Computer Graphics Software & Hardware

NBAY 6120

Lecture 6

Donald P. Greenberg

March 16, 2017

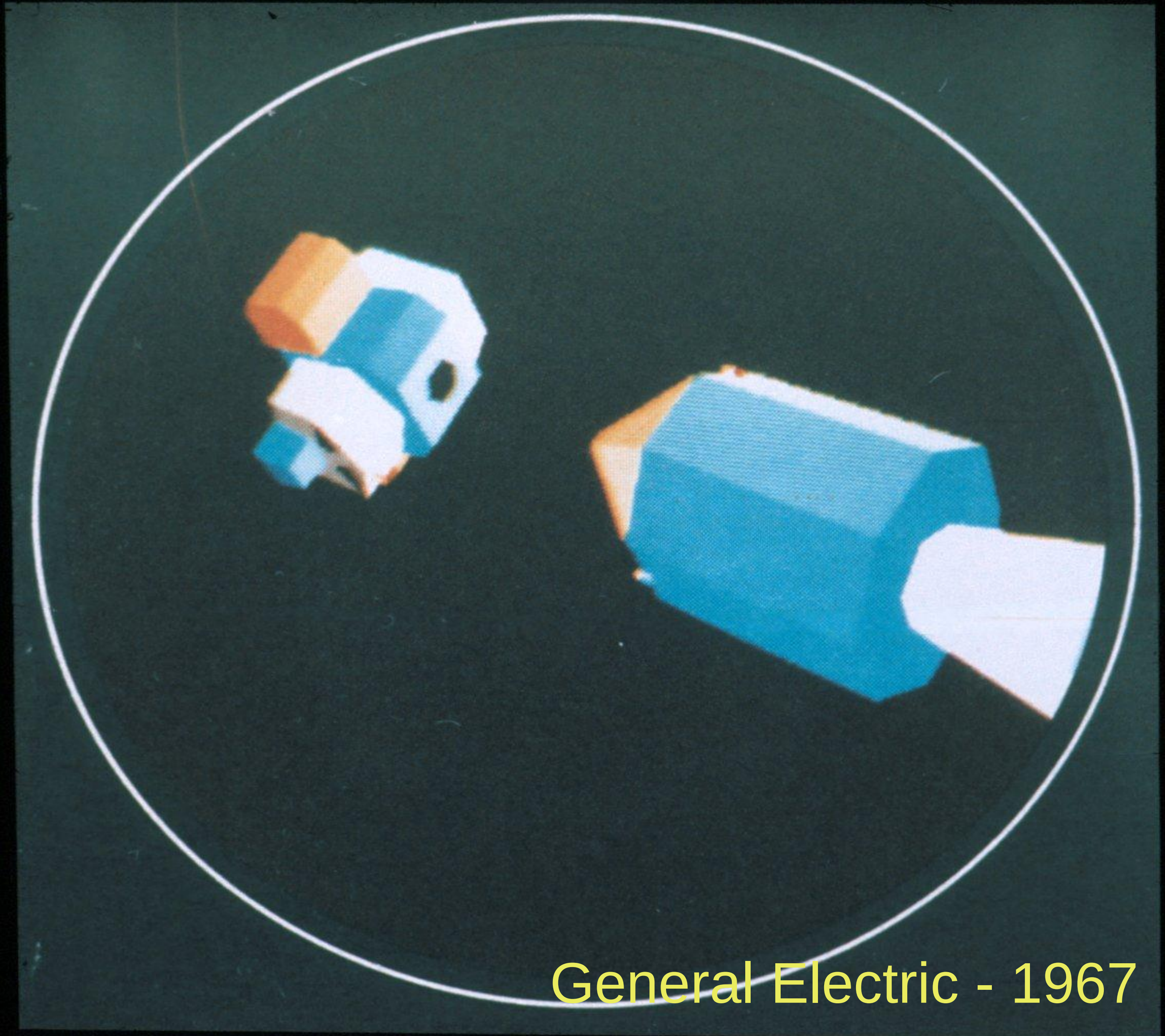
Recommended Readings for Lecture 6

- Mike Seymour. "The State of Rendering, Part 1," fxguide.com, July 15, 2013. FXGuide.
- Mike Seymour. "The State of Rendering, Part 2," fxguide.com, July 17, 2013. FXGuide.

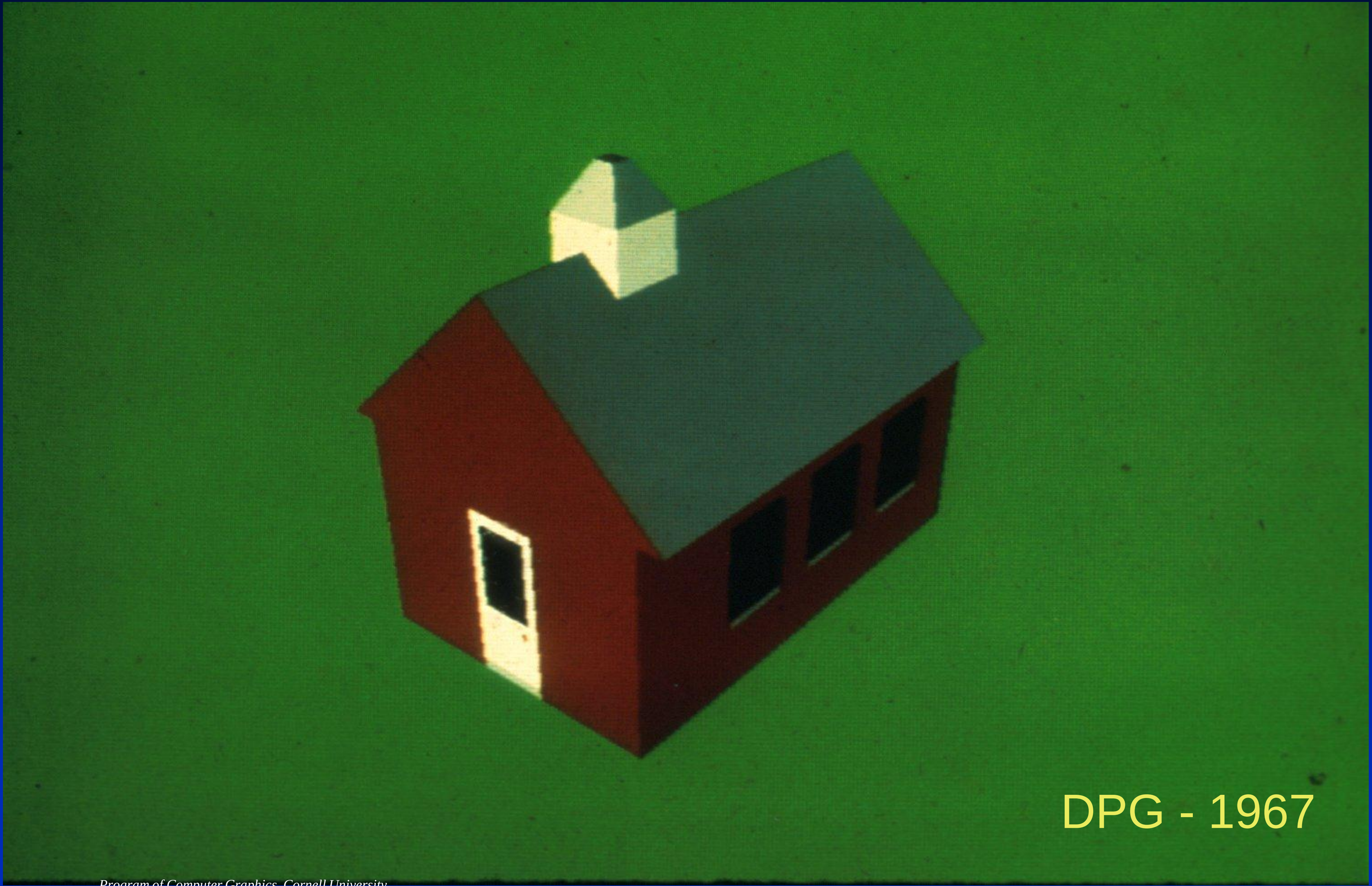
Why Is It Important?

- 99% of our information intake is pictorial through our eyes
- Educational Modules
- Entertainment
- Games
- Advertising
- Medical
- Computer Aided Design
- Data Visualization

Ivan Sutherland 1963



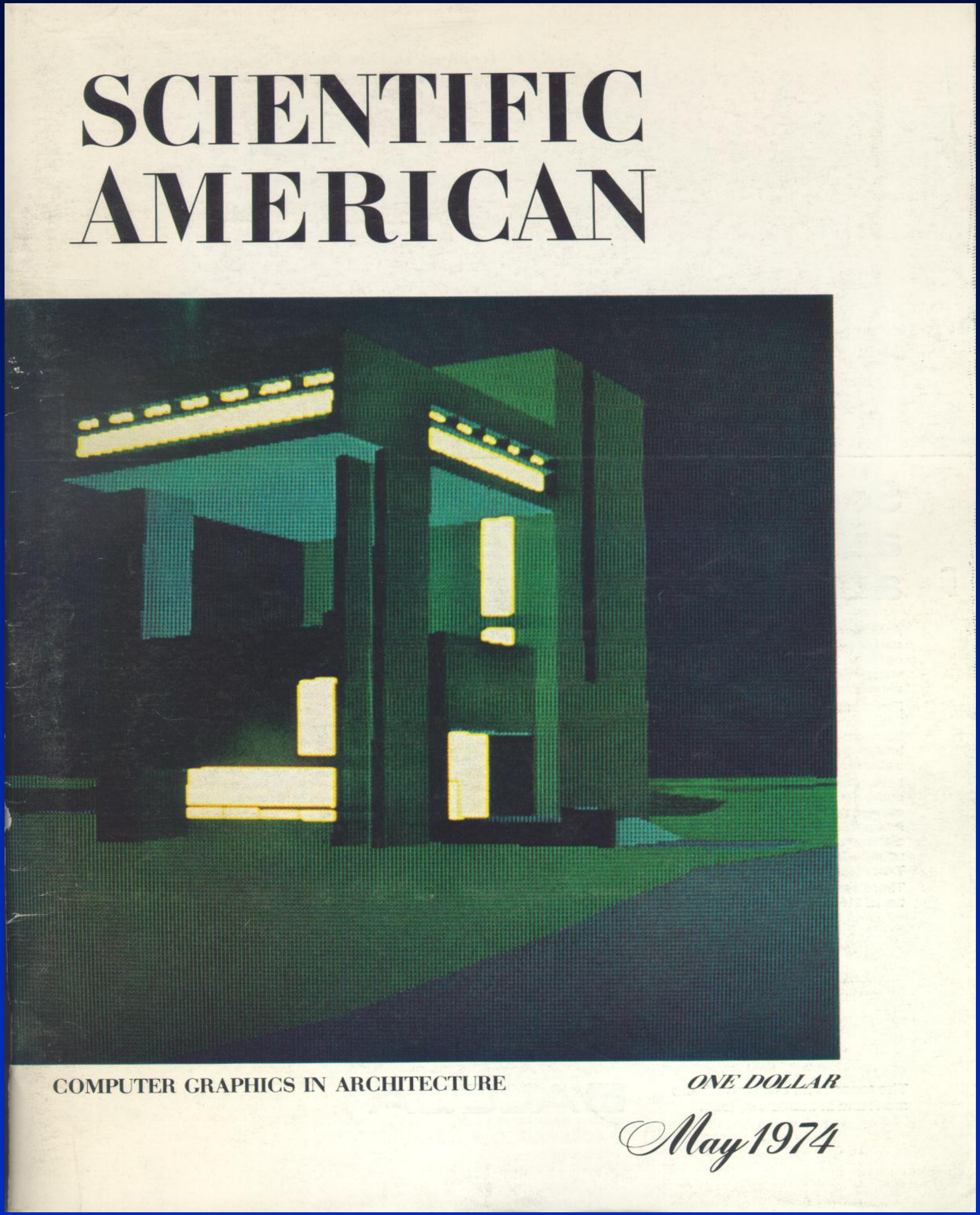
General Electric - 1967



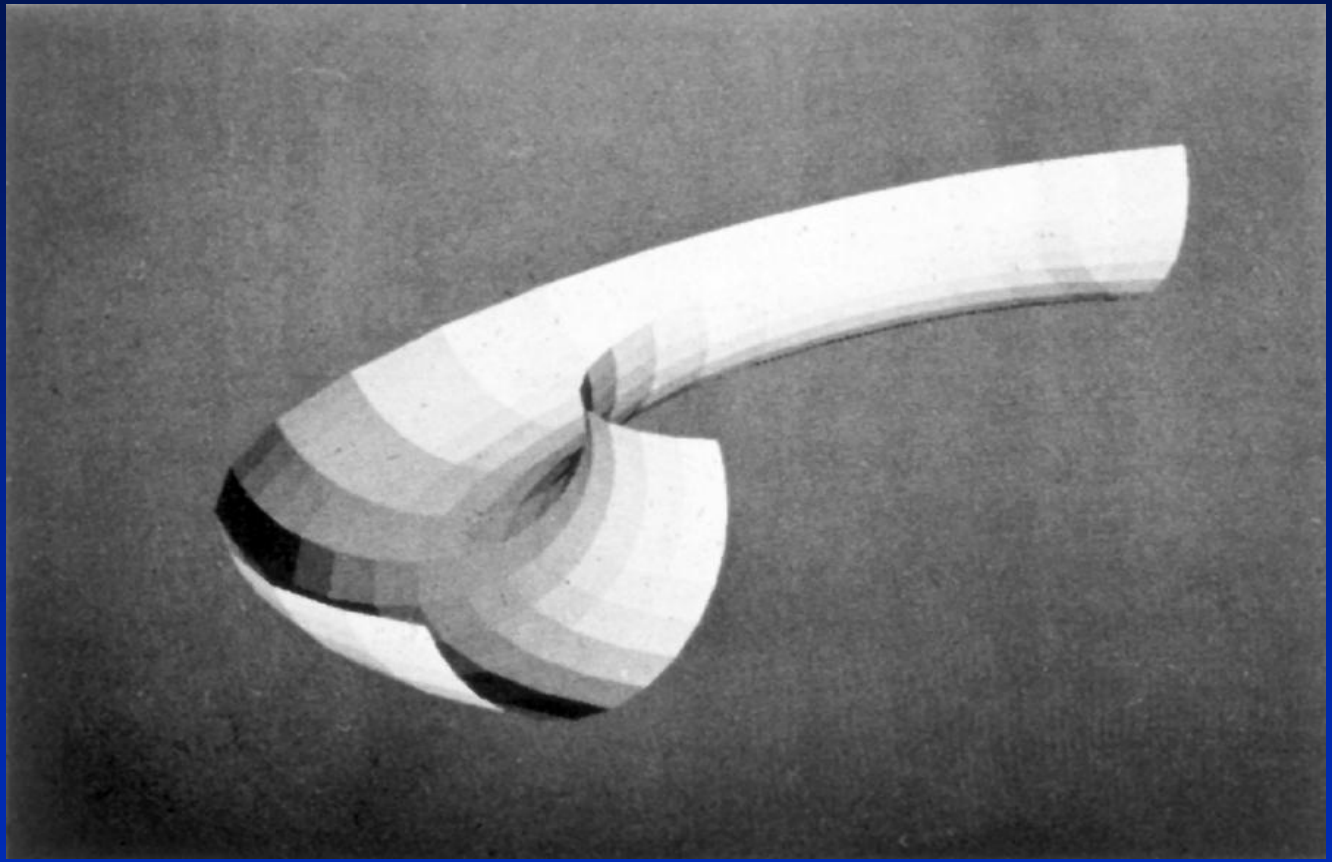
Program of Computer Graphics, Cornell University

Cornell in Perspective Film 1972

Program of Computer Graphics, Cornell University


SCIENTIFIC
AMERICAN
COMPUTER GRAPHICS IN ARCHITECTURE
ONE DOLLAR
May 1974

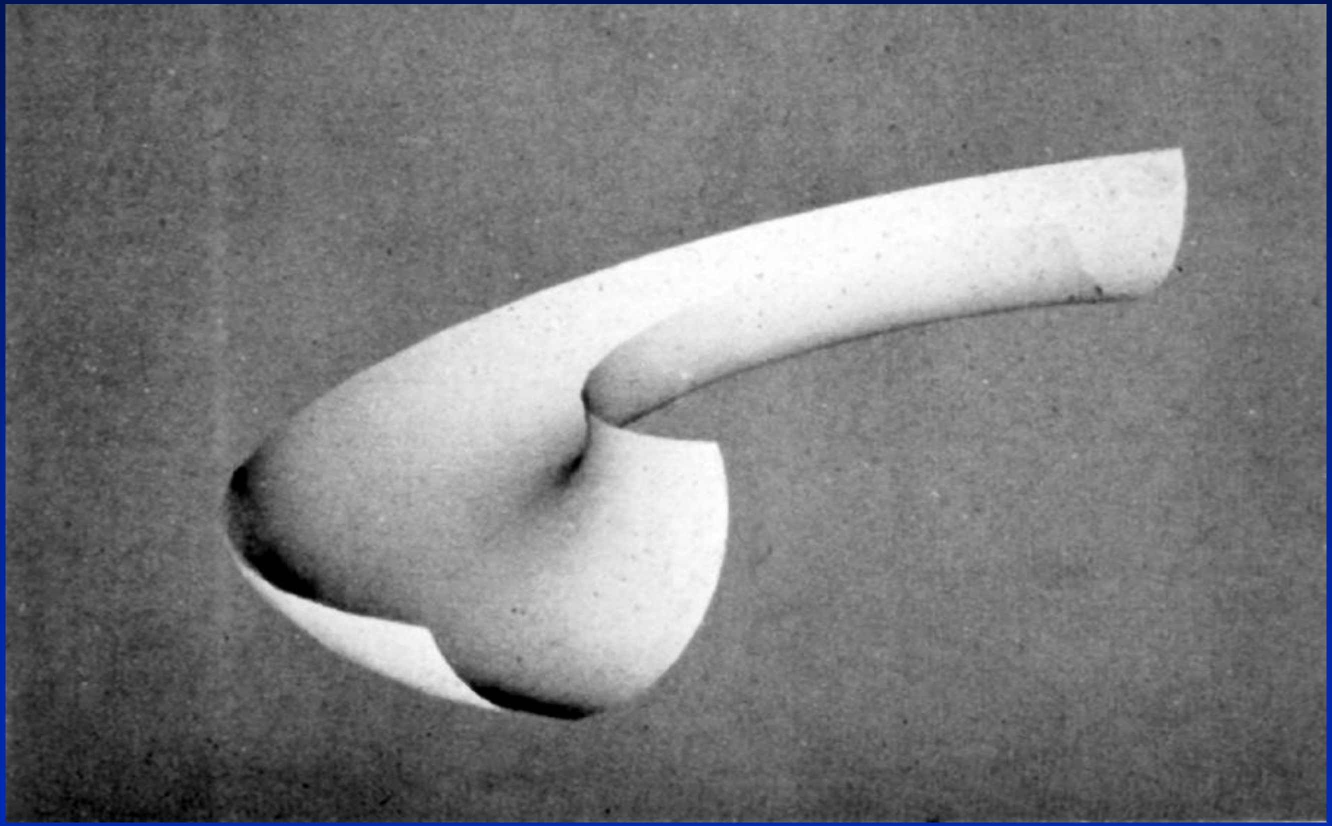
Gouraud Flat Polygon Shading 1972



Each polygon is shaded based on a single normal.

Gouraud Thesis

Gouraud Smooth Shading 1972



Each pixel is shaded by interpolating intensities computed in each of the polygon's vertices.

Gouraud Thesis

Phong Shading 1974

Model

- Environment

  Geometry & topology

  Material properties

  >Color, reflectance, textures

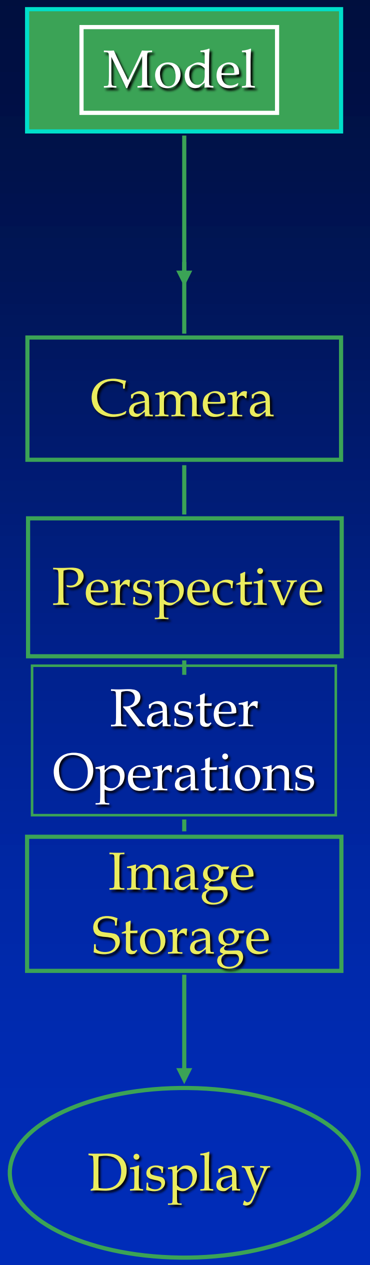
  >(Cost, strength, thermal properties)

- Lighting

  Geometry & position

  Intensity, spectral distribution

  Direction, spatial distribution



Camera

- Viewer Position
- Viewer direction
- Field of view

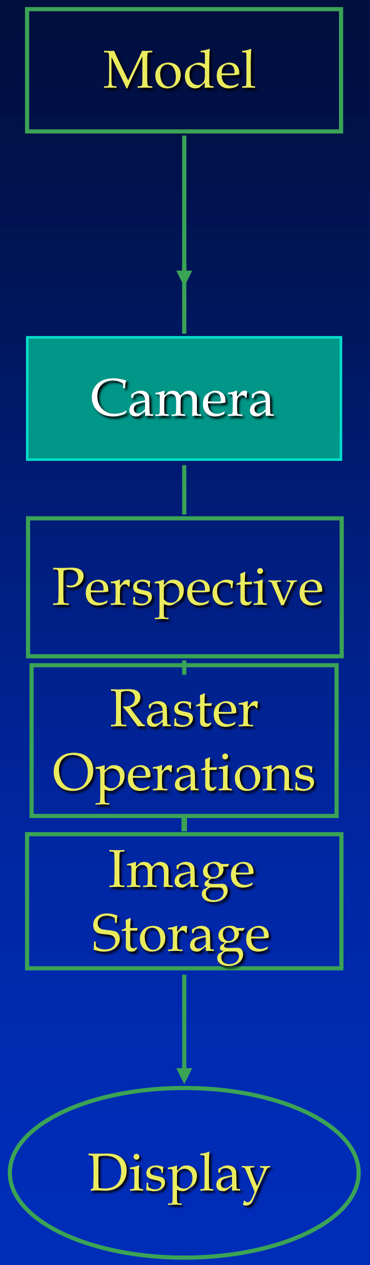
    Wide angle

    Telephoto

- Depth of focus

    Near

    Far



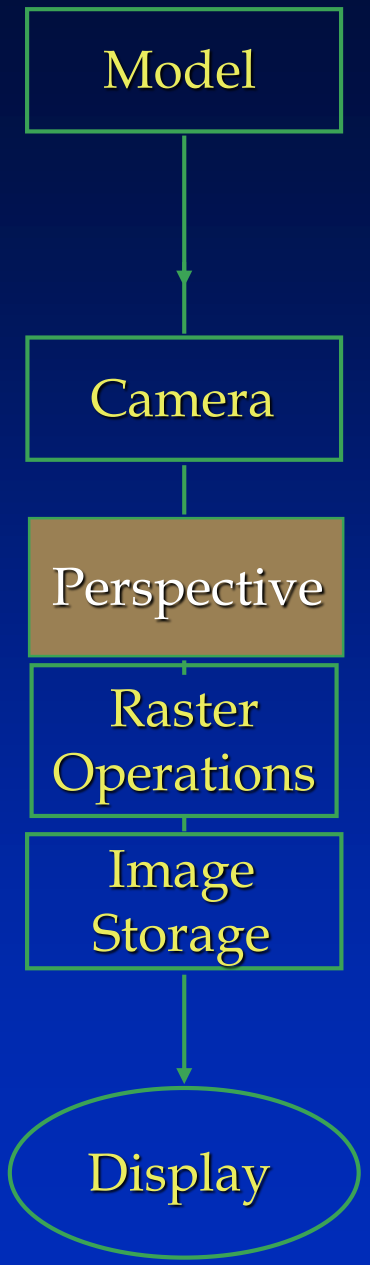
Perspective Transformation

- Perspective transformation

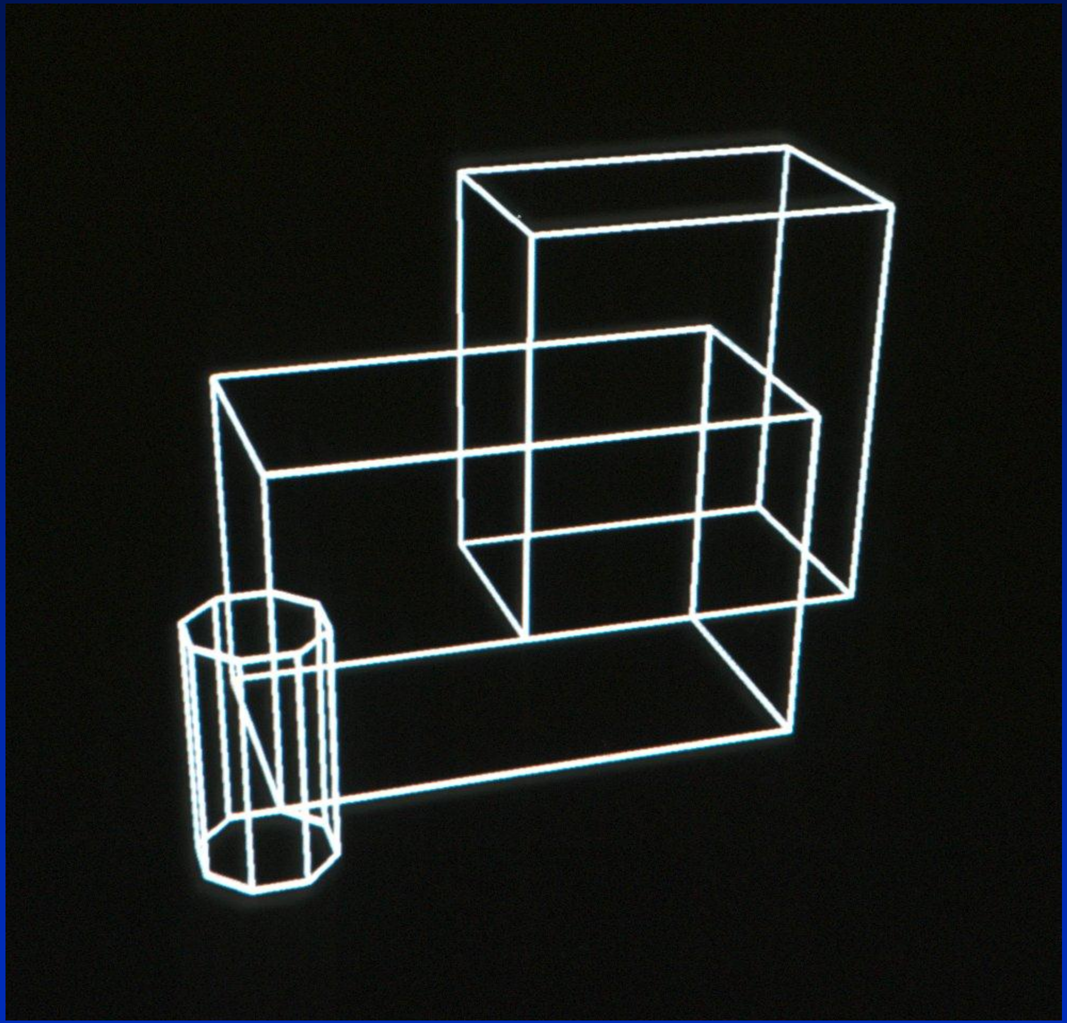
  Matrix multiplication (4 x 4)

- Clipping objects outside of the field of view

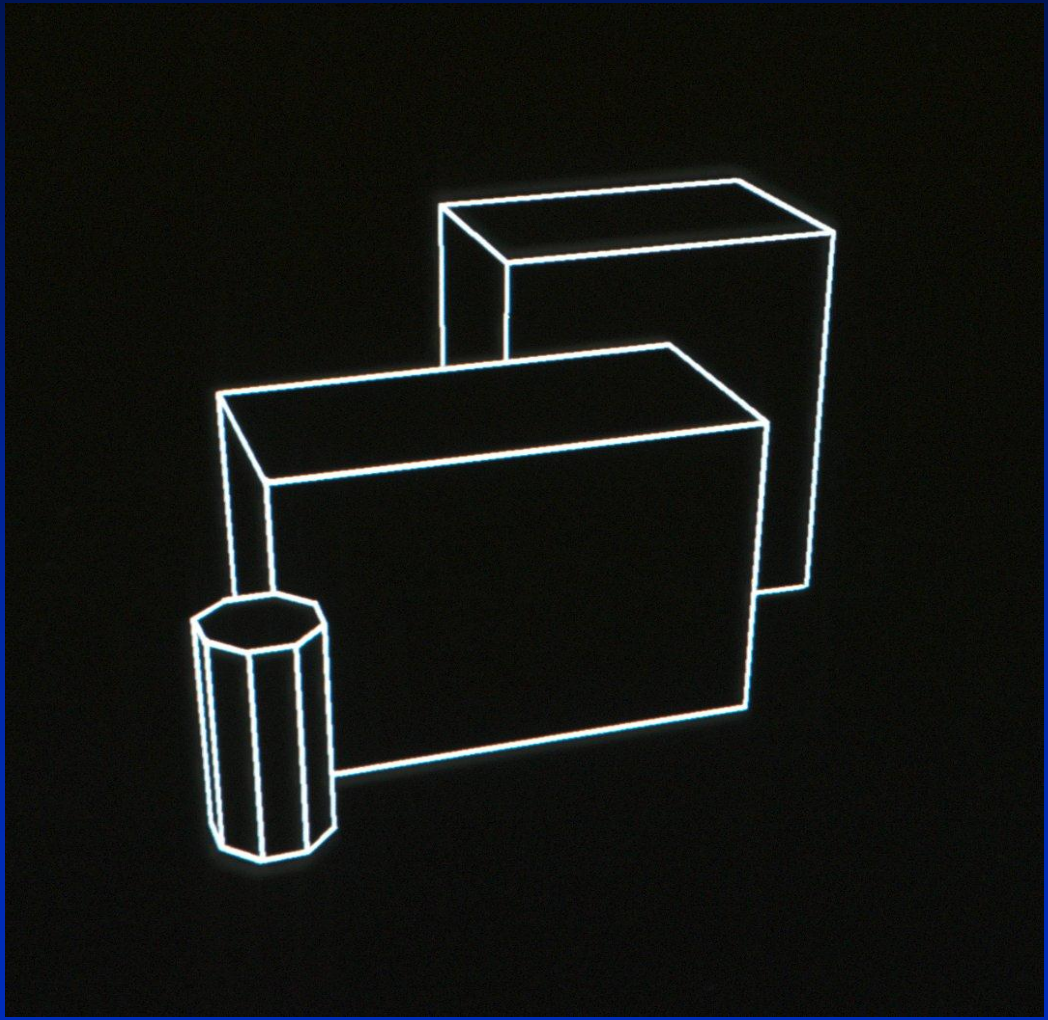
- Culling back-facing surfaces



Hidden Line Algorithm



Hidden Line Algorithm



Raster Operations

- Conversion from polygons to pixels
  Color computation
- Hidden surface removal (z-buffer)

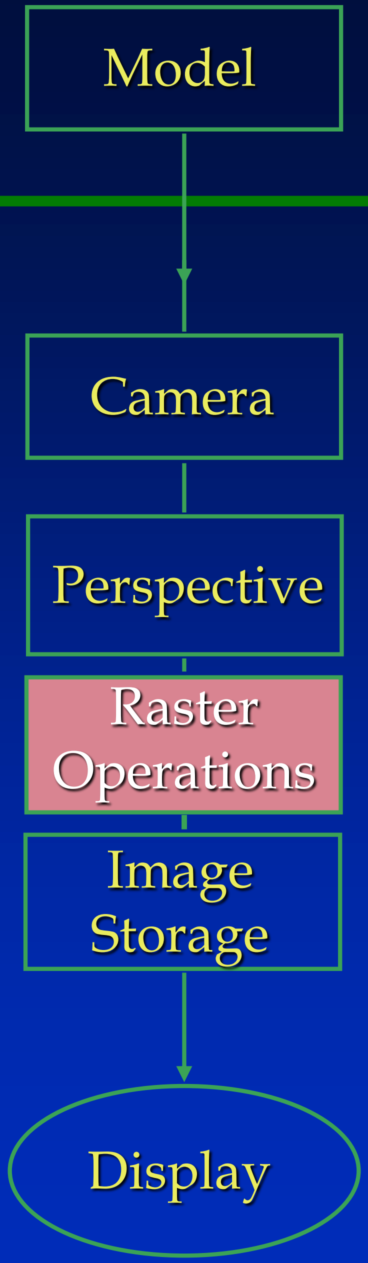


Image Storage

- Typical frame buffer

  1280 x 1024 pixels

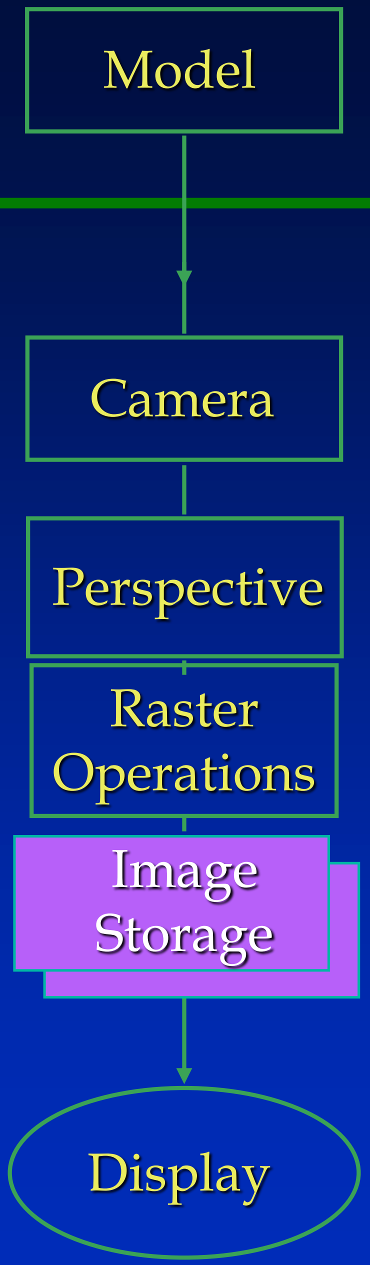
  3 channels (red, green, blue)

  1 byte/channel

- Total memory

  3 3/4 megabytes - single buffer

  7 1/2 megabytes - double buffer



Display

- Digital to analog conversion

  1280 x 1024 resolution

  60 frames per second
- Total data rate

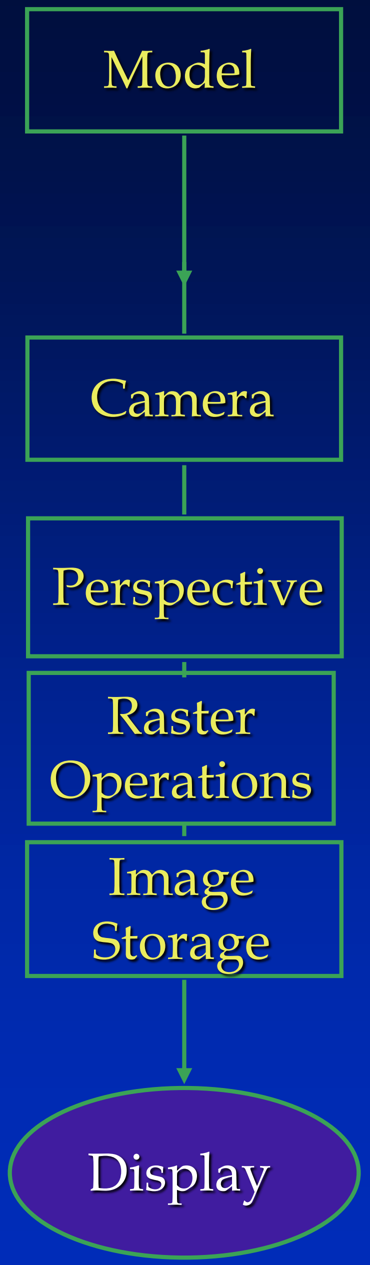
  1 1/4 million pixels

  x 3 bytes/pixel

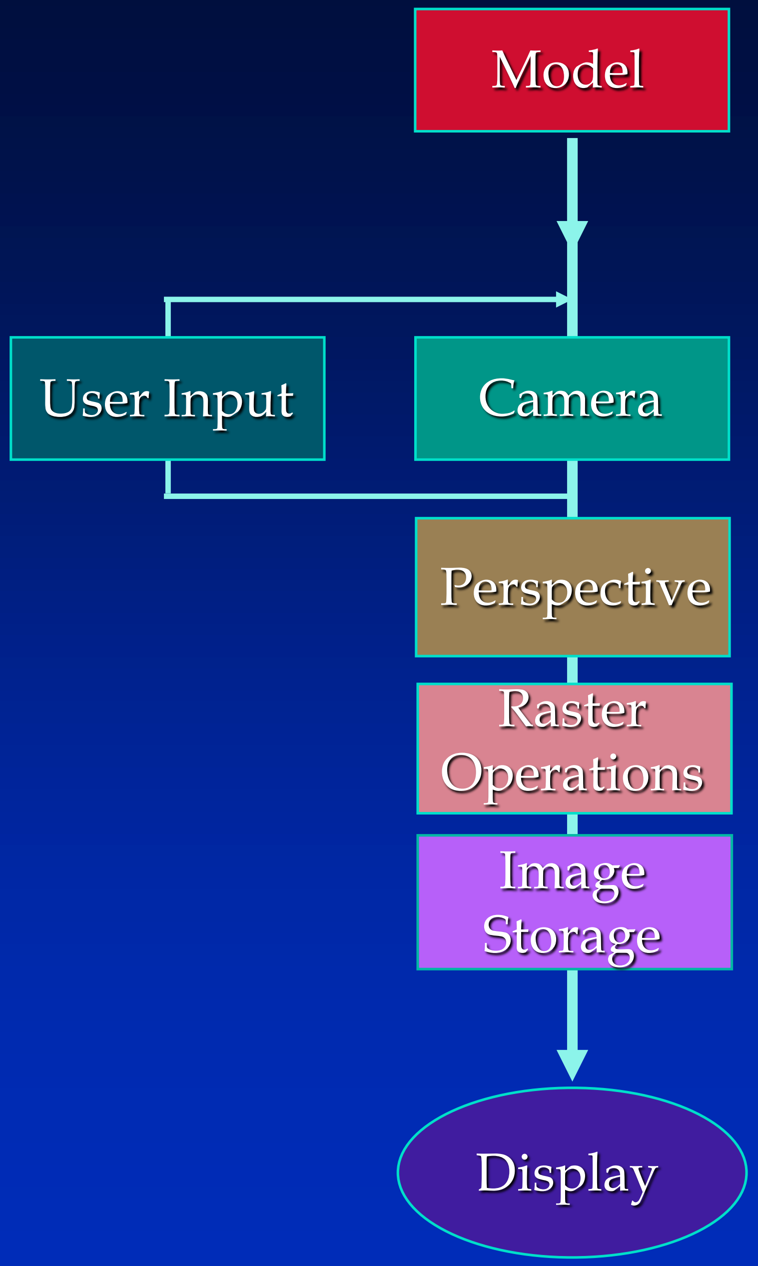
  x 60 frames/second

  = 225 megabytes/second

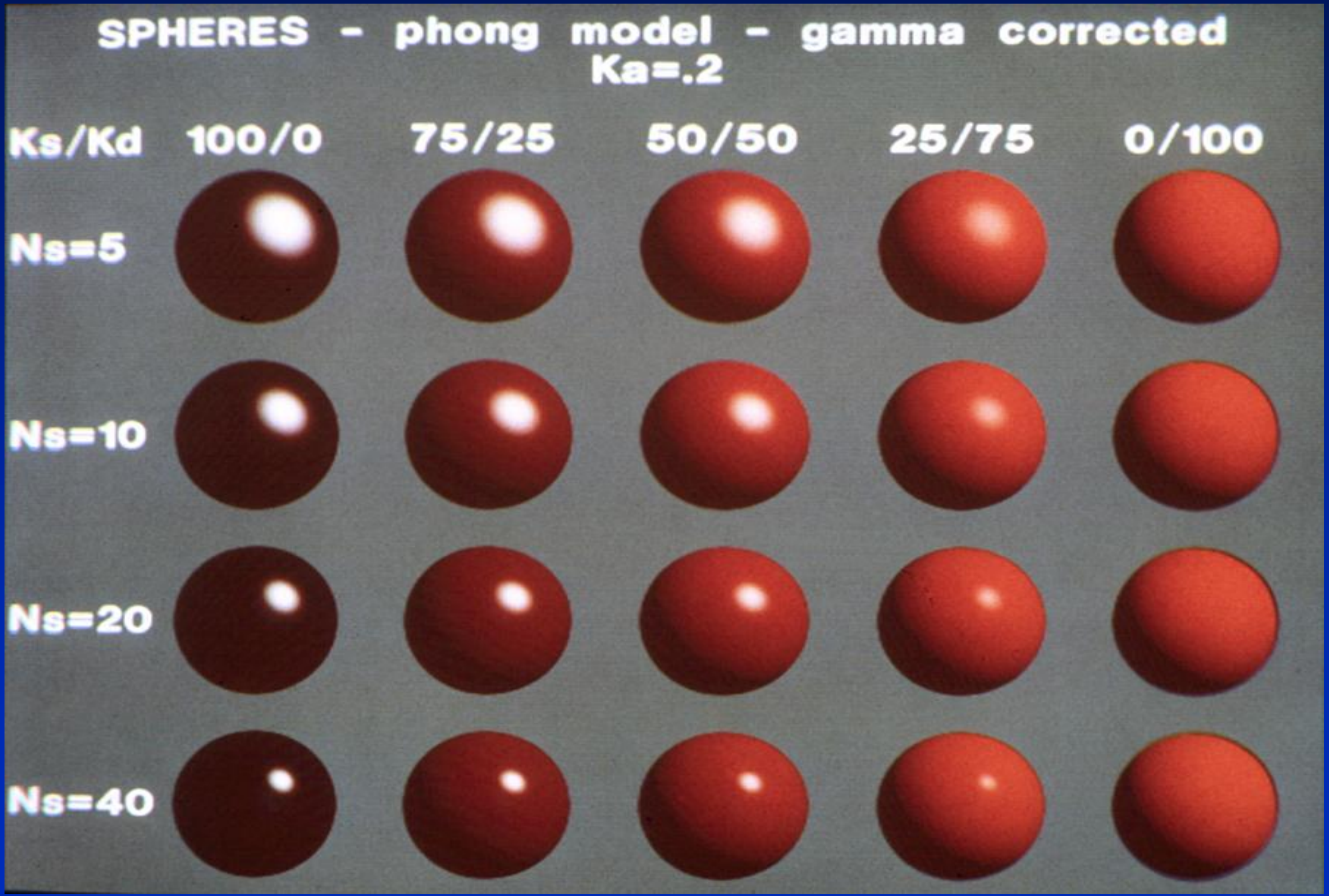
  = 1.8 gigabits/second



Direct Illumination

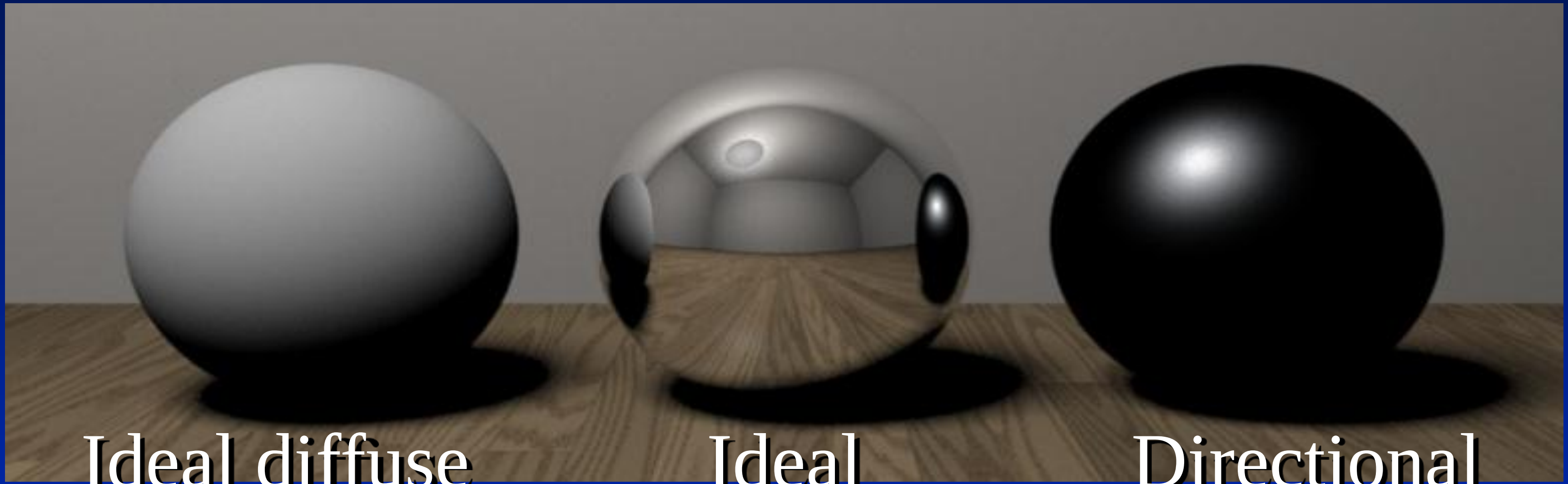


Phong Model: Variations of Specular Exponent

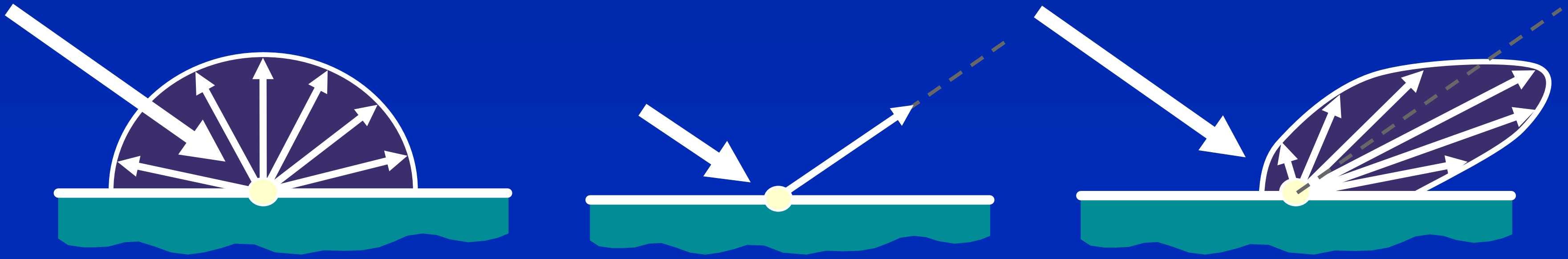


Roy Hall

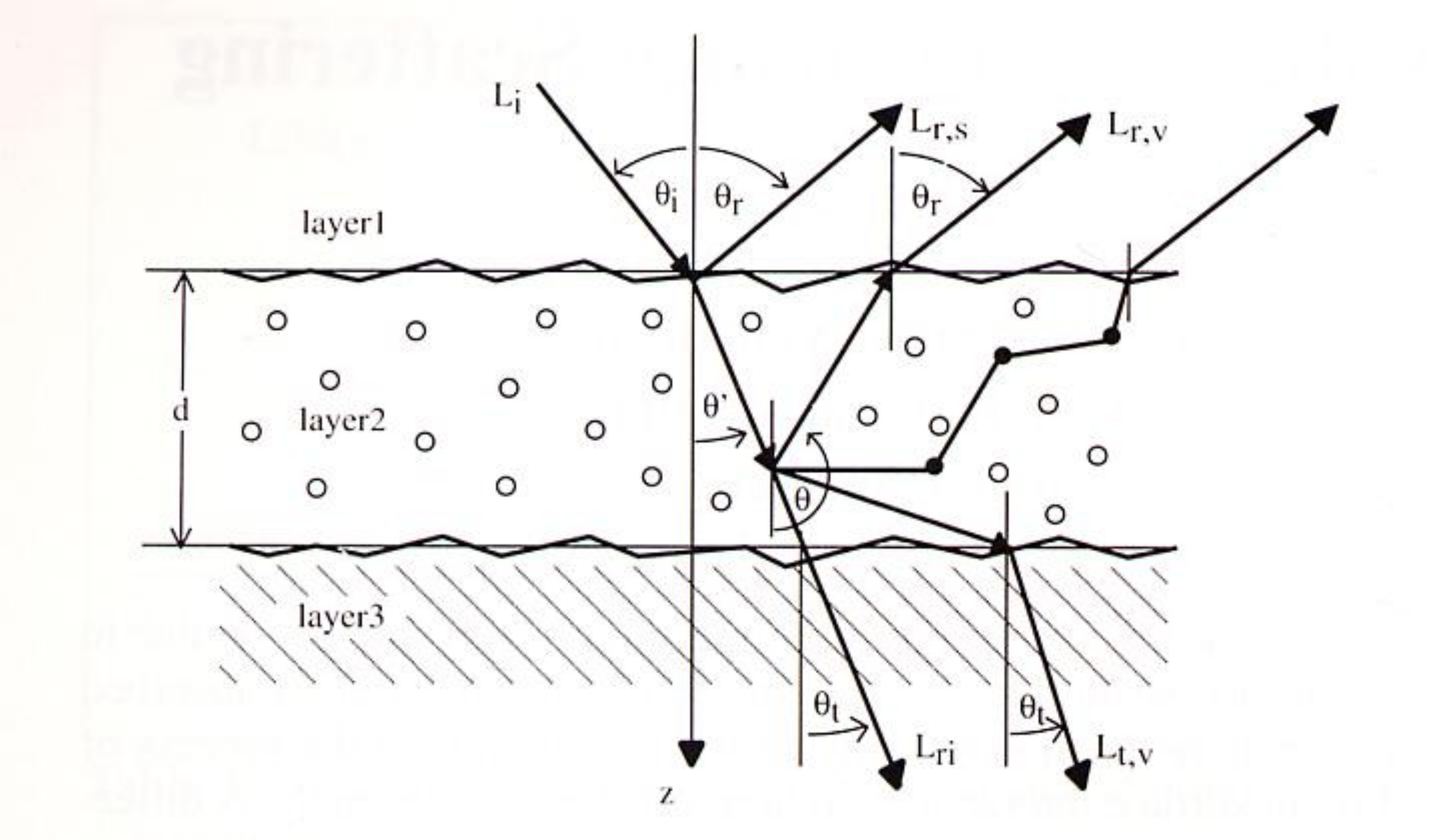
Reflectance Three Approximate Components



Ideal diffuse (Lambertian) | Ideal specular | Directional diffuse



Cook-Torrance Renderings 1979

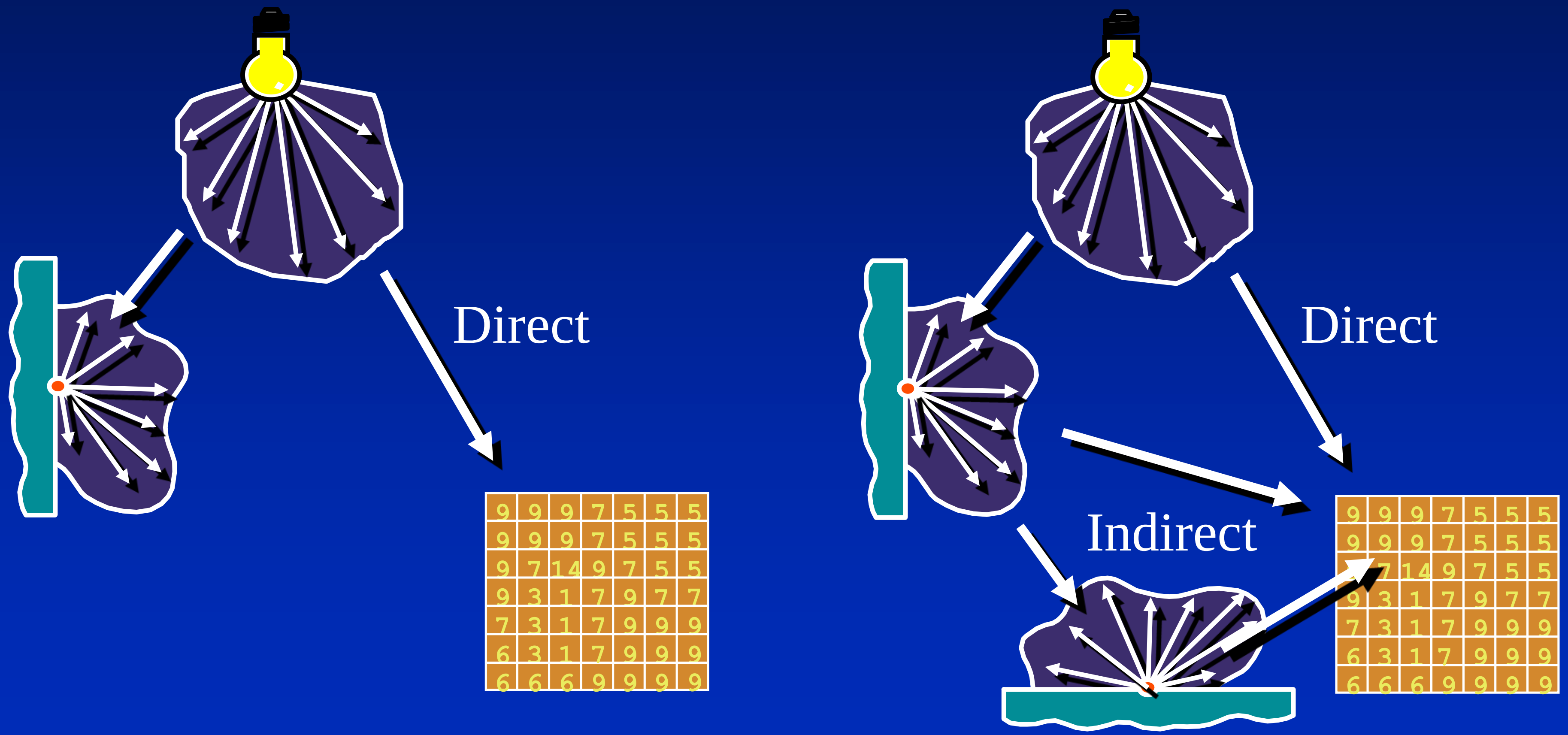


The geometry of scattering from a layered surface

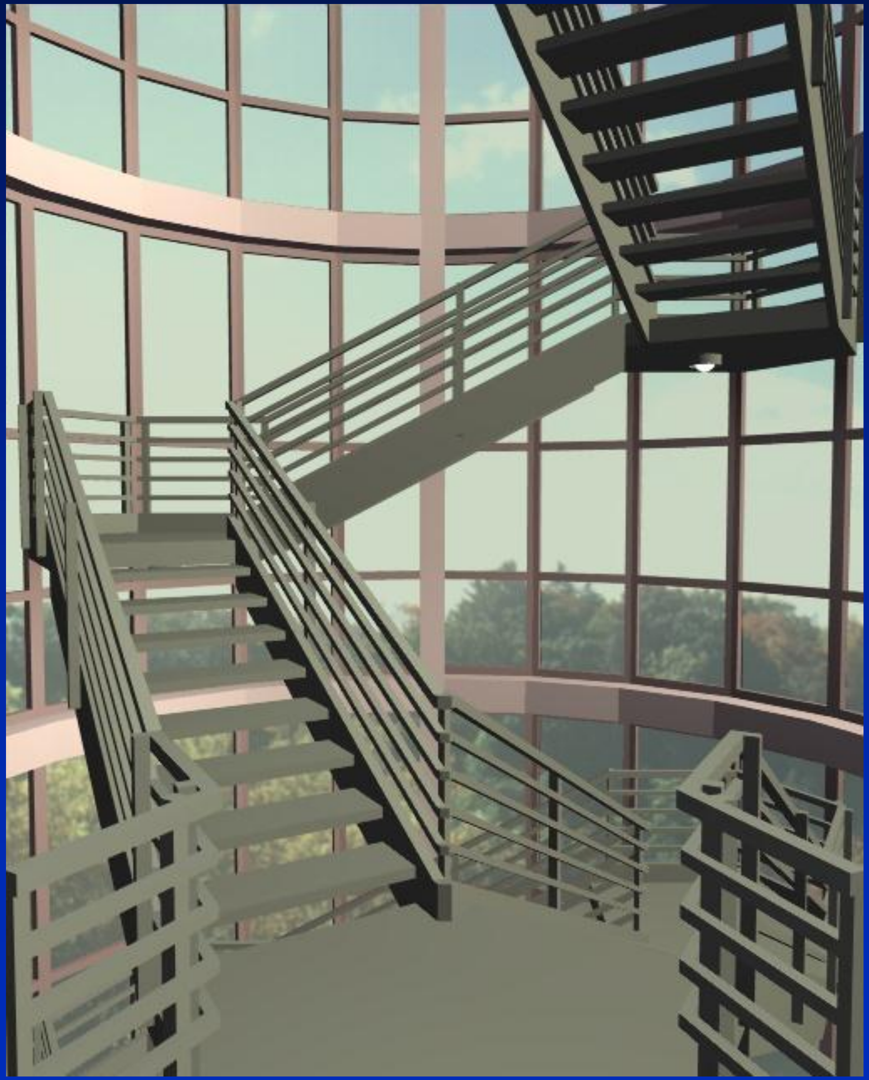
acm Computer Graphics, Siggraph 1993 p. 166

Henrik Wann Jensen, Stephen R. Marschner, Marc Levoy, Pat Hanrahan. "A Practical Model for Subsurface Light Transport," ACM Siggraph 2001, August 2001, Los Angeles, CA, pp. 511-518.

Direct Lighting and Indirect Lighting

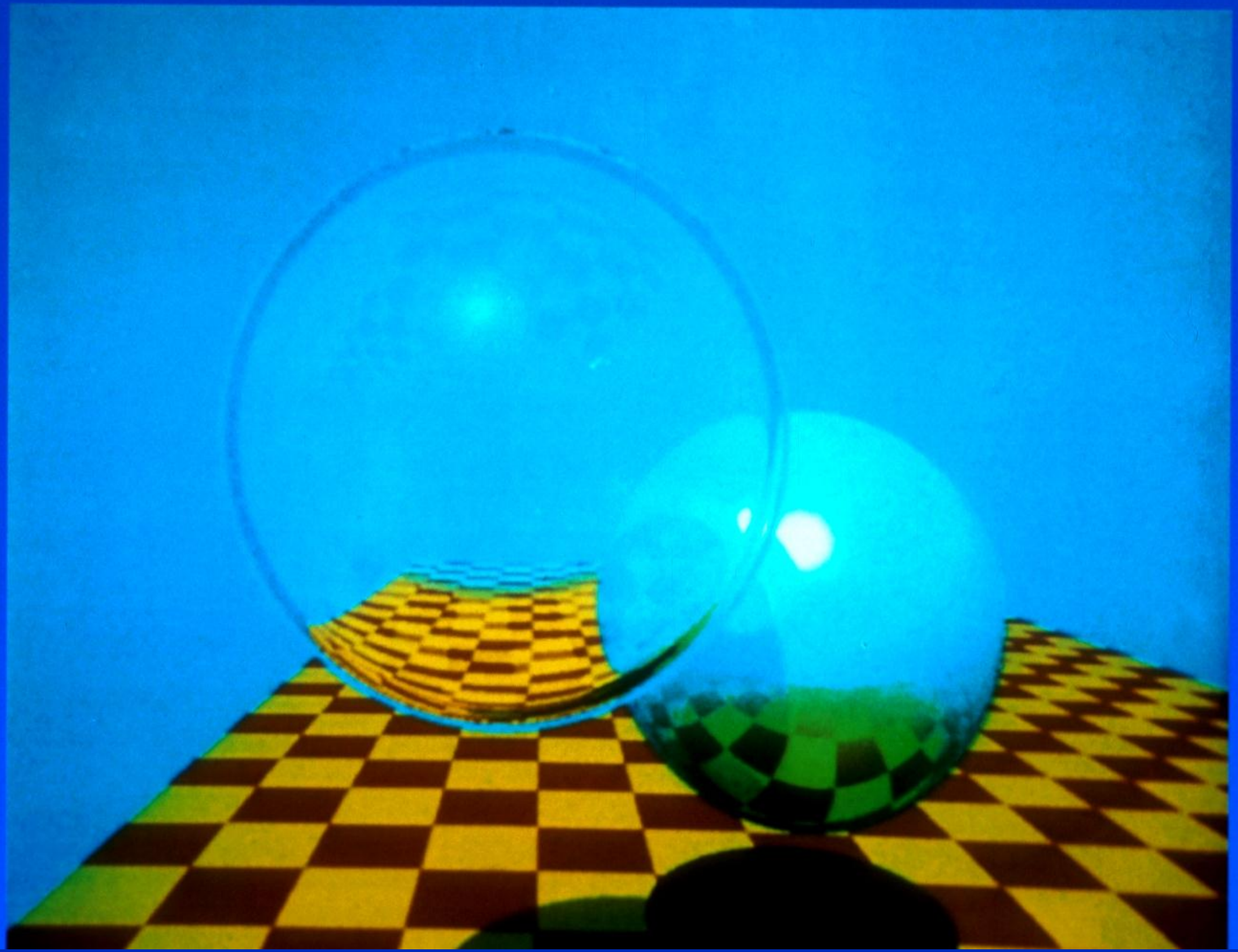


Direct Lighting Only



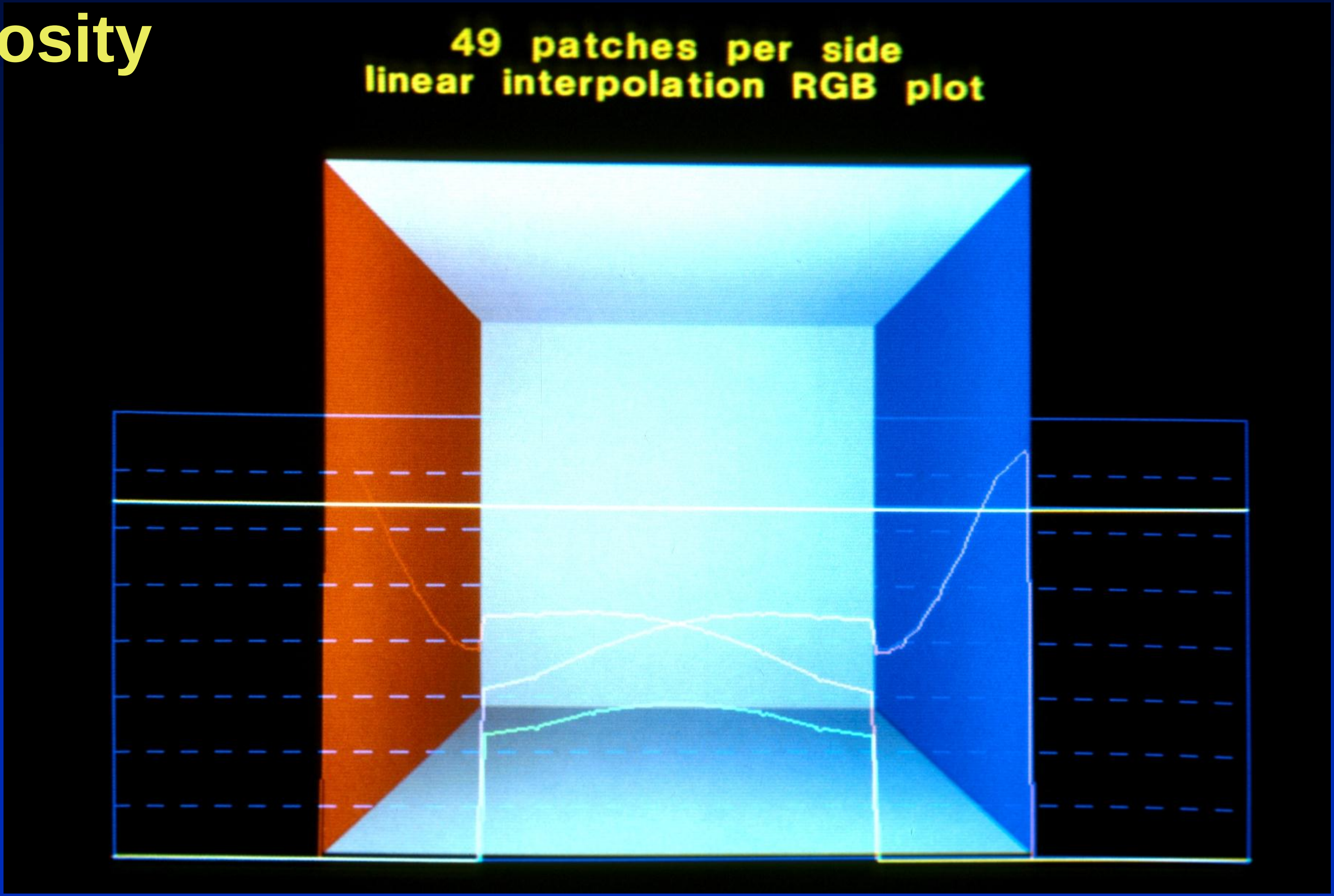
Global Illumination

Ray Tracing
Turner Whitted, 1979



Ray Tracing Eric Haines 1985

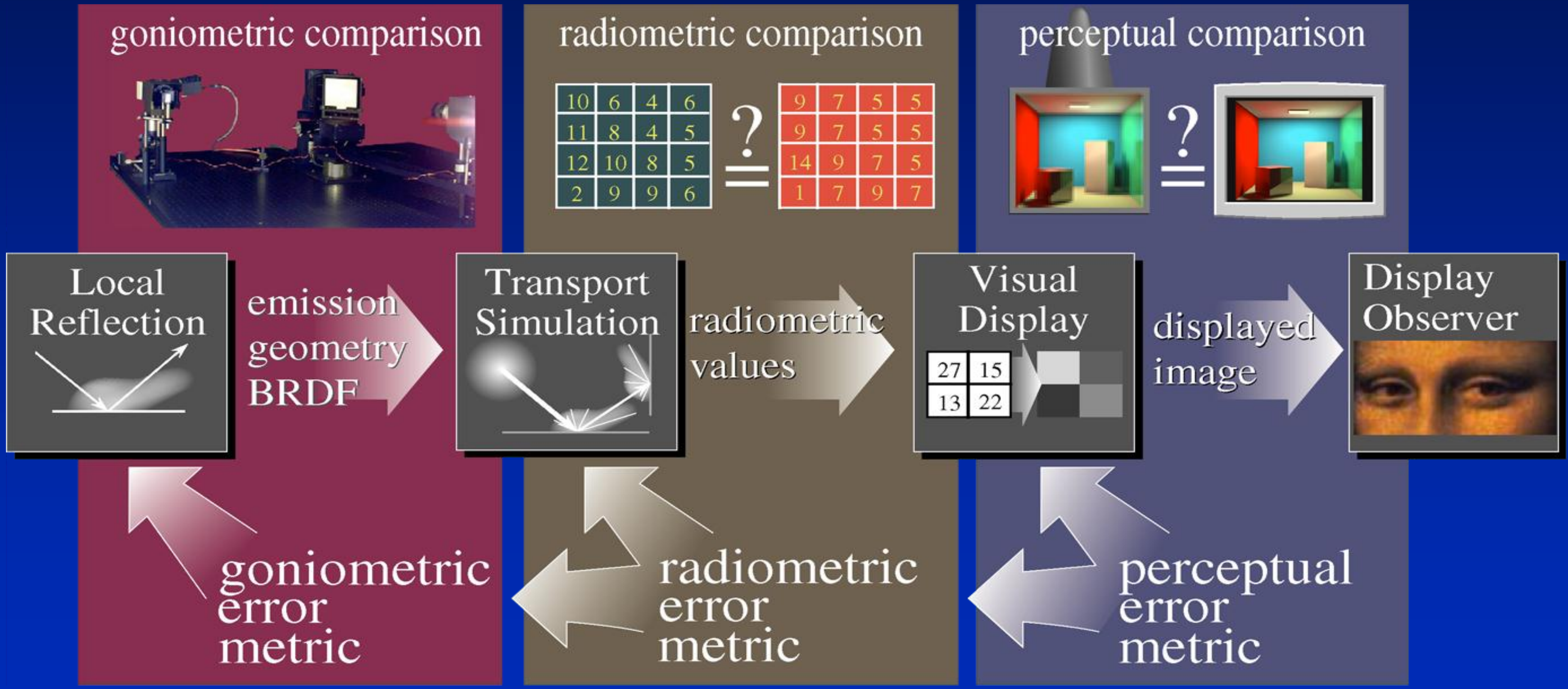
Radiosity
1984



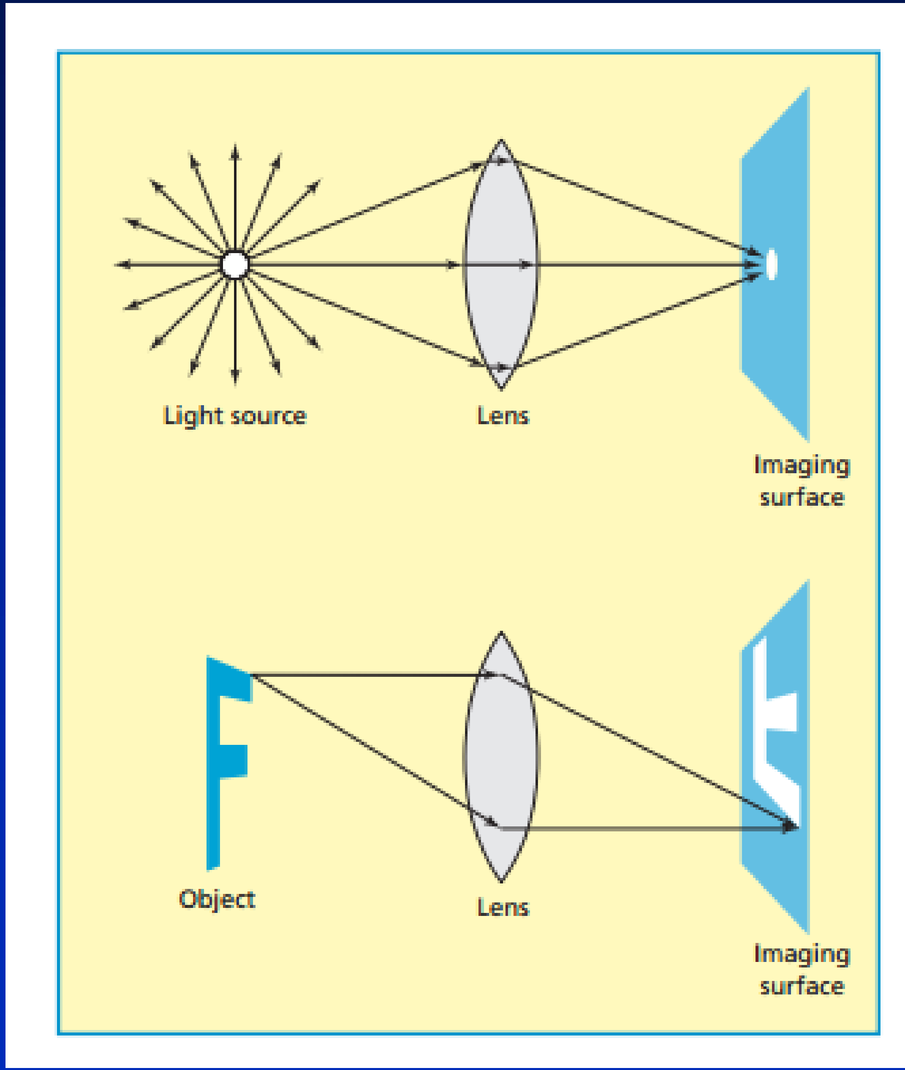
Radiosity
Eric Chen 1986

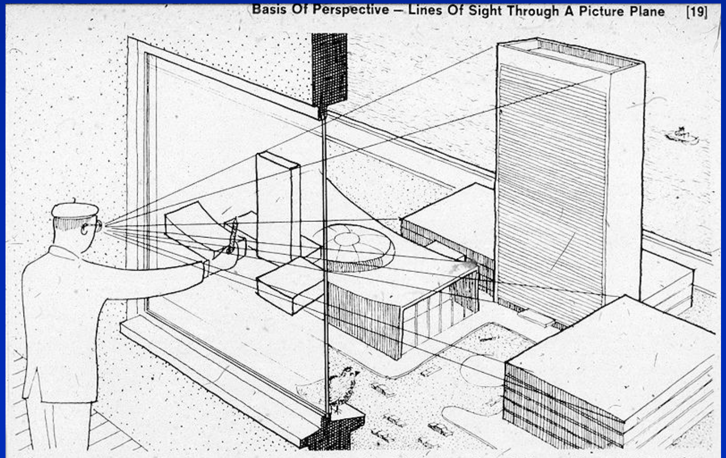
Radiosity 1990s

Rendering Framework 1997



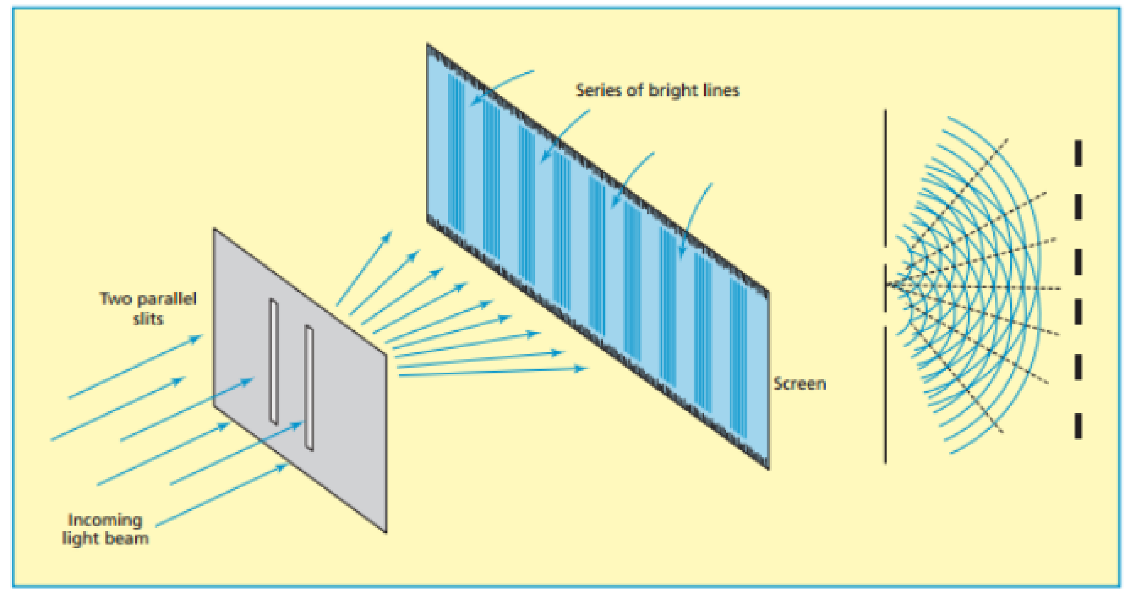
Light as Rays

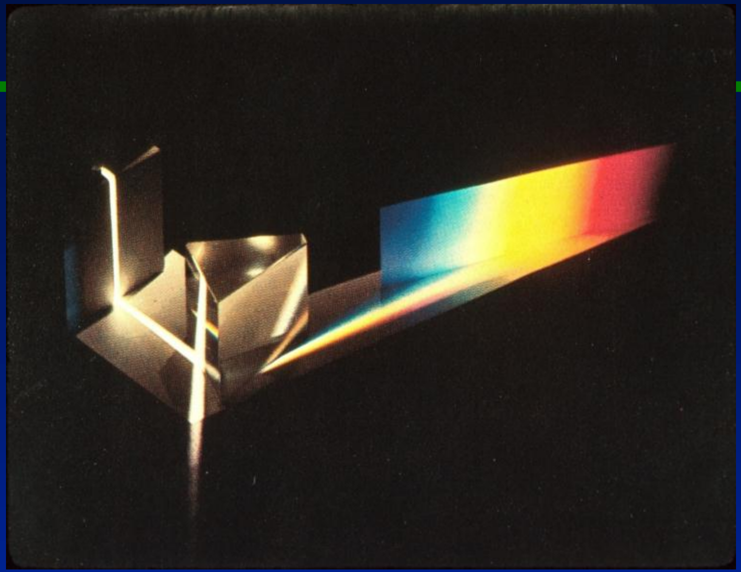


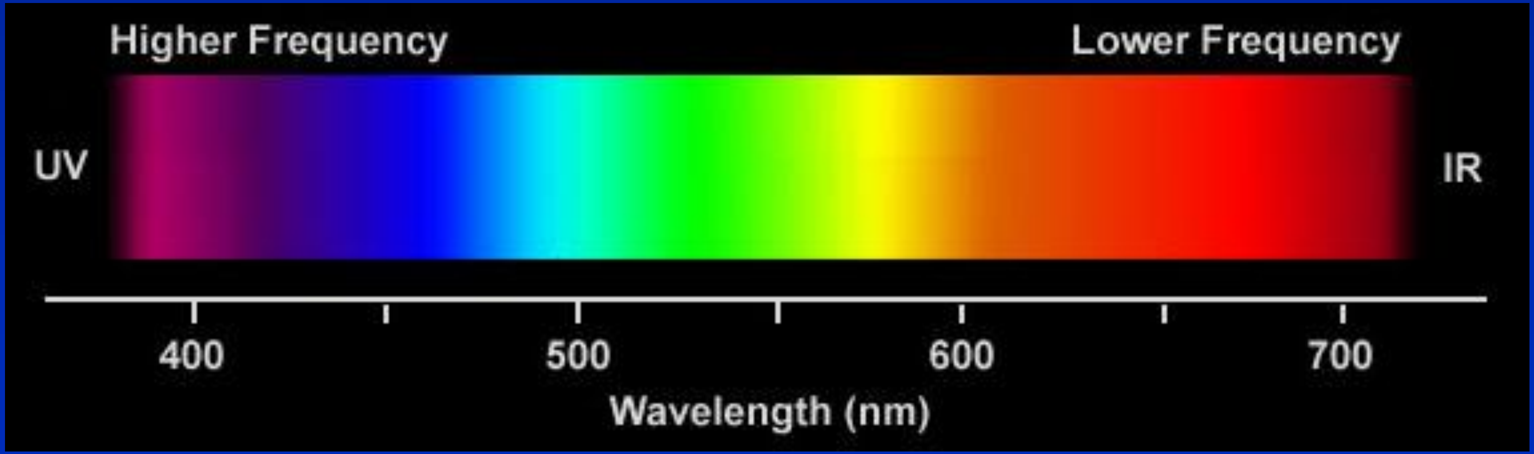


The concept of the picture plane may be better understood by looking through a window or other transparent plane from a fixed viewpoint. Your lines of sight, the multitude of straight lines leading from your eye to the subject, will all intersect this plane. Therefore, if you were to reach out with a grease pencil and draw the image of the subject on this plane you would be "tracing out" the infinite number of points of intersection of sight rays and plane. The result would be that you would have "transferred" a real three-dimensional object to a two-dimensional plane.

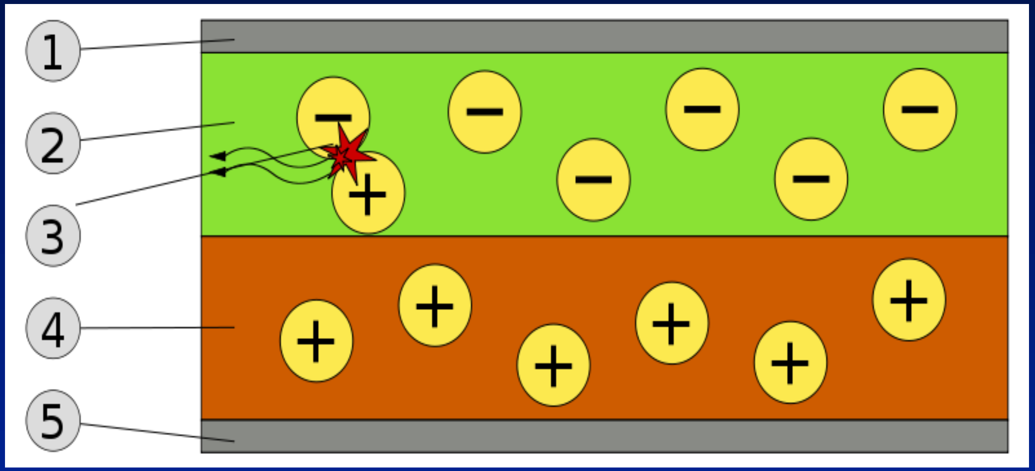
Light as Waves

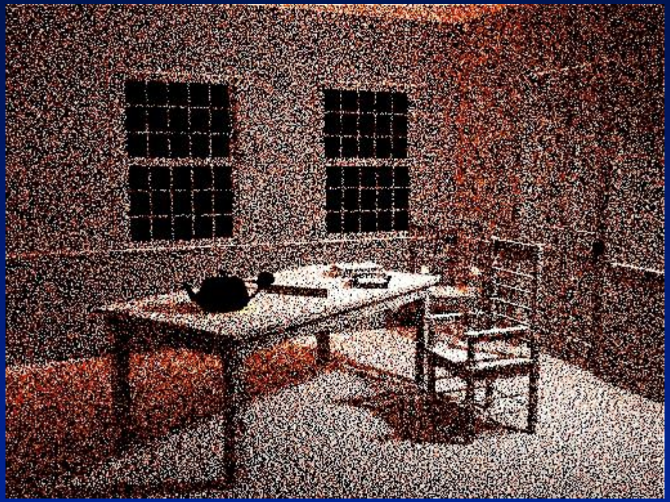


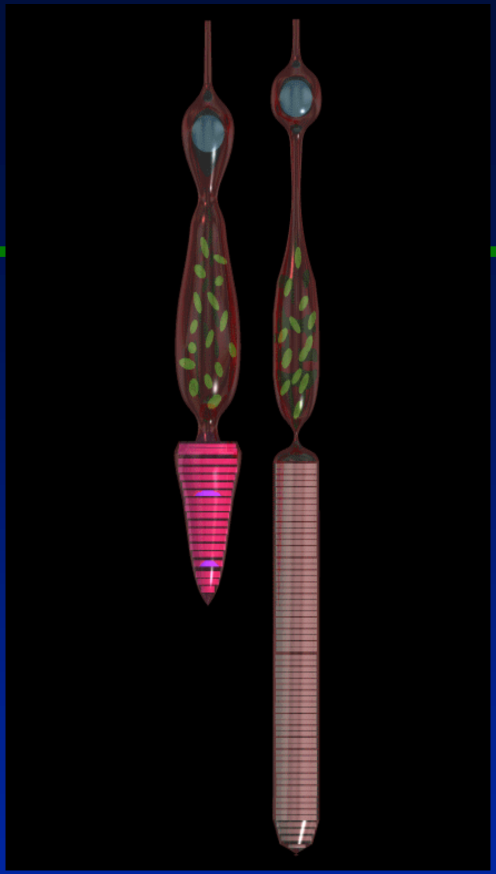


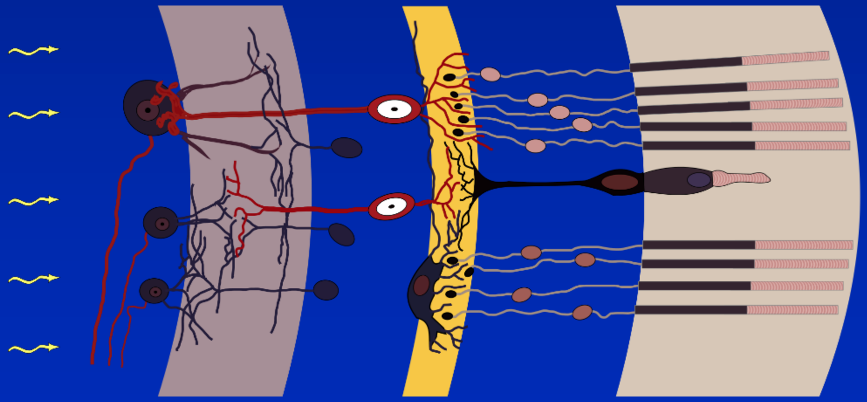


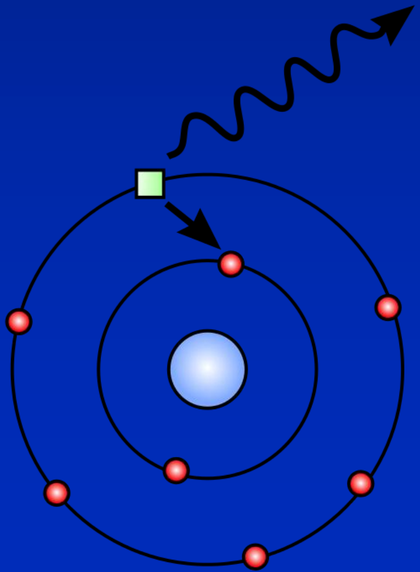
Light as Photons

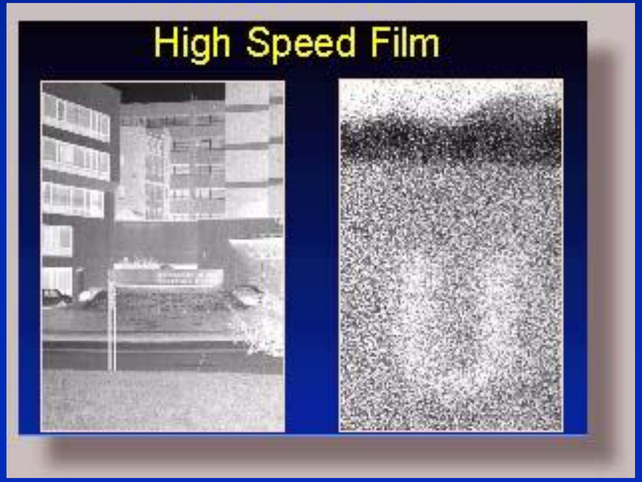




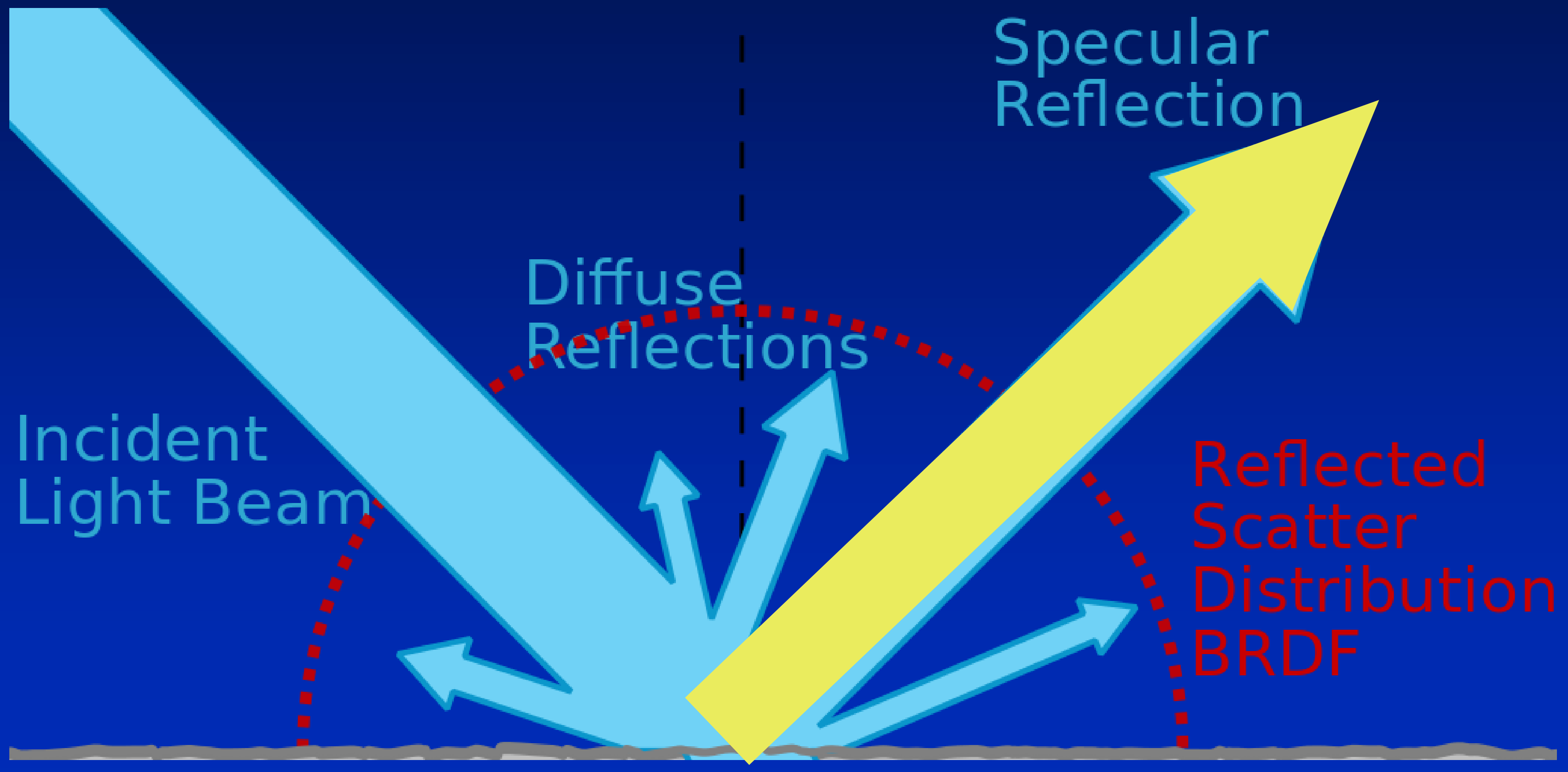








Ray Tracing

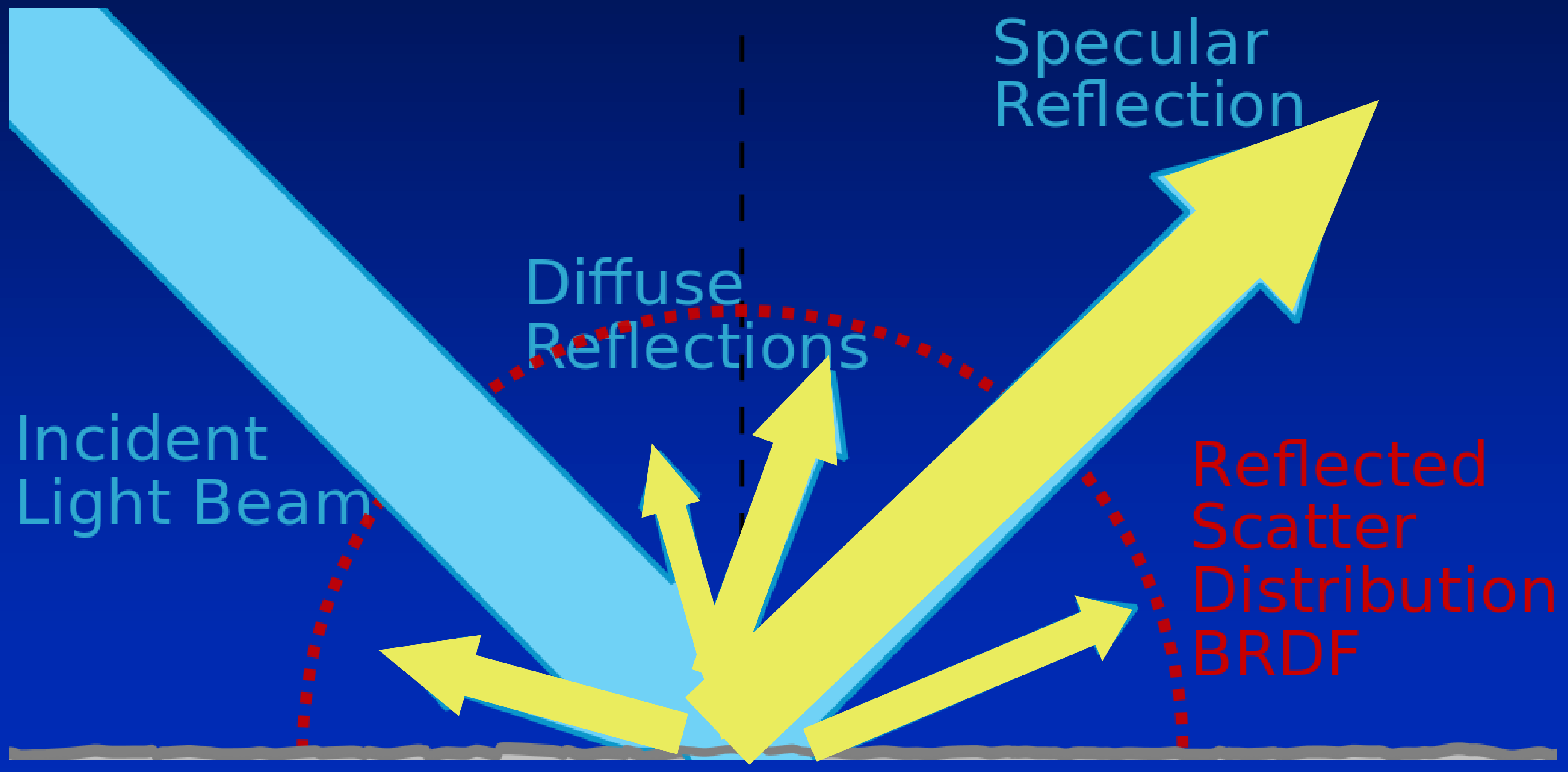


Specular Reflection
Diffuse Reflections
Incident Light Beam
Reflected Scatter Distribution BRDF

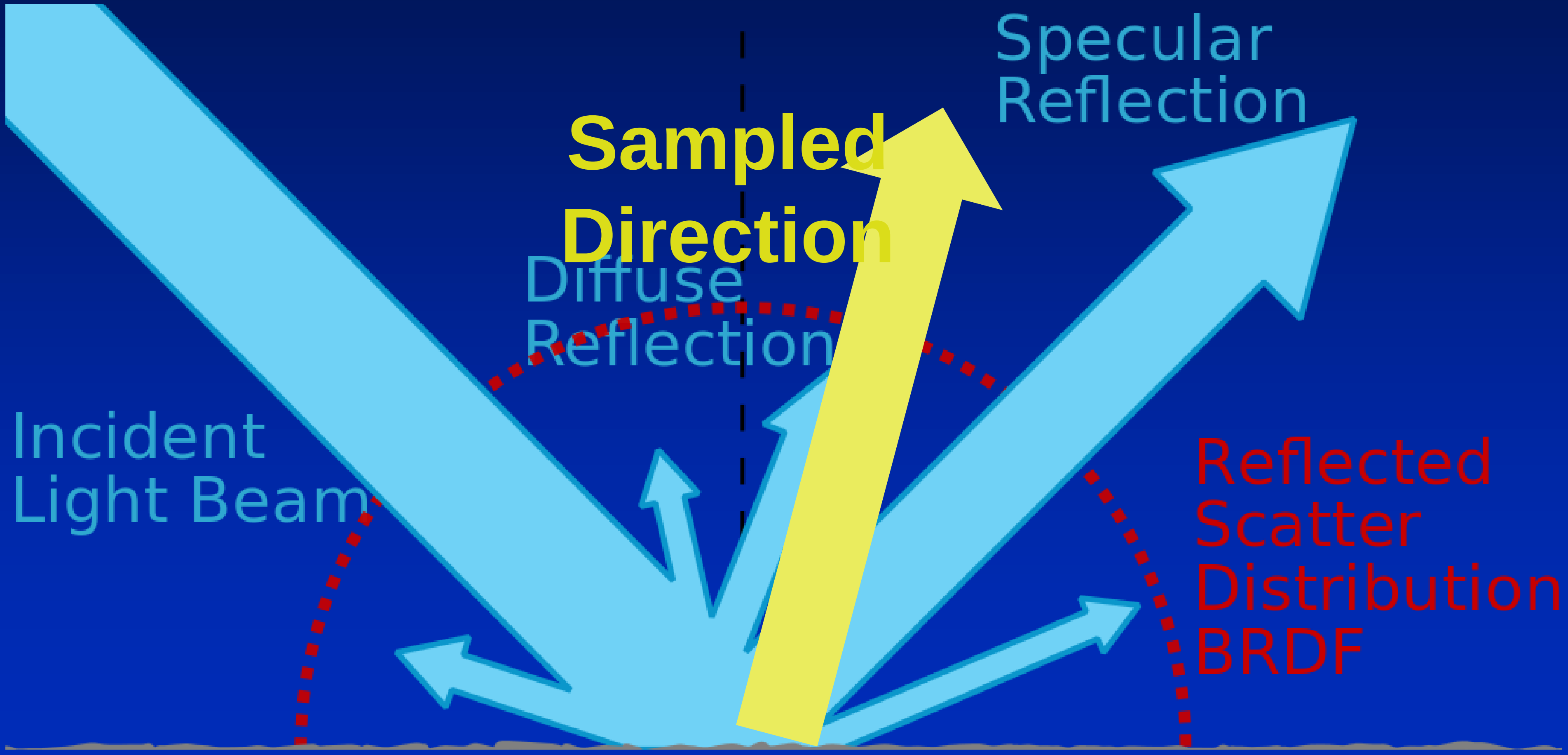
Path Tracing

- Path Tracing is similar to ray tracing except that many rays are sent for each pixel.
- Rays are sent out on a probabilistic basis depending on the reflectance (transmittance) distributions of each surface that is struck.
- Computations can be accelerated by using “importance sampling”, where the ray directions are dependent on the magnitude of the potential effects.

Path Tracing

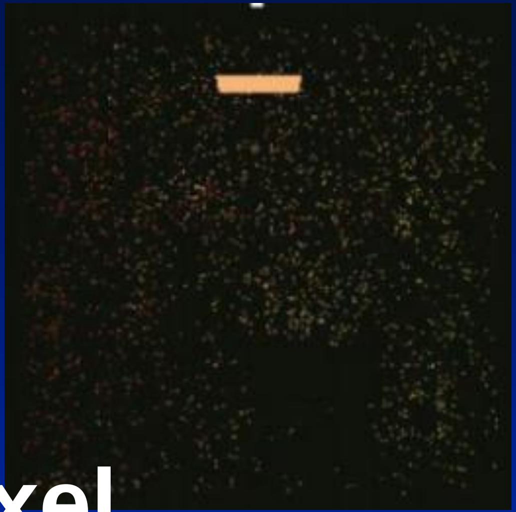


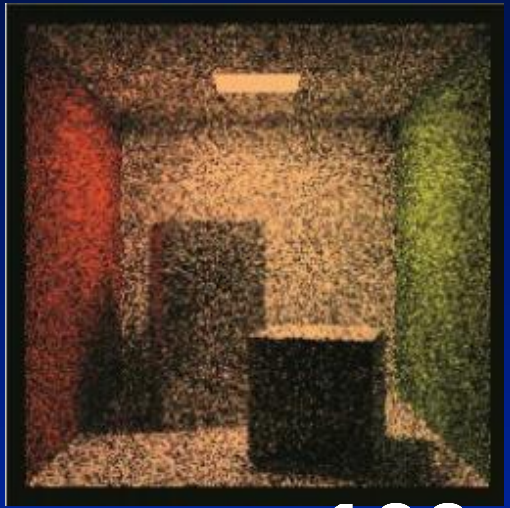
Probabilistic Sample Direction for Path Tracing



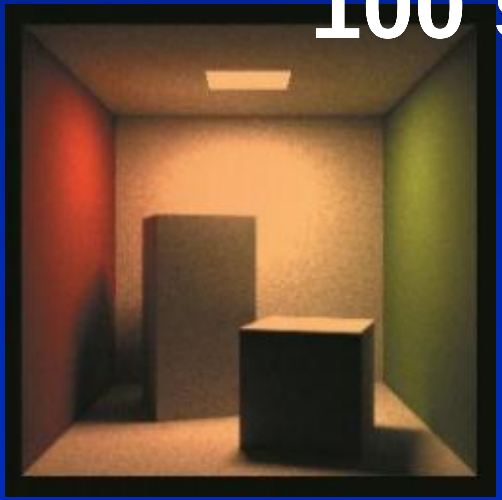
Path Tracing

1 sample/pixel





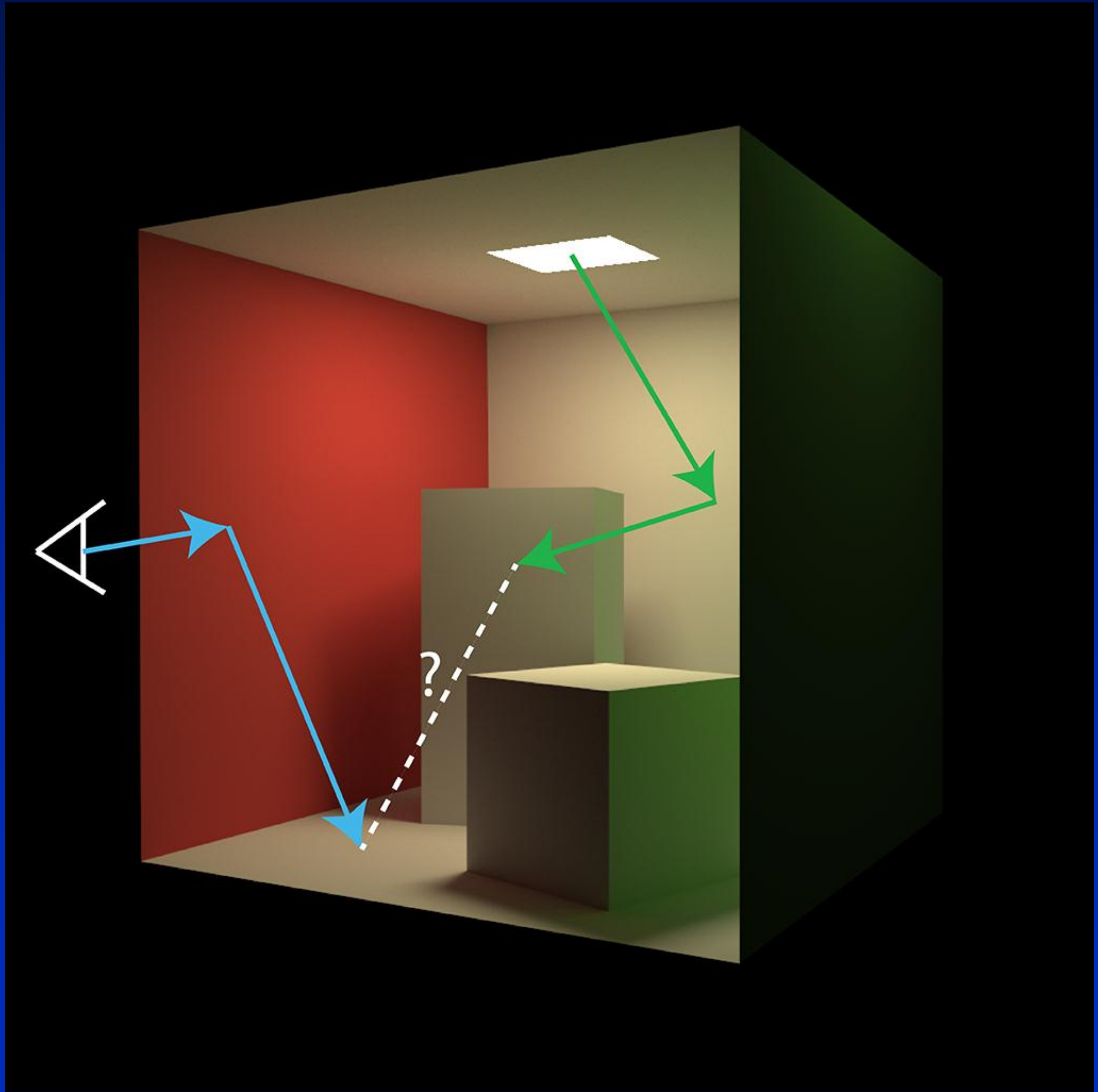
100 samples/pixel



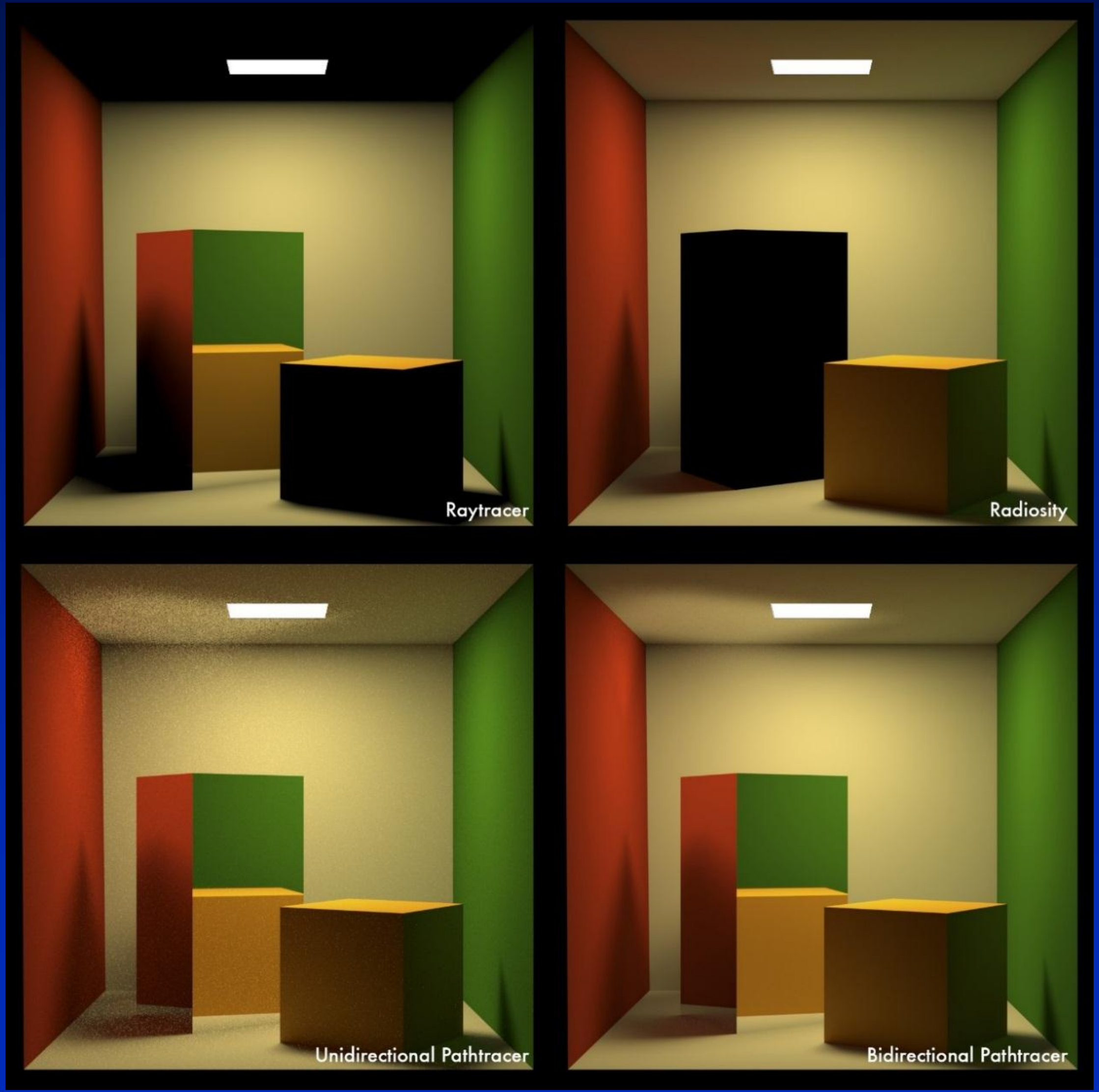
,000 samples/pixel

10,000 samples/pixel

Bi-Directional Path Tracing

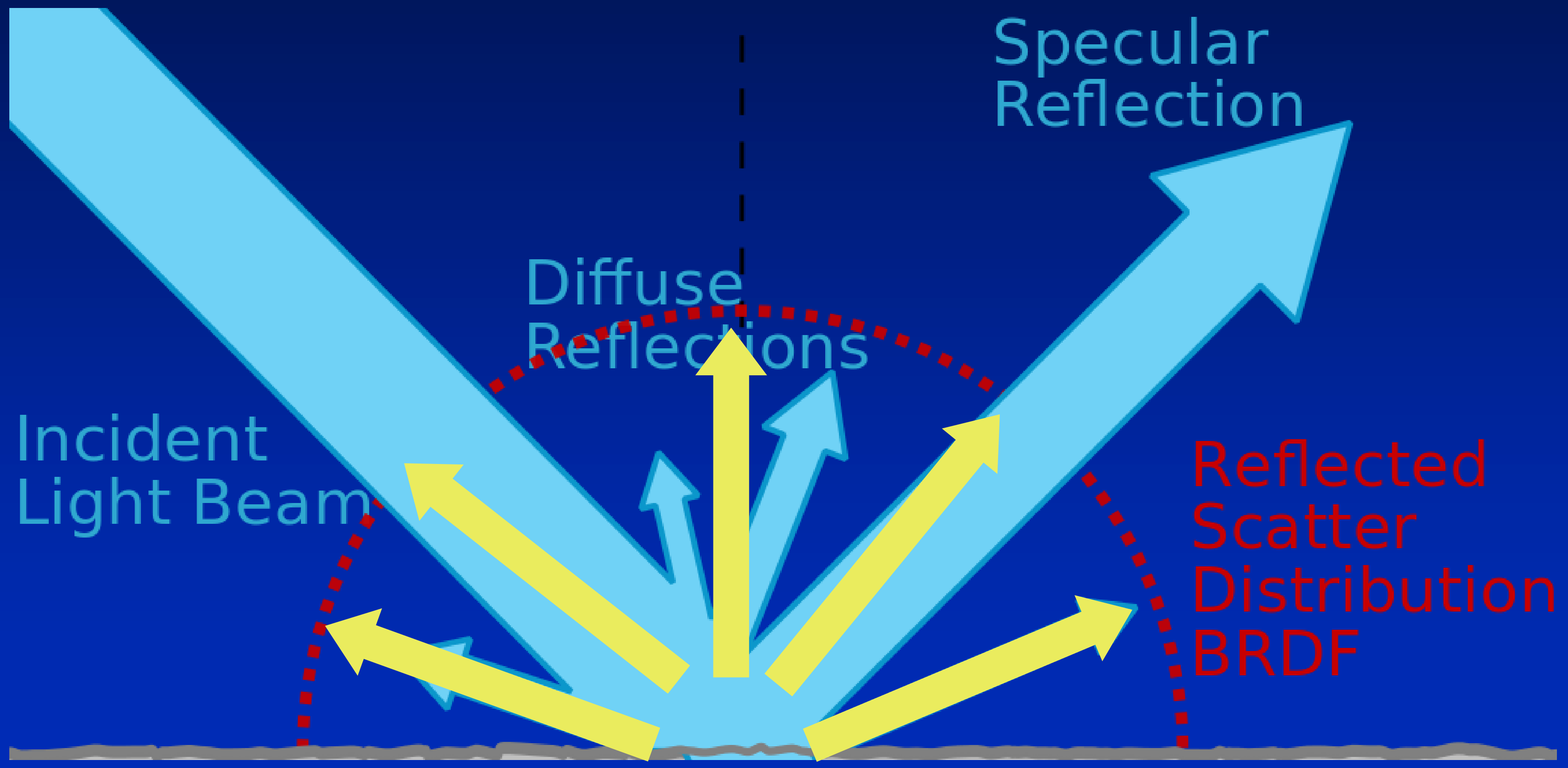


Bi-directional Path Tracing



Photograp

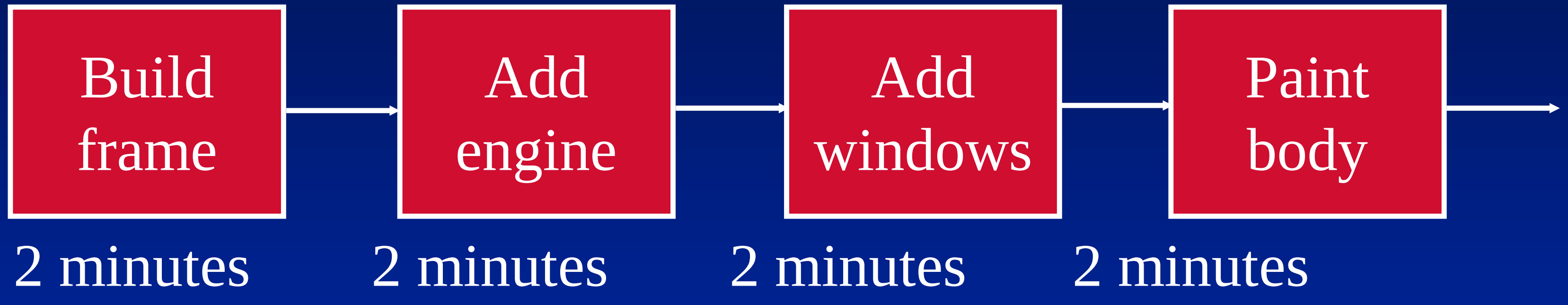
Radiosity

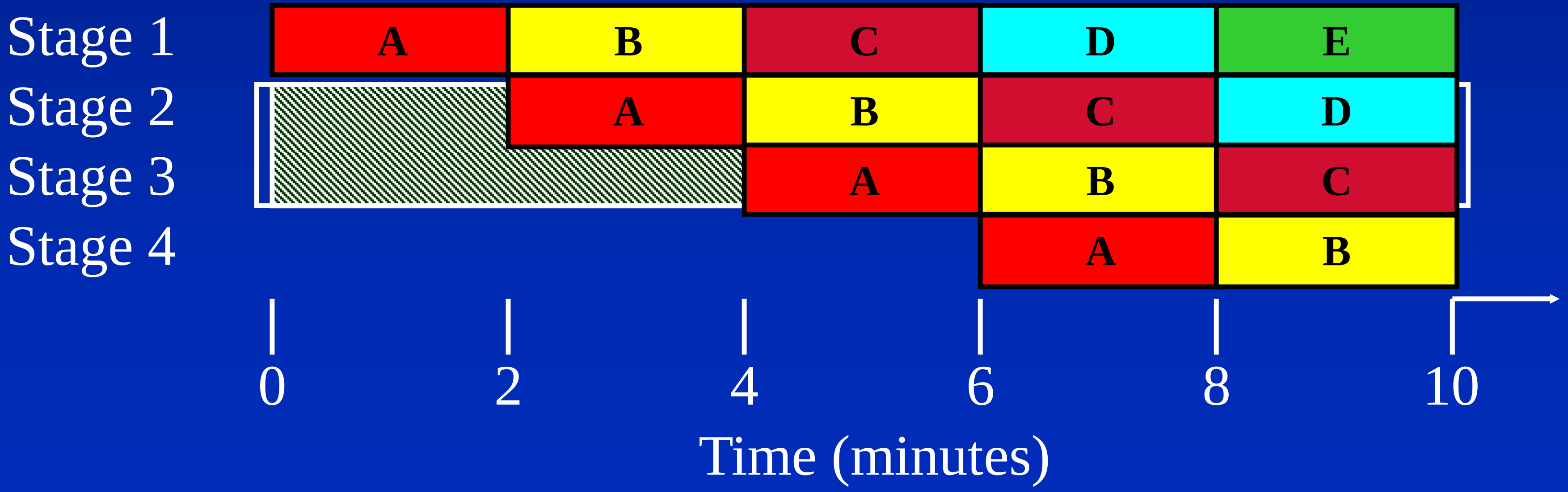


Specular
Reflection
Diffuse
Reflections
Incident
Light Beam
Reflected
Scatter
Distribution
BRDF

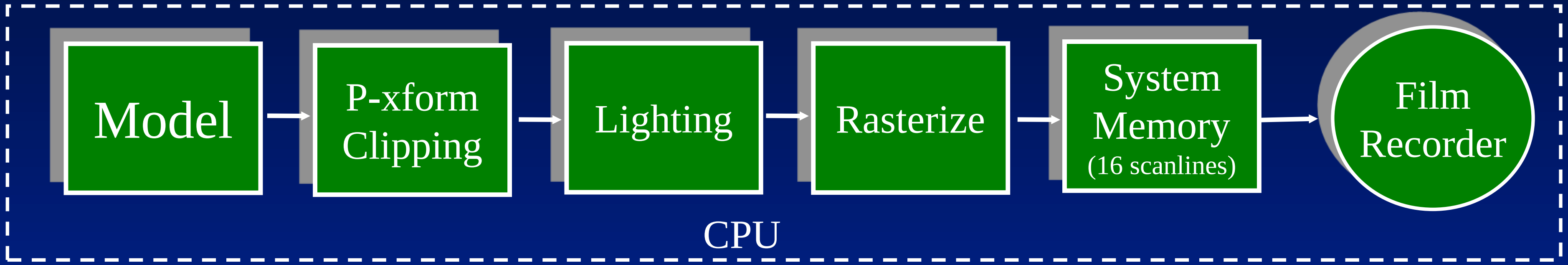
Example: Automobile Pipeline

Automobile takes 8 minutes to make, but the assembly line makes a car every two minutes.





Graphics Hardware circa 1970



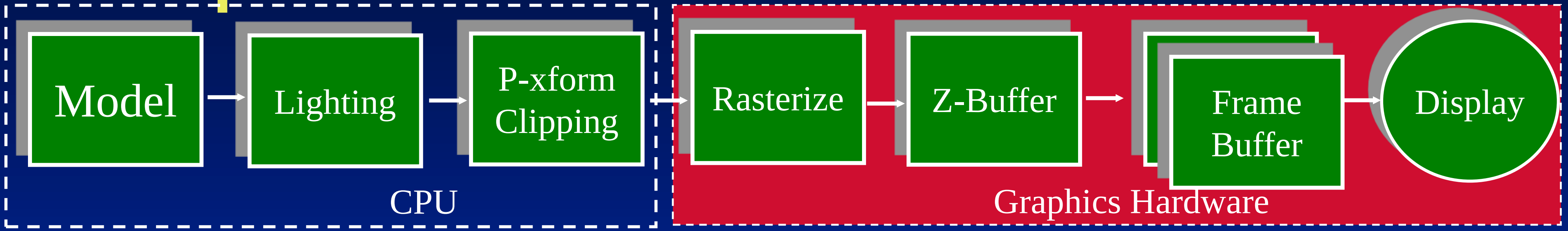
- System used to generate Phong goblet

Graphics Hardware circa 1980

Cost of Memory was Prohibitive

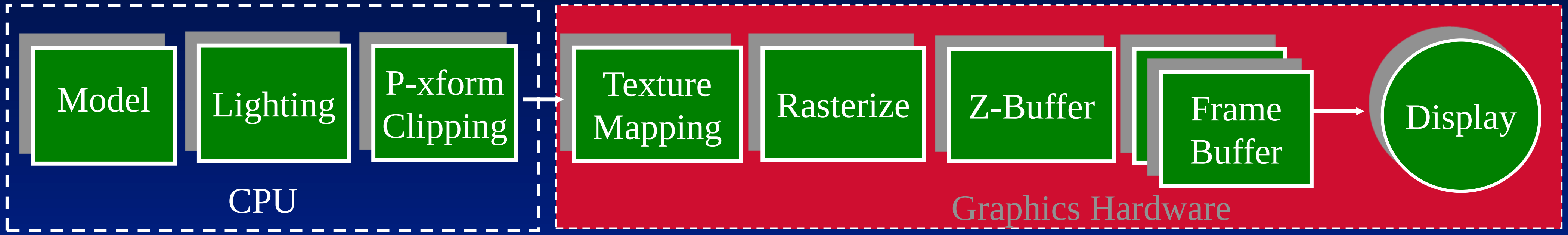
- 512x480x8 bit frame buffer cost $80,000!
- No z-buffer (at 24 or 32 bits/pixel, it requires even more memory than FB)
- Only single frame buffer
- All work done in CPU until frame buffer(slow!)

Graphics Hardware circa 1986



- Added Z-Buffer
- Added Double Frame Buffer
- Rasterization and visible surface computations performed in hardware

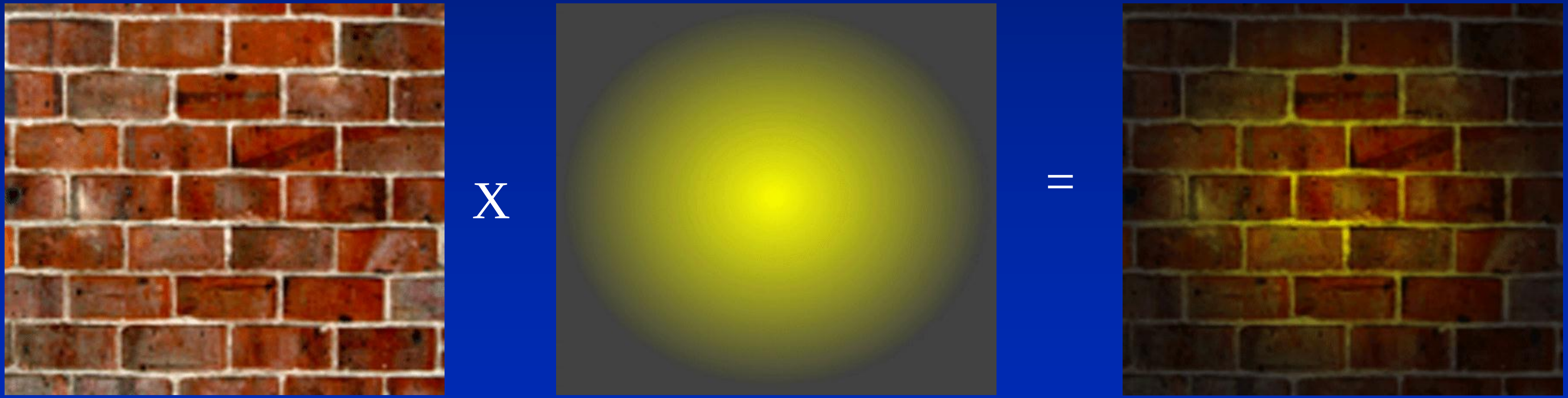
Graphics Hardware 1999



- Addition of texture mapping units
- With texturing, high resolution detail is possible with relatively simple geometry

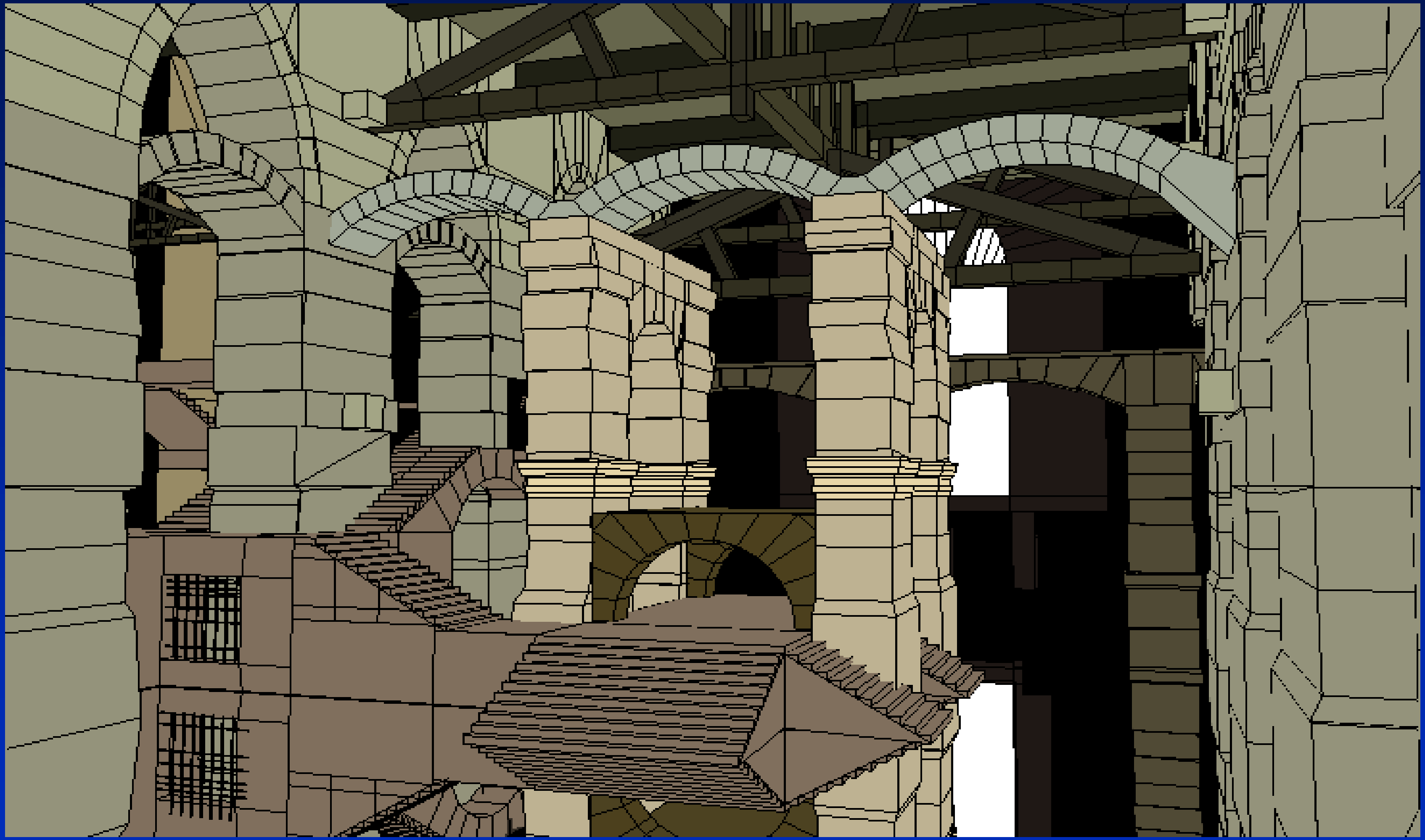
Multipass Example: Light Maps

- Two separate textures, one for the material's composition, one for the lighting



J.L.Mitchell, M. Tatro, and I. Bullard

Castle’s Geometry

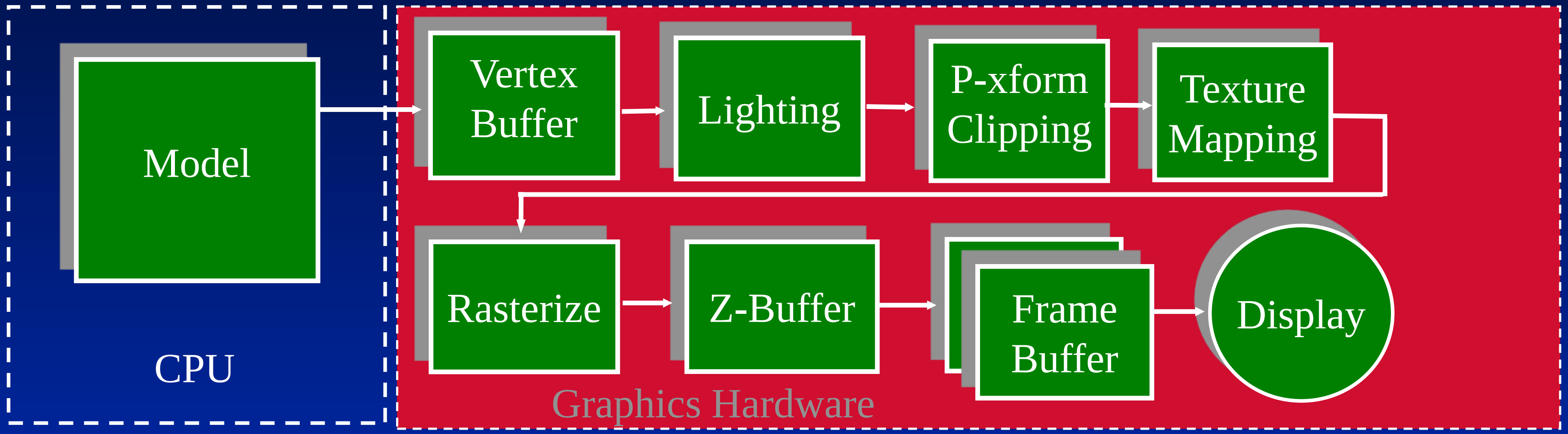


Agata & Andrzej Wojaczek, Advanced Graphics Applications Inc.

Reflection Example - Castle

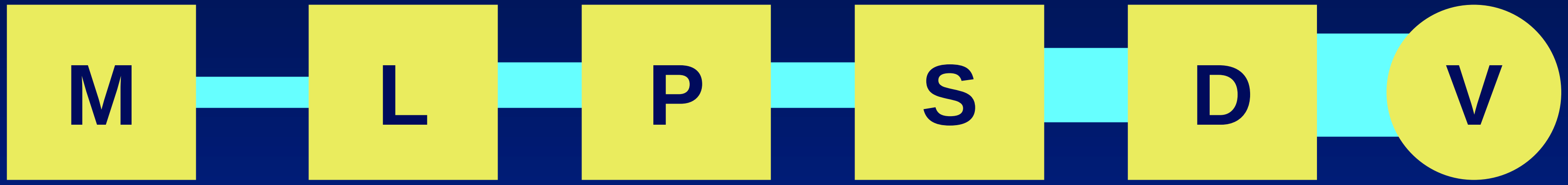
Agata & Andrzej Wojaczek, Advanced Graphics Applications Inc.

Graphics Hardware 2000



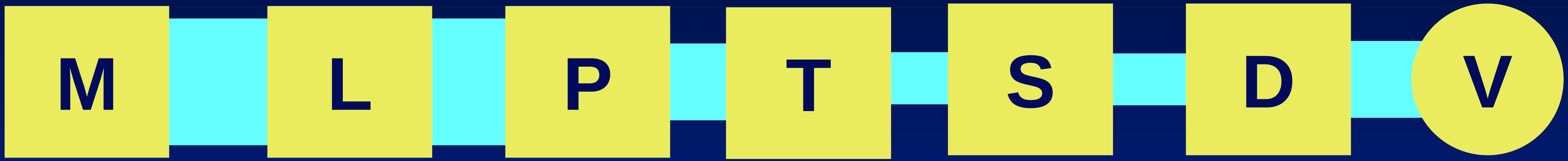
- Vertex buffer (model data) added to reduce bandwidth requirements between CPU and graphics board

Graphics Pipeline - 1980’s



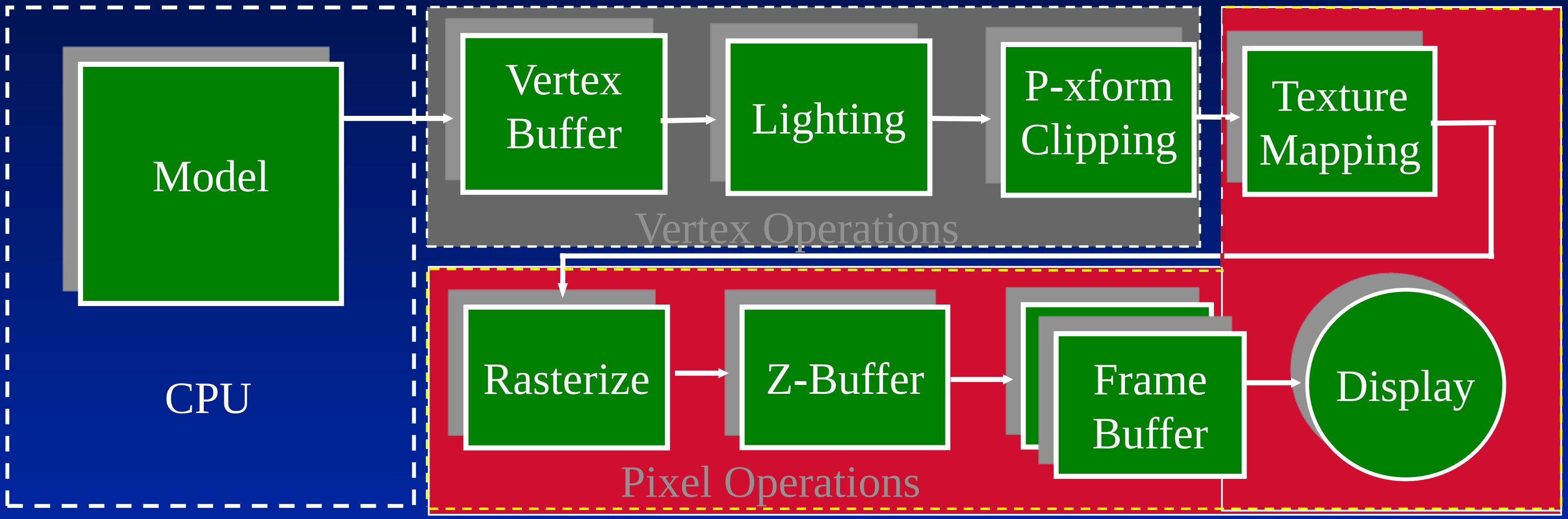
M — Model
L — Lighting
P — Perspective/Clipping
S — Scan Conversion/Z-buffer
D — Display Storage
V — Video

Graphics Pipeline - 2000 +



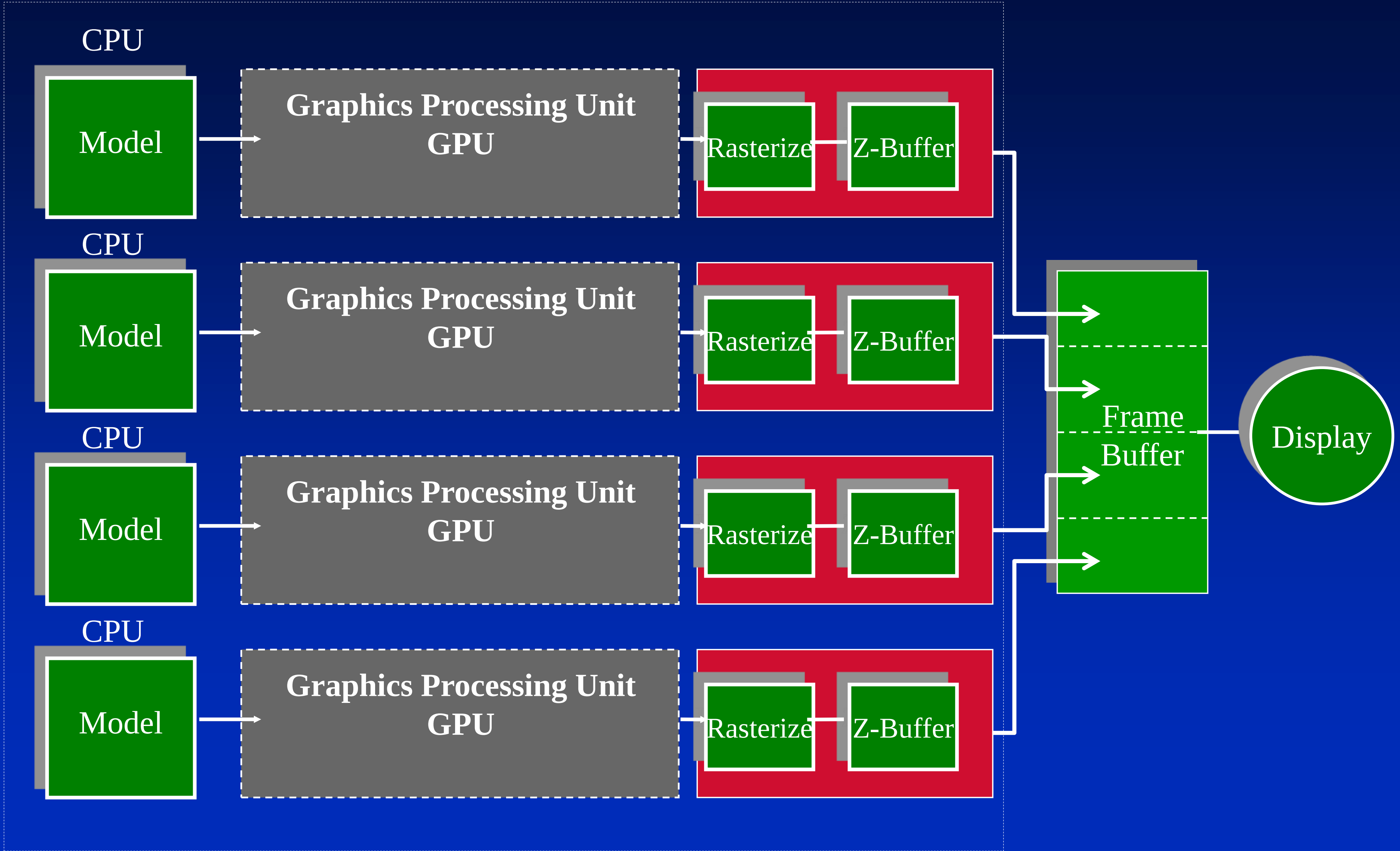
M — Model
L — Lighting
P — Perspective/Clipping
T — Texturing
S — Scan Conversion/Z-buffer
D — Display Storage
V — Video

Graphics Hardware 2003

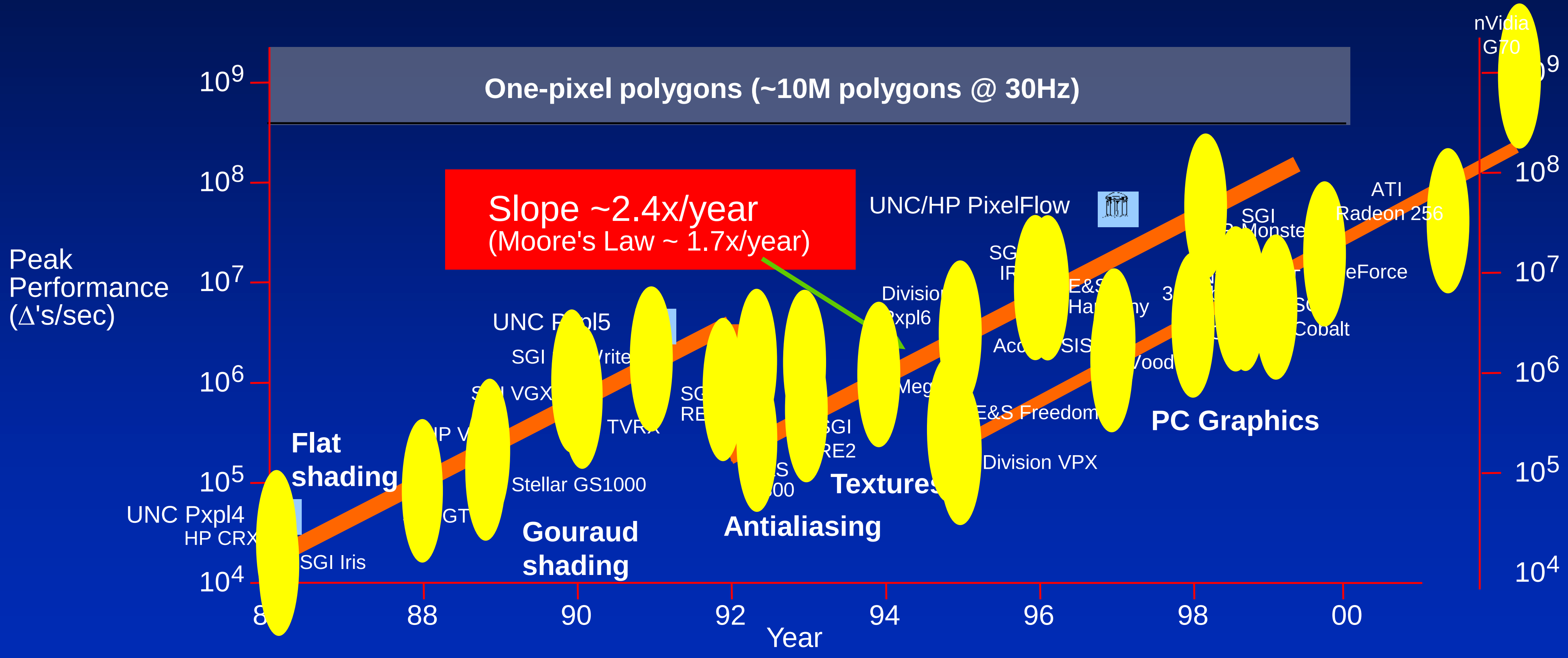


- Early GPU’s performed lighting and clipping operations on locally stored model

Graphics Hardware 2009



Faster than Moore's Law

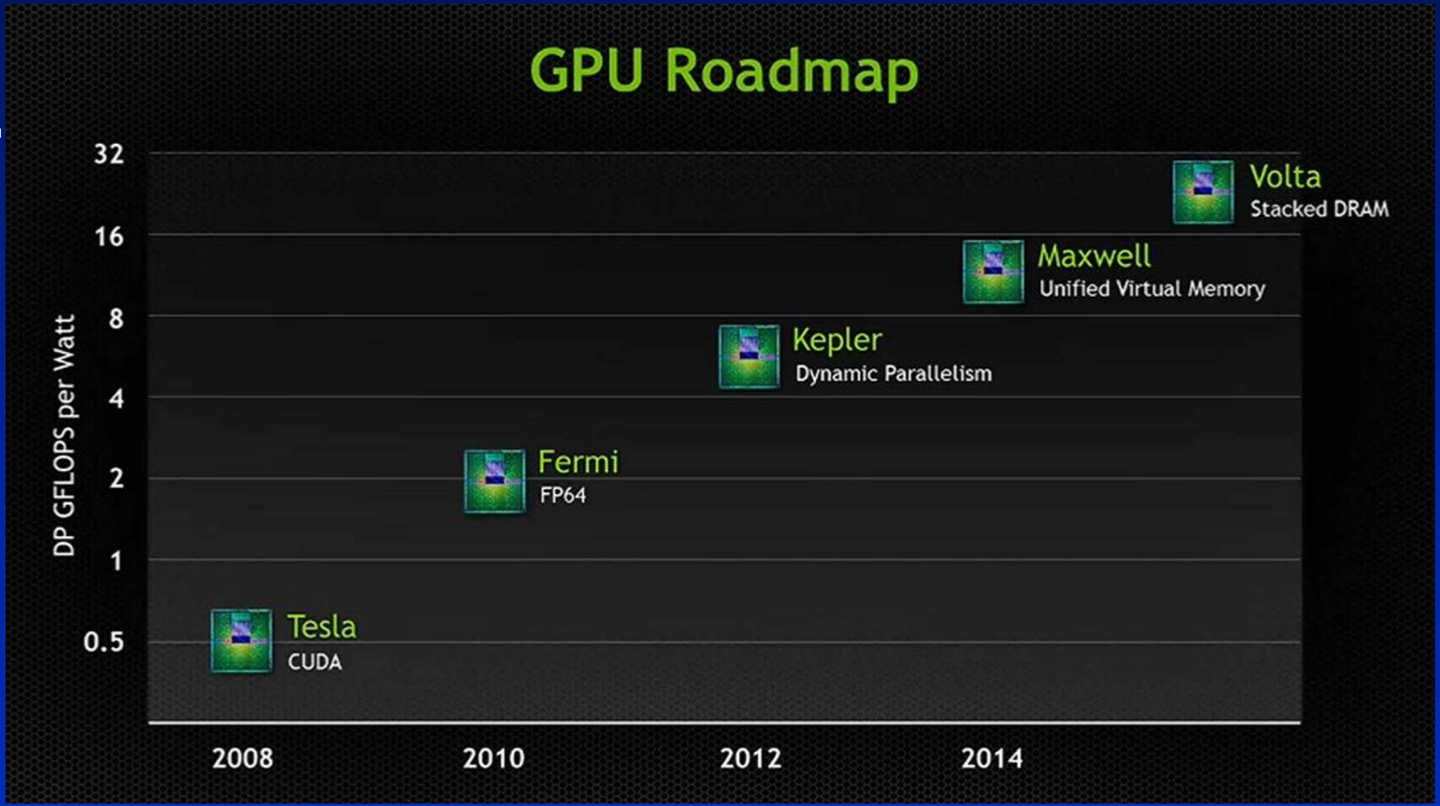


Graph courtesy of Professor John Poulton (from Eric Haines)

nVidia's Kepler Chip 2012

NVIDIA's new Maxwell Chip 2014

- 6144 processor cores (rumor)
- 20 nm
- Q4 2014



Moore’s Law – GPU Transistor Counts

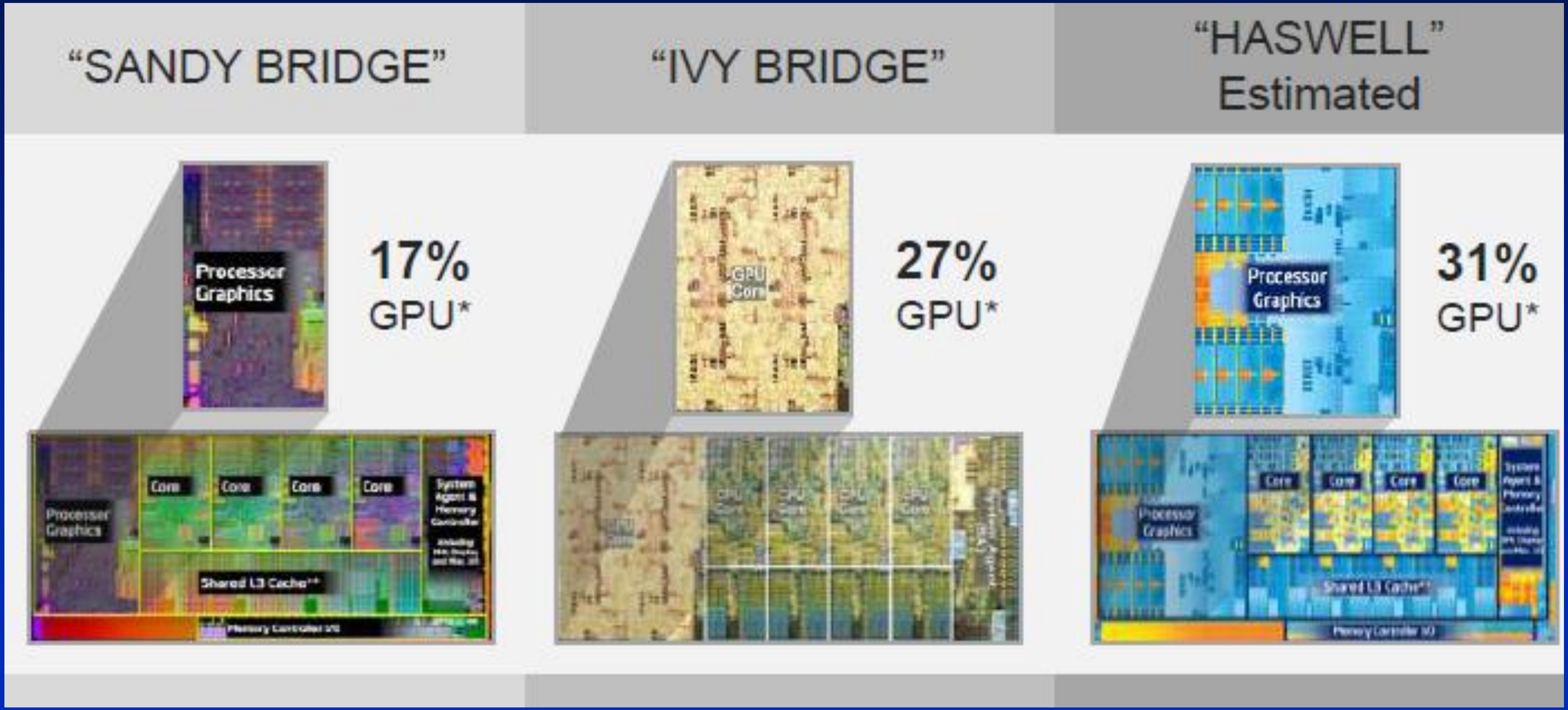
Processor	Transistor count	Date of introduction	Manufacturer	Process	Area
R520	321,000,000	2005	AMD	90 nm	288 mm^2
R580	384,000,000	2006	AMD	90 nm	352 mm^2
G80	681,000,000	2006	NVIDIA	90 nm	480 mm^2
R600 Pele	700,000,000	2007	AMD	80 nm	420 mm^2
G92	754,000,000	2007	NVIDIA	65 nm	324 mm^2
RV790XT Spartan	959,000,000	2008	AMD	55 nm	282 mm^2
GT200 Tesla	1,400,000,000	2008	NVIDIA	65 nm	576 mm^2
Cypress RV870	2,154,000,000	2009	AMD	40 nm	334 mm^2
Cayman RV970	2,640,000,000	2010	AMD	40 nm	389 mm^2
GF100 Fermi	3,200,000,000	Mar 2010	NVIDIA	40 nm	526 mm^2
GF110 Fermi	3,000,000,000	Nov 2010	NVIDIA	40 nm	520 mm^2
GK104 Kepler	3,540,000,000	2012	NVIDIA	28 nm	294 mm^2
Tahiti RV1070	4,312,711,873	2011	AMD	28 nm	365 mm^2
GK110 Kepler	7,080,000,000	2012	NVIDIA	28 nm	561 mm^2
RV1090 Hawaii	6,300,000,000	2013	AMD	28 nm	438 mm^2
GM204 Maxwell	5,200,000,000	2014	NVIDIA	28 nm	398 mm^2
GM200 Maxwell	8,100,000,000	2015	NVIDIA	28 nm	601 mm^2
Fiji	8,900,000,000	2015	AMD	28 nm	596 mm^2
GP104 Pascal	7,200,000,000	2016	Nvidia	16 nm	314 mm^2
GP100 Pascal	15,300,000,000[43]	2016	Nvidia	16 nm	610 mm^2

http://en.wikipedia.org/wiki/Transistor_count

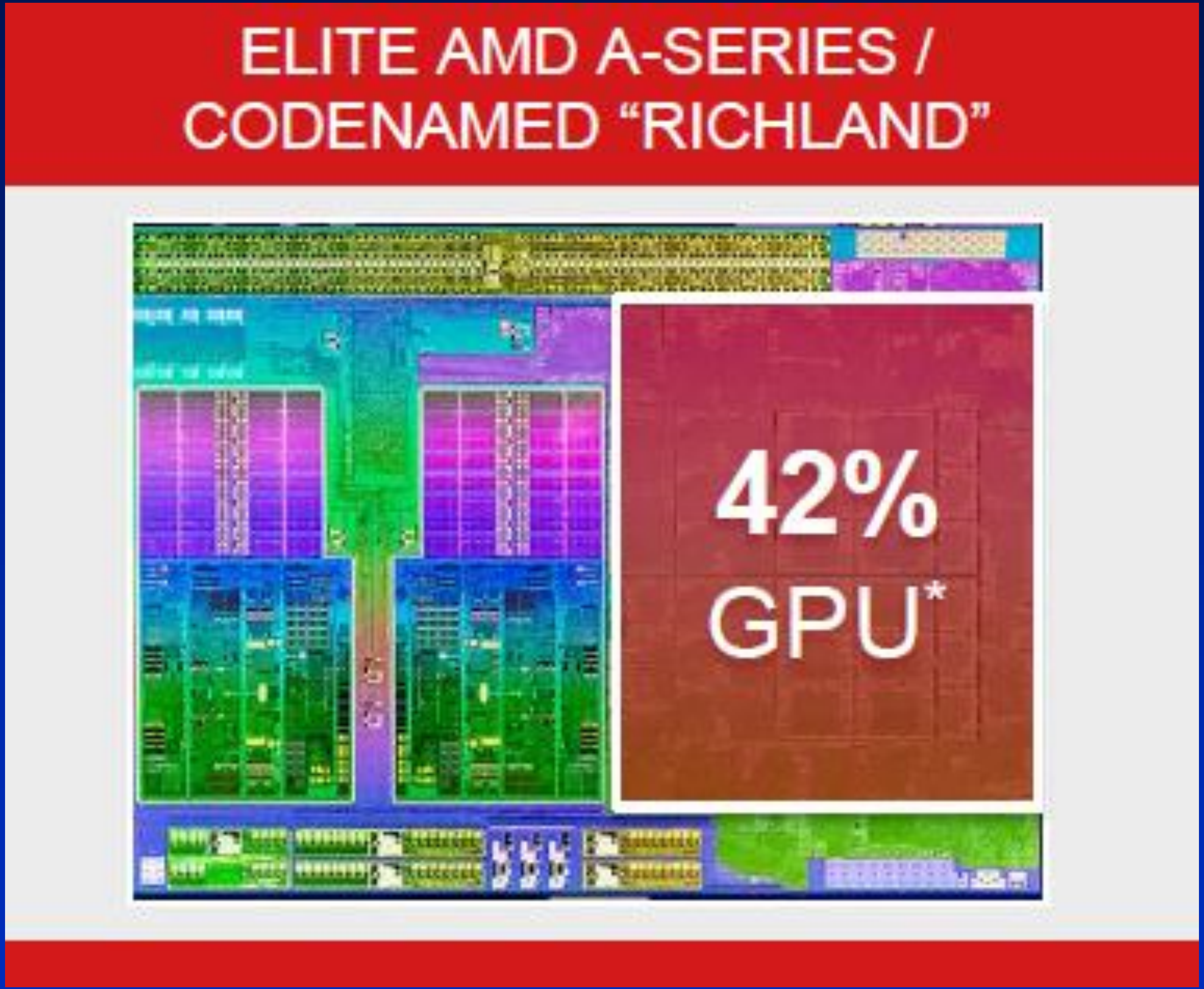
nVidia iray® 2012

- nVidia has designed a series of rackable Tesla servers for very fast computation using parallel sets of their GPU hardware
- They developed a novel programming language (CUDA) to take advantage of their unique hardware architectures. This can be used for many other disciplines
- They now offer a product called Iray which computes photorealistic imagery on a cloud

Intel – Integrated Graphics 2013

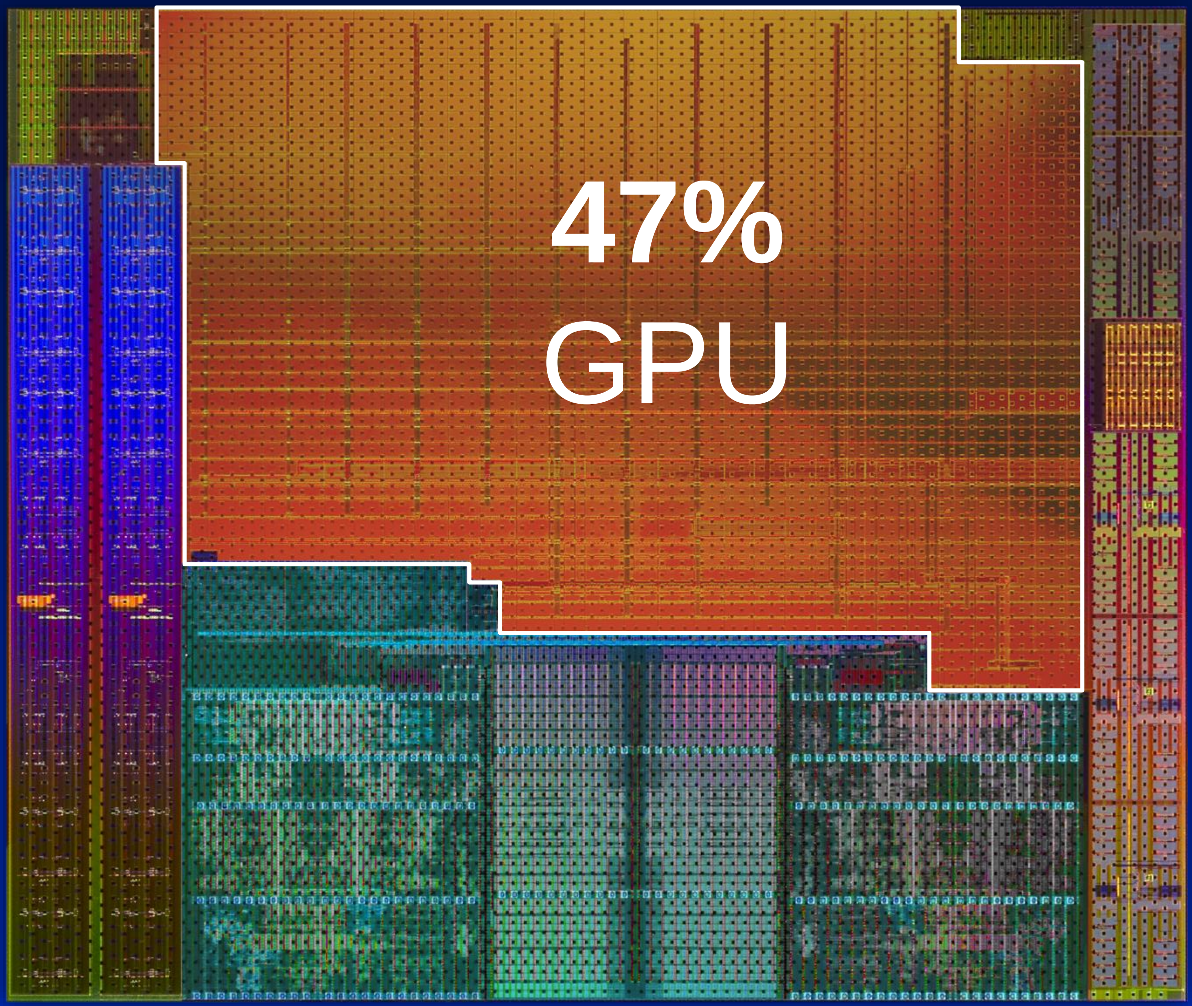


AMD – Integrated Graphics 2013



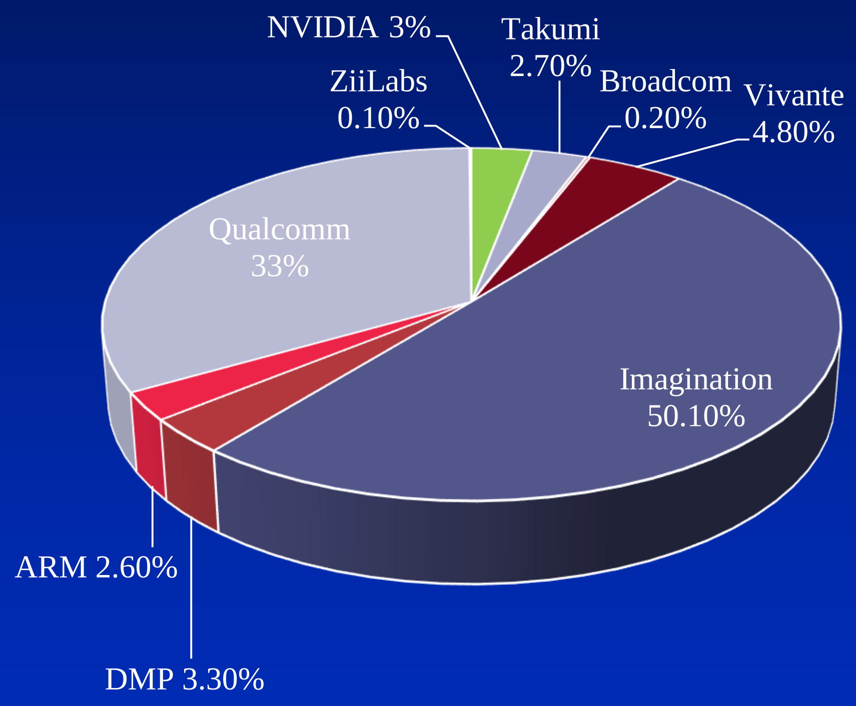
AMD – Integrated Graphics 2014

- "Kaveri"
- 28 nm
- 47% GPU

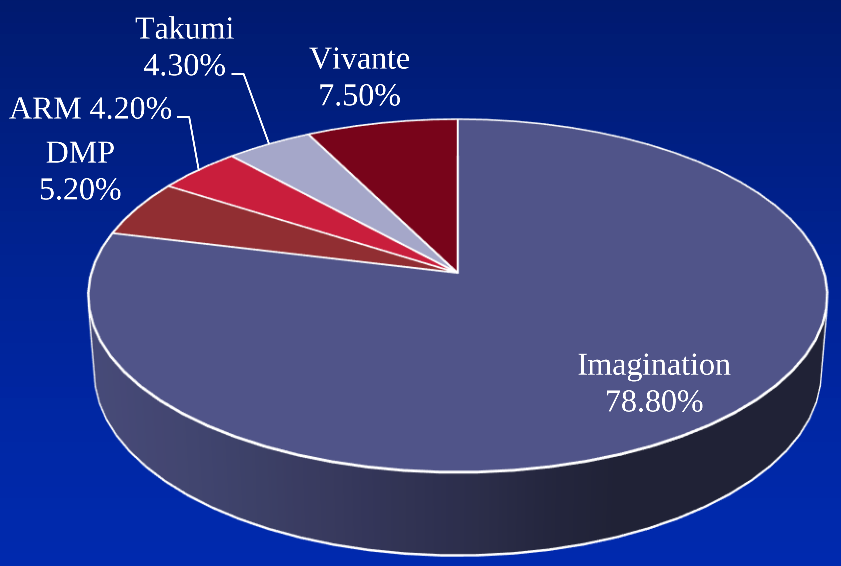


Mobile GPU market share 2013

All GPU Suppliers



All GPU IP Suppliers



Source: Imagination Technologies, via http://technewspedia.com/imagination-technologies-nvidia-we-do-not-compete-against-our-customers/

End. . .