# Towards an Iris Device Qualification Test

*Work Supported by the DHS Science and Technology Division*

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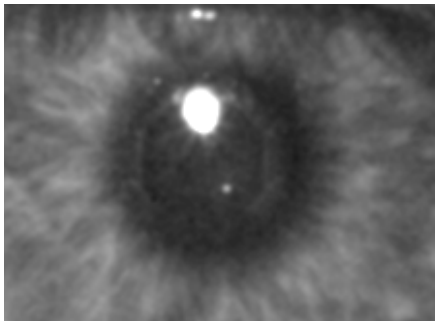
# Why Develop a Qualification Test?

- Due diligence tool for selecting iris image collection devices for consideration in US Government applications
  - Goal: Unbiased Comparative Metrics
    - Inter-device (What is the best device for a given application?)
    - Intra-device versus application (what application is best suited for a given device?)

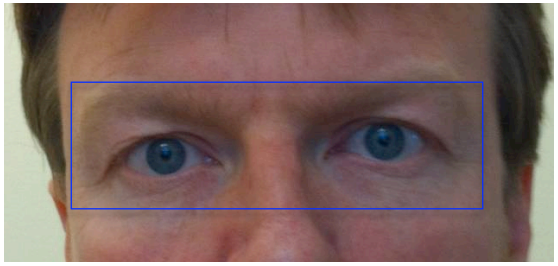
- Farther in the Future: Preliminary step for something to offer to ISO standards body for commercial industry

# Why not use established image quality targets?

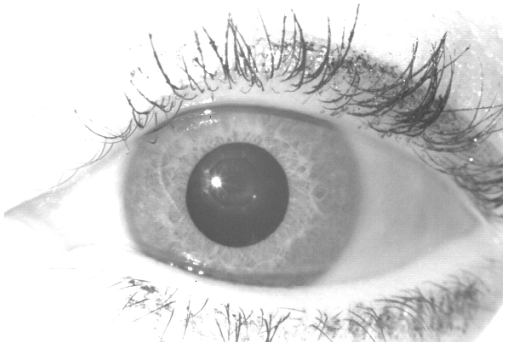
- Standard targets use information not representative of optical properties of eye
- Iris capture devices may require the presentation of face/periocular features, as well as features specific to the eye such as specular reflections from the cornea



Primary Specular Reflection



Face/periocular features



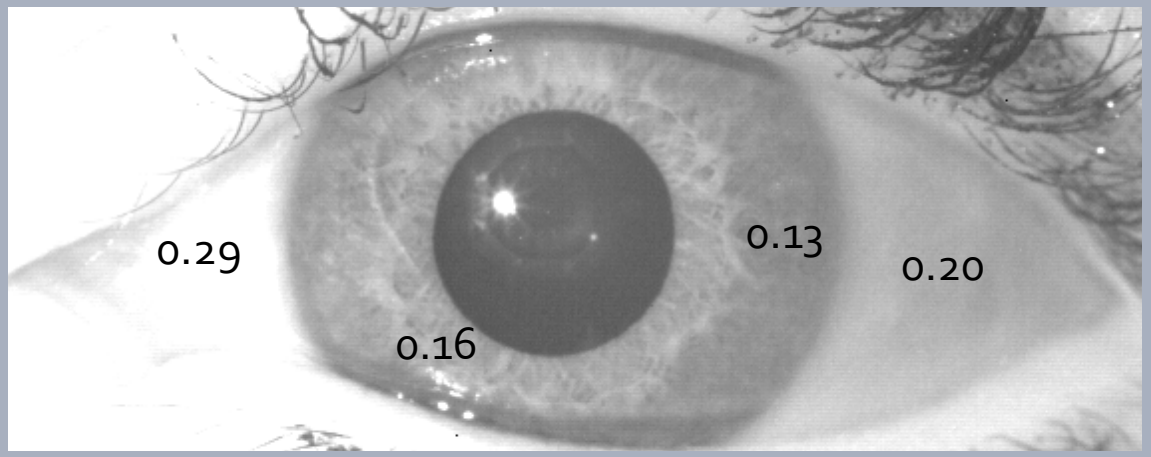
Iris border features and texture

# Target Requirements

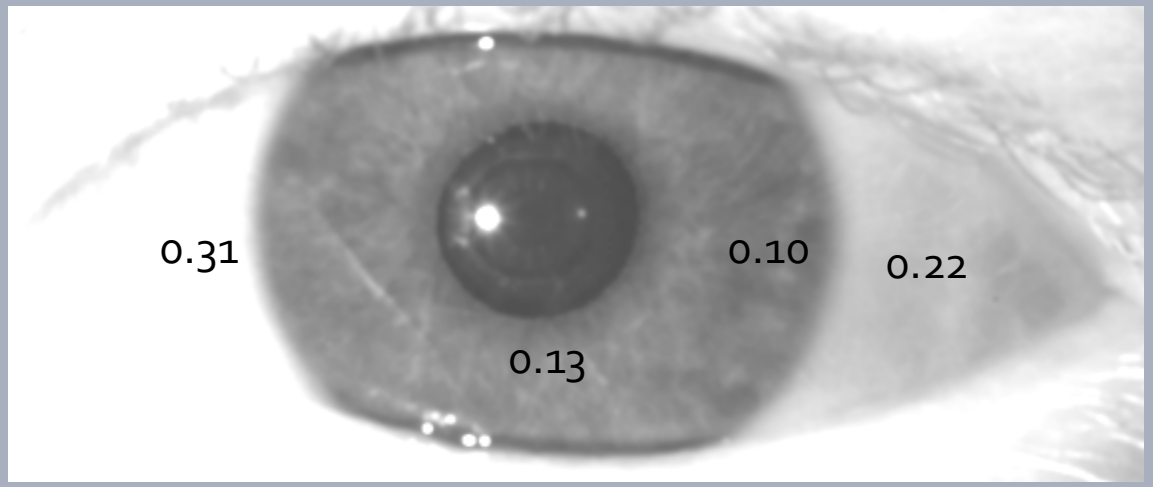
- Be able to capture iris images in the native operational mode of the tested device ("faceness"+"eyeness")
  - Without bias for or against a particular device
- Succinctly measure performance relevant to iris biometrics
  - Challenge lies in controlling and/or adequately sampling the many covariates.

# Optical Properties of Eye/Iris: Albedo

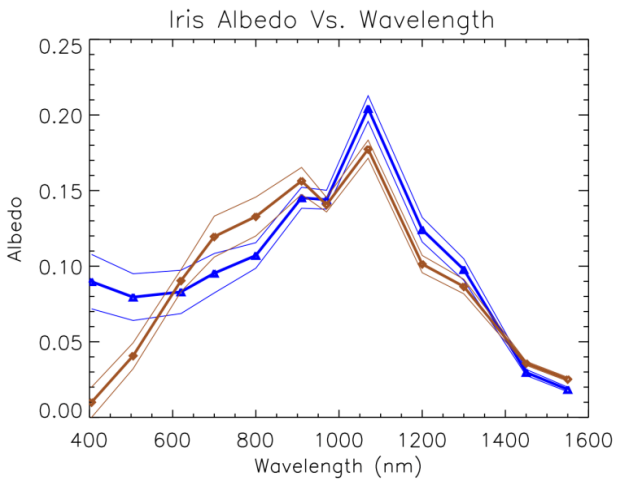
Brown Eye

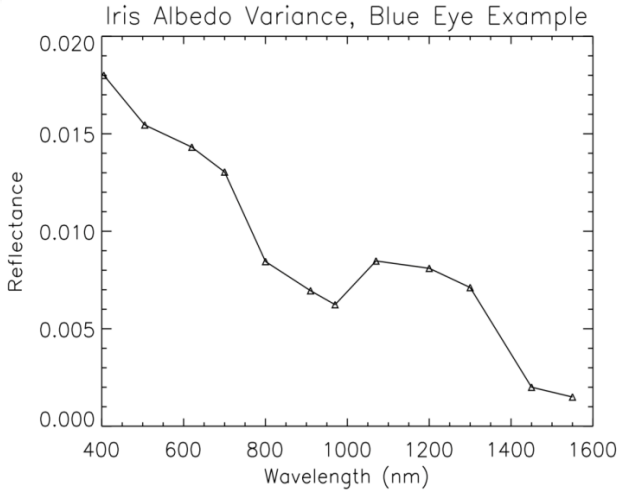


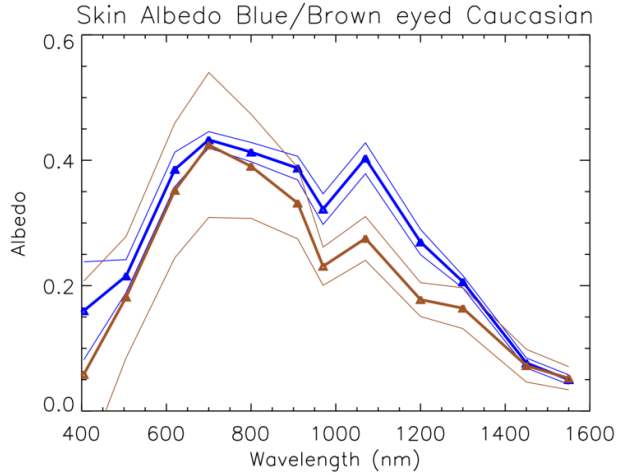

Blue Eye

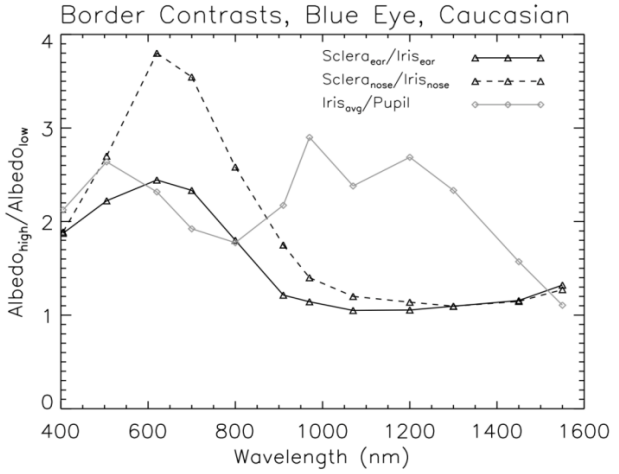


# Observed Optical Properties of the iris



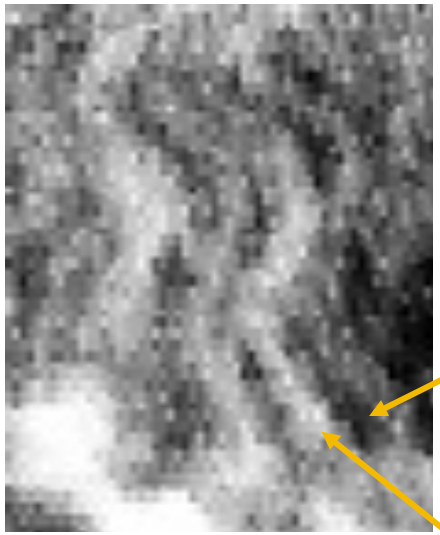



# Observed Optical Properties of the Iris: Spatially Varying Albedo

Signal-to-Noise Ratio can be expressed as a function of device variables (assuming photon noise):

$$SNR_{850nm} \sim 10 \left(\frac{\gamma_a}{0.15}\right)\left(\frac{F_i}{1mW/cm^2}\right)^{1/2}\left(\frac{a}{0.12}\right)^{1/2}\left(\frac{Q}{0.1}\right)^{1/2}\left(\frac{t}{25msec}\right)^{1/2}\left(\frac{\ell}{0.5mm}\right)\left(\frac{d}{5mm}\right)\left(\frac{D}{50cm}\right)^{-1}$$



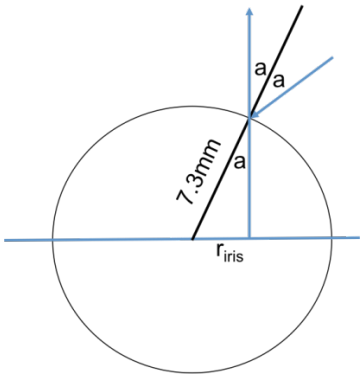
Iris Texture

$$a_{low} = a(1 - \frac{\gamma_a}{2})$$

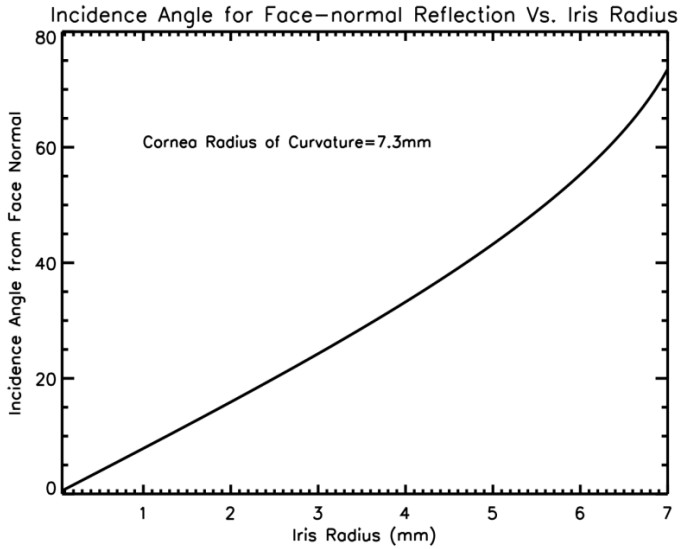
$$\Delta a = a_{high} - a_{low} = \gamma_a a$$

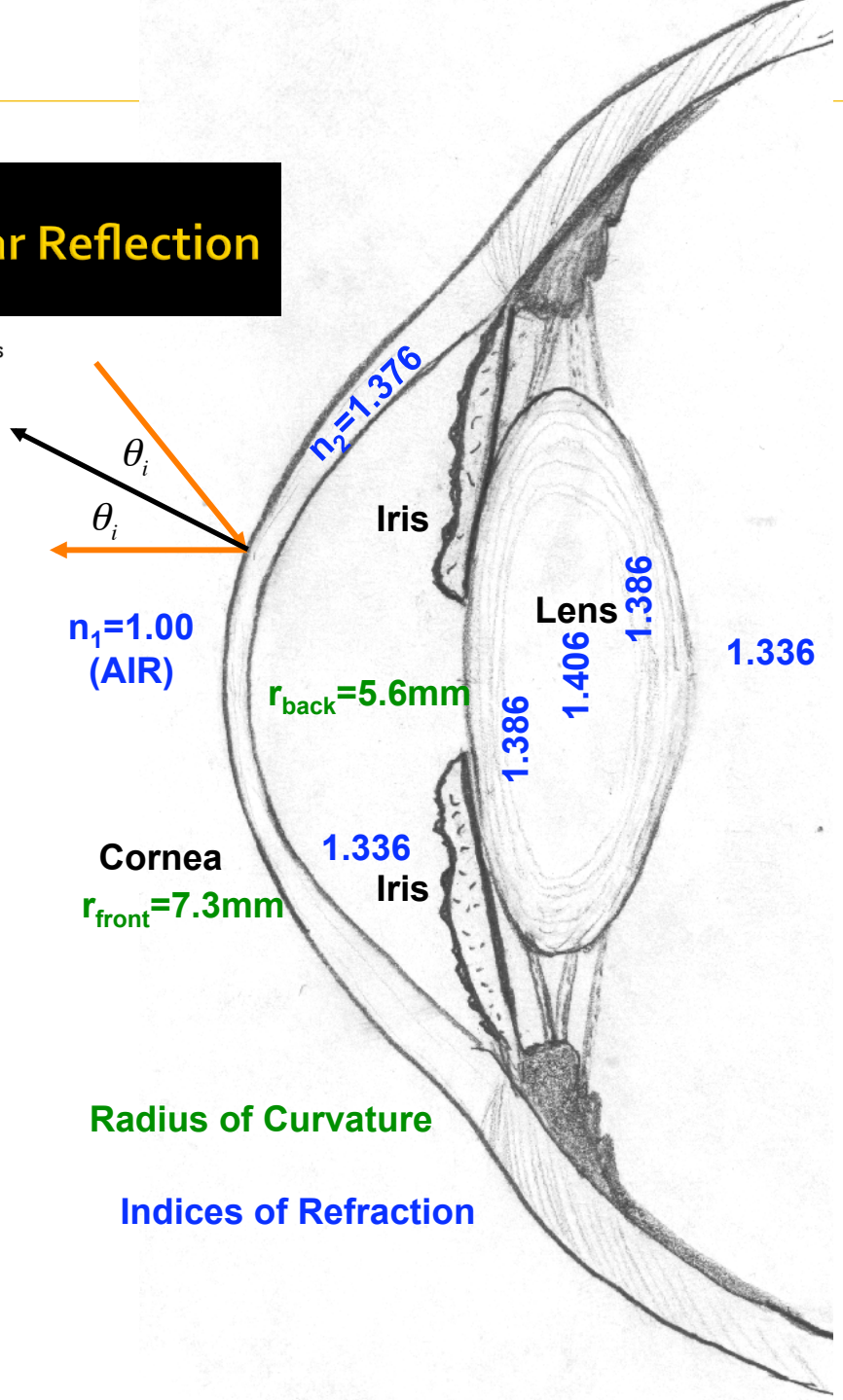
$$a_{high} = a(1 + \frac{\gamma_a}{2})$$

# Optical properties of eye/iris: Specular Reflection




$$\theta_i = \sin^{-1}\left(\frac{r_{iris}}{7.3mm}\right)$$



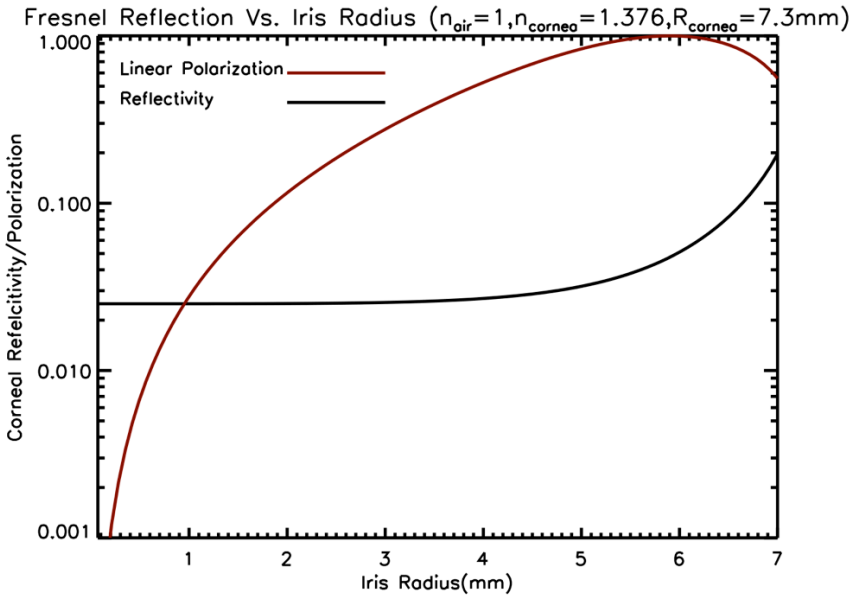




**Fresnel Reflection Coefficients:**
**Estimate for Percent reflected off corneal**

$$R_{\perp} = \left(\frac{n_1 \cos\theta_i - n_2 \cos\theta_t}{n_1 \cos\theta_i + n_2 \cos\theta_t}\right)^2$$

$$R_{\parallel} = \left(\frac{n_1 \cos\theta_t - n_2 \cos\theta_i}{n_1 \cos\theta_t + n_2 \cos\theta_i}\right)^2$$

$$< R >= \left(\frac{R_{\perp} + R_{\parallel}}{2}\right)$$

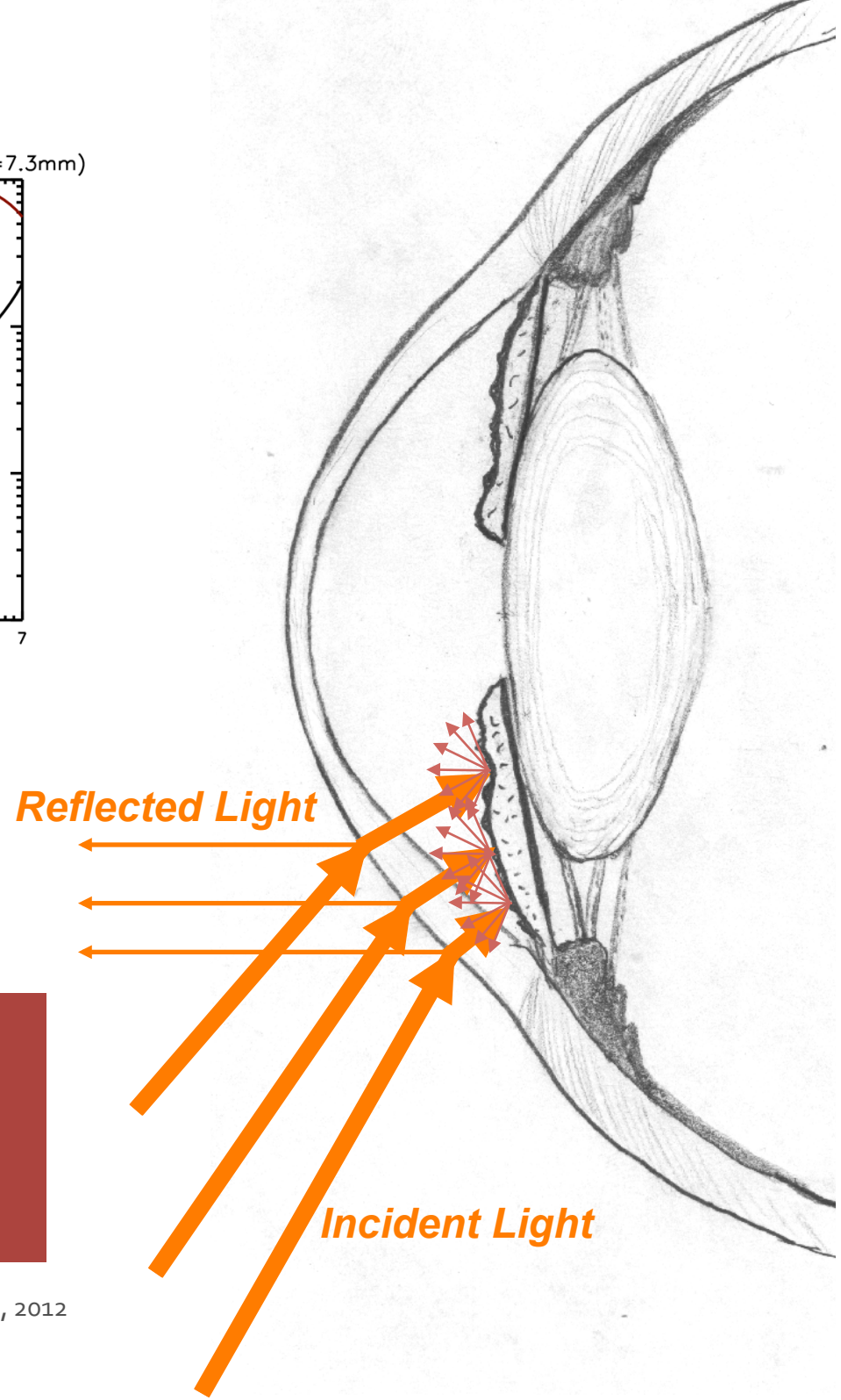



**Cornea surface**

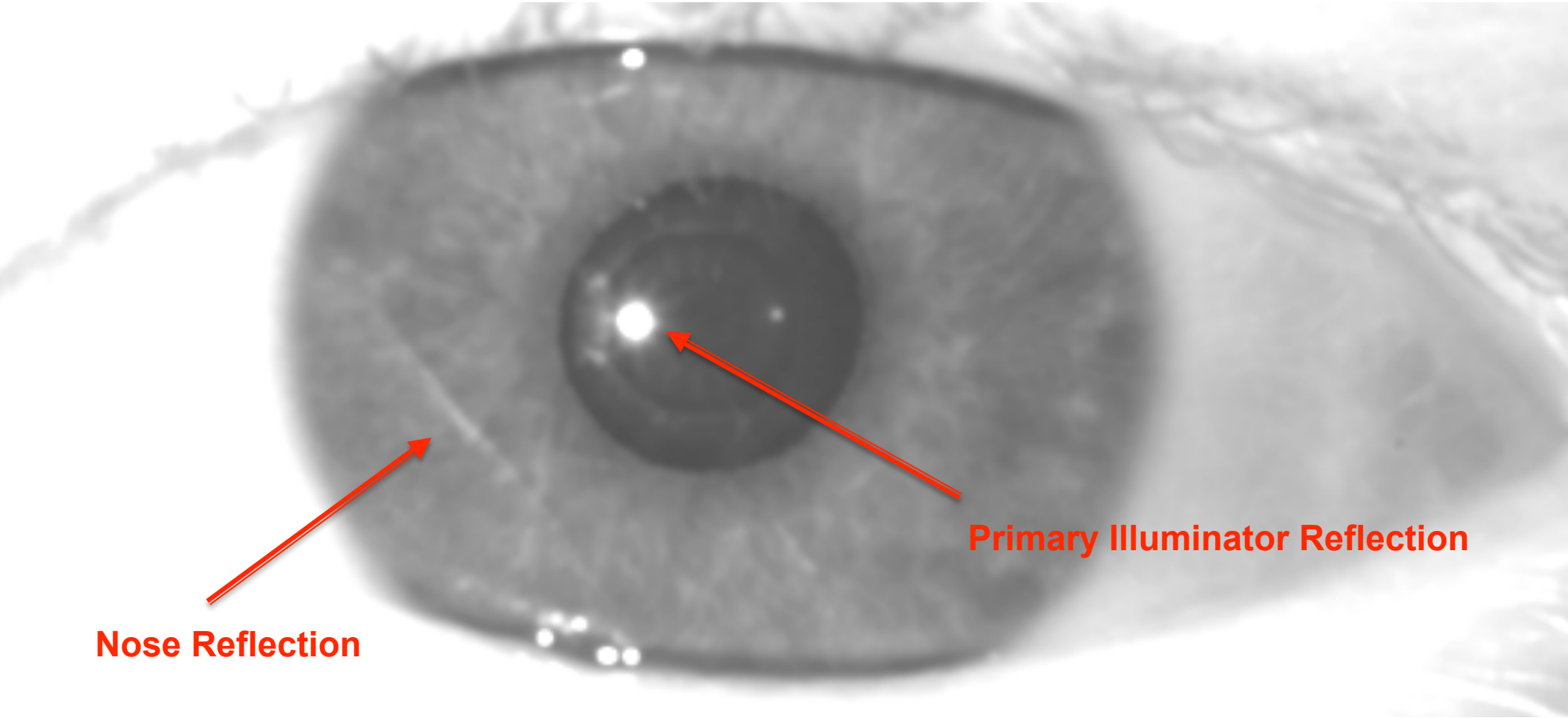
- Reflects ~2-3% of incident NIR light
- Fish-eye de-magnification
- Polarized

**Iris surface**

- Scatters ~10-16% of incident NIR Light
- Lambertian?

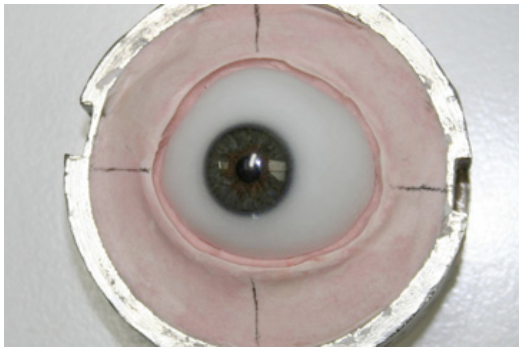


# Specular Reflections



# Target prototypes

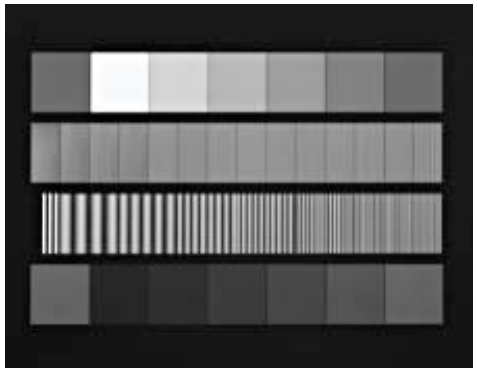
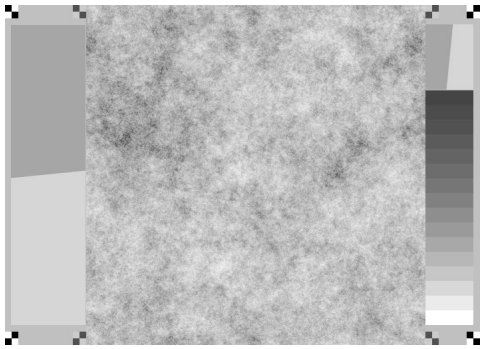
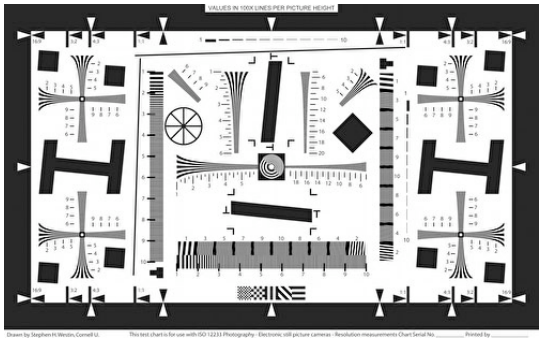
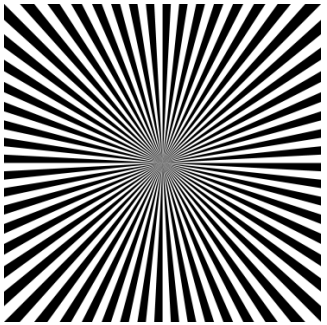
- Leverage methods used in making Prosthetic eyes and Hollywood Special effect
  - use casting process with Polymethyl Methacrylate (PMMA)
- Use high DPI printer to print out any target pattern, embed in 2 part casting mold, and polish…



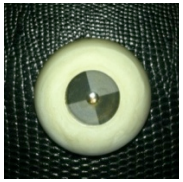
# Candidate Metrics Considered

- Spatial Frequency Response (Modulation Transfer function)
- Linearity of detector response
- Specular Reflection Noise From Corneal Surface
- Contrast SNR Vs. spatial Frequency
  - Border Contrast
  - Iris texture
- Matching Algorithm-Based Intercomparison
  - Degradations specific to a matching algorithm

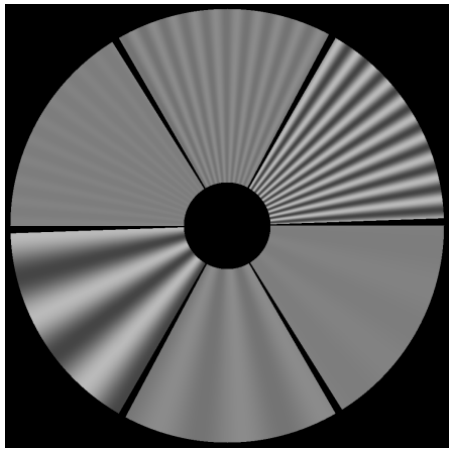
# Target Pattern Selection

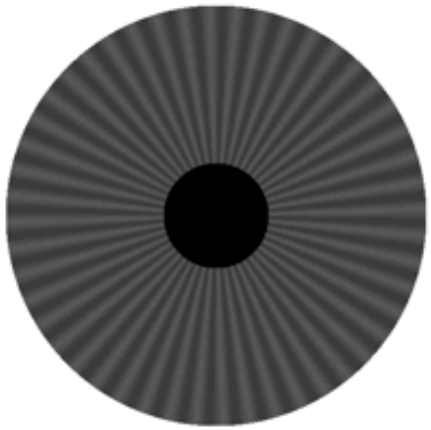





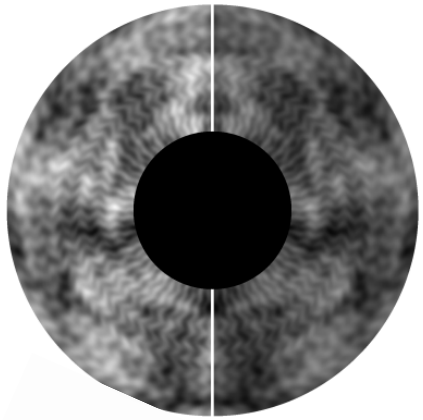
Goal to consolidate purposes into package which can pass device collection criteria

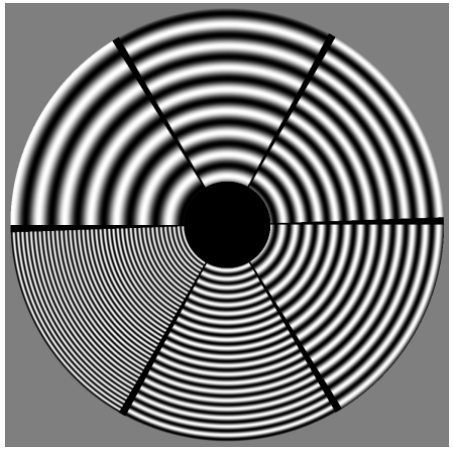



# Target Patterns Considered

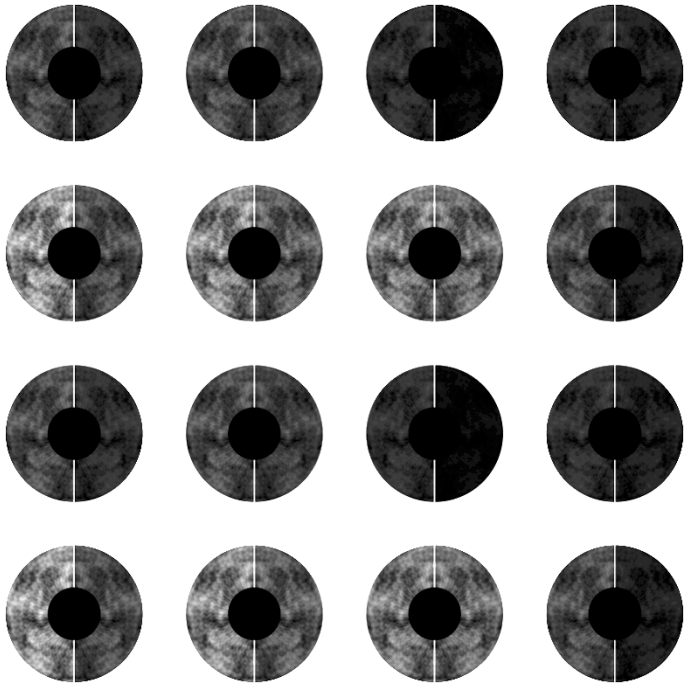




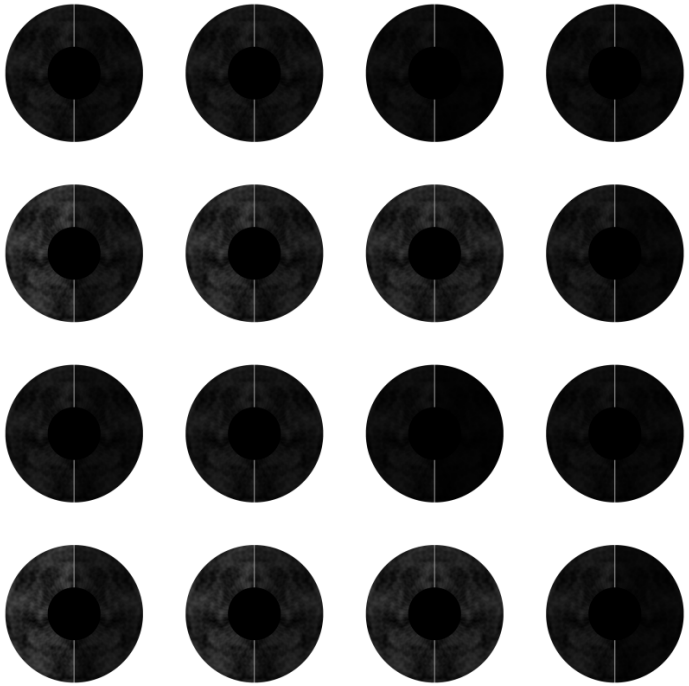




# Albedo Calibration of Printer



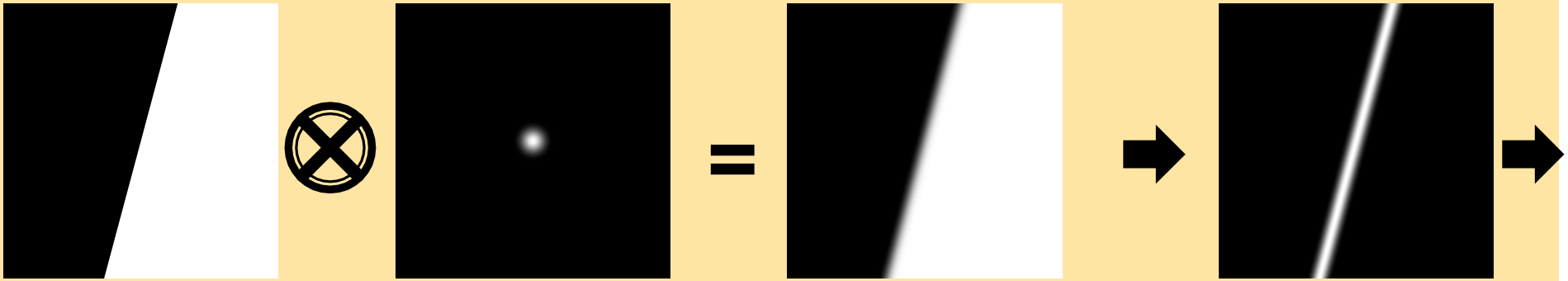
**Creation Greyscale**



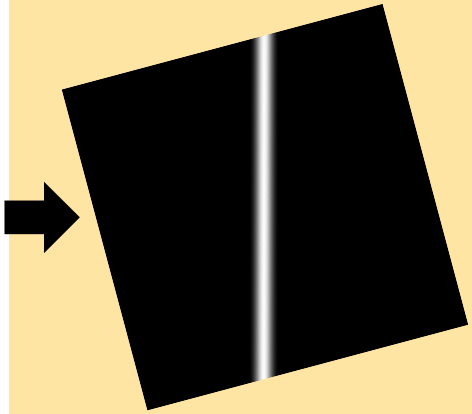
**Printer Ink Albedo Calibrated Greyscale (low dynamic range!)**

# Method for MTF extraction

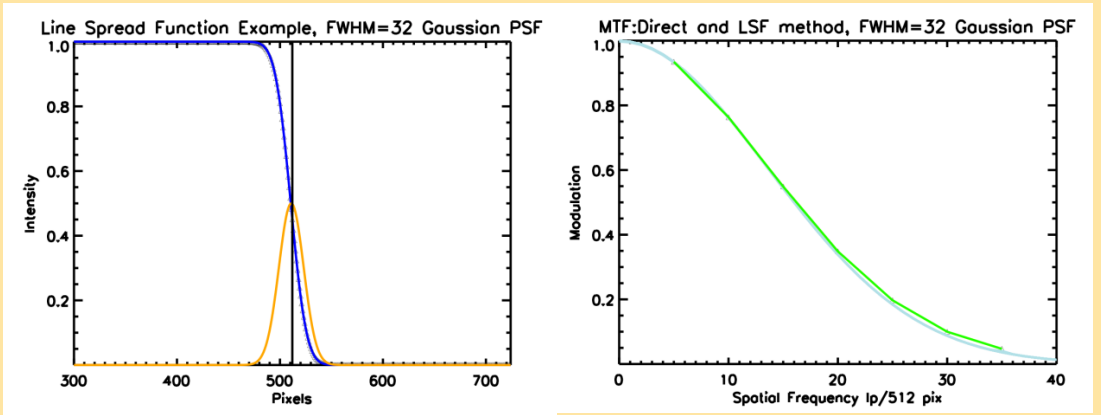
ISO 12233 slanted edge test



df/dx

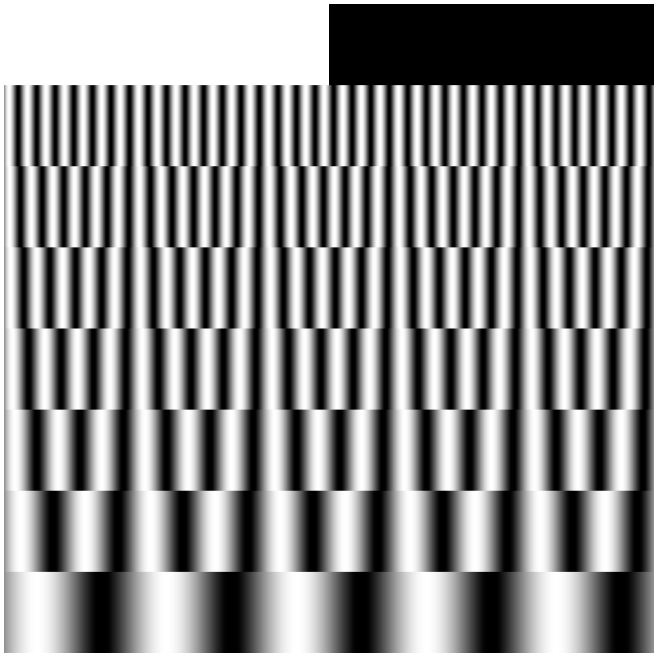


Rotate



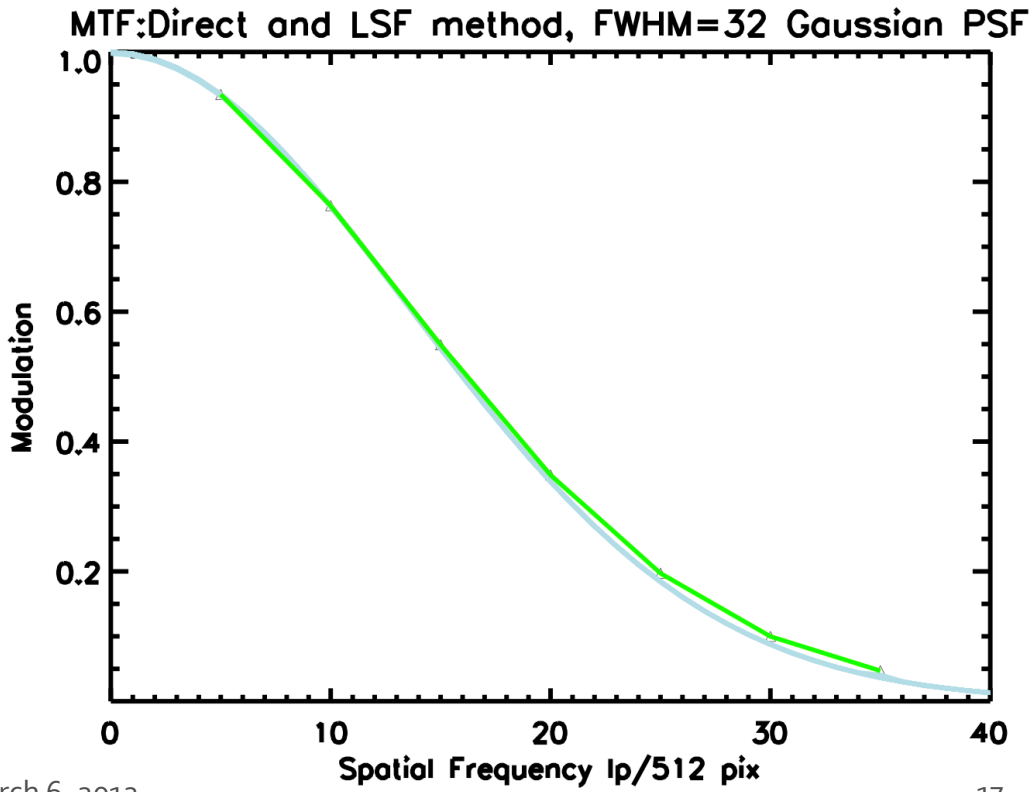

1d fft

# Analysis Method: MTF

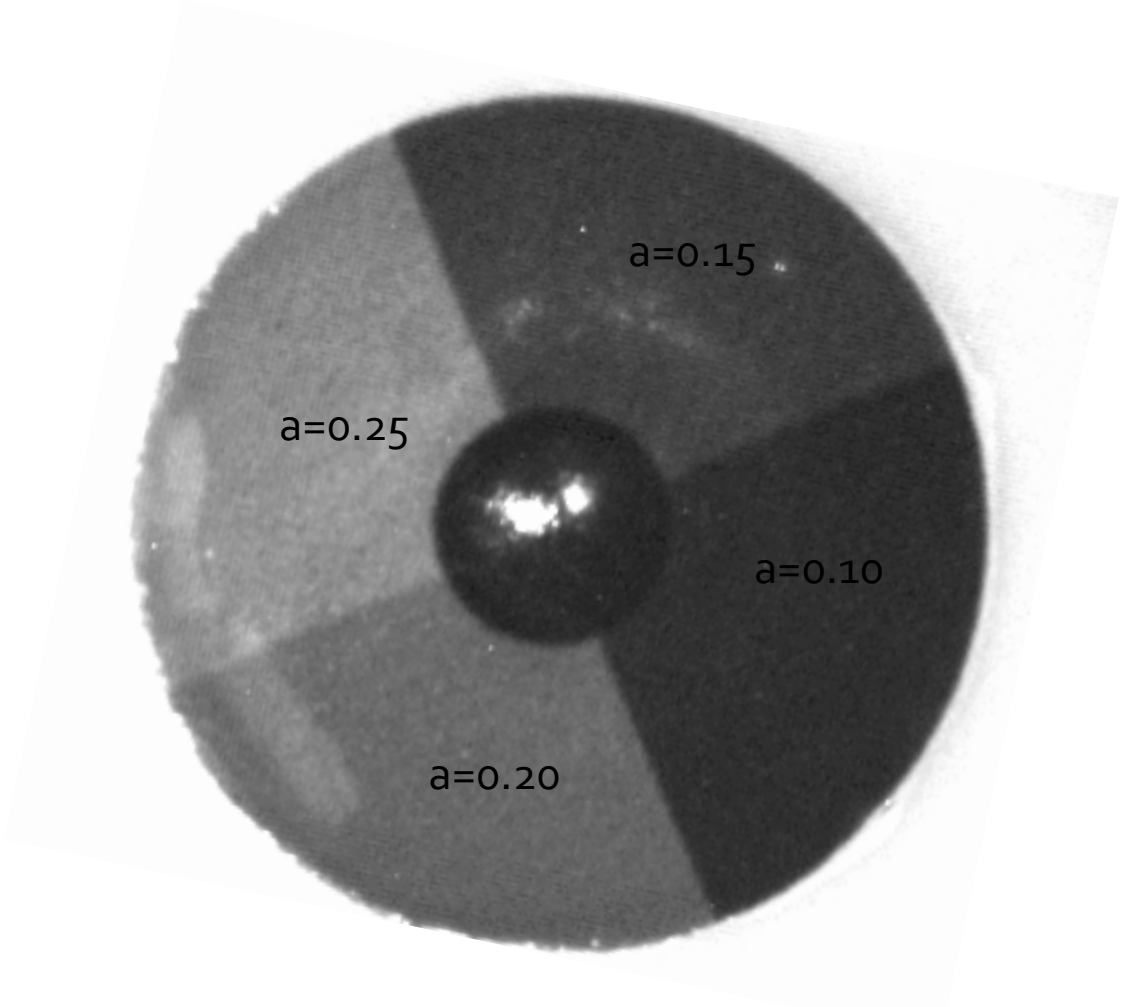


Both Edge and
Sin Modulation Information
Convolved with same PSF

ISO 12233 Edge method = **Blue**
Direct Modulation method = **Green**

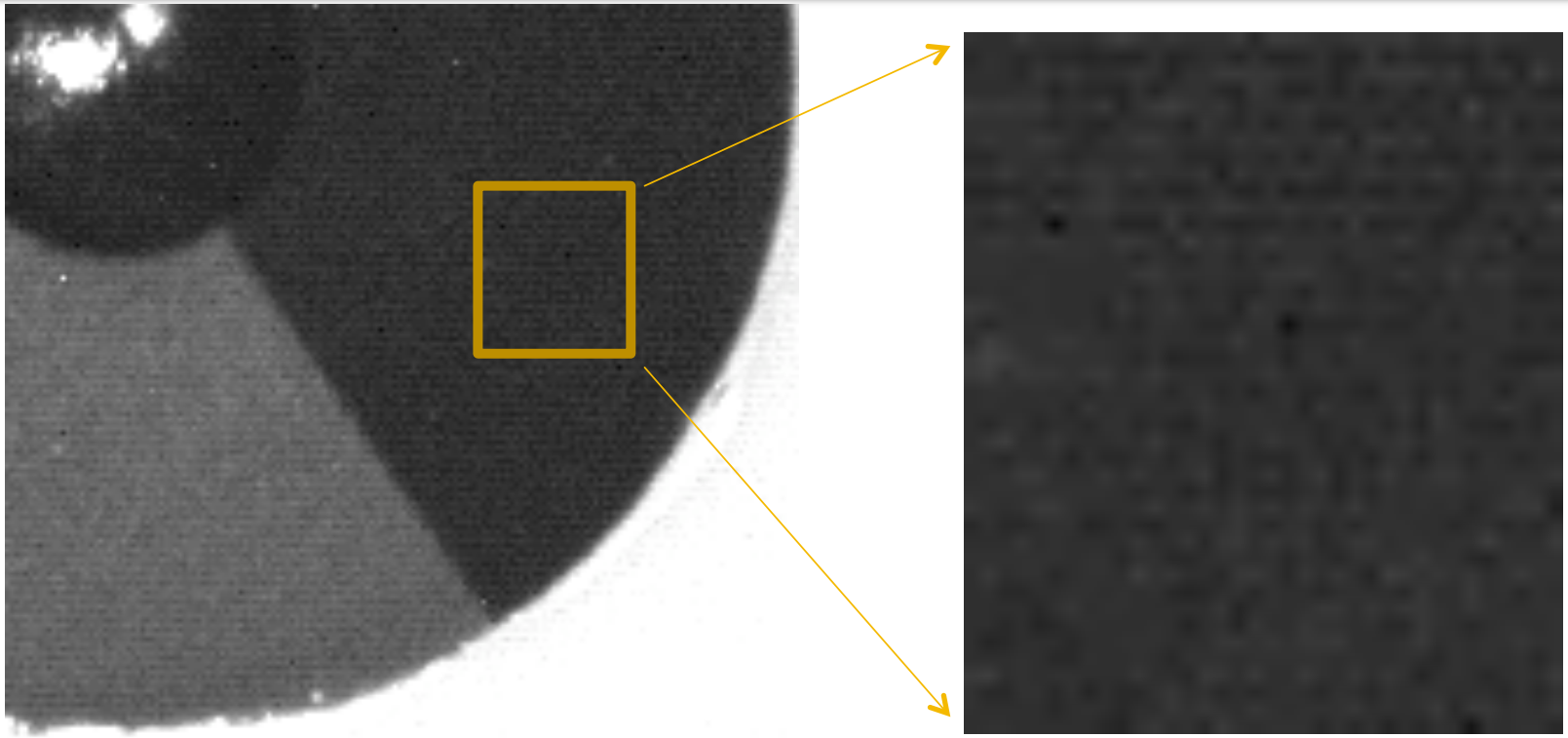


# Analysis Method: Detector Linearity



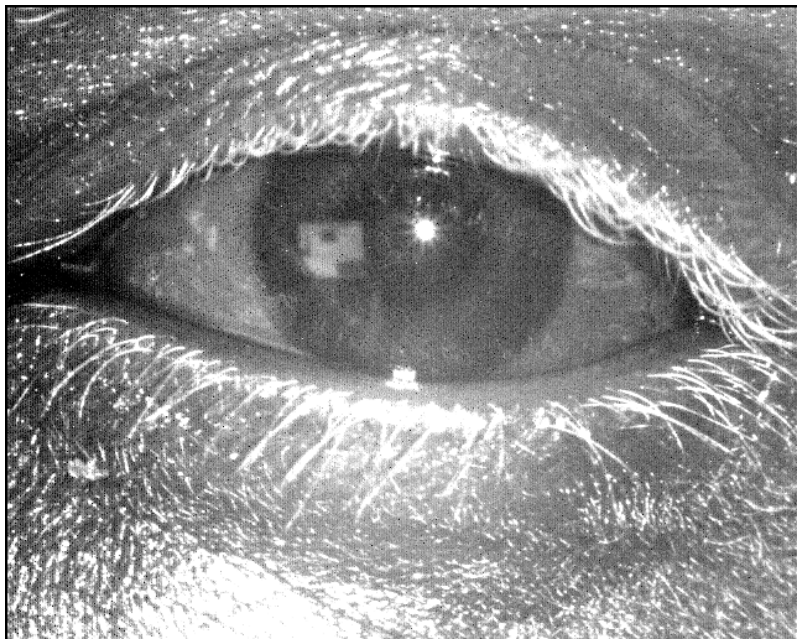

- Target has albedo calibrated graded steps
- Fit line to model, statistical analysis on errors
- Check systematics (specular reflections) by rotating target via test protocol

# Analysis Method: Contrast SNR



- Establish Distribution Type (Gaussian)
- Calculate Standard Deviation versus cell size and albedo
- Propagate through definition of feature function (ridge, slope, spatial freq.)
- Use (hopefully) Gaussian Statistics for simplicity (i.e. 1,2,3.. Sigma Vs. feature type)

# Analysis Method: Specular Reflection Noise



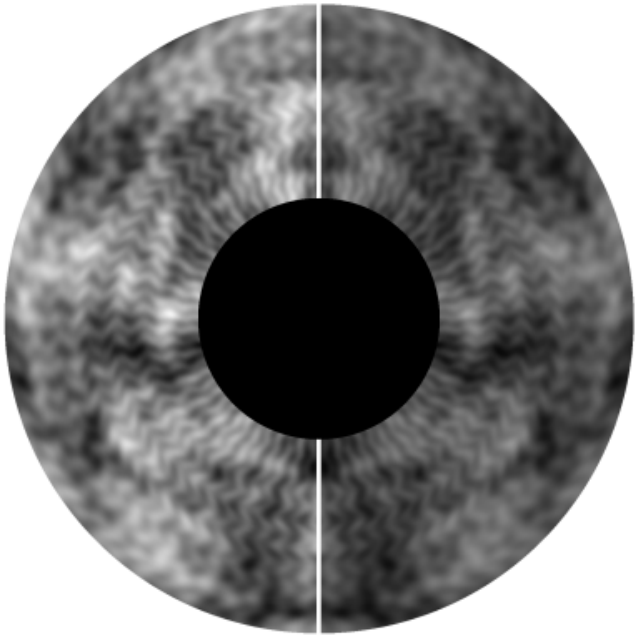
1550nm multispectral image
(Albedo of iris~2%)

- Use a dark, homogeneous low albedo
- Calibrate reflectivity of surface
  - -Need to do this still for corneal reflection, and target
- Control periocular Scene
  - -3-D scattering parameters!
  - - (could get complicated)

# Analysis Method (Algo explicit Feedback)

- If the image can pass the algorithm segmenter, one can use encoding/matching as a metric with a ***controlled pattern.***

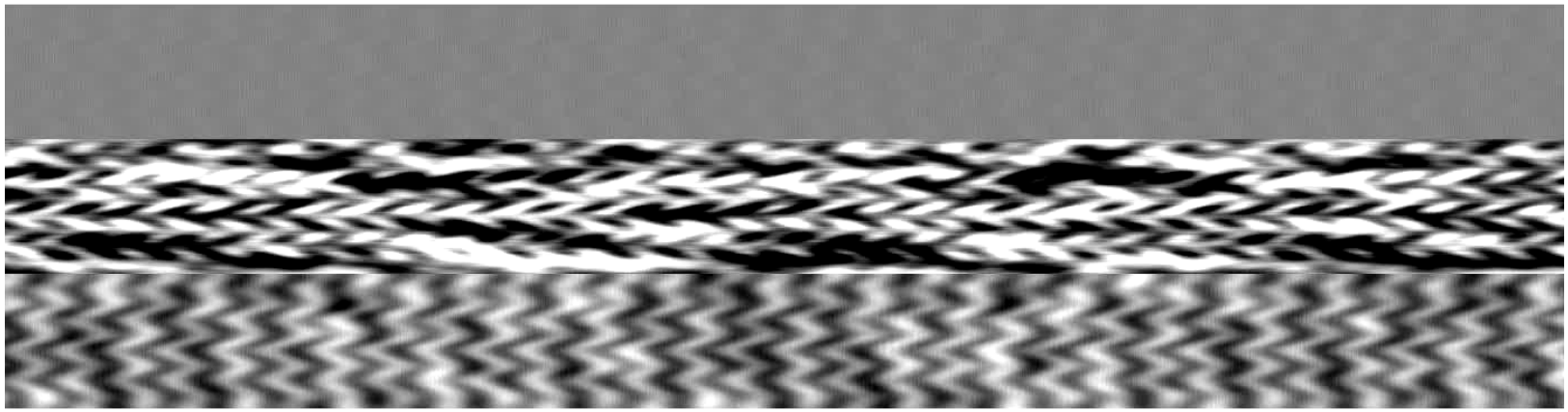
- Broadband Encoder Response



# Illustrative example: Broadband Encoder Response

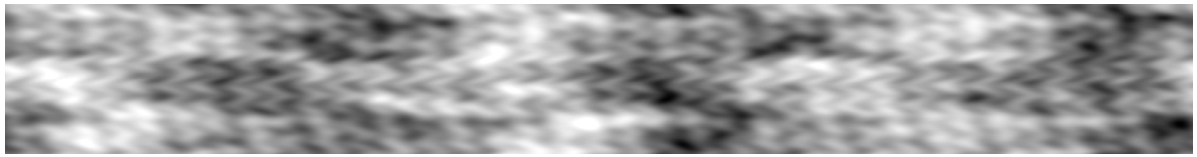
Psuedo-Polar Normaized

Encoded signal (3 Haar filters varying Spatial Freq. to make cube)

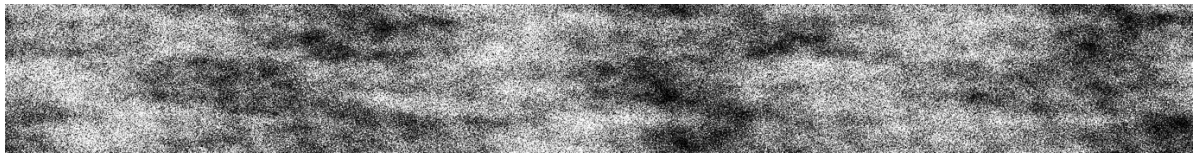


# Illustrated Example: Broadband Encoder Response

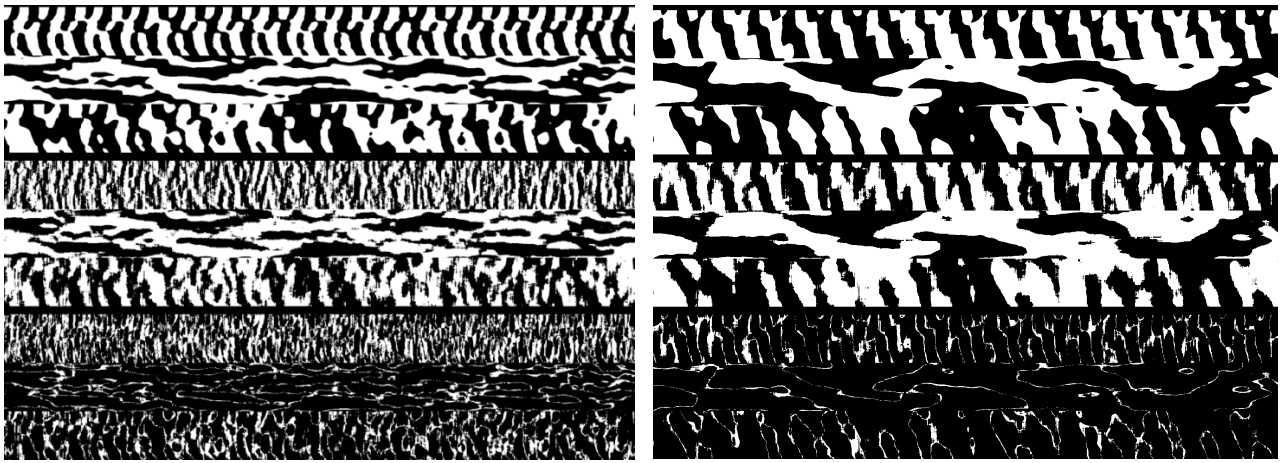
Normalized Image (PRISTINE)



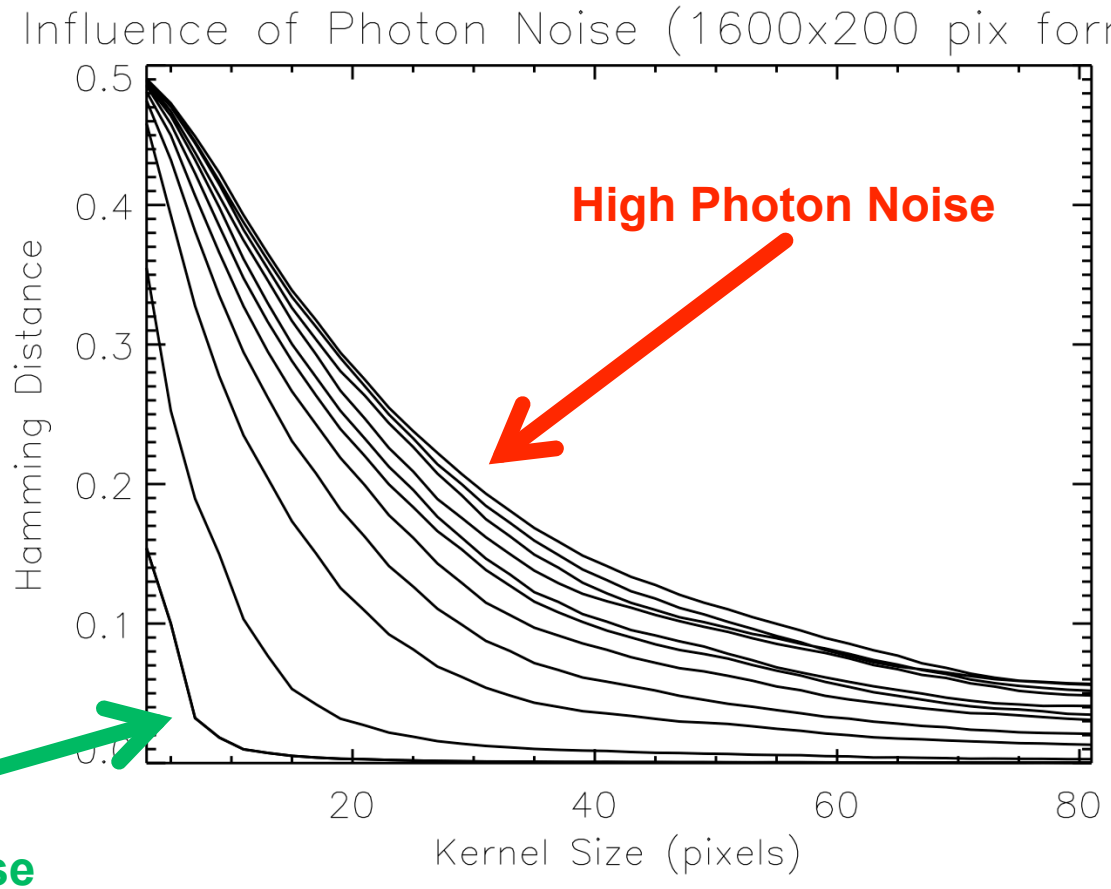
Normalized Image (Noisy)



| | High Frequency | Middle Frequency |
|---|---|---|
| Template (PRISTINE) | | |
| Template (Noisy) | | |
| XOR RESULT | | |



# Influence of photon Noise (con't)

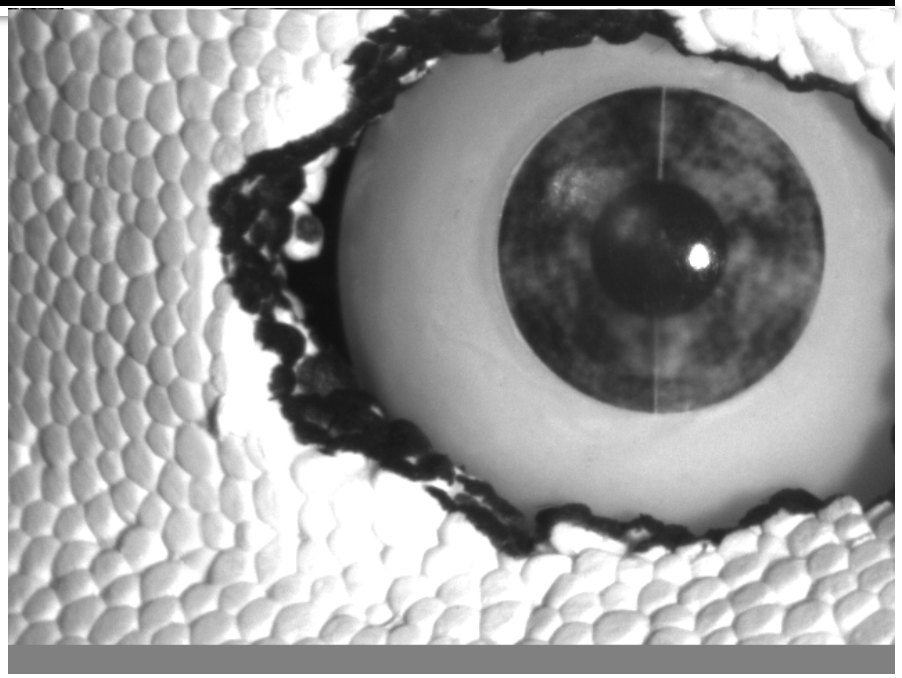


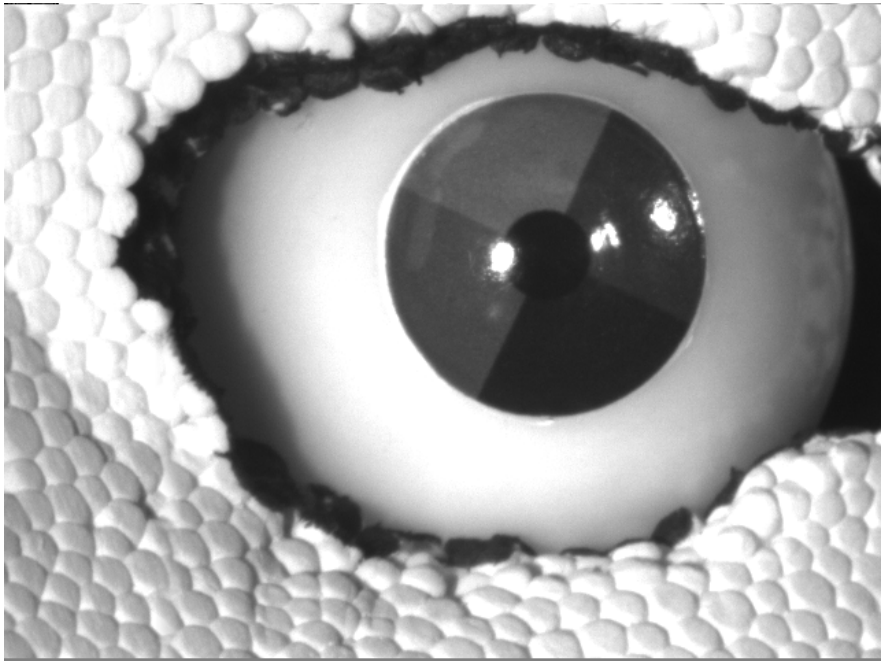

**High Frequency** **Low Frequency**

# Current Status

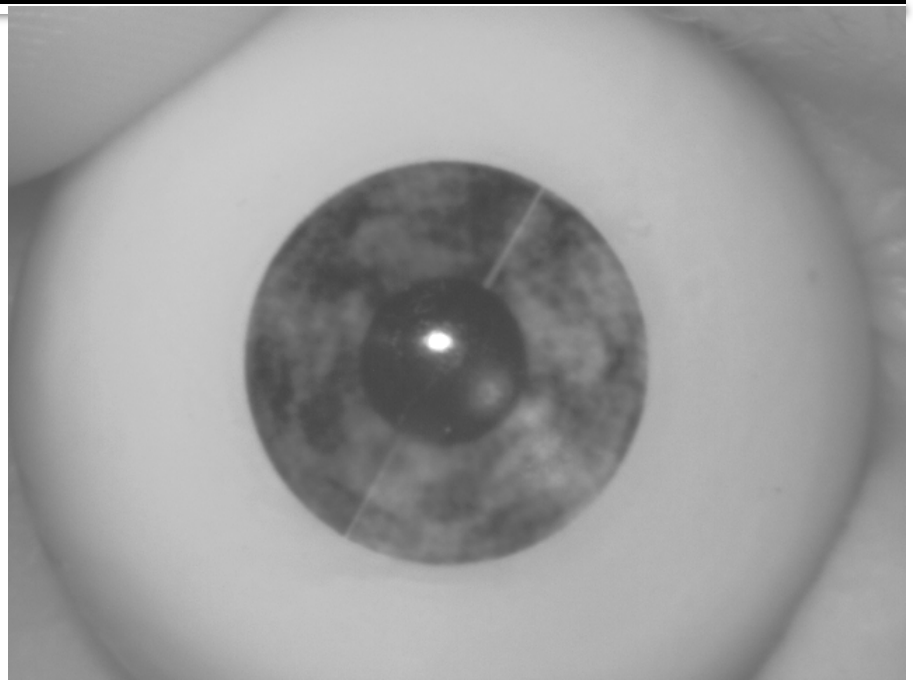
- Have calibrated multiple targets in albedo, and spatial frequency response (losses from printer)
- Have working "High Level" algorithms to process data to and produce output metrics mentioned in this presentation
- Have collected using 3 devices

# Captures with Real Devices – D1

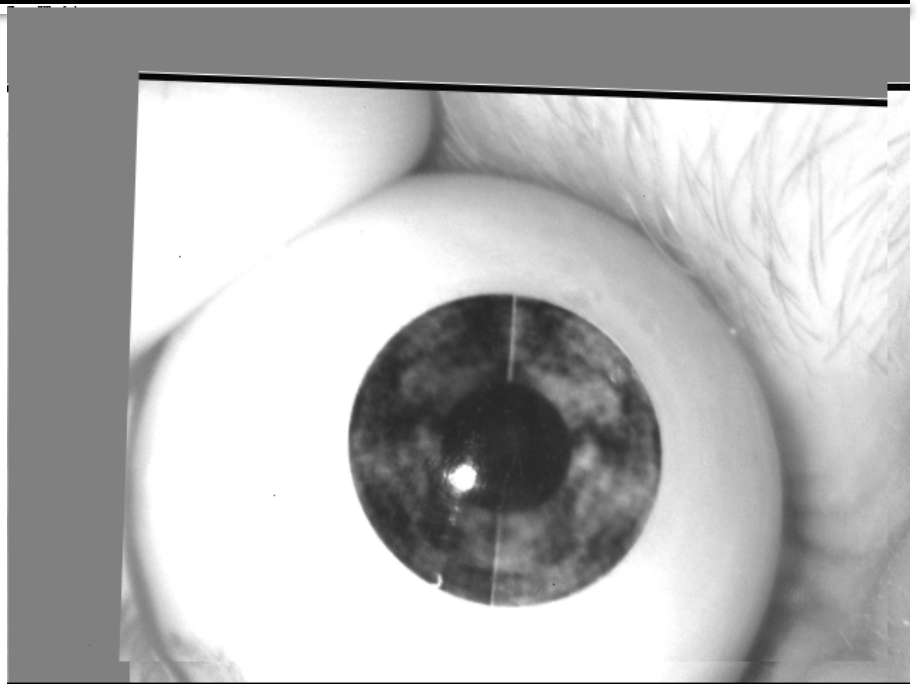


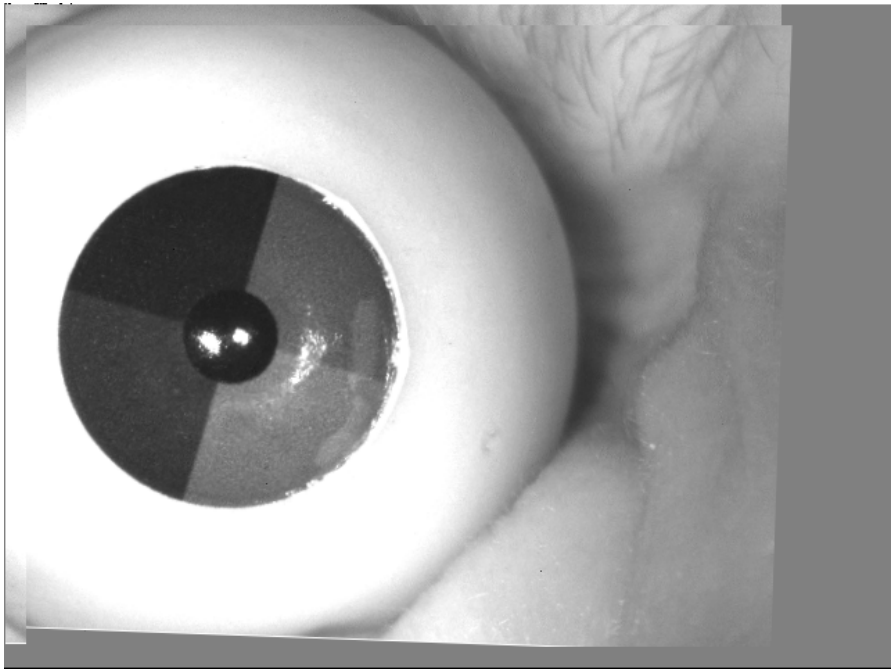


# Captures with Real Devices – D2



# Captures with Real Devices – D3





# Where do we draw the line?

- Needs to be tied to matching accuracy
- Application Dependent?
- Guidance from ISO standards and NIST studies?

# work ahead immediate future

- Identifying target manufacturers
- Calibration of specular reflection –Realistic 3-D Face Scene
- Iterative improvements on metrics

# Acknowledgements

Work Supported by ***DHS S&T…***

# IDQT Development roadmap