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Introduction

Optical systems are used just about everywhere today, in systems that both image and illuminate. From eyeglasses to machine vision/robotics to automotive uses, from commercial reprographic equipment to medical instrumentation to the production of integrated circuits, and from telecommunications through Earth observations, space exploration, interferometers, nullers, and weaponry, optical systems are making a difference in our world. This conference is part of a sequence of similar conferences held in prior years that are dedicated to the optical modeling of these evolving imaging and non-imaging systems, be they active, deployable, or passive, and the associated test-equipment needed to bring them forward with performance certainty. Note that models continue to be increasingly important as new missions are at times extending beyond the ability to accurately pre-test performance. Of special interest are new methods of analysis, and contributions to a body of work that help provide various model "anchors" and parametric relationships that correlate results with predictions.

To predict performance over such a broad range of optical systems and engineering disciplines, there are a great many mathematical methods and tools that are needed. Some need to correctly model nano-scale systems with feature sizes comparable to the wavelengths of illumination, while others may need to address precise representations of controlled LED light leakage out of purposely-roughened fibers or the fluorescent behavior of specific phosphors. Still others need to contend with components ranging from meta-materials with negative refractive index for cloaking to quantum dots, to special prisms or gratings and holographic optical elements, to large deployable telescopes where accuracies are measured in picometers or at levels approaching $1/10{,}000^{th}$ wave RMS WFE. When we add in wavelengths and configurations that range from X-Rays to THz and micro/mm-waves, and environmental aspects spanning HEL through cryogenic in configurations from the laboratory to aircraft/UAVs to underwater and outerspace, the number of modeling developments needed to accurately predict optical performance is immense.

Electro-optical modeling and performance predictions also often require integrating many interdisciplinary techniques and mathematical methods with underlying physics that build-upon and/or utilize (arranged by similarity):

- Geometrical and Physical Optics
- Fiber Optics
- Interferometers and Nullers
- Evolving Photonic & Plasmonic Models
- Diffractive & Holographic Optics – incl. Coherence & Speckle
- Illumination Design - incl. Lasers, LEDs, OLEDs, Solar, etc
- Optimization & Global Optimizers
- Meta-Materials – incl. Negative Index, Photonic Crystals, Cloaking

Fluorescence & Scattering
Polarization
Stray Light/Ghosts
Adaptive Optical Models
Detector Quantum Efficiency & E-O Performance
Phase/Prescription Retrieval
EMI/EMC Influences
Material Removal, Heat Treating
Testing & Calibration Models
Laser and Laser Communication Models
Models of Vision Systems - incl. HUDs and HMDs
MEMS and MOEMS
Mounting Stress, G-Release, Launch/Deployment
Vibration & Damping
Mechanical Influences/Scanning Deformations Inertia, Shock Loads
Material Stability & Fracture Mechanics
Material Factors/Lay-Up Anisotropy; Inhomogeneity
Thermo-Elastic & Thermo-Optical Effects
Thermal Run-Away in IR Elements
T/O Material Characterization – New a's/Temp's
System Sterilization
Solar Loading
Joint Resistance/Surf. Finish & Conduction Changes
Convective Effects & Air-Path Conditioning
Aero-Optics, Boundary Layers & Shock Waves
Image Doubling
Integrated Models, Nodal Ties/Accuracies
Closely Coupled Thermal-Structural-Optical Models
Radiative Damage
Contamination Control, Sterilization
Particulate Models
S/C Charging; Photopolymerization, Atomic O_2
Phenomenology
Weight Models; Power Models
Rules of Thumb

Beam Propagation
Radiometry
Narcissus
Influence Function Treatment
Charge Diffusion
Computational Optics
Tolerancing
Probabilistic Design
Optical Coating & Filters and Laser Damage Resistance
Modeling of Bio/Medical Devices
Quantum Dots
Electrostatics & Structures
Ultra-Lightweight Optics/Nano-Laminates, & Membrane Mirrors
High Impact/Shock Loading
Micro-Dynamics & Influences of Piece-Part
Special Zoom/Servo Effects
Stress Birefringence
Proof Testing Models
Energy Absorption With Depth in Transmissive Elements
Recursive Models Where T/S Changes Impact Heating
Sources – incl. THz, Fiber Lasers, & Wall Efficiency Factors
Absorptive/Reflective Baffles/Structures
HEL Effects Including Survivability & Hardening
Hole Drilling, Welding, and Laser Heat Treating
Aircraft/UAV Windows, Missiles, & Domes
Self-Induced Turbulence
Error Budgets
STOP; Optical Control Systems
Acquisition, Pointing, and Tracking
Atmospheric Refraction & Scattering
NVR Models
Micro-Meteoroid Modeling – incl. Models of Spalling
Reliability
Schedule and Cost Models of Optical Systems
Scale Factors of Use to Individual Disciplines

This Conference brought forward new work in several of these areas. Our intent was to provide special attention to new methods of analysis that would help "anchor" various models and/or also provide parametric relationships to help correlate results with predictions. In this regard, several authors have helped to advance the state-of-the-art by contributing work that provides new insight into different aspects of optical modeling and predicting performance.

M. A. Golub (Tel Aviv Univ., Israel) provided some new results pertaining to the design of nonparaxial optical systems with refractive and diffractive elements using as a base a local thin optics model. Whereas quality optical systems demand essentially nonparaxial geometrical optics, diffraction calculations are often restricted to paraxial approximations and thin lens models of Fourier optics. Main and ghost nonparaxial diffraction orders were considered in the frame of polychromatic interference and diffraction, as was the effect of accumulated sampling and aliasing errors. The intent of Michael's work was to help a designer develop a deeper understanding of the models used to optimize hardware. A model of cascaded multi-lens optical systems was shown that combined modern optical design with ideas of photonic structures, and non-paraxial estimations of the impact of wavelength change, mismatch of diffractive groove depths, phase nonlinearity, and staircase approximations. This new generalized ray tracing method treats diffractive, refractive and reflective surfaces based on finding a local focus positions through direct calculation of local wavefront curvatures, and it separates ray-traces for several diffraction orders with subsequent superposition of complex/weighted amplitudes. Closed form analytical solutions were given for diffraction efficiency of photonic structures with periods slightly exceeding the wavelength of interest (the audience recommended future papers that also cover experiments in this important area).

G. N. Lawrence (Applied Optics Research with A. W. Yu, NASA Goddard Space Flight Ctr.) discussed "reverse optimization" in physical optics modeling where parameters of a perfect design are adjusted so that the performance matches experiment to help identify root causes of defects and where changes might be warranted. George noted that in the late 80's reverse optimization using geometrical ray tracing was applied to help align complex, highly asymmetric mirror systems, and now, with great advances in computer speed, we can apply the reverse optimization method to full physical optics systems including full diffraction at all steps, and account for laser gain, nonlinear optics, resonant oscillations, etc. The targets for optimization may consist of specific performance measures and wavefront errors, or or irradiance maps available from beam diagnostic instruments. With many millions of targets, some reformulation of the Damped Least Square mathematics was used to speed the calculations. Some simple examples were discussed that served to illustrate this new method.

G. N. Lawrence (Applied Optics Research, with D. B. Coyle, D. Poulios, and A. W. Yu, NASA Goddard Space Flight Ctr.) also discussed the optical modeling done for NASA GSFC's High Output Maximum Efficiency Resonator laser (HOMER), intended for use in the DESDynI mission (Deformation, Ecosystems Structure and Dynamics of Ice). For modeling the zigzag amplifier, a 3D exact pixel matching algorithm was developed that can model all folding and complex spatial overlap interactions that occur in the 3D volume. In spite of the many millions of points in the volume, the exact pixel matching algorithm facilitated rapid calculation. George also reported on the progress made in incorporate thermal modeling, detailed diode side pumping, a Graded Reflectivity Mirror (GRM), and unstable resonator convergence into the model. Central issues in the modeling included ways to streamline/organize the calculations for efficient handling of the gigabyte of data that was generated using 64 bit code and a high degree of multithreading. The system was studied for pitch and yaw stability of the end mirrors, detailed defects and failures of individual diode pumps, and other real-world errors in the system that could affect long term performance.

K. Nagai, (with H. Itoh, G. Sato, T. Nakamura, K. Yamaguchi, T. Kondoh, S. Handa, T. Den, Canon Inc., Japan) provided information on the 2-D phase retrieval of a single-shot X-ray Talbot interferometer using a Windowed Fourier Transform (WFT) method to improve the noise robustness seen in Fourier Transformation. In the WFT method, the phase map is retrieved from the spectrum corresponding to the carrier fringe, and the spatial resolution increases as the window function narrows. However, the spatial resolution is limited because an undesired pattern is superposed on the retrieved phase map when the width of the window function is narrower than a certain size. This overlap interferes with the retrieved phase and causes the undesired pattern. In the proposed method, an additional step is used to analytically remove the undesired pattern from the phase map. With this additional step, the high-resolution phase map can be obtained because the window function can be narrower than that used in the original WFT method. As an example, Kentaro showed where differential phase maps of a complex-shaped object along both x and y axes were retrieved from a single fringe pattern at high resolution and with an effective noise reduction.

C. F. Hahlweg (Helmut-Schmidt Univ., Germany) covered new insights gained in considering Lambert's multiple reflection model. In a prior SPIE paper on Lambertian reflection Cornelius gave a partial translation of an almost lost chapter by Johann Heinrich Lambert on multiple reflection in dioptric systems. The control of multiple reflections in optical systems is of special interest in scatterometric devices, and in high dynamic range imaging, and this new work provides a deeper discussion of the model proposed by Lambert. Beyond the use of ray tracing methods, this new work leads to improved understanding/simulation, and to a theoretical approach including Fourier optical consequences. An update of the earlier work, and the completion of the translation of Lambert's work was also covered.

C. F. Hahlweg (Helmut-Schmidt Univ., Germany) continued his nice pair of presentations, here discussing Fourier planes vs. the Scheimpflug principle in microscopic and scatterometric devices. Cornelius noted that scatterometric methods usually concentrate on gathering and analyzing scatter distributions in the power domain, and the analysis is mainly based on the relation between scatter distribution and Fourier transform of the reflection function of the surface under consideration. Imaging scatterometers in principle gather the Fourier image of the illuminated spot, which in microscopy would be the primary diffraction image. Therefore imaging scatterometers can be used as microscopes as well, though this requires an additional positive lens or equivalent mirror.

Combined designs are clearly interesting in surface inspection, and though there is loss of phase information in both the direct and scatter image, there is still non-redundant information beyond the intersection set of both images. For the design and adjustment of such combined devices it the Fourier images are of high interest. While a more or less paraxial dioptric device configured to provide an orthogonal view has well defined Fourier planes, in an off-axis device, with paraboloid or elliptical mirrors, the Fourier image is subject to the Scheimpflug relations, as well as a significant vignetting effect, and both of these effects have to be considered in designing and aligning the hardware. In this present paper the author discusses both the underlying theory as well as practical applications, design, and adjustment strategies.

L. Wu, (with Y. Zhao, Y. Zhang, Y. Zhang, J. Wu, Harbin Institute of Technology, China) reported on optimizing system gain in a direction detection lidar. An equivalent direct detection statistical receiver model was developed, based on a Gaussian random process with high enough gain, to evaluate the signal produced by counting random impulse responses of returned electrons, background radiation, and dark current. An investigation of an ICCD scannerless range-gated lidar system was conducted using this model to compute error probability, absolute error and relative error. As the unique manipulated variable, optimized system gains was calculated so as to achieve the lowest error probability, the lowest absolute and relative error. The results that Long showed indicated that the values of optimized gain tend to increase with target distance, although the rates of increase for each are different. To meet multiple needs, an evaluation model was constructed involving variable/weighted cost functions. These simulations showed that the evaluation model is capable of setting the optimized gain for different circumstances as well as how the settings of these weights are so important to determining key aspects of a lidar system's configuration and performance.

G. Z. Angeli (Thirty Meter Telescope) provided an overview of the various image quality metrics used in astronomical imaging, and proposed a convenient new telescope performance metric for imaging through turbulence, the Normalized Point Source Sensitivity. This metric is based on the Equivalent Noise Area concept, an extension of the 80% Encircled Energy metric, and is intuitively linked to the required science integration time. As it was proved in recent studies, this new metric properly accounts for image degradation due to the spatial frequency content of a given telescope aberration and the effects of various errors can be multiplicatively combined, like those sometimes used relative to image Central Intensity Ratios. Extensions of the metric for off-axis imaging and throughput degradation were also presented, and wavelength and spatial frequency dependence of the new metric were discussed. While the proper calculation of the metric requires the precise knowledge of the Point Spread Function of both the optics and the atmosphere, there are useful approximations capable of linking the metric to the Zernike decomposition as well as the Power Spectral Density of the aberrations present. Besides the summary of various aspects of the Point Source Sensitivity, George provided many numerical examples of relevance to the Thirty Meter Telescope.

M. Panthaki (Comet Solutions Inc. with S. C. Coy, now of Timelike Systems, LLC and formerly of MZA Associates Corp. when this work was performed) discussed the work that has been done to extend the Comet's integrated, multi-disciplinary modeling and design/simulation process-automation workspace through to the integration of the WaveTrain™ Wave Optics software. One of the many multi-disciplinary applications of the Comet Workspace is for the integrated Structural, Thermal, Optical Performance (STOP) analysis of complex, multi-disciplinary space systems containing Electro-Optical (EO) sensors such as those which are designed and developed by and for NASA and the Department of Defense. Malcolm noted that the Comet™ software is currently able to integrate performance simulation data and processes from a wide range of 3-D CAD and analysis software programs including CODE V® from Synopsys (formally Optical Research Associates) and SigFit™ from Sigmadyne Inc. which are used to simulate the optics performance of EO sensor systems in spaceborne applications. Over the past year, Comet Solutions has been working with MZA Associates under a contract with the Air Force Research Laboratories to extend the use of the Comet commercial software by creating a custom adaptor for MZA's WaveTrain software to help enable the AF in its STOP modeling of optical systems deployed on air-borne platforms. This presentation reviewed the current status of this code integration effort, as well as projected areas of application in directed energy programs conducted for the U.S. government and aerospace/defense industry organizations.

M. Hsu's (Instrument Technology Research Ctr., Taiwan, as presented by W.-Y. Hsu) paper covered analyses made to choose the correct lens-cell/mounting materials (including lens spacers/retainers) for a lightweight space-borne Cassegrain telescope with a 4-element field lens under thermal loading. The system mass budget allocated to the lens assembly was 5 Kg. The mirrors were made of fused silica, and the lens diameter was 130mm, and the mass of these components was 2.3 Kg, leaving 2.7 Kg for the structural piece-parts. Ming-Ying/Wai-Yan showed that the best lens mount relative to wavefront error was invar which has a low Coefficient of Thermal Expansion/CTE (1x 10^{-6}/°C), but a density of 8x 10^{-6} Kg/mm^3. If all the structural components were made of invar, the total mass was over 2.7 Kg. A titanium alloy (CTE of 8.6 x 10^{-6}/°C, and density of 4.43x 10^{-6} Kg/mm^3) and an aluminum alloy (CTE was 23.6 x 10^{-6}/°C, and density of 2.81x 10^{-6} Kg/mm^3) were also considered. The titanium alloy density was lighter then invar by 1.83X, but the CTE was higher by 8.6X, and the aluminum alloy density was lighter then invar 2.84X, but the CTE was higher than invar by 23.6X. Using FEM methods, the lens mount thermal deformations and their effects on wavefront error and optical aberrations were evaluated. The titanium alloy saved 0.8 Kg and resulted in little (0.04%) loss in MTF over the FOV for a ±5°C change in temperature but the aluminum alloy, which saved 1.2Kg, lost significant MTF at the edge of the FOV and would require tight thermal control if it were to be chosen for the structure.

F. E. Penado (Northern Arizona Univ. with J. H. Clark III, U.S. Naval Observatory, and J. Dugdale, Lowell Observatory) discussed the use of a deformable mirror for wavefront error cancellation in the Navy Prototype Optical Interferometer (NPOI) array, located near Flagstaff, Arizona. This array transports stellar radiation from six 38 mm primary collectors through a 9-reflection vacuum relay system with 12mm beam sizes, resulting in six separate combinable wavefronts. A total of 54 reflection mirrors (6 collectors x 9 reflections each) is required for all six primary collectors. Ground-based optical interferometry requires very high quality, ideally flat, relay mirrors. In practice, Ernesto noted that the manufacturing methods available do not produce perfectly flat mirrors, so, for fabrication purposes, the surface error of each of the 54 mirrors is specified to be no greater than 32 nm peak-to-valley. However, once mounted in the 9-element optical train, the errors from each mirror do not necessarily cancel one another, but can actually add and increase the resultant wavefront distortion for that path. This leads to fringe contrast reduction, reduced ability to fringe track, and a reduction in the limiting magnitude of observable objects. In a previous paper by the author(s), it was shown that it is possible to mitigate the resultant wavefront distortion by using a phase-shifting interferometer combined with a single compliant static deformable mirror and control system. In that work, the mirrors tested showed a fairly uniform, concentric concavity deformation, which a single, centrally located actuator could significantly improve. In this paper, the author(s) extend the previous analysis to consider an off-center actuator acting on a mirror having an equivalently deformed surface resulting from the superposition of manufacturing errors of several flat relay mirrors. This initial shape applied to a single mirror was determined from the resultant wavefront distortion of a 7-reflection optical relay system using phase-shifting interferometer data. Finite element analysis results were shown that indicated how well the resultant wavefront error in the initially deformed mirrors can be collectively cancelled.

M. J. Sholl (Univ. of California, Berkeley) presented information on BigBOSS, a proposed DOE-NSF Stage IV ground-based dark energy experiment designed to study baryon acoustic oscillations (BAO) and the growth of large-scale structure via an all-sky galaxy redshift survey. The project involves modification of existing facilities operated by the National Optical Astronomy Observatory (NOAO). Michael presented data on the design and systems engineering of a 3-degree field of view 467 mm diameter transmissive corrector, atmospheric dispersion corrector, and a 5,000 actuator fiber positioning system. Areas discussed included overall systems engineering budgets, the survey plan, optical performance, throughput, thermal design and stray light.

C. Chan (Instrument Technology Research Ctr., Taiwan) reported on the use of FEM to determine the effects of gravity and launch accelerations on the Zernike representations of surface deformations in a Cassegrain telescope's predesigned ZERODUR® lightweight primary mirror. Chia-Yen discussed the relation between several surface treatments and the mirror's characteristic strength, and he also investigated safety factors under various launch accelerations. It was found that the surface of the mirror needs to be ground using a D251 or finer tool to keep the load safety factor of the primary mirror telescope higher than 1.5.

K. E. Nevin's (with K. B. Doyle, MIT Lincoln Lab) reviewed the line-of-sight jitter analysis that was done for the LLCD space terminal telescope. An earth-based ground terminal and a lunar orbiting space terminal are being developed as part of NASA's Lunar Laser Communications Demonstration (LLCD) program, and the space terminal is needed to minimize mass and power requirements while delivering high bandwidth data rates using a four-inch aperture telescope and a 0.5 watt beam. Design challenges noted by Kate included the need for the space terminal to meet pointing stability requirements of 5μrad while maintaining diffraction-limited wavefront error. Efficient opto-mechanical analysis simulations were used to drive the material selection and mounting methods for the space terminal Cassegrain telescope. Analyses discussed included those that related to the design of the primary mirror in order to insure it would meet system LOS jitter, thermal, assembly distortion, and stress requirements, that it would provide acceptable performance under operational vibration and thermal disturbances , and that it would survive the non-operational launch load environment.

V. L. Genberg (Sigmadyne, Inc., with K. B. Doyle, MIT Lincoln Lab., and G. J. Michels, Sigmadyne, Inc.) discussed the work which is underway on the integrated modeling of jitter MTF due to random loads. Victor noted that spaceborne astronomical telescopes are subjected to random dynamic disturbances from the host spacecraft that create line-of-sight (LoS) jitter errors, and that these then decrease image quality. Special software tools and techniques have been developed to determine the degradation in image quality as measured by the modulation transfer function (MTF) and to identify regions of a telescope that should be redesigned in order to minimize the LoS jitter response. A general purpose finite element program is used to find the natural frequencies and mode shapes of a telescope. Each of the optical surfaces for each mode shape is then decomposed into average rigid body motion and elastic deformation. Automated calculation of the LoS equations based on the optical prescription of the telescope provides the LoS response due to expected random loads. The percent contribution of each mode shape to the total LoS jitter is reported. This identifies regions of the telescope structure that should be redesigned so as to minimize the response of the telescope. The LoS error due to the random input is then decomposed into drift and jitter components based on a specified sensor integration time. The random jitter is converted to a jitter MTF response function which may be used to modify the MTF function of the nominal optical system, yielding the MTF of the optical system in the operational random environment.

J. E. Krist (Jet Propulsion Lab., and R. N. Hook, European Southern Observatory, Germany) presented information on 20 years of Hubble Space Telescope optical modeling using Tiny Tim. Optical modeling is typically done during the design phase by experienced engineers, but for astronomers using the Hubble Space Telescope (HST), knowledge of the point spread function (PSF) is often critical to analyzing data obtained from orbit. Astronomers unfamiliar with optical simulation techniques need access to PSF models that properly match the conditions of their observations (i.e., instrument, filter, stellar color, field position), so any HST modeling software needs to be both easy-to-use and have detailed information on the telescope and instruments. The Tiny Tim PSF simulation software package has been the standard HST modeling software since its release in early 1992. It's a stand-alone, freely-available program written in C, that can compute PSFs for all of the HST imaging instruments. The user simply answers a few basic questions (PSF size, field position, filter, object spectrum, sub-sampling) and Tiny Tim will compute the PSF using simple far-field propagation. John discussed the evolution of Tiny Tim over the years as new instruments and optical properties have been incorporated (optical surface error maps derived from phase retrieval, field dependent CCD charge diffusion, optical distortions, etc.). He also demonstrated how Tiny Tim PSF models have been used for HST data analysis.

G. J. Michels (with V. L. Genberg, Sigmadyne, Inc., who presented the paper) covered some new integrated modeling improvements relative to evaluating thermo-optic effects. Victor noted that accurate optical analysis of thermo-optical effects in refractive lenses requires representation of complex distributions of refractive index that relate to the thermal profile within the optical media. Such complex refractive index representations must be available to ray-tracing calculations while the ray-trace computations are performed along each ray path. The process begins with a thermal analysis to determine the temperatures throughout each optical element in the system. Once the temperature profile is known, the refractive index profiles are then determined and supplied to the optical analysis. This paper describes an interface between Sigmadyne/SigFit and a user defined gradient index lens commonly available in commercially available optical analysis software. The interface consists of a dynamic link library (DLL) which supplies indices of refraction to a user defined gradient index lens as ray tracing calculations are being performed. The DLL obtains its refractive index description from a database derived from the thermal analysis of the optics. This process allows optical analysis software to perform accurate ray tracing analysis for an arbitrary refractive index profile induced by the change in the index of refraction due to temperature changes (dn/dT). The process is demonstrated with Synopsys' (ORA) CODE V as the optical analysis software and MD Nastran as the finite element thermal analysis software. The DLL will provide more accurate results than current approaches involving the application of an integrated OPD map to lens element surfaces.

D. A. Thomas (and J. Geis, J. Lang, L. Peterson, F. Roybal, J. Tanzillo, The Aerospace Corp.) discussed their latest work in the concurrent engineering of an infrared telescope system. David explained how the numerous/complex outputs required are best developed in a collaborative design environment where engineering data and CAD/CAE results can be shared across engineering discipline boundaries within a common software interface. This paper provides an example of an infrared telescope and spectrometer system designed in a Simulation Driven Engineering (SDE) software environment by an integrated interdisciplinary team consisting of mechanical, structural, thermal, optical, and controls engineers.

Last but not least, **E. J. Cady (with M. Chainyk, A. Kissil, M. B. Levine, and G. J. Moore who presented the paper, of Jet Propulsion Lab., and C. C. Hoff, of Cielo Software Engineering)** reported on the high precision thermal, structural, and optical analysis of an external occulter using a common model and the general purpose multi-physics analysis tool Cielo. The design and analysis of external occulters has relied on numerous feature-rich commercial toolsets which do not share the same finite element basis, level of mesh discretization, data formats, and compute platforms. Accuracy requirements, design change turnaround time and design space investigations are challenges in the current process. Cielo is an open, object-based, multidisciplinary, high-performance compute environment that addresses these major shortcomings. Funded through the Jet Propulsion Laboratory's internal Research and Technology Development program, Cielo combines state-of-the art best practices from industry and academia and offers high-performance computing and third-party software development to create an extensible framework. Cielo is MATLAB-hosted, can run on serial and massively parallel architectures, includes native high-performance modules for thermal, structural, and optical aberration analyses, and offers plug-in technologies for finite element methods development and utilization of external numerical libraries. Cielo works from a common model with multi-physics attributes. The ASCII data input format is based on Nastran which is the industry standard. Greg outlined the optical performance requirements of the occulter, giving special attention to in- plane deformations of the occulter petal edges. He presented steady state and transient thermal analyses based on a detailed finite element model resulting in high precision temperature fields which were then directly used for subsequent structural deformation analyses without interpolation or data transfer. He also compared the results of Cielo with results from commercial off the shelf tools and demonstrated the need for detailed models for both thermal and structural analysis to predict edge deformations at quality levels sufficient to demonstrate how the design meets stringent accuracy requirements.

There were no Poster Papers this year.

The full richness of application diversity and increasingly sophisticated operational requirements combine to make Optical Modeling and Performance Predictions an area where challenges continue to abound. Clearly clever modeling can return high intellectual rewards while significantly contributing to our collective ability to understand and improve the hardware of tomorrow.

Mark Kahan