



# Autodesk® 360 Rendering

Scalable and Robust Rendering In the Cloud

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Principal Software Engineer, Cloud Rendering



Cloud Platforms

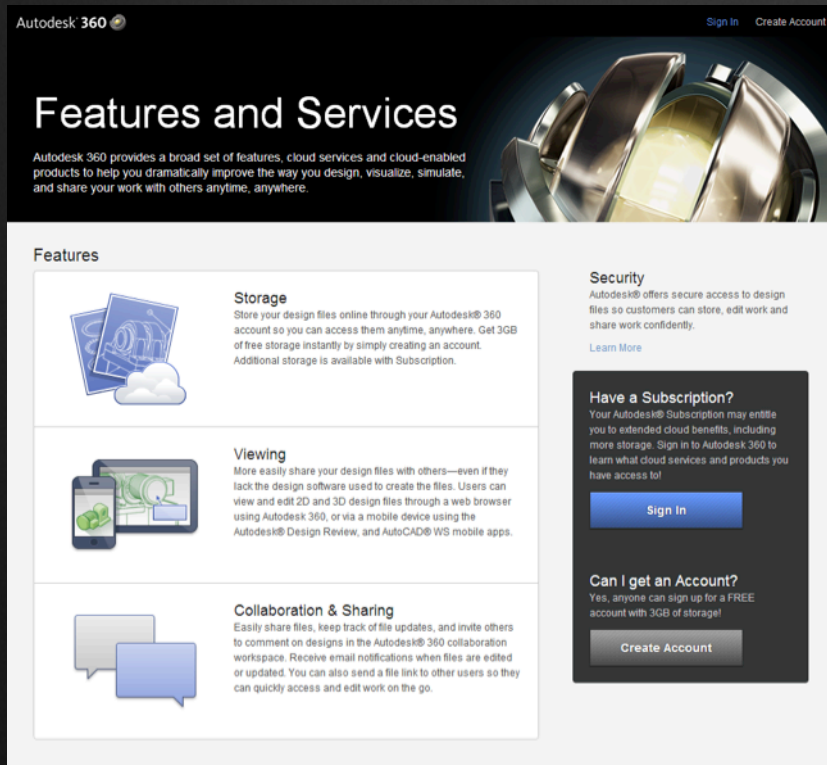
Autodesk

# Agenda

- Introduction to Autodesk 360
- Scaling Services
- Reducing Data
- Efficient and Easy to Rendering
- Features Discussion



# Introduction to Autodesk® 360



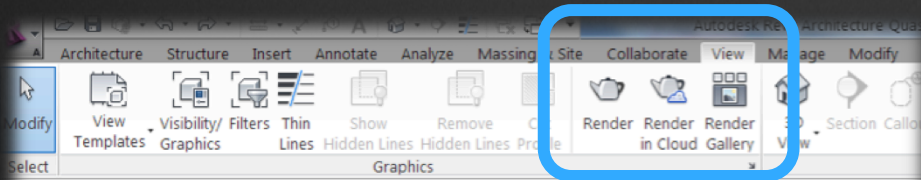
The screenshot shows the Autodesk 360 website. At the top, there are links for "Sign In" and "Create Account". The main heading is "Features and Services". Below this, a paragraph states: "Autodesk 360 provides a broad set of features, cloud services and cloud-enabled products to help you dramatically improve the way you design, visualize, simulate, and share your work with others anytime, anywhere." The page is divided into several sections:

- Features**
  - Storage**: Store your design files online through your Autodesk® 360 account so you can access them anytime, anywhere. Get 3GB of free storage instantly by simply creating an account. Additional storage is available with Subscription.
  - Viewing**: More easily share your design files with others—even if they lack the design software used to create the files. Users can view and edit 2D and 3D design files through a web browser using Autodesk 360, or via a mobile device using the Autodesk® Design Review, and AutoCAD® WS mobile apps.
  - Collaboration & Sharing**: Easily share files, keep track of file updates, and invite others to comment on designs in the Autodesk® 360 collaboration workspace. Receive email notifications when files are edited or updated. You can also send a file link to other users so they can quickly access and edit work on the go.
- Security**: Autodesk® offers secure access to design files so customers can store, edit work and share work confidently. [Learn More](#)
- Have a Subscription?**: Your Autodesk® Subscription may entitle you to extended cloud benefits, including more storage. Sign in to Autodesk 360 to learn what cloud services and products you have access to! [Sign In](#)
- Can I get an Account?**: Yes, anyone can sign up for a FREE account with 3GB of storage! [Create Account](#)

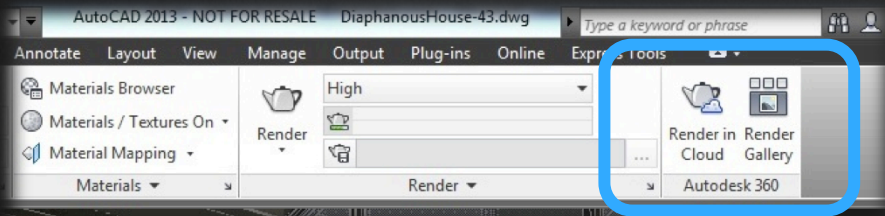
- Cloud Application Suite
- Goals of A360
  - Storage
  - Sharing
  - Collaboration



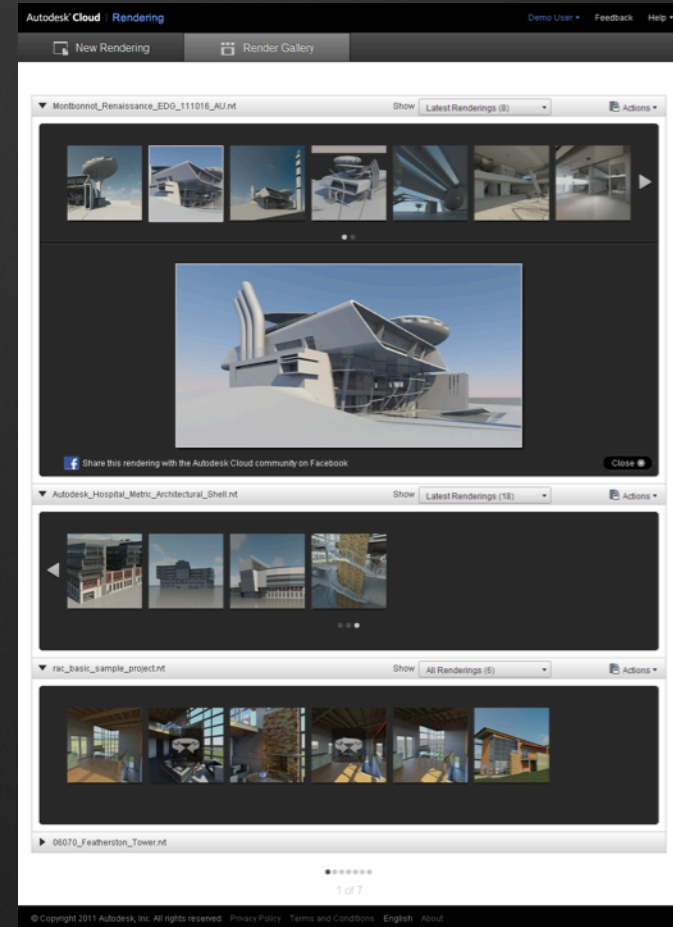
# Autodesk® 360 Rendering



## Autodesk® Revit® 2013



## Autodesk® AutoCAD® 2013



## Rendering Portal / Gallery



# Autodesk® Homestyler®

Autodesk® Homestyler®

DESIGNER

DESIGN GALLERY

MY DESIGNS

Language ▾

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Help

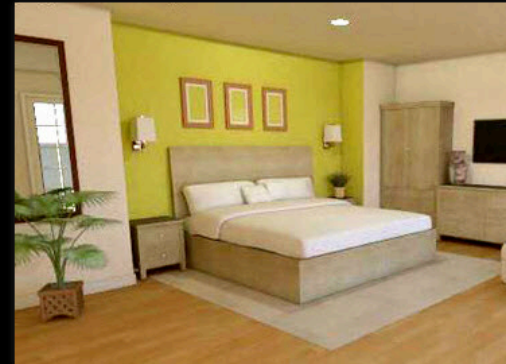
FEEDBACK

## The fast, **easy** way to design your dream home

Take the guesswork out of home remodeling projects! Get started by laying out your floor plans and experimenting with real products and colors.

[Learn More »](#) [For Design Pros »](#) [For Manufacturers & Retailers »](#)

Start Designing »



### GET INSPIRED

See what the world is sharing on MIMI.

Get Started »



In the Gallery **Featured** Popular



Master Bedroom with Sitting Area



House Beautiful 2011 Kitchen of the Year

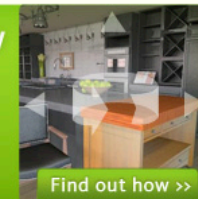


Kitchen Design with Terrace and Pool

Try the new  
Panorama  
View

Get a 360 degree  
perspective on  
your design.

Find out how >>



Explore the 2011  
House Beautiful

Cloud Platforms

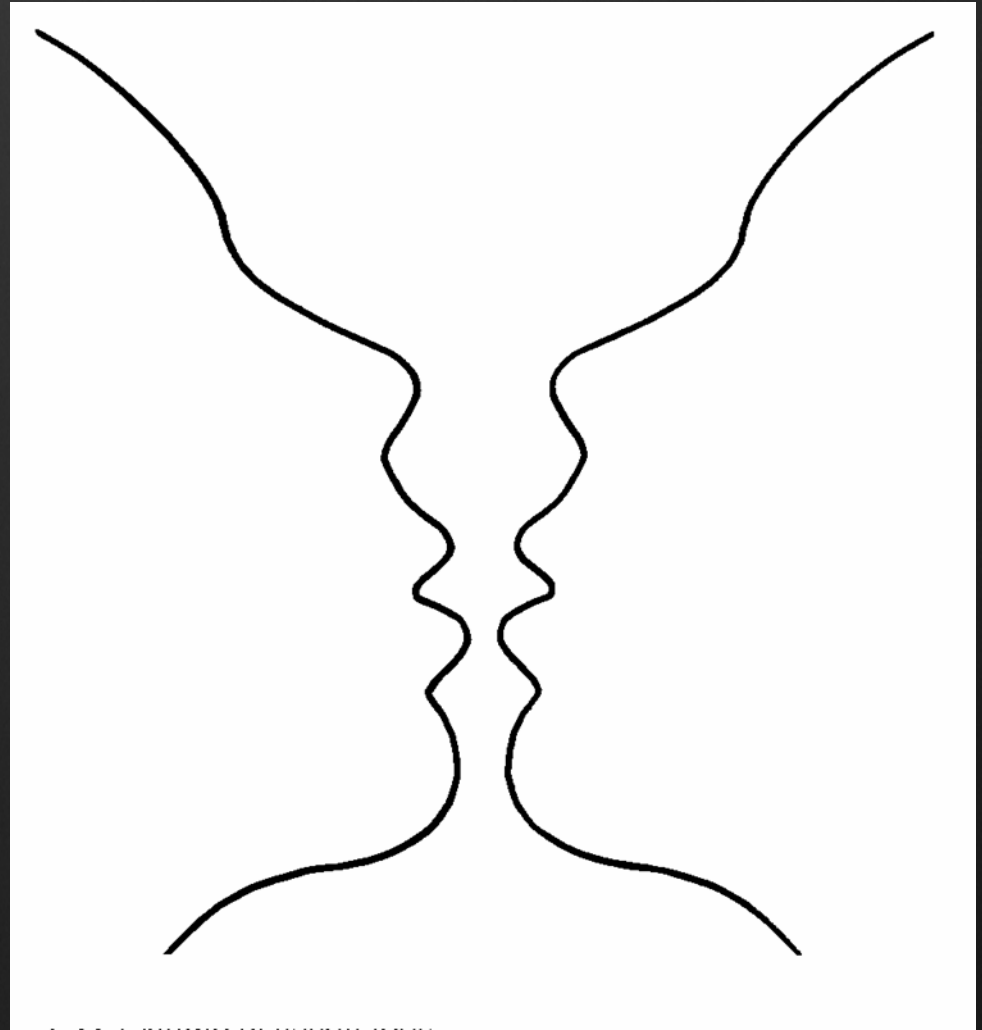
Autodesk

# Perception vs Reality

User Perspective

VS

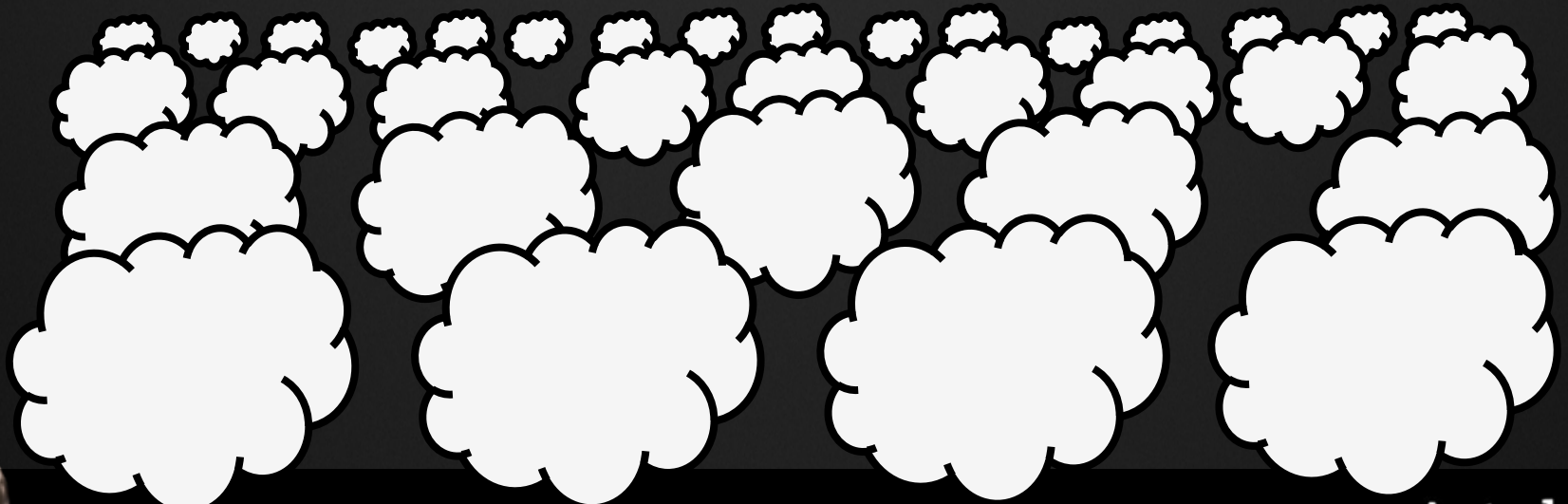
Developer Perspective



# Problem: Conflicting Perspectives

## User Perspective

The cloud is infinite; I can render anything.



Cloud Platforms

Autodesk



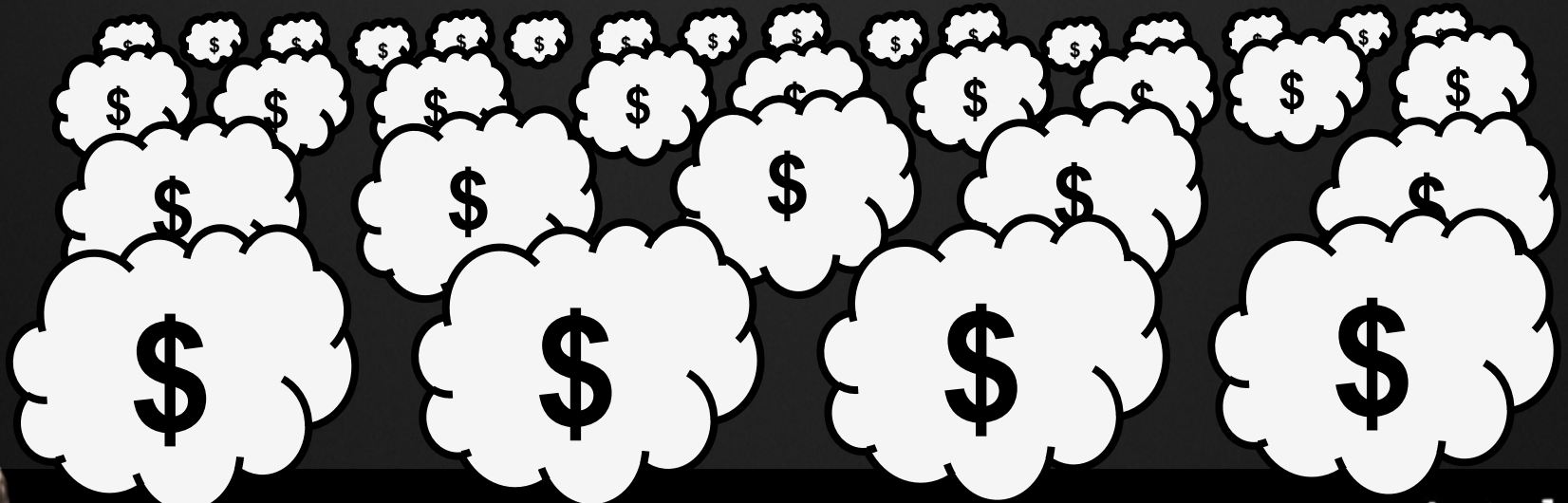
# Problem: Conflicting Perspectives

## User Perspective

The cloud is infinite; I can render anything.

## Developer Perspective

The cloud isn't free; Rendering costs Autodesk money.



Cloud Platforms

Autodesk



# Quality of Service

Vs.

# Cost



# Quality of Service Vs Costs

- Try to maintain user's vision of infinite cloud
  - Wait time
  - User empowerment
  - New features immediately
  - Infinite and secure storage
  - Rendering by anyone
  - Quick and painless
- Cut costs
  - Scale down compute
  - Minimize data
  - Efficient rendering

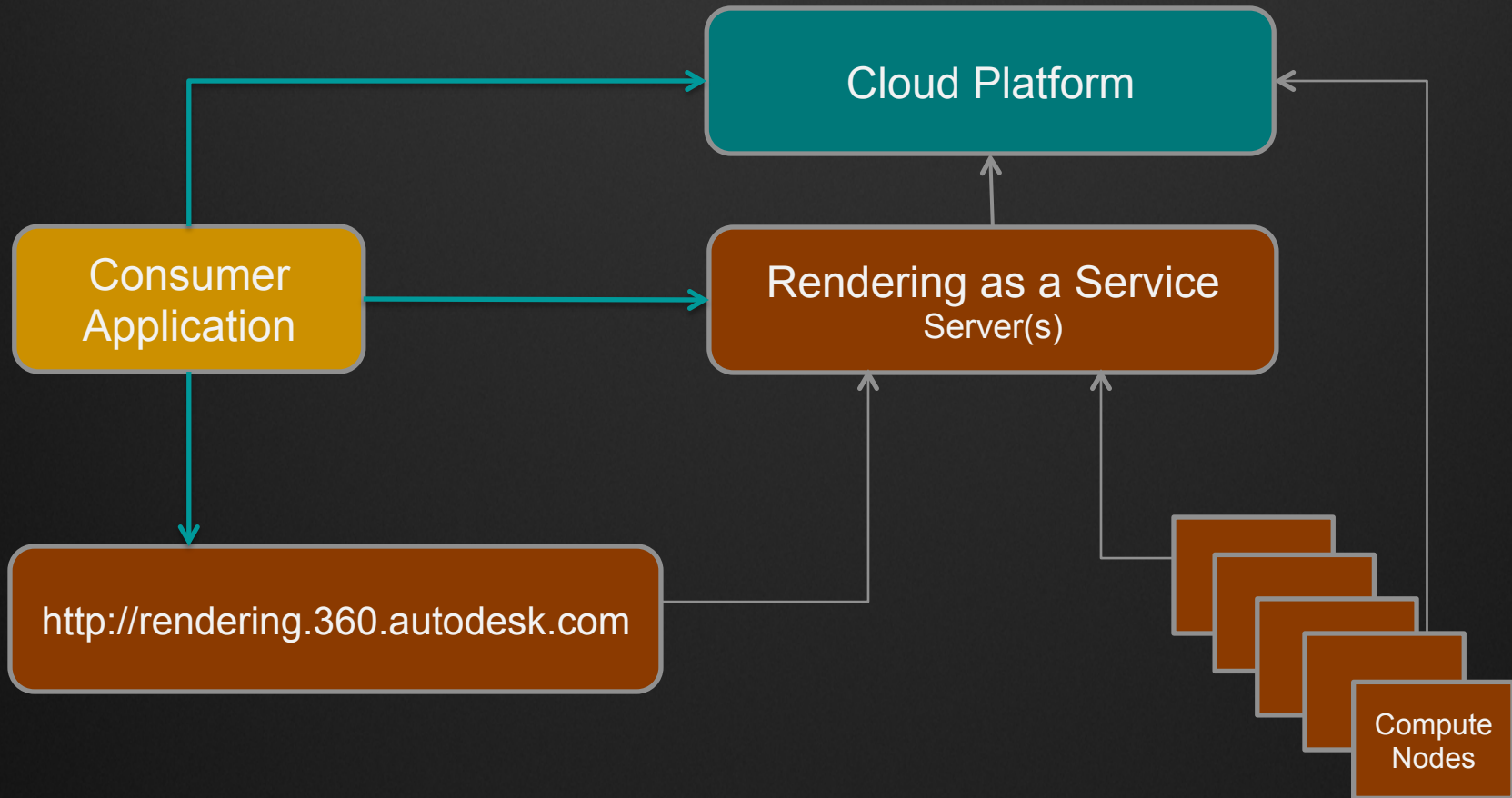


# Cost vs Quality of Service

- Try to maintain user's vision of infinite cloud
  - Wait time
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# Integrating Cloud rendering in Autodesk products



# Scalability Axes

- Integrations and updates for applications
- Managing compute for efficiency

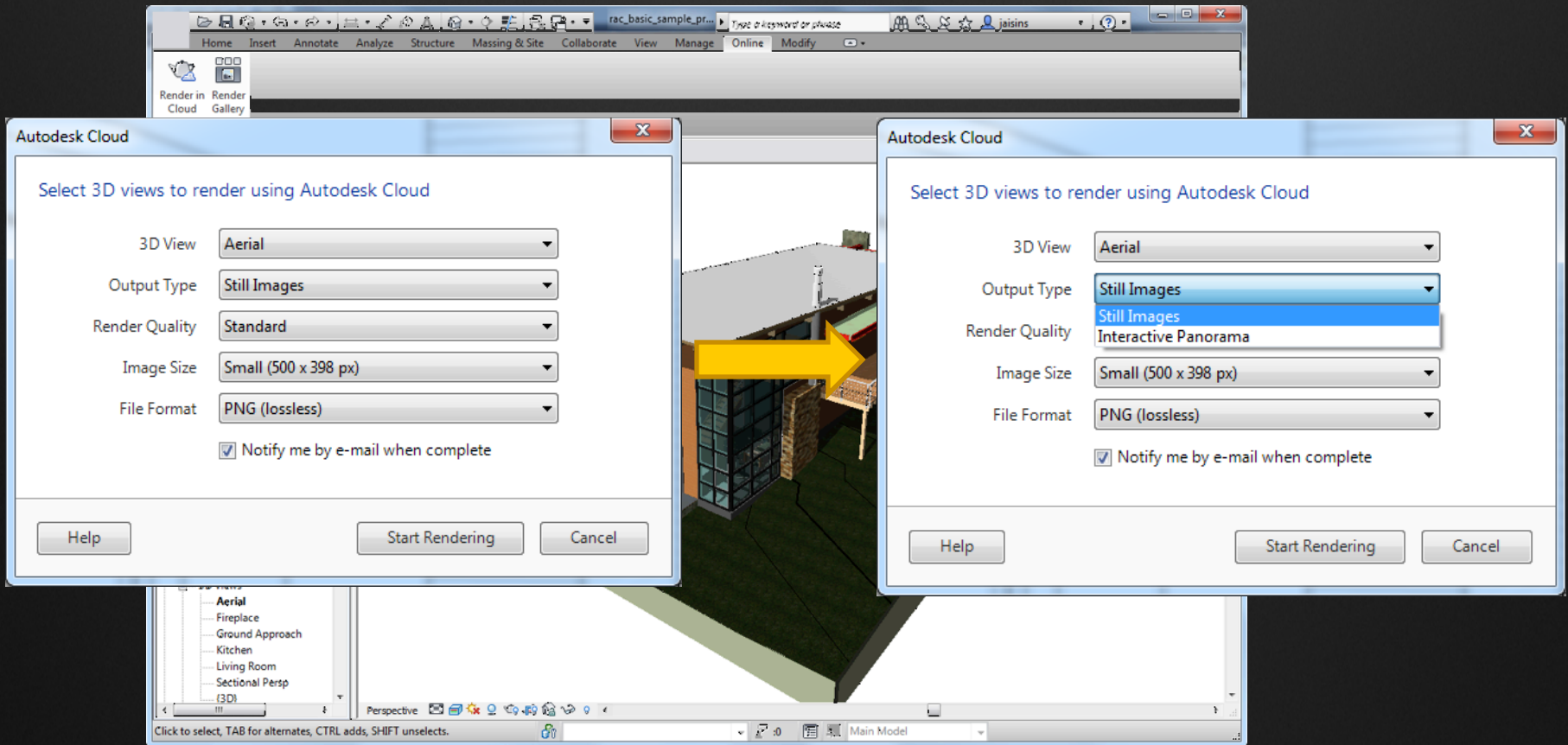


# Problem: Difficult Adoption in Applications

- Support many apps
- Quickly out-of-sync
- Results non-trivial to view



# Example: Plugin Update



Plugin V1

Plugin V2

Cloud Platforms

Autodesk

# Solution: Service Updates in the Cloud

Render in Cloud

**Autodesk**

Select 3D views to render using Autodesk Cloud

3D View: Render Multiple 3D Views (3)

Output Type: Still Image

Render Quality: Draft

Image Size: Small (500x411px)

Exposure: Advanced

File Format: JPEG (High Quality)

Notify me by e-mail when complete

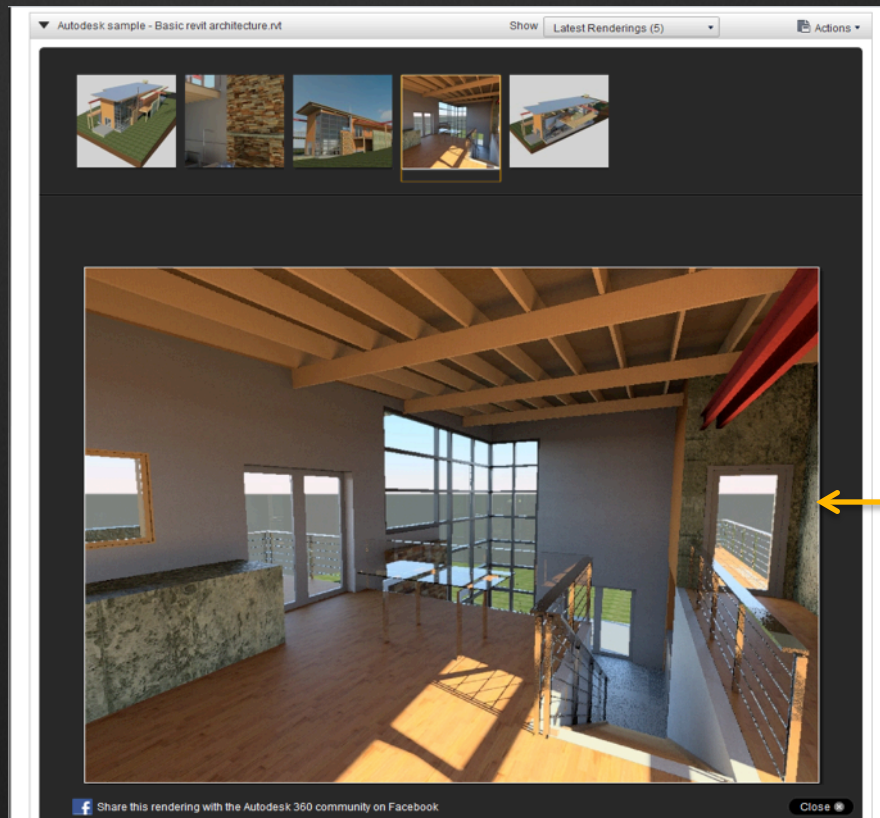
Start Rendering Cancel





# Solution: HTML Viewer Widgets

1. Simple html, 1-5 lines code
2. Iframe sets up source URL to viewer URL
3. RaaS displays content by mode + type
4. API can be customized



← Gallery viewer

← Image viewer



# Solution: HTML Viewer Widgets



**Adjust Exposure** ×

Exposure Value:

Highlights:

Midtones:

Shadows:

Saturation:

White Point:

←  
Image viewer

# Scalability Axes

- Integrations and updates for applications
- **Managing compute for efficiency**



# Scaling compute resources

## Base capacity: Data Center in Santa Clara

- 104 8-core Dell servers, Intel® Xeon® CPU E5420 @ 2.50GHz
- Megapixel capacity – At quality “*high*” render 1560 MP of rendering per day
- Typical loads – 5000 MP a day.

## Spill over resources: Amazon® EC2

- Cluster compute cc1.4xlarge and cc2.8xlarge instance types.



# Quality and Cost of Service

- Try to maintain user's vision of infinite cloud
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  - New features immediately
  - **Infinite and secure storage**
  - Rendering by anyone
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- Cut costs
  - Scale down compute
  - **Minimize data**
  - Efficient rendering



# Problem: Too Much Data in the Cloud

- Serialization every time is expensive
- Bandwidth needs are high
- Data can be re-rendered
  - Must be stored at the cloud.
    - Costs \$ (€, £, etc...).
    - Some data stored millions of times!



# Solution

1. Distribute scene
2. Reduce duplication

These things are accomplished using unique\* asset hashes



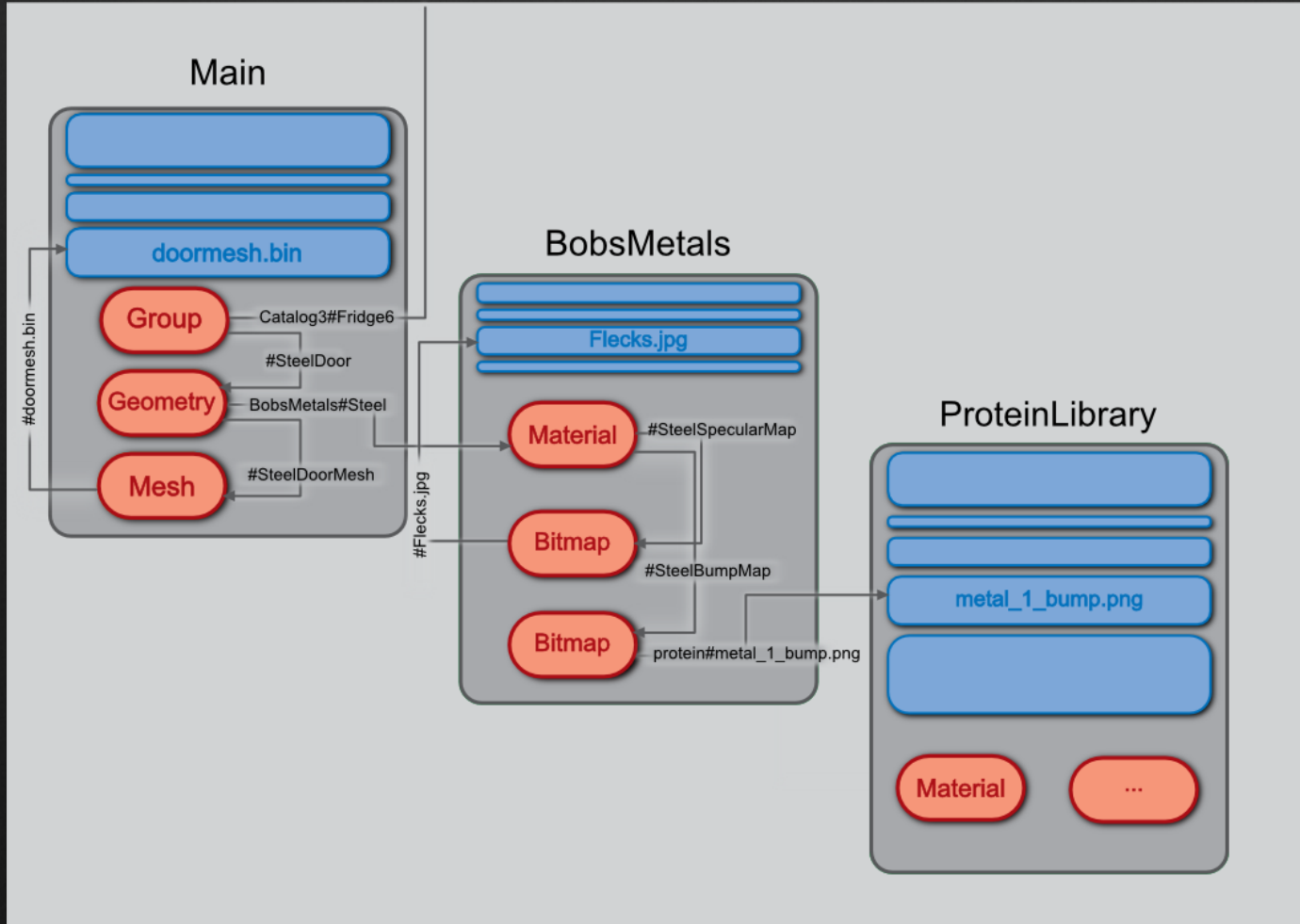
# Example

- Terminology
  - Scene graph has
    - Metadata nodes
    - Binary data nodes
  - URI “location#name” => edge to node “name” in package “location”
    - location == “” => edge points to node in same package





# A Traversal Example



# Data Problem Solved!

- Really just mitigated 😊
- Automatic hash de-duplication
- Hash + database



# Quality and Cost of Service

- Try to maintain user's vision of infinite cloud
  - Wait time
  - User empowerment
  - New features immediately
  - Infinite and secure storage
  - **Rendering by anyone**
  - **Quick and painless**
- Cut costs
  - Scale down compute
  - Minimize data
  - **Efficient rendering**



# Problem

1. Automatic, efficient, reliable, predictable
2. Reduce (eliminate?) user assistance.
  - No portals.
  - No setting of number of photons
  - No setting of final gather rays
  - No user control of ray epsilons, etc...



# MDLC and Spectrum

To appear in the ACM SIGGRAPH 2005 conference proceedings

## Lightcuts: A Scalable Approach to Illumination

Bruce Walter Sebastian Fernandez Adam Arbrece Kavita Bala Michael Donikian Donald P. Greenberg  
Program of Computer Graphics, Cornell University\*

### Abstract

Lightcuts is a scalable framework for computing realistic illumination. It handles arbitrary geometry, non-diffuse materials, and illumination from a wide variety of sources including point lights, area lights, HDR environment maps, sun/sky models, and indirect illumination. At its core is a new algorithm for accurately approximating illumination from many point lights with a strongly sublinear cost. We show how a group of lights can be cheaply approximated while bounding the maximum approximation error. A binary light tree and perceptual metric are then used to adaptively partition the lights into groups to control the error vs. cost tradeoff.

We also introduce reconstruction cuts that exploit spatial coherence to accelerate the generation of anti-aliased images with complex illumination. Results are demonstrated for five complex scenes and show that lightcuts can accurately approximate hundreds of thousands of point lights using only a few hundred shadow rays. Reconstruction cuts can reduce the number of shadow rays to tens.

**CR Categories:** I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Color, shading, shadowing, and texture;  
**Keywords:** many lights, raytracing, shadowing

### 1 Introduction

While much research has focused on rendering scenes with complex geometry and materials, less has been done on efficiently handling large numbers of light sources. In typical computer graphics



Figure 1: Bigscreen model: an office lit by two overhead area lights, two HDR flat-panel monitors, and indirect illumination. Our scalable framework quickly and accurately computed the illumination using 639,528 point lights. The images on the monitors were also computed using our methods: lightcuts and reconstruction cuts.

demonstrate three examples: illumination from area lights, from high dynamic range (HDR) environment maps or sun/sky models, and indirect illumination. Unifying different types of illumination within the lightcuts framework has additional benefits. For example,

## Lightcuts Siggraph 2005

## Multidimensional Lightcuts Siggraph 2006

To appear SIGGRAPH 2006.

### Multidimensional Lightcuts

Bruce Walter Adam Arbrece Kavita Bala Donald P. Greenberg  
Cornell University\*

### Abstract

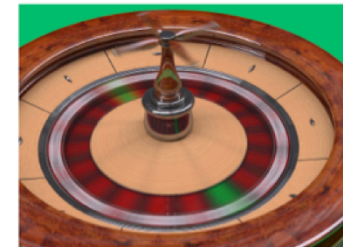
Multidimensional lightcuts is a new scalable method for efficiently rendering rich visual effects such as motion blur, participating media, depth of field, and spatial anti-aliasing in complex scenes. It introduces a flexible, general rendering framework that unifies the handling of such effects by discretizing the integrals into large sets of gather and light points and adaptively approximating the sum of all possible gather-light pair interactions.

We create an implicit hierarchy, the product graph, over the gather-light pairs to rapidly and accurately approximate the contribution from hundreds of millions of pairs per pixel while only evaluating a tiny fraction (e.g., 200-1,000). We build upon the techniques of the prior Lightcuts method for complex illumination at a point, however, by considering the complete pixel integrals, we achieve much greater efficiency and scalability.

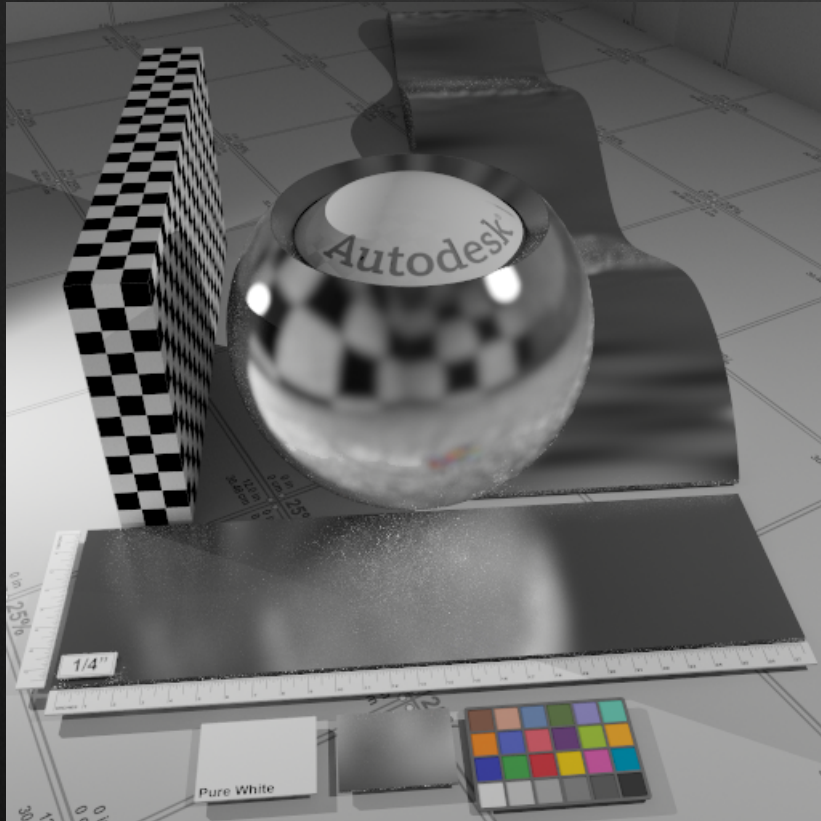
Our example results demonstrate efficient handling of volume scattering, camera focus, and motion of lights, cameras, and geometry. For example, enabling high quality motion blur with 256x temporal sampling requires only a 6.7x increase in shading cost in a scene with complex moving geometry, materials, and illumination.

**CR Categories:** I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Color, shading, shadowing, and texture;  
**Keywords:** motion blur, volume rendering, depth of field

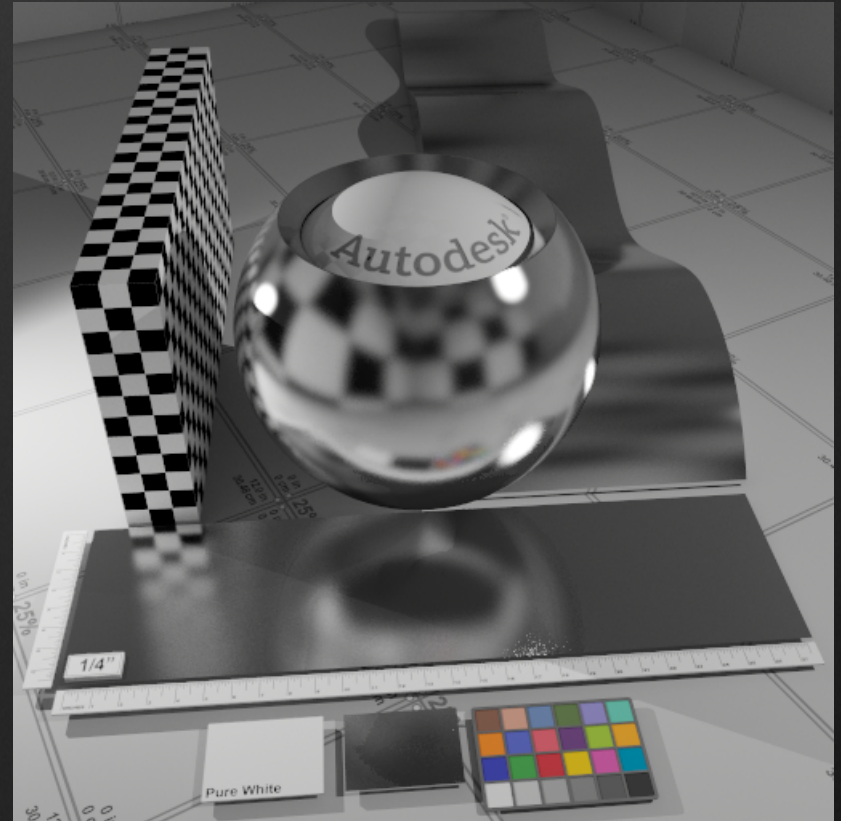
### 1 Introduction



# Problem: Glossy Objects



Basic VSLs

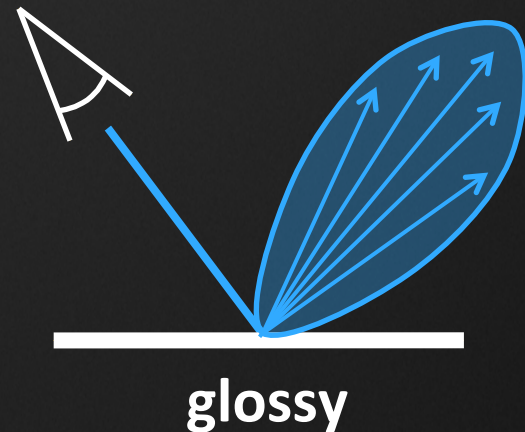
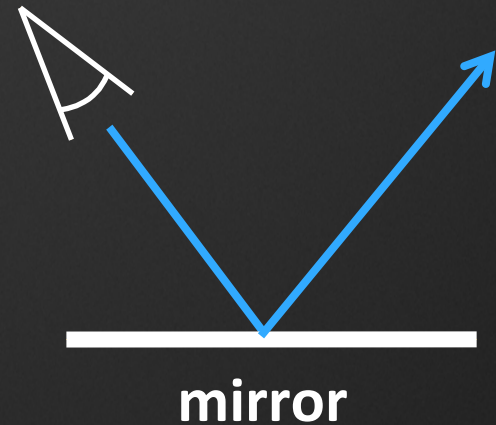


Our Solution



# Solution: Eye Ray Splitting

- Split and recursively trace eye rays for glossy materials
- Heuristic determines split rate from material's glossiness
- Increase maximum cut size to accommodate increased sampling



# Problem: High Occlusion



**Our Solution**



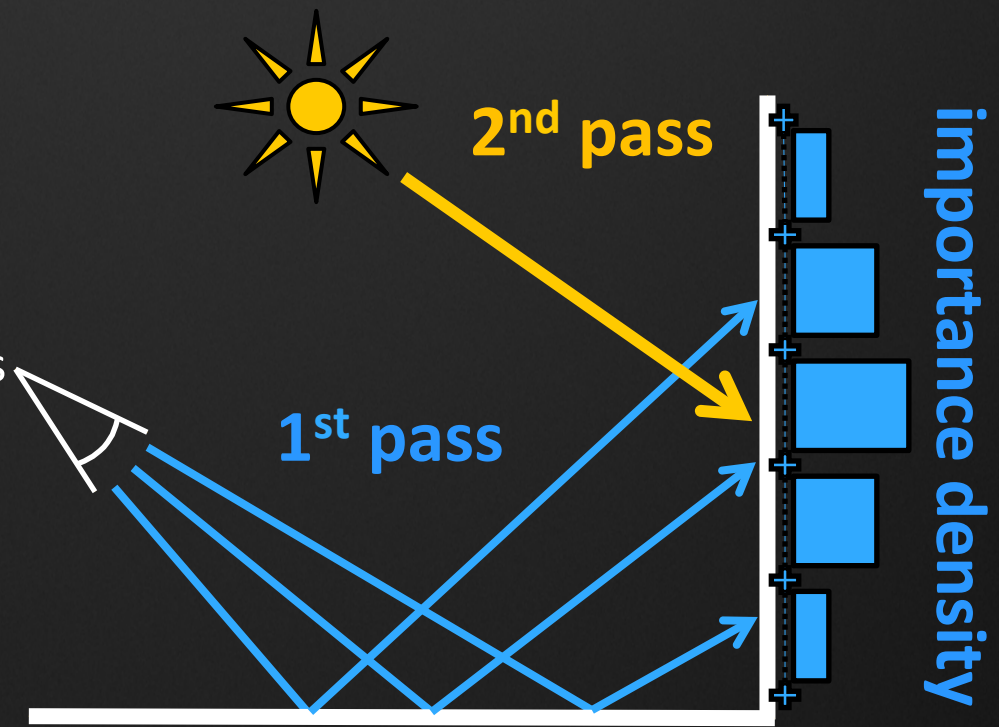
**Naïve MDLC**





# Solution: VPL Targeting

- Modeled on [photon mapping with importance](#)
- Two pass algorithm
  - 1<sup>st</sup> pass: Trace eye ray samples
  - 2<sup>nd</sup> pass: Use importance density estimates to reject VPLs with Russian roulette



# Advantages

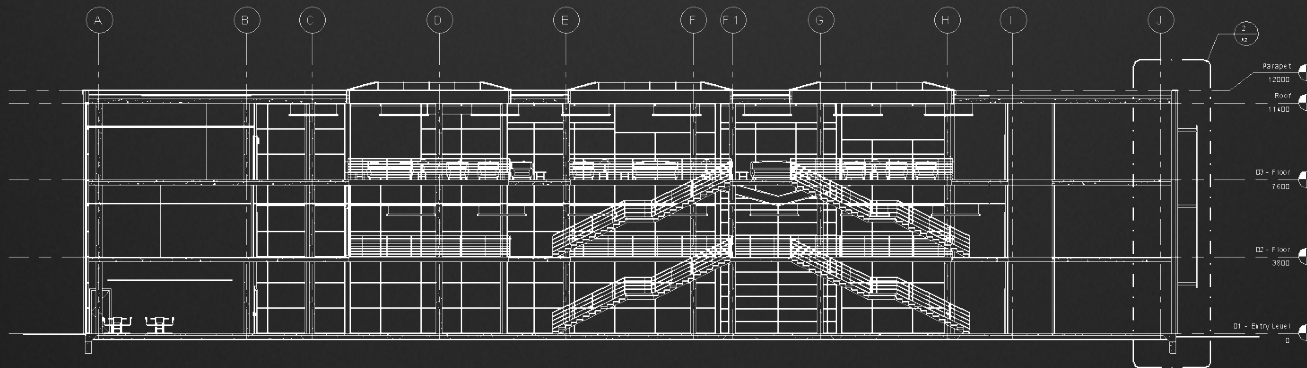
MDLC combined with our heuristics gives many advantages



# Advantages

MDLC combined with our heuristics gives many advantages

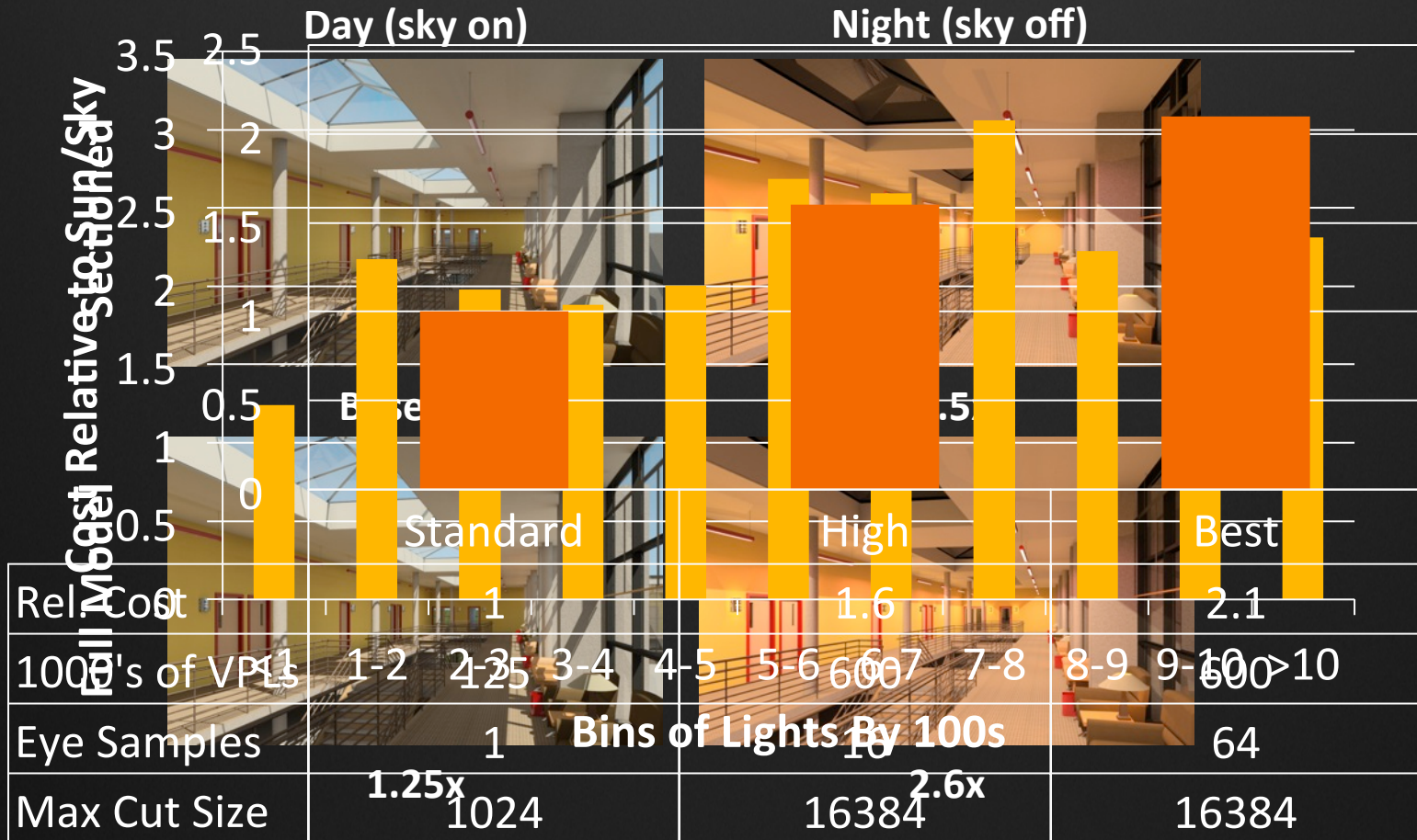
Makes design-size models feasible to render without impacting designer's work



# Advantages

MDLC combined with our heuristics gives many advantages

Allows more predictive costs with scene complexity and render quality

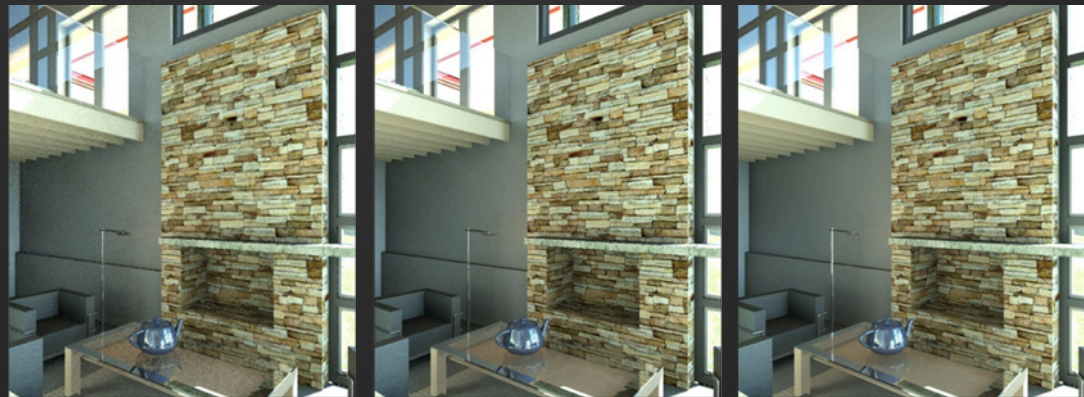


# Advantages

MDLC combined with our heuristics gives many advantages

Cheap low-quality modes consistent with higher-quality modes

Autodesk® 360  
Renderer  
(Spectrum)

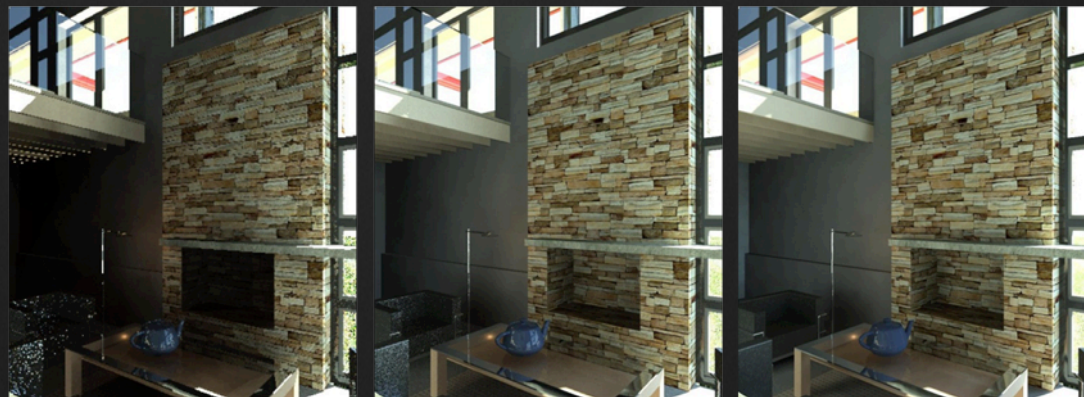


1x



10x

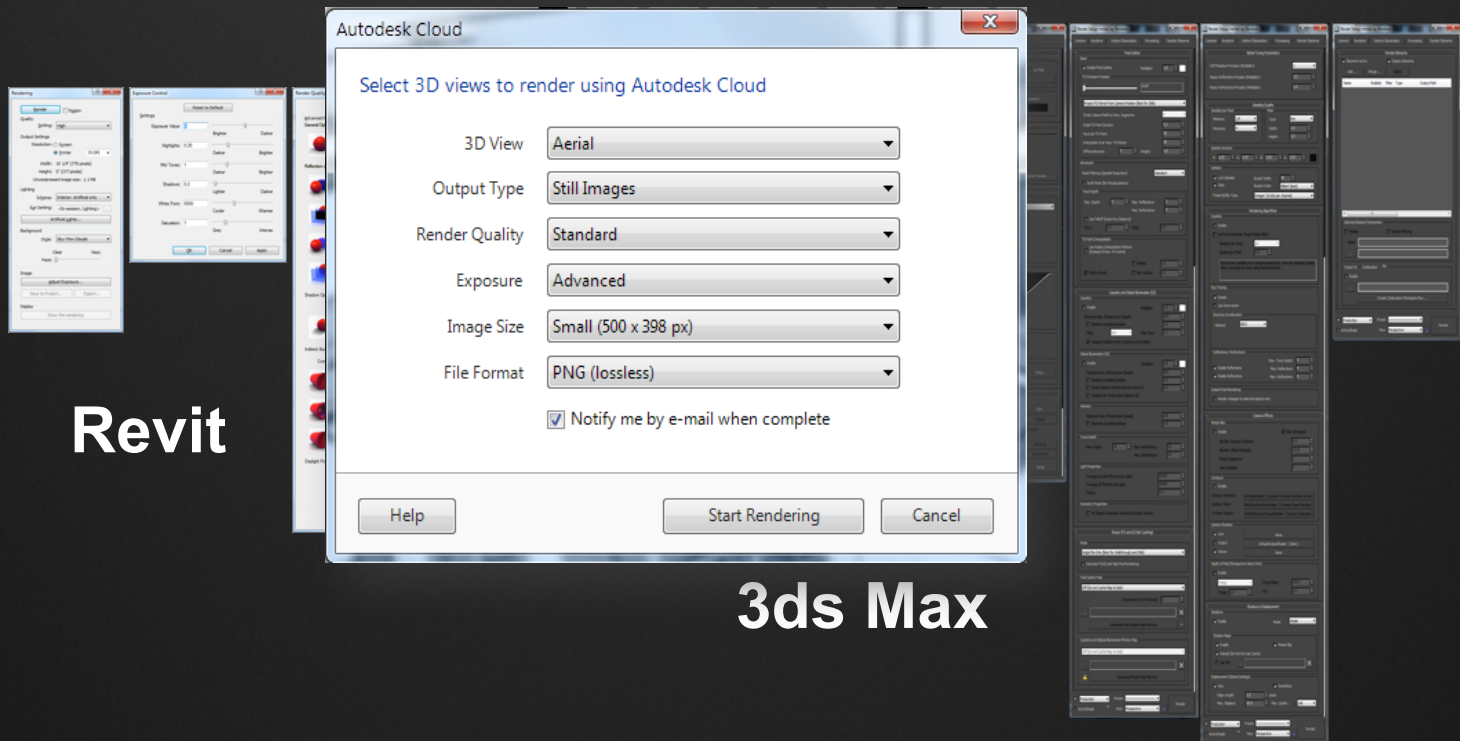
Path Tracer  
with Irradiance  
Caching



# Advantages

MDLC combined with our heuristics gives many advantages

Eliminate need for render-expert users; No portals, reduced parameters



Revit

3ds Max

Users focus on their job. Renderer figures out “important” illumination, decides when image is done enough.



Cloud Platforms

Autodesk

# Case 1 – Global Illumination

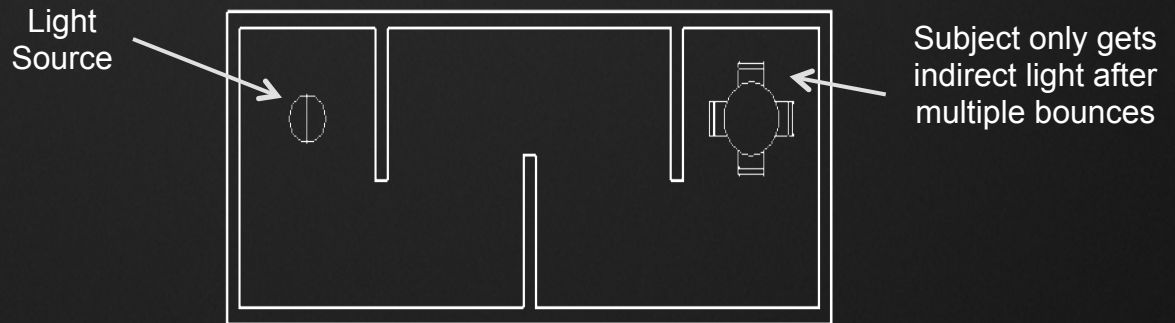
Mental Ray has two choices

- Final Gather (approximated, slow with multiple bounces)
- Photons (faster, deeper, requires knowledge and testing)

Parameters not always universal, or inefficient in most cases if tuned high

Spectrum attempts to be adaptive, requiring few user parameters

The Test:

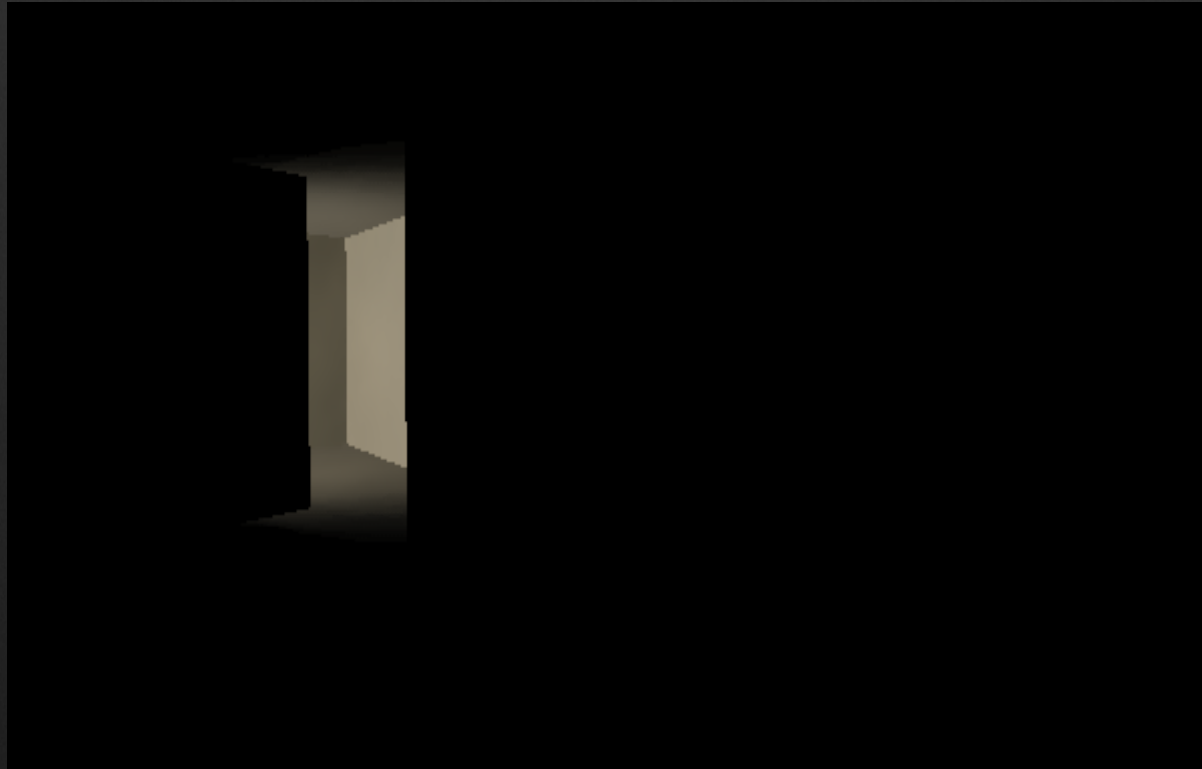


# Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



Draft  
10s

Medium  
28s

High  
1m 55s

Best  
11m 28s

Custom 1 (FG 5 bounces)  
2m 45s



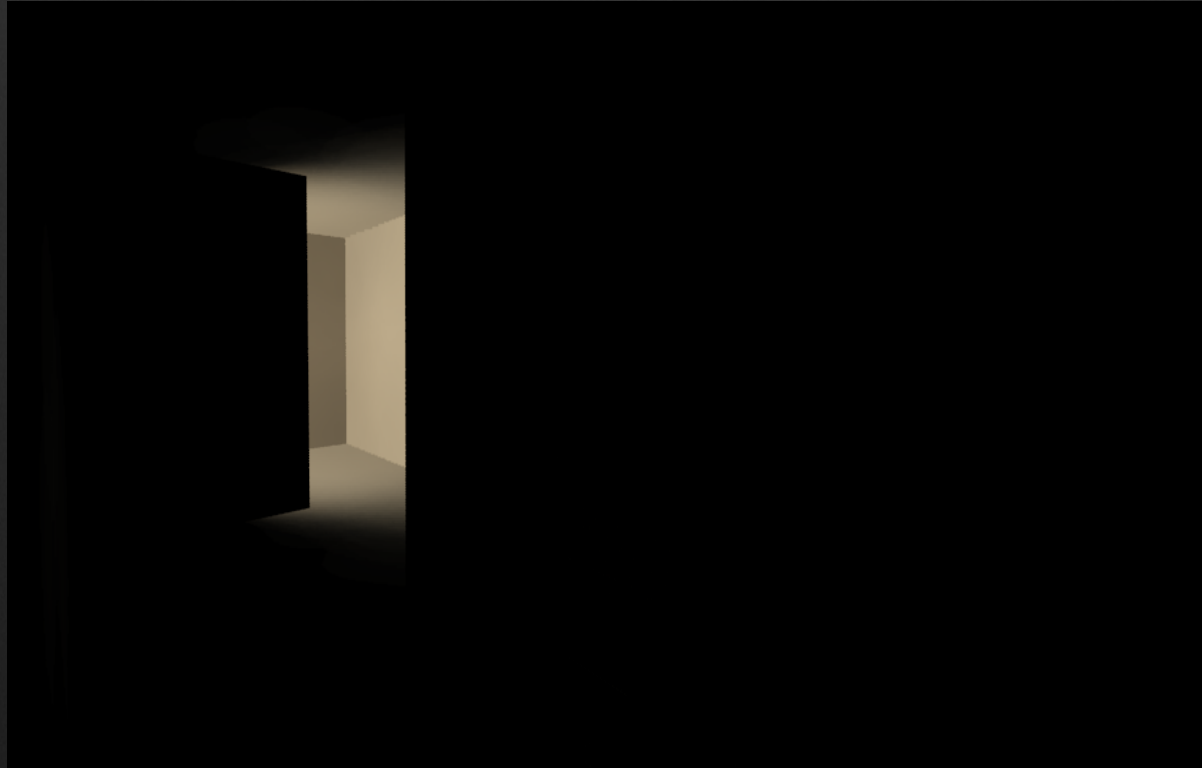


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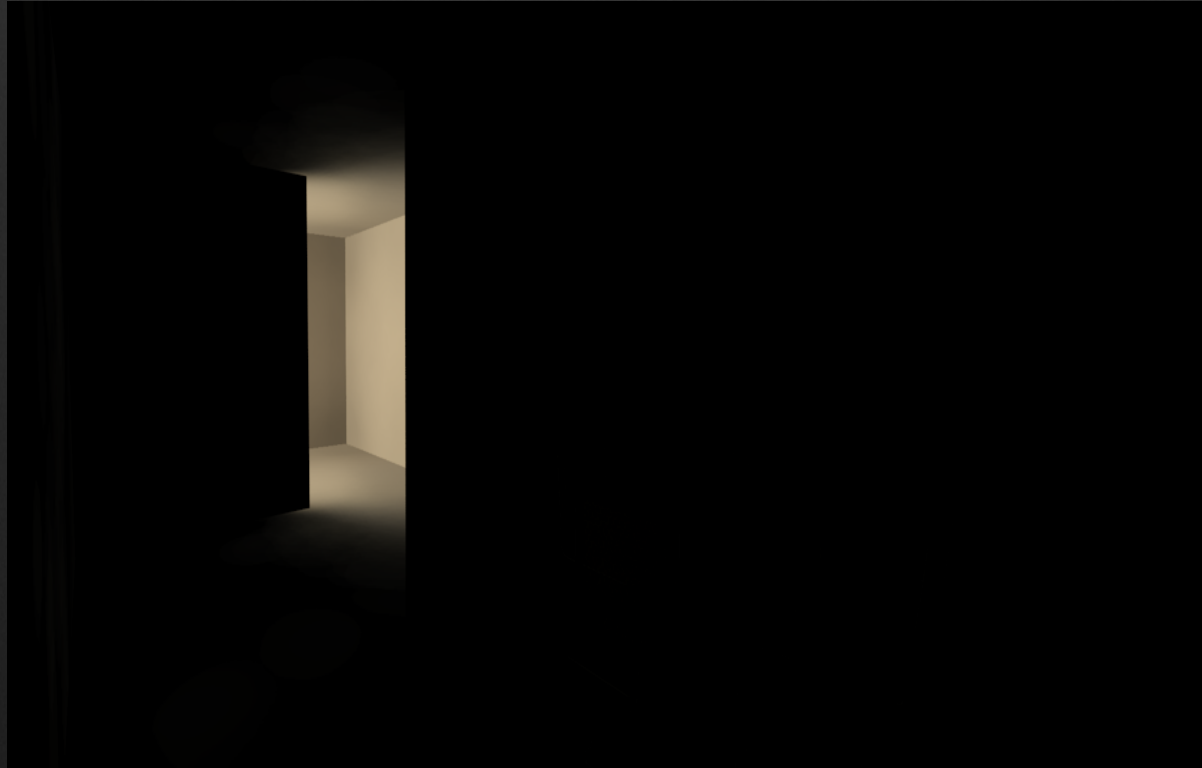


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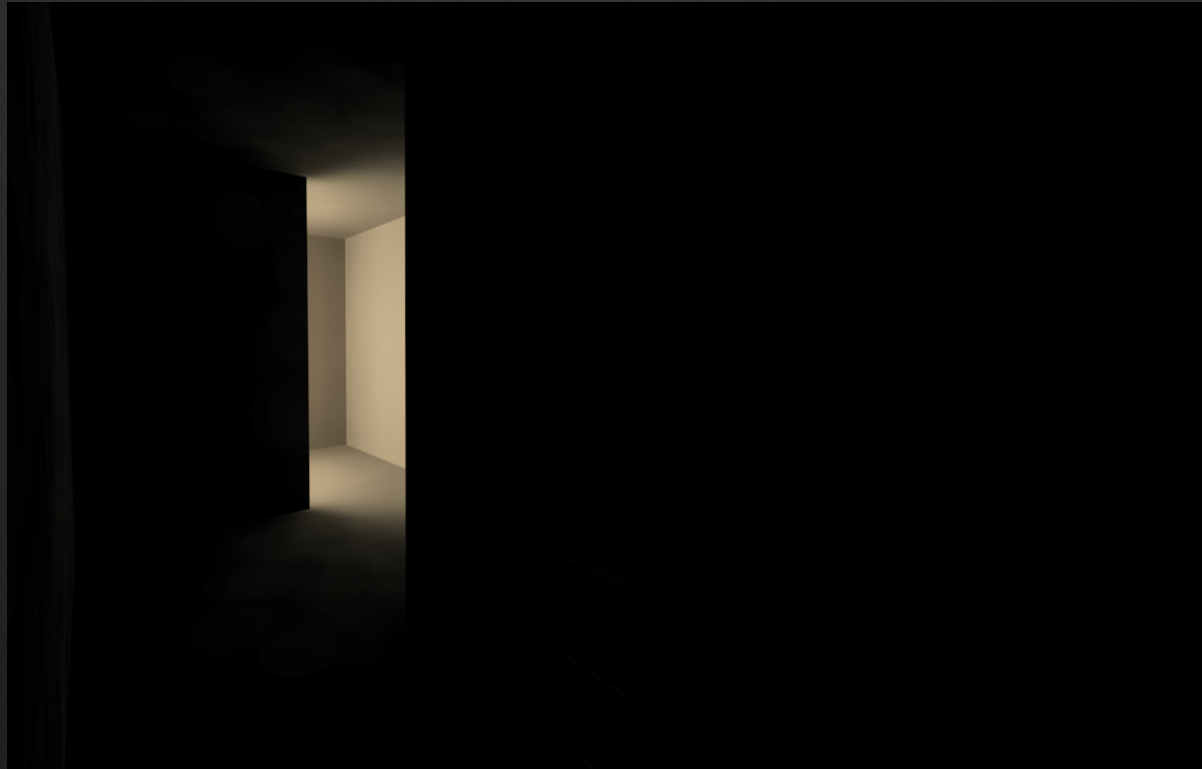


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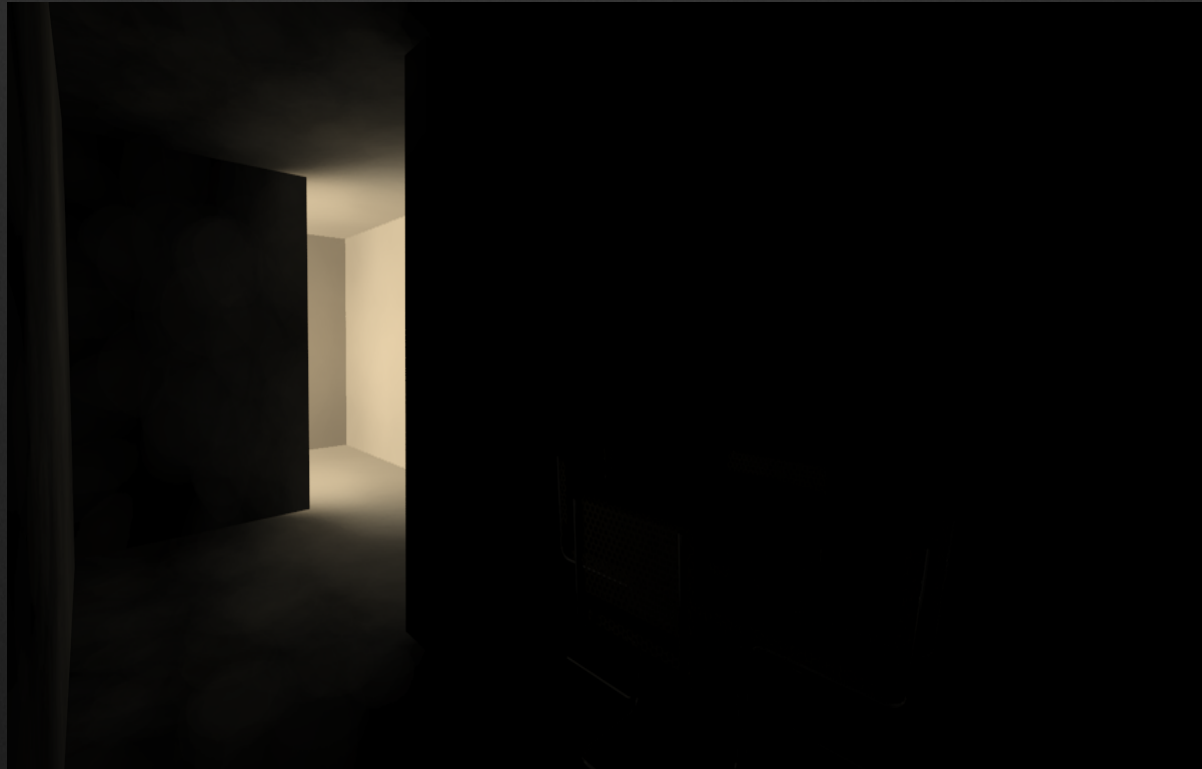


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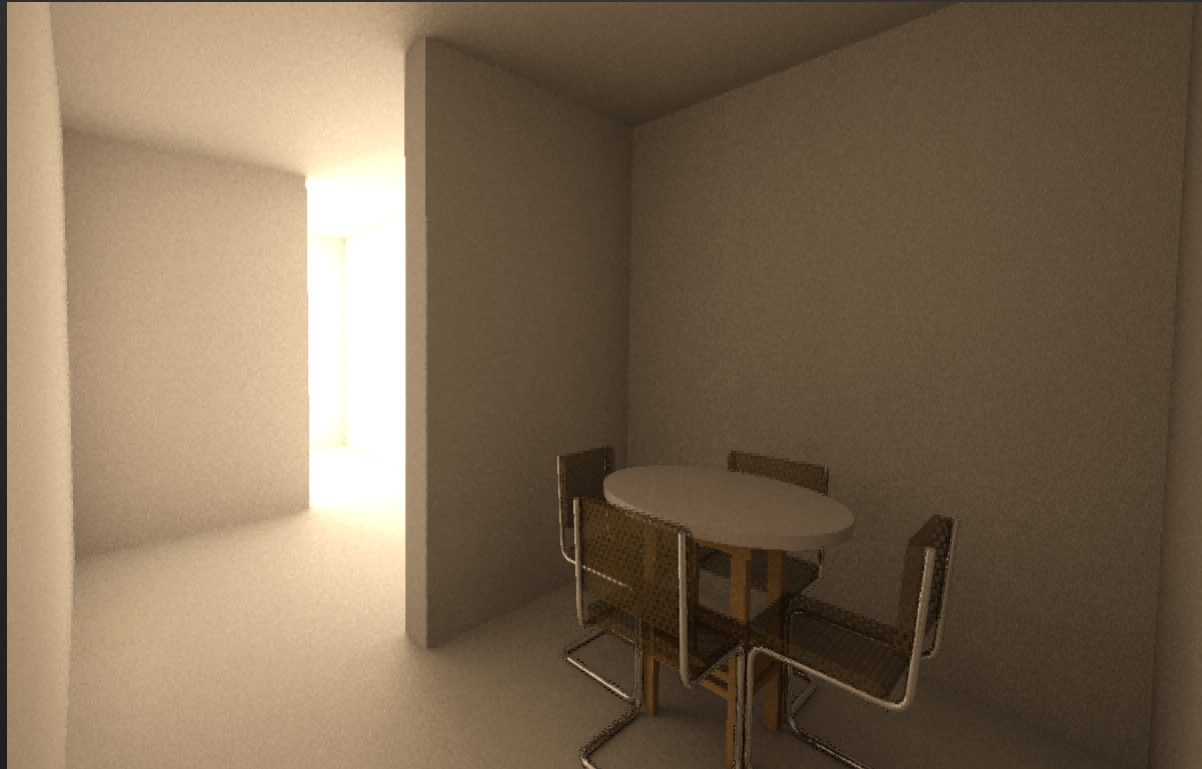


# Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



Draft  
37s

Standard  
1m 46s

High  
5m 26s

Best  
8m 7s



# Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



Draft  
37s

Standard  
1m 46s

High  
5m 26s

Best  
8m 7s



# Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



Draft  
37s

Standard  
1m 46s

High  
5m 26s

Best  
8m 7s



# Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



Draft  
37s

Standard  
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High  
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Best  
8m 7s



Cloud Platforms

Autodesk

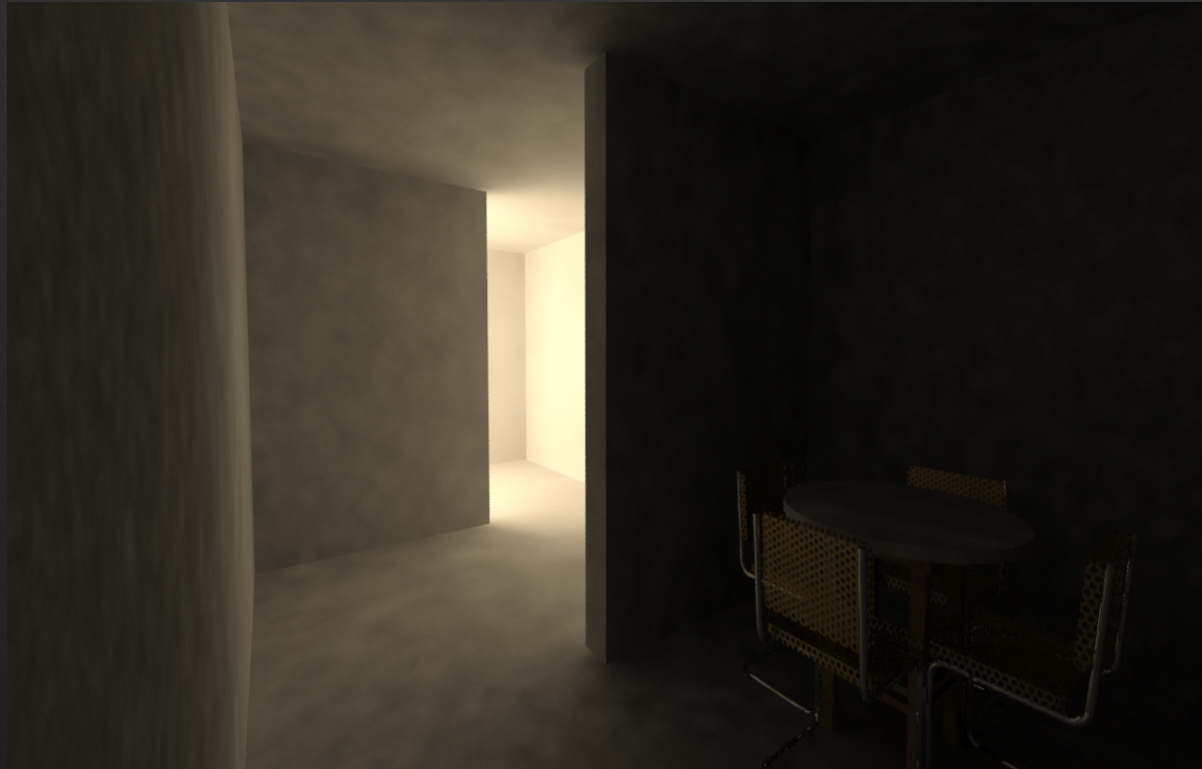


# Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



FG 10 bounces  
2h 15m 28s

50 million Photons 10 bounces and FG  
12m 9s

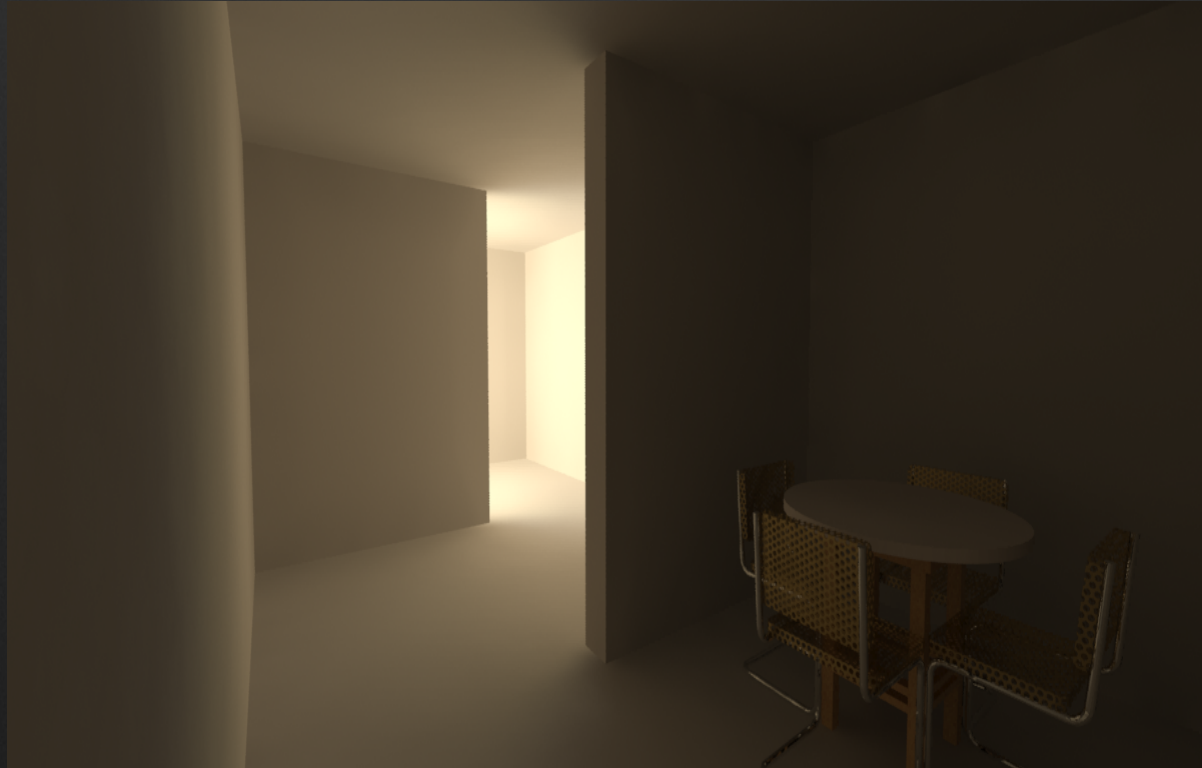


# Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



FG 10 bounces  
2h 15m 28s

50 million Photons 10 bounces and FG  
12m 9s



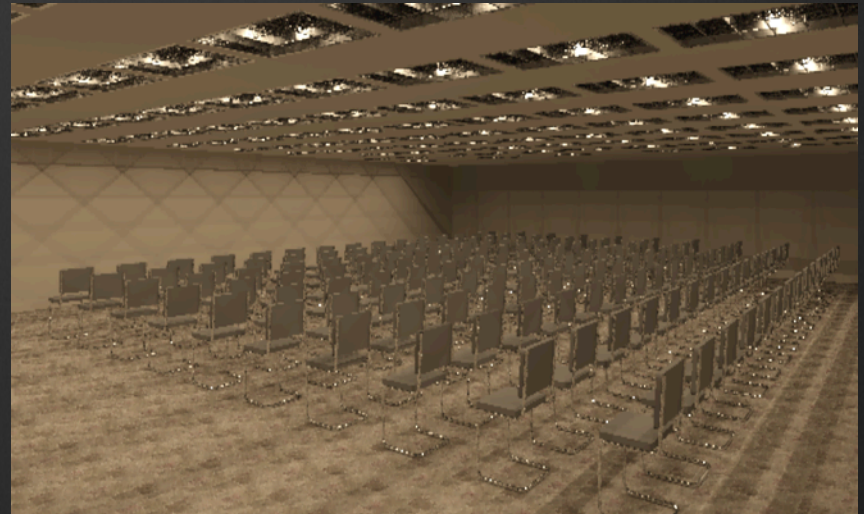
Cloud Platforms

Autodesk

# Case 2 – Area Lights, Draft



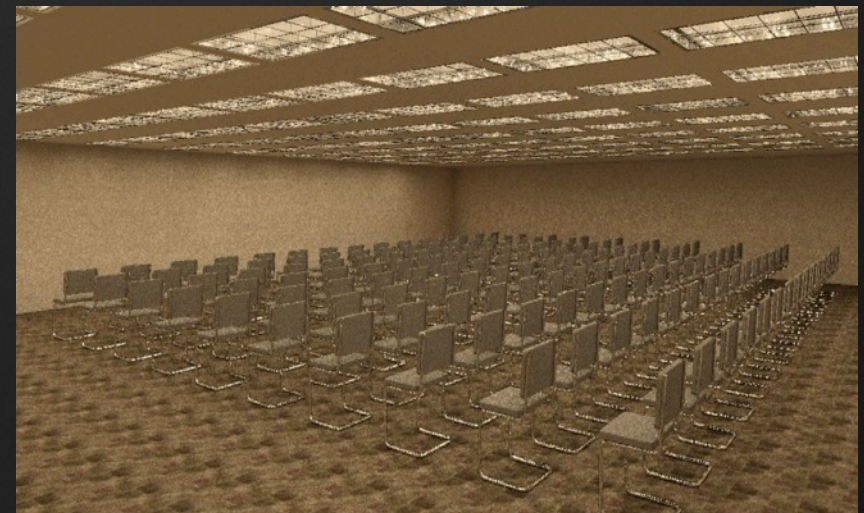
Revit® 10 lights  
43s



Revit® 100  
9m 57s (13.9X)



Spectrum 10  
Cloud Platforms 33s

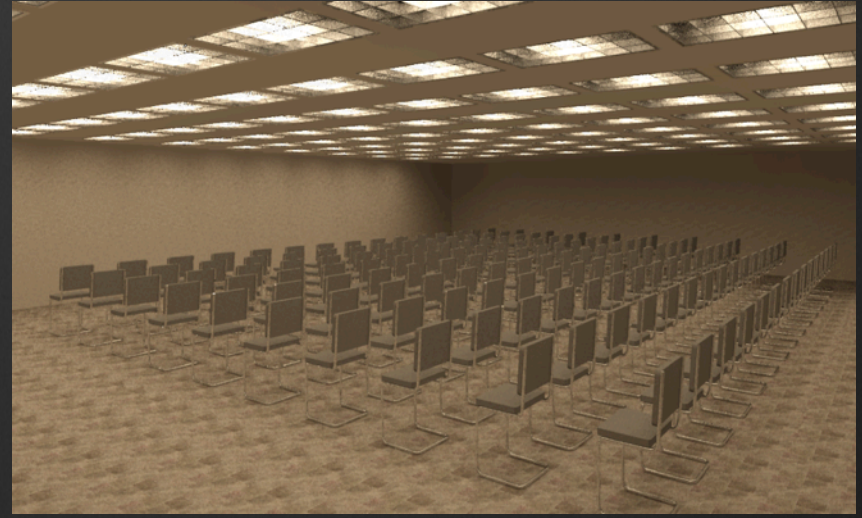


Spectrum 100  
58s (1.7X)

# Case 2 – Area Lights, Standard



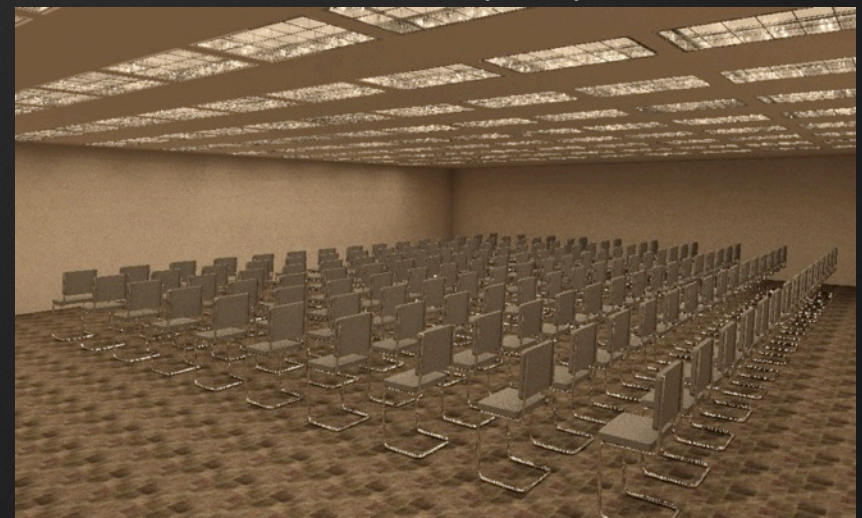
Revit® 10 lights  
9m 31s



Revit® 100  
2h 29m 41s (15.7X)



Spectrum 10  
1m 12s



Spectrum 100  
1m 47s (1.5X)



# Case 2 – Area Lights, High



Revit® 10 lights  
45m 5s



Revit® 100  
11h 26m 39s (15.2X)



Spectrum 10  
Cloud Platform  
5m 16s



Spectrum 100  
13m 24s (2.5X)

# Cloud Rendering Performance and Quality

Revit® >

Quality: High  
Render time: **23:09**



< Cloud Rendering

Quality: High  
Render time: **5:48**



# Cloud Rendering Performance and Quality

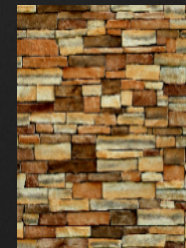
Revit® >

Quality: Best  
Portals: Enabled  
Render time: **9:06:00**



< Cloud Rendering

Quality: Best  
Advanced Exposure  
Render time: **1:06:00**



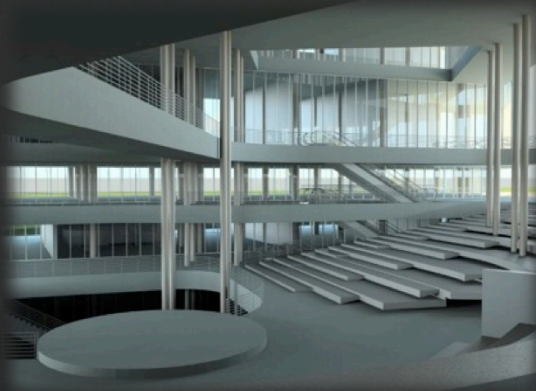
original brick  
wall texture



# Some Results



Over 30,000 users



More than half million render jobs

Thousands of jobs per day



150 s/megapixel average (64 cores)







<http://www.facebook.com/Autodesk360Rendering>



# For More Details...

## SIGGRAPH 2012 Course

### Optimizing Realistic Rendering With Many-Light Methods

Jaroslav Krivanek, Milos Hasan, **Adam Arbree**, Carsten Dachsbacher, Alexander Keller, Bruce Walter

Sunday, 5 August, 2-5:15 pm



# Obligatory Features Discussion

- Several rendering workflows: Stills, Solar Studies, Panoramas
- Scalable rendering many light sources
  - Points, spheres, rectangles, etc... with IES distributions
  - Mesh lights with diffuse emission
  - Physically based sky model or HDR environment lighting
- Autodesk Protein materials
  - Physically-plausible BRDFs
  - Color and bump textures, bitmaps or procedurals, decals
- Limited instancing support
- Depth of field
- Ray differentials, texture filtering
- Robust single precision rendering
  - scene re-centering
  - Relative ray offsets ala Carsten Wächter
- Scalable across cores and nodes



# Features TODO

- More algorithms
- Caustics
- Subsurface scattering
- Motion blur
- Surface displacement
- More render workflows
- NURBS/high-order surfaces
- Double precision
- Better instancing



# Bonus: Call for Research

- Acceleration structures with instancing
  - Problem: No simple method always good
    - Scene one: 10000 identical chairs
    - Scene two: 10000 nested soup bowls
    - Scene three: both
  - How to get fast intersection with high memory savings?



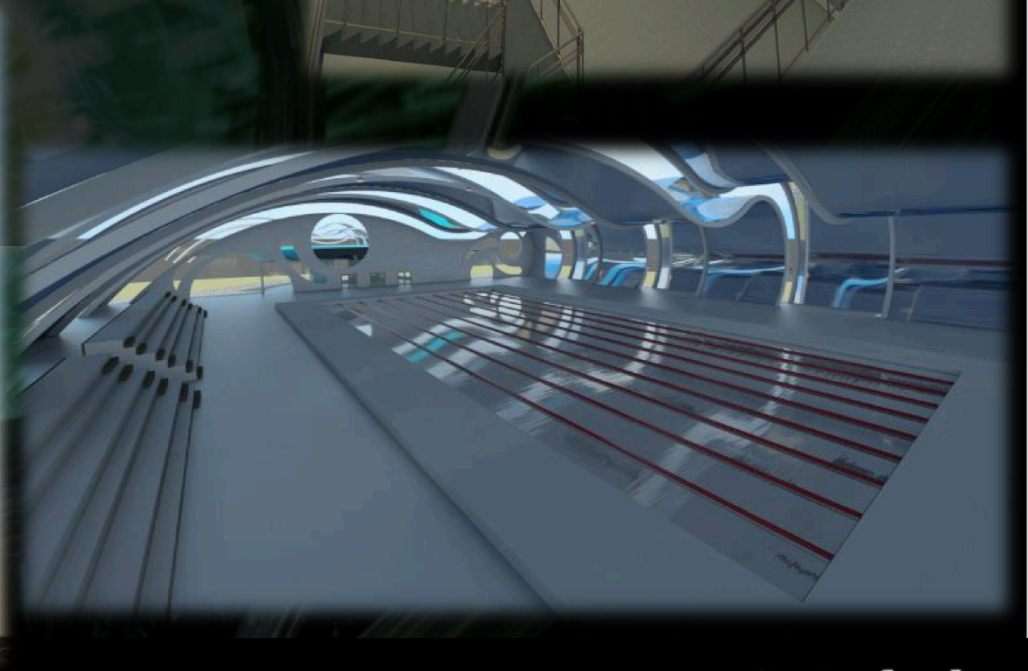
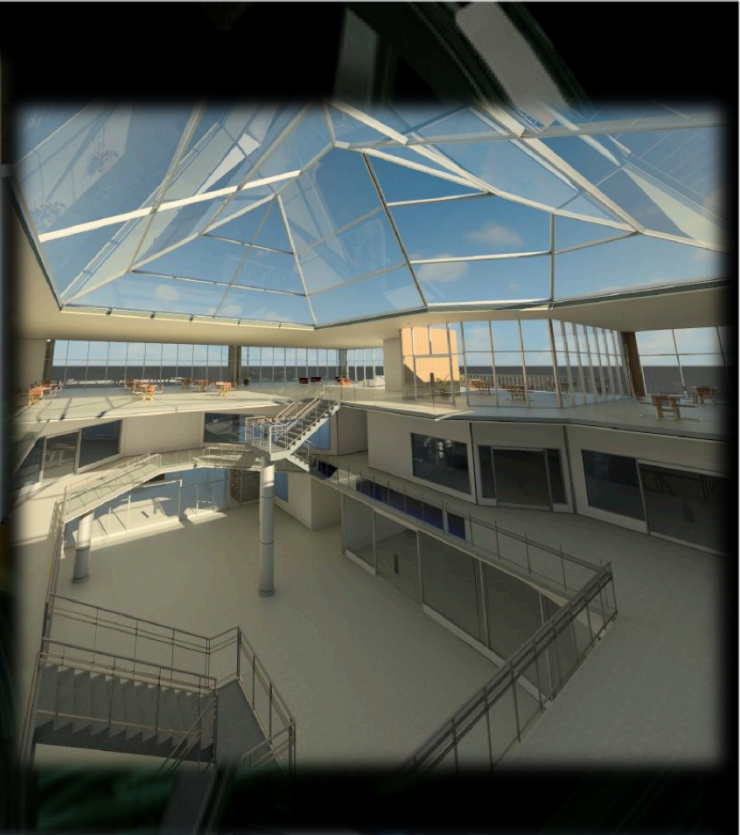
# Acknowledgements

- Thanks to teammates for help with the talk
  - Adam Arbree, Roberto Ziche, and Seema Jaisinghani
- Images from Autodesk® 360 Rendering facebook page
  - Andreas Nayström
  - Aroud Anis
  - Carlos Cardona
  - Carlos Paz
  - Charlie Marsan
  - Erick Paneda
  - Igor Sayenko
  - Jenny Chu
  - Jose Cabral
  - Lorena Fasolini
  - Nayaly Funez
  - Ogun Tuzcuoglu
  - Omar Burgos
  - Othman Elali
  - Pablo Diaz
  - Pietrangelo Magnani
  - Sherry Pittman
  - Tran Hai
  - Victor Castro
  - Wiodzimierz Kwiecinsk
  - Yamil Cruz



Questions?

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Cloud Platforms

Autodesk