# Course on Virtual Reality

Introduction

# Virtual Reality – A First Definition

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Virtual Reality (VR) is a computer generated world. A user can interact with this world and experience it with her natural senses.

# Computer-Generated Worlds

- Worlds …
  - … that are a copy of reality as realistic as possible
    - Simulation: physical/technical phenomena, battle/war …
  - … that existed in the past or do not exist yet
    - Planned buildings, products
    - Ancient temples
  - … that cannot be entered or perceived in reality
    - Human body, Molecules, Planets
  - … that are “phantastic”
    - “Artificial Reality”

# Virtual Reality – A First Definition

Virtual Reality (VR) is a computer generated world. A user can interact with this world and experience it with her natural senses.

# Features

- Interaction
  - Navigation: User can move within the virtual world
  - Manipulation of virtual objects
- Natural, intuitive user interface
  - Three-dimensional input and output
  - Multimodality: Include more senses!
    - visual, acoustic, haptic/tactile, proprioceptive ...
- „Immersion“
  - The user is fully surrounded by the virtual world
  - Presence: „Illusion of being there“

# What is Virtual Reality all about?


I³


- Navigation
- Manipulation

... in real-time!


- 3-D & multimodal
  - visual
  - acoustic
  - haptic/tactile
  - proprioceptive

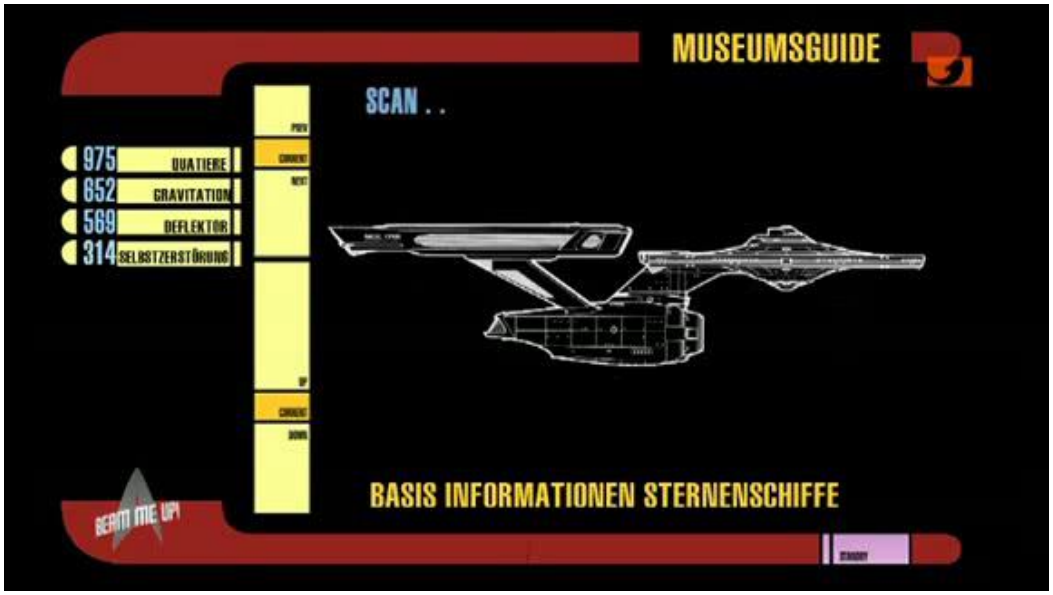
# Virtual Reality – The Vision

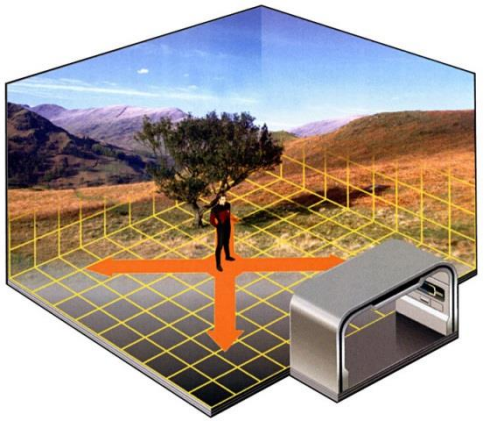
"The perfect Virtual Reality is a perfect illusion: The user can no longer distinguish the virtual world from the real, physical world."

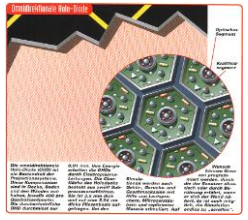
# Ivan Sutherland: The Ultimate Display, 1965

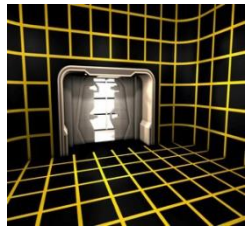
*„The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming, such a display could literally be the Wonderland into which Alice walked.“*

# Virtual Reality in Science Fiction







# Virtual Reality in Science Fiction



# Virtual Reality – Techniques in a Nutshell

# Head-Mounted Display


The Oculus Rift HMD, 2015

Ivan Sutherland, 1965

# Classical VR System of the 90's

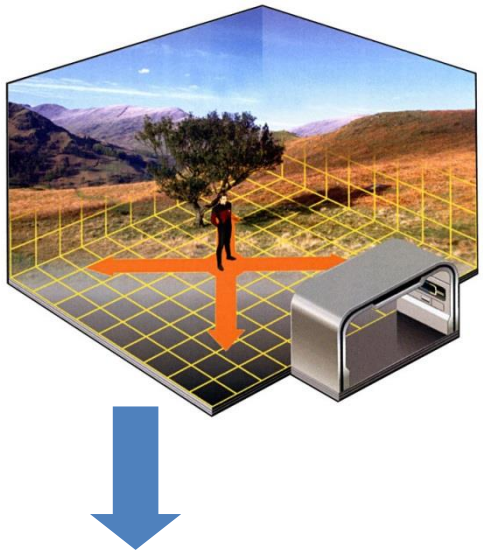
Graphics Computer

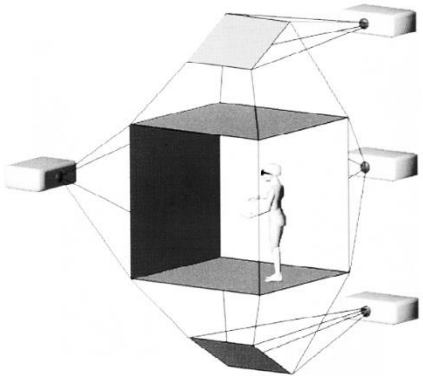
Head Mounted Display

(electromagnetic) Tracking System

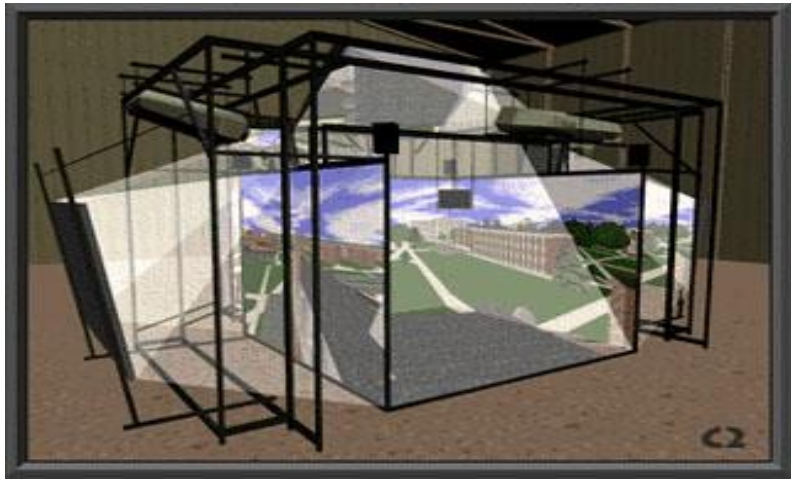
Instrumented Glove

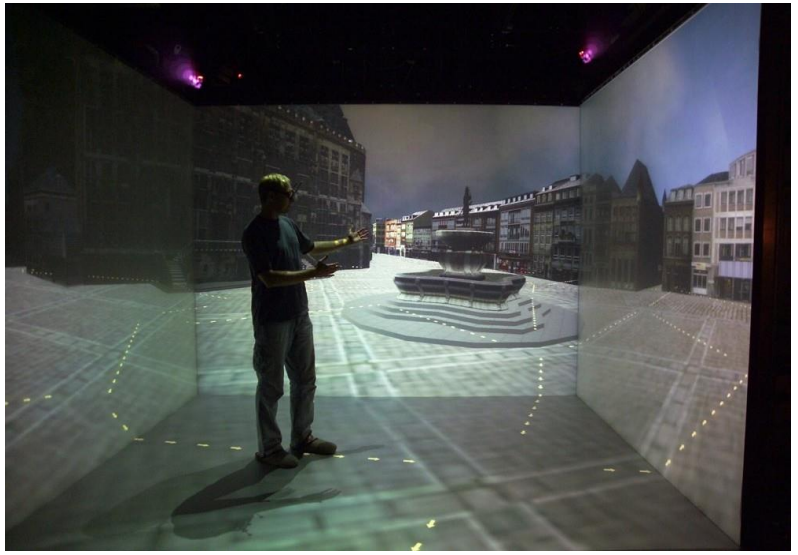
# Immersive Displays: CAVE



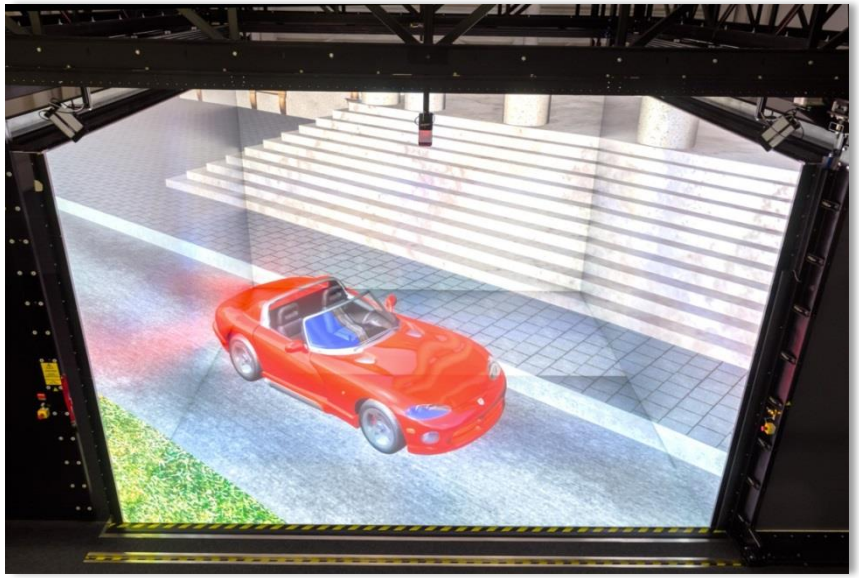


„The CAVE“, Carolina Cruz-Neira et al., 1993





# The aixCAVE @ RWTH Aachen

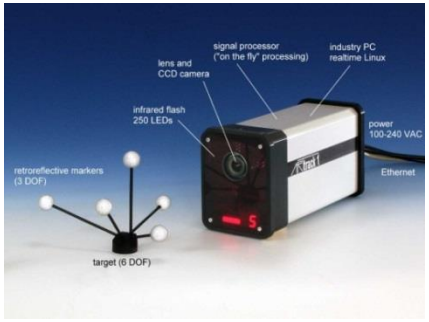
**Same visual perception in real & virtual world!**

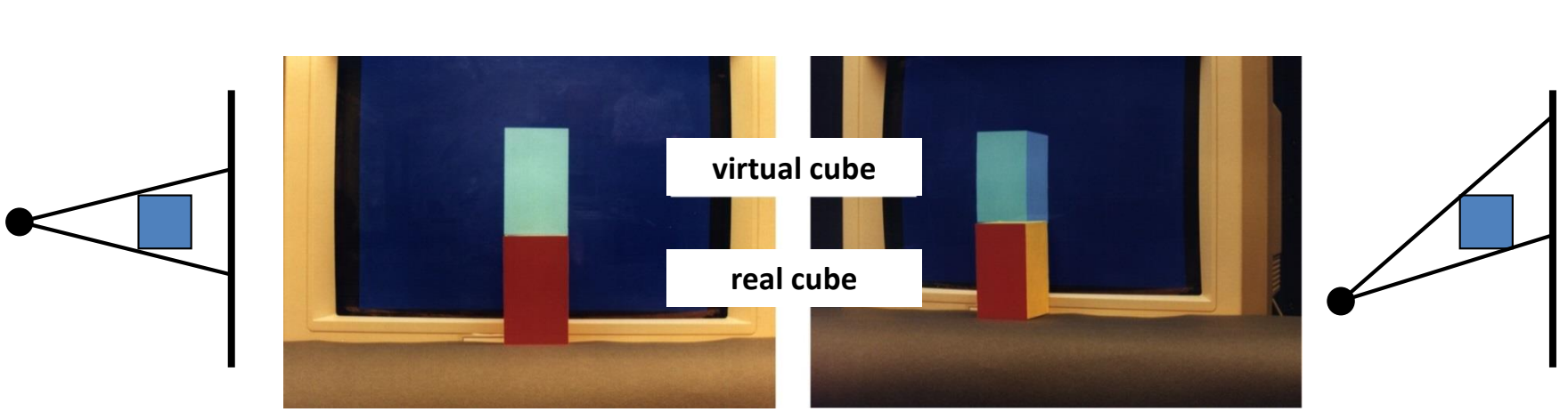
➡ Realize stereo **AND** motion parallax


# Motion Parallax & Viewer Centered Projection

## Stereo parallax

## Motion parallax



# VCP on a Workbench

Video: Courtesy of VRVis, Vienna

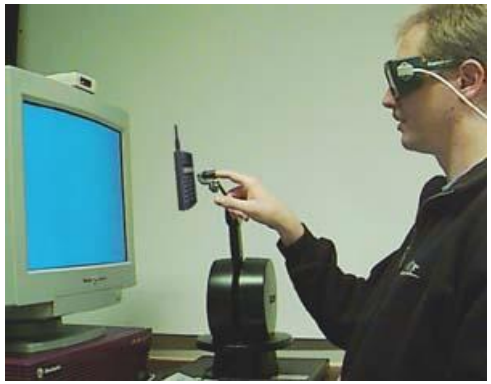
# VCP in the aixCAVE

# Stuttgart Stammheim as an Example for the Illusion of Presence

# Interaction Hardware

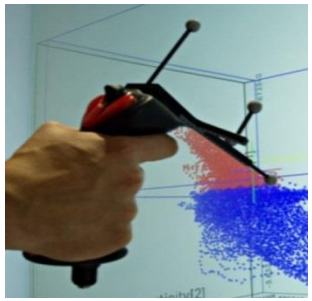
CyberGlove

CyberGrasp



PHANToM
Haptic Device

SpaceMouse



„Flying“ Joystick

Handhelds

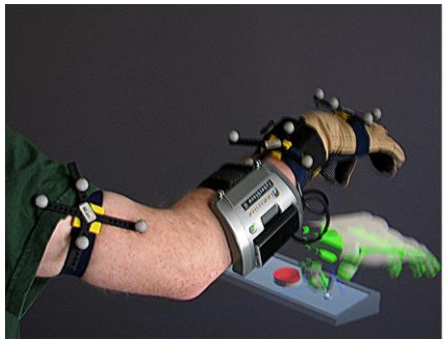
Nintendo
Wii

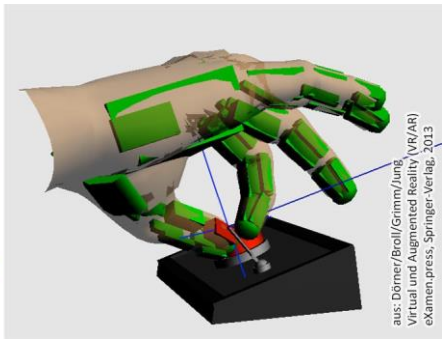
(Infrared) Tracking

Microsoft
Kinect

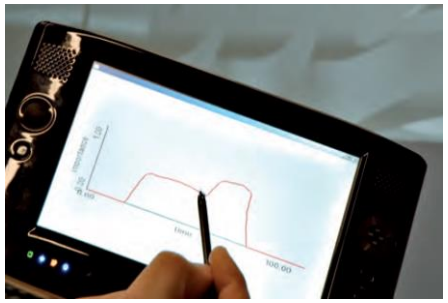
# „Visionary“ View versus „Pragmatic“ View

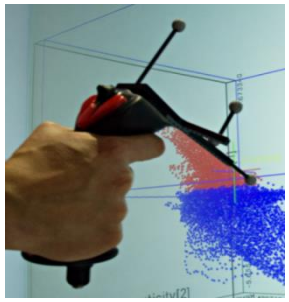
- The visionary view requires natural interaction:
  Create interfaces that imitate interaction with the real world

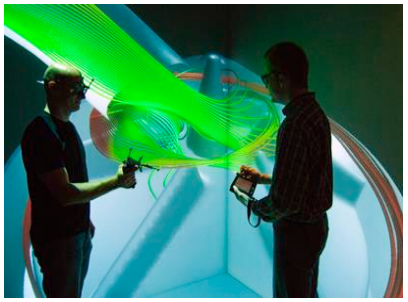





- VR as a tool for science and industry:
  Create interfaces that are designed to solve your problem







# What is a Virtual Reality System all about?


I³


- Navigation
- Manipulation

... in real-time!


- 3-D & multimodal
  - visual
  - acoustic
  - haptic/tactile
  - proprioceptive

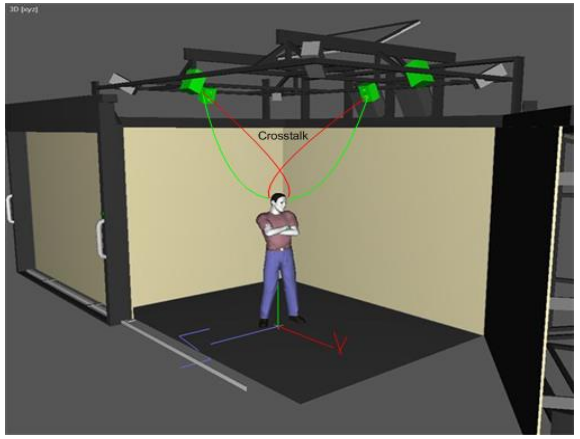
# Head-Mounted Display


The Oculus Rift HMD, 2015

# High Quality 3-D acoustics in the RWTH CAVE

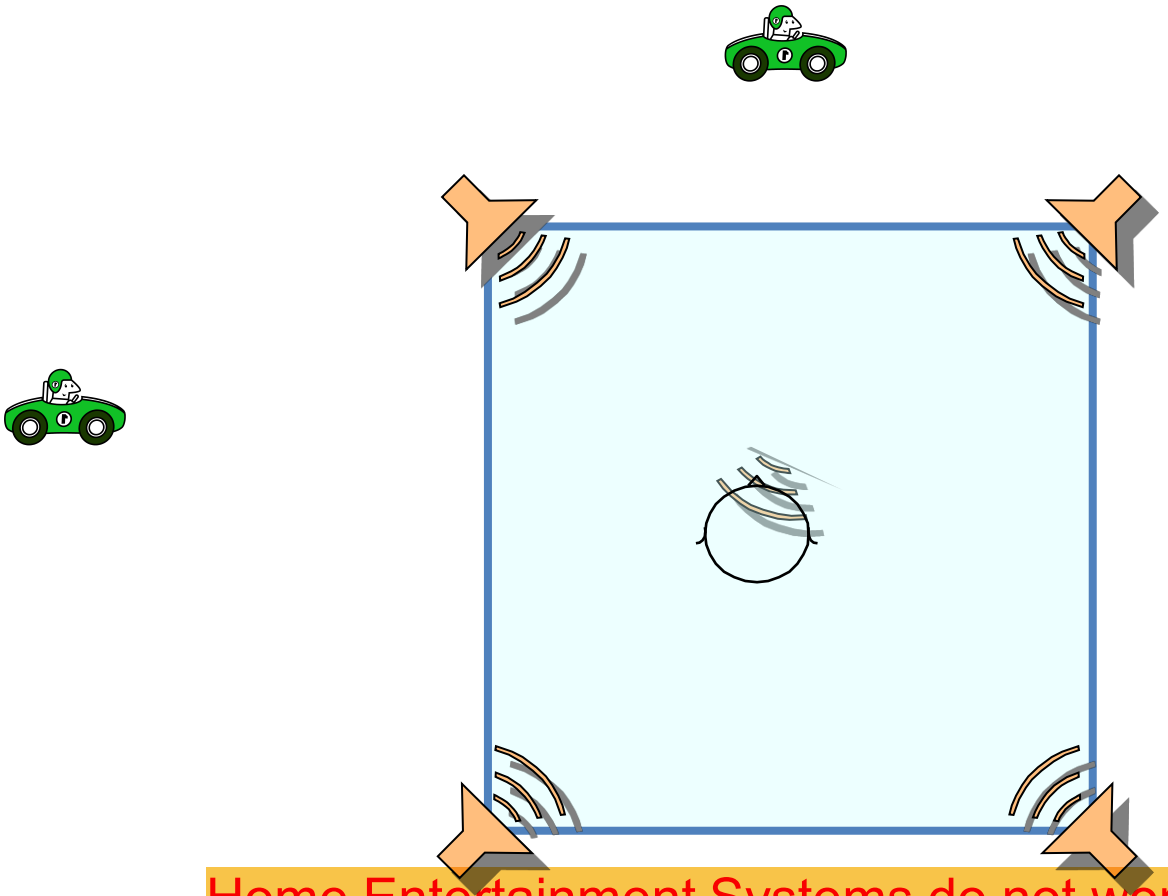
F. Wefers, D. Rausch, T. Lentz, I. Assenmacher, D. Schröder

- Dynamic binaural synthesis with loudspeakers




Institute of Technical Acoustics, VR Group

# Situation in CAVE-like Environments



Home Entertainment Systems do not work for virtual near-body sound sources!

# Virtual Reality – Definitions Revisited

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# Ivan Sutherland: The Ultimate Display, 1965

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# Jaron Lanier: The Pioneer of Virtual Reality

In the 80's, Jaron Lanier created the term "Virtual Reality" without giving a definition of it: "It's about the system I created."

More details → Chapter on History of VR

Jaron Lanier
(WWW pic)

# The Pioneer of Virtual Reality

Jaron Lanier
(WWW pic)

Frankfurt/Main - Der US-amerikanische Internetpionier und Autor Jaron Lanier erhält den Friedenspreis des Deutschen Buchhandels 2014. Der 54-jährige Informatiker, der als Erfinder des Begriffs "virtuelle Realität" gilt, wurde einem breiteren Publikum durch sein Sachbuch "You Are Not A Gadget" (2011) bekannt, zuletzt erschien von ihm auf deutsch "Wem gehört die Zukunft?".

Lanier habe erkannt, welche Risiken die digitale Welt für die freie Lebensgestaltung eines jeden Menschen habe, heißt es in der Begründung des Stiftungsrats. Lanier weise auf die Gefahren hin, "die unserer offenen Gesellschaft drohen, wenn ihr die Macht der Gestaltung entzogen wird und wenn Menschen, trotz eines Gewinns an Vielfalt und Freiheit, auf digitale Kategorien reduziert werden".

June 5, 2014

SPIEGEL ONLINE

# Friedenspreis des dt. Buchhandels für Lanier

„ … Lanier kritisiert das Geschäftsmodell von Internetunternehmen wie Google und Facebook, die massenhaft persönliche Daten von Internetnutzern sammeln und die damit verbundene Reichweite für Werbung nutzen. Der Reichtum werde so in den Händen einiger weniger Unternehmer konzentriert, fürchtet Lanier, während die breite Mitte der Gesellschaft leer ausgeht. "Wir brauchen eine neue Art von Balance", sagte Lanier in Frankfurt. … Der Schriftsteller plädiert für die schrittweise Einführung eines neuen Modells der Internetwirtschaft, bei dem die privaten Urheber von Informationen für jeden Aufruf ihrer Daten mit Kleinstbeträgen vergütet werden sollen. … Die Auszeichnung Laniers mit dem Friedenspreis, stieß gerade im Internet auch auf Kritik. Jürgen Geuter schrieb, der Preis für Lanier sei "eine Kampfansage an das 'Netz des Everybody'": "Er ist eine Ablehnung von Ideen wie OpenSource und Crowdsourcing, eine Forderung der Rückbesinnung auf traditionelle Macht- und Produktionsstrukturen."


October 12, 2014 SPIEGEL ONLINE

# Technology Perspectives of VR

Virtual Reality refers to the use of three-dimensional displays and interaction devices to explore real time computer-generated environments.

(Steve Bryson, IEEE Symposium 1993)

Virtual Reality refers to immersive, interactive, multi-sensory, viewer-centered, three-dimensional computer-generated environments and the combination of technologies required to build these environments.

(Carolina Cruz-Neira, SIGGRAPH 1993).

# HCI Perspectives of VR

The promise of immersive virtual environments is one of a three-dimensional environment in which a user can directly perceive and interact with three-dimensional virtual objects. The underlying belief motivating most VR research is that this will lead to more natural and effective human-computer interfaces.

(Mark Mine et al., 1997)

The primary defining characteristic of VR is inclusion; being surrounded by an environment. VR places the participant inside information.

(Meredith Bricken, 1990)

# Virtual Reality versus Computer Graphics

| Computer Graphics | Computer Games | Virtual Reality |
|---|---|---|
| 2D interaction | | 3D interaction |
| not time-critical | real-time rendering & interaction | |
| just visual | mostly visual | multimodal |
| static scene or animation | real-time simulation (focus on visual effects) | real-time simulation (focus on physical correctness) |
| non-immersive | | immersive |
| exocentric perspective | | egocentric perspective |

VR games are on the rise

# Related Expressions

- Virtual Reality System

  System of computer hardware & software to realize a virtual world

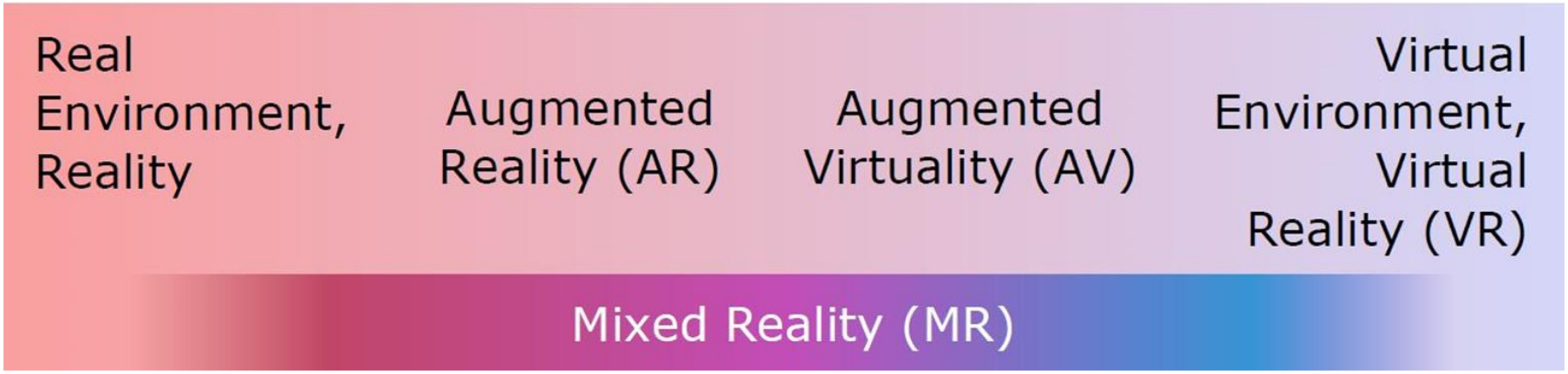
- Virtual World ("Cyberspace" in the 90's)

  Content shown via a VR system, comprising computer-generated (geometrical) models and their behaviour, and their arrangement in 3D space

- Virtual Environment

  Virtual Reality System & Virtual World

# The Mixed Reality Continuum




- Augmented Reality is not a topic of this course although many techniques are identical or at least similar

# Virtual Reality – The Challenges for Computer & Engineering Sciences

# What is a Virtual Reality System all about?




- Navigation
- Manipulation

... in real-time!


- 3-D & multimodal
  - visual
  - acoustic
  - haptic/tactile
  - proprioceptive

# VR Challenges

- How to create good 3D interfaces and devices?
- How to create good multimodal interfaces and devices?
- How to create good immersive displays?
- How to create and simulate rich, dynamic virtual worlds?
- How to develop powerful Virtual Reality software?
- How to achieve real-time performance?

# For VR Systems, Real-Time is a Big Challenge!

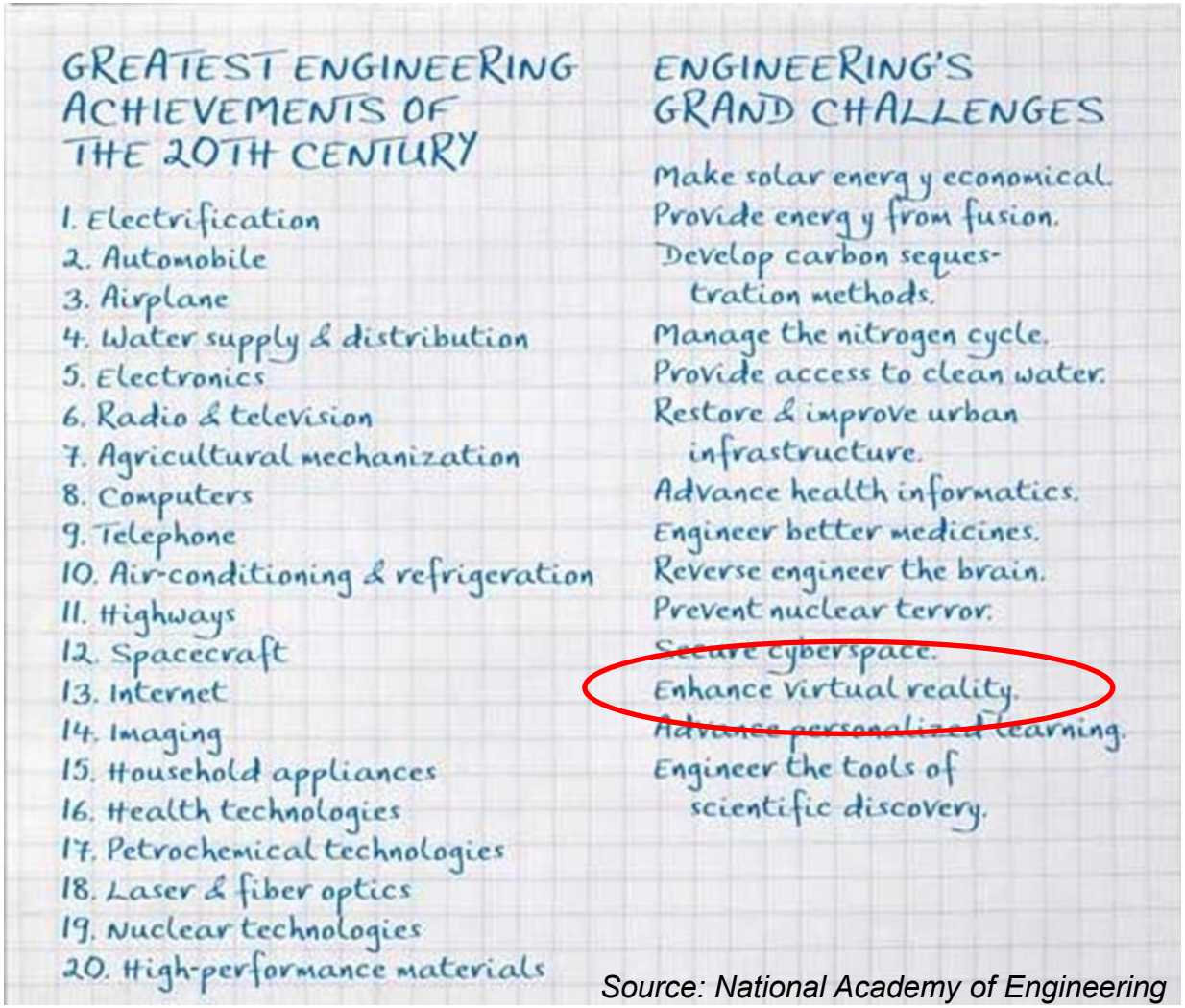
- Rendering of the virtual world
  - Visual Rendering: 60 Hz
  - Haptic Rendering: 1000 Hz
- Behaviour of the virtual world
  - Physics of solid objects
  - Physics of deformable objects
  - Behaviour of virtual ceatures
  - Artificial intelligence of virtual humans
  - Physical effects: light, wind, …
- User interaction in the virtual world
  - Latency: Time from user action to system reaction

# Virtual Reality – Is it important?

# Motivation for Virtual Reality

- Flight and drive simulators
- Computer games
- Product development: Virtual Prototyping
- Factory planning
- Architecture
- Cultural heritage
- Data analysis in Computational Engineering Science
- Medical simulation
- Psychatric therapy
- VR as the better user interface
- VR as a goal in it’s own right

# Engineering's Great Challenges



GREATEST ENGINEERING ACHIEVEMENTS OF THE 20TH CENTURY

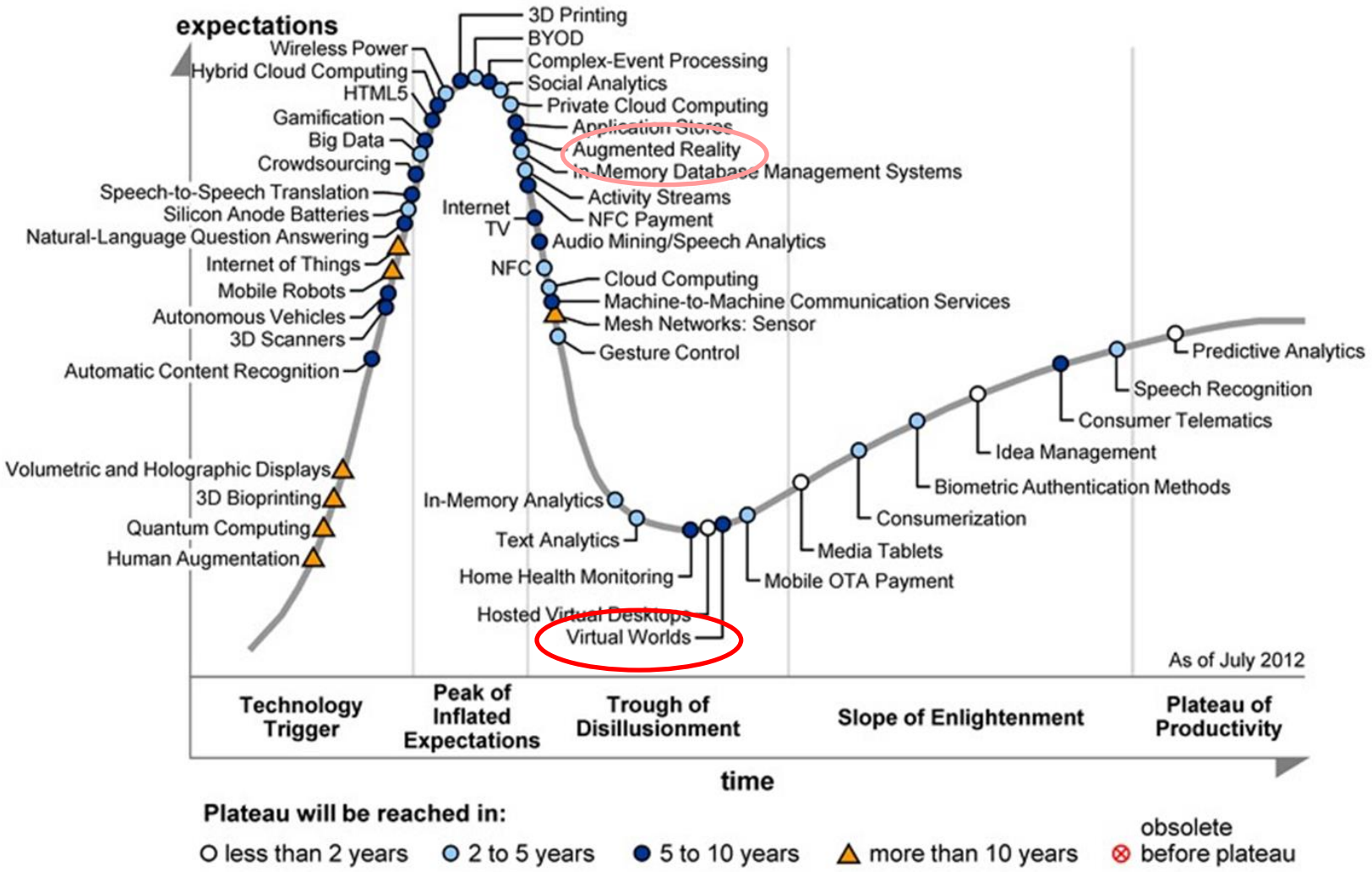
1. Electrification
2. Automobile
3. Airplane
4. Water supply & distribution
5. Electronics
6. Radio & television
7. Agricultural mechanization
8. Computers
9. Telephone
10. Air-conditioning & refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household appliances
16. Health technologies
17. Petrochemical technologies
18. Laser & fiber optics
19. Nuclear technologies
20. High-performance materials

ENGINEERING'S GRAND CHALLENGES

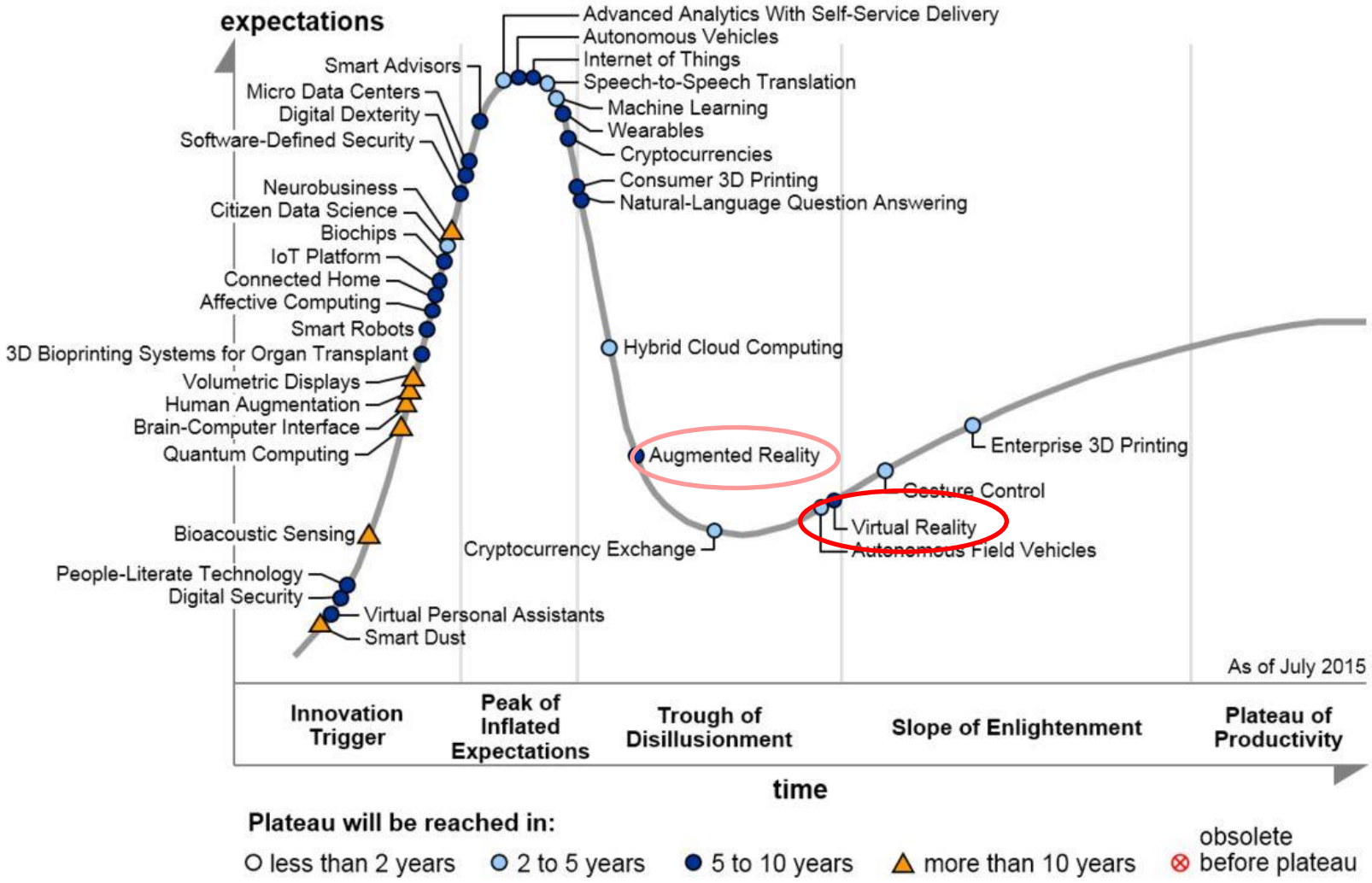
Make solar energy economical.
Provide energy from fusion.
Develop carbon sequestration methods.
Manage the nitrogen cycle.
Provide access to clean water.
Restore & improve urban infrastructure.
Advance health informatics.
Engineer better medicines.
Reverse engineer the brain.
Prevent nuclear terror.
Secure cyberspace.
Enhance virtual reality.
Advance personalized learning.
Engineer the tools of scientific discovery.

*Source: National Academy of Engineering*

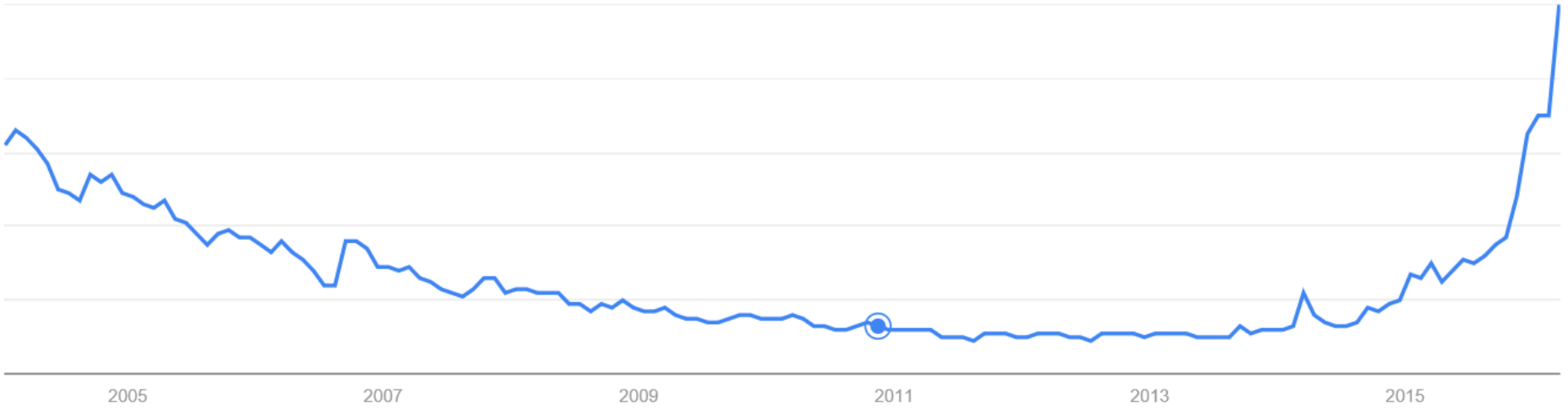
# Gartner's 2012 Hype Cycle for Emerging Technologies



# Gartner's 2015 Hype Cycle for Emerging Technologies

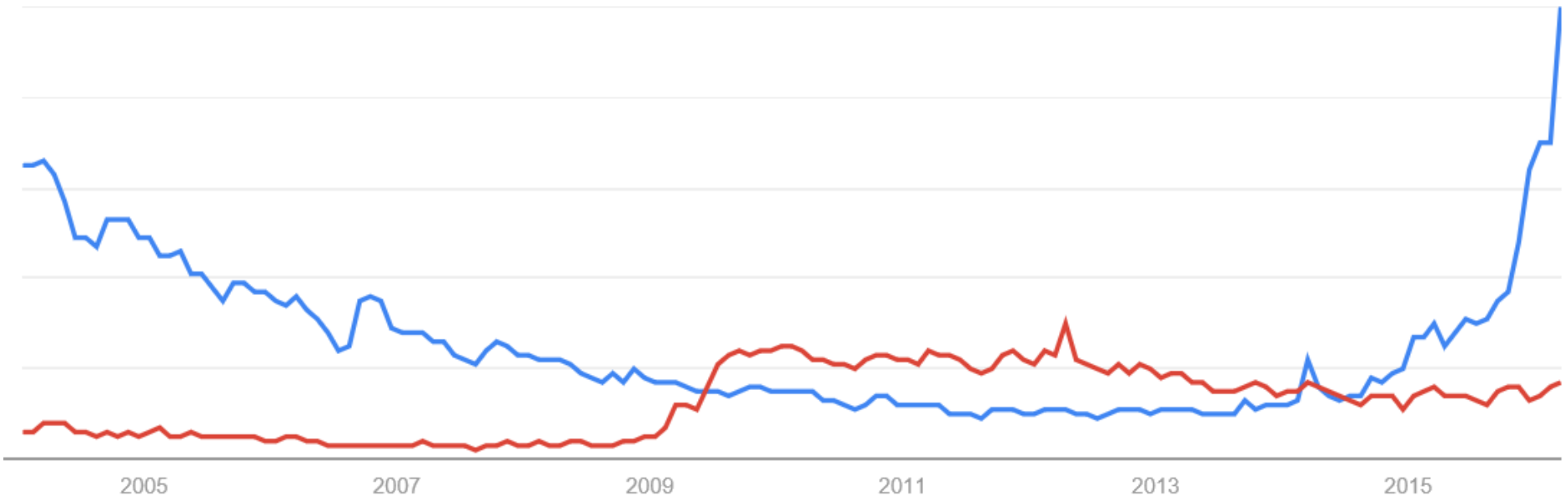


# Google Trends




## Virtual Reality

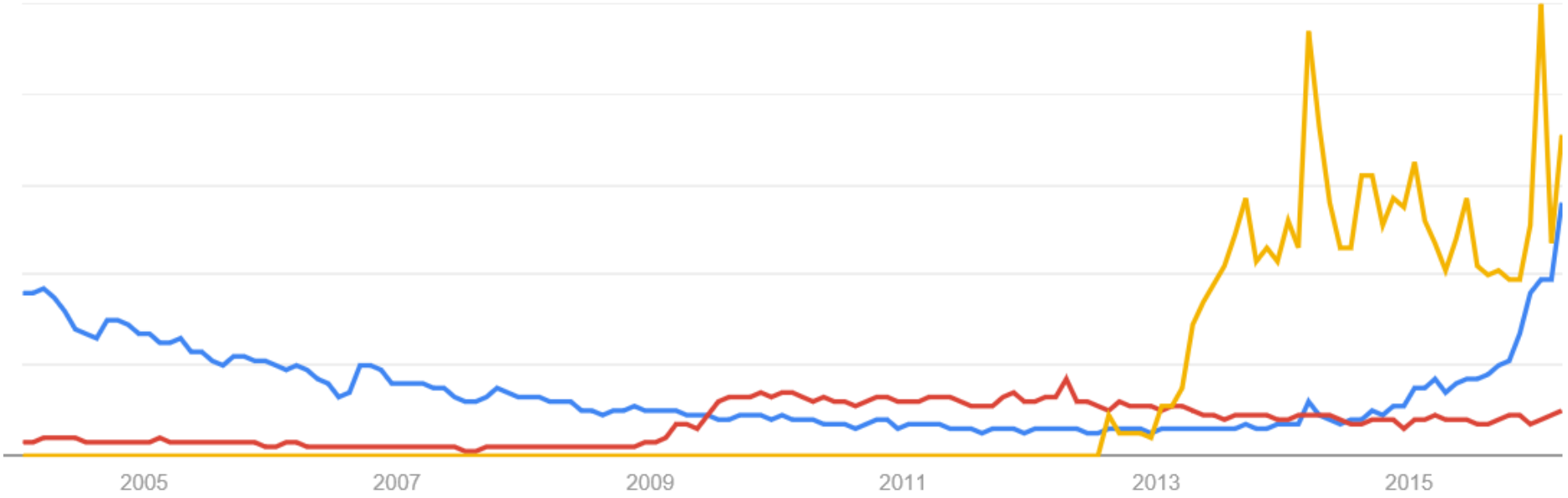
# Google Trends




**Virtual Reality**

**Augmented Reality**

# Google Trends



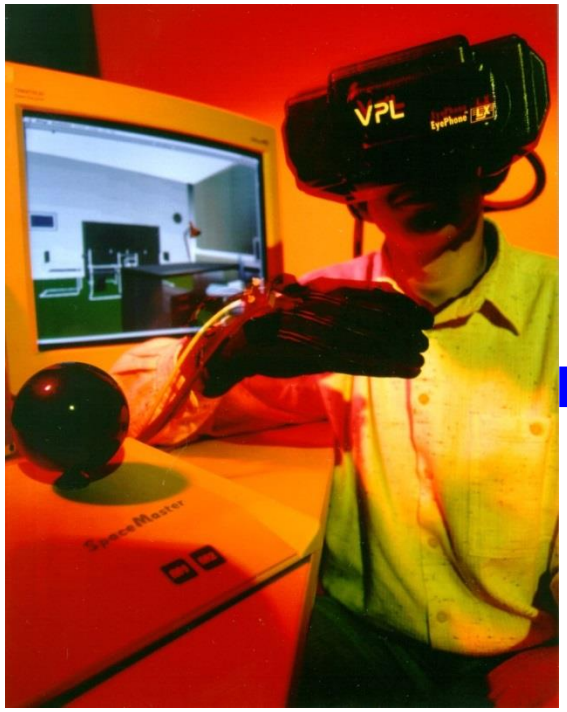

Virtual Reality

Augmented Reality

Oculus Rift

# Head-Mounted Displays versus Stereo Glasses

**Until 1994:**
**VR = HMD + Instrumented Glove**




**1995 – today**
**Stereo Glasses (here: Shutter)**

**Back to the future!?**
**Time Magazine, August 2015**