Computer Graphics
Software & Hardware

NBA 6120

Lecture 7

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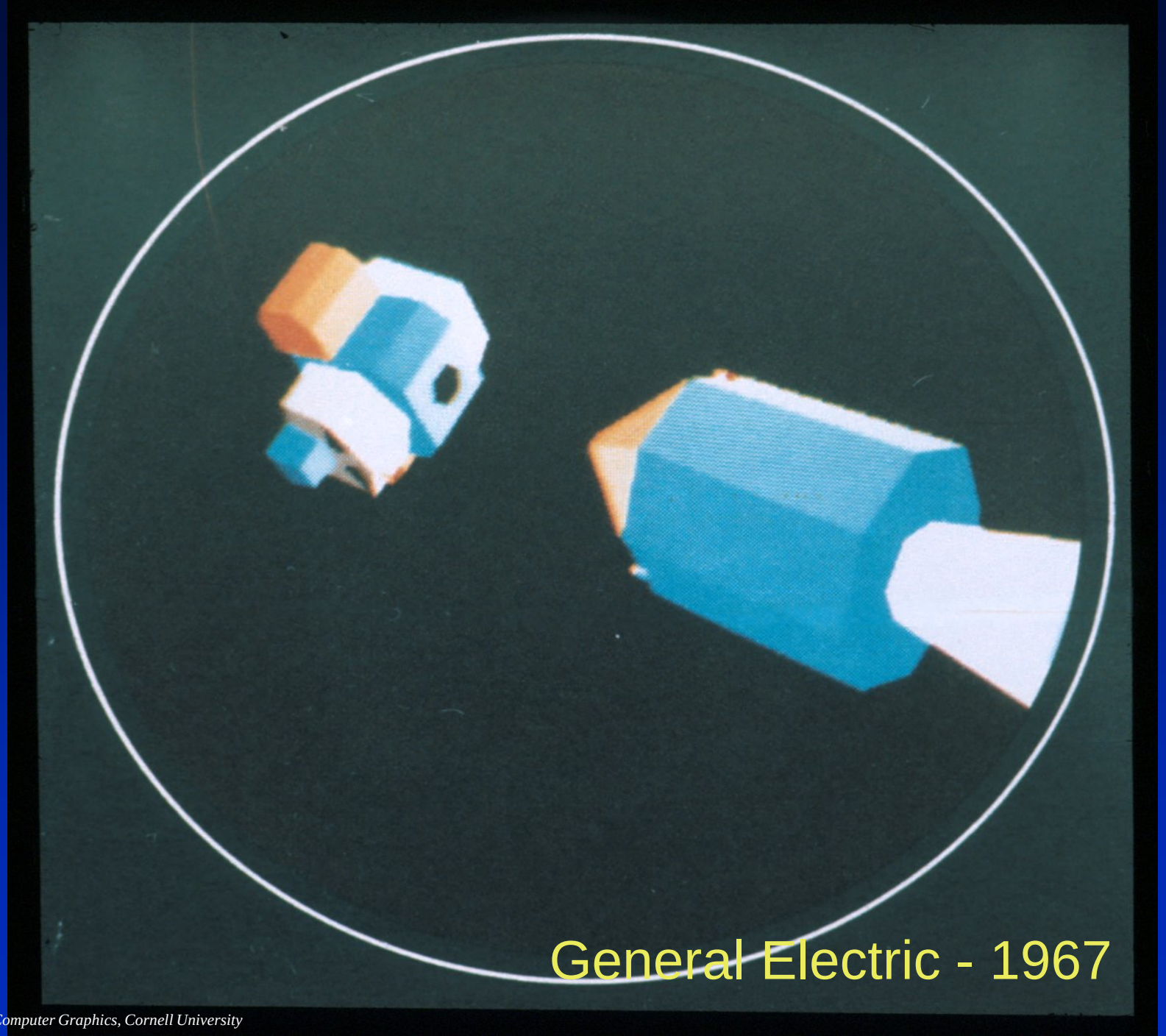
September 16, 2015

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



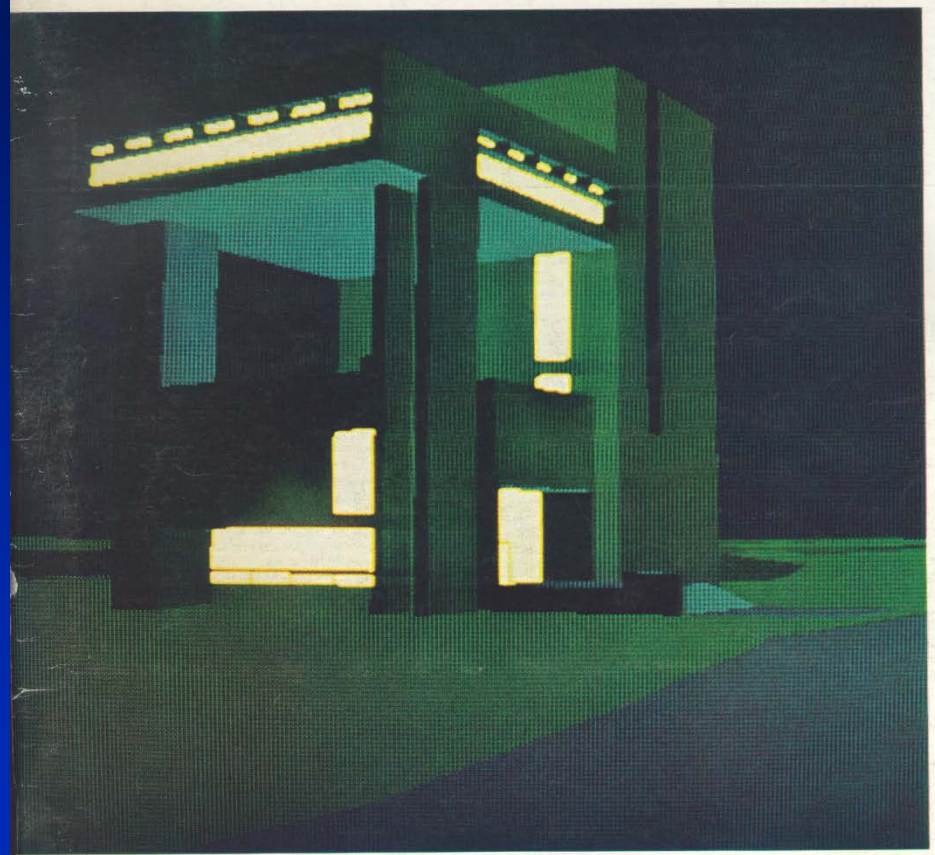
Program of Computer Graphics, Cornell University

Program of Computer Graphics, Cornell University

Cornell in Perspective Film 1972

Program of Computer Graphics, Cornell University

SCIENTIFIC AMERICAN

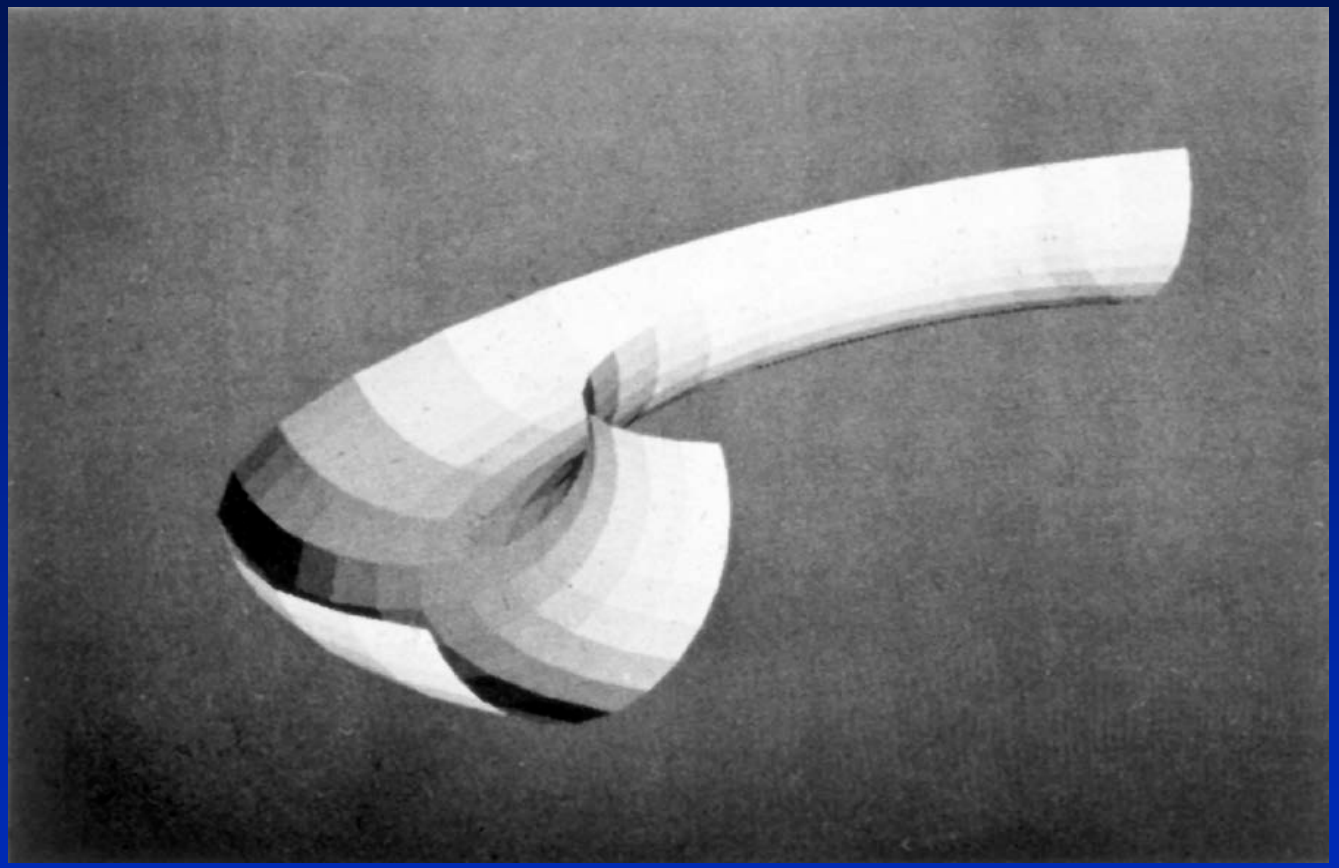


COMPUTER GRAPHICS IN ARCHITECTURE

ONE DOLLAR

May 1974

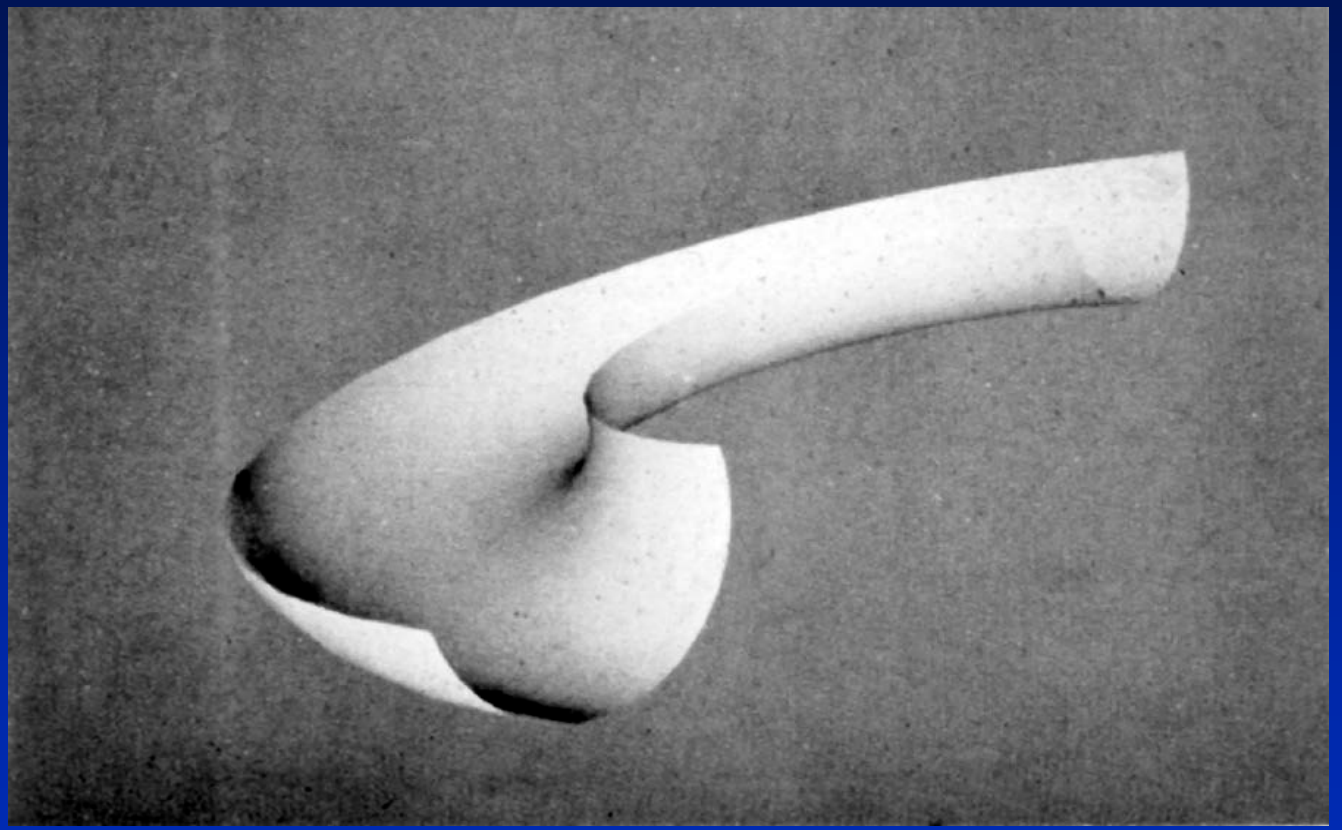
Gouraud Flat Polygon Shading 1972



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

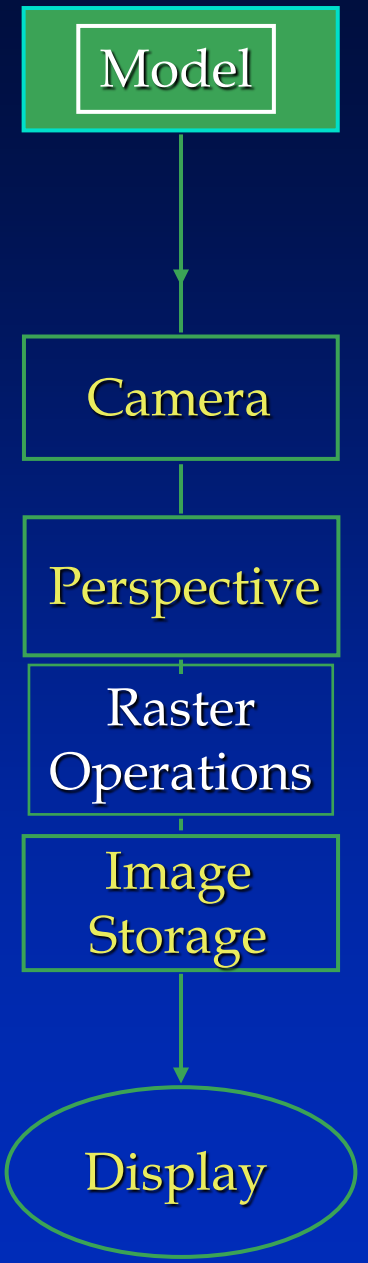
  >(Cost, strength, thermal properties)

- Lighting

  Geometry & position

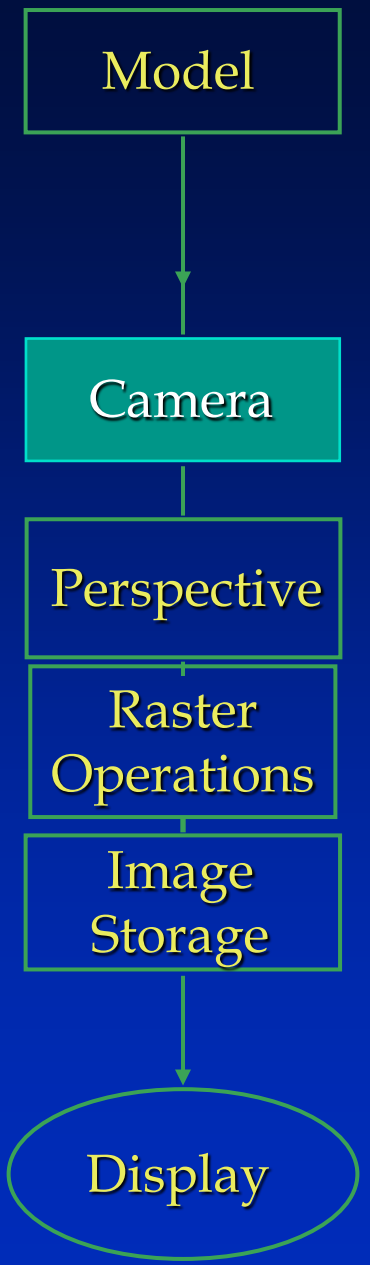
  Intensity, spectral distribution

  Direction, spatial distribution



Camera

- Viewer Position
- Viewer direction
- Field of view
  - Wide angle
  - Telephoto
- Depth of focus
  - Near
  - Far



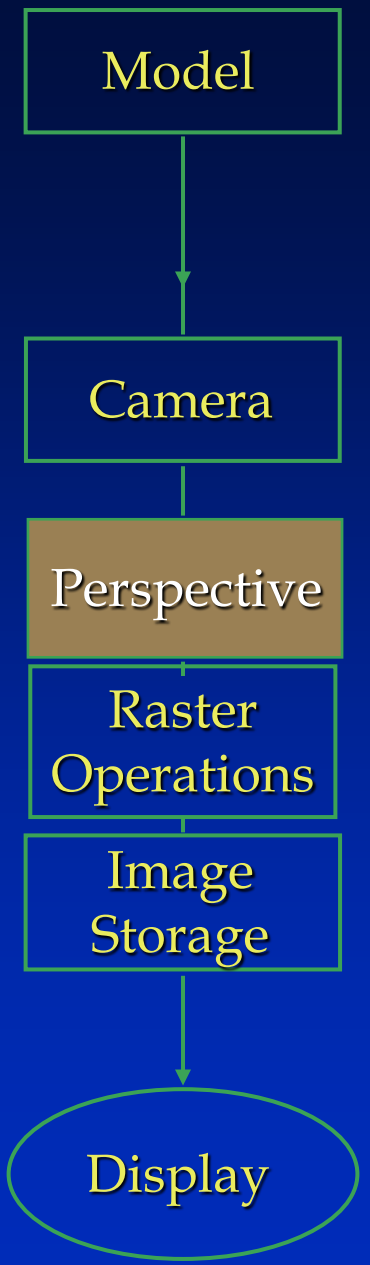
Perspective Transformation

- Perspective transformation

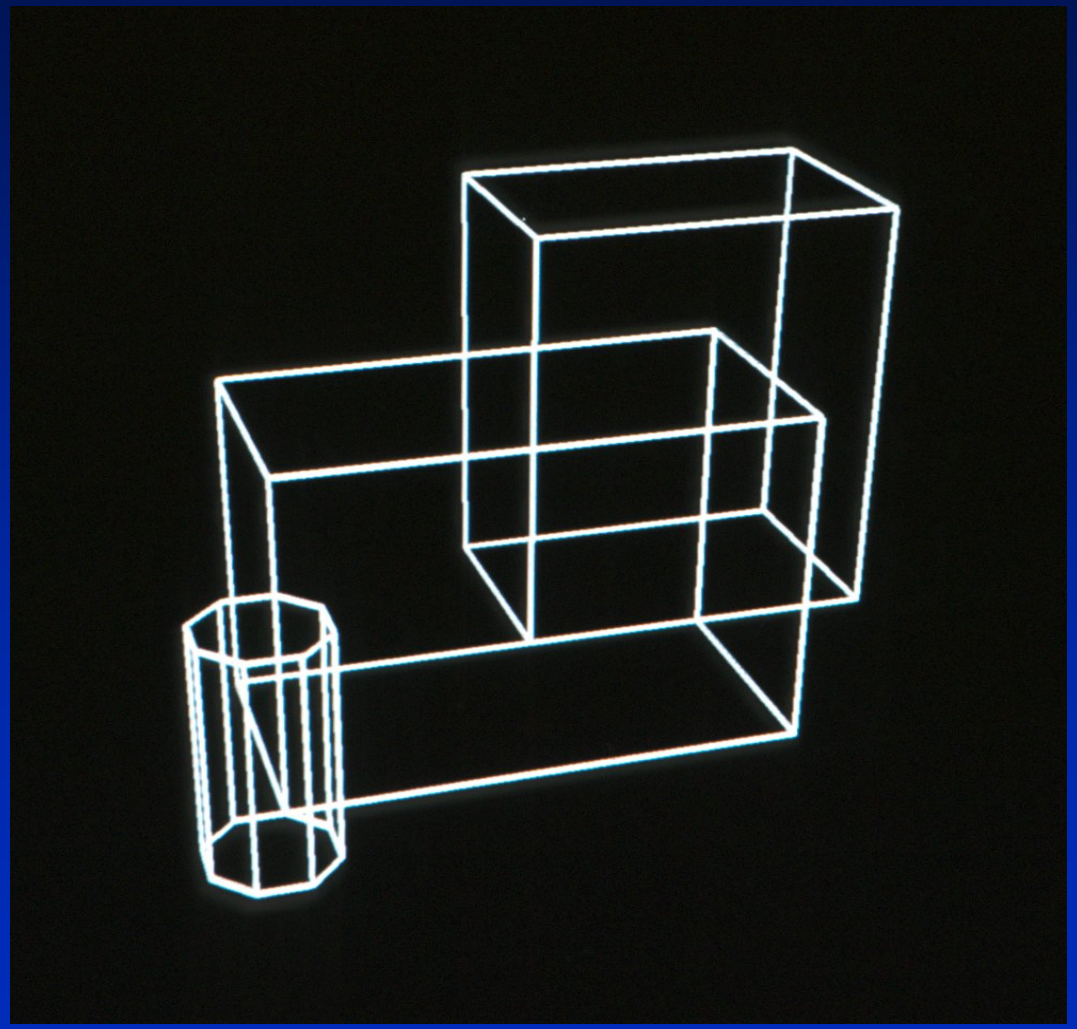
  Matrix multiplication (4 x 4)

- Clipping objects outside of the field of view

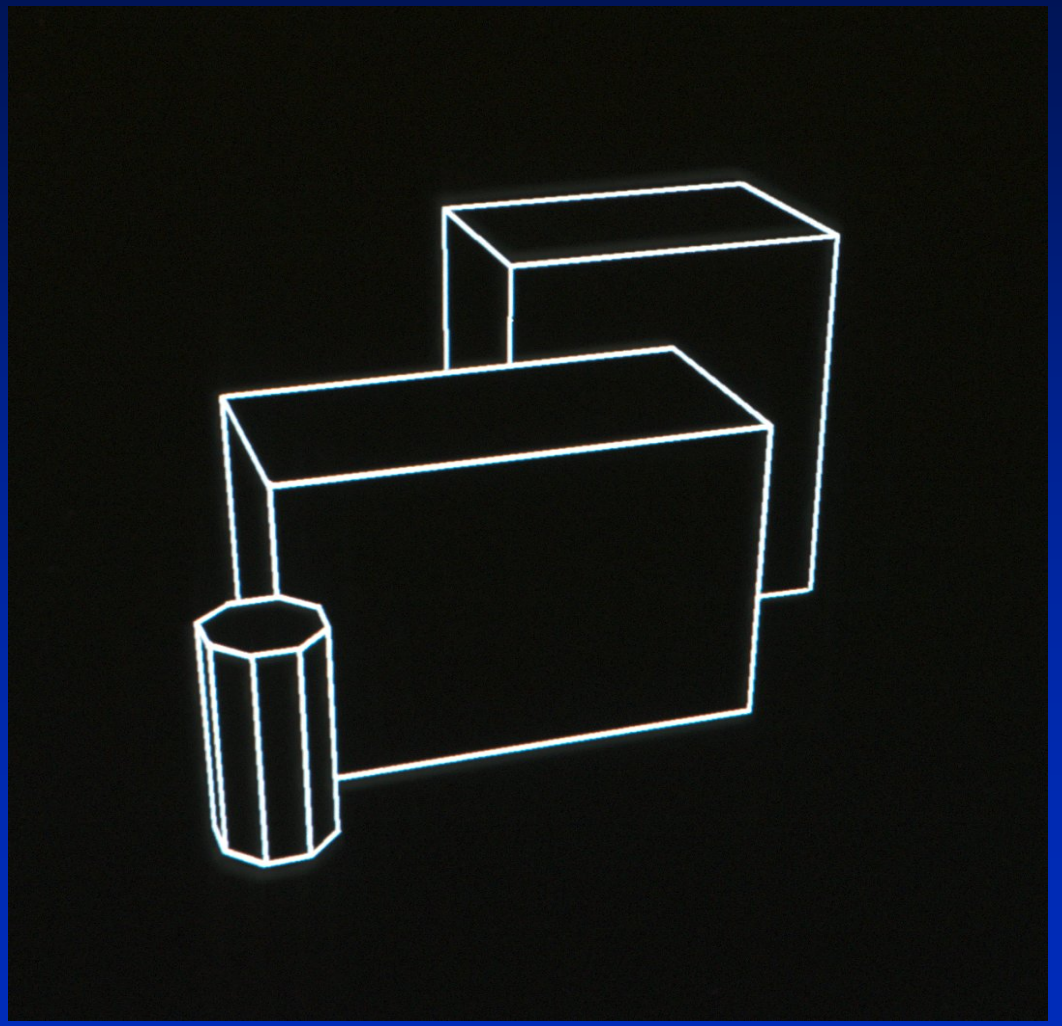
- Culling back-facing surfaces



Hidden Line Algorithm



Hidden Line Algorithm



Raster Operations

- Conversion from polygons to pixels

  Color computation
- Hidden surface removal (z-buffer)

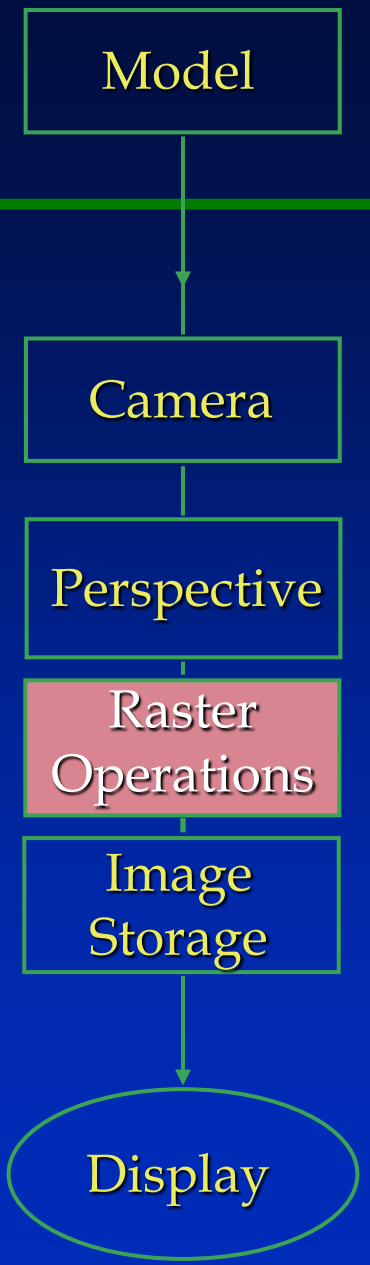
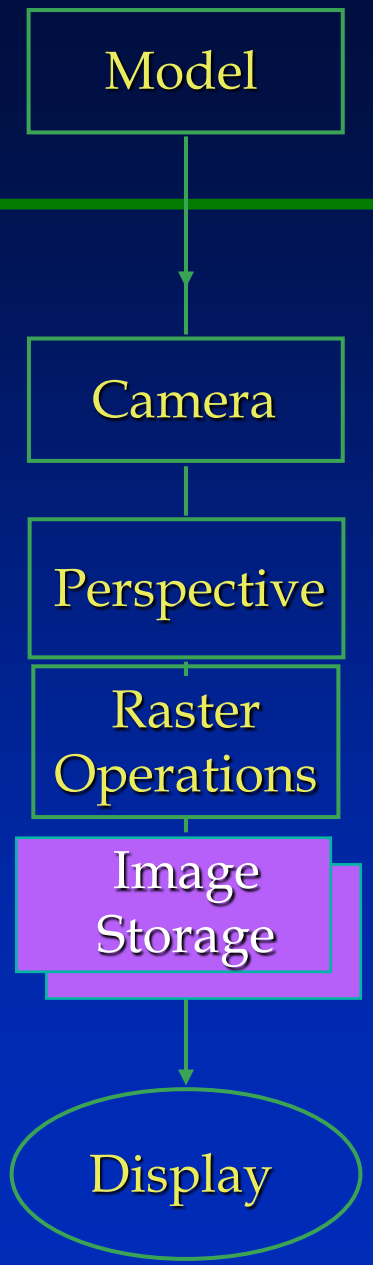


Image Storage

- 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

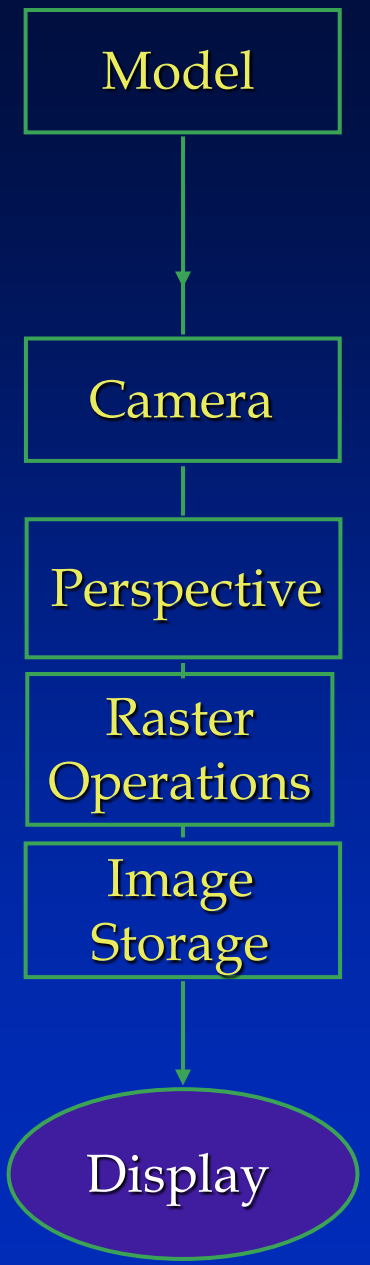
  1 1/4 million pixels

  x 3 bytes/pixel

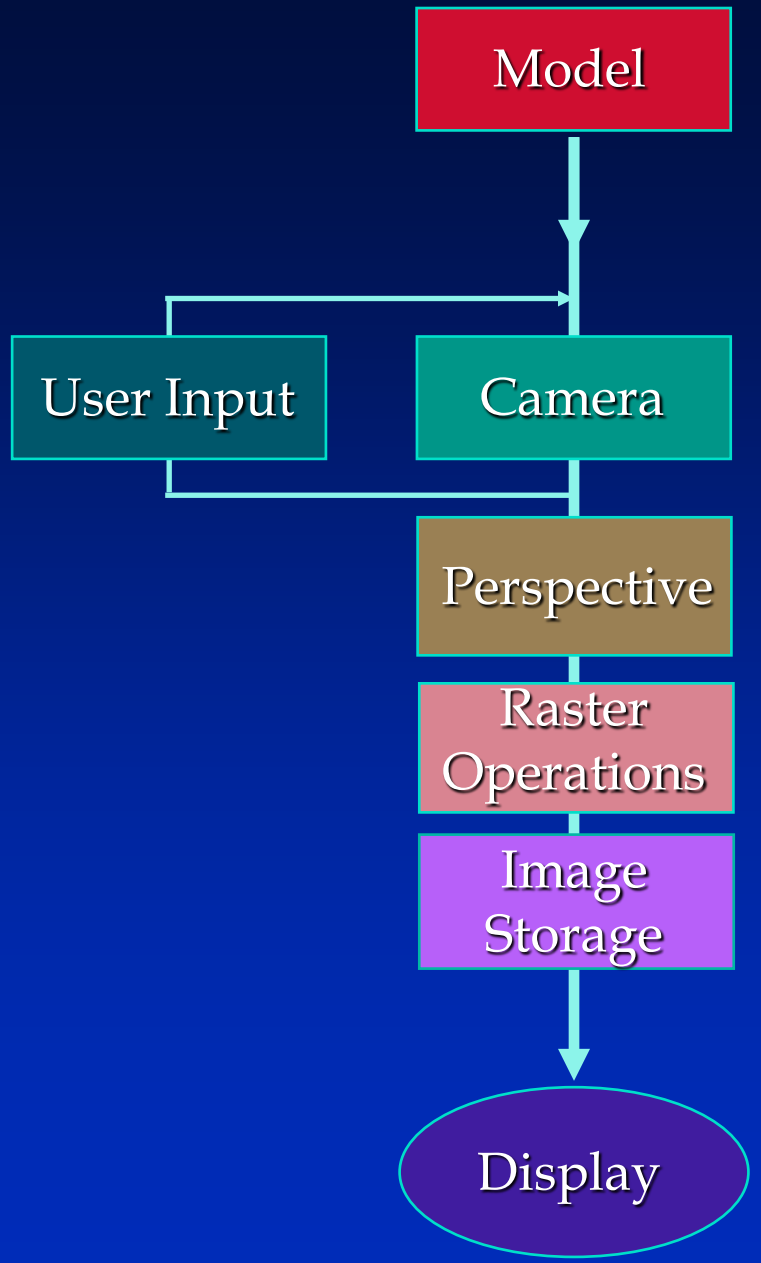
  x 60 frames/second

  = 225 megabytes/second

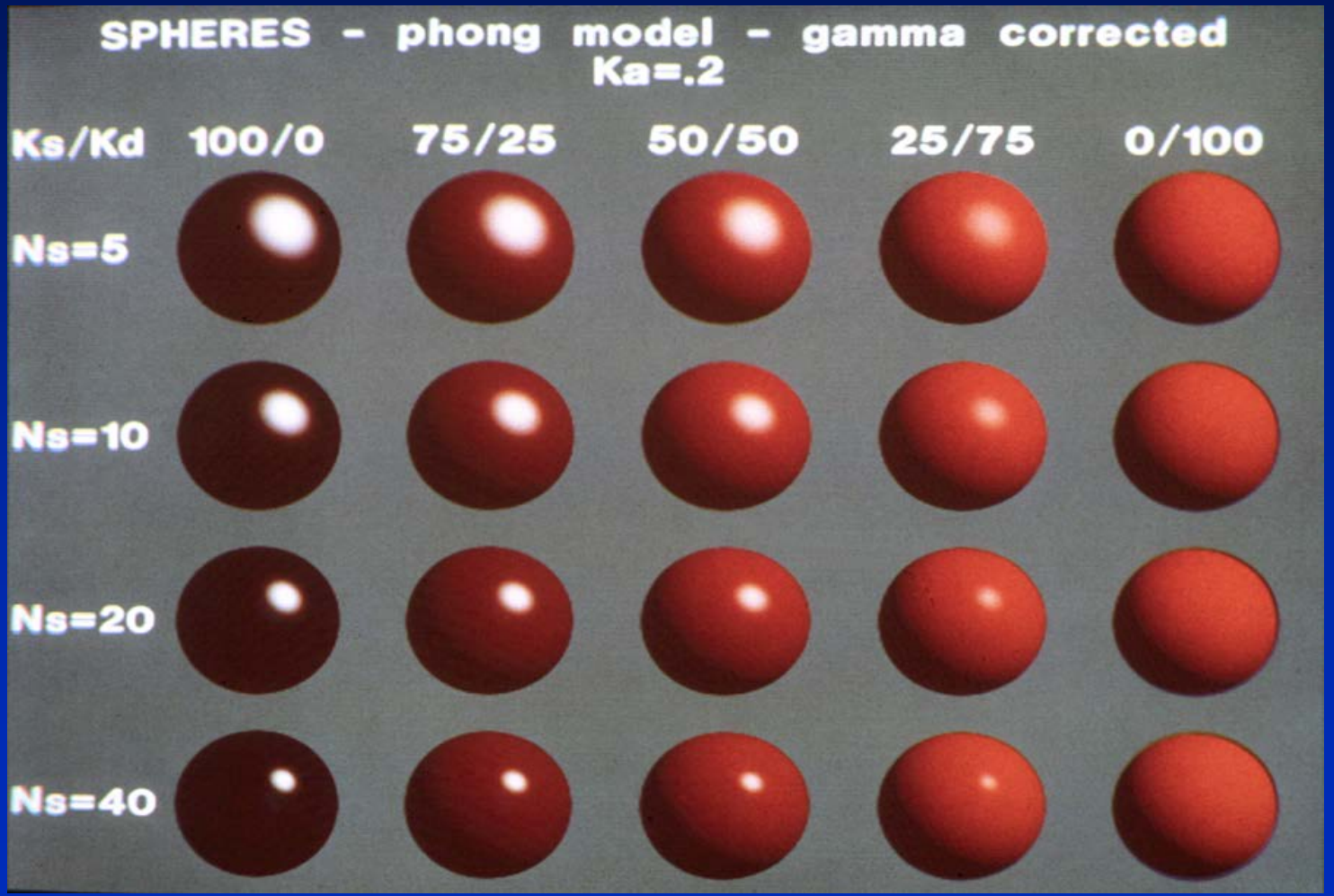
  = 1.8 gigabits/second



Direct Illumination



Phong Model: Variations of Specular Exponent



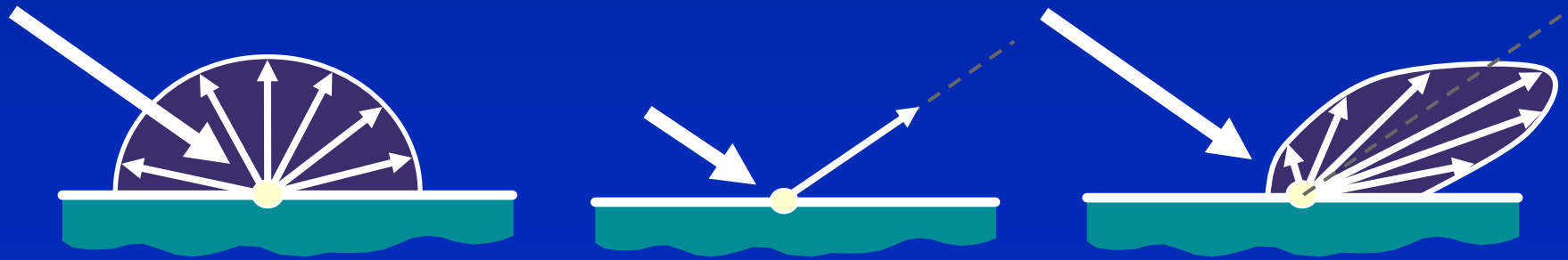
Roy Hall

Reflectance Three Approximate Components

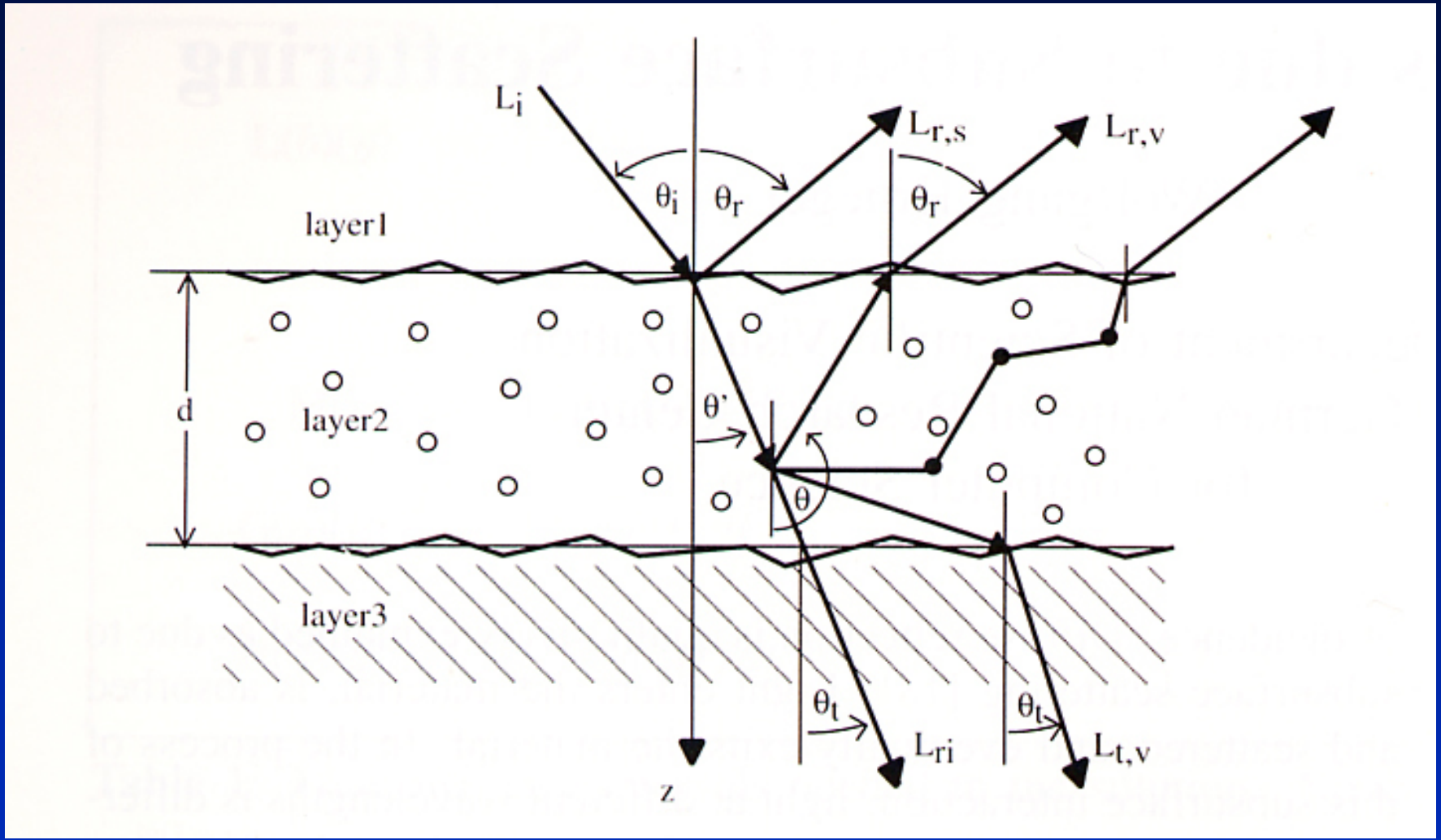
Ideal diffuse (Lambertian)

Ideal specular

Directional diffuse



Cook-Torrance Renderings 1979

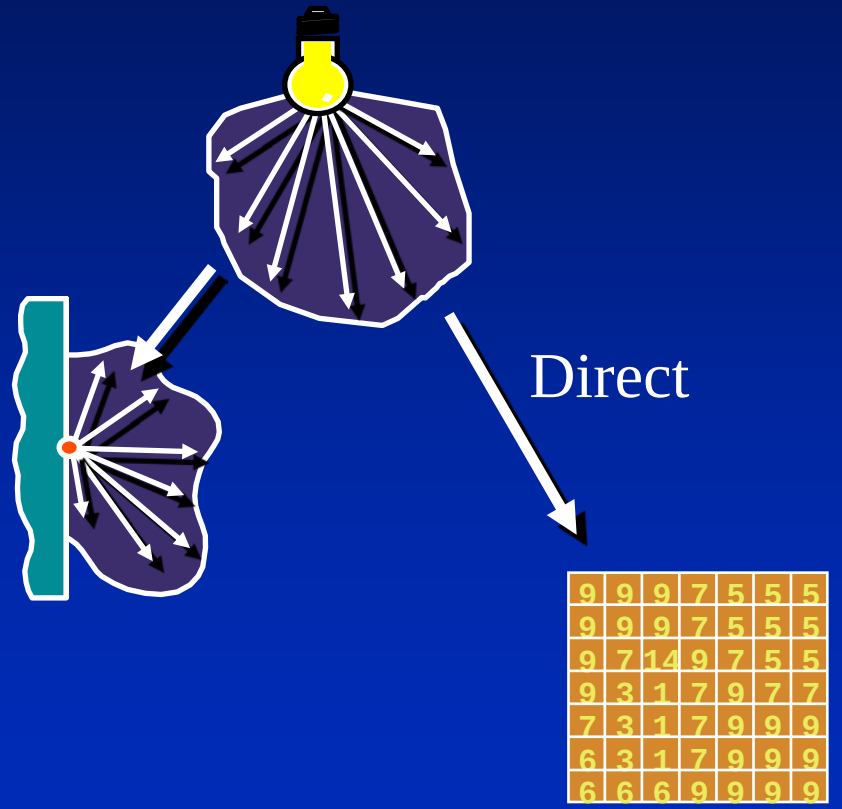


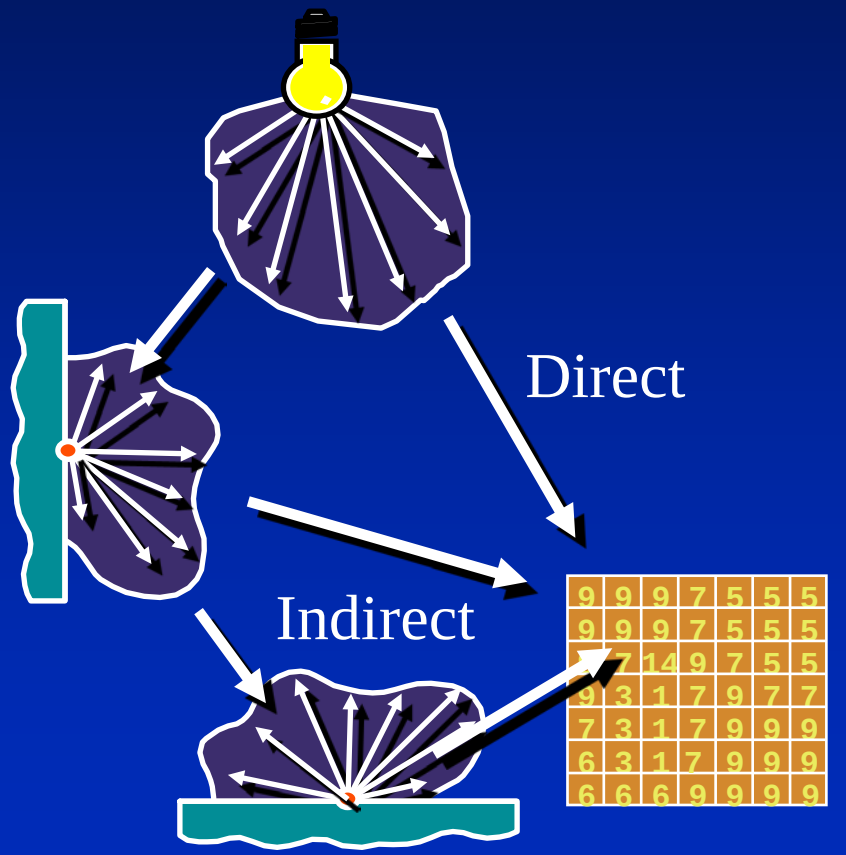
The geometry of scattering from a layered surface

acm Computer Graphics, Siggraph 1993 p. 166

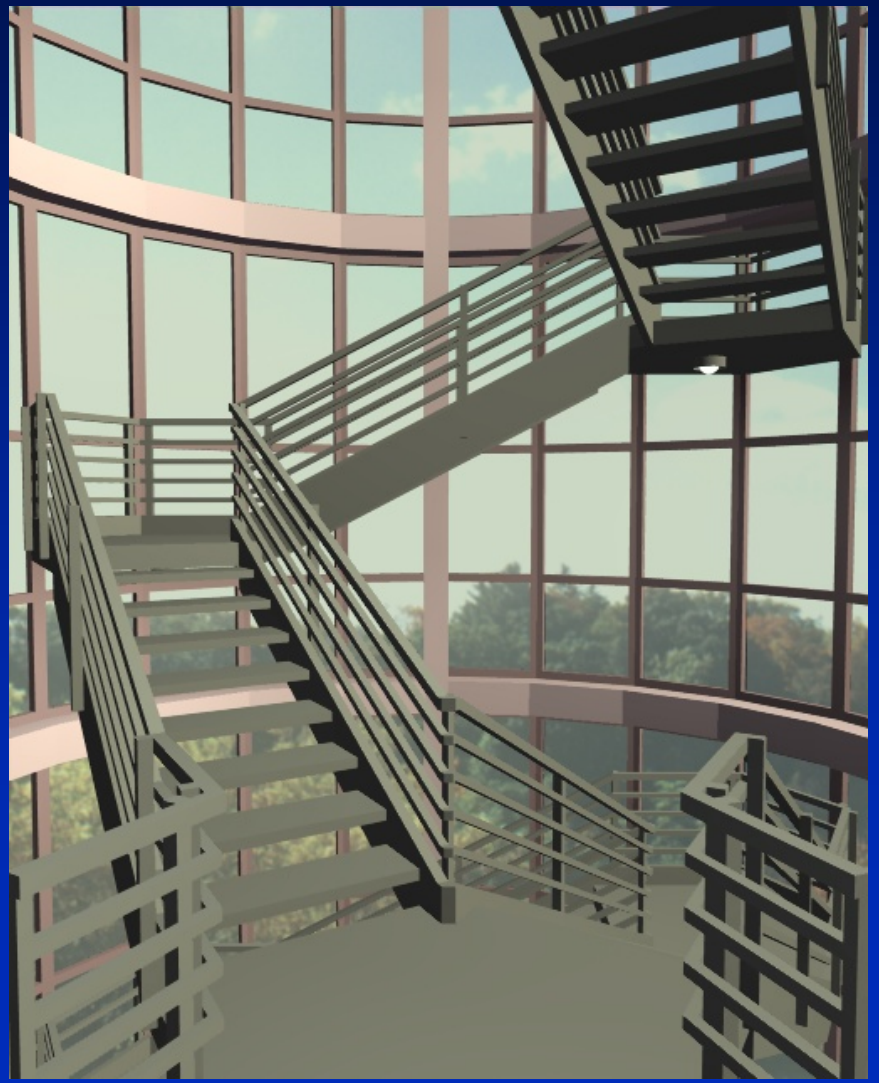
Henrik Wann Jensen, Stephen R. Marschner, Marc Levoy, Pat Hanrahan. “A Practical Model for Subsurface Light Transport,” ACM Siggraph 2001, August 2001, Los Angeles, CA, pp. 511-518.

Direct Lighting and Indirect Lighting





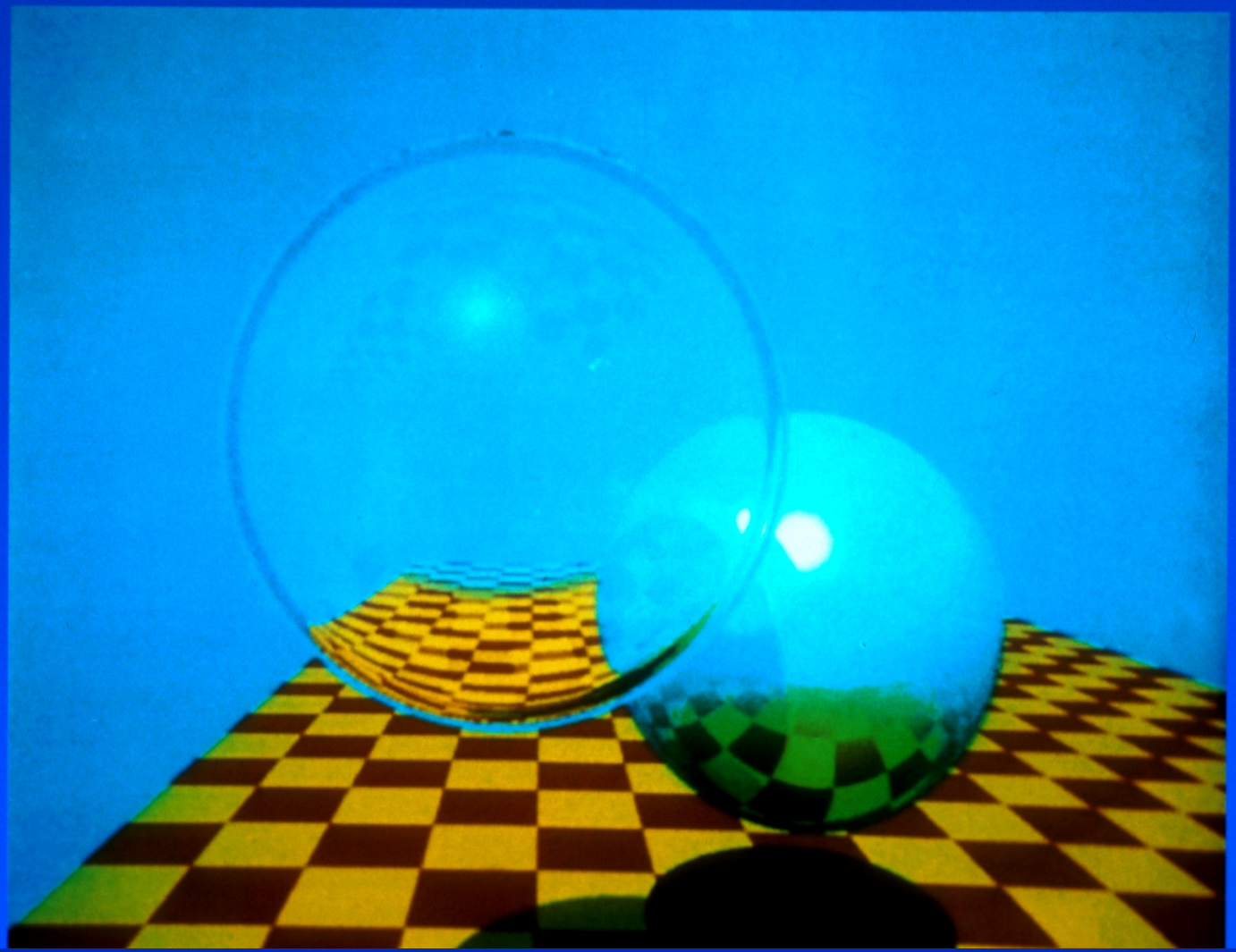
Direct Lighting Only



Global Illumination

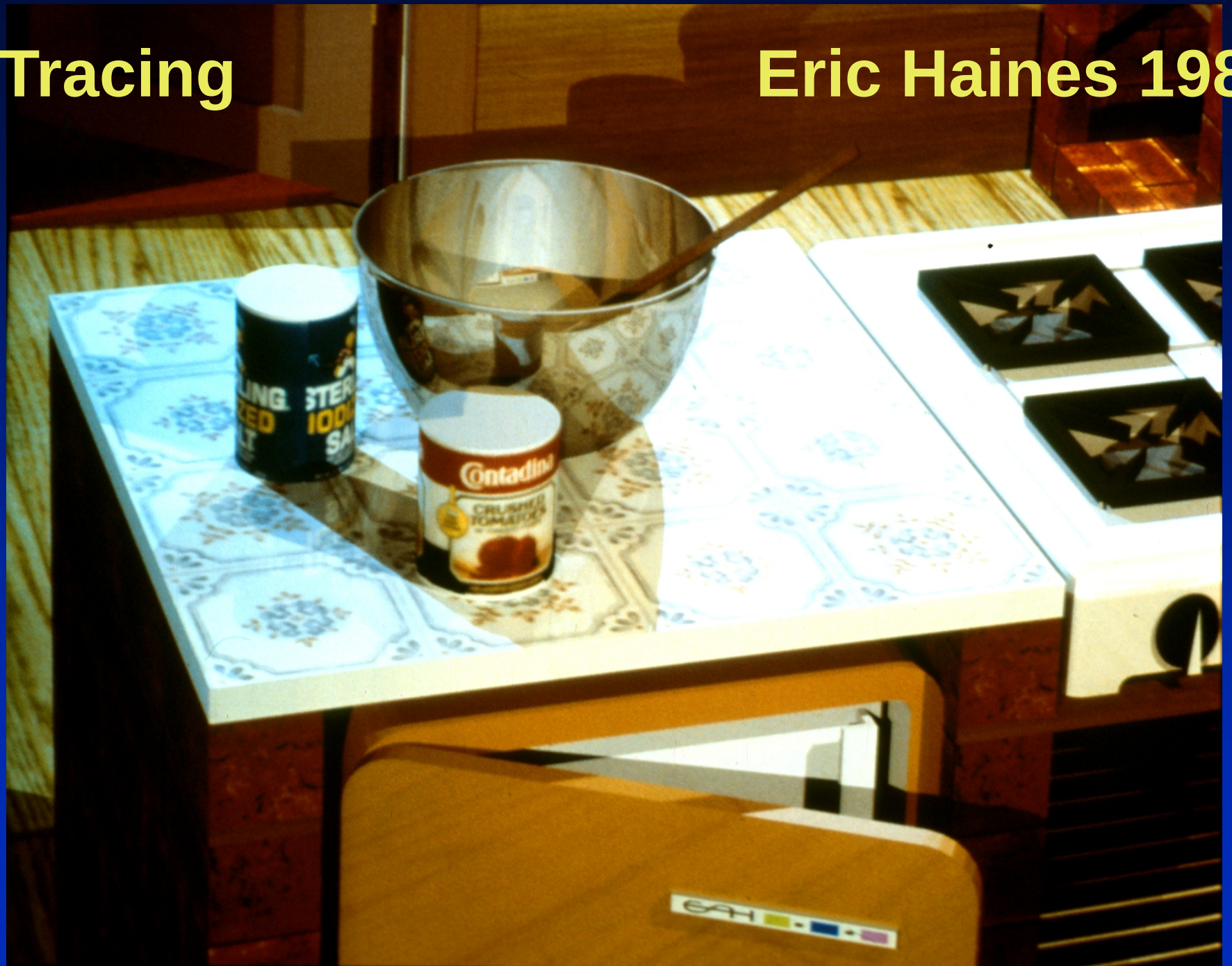
Ray Tracing

Turner Whitted, 1979

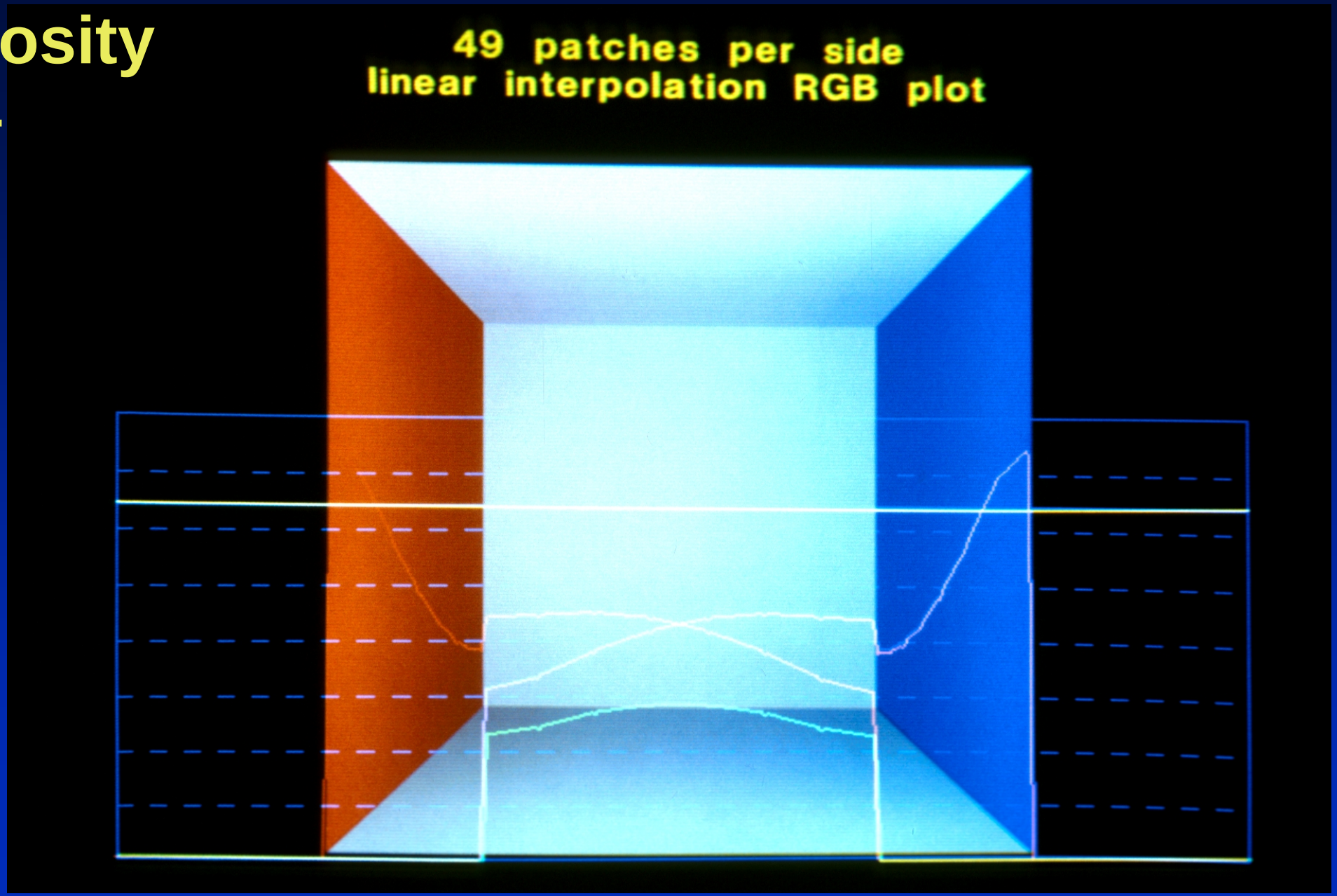


Ray Tracing

Eric Haines 1985



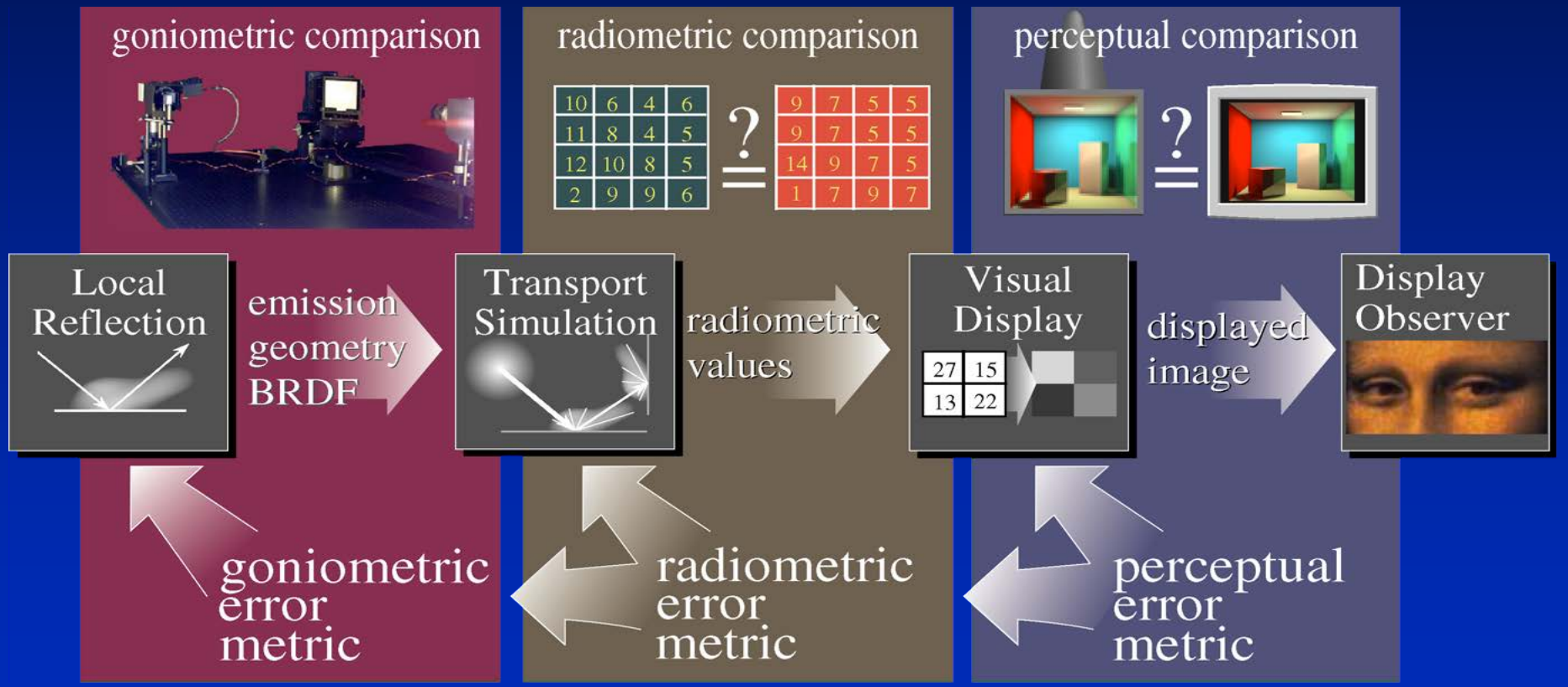
Radiosity
1984




Radiosity
Eric Chen 1986

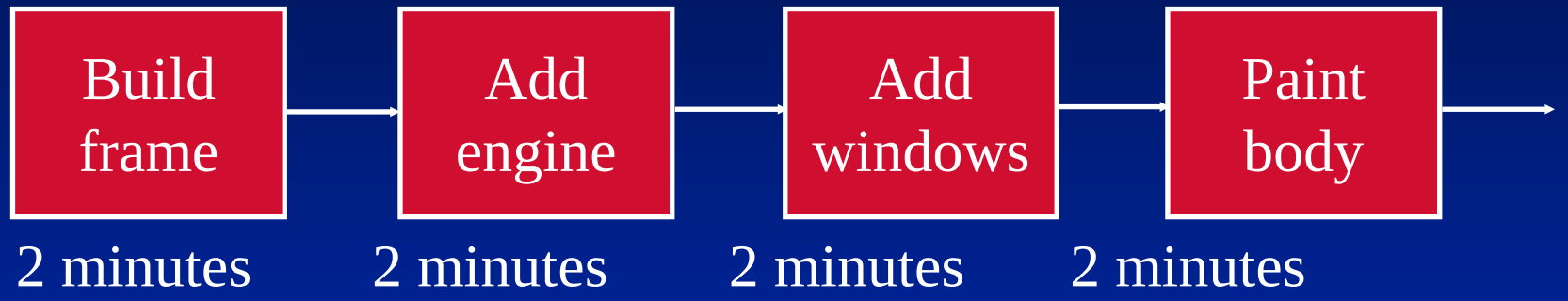
Radiosity
1990s

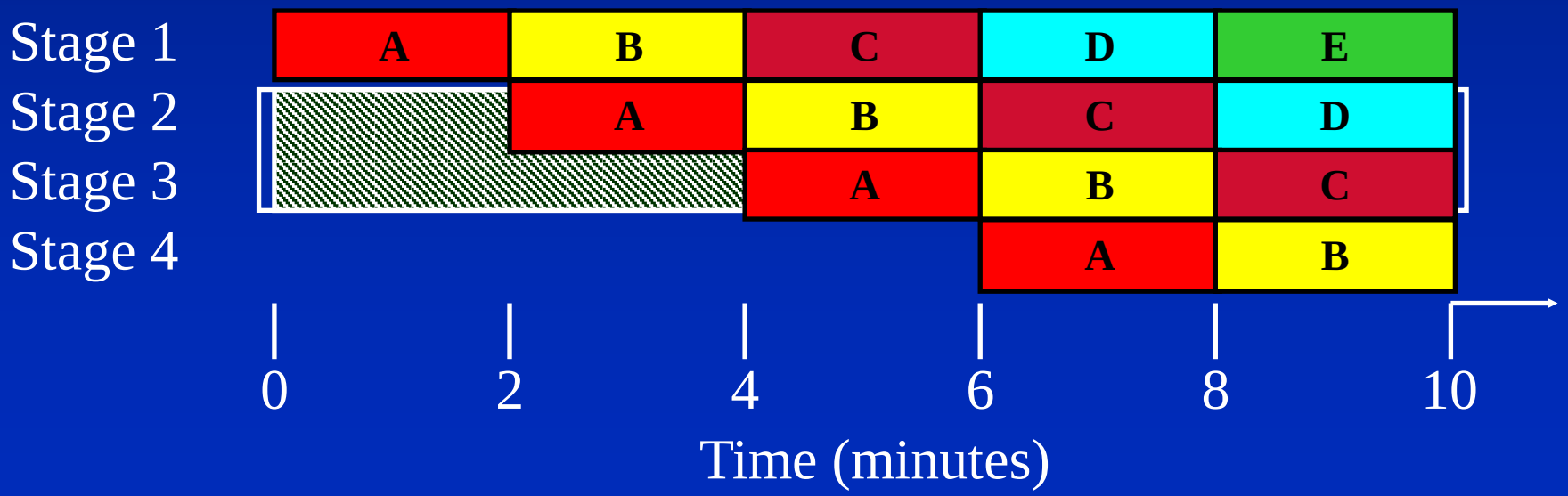
Rendering Framework 1997



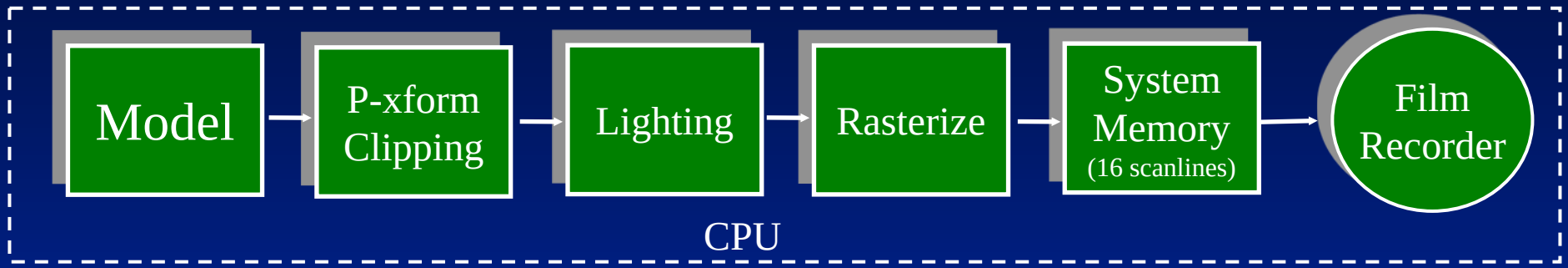
Example: Automobile Pipeline

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





Graphics Hardware circa 1970



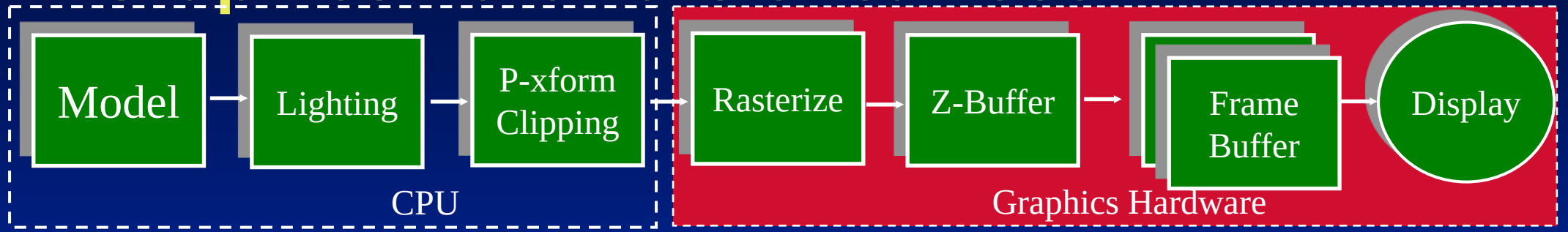
- System used to generate Phong goblet

Graphics Hardware circa 1980

Cost of Memory was Prohibitive

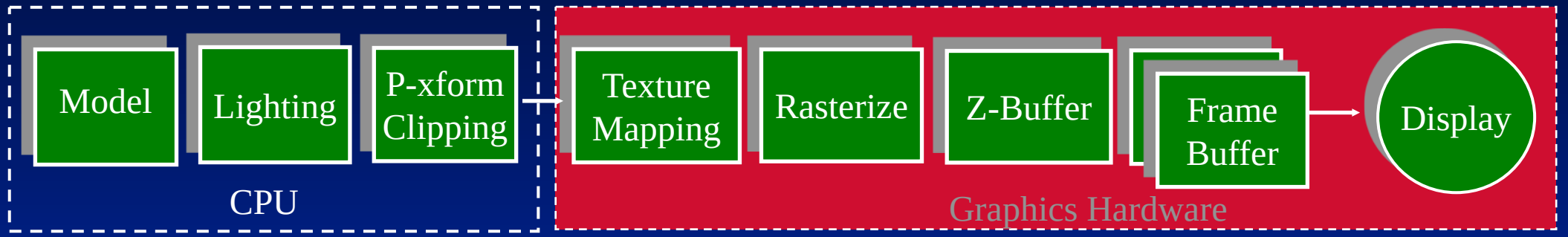
- 512x480x8 bit frame buffer cost $80,000!
- No z-buffer (at 24 or 32 bits/pixel, it requires even more memory than FB)
- Only single frame buffer
- All work done in CPU until frame buffer(slow!)

Graphics Hardware circa 1986



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

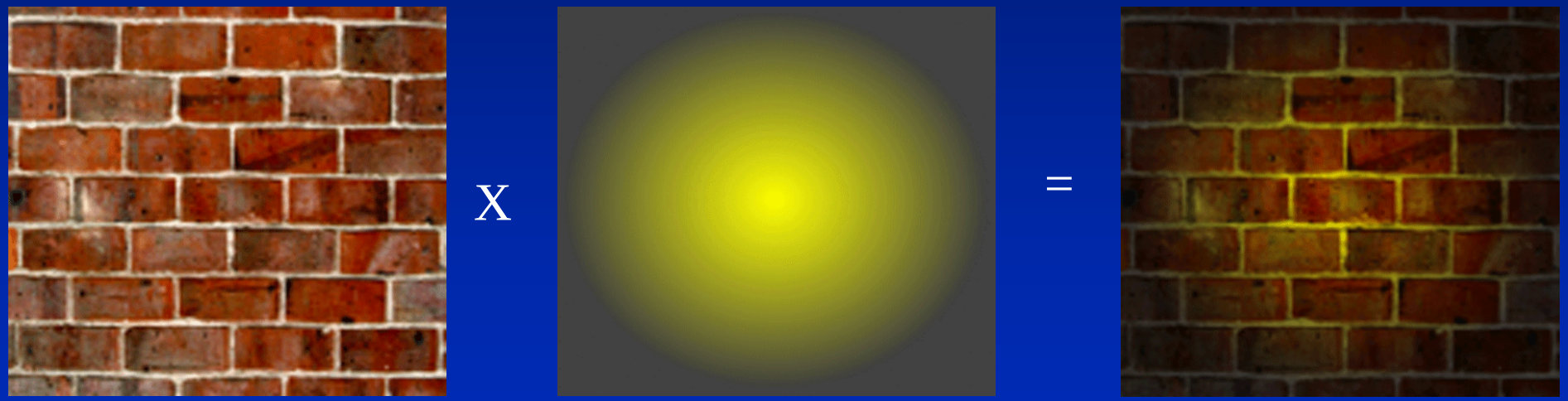
Graphics Hardware 1999



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

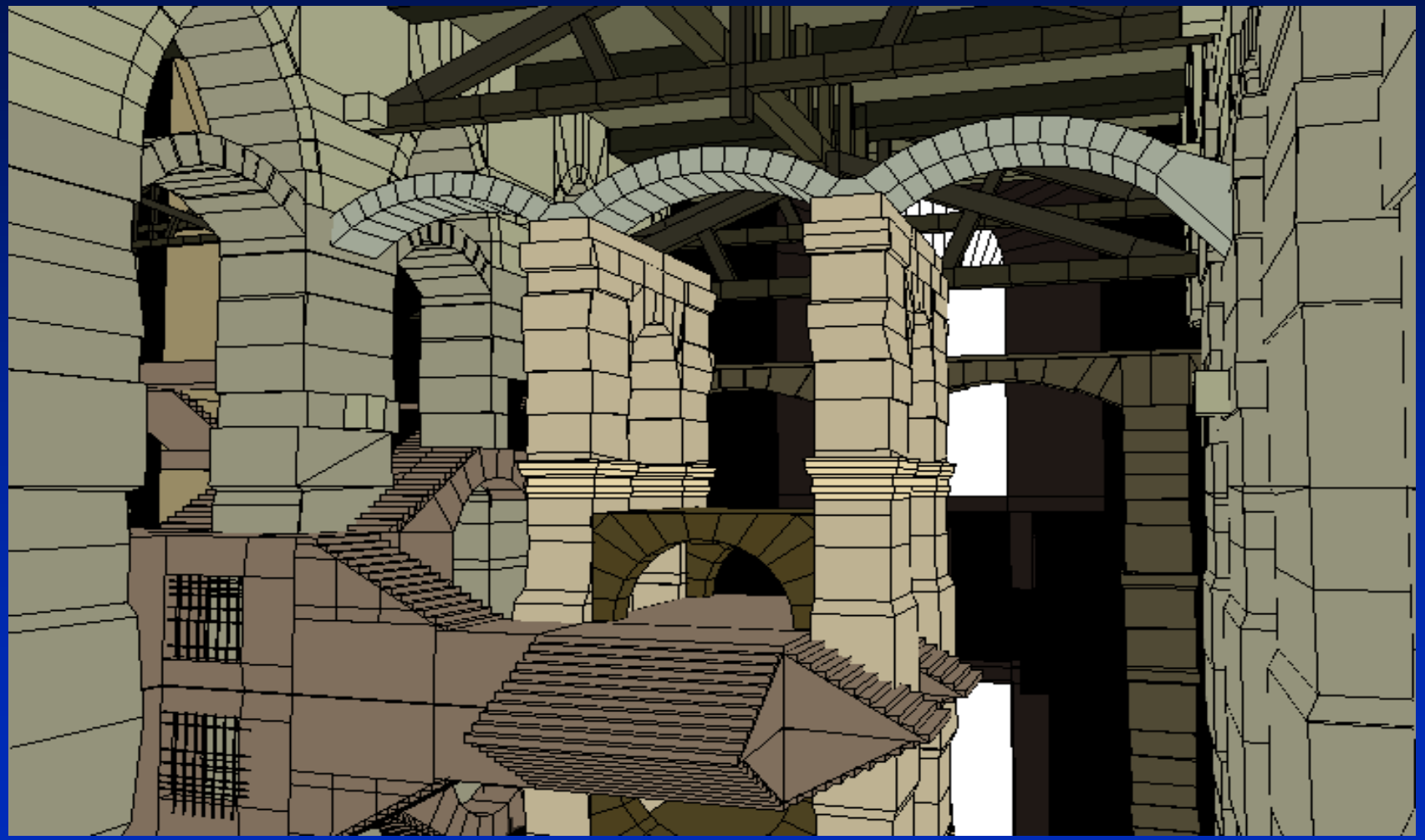
Multipass Example: Light Maps

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



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

Castle’s Geometry

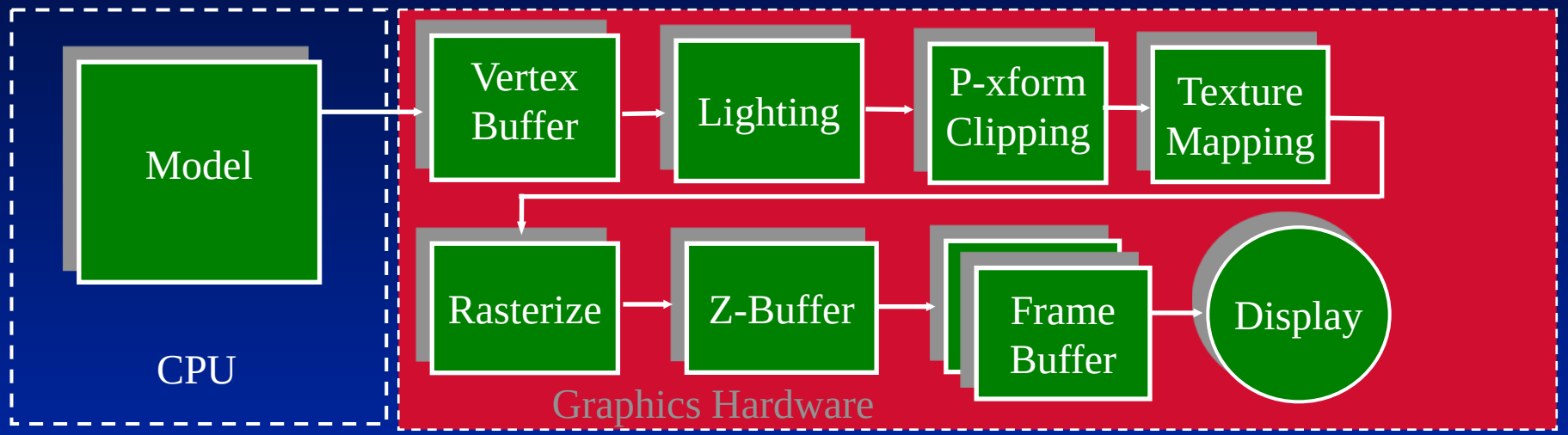


Agata & Andrzej Wojaczek, Advanced Graphics Applications Inc.

Reflection Example - Castle

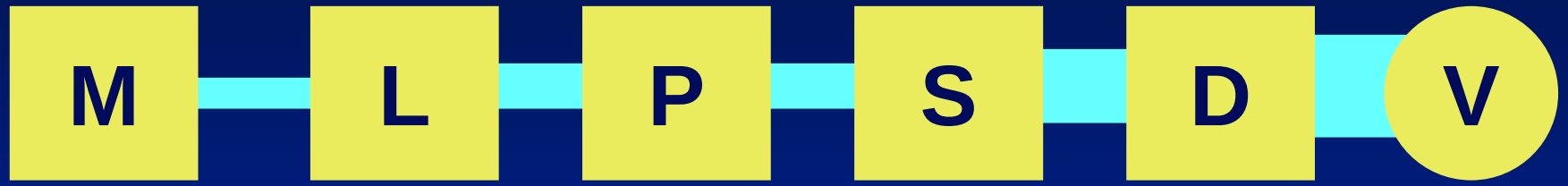
Agata & Andrzej Wojaczek, Advanced Graphics Applications Inc.

Graphics Hardware 2000



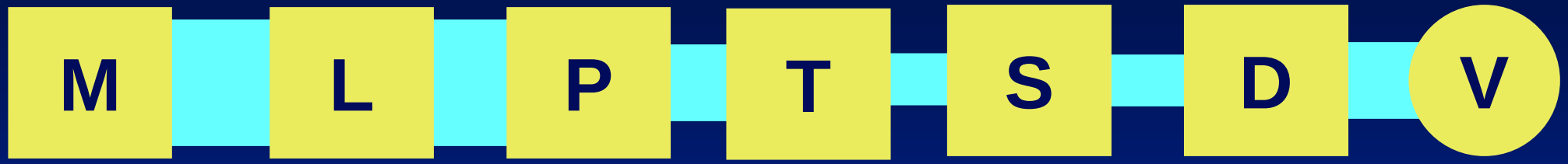
- Vertex buffer (model data) added to reduce bandwidth requirements between CPU and graphics board

Graphics Pipeline - 1980's



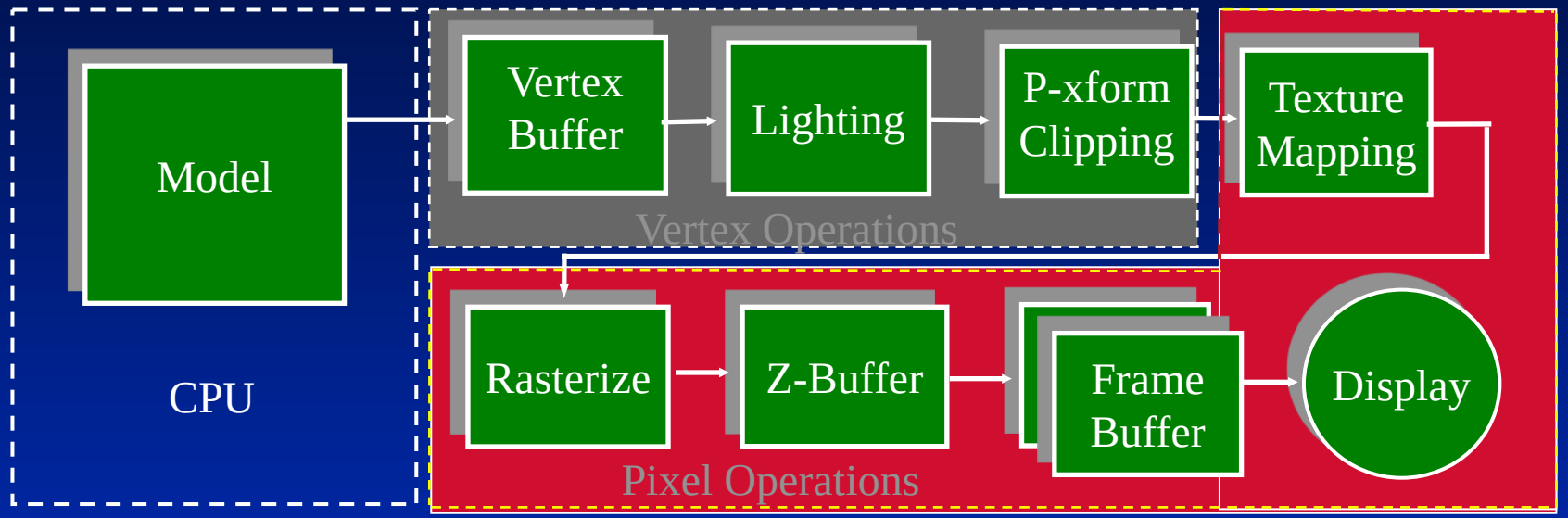
M — Model
L — Lighting
P — Perspective/Clipping
S — Scan Conversion/Z-buffer
D — Display Storage
V — Video

Graphics Pipeline - 2000 +



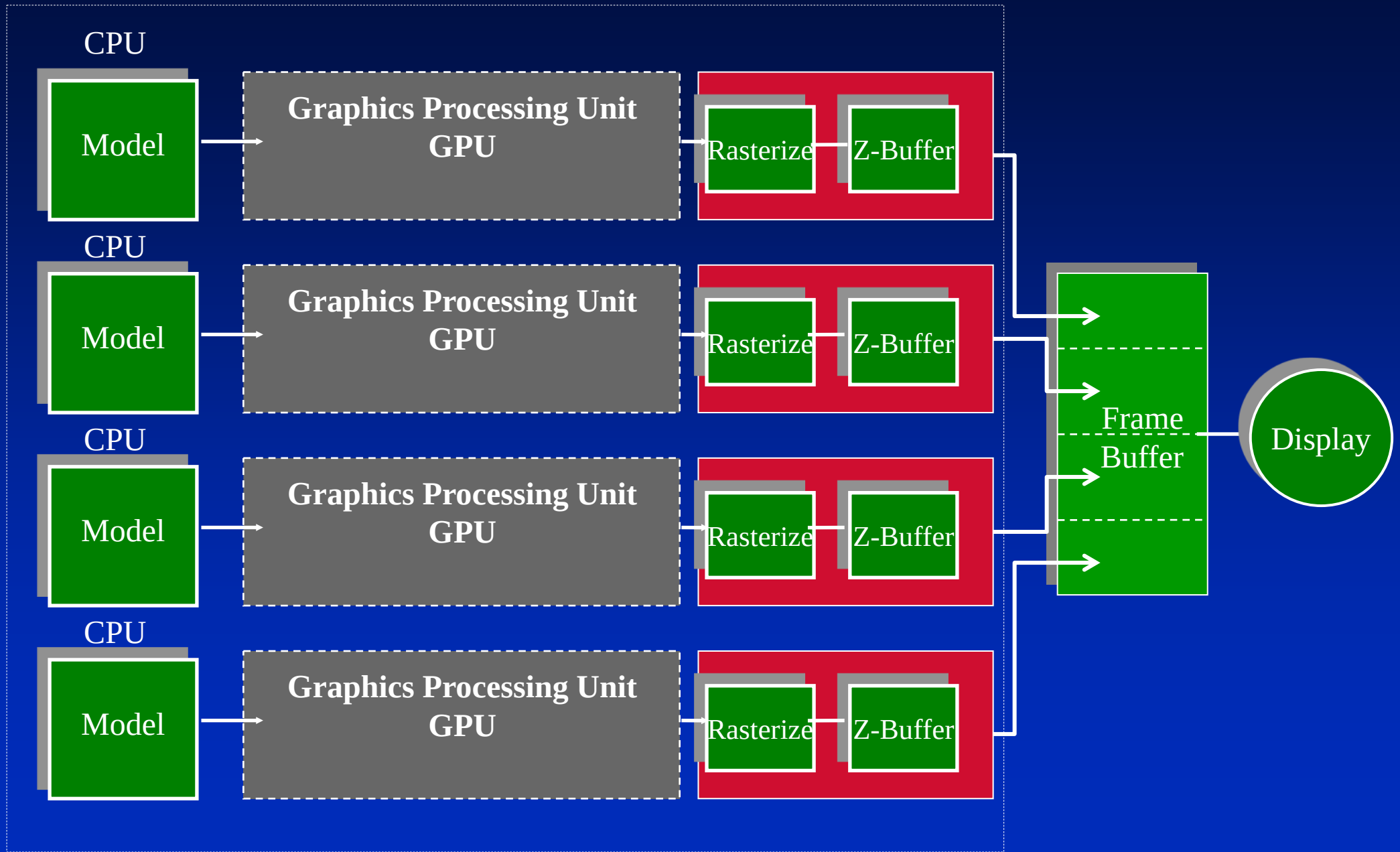
M — Model
L — Lighting
P — Perspective/Clipping
T — Texturing
S — Scan Conversion/Z-buffer
D — Display Storage
V — Video

Graphics Hardware 2003

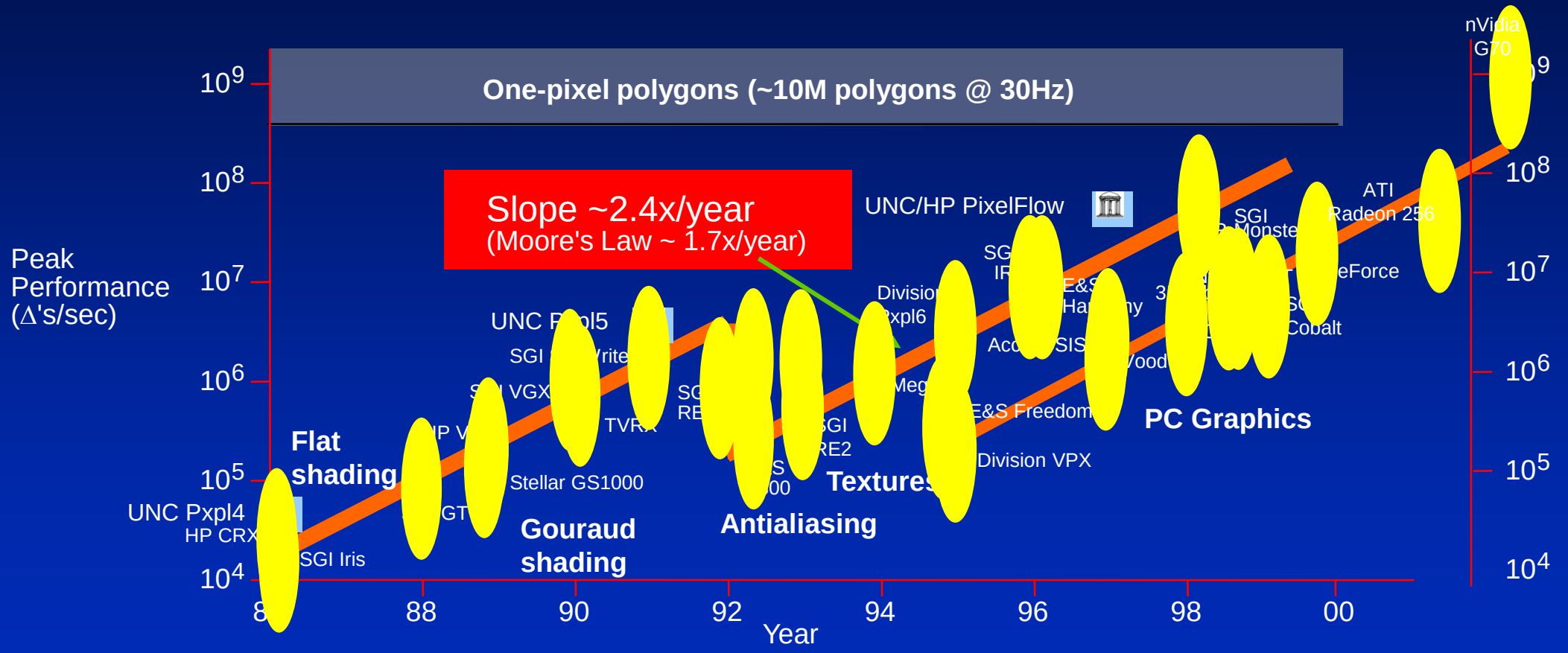


- Early GPU's performed lighting and clipping operations on locally stored model

Graphics Hardware 2009



Faster than Moore's Law

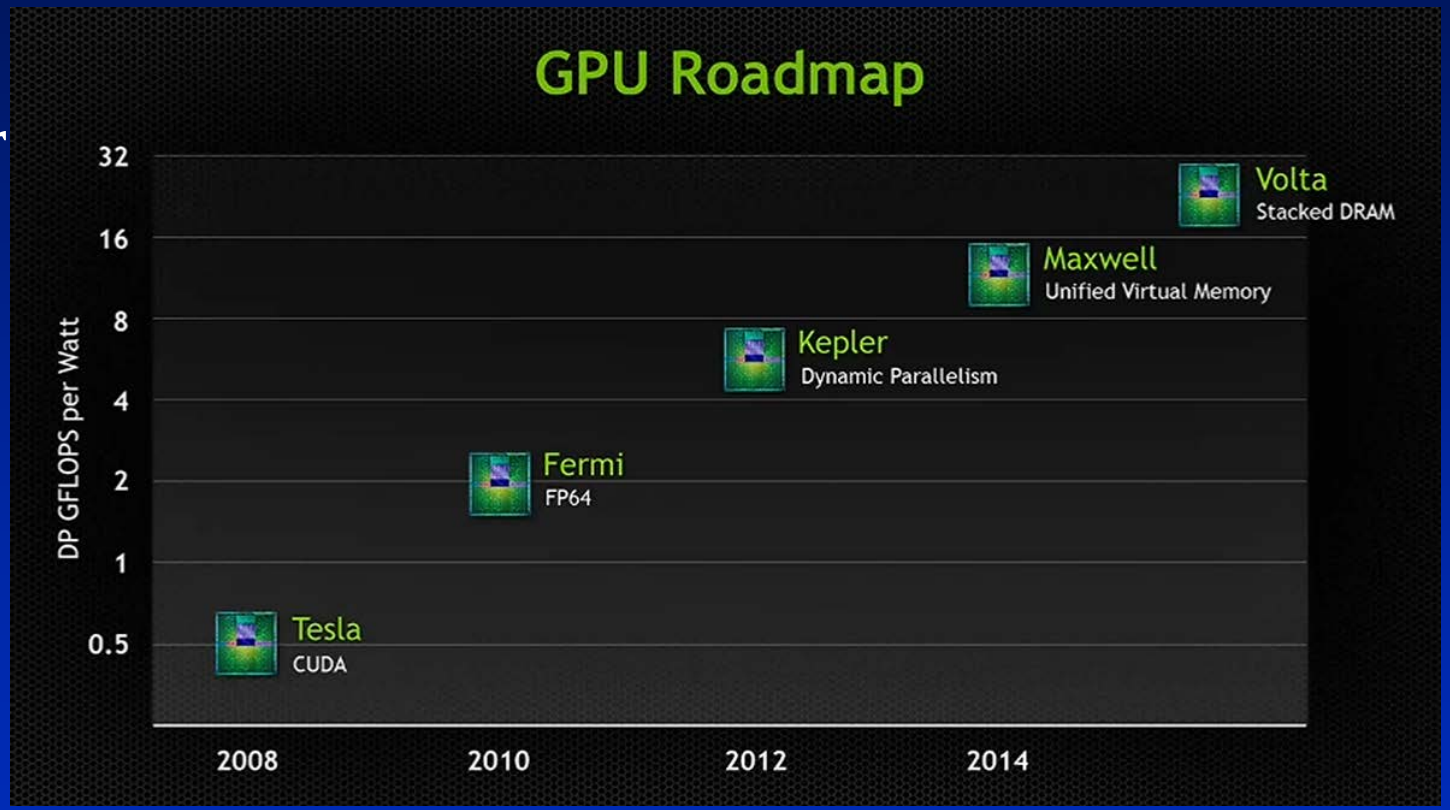


Graph courtesy of Professor John Poulton (from Eric Haines)

nVidia's Kepler Chip 2012

NVIDIA's new Maxwell Chip 2014

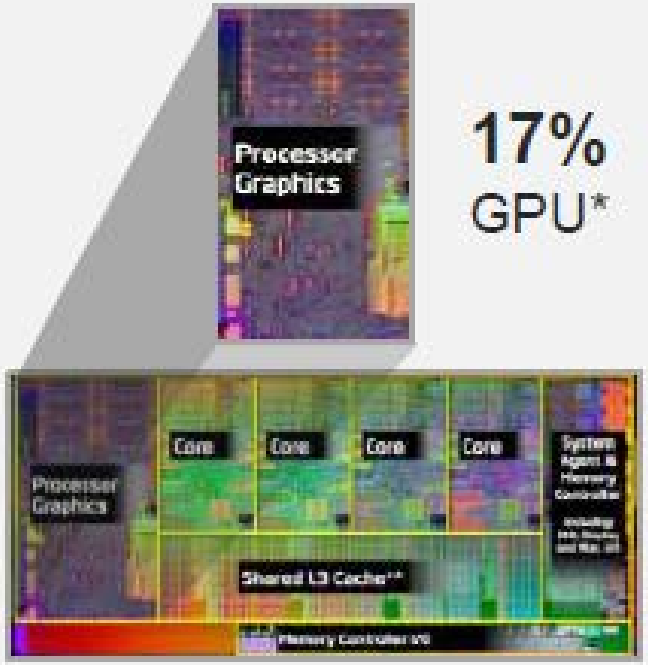
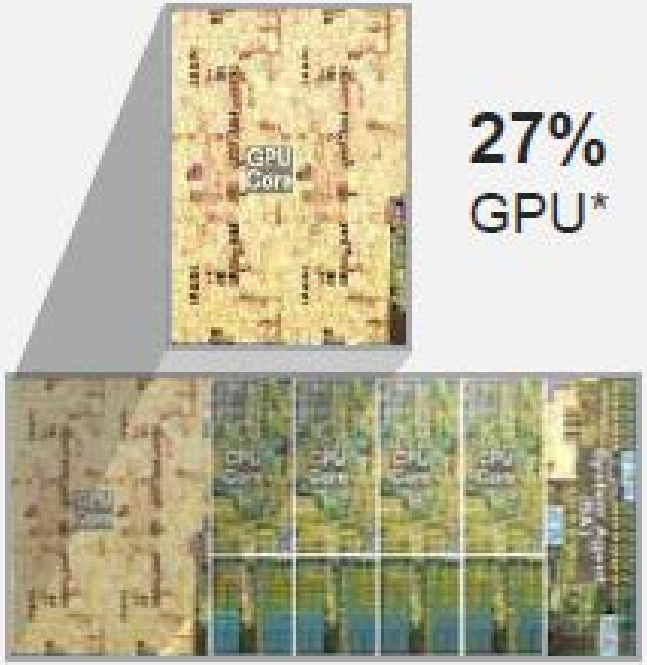
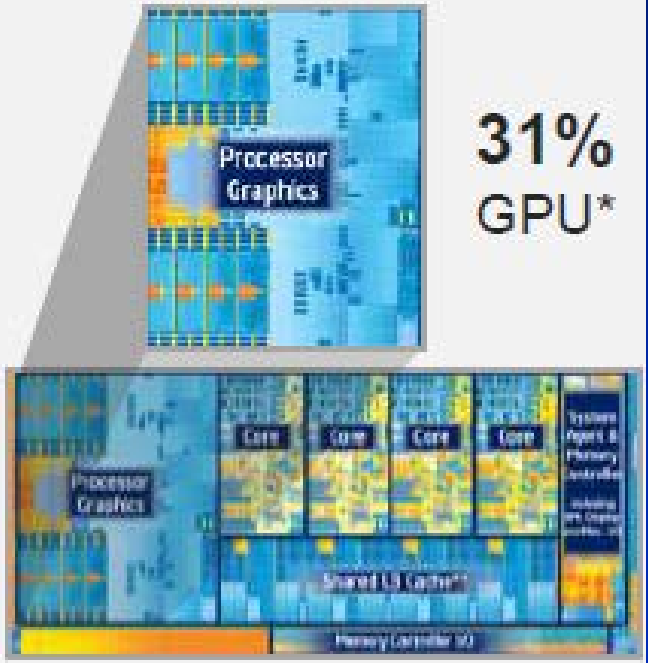
- 6144 processor cores (rumor)
- 20 nm
- Q4 2014



nVidia iray® 2012

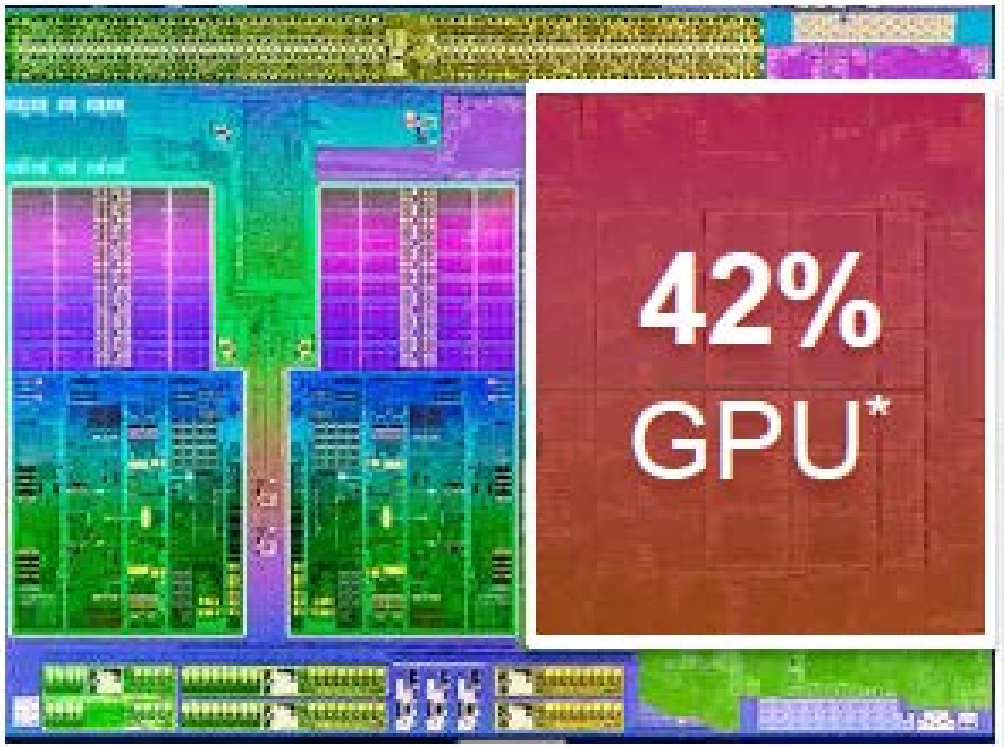
- nVidia has designed a series of rackable Tesla servers for very fast computation using parallel sets of their GPU hardware
- They developed a novel programming language (CUDA) to take advantage of their unique hardware architectures. This can be used for many other disciplines
- They now offer a product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

Intel – Integrated Graphics 2013

"SANDY BRIDGE"	"IVY BRIDGE"	"HASWELL" Estimated
		
17% GPU*	27% GPU*	31% GPU*

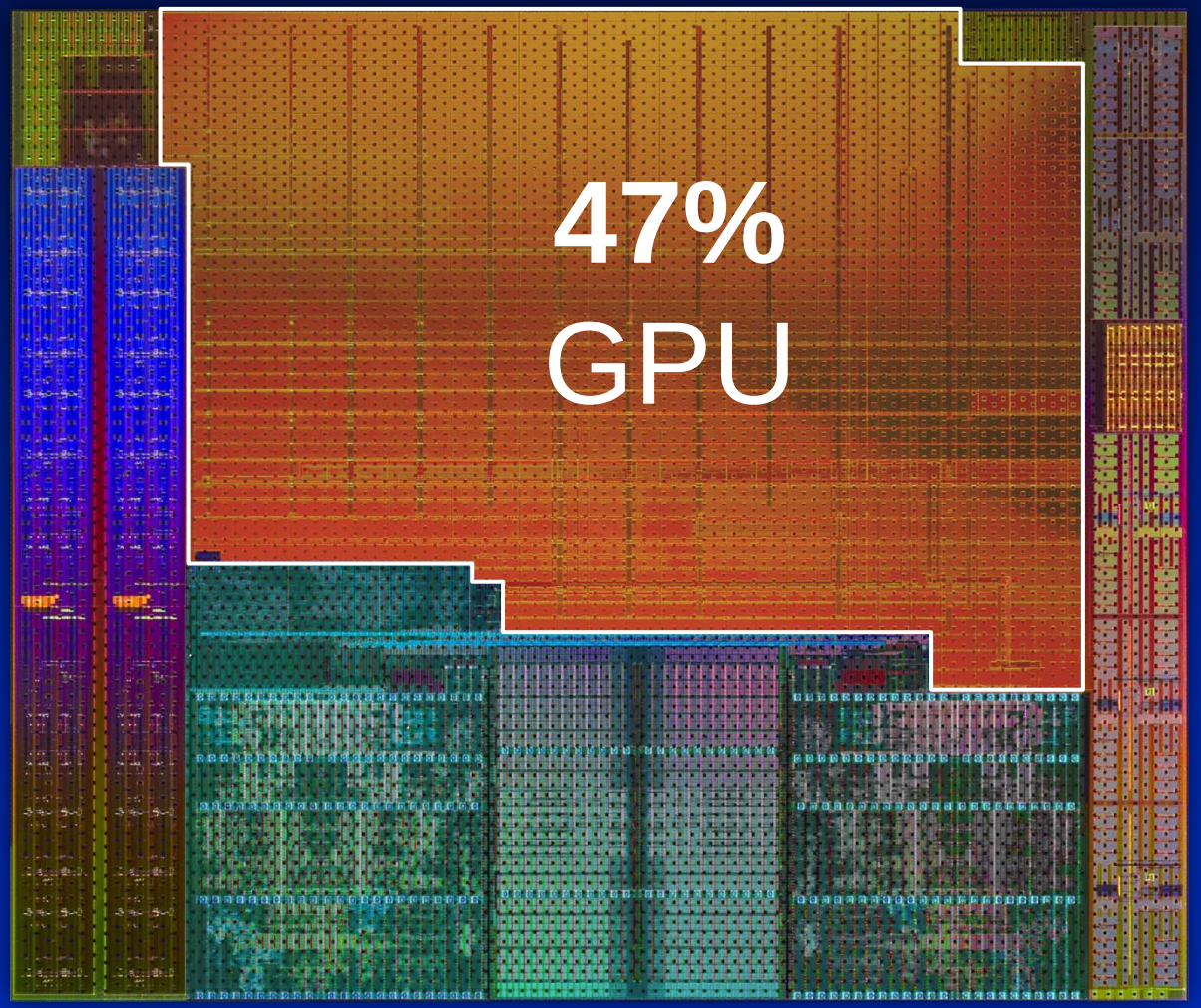
AMD – Integrated Graphics 2013

ELITE AMD A-SERIES /
CODENAMED “RICHLAND”



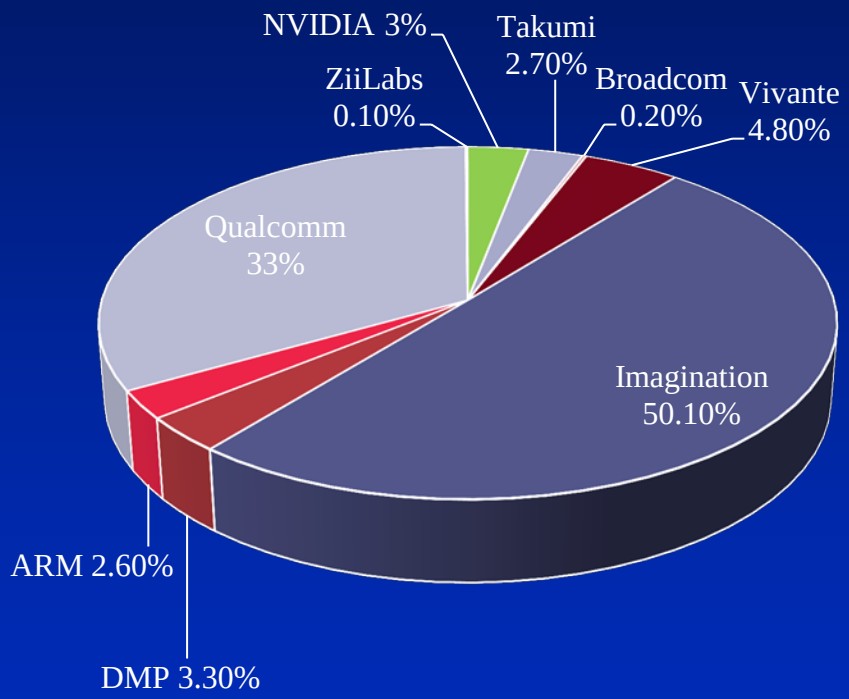
AMD – Integrated Graphics 2014

- “Kaveri”
- 28 nm
- 47% GPU

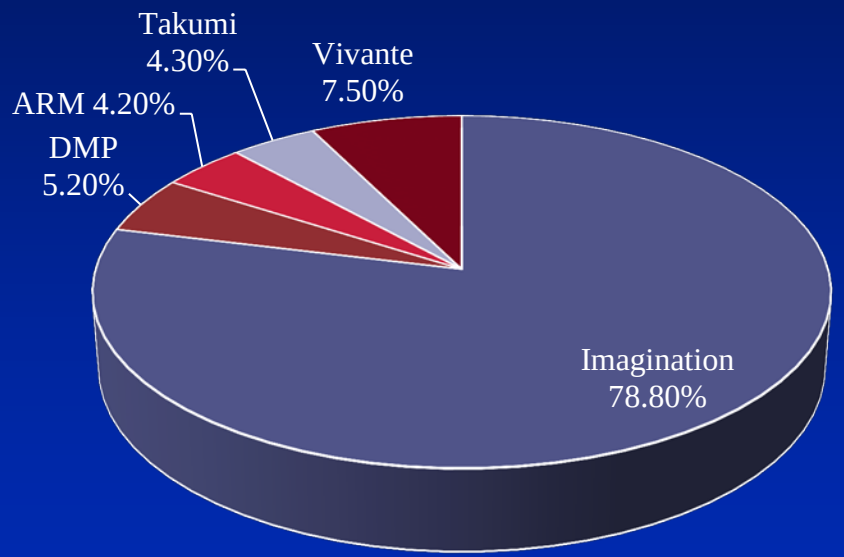


Mobile GPU market share 2013

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. . .