Autodesk® 360 Renderin

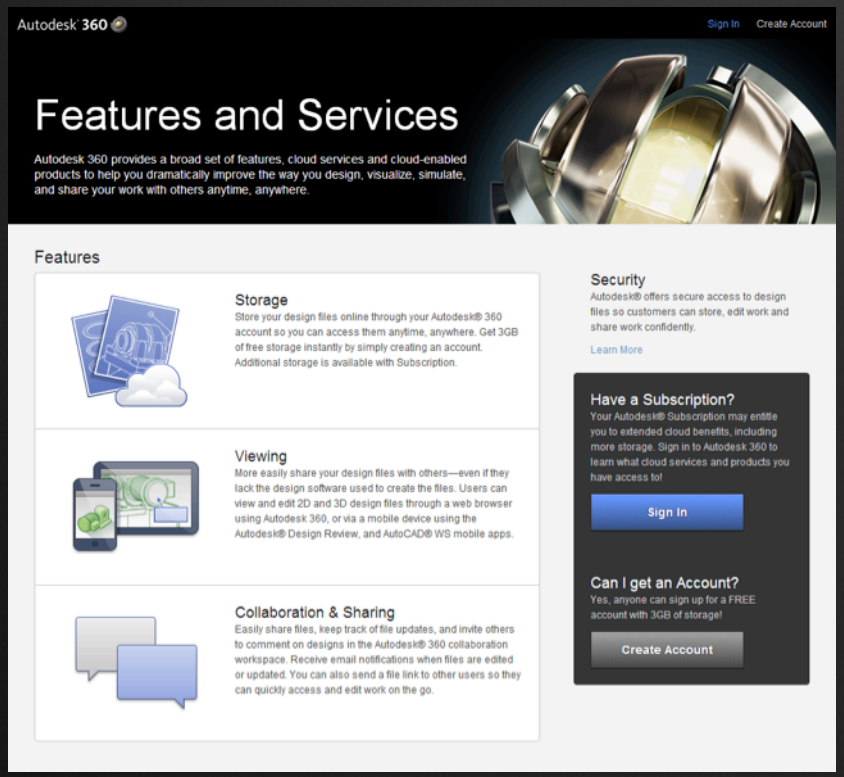
Scalable and Robust Rendering In the Cloud

Brian Budge
Principal Software Engineer, Cloud Rendering

Agenda

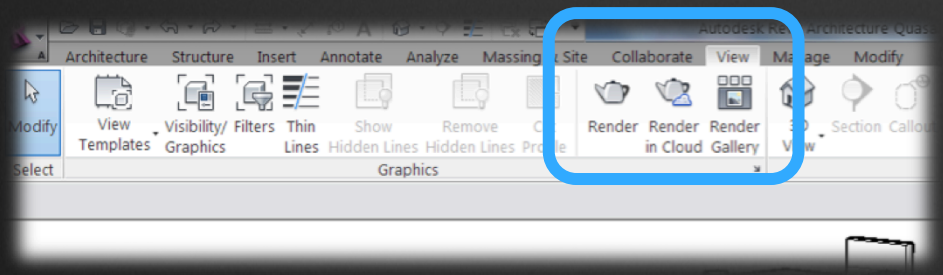
- Introduction to Autodesk 360
- Scaling Services
- Reducing Data
- Efficient and Easy to Rendering
- Features Discussion

Introduction to Autodesk® 360

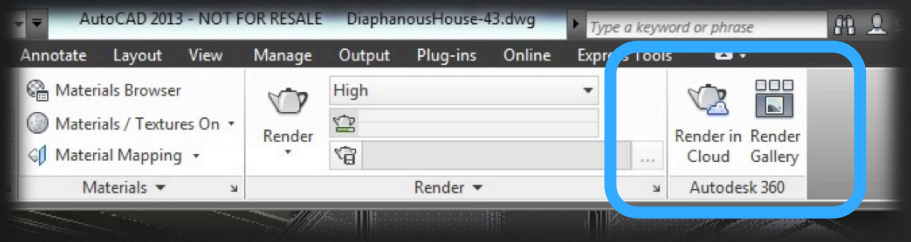


- Cloud Application Suite
- Goals of A360
  - Storage
  - Sharing
  - Collaboration

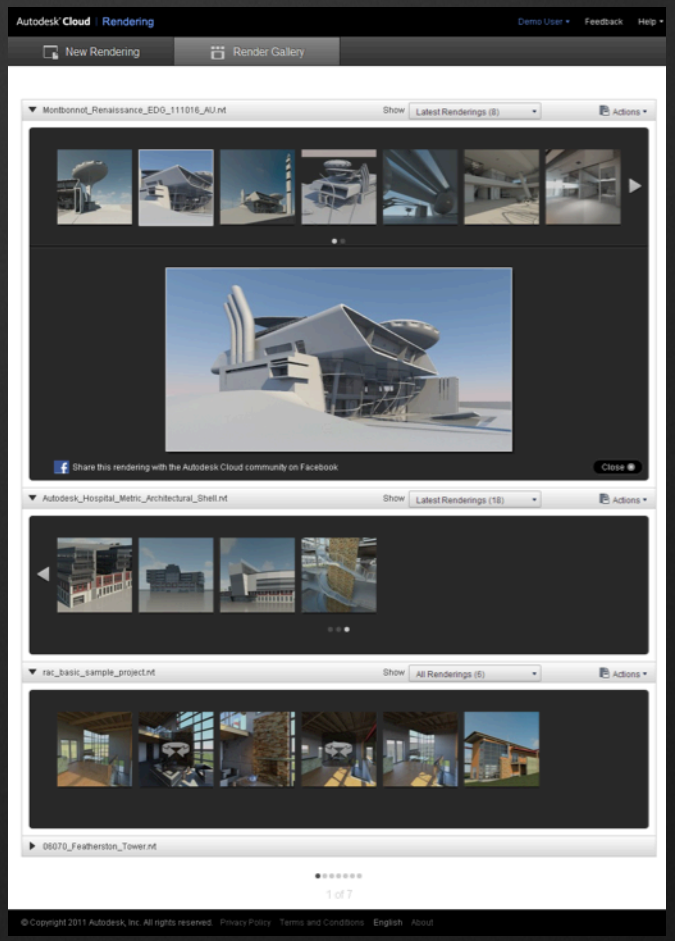
Autodesk® 360 Rendering



Autodesk® Revit® 2013

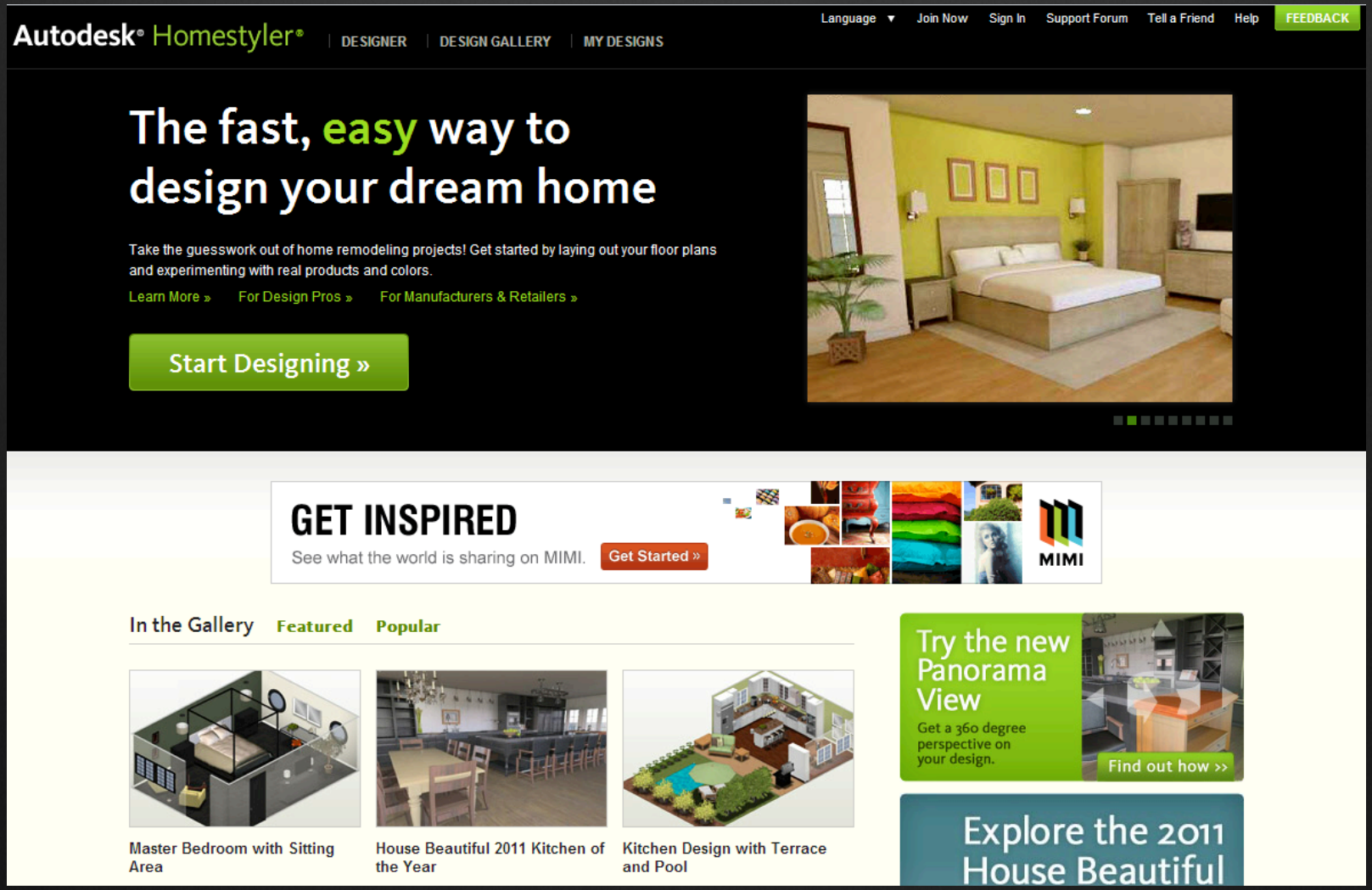


Autodesk® AutoCAD® 2013



Rendering Portal / Gallery

Autodesk® Homestyler®

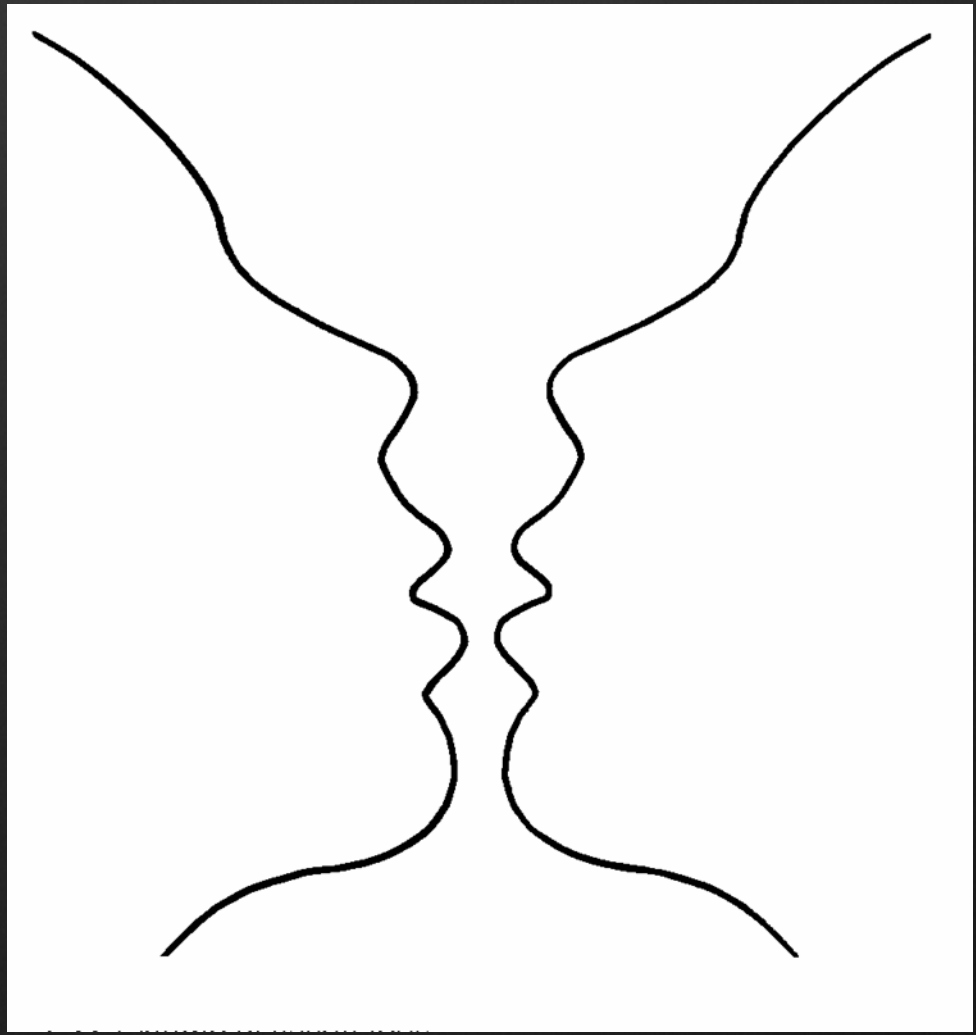


Perception vs Reality

User Perspective

VS

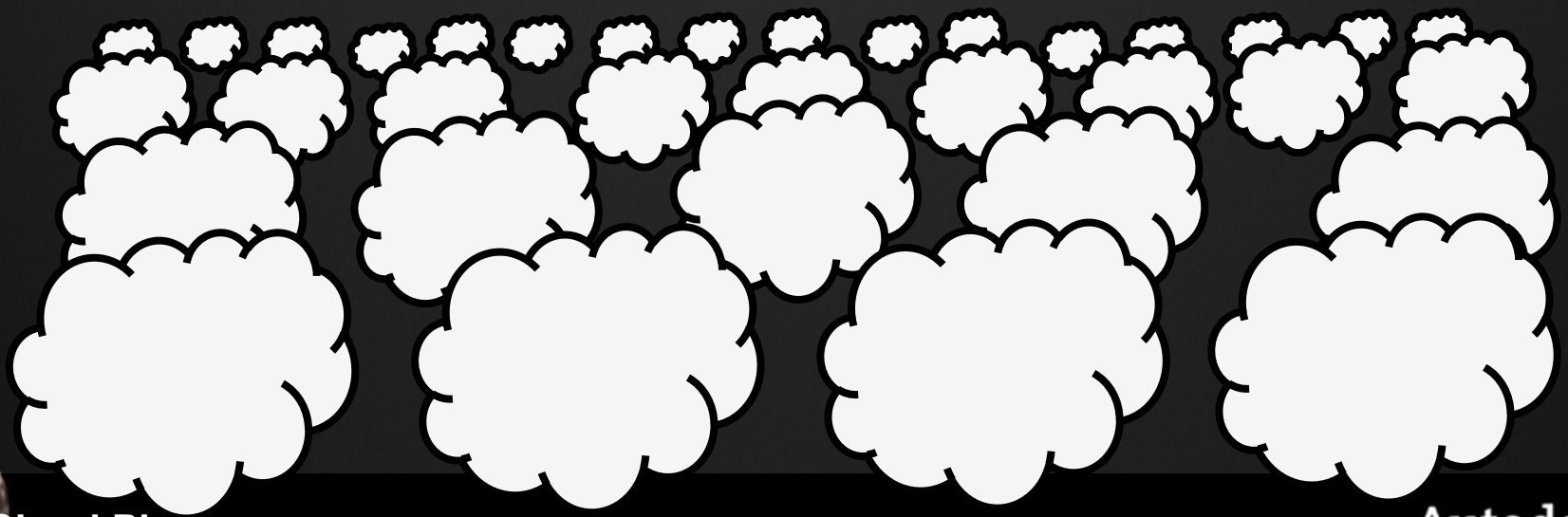
Developer Perspective



Problem: Conflicting Perspectives

User Perspective

The cloud is infinite; **I can render anything.**



Problem: Conflicting Perspectives

User Perspective

The cloud is infinite; **I can render anything.**

Developer Perspective

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

Quality of Service

Vs.

Cost

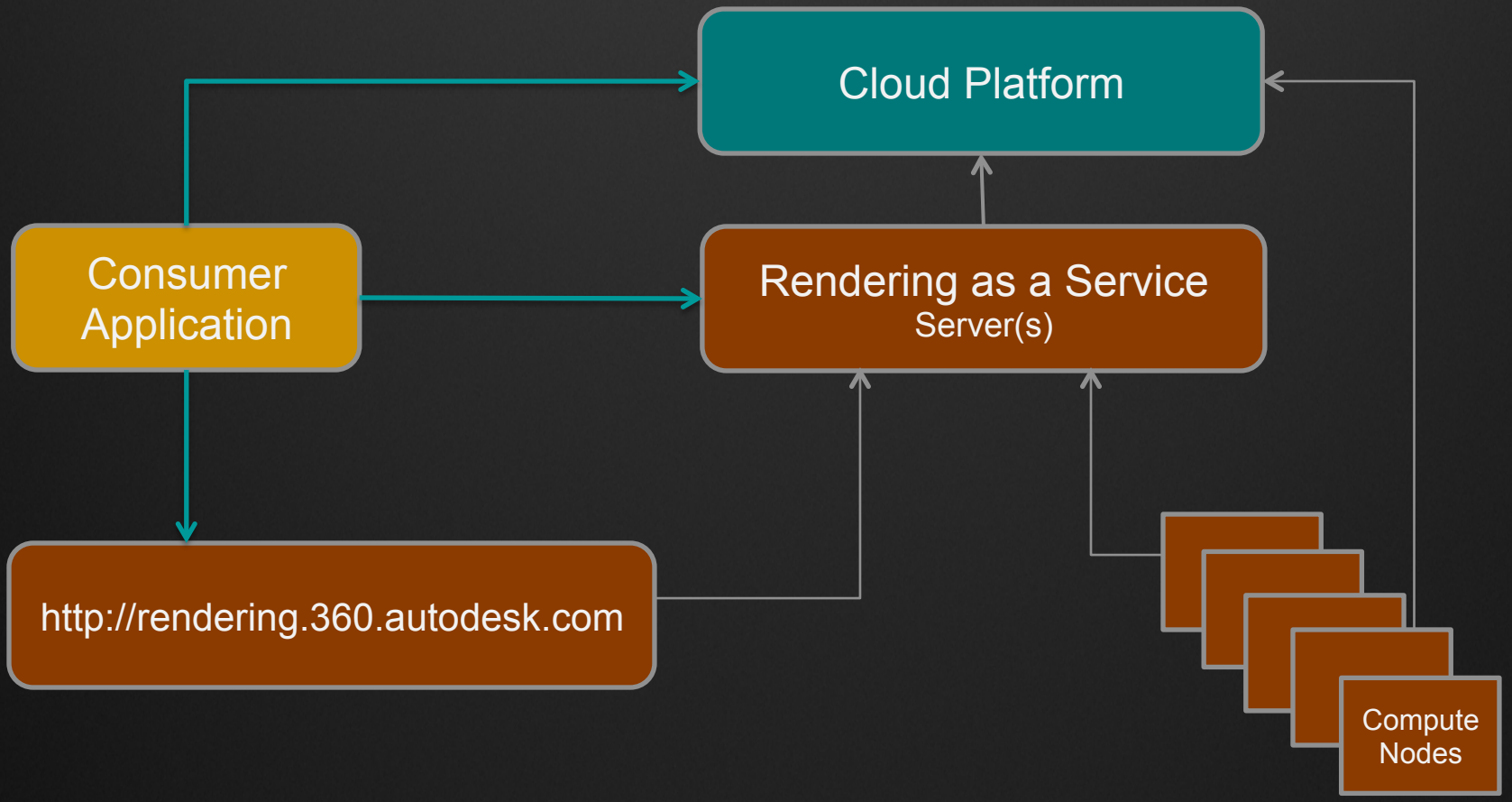
Quality of Service Vs Costs

- 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
  - User empowerment
  - New features immediately
  - Infinite and secure storage
  - Rendering by anyone
  - Quick and painless
- Cut costs
  - Scale down compute
  - Minimize data
  - Efficient rendering

Integrating Cloud rendering in Autodesk products



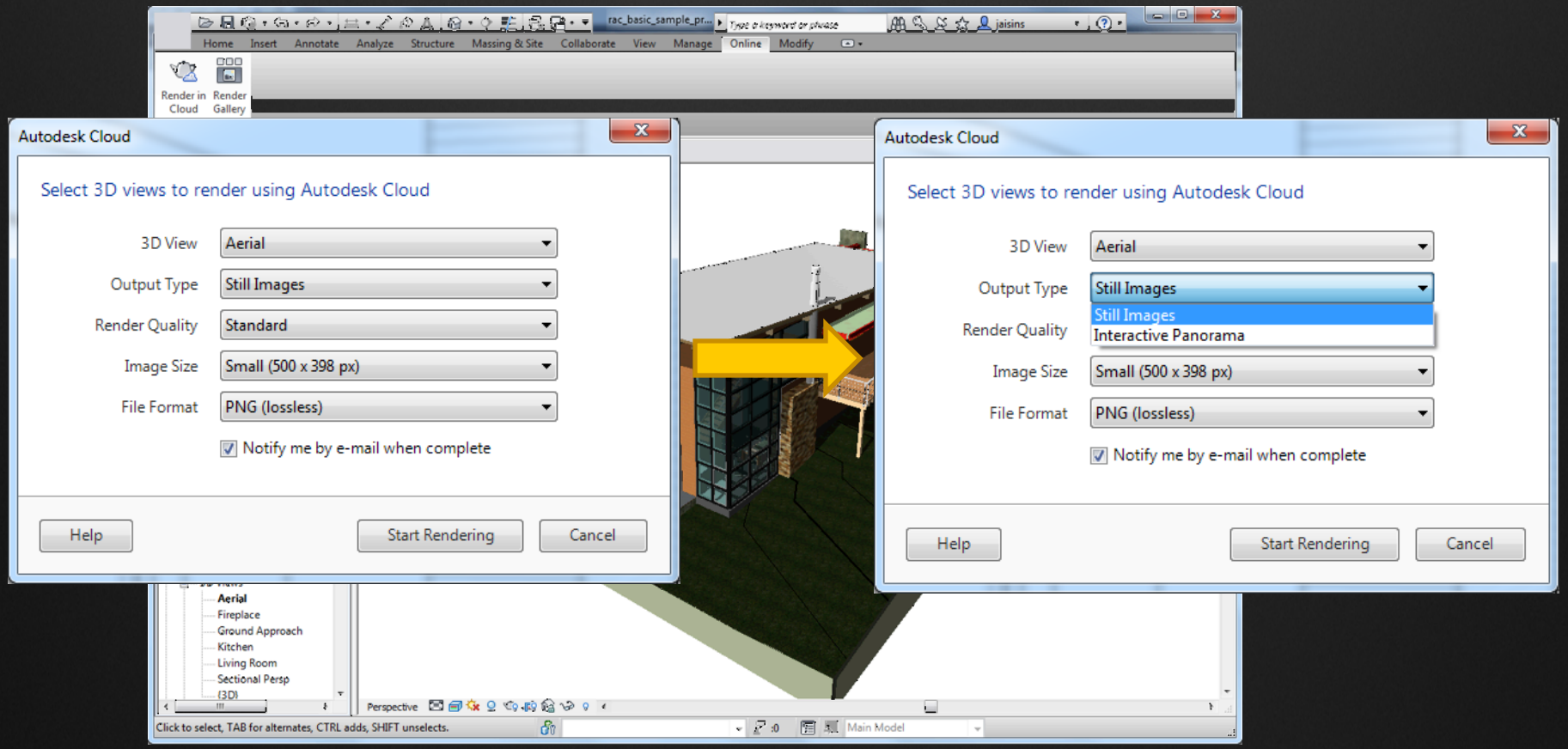
Scalability Axes

- 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

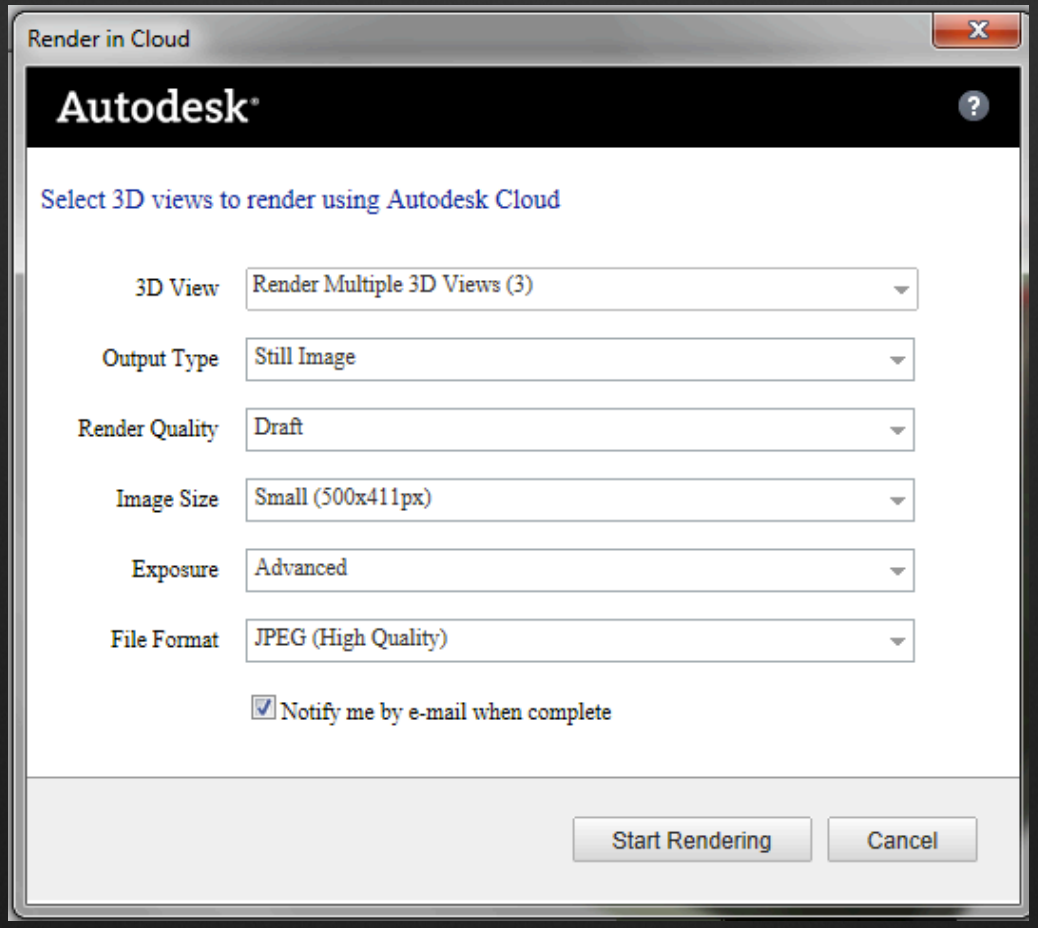
Example: Plugin Update



Plugin V1

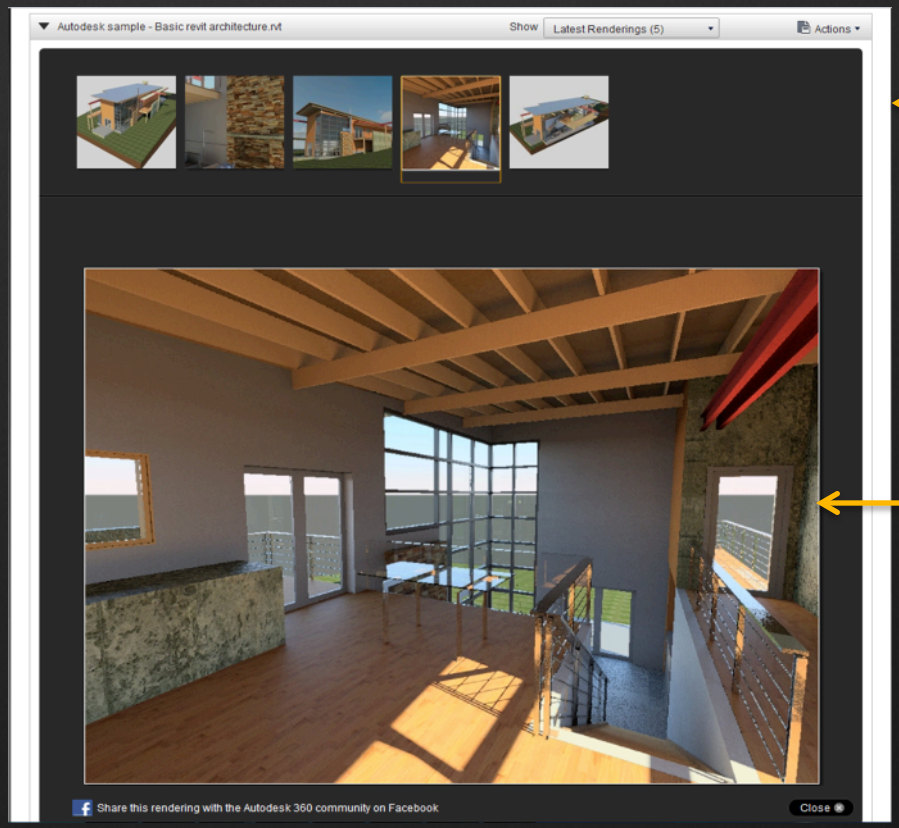
Plugin V2

Solution: Service Updates in the Cloud



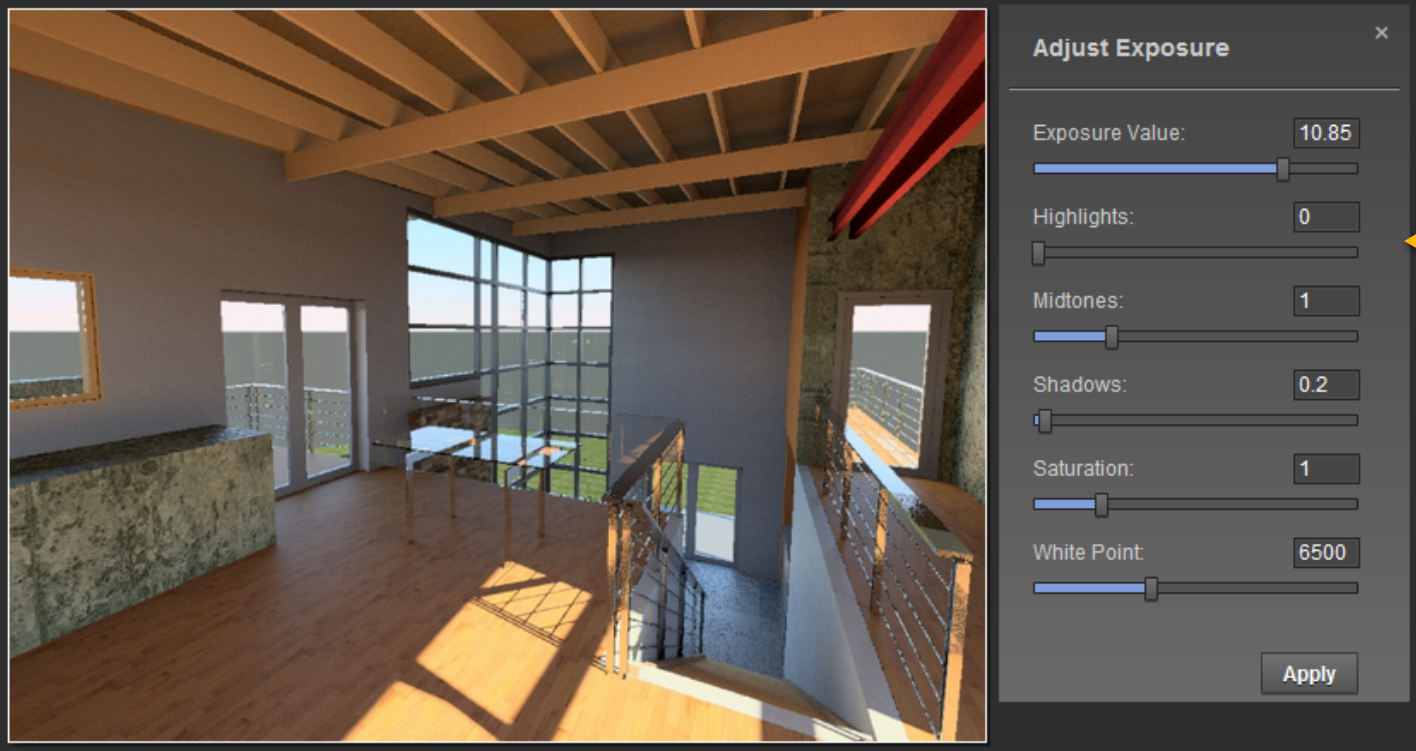
Solution: HTML Viewer Widgets

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



http://raas.autodesk.com/gallery/basic_arcitecture.rvt

Solution: HTML Viewer Widgets



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
  - 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: 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

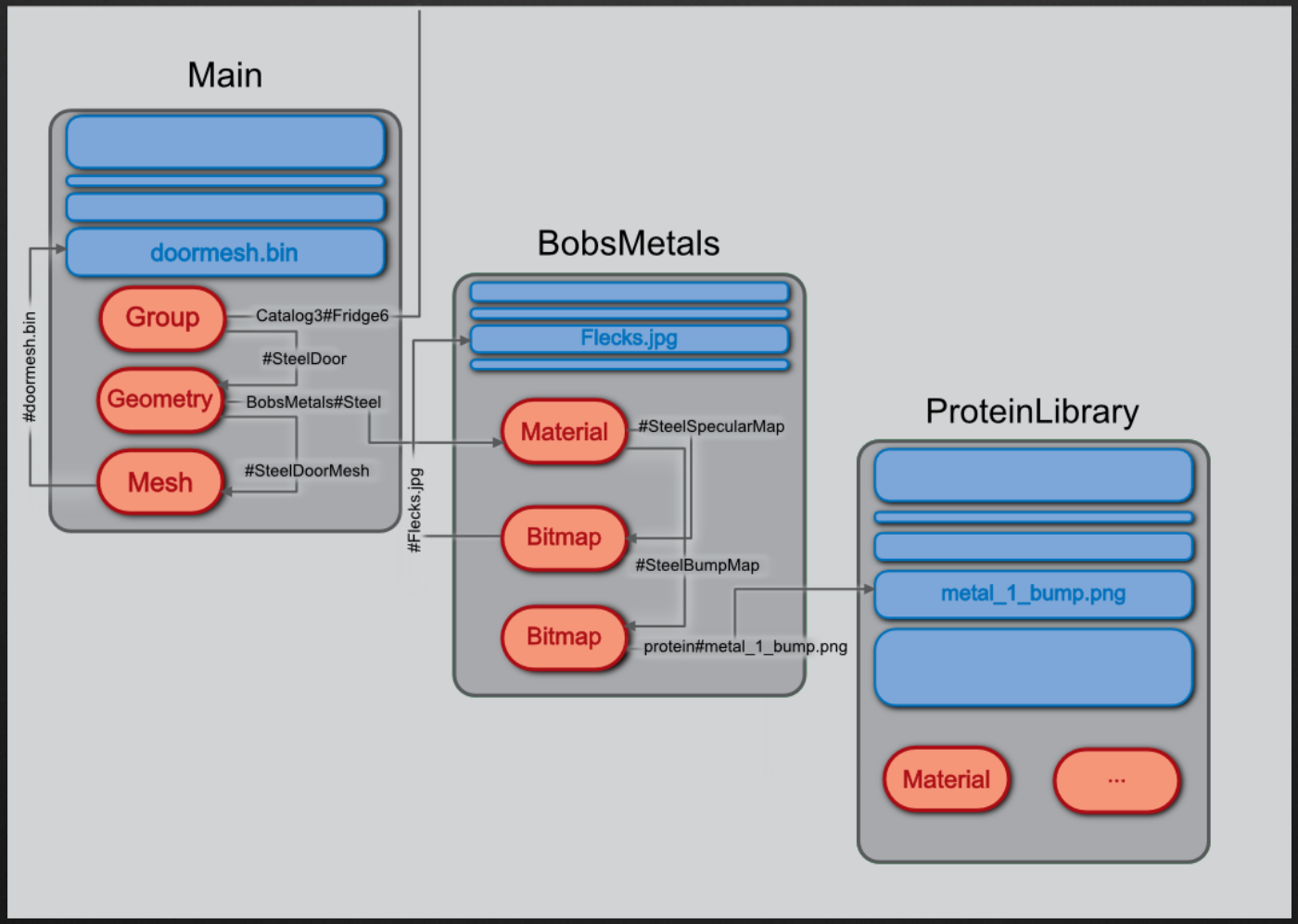
2. Reduce duplication

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 Arbree 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 han-

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

Lightcuts
Siggraph 2005

Multidimensional Lightcuts
Siggraph 2006

To appear SIGGRAPH 2006.

Multidimensional Lightcuts

Bruce Walter Adam Arbree 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.

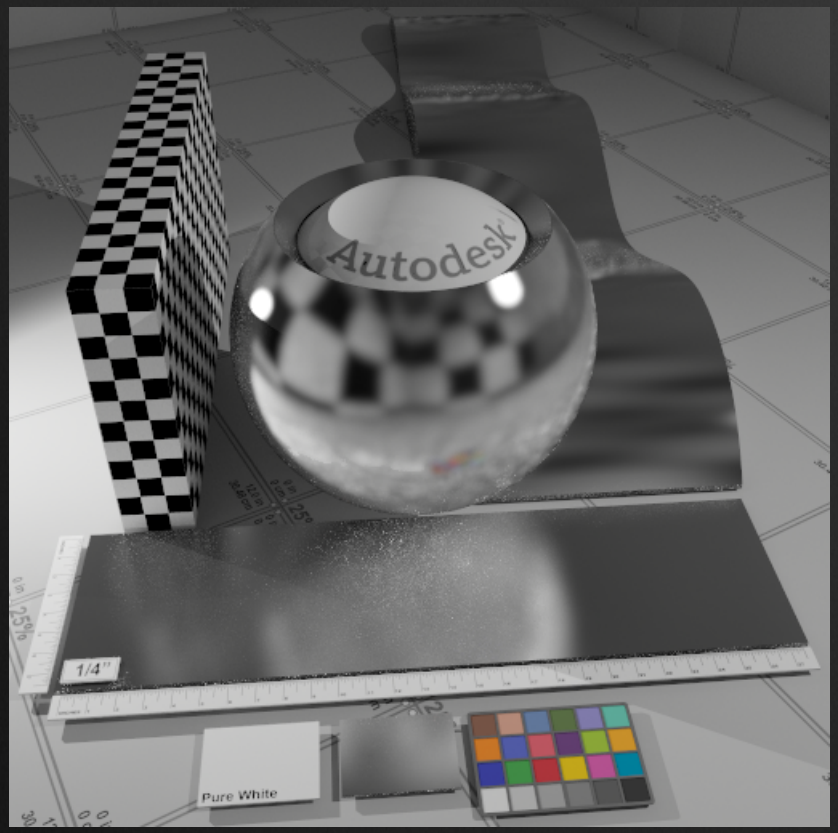
We create an implicit hierarchy, the product graph, over the gather-light pairs to rapidly and accurately approximate the contribution from hundreds of millions of pairs per pixel while only evaluating a tiny fraction (e.g., 200–1,000). We build upon the techniques of the prior Lightcuts method for complex 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 256× temporal sampling requires only a 6.7× increase in shading cost in a scene with complex moving geometry, materials, and illumination.

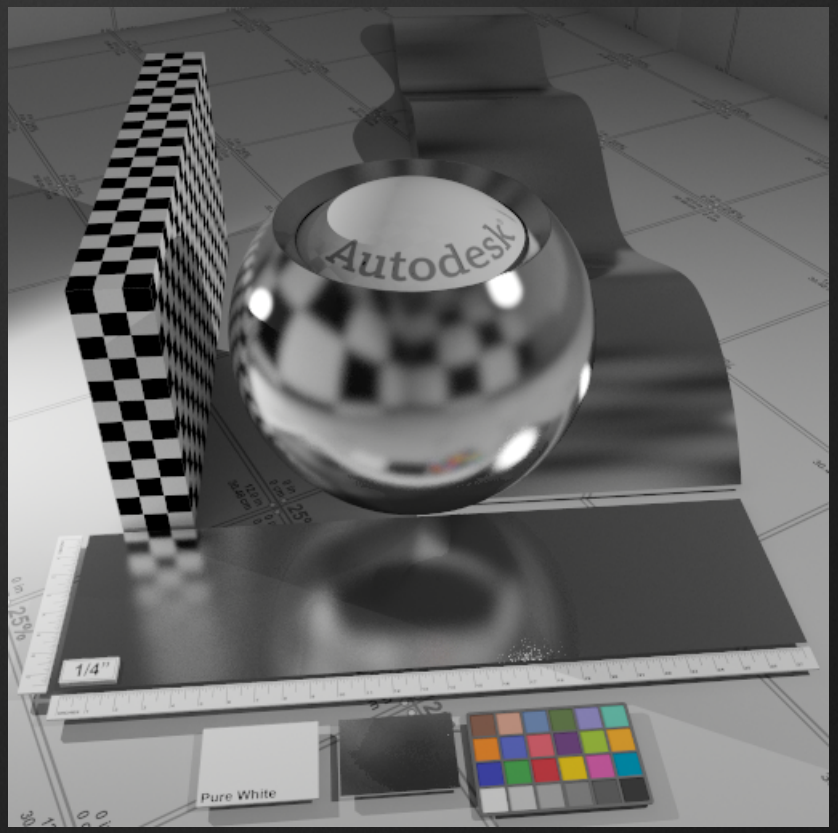
CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Color, shading, shadowing, and texture;
Keywords: motion blur, volume rendering, depth of field

1 Introduction

Problem: Glossy Objects



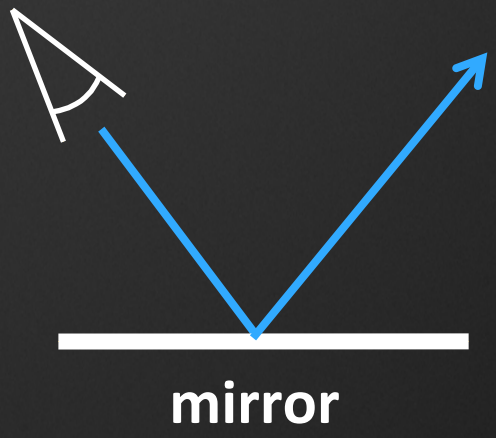
Basic VSLs

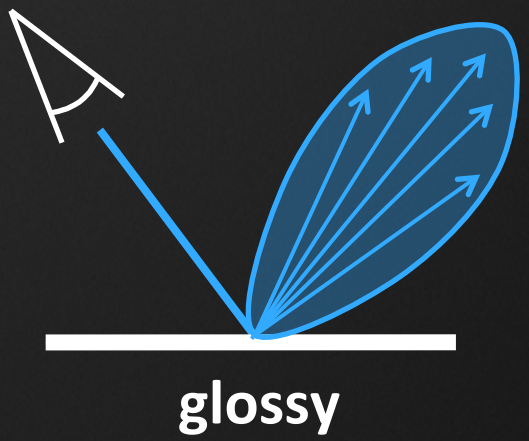


Our Solution

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

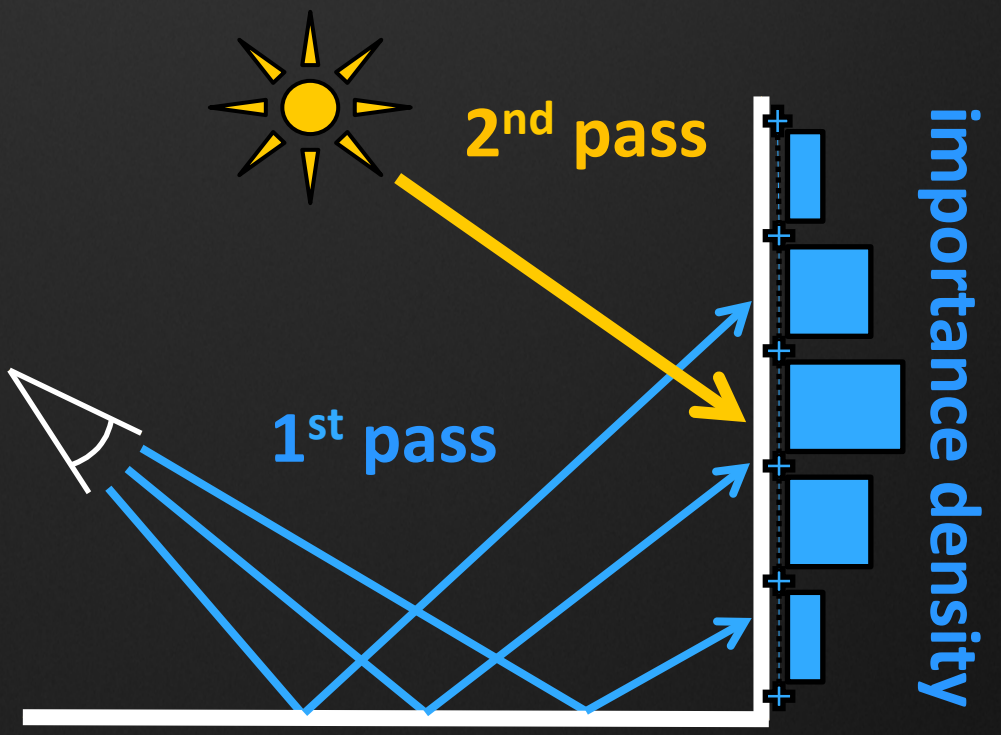
Our Solution

Naïve MDLC

Solution: VPL Targeting

- Modeled on photon mapping with importance

- Two pass algorithm
  - 1st pass: Trace eye ray samples
  - 2nd pass: Use importance density estimates to reject VPLs with Russian roulette



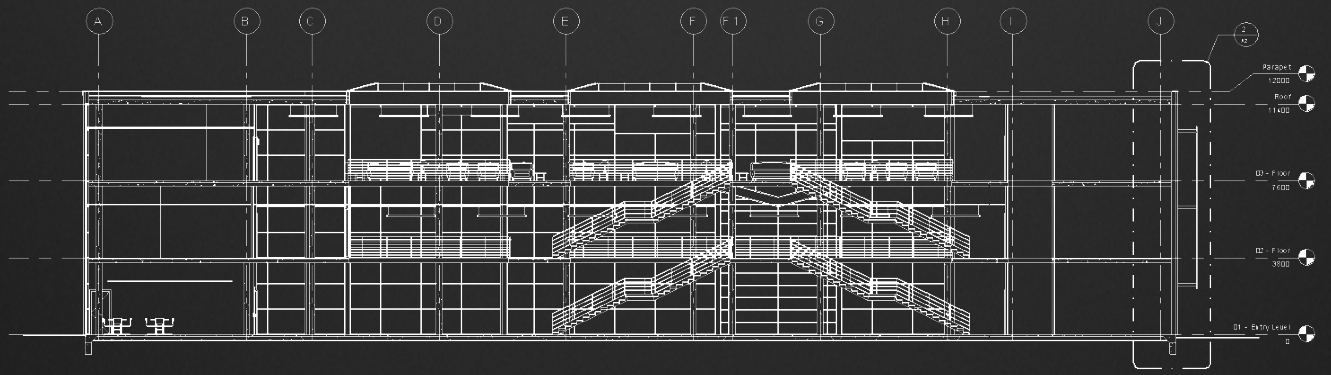
Advantages

MDLC combined with our heuristics gives many advantages

Advantages

MDLC combined with our heuristics gives many advantages

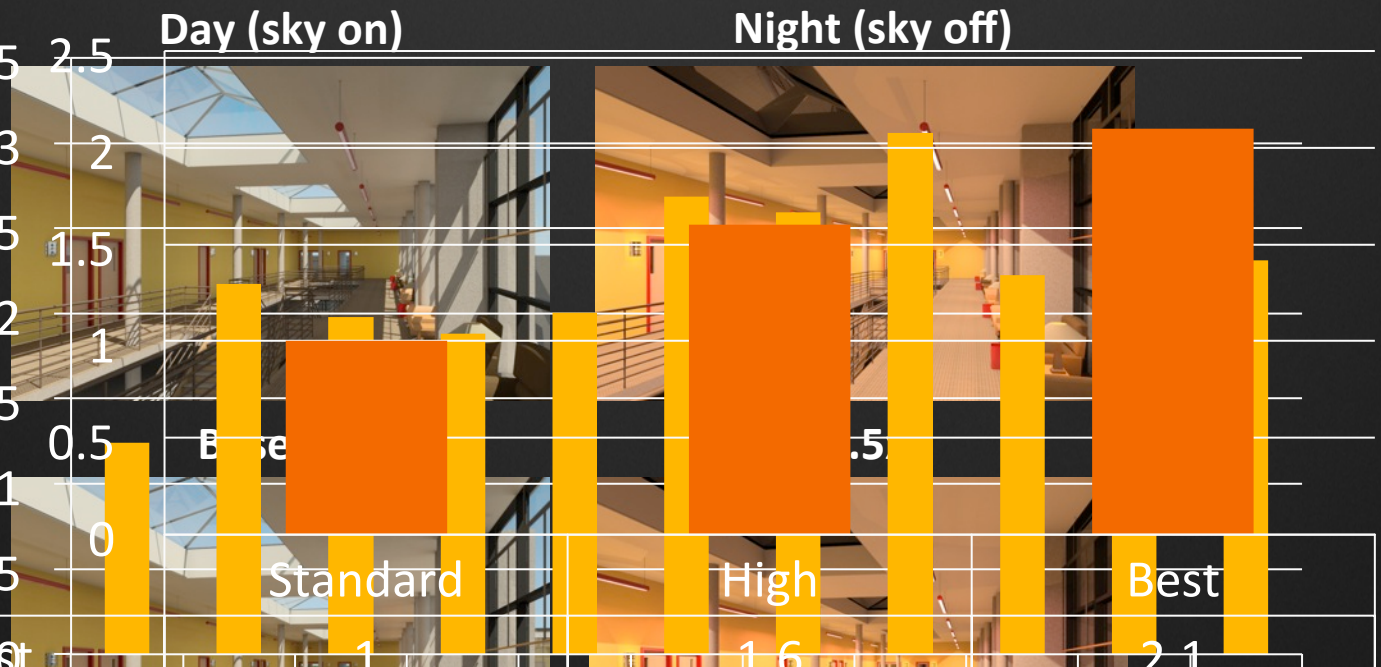
Makes design-size models feasible to render without impacting designer's work



Advantages

MDLC combined with our heuristics gives many advantages

Allows more predictive costs with scene complexity and render quality



	Standard	High	Best
Rel. Cost	1	1.6	2.1
100's of VPLs	125	600	600
Eye Samples	1	16	64
Max Cut Size	1024	16384	16384

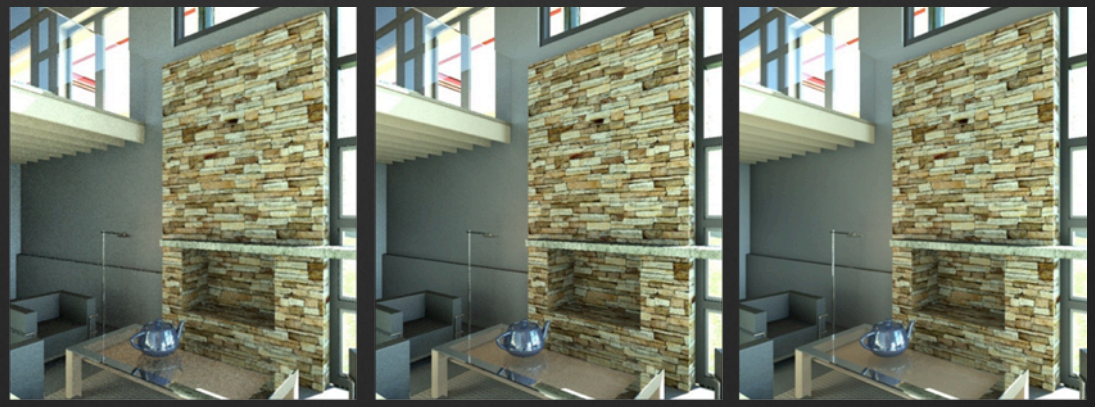
Advantages

MDLC combined with our heuristics gives many advantages

Cheap low-quality modes consistent with higher-quality modes

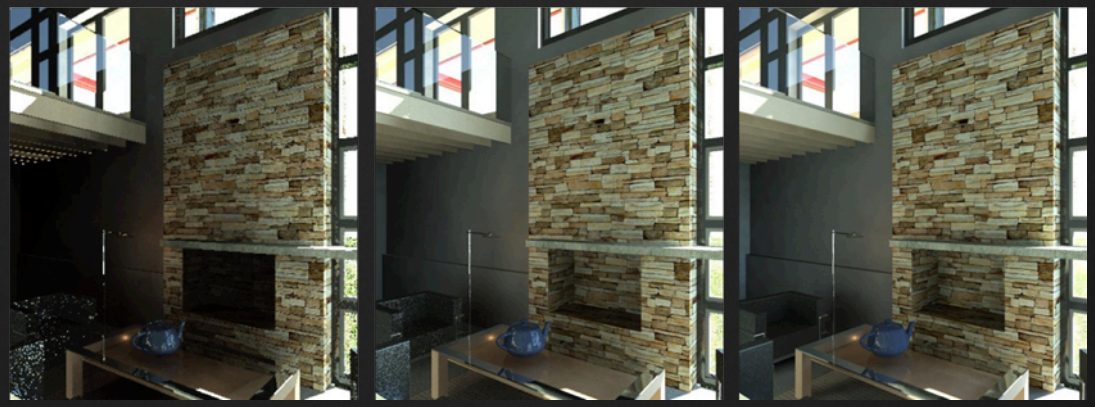
Autodesk® 360 Renderer

(Spectrum)



1x → 10x

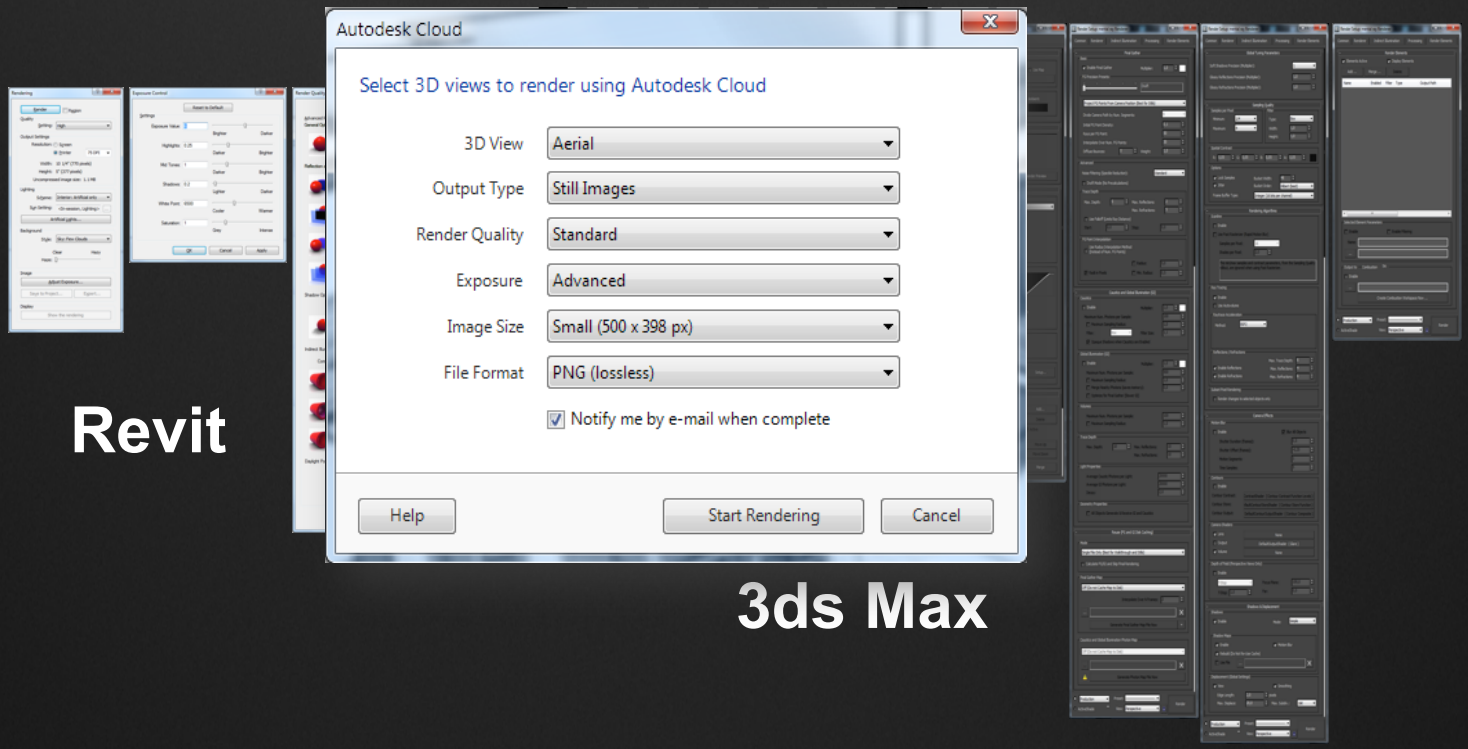
Path Tracer with Irradiance Caching



Advantages

MDLC combined with our heuristics gives many advantages

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



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

Case 1 – Global Illumination

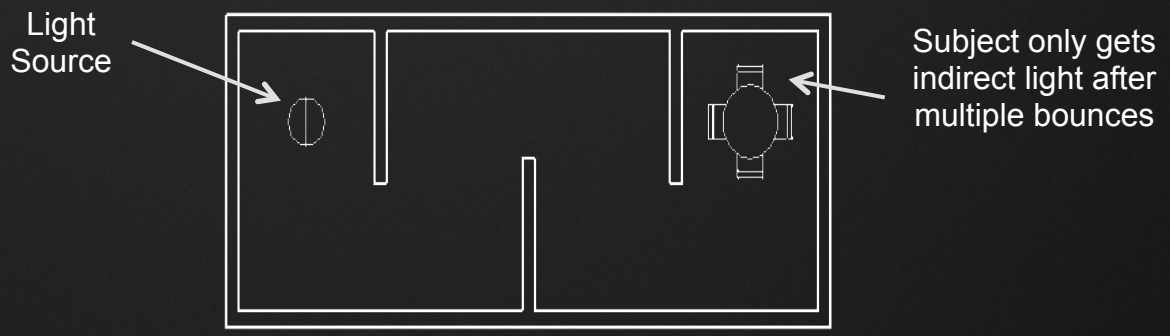
Mental Ray has two choices

- 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:

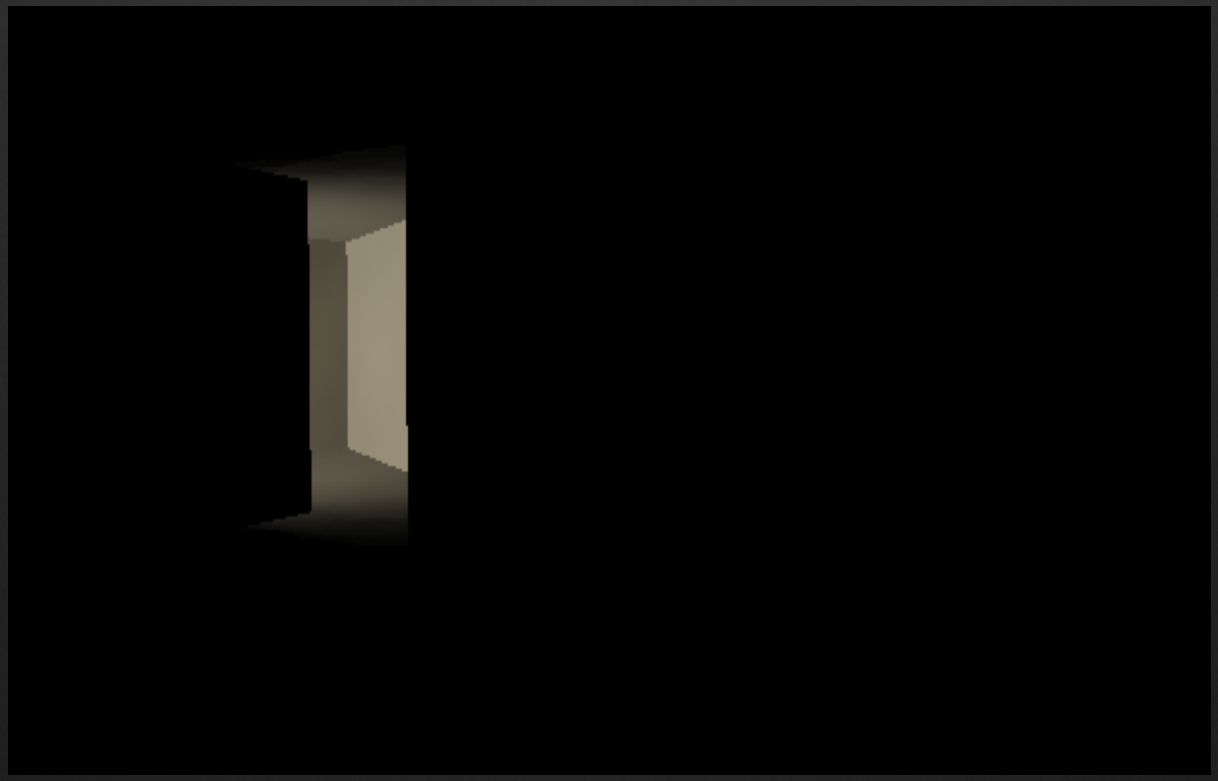


Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



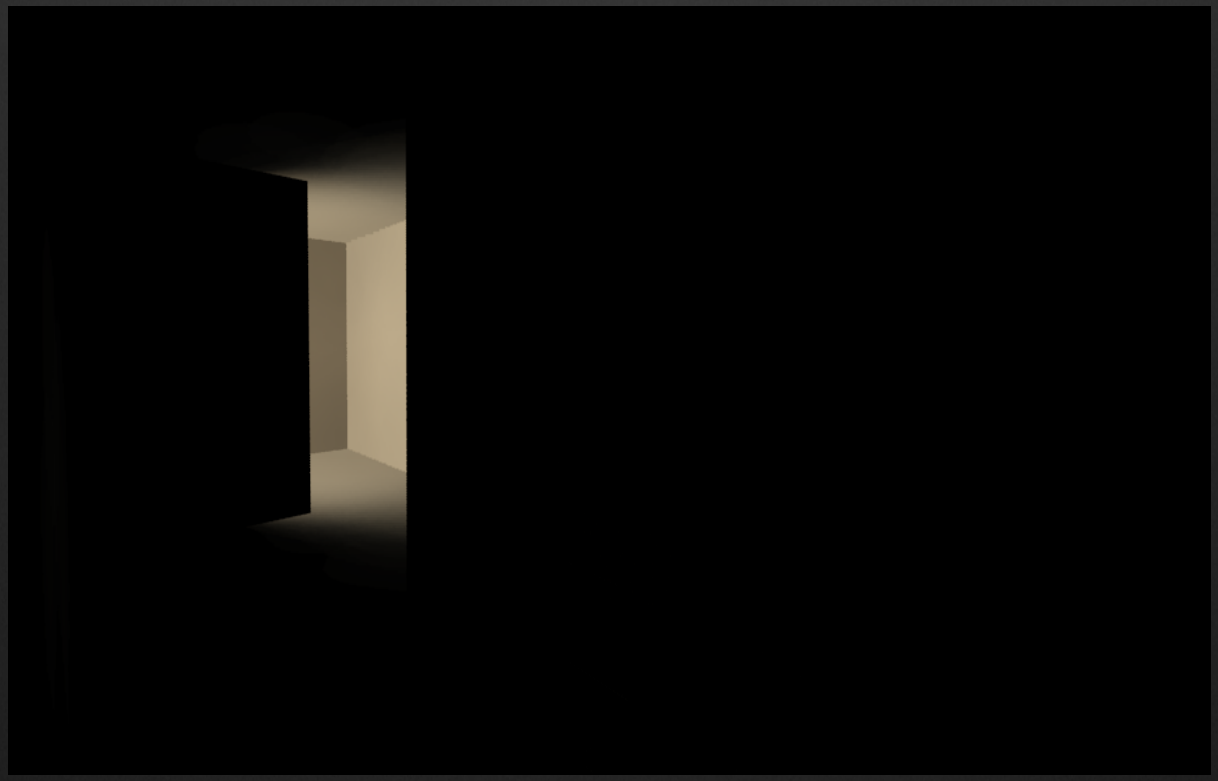
Draft	Medium	High	Best	Custom 1 (FG 5 bounces)
10s	28s	1m 55s	11m 28s	2m 45s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



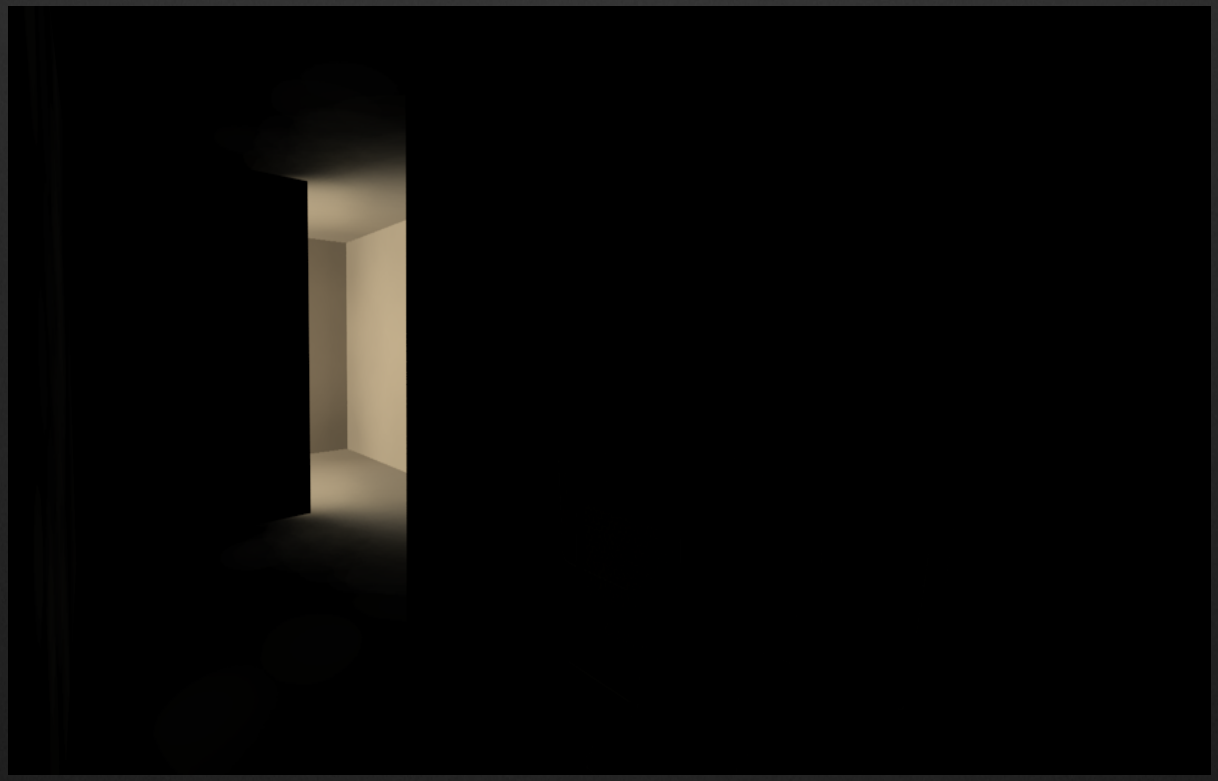
Draft	Medium	High	Best	Custom 1 (FG 5 bounces)
10s	28s	1m 55s	11m 28s	2m 45s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



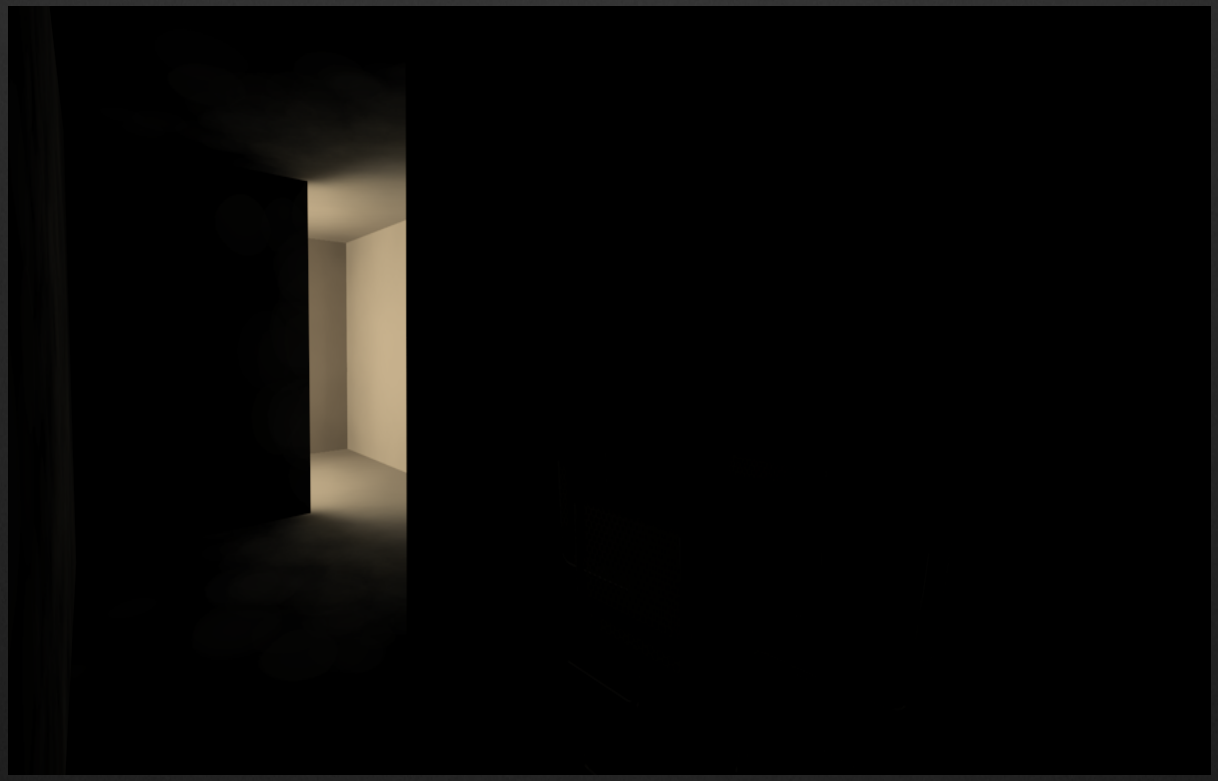
Draft	Medium	High	Best	Custom 1 (FG 5 bounces)
10s	28s	1m 55s	11m 28s	2m 45s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



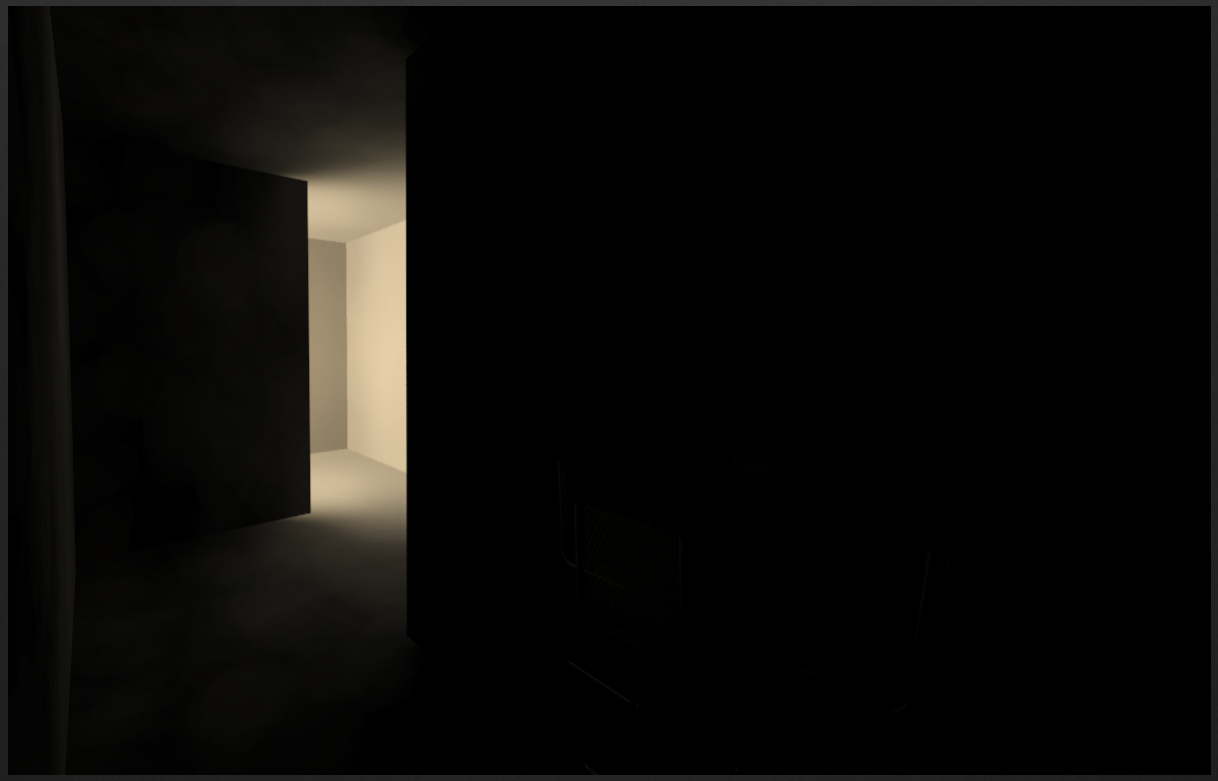
Draft	Medium	High	Best	Custom 1 (FG 5 bounces)
10s	28s	1m 55s	11m 28s	2m 45s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



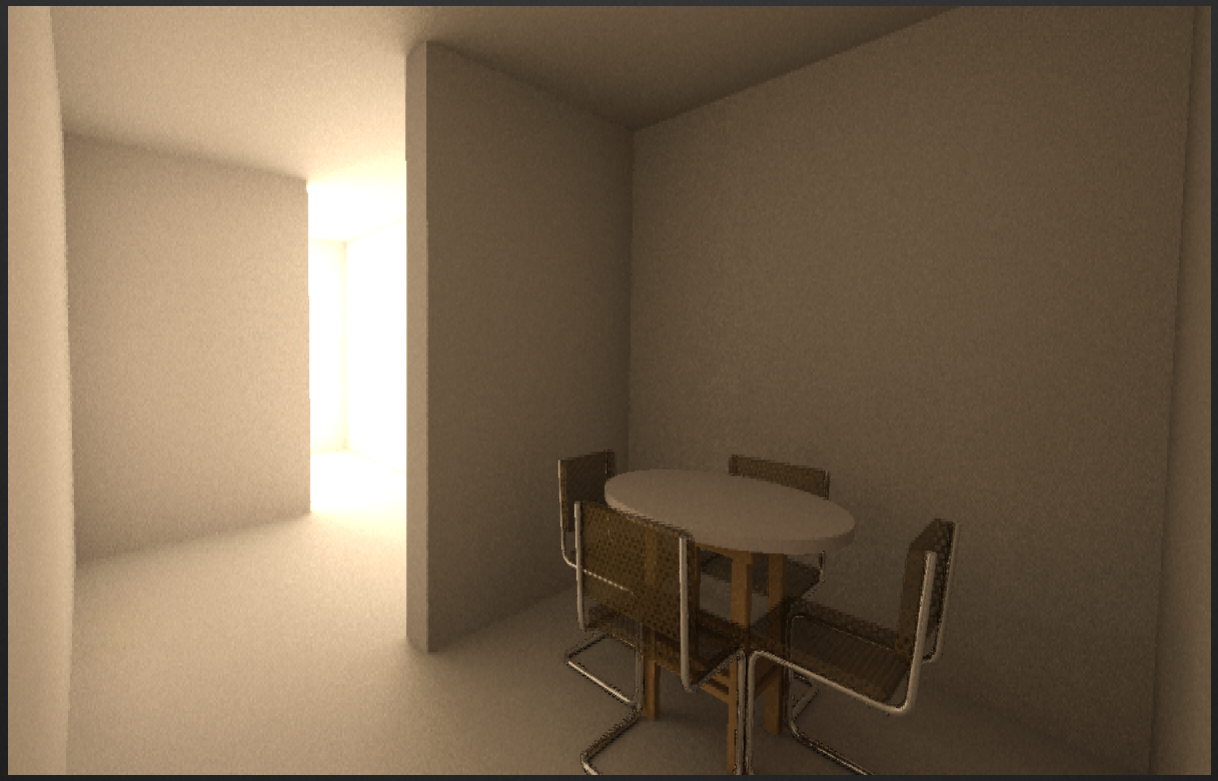
Draft	Medium	High	Best	Custom 1 (FG 5 bounces)
10s	28s	1m 55s	11m 28s	2m 45s

Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



Draft
37s

Standard
1m 46s

High
5m 26s

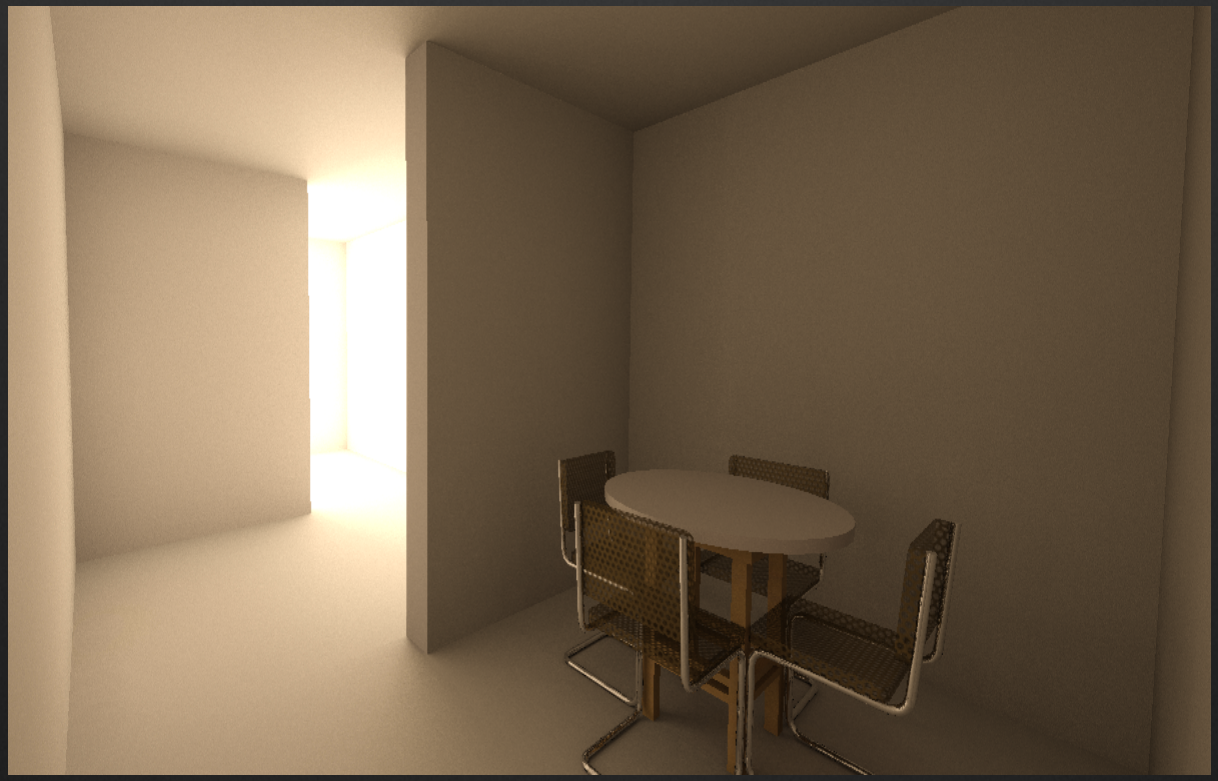
Best
8m 7s

Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



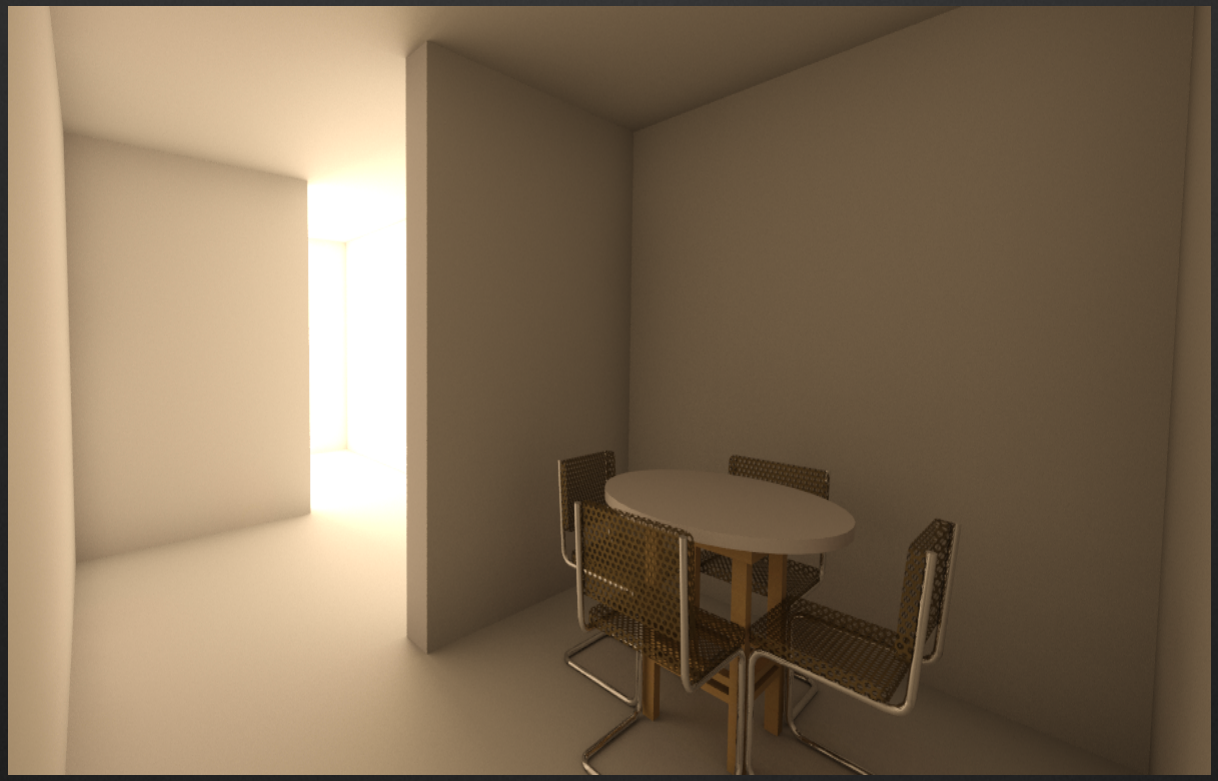
Draft 37s | **Standard 1m 46s** | High 5m 26s | Best 8m 7s

Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



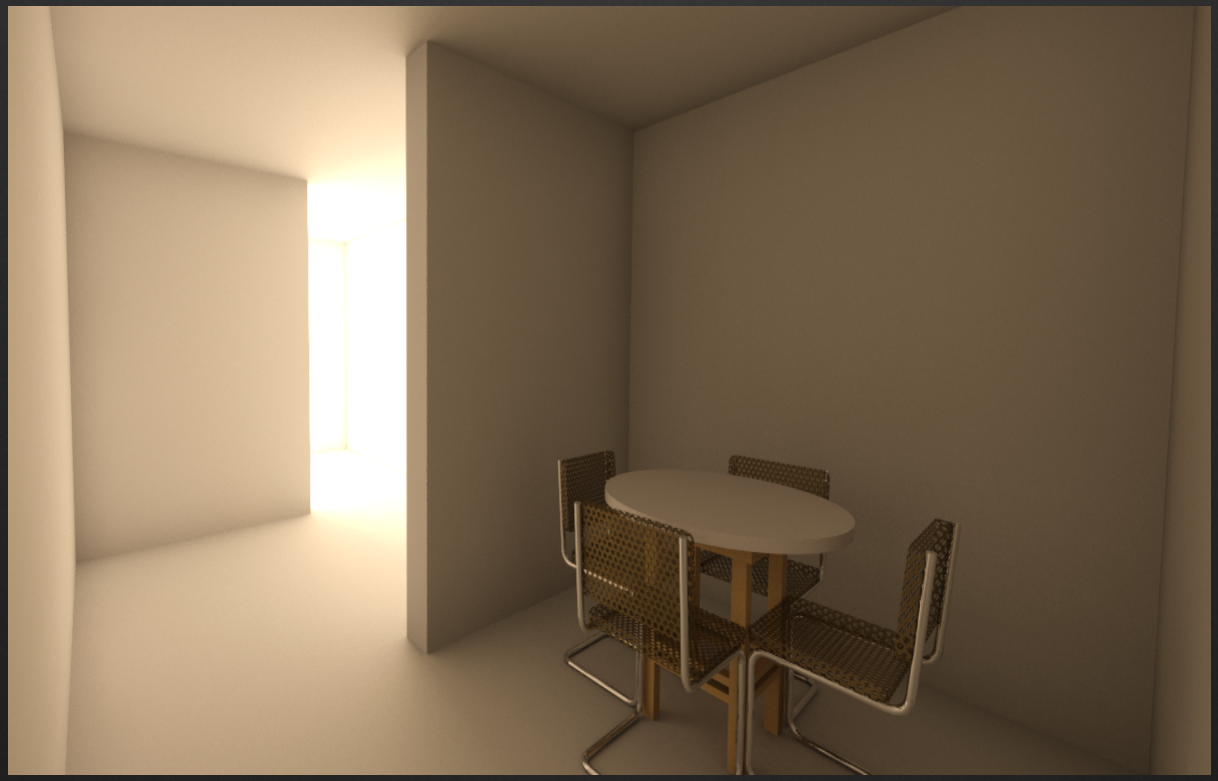
Draft 37s | Standard 1m 46s | **High 5m 26s** | Best 8m 7s

Case 1 – Global Illumination

Revit

Spectrum

3ds Max®



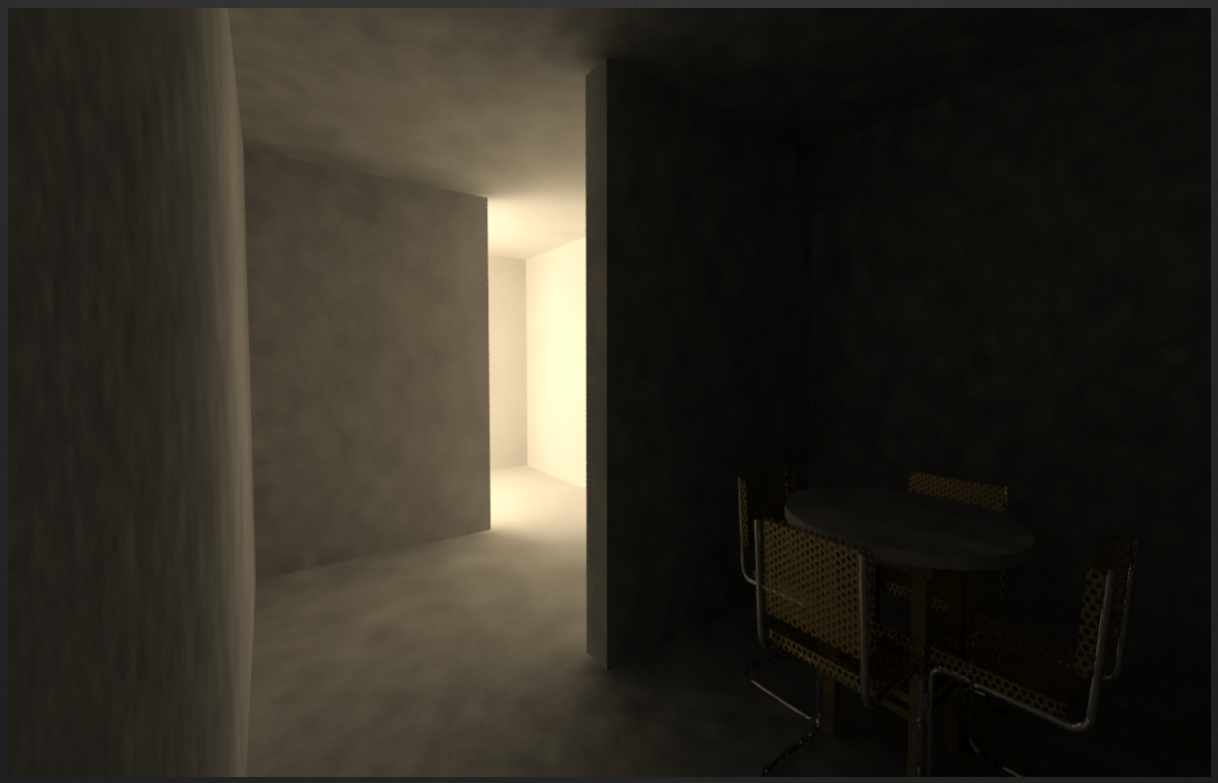
Draft	Standard	High	Best
37s	1m 46s	5m 26s	8m 7s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®



FG 10 bounces
2h 15m 28s

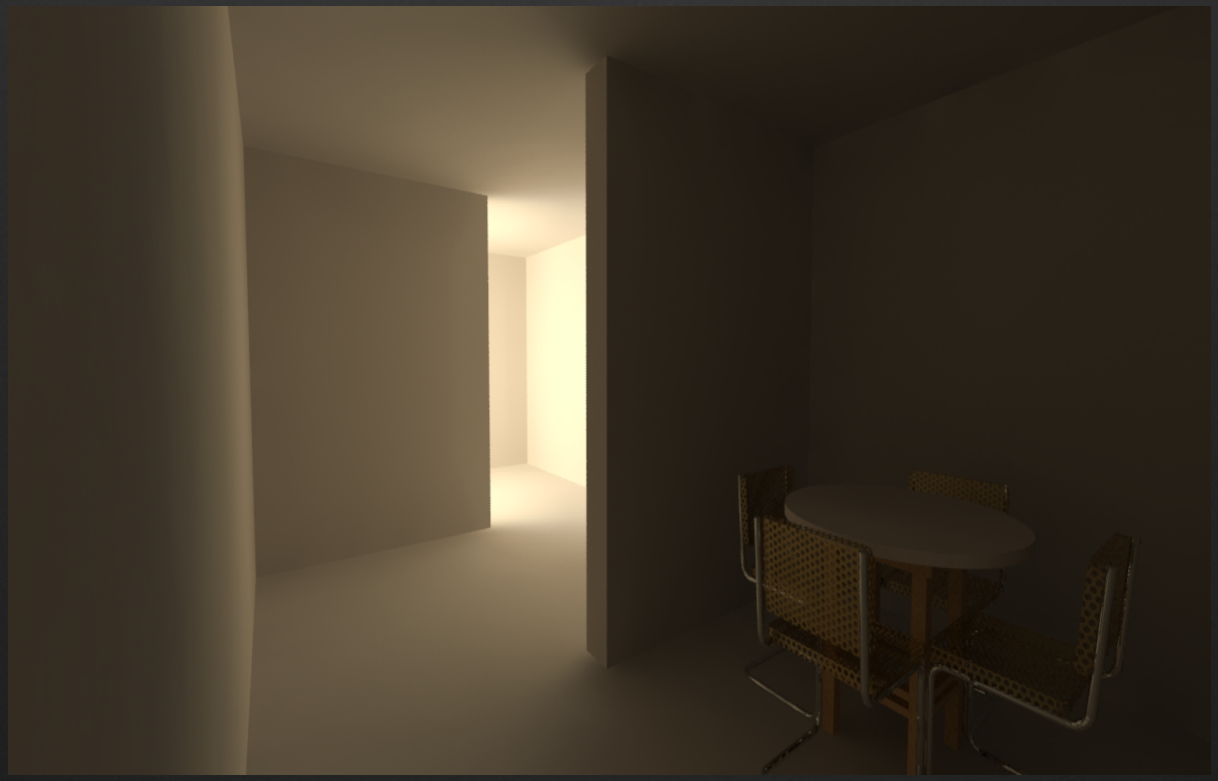
50 million Photons 10 bounces and FG
12m 9s

Case 1 – Global Illumination

Revit®

Spectrum

3ds Max®

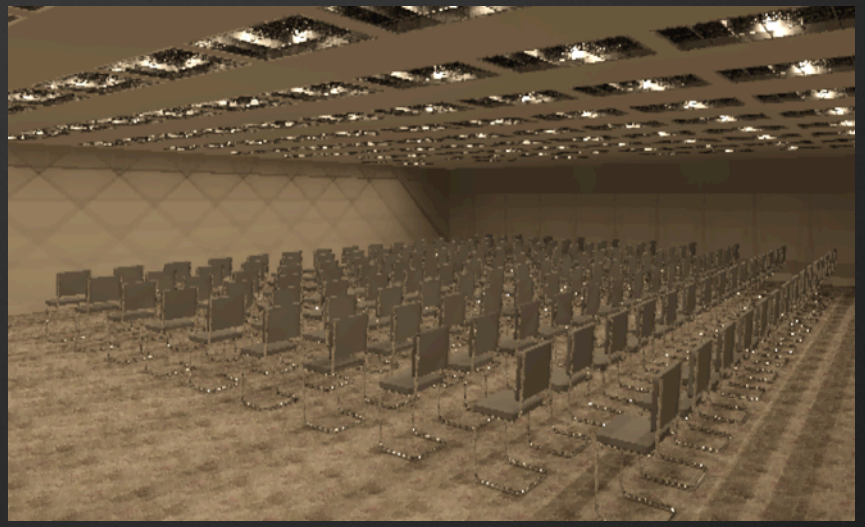


FG 10 bounces
2h 15m 28s

50 million Photons 10 bounces and FG
12m 9s

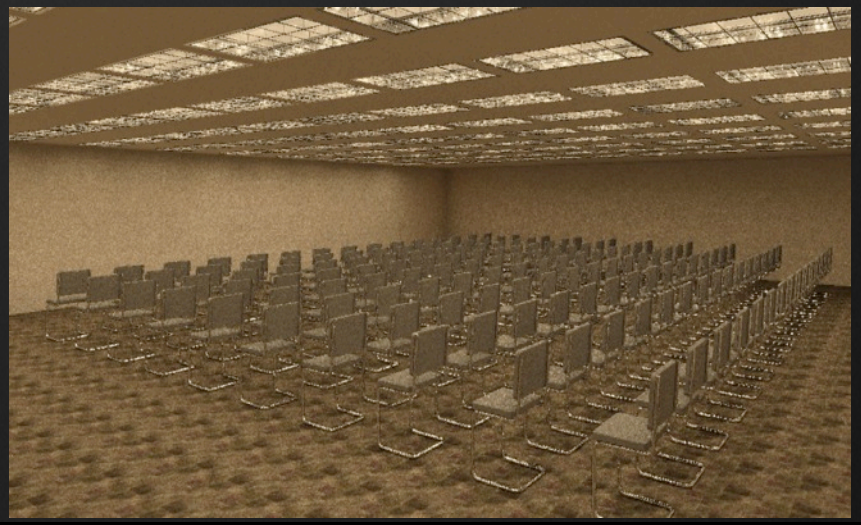
Case 2 – Area Lights, Draft

Revit® 10 lights
43s



Revit® 100
9m 57s (13.9X)

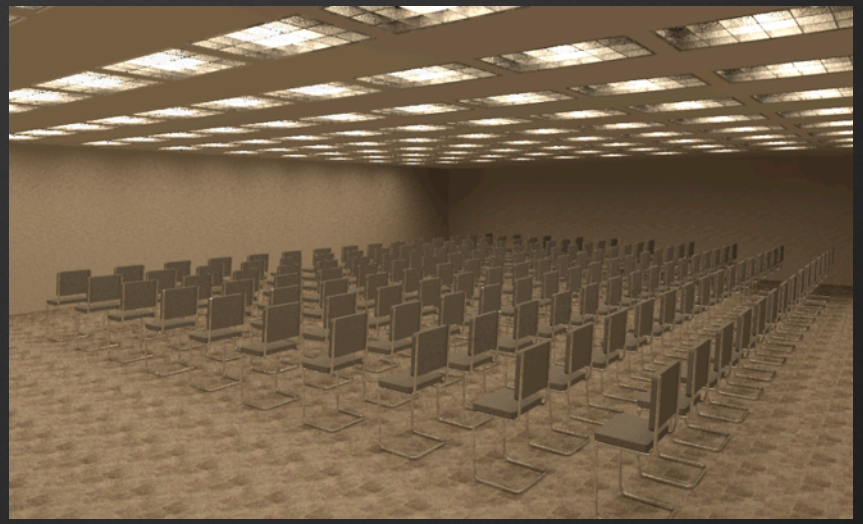
Spectrum 10
33s



Spectrum 100
58s (1.7X)

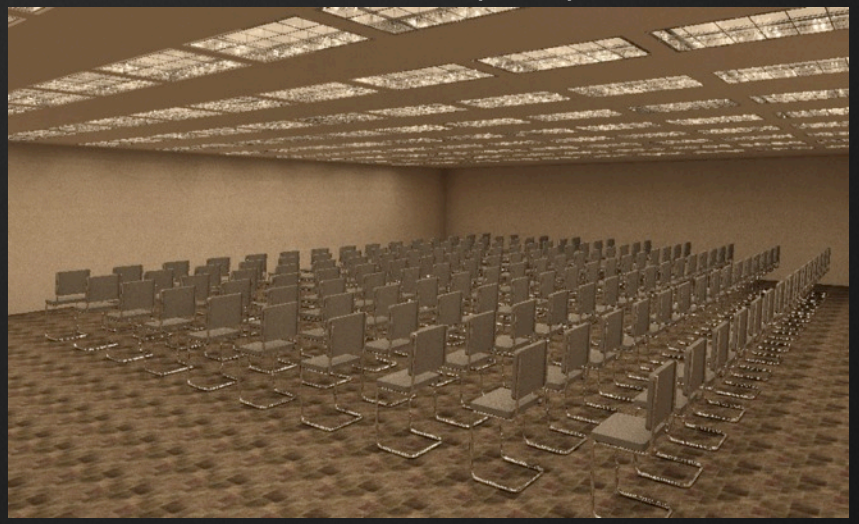
Case 2 – Area Lights, Standard

Revit® 10 lights
9m 31s



Revit® 100
2h 29m 41s (15.7X)

Spectrum 10
1m 12s



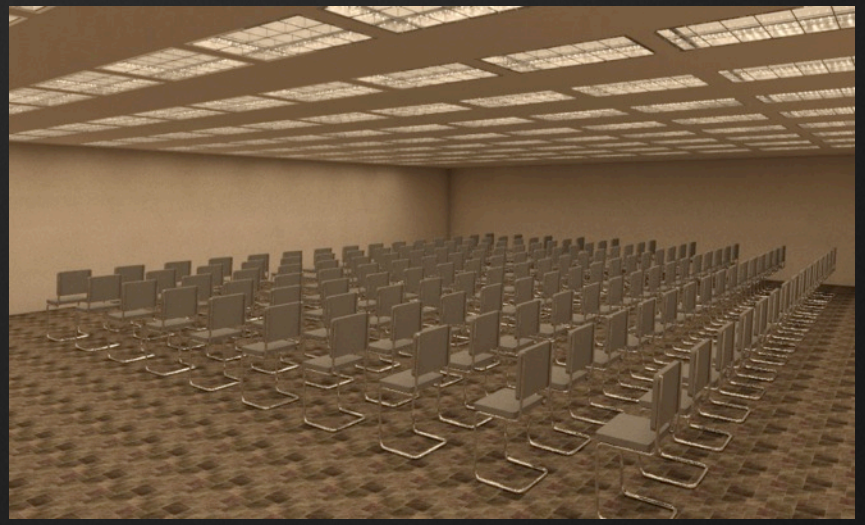
Spectrum 100
1m 47s (1.5X)

Case 2 – Area Lights, High

Revit® 10 lights
45m 5s

Revit® 100
11h 26m 39s (15.2X)

Spectrum 10
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**

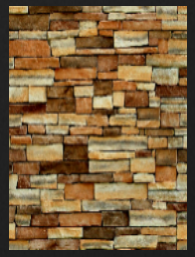
Cloud Rendering Performance and Quality

Revit® >

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

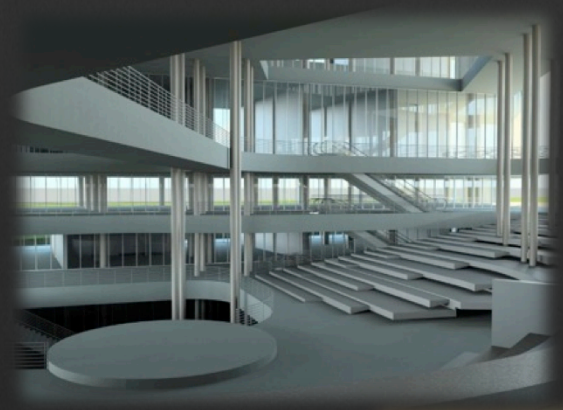
< Cloud Rendering

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

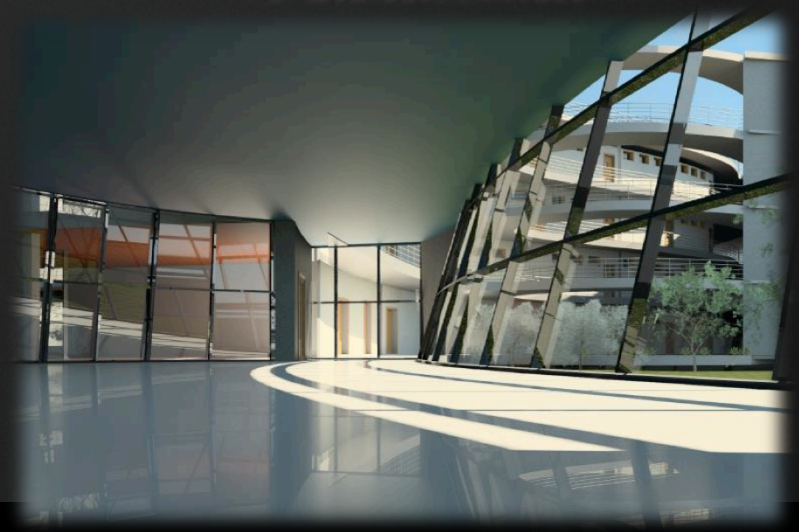
Optimizing Realistic Rendering With Many-Light Methods

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?
brian.budge@autodesk.com
Cloud Platforms
Autodesk