Simplified Software Tools for Beam Control System Evaluation and Development

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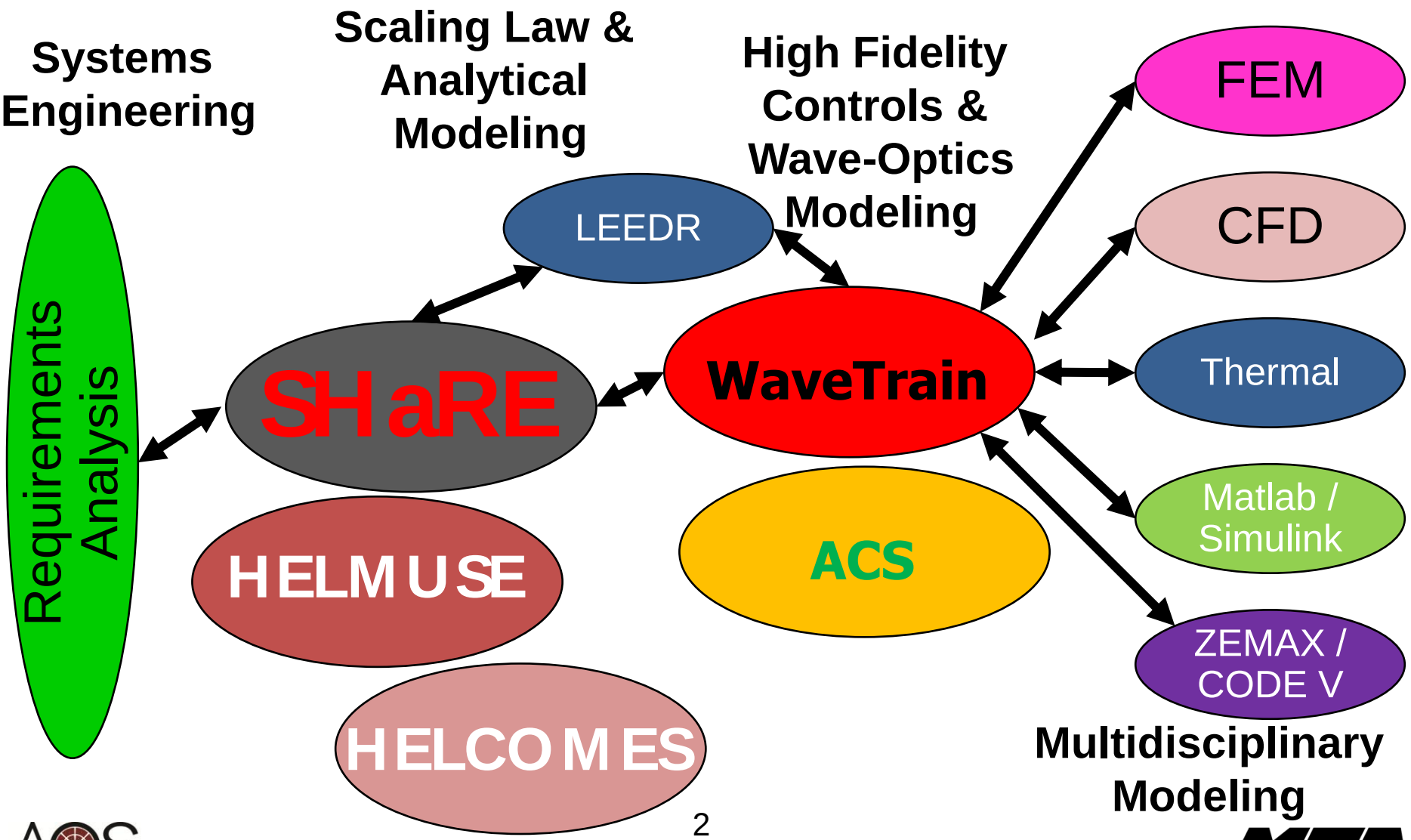
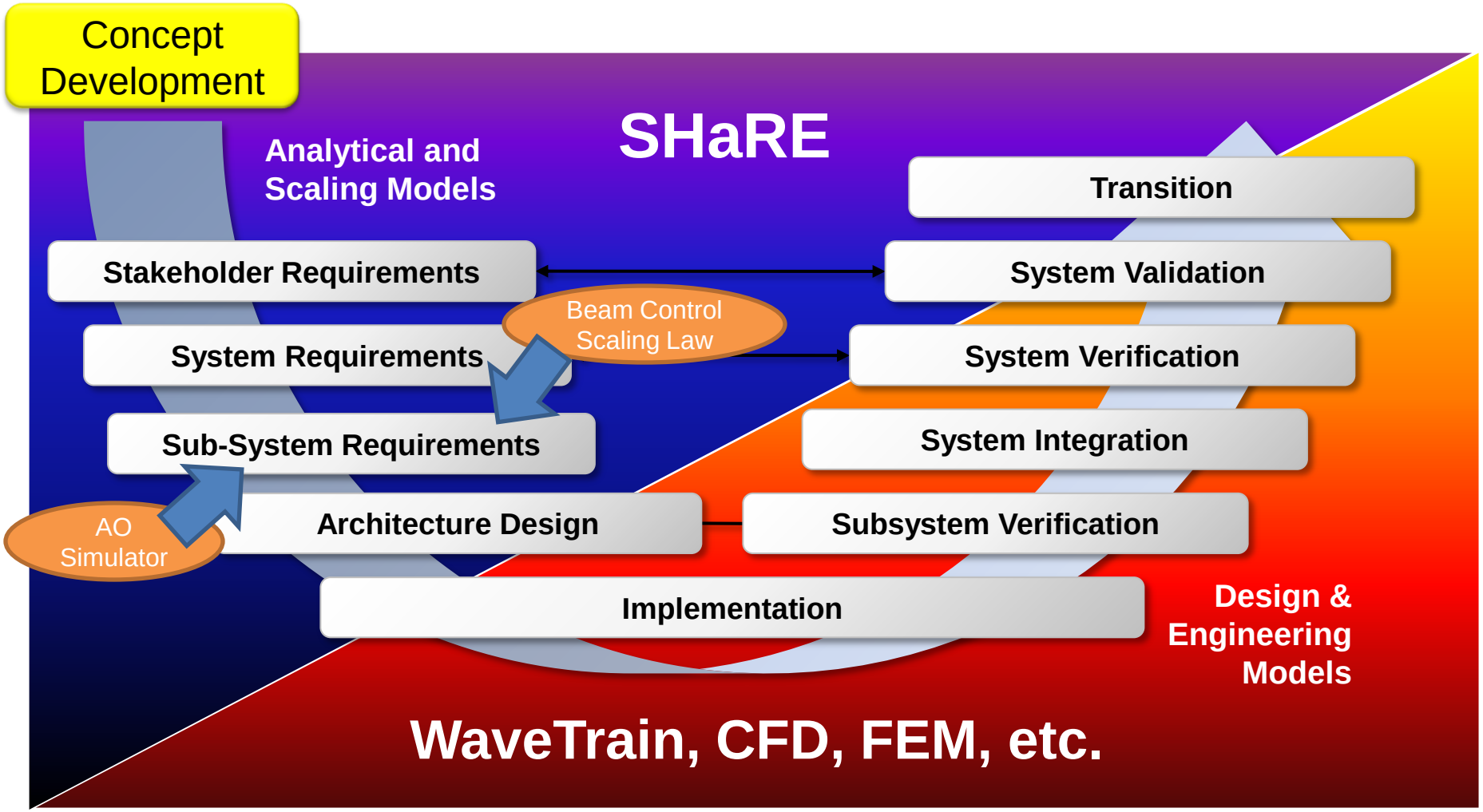
MZA's Tools Cover Every Part of HEL Weapons System Performance Prediction.



These New GUI Tools Facilitate Beam Control Sub-System Design.



GOAL: GUI tools for rapid design trades and ease of use

- Although MZA's tools cover the entire spectrum of modeling needs, we want to maximize ease of use with GUI interfaces that are:
  - Simple to use and install,
  - Give good fidelity results, and
  - Execute quickly
  - Common Graphical Format
    - Inputs on Left
    - Outputs on Right

BC Sim

Beam Control Design Software is based on Analytical Expressions

- Used relationships in the open literature to model performance.
- Attempted to create a GUI that is easy to use, fast, and convenient.

$$r_0 = \left[\frac{0.423k^2}{\cos(\beta)} \int_0^L C_n^2(z)dz \right]^{-3/5}$$

$$\theta_0 = \left[2.91k^2 \int_0^L C_n^2(z) z^{5/3} dz \right]^{-3/5}$$

$$\sigma_{uncomp}^{\ 2} = 1.02\left(\frac{D}{r_0}\right)^{5/3}$$

$$\sigma_{tilt-comp}^{\ 2} = 0.134\left(\frac{D}{r_0}\right)^{5/3}$$

$$f_G = 2.31\lambda^{-6/5}\left[\frac{1}{\cos(\beta)} \int_0^L C_n^2(z) v_w^{5/3}(z) dz \right]^{3/5}$$

$$f_{T_G} = 0.331 \frac{D^{-1/6}}{\lambda} \left[\frac{1}{\cos(\beta)} \int_0^L C_n^2(z) v_w^2(z) dz \right]^{1/2}$$

$$\sigma_{\chi}^{\ 2} = 0.307k^{7/6}L^{11/6}C_n^2$$

$$\sigma^2_{fit} = \kappa\left(\frac{r_s}{r_0}\right)^{5/3}, \kappa \approx 0.35$$

$$\sigma_{temporal}^{\ 2} = \left(\frac{f_G}{f_{3dB}}\right)^{5/3}$$

$$\sigma_{tilt}^{\ 2} = \left(\frac{f_{T_G}}{f_{3dB}}\right)^2 \lambda^2$$

$$\sigma_{total}^{\ 2} = \sigma_{fit}^2 + \sigma_{temporal}^2 + \sigma_{tilt}^2$$

$$\text{Strehl Ratio} = \exp\left(-\sigma_{total}^{\ 2}\right)$$

R. Tyson, Principles of Adaptive Optics

BC Sim

Engagement Definition

Inputs

Outputs

BC Scaling Law, (c… Optical Systems, LLC (BETA)

Engagement | Tilt | AO

Engagement

Platform Altitude (m): 2,000
Target Altitude (m): 10
Ground Range (m): 5,000
Aperture Diameter (m): 0.300
Wavelength (nm): 1,064.0

ACTIVE OPTICAL SYSTEMS

Save | Load

Atmosphere

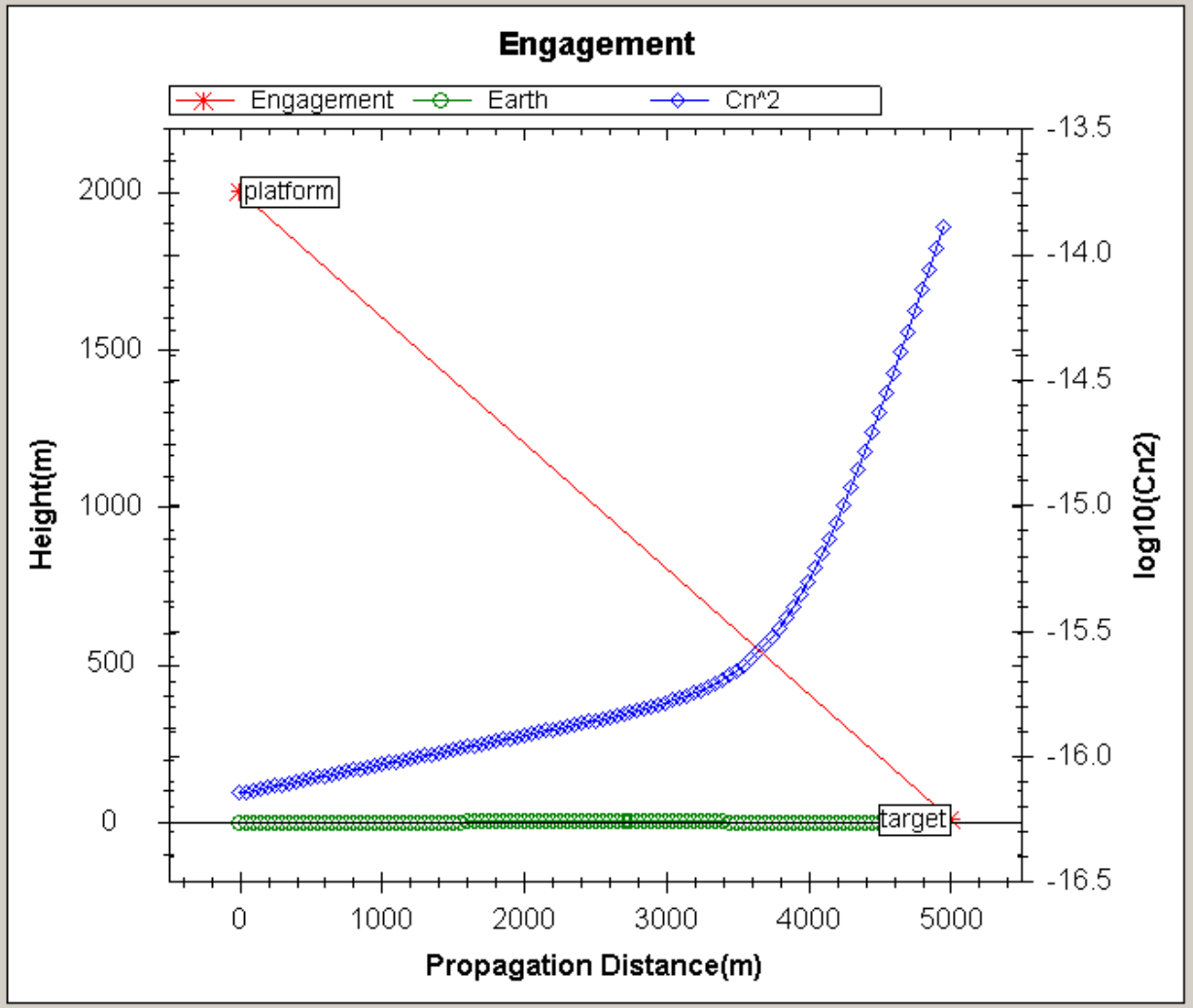
Profile: HV 5/7
Cn2 (log10): -13.50
Multiplier: 1.000
3.16e-14

Velocity

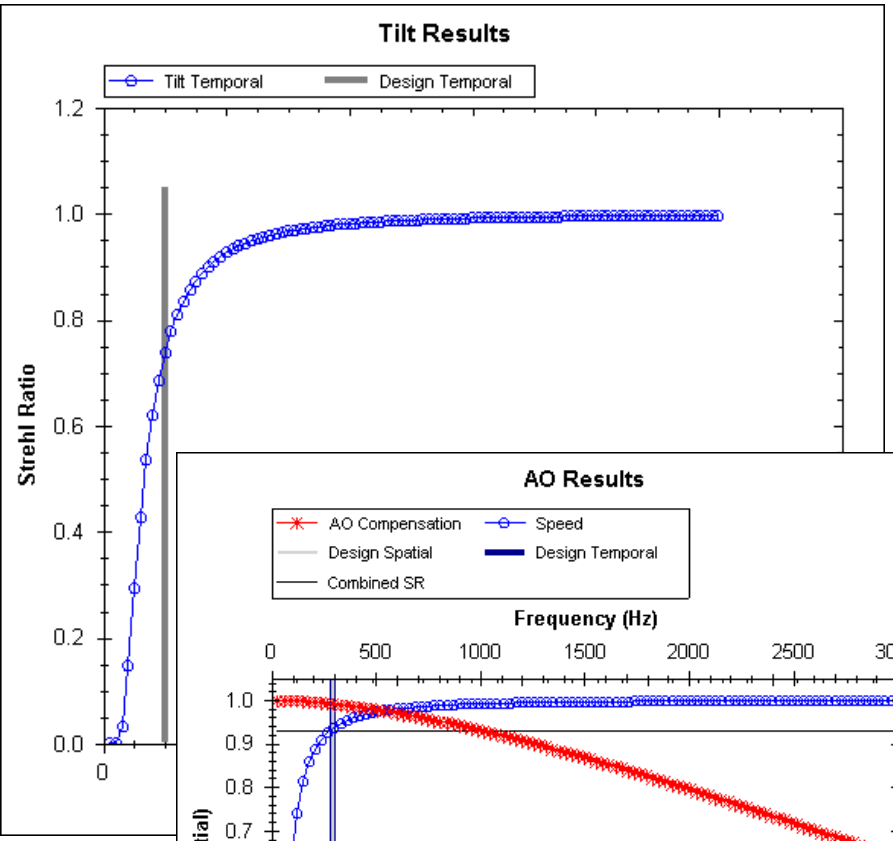
	Magnitude	Direction
HEL Direction		90.0
Wind (m/s)	10.0	0.0
Platform (m/s)	0.0	0.0
Target (m/s)	0.0	0.0

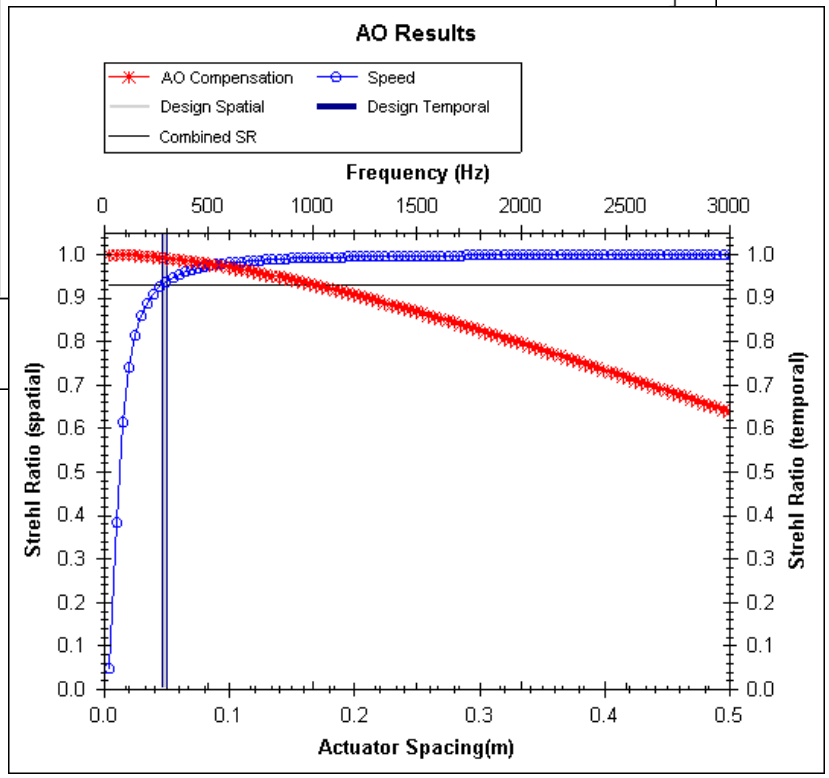
Property	Value	Notes
r0	0.4303	Fried's Coherence Length usec
D/r0	0.6972	
D_DL	0.0433	Diffraction Limited Spot Diamet
q0	0.0002	Isoplanatic Angle (radians)
fG	58.6292	Greenwood Frequency (Hz)
fT	8.7914	Tilt/Tyler Frequency (Hz)
WFE_Tilt	0.6969	Tilt WFE (radians)
WFE_HO	0.2710	Higher-Order WFE (radians)
WFE_Total	0.7477	Total WFE (radians)
SR_HO	0.9292	Higher-Order Strehl Ratio
SR_Total	0.5717	Uncompensated Strehl Ratio

Engagement | Tilt | AO | Wind | Results



Example Results





Engagement | Tilt | AO | Wind | Results

Property	Value	Notes
Engagement		
r0	0.4303	Fried's Coherence Length used in Calculati
r0_plane	0.0696	Plane Wave (m)
r0_sph_target	0.0761	Spherical Wave Target (m)
r0_sph_platform	0.4303	Spherical Wave Platform (m)
D/r0	0.6972	
D_DL	0.0433	Diffraction Limited Spot Diameter
q0	0.0002	Isoplanatic Angle (radians)
fG	58.6292	Greenwood Frequency (Hz)
fT	8.7914	Tilt/Tyler Frequency (Hz)
WFE_Tilt	0.6969	Tilt WFE (radians)
WFE_HO	0.2710	Higher-Order WFE (radians)
WFE_Total	0.7477	Total WFE (radians)
SR_HO	0.9292	Higher-Order Strehl Ratio
SR_Total	0.5717	Uncompensated Strehl Ratio
Tilt Compensation		
Tilt Temporal Variance	0.5524	Tilt Variance
Tilt Temporal SR	0.7370	Tilt Temporal Strehl Ratio
AO Compensation		
Nact_est	28	Estimated Number of Actuators
WFE_Comp_Spatial	0.0984	Compensated Spatial WFE
WFE_Comp_Temporal	0.2565	Compensated Temporal WFE
SR_Comp_Spatial	0.9904	SR from Compensated Temporal WFE
SR_Comp_Temporal	0.9363	SR from Temporal WFE
System Performance		
WFE_Compensated	0.6153	Compensated WFE
SR_Compensated	0.6848	Compensated Strehl Ratio

XML Configuration Saving and Loading

- Results and setup can be saved and load with XML files.
- Working on SHaRE compatibility.

```
<?xml version="1.0" encoding="Windows-1252"?><!--Beam Control Scaling Law Simulation
--><root>
<nudWavelengthNM>1064</nudWavelengthNM>
<nudRange>5000</nudRange>
<nudTargetAltitude>2000</nudTargetAltitude>
<nudPlatformAltitude>1</nudPlatformAltitude>
<nudDap>0.3</nudDap>
<tbDr0>4.3122</tbDr0>
<tbPlatformTheta0>0.0006</tbPlatformTheta0>
<tbGreenwoodFreq>141.4163</tbGreenwoodFreq>
<tbRytov>0.0118</tbRytov>
<tbRMSWFE>8.8656</tbRMSWFE>
<tbUncompStrehlRatio>7.33e-35</tbUncompStrehlRatio>
<tbPlatformr0>0.0696</tbPlatformr0>
<nudHELDirection>90</nudHELDirection>
<nudTargetDirection>0</nudTargetDirection>
<nudPlatformDirection>0</nudPlatformDirection>
<nudWindDirection>0</nudWindDirection>
<nudTargetVelocity>100</nudTargetVelocity>
<nudPlatformVelocity>0</nudPlatformVelocity>
<nudWindVelocity>10</nudWindVelocity>
<nudTiltBandwidth>300</nudTiltBandwidth>
<tbTiltStrehl>0.7897</tbTiltStrehl>
<tbTiltTempVariance>0.2361</tbTiltTempVariance>
<tbTiltGreenwoodFreq>23.2008</tbTiltGreenwoodFreq>
<tbNact2D>78.5398</tbNact2D>
<tbCompStrehlRatio>0.6181</tbCompStrehlRatio>
<tbCompWFE>0.6936</tbCompWFE>
<tbSpatialWFE>0.2935</tbSpatialWFE>
<tbTemporalSR>0.8648</tbTemporalSR>
<tbTempWFE>0.3811</tbTempWFE>
<tbSpatialSR>0.9175</tbSpatialSR>
<nudActSpacing>0.03</nudActSpacing>
<nudKappa>0.35</nudKappa>
<nudAOBandwidth>450</nudAOBandwidth>
<tbCombinedVariance>0.7172</tbCombinedVariance>
<tbCombinedStrehl>0.4881</tbCombinedStrehl>
</root>
```

AO Simulator: Goals & Objectives

- Enable GUI interactive AO Simulation
- Easy to use and install
- Strong Physics-Based Approach
- Accurate adaptive optics system modeling
- Flexible
  - Different types of DMs
  - Different kinds of WFS feedback
- WaveTrain Compatible
  - Enable outputs to be read into WaveTrain

AO Setup

Inputs

Outputs

AO Simulator (BE ctive Optical Systems, LLC 2010

DM | WFS | Aberration | AO | Settings

DM Configuration

Act. Grid Type: (•) Rect. ( ) Hex

	Count	Spacing	Clip Diameter
X	7	0.150000	1.100000
Y	7	0.150000	1.100000

IF Shape: (•) Gaussian ( ) Plate ( ) Membrane

DM Diameter: 8.000000

DM Throw (Phase): 1000.00000000

[ ] Draw Actuator Box: 0.500000

Slaving (BETA)

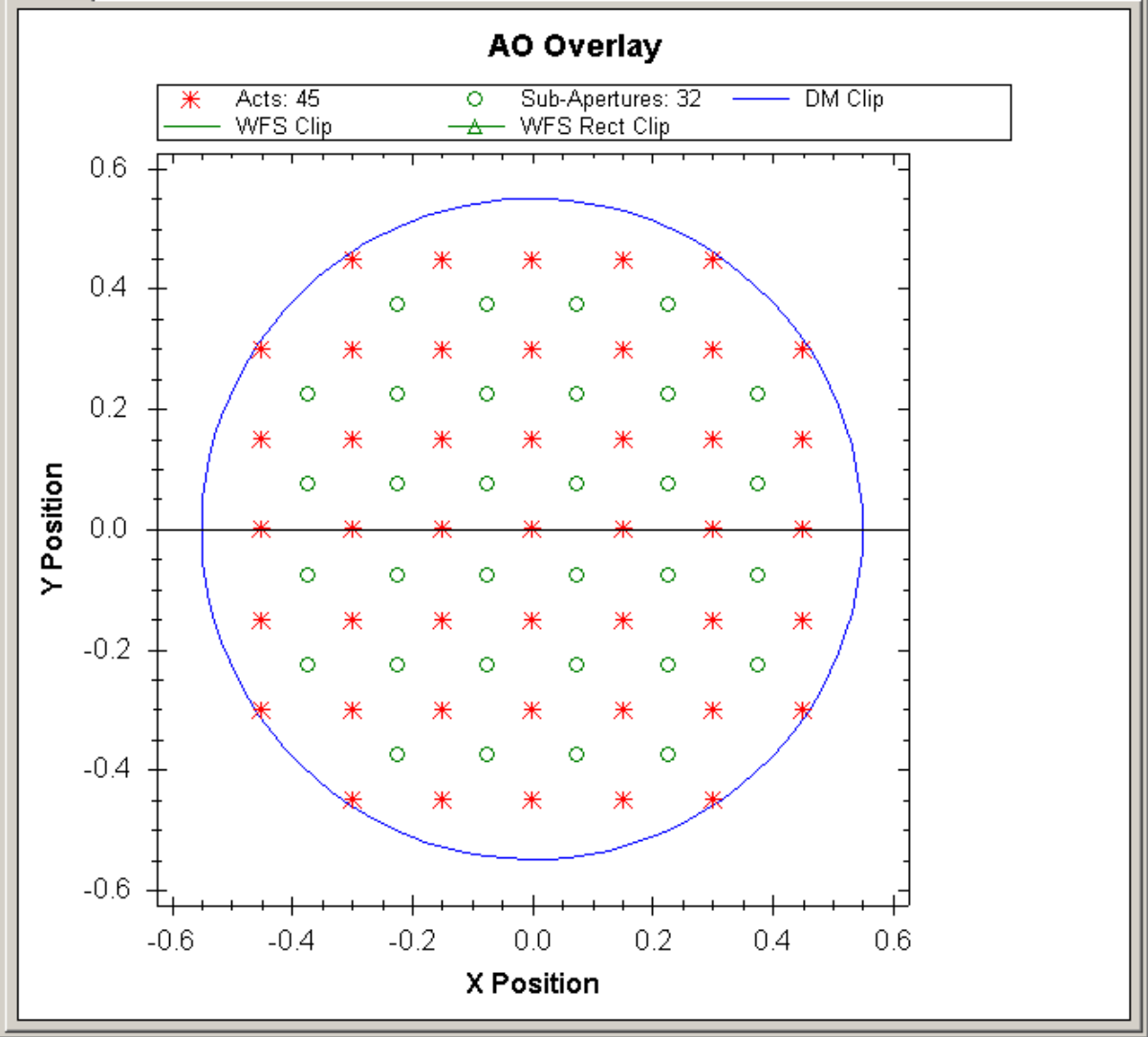
[ ] Calculate Slaving

	Rect. Size	Outer Diameter	Inner Diameter
X	4.000000	5.000000	-0.100000
Y	4.000000	5.000000	-0.100000

Max Count: 4

Max Radius: 1.000000

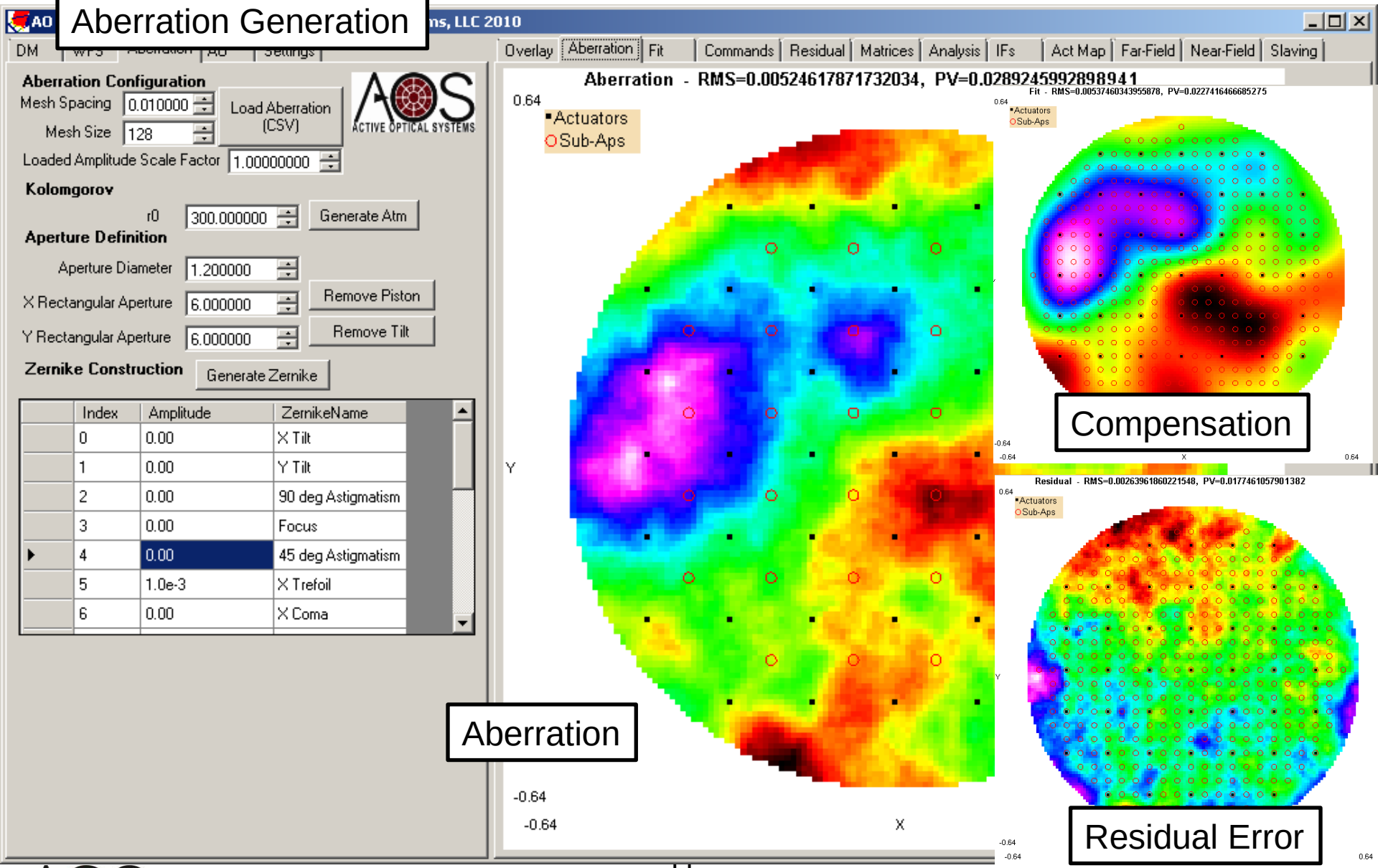
Overlay | Aberration | Fit | Commands | Residual | Matrices | Analysis | IFs | Act Map | Far-Field | Near-Field | Slaving



AO Sim

Aberration Compensation

Aberration Generation

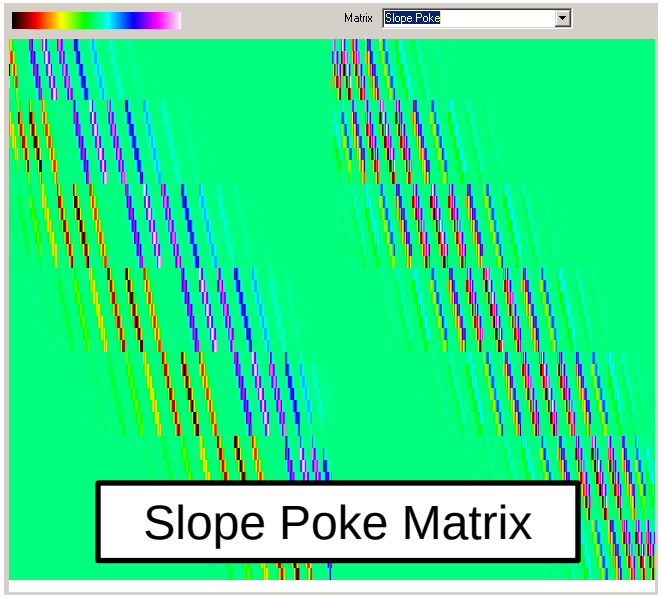


Compensation

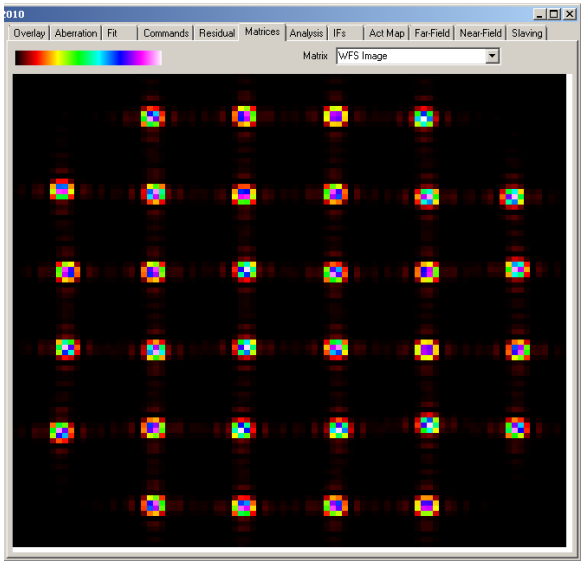
Aberration

Residual Error

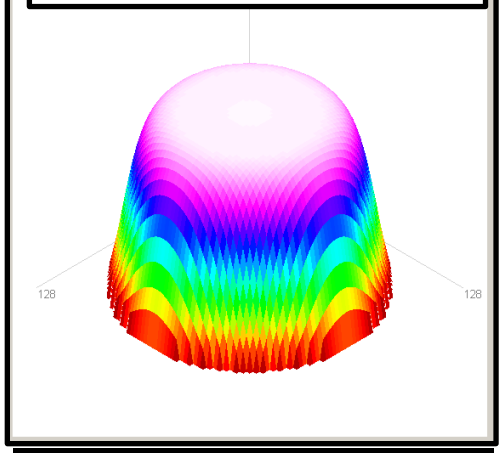
Generates Control Matrices, Far-Field Images, and WFS Images

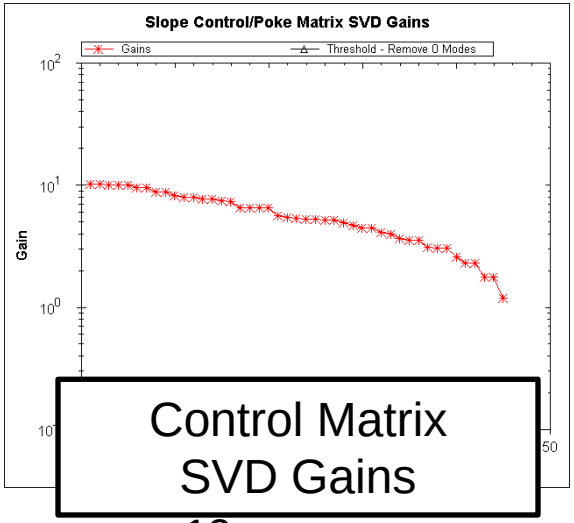


SHWFS Image

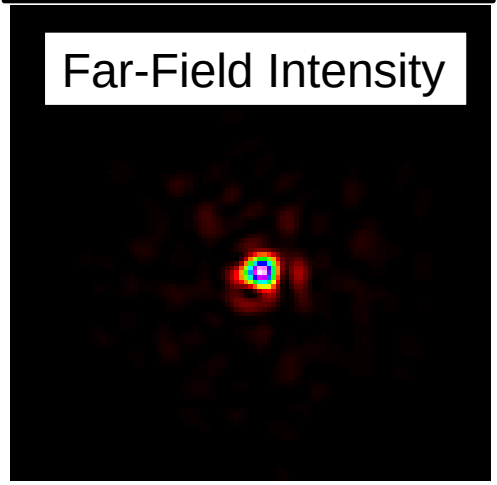


Near-Field Intensity



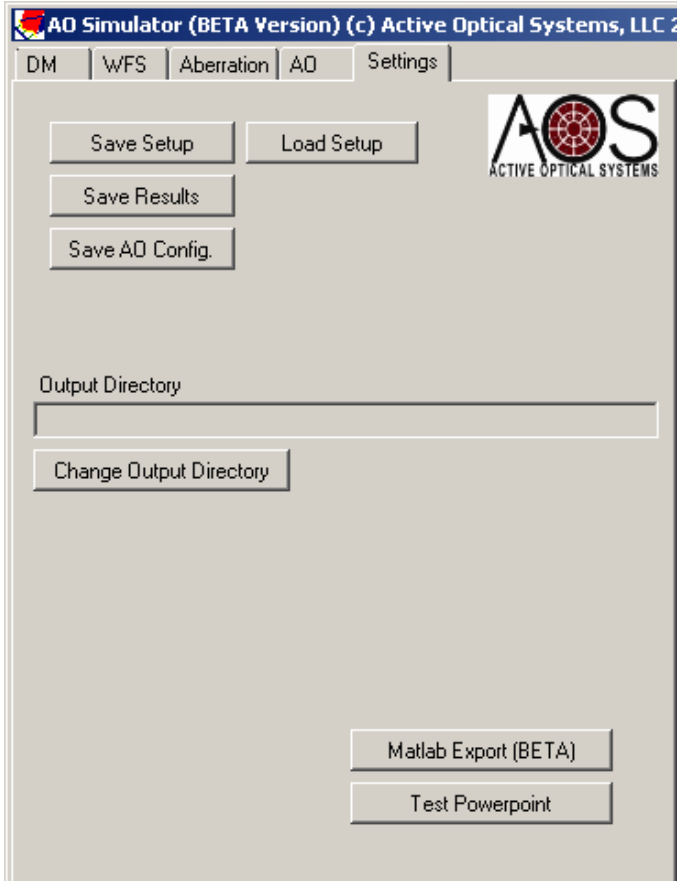


Far-Field Intensity



File Exporting to .XML, .PPT, and .MAT

- Saves and loads setup to an XML file.
- Saves results and AO configuration to XML.
- Saves a WaveTrain & Matlab compatible .MAT file of the AO setup.
- Saves results to PowerPoint.



Conclusions & Future Work

- We presented a beam control system evaluation tool and an AO system evaluation tool with a simple GUI interface for non-programmers.
- We are going to continue verification and validation and look toward a tighter integration with WaveTrain and SHaRE.
- Enable system setup to be loaded directly into SHaRE and WaveTrain

Questions?

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