
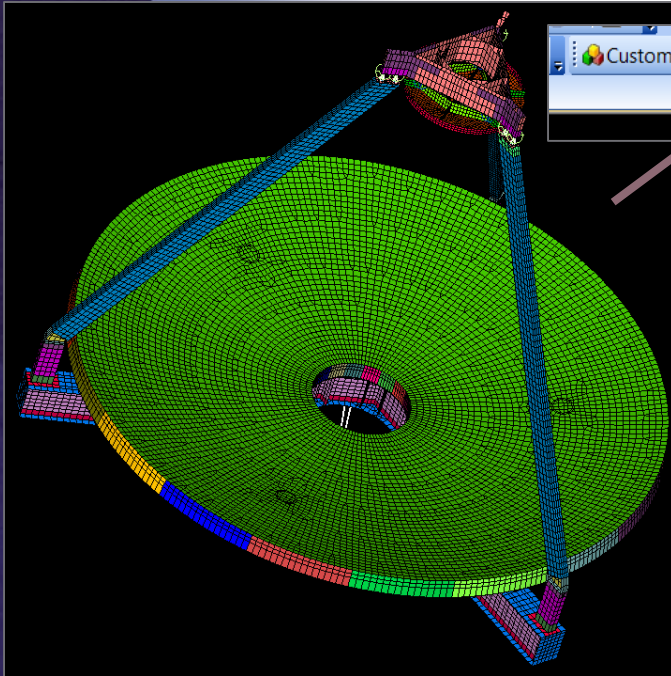


- Lightweight CFRC Telescope
 - Structurally Efficient
 - Balloon Borne Temperature Environment
 - Pointing from near Horizon to near Zenith
- Support Development of Mechanical Structure
 - Rapid Turn Around WFE Evaluation
 - Evaluate PSF / WG Coupling

WorkFlow for BLAST

1. Push Button Export from Femap
2. Best Fit
 - Rigid Body, Optical Rx (RoC, Conic)
 - Zernike + Residuals
3. Data Output
 - Femap for Structural Improvement
 - Zemax for PSF Evaluation

Femap / Nastran Export



Analysis of Surface

Rigid Body Fit



Fit to Zemax Conic
 $R_c = -4161.112$
 $k = -1.000$
 Vertex offset = -2.318

OK



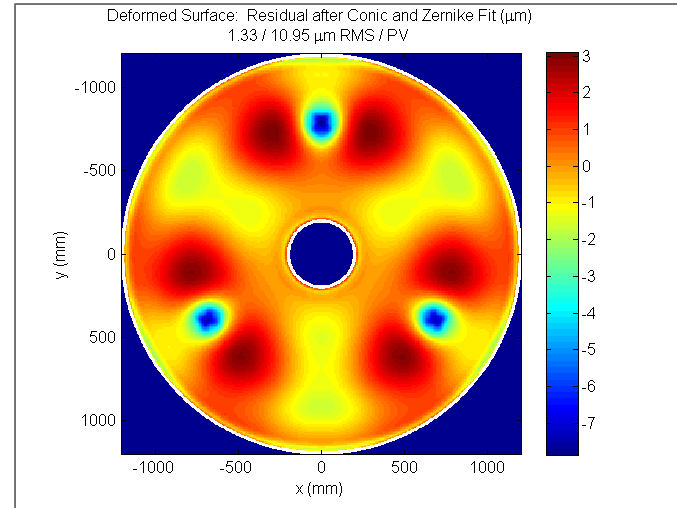
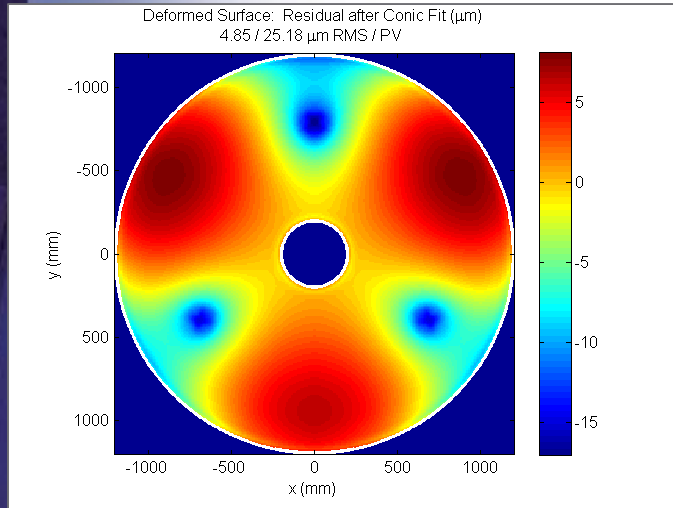
Rigid Body Rotation
 Model: (Deformed) = (Undeformed)*mRot -
 $\theta_x = 0.000026$ rad
 $\theta_y = 0.000000$ rad
 $\theta_z = -0.000000$ rad

OK



Rigid Body Translation
 Model: (Deformed) = (Undeformed)*mRot -
 $dx = 0.000$
 $dy = 0.020$
 $dz = -0.636$

OK

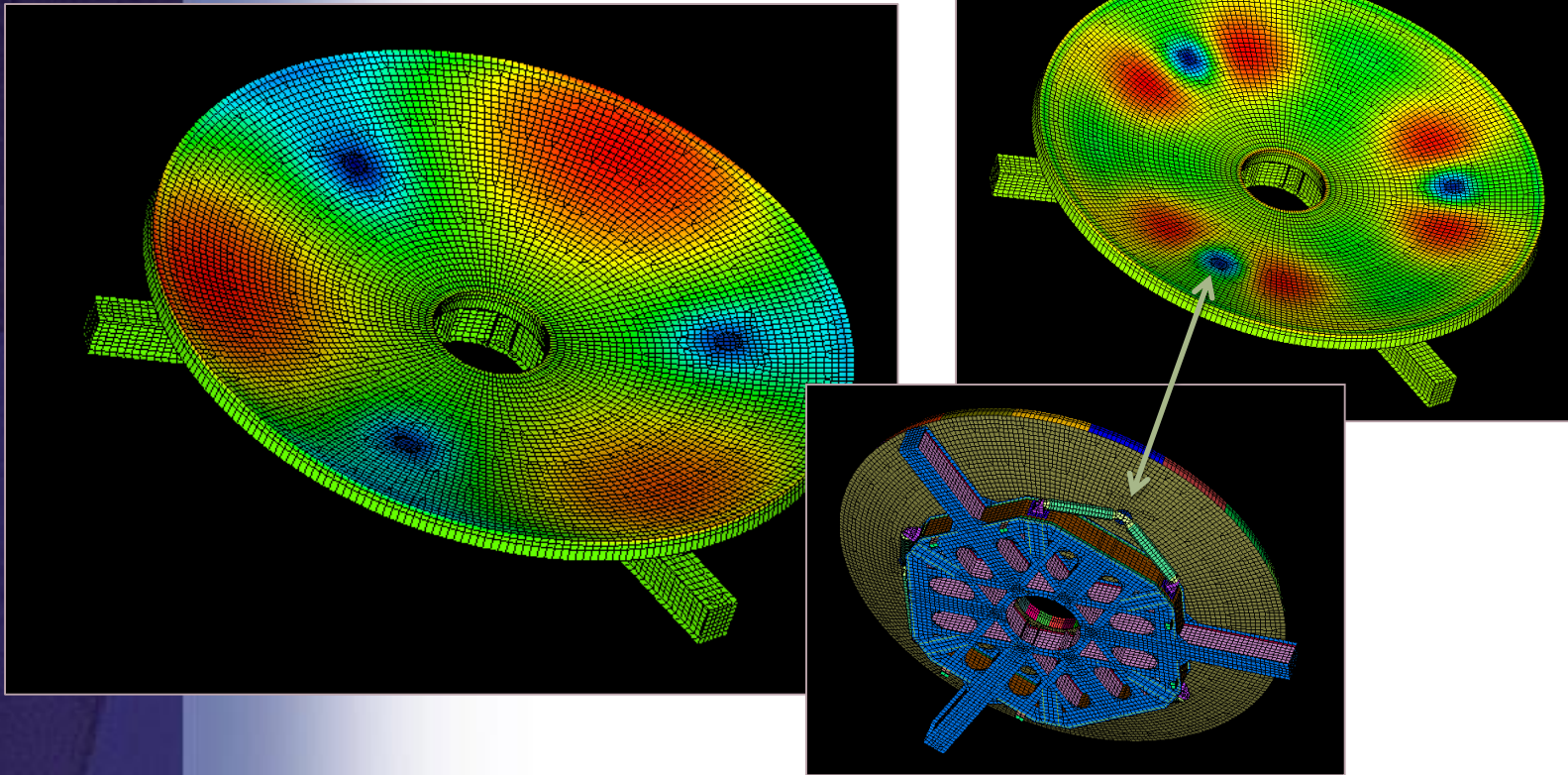


$$W_{Aberr} = W - W_{conic}$$

$$W_{non-Zern} = W_{Aberr} - W_{Zern}$$

$$= W_{Aberr} - \sum_{i=1}^{36} A_i \cdot Z_i(x, y)$$

Pull Into Nastran



- Correlation Between Aberrations and Structure more Clear in Femap

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Push to Zemax

- Using DDE, Data Directly Pushed into Zemax



Lens Data

Surface 7 Properties

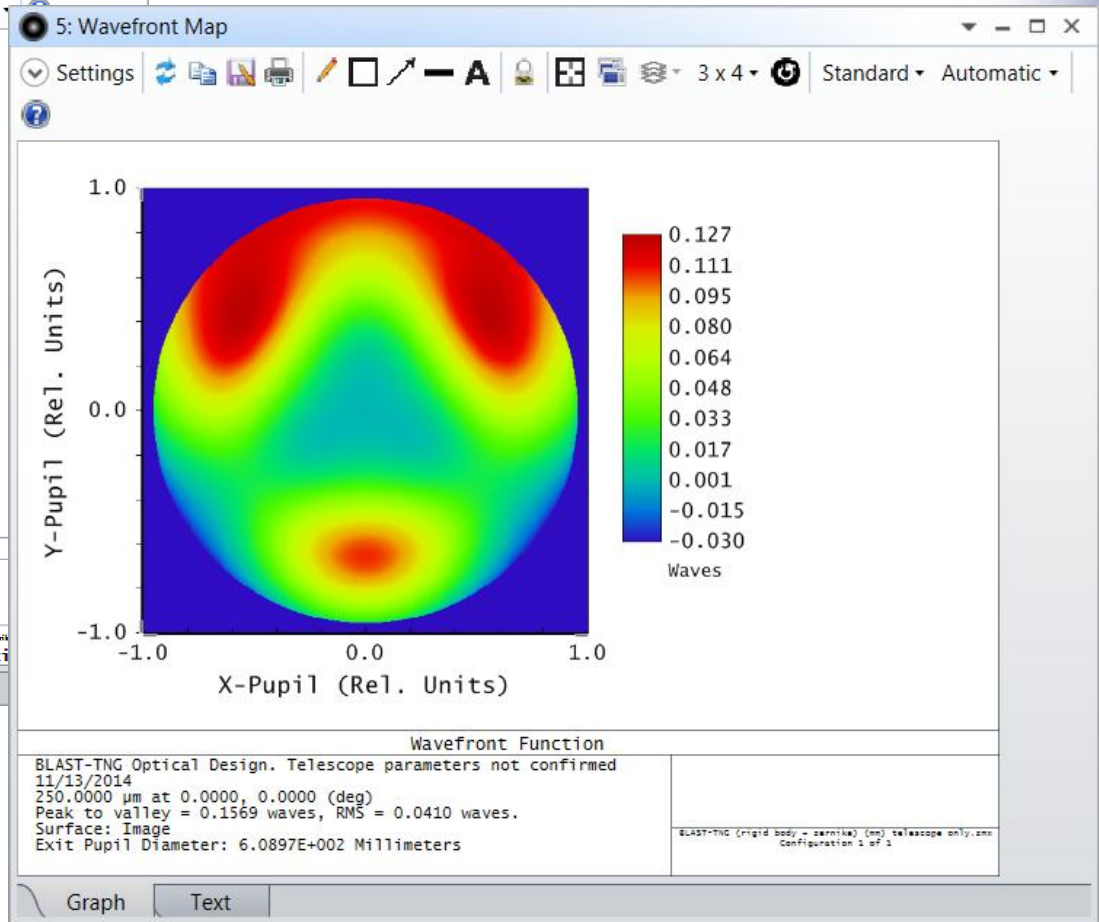
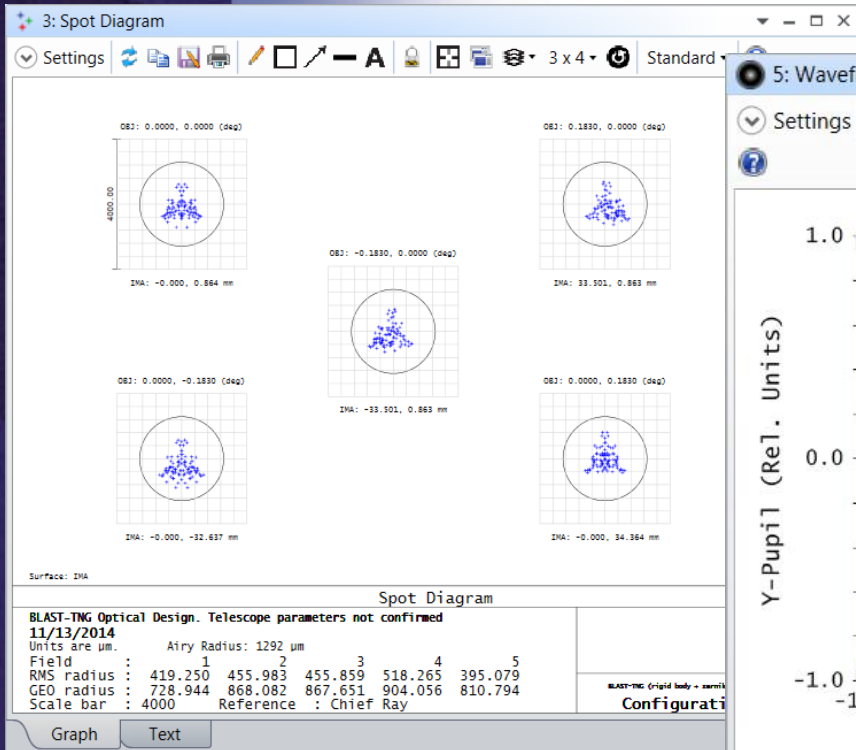
	Surf.Type	Comment	Radius	Thickness	Material	Coating	Semi-Diameter	Conic	TCE x 1E-6	Extrapolate	2nd Order Term	4th Order Term	6th Order Term	8th Order Term	10th Order Term	12th Order Term	14th Order
0	OBJECT	Standard	Infinity	Infinity			Infinity	0.000	0.000								
1	Coordinate Break	rot th		.581			0.000				2.487E-006				0.000	1	
2	STOP (aper)	Zernike Fringe Sag	PRIMARY	0.000	MIRROR		1250.000 U	-1.003	0.000	1	0.000				0.000	0.000	0.000
3	Coordinate Break			.581 P			0.000				-2.487E-006 P				0.000 P	0	
4	Standard			0.000			9.999	0.000	0.000								
5	Standard	Secondary Offset	Infinity	0.000			7.402	0.000	0.000								
6	Coordinate Break			-3.356			0.000				3.503E-005	-0.479	8.928E-003	0.000	0.000	1	
7	(aper) Zernike Fringe Sag	SECONDARY (AS C)	-1065.296	0.000	MIRROR		258.110 U	-2.183	0.000	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Coordinate Break			0.000 P			0.000				-3.503E-005 P	0.479	-8.928E-003 P	0.000 P	0.000 P	0	
9	Standard		Infinity	1650.000			7.436	0.000	0.000								
10	Standard		Infinity	430.700			28.084	0.000	0.000								
11	(aper)	Standard	Rec-Filter Surface	Infinity	25.700		90.500 U	0.000	0.000								
12	(aper)	Standard	Window Aperture	Infinity	26.000		53.000 U	0.000	0.000								
13	(aper)	Standard	VCS2 Filter	Infinity	25.400		50.000 U	0.000	0.000								
14	(aper)	Standard	VCS1 Filter	Infinity	59.700		47.500 U	0.000	0.000								
15	(aper)	Standard	4K Filter	Infinity	17.500		45.000 U	0.000	0.000								
16	Standard	Cass focus	Infinity	-86.430			35.621	0.000	0.000								
17	IMAGE	Standard	Infinity	-			34.368	0.000	0.000								

$R_c + k$

Rigid Body

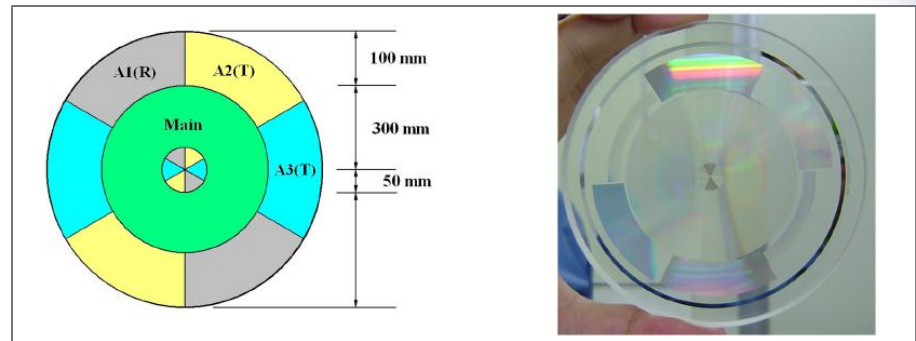
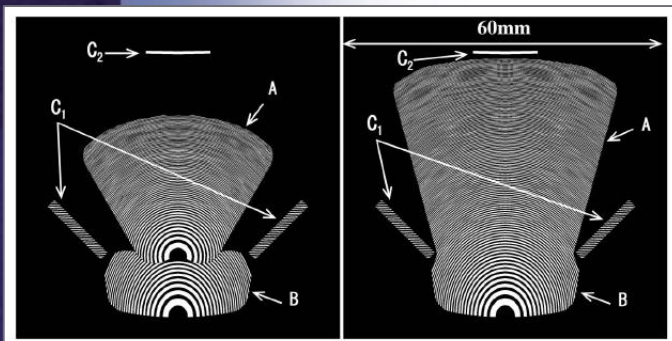
Zernikes

Optical System Performance



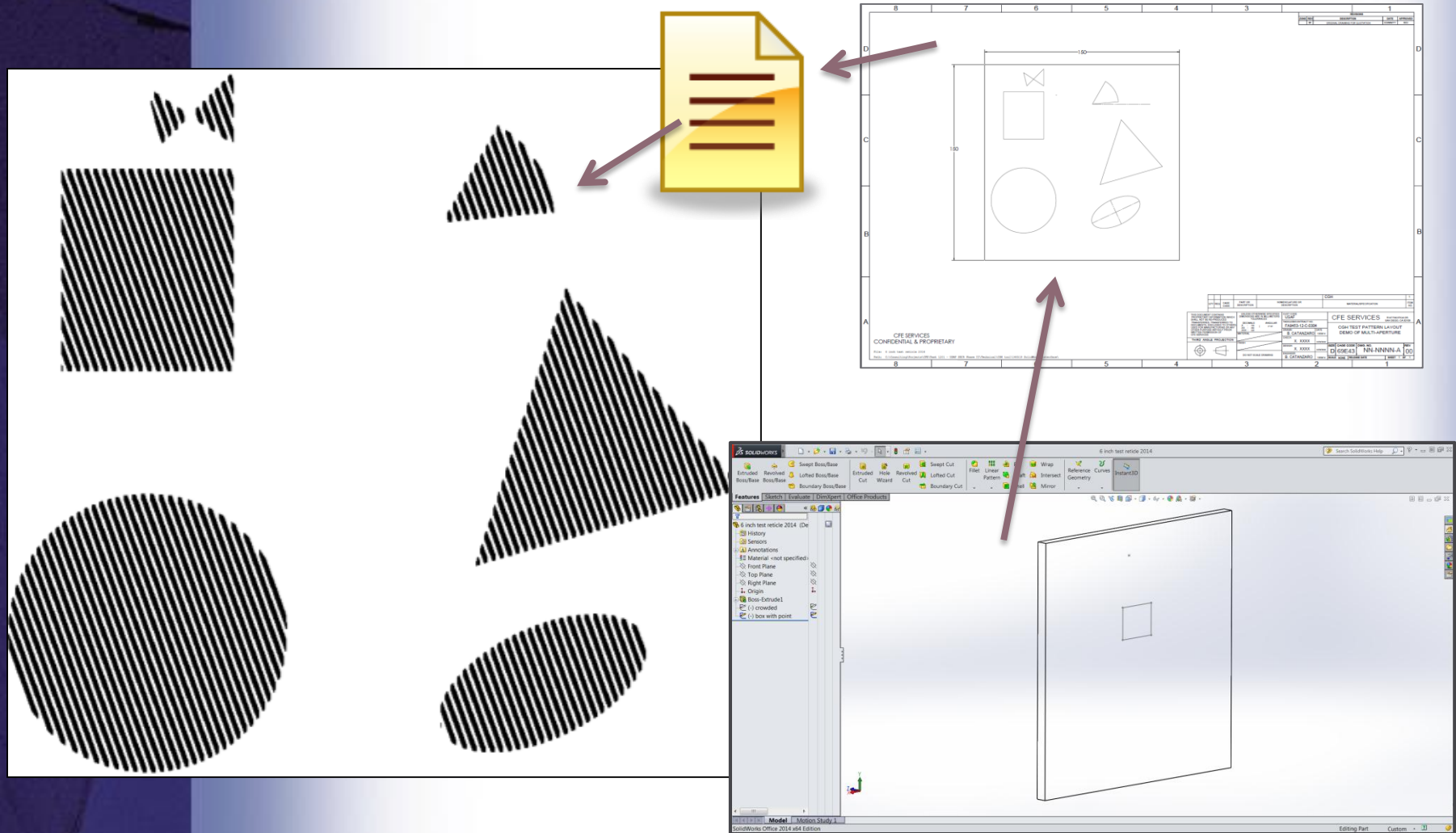
Case Study: CGH Design

- Applications in Optical Metrology and AI/T
 - Require Complex Apertures
 - Precisely Aligned Fiducials



Write Your Own GUI?
Open Source GUI?
Leverage Commercial Design Software?

Parametric Mechanical Layout for CGH



After this Journey, Lessons Learned

- Working with API's is Not that Hard
 - Modern S/W Lifted Much of the Burden
 - OOP (Java, C#) + Testing Frameworks
 - Open Source for Graphics / XML / MySQL
- Don't Reinvent the Wheel
 - Interfacing is more Value Added than Writing Your Own Code
- Engineering Interface Standard is Needed
 - Won't Necessarily Come from S/W Industry
- CAD Frees Your Mind for Higher Work
 - One S/W to Rule them All?
 - App's?