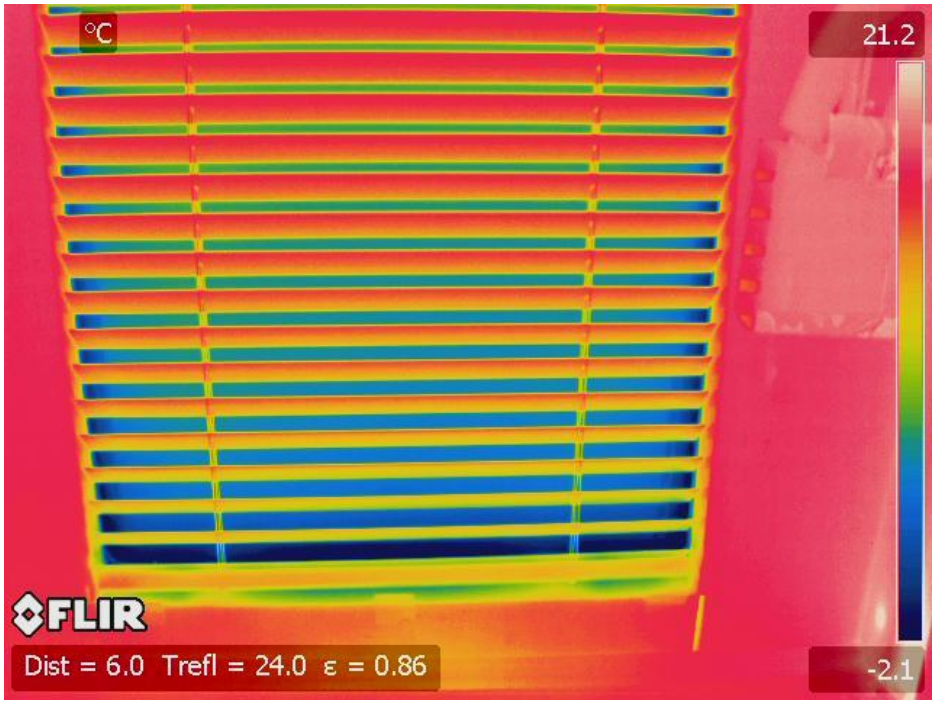
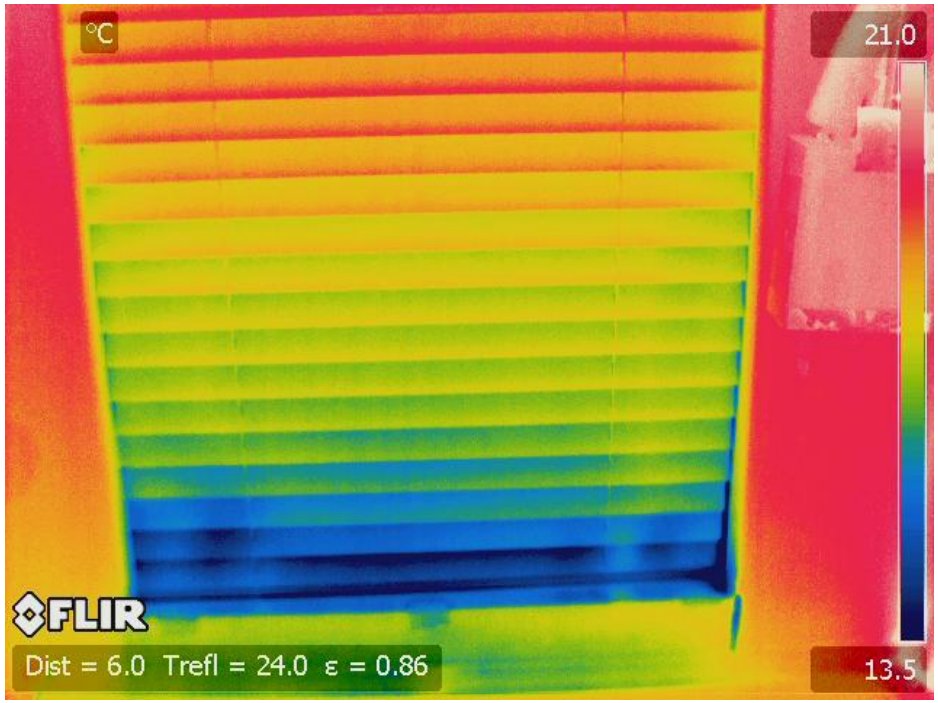
Fenestration Attachments

2016 Building Technologies Office Peer Review





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Project Summary

Timeline:

Start date: 10/1/2013

Planned end date: 9/30/2018

Key Milestones:

1. CGDB Releases (2); 3/31/16; 9/30/16
2. Validated simulation methods for AERC priority window attachments; 9/30/2016

Budget:

Total Project $K to Date:

- DOE: $1,950
- Cost Share: $1,330

Total Project $K:

- DOE: $3,750
- Cost Share: $2,000 (expected)

Key Partners:

AERC	PAMA
Hunter-Douglas	ESSA
Levelor	NEEA
Rollease	
ES-SO	

Project Outcome:

Develop validated simulation models and procedures for characterizing properties and energy impacts of a wide range of window attachments. Develop test methods for measurements of material properties and whole product performance. Implement validated simulation models in software tools for use in rating and product development.

Purpose and Objectives

Problem Statement: Window attachments have the economic potential to save nearly 800 TBtus in cooling and heating energy by 2030. However, there are currently no performance rating mechanisms for assessing energy performance of fenestration attachments. As a result, available energy savings cannot be fully realized because consumers are unable to identify fenestration attachments that maximize energy savings and manufacturers lack guidance to optimize technology innovation for new product development.

Target Market and Audience: All existing and new windows for residential and commercial buildings. Attachments Energy Rating Council (AERC), National Fenestration Rating Council (NFRC), window coverings manufacturers, window attachments other than coverings manufacturers, code officials, utilities, state and federal energy policy decision makers.

Impact of Project: Windows are responsible for 4 quads of energy used for heating and cooling of buildings, with one additional quad that can be saved through effective daylighting. Window attachments and coverings, including integral shading devices have an opportunity to affect large portions of this energy use, thus reducing energy penalty of windows and façade elements. Credible rating and certification provides impetus to improve products, since it provides a common measuring stick. This project provides the technical backbone for the DOE supported and funded AERC organization. Validated algorithms and databases developed during this project provide the necessary credibility for simulation tools that will be used for rating and certification. Replicate success of NFRC in changing product offerings and encouraging innovation.

Approach

Approach: Develop and validate simulation methods to model thermal, optical and energy performance of fenestration attachments. Develop associated test methods and lead the effort to incorporate standardized measurement procedures in ASTM and ISO standards. Incorporate validated simulation methods and algorithms into associated software tools for rating and certification as a cost-effective alternative to physical testing. Assist AERC in the development and establishment of technical documents and rating procedures.

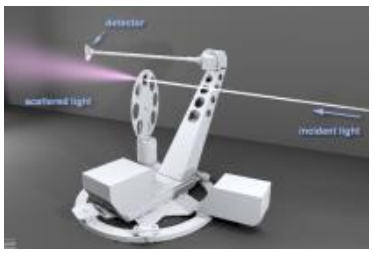
Key Issues:

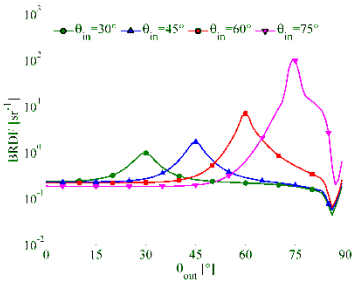
- Enable rapid, cost-effective rating/certification of window attachments
- Create validated technology simulation platform to enable rapid, low cost development of new optimized window attachment and window shading technologies
- Lab and field testing to build confidence in energy savings claims
- Address visual and thermal comfort to aid market impact

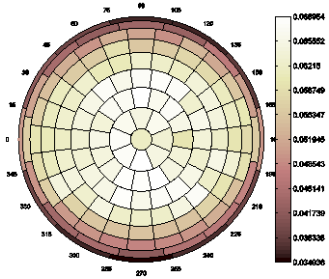
Distinctive Characteristics:

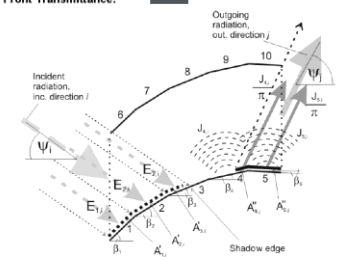
- Credible simulation methods and algorithms that will provide technical foundation for software tools used in AERC rating and certification
- Standardized, internationally harmonized simulation and test methods, and data bases.
- All attachment products, new and retrofit, residential and commercial
- Active industry engagement and participation throughout the process w/AERC

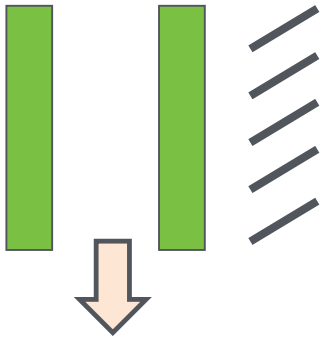
From Components To Systems: A Modular, Efficient Process for Combining the Best of Simulation and Measurement

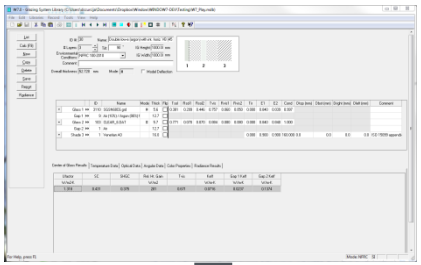


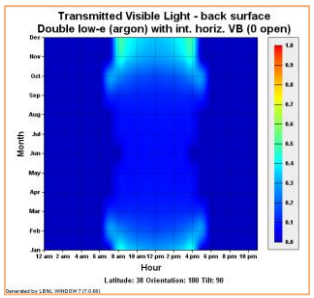












Material ← **Measurements**

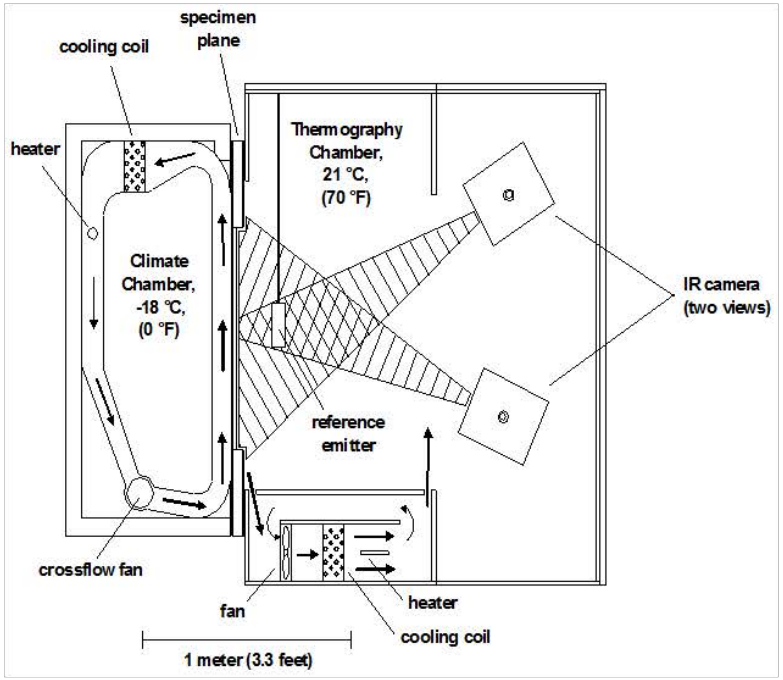
Layer ← **Modeling or Measurements**

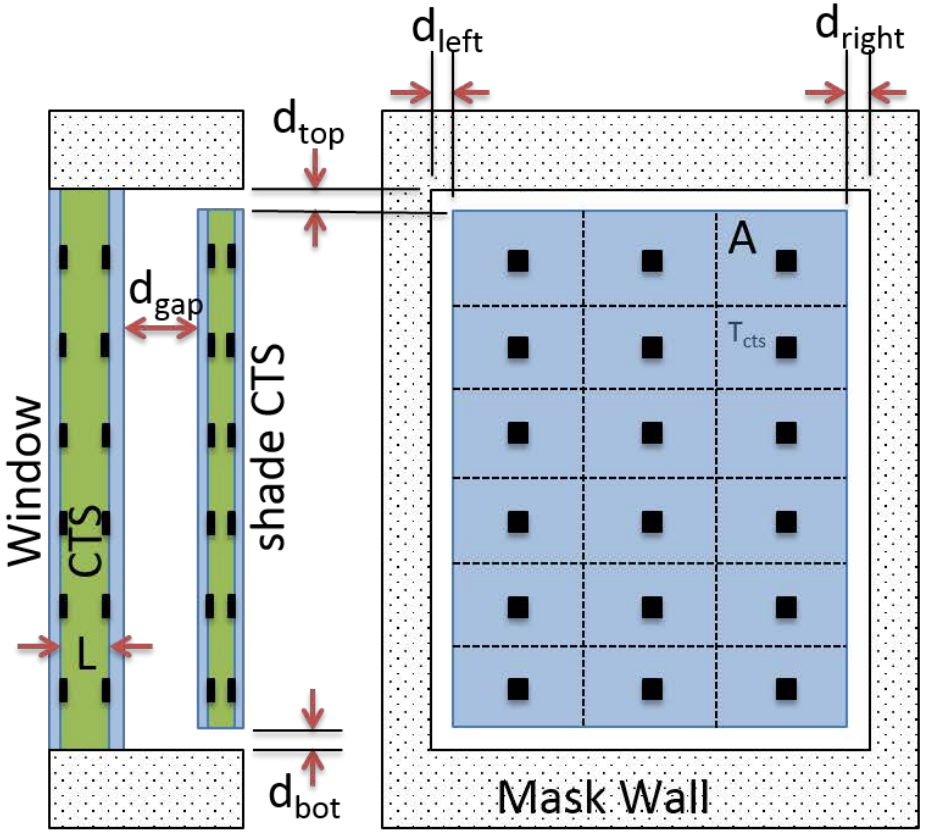
System ← **Modeling**

Methods – Measurements

Calibration Transfer Standards (CTS)

Novel approach to measure window attachments heat transfer with secondary "attachment" CTS

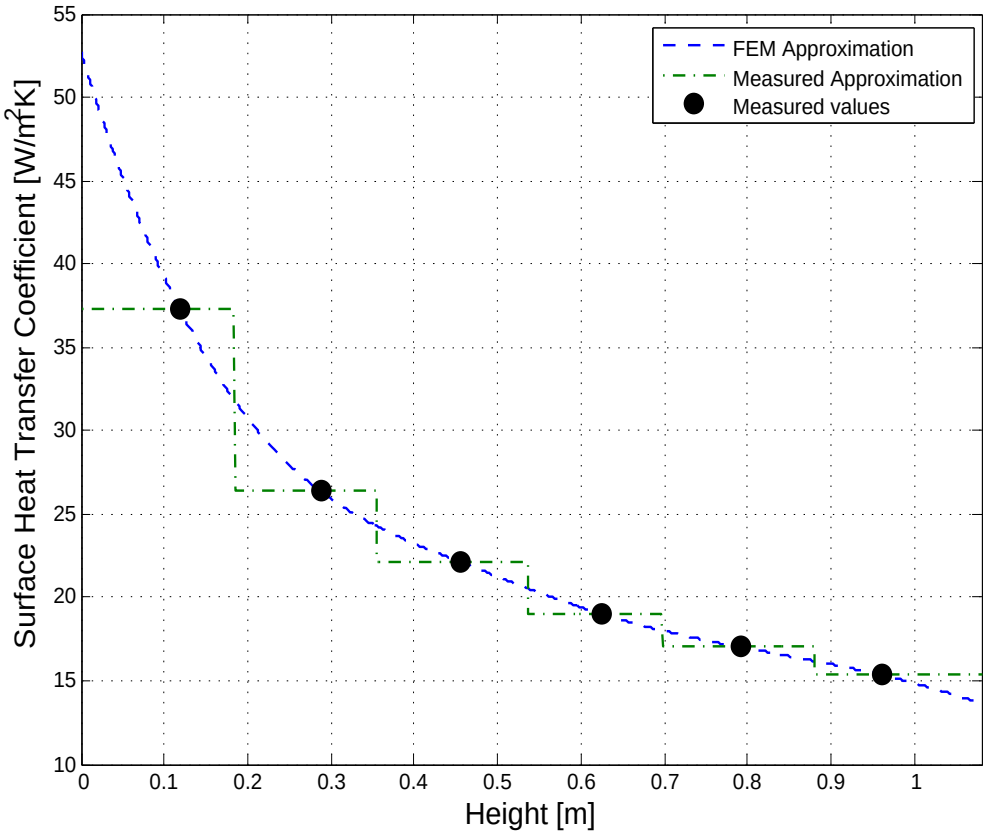


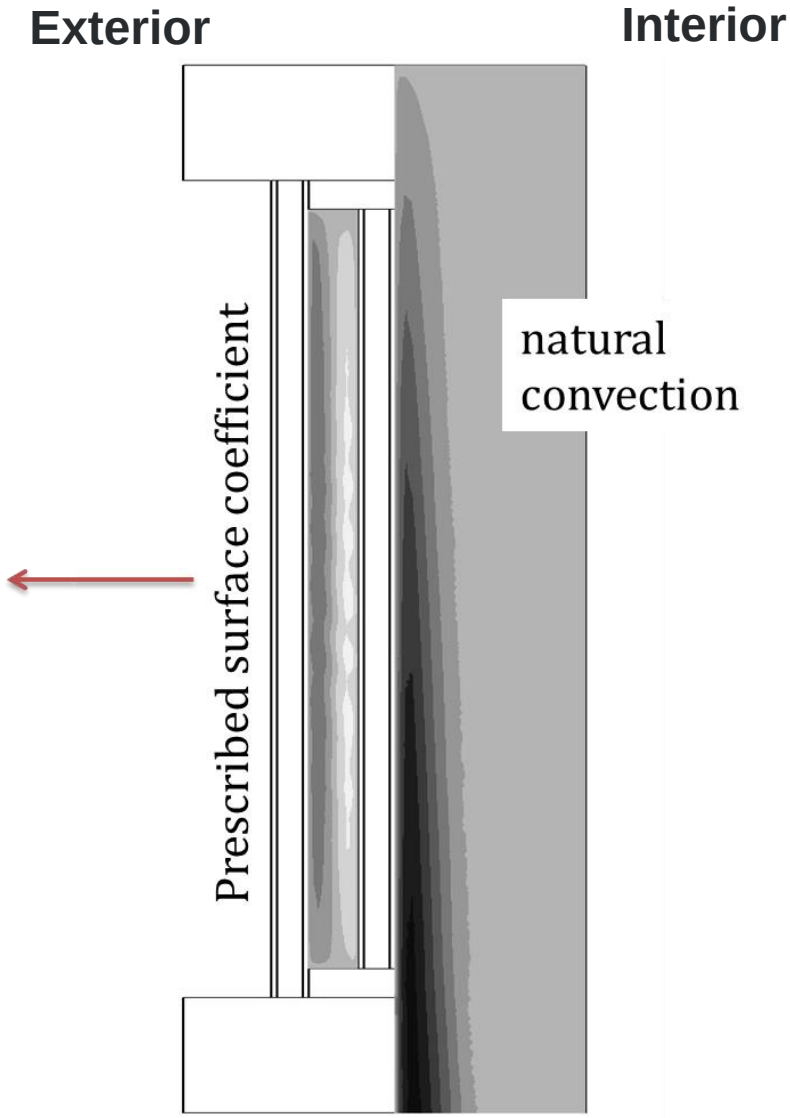


$$Q_{CTS} = k/L \bullet \Sigma A(T_{CTS\_f} - T_{CTS\_b})$$

Methods – CFD (Computational Fluid Dynamics)

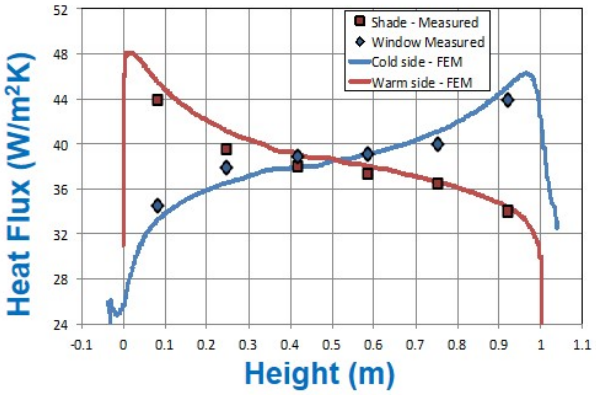
Validation of Heat Transfer in a gap between window and attachment & on the room side of attachment

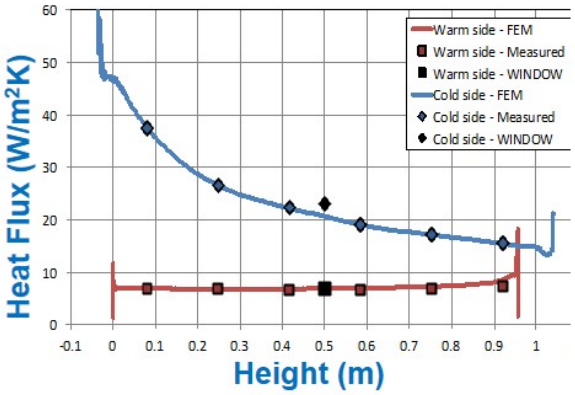


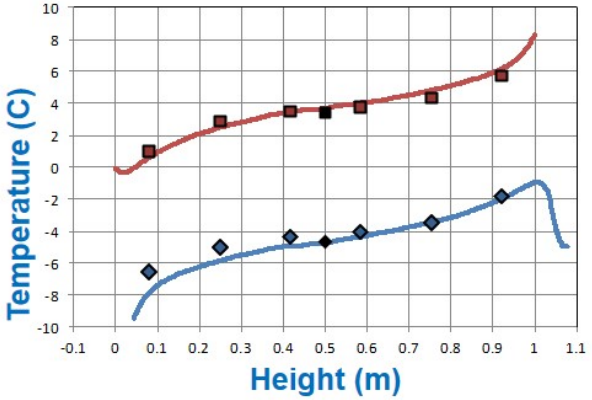


Comparison of Measurements and Simulation Methods; Excellent Agreement Validates the Simulation-based Approach

Method	Window CTS				Shade CTS				U-factor [W/m²K]	U-factor [% diff]
	Avg Tc [deg C]	Avg Tw [deg C]	Avg hc [W/m2K]	Avg q [W/m²]	Avg Tc [deg C]	Avg Tw [deg C]	hw [W/m2K]	Avg q [W/m²]		
Measured	-16.34	-4.24	22.87	39.01	3.51	15.35	6.66	38.17	0.99	-
WINDOW (Software)	-16.53	-4.68	22.87	39.30	3.34	15.18	6.66	39.30	1.00	0.8%
CFD	-16.12	-4.65	23.76	39.15	3.62	15.39	7.09	39.06	1.00	1.3%



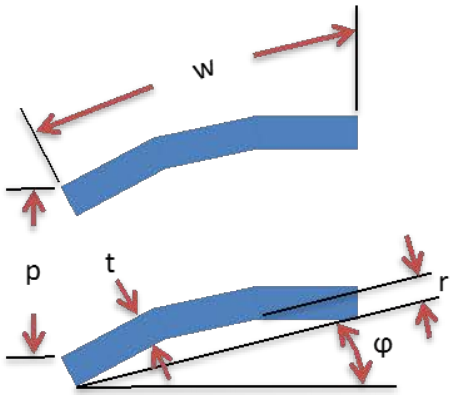




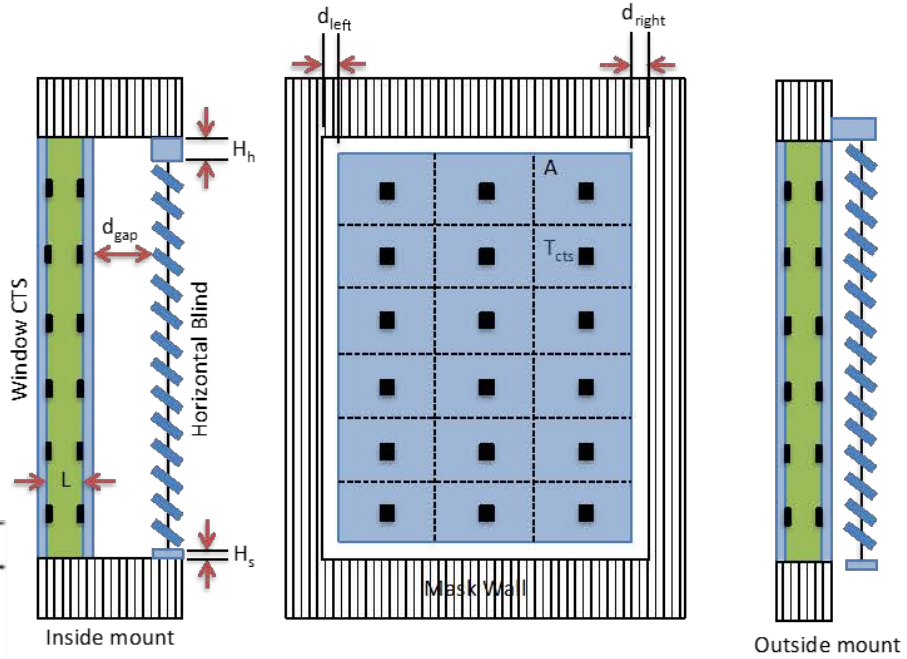
Test Configurations – Horizontal Blinds

15 total horizontal blind samples from two manufacturers

176 total combinations of seven parameters measured

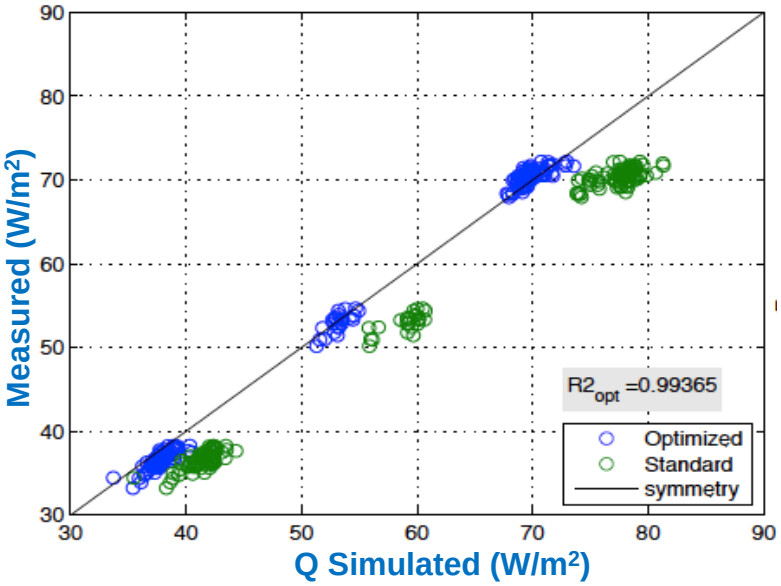


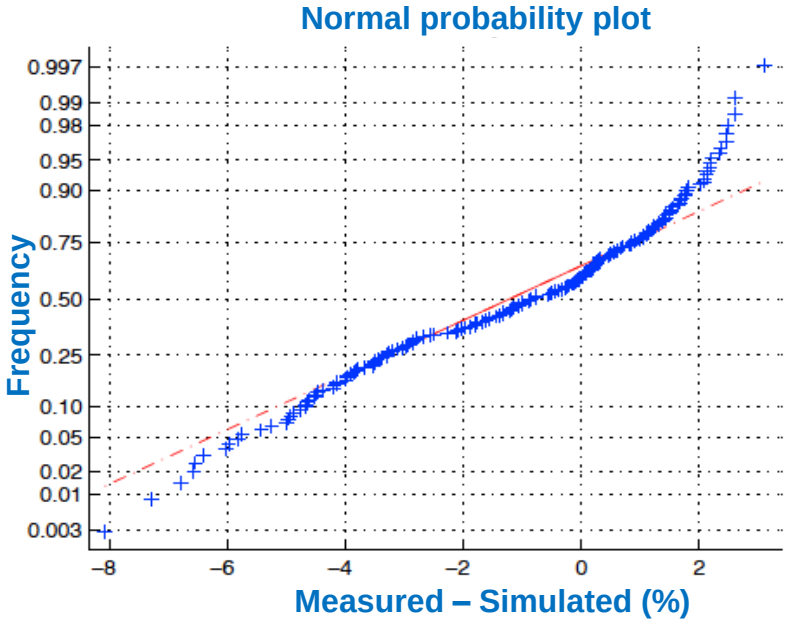
Parameter	Set points	Unit
Slat width, w	Table 2	mm
Pitch, p	Table 2	mm
Rise, r	Table 2	mm
Conductivity, k_s	Table 2	W/mK
Cold side temperature	-18, -9, 0	C
Side gap width	0, 12.7	mm
Tilt angle, ϕ	~80,45,0,-45,~-80	Deg

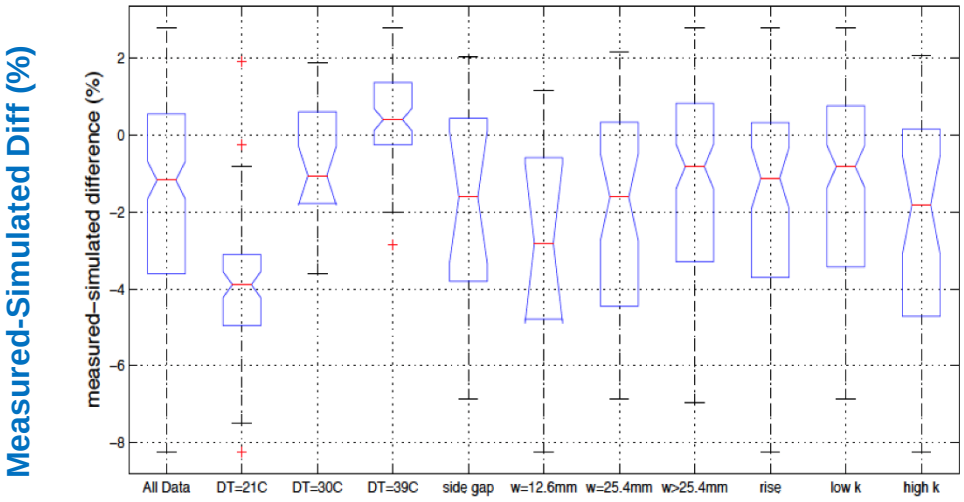


Measured vs Simulated Performance – Venetian Blinds: Led to the Development of New Algorithm

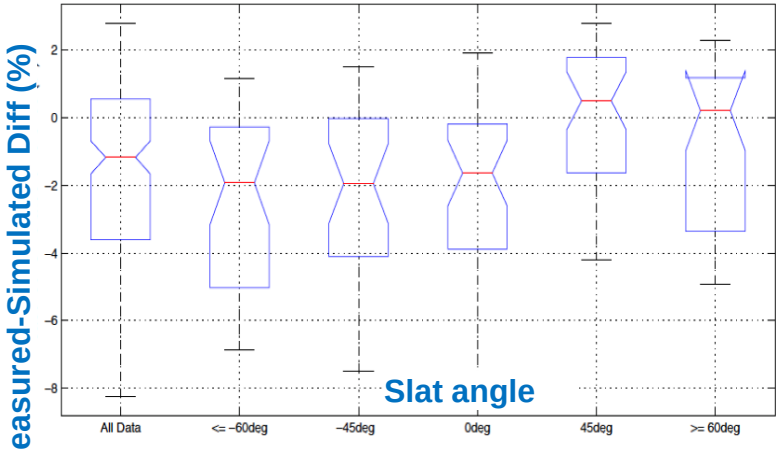
Optimized results used for new algorithms







ΔT; Side gap, Gap width; Slat rise; Conductivity



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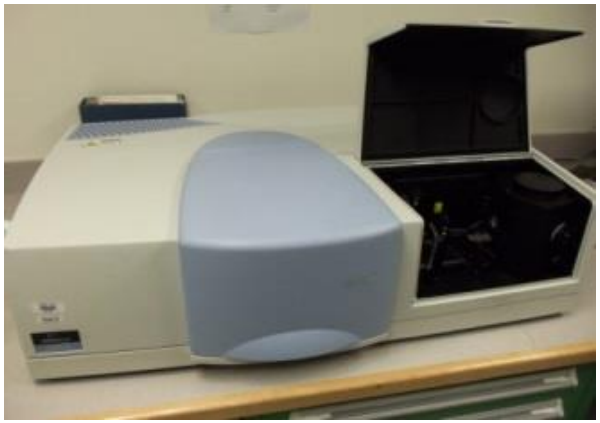
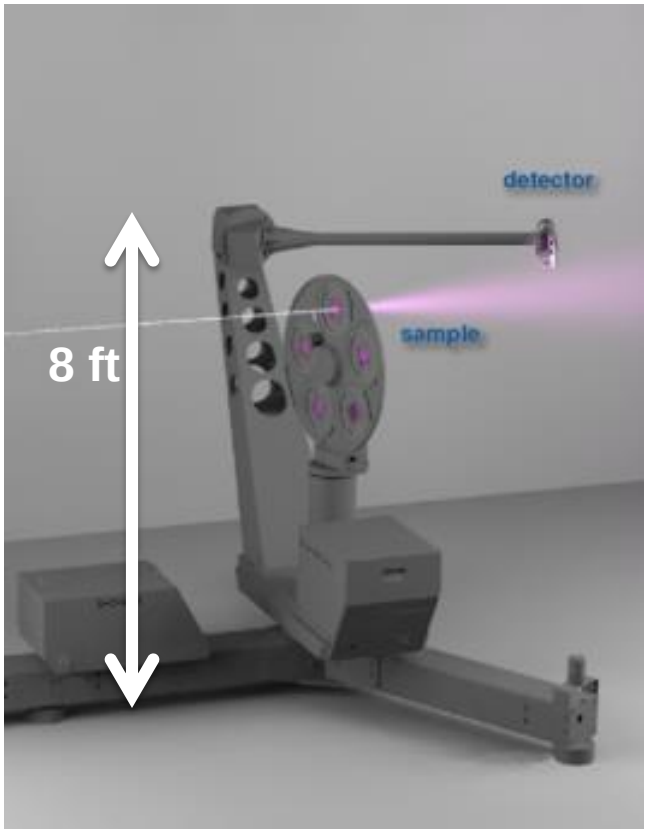
Unique LBNL Facilities for Optical Measurements for Optically Complex Products

- Two methods for measuring optical properties
  - Simple and faster with modified spectrometer/angle tubes if sample is diffusing;
  - State of the art goniophotometer for optically complex materials and to assess glare, etc.
- The sphere response is linear as long as the tube presents its white underside to the detector

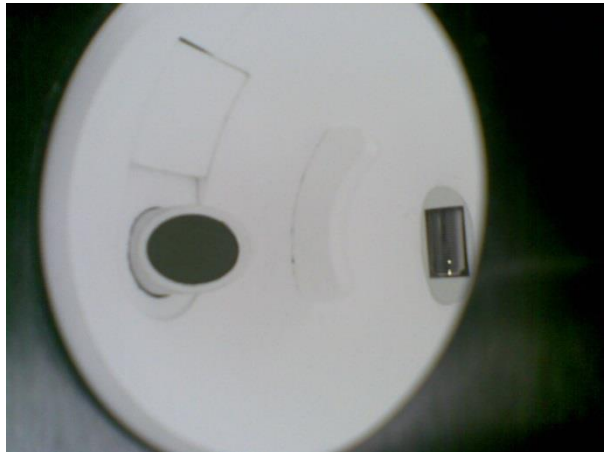


Spectrophotometer
Scale: 2 feet



Goniophotometer – full angular
Scale: 8 feet

Angle tube accessories. Scale: 1-4 in.



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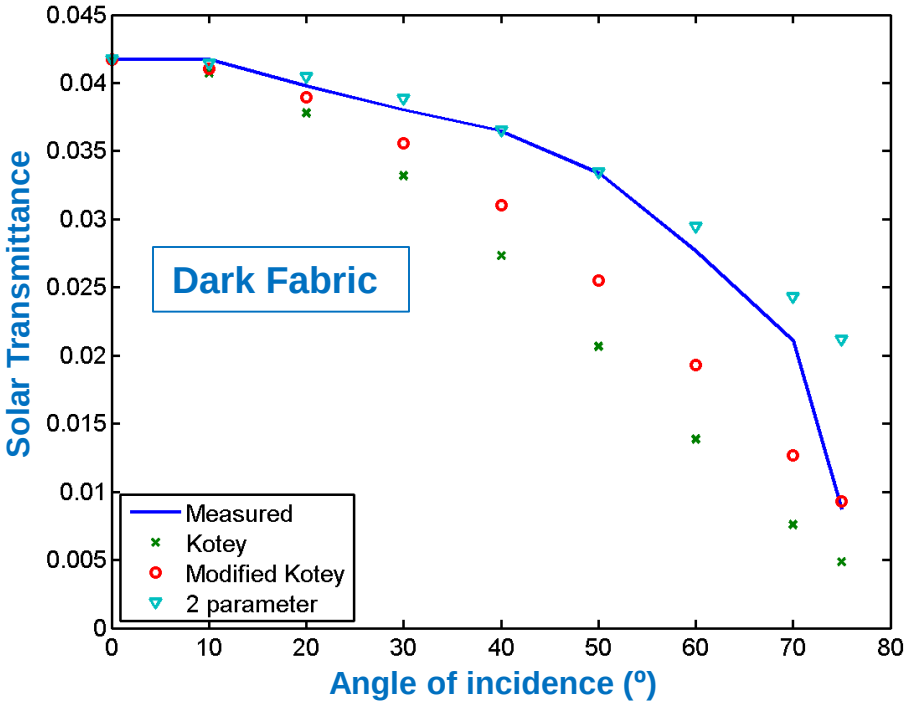
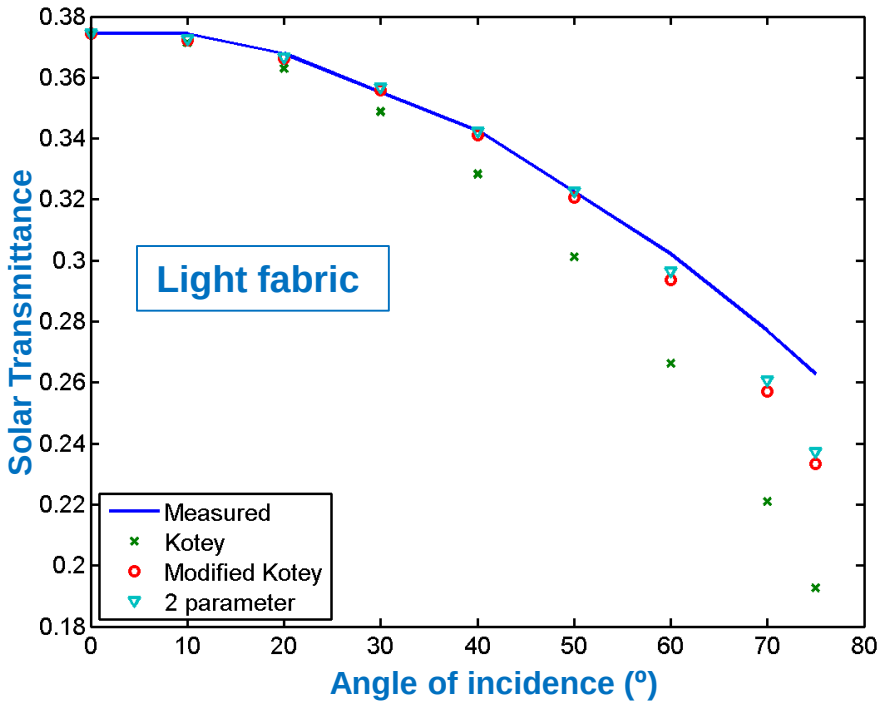
Qualitative Comparison of Different Angular Correction Methods Selection of Method That Will Be Recommended for Testing

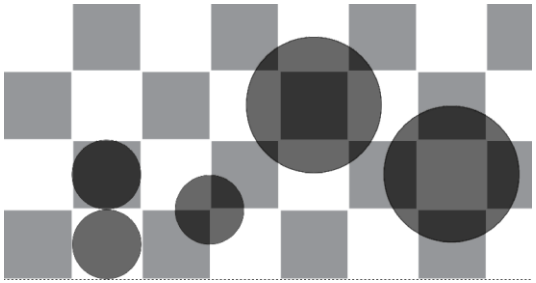


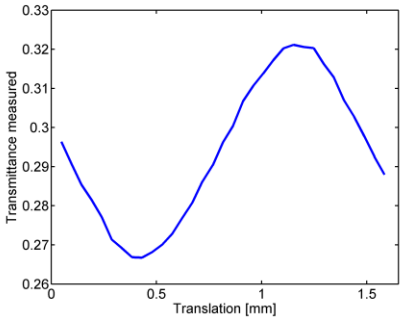


Method	**Kotey**		**Mod Kotey**		Two angle 40		**Two angle 50**		Two angle 60	
Delta	mean	max	mean	max	mean	max	mean	max	mean	Max
Visible	.007	.032	.001	.036	-.003	.023	-.002	.020	.001	.016
Solar	.010	.036	-.001	.036	-.003	.024	-.002	.021	.001	.016

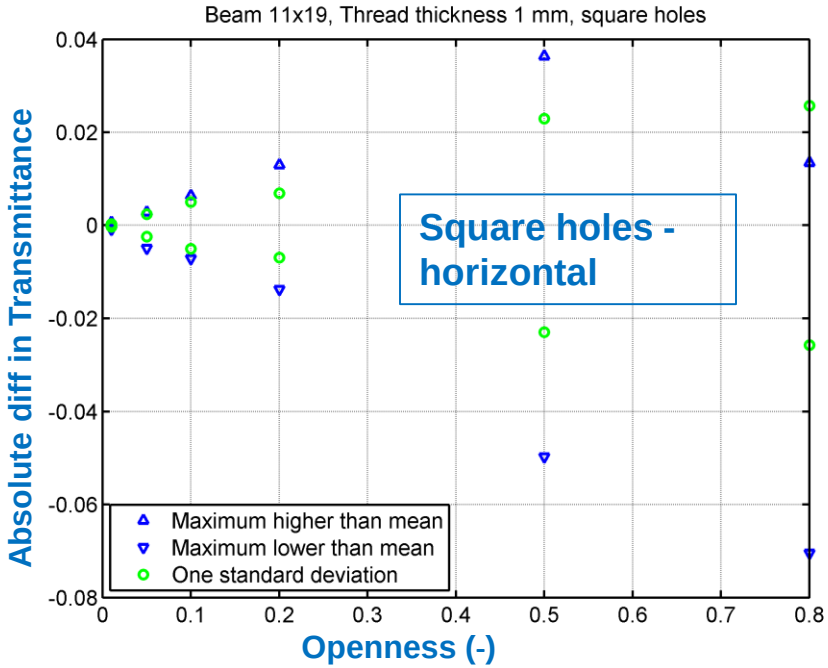
Characterization of shade fabrics – Homogeneity

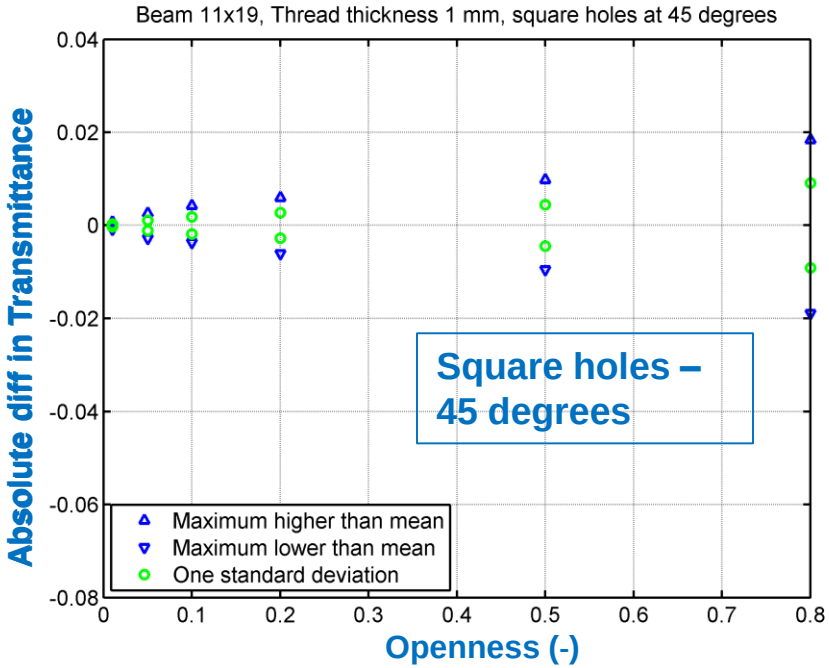
- Simulate result for a range of patterns and instrument
- Quantify expected errors based on simulations





Transmittance variation vs. relative position of the beam





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Progress and Accomplishments

Accomplishments:

- Completion of new simulation models (thermal and optical):
  - Additional cellular shade models: double, triple, cell-in-cell, cell-in-cell-in-cell
  - Optical modeling of arbitrary shading geometry using run-time radiance engine
- Validation and refinement of existing thermal models
  - porous shades (fabrics); Air flow for side (edge) gaps; Horizontal blinds
- Development of new standards for thermal and solar-optical measurements
- Sensitivity analysis of material properties on window attachment rating
- Multiple releases of Complex Glazing Data Base with growing content
- Started development of new annual energy calculation method for operable attachments; critical for simple rating indices for window attachments (EP_C, EP_H)

Market Impact:

- AERC in process of adoption of LBNL software tools in rating and certification
- Work closely with shading system manufacturers to provide products and systems for validation measurements

Lessons Learned:

- Close working with industry leads to consensus energy rating system
- International harmonization is within reach

Project Integration and Collaboration

Project Integration:

- Rating and certification organizations:
  - NFRC – adopted new models for integral shading systems
  - AERC – working closely with newly established organization to provide credible simulation and testing methods and software tools
  - Collaborate with industry to quantify the scope of attachment product variances including: fabrics, installations, gaps, etc.
  - All test samples are provided by industry partners

Partners, Subcontractors, and Collaborators:

- AERC, NFRC
- Shading Manufacturers: Hunter-Douglas, Levelor, Rollease, etc.
- Window manufacturers: Pella, Marvin, etc.
- Architects, Engineers, building owners, utilities

Communications: AERC and NFRC technical committee and membership

Technical Research Plan

Phase	No.	Product Type		Test Procedure									Simulation - U; SHGC; VT						Simulation - EP		
				IN			OUT			BG			IN		OUT		BG		IN	OUT	BG
				T	S	O	T	S	O	T	S	O	T	S	T	S	T	S			
Phase 1	1	Cellular Shade	Research	09/15	03/16	09/15						09/15	09/15	06/16					09/16		09/16
			Deployable	09/16	09/16	03/16						12/15	03/16	09/16					06/17		06/17
	2	Slat Shade	Research	09/15	03/16	09/15	06/16	03/17	09/15			09/15	09/15	06/16					09/16	09/16	09/16
			Deployable	09/16	09/16	12/15	12/16	09/17	12/15			12/15	03/16	09/16					06/17	09/16	06/17
	3	Roller Shade	Research	09/15	06/16	09/15	09/16	03/17	09/15			09/15	09/15	08/16					09/16	09/16	09/16
			Deployable	09/16	09/16	12/15	12/16	09/17	12/15			12/15	03/16	09/16					06/17	09/16	06/17
	4	Window Panel	Research																09/16	09/16	09/16
			Deployable																06/17	09/16	06/17
Phase 1 - Maybe	5	Pleated Shade	Research	09/15	03/16	09/15						09/15	09/15	06/17					09/16		09/16
			Deployable	09/16	09/16	12/15						12/15	03/16	09/17					06/17		06/17
	6	Solar Screen	Research	09/15	06/16	09/15	06/16	03/17	09/15			09/15	09/15	03/17					09/16	09/16	09/16
			Deployable	09/16	09/16	12/15	12/16	09/17	12/15			12/15	03/16	09/17					06/17	09/16	06/17
	7	Surface Applied Films	Research																09/16	09/16	09/16
			Deployable																06/17	09/16	06/17
Phase 2	8	Window Quilts	Research	09/16	03/17	06/16							03/16	06/16					03/17		
			Deployable	09/17	09/17	06/17							09/16	09/16					09/17		
	9	Roller Shutter	Research				12/16	03/17	03/16						03/17	06/17				03/17	
			Deployable				06/17	09/17	09/16						09/17	09/17				09/17	
	10	Awnings	Research					12/17	09/15						06/17	06/17				06/17	
			Deployable					06/18	12/15						12/17	12/17				12/17	
Phase 3	11	Louvered Shutter	Research																		
			Deployable																		
	12	Roman Shade	Research																		
			Deployable																		
	13	Drapes	Research																		
			Deployable																		
	14	Sheer Shade	Research																		
			Deployable																		

Currently Available
Under development
Development not started
Under revision
Revision not started
Not Aplicable

IN: Indoor mounted
OUT: Outdoor mtd.
BG: Between glazing

T: Thermal
S: Solar Heat Gain
O: Optical

Next Steps and Future Plans

Technical:

- Validation of SHGC model for phase 1 products
- Development of optical and thermal models for Phase 2 products
- Conduct measurements and modeling to validate solar-optical results and develop improved methods, if appropriate
- Complete development & validation of software tool to calculate annual energy indices, EP_C, EP_H
- Validation of energy impacts of dynamic products a key challenge

Organizational:

- Support for NFRC efforts to rate and certify integrated shades
- Support for AERC efforts to develop rating and certification system for window attachments, from technical to rating issues
- Support for EPA to decide about future EnergyStar rating for window attachments
- Engagement (WFO) with utilities, building owners to demonstrate and promote high performance attachments
- Work with industry to further develop Efficient Window Coverings web site for the promotion of energy efficient products.

REFERENCE SLIDES

Project Budget

Project Budget: So far $1,950k for three years. Estimated $1,800k over the next two years. Cost share so far $1,330K with estimated cost share over next 2 years $670K
Variances: None
Cost to Date: 40%
Additional Funding: NEEA, CBERD, PG&E, GSA GPG, AERC in-kind technical support

Budget History					
FY2014 – FY2015 (past)		FY2016 (current)		FY2017 – FY18 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,100k	$750K	$850k	$580K	$1,800k	TBD

Project Plan and Schedule