

# **Energy Simulation Training**

**Prepared for the**

**U.S. Department of Energy  
Office of Electricity Delivery and Energy Reliability**

**Under Cooperative Agreement No. DE-EE0003507  
Hawai'i Energy Sustainability Program**

**Subtask 3.5: End-use Energy Efficiency and Demand Response**

**Prepared by**

**University of Hawai'i's  
Environmental Research and Design Laboratory,  
Sea Grant Center for Smart Building and Community Design,  
and Hawai'i Natural Energy Institute**

**Submitted by**

**Hawai'i Natural Energy Institute  
School of Ocean and Earth Science and Technology  
University of Hawai'i**

**April 2013**

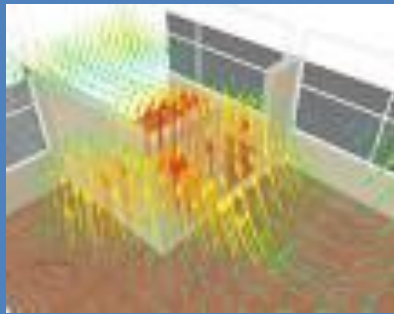
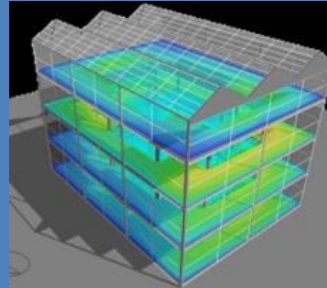
*Acknowledgement:* This material is based upon work supported by the United States Department of Energy under Cooperative Agreement Number DE-EE0003507.

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# Project Report 3: Energy Simulation Training

Provided to the Hawai'i Natural Energy Institute

April 1, 2013



**Project funded by US Department of Energy**

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*University of Hawai'i Manoa*







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## **HNEI FUNDING**

This overall project has been funded by two consecutive agreements between the Hawai'i Natural Energy Institute (HNEI) and the School of Architecture (SOA). These have been account #6660925 (dates: 7/15/10 to 8/31/12) for \$119,111 and account #6662338 (dates: 1/1/11 to present) for \$264,721.

## **OVERALL PROJECT OBJECTIVES**

The intent of the relationship between the Hawai'i Natural Energy Institute and the School of Architecture's Environmental Research and Design Laboratory (ERDL) is to change the current approach to architectural design and energy use in the State of Hawai'i. The overall objectives of this project were:

1. Expand technical capacity of the interdisciplinary ERDL Team; ensure knowledge transfer and institutional program stability:
  - a. Expand core team of staff; and
  - b. Obtain training opportunities for staff and students.
2. Leverage local projects as learning opportunities for team members in order to build capacity, publish research, and enhance the team's value to the community.
3. Leverage outside public and private sector resources to expand scope and assist program sustainability.
4. The long-term goal is to build a strong research team that conducts innovative research, provides extension services to influence the design and energy consumption of buildings in our climate zone, and provides education and field experience for university students.

## **PROJECT SHORT-TERM GOALS**

The short-term goals of this project were to develop technical skills for the ERDL team in the following disciplines:

1. Building simulation;
2. Energy modeling; and
3. The use of computational fluid dynamics to improve design for natural ventilation.

## **PROJECT STAFF**

In July, 2011, two part-time professionals were hired onto the project to help introduce energy simulation analysis techniques to the research and education programs at the School of Architecture's Environmental Research and Design Laboratory (ERDL). Manfred Zapka is a professional engineer (PhD, LEED AP, and certified energy manager). Kim Claucherty is a mechanical engineer (B.S.) as well as an architect (doctorate). George Somers Reid, a recent graduate in interdisciplinary studies with a strong background in architecture, assisted on this project part-time. Eileen Peppard, Sustainability Specialist at the Sea Grant Center for Smart Building and Community Design, coordinated the project.

## **LEVERAGED ADDITIONAL FUNDING**

In October 2011, an opportunity surfaced to apply for training funds through the Oahu Workforce Investment Board's (OWIB) "Oahu Worklinks" program. The proposal was approved for a total of \$81,000 in funding to provide a semester-long course in energy simulation, workshops in Advanced Lighting Design, and a summer internship program for five class graduates. Due to the timing and nature of the OWIB funding, the short lead time to the start of the January 2012 spring semester, and the large expense involved in developing this type of program, this project would not have been possible without the project funding from HNEI. Two more sources of funding, \$5,000 from the Hawai'i State Department of Business, Economic Development and Tourism, and \$720 from the UH Foundation, helped to fund the two, one-day workshops in Advanced Lighting Design.

## **TRAINING**

### **Part 1: Semester Course in Whole Building Energy Simulation**

A whole building energy simulation course was taught at the School of Architecture, educating 17 students. This was a 3-credit course offered at the graduate and undergraduate levels in the spring of 2012. The course was offered in the evenings to encourage professionals to participate. Of the 17 students who completed the course, four were professional architects from the local community; ten were doctoral graduate students at SOA; three were undergraduate students. Three of the graduate students were participating online because they were located on the mainland US for their semester of practicum experience as a requirement for their degree. One undergraduate student was from a community college and participated online for logistical reasons. Three additional participants (two professionals and one graduate student) started the course but had to drop for reasons of personal time constraints.

The course taught the fundamentals of building science: building systems and components, physics, energy and the utilization of energy simulation software to inform building design. The software used for this course was Design Builder which has an EnergyPlus engine with a graphical interface. All three instructors received online training from a Design Builder instructor in England, Paul Carey. This consisted of 6 sessions of 1 to 2 hours each. Kim Claucherty also funded her own training by flying to England to attend a 1-week intensive course in Design Builder. A perpetual license with 20 seats for Design Builder Version 3 was purchased with the following modules: Visualization, Certification, EnergyPlus, CFD, Daylighting, and HVAC. A student package of 50 users was provided free of charge. (See Appendix A for class flyer and syllabus; slides can be found in the accompanying digital copy of the wiki; see Sea Grant publication, Ka Pili Kai, page 10, for article on the course: [http://sbcd.seagrant.soest.hawaii.edu/sites/seagrant.soest.hawaii.edu/files/publications/ka\\_pili\\_kai-summer2012\\_1.pdf](http://sbcd.seagrant.soest.hawaii.edu/sites/seagrant.soest.hawaii.edu/files/publications/ka_pili_kai-summer2012_1.pdf))

### **Part 2: Whole Day Workshops in Advanced Lighting Design**

Two, all-day workshops were conducted on April 13 and 14, 2012, titled “Methods and Tools for Efficient Lighting Design.” The instructors were: George Loisos, Susan Ubbelohde, and Abe Shameson of LOISOS + UBBELOHDE Architects, Alameda, CA. At the time of the workshop, their company’s projects had received 33 AIA awards, three AIA/COTE Top Ten Green Projects, and six LEED platinum certifications. Two completed buildings and four under construction are net-zero.

A total of 59 people attended the workshops, including college students (13), architects, design professionals and state employees. The workshop covered: the integration of day-lighting and electric lighting; day-lighting components such as sky component, external reflected component, glazing transmission, and internal reflected component; side-lighting and top-lighting; simulation for day-light; and case studies. There were hands-on exercises for conducting light measurements and calibrating a camera in order to capture a high dynamic range image for glare analysis. (See Appendix B for workshop flyer, agenda, and slides.)

### **Part 3: Summer Internships**

Five students participated in part-time summer internships (salaries funded by OWIB) at three local architecture firms (Ferraro and Choi, Architects Hawai'i, and KYA Architects), the Hawaiian Electric Company, and the University of Hawai'i Manoa Campus Planning Office. The purpose of the internship was to allow the interns to utilize and develop their energy simulation skills and to introduce this technology to professionals at their host agencies. Two of the interns were SOA graduate students, two were undergraduate students, and one was an unemployed professional architect.

The interns applied energy simulation analysis to a project at their host agency for 12 weeks. At the end of their term, they presented their final project to the firm. A total of 58 professionals attended presentations, introducing them to the technology of energy simulation.

### **Part 4: Development of Workflow for Using Computational Fluid Dynamics to Study Natural Ventilation.**

Manfred Zapka supervised doctoral student Sanphawat Jatupatwarangkul during an internship in the fall of 2012. This study utilized advanced computational fluid dynamics (CFD) to study natural ventilation. The software used was STAR-CCM+, a comprehensive engineering physics simulation package. The objective was to study the wind pattern around a building and its surrounding buildings, and to determine the pressure differential on the building façade. A work flow was developed that can be used in future studies to use CFD analysis for architectural design. (See Appendix C for a full report.)

## INITIAL OUTCOMES

The effectiveness of an educational program is usually very difficult to evaluate in the short term. This particular program has seen some short-term results that are impressive:

- Five of the ten graduate students in the course have used energy simulation as part of their Doctorate of Architecture dissertation research (graduation date): Christopher Strahle (May 2012); Sanphawat Jatupatwarangkul (Dec 2012); Junghwa Suh, Tuan Tran, and Frank Alsup (scheduled May 2013). Three of these students participated in the class online while they were completing their practicum experience requirement on the US mainland.
- The lighting workshop helped to introduce a student, Tuan Tran, to the principals of the consulting firm, Loisos and Ubbelohde, where he eventually conducted his fall 2012 practicum requirement for his doctorate. This contact greatly influenced his learning and the direction of his doctoral research.
- Tuan Tran also went on to win first prize in an international competition for Design Optimization using energy simulation in December 2012, see link: <http://www.designbuilder.co.uk/content/view/135/206/>.
- Graduate student, Junghwa Suh, has had a paper, "Daylighting as a synthesis tool in the early stage of an urban-scape design," accepted for presentation at two conferences in 2013: "The 18th International Conference of the Association of Computer-Aided Architectural Design Research" to be held at the National University of Singapore and "The 15th CAAD Futures 2013 International conference " to held at Tongji University, Shanghai, China.
- The most promising result of this initial effort, which could have very long-term effects, is that the success of this program has stimulated the School of Architecture to elect to continue offering the course. The spring 2013 course is taught by Manfred Zapka who has now earned the status of adjunct professor at the School of Architecture and has proven to be an excellent instructor. The course is supported by tuition funds.





## **APPENDIX A**

Energy Simulation Class Flyer

Energy Simulation Class Syllabus

Energy Simulation Class Syllabus Addendum



# Energy Simulation Training

Interested in learning and understanding energy analysis?

Sign up for a spring semester energy simulation training class Application Required for Scholarships  
Offered through the Environmental Research and Design Laboratory (ERDL) and UH Physical,  
Environmental, and Long Range Planning Office and Funded by Oahu Workforce Investment Board



## Course Information

Up to 15 scholarships will be awarded

Starts: January 10, 2012

Ends: May 2, 2012

Course Hours: Tuesdays and Thursdays 5:30pm-7:30pm

Class Location: ERDL and online

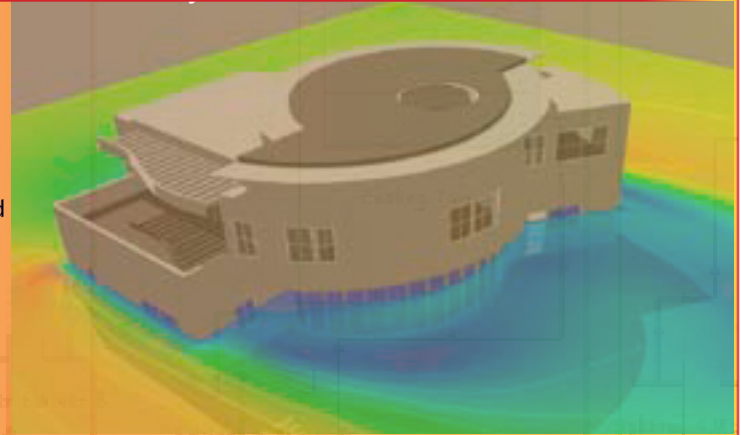
Applicants not offered scholarship must register and pay through UH

Outreach College for credit (3)

Contact: Eileen Peppard

E-mail: epeppard@hawaii.edu

Phone: 808-956-2861



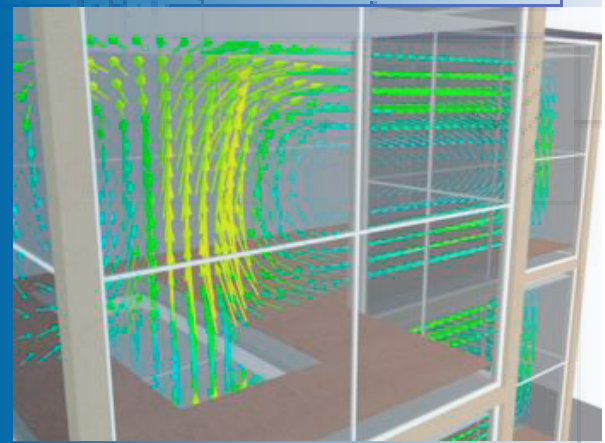
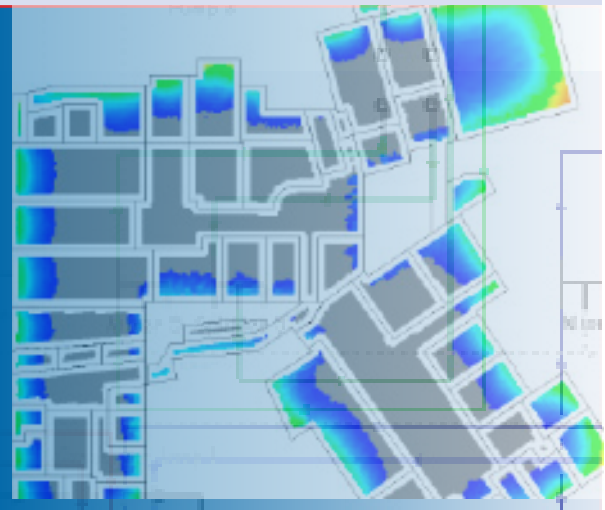
# Using DesignBuilder Software

## Course Objective:

To instruct students to a level of technical proficiency where basic building modeling and energy analysis can be undertaken. The student will learn how the energy analysis informs building design. Upon completion of the course and lab, student should be able to:

- Input and model a basic structure with multiple walls and wall planes, a roof, at least one mechanical system, various lighting systems, building projections including vertical fins and window overhangs, and thermal mass in the floor.
- Run parametric analyses varying one variable at a time to determine the impact of that particular variable. Variables include HVAC efficiency, overhang depth, window characteristics, etc.
- Be familiar with using and building system libraries such as mechanical systems, window types, wall and roof assemblies, etc. This would require fundamental knowledge of building systems including R Value, U-value, film coefficients, and HVAC efficiency terminology. Also will need familiarity with basic thermodynamics: conduction, convection, radiation, familiarity with basic solar principals such as sun path, altitude, azimuth, etc.
- Understand the capabilities and constraints of the software program and resulting analysis.

8 students will be selected for a paid practicum after a thorough interviewing process at the end of the course.



"We are a community partner creating opportunities to improve the quality of life for the people of Oahu".  
Department of Community Services  
City and County of Honolulu

The State Energy Sector Partnership is funded by the American Recovery and Reinvestment Act of 2009 and made available through the U.S. Department of Labor - Employment and Training Administration. All American Recovery and Reinvestment Act funds must be used in compliance with Federal Equal Employment Opportunity regulations



DRAFT

## Arch 692: Whole Building Energy Simulation: Using DesignBuilder

Instructors: Kim Claucherty  
Manfred Zapka  
Somers Reid

Email: [suman@hawaii.edu](mailto:suman@hawaii.edu)  
[mzapka@hawaii.edu](mailto:mzapka@hawaii.edu)  
[somersr@gmail.com](mailto:somersr@gmail.com)

### **Course Organization:**

Credit Hours: 3  
Room: Arch 101C – Environmental Research and Design Lab and ONLINE through GoToMeeting  
Class Hours: T/R 5:30-7:30 pm (January 10 thru May 2, 2012)

### **Course Contact:**

Eileen Peppard 808-956-2861  
[epeppard@hawaii.edu](mailto:epeppard@hawaii.edu)

### **Course Description:**

This course will provide a solid background in the fundamentals and analysis of building energy simulation and will teach the use of DesignBuilder energy simulation software to analyze whole building energy use. Both modeling and analysis in DesignBuilder will be done. DesignBuilder provides a user-friendly interface to the EnergyPlus building simulation engine, a free software developed by US DOE.

### **Instructional Methodology:**

The class will meet twice weekly for 13 weeks followed by 3 – 4 weeks of final project specific guidance. Additionally, for students seeking course credit, 2 to 3 research papers will be assigned that will involve separate discussion from normal class meetings.

### **Course Objectives:**

To instruct students to a level of technical proficiency where basic building modeling and energy analysis can be undertaken. The student will learn how energy analysis informs building design. Upon completion of the course, student should be able to:

- a. Input and model a basic structure with multiple walls and wall planes, a roof, at least one mechanical system, various lighting systems, building projections including vertical fins and window overhangs, and thermal mass in the floor.
- b. Run parametric analyses varying one variable at a time to determine the impact of that particular variable. Variables include HVAC type and efficiency, building operating schedules, overhang depth, window characteristics, etc.
- c. Be familiar with using and developing system libraries such as mechanical systems, window types, wall and roof assemblies, etc. This would require fundamental knowledge of building

systems including R-value, U-value, film coefficients, and HVAC terminology. Students will also develop familiarity with basic thermodynamic: conduction, convection, radiation, familiarity with basic solar principals such as sun path, altitude, azimuth, etc.

- d. Students will develop an understanding of the capabilities and limitations of DesignBuilder and the resulting analysis.

**Course Material (posted on Laulima):**

Weekly presentations  
Weekly class video  
Section quizzes  
Recommended readings  
Etc.

**System Requirements (to use DesignBuilder and EnergyPlus):**

Software: DesignBuilder and CD-Adpco (We will forward more Information on CD-Adpco).  
Student licenses to both software programs will be provided to each student.  
Hardware: **See Hardware requirements below.**

**Prerequisites:**

For upper level architectural students only (if credit is desired). No prerequisites.

**Policies/Late Assignments:**

Attendance at all classes is expected (either online or in person). Unexcused absence, tardiness, disturbing the learning of others, or poor performance is grounds for administrative action. Late assignments, failure to participate in class discussions and presentations, etc. will not be excused.

**Grade:**

The final grade will be based on class assignments, quizzes, class attendance/participation, and work progress/effort. A letter grade drops per day for each late assignment; no late final projects will be accepted.

Final project (30%)  
Section quizzes (15% for 4 quizzes)  
Class attendance (10%)

**Notes:**

1. The above grading breakdown is approximate.
2. Grades will be awarded in accordance with University Rules: For the grade of "A", the student must satisfy the course objectives excellently; for "B", in an above average manner; for "C", in an average manner; for "D" in the lowest acceptable manner; and an "F" denotes that the student has not satisfied the course objectives. A curve will be applied to the final grade distribution.
3. Examinations, quizzes, homework, and projects must be the individual work of the student who submits it unless assigned as a joint assignment. It is dishonest to submit as your own work anything that is copied, reproduced electronically or in any other way not done completely by

yourself. Incidents of dishonesty will be handled according to University procedures governing cheating and plagiarism. The following penalties may be assessed:

- a. An "F" in the course for dishonesty in any assignment, examination, paper, quiz or project.
- b. Any students who are involved in group action which makes possible cheating or plagiarism shall be subject to the same penalties as if they themselves had cheated or plagiarized.

**Recommended Tutorials (DesignBuilder):**

<http://www.designbuilder.co.uk/content/view/105/161/>

**Office Hours/By Appointment:**

Kim Clacherty: Email – [suman@hawaii.edu](mailto:suman@hawaii.edu) (808-956-2861)  
Tues, 9:00 to 11:00 am (HIG 205)

Manfred Zapka: Email – [mzapka@hawaii.edu](mailto:mzapka@hawaii.edu)

Somers Reid: Email – [somersr@hotmail.com](mailto:somersr@hotmail.com)  
Mon-Friday, ERDL, (Architecture (101C)  
Phone: (808-956-0487)

# Hardware Requirements

## Solution

DesignBuilder is a professional graphics application and requires a reasonably high standard of computer hardware for successful use. This page contains information on the minimum system requirements and also the recommended specification. The main areas you should pay attention to if you are buying or upgrading your computer system to run DesignBuilder are:

- **Graphics adapter** - A good 100% OpenGL compatible graphics adapter is required to run DesignBuilder. The mid-range and better NVIDIA cards seem to be the most reliable. Some graphics adapters integrated with the motherboard are unable to run DesignBuilder. See also note below on Windows Vista.
- **Memory** - DesignBuilder will use all the memory you can throw at it - at least 2 GB is recommended.
- **CPU speed** - Get as fast as you can afford.
- **Cores** - Having more than one processor core does not necessarily speed up simulations in DesignBuilder but it does allow you to continue using your computer while simulations are running. Dual and Quad core processors also make the software more responsive in use.

### Minimum Requirements

Windows 7, Vista, XP running on 1000 MHz processor  
800x600 pixel screen  
2 GB RAM  
200 MB free disk space  
Pointing device  
100% OpenGL compatible  
3D graphics adapter with hardware acceleration running in 32-bit color mode

The above specification will allow you to successfully model small buildings with DesignBuilder but a more powerful computer is recommended especially when working with larger building models.

### Recommended

Windows 7  
2.4 GHz dual core processor or faster  
Dual or Quad Core processors are recommended as they allow you to continue using your computer while simulations are carried out  
4 GB (or more) RAM  
5 GB free disk space  
Pointing device

100% **NVIDIA graphics adapter** with hardware acceleration running in 32-bit color mode. 1280x1024 pixels or larger screen for efficiency during the modeling process and for displaying high-quality visualization images and walk-through of DesignBuilder models and CFD results. DesignBuilder works well with wide screens, but very high screen resolutions can cause problems, e.g. large Mac screens.

### Windows 7 and Vista

DesignBuilder works well under Windows 7 and Vista, but you must ensure that you follow the advice on the support knowledgebase to switch off desktop composition and set XP-compatibility mode.



## **ARCH 692**

### **Addendum to course syllabus: (February 26, 2012)**

There have been some changes to the original course content, schedule and class assignments.

The methods to determine the overall grade of the course, e.g. allying distributed weights to the different class assignments, exams, class project work and attendance has been reported to you in a separate document and this was discussed in class.

#### **Course project work:**

The project work will be carried out in groups of preferably not more than three members, but can also be carried out on an individual level; e.g. having one person working on the project rather than a group. If the project work is carried out by an individual person, the expected scope of the elaborated report and building analysis will be less than the scope of report and analysis conducted by a group. The details of the assessment will be made on an individual level by the assigned instructor.

#### Steps in the project work:

1. Form groups of decide to do an individual course project.
2. Get an understanding of what the project will be about
3. Select an assigned instructor.
4. Work with the assigned instructor to delineate the project work proposals.
5. Write the proposal and submit to assigned instructor. (Due March 29, 2012)
6. Get the approval of the assigned instructor
7. Prepare a presentation to explain the proposal to the class (Class session April 3, 2012)
8. Commence project work and work with assigned instructor as needed
9. Compile the report and prepare the most important findings in forma of a PPT presentation
10. Present the major findings and conclusions in front of class (Class session April 19, 2012)
11. Depending on the feedback received in the presentation in class and final input of the assigned instructor compile the report and submit the completed report not later than April 26, or arrange with assigned instructor if different date is needed.

The grade for the project will be an evaluation of the entire process of the course work by the assigned instructor.

**Added:** Office hours of Manfred Zapka are Thursdays, 11:45 am to 1:45 pm, or by appointment or by e-mail for the online course participants; room ARCH 310 M. If you have questions or if you want to evaluate prospects of working with Manfred, please contact me at [Mzapka@hawaii.edu](mailto:Mzapka@hawaii.edu)

**Research paper:**

As already discussed in class the research paper is not mandatory but it is an elective, for which up to 20% (25% for an exceptional research paper) extra grade points can be awarded that will count towards the overall course grade.

The approach how to conduct the work on the research paper as well as the method of grading will be dependent on which assigned instructor you work with:

**Steps in the research paper:**

1. Conduct initial research on what aspect of building analysis you want to work in the research paper.
2. Write a draft proposal outlining the areas that you want to address and what you hope to achieve. (due March 1, 2012)
3. Select an assigned instructor who will be working with you. (Note you will work with the assigned instructor for the entire length of the research paper)
4. Work with the assigned instructor on the final proposal; which should be the plan and schedule for the research project. Note that the finalized proposal will lay out a concise planning of the research and establish a framework of purpose, approach and resources. The work on the plan and schedule for the research paper will be an integral part of the learning experience of research paper. Learning more about how to plan and execute research will help you in your future studies and projects.
5. Conduct the research and hold weekly discussions with the assigned instructor.
6. Write a draft report and discuss with the assigned instructor. (Due April 19, 2012)
7. Prepare and deliver a presentation to the class (on April 24 or 26, 2012; TBD)
8. Complete the final paper not later than May 1, 2012 and submit to the assigned instructor.

## **APPENDIX B**

Lighting Workshop Flyer

Lighting Workshop Agenda

Lighting Workshop Slides

Lighting Workshop Camera Calibration



# METHODS AND TOOLS FOR EFFICIENT LIGHTING DESIGN WORKSHOP

Lighting costs U.S. businesses and consumers more than \$50 billion each year and accounts for 18% of the total energy use of buildings - LBNL.

Friday, April 13, 2012

8:00 am - 12:00 noon

State Office Tower #1403

235 S. Beretania Street

or

Saturday, April 14, 2012

9:00 am - 1:00 pm

UH Manoa, School of Architecture #215

2510 Campus Road

Breakfast will be provided both days

These 4-hour workshops will explore cutting edge methods and tools available to lighting and other design professionals, and industry representatives to design effective, creative, low energy luminous environments.



To Register:

IES members/lighting industry,  
please contact-

Howard Wiig at 587-3811

hwiig@dbedt.hawaii.gov

Design professionals/students,  
please contact-

Kim Suman Claucherty at 956-2861

suman@hawaii.edu

State employees/interns, please contact-

Gail Suzuki-Jones at 587-3802

gsuzuki@dbedt.hawaii.gov

Unemployed/underemployed building  
professionals, please contact-

Eileen Peppard at 956-2861

epeppard@hawaii.edu

Please Contact

<http://sbcd.seagrant.soest.hawaii.edu/lighting-workshop>

for parking and other information

Sponsors



University of Hawaii at  
Manoa



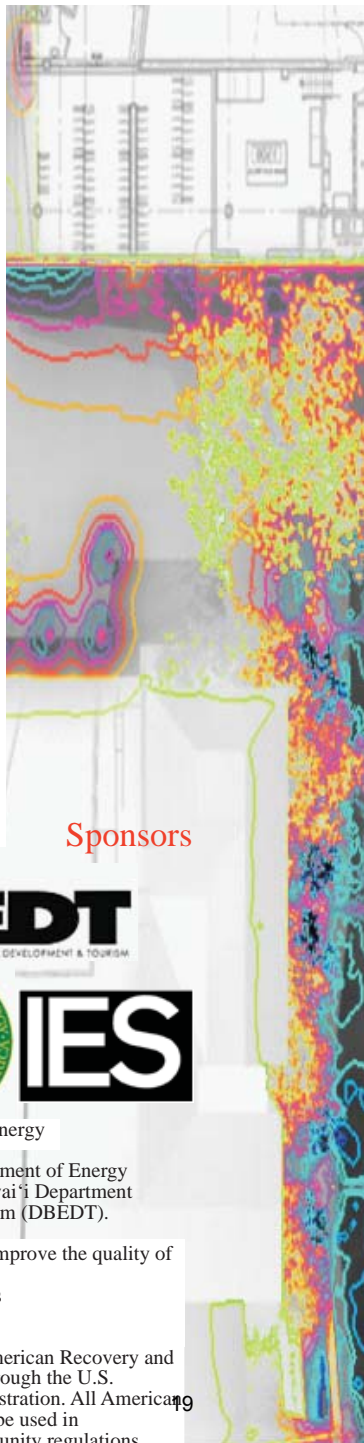
US Department of Energy

This workshop is partially funded by a U.S. Department of Energy (DOE) award #DE-EE0000216 to the State of Hawaii's Department of Business, Economic Development and Tourism (DBEDT).

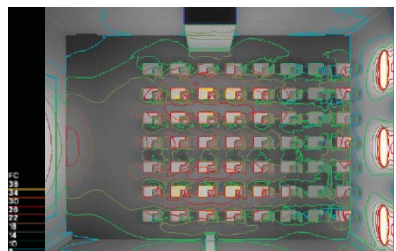
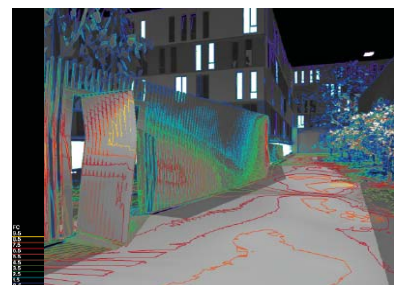
"We are a community partner creating opportunities to improve the quality of life for the people of Oahu".

Department of Community Services  
City and County of Honolulu

The State Energy Sector Partnership is funded by the American Recovery and Reinvestment Act of 2009 and made available through the U.S. Department of Labor - Employment and Training Administration. All American Recovery and Reinvestment Act funds must be used in compliance with Federal Equal Employment Opportunity regulations



This workshop will be taught by George Loisos, AIA, LEED AP and Susan Ubbelohde, LEED AP, of Loisos + Ubbelohde, San Francisco. Their projects have received 33 AIA awards, three AIA/COTE Top Ten Green Projects, and six LEED platinum certifications. Two completed buildings and four under construction are net-zero energy buildings.



LOISOS + UBBELOHDE

ARCHITECTURE. ENERGY  
[www.coolshadow.com](http://www.coolshadow.com)



## METHODS AND TOOLS FOR EFFICIENT LIGHTING DESIGN

April 13 and 14, 2012

Introductions and breakfast

### I. A NEW APPROACH TO LIGHTING: Daylighting and Energy Efficiency

Case Study: Loisos + Ubbelohde Office, Alameda CA

Integration of Daylighting and Electric Lighting

Exhibition Gallery

University Dormitory

Auditorium

Daylighting Components

Sky Component

External Reflected Component

Glazing Transmission

Internal Reflected Component

Sidelighting (windows and curtain wall)

Toplighting (skylights)

Simulation for Daylight

Case Study: NASA Sustainability Base

### II. MEASUREMENT: A Hands-on Exercise

### III. STRATEGIES, SOURCES AND FIXTURES

The Energy Context

Strategies: Lobby, Laboratory, Classroom, Office, Hallway, Decorative

Sources & Fixtures: T5, T8, LED, OLED

### IV. CONTROLS

Sun Control

Electric Lighting Controls

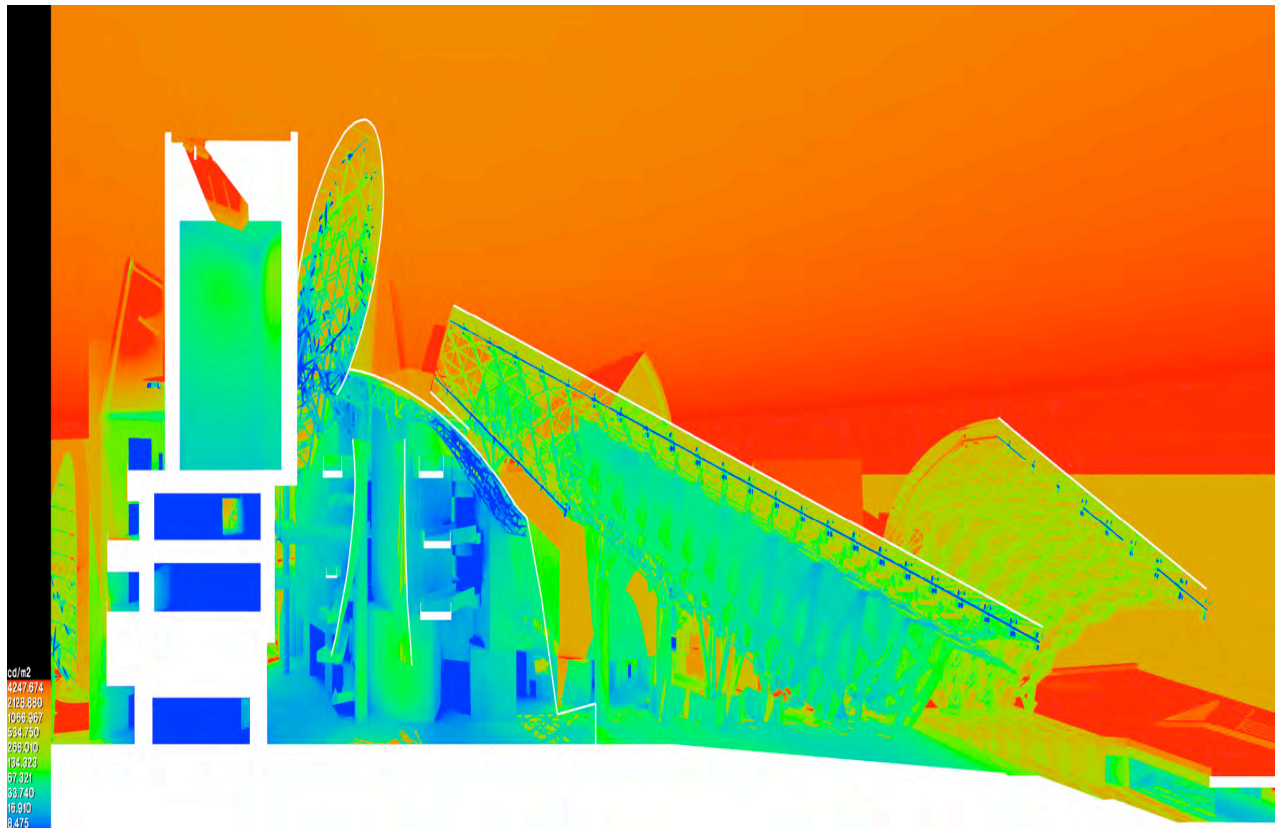
### V. High Dynamic Range (HDR): A Hands-on Exercise





# METHODS AND TOOLS FOR EFFICIENT LIGHTING DESIGN WORKSHOP

April 13 and 14, 2012

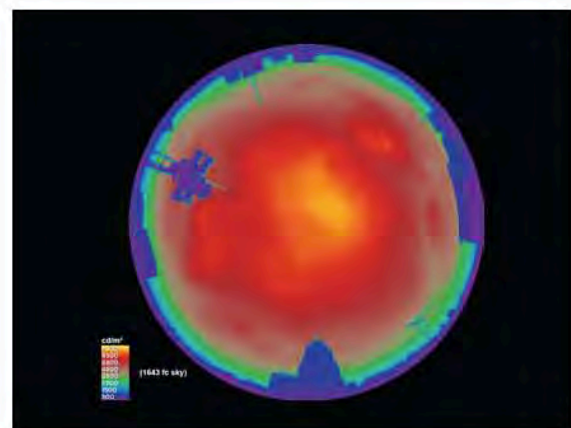
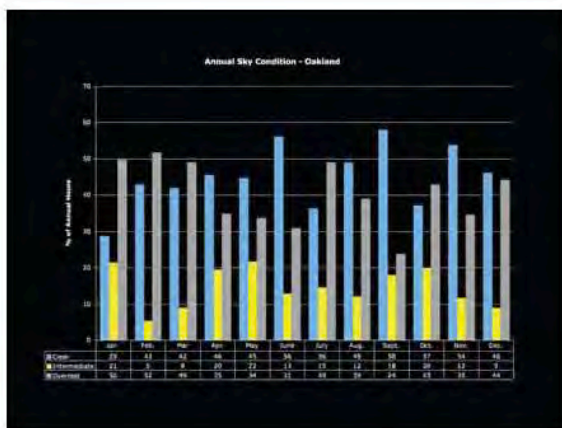
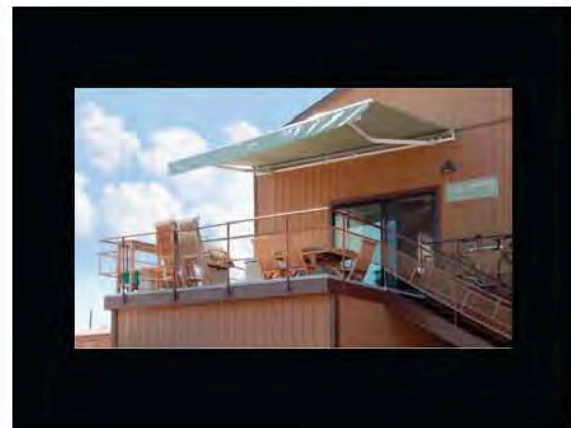




I. A NEW APPROACH  
TO LIGHTING:

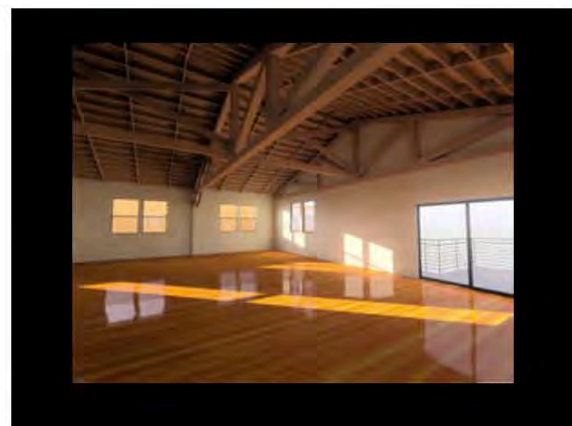
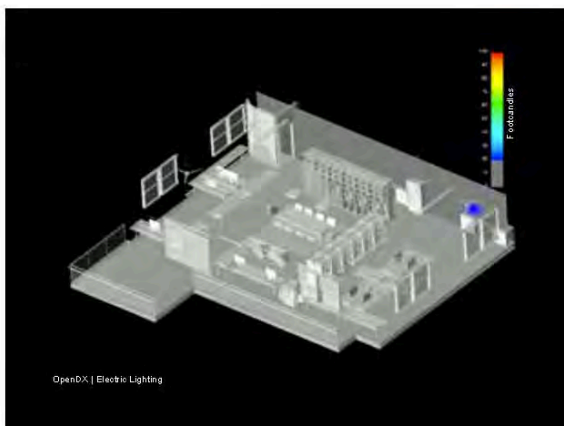
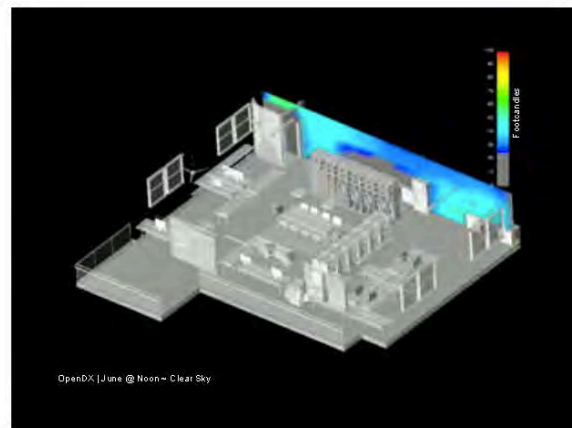
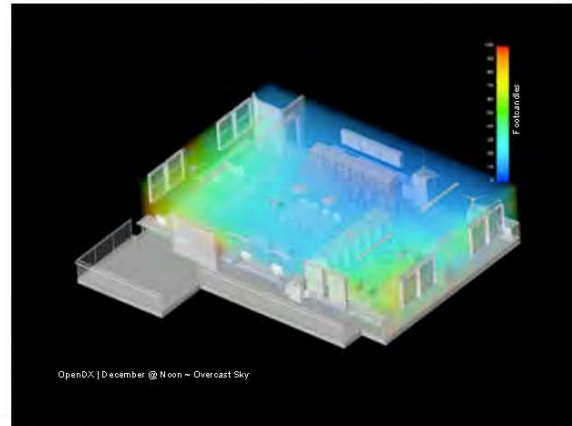
DAYLIGHT & ENERGY EFFICIENCY

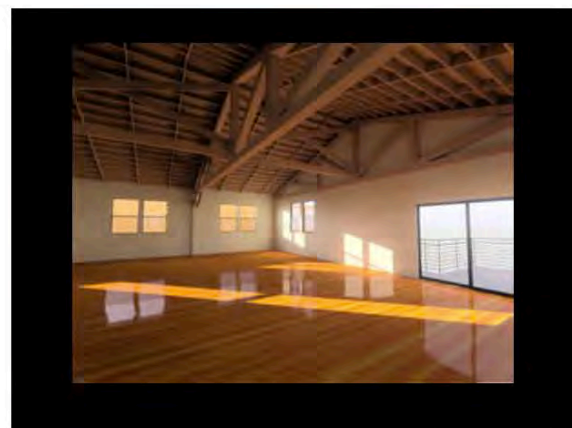
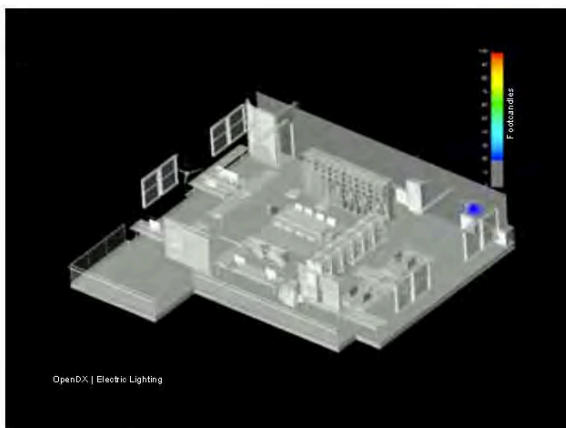
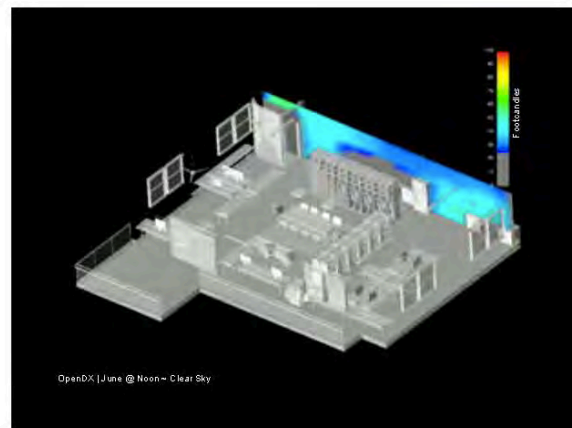
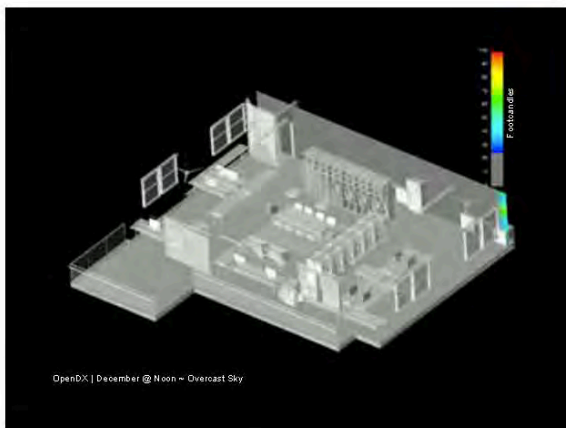
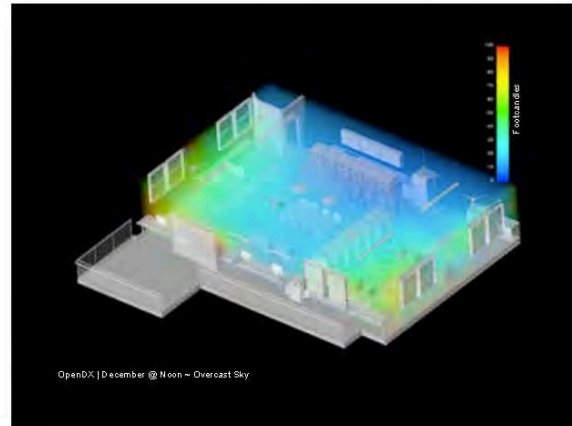
LOISOS + UBBELOHDE  
ARCHITECTS

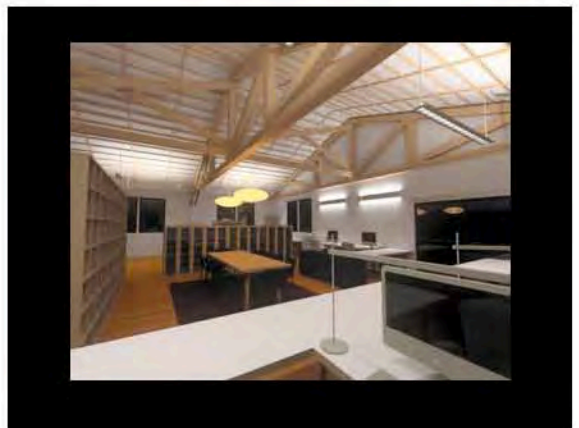
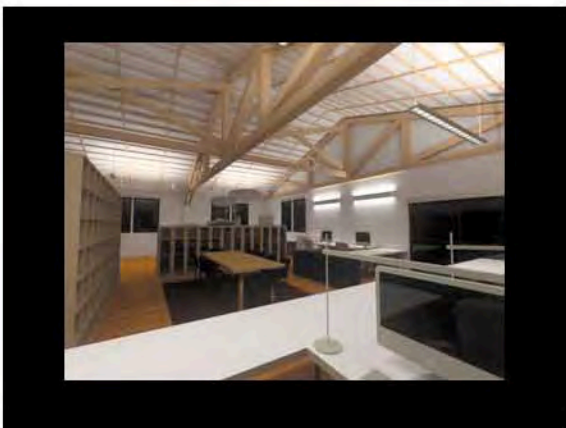
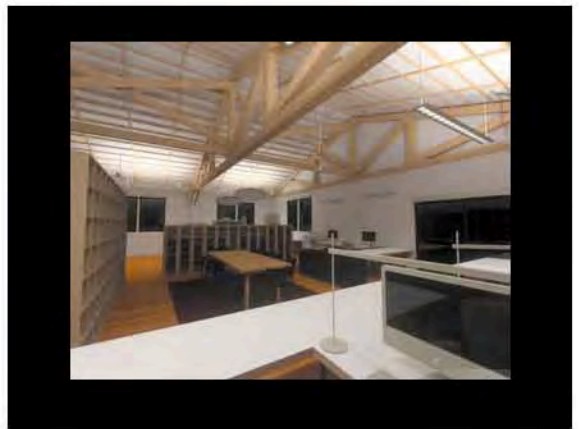




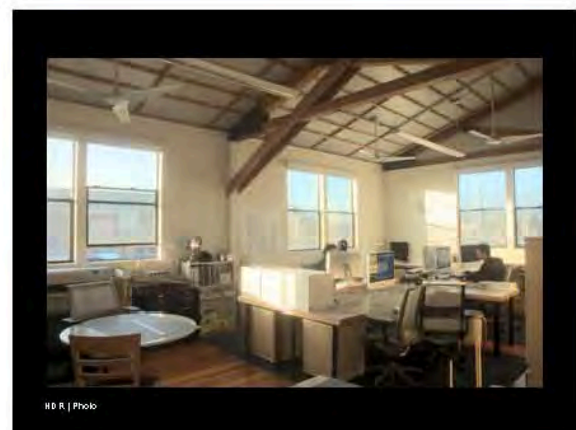
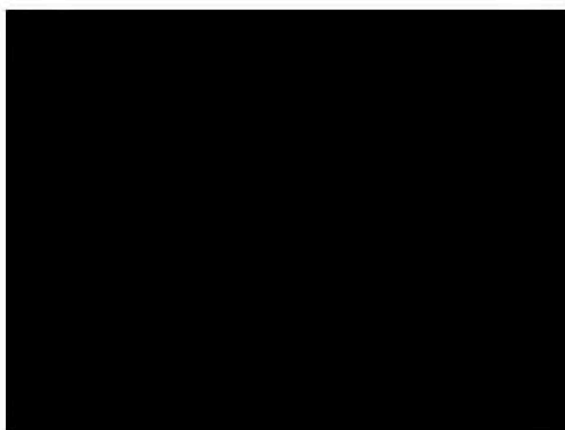
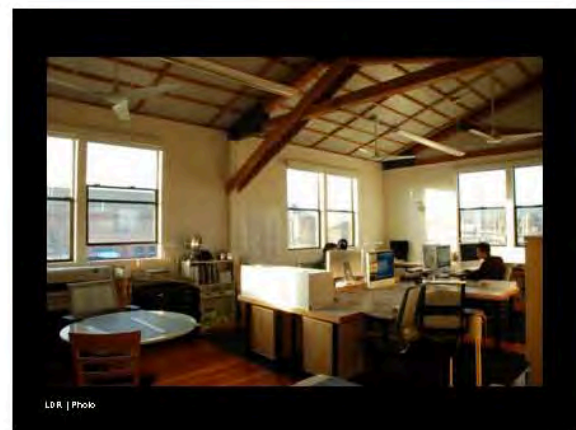
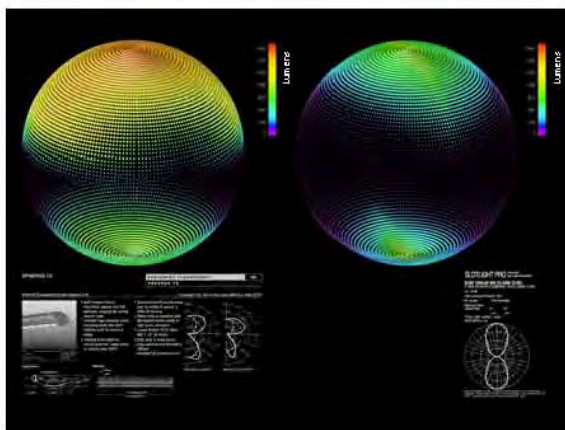
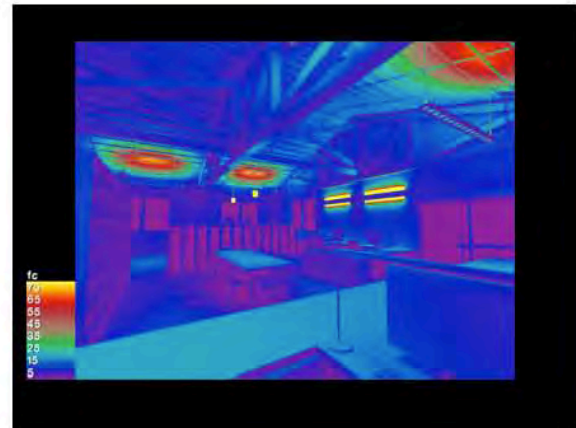
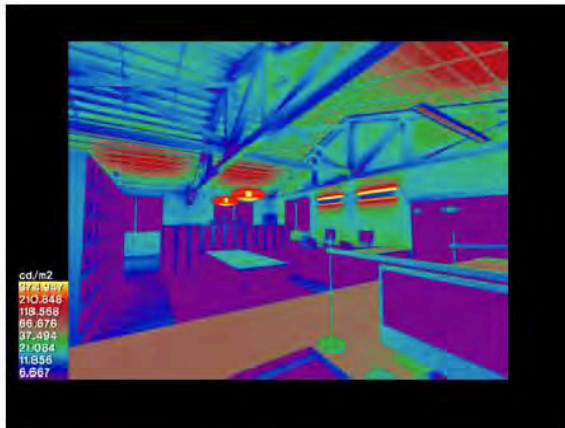


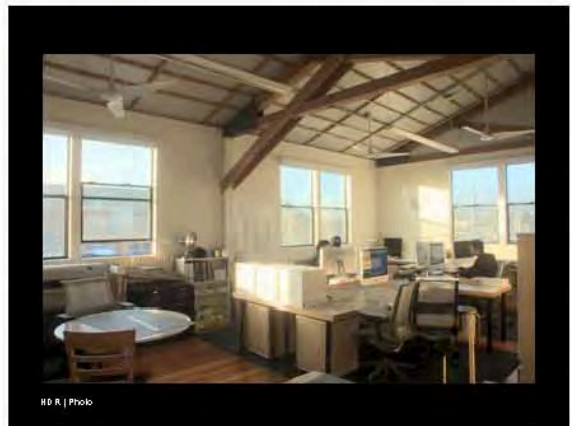
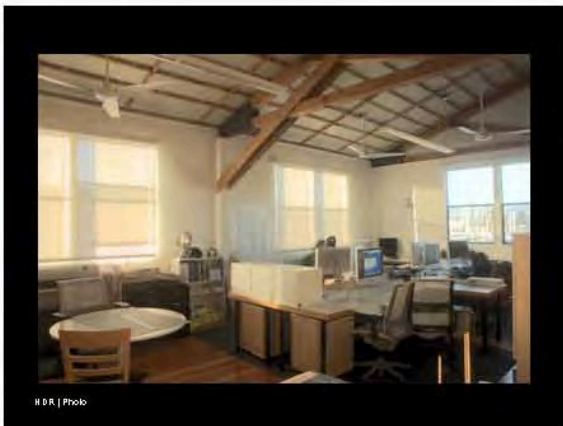
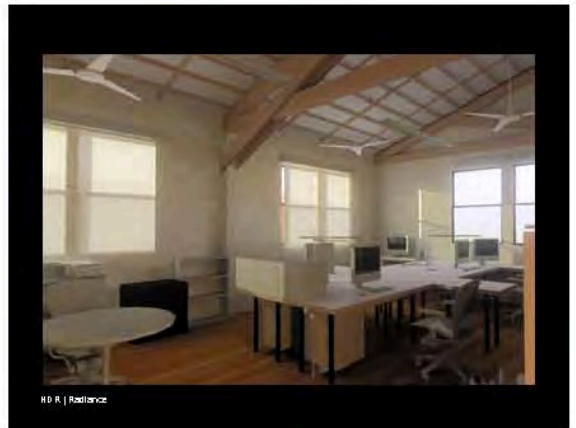
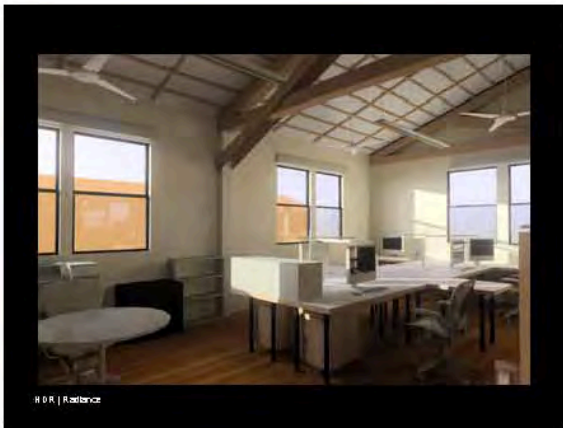




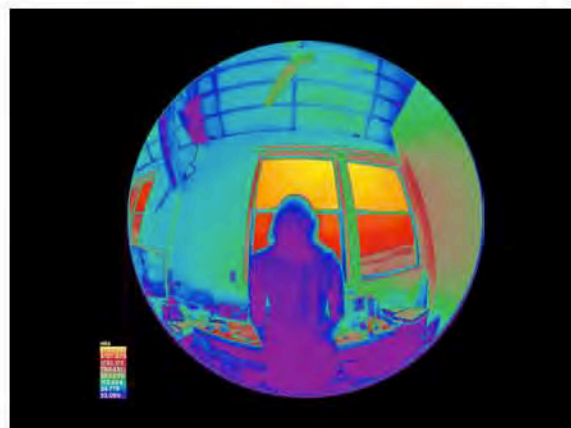
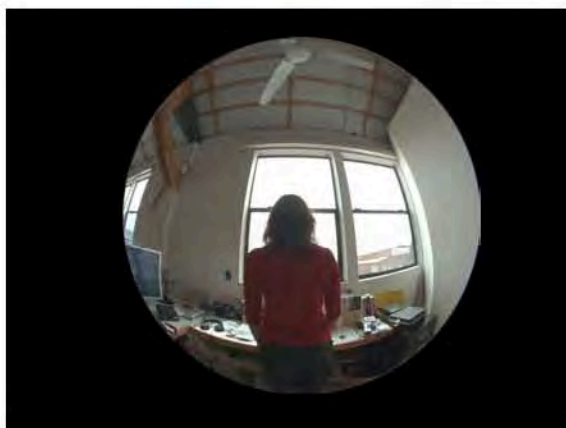
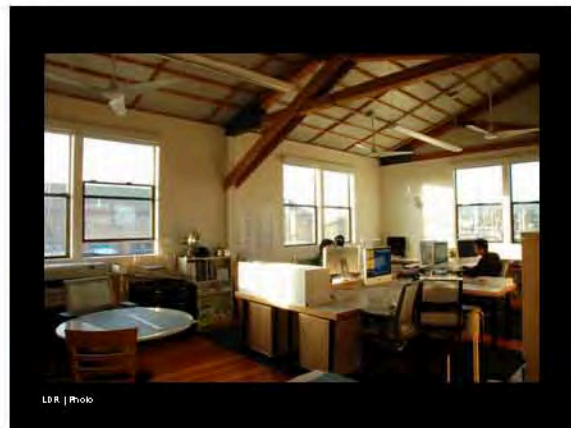
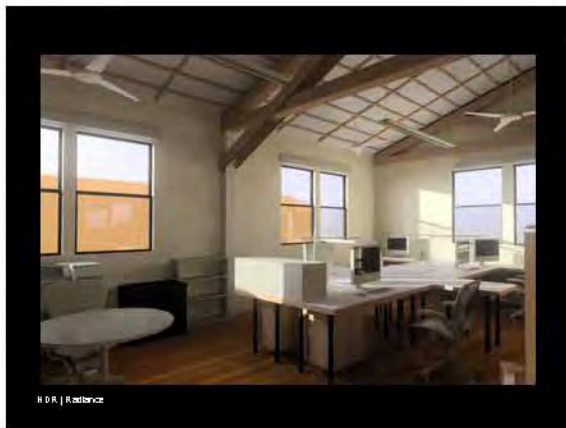


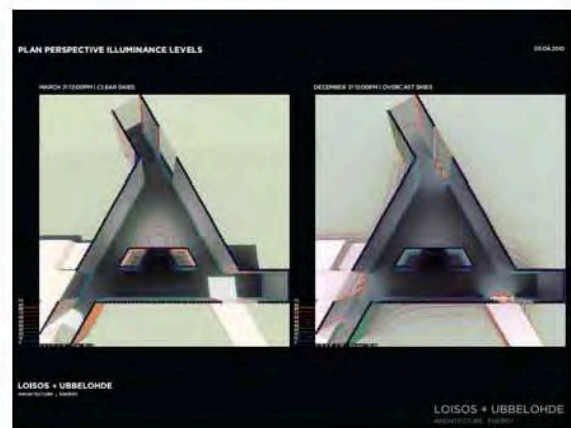
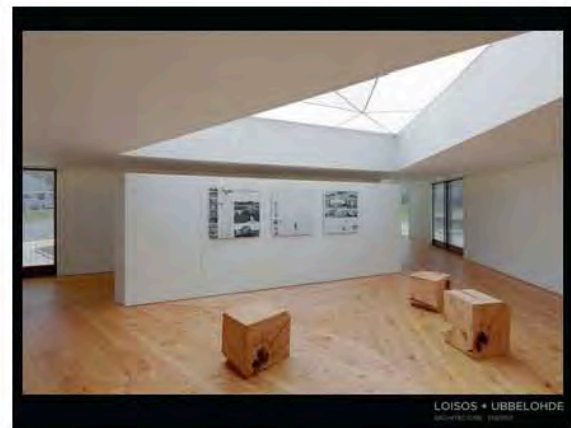
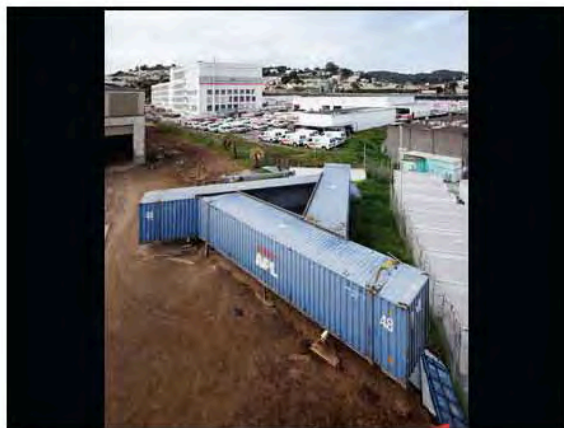


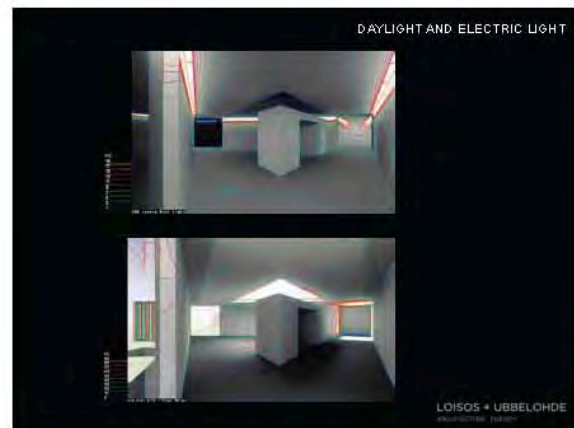
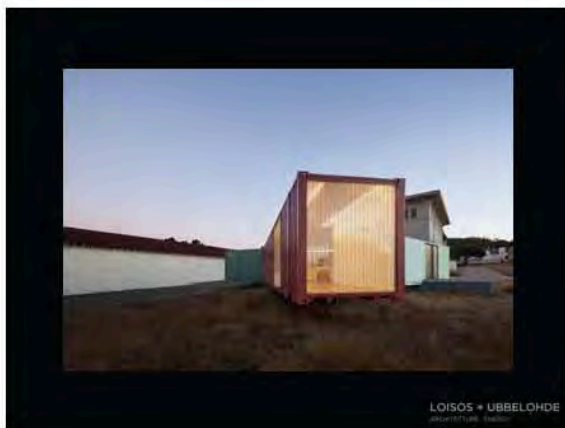
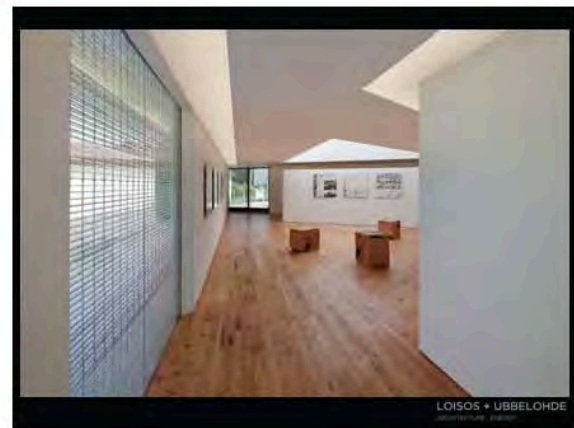
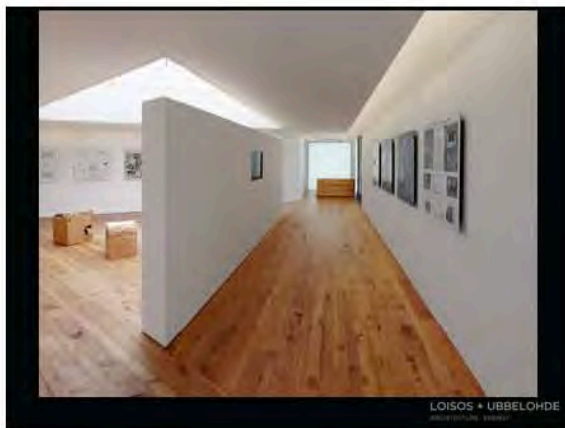
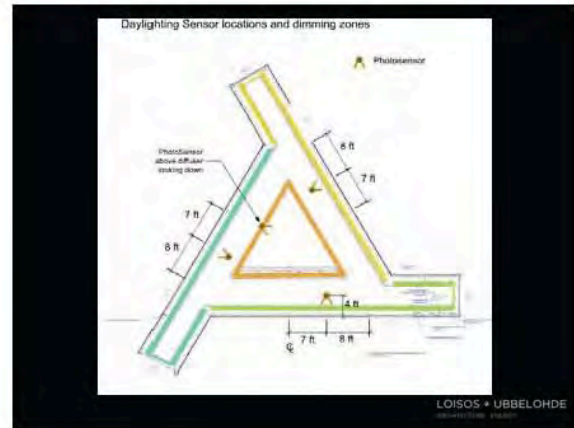




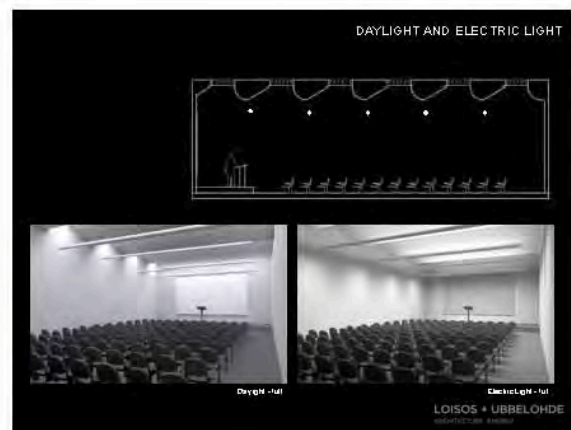
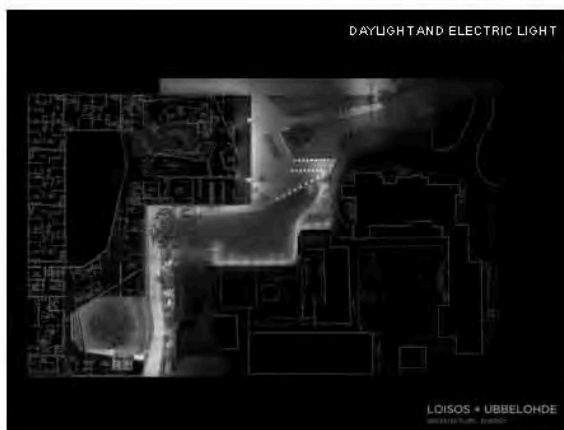
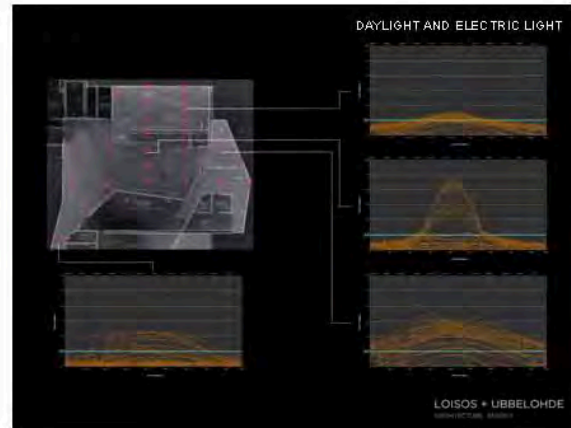
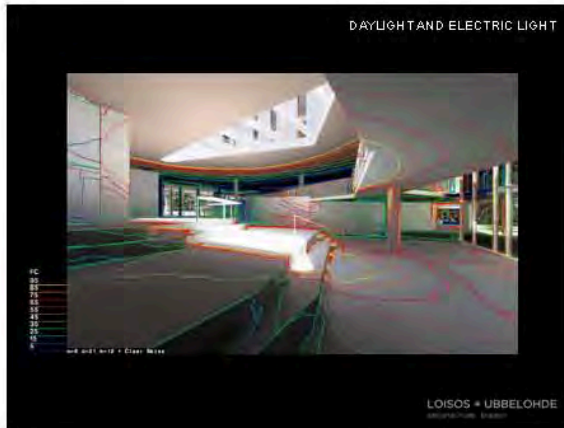


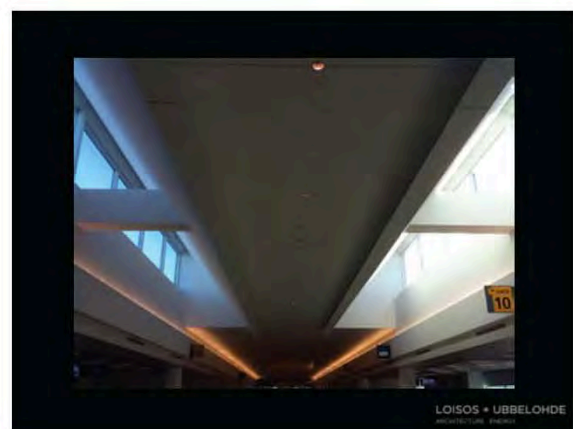
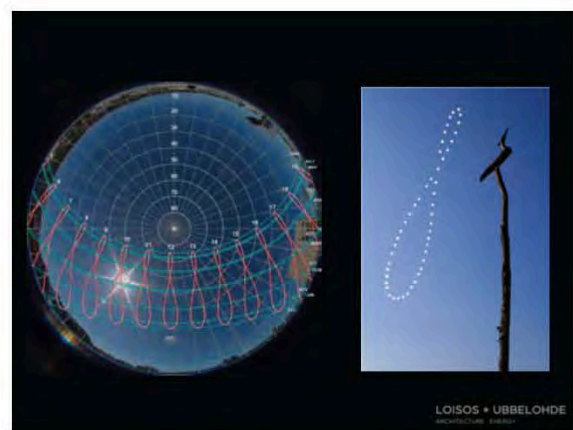
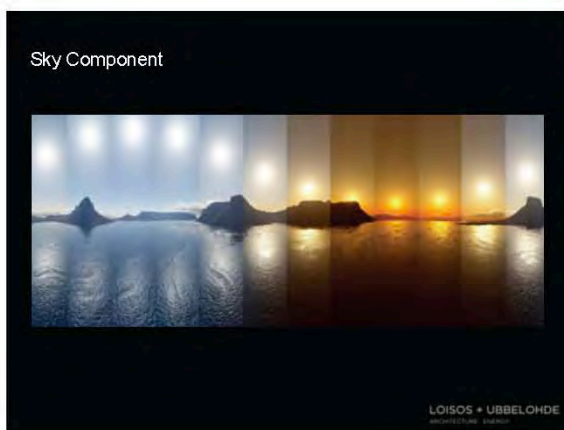
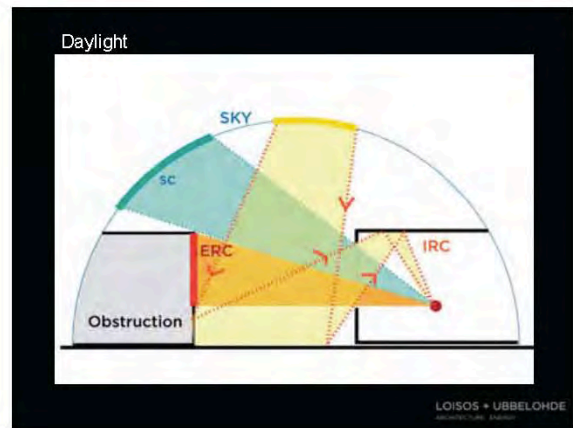
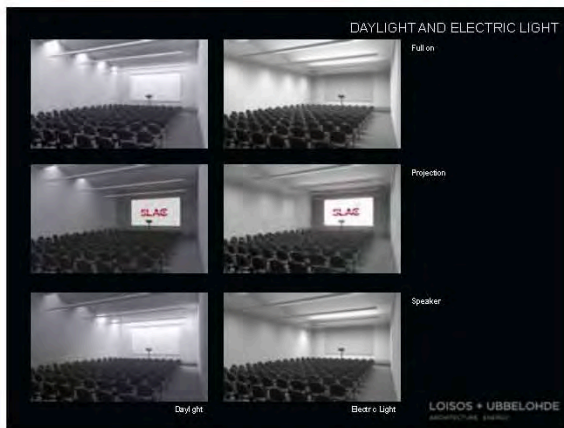


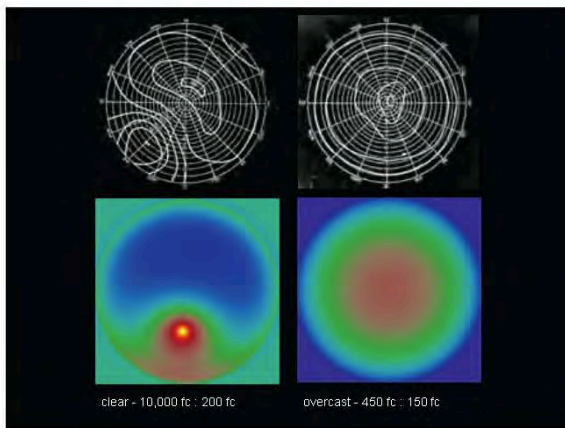
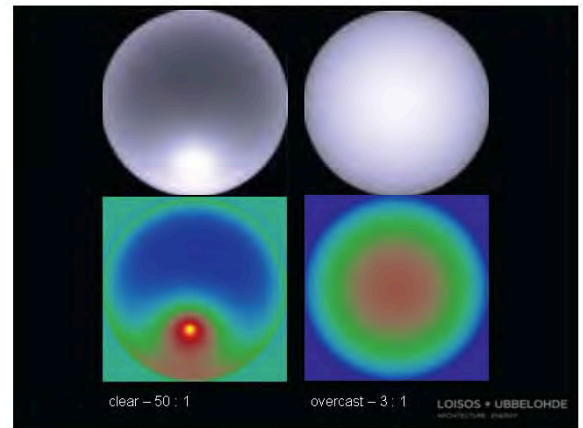





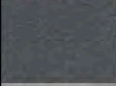





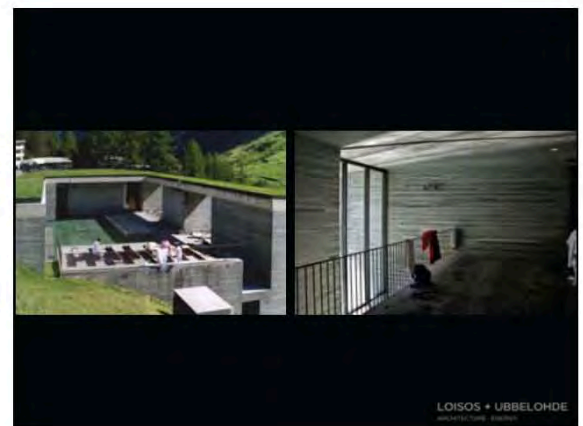




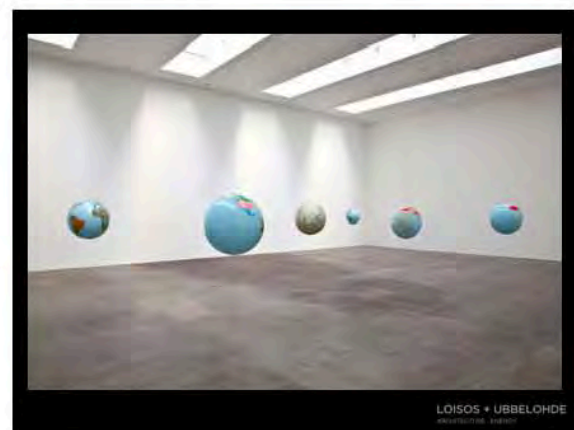
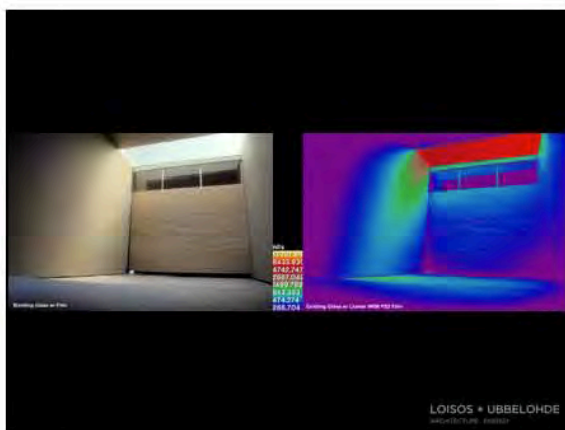
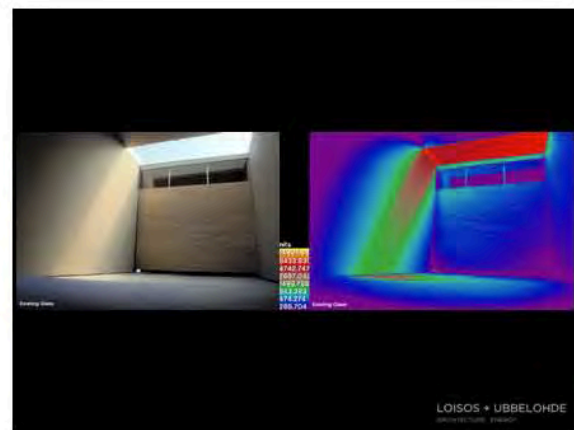
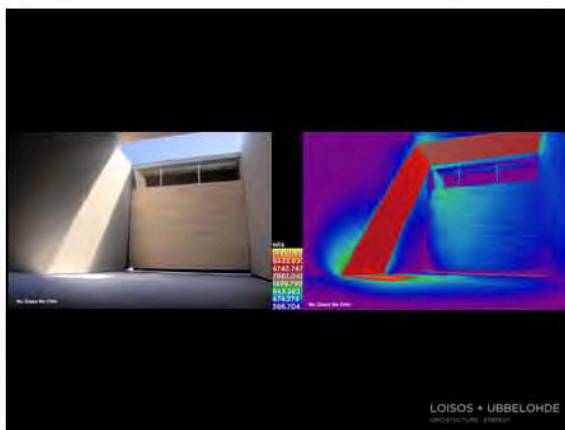
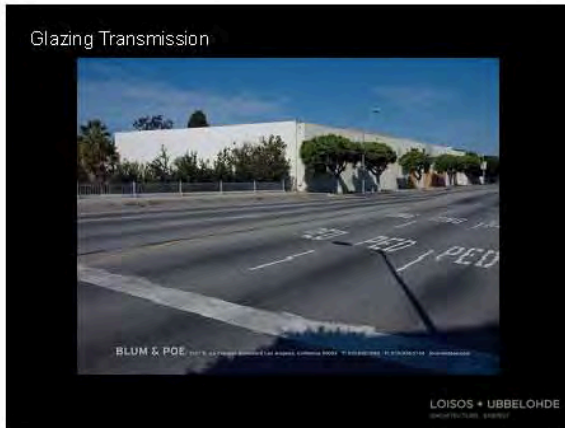
LRV - light reflectance value  
MEEB Table 14.9 Reflectances of Building Materials and Outside Surfaces

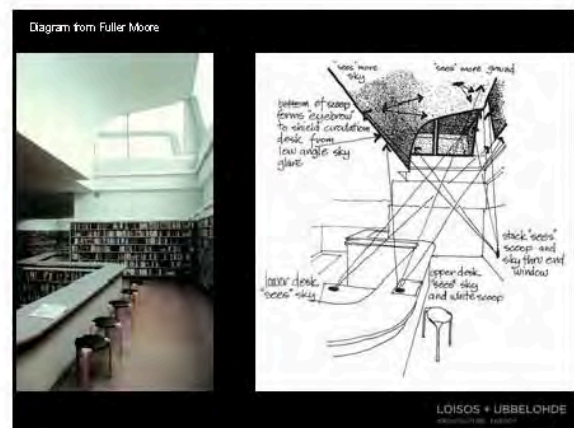
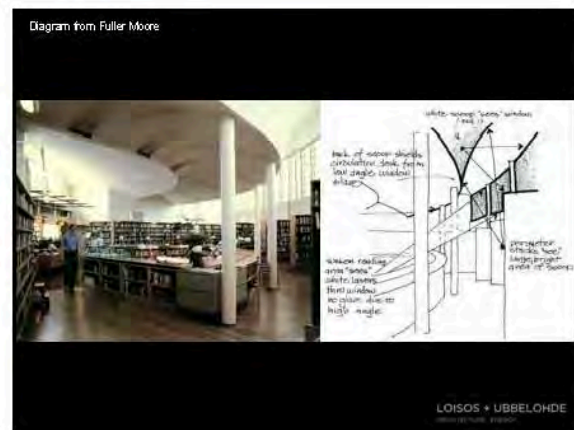
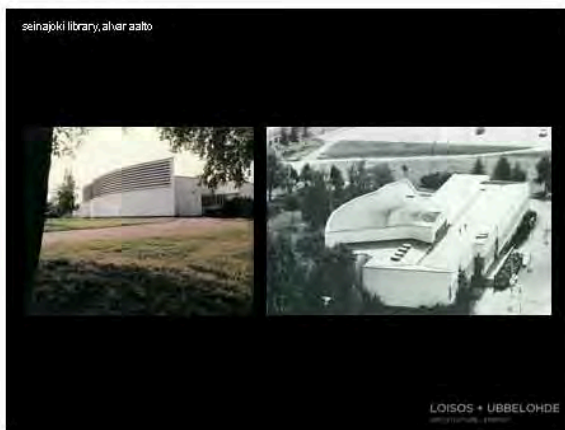
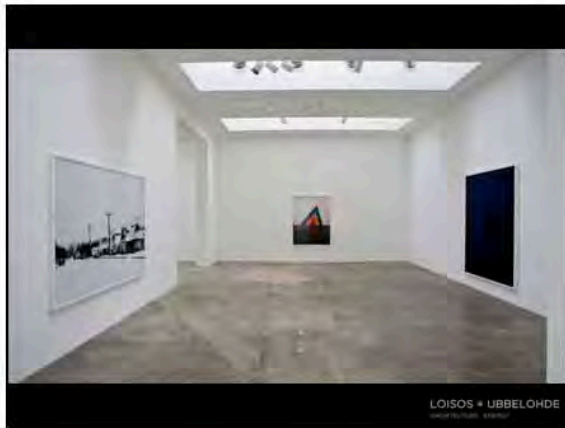
	Grass	6%
	Asphalt	7%
	Concrete	55%
	White Matte	80%

LOISOS + UBBELOHDE  
ARCHITECTURE + ENGINEERING



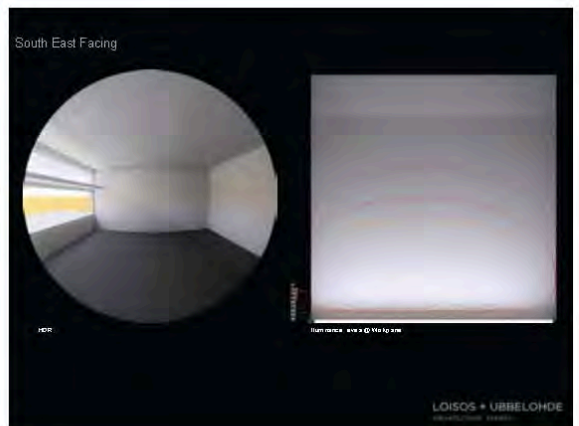
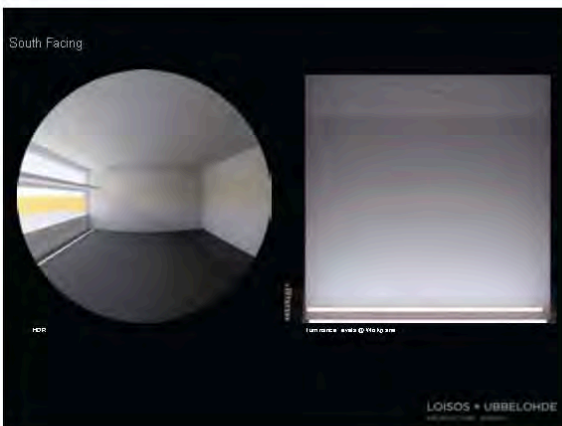
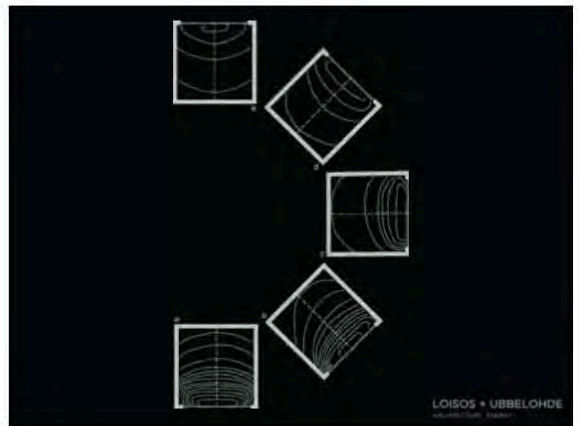
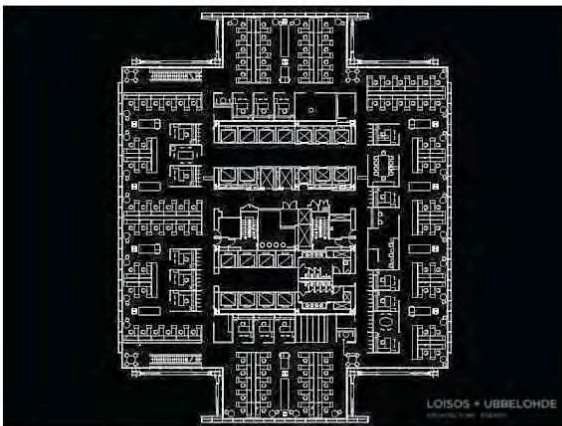


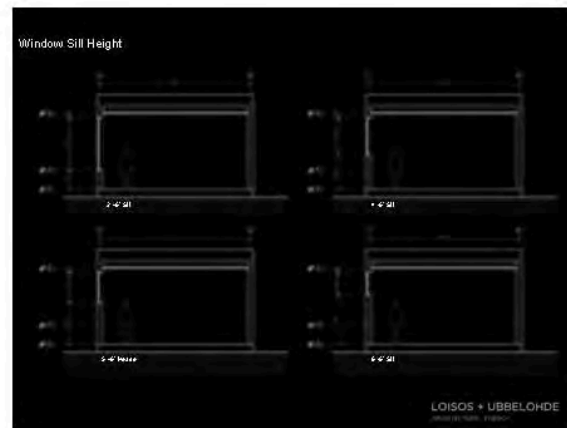
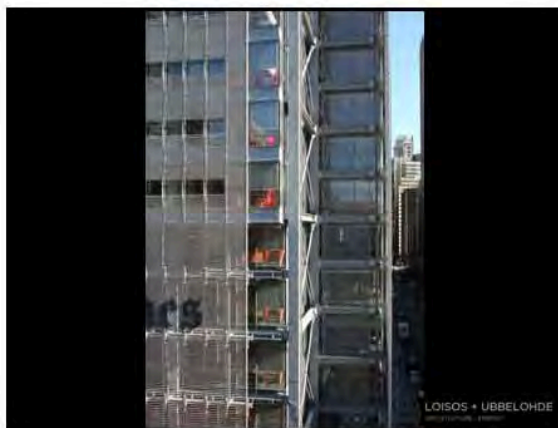
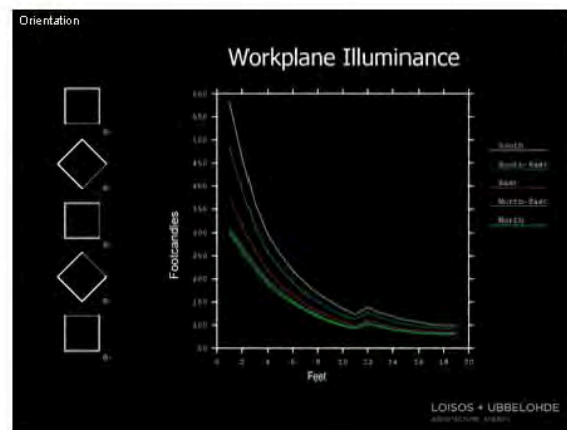
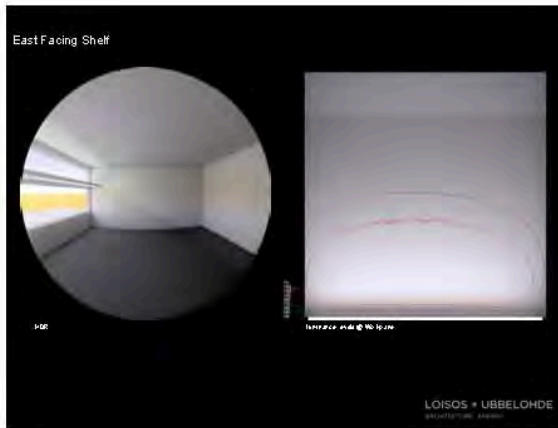


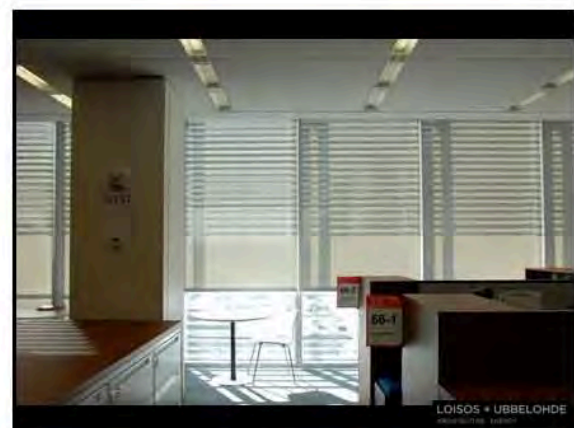
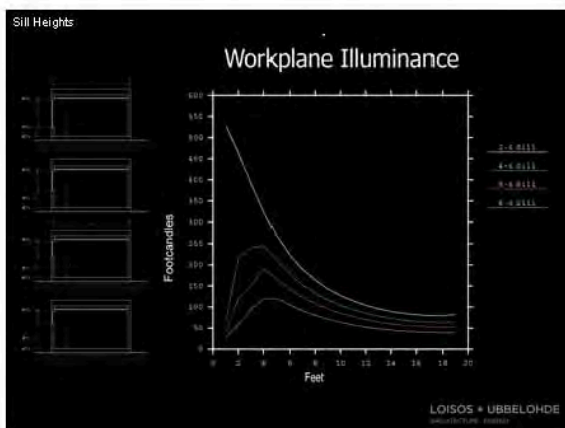
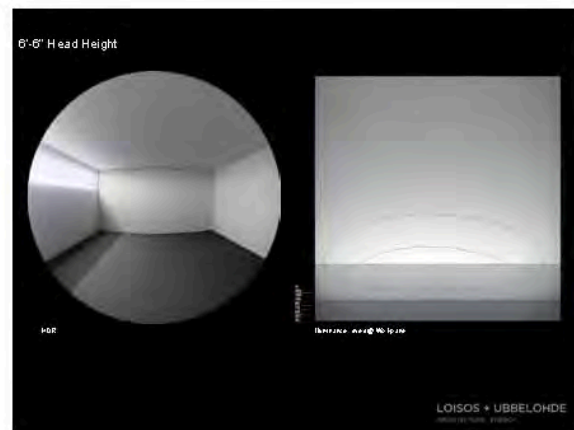
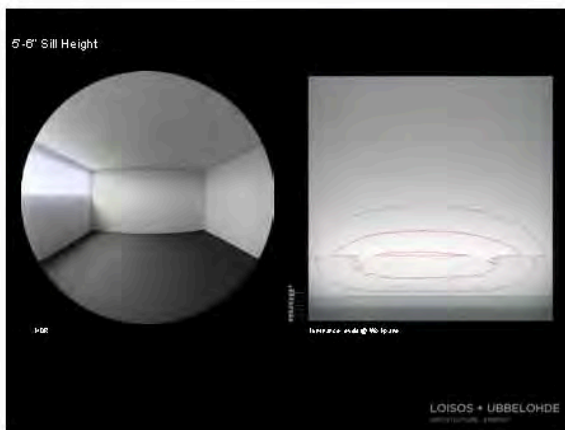
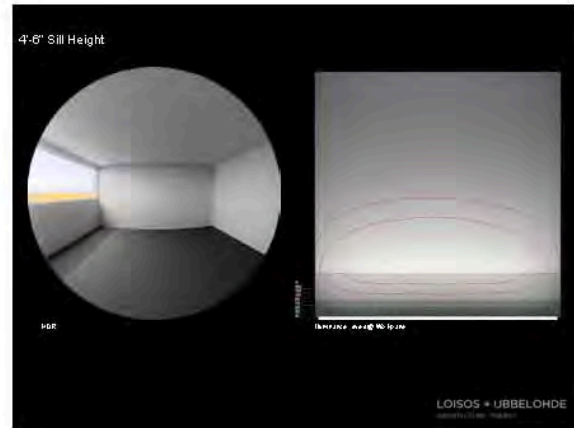
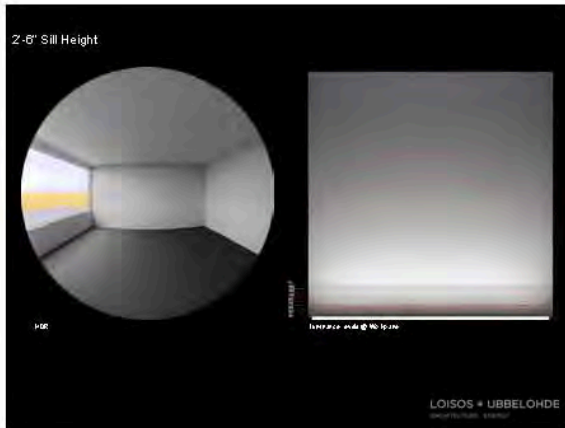


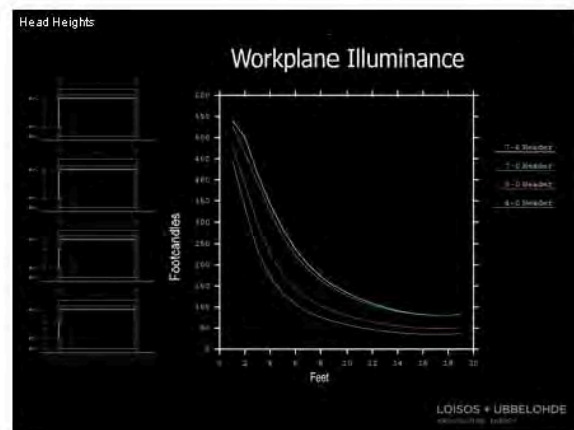
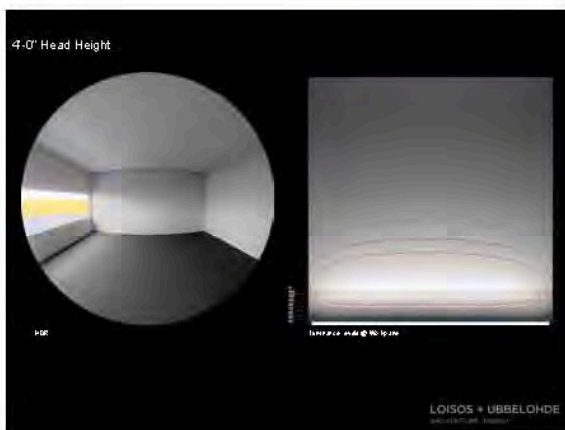
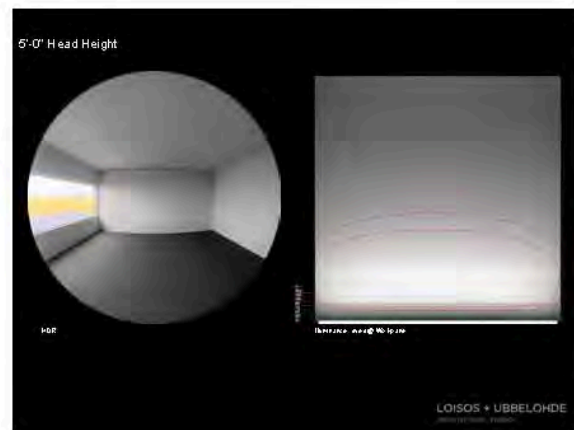
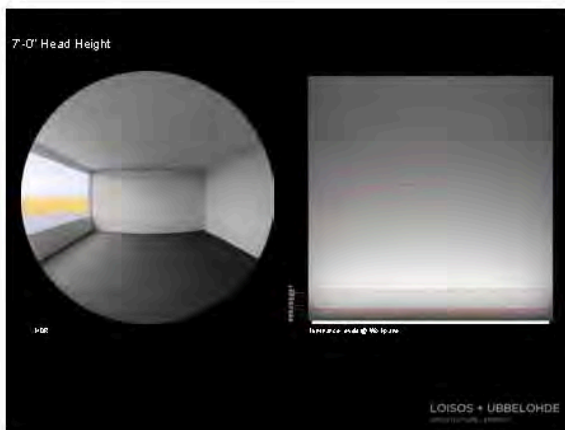
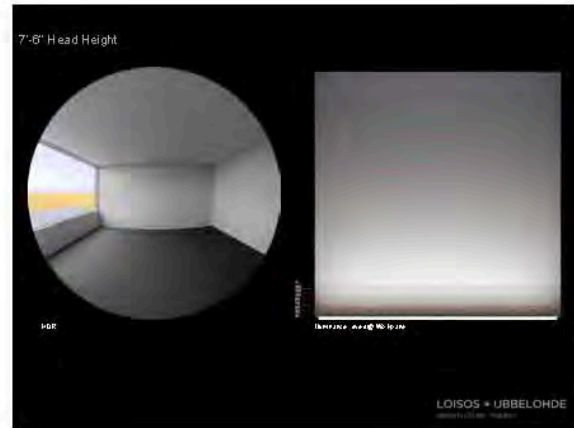


Side Lighting (windows, curtain wall)

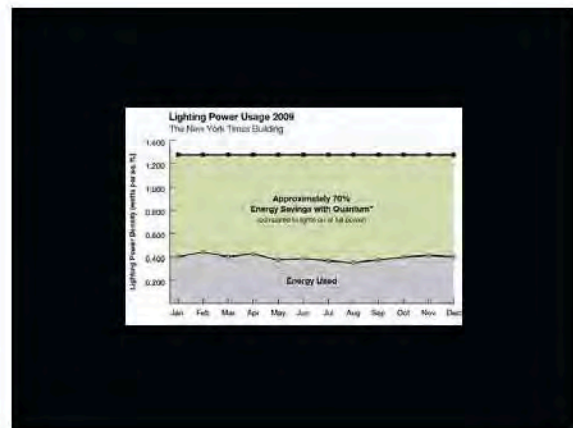
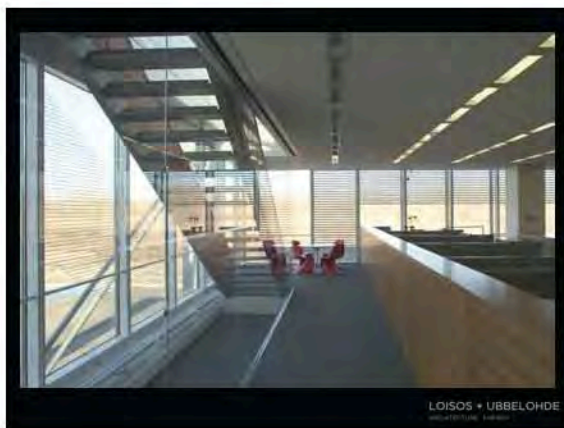
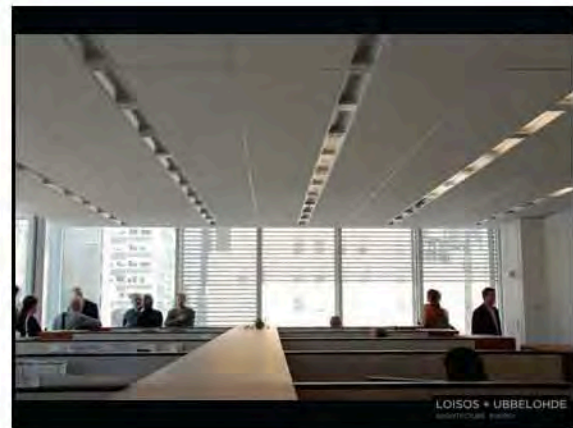
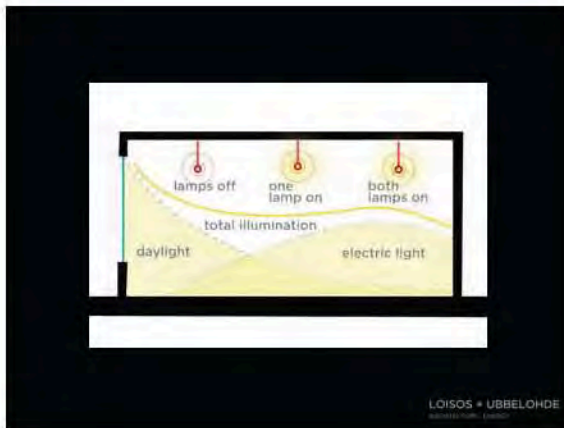


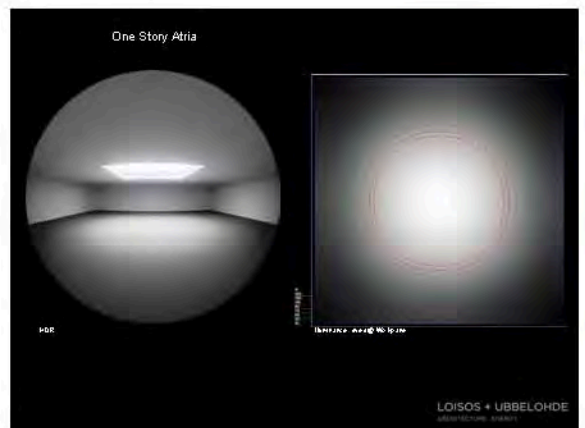
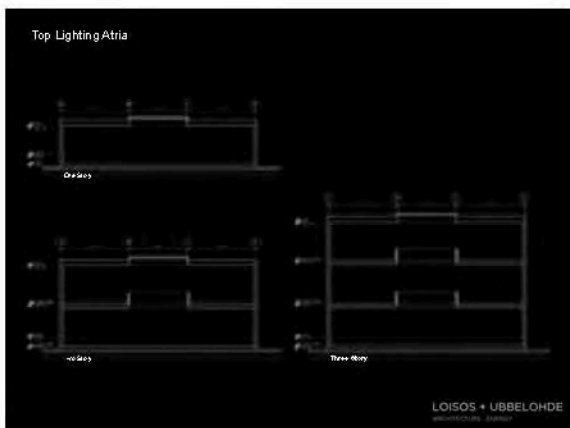
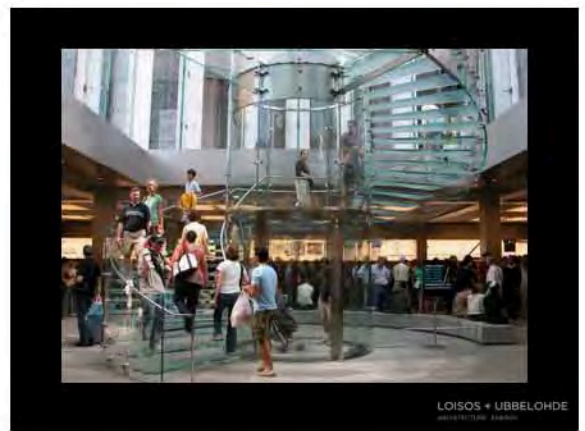
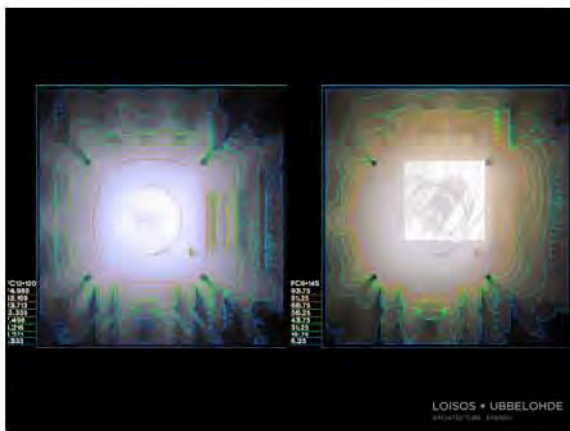
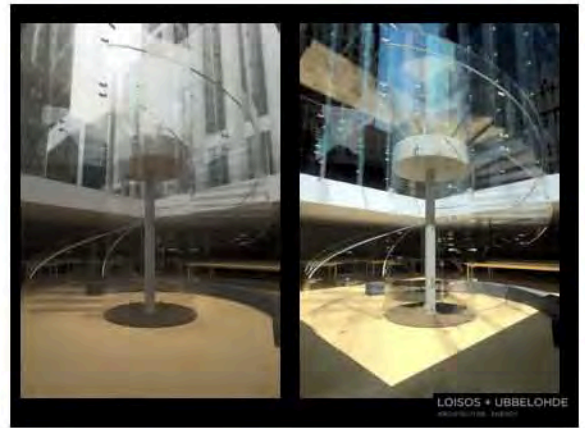


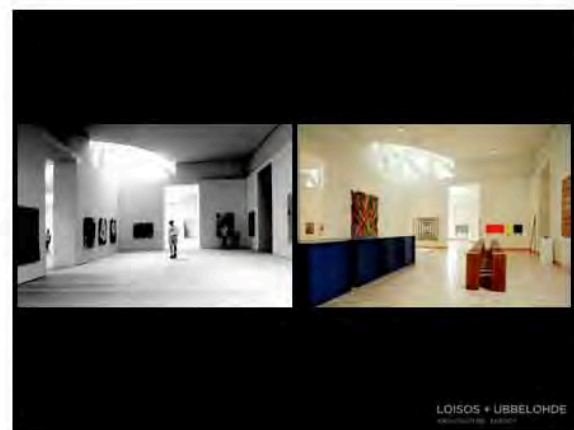
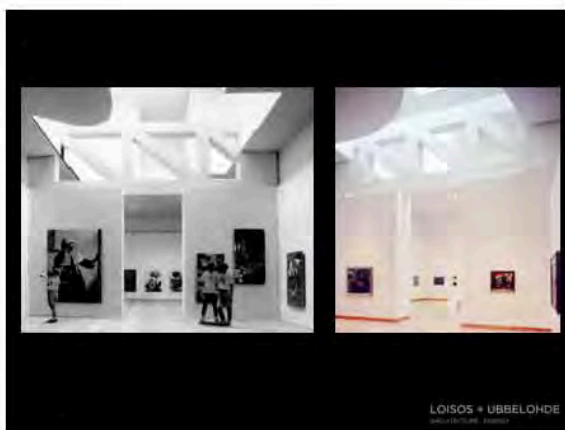
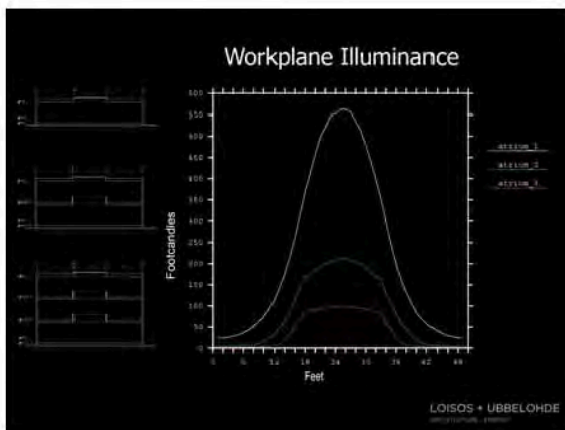
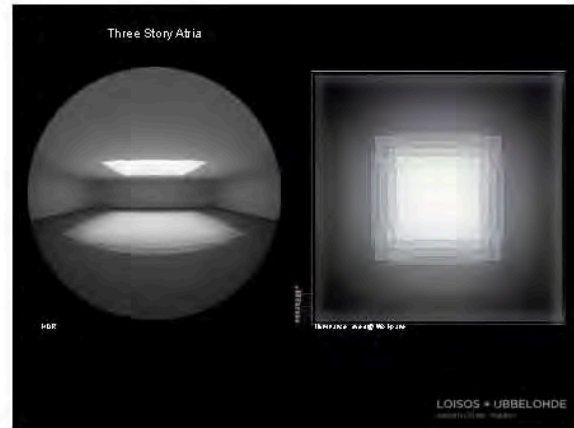
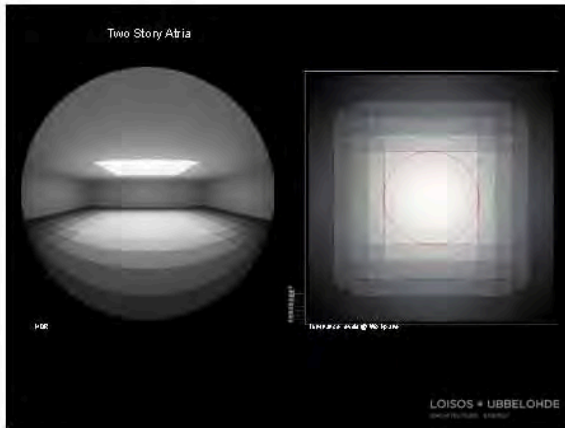




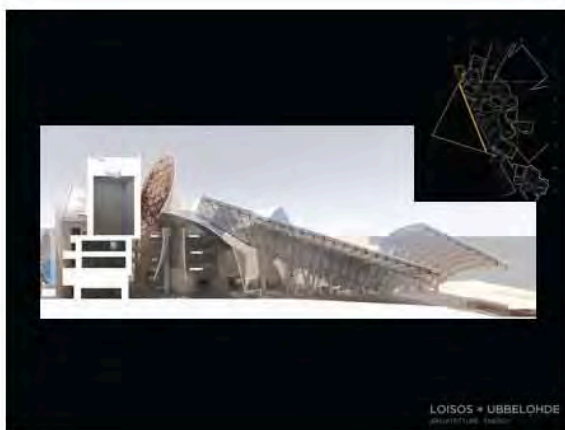
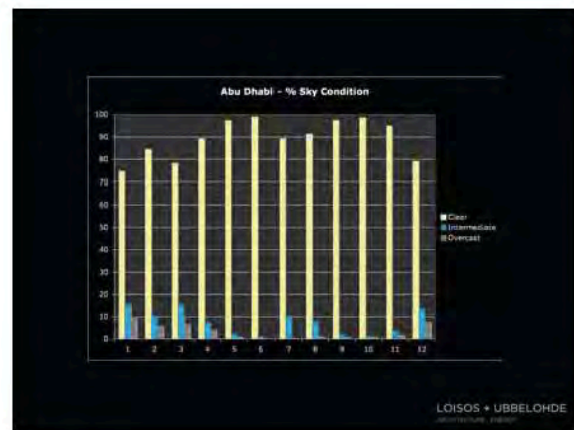
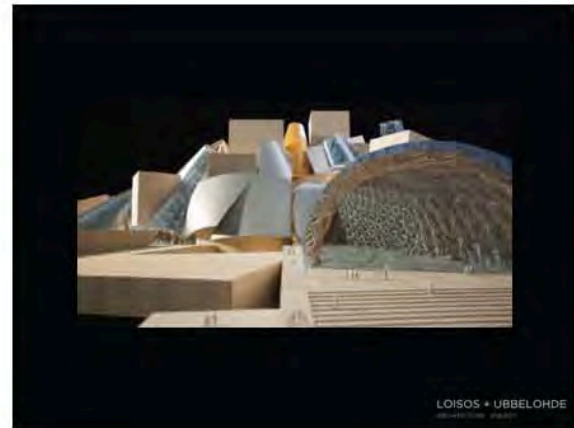




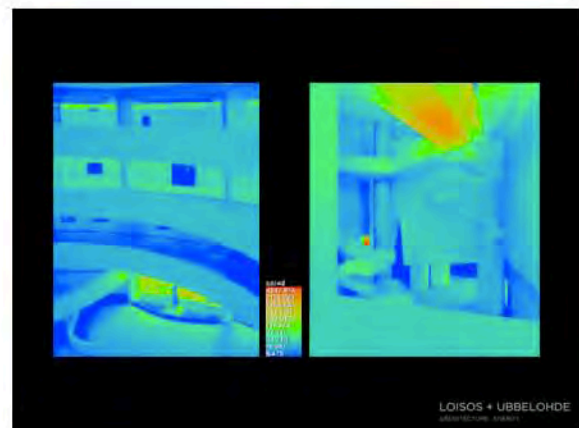
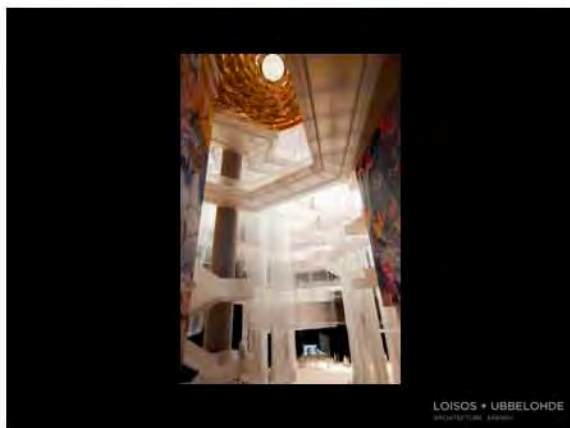
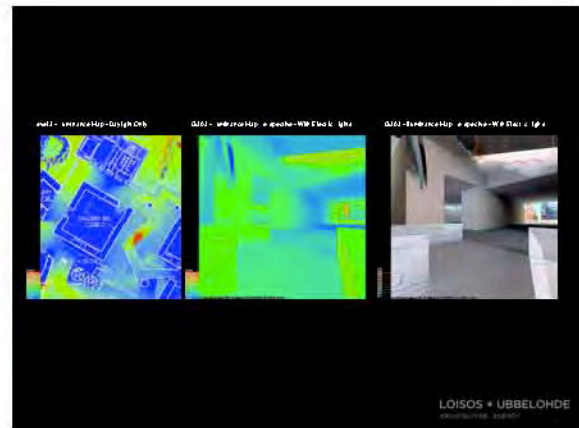
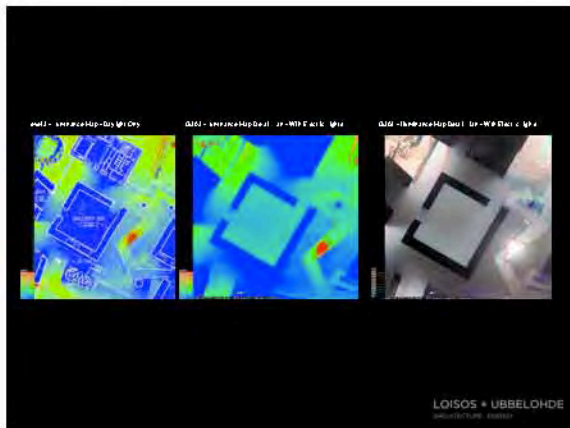


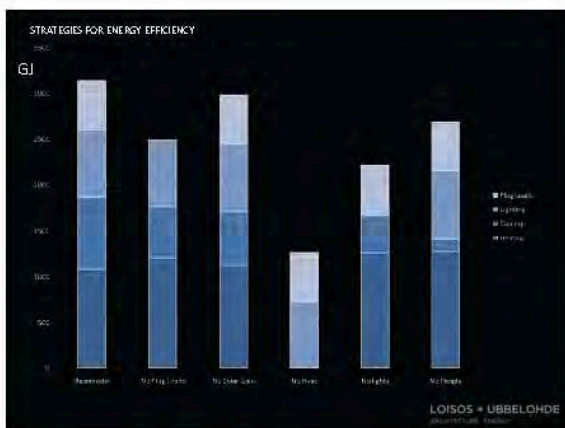
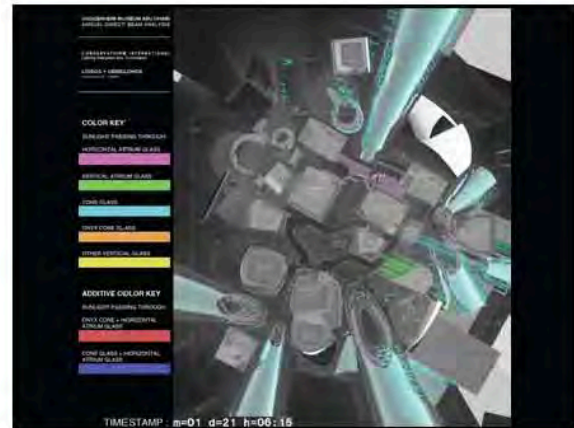


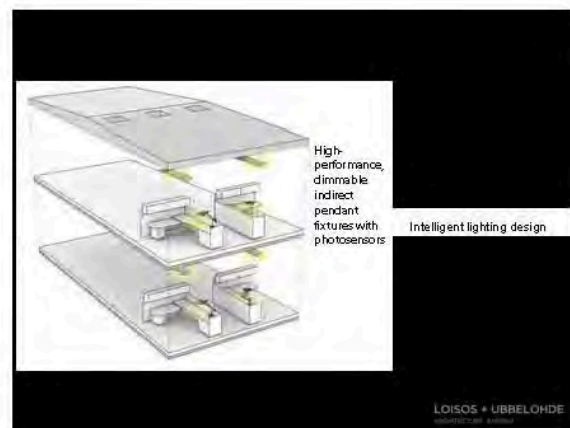
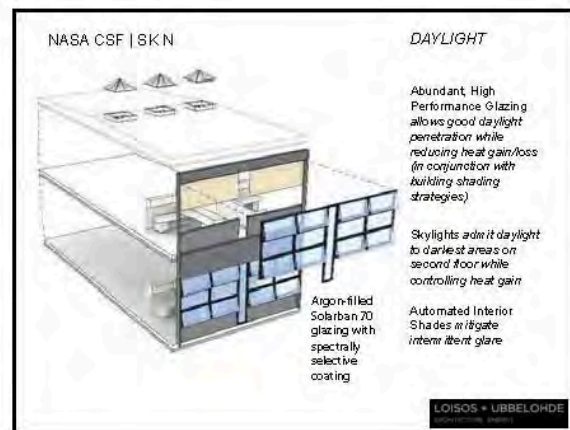
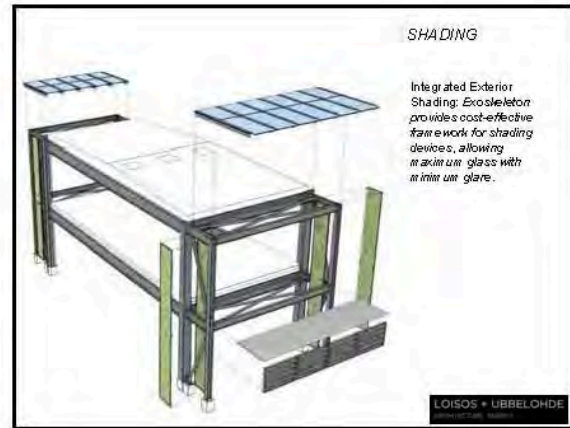
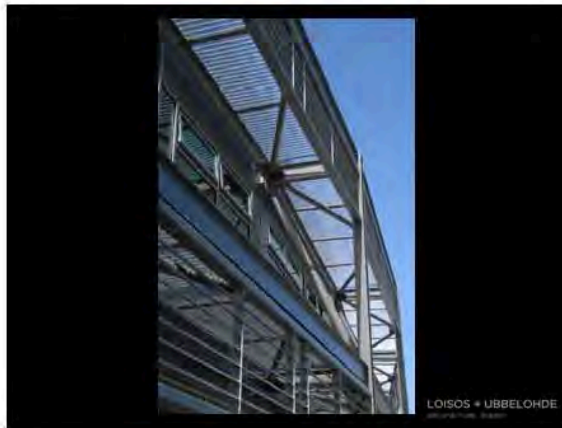




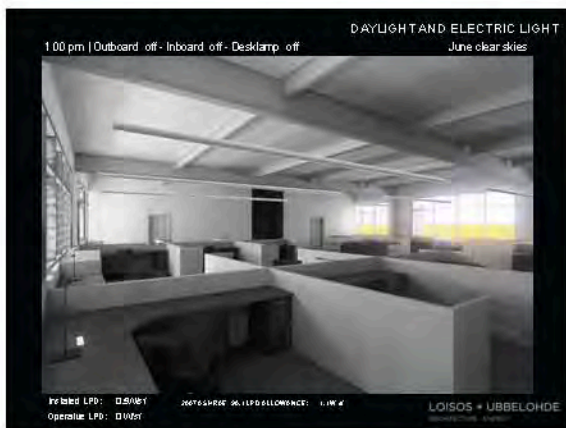
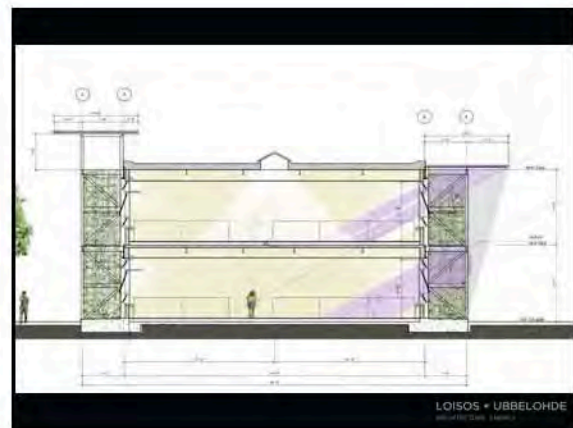
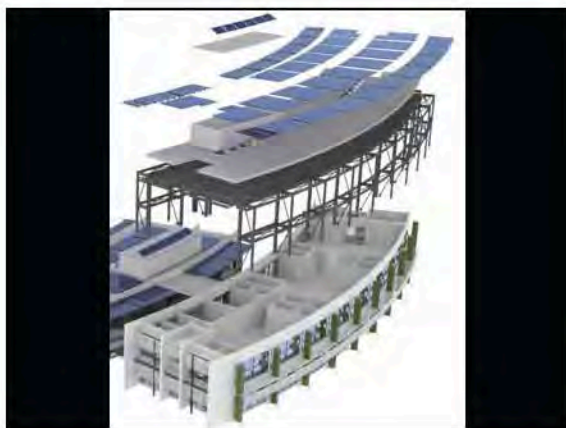








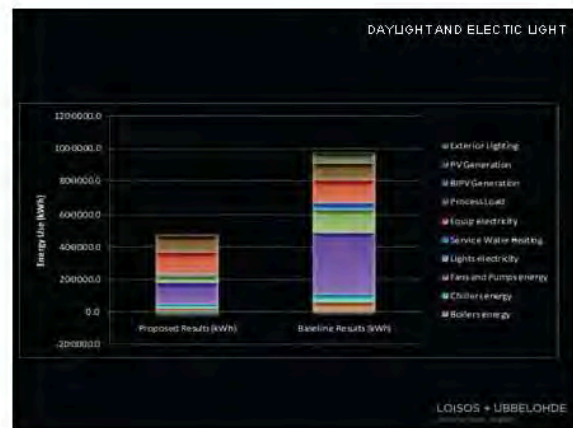
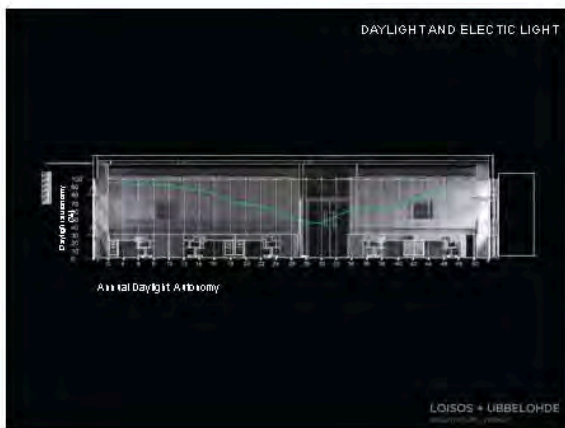








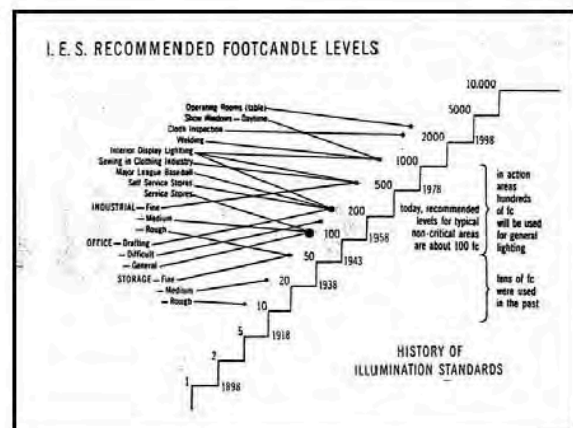


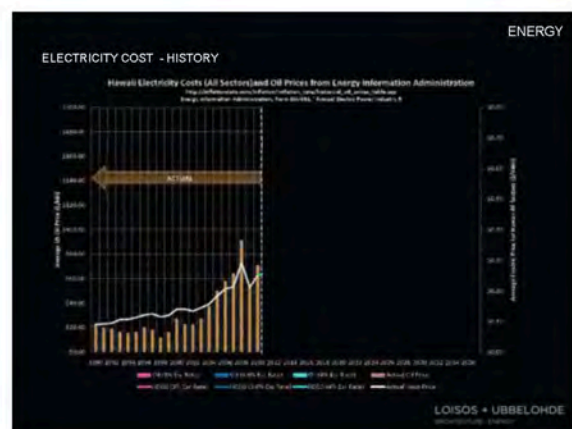
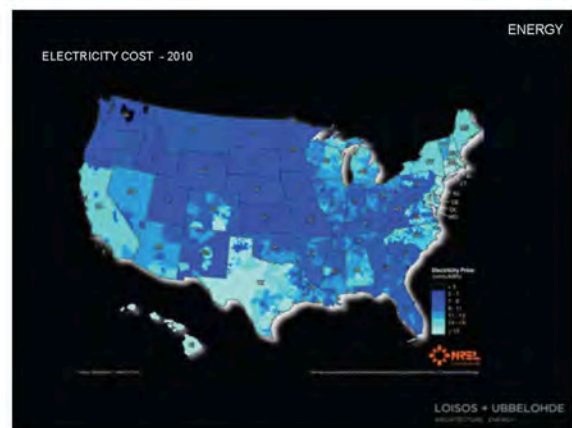


## II. MEASUREMENT

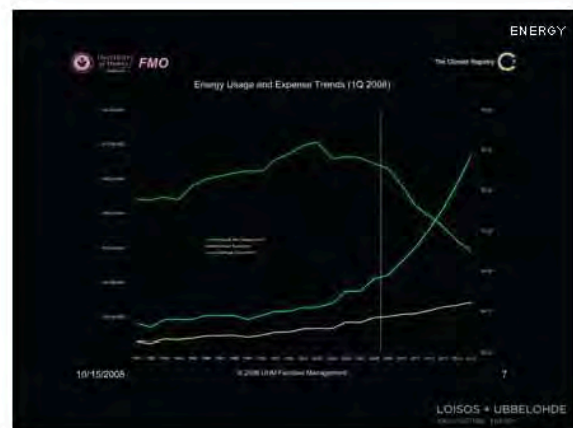
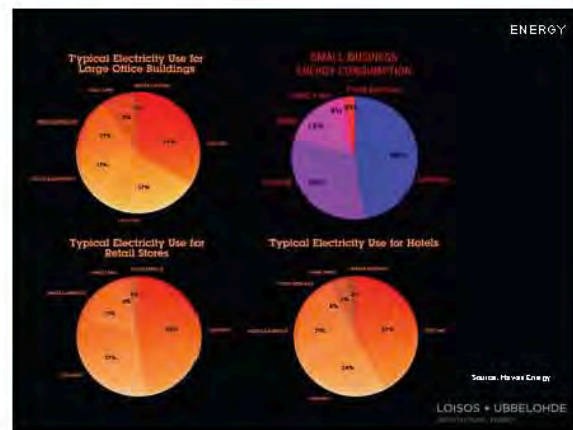
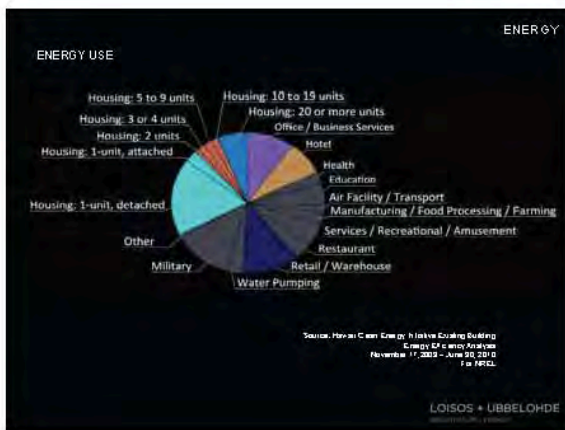
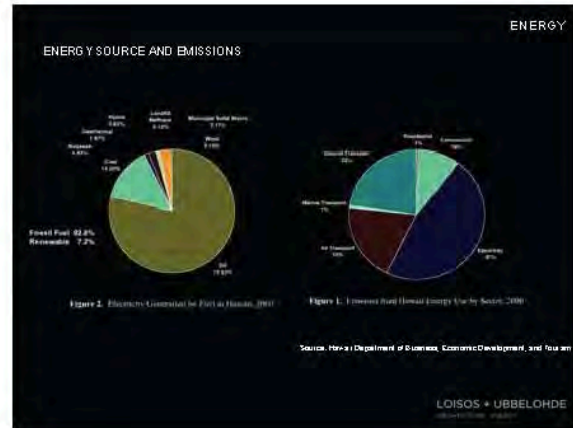
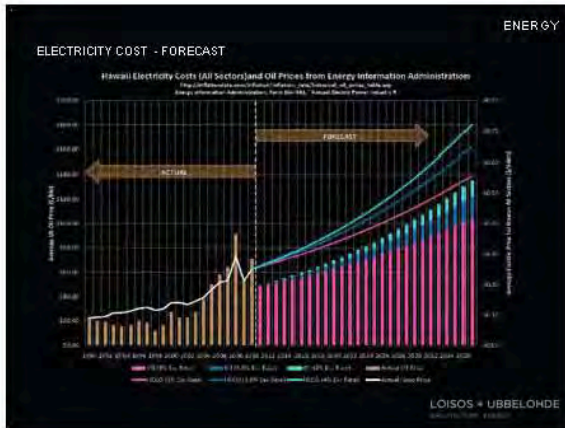
ILLUMINANCE,  
LUMINANCE,  
AND LPD

LOISOS + UBBELOHDE









## UHM GOALS

- Goals established by Chancellor Denise Konan in 2006

A person wearing a red shirt is standing on a sidewalk at night, near the entrance of a building. The scene is dimly lit, with some light coming from the building's entrance and streetlights.

Scheme A: Luminous Blinks

**Concept**  
Diffusing pendams fill the volume of the high bay. Reception and waiting areas are articulated by whether is the tall lighting and wall weather.

Metrics	
LFD	0.70 WAF
Fixture Cost	\$9.00 /M
Installation Cost	\$6.00 /M

**Fixture Legend**

- F10 Recessioned downlight celi
- F9 Recessed linear wallwash
- F12 Diffusing grid pendant
- F11 Recessed downlight can
- F11A Recessed wallwash can
- F21 Recessed can w/ decorative ring
- F21A Linear about linear
- F40 Task light



Scheme 8: Perdant Rows

**Concept:**  
Large circular clearings effectively lower the peripheral vision safety warning. Vertical surfaces in recreation and

Metrics	
LFE2	0.51 Wins
Flanagan's C-ratio	1.9 (No. of)

**Picture Legend**

FB = Faintest linear resolution  
F12 = 3 pendant cylinder elements  
F12A = Reversed F circular elements  
F13A = Reversed spatially ran.  
E21 = Reversed dot-hel crosshatch lines  
F26A = Underlabeled image  
F26 = Test image



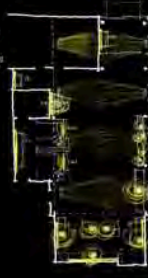
Scheme C: Washes of Light

**Concept**  
Organized like a living room, these  
supercenters are anchored to the top of  
the beams and with the ceiling with  
light. Floor and table lamps provide  
localized areas of warmth in the waiting  
area. Small LED accents in the plaster  
provide subtle visual sparkle.

Metrics	
LPI	0.97 Avg
Feature Count	\$9.30 /s
pyLSTM Count	\$4.60 /s

**Fixture Legend**

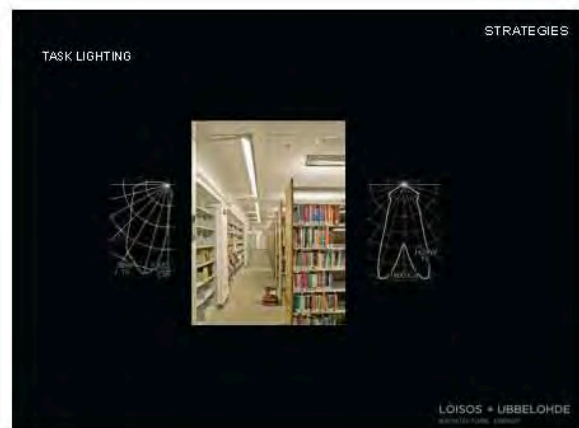
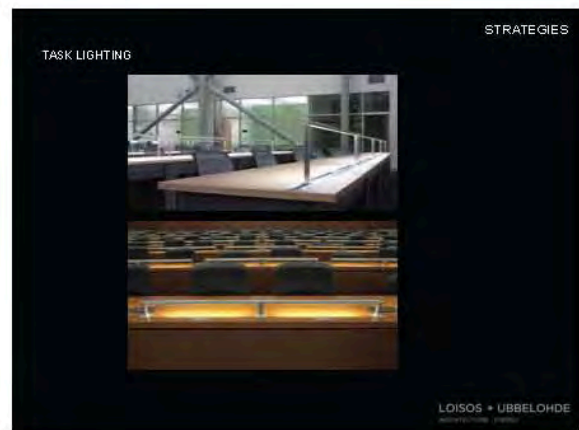
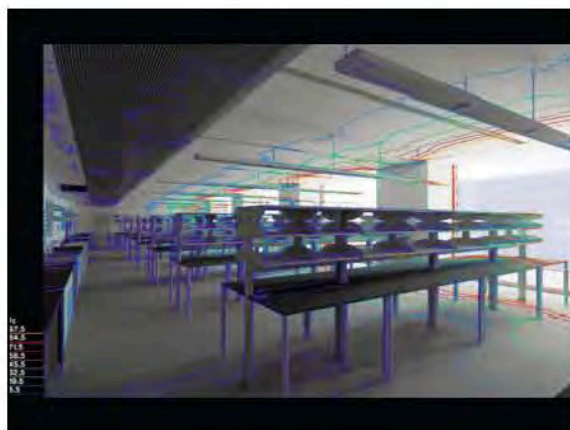
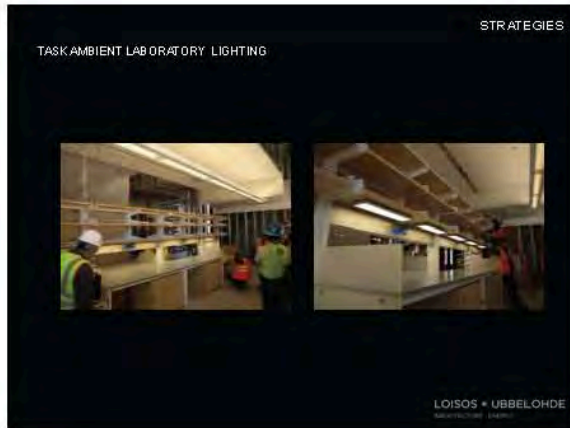
- F&T: Table with Accents
- F9: Rectangular linear wall-wash
- F16: Cylindrical linear wall-wash
- F22A: Undercabinet linear
- F41A: Floor Lamp
- F41B: Table Lamp
- F42: Linear Ceiling Voucher
- F42: Task light



STANDARD LABORATORY LIGHTING



56



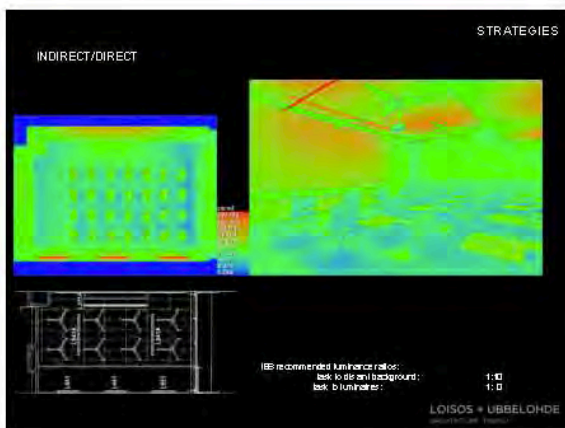
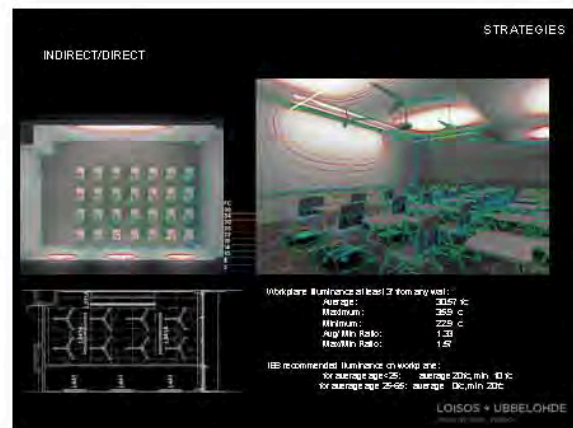
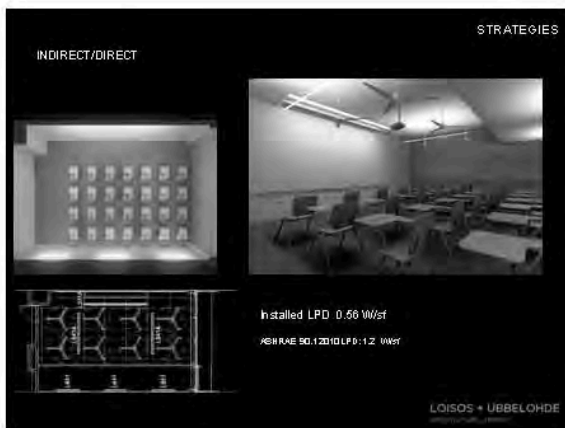


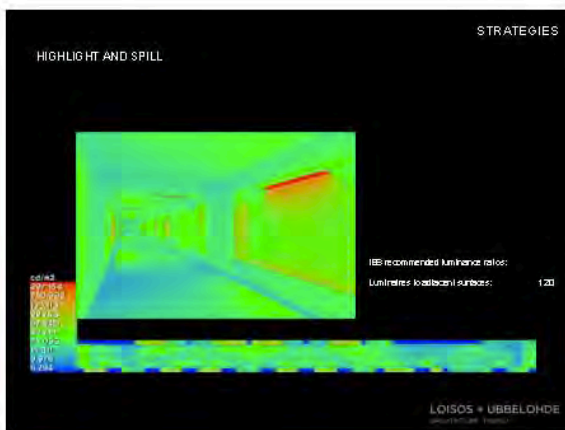
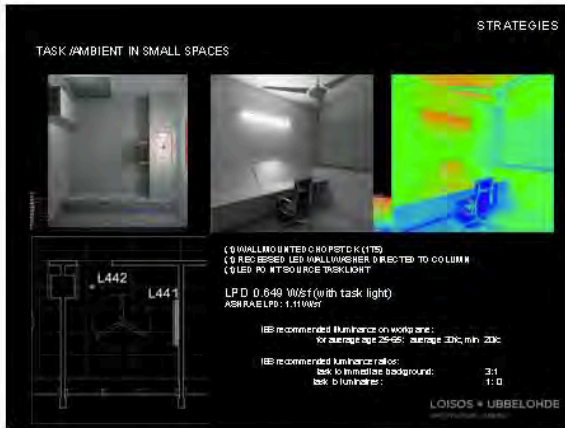
STANDARDS

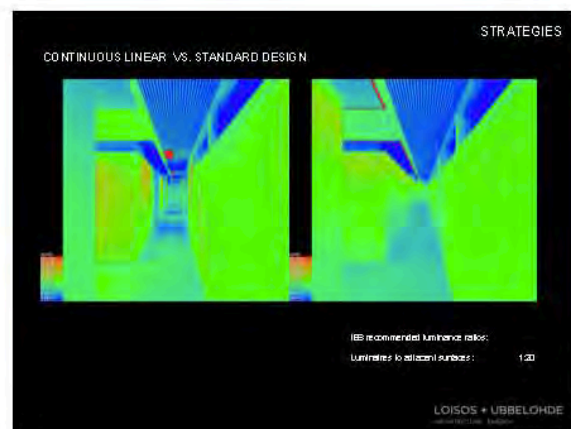
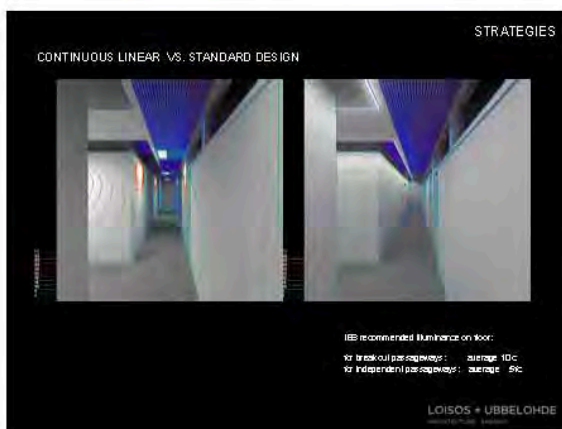
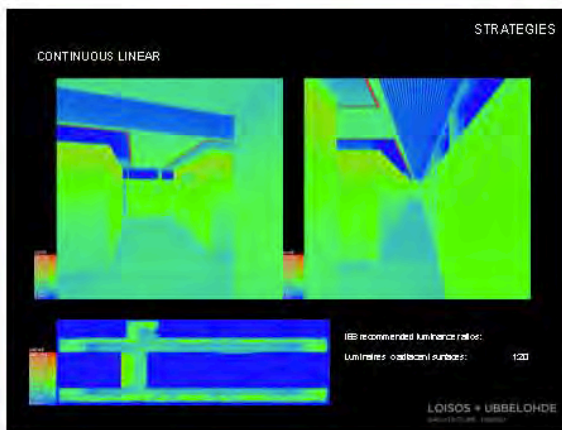
LIGHTING POWER DENSITY

	LPD (W/sf) 2007 ASHRAE 90.1	LPD (W/sf) 2010 ASHRAE 90.1	LPD (W/sf) 2008 CA Title 24
Spacetype			
Classroom	1.4	1.24	1.2
Office (private)	1.1	1.11	1.1
Office (open)	1.1	0.98	0.9
Corridor > 8' wide		0.66	
Corridor < 8' wide	0.5	0.792	0.6
Laboratory (Research)	1.4	1.81	1.4
Library Reading Area	1.2	0.93	1.2
Parking Area	0.2	0.19	0.2

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ARCHITECTURAL FIRM







FIXTURES DESIGNED FOR LED

SOURCES & FIXTURES

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ARCHITECTURAL LIGHTING

FIXTURES DESIGNED FOR LED

SOURCES & FIXTURES

New with 49% increase in efficacy and improved asymmetric distribution.

90-100° Beam Spread

90-100° Beam Spread

Testing period and new versions done 1 year apart, September 2010 and September 2011

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Installed LPD 0.5 W/sf

ASHRAE LPD 1.1 W/sf (Minimum)

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ONLY 1 FIXTURE IS SOLD.  
R.R. L&L TO LAMP SOLD SEPARATELY.  
Never Install Fluorescent Fixture in This Fixture.

With Heavy Duty On / Off Safety Switch

ETL Intertek

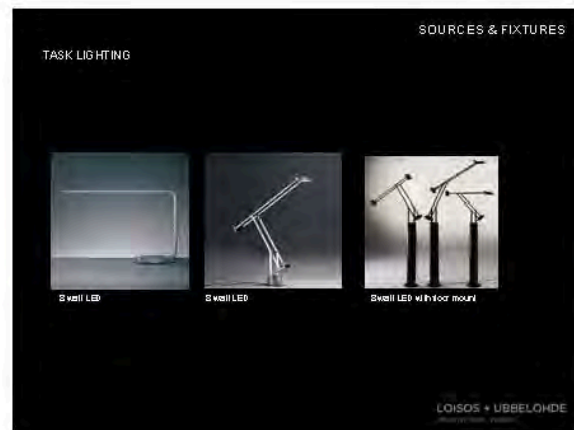
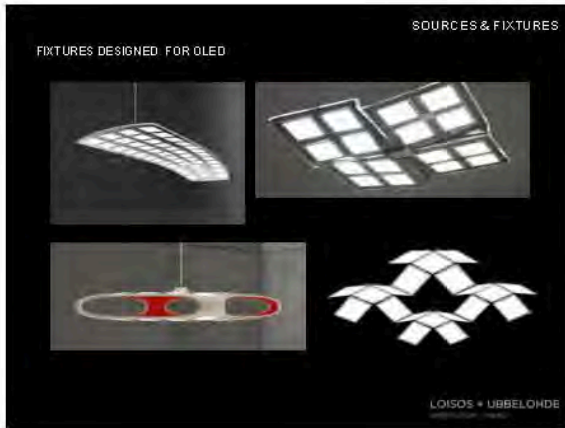
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ARCHITECTURAL LIGHTING

FIXTURES DESIGNED FOR LED

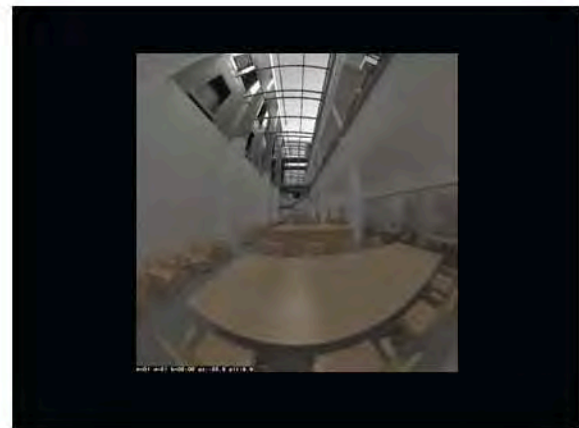
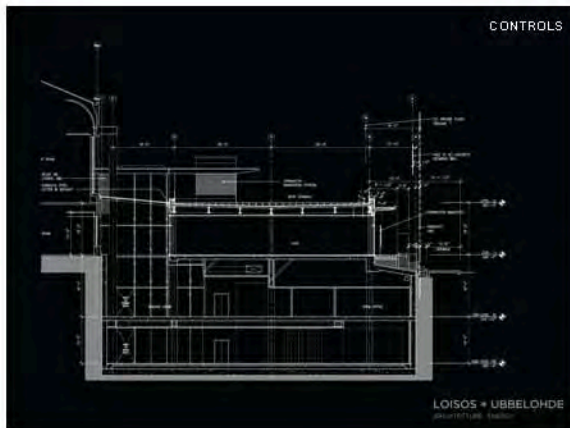
SOURCES & FIXTURES

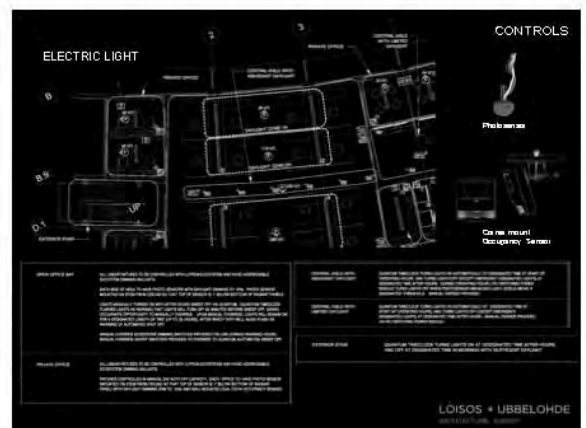
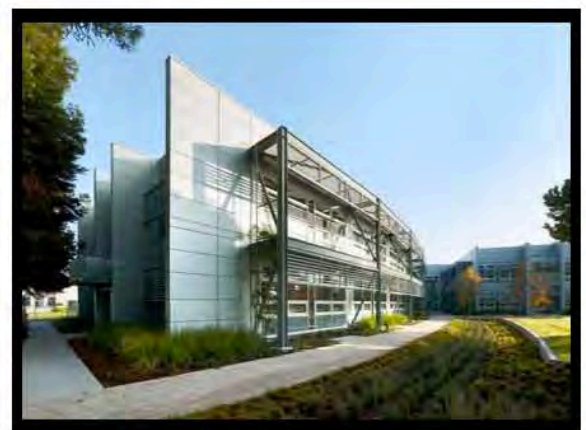
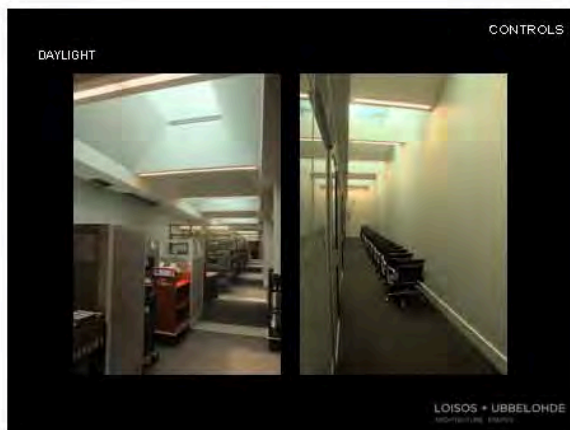
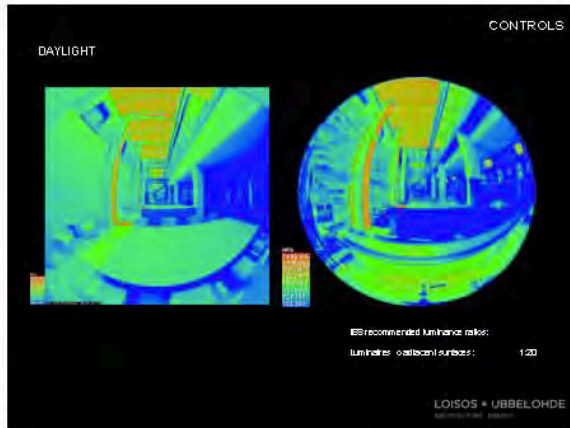
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ARCHITECTURAL LIGHTING











STANDARDS

ELECTRIC LIGHT CONTROL

ASHRAE 90.1 2010 REQUIREMENTS

Automatic Daylighting Controls required for:

- A) Primarily Side-lit Area > 250 sf
- B) Day-lit Area in Non-lit Space > 500 sf

(newly introduced & is a penalty and exceeds CA-T24-2008 which requires daylight only for daylight > 2500 ft)

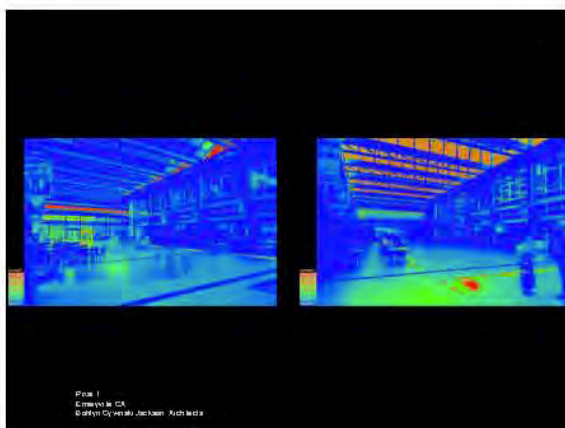
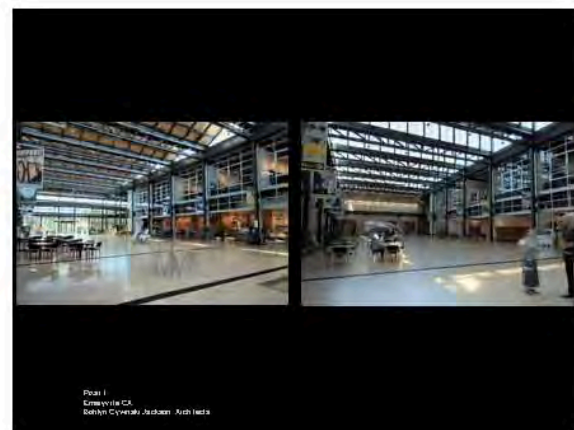
Automatic Lighting Shutoff to be provided by:

- A) Time clock, battery lighting off or a schedule
- OR
- B) Occupancy Sensor, battery lighting off within 30 min after occupants leaving a space (same as CA-T24-2008)

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V. HDR DOCUMENTATION

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Harvard University  
Graduate School of Design

High Dynamic Range Imaging & Glare Analysis

II. HDR PHOTOGRAPHY USING PHOTOSPHERE

Shelby Doyle | Christoph Reinhart  
Harvard Graduate School of Design

LOISOS + UBBELOHDE



## HDR Imaging and Glare Analysis

This document is one out of a series of three tutorials that introduce the reader to high dynamic range (HDR) imaging, photography and how to analyze an HDR photo or simulation for potential glare.

The tutorials can be downloaded from the G(SD)<sup>2</sup> website:

First tutorial that introduces some basic terminology related to high dynamic range imaging.

Second tutorial that shows how to generate a calibrated HDR image using a digital camera, the Photosphere program written by Greg Ward and a luminance meter.

Third tutorial that shows how to interpret an HDR image (photo or simulation) using the 'exposure' program written by Jan Vignelli as well as the Radiance Image Viewer from Autodesk's Ecotect written by Anthony Manti.

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## In This Tutorial

~~Download, View and Read a File, or Download a File~~

- Download Photosphere Software
- Set Up Camera
- Select a Scene
- Capture Luminance Reading
- Take Photo Series
- Make an HDRI Photo
- Calibrate Camera
- Save the Image for Glare Analysis
- More available tools.

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## Photosphere

Download and install a copy of Photosphere a software designed to easily create HDRI images from multiple images. ~~Link: [www.anywhere.com](http://www.anywhere.com)~~

[www.anywhere.com](http://www.anywhere.com)

Link named:  
→ Download a copy of Photosphere

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## Setting Up

What you need:


- Digital Camera w/Manual Settings
  - Aperture
  - Shutter Speed
  - Exposure Value
- Mac Computer
- Luminance Meter (+ Tripod)



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## Aperture

Controls the amount of light reaching the image sensor. In combination with variation of shutter speed, the aperture size will regulate the image sensor's degree of exposure to light.



f 2.8    f 3.5    f 4.0    f 5.6    f 8.0

The smaller F-Stop number the larger the opening and the greater the amount of light entering the camera.

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## Shutter Speed

The effective length of time a shutter is open or duration of light reaching the image sensor. The longer the shutter is open the more light reaches the image sensor.

Faster

1/1000 s  
1/500 s  
1/250 s  
1/125 s  
1/60 s  
1/30 s  
1/15 s  
1/8 s  
1/4 s  
1/2 s  
1 s

Slower

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Graduate School of Design

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## Exposure Value

1. How much light will be admitted to the film by the combination of lens aperture and shutter speed.
2. How much exposure is required by the combination of subject luminance (e.g., how bright it is) and film speed.

Under Exposed (Too little light)      Correctly Exposed      Over Exposed (Too much light)

-2    -1    0    +1    +2

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lectures/1001/01010101

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## Set Aperture

Take a photo at each EV to capture a full range of light.

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## Upload Photos

Save the photos in an easy to locate folder.

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## Open Photosphere.

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lectures/1001/01010101

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## Double click the folder name to load the photos.

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lectures/1001/01010101

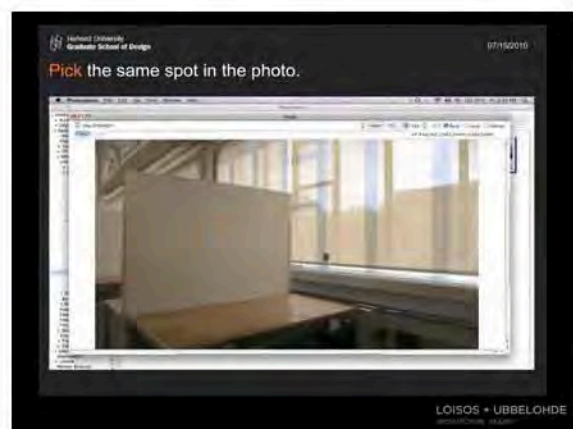
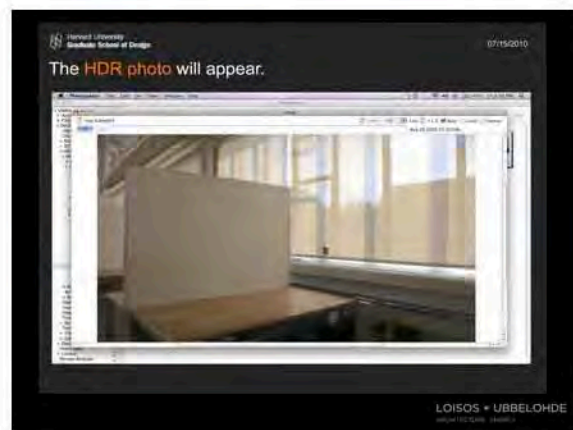
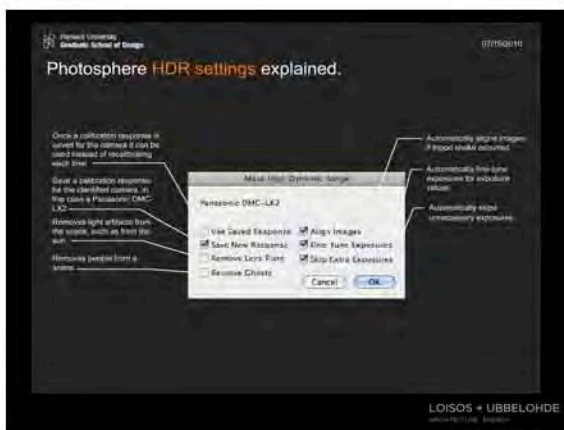
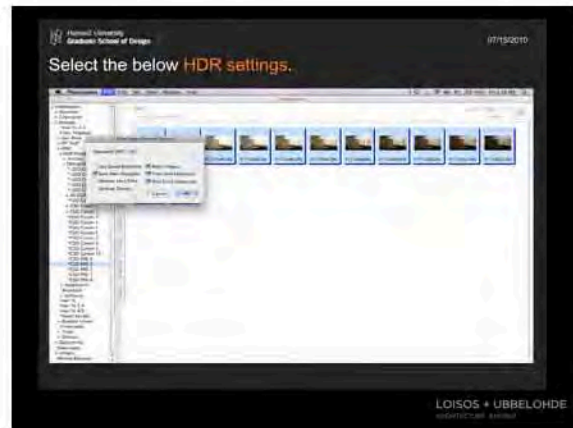
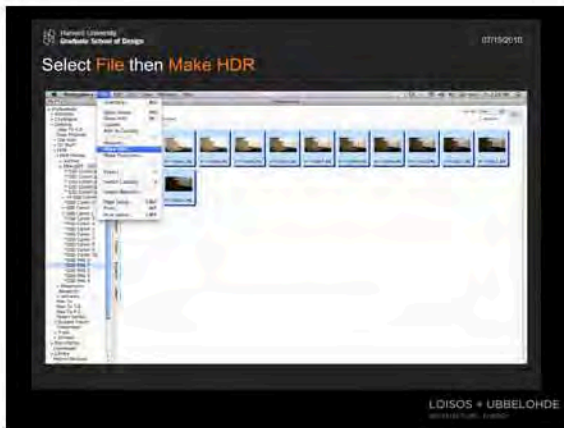
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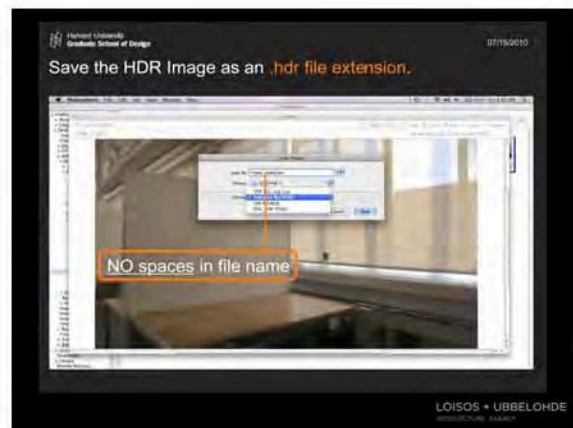
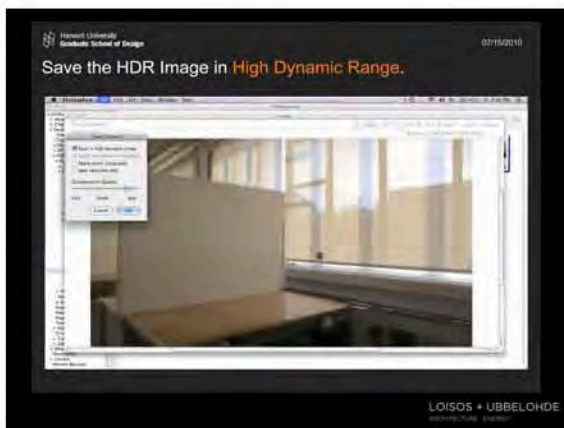
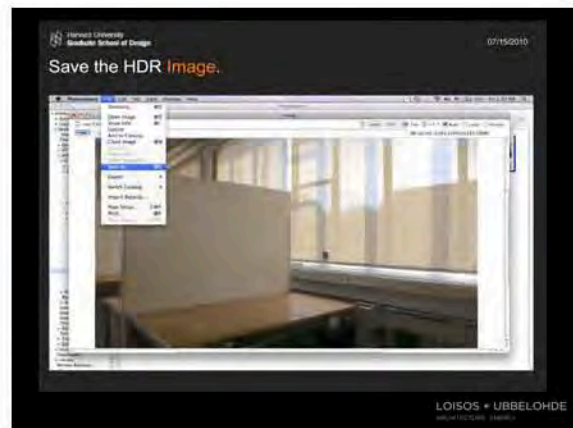
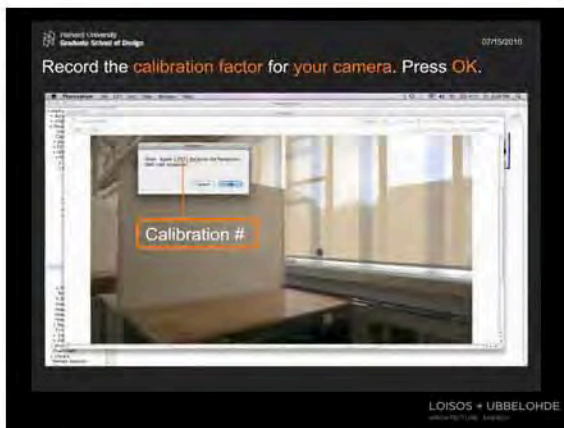
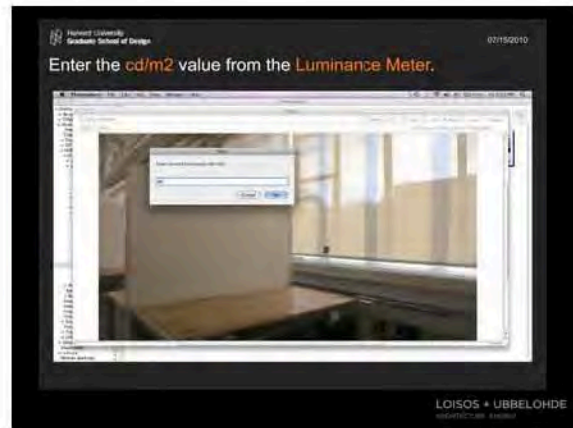
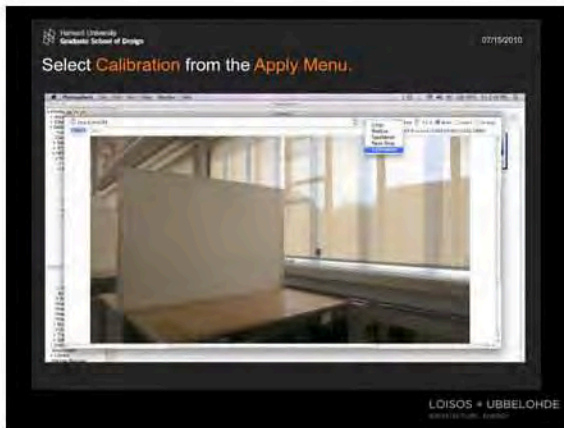
07/15/2010

## Select the photos needed to make an HDR photo.

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lectures/1001/01010101











# High Dynamic Range Imaging & Glare Analysis

## II. HDR PHOTOGRAPHY USING PHOTOSPHERE



Shelby Doyle | Christoph Reinhart  
Harvard Graduate School of Design



# HDR Imaging and Glare Analysis

This document is one out of a series of three tutorials that introduce the reader to high dynamic range (HDR) imaging, photography and how to analyze an HDR photo or simulation for potential glare.

The tutorials can be downloaded from the G(SD)<sup>2</sup> website.



First tutorial that introduces some basic terminology related to high dynamic range imaging.



Second tutorial that shows how to generate a calibrated HDR image using a digital camera, the Photosphere program written by Greg Ward and a luminance meter.

**Note: A MAC is needed for this tutorial!**



Third tutorial that shows how to analyze an HDR image (photo or simulation) using the 'evalglare' program written by Jan Wienold as well as the Radiance Image Viewer from Autodesk Ecotect written by Andrew Marsh.

**Note: A PC is needed for this tutorial!**



# In This Tutorial

- \* *Note: You will need a MAC to follow this tutorial.*
- Download Photosphere Software
- Set Up Camera
- Select a Scene
- Capture Luminance Reading
- Take Photo Series
- Make an HDRI Photo
- Calibrate Camera
- Save the image for Glare Analysis
- More available tools.

# Photosphere

Download and install a copy of Photosphere a software designed to easily create HDRI images from multiple images. *Note: This is a Mac program.*

[www.anyhere.com](http://www.anyhere.com)

Link named:

→ Download a copy of Photosphere

# Setting Up

What you need:

Digital Camera w/Manual Settings

Aperture

Shutter Speed

Exposure Value

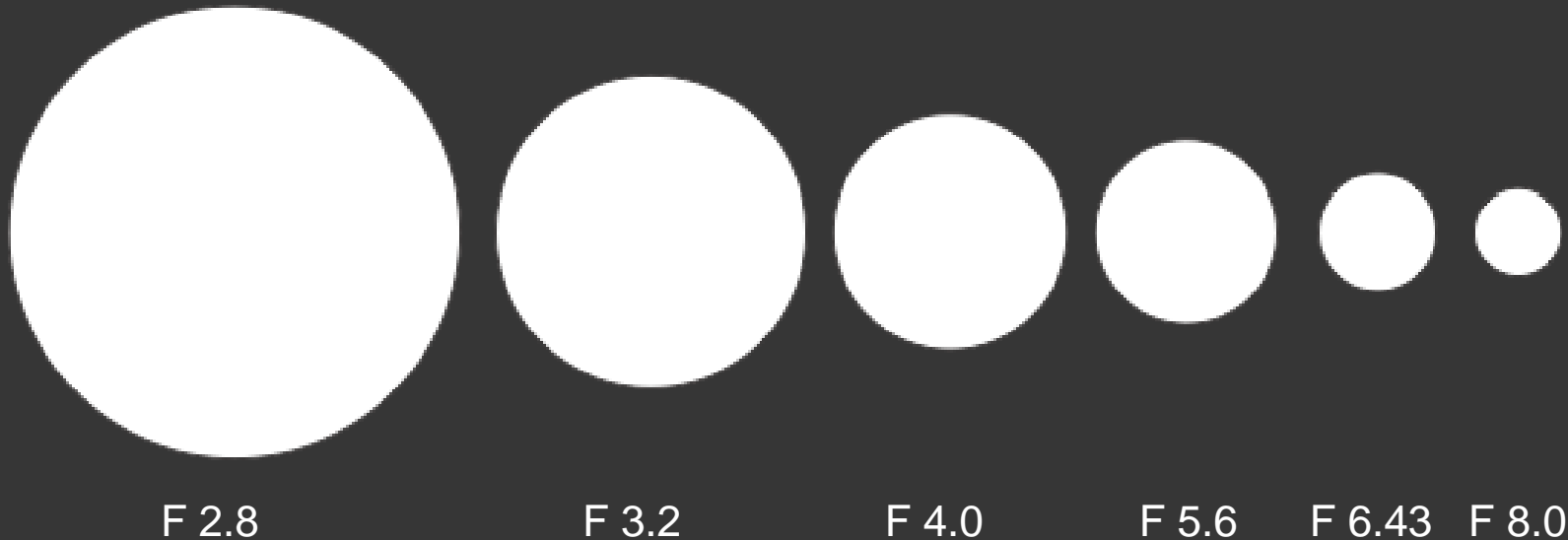
Mac Computer

Luminance Meter (+ Tripod)



# Aperture

Controls the amount of light reaching the image sensor. In combination with variation of shutter speed, the aperture size will regulate the image sensor's degree of exposure to light.



The smaller F Stop number the larger the opening and the greater the amount of light entering the camera.

# Shutter Speed

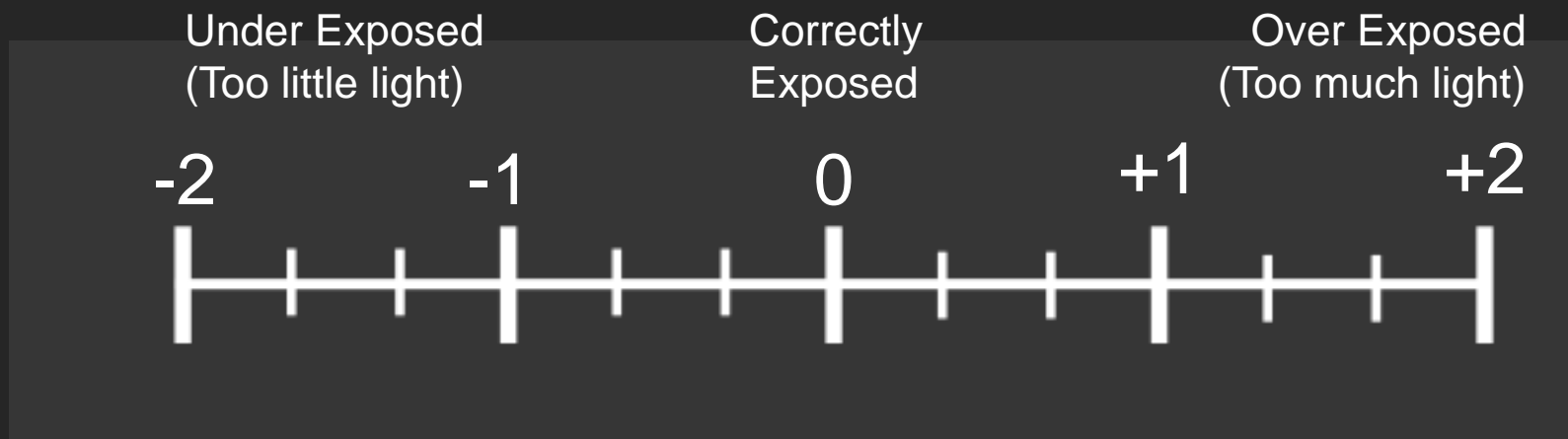
The effective length of time a shutter is open or duration of light reaching the image sensor. The longer the shutter is open the more light reaches the image sensor.

Faster — Slower	1/1000 s
	1/500 s
	1/250 s
	1/125 s
	1/60 s
	1/30 s
	1/15 s
	1/8 s
	1/4 s
	1/2 s
	1 s



# Exposure Value

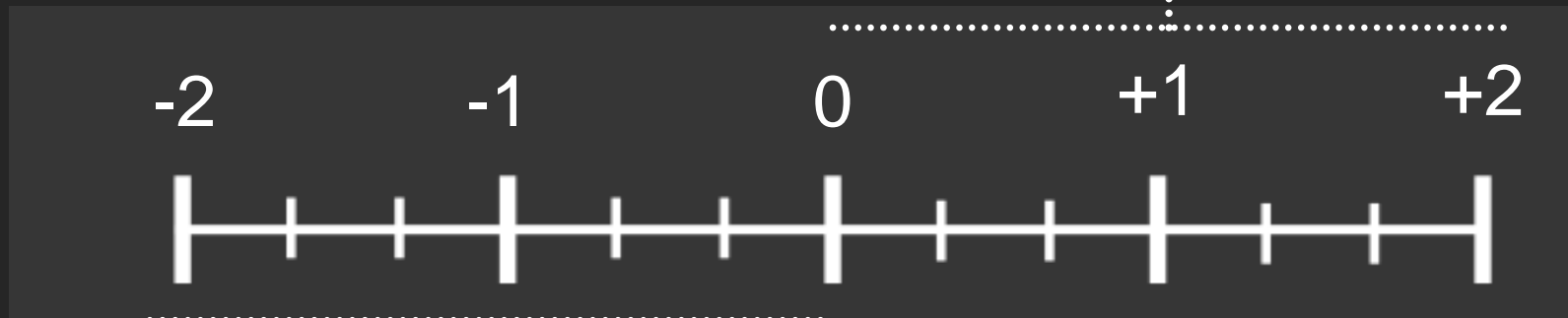
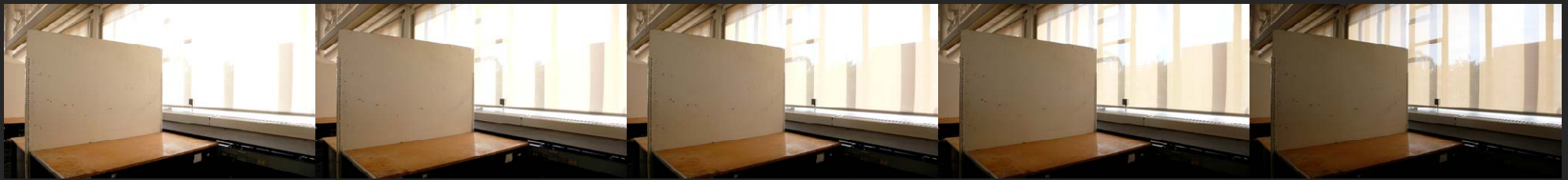
1. How much light will be admitted to the film by the combination of lens aperture and shutter speed.
2. How much exposure is required by the combination of subject luminance (e.g., how bright it is) and film speed.



It is common practice among photographic equipment manufacturers to express luminance in EV for ISO 100 speed.  
**Set your camera's ISO speed to 100.**

# Set Aperture

Take a photo at each EV to capture a full range of light.

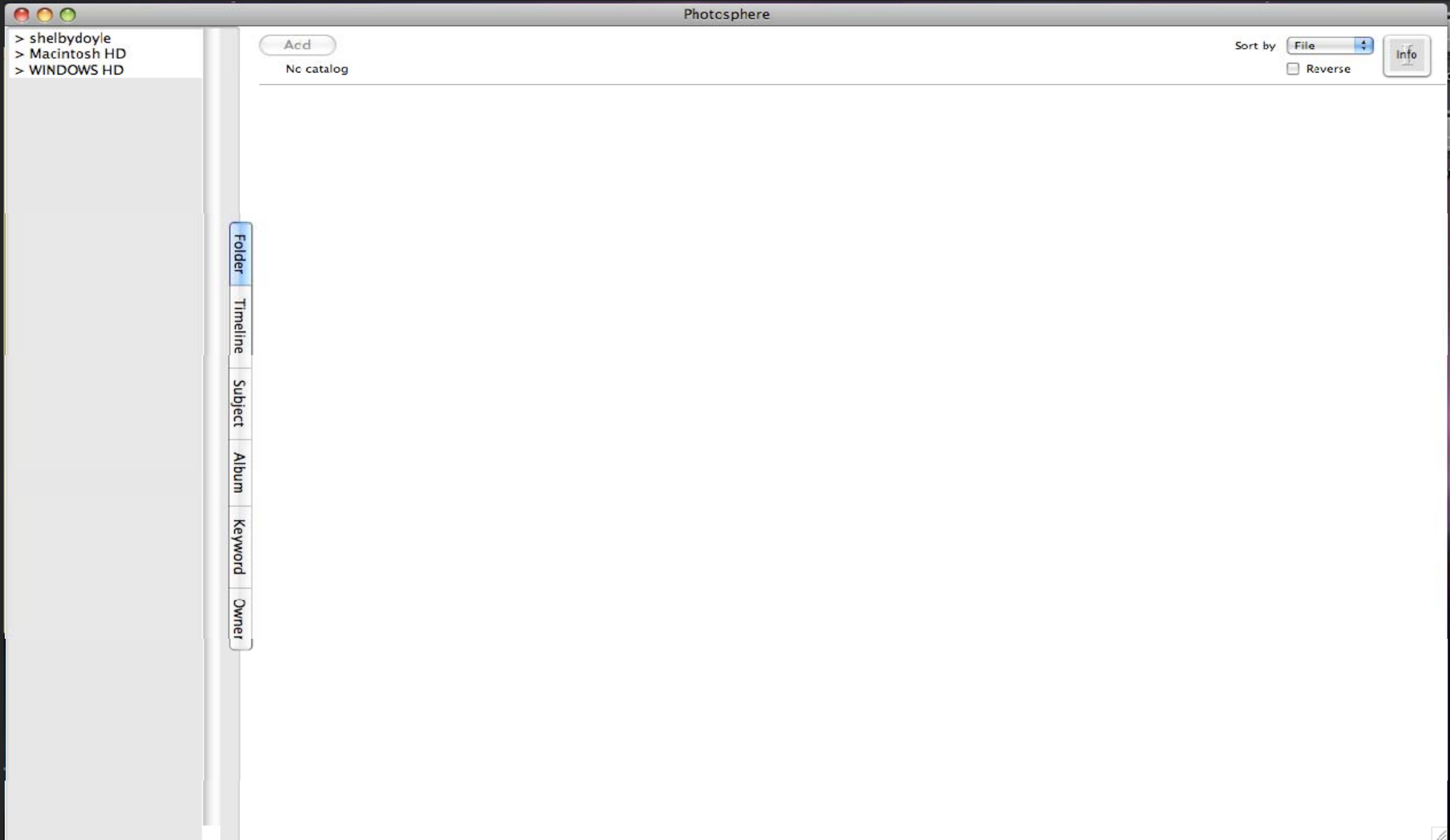


# Upload Photos

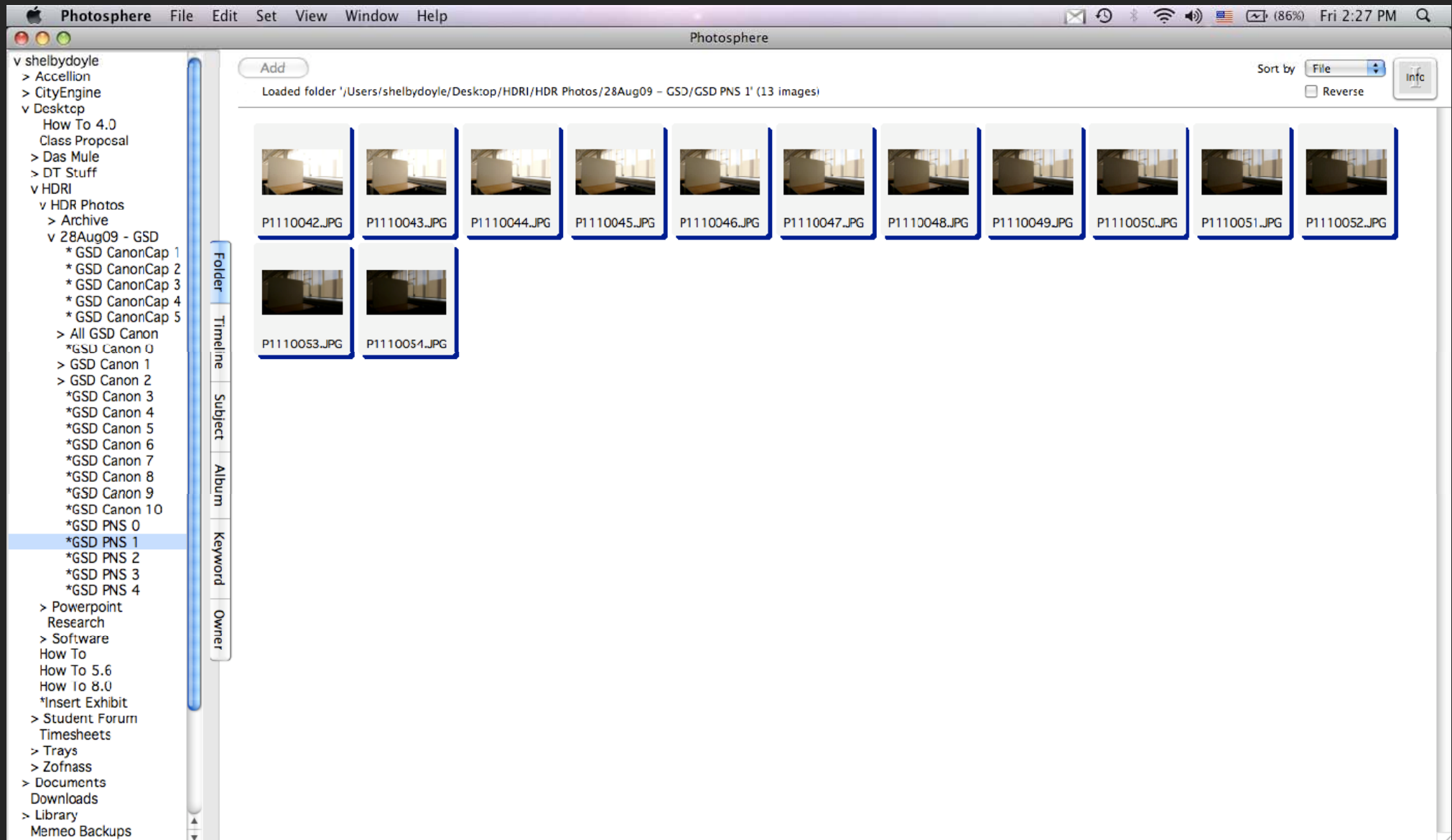
Save the photos in an easy to locate folder



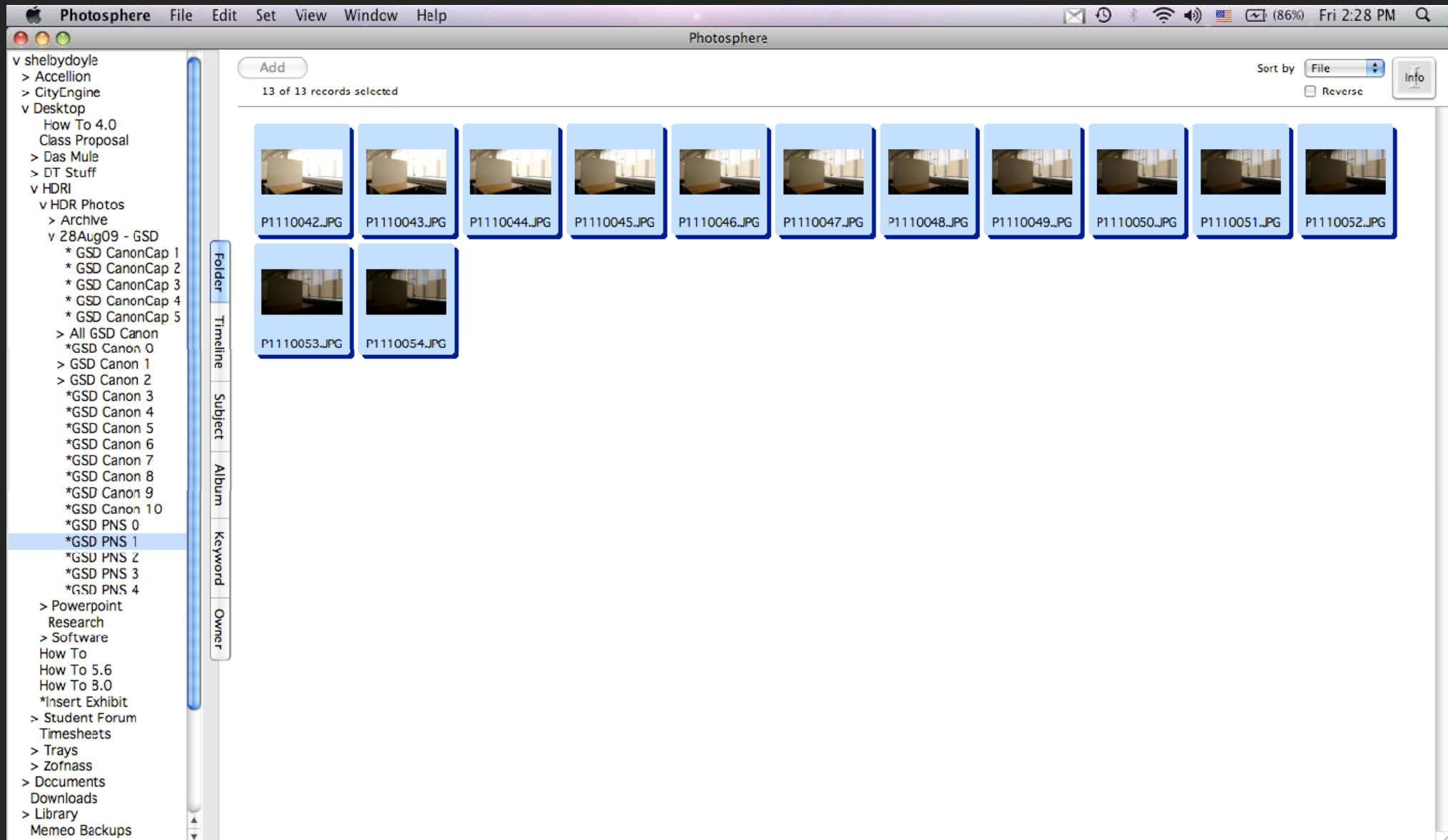
# Open Photosphere.



Double click the folder name to load the photos.

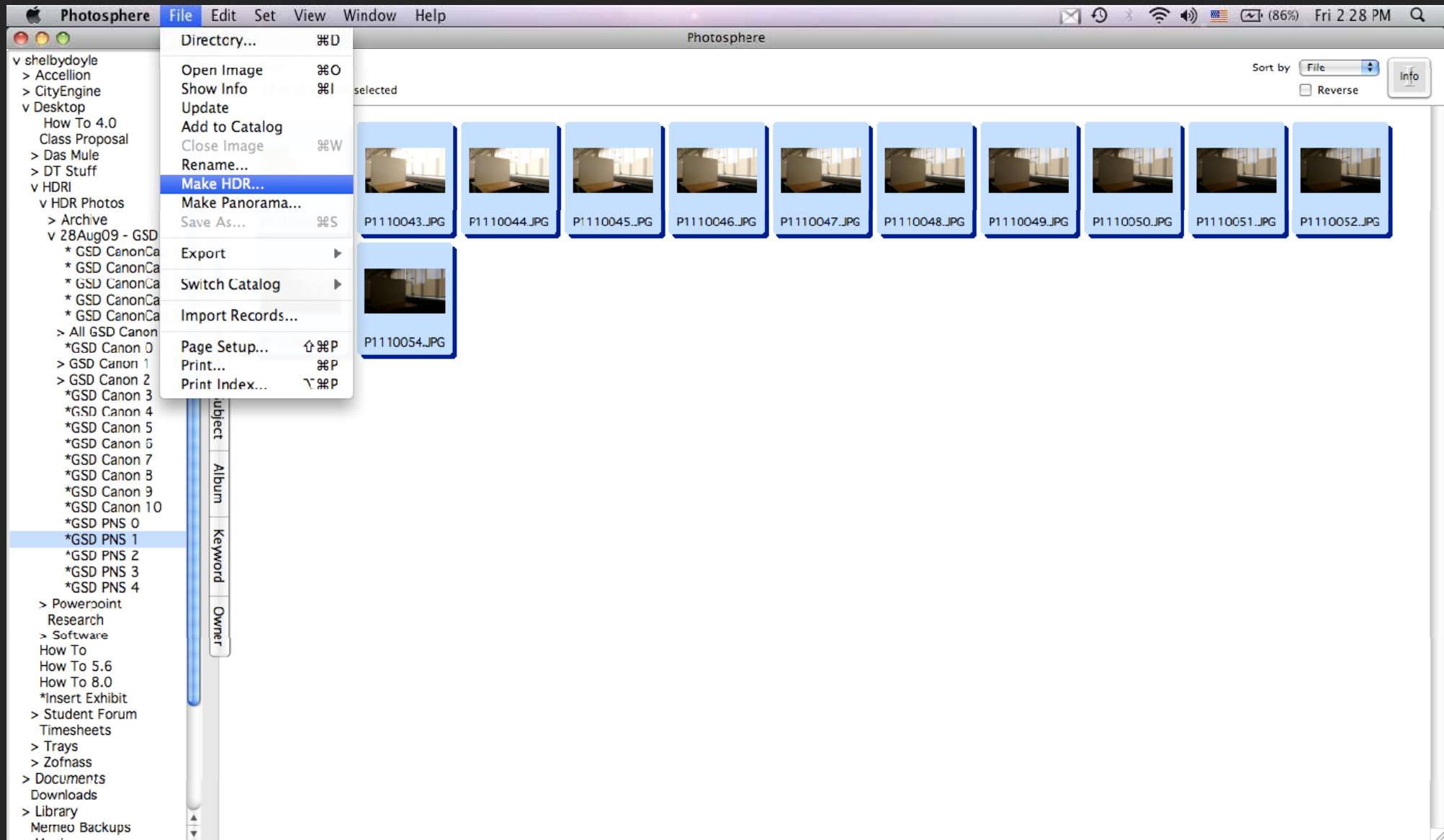


Select the photos needed to make an HDR photo.

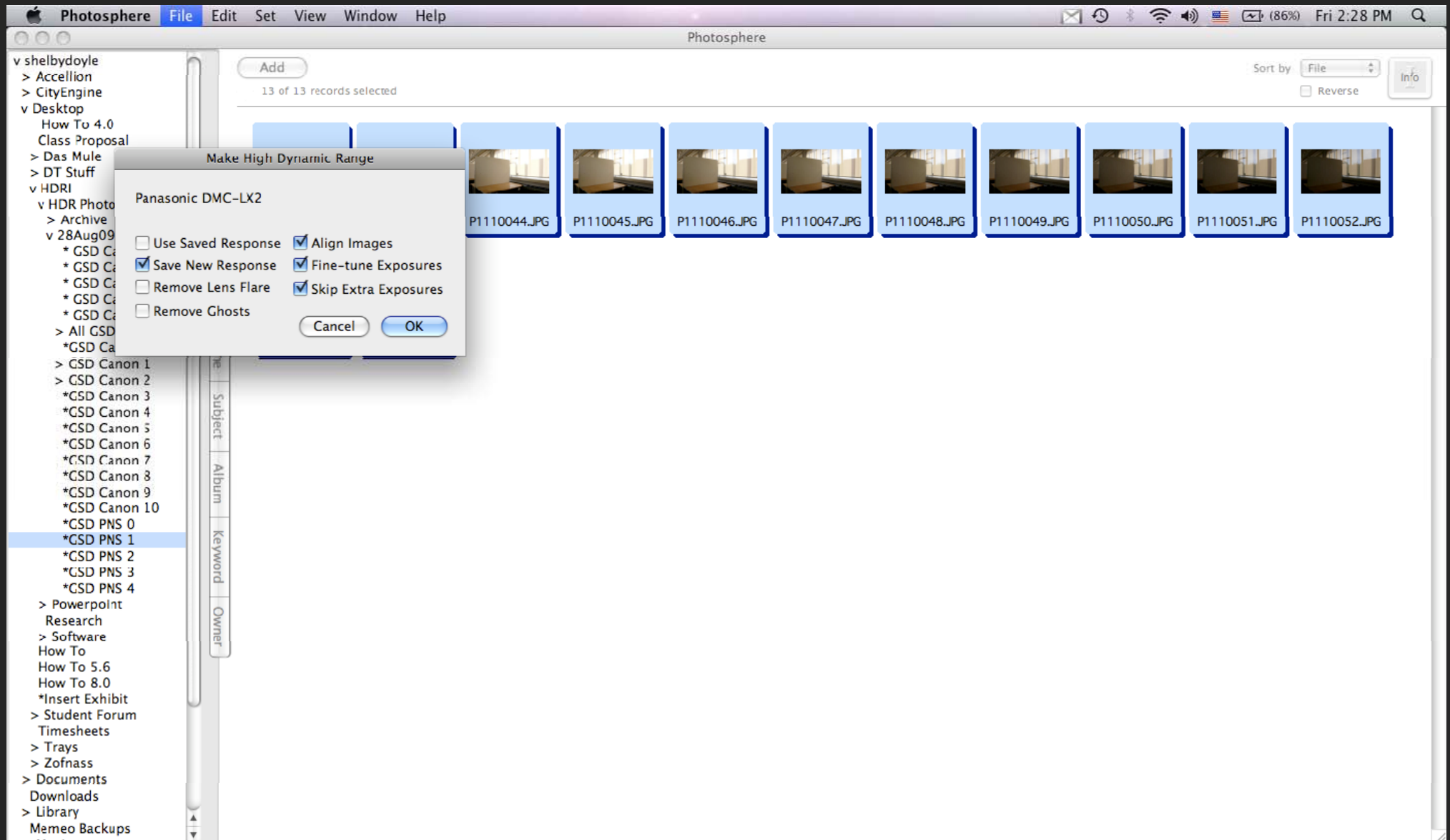




# Select File then Make HDR



Select the below **HDR** settings.



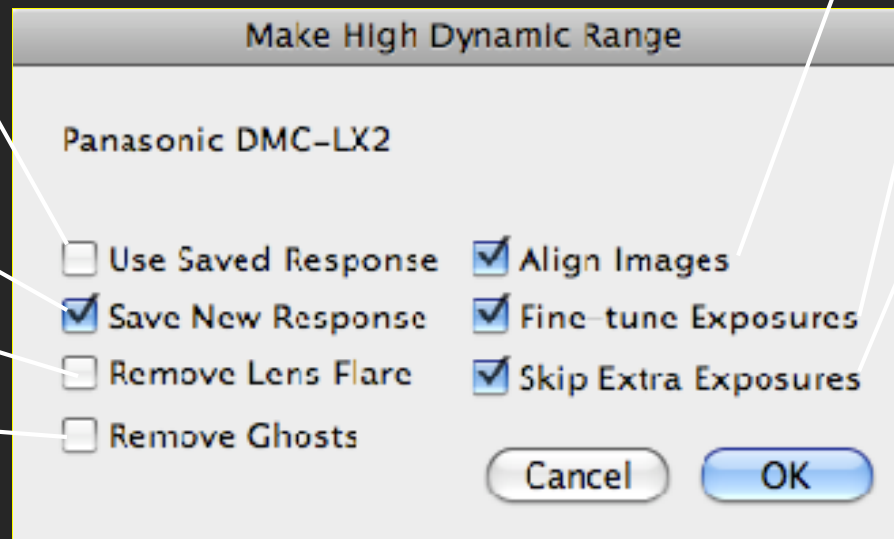
# Photosphere HDR settings explained.

Once a calibration response is saved for the camera it can be used instead of recalibrating each time

Save a calibration response for the identified camera, in this case a Panasonic DMC-LX2

Removes light artifacts from the scene, such as from the sun.

Removes people from a scene

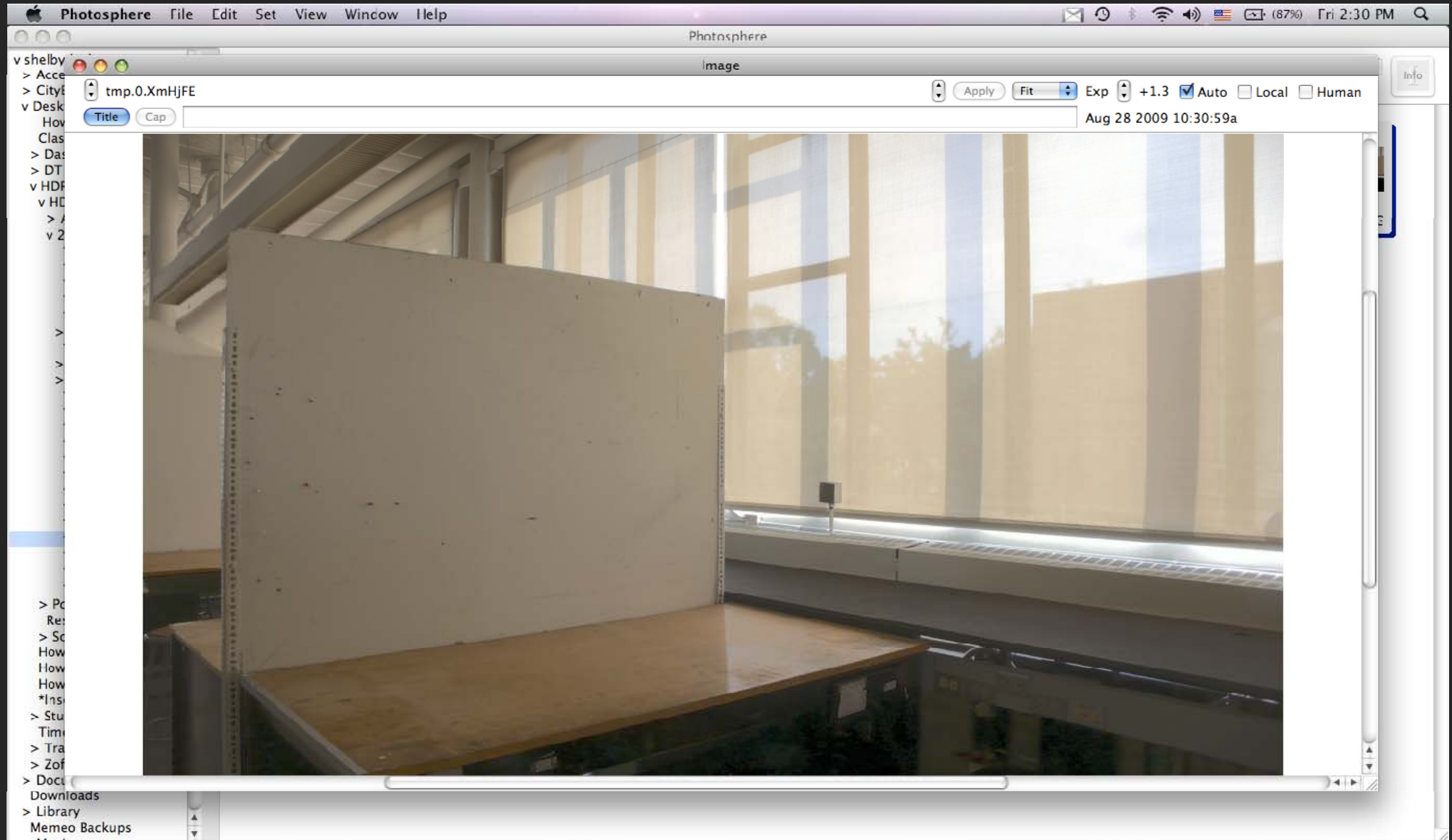


Automatically aligns images if tripod shake occurred

Automatically fine-tune exposures for exposure values

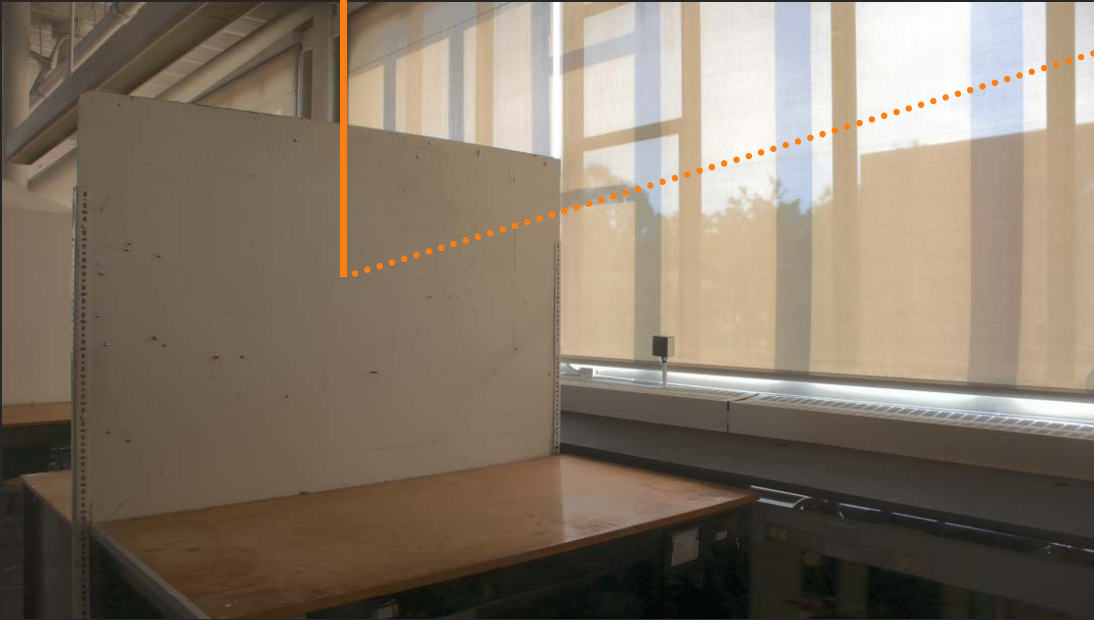
Automatically skips unnecessary exposures

The **HDR photo** will appear.

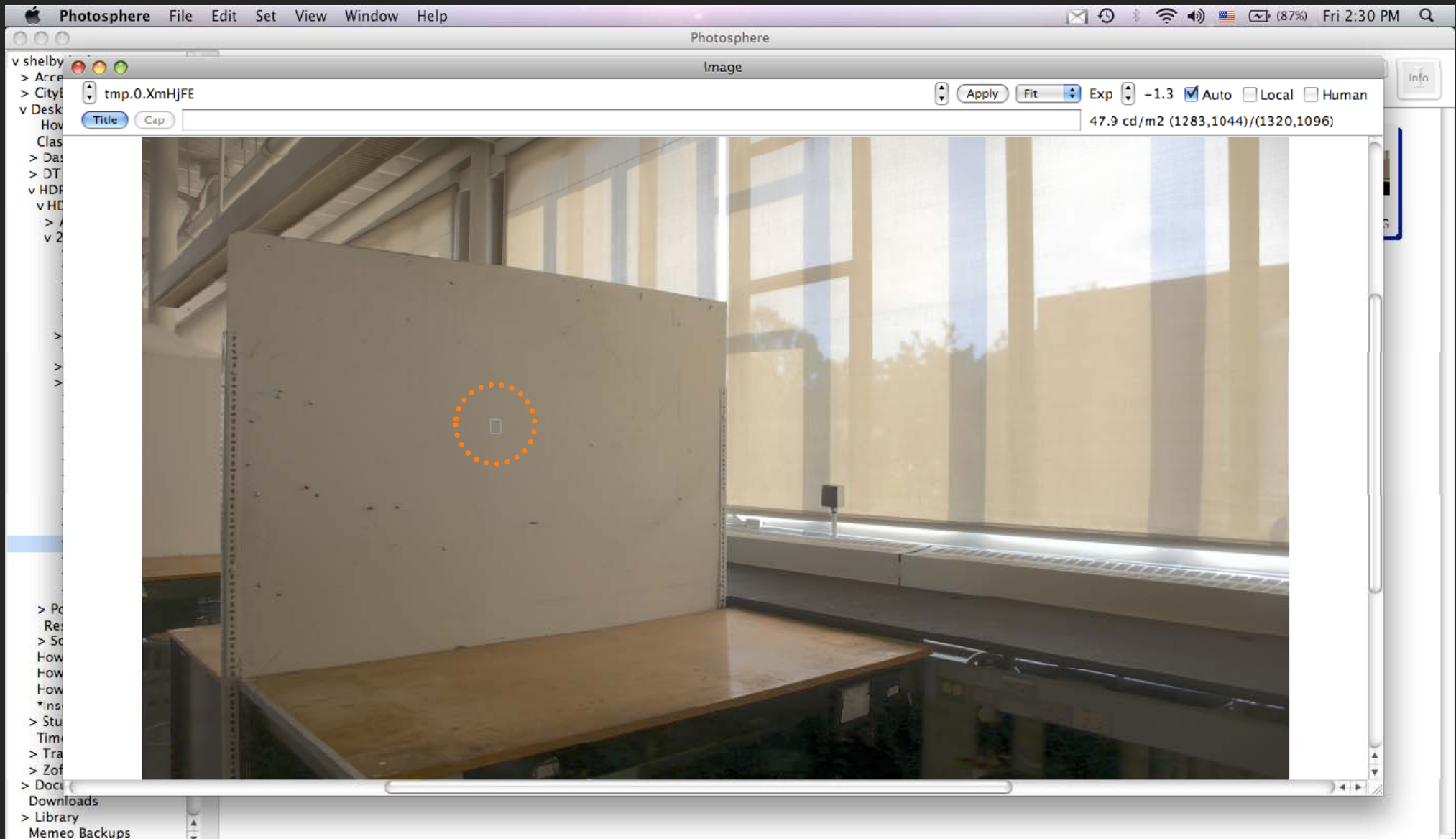


Pick a spot in the actual space to **calibrate** with the  
**Luminance Meter**.

Record the  $\text{cd/m}^2$

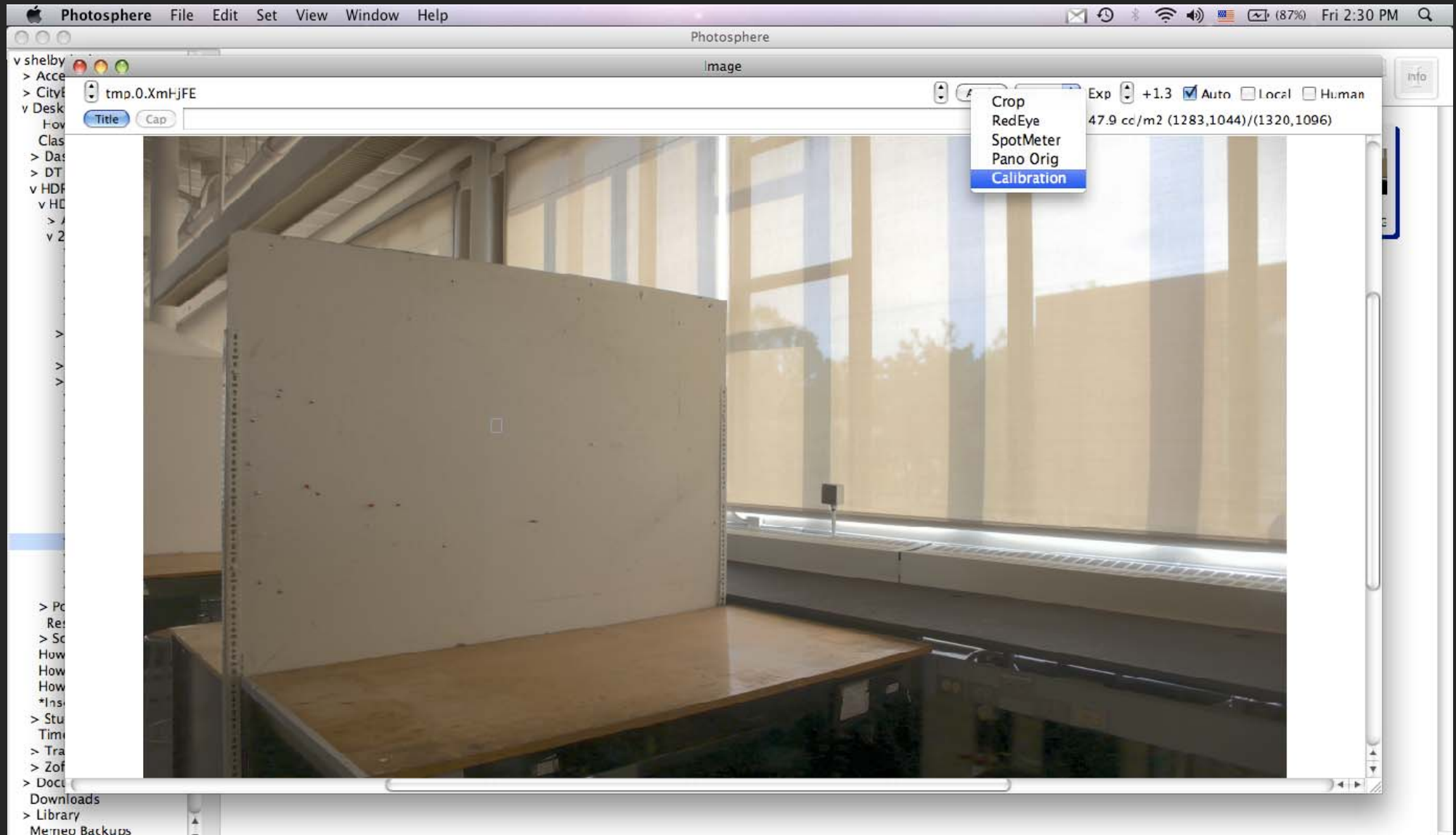


Pick the same spot in the photo.

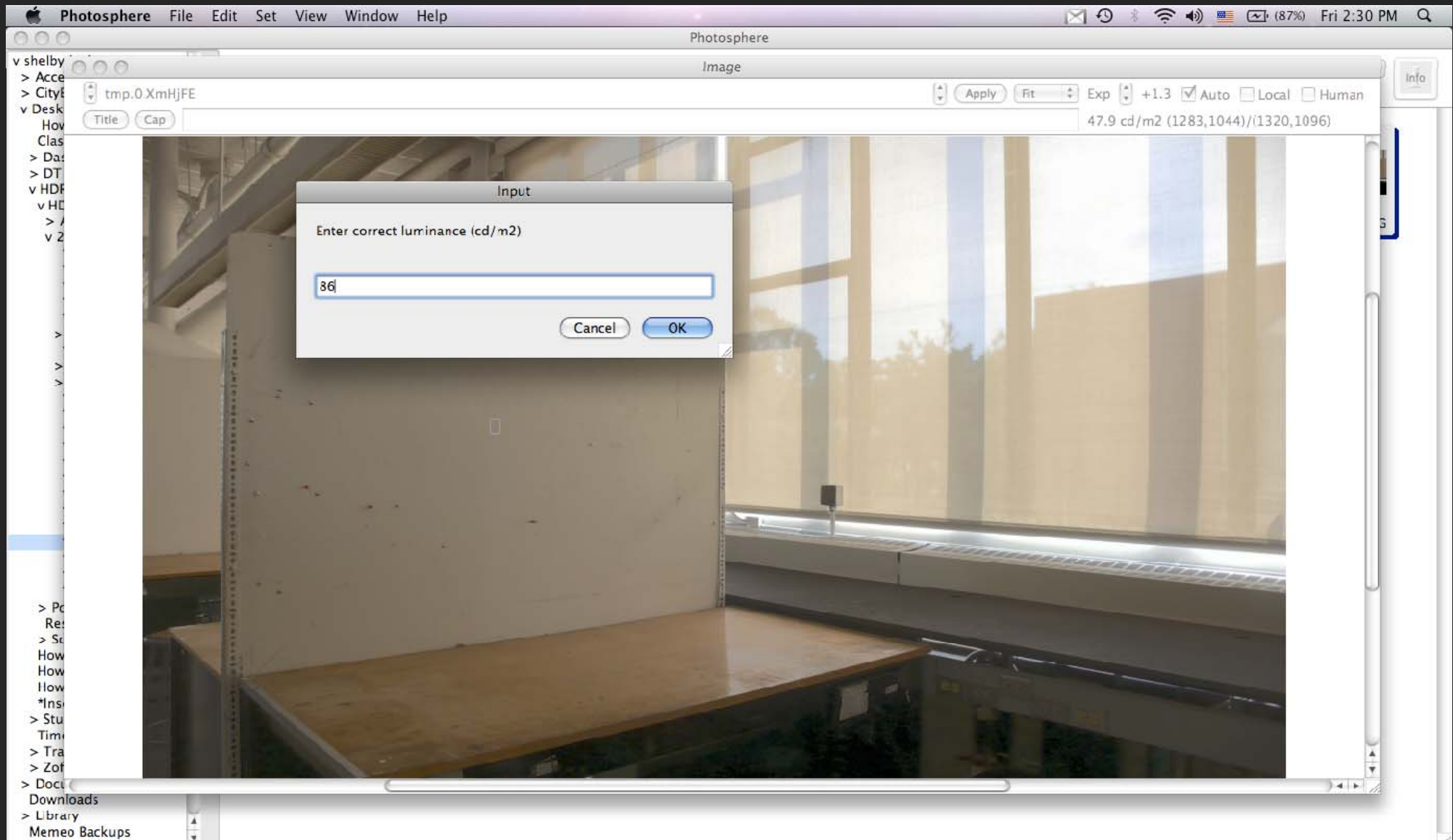




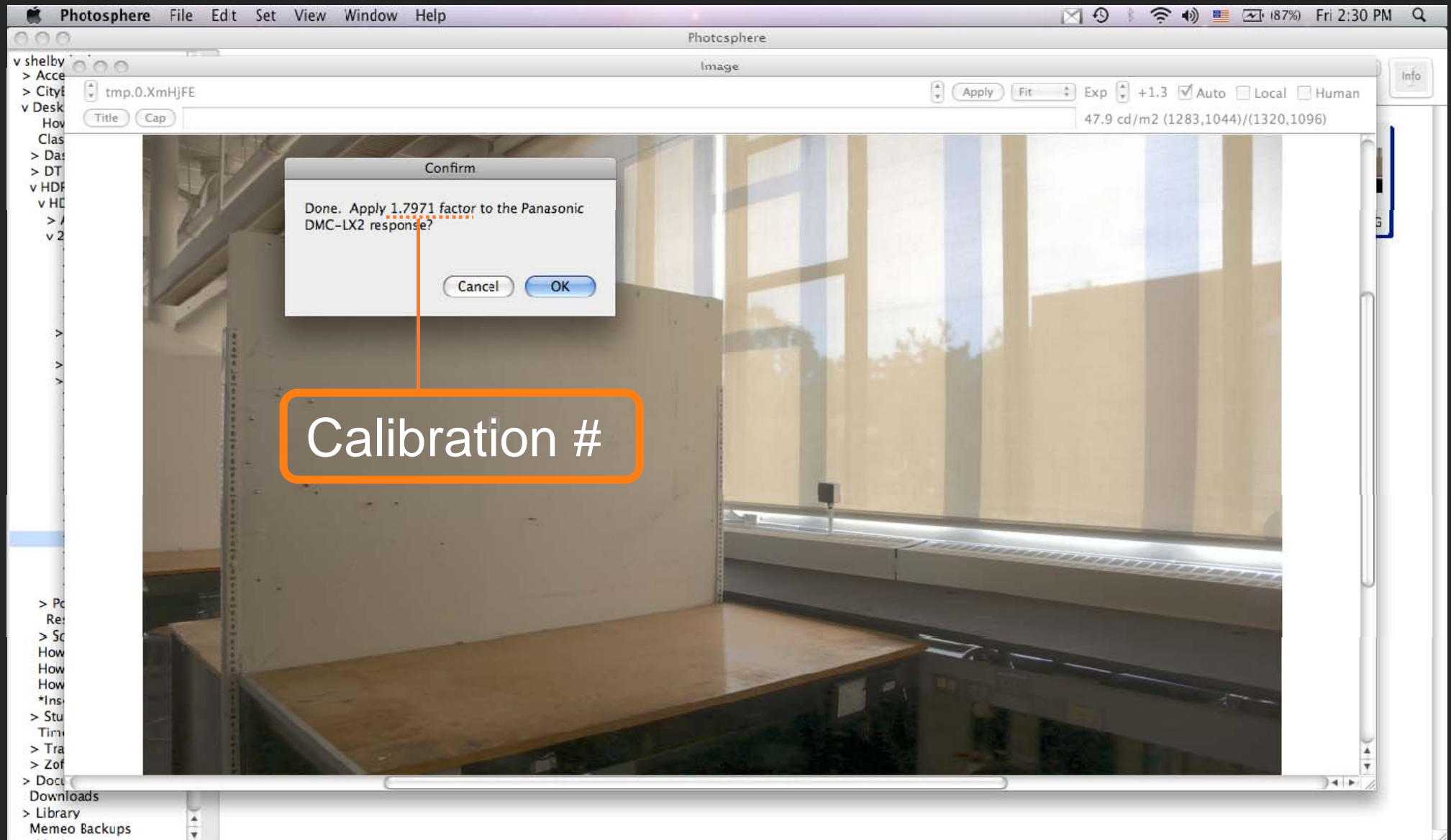
# Select **Calibration** from the **Apply** Menu.



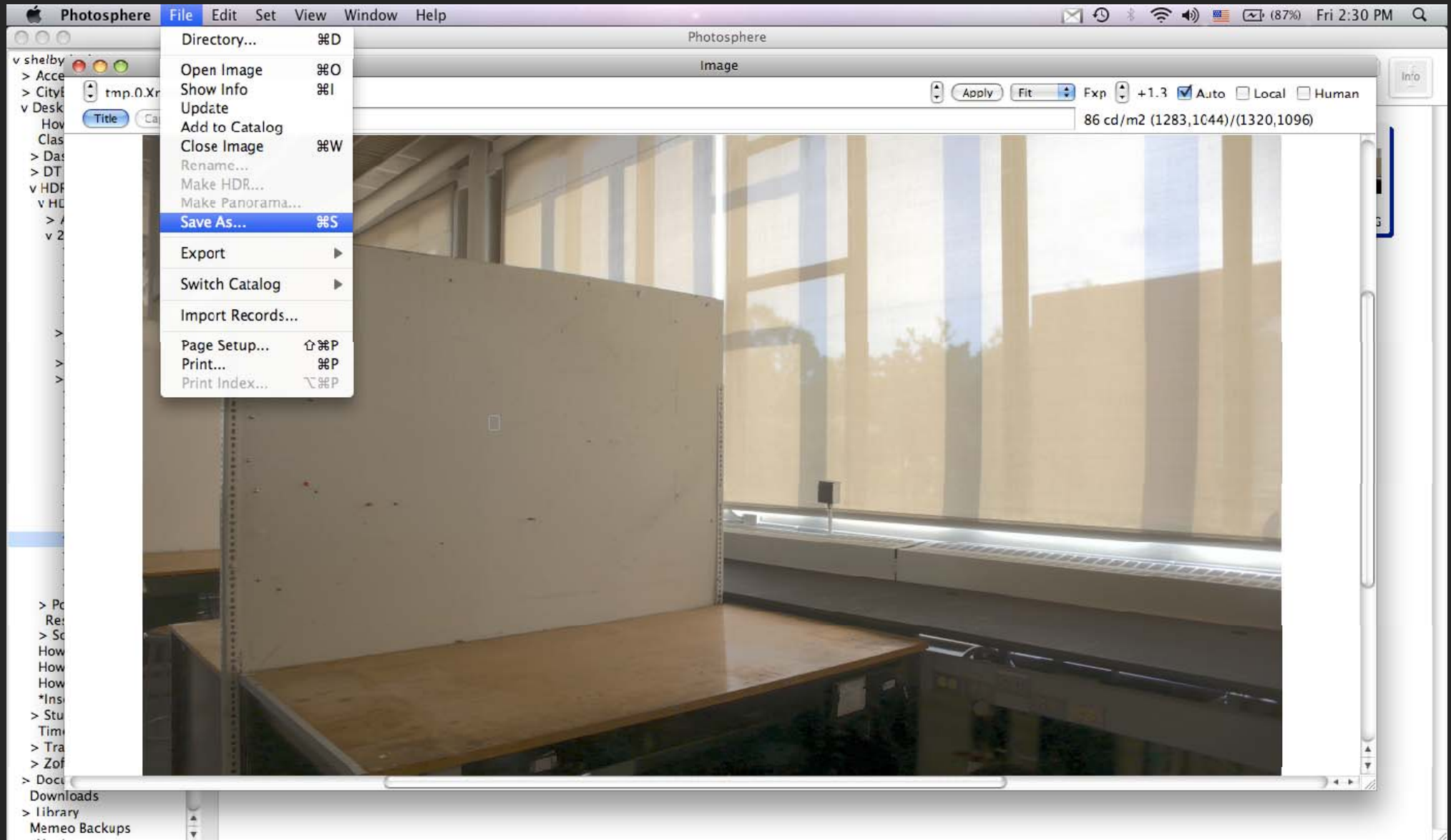
Enter the **cd/m2** value from the **Luminance Meter**.



Record the **calibration factor** for **your camera**. Press **OK**.

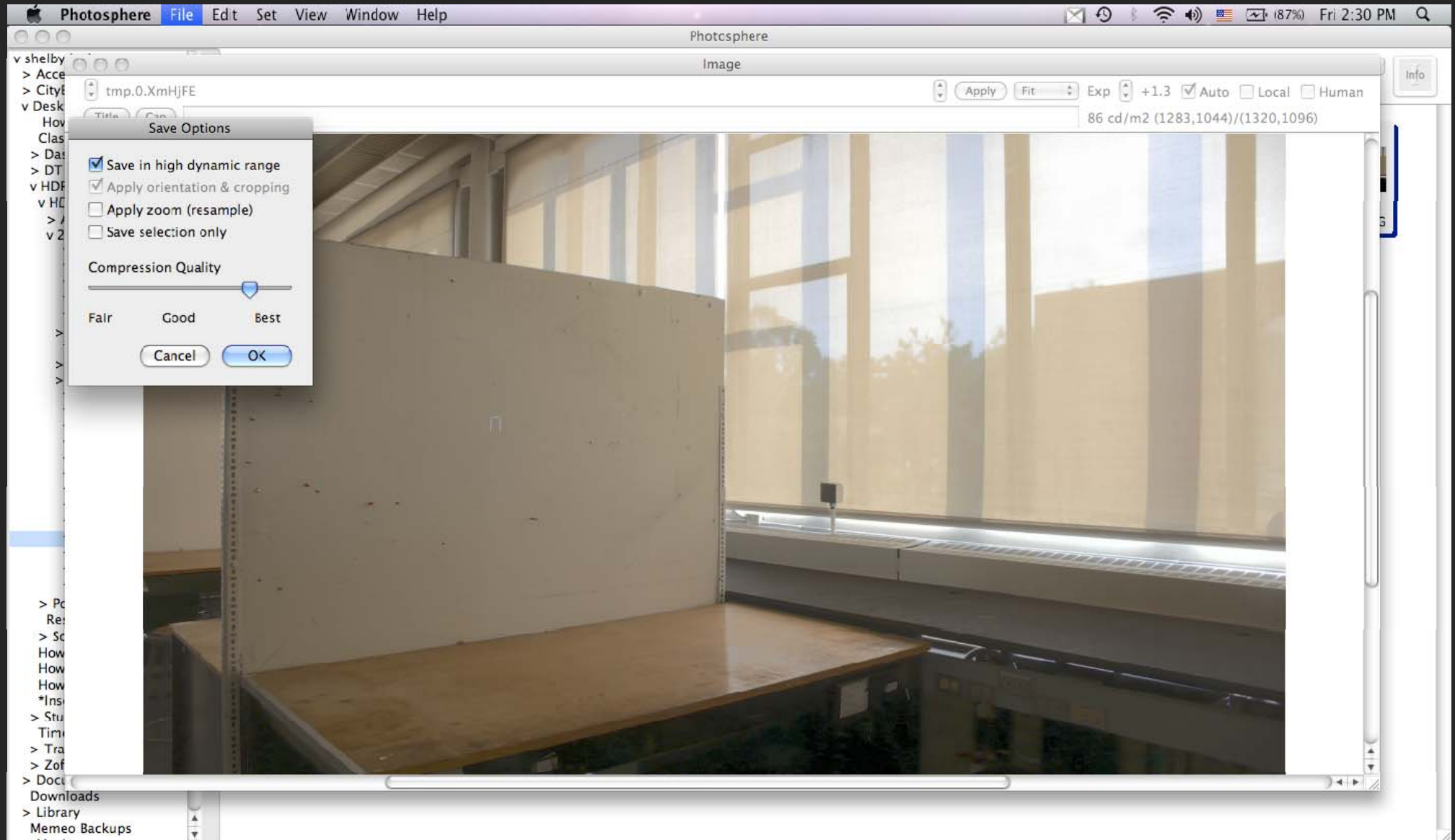


# Save the HDR Image.



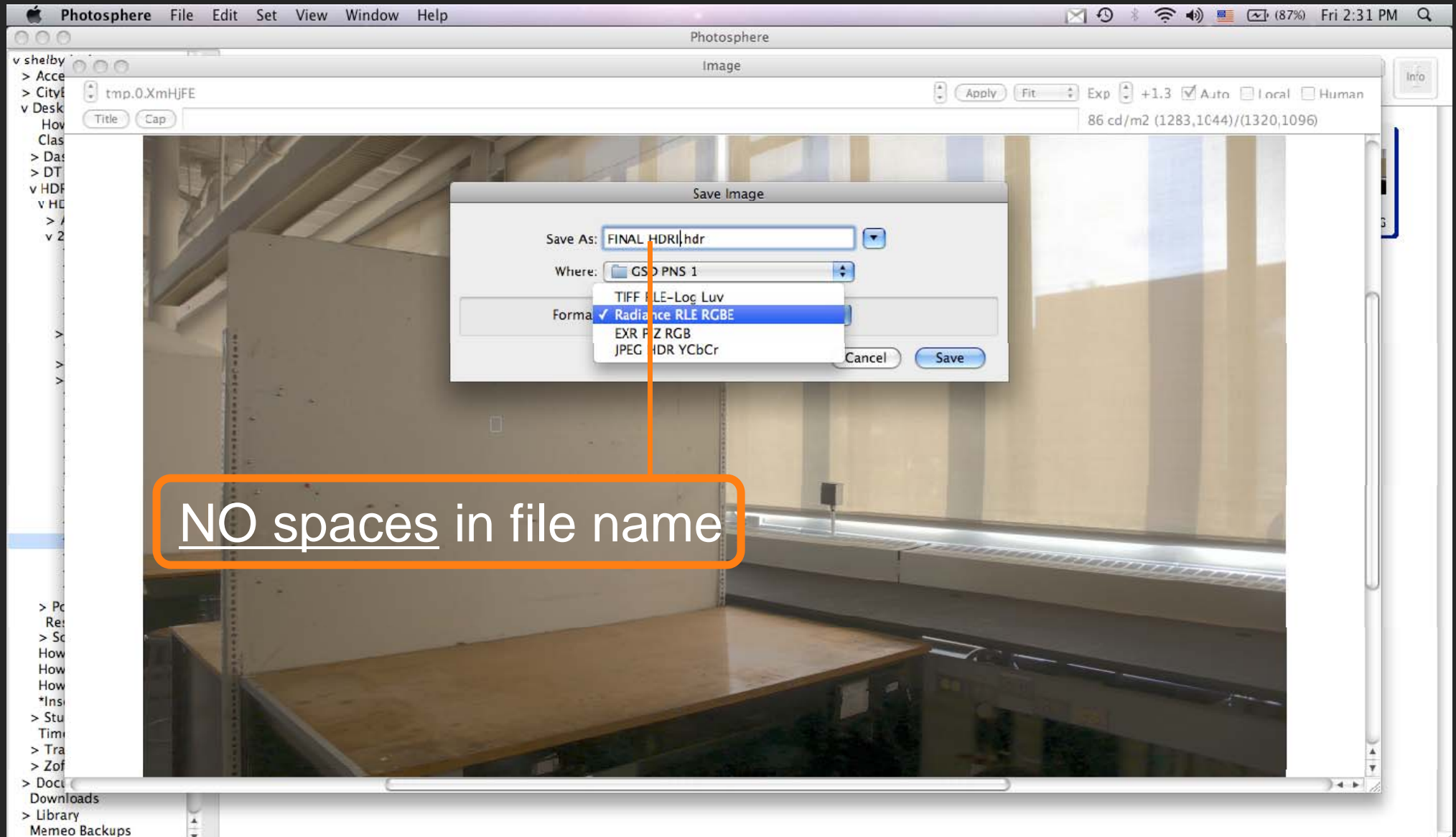


# Save the HDR Image in High Dynamic Range.





Save the HDR Image as an **.hdr** file extension.





Note that an **.hdr file extension** is the **SAME** file format as a **Radiance .pic file extension** which is created during a simulation. Both file types can be used to do an **Evalglare glare analysis**.

**.hdr = .pic**

To run Evalglare an image of **less than 800x800 pixels** is needed. If possible adjust the size of the image now. Otherwise this can be done in Evalglare.

*Switch to a PC to begin HDRI Glare Analysis.*

## High Dynamic Range Imaging

### III. GLARE ANALYSIS: EVALGLARE

<http://www.gsd.harvard.edu/research/gsd-square/tutorials.html>

*For HDRI Background Information.*

## High Dynamic Range Imaging

### I. DEFINITIONS

<http://www.gsd.harvard.edu/research/gsd-square/tutorials.html>



## **APPENDIX C**

### **Summary of Research on Natural Ventilation using Advanced CFD**

Duration September through December, 2012

By

Manfred Zapka, PhD, PE

Sanphawat Jatupatwarangkul, D.Arch

Environmental Research & Design Laboratory (ERDL)

School of Architecture, University of Hawaii at Manoa

December, 2012



**Objective:**

Research will be conducted in simulating basic settings of natural ventilation in buildings to create initial benchmarks for applicability of CFD in architectural design at the School of Architecture and to establish a workflow that can be used for subsequent research projects in the Environmental Research & Design Laboratory (ERDL).

**Timeline:**

The research will be conducted from September through November 30th, 2012.

**Participants:**

The research will be carried out by Manfred Zapka, project lead, and Sanphawat Jatupatwarangkul, graduate research assistant.

**Preliminary schedule and time commitment:**

The planned duration of the research work is September 1st through November 30, 2012.

The initially estimated time commitment to the project is a minimum of about 80 hours, for each of the team members. Sanphawat will work on the modeling, simulation and analysis in the ERDL lab. Manfred will contribute approximately the same time for person-to-person meetings and project work as well as for building scientific evaluation of results and specify the scope of investigation as the research progresses. In addition, both Manfred and Sanphawat will dedicate time to literature research and writing the final internal report.

**Approach:**

The research work is open ended, which means as much analysis work as achievable will be carried out during the projected three month of research work. In accordance with developments of the research the scope of modeling, simulation and analysis will be adjusted depending on the of progress and evolving challenges. The actually anticipated results will be subject to availability on computer facilities, time of the team to invest in the project and available facilitation by software support, if the team encounters challenges in the modeling, simulation and visualization process. The team members recognize that the use of the expert CFD creates challenges of an intricate workflow, and firm goals of analysis cannot be delineated without having the standard workflow established.

The team will endeavor to work on the following topics of natural ventilation:

1. External wind pattern around buildings and the determination of pressure distribution on the building façade
2. Internal ventilation of spaces as a result of pressure driving forces on ventilation interface openings.
3. Internal comfort assessment as a function of ventilation rates in the naturally ventilated spaces.

The sequence of work on these research topics is as reflected in the numbering of the three research topics above.

## What Is STAR-CCM+?<sup>1</sup>

STAR-CCM+ provides the world's most comprehensive engineering physics simulation inside a single integrated package. Much more than just a CFD solver, STAR-CCM+ is an entire engineering process for solving problems involving flow (of fluids or solids), heat transfer and stress. It provides a suite of integrated components that combine to produce a powerful package that can address a wide variety of modeling needs. These components include: 3D-CAD modeler ,CAD embedding ,Surface preparation tools ,Automatic meshing technology ,Physics modeling ,Turbulence modeling ,Post-processing , CAE Integration STAR-CCM+ is based on object-oriented programming technology. It is specifically designed to handle large models quickly and efficiently using a unique client–server architecture that seamlessly meshes and simultaneously solves and post-processes over multiple computing resources without requiring additional effort from the user.

### Research task No. 1.1: External wind pattern around building and the determination of pressure distribution on the building façade.

#### Description of research task:

CFD models will be used to determine wind pattern around buildings as a function of wind direction and speed as well as the distribution of pressure on the building skin.

#### Workflow for the external CFD:

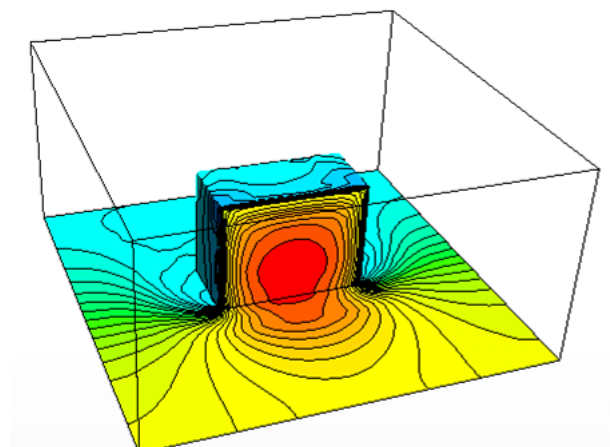
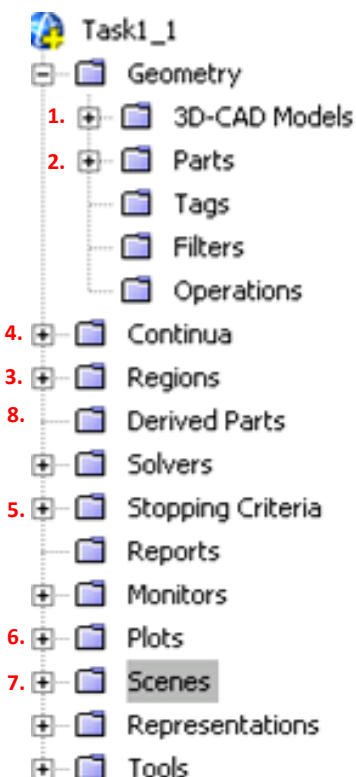


Figure 1: Simply Building box  
Dimension = 12m. x 6 m. x 9 m.

Figure 2: Workflow for the external CFD

<sup>1</sup> STAR-CCM+ Version 7.04.011 user guide, page 34

1. **Create 3D-CAD<sup>2</sup>** is a feature-based parametric solid modeler within STAR-CCM+ that allows geometry to be built from scratch. The geometry created with 3D-CAD is stored as 3D-CAD models, which can subsequently be converting to geometry parts for integration with the meshing and simulation process.

Key modeling: building object, wind tunnel, and external extraction object

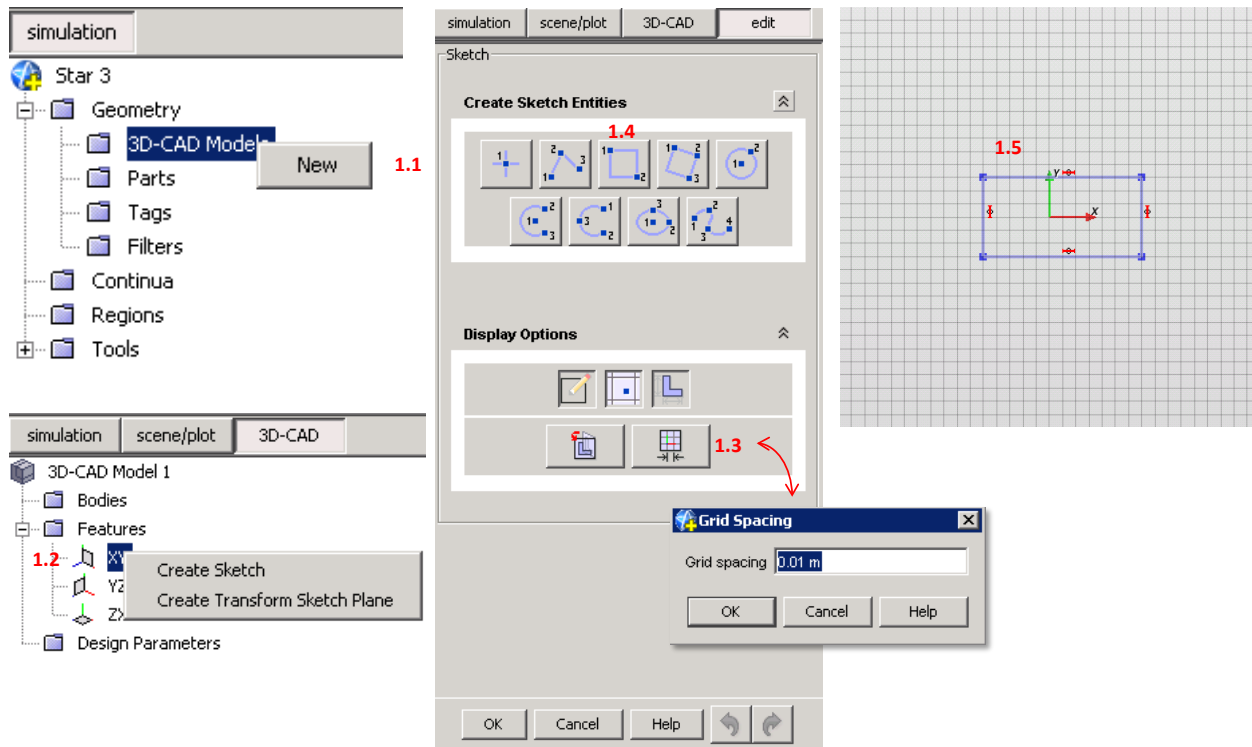


Figure 3: Create 3D-CAD part 1

- 1.1 Create a new 3D-CAD
- 1.2 Create Sketch<sup>3</sup>
- 1.3 Modify grid spacing ( trend to enlarge a grid size)
- 1.4 Create sketch entities ; choose suitable sketch shape for models
- 1.5 Draw sketch shape on the grid plane (Sketch 1 is building object)

<sup>2</sup> STAR-CCM+ Version 7.04.011 user guide, page 807

<sup>3</sup> STAR-CCM+ Version 7.04.011 user guide, page 841

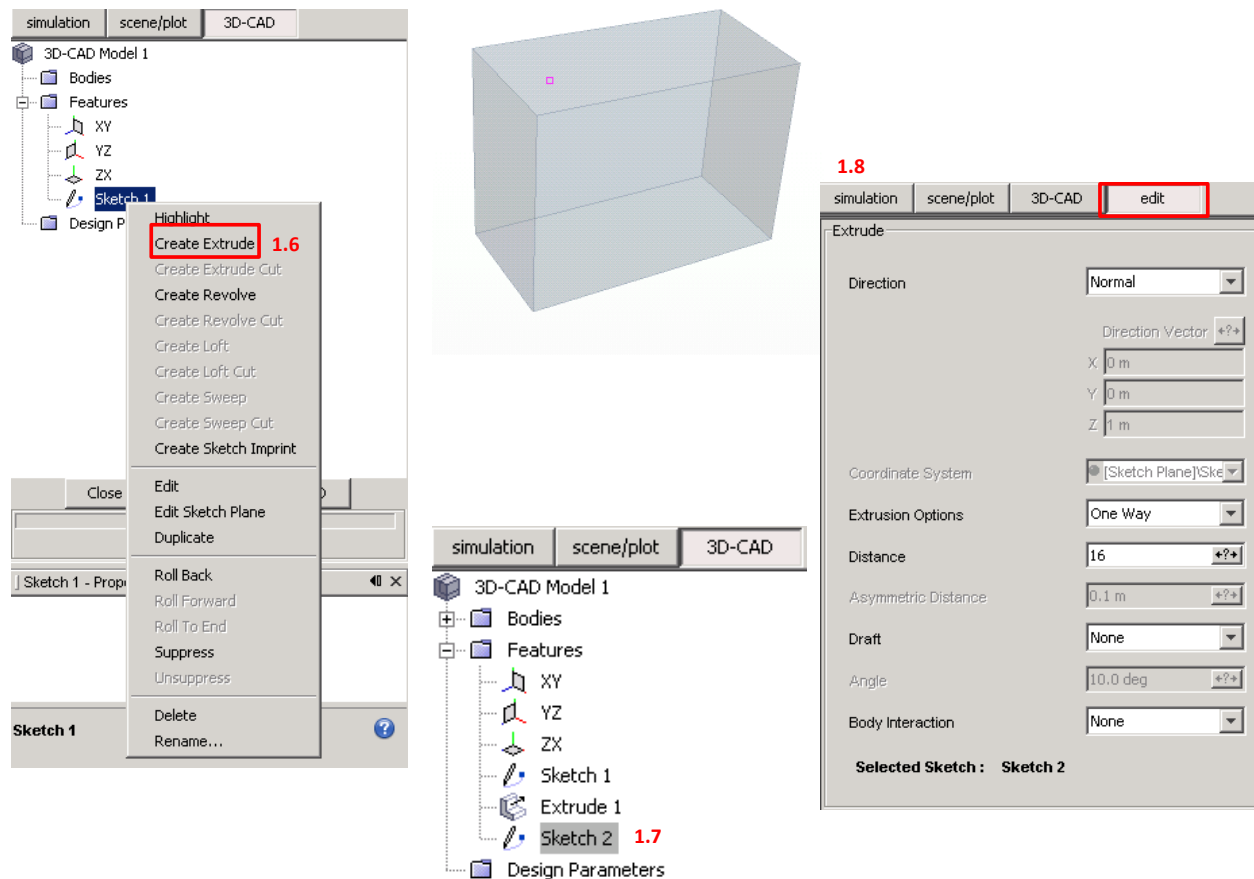


Figure 4: Create 3D-CAD part 2

- 1.6 Create extrude model after 2D sketch 1 created so 3D model is “Extrude 1”
- 1.7 Create sketch 2 (wind tunnel)
- 1.8 Create extrude model from sketch 2 and set body interaction as “None” so both extrude models will not be merged.

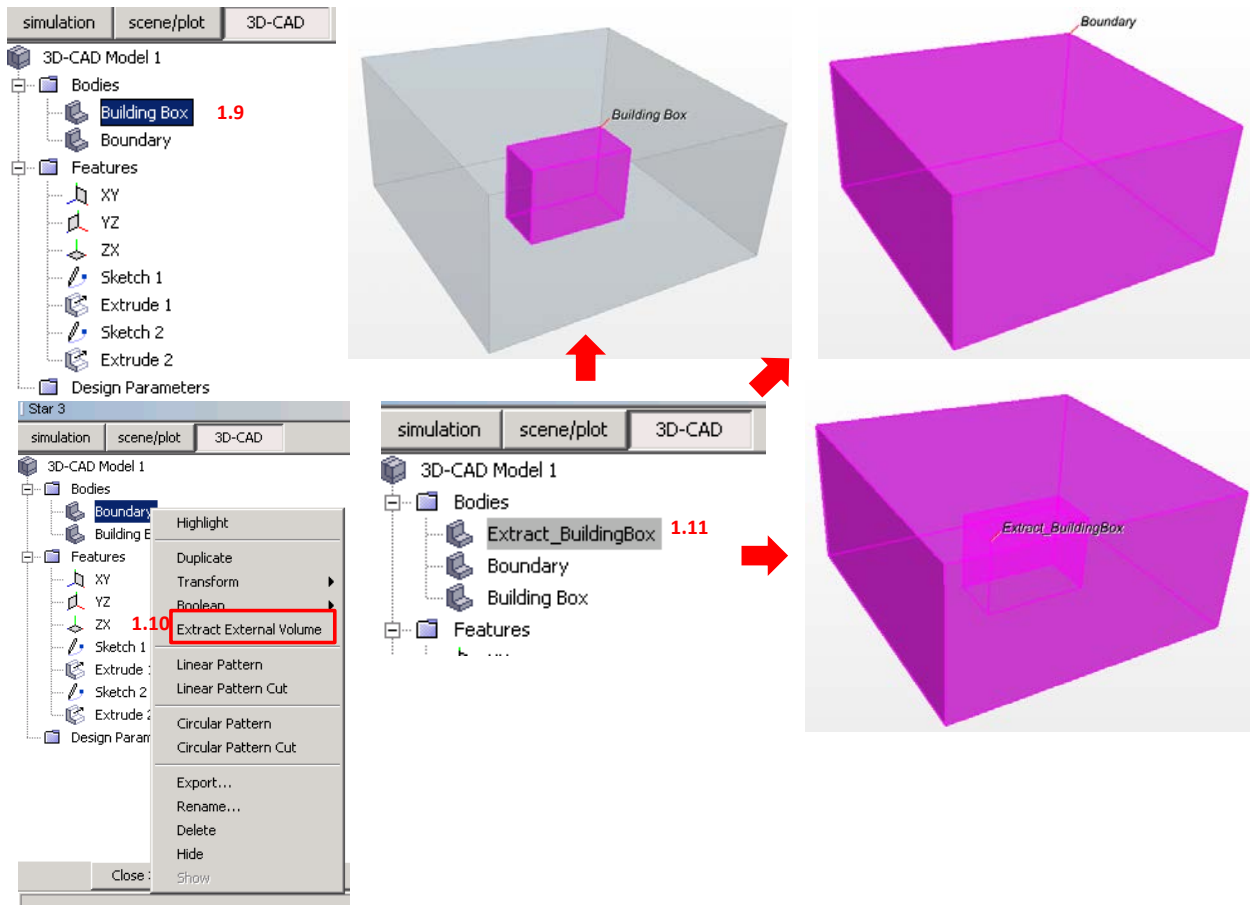


Figure 5: Create 3D-CAD part 3

- 1.9 Rename extrude models into; building box, boundary box
- 1.10 Create *extract external volume*<sup>4</sup> from boundary box model.
- 1.11 Rename and reorganize extrude models

<sup>4</sup> STAR-CCM+ Version 7.04.011 user guide, page 1134



2. **Geometry parts**<sup>5</sup> manager node provides an optional feature that can be used to make the meshing setup for an analysis easier and more efficient.

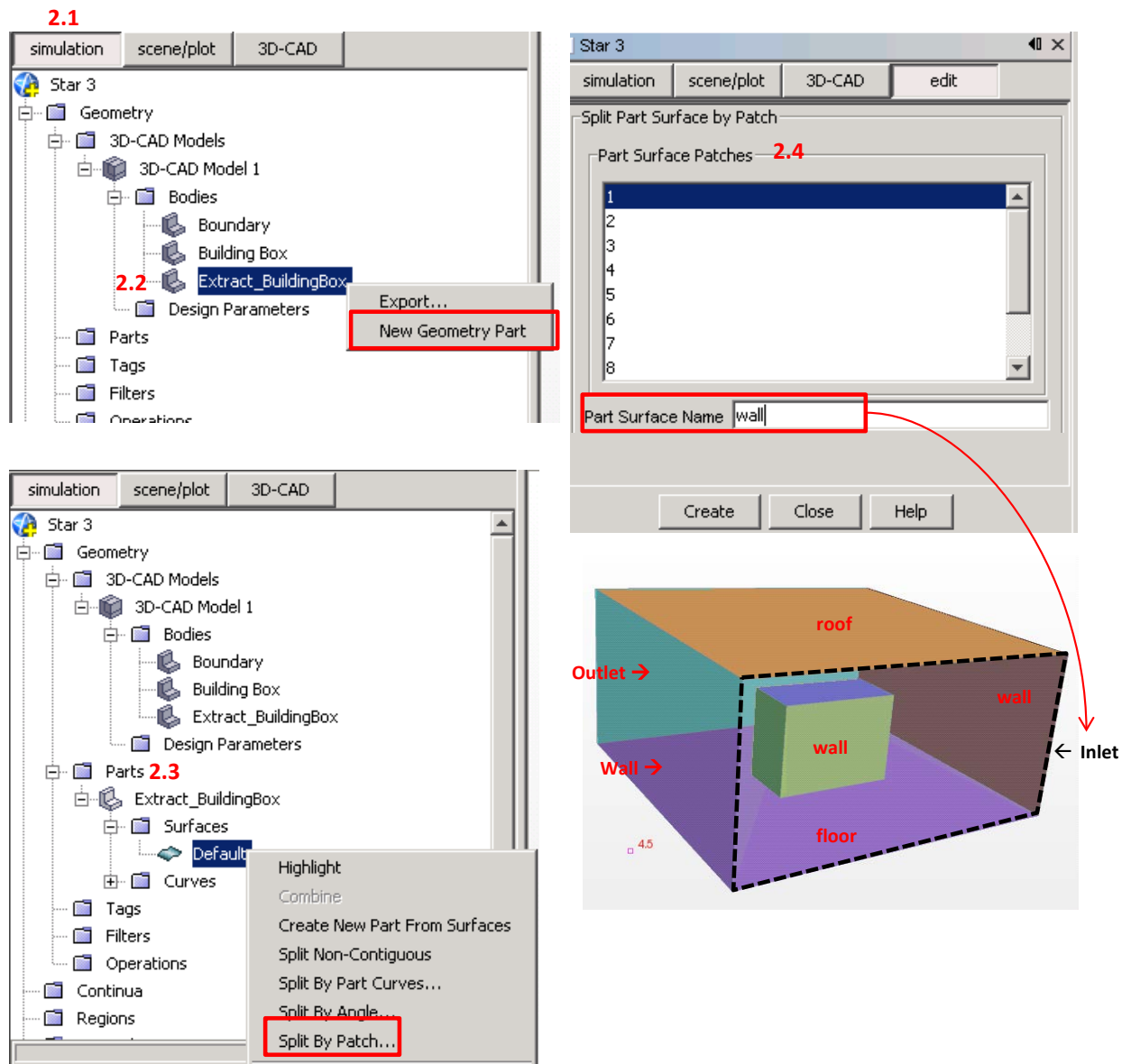


Figure 6: Convert extracted model to geometry part

- 2.1 At simulation tab; create new geometry part from extracted model.
- 2.2 *Create a new geometry part*<sup>6</sup>
- 2.3 At Parts; create a split by patch to explode all surfaces
- 2.4 Split surfaces by patches, then assign proper function in each surfaces

<sup>5</sup> STAR-CCM+ Version 7.04.011 user guide, page 293

<sup>6</sup> STAR-CCM+ Version 7.04.011 user guide, page 1178

3. **Regions**<sup>7</sup> are volume domains (or areas in a two-dimensional case) in spaces that are completely surrounded by boundaries. They are not necessarily contiguous, and are discretized by a conformal mesh consisting of connected faces, cells and vertices.

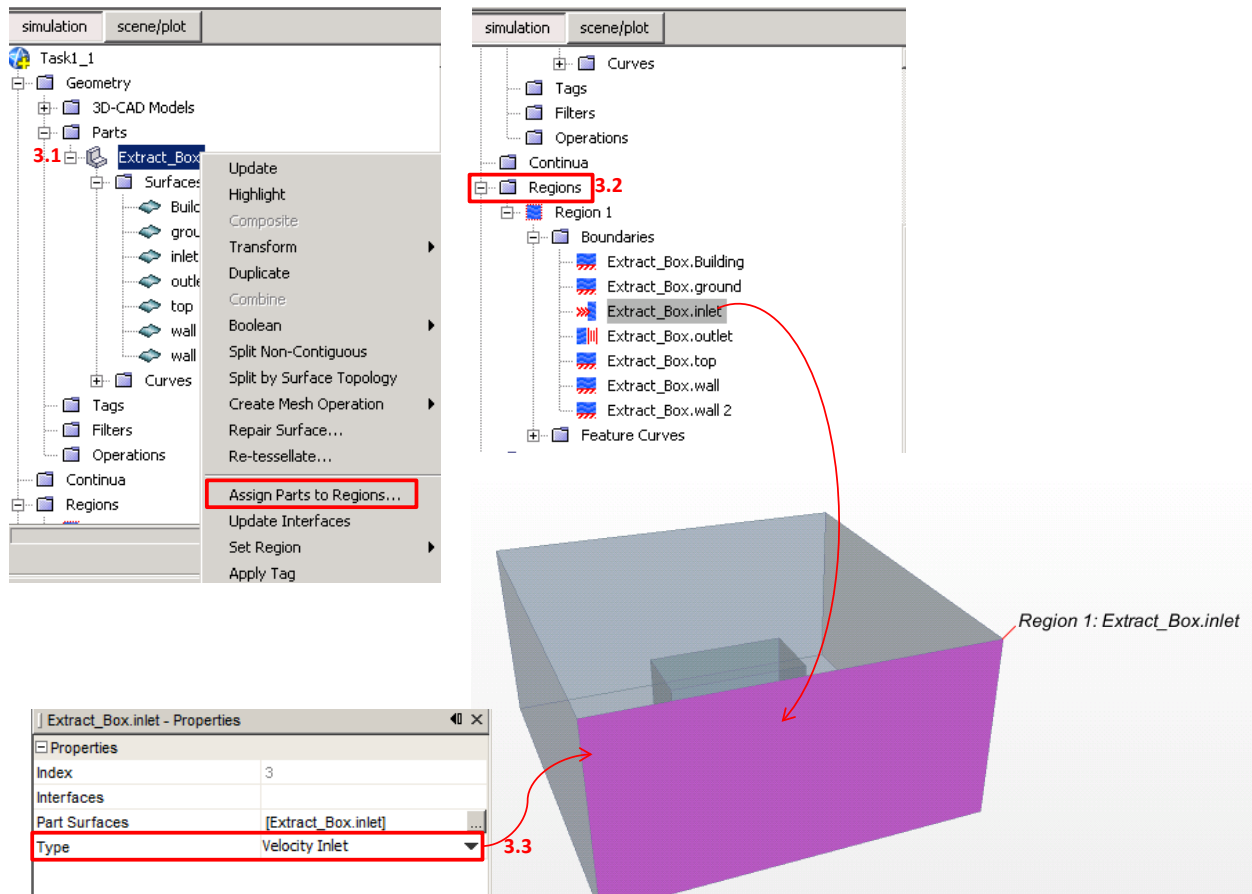


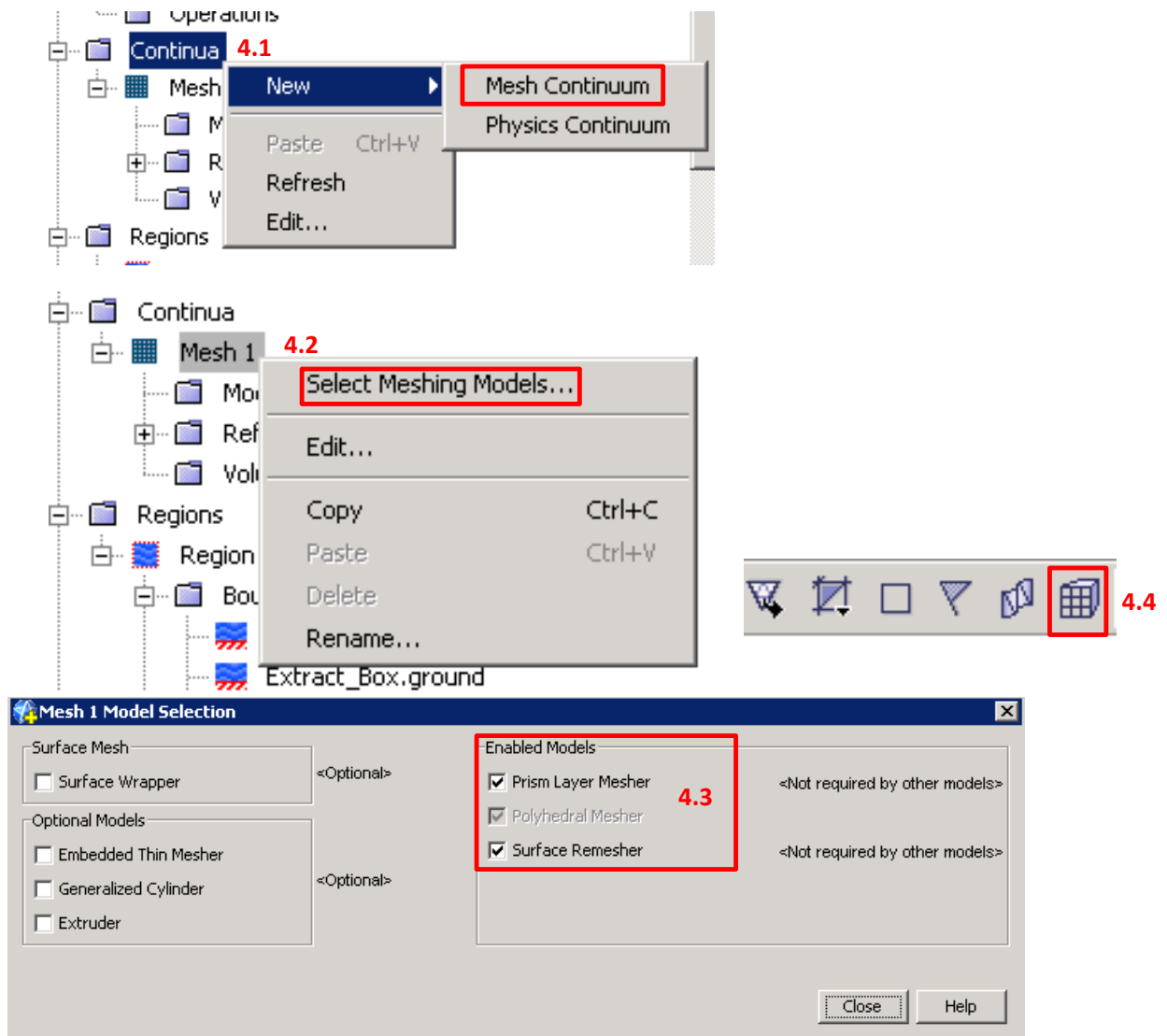
Figure 7: Regions setting

- 3.1 *Assign parts to regions*<sup>8</sup> ; convert parts surface to regions
- 3.2 Boundaries; assign boundary condition to region surfaces such as where is velocity inlet (windward ) and pressure outlet ( leeward)
- 3.3 Boundaries properties; select appropriate boundary type.

<sup>7</sup> STAR-CCM+ Version 7.04.011 user guide, page 302

<sup>8</sup> STAR-CCM+ Version 7.04.011 user guide, page 1645

4. **Continua**<sup>9</sup> are used to contain selections of physics or meshing models that are subsequently applied to one or more regions. Continua have no geometric definition associated with them. Continua and regions are used together to capture the physical and material properties of a model. A continuum represents a material in combination with a set of physics models that will be used to simulate the response of the material to the conditions imposed upon it.



<sup>9</sup> STAR-CCM+ Version 7.04.011 user guide, page 296

<sup>10</sup> STAR-CCM+ Version 7.04.011 user guide, page 1860

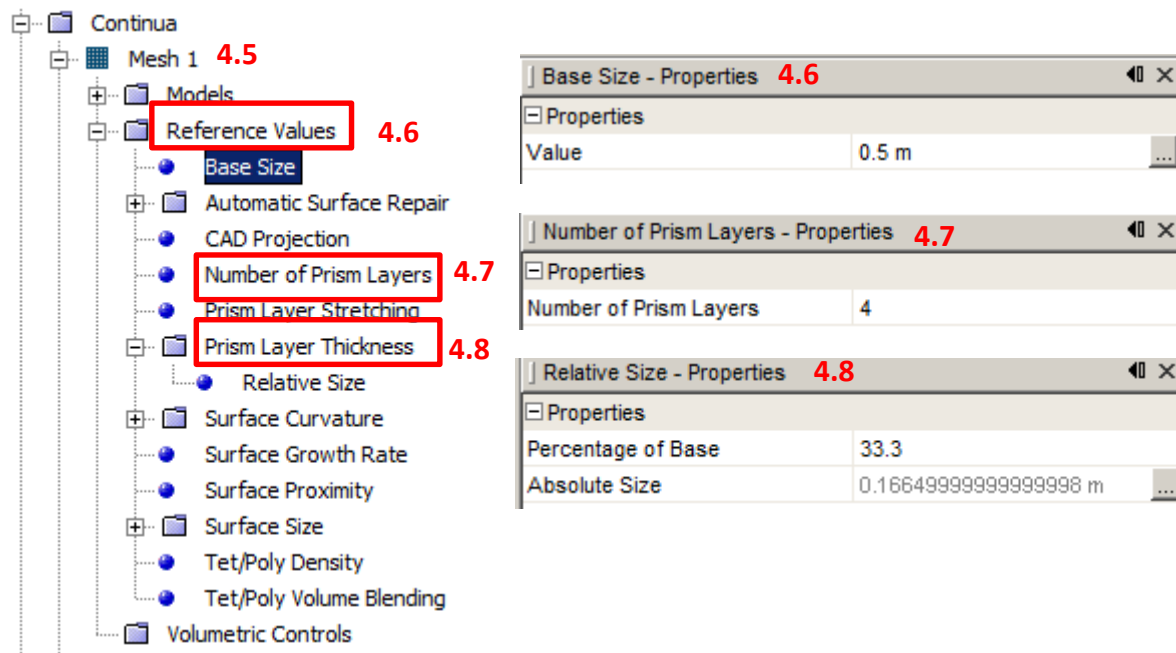


Figure 9: Continua setting part 2

#### 4.5 Modify Mesh continuum

4.6 *Reference values*<sup>11</sup> –the Reference Values manager node. These nodes affect things such as the size of mesh faces, behavior within complex geometry, projection to CAD surfaces, and so on. The particular nodes that are added depend on the chosen meshing models, and some nodes are common to more than one meshing model. The **base size** is always available, as this value is common to all meshing models. The example below shows the value nodes that are added when the surface remesher model is chosen.

4.7 The *number of prism layers*<sup>12</sup> parameter controls the number of cell layers that are generated within the prism layer on a boundary surface. This number is set using the Number of Prism Layers node.

4.8 The *prism layer thickness*<sup>13</sup> controls the total overall thickness of all the prism layers. Selecting the Prism Layer Thickness node allows the choice of a relative or absolute Size type to be made. Depending on the Size type selection, a Relative Size or Absolute Size can be set to provide the value of the thickness. The example below shows how the prism layer thickness is measured.

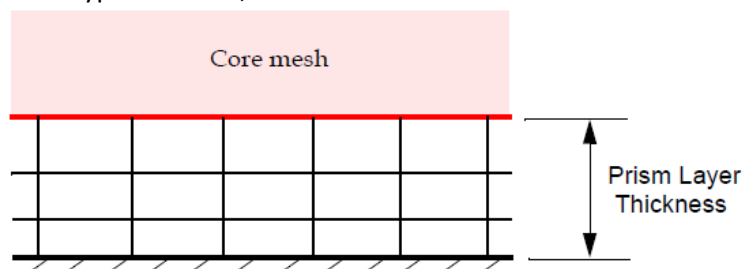


Figure 10: Prism layer thickness

<sup>11</sup> STAR-CCM+ Version 7.04.011 user guide, page 1868

<sup>12</sup> STAR-CCM+ Version 7.04.011 user guide, page 2070

<sup>13</sup> STAR-CCM+ Version 7.04.011 user guide, page 2069

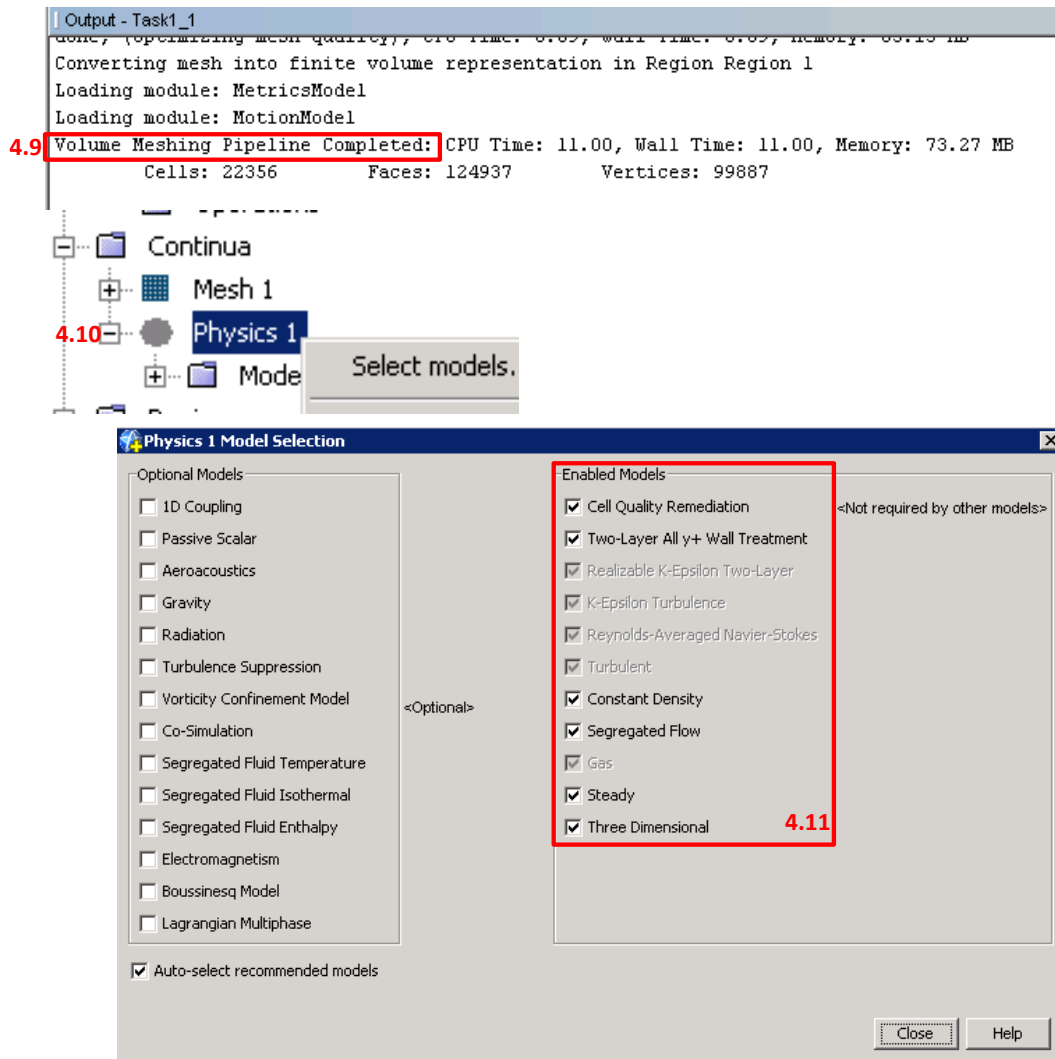


Figure 11: Continua setting part 3

4.9 The meshers run and the progress are displayed in the Output window.

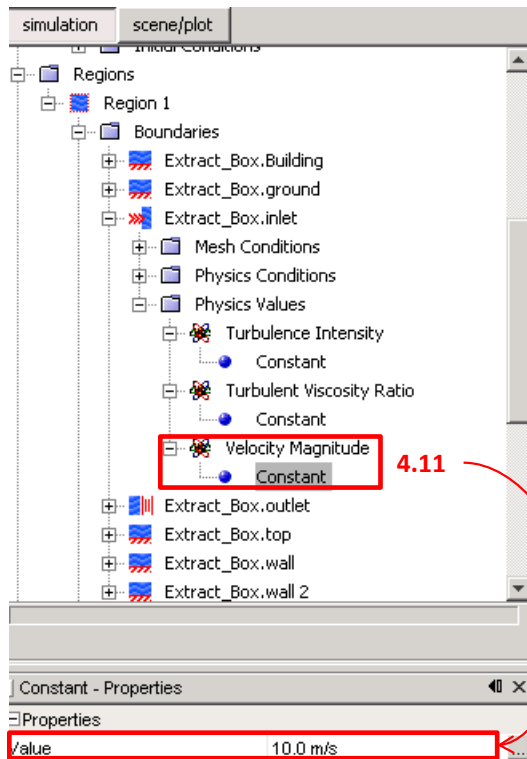
4.10 *Create Physics*<sup>14</sup>; the models define the primary variables of the simulation, including pressure, temperature, velocity, and which mathematical formulation will be used to generate the solution. In this example, the flow is turbulent so the k-omega turbulence model will be used. We will use the option of cell quality remediation to limit the effect of bad cells on the solution.

4.11 *Using the Physics Model Selection Dialog*<sup>15</sup>, the Enabled Models group box on the right-hand side of the dialog will be empty, indicating that no models have yet been selected. Two models are available for selection, the Space model and the Material model. The <Optional> labels indicate that the selection of these items is not mandatory.

<sup>14</sup> STAR-CCM+ Version 7.04.011 user guide, page 1860

<sup>15</sup> STAR-CCM+ Version 7.04.011 user guide, page 2414



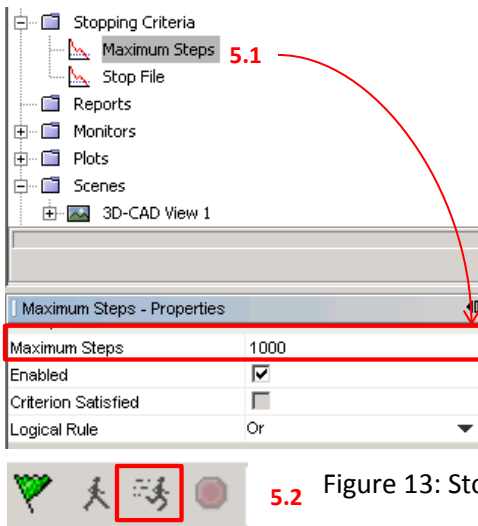


4.12 Physic modification; adjust velocity magnitude on “Inlet region”

Figure 12: Continua setting part 4

## 5. Stopping criteria <sup>16</sup>

Stopping criteria allow you to specify how long the solution should run and under what conditions it should stop iterating and/or marching in time. Each enabled stopping criterion is evaluated at the completion of every simulation step and a logical rule is used to determine if the interaction of all the criteria should stop the solver.



5.2 Figure 13: Stopping criteria

5.1 Maximum steps, The Maximum Steps stopping criterion allows you to specify the maximum number of iterations in a steady solver or the maximum number of time-steps in an unsteady solver.

5.2 *Running simulation* <sup>17</sup>; once a simulation has been set up and there is reasonable confidence that the setup is correct, solution iteration can commence. If the solution is not already initialized, it will be automatically initialized before iterations commence. The iterations will be displayed in the residual plot in real time.

<sup>16</sup> STAR-CCM+ Version 7.04.011 user guide, page 5544

<sup>17</sup> STAR-CCM+ Version 7.04.011 user guide, page 5575

6. **Residual plot**; the residual plot is a monitor plot that is automatically created from the active residual monitors on semi-log axes when iterating starts.

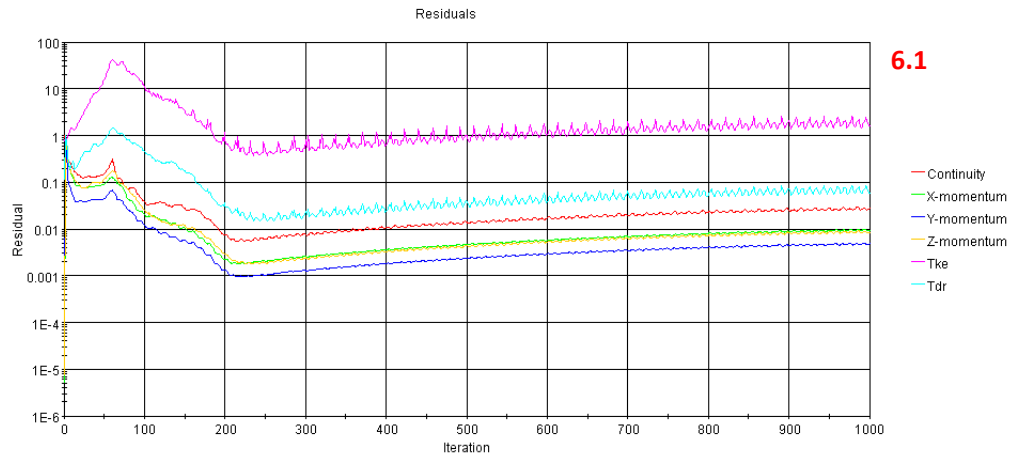


Figure 14: Residual plot

7. **Scene<sup>18</sup>**; allows you to visualize the model. The scene node, which has its own properties and pop-up menu, defines annotations and coordinate systems to be displayed, and serves as a manager node for additional objects that control various aspects of that scene.

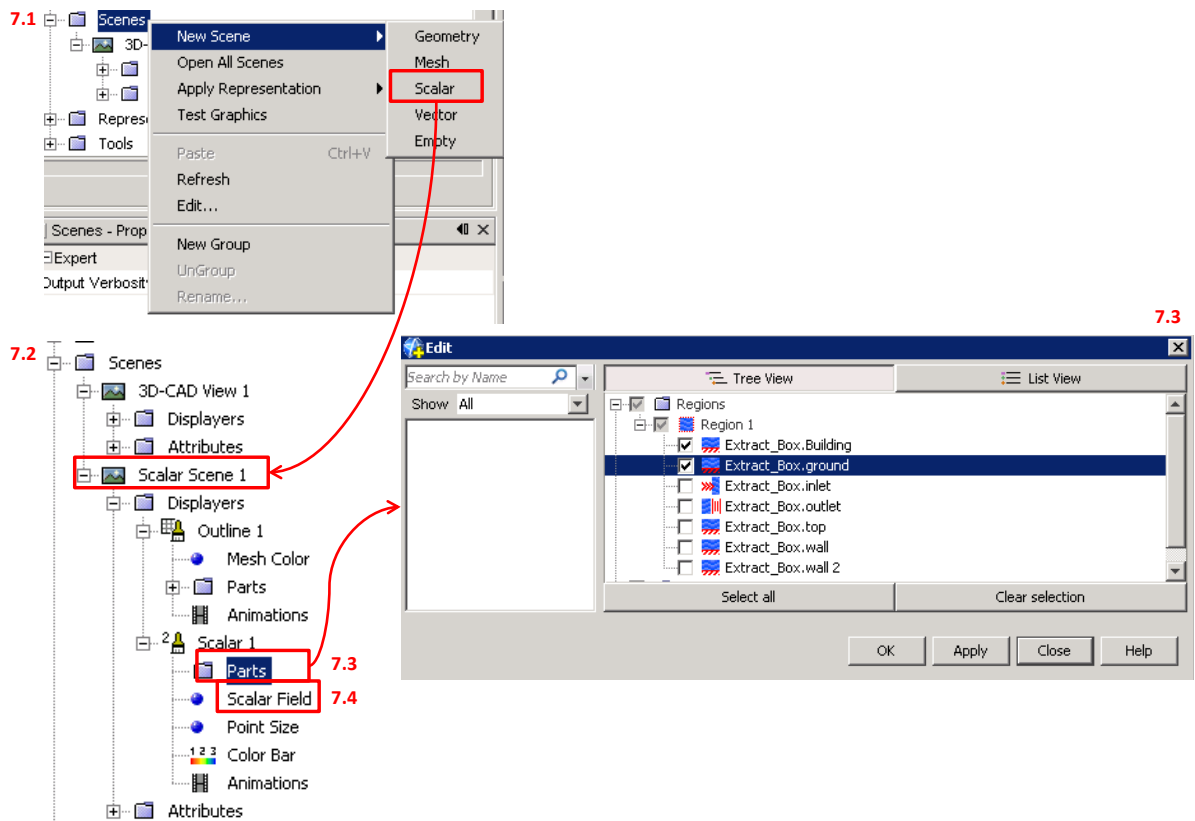


Figure 15: Scene setting

<sup>18</sup> STAR-CCM+ Version 7.04.011 user guide, page 5838

- 7.1 Create new scene, Scalar
- 7.2 Scalar setting
- 7.3 Select part; visualize regions
- 7.4 Scalar field setting; below is an example of scalar field of pressure coefficient

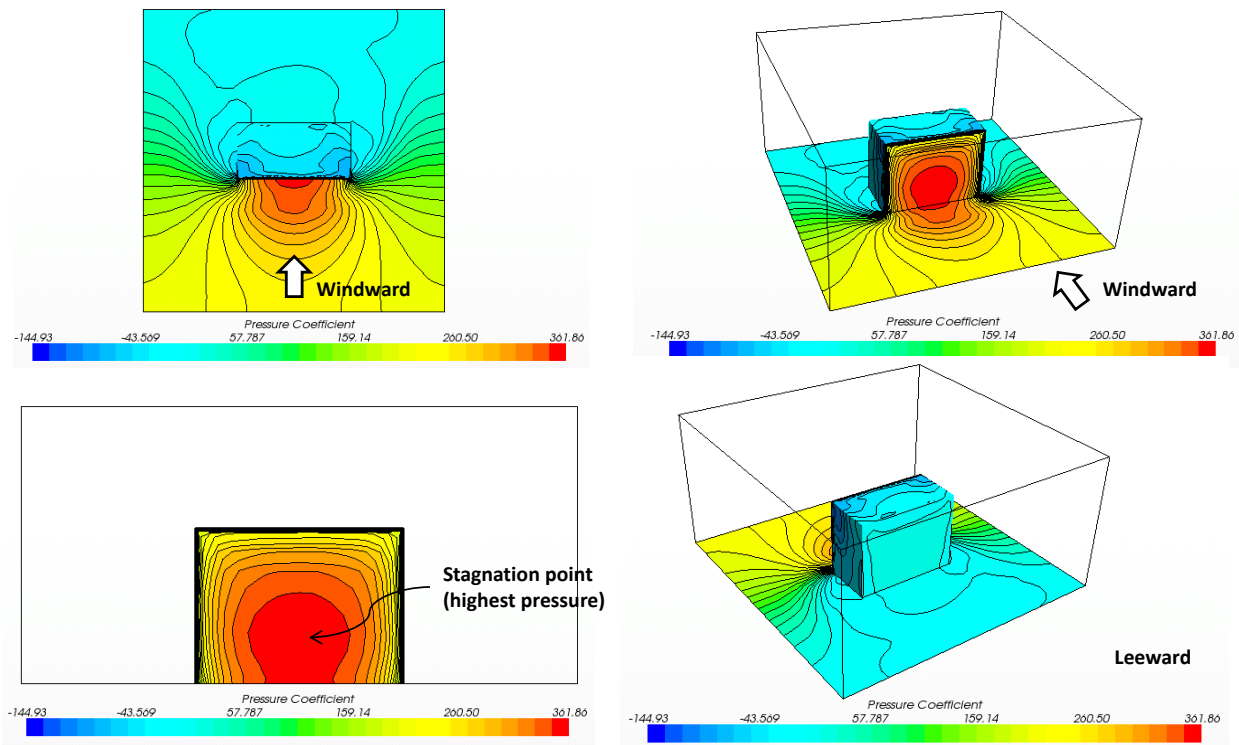


Figure 16: Pressure coefficient; scalar field

8. **Derived Parts**<sup>19</sup> are used in STAR-CCM+ for the purposes of displaying, analyzing and reporting simulation data. This section includes general information on working with derived parts, as well as specific information for the following derived parts: Implicit sections, Scalar value-based parts, Vector value-based parts, Streamlines, Vortex cores, Separation/Attachment Parts, Probes, Topological parts

- 8.1 Create new derived parts; section slice plane<sup>20</sup>
- 8.2 Section plane setting; x, y, z
- 8.3 Scalar setting

<sup>19</sup> STAR-CCM+ Version 7.04.011 user guide, page 5682

<sup>20</sup> STAR-CCM+ Version 7.04.011 user guide, page 7712

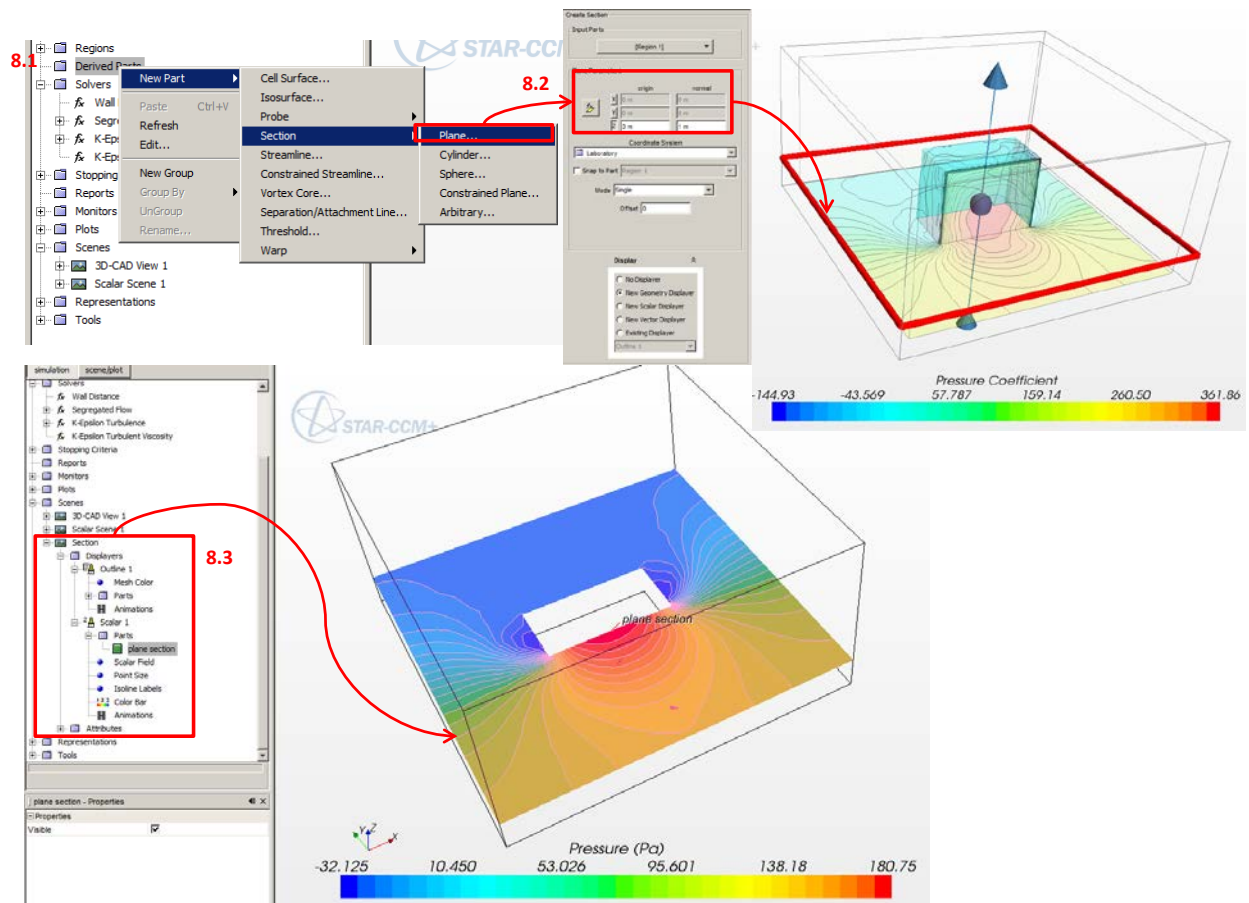


Figure 17: Derived parts setting; section plane

**Research task No. 1.2: External wind pattern around building and surrounded buildings. To determine the pressure distribution on the building façade.**

**Description of research task:**

Wind pattern around the building to be evaluated as well as adjacent building and structures if applicable. Wind pattern and velocities will be illustrated with equipotential lines and streamlines.

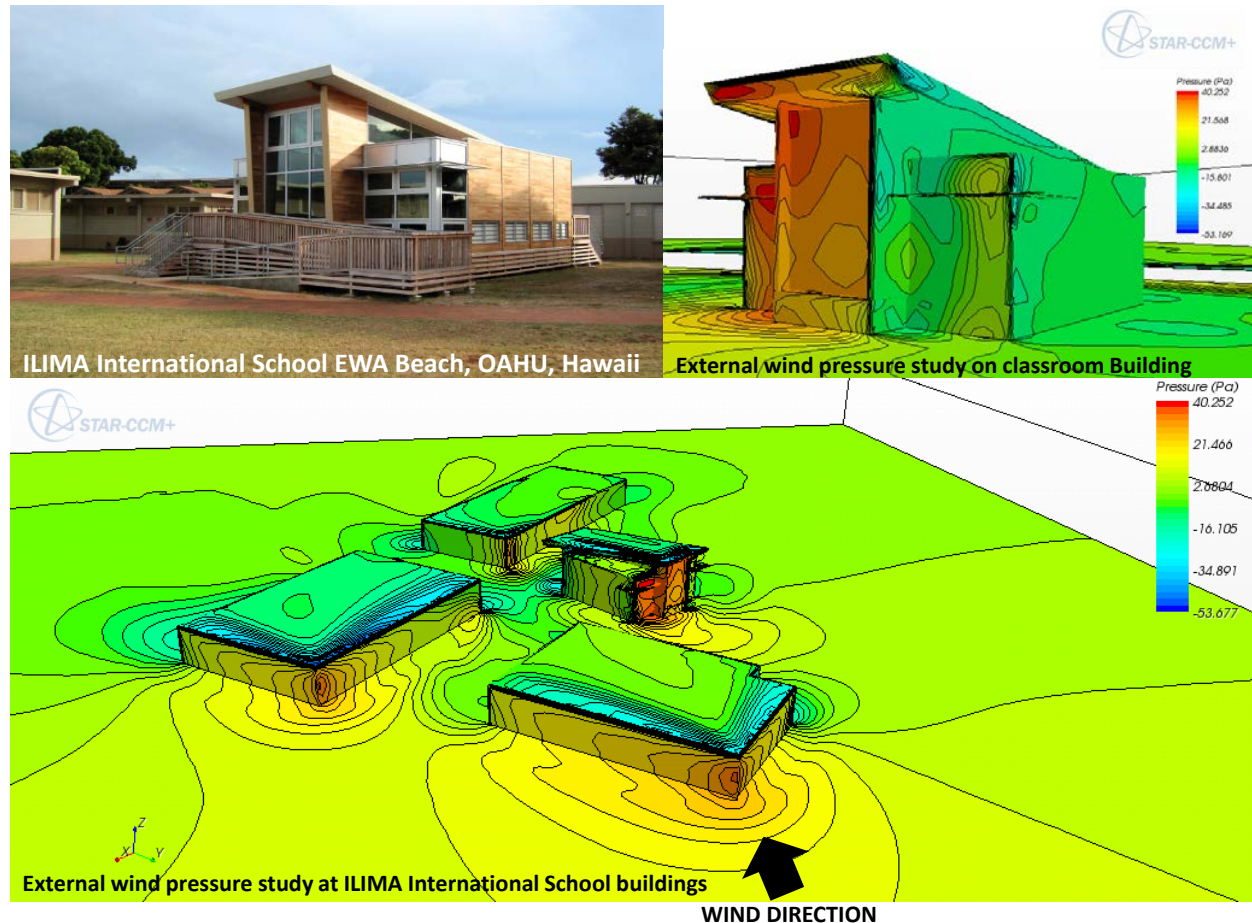


Figure 18: Wind pressure study of ILIMA project

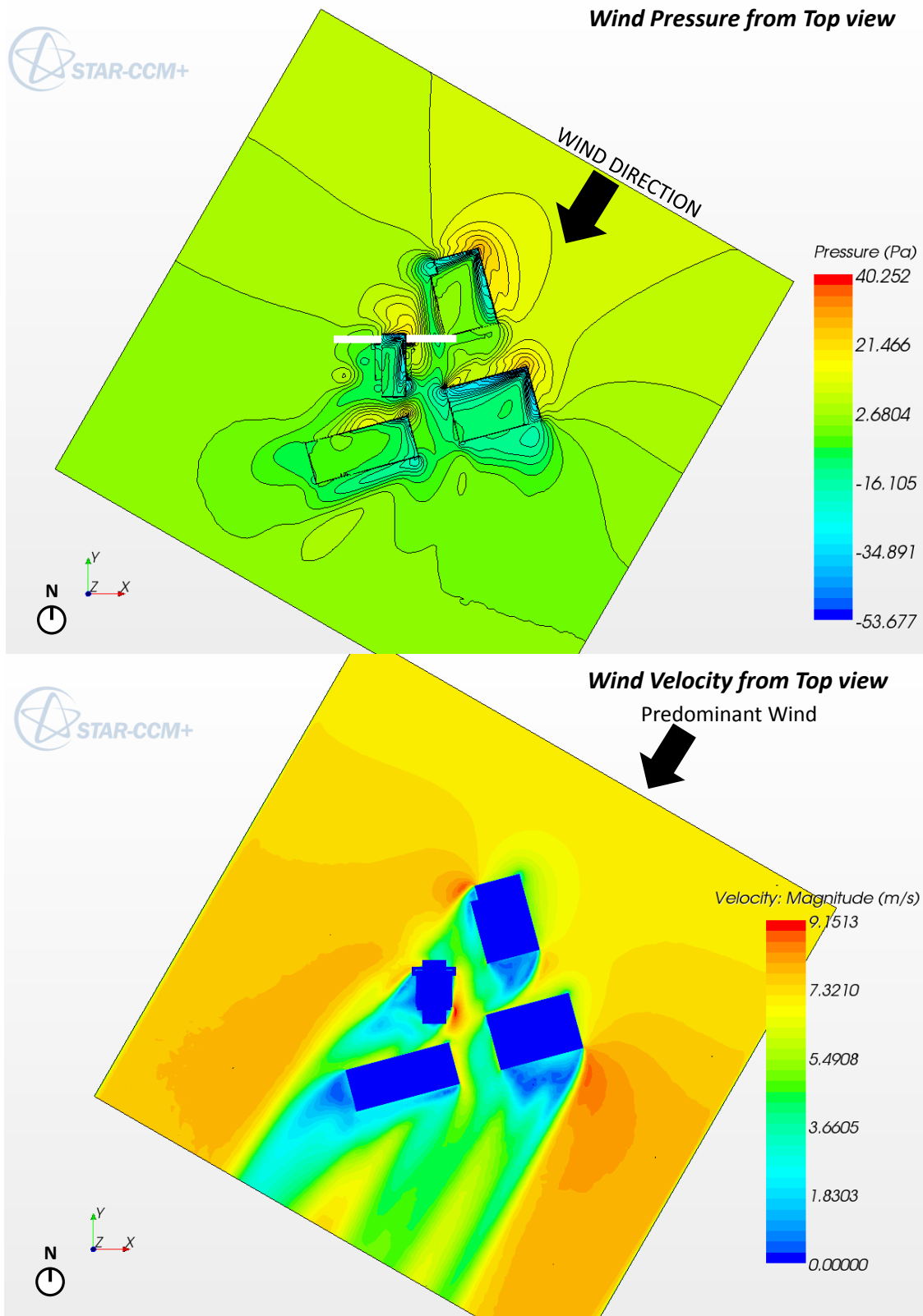
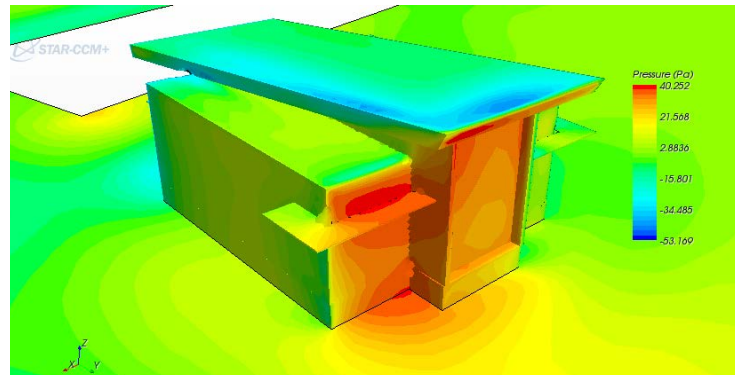
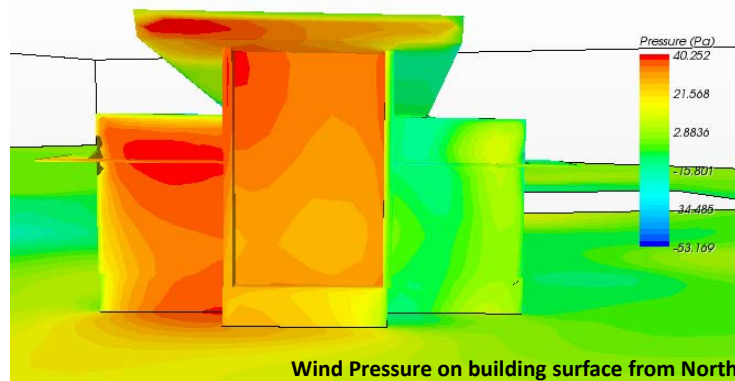


Figure 19: Wind pressure on building façade and surrounded buildings; pressure study (Top) and velocity study (Bottom).

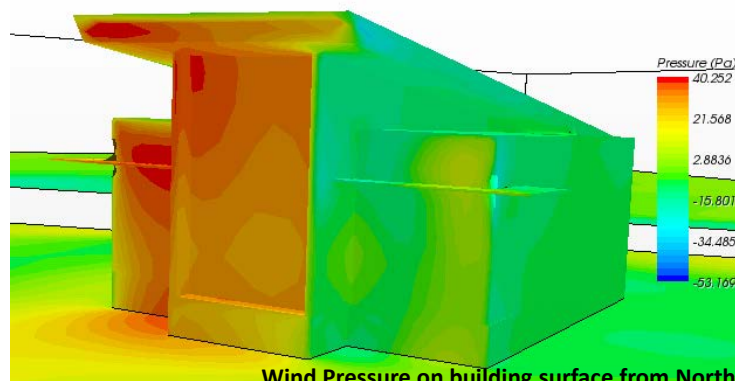




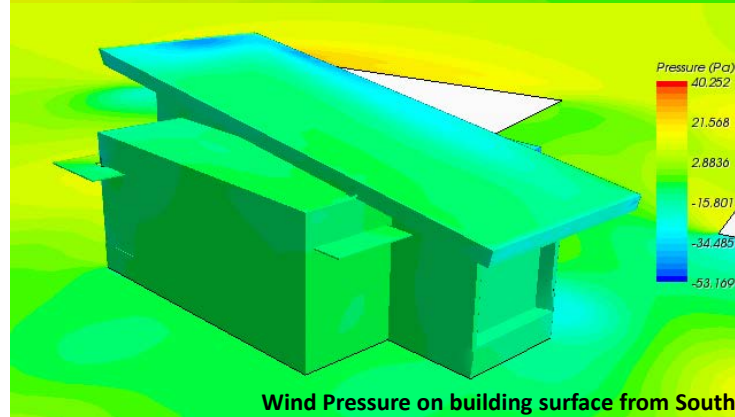
Wind Pressure on building surface from North



Wind Pressure on building surface from North



Wind Pressure on building surface from North



Wind Pressure on building surface from South

Figure 12: Wind pressure on building façade

## Research task No. 2: Internal ventilation of spaces as a result of pressure driving forces on ventilation interface openings.

### Description of research task:

CFD models will be used to determine ventilation pattern inside interior spaces as a function of pressures differentials exerted on ventilation interfaces.

### Workflow for external to internal CFD

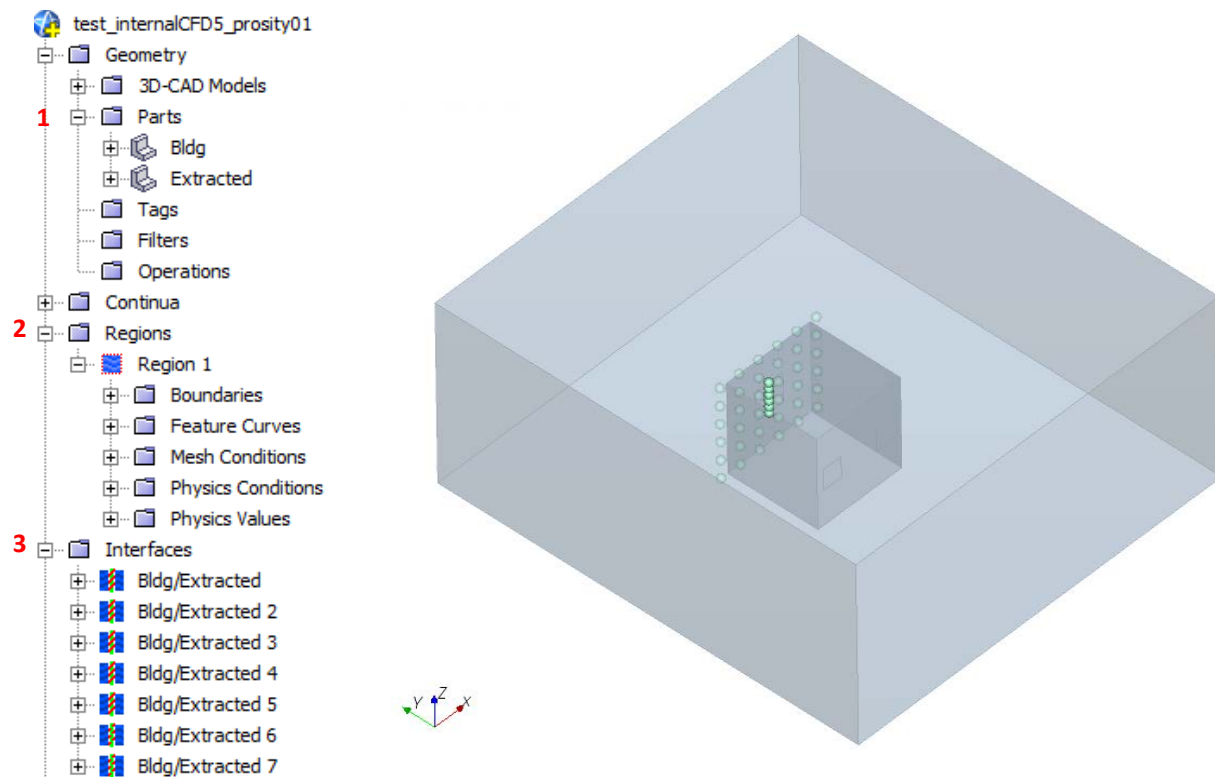


Figure 13: Workflow for external to internal CFD

1. **Parts setting** ; required two object parts, first is building parts and second is the extracted parts.

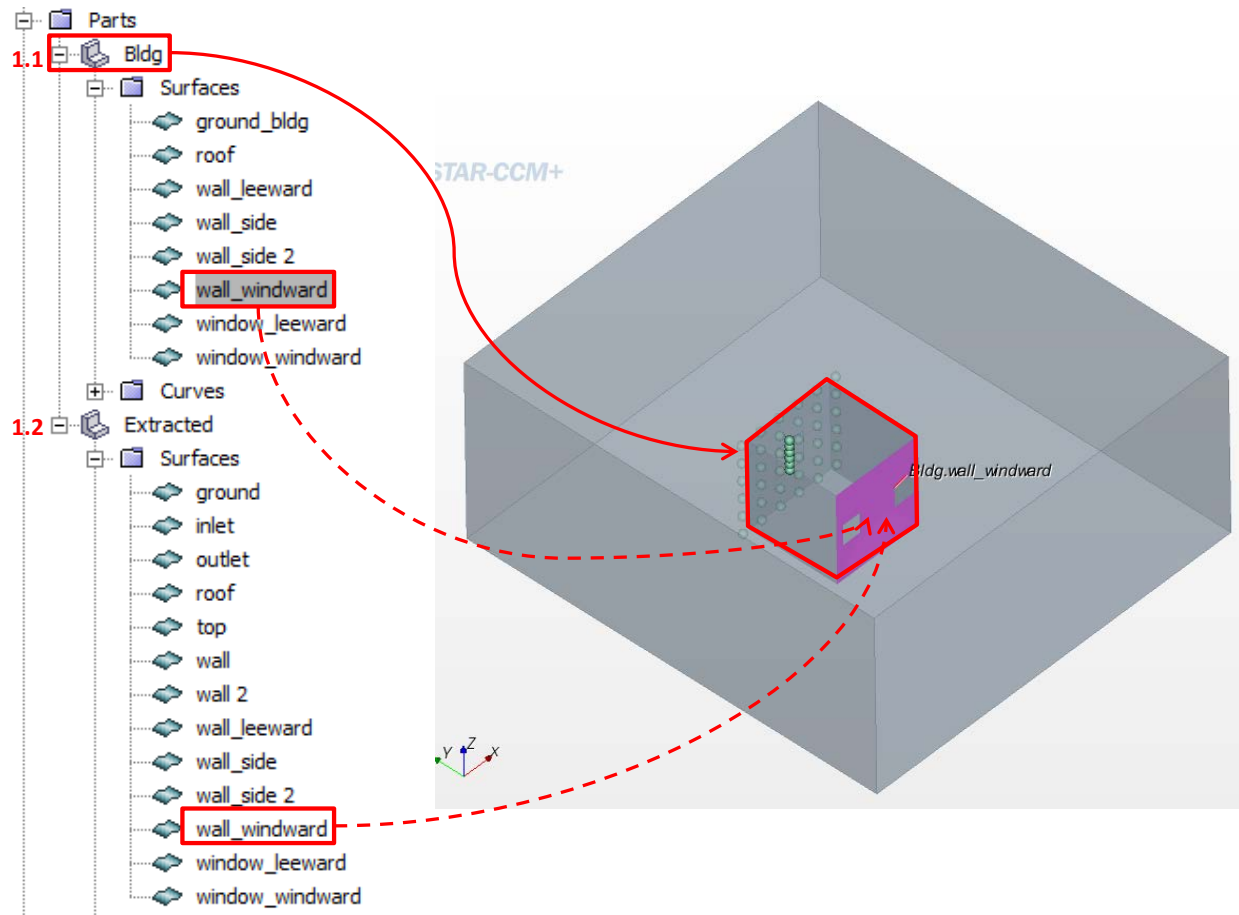


Figure 14: Parts setting

1.1 Building parts; split by patch for every building parts such as, walls, roof, ground, and windows

1.2 Extracted parts; split by patch for every building parts and boundary box such as, walls, roof, ground, windows, inlet, and outlet

## 2. Region setting

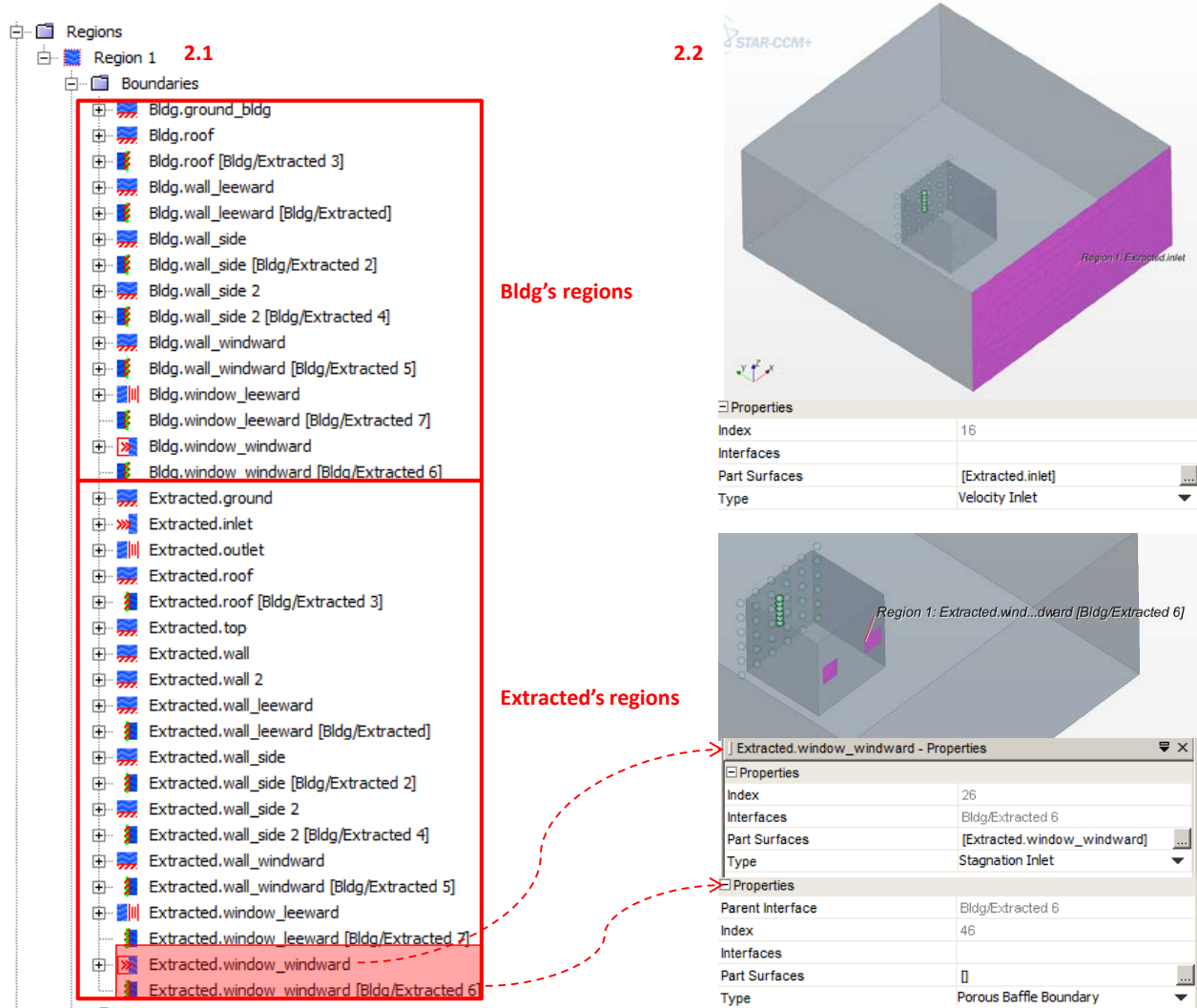


Figure 15: Regions setting

2.1 Assign parts to regions; assign both building and extracted parts into the same region (Region 1), which will cause overlapped regions (interface).

2.2 Region property setting; assign part surface into the right region property. For interface surfaces check interface setting

3. **Interfaces**<sup>21</sup> provide a connection between boundaries during the simulation meshing setup and/or analysis process. They are always composed of boundary pairs, either in the same region or in different regions. In a volume mesh, interfaces permit mass, energy and other continuum quantities to pass from one region to another. In the illustration below, the dotted black line indicates the location of the interfaces that are created using the coincident boundaries between each region:

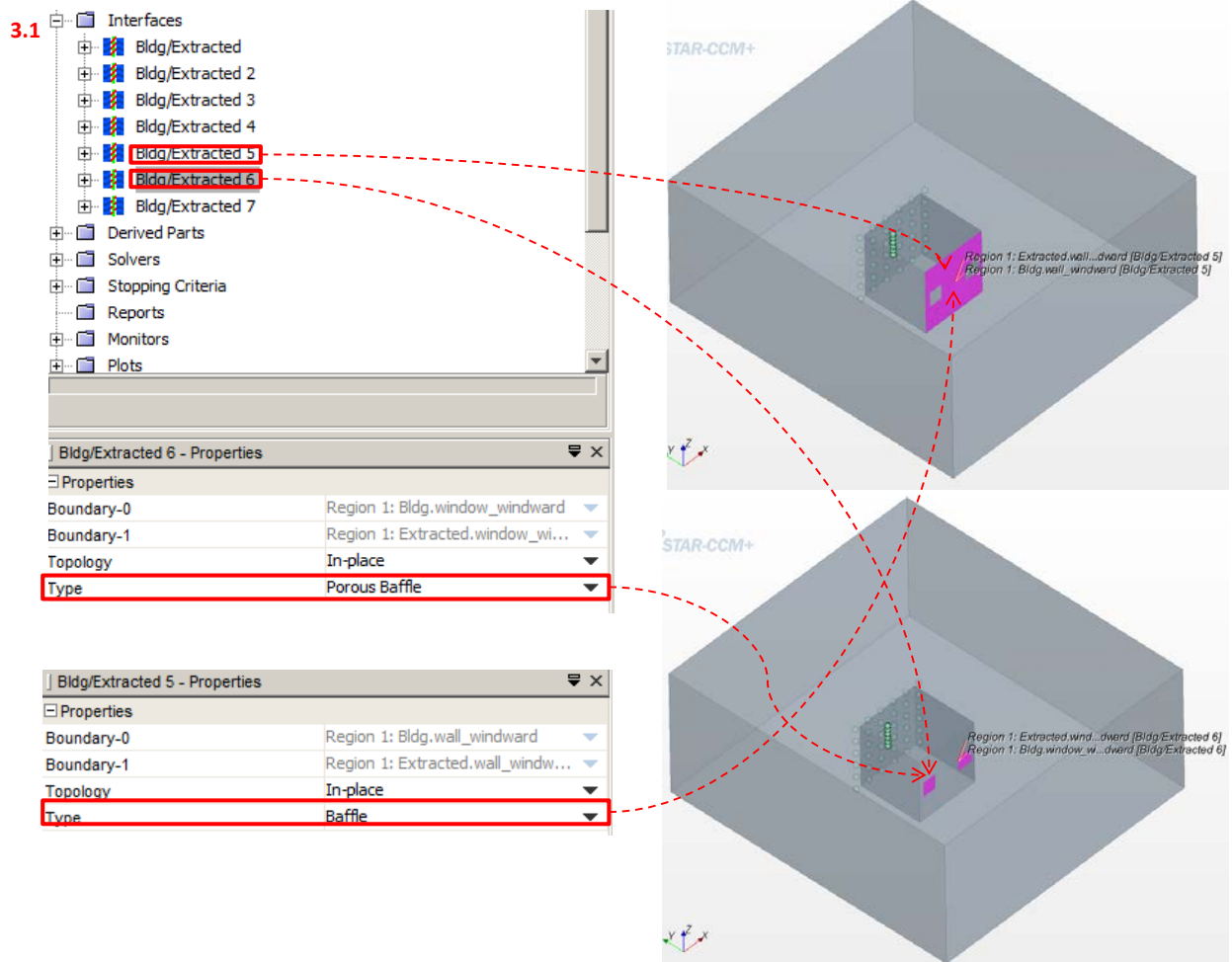
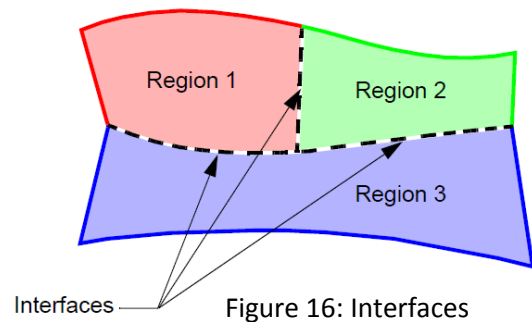


Figure 17: Interface setting

<sup>21</sup> STAR-CCM+ Version 7.04.011 user guide, page 340

**Baffle interface**<sup>22</sup> physically represents one or more thin sheets of impermeable, conducting materials in a fluid. It can be placed between regions of the same continuum or of different continua. It has properties, conditions, values and a pop-up menu.

**Porous baffle**<sup>23</sup> represents a porous membrane through which fluid passes and experiences a pressure drop. Conductive heat transfer is modeled in the impermeable portion of the baffle. Porous baffles can be used to model perforated plates, thin screens and wire screens. It has properties, values and a pop-up menu.

**In-place interface**<sup>24</sup>, there is no physical separation in space between the two boundaries comprising the interface. Furthermore, there is no requirement that the two boundaries have the same perimeter. After the imprinting (for surface remeshing), or intersection (for volume meshes used in an analysis) occurs the original boundaries maintain their boundary type and retain whatever surface area remains.

3.1 Interface setting; interface type of wall interfaces are baffle. Interface types of windows are porous baffle.

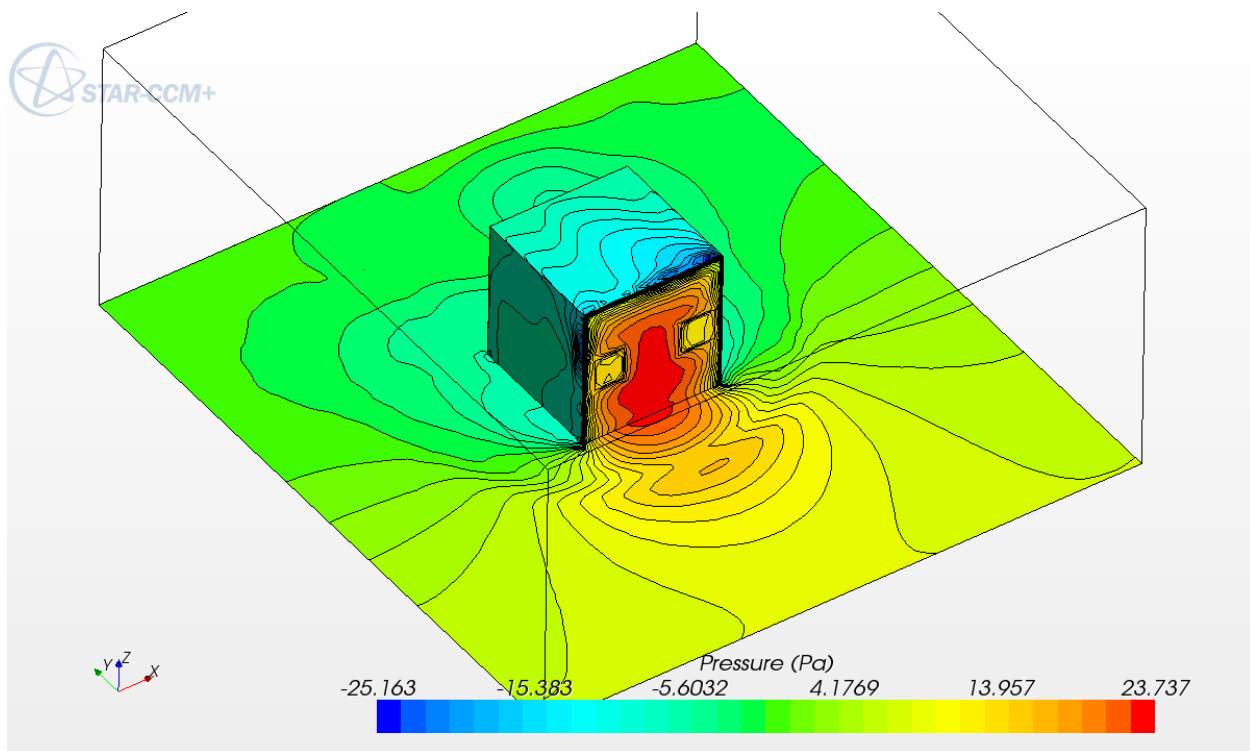


Figure 18: Pressure study

<sup>22</sup> STAR-CCM+ Version 7.04.011 user guide, page 1813

<sup>23</sup> STAR-CCM+ Version 7.04.011 user guide, page 1817

<sup>24</sup> STAR-CCM+ Version 7.04.011 user guide, page 1808



**Porosity**<sup>25</sup> is the factor that is used in calculating heat transfer and optionally viscous shear. If the porous baffle is thought of as a perforated surface, then may be interpreted as the ratio of the area of the holes to the area of the surface.

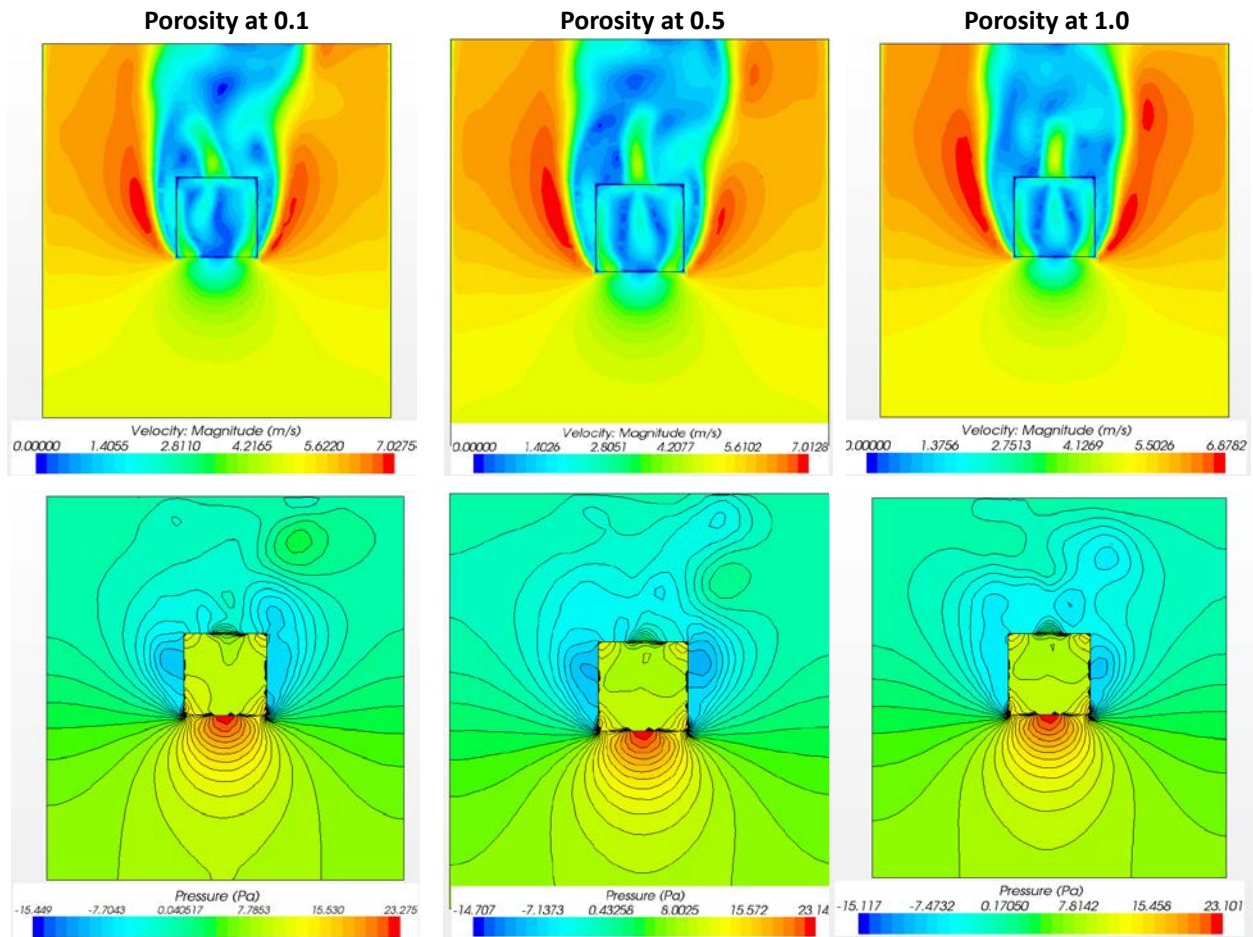
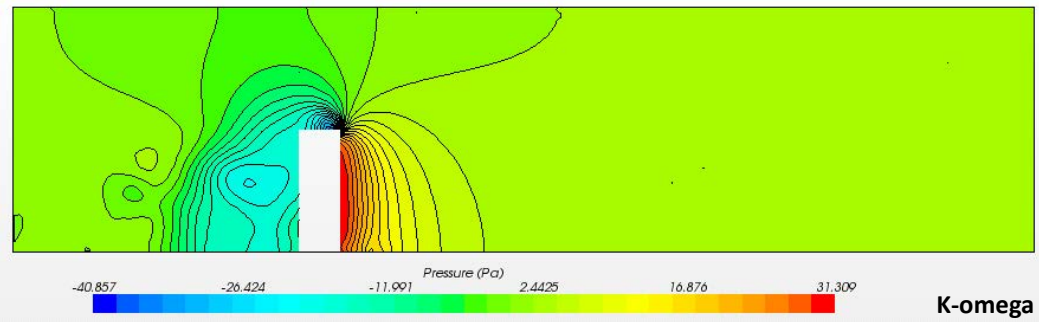
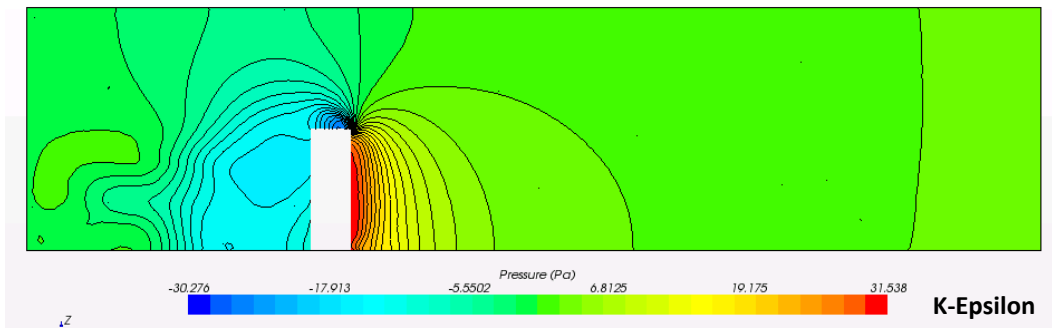


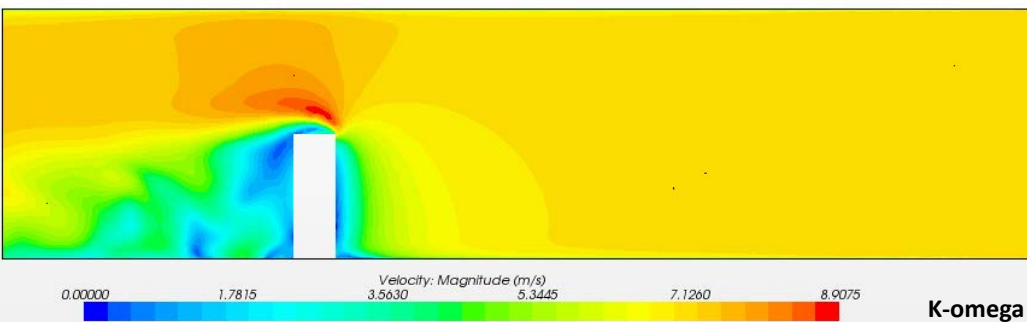
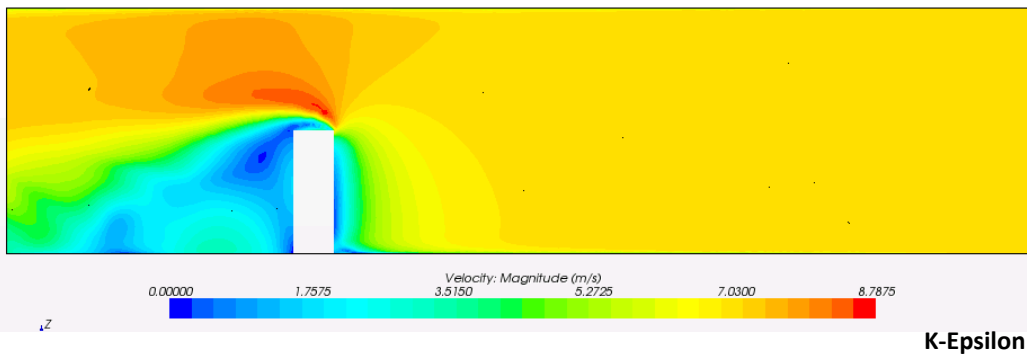
Figure 19: Porosity study of pressure and velocity on building floor plan

<sup>25</sup> STAR-CCM+ Version 7.04.011 user guide, page 1820

## K-Epsilon turbulence VS K-Omega turbulence



### PRESSURE



### VELOCITY

Figure 20: Comparative study of K-Epsilon turbulence VS K-Omega turbulence

**The K-epsilon model<sup>26</sup>** is one of the most common turbulence models, although it just doesn't perform well in cases of large adverse pressure gradients. It is a two equation model, that means, it includes two extra transport equations to represent the turbulent properties of the flow. This allows a two equation model to account for history effects like convection and diffusion of turbulent energy. The first transported variable is turbulent kinetic energy,  $k$ . The second transported variable in this case is the turbulent dissipation,  $\epsilon$ . It is the variable that determines the scale of the turbulence, whereas the first variable,  $k$ , determines the energy in the turbulence.

**The K-omega model<sup>27</sup>** is one of the most commonly used turbulence models. It is a two equation model that means, it includes two extra transport equations to represent the turbulent properties of the flow. This allows a two equation model to account for history effects like convection and diffusion of turbulent energy. The first transported variable is turbulent kinetic energy,  $k$ . The second transported variable in this case is the specific dissipation,  $\omega$ . It is the variable that determines the scale of the turbulence, whereas the first variable,  $k$ , determines the energy in the turbulence.

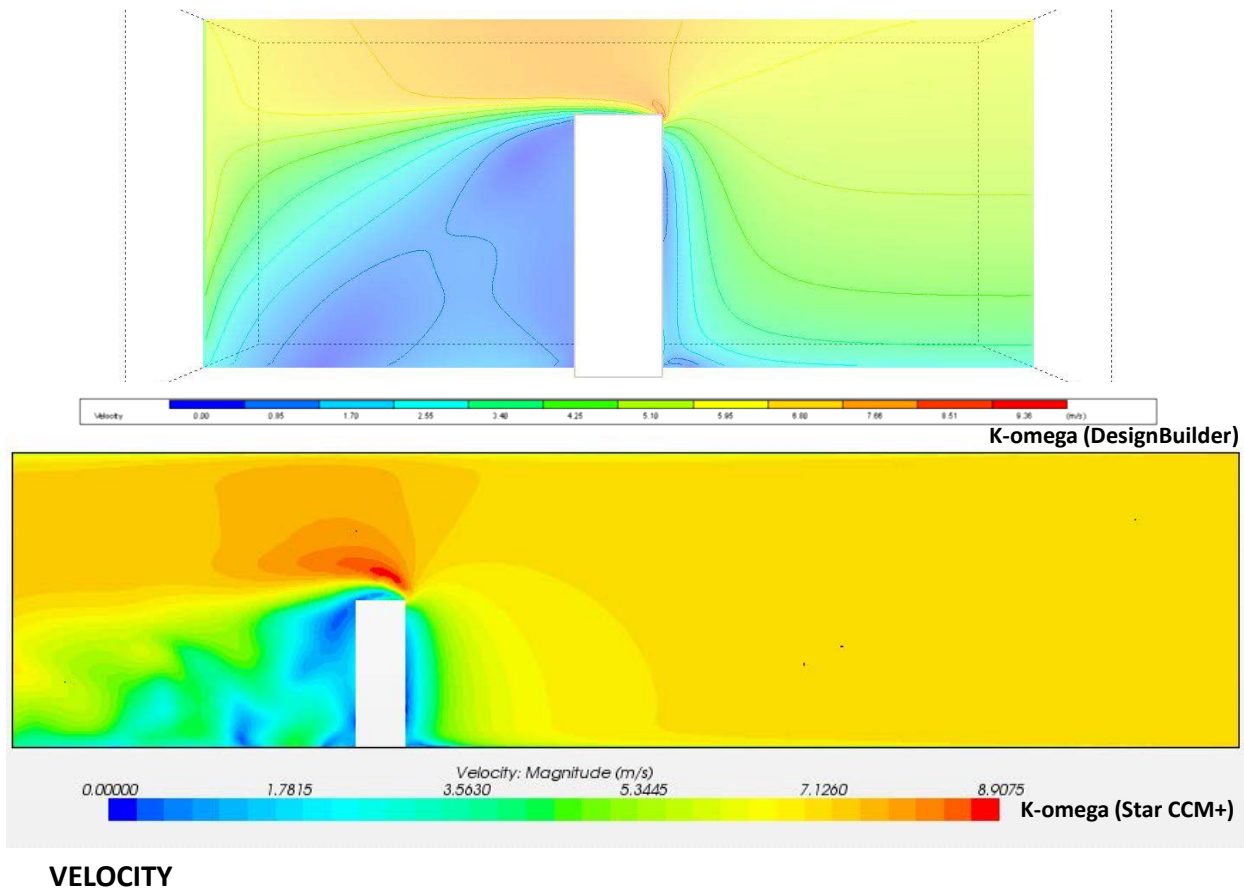


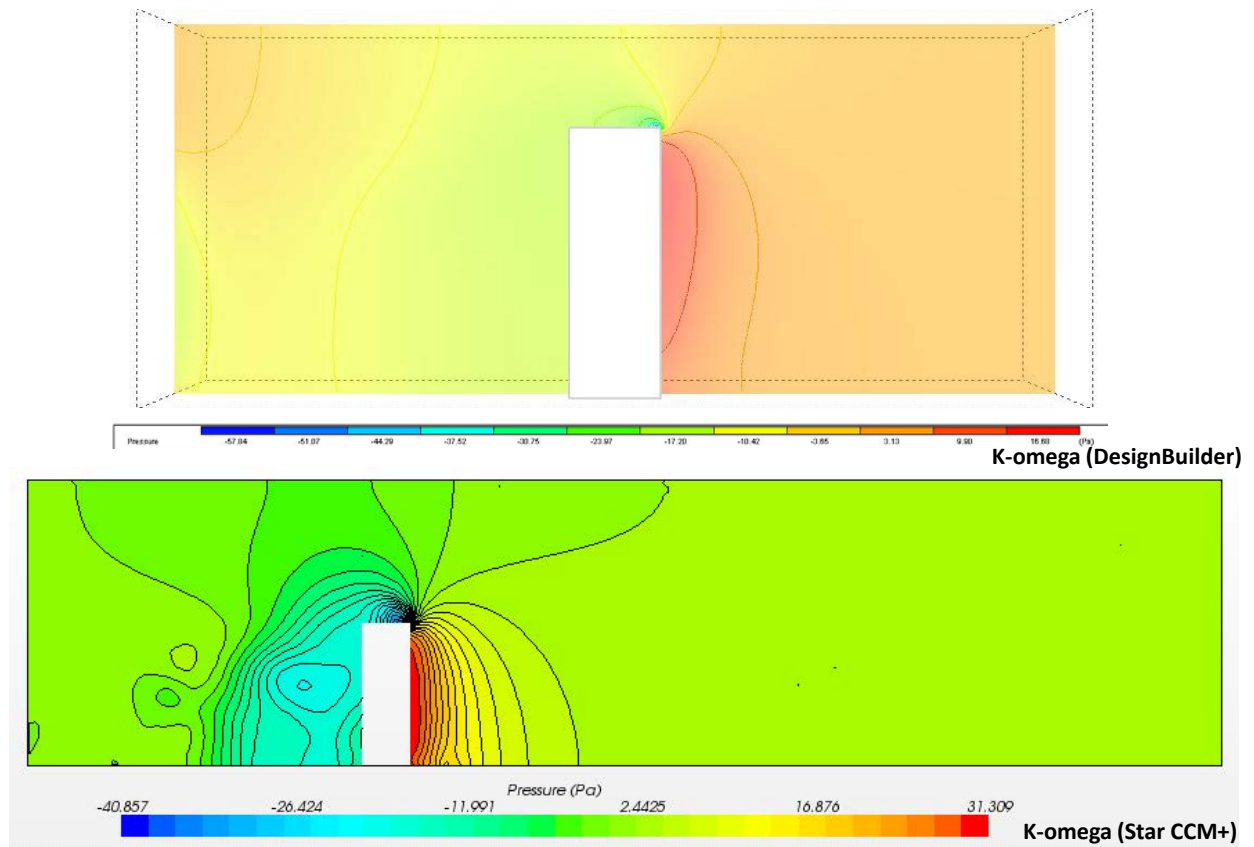
Figure 21: Comparative velocity study between DesignBuilder and Star CCM+ applications

<sup>26</sup> <http://www.cfd-online.com/Forums/main/75554-use-k-epsilon-k-omega-models.html>

and STAR-CCM+ Version 7.04.011 user guide, page 3111

<sup>27</sup> [http://www.cfd-online.com/Wiki/K-omega\\_models](http://www.cfd-online.com/Wiki/K-omega_models)

and STAR-CCM+ Version 7.04.011 user guide, page 3177



## PRESSURE

Figure 22: Comparative pressure study between DesignBuilder and Star CCM+ applications

## Import mesh<sup>28</sup> geometry

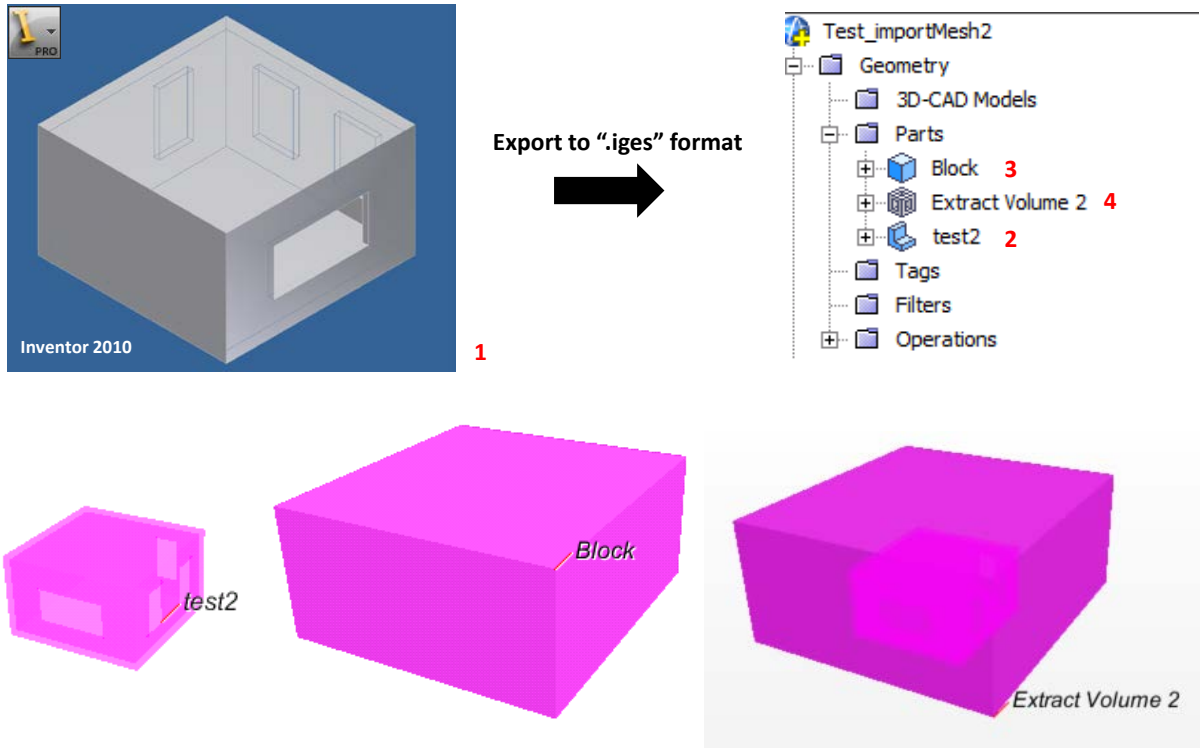


Figure 23: Import mesh geometry part 1

1. Create geometry in the Inventor then export as ".iges" format
2. Import surface mesh
3. Create a new shape part; block
4. Extract volume

<sup>28</sup> STAR-CCM+ Version 7.04.011 user guide, page 1842

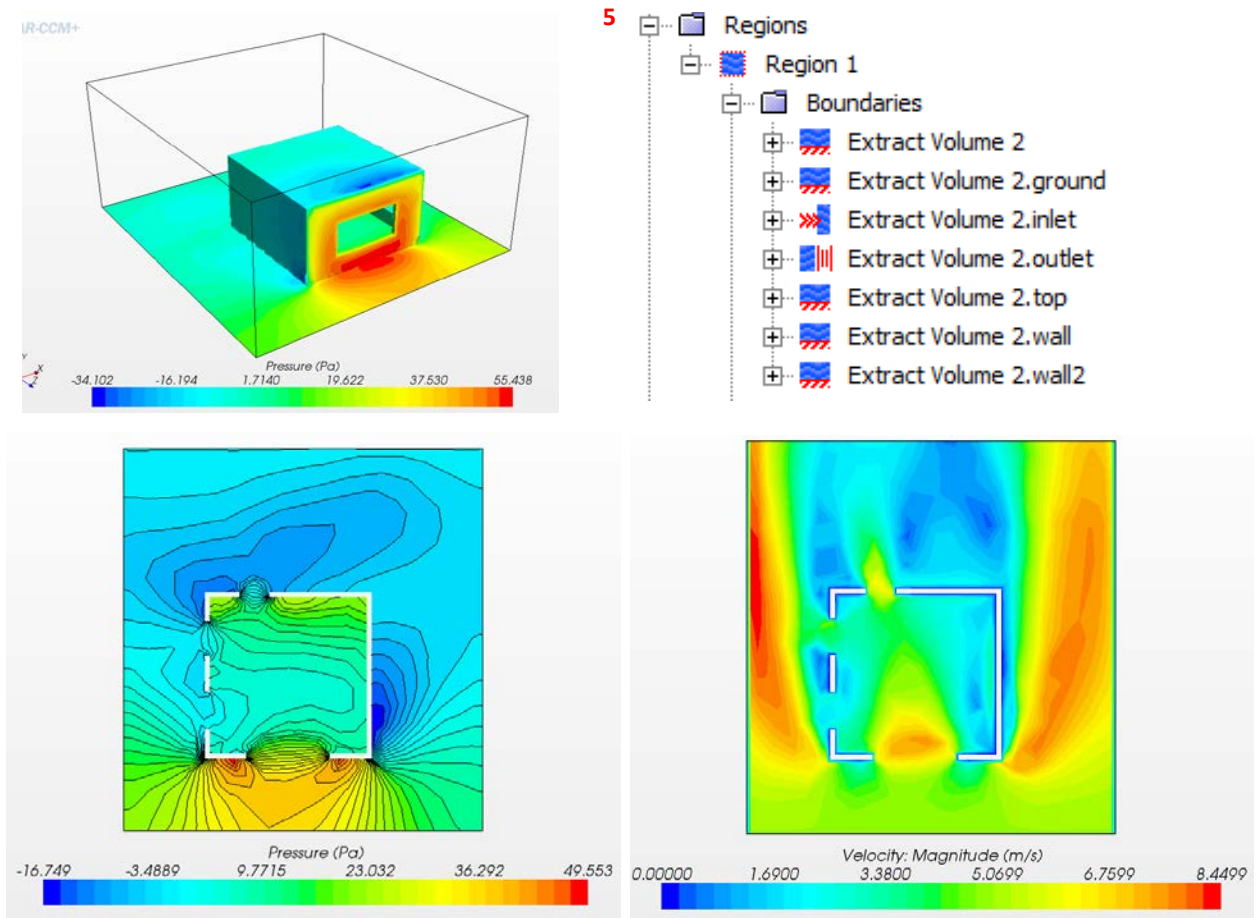


Figure 24: Import mesh geometry part 2

5. Assign parts to regions; the same as work flow in task 1