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High Performance Computing (HPC)-Accelerated Inverse Deflectometry for Mirror Segment Metrology

Presentation to

NASA Mirror Tech / SBIR / STTR Workshop 2015

Presentation by

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11 NOV 2015

NASA GSFC Technical Representative

Dr. Raymond G. Ohl

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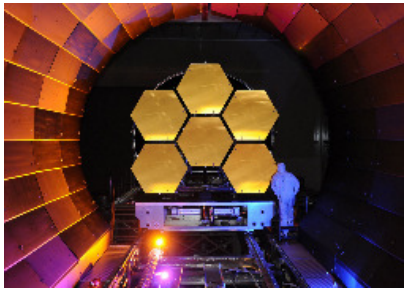
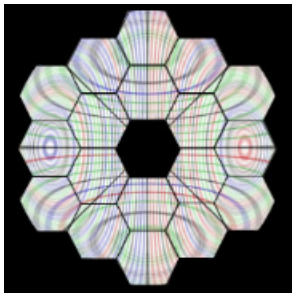
Introducing: *inverse* deflectometry + HPC = M-TEC™

- Instead of using *deflectometry* to determine the optical prescription (shape) of a telescope mirror
- We have been developing *inverse* deflectometry
- We start by assuming we already know the actual optical prescription and low-order figure error of the telescope mirror
  - Then use inverse deflectometry to determine 6 DOF misalignment of mirror segments in the telescope
  - And accelerate the process with *high performance computing* (HPC) to rapidly determine misaligned 6 DOF condition
- Our name for this new metrology technology is *M-TEC™*





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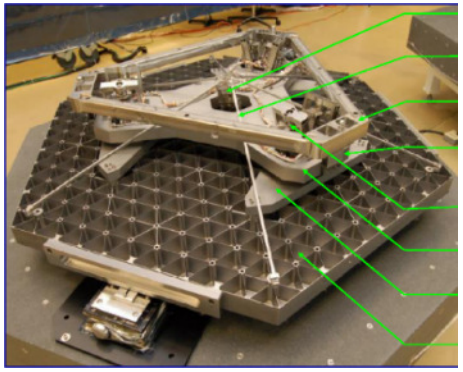
M-TEC™ Permits Direct (Front-Viewing) Determination of Segment Alignment

- Allows front-viewing, *in situ* alignment-testing of mirror segments or other aspheres
- Versus metrology-references integral to the back or sides of each mirror segment



- *Note: Images shown here are examples only and do not indicate the baseline alignment technique used for the JWST mirror segments*

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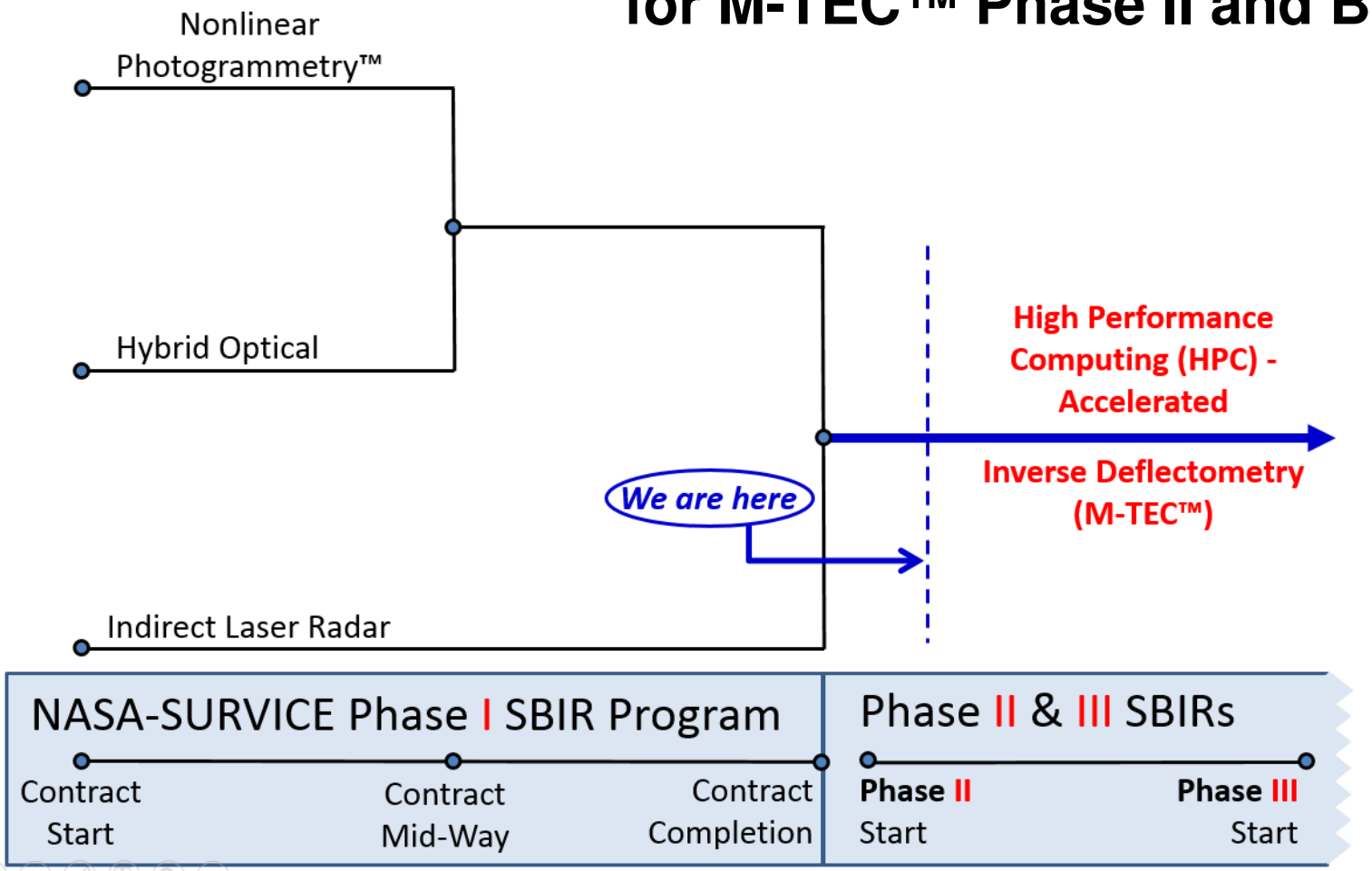
Successful Phase I SBIR Set Stage for M-TEC™ Phase II and Beyond



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Overall Phase II / III Goals

- Develop and validate M-TEC™ technology to accurately measure the global position and orientation of mirror segments or other aspheres for large telescopes
  - As-installed mirror configuration
  - Non-contact
  - At safe distance (greater than one meter)
- Transition and commercialize technology for NASA via collaboration with major OEM contractors
  - Projects like the James Webb Space Telescope
  - Other multi-segmented telescopes and optics

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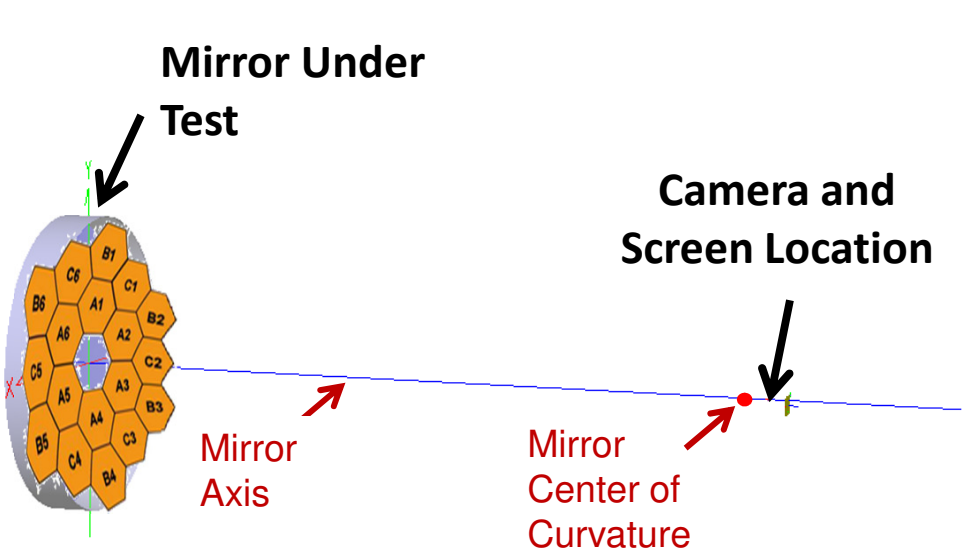
Inverse Deflectometry = New Twist on Prior Art

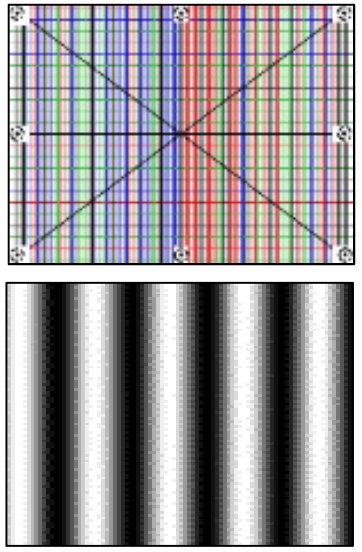
(Phase Measuring Inverse Deflectometry, or PMID)

- Leverages prior work in deflectometry; for example
  - PMD (Phase Measuring Deflectometry) work by Knauer *et al.*, SPIE Proc. 5457, 366 -376 (2004)
  - SCOTS (Software Configurable Optical Test System) work by Su *et al.*, Appl. Opt. 49, 4404 – 4412 (2010)



Screen Options:

1. **Geometric (static)**
2. **Sine wave (dynamic)**



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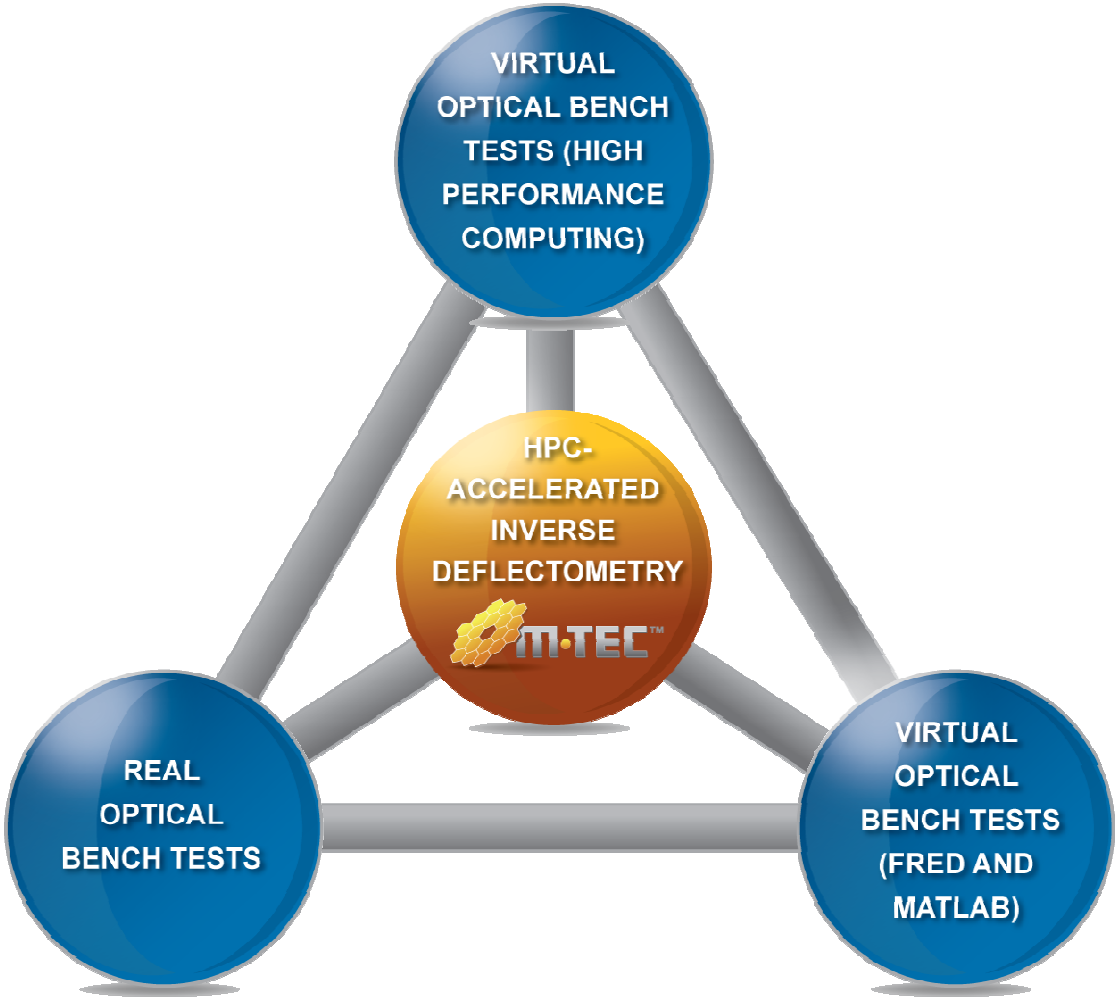
M-TEC™ Development & Validation Process



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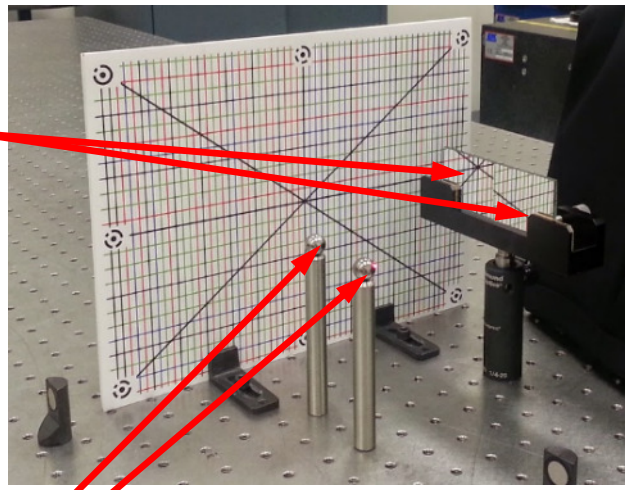
Phase I Optical Bench Tests

Mirror Segments Under Test



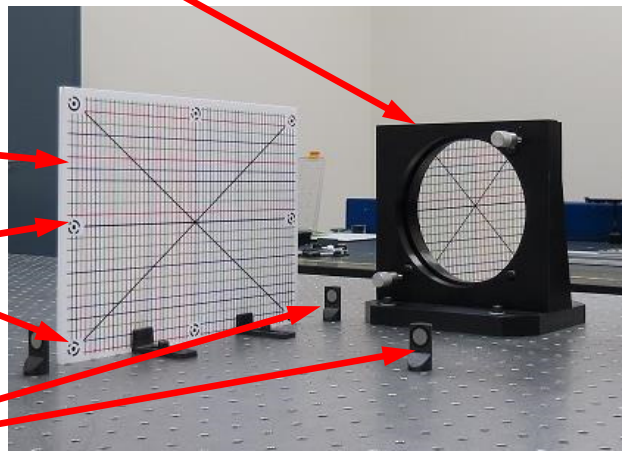
Tooling Balls

Target Screen

Photogrammetry Targets

Additional Reflecting Targets

Mirror Under Test



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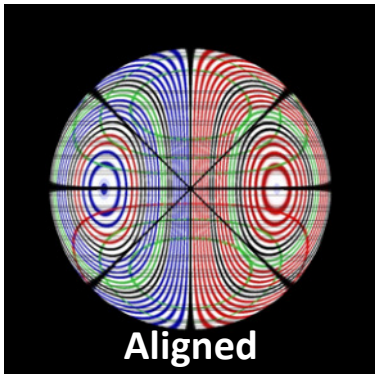
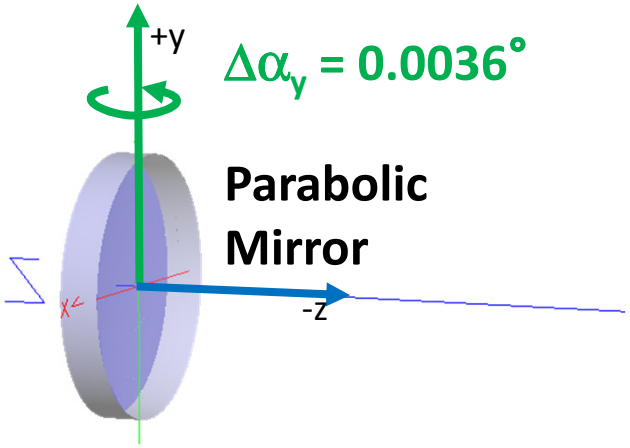
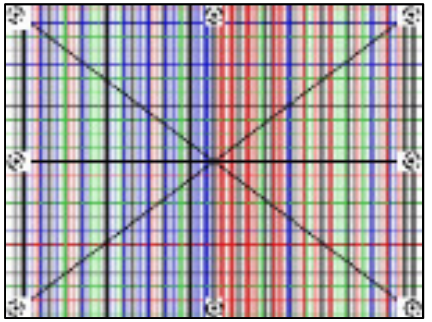
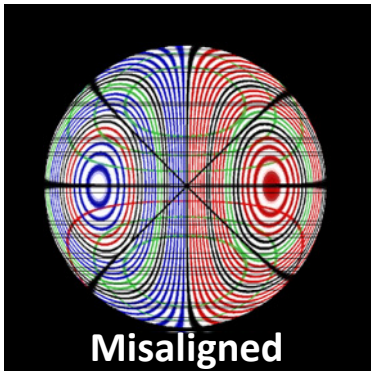
Sample Phase I Misalignment Analysis

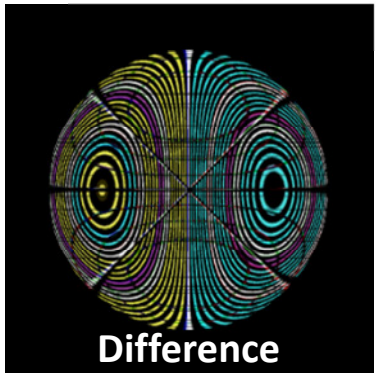




Screen Pattern







- Difference plots reveal small deviations in mirror alignment
- Sensitivity simulations include rotations, translations, and combinations

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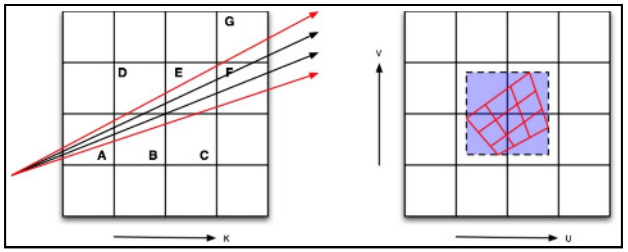
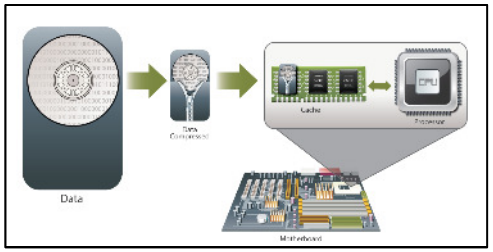
Application of High Performance Computing (HPC) to Inverse Deflectometry

- Compare actual digital image from optical test of mirror to physics-based simulated images computed via HPC
- Iteratively solve for mirror segment position



Best known methods in real-time ray tracing



Low-level, architecture-specific optimization

HPC-Accelerated Inverse Deflectometry

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SURVICE Engineering Company

www.survice.com

- Nationwide 350+ employees
  - Specialty engineering consulting & design
  - Serving US DoD for over 30 years
- Recognized expert in visualization and high performance computing (HPC)
  - Only small business with NVIDIA CUDA Research Center accreditation
- Recognized leader in metrology and reverse engineering services (metrology.survice.com)
- Dozens of highly competitive Small Business Innovation Research (SBIR) and other awards

SURVICE leverages massively parallel computing architectures from NVIDIA and Intel

SmartCEO's VOLTAGE awards LEADERS IN TECHNOLOGY

SmartCEO Magazine *Voltage Award* for Technology Innovation

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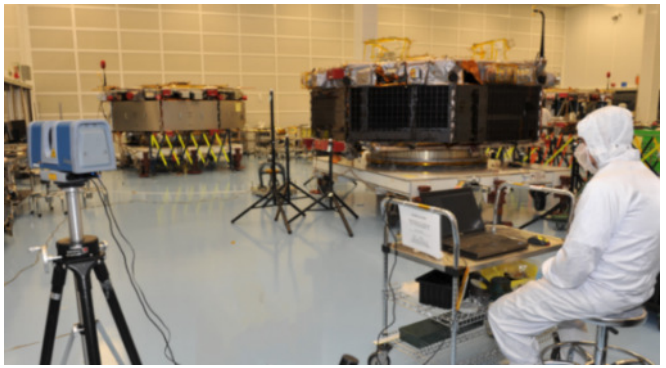
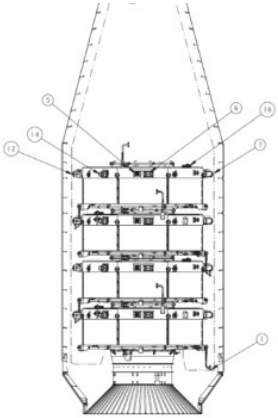
Previous SURVICE Metrology Support to NASA

- James Webb Space Telescope
  - NASA POC: Dr. Ray Ohl
  - Verification inspection with Nikon Coherent Laser Radar (CLR) for metrology inspection
- Magnetospheric Multiscale (MMS) Stack
  - NASA POC: Henry Sampler
  - Vantage POC: John Carro
  - Surphaser scanner verifies alignment and fit metrology regarding Atlas rocket payload section





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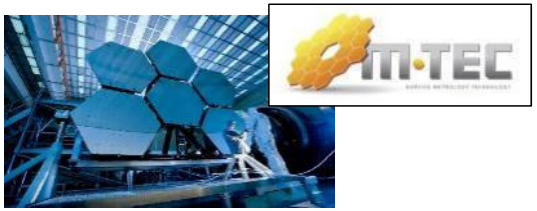
SURVICE Engineering CR&D
HPC and Metrology Devices & Tech



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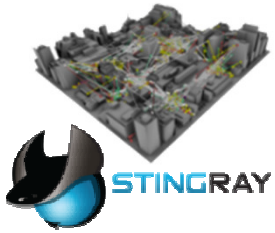
NASA SBIR to develop HPC metrology tech, like James Webb Space Telescope

Hoverbike

DSIAC task with US Army & Malloy Aeronautics Ltd.



New RF propagation model built for Intel to showcase Xeon Phi

Enhanced-CLR™

Completed MRL-7 demo on **F-35** production line in Palmdale CA.

HOLOS™

Working with Intelligent Earth Ltd. on low-cost touch-probe metrology tech

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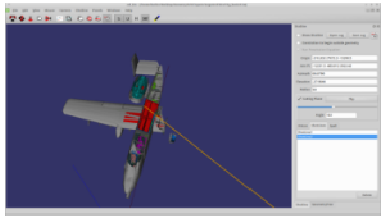
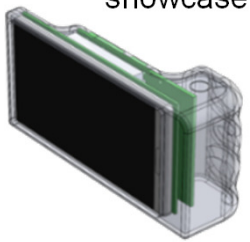


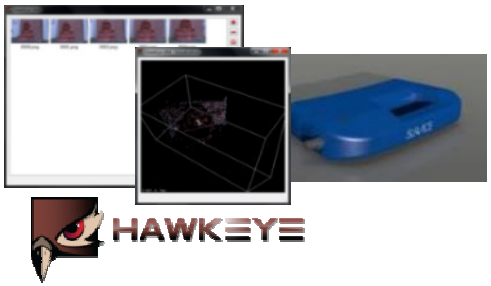
VSL (Visual Sim Lab)

High performance V/L analyses to be part of next AJEM release.

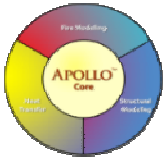


P&W (Pratt & Whitney) FAST *II*

Custom H/W & S/W solution for **F-22** engine exhaust duct data collection



SURVICE-developed 3D scanning hardware & software



Apollo™

CFD running NVIDIA's CUDA on GPU

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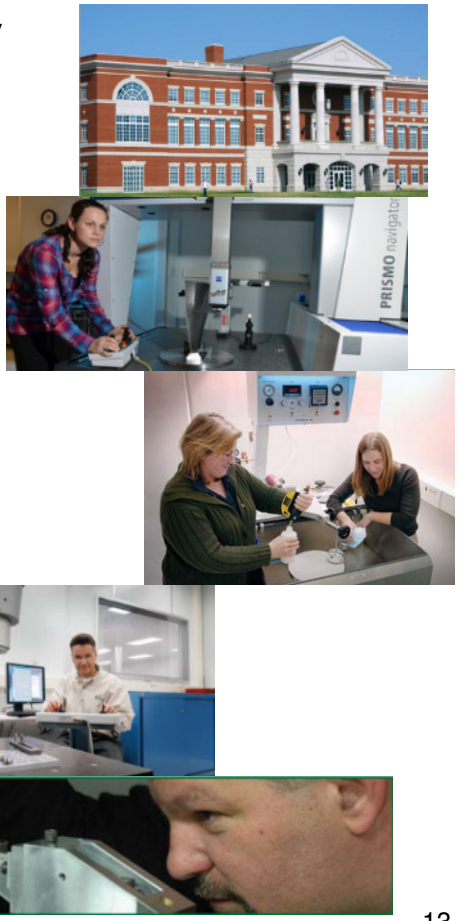
Subcontractor: UNC Charlotte Center for Precision Metrology (CPM)

- Research: Development and integration of precision metrology as applied to manufacturing
- Facilities:
  - 4,000 sq. ft. of controlled environment for metrology and instrument development
  - 1,500 sq. ft. controlled environment, 20± 0.1º C, class 10,000 metrology laboratory
  - 33,000 sq. ft. laboratories & offices Duke Centennial Hall
- Extensive capabilities
  - Metrology
  - Precision manufacturing
- CPM Affiliates: B&W Y-12, Zeiss, Caterpillar, Corning Cable, Cummins, GE Energy, General Dynamics, Intel, LLNL, Micro Encoder, NIST, Renishaw, United Technologies



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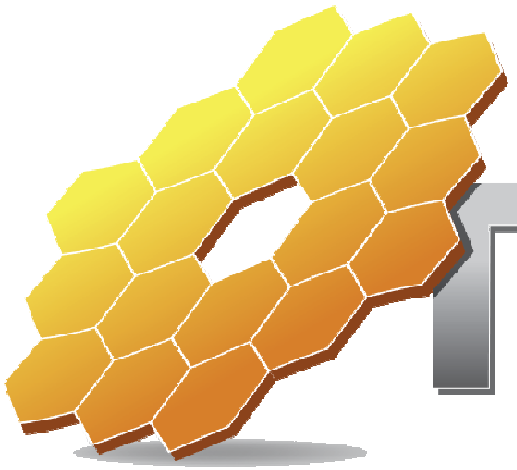
We are looking for partners (under an NDA)

Dr. John F. Ebersole, Principal Investigator

John.Ebersole@survice.com

603.714.4559

www.survice.com



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