WFIRST
Exoplanets Parallel Session: Demonstration of Starshade Technologies

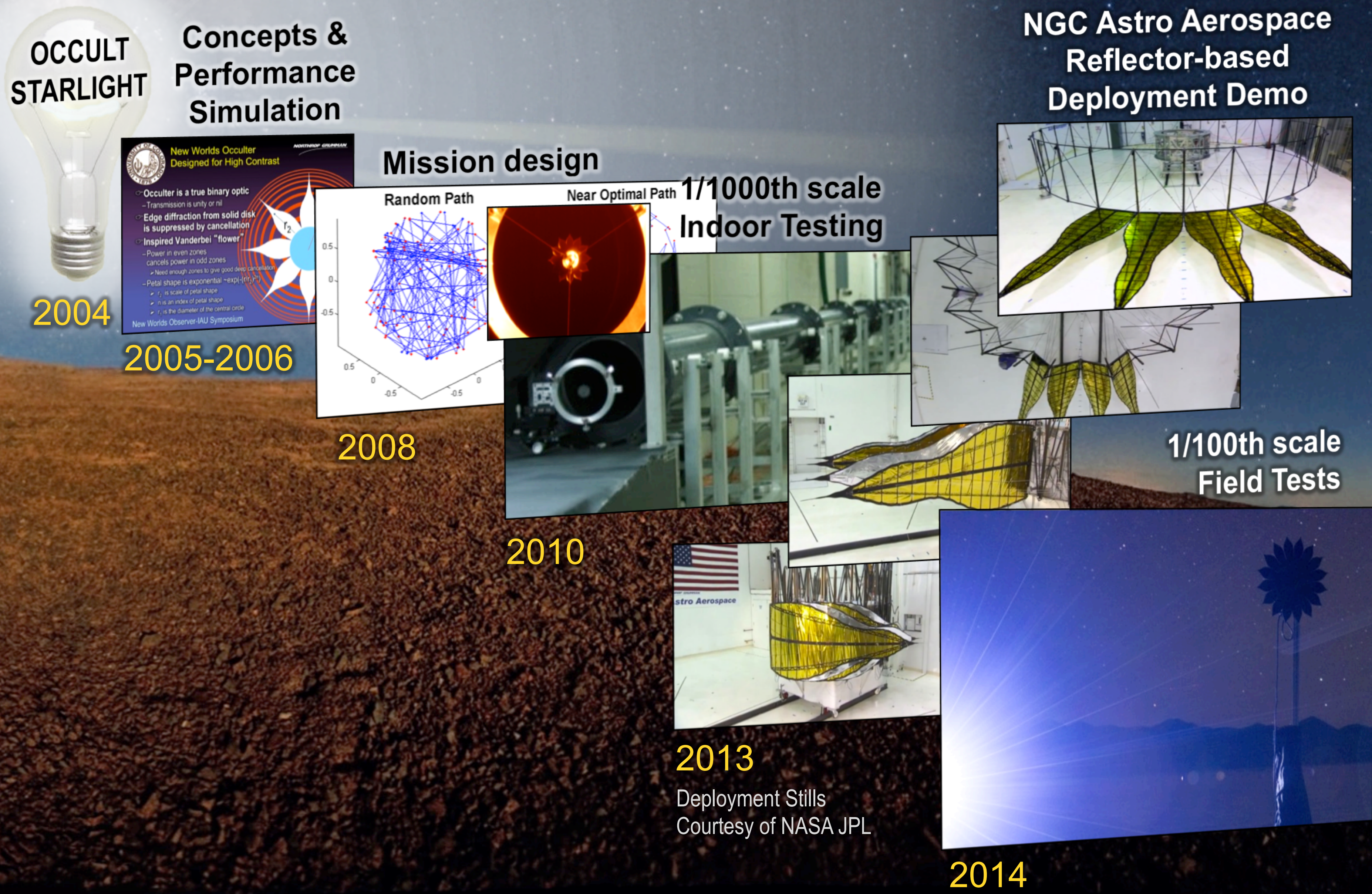
THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

November 18th 2014

Tiffany Glassman, PhD

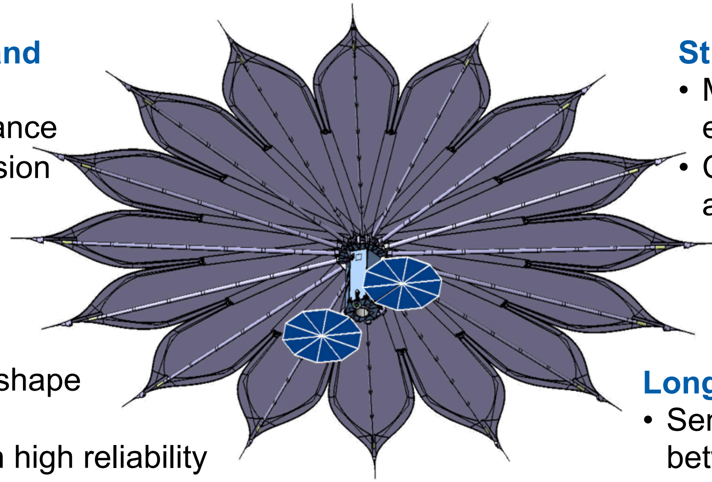
Northrop Grumman Starshade History



Purpose of Optical Performance Testing

NORTHROP GRUMMAN

Critical Technologies



Performance Verification and Modeling
- Predict diffraction performance at better than ~10^{-12} precision
- Validate that models are accurate to this level

Precision Deployment and Shape Control
- Build structure that meets shape requirements
- Deploy accurately and with high reliability
- Maintain shape during on-orbit disturbances such as jitter and thermal gradients

Stray Light Control
- Mitigate scattering of sunlight off edge of starshade petals
- Control transmission of sunlight and starlight through membrane

Long Distance Formation Flying
- Sense cross-track alignment errors between starshade and telescope
- Control starshade position relative to telescope line of sight

- Optical performance verification is a critical technology for the starshade
  - Starshade must block the light of the central star by more than 10^{10} – cannot be tested on the ground at full scale, given required separation
  - Modeling will be key to validating the mission performance
  - Optical diffraction modeling effort has been under way for many years – must be verified with test measurements

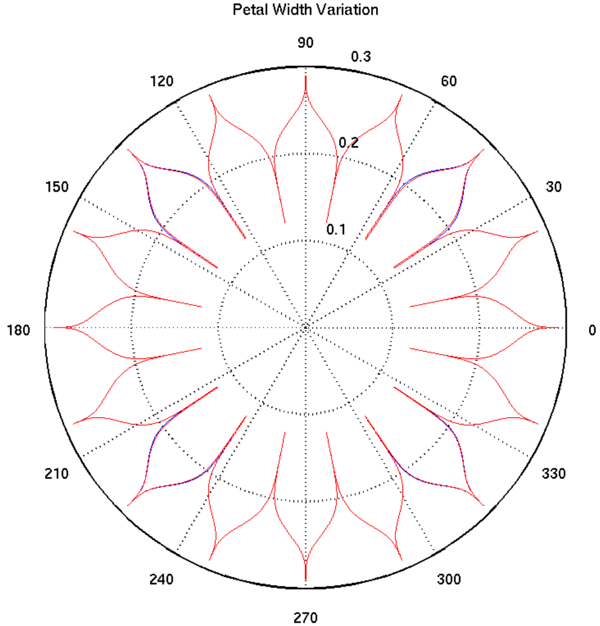
Field Testing 2014

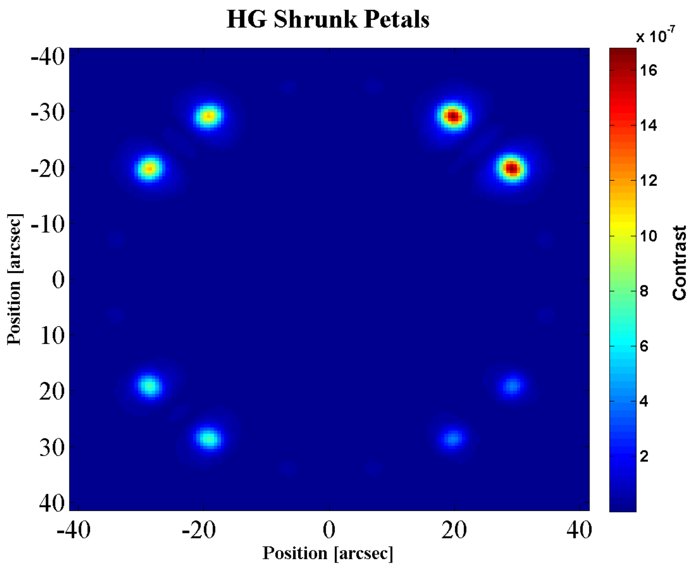
NORTHROP GRUMMAN

NASA JPL / Northrop Grumman 100^{th} Scale Starshade

Light Sources

Testing Engineering Sensitivities –
Flawed Starshade Performance



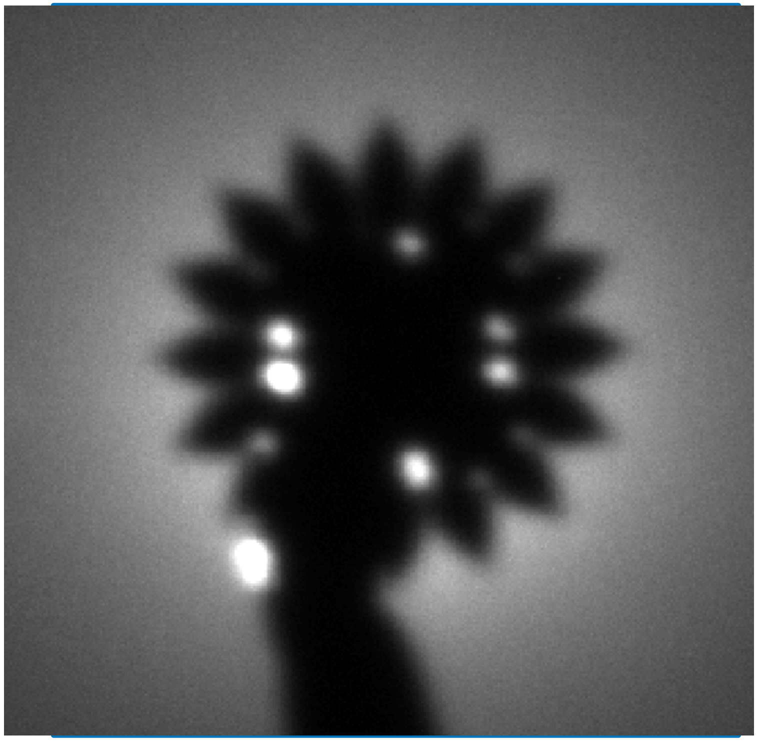


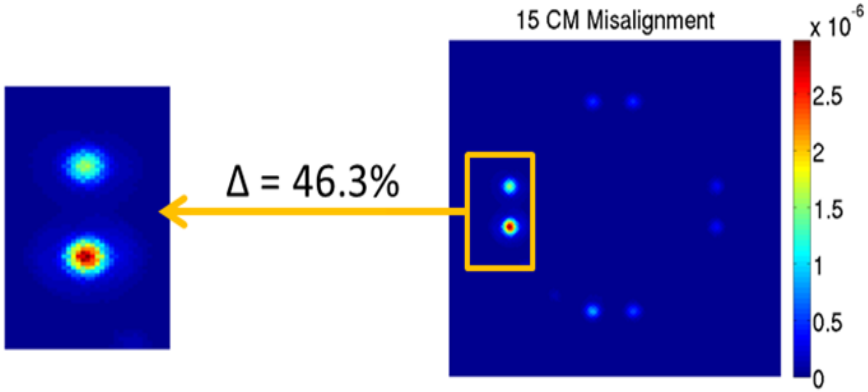
- Added "flaws" to Starshades to mimic in-space errors and validate models
- 6 families of flaws applied to two designs
- Models predicted performance with field test dimensions

Comparison of Simulations to Field Data

NORTHROP GRUMMAN

- Shown here is a Hypergaussian Starshade with a range of petal width variations
  - Clockwise from 9:00 position: -5%, -2%, and -3%
  - Starshade stand obscures the true effects of the -4% petal
- Simulations predict equal brightness flaws on each side of the petal
  - Differing brightness in field test likely due to misalignment
  - Preliminary match to model points to a source shift down and to the right



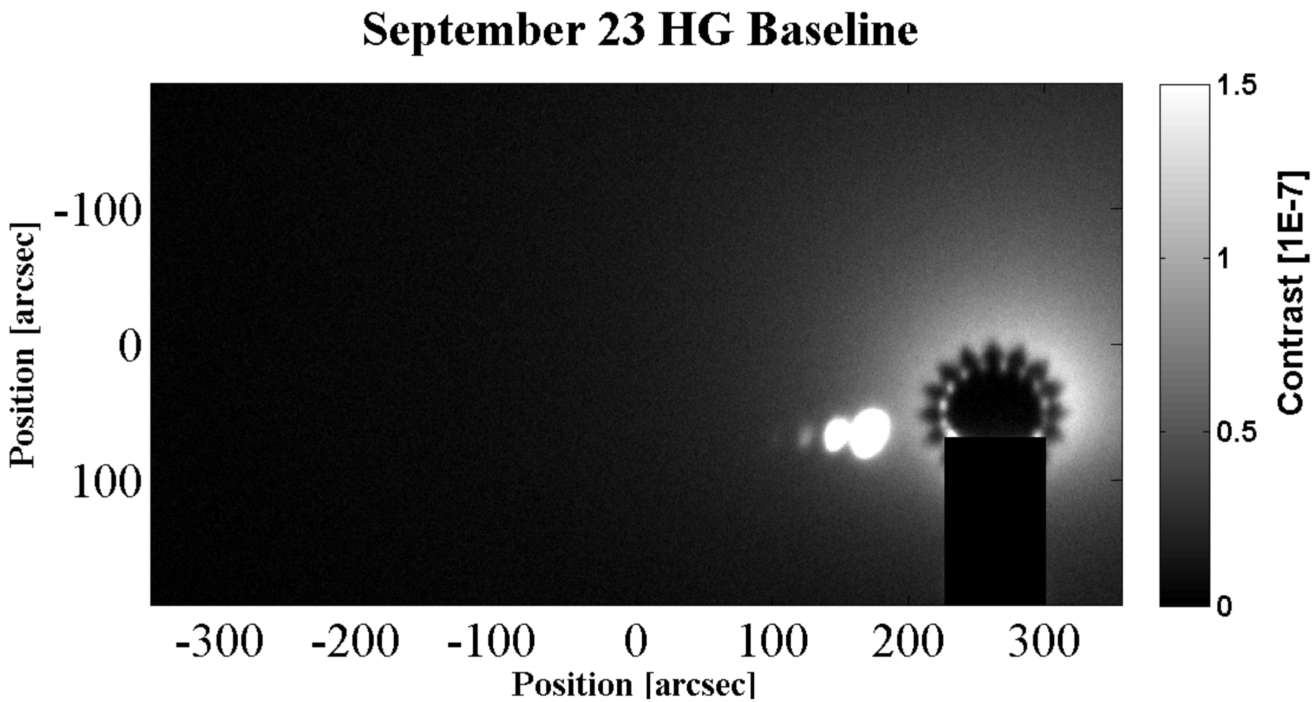


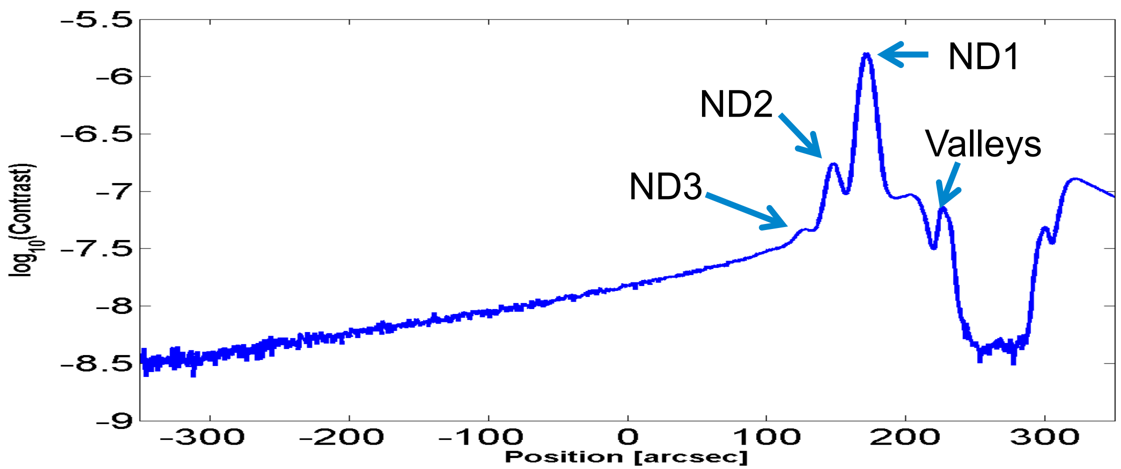
Change in Petal Width	-2%	-3%	-5%
Predicted Contrast	$0.4\text{-}4\times10^{-6}$	$0.5\text{-}7.4\times10^{-7}$	$0.1\text{-}1.7\times10^{-5}$
Estimated Contrast	1×10^{-6}	$1.5\text{-}2.3\times10^{-6}$	$3.2\text{-}5.5\times10^{-6}$

Best Contrast Result to Date – Hypergaussian Starshade

- Image is a combination of 20, 5 sec images
- The curve is cross section through the image, averaging over a 65 pixel wide strip
- ND1 Planet (7×10^{-6}), ND2 Planet (6×10^{-7}), and ND3 Planet (4×10^{-8}) LEDs are indicated, a 4th LED is present ($\leq \sim 10^{-8}$)

Distance from center	70"	100"
Mean Background	7.7×10^{-8}	5.5×10^{-8}
3σ Contrast Upper Limit	**2.1×10^{-8}**	**1.5×10^{-8}**

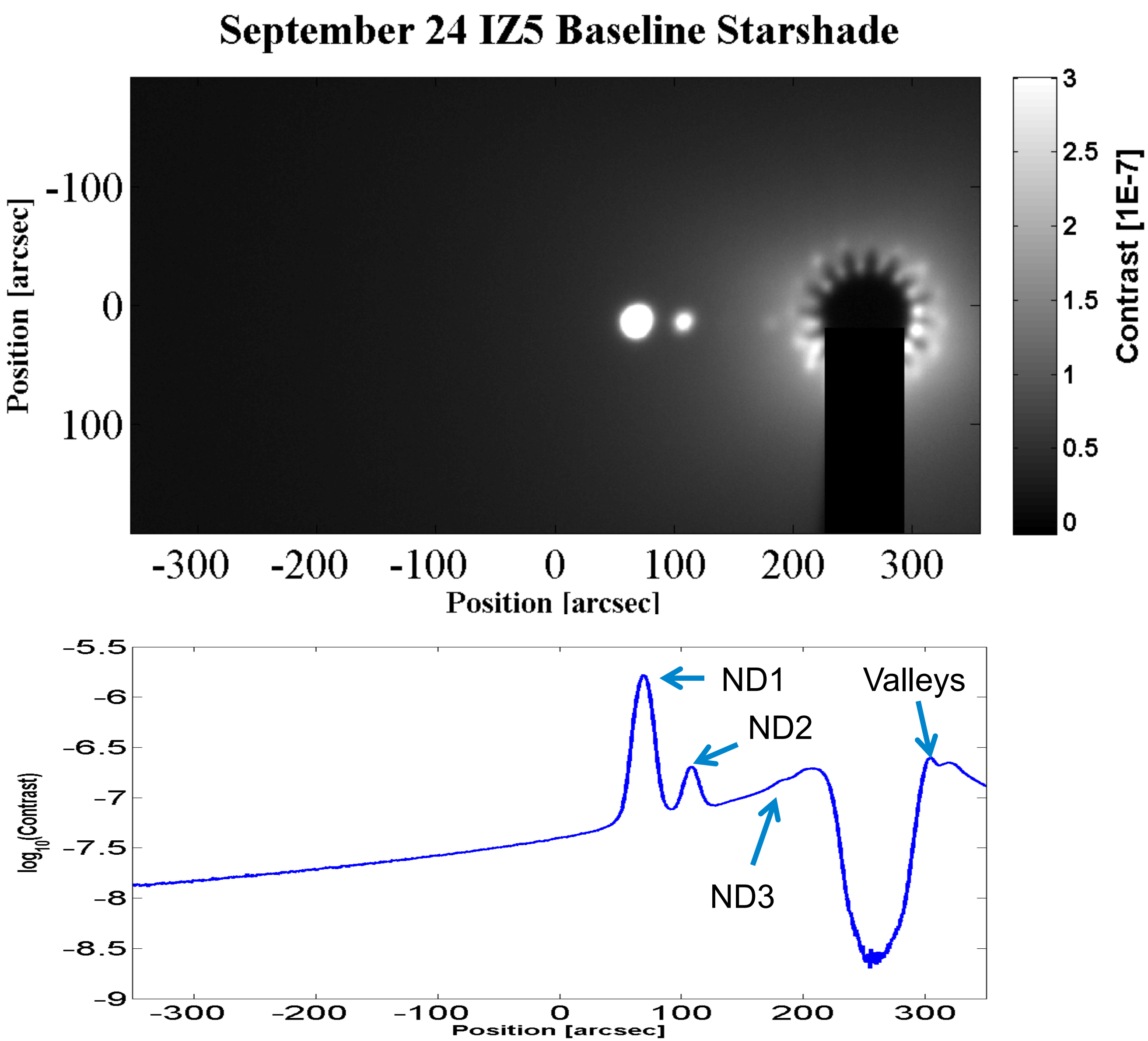




Best Contrast Result to Date – IZ5 Starshade

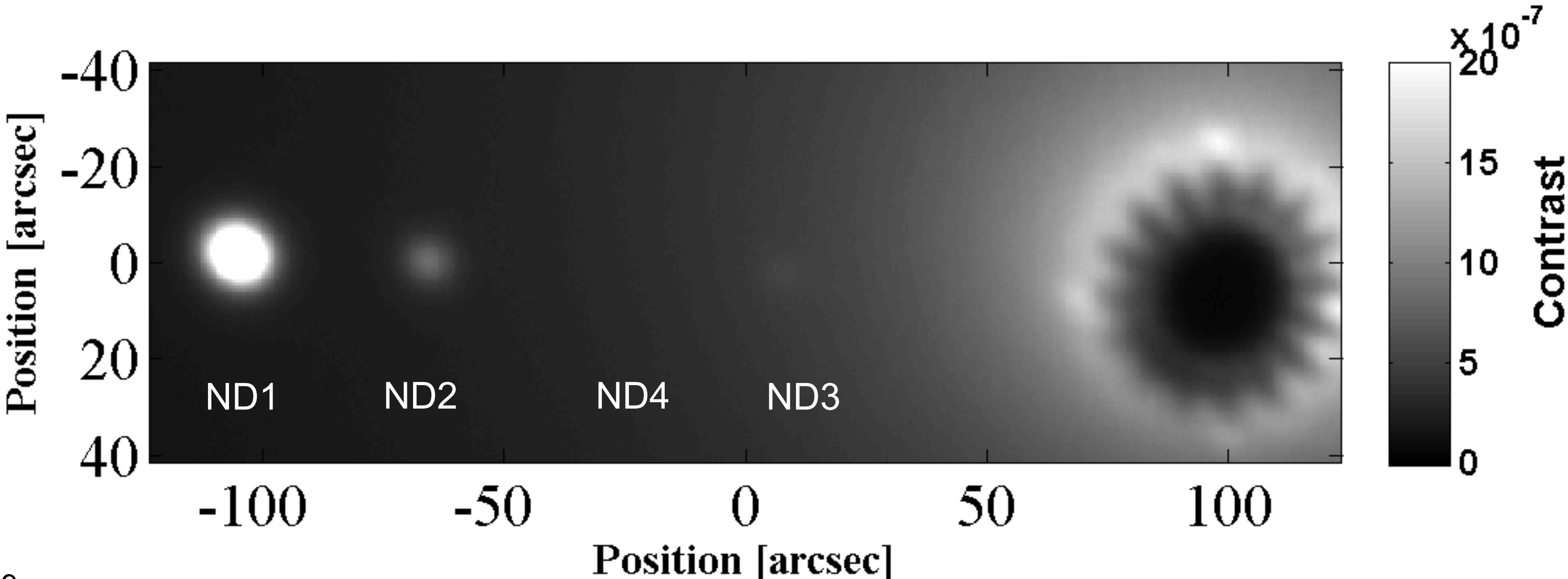
- Image is a combination of 39, 5 sec images
- The curve is cross section through the image, averaging over a 65 pixel wide strip
- ND1 Planet ($7x10^{-6}$), ND2 Planet ($6x10^{-7}$), and ND3 Planet ($4x10^{-8}$) LEDs are indicated, a 4th LED is present ($\leq\sim10^{-8}$)

Distance from center	70"	100"
Mean Background	1.1×10^{-7}	7.8×10^{-8}
3σ Contrast Upper Limit	**4×10^{-8}**	**1.6×10^{-8}**



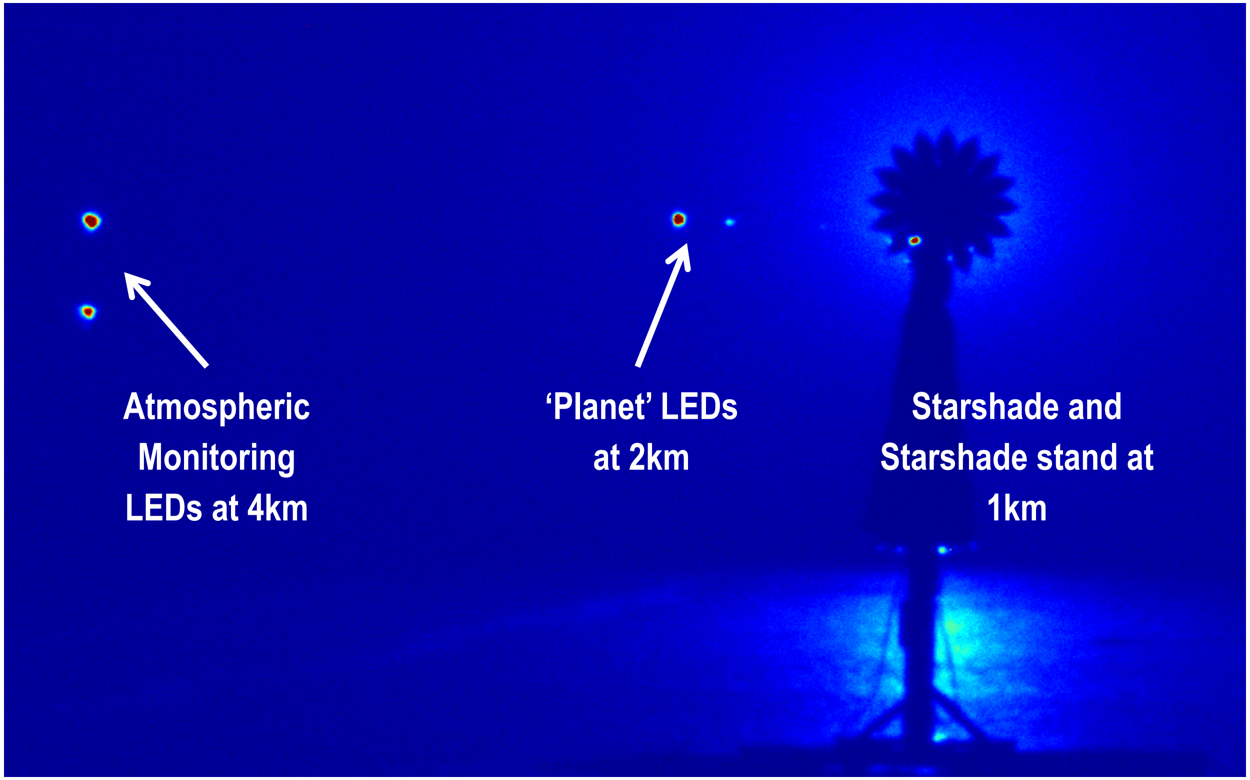
Small Starshade

- The feasibility of small Starshades were tested
  - ~12” diameter compared to the 24” used for most of the testing
  - Tests the Starshade at closer to the space mission optics 4x Fresnel Number compared to 16x Fresnel Number
  - Alignment was possible and good images could be taken
  - ND1 Planet ($7x10^{-6}$), ND2 Planet ($6x10^{-7}$), and ND3 Planet ($4x10^{-8}$) LEDs are indicated, ND4 LED is also present ($\leq \sim 10^{-8}$)



Future Tests

- Results from this test indicate that tests to space-like Fresnel Number are possible
  - 20cm Starshade, star at 4km, Starshade at 2km gives a Fresnel number of 20
  - For most recent test, placed LED station at 4km to measure seeing during the night
  - Alignment stable enough – expect to get enough reliable measurements during an observing run (hours of total integration time)



THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN