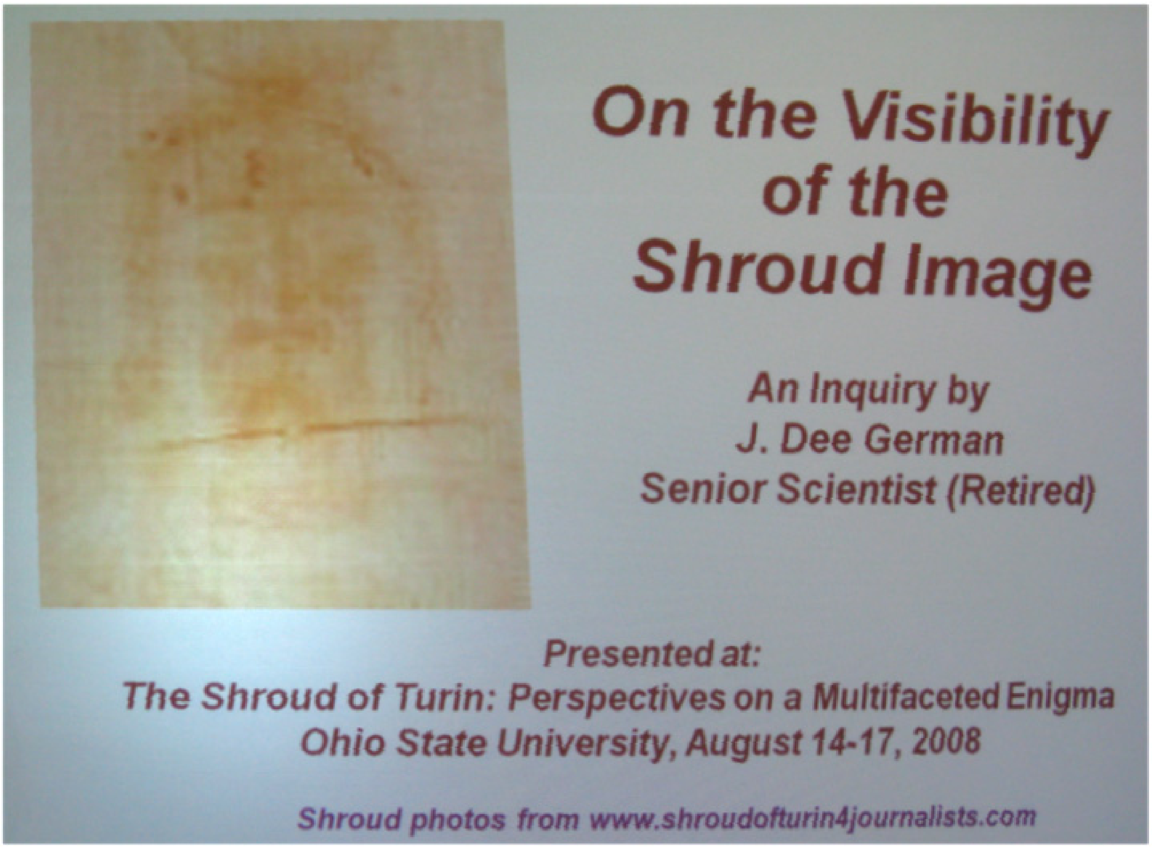
Visibility of the Shroud Image: An Optical Physicist's Perspective

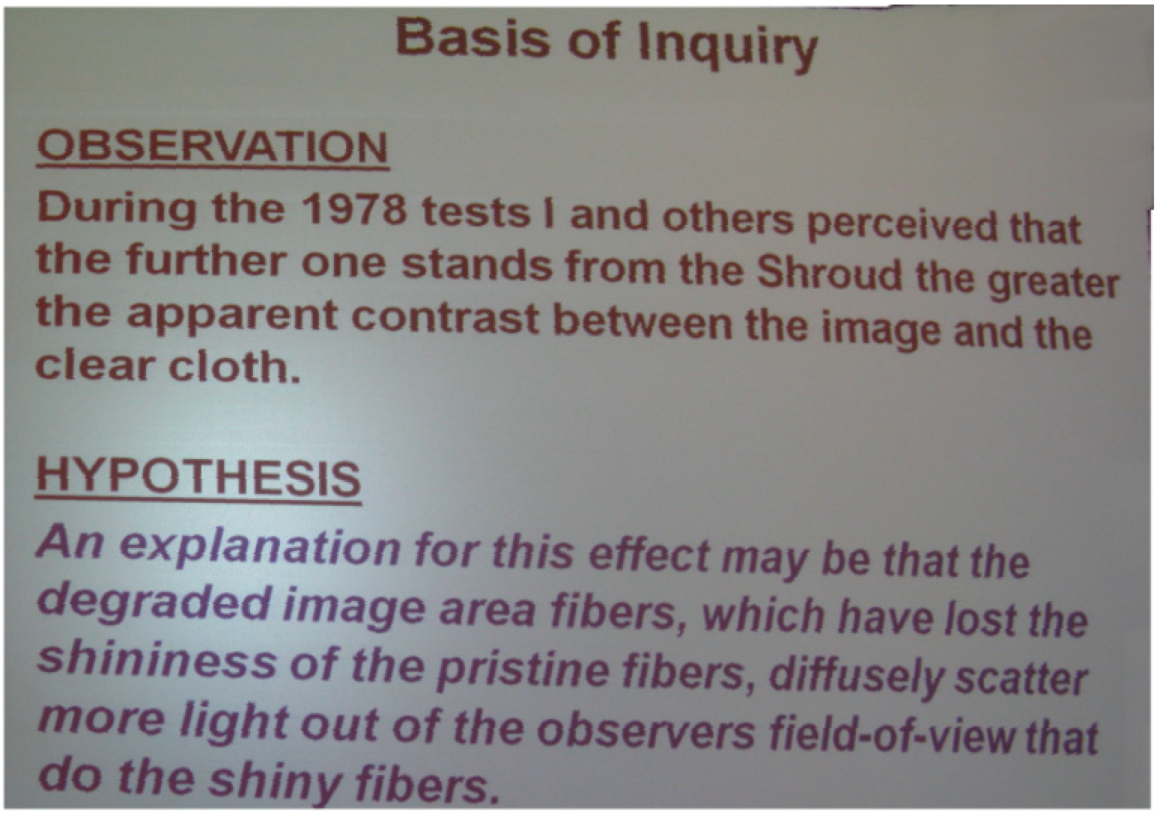
by John Dee German
deegerman@comcast.net

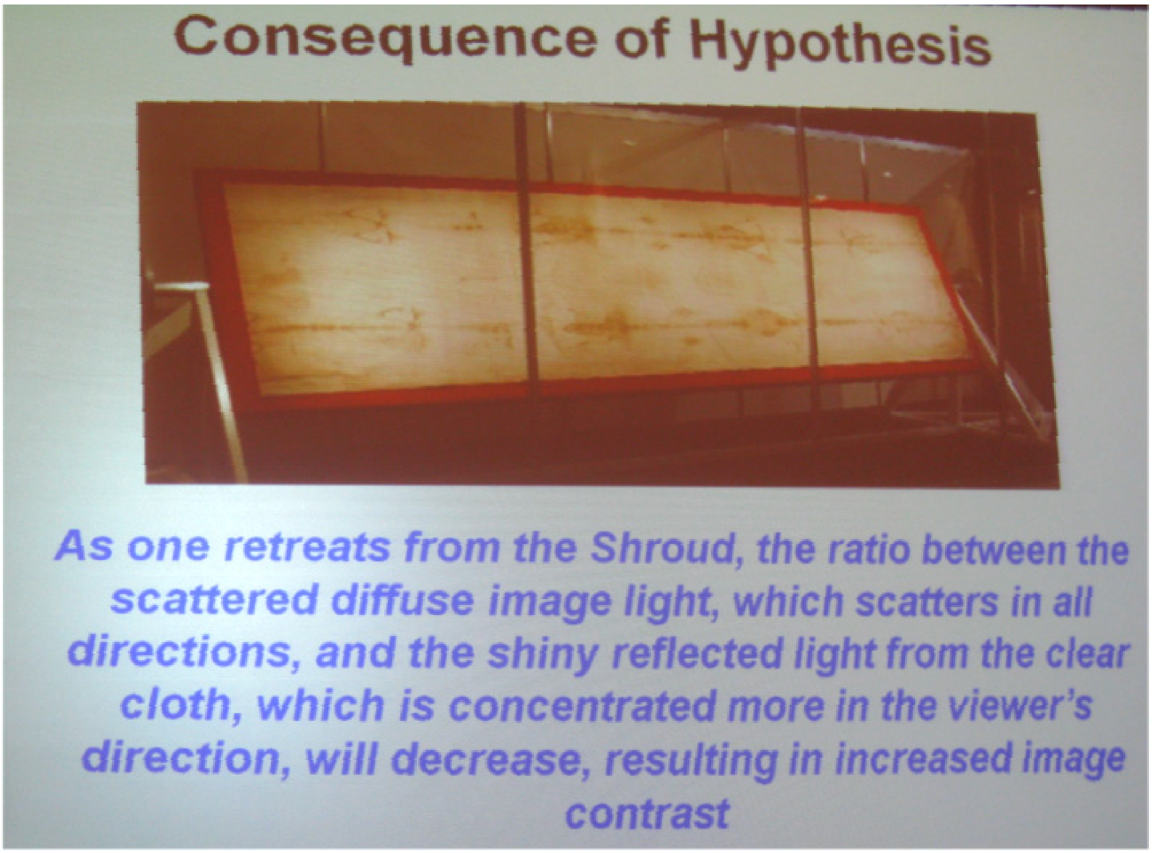
ABSTRACT

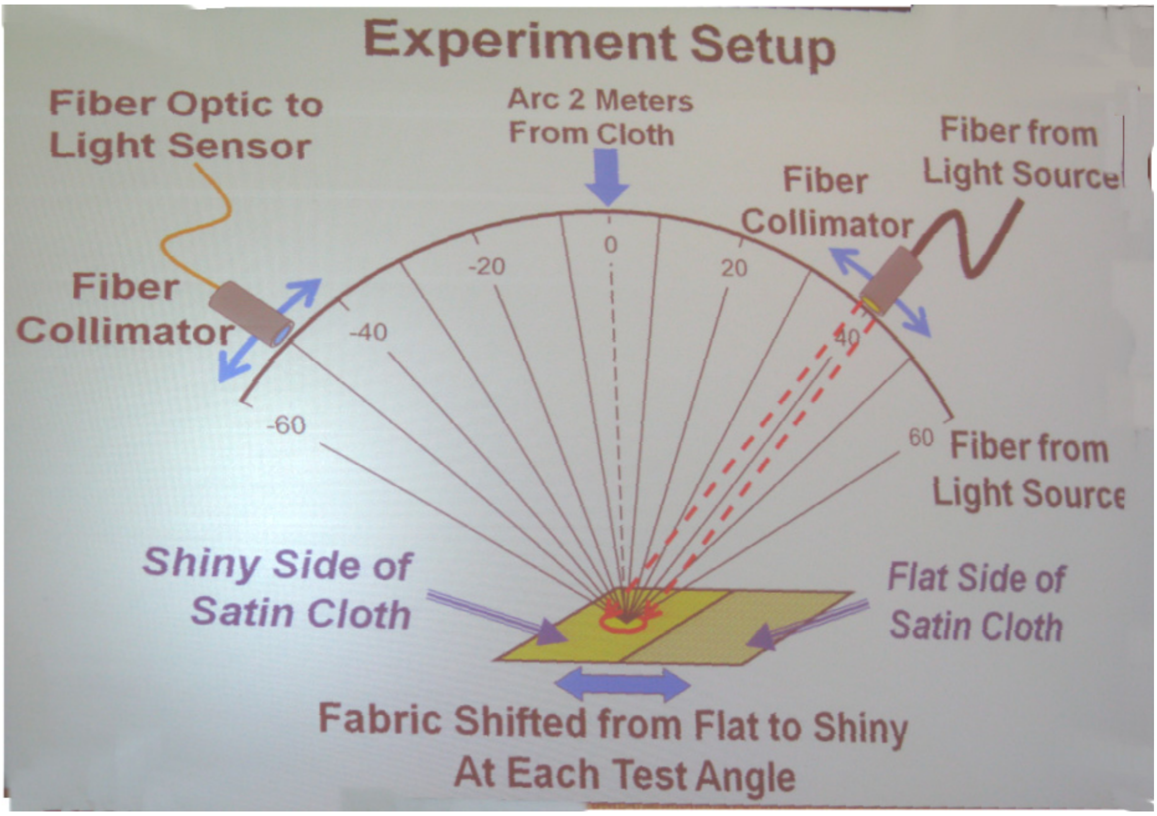
During the 1978 STURP tests on the Shroud of Turin, the author observed an interesting phenomenon: the contrast between the image and the non-image areas of the cloth appears to increase as the distance between the Shroud and the observer (or camera) increases. At very close distances, much of the image is barely perceptible. However, at longer distances, the image becomes more perceptible and the level of discernible detail increases. At close distances, much of the image is barely perceptible. However, at longer distances, the image in general appears darker than the surrounding native cloth and the relative shade difference between the more intense image areas; such as the nose, cheeks, pectorals and knees; and the lighter portions of the image increases. The author, being an optical physicist, formed a hypothesis for the cause of this counter-intuitive phenomenon (longer distance produces increasing perception of detail) based on varying diffusivity of light reflections from the cloth. In this paper, support for the hypothesis is developed analytically
and demonstrated with experimental results. Conclusions include a discussion of the implications of these results to other areas of Shroud research.

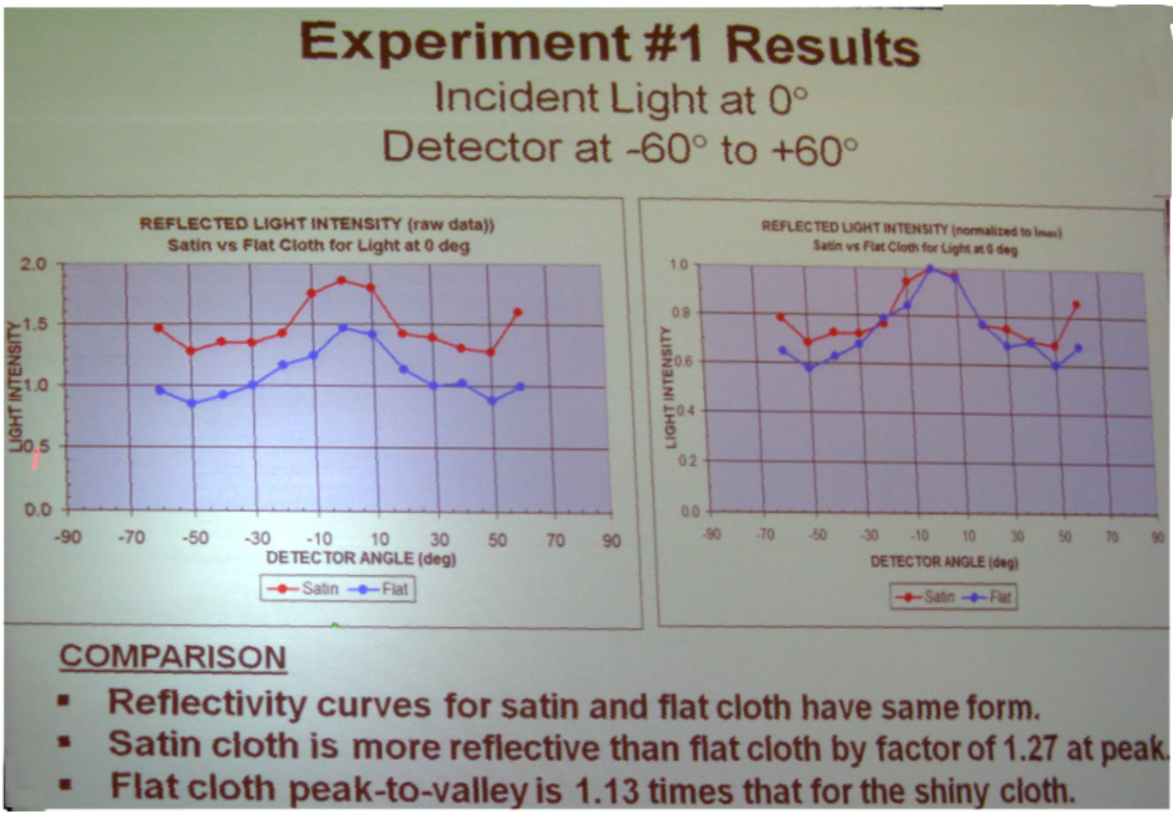
PRESENTATION

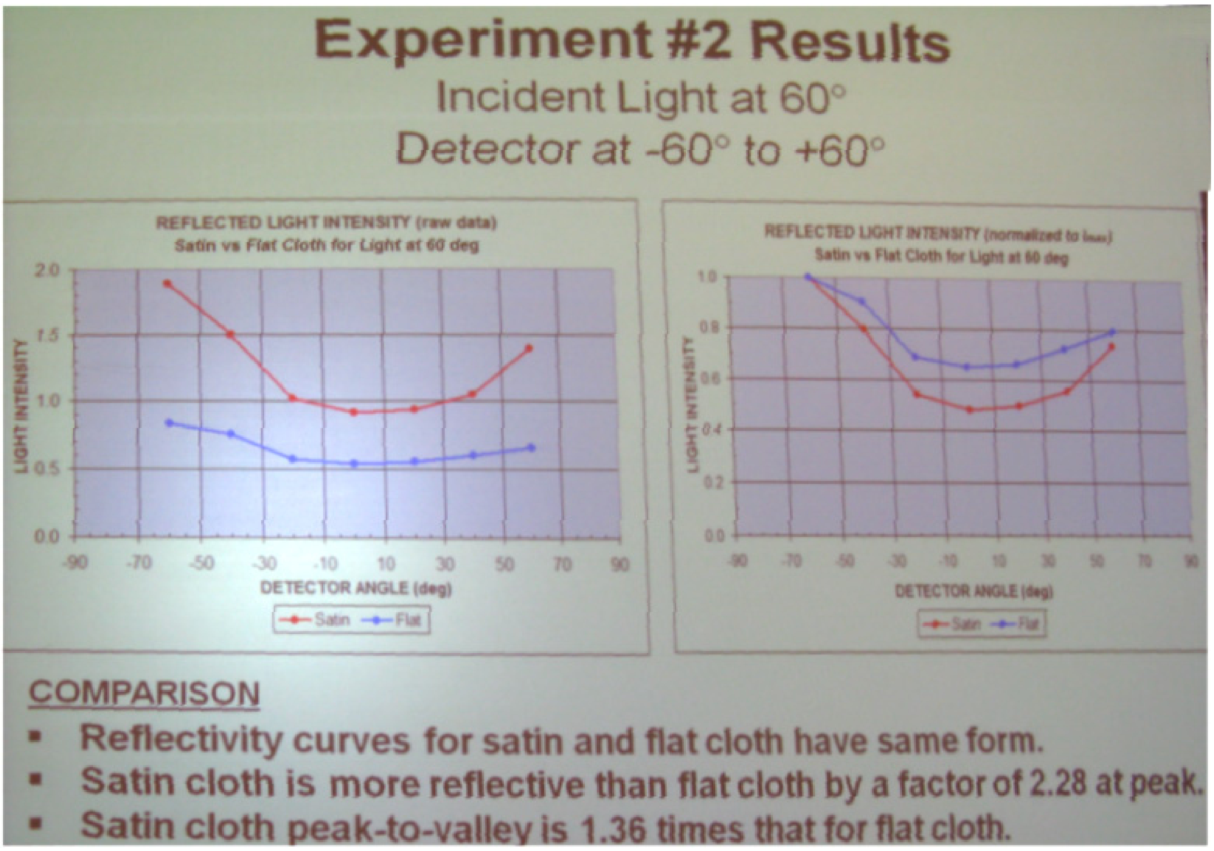

On the Visibility of the Shroud Image
An Inquiry by
J. Dee German
Senior Scientist (Retired)
Presented at:
The Shroud of Turin: Perspectives on a Multifaceted Enigma
Ohio State University, August 14-17, 2008
Shroud photos from www.shroudofturin4journalists.com

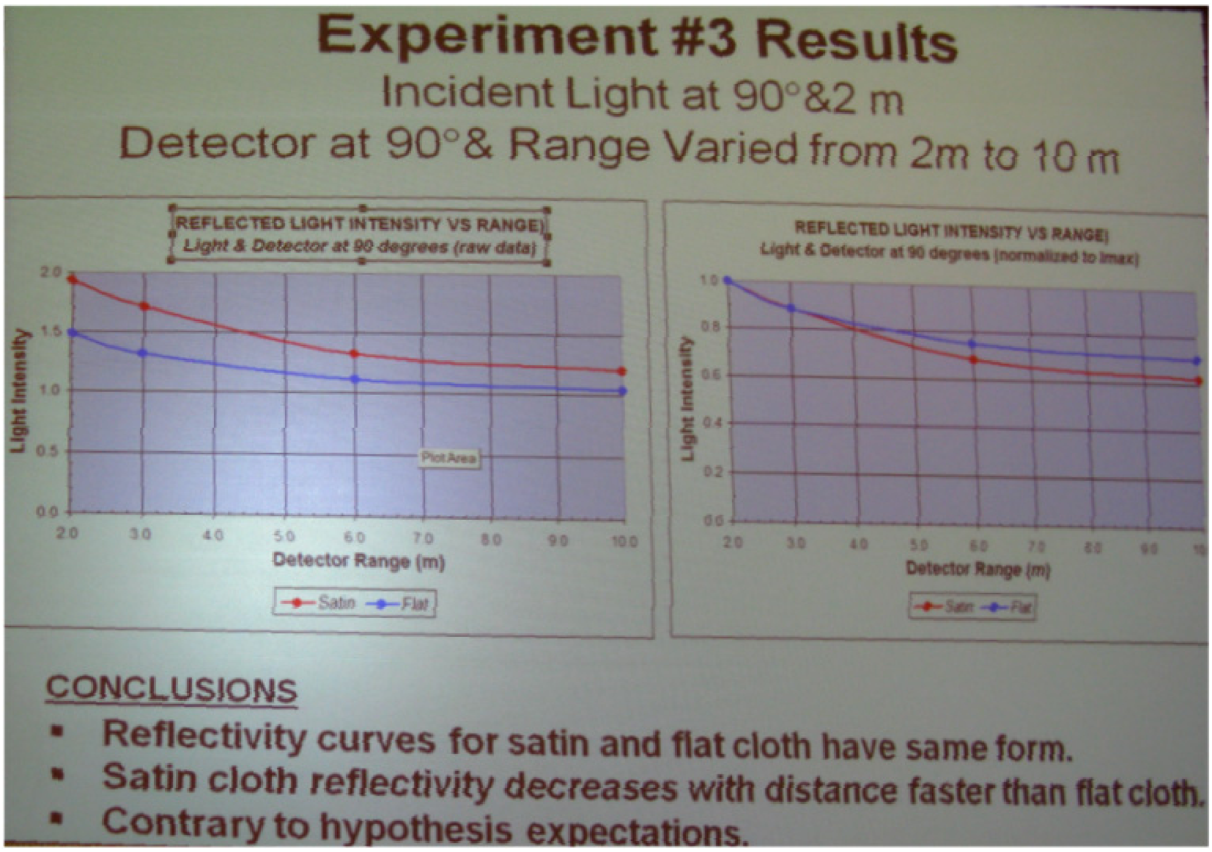

Basis of Inquiry
OBSERVATION
During the 1978 tests I and others perceived that the further one stands from the Shroud the greater the apparent contrast between the image and the clear cloth.
HYPOTHESIS
An explanation for this effect may be that the degraded image area fibers, which have lost the shininess of the pristine fibers, diffusely scatter more light out of the observers field-of-view that do the shiny fibers.


Consequence of Hypothesis
As one retreats from the Shroud, the ratio between the scattered diffuse image light, which scatters in all directions, and the shiny reflected light from the clear cloth, which is concentrated more in the viewer's direction, will decrease, resulting in increased image contrast

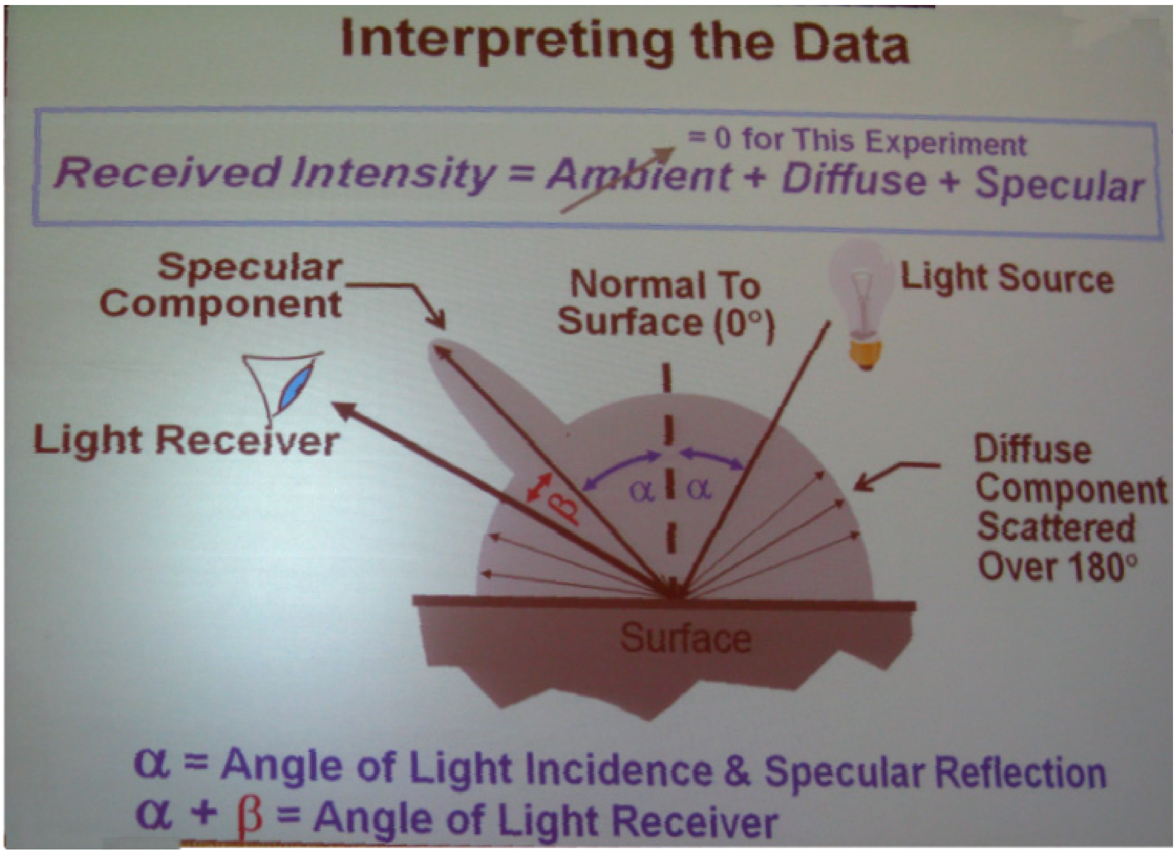

Experiment Setup
Fiber Optic to Light Sensor
Arc 2 Meters From Cloth
Fiber from Light Source
Fiber Collimator
Fiber Collimator
0
-20
20
-40
40
-60
60
Fiber from Light Source
Shiny Side of Satin Cloth
Flat Side of Satin Cloth
Fabric Shifted from Flat to Shiny At Each Test Angle


Experiment #1 Results
Incident Light at 0°
Detector at -60° to +60°
REFLECTED LIGHT INTENSITY (raw data))
Satin vs Flat Cloth for Light at 0 deg
LIGHT INTENSITY
DETECTOR ANGLE (deg)
Satin
Flat
REFLECTED LIGHT INTENSITY (normalized to Imax)
Satin vs Flat Cloth for Light at 0 deg
LIGHT INTENSITY
DETECTOR ANGLE (deg)
Satin
Flat
COMPARISON
Reflectivity curves for satin and flat cloth have same form.
Satin cloth is more reflective than flat cloth by factor of 1.27 at peak.
Flat cloth peak-to-valley is 1.13 times that for the shiny cloth.

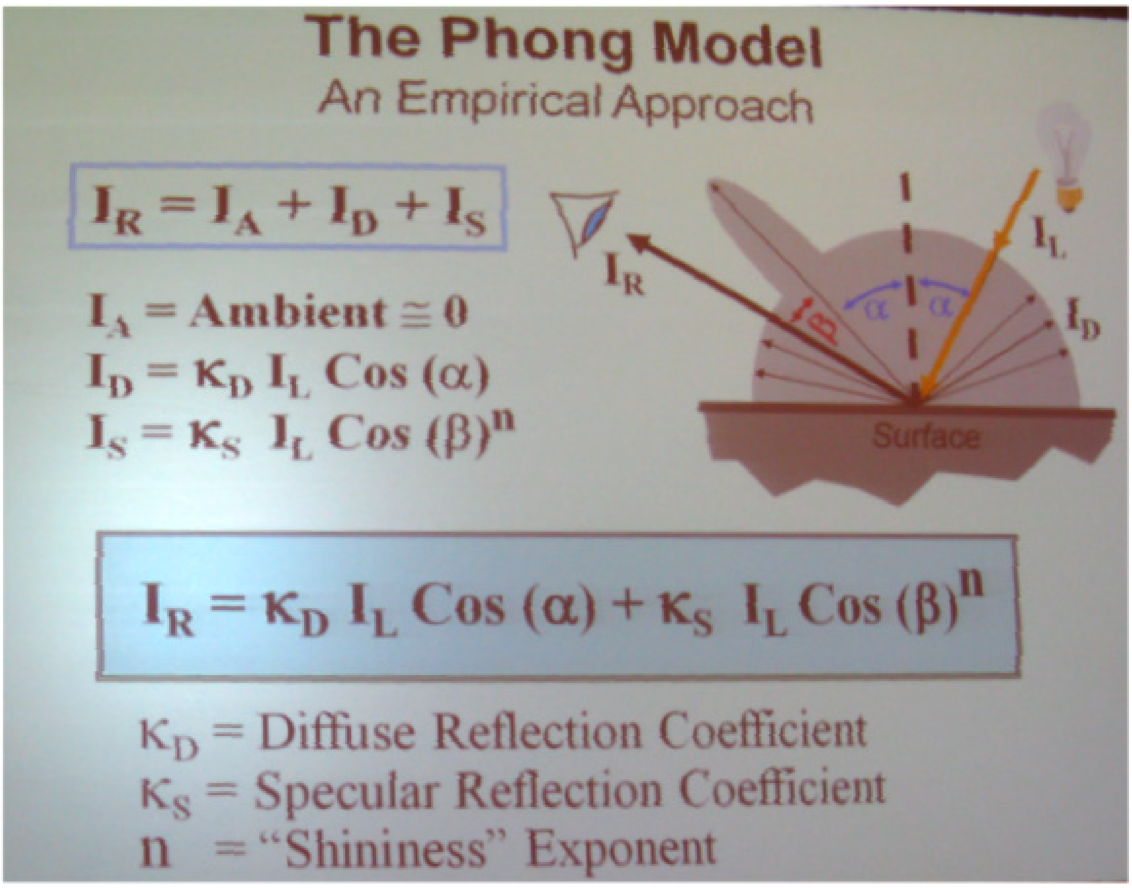

Experiment #2 Results
Incident Light at 60°
Detector at -60° to +60°
REFLECTED LIGHT INTENSITY (raw data)
Satin vs Flat Cloth for Light at 60 deg
LIGHT INTENSITY
DETECTOR ANGLE (deg)
Satin
Flat
REFLECTED LIGHT INTENSITY (normalized to Imax)
Satin vs Flat Cloth for Light at 60 deg
LIGHT INTENSITY
DETECTOR ANGLE (deg)
Satin
Flat
COMPARISON
Reflectivity curves for satin and flat cloth have same form.
Satin cloth is more reflective than flat cloth by a factor of 2.28 at peak.
Satin cloth peak-to-valley is 1.36 times that for flat cloth.

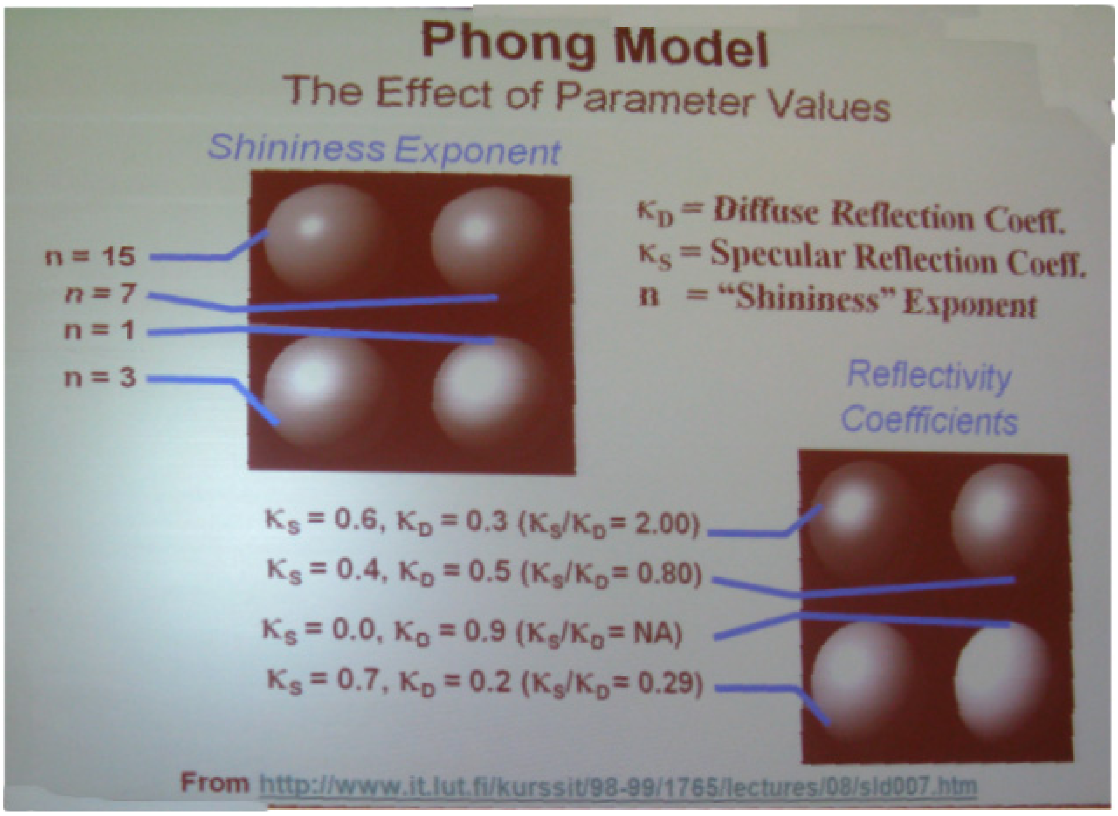


Experiment #3 Results
Incident Light at 90°&2 m
Detector at 90°& Range Varied from 2m to 10 m
REFLECTED LIGHT INTENSITY VS RANGE)
Light & Detector at 90 degrees (raw data)
Light Intensity
Detector Range (m)
Plot Area
Satin
Flat
REFLECTED LIGHT INTENSITY VS RANGE)
Light & Detector at 90 degrees (normalized to Imax)
Light Intensity
Detector Range (m)
CONCLUSIONS
Reflectivity curves for satin and flat cloth have same form.
Satin cloth reflectivity decreases with distance faster than flat cloth.
Contrary to hypothesis expectations.



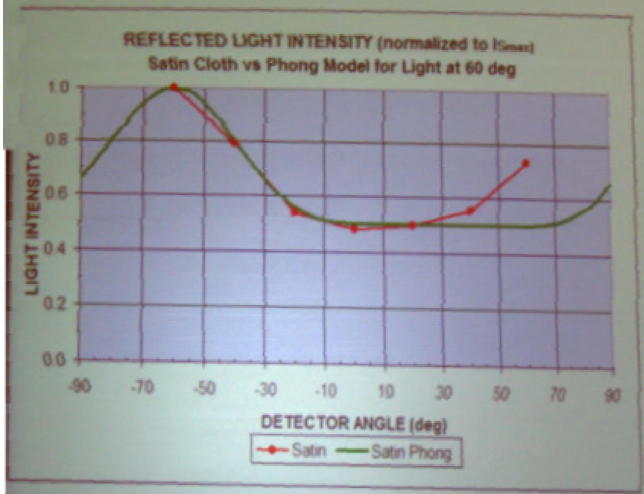
Interpreting the Data
= 0 for This Experiment
Received Intensity = Ambient + Diffuse + Specular
Specular Component
Normal To Surface (0°)
Light Source
Light Receiver
Diffuse Component Scattered Over 180°
β
α
α
Surface
α = Angle of Light Incidence & Specular Reflection
α + β = Angle of Light Receiver

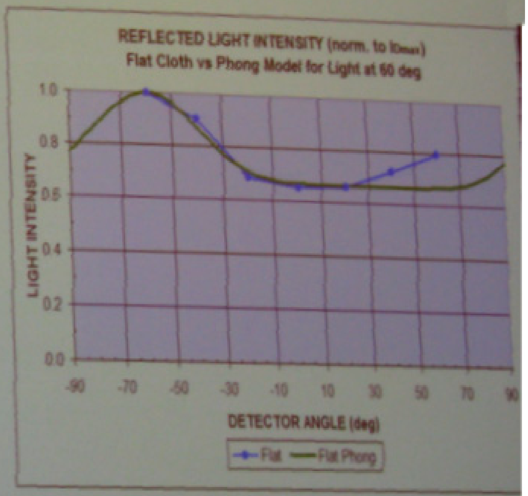

The Phong Model
An Empirical Approach
$I_R = I_A + I_D + I_S$
I_A = Ambient ≅ 0
$I_D = \kappa_D I_L \cos(\alpha)$
$I_S = \kappa_S I_L \cos(\beta)^n$
I_R
I_L
I_D
α
α
β
Surface
$I_R = \kappa_D I_L \cos(\alpha) + \kappa_S I_L \cos(\beta)^n$
κ_D = Diffuse Reflection Coefficient
κ_S = Specular Reflection Coefficient
n = "Shininess" Exponent


Phong Model
The Effect of Parameter Values
Shininess Exponent
n = 15
n = 7
n = 1
n = 3
κ_D = Diffuse Reflection Coeff.
κ_S = Specular Reflection Coeff.
n = "Shininess" Exponent
Reflectivity Coefficients
κ_S = 0.6, κ_D = 0.3 (κ_S/κ_D = 2.00)
κ_S = 0.4, κ_D = 0.5 (κ_S/κ_D = 0.80)
κ_S = 0.0, κ_D = 0.9 (κ_S/κ_D = NA)
κ_S = 0.7, κ_D = 0.2 (κ_S/κ_D = 0.29)
From http://www.it.lut.fi/kurssit/98-99/1765/lectures/08/sld007.htm

Matching Phong Model to Data

Incident Light at 60° & Detector at -60° to +60°





$\kappa_D = 0.80, \kappa_S = 0.40, n = 8$

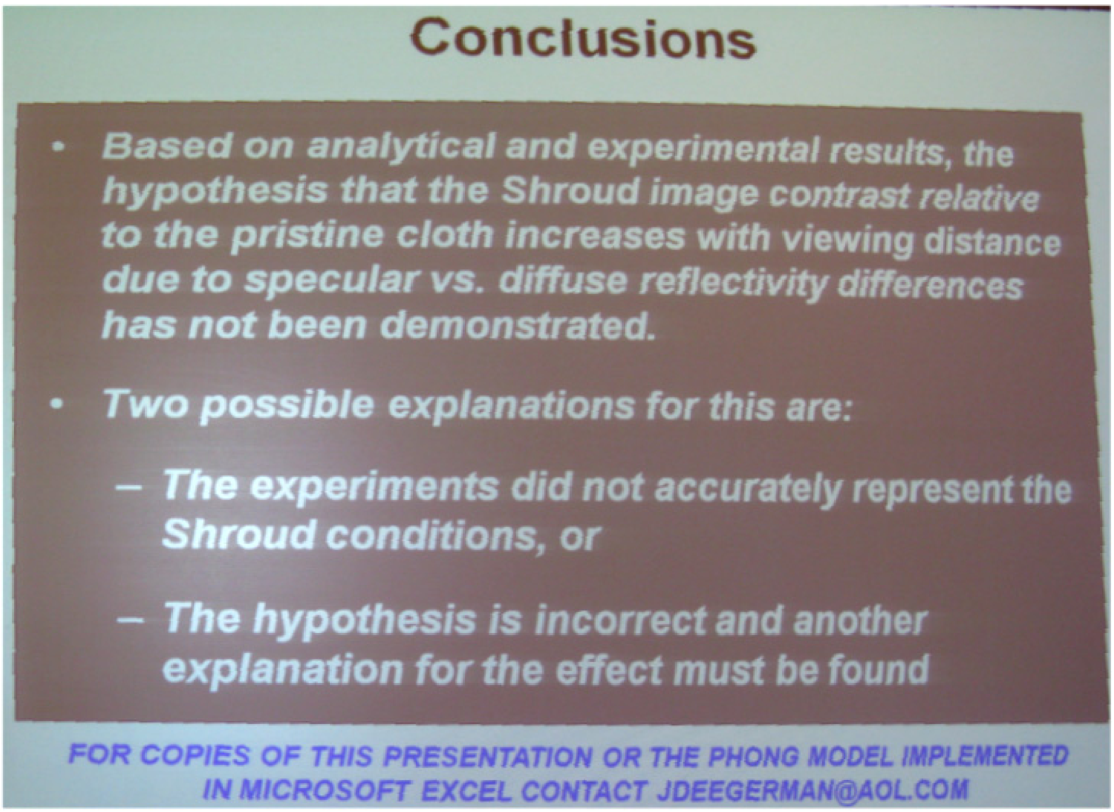
$\kappa_D = 0.80, \kappa_S = 0.20, n = 8$

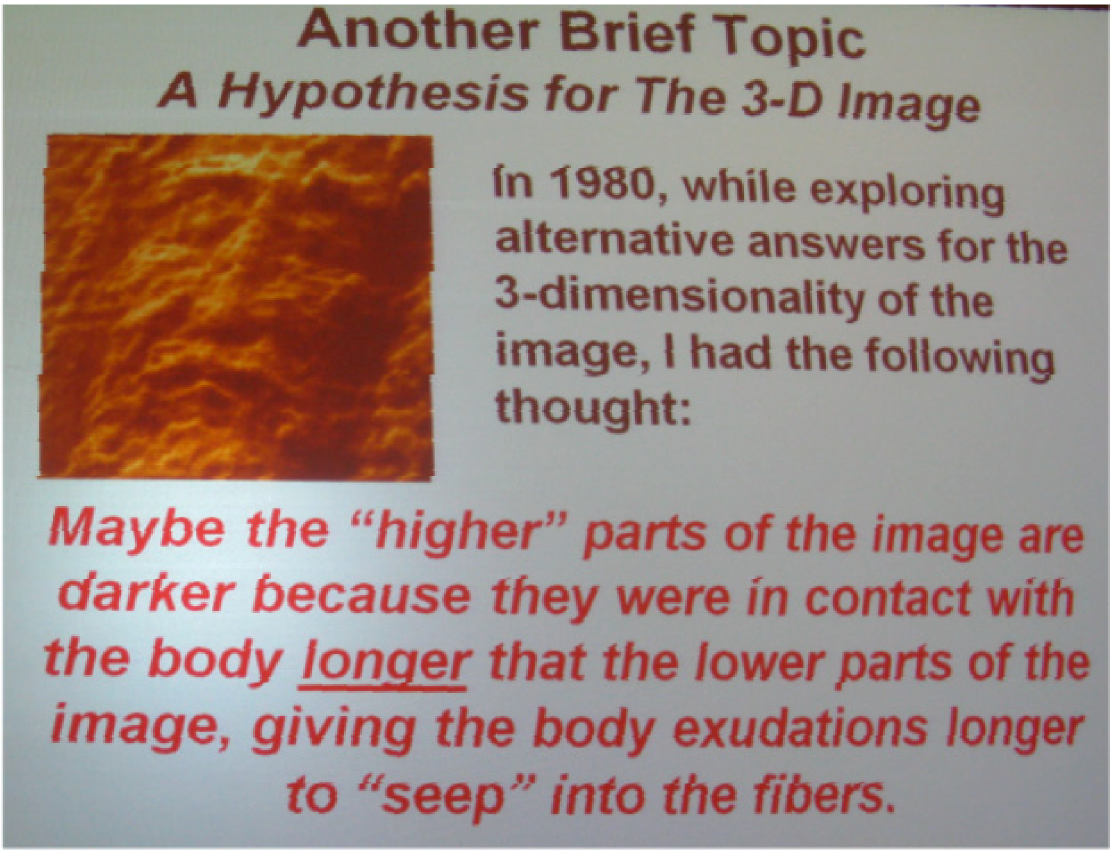
$$I_R = \kappa_D \cos(\alpha) + \kappa_S \cos(\beta)^n$$

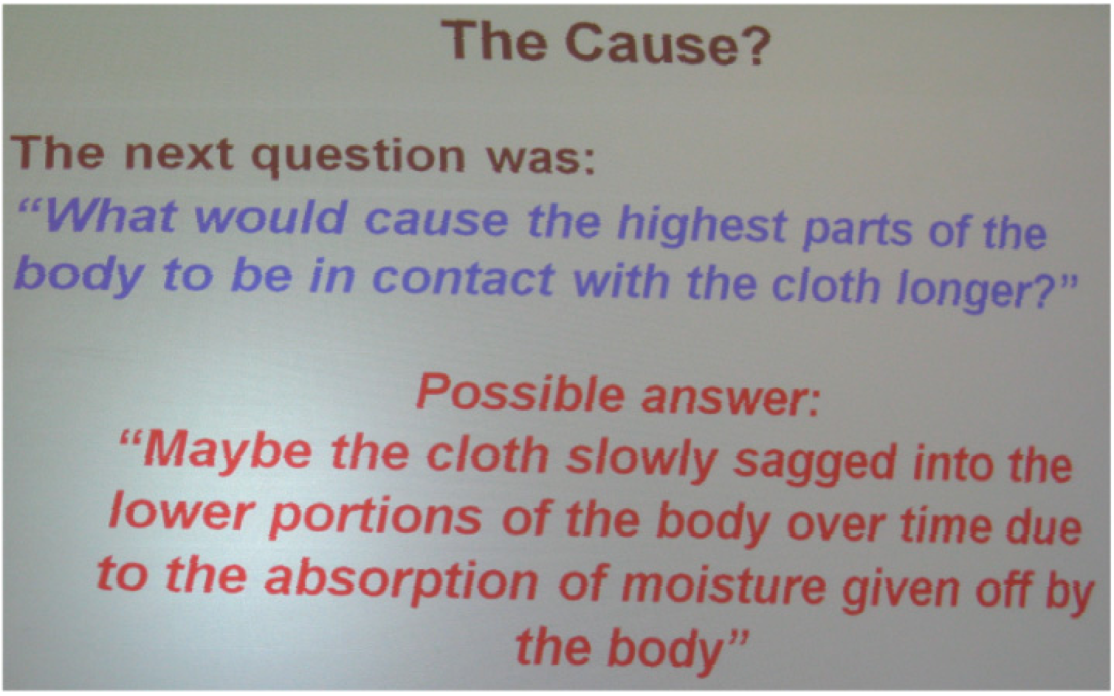
Results from Phong Model Fit

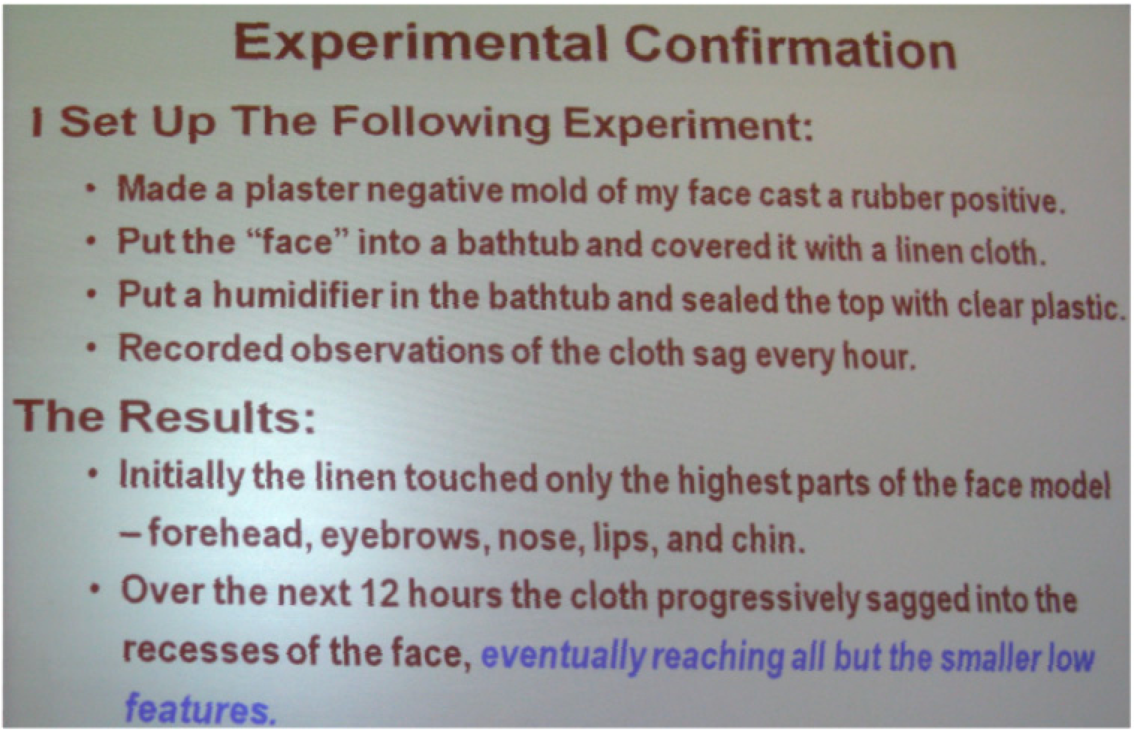
For Light Incidence Angle of 0° (Normal to Cloth)

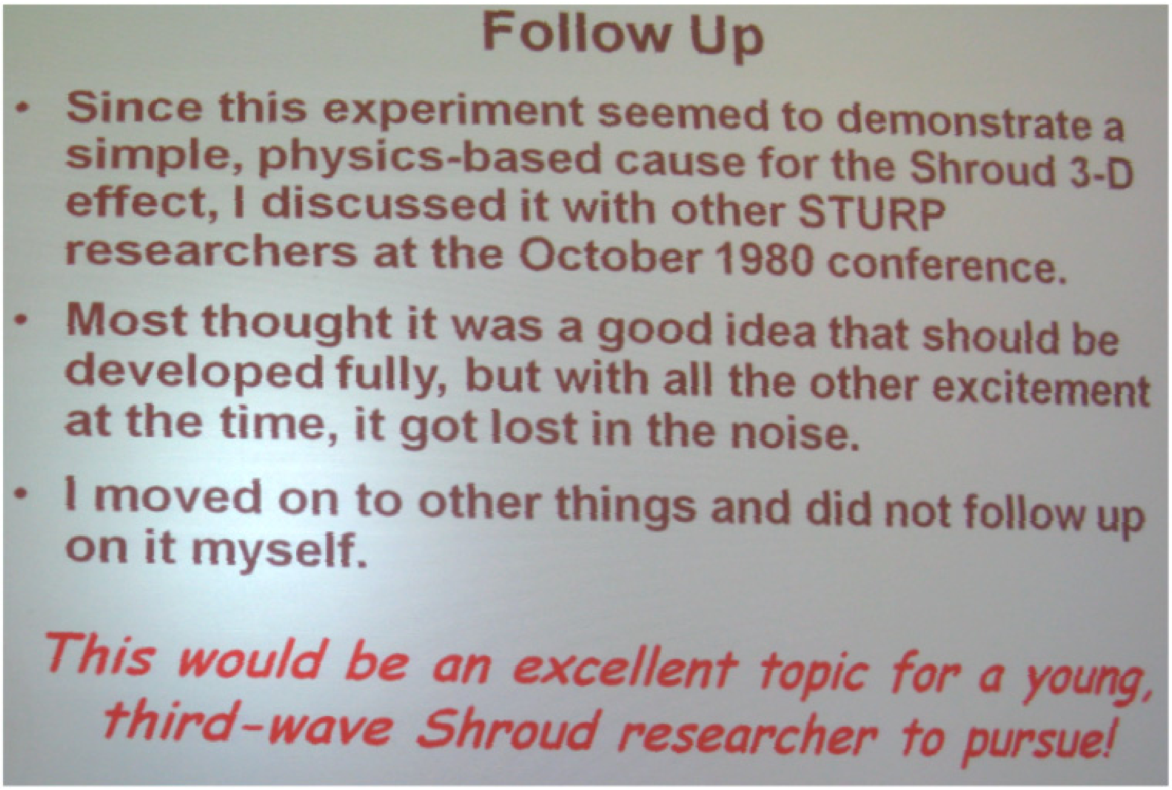
DERIVED PARAMETERS	*VALUES*	*COMMENTS*
Satin Cloth K_S/K_D	0.42	Larger Ratio for Flat Cloth Implies Higher Specular Content for Flat Cloth - Counter to Hypothesis and Intuition
Flat Cloth K_S/K_D	0.58	
n_{SATIN}/n_{FLAT}	1.38	Larger Exponent for Satin Cloth Implies Higher Specular Contnet for Satin - Agrees with Hypothesis and Intuition
Satin Specular Diverg. Angle @ FWHM	32°	*Identical Divergence Angles for Satin and Flat Cloth Specular Components* - Counter to Hypothesis and Intuition
Flat Specular Diverg. Angle @ FWHM	32°	


Conclusions
Based on analytical and experimental results, the hypothesis that the Shroud image contrast relative to the pristine cloth increases with viewing distance due to specular vs. diffuse reflectivity differences has not been demonstrated.
Two possible explanations for this are:
– The experiments did not accurately represent the Shroud conditions, or
– The hypothesis is incorrect and another explanation for the effect must be found
FOR COPIES OF THIS PRESENTATION OR THE PHONG MODEL IMPLEMENTED IN MICROSOFT EXCEL CONTACT JDEEGERMAN@AOL.COM


Another Brief Topic
A Hypothesis for The 3-D Image
In 1980, while exploring alternative answers for the 3-dimensionality of the image, I had the following thought:
Maybe the "higher" parts of the image are darker because they were in contact with the body longer that the lower parts of the image, giving the body exudations longer to "seep" into the fibers.


The Cause?
The next question was:
"What would cause the highest parts of the body to be in contact with the cloth longer?"
Possible answer:
"Maybe the cloth slowly sagged into the lower portions of the body over time due to the absorption of moisture given off by the body"


Experimental Confirmation
I Set Up The Following Experiment:
• Made a plaster negative mold of my face cast a rubber positive.
• Put the "face" into a bathtub and covered it with a linen cloth.
• Put a humidifier in the bathtub and sealed the top with clear plastic.
• Recorded observations of the cloth sag every hour.
The Results:
• Initially the linen touched only the highest parts of the face model – forehead, eyebrows, nose, lips, and chin.
• Over the next 12 hours the cloth progressively sagged into the recesses of the face, eventually reaching all but the smaller low features.



Editor's note: it is very hard if not impossibile to deform a fabric like the Turin Shroud in such a way that, when enveloping the body, it touches the skin in the area between nose and cheeks, but a body image is detectable in that area of the Shroud.