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# ***Summary & Concluding Remarks***

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*Visual Imaging in the Electronic Age*

Donald P. Greenberg

December 15, 2020

# Moore's Law

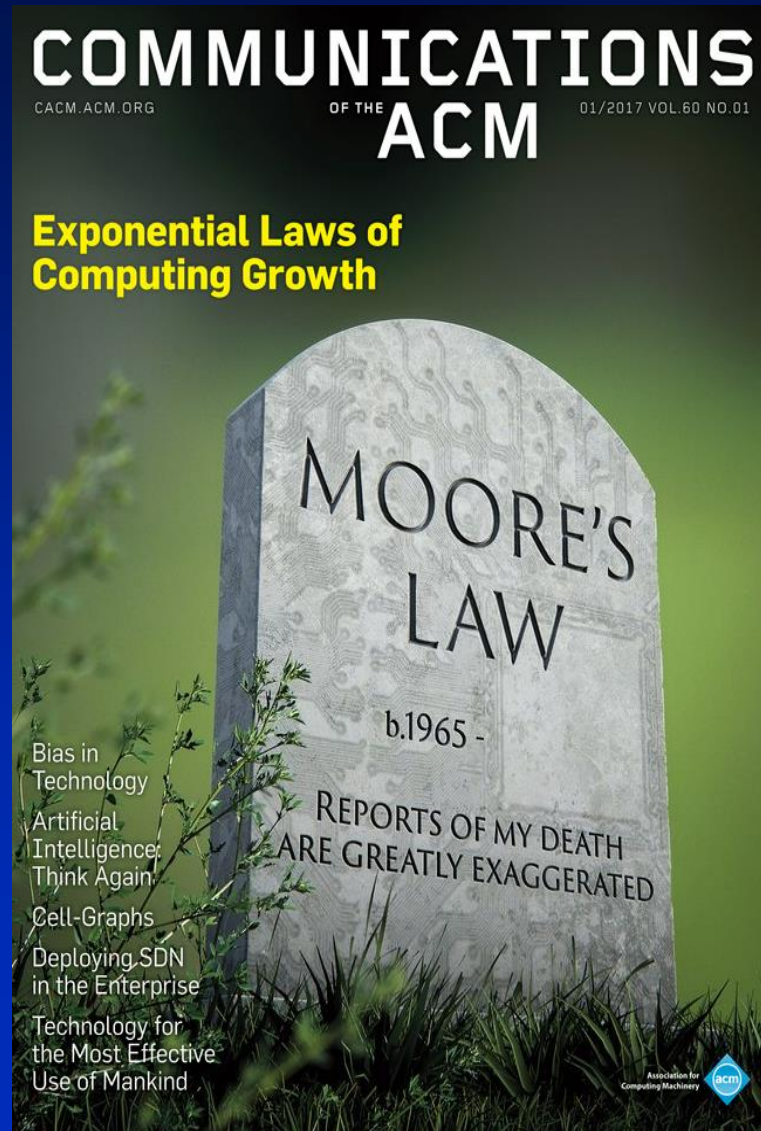
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*“Chip density doubles every 18 months.”*

Processing Power (P) in 15 years:

$$\begin{aligned} P &= P_{today} (2)^{\frac{15 \text{ years}}{18 \text{ months}}} = P_t (2)^{\frac{15}{1.5}} \\ &= P_t (2)^{10} = 1000 P_t \end{aligned}$$

# Exponential Laws of Computing Growth



# Nvidia DGX

2018



4X Tesla V100  
500 TFLOPS  
20,480 CUDA Cores  
256 GB memory



# Brunelleschi's Experiment



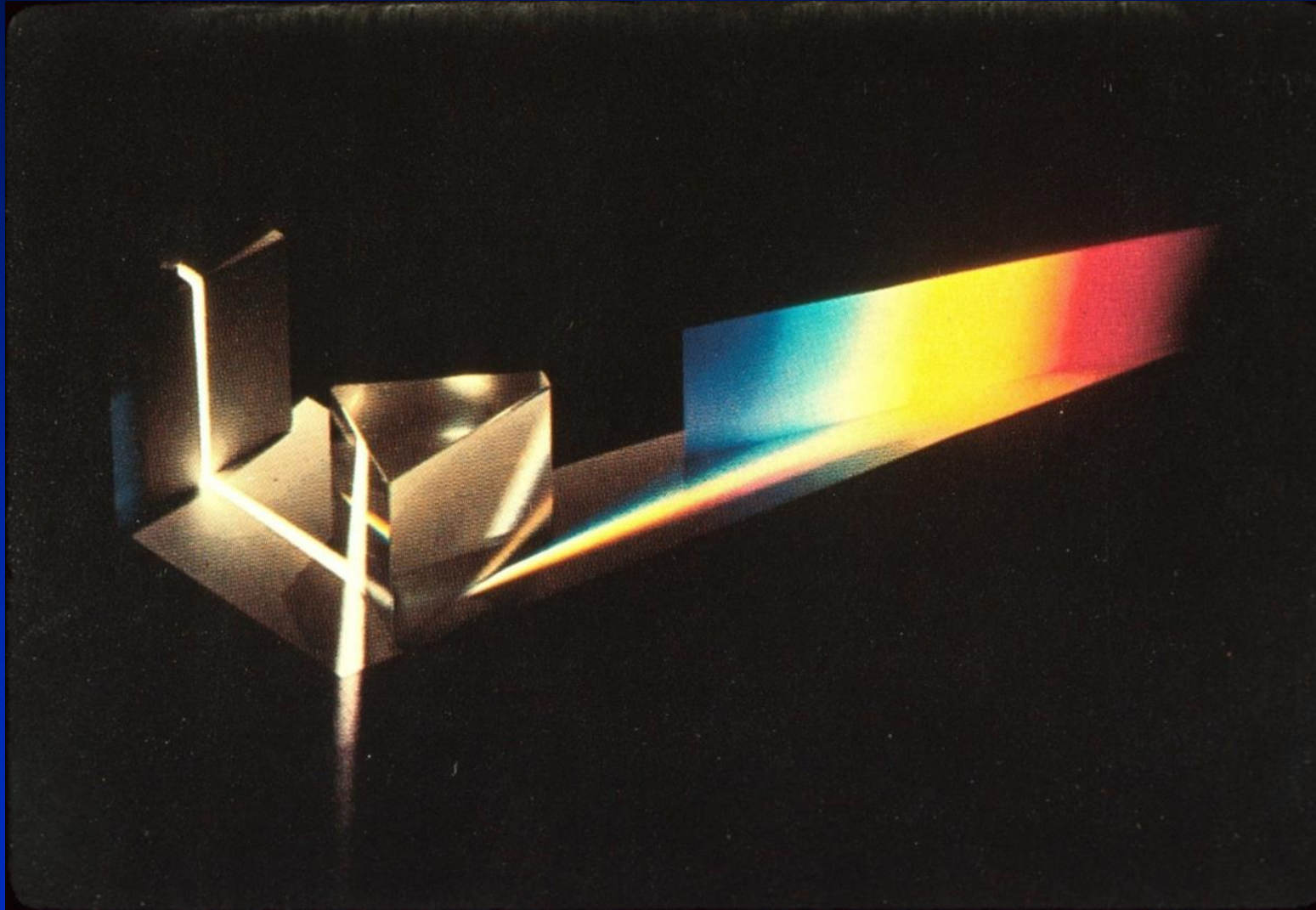
# Julian Beever

# Chalk Drawings



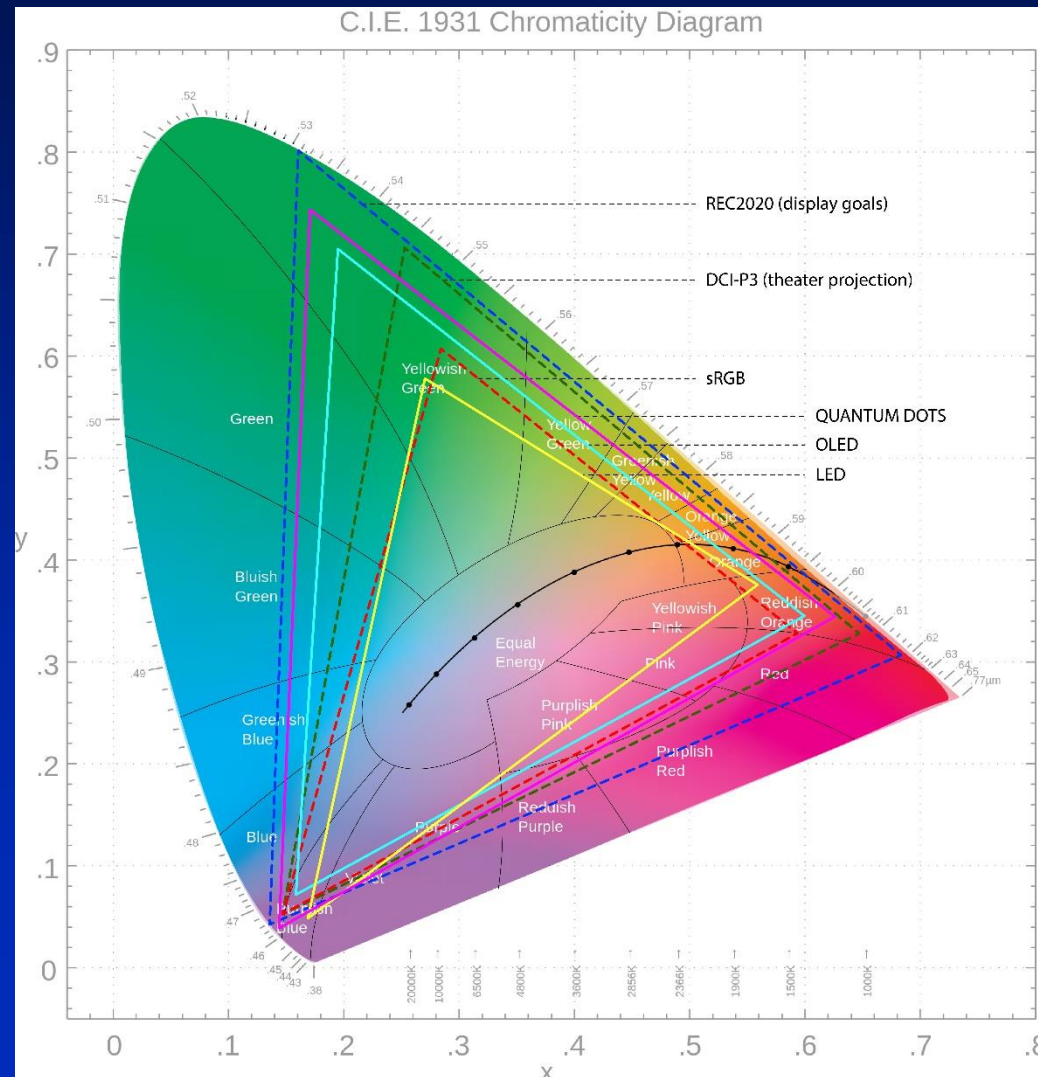
**Color Science**

**Newton**



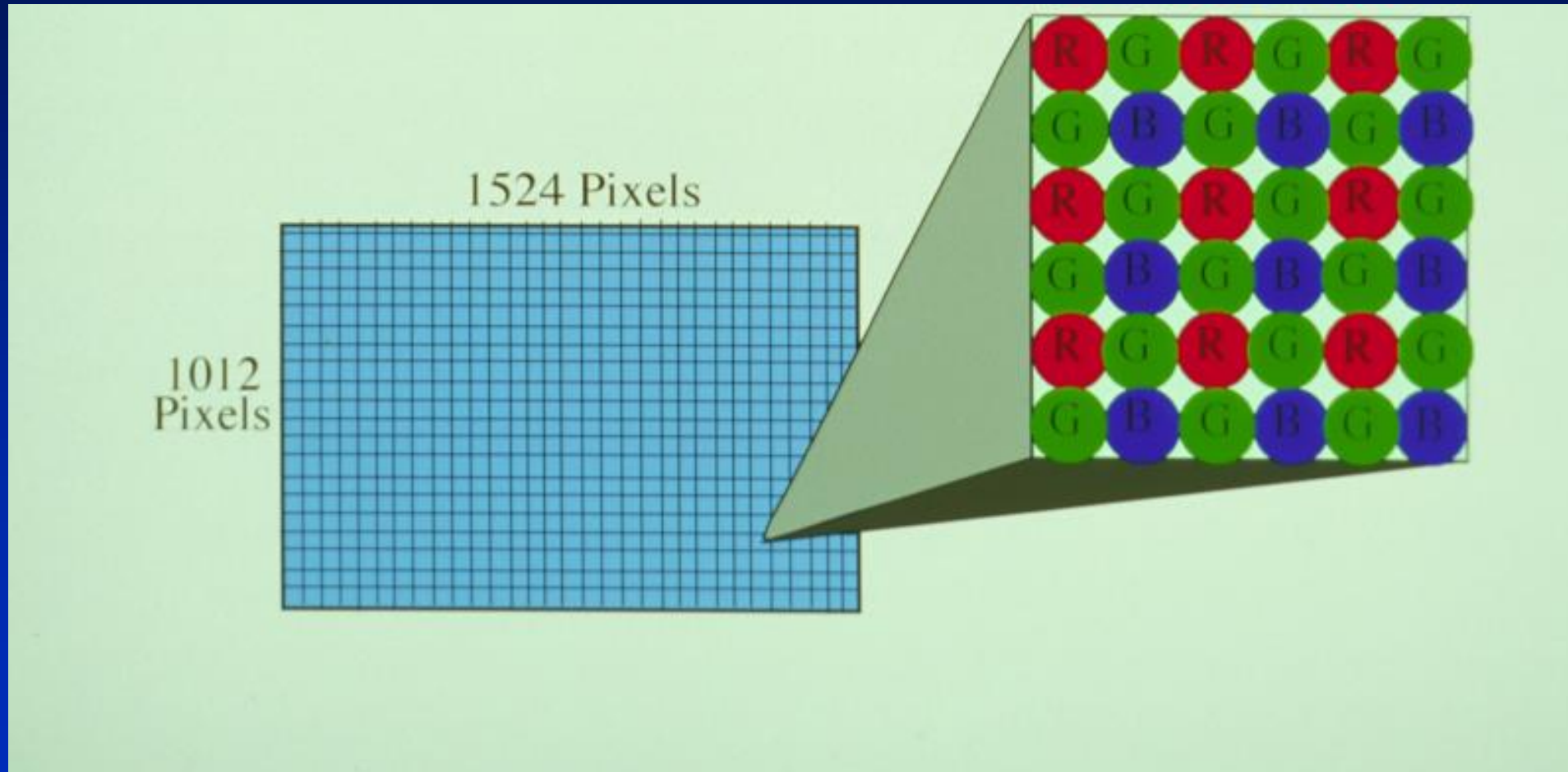
# Display and Camera Color Gamuts

2019





# Kodak DCS420 (Charge-Coupled Device)



**\$14,000 -  
June 1994**

# Key LF-camera advantage: a single lens

- (more familiar, reduces complexity, simplifies calibration, ...)



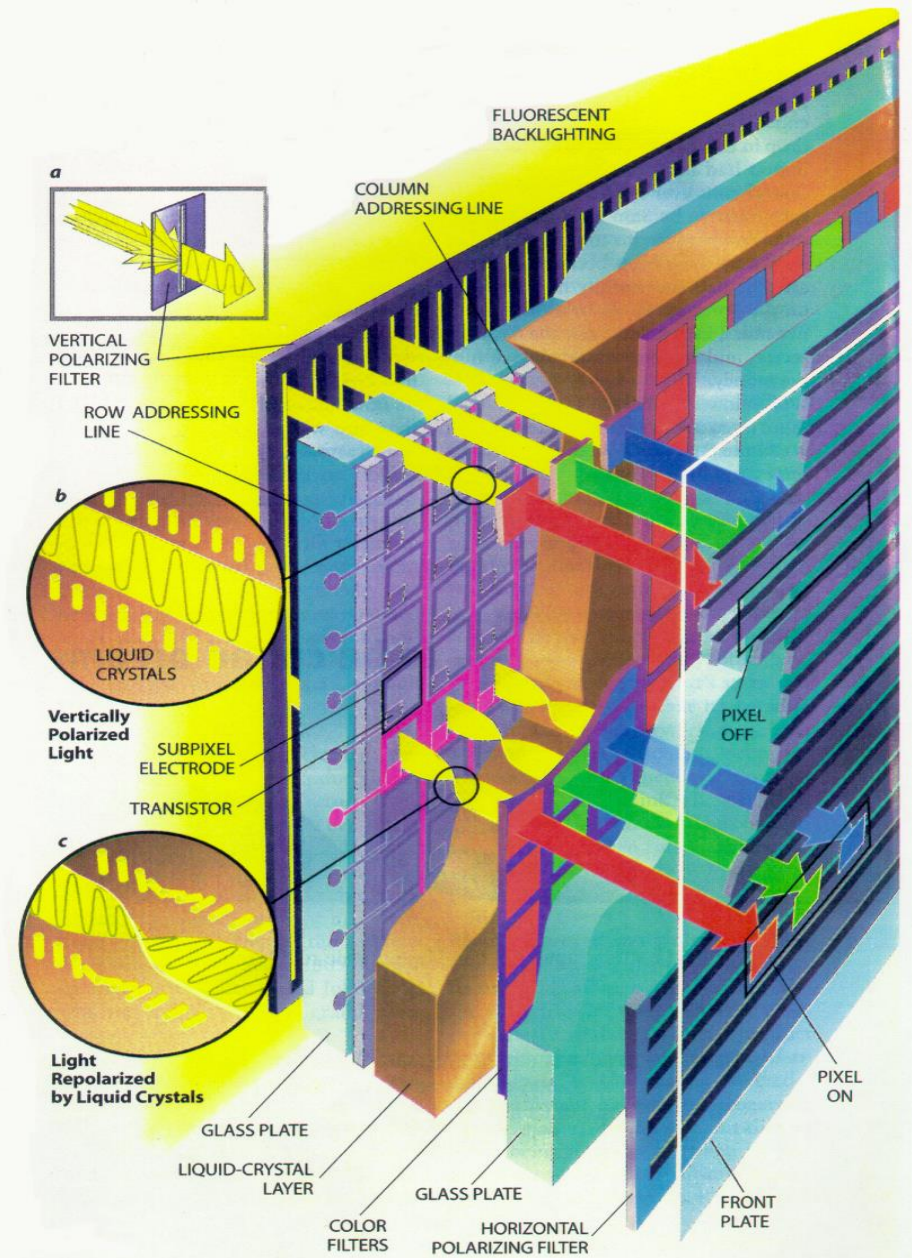


c

b

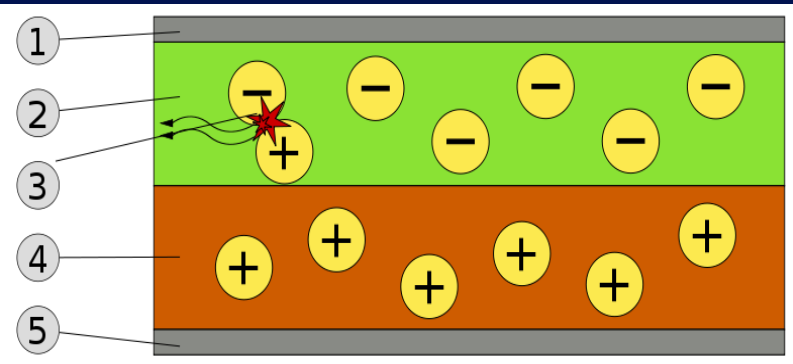
a

# LCD Display



# Samsung Curved OLED TV

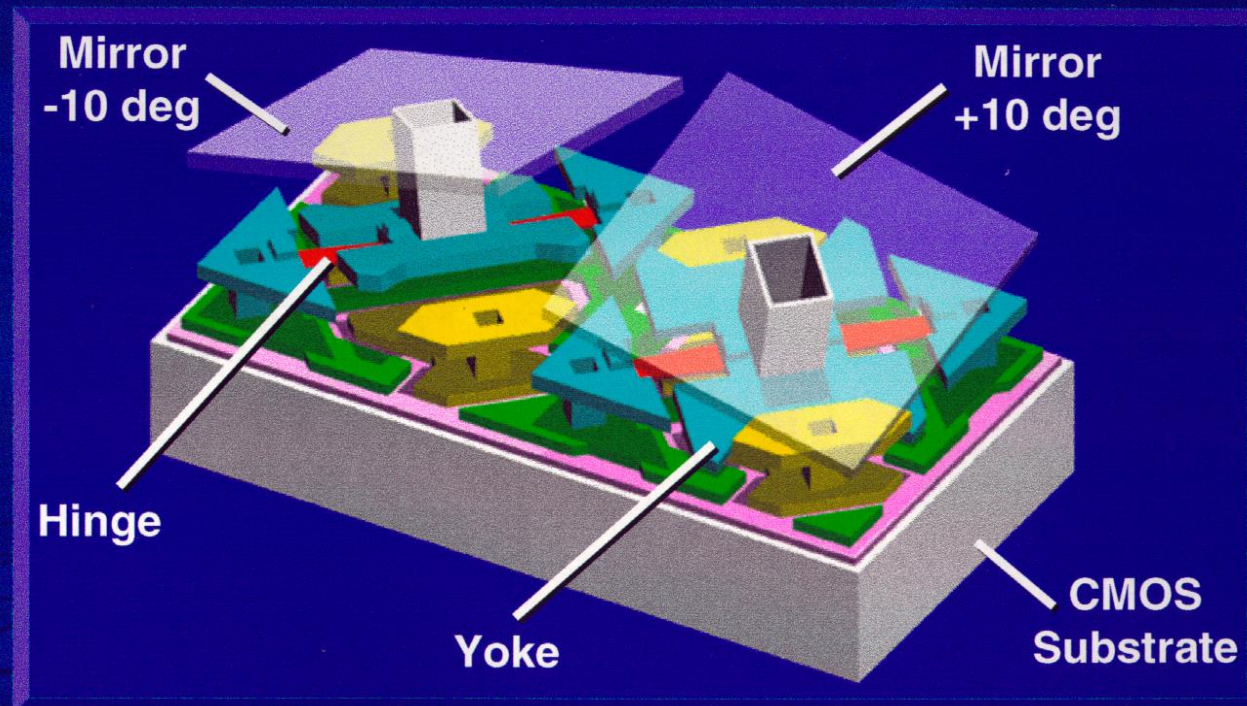
55 in''



# LG press-on 'wallpaper' TV under 1mm thick



## DMD Structure



**Digital Micromirror Device (DMD™)**  
A True Microelectromechanical System

# Twilight Scene, Pixel 3

2019



Marc Levoy. "Night Sight: Seeing in the Dark on Pixel Phones"



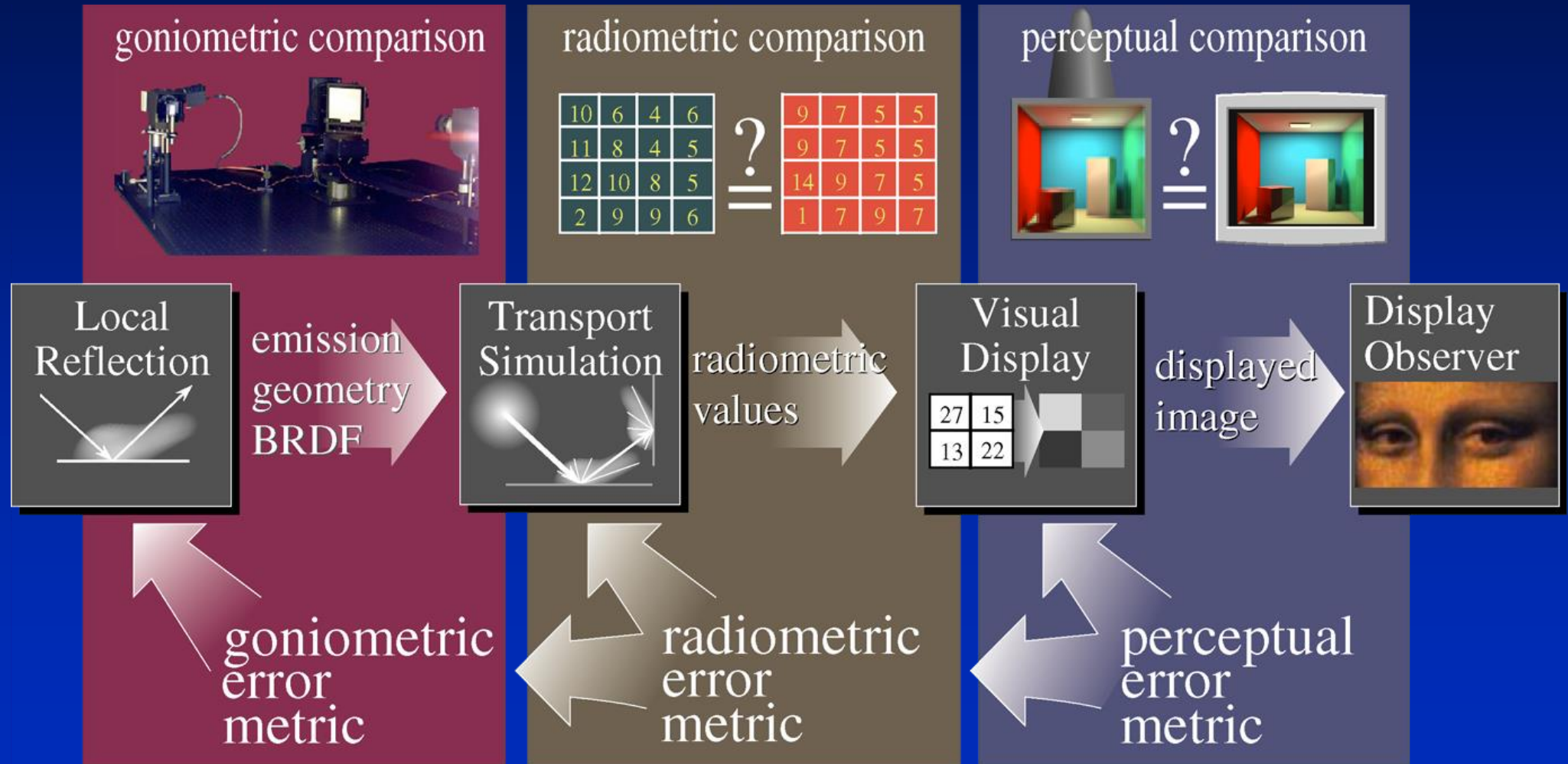
# 3D Geometries Captured Photographically

2016



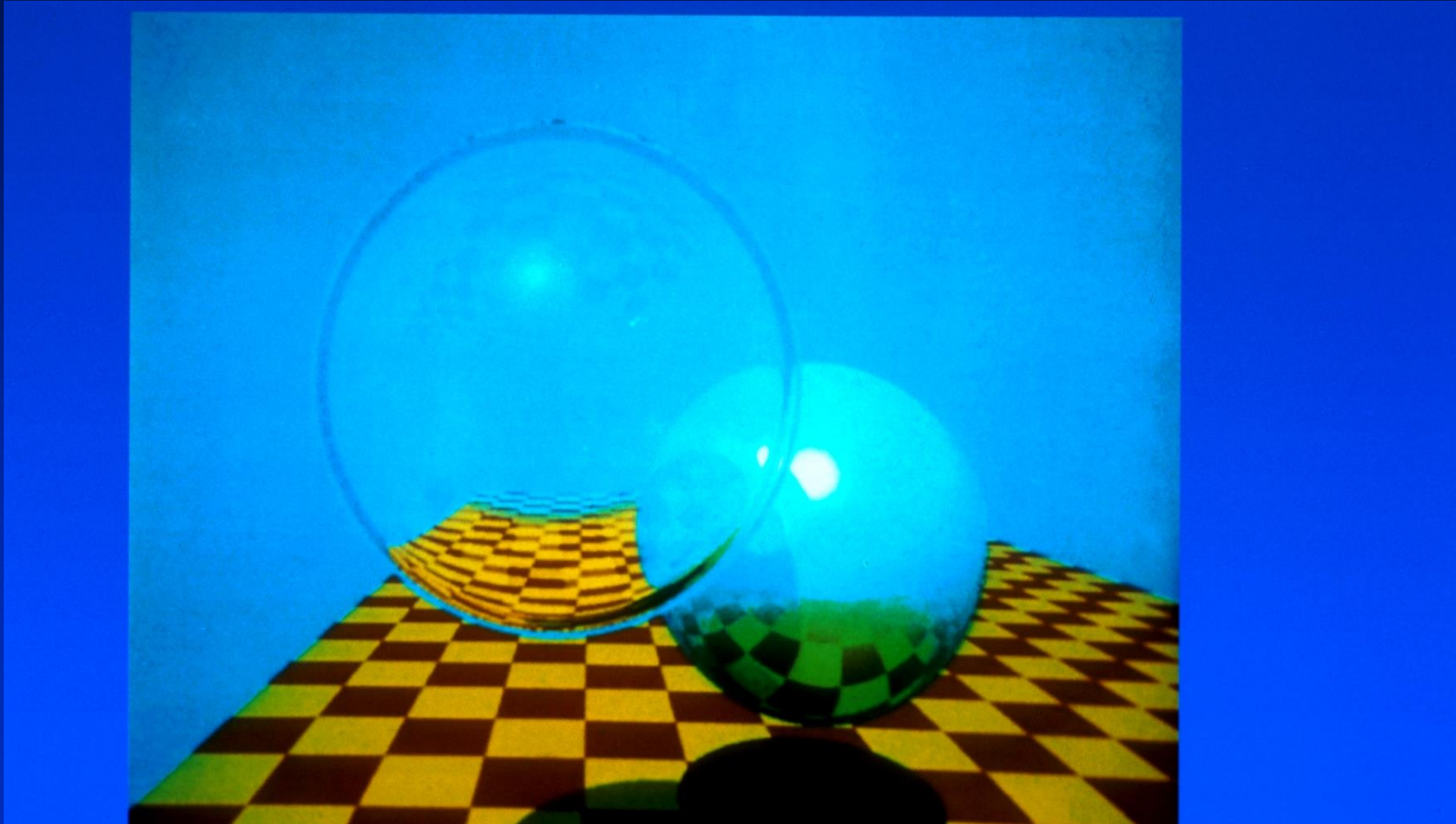
# Rendering Framework

1997



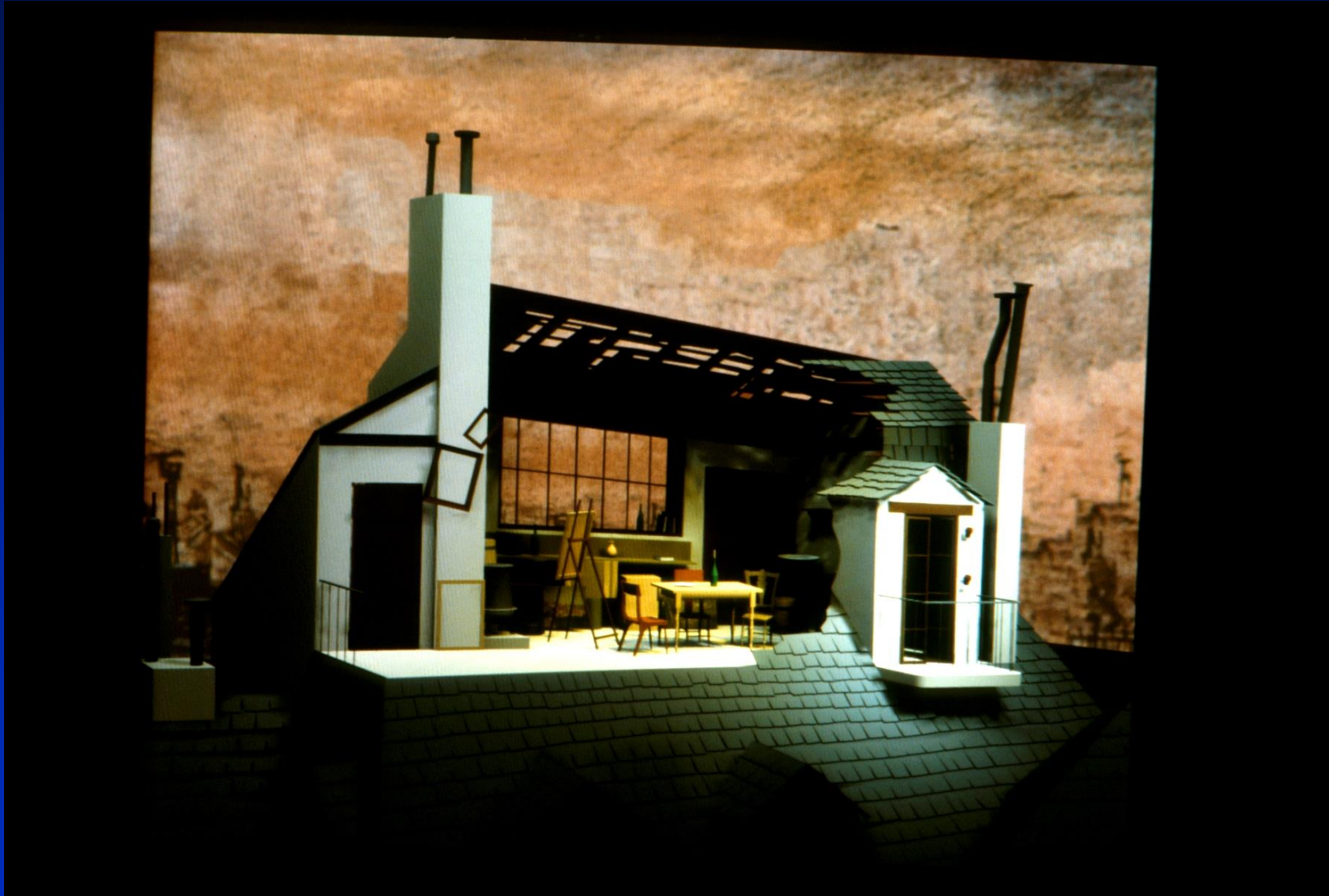
# Ray Tracing

Whitted 1979



# Radiosity

~1985



# Toy Story 3

2010



# Life of Pi

2012



# War for the Planet of the Apes

2017



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Computer power is growing exponentially and but so is  
complexity!

Which is growing faster?



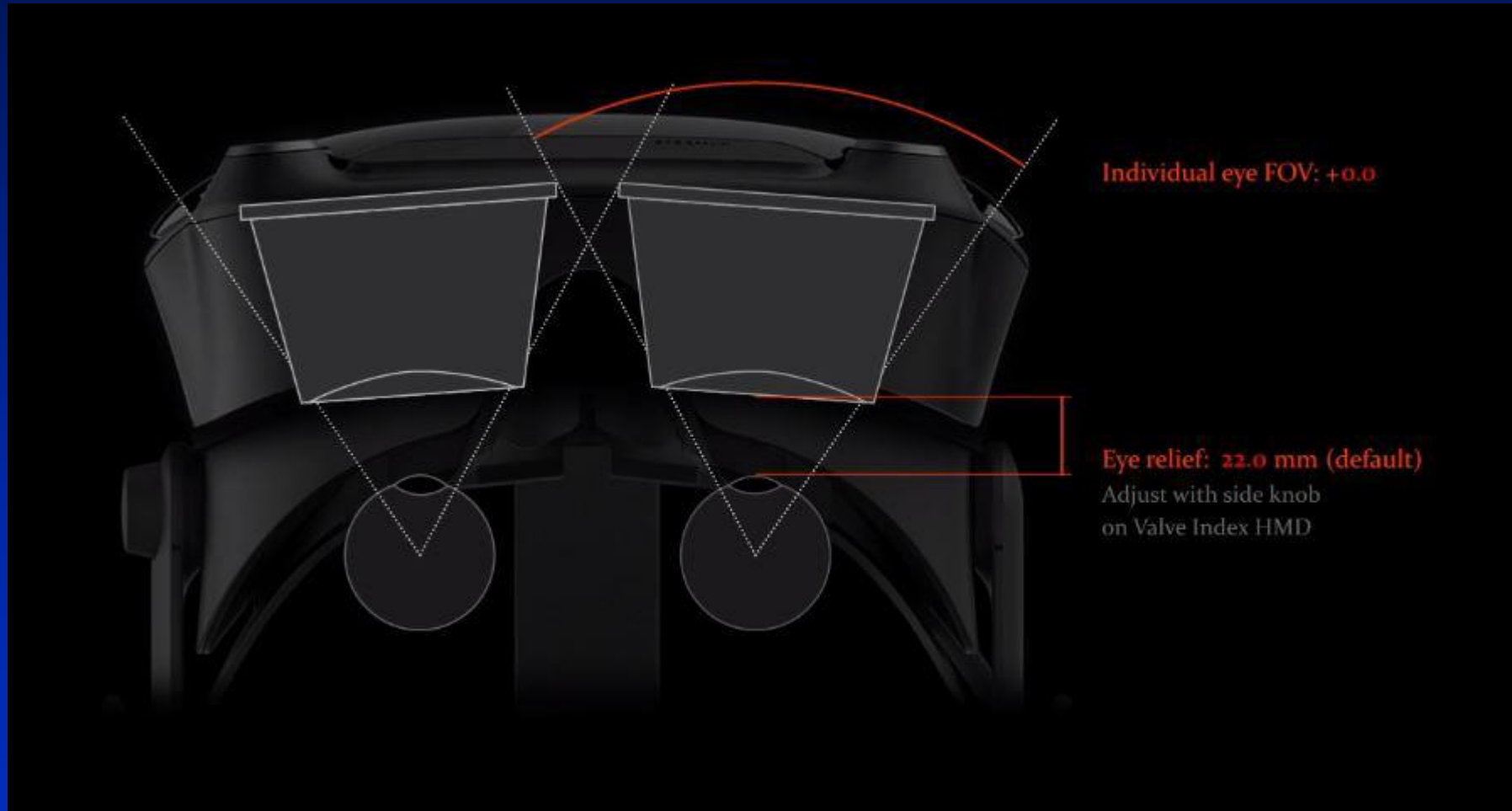
# Offline Rendering vs. Online Rendering

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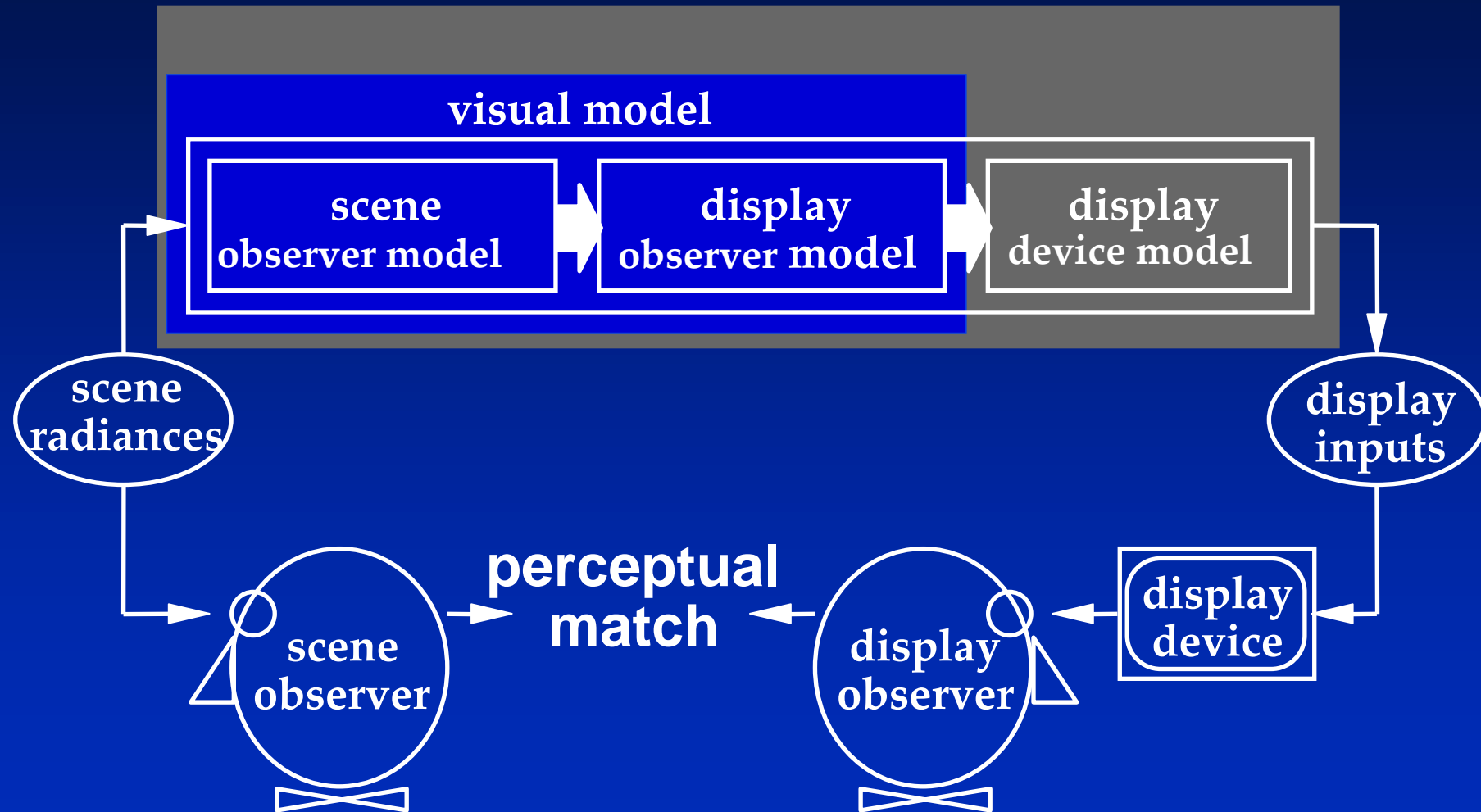
- $\frac{2 \text{ eyes} \times 10 \text{ hours}}{10 \text{ milliseconds}} = 7.2 \times 10^6$

# Valve Index

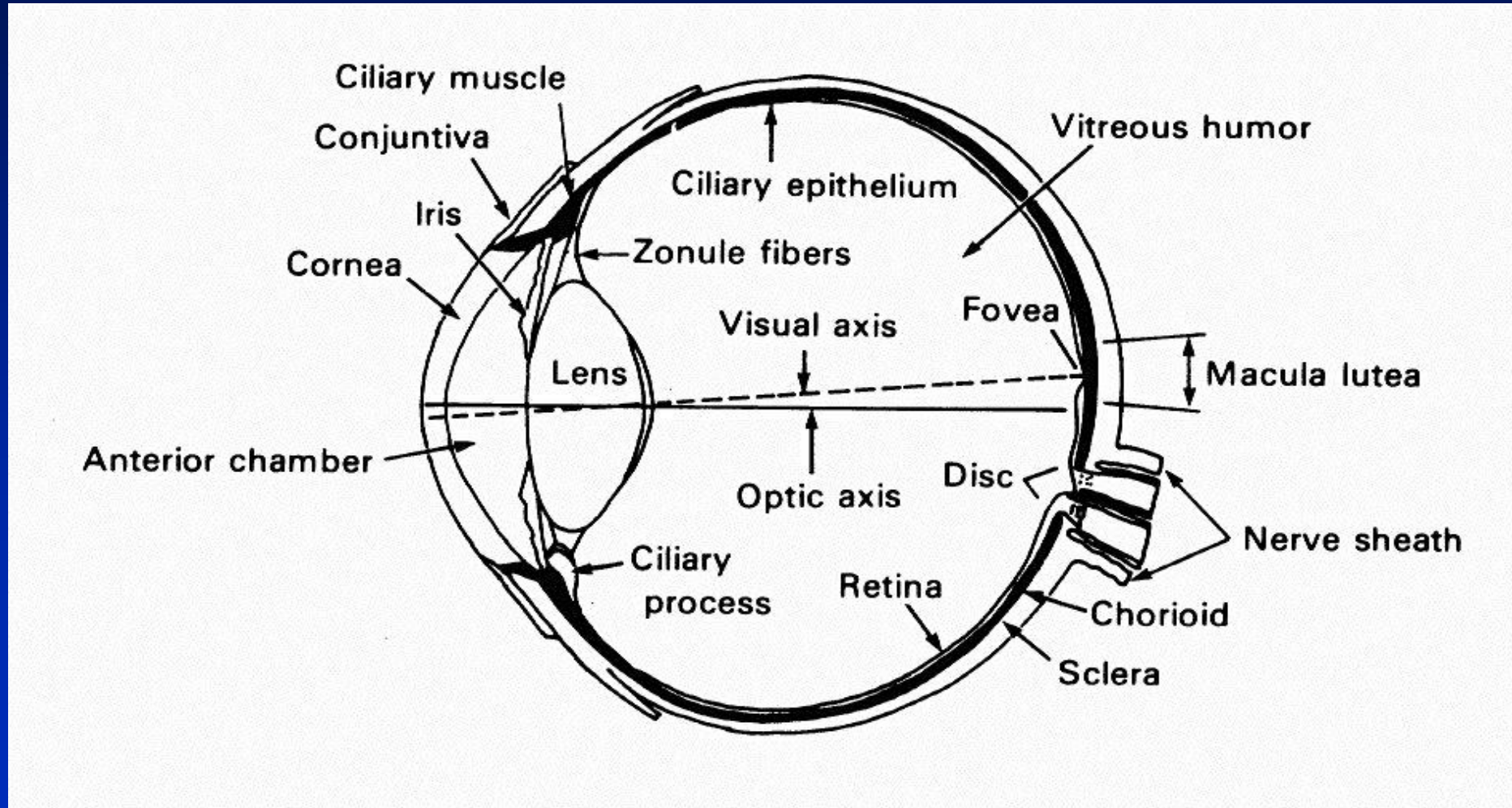
2019



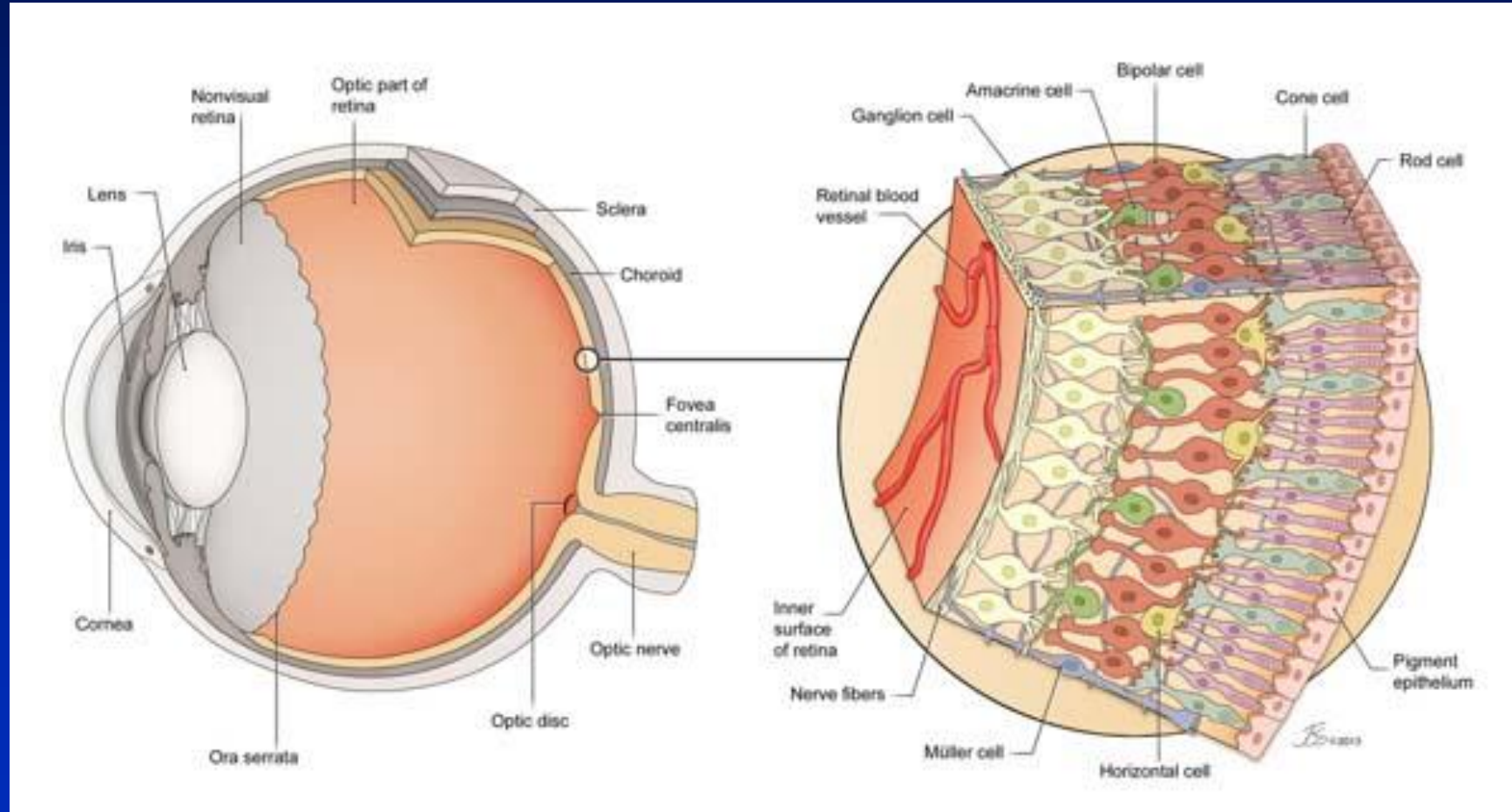
# The Goal of Photorealistic Rendering



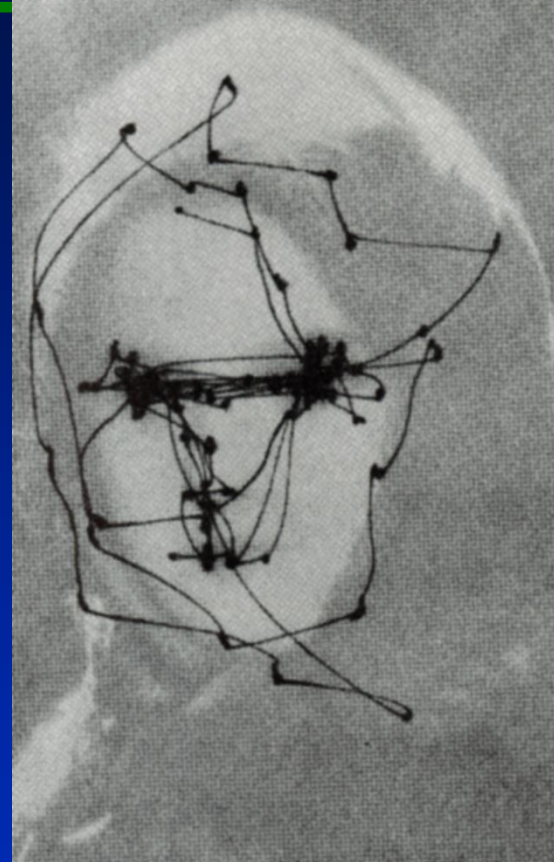
# Cross Section of Eye & Retina



# Rods and Cones and Neural Connections



# Saccadic Motion

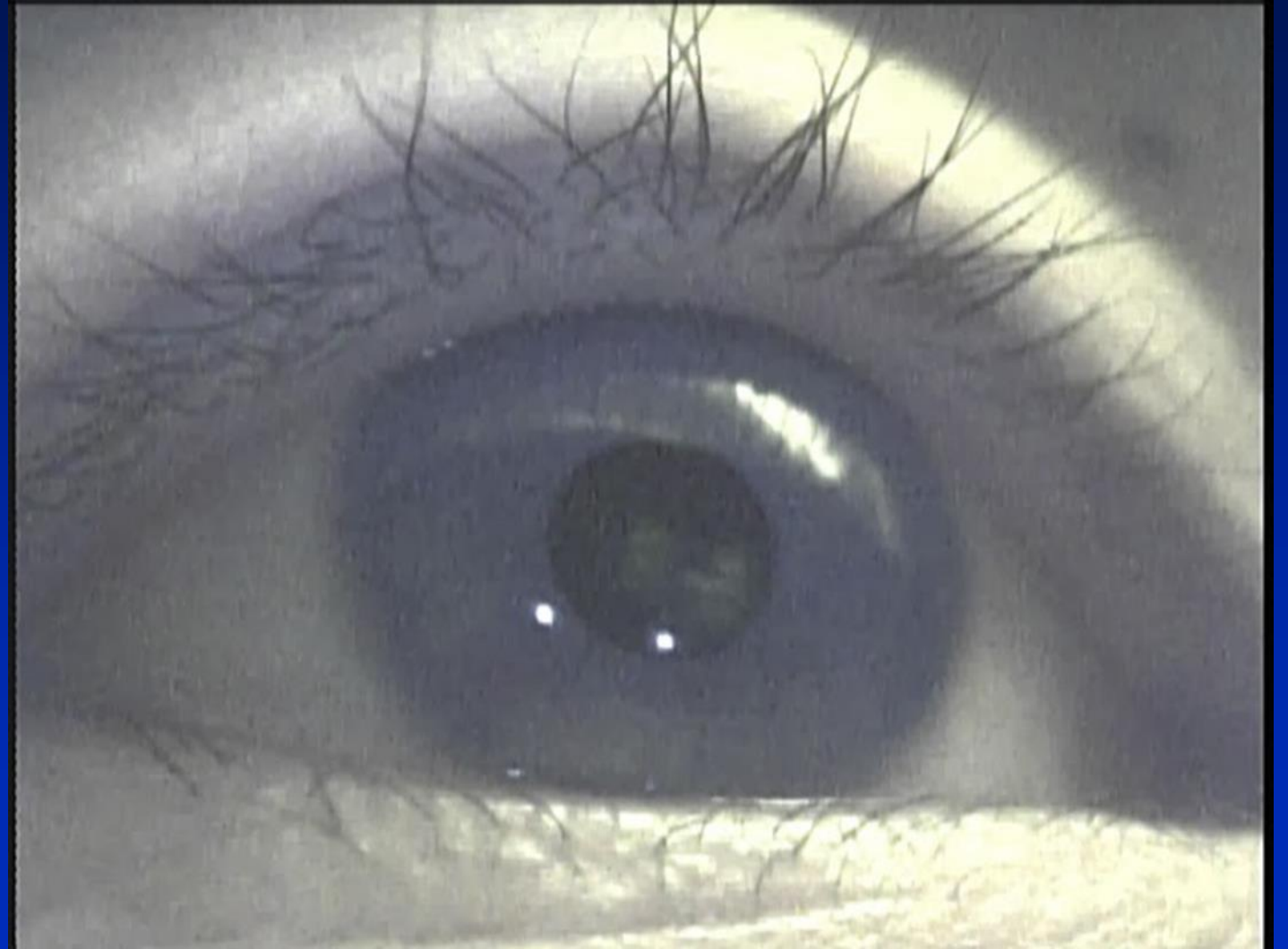


The eye jumps, comes to rest momentarily (producing a small dot on the record), then jumps to a new locus of interest.

# Eye Tracking

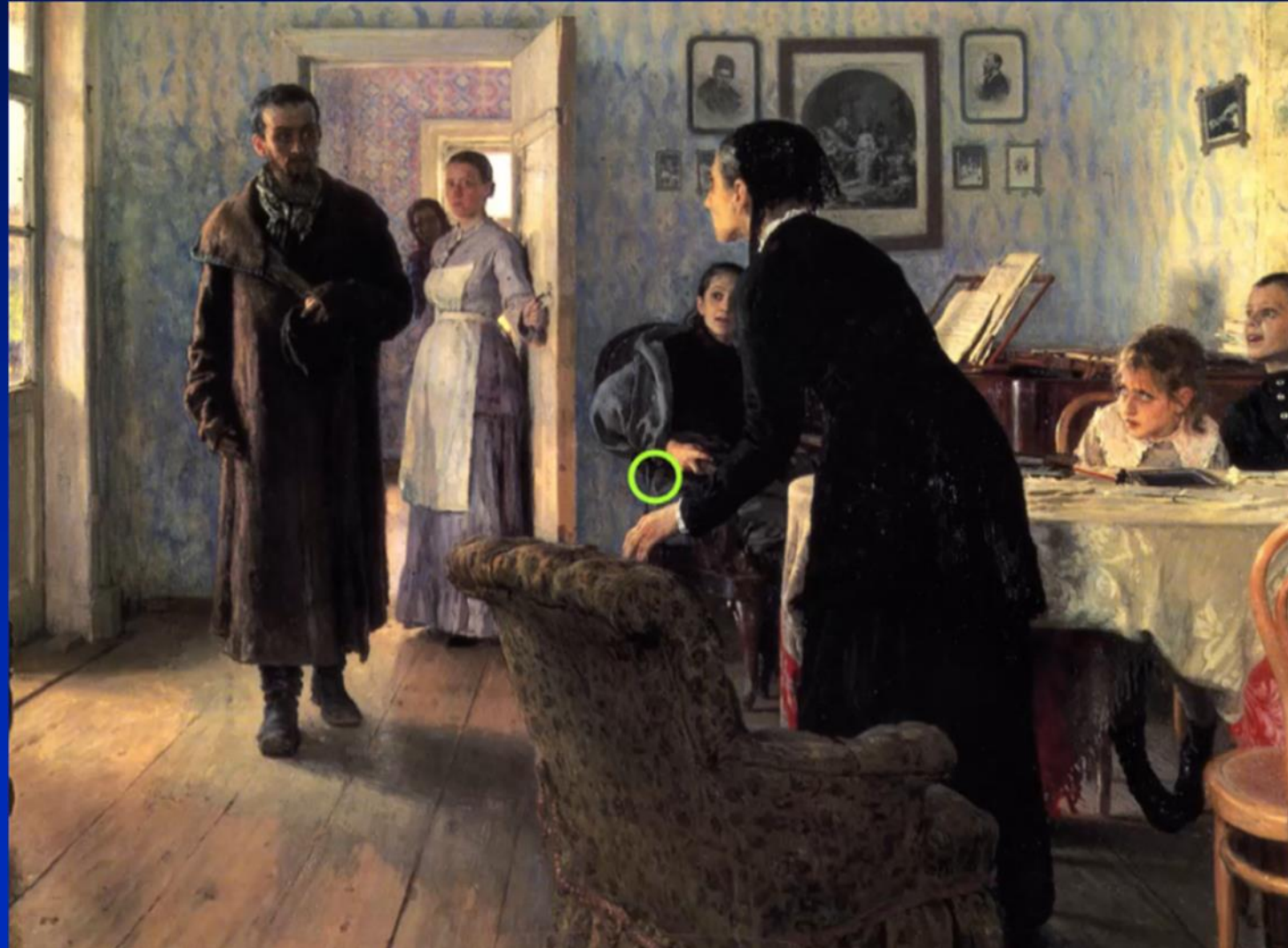
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1<sup>st</sup> and 4<sup>th</sup> Purkinje  
Reflections



# The Unexpected Visitor

Ilya Repin, 1888





# No Foveated Rendering



# Contemporary 'blur' foveated rendering



**Magic Leap**

**Mica 2018**



# Magic Leap

# Mica 2018



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**Have we passed the  
Uncanny Valley?**

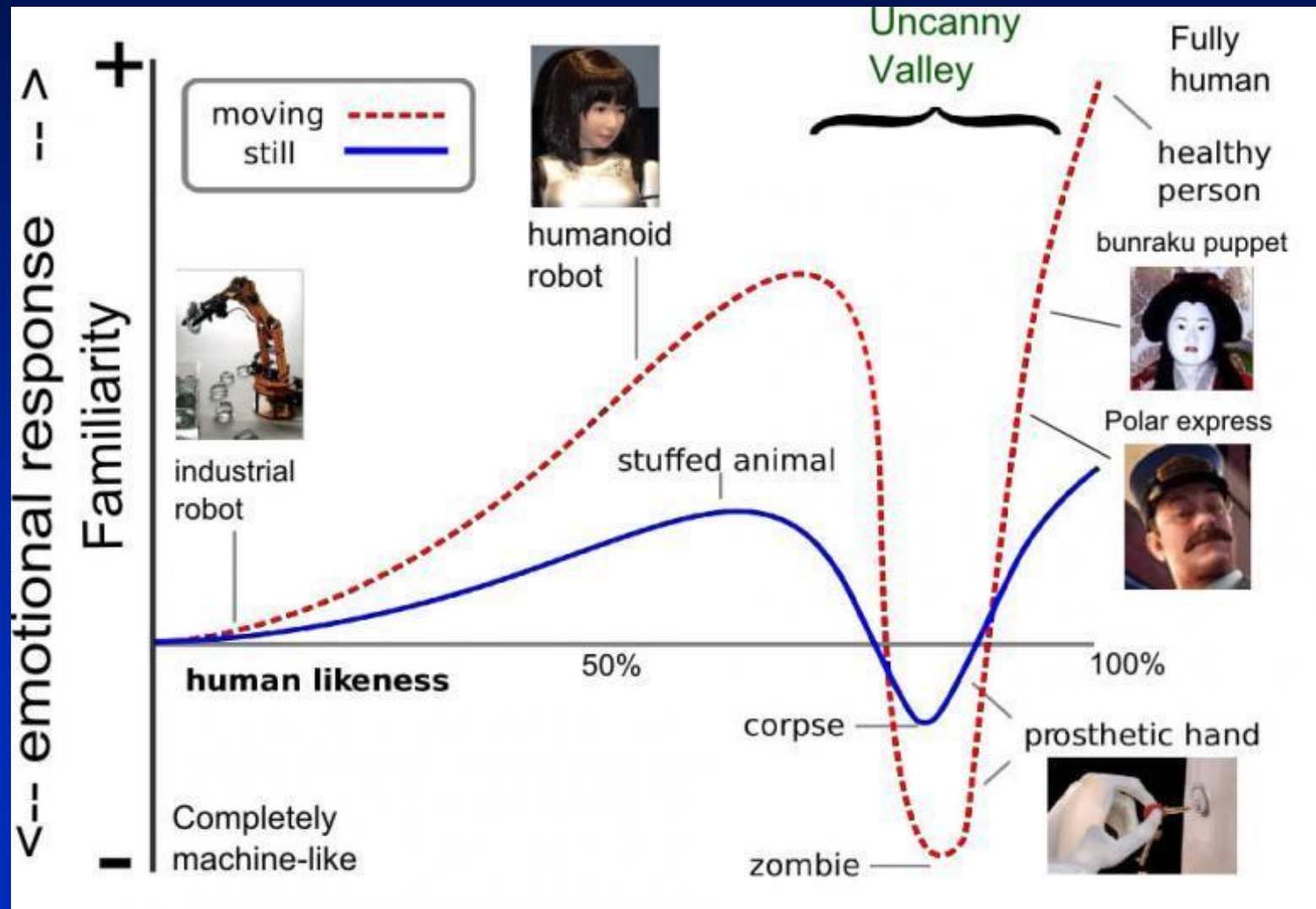
**Gemini Man**

**2019**



# Uncanny Valley

Mori



# Sixth Generation Networks (6G)

2030

## TELECOM NETWORK PROGRESSION BY GENERATION

	INTRODUCTION YEAR	TOP DOWNLOAD SPEEDS	TIME TO DOWNLOAD A MOVIE (3GB)
<b>1G</b>	1979	<i>2 Kbps</i>	1 movie - Nearly 6 days
<b>2G</b>	1991	<i>100 Kbps</i>	1 movie - More than 2.5 hours
<b>3G</b>	1998	<i>8 Mbps</i>	1 movie - Nearly 2 minutes
<b>4G</b>	2008	<i>150 Mbps</i>	1 movie - 20 seconds
<b>5G</b>	2018	<i>10 Gbps</i>	3 movies - 1 second
<b>6G</b>	2030 <i>[Expected]</i>	<i>1 Tbps</i>	300 movies - 1 second

Note: For 1G and 2G, these download speeds are only theoretical. 1G was an analog system and 2G was only partly connected to the internet.



# Streaming Movies

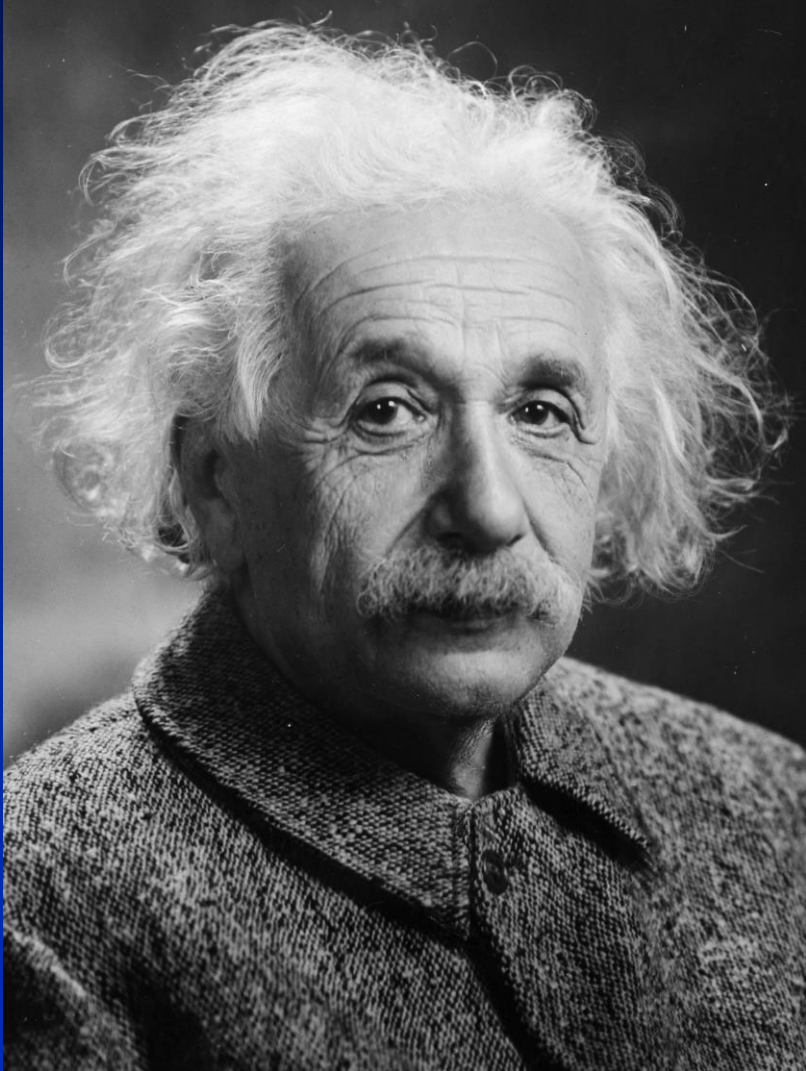
12/9/2020

- HBO Max will stream all Warner Brother movies that were set to release in 2021.



Einstein

1905



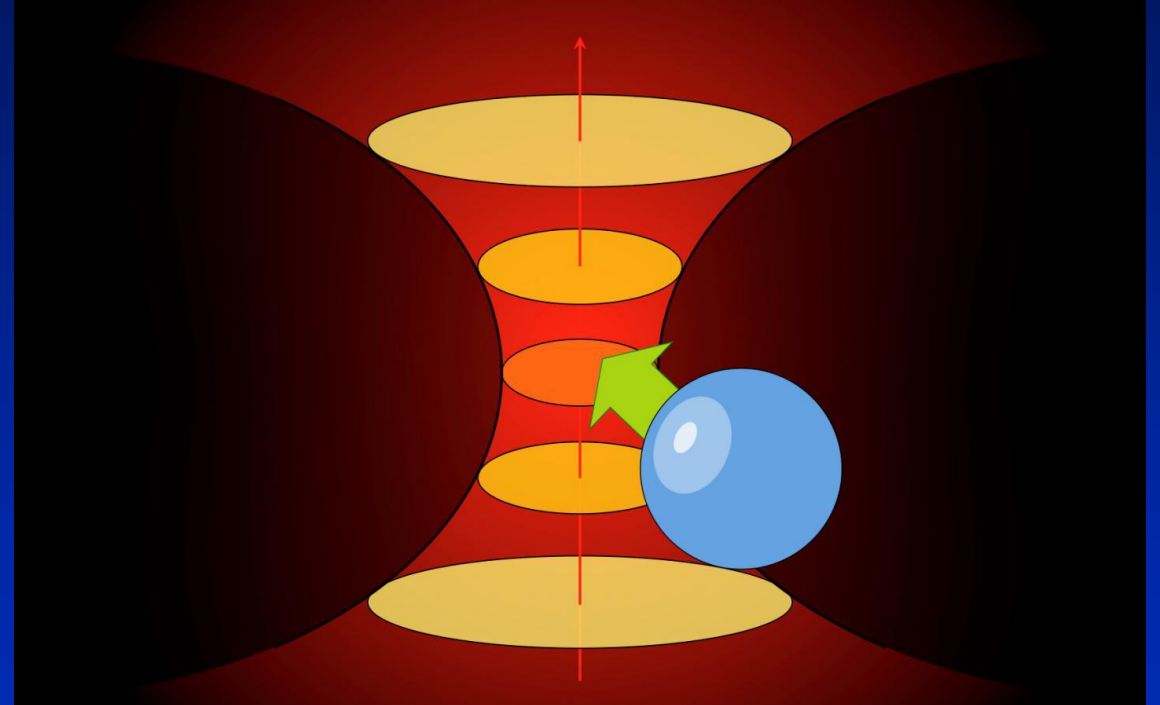
$$E = mc^2$$

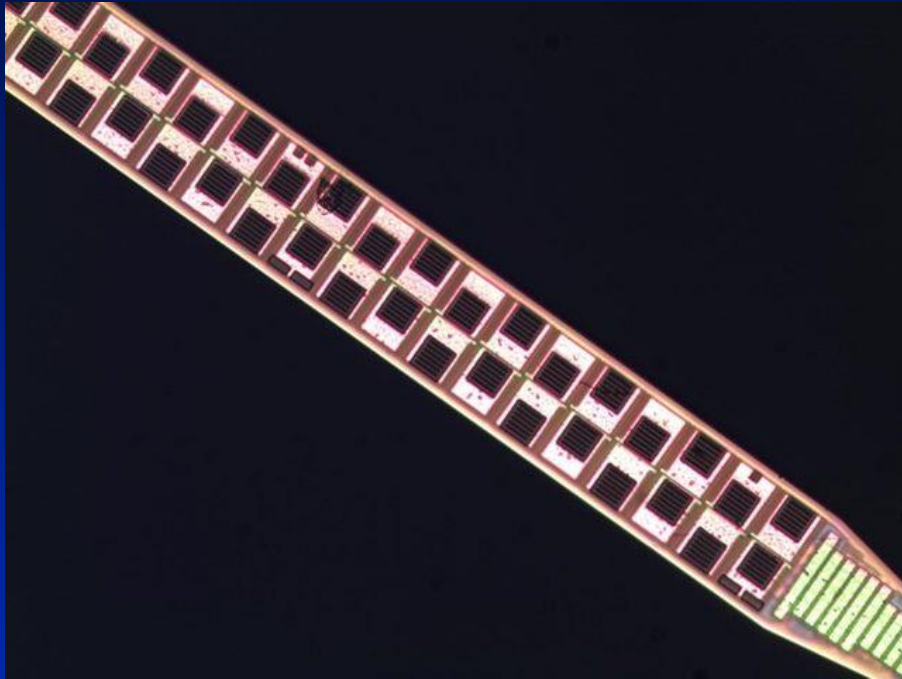
# Optical Tweezers

Nobel Prize- 2018



Arthur Ashkin, Cornell Ph. D 1952





New silicon probes record  
Activity of hundreds of neurons  
simultaneously



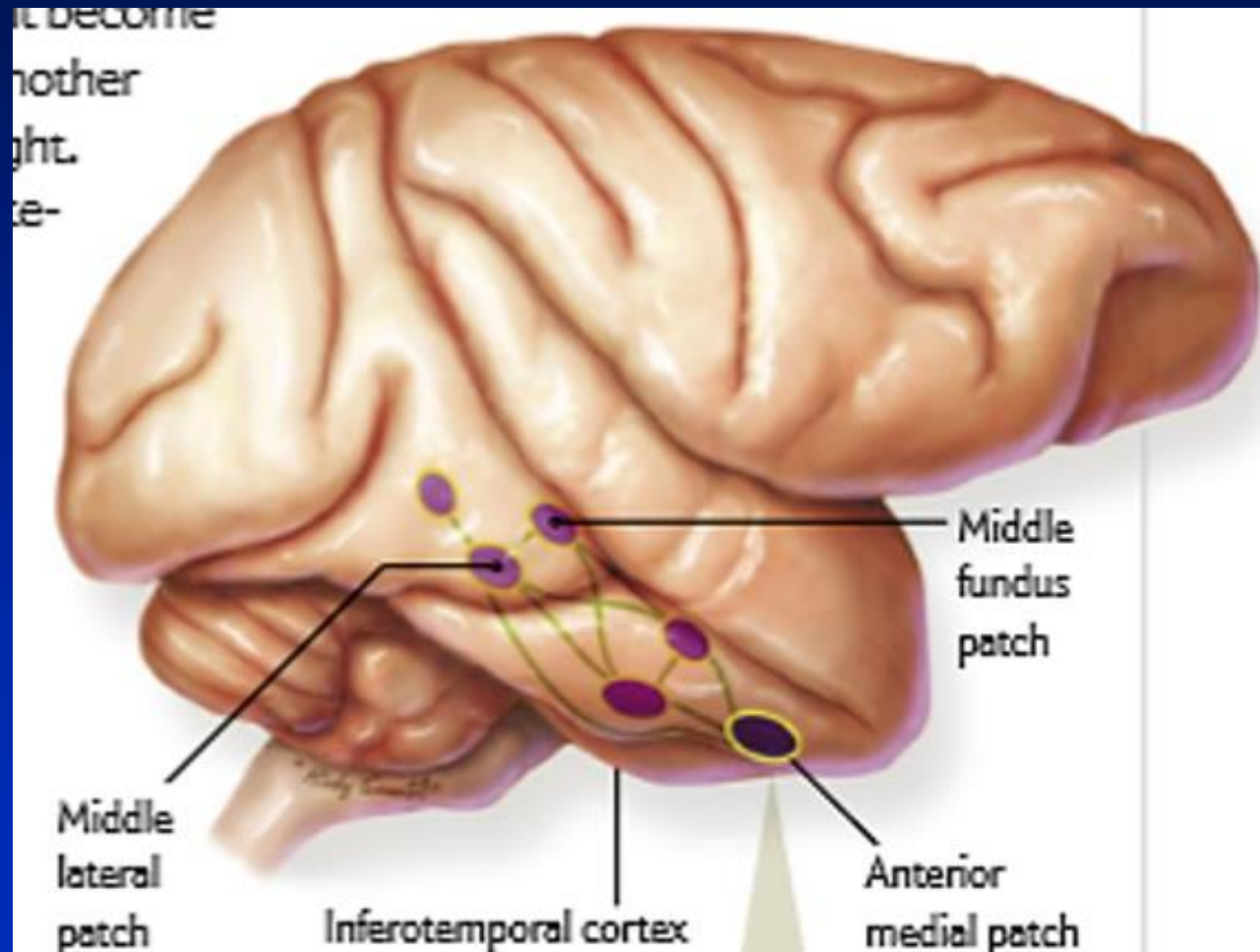
# Open Water Technology

2019



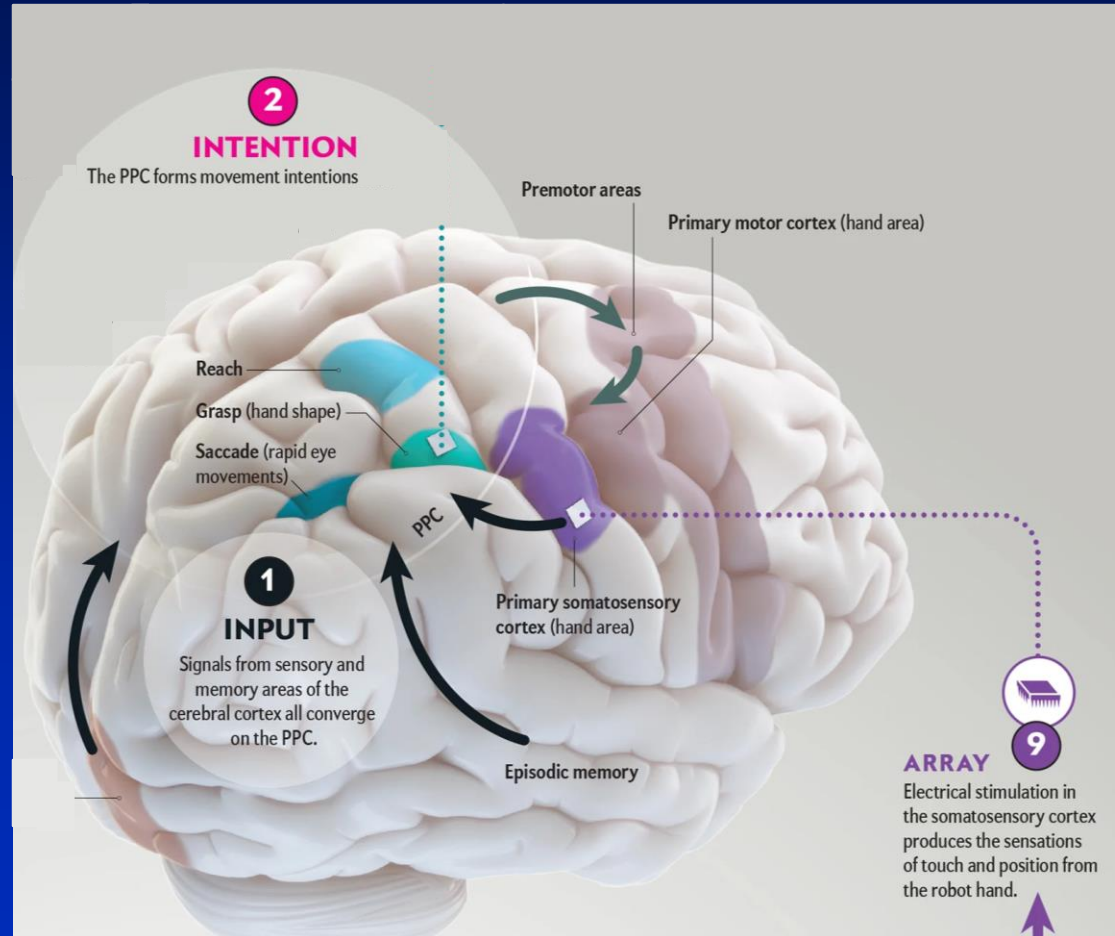
# Where are the Face Detectors

2019



# The Intention Machine

Caltech 2019



# The Intention Machine

## Caltech 2019





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# **Freedom of Speech, Privacy, Security, and Regulations**

# History Of The Internet

# ARPA Team



# Original Rules of the Internet

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- Free
- First come, first serve
- Anyone can say anything (Legal)

# The First Amendment

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“Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof; or abridging the freedom of speech, or of the press, or the right of the people peaceably to assemble, and to petition the Government for a redress of grievances.”

# The Fourth Amendment

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“The right of the people to be secure in their persons, houses, papers, and effects, **against unreasonable searches and seizures**, shall not be violated, and no warrants shall issue, **but upon probable cause**, supported by oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized.

# Privacy and Security: Challenges of the new Internet Regulations

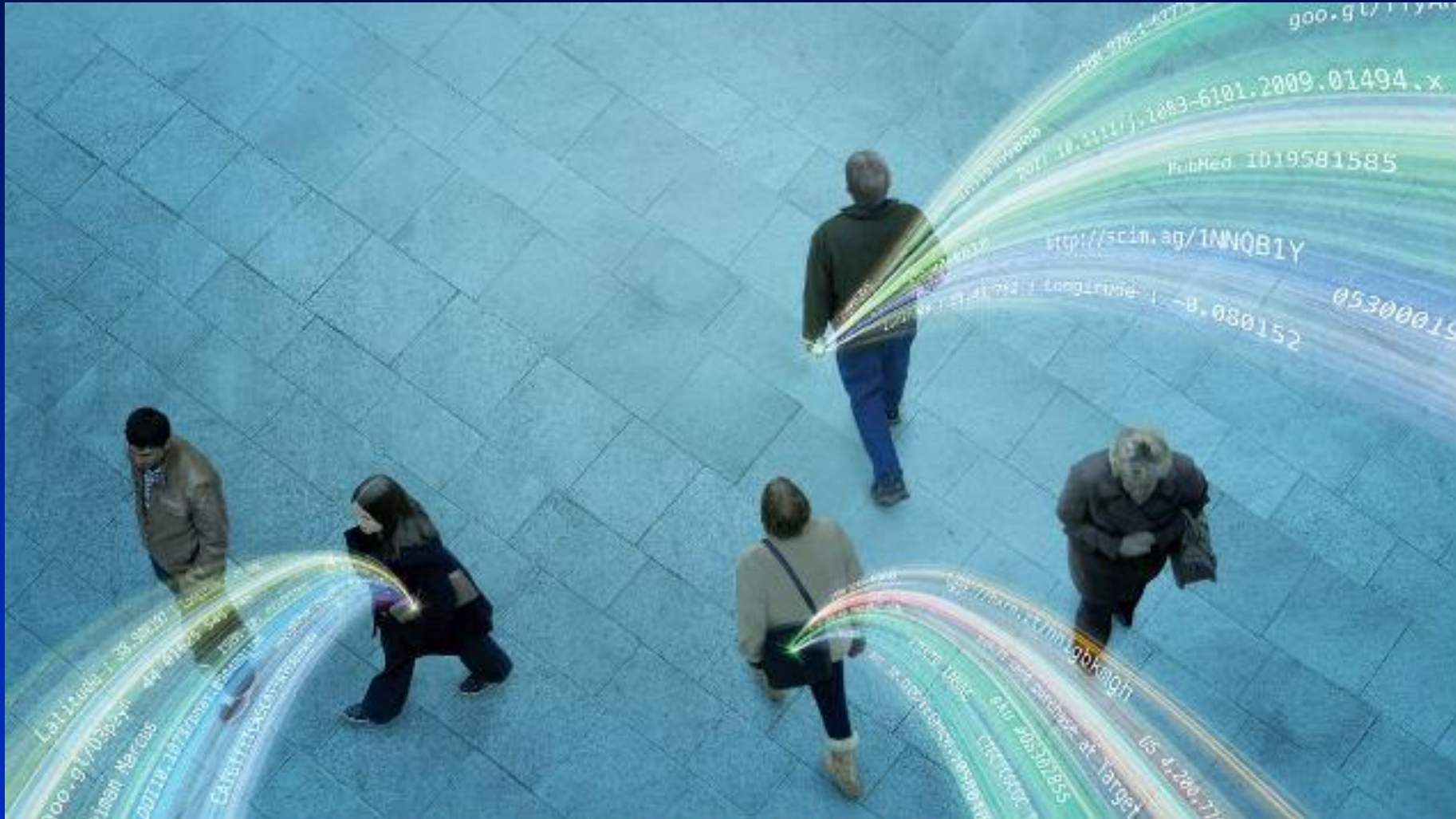
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- Freedom of Speech vs. Security vs. Privacy?
- Maintenance of net neutrality and a free Internet?

# On the Internet, Nobody Knows You're a Dog



# Data streams continuously from your device





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**“The word ‘privacy’ may become an oxymoron.”**

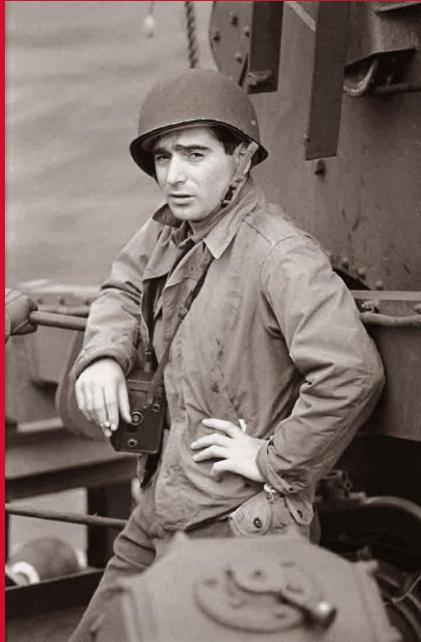
**- Uncle Don**

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What should be the ethics and rules in this age of digital photography?

# Magnum Photographers

Robert Capa



Henri Cartier-Bressone

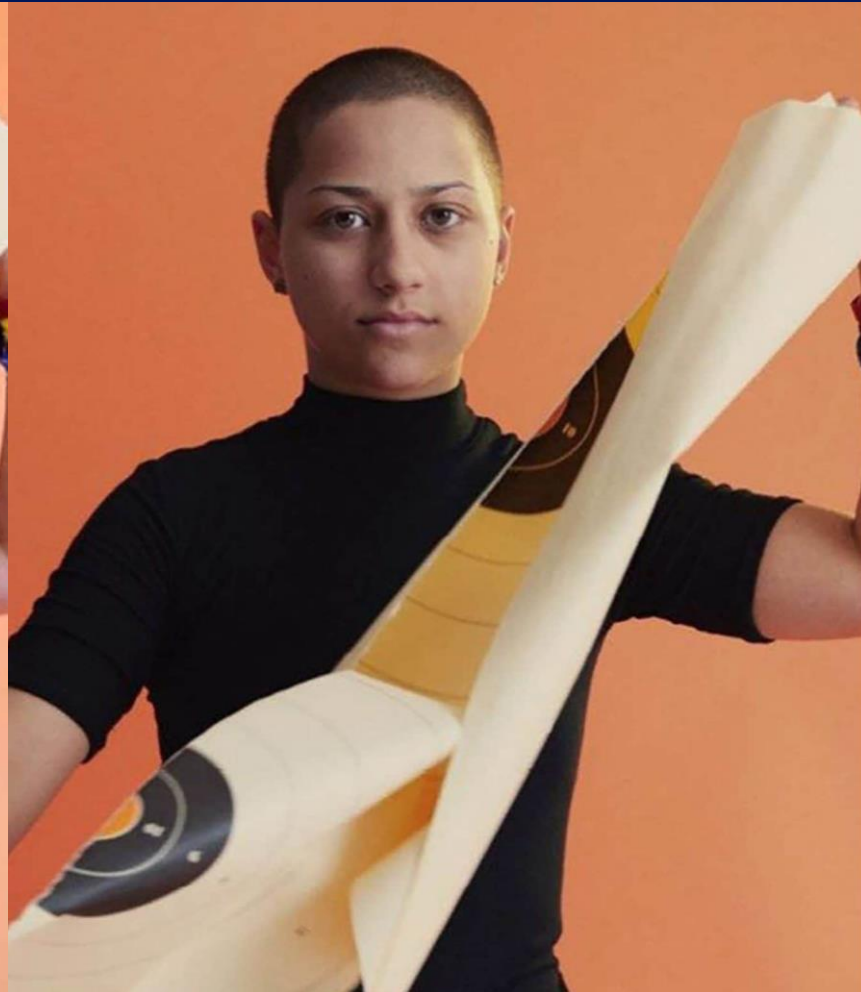


- Organization was founded on the ideal that photographs must not be altered, cropped, or manipulated in any form.

# Emma Gonzalez

2018

“We the People”



Target Bullseye

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“A lie can travel halfway around the world  
while the truth is putting on its shoes”

- *(attributed to) Mark Twain*

NYT

2020

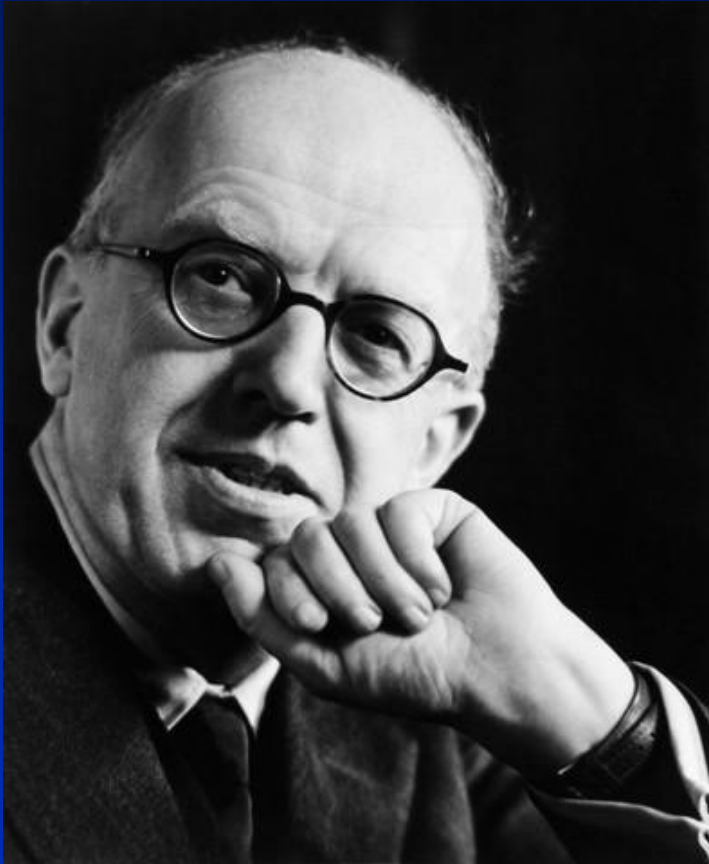


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Who should be responsible for content distributed  
by carriers or social media?

# C.P. Snow

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“The Two Cultures and  
the Scientific Revolution”  
The Rede Lecture, 1959



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**“If the scientists have the future in their bones,  
the traditional culture  
responds by wishing the future didn’t exist.”**

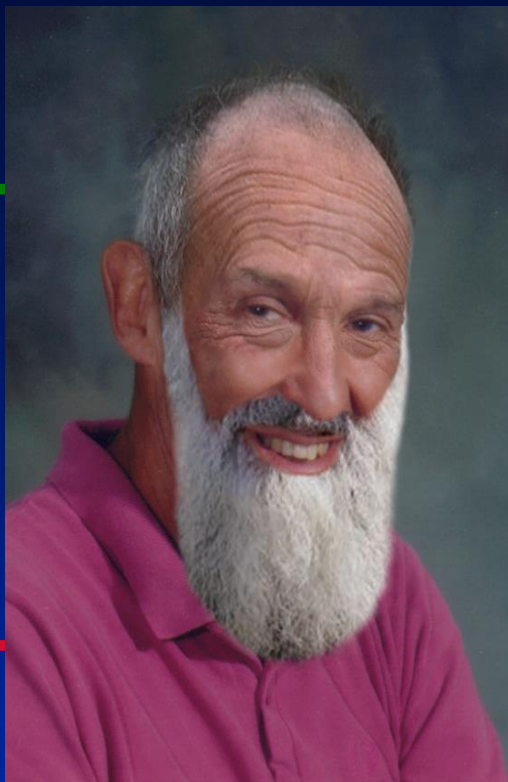


**Are you willing to take a risk?**

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“It’s the Wild West again!”  
(Or why I don’t want to retire)

-Uncle Don



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**December 10, 2019**

**End**

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