Stereoscopic-3D
Looking at the Next Decade

Buddha: Do not dwell in the past, do not dream of the future, concentrate the mind on the present moment!

Einstein: The distinction between the past, present and future is only a stubbornly persistent illusion…

Sunil Jain
Lead Architect & Strategist
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About the Author

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"While I take inspiration from the past, like most Americans, I live for the future" **- Ronald Reagan**

Sunil Jain is Lead Architect and Strategist at Intel. As part of the PC Client Group, Sunil is responsible for bringing innovative technologies to PC platforms such as Desktops, Notebooks, and handheld devices. Sunil joined Intel in 1999 and has played several roles – chip Architect, platform Architect, Manager of the Video and Display Architecture teams, Director of Strategic Technology Programs, and now he is the Lead Architect and Strategist. Sunil started his career in 1985 at Siemens Medical and served as founder managing-director of Span Mechnotronix Ltd. from 1991-98. Sunil has multiple patents and innovations to his credit including world's first power-analog-mixed signal SoC for Intel Atom based X-86 systems, and first true universal stereoscopic 3D glasses that work for Active and Passive and PC and CE in many:many usage scenarios.
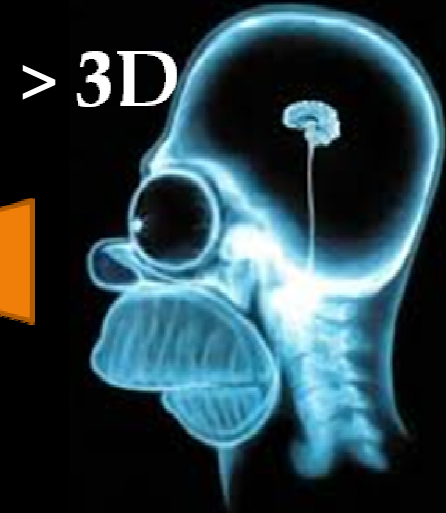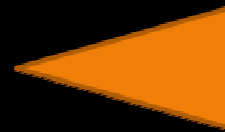
Agenda

- 3D Terminology & Basics… [15 mins]
- 3D State of Union in 2011… [15 mins]
- What's feasible in the decade ahead… [15 mins]
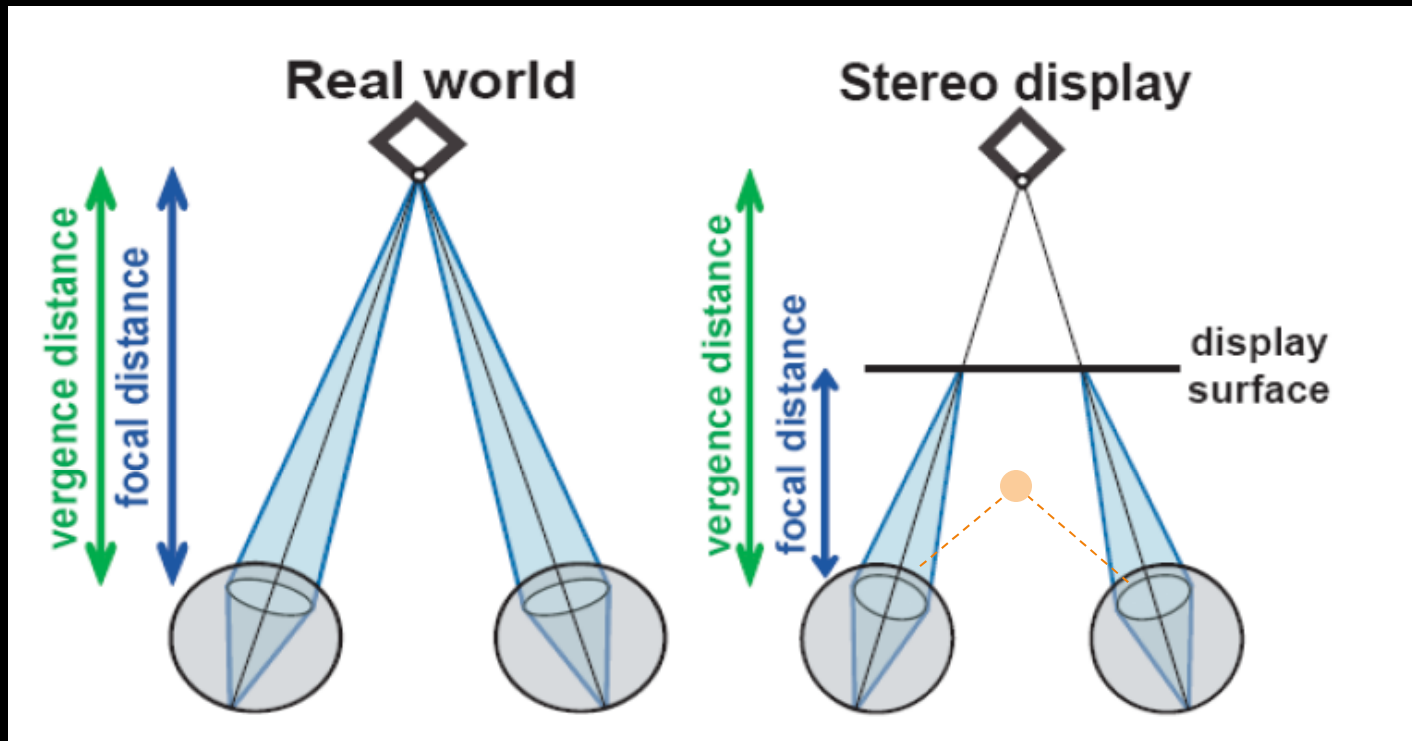- Q&A and discussions…

3D Terminology & Basics

If Simpson has to watch Homer in 2D, blame it on IEEE... Compute & Display engineers are too slow to solve trivial problems...

Modern displays cause visual discomfort

Accommodation: Ability of our eyes to focus on points of interest at different distances

Con-Divergence: Angle between the lines of sight of both eyes linked by muscle reflex

Clear & single binocular vision - for normal human visual dev - is achieved through accommodation & vergence

Prolonged Acc-Vergence conflict = viewing discomfort, eye strain, fatigue
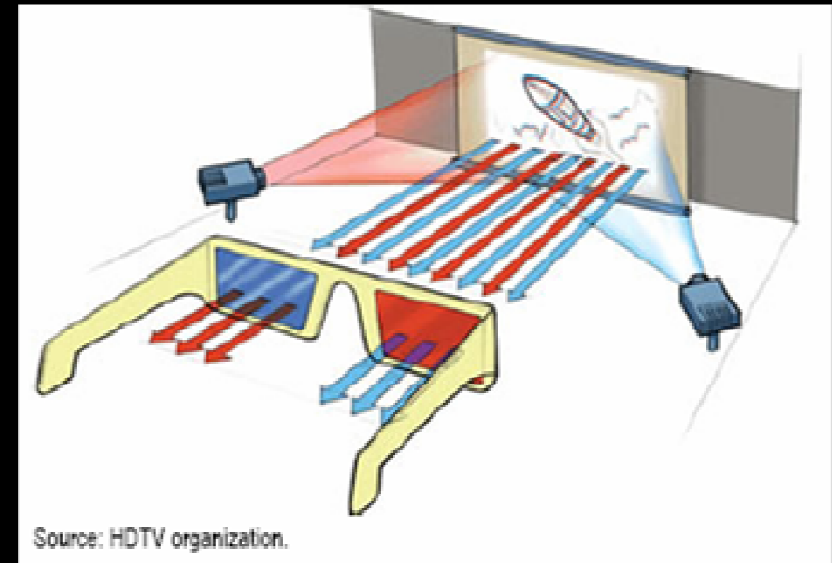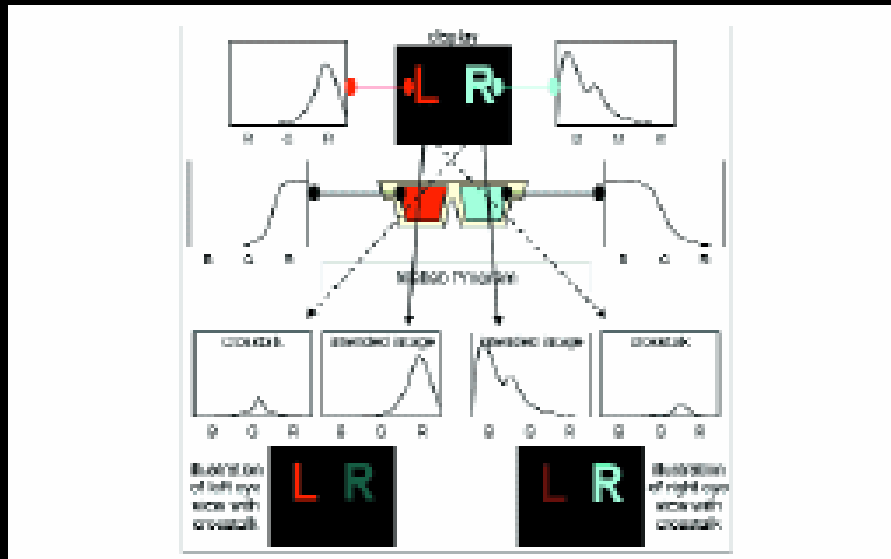
Stereoscopy >150 yrs of Novelty!

In 1838 Sir Charles Wheatstone described the theory of stereoscopic vision

Simple concept: Present each eye with a slightly different image; and brain will compute depth from the parallax
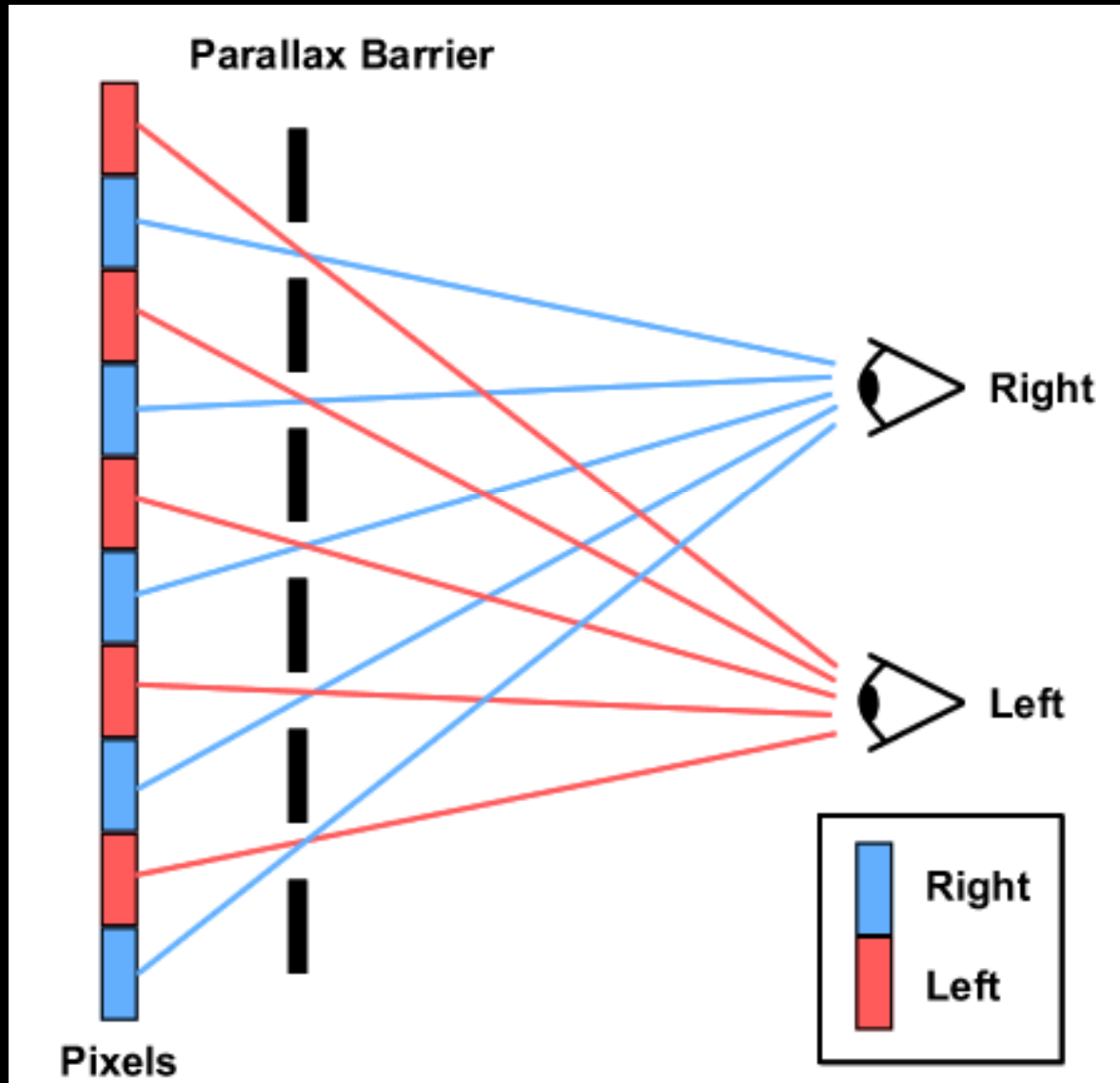
Spectral Barrier (a.k.a Anaglyph)

Source: HDTV organization.

1853: W. Rollman illustrated Anaglyph
1891: Louis Hauron printed Anaglyphs

1889: William Friese-Green created the first 3D Anaglyphic motion picture

Lenticular Barrier
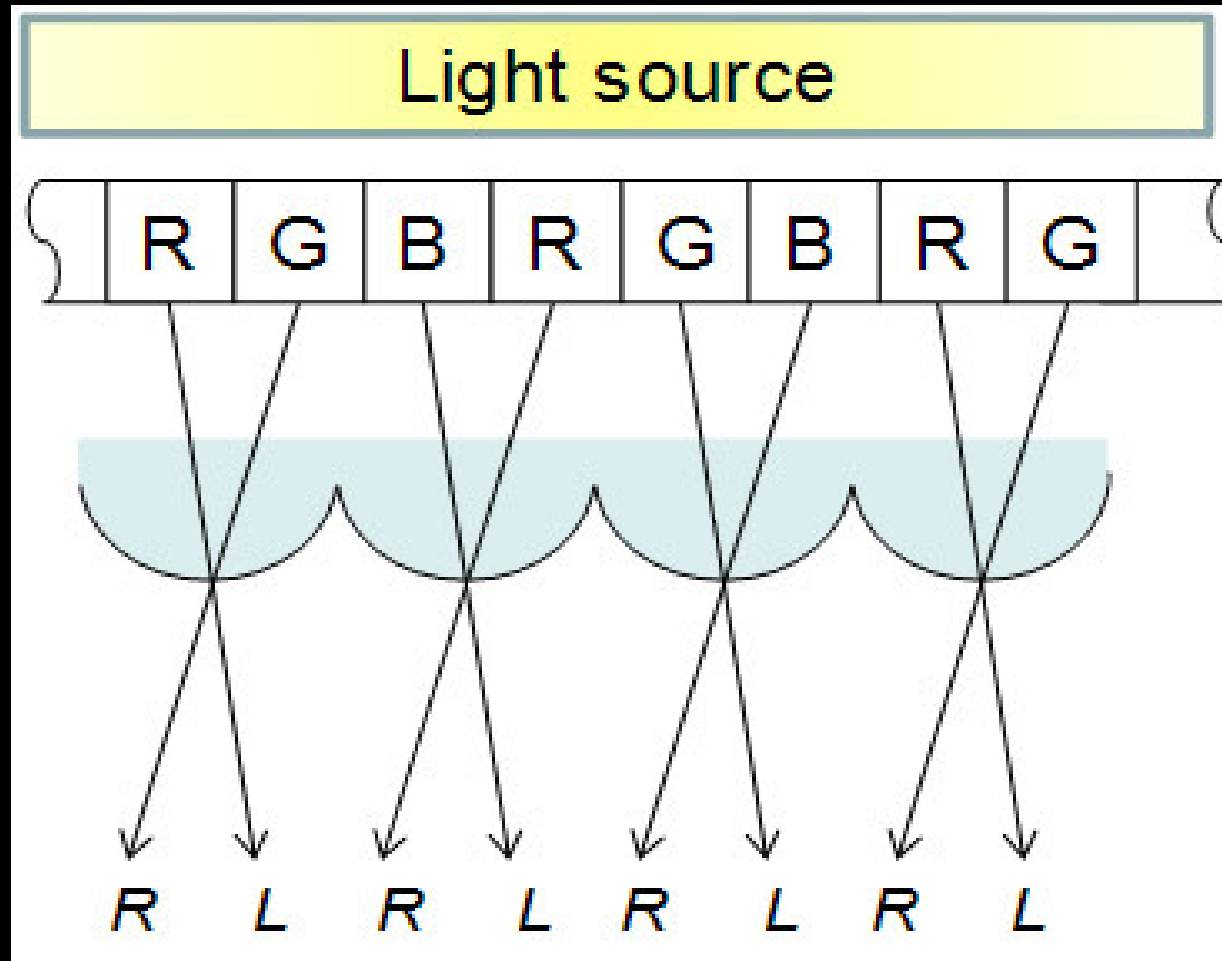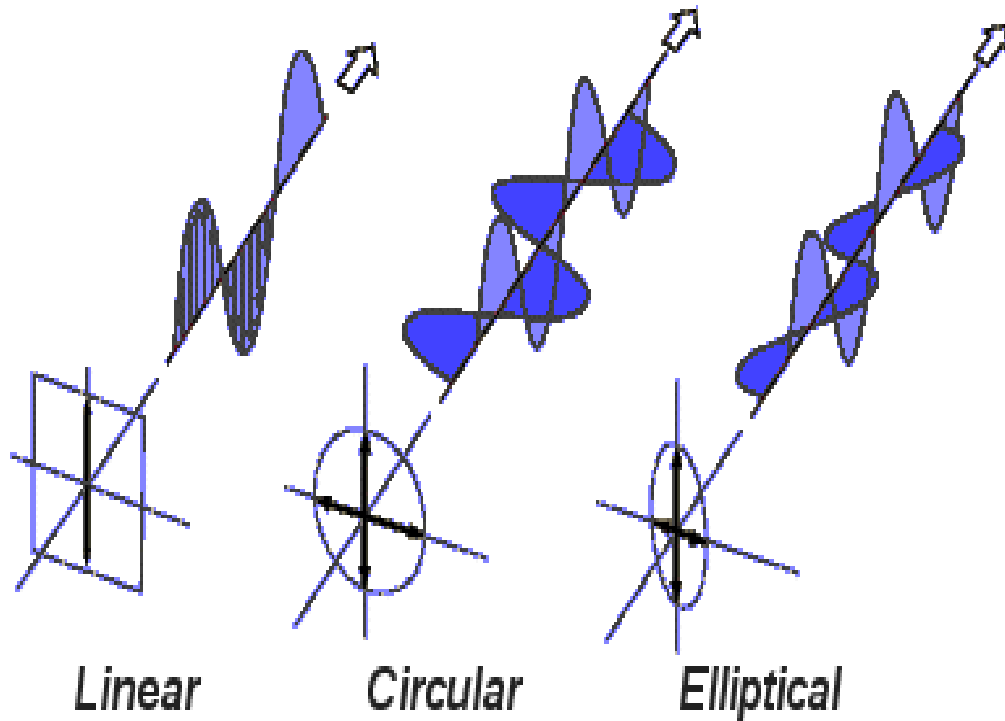

1908: Lippmann, M. G. "Épreuves réversibles. Photographies intégrales"

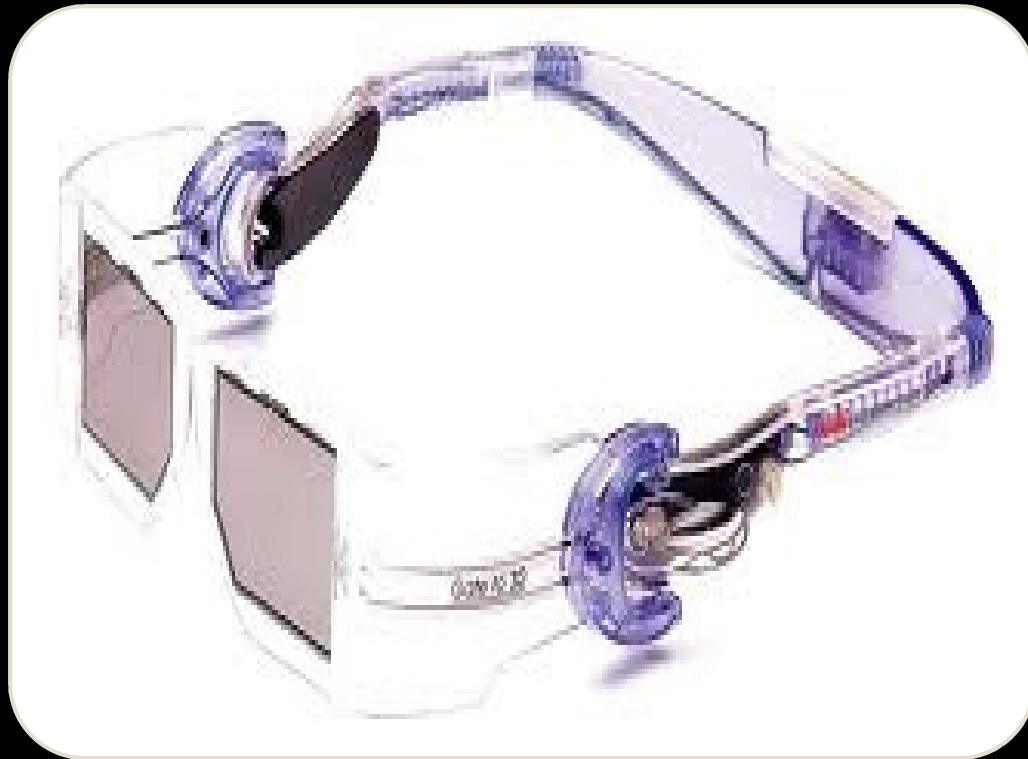**1915:** Patent #1128979, Hess, Walter, "Stereoscopic picture"

Polarization Barrier

Polarization of electromagnetic waves

Linear   Circular   Elliptical

LCD Shutter/ Retarder

- First proven by Stephen McAllister in the mid-1970s
- Active Shutter & Active Retarder popular in 3DTV, 3DPC and Cinema

S3D Technology Summary (2011 snapshot)

3D Technology	Display	Glasses	VQ	Suitability	Cost
Anaglyph	**Any**	Spectral	**Bad**	PC, TV, Projector	**Low**
Passive Polar	Polarizer	Polarizer	Half Res		Mid
Active Retarder	Shutter+Polarizer	Polarizer	<Full Res		High
Active Shutter	**Any <2ms**	Shutters	**Full Res**		**Mid**
Auto-Stereo (BL-temporal)	Optical Barrier (Active or Passive)	-	<Full Res	Phone, Tablet	Mid
Auto-Stereo (eye-tracking)				PC, TV, Projector	High
Multi-View 3D					High
Holo-Video	TBD?	-	Low?	Signage, Misc	R&D
Volumetric	TBD?	-	Low?	Signage, Misc.	R&D

Quick Recap

- ▣ Humans perceive depth using 4 physiological factors:-
  - a) Binocular disparity b)Motion parallax c) Accommodation , and d) Vergence
- ▣ 3D rendering is possible with fundamentally two different approaches:
  - a) Stereoscopic Viewing (each eye is presented with a different image)
  - b) Natural Viewing (both eyes look at the light field in a normal manner)
- ▣ Conventional 3D schemes are based on:
  - a) Two view (a.k.a. Stereoscopic-3D or S3D) b) Multi-view (a.k.a. Multi-scopic)

- ▣ Accommodation-vergence conflict and cross talk result into visual discomfort in viewing 3D. Visual quality can be improved or compensated for at each stage - Content generation, processing & rendering

- ▣ Stereoscopy requires each eye to be presented with a different image. This requires creating some kind of optical barrier between the eyes, through:-
  - a) Special eyewear (Anaglyph, Spectral, Passive Polarized, Active Retarder, Active Shutter)
  - b) Special optics on the display screen (a.k.a Auto-stereo)

- ▣ Holographic and Volumetric approaches emulate natural 3D viewing. Both approaches in R&D, require special transducers and extensive computations.

Key challenge and opportunity in the decade ahead is to deliver realism in 3D viewing.

Agenda

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- **3D State of Union in 2011… [15 mins]**
- What's feasible in the decade ahead… [15 mins]
- Q&A and discussions…
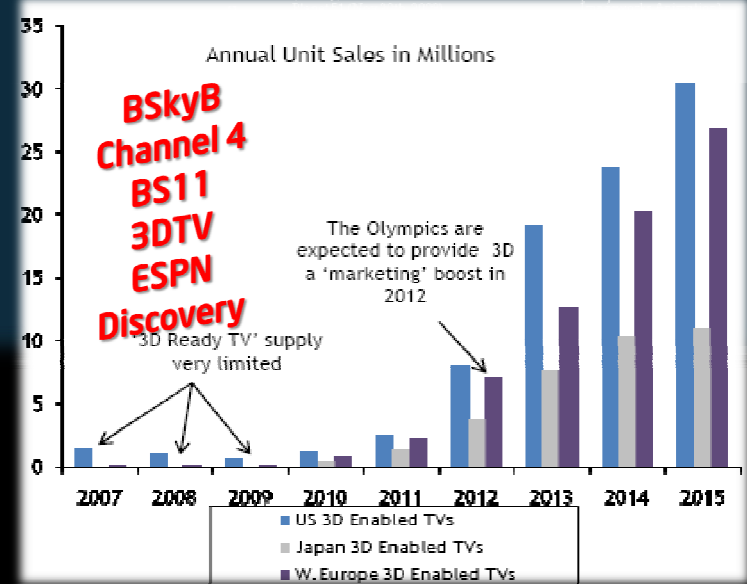
3D Technology is at an inflection point

U2 Concert filmed in 3D

World class events from all walks of life

1. U2 3D(IMAX as well as Real-D theaters)
2. English Ballet
3. Orange Bowl 2009
4. BCS Bowl 2009
5. French Open 2009
6. English Ballet Swan Lake
7. Jonas Brothers
8. Keane
9. Step Up 3D
10. 10 Broadway Musical will be shot in Stereo 3D Fugobi
11. Michael Jackson Concert
12. Brittany Spears
13. USC Ohio State Game 2009 ESPN
14. NBA All Star Game 2009
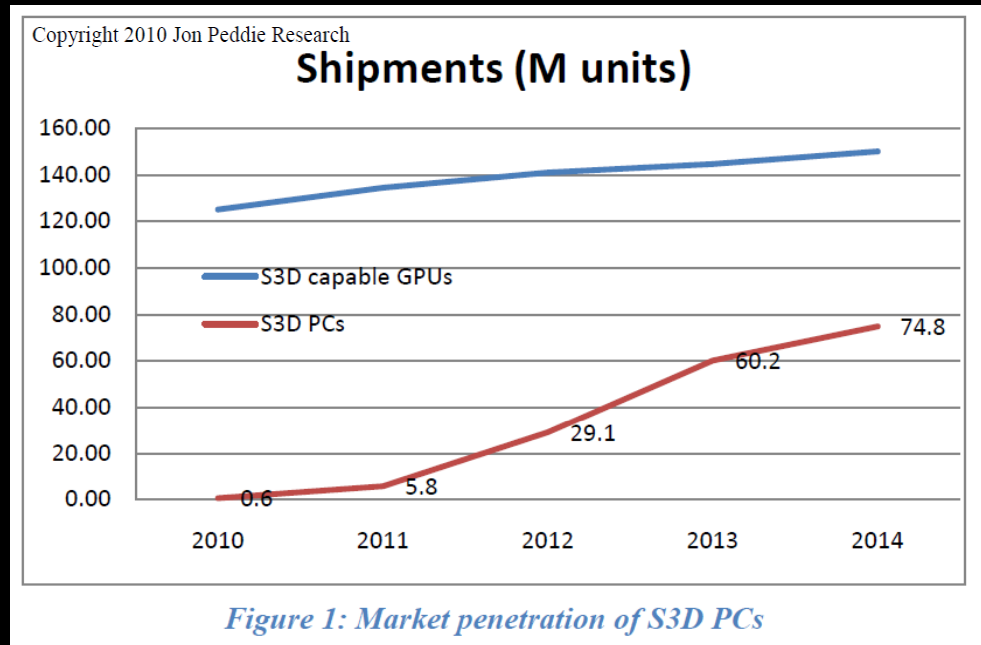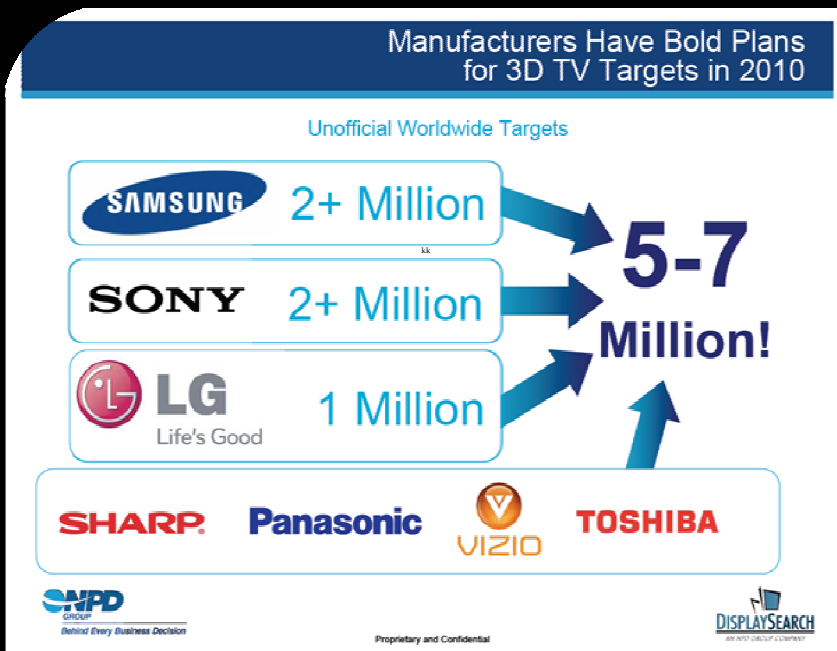15. Hannah Montana/Miley Cyrus: Best of Both Worlds

97 S3D Movie Titles and still counting....

1. Mars needs Mom Disney
2. The Forever War Ridley Scott
3. The Child Eye in 3D Pang Brothers
4. Cane Toads 2
5. Journey to Center of the Earth 2
6. Ocean 3D into the Deep
7. Puppet Master
8. Humpty Dumpty Amber Entertainment
9. Final Destination : Death trip 3D
10. Spiderman 4
11. Battle Angel James Cameron
12. Tintin Peter Jackson
13. The Legend of Spyro 3D
14. Hairspray 2
15. Rendezvous with Rama
16. Star Trek 3D
17. Step Up 3D
18. The Ushers Green Knight Ventures
19. Friends Life
20. Call of the Wild
21. Piranha 3-D (Alexandre Aja) (Dimension Films
22. RIO Blue Sky / Fox
23. Happy Feet 2
24. Gear of War 3D
25. Hubble 3D

54. Journey to the Center of the Earth 3D (July 11th, 2008) (New Line)
55. Fly Me to the Moon 3D (August 15, 2008)
56. Harry Potter and the Half Blood Prince (November 21, 2008) (Warner Bros)
57. Bolt (November 21, 2008) (Disney) (Chris Williams, Director) (Score by John Powell)
58. Coraline (Limited December 2008 Release) (Laika / Focus Features)
59. My Bloody Valentine 3D (January 16, 2009) (Lionsgate Entertainment)
60. Monsters vs. Aliens (March 27th, 2009) (Dreamworks Animation)
61. Under the Sea 3D (Spring) (IMAX) UNDER THE SEA 3D
62. Up (May 29th, 2009) (Disney-Pixar)
63. Ice Age Dawn of the Dinosaurs (July 1st, 2009) (Fox).
64. G-Force (July 24th, 2009) (Disney)

78. Alice in Wonderland (March 19th, 2010) (Tim Burton / Disney)
79. How To Train Your Dragon (March 26th, 2009) (Dreamworks Animation)
80. Alpha And Omega (April 16th, 2010) (Lionsgate)
81. Shrek 4 (May 2010) (Dreamworks Animation)
82. BlueMan IMAX 3D June 2010
83. Toy Story 3 (June 18th, 2010) (Disney)
84. Rapunzel (Christmas 2010) (Disney-Pixar)
85. Boat (2010) (Gaumont)
86. Around The World in 50 Years (2010?) (nWave)
87. Cereal Heroes (2010) (FableWorks LLC) (Sparx Animation Studios)
Cloudy With A Chance Of Meatballs (Sept. 2009) (Sony Pictures)

Annual Unit Sales in Millions

BSkyB
Channel 4
BS11
3DTV
ESPN
Discovery

The Olympics are expected to provide 3D a 'marketing' boost in 2012

'3D Ready TV' supply very limited

- ■ US 3D Enabled TVs
- ■ Japan 3D Enabled TVs
- ■ W. Europe 3D Enabled TVs

(chart years: 2007 2008 2009 2010 2011 2012 2013 2014 2015; y-axis 0–35)

Decade ahead: Realism in 3D at PC & CE Price Points!

3DTV and 3DPC - Analyst Projections
(2011 Snapshot)

Manufacturers Have Bold Plans for 3D TV Targets in 2010

Unofficial Worldwide Targets

SAMSUNG 2+ Million
SONY 2+ Million
LG Life's Good 1 Million

5-7 Million!

SHARP   Panasonic   VIZIO   TOSHIBA

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Shipments (M units)

S3D capable GPUs
S3D PCs

0.6   5.8   29.1   60.2   74.8

2010   2011   2012   2013   2014

Figure 1: Market penetration of S3D PCs

Actual 3D shipments in 2010: Lower than projected?

New Technology Challenges: *3D Content, System Cost, Bulky Glasses, Fragmented Solutions*

Practical 3D-PC configurations (2011 snapshot)

Content Cloud → Comcast → 802.11 Router

Disc

3DPC
Intel Graphics Driver Extensions
HW Decoder/Accelerator/Media Pipe
3D-Player and 2D-3D converter SW

PC Native Display
(Active Shutter 120Hz)

PC Native Display
(Circular Polarized)

PC Native Display
(Color Anaglyph)

3D TV

Active shutter glasses (triggered by TV)

120Hz Monitor

120Hz Projector

Active shutter glasses (triggered by PC)

Polarized Monitor

Polarized Projector

Polarized Glasses
(Linear, Circular, Elliptical)

Any Monitor

Any Projector

Any TV

Anaglyph Color Glasses

Expected Worldwide PC Sales (in Million Units)
[Market for 3DPC could be significant – still early]

(Data Source: IDC)

Year	Sales
2008	287.6
2009	291.4
2010	321.4
2011	360.1
2012	402.9
2013	444.4
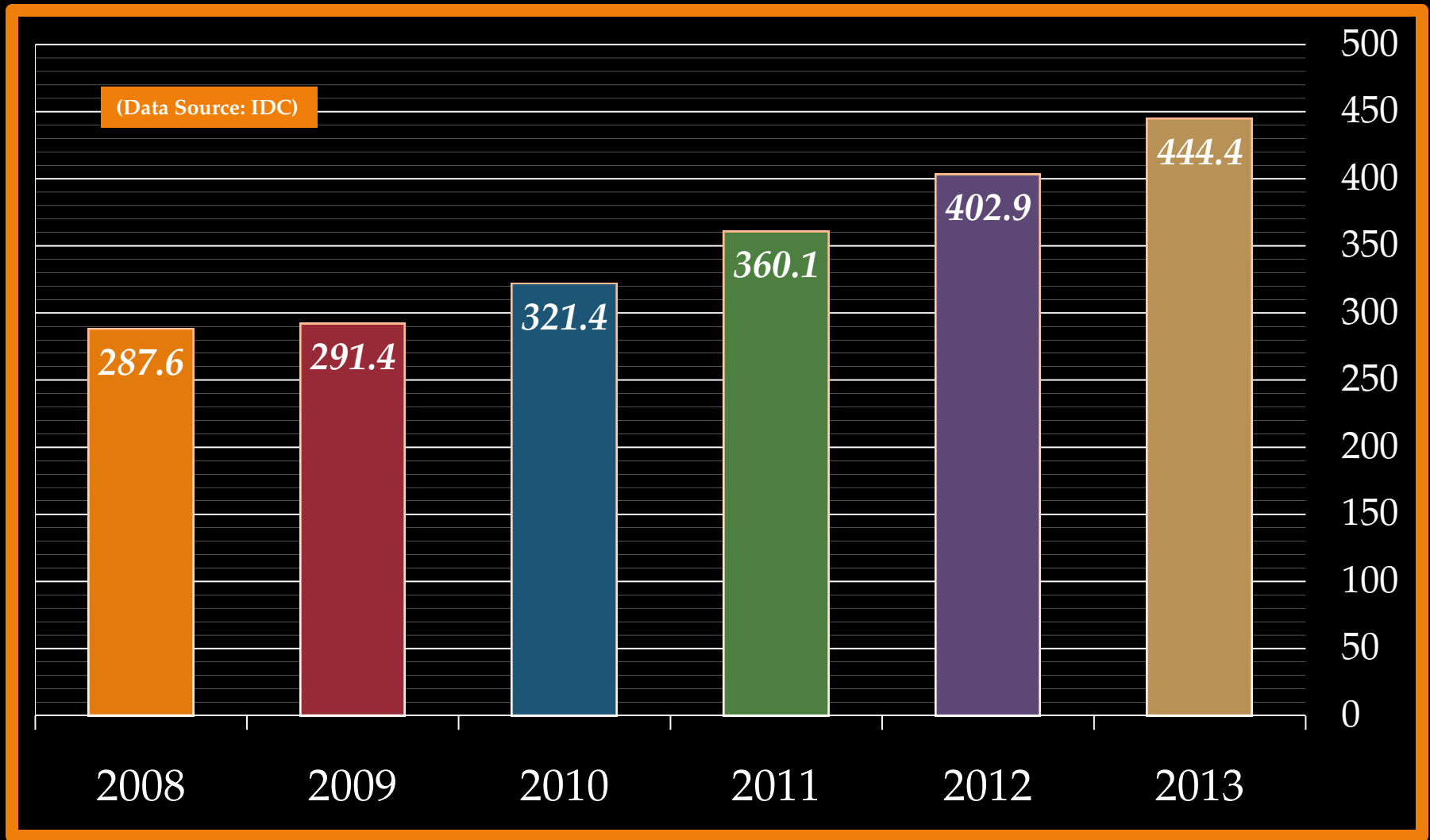
Personal-3D: Focus-Fixation challenge gets harder

Lens Power (diopters)

Screen Distance from Eyes (meters)

Personal 3D Space

Home/Living Room Office Meeting Room

Theatres/ Events

Data: Sunil Jain Dec 2009
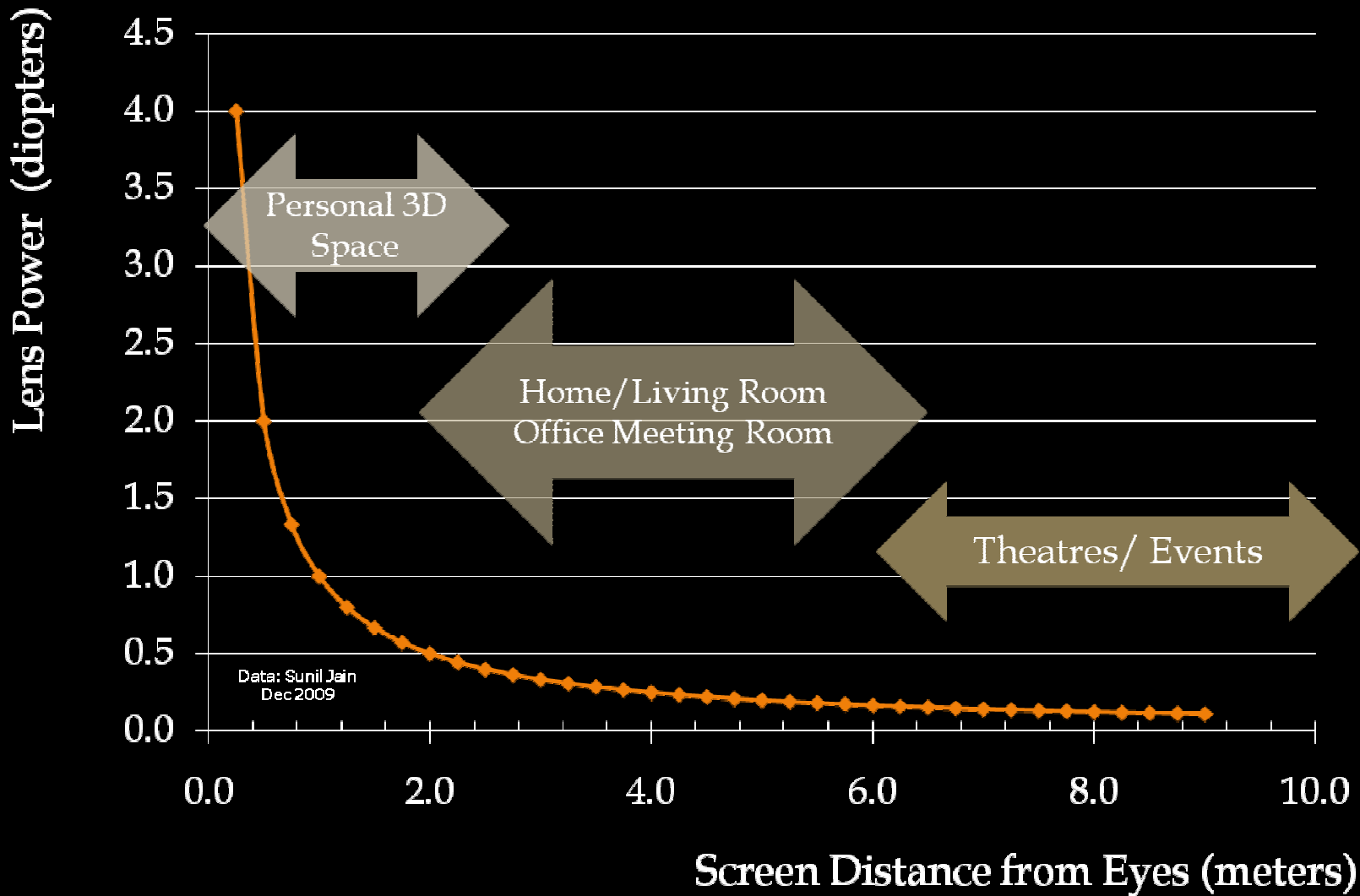
Which device(s) did you use to watch the show(s) you purchased and downloaded from the Internet? (Select all that apply)

On my PC — 71.4%
On TV using a burned DVD — 15.7%
On Portable media player — 12.9%
PC directly connected to TV — 11.4%
Portable gaming device — 8.6%
Game console connected to the TV — 7.9%
Portable device connected to the TV — 5.0%
Mobile phone — 2.9%

More than 70% people with subscription today use PC to watch paid streaming video

3D CAD Acceptance

Totally 3D: 6%
Totally 2D: 20%
Mainly 3D with legacy 2D: 12%
Totally 2D but studying 3D: 10%
Half 2D, half 3D: 22%
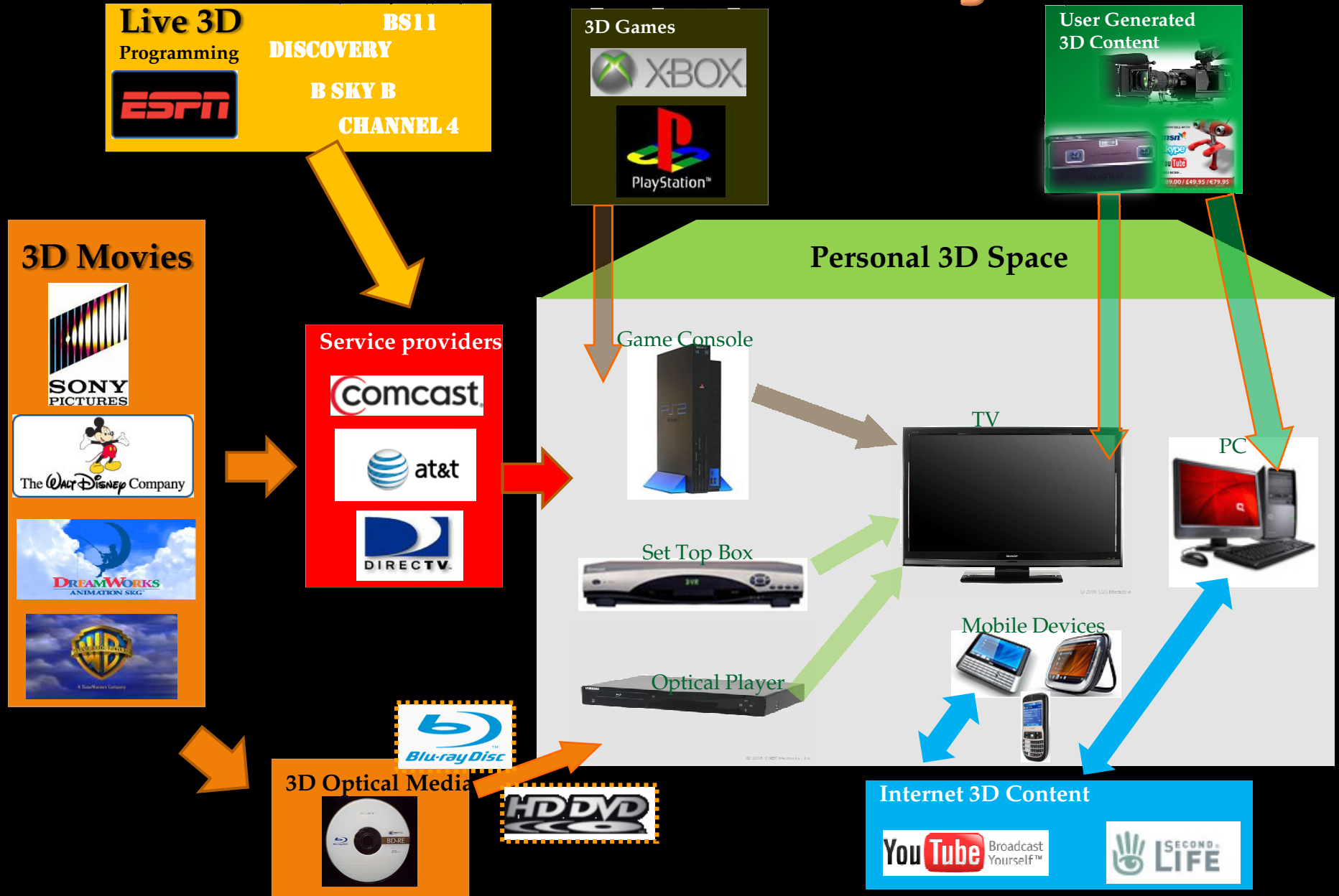Mainly 2D with some 3D: 30%

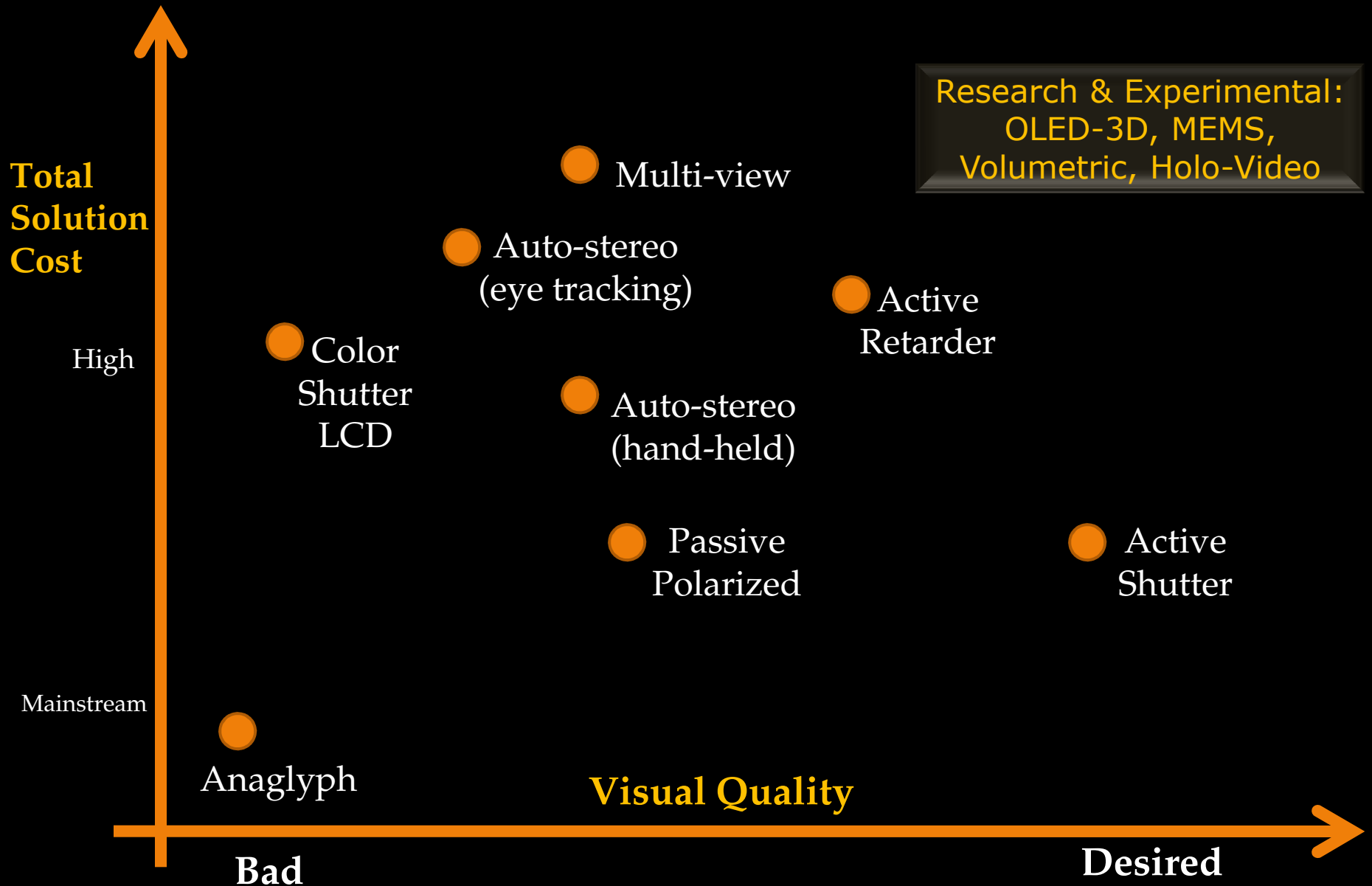Streaming 3D Video content and CAD could be big drivers for 3DPC

(Source: ABI Research)
S =140
(This represents the number out of our total sample of 1155 who purchased video online to watch on a device at home)

3D State of Union in 2011

Total Solution Cost

Research & Experimental: OLED-3D, MEMS, Volumetric, Holo-Video

Multi-view

Auto-stereo (eye tracking)

Active Retarder

High

Color Shutter LCD

Auto-stereo (hand-held)

Passive Polarized

Active Shutter

Mainstream

Anaglyph

Visual Quality

Bad

Desired

Agenda

- 3D Terminology & Basics... [15 mins]
- 3D Challenges & Opportunities... [15 mins]
- What's feasible in the decade ahead... [15 mins]
- Q&A and discussions...

S3D Key Technical Challenges

1. **Crosstalk** = Func {Leakage of images between L/R}

   - Optical barriers are limited by geometry, and result in crosstalk
     - *Mechanical Stereoscope quality can be matched by Binocular displays, closely followed by Active Shutter based Eyewear*

2. **Acc-Vergence** = Func {Distance-Size, Content, Display}

   - Conflict between acc-vergence dilutes 3D realism + adds discomfort
     - *Careful content generation, Distance-Resolution adaptive algorithms; Holo-video & Volumetric display approaches could lead to realism in 3D*

3. **Resolution** = Func {pixel density and # of frames}

   - To act as barriers, state of the art optical barriers cut resolution ☹
     - *Resolution can be recovered by combo of faster, higher pixel density displays as well as synthetic pixel enhancements algorithms*

What's feasible in the decade ahead...

1. Auto-S3D widely deployed in handheld & wearable compute
2. Full HD resolution 3D waterfall to mainstream PC and TV
3. Content distribution & monetization models figured out
4. Ubiquitous tools/techniques for user generated 3D content
5. Real time Viewer & Usage Adaptive quality enhancements
6. Fully stereo and multi-view enabled browsers and OS
7. 3D realism via dense viewing zones in Auto-S/MV-3D (pitch of viewing zone smaller than pupil diameter pitch)
8. 2K, 4K and 8K resolution 3D displays built with variety of technologies - LCD, OLED, MEMS, and laser projection
9. Practical Holo-video & Volumetric displays @ premium
10. Proof points for human size volumetric displays and immersive holo-decks for rendering; camera array capture

"The best way to predict the future is to invent it" - Alan Kay

3D State of Union – Envisioned in 2020

*"If I had asked people what they wanted,
they would have said faster horses" – H. Ford*

Total Solution Cost

Research & Experimental:
Immersive Holo-Deck,
Human size Volumetric

● Holo-Video

● Volumetric

High

● Color Shutter LCD

● Multi-view

● Auto-stereo (eye tracking)

● Passive Polarized   ● Active Retarder

Mainstream

Auto-stereo (hand-held) ●   ● Active Shutter

● Anaglyph

Sunil Jain, March 08, 2011

Bad   **Visual Quality**   **Desired**

Questions?

Please contact:

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What's unique about IA-SIT Glasses?

Applications:

- **Devices**: 3D-PC, 3D-TV, 3D-Monitor
- **Technologies**: Active Shutter, Active Retarder, Passive
- **Usage**: 1-1, 1-many, many-many

Unique features:

- *Universal Optical Stack: display technology agnostic*
- *Semi-intelligent IR sniffing: protocol agnostic algorithm*
- *Scalable design: Refresh rate agnostic (48hz-480Hz)*

Other salient features:

- Stylish: Ergonomics, Weight, Ambient Light, Quality
- RF based: Many-many usage, program pair and lock
- Affordable: PC Peripheral Price Points, lower solution cost

Universal S3D Glasses for PC & CE Interoperability
(Based on Intel Adaptive Stable Image Technology)

Intel S3D Solution

Intel-based PCs featuring Intel® InTru3D™ technology

Validated Panels/Monitors
(IA-SIT Spec Compliant)

Intel Eyewear
(IA-SIT Spec Compliant)

OEM or Intel partnered 3D content portals

3D games via conversion MW Support for 3D Blu-ray playback

Support for HDMI 1.4 S3D-Ready TVs

Stereoscopic 3D Terminology

3D Artistic Perspective

60 Second Experiment

- ➢ Focus on this pattern
- ➢ Cover your Left eye and observe the pattern for 1-2 seconds with your Right eye.
- ➢ Now alternate; Cover your Right eye and observe the pattern for 1-2 seconds with your Left eye.
- ➢ Did you notice the pattern moved?
- ➢ This movement is because of the two different perspectives that both eyes separated by ~6.5cms present.
- ➢ Refined since childhood, algorithms to determine quality and accuracy of depth are embedded in brain.

- *3D viewing on 2D surfaces is about artificial stimulation of brain.*
- One popular technique involves separately presenting Left & Right images at fast enough speed.
- Challenge is to stop leakage (crosstalk) between the Left & Right

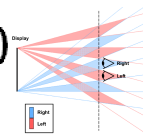| L/R Separation Techniques	Pros	Cons
Spectral — Color Anaglyph: Filtered Left-Right images are presented simultaneously {Examples: Intel Super Ball Ads}	Low Cost, Works on any existing PC/TV, with color Eyewear	Cross Talk, Color Accuracy, Brightness
Spatial — Optical Polarized: Linear or Circular, each eye gets only one polarization {Examples: 3D Cinema, Acer NB}	Add Polarized Display AND Eyewear to any PC/TV design	Half Resolution, Costly display due to low-yield Cross –Talk
Temporal R L R L R L — Sequential: Alternate L-R full frames, matching eyewear Actively shutters {Examples: nVidia 3D vision, Xpand}	Full Resolution, 120Hz Refresh, Electronics	Low brightness due to short duty cycle of stable image, Different eyewear across PC-TV.
Auto-Stereo (Eyewear Free) — Micro lenses on display, multi-views {Examples: Fuji Camera; Phones}	Eyewear Free	Technology in infancy