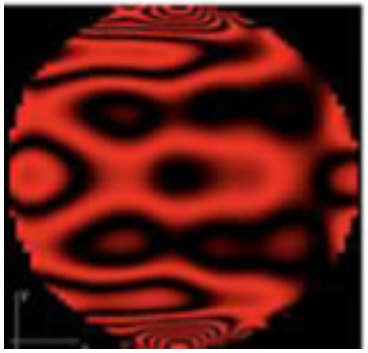


Freeform Optics Incubator

30 OCTOBER - 1 NOVEMBER 2011

OSA Headquarters • Washington, D.C., USA

Hosted by: Pablo Benitez, *Universidad Politecnica de Madrid, Spain*
and Kevin Thompson, *Synopsys, Inc., USA*

Highlights of Presentations
Appendix
Miscellaneous Contributions

compiled by

Kevin Thompson, PhD
Synopsys, Inc.

Appendix
Miscellaneous Contributions

A **Hands-Free zoom system for the SCENNIC program**
Bill Sweatt, Rob Boye, Brad Jared, Mike Descour, and Mark Neifield

B **Diamond machining as basis technology for optical freeforms**
XXX, *Fraunhofer, Germany*

C **Freeform reflector design for illumination**
Florian Fournier *Synopsys, Inc., USA*

D **Freeform optics at NASA Goddard Space Flight Center**
Joe Howard, *NASA Goddard, Greenbelt Maryland, USA*

E **OptiPro – Capabilities for freeform optics**
XXX, *Rochester, New York, SA*

Hands-Free Zoom System for the SCENICC Program

(Soldier Centric Imaging via Computational Cameras)

Bill Sweatt, Rob Boye, Brad Jared, & Mike Descour

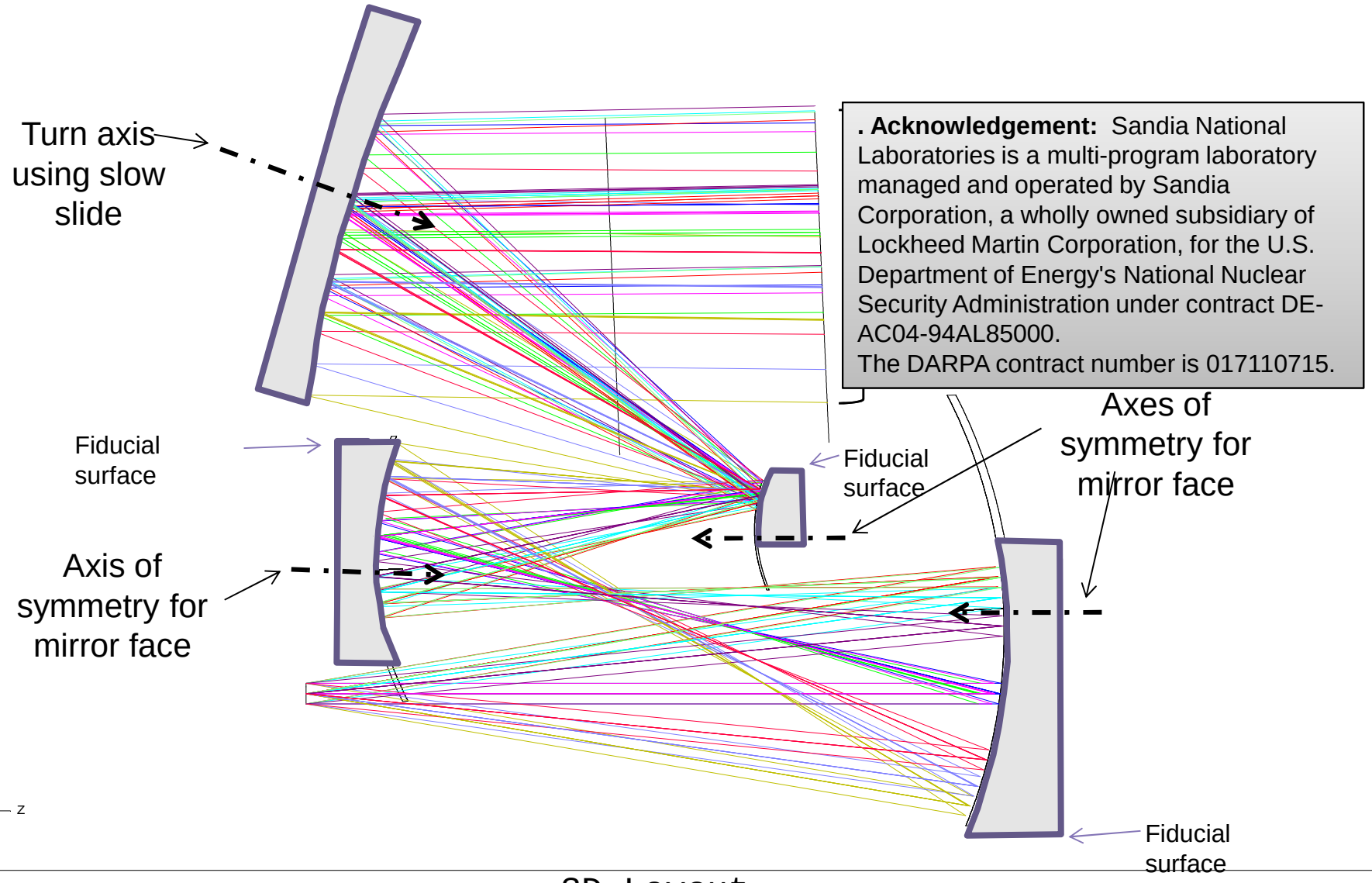
Sandia National Lab, Albuquerque, NM

Mark Neifeld

Defense Sciences Office,
DARPA

. Acknowledgement: Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The DARPA contract number is 017110715.



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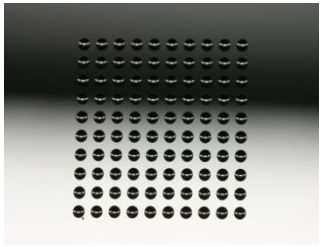
The DARPA contract number is 017110715.

3D Layout

Telescope for Mark Neifeld
10/20/2011

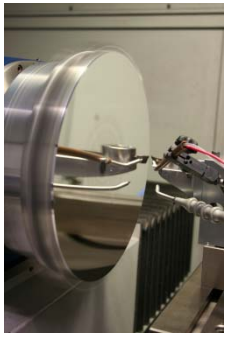
11-09-27 Neifeld 100-mm for Brad.ZMX
Configuration 2 of 4

DIAMOND MACHINING AS BASIS TECHNOLOGY FOR OPTICAL FREEFORMS

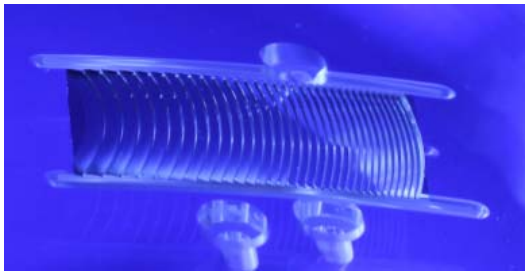


Milling
(Example of a lens array)

Slow Tool Servo Turning
(Example of a telescope mirror)



Fast Tool Servo Turning
(Example of a illumination optic)



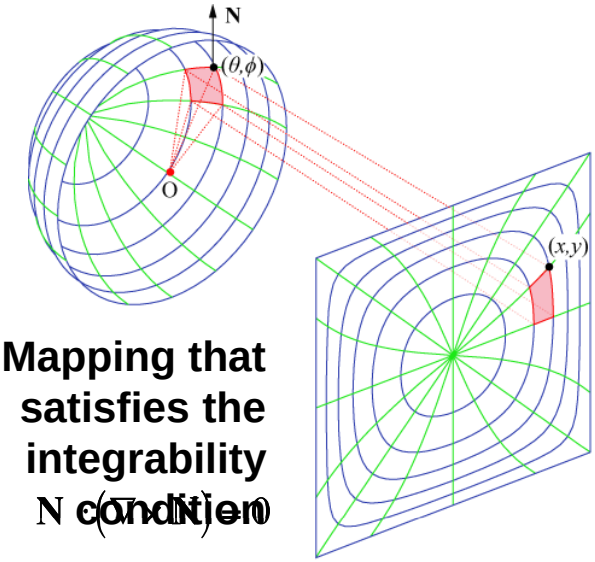
Shaping
(Example of a freeform Fresnel structure on a curved substrate)

From design to system

Optical systems for:
aerospace, automotive,
defense, health care,
…

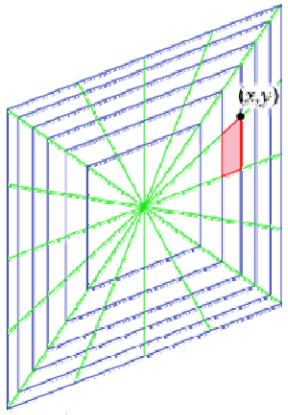
Fraunhofer IOF

Freeform reflector design for illumination



Mapping that satisfies the integrability condition

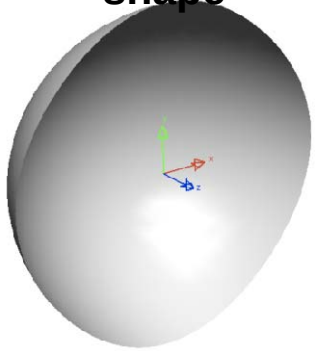
$\nabla \times \vec{N} = 0$

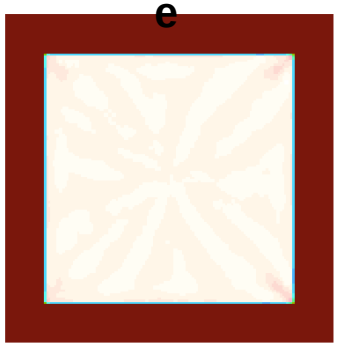


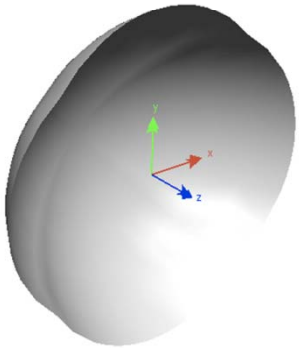
Non-integrable mapping

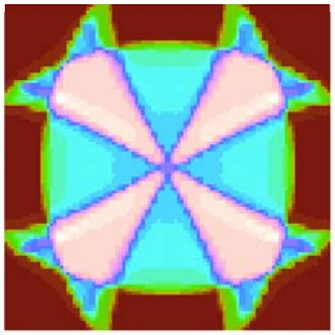
Reflector shape

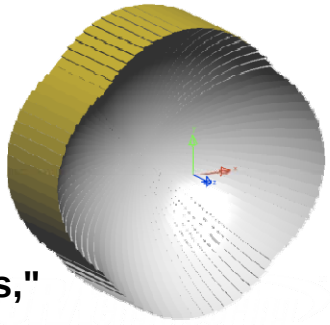
Target illuminance

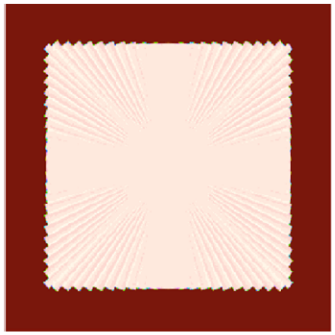












F. R. Fournier, W. J. Cassarly, and J. P. Rolland, "Fast freeform reflector generation using source-target maps," Opt. Express 18, 5295-5304 (2010).

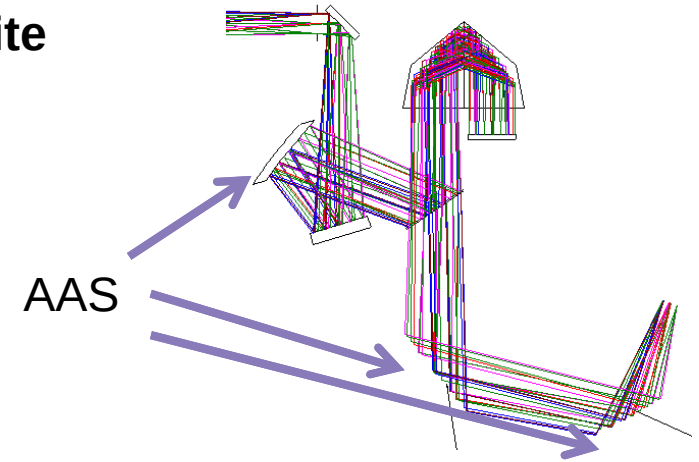
FREEFORM OPTICS at NASA Goddard Space Flight Center

GSFC Code 551

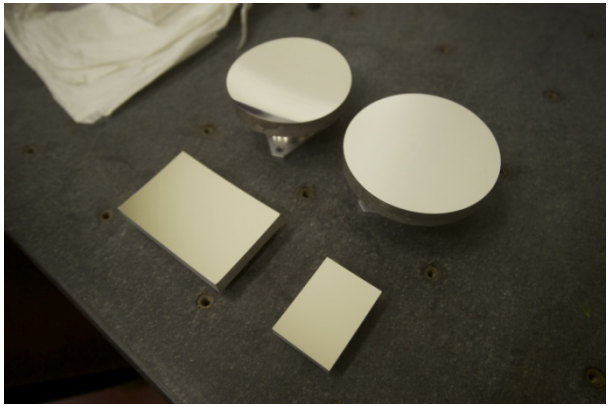
Optical Design

- Wide Field Reflective Systems are requiring aspheres beyond conic definition to achieve image requirements
- Anamorphic surfaces, Zernike polynomial surfaces, biconic
- Example: WFIRST

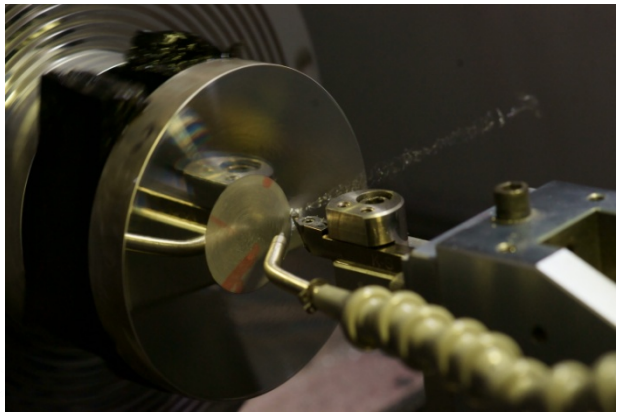
CIRS-Lite



Planetary Mission: **CIRS-Lite**
FT Spectrometer uses high-order biconic



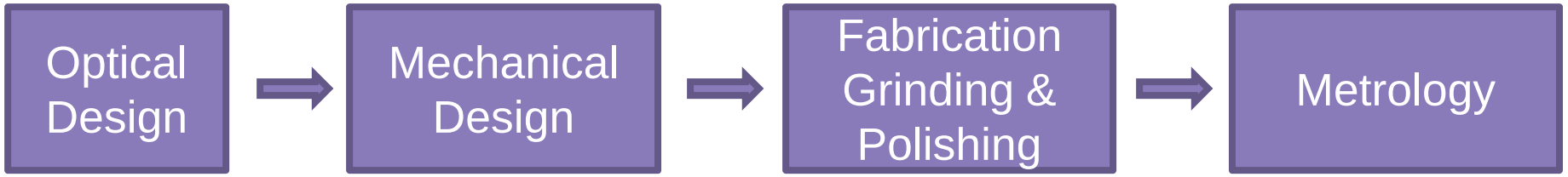
Fabrication with slow-tool servo
Metrology with CGH, Wavefront Sensing



Freeform Surface Definition

- Mathematical Equation
- Cloud of x,y,z data points
- CAD model : NURBS, B-Splines, Parametric
- Zernike Terms
- Radial basis functions
- Orthonormal wavelet series

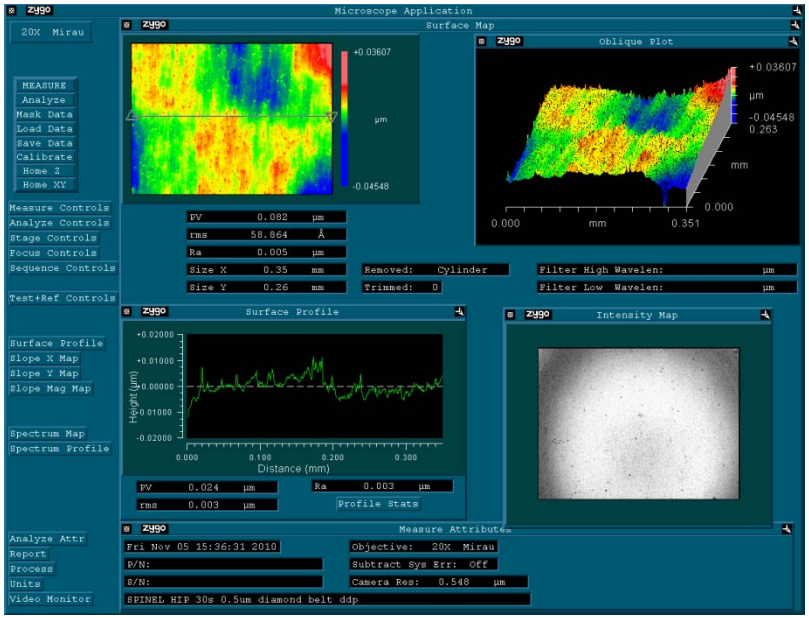
Surface data transfer



1. Accuracy and decimal precision of software
2. Surface tolerance definitions
3. Fabrication limitations and cycle time
4. Mid-spatial / slope irregularity challenges
5. Best fitting routines
6. Metrology limitations – Contact vs. Non-contact

UFF Freeform Surfaces

Stainless steel mold finishing



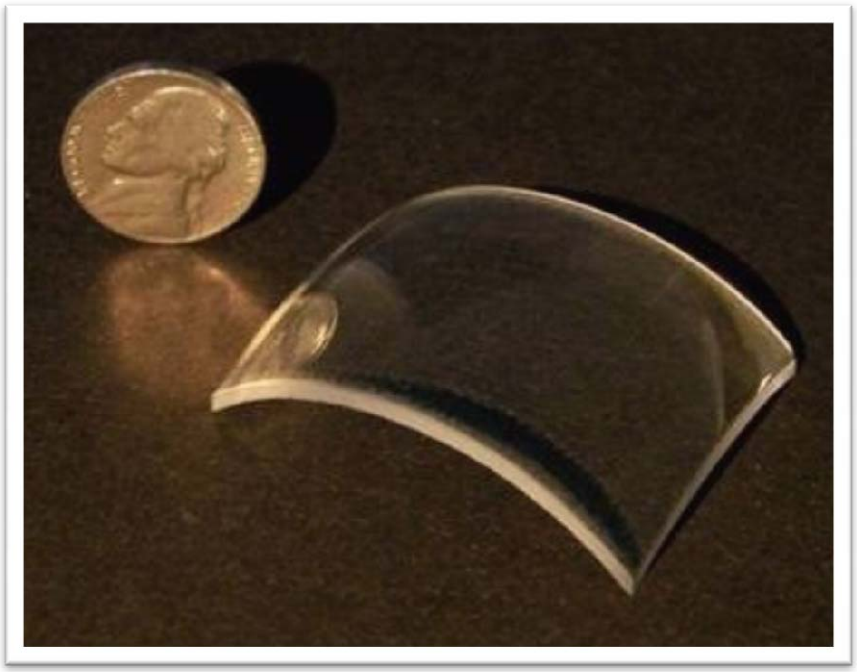
BK7 Glass Toroid finishing

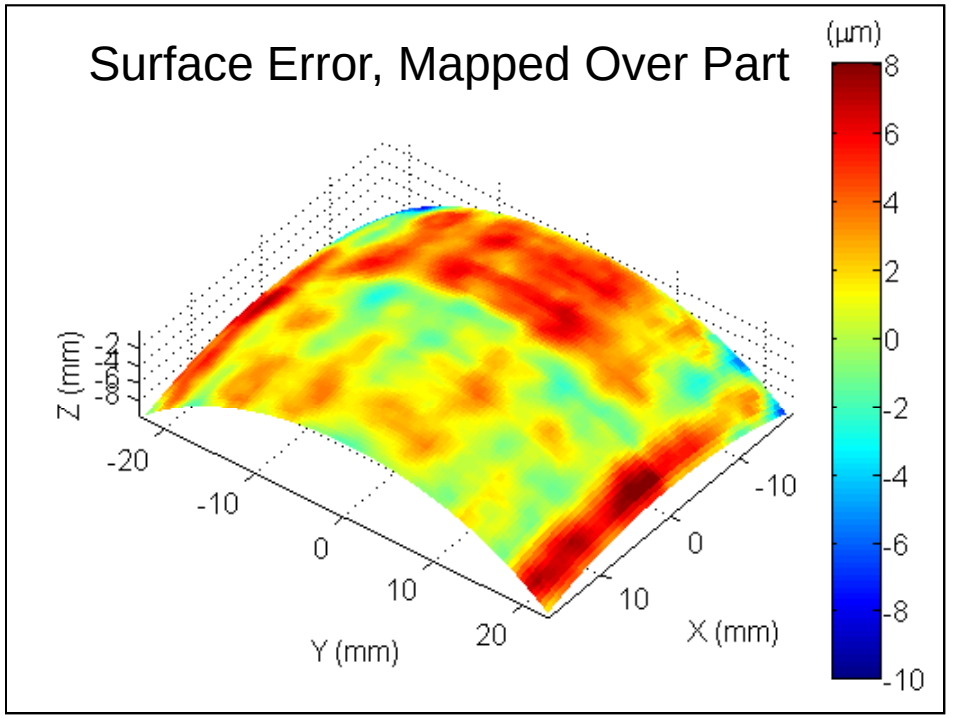
SS Surface Finish NewView Results

- PV: 82 nm
- Ra: 50 Angstroms
- rms: 60 Angs

Aspheric Window

Bi-Aspheric Window



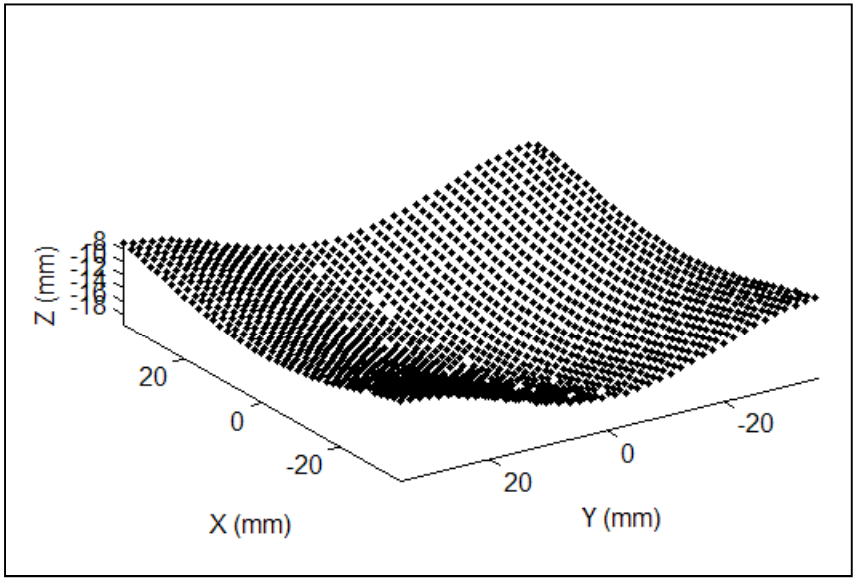


Asphere Radii: 34 mm & 75 mm

UltraSurf measurement

Freeform surface CAD model

Measured cloud of points



Non-contact 3D measurement -> Fast and accurate data

8:40	**Opening Remarks: Is This History in the Making?** Kevin Thompson, *Synopsys, Inc., USA*
9:00	**Freeform Surfaces for Imaging Systems** Norbert Kerwien, *Carl Zeiss Corp., Germany*
9:25	**Current Techniques for Diamond Machining Freeform Optics** Gregg Davis, *II-VI, Inc., USA*
9:50	**Realizing an Optical System with Phi-Polynomial Freeform Surfaces** Kyle Fuerschbach, *University of Rochester, USA*
11:00	**Specifying Shape…What Could We Hope For and Can It Be Achieved** Gregory Forbes, *QED Technologies Inc., Australia*
11:25	**Smooth Radial Basis Functions Viewed as a Generalization of Multivariate Polynomials** Gregory Fasshauer, *Illinois Institute of Technology, USA*
11:50	**Moving from Phi-Polynomial to Multi-centric Radial Basis Functions** Aaron Bauer, *University of Rochester, USA*
13:15	**SMS 3D: A Free-form Optics Design Method** Juan-Carlos Miñano, *LPI, Universidad Politecnica de Madrid, Spain*
13:40	**Geometric Methods of Design of Freeform Surfaces with Prescribed Optical Properties** Vladimir Oliker, *Emory University, USA*
14:05	**A Starting Point Approach for Nonimaging Reflector Design** Cristina Canavesi, *University of Rochester, USA*
15:10	**40 years of Freeform Surfaces** Daniel Bajuk, *ZYGO EPO, USA*
15:35	**Freeform Surfaces Have Aberration Fields Too** Kevin Thompson, *Synopsys, Inc., USA*
16:00	**Two Freeform Mirror Designs with SMS 3D** Lin Wang, *Universidad Politecnica de Madrid, Spain*
17:30	**BIG BIRD** Phil Pressel, *Quartus Engineering Company, USA*
9:00	**The Art of Tailoring Freeform Surfaces for Illumination** William Cassarly, *Synopsys, Inc., USA*
9:25	**Freeform Optics at OSRAM: What We Have, What We Miss, What We Need** Julius Muschaweck, *OSRAM GmbH, Germany*
9:50	**Free Form Optics for a Linear Field of View** Fabian Duerr, *Vrije Universiteit Brussel, Belgium*
11:00	**Nonimaging Freeform Optics Applications at LPI** Pablo Benitez, *Universidad Politecnica de Madrid, Spain*
11:25	**F-RXI Photovoltaic Concentrator: A High Performance SMS-3D Freeform Köhler Design** Marina Buljan, *Universidad Politecnica de Madrid, Spain*
11:35	**Augmented Reality Displays a Playground for Freeform Surfaces** Jannick Rolland, *University of Rochester, USA*

And then there is optics we don't know a lot about

Pressel, P., Big Bird,
http://www.space.com/12996-secret-spy-satellites-declassified-nro.html
(2011)