

# Optical Crosstalk and Visual Comfort of a Stereoscopic Display used in a Real-Time Application

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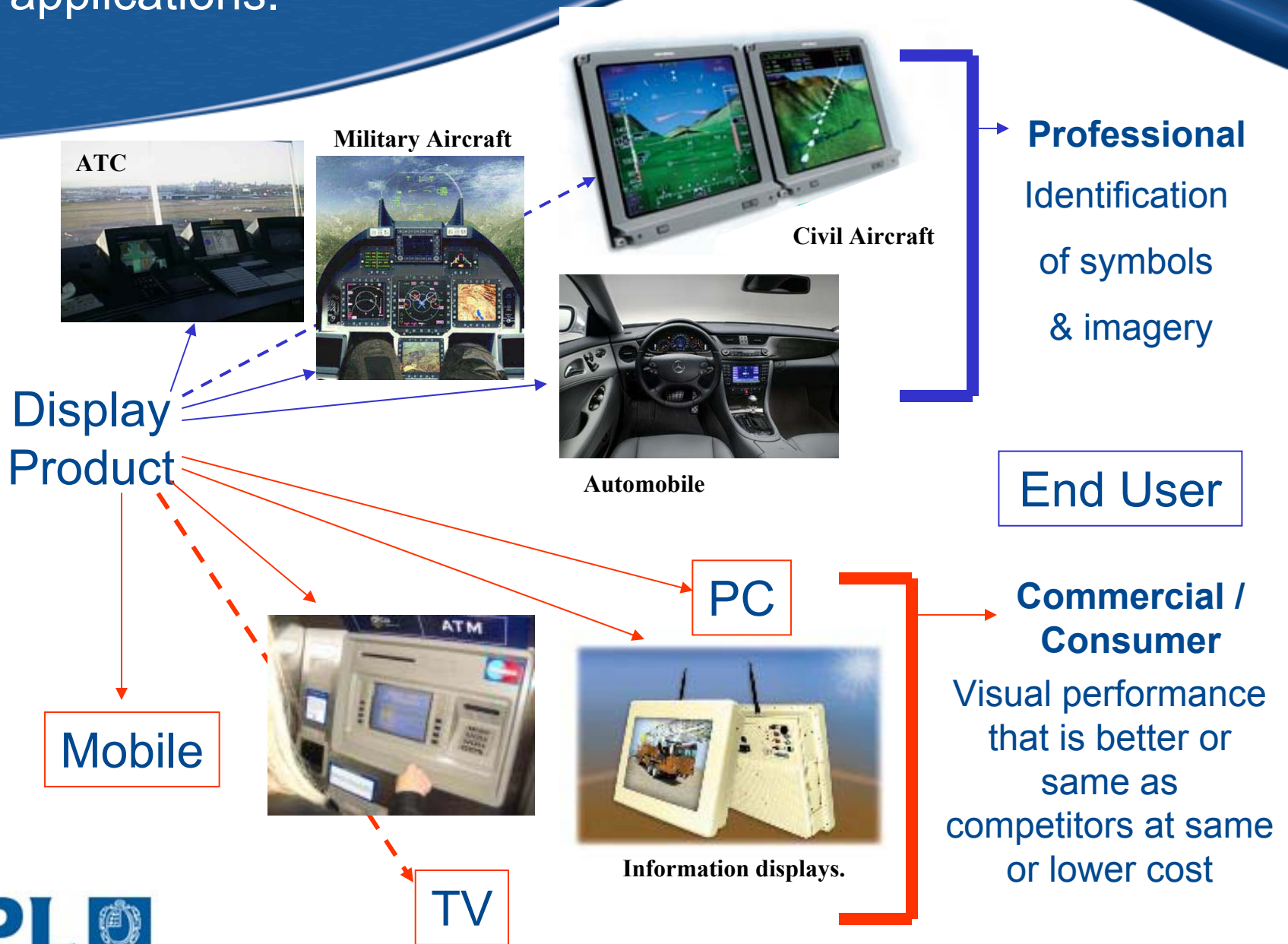
# National Physical Laboratory

- The UK's national standards laboratory
- A world-leading national measurement institute (top 3 among 54) for precise measurement techniques and standards
- Over 600 specialists dedicated to providing measurement solutions
  - Scientists
  - Engineers
  - Support staff
- Owned by the dti, but privately operated by Serco (GOCO)

- New state of the art laboratory



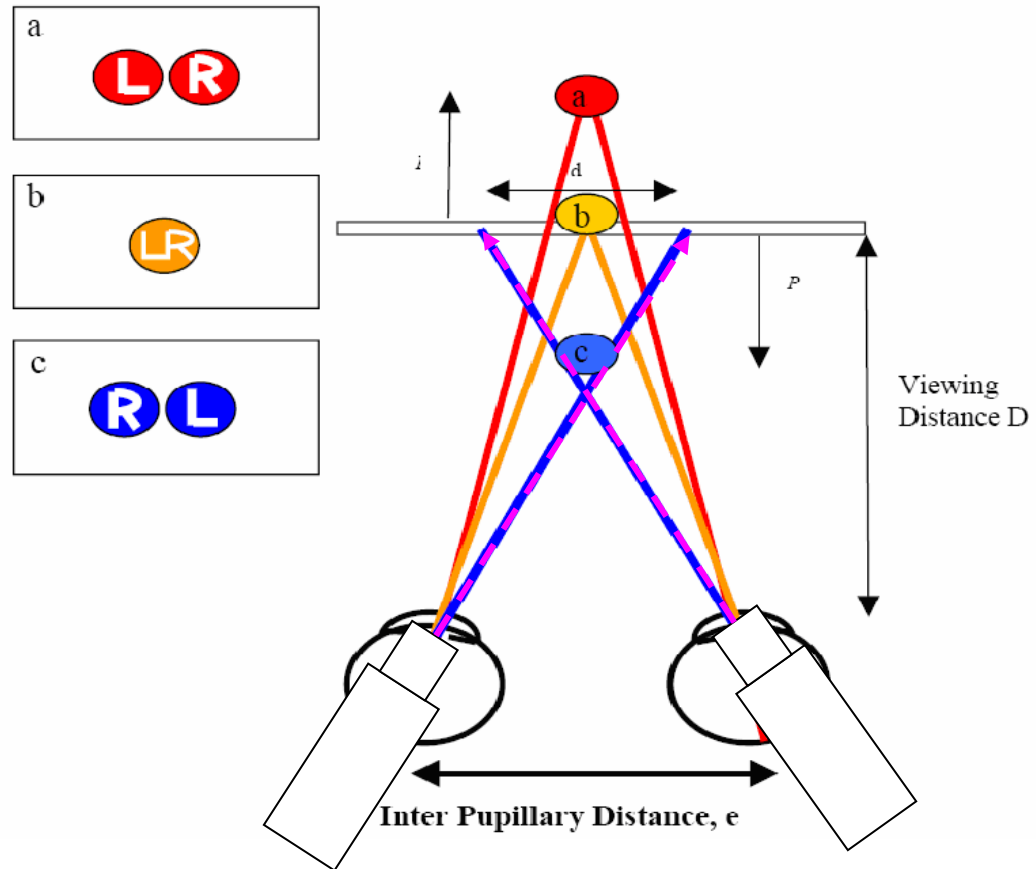
# Professional and Consumer display applications.



## Stereoscopic Displays

- Volumetric Displays first postulated in 1912
- 3D displays present the advantage of enhanced depth perception
- Mainstream use of prevented so far due to reports of user discomfort
- A common cause of eyestrain & nausea is optical cross-talk

# Measurement of cross talk



perceived depth (p)

$$p = \frac{D}{\left(\frac{e}{d}\right)^{-1}}$$

## Background

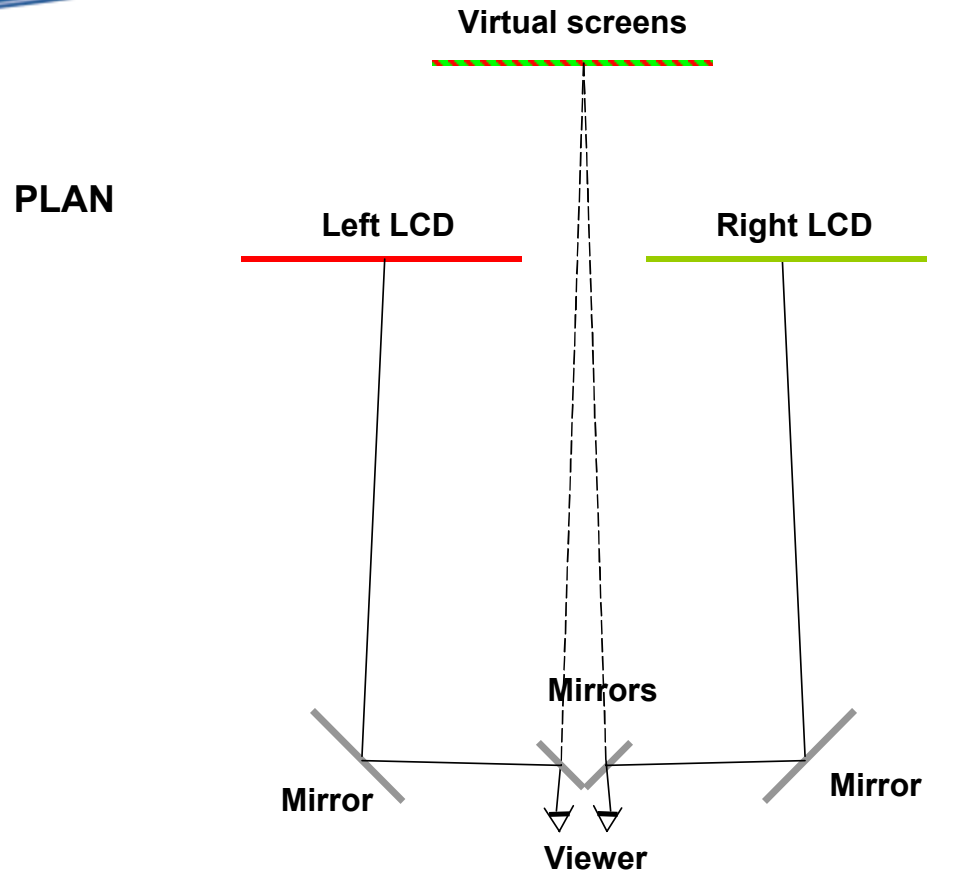
- An estimated two thousand major medical procedures make use of visual displays
- In principle surgeons agree that a stereoscopic view would enhance their visual experience
- Large scale uptake is prevented by visual discomfort during procedures that can take several hours
- One of the largest contributing factors is cross-talk



## Aims

- Design a system inherently free of crosstalk into which controlled amounts of crosstalk can be introduced
- Design a set of tasks that fulfil a given criteria with possible medical relevance
- We look for the effects of cross-talk on task performance in real-time as opposed to still or pre-recorded images

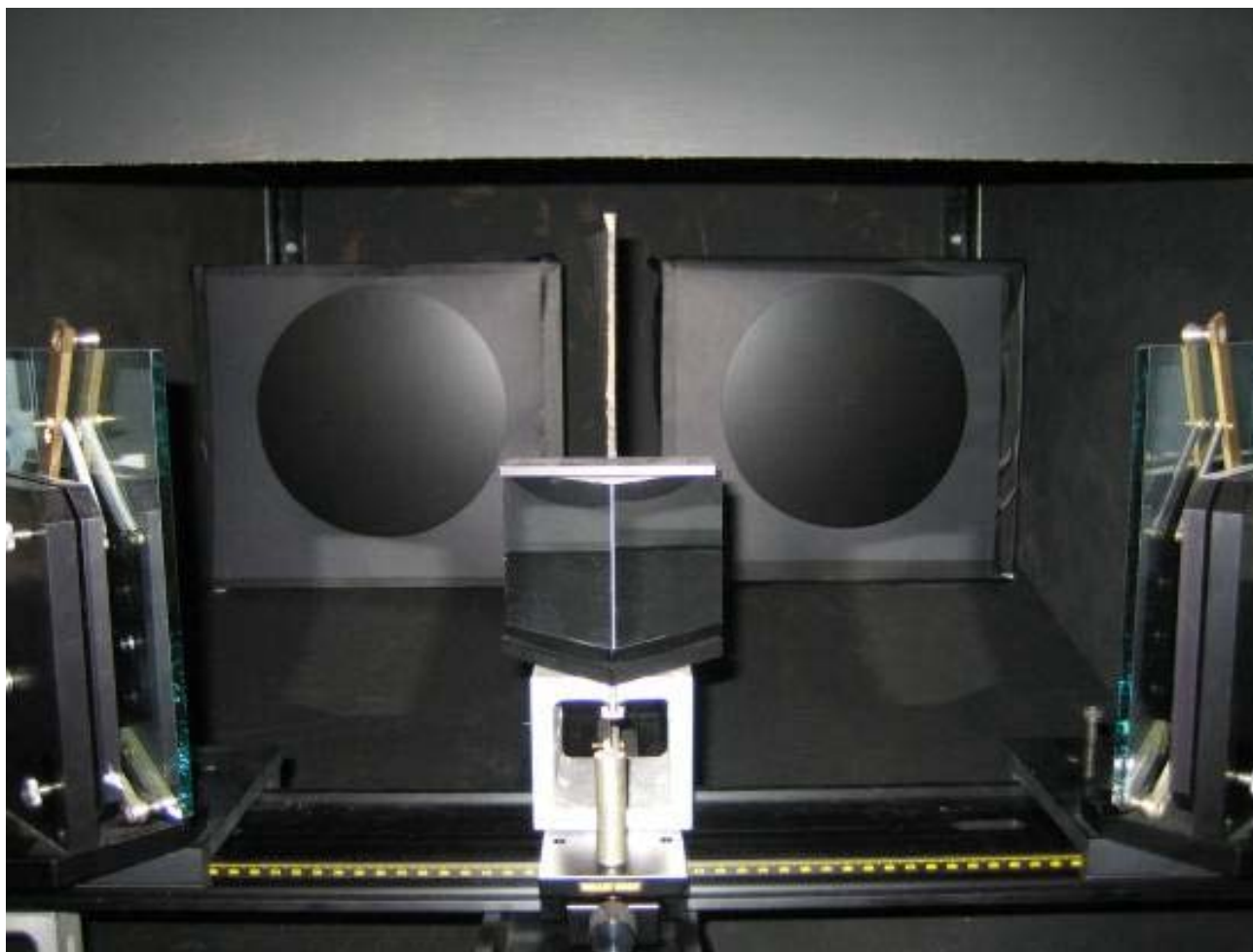
# Helmholtz Stereoscope



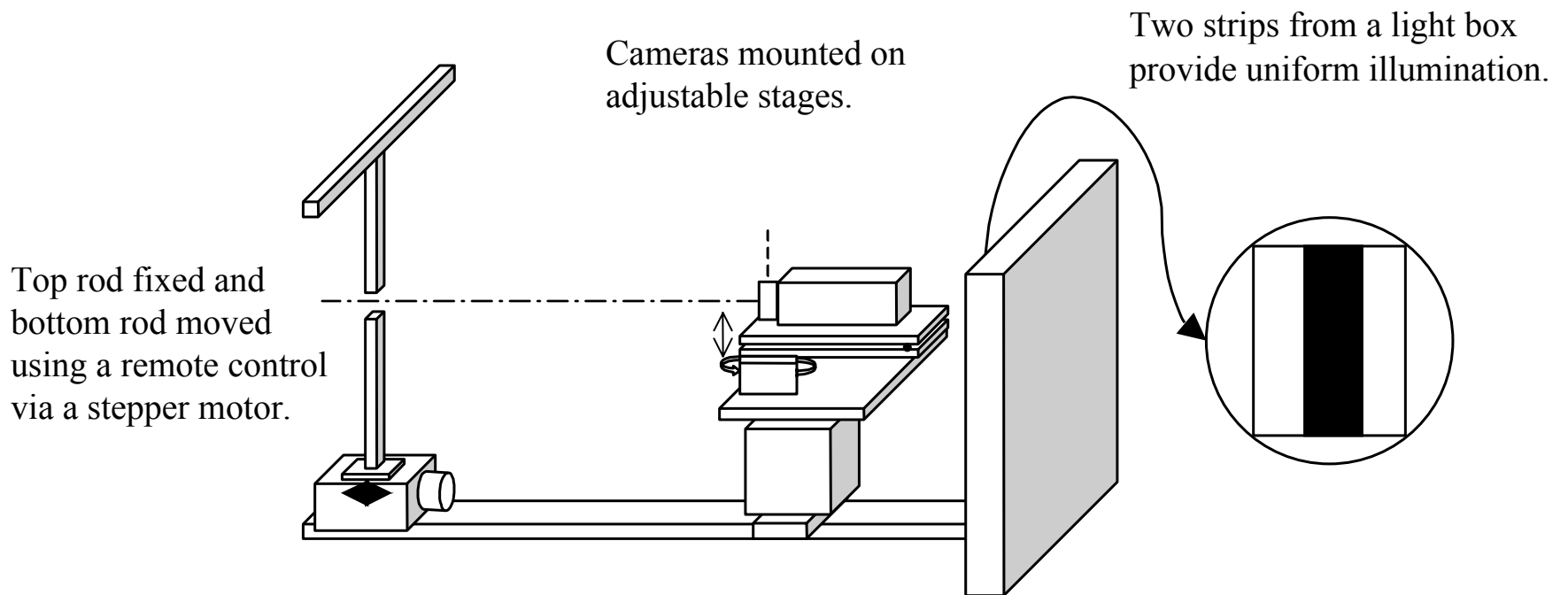
HELMHOLTZ STEREOSCOPE



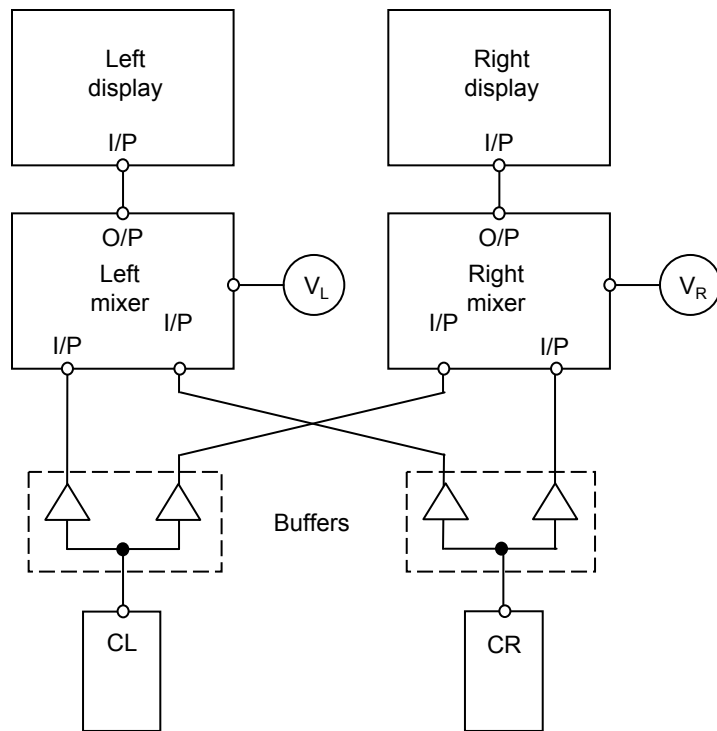
# Helmholtz Stereoscope in the Laboratory



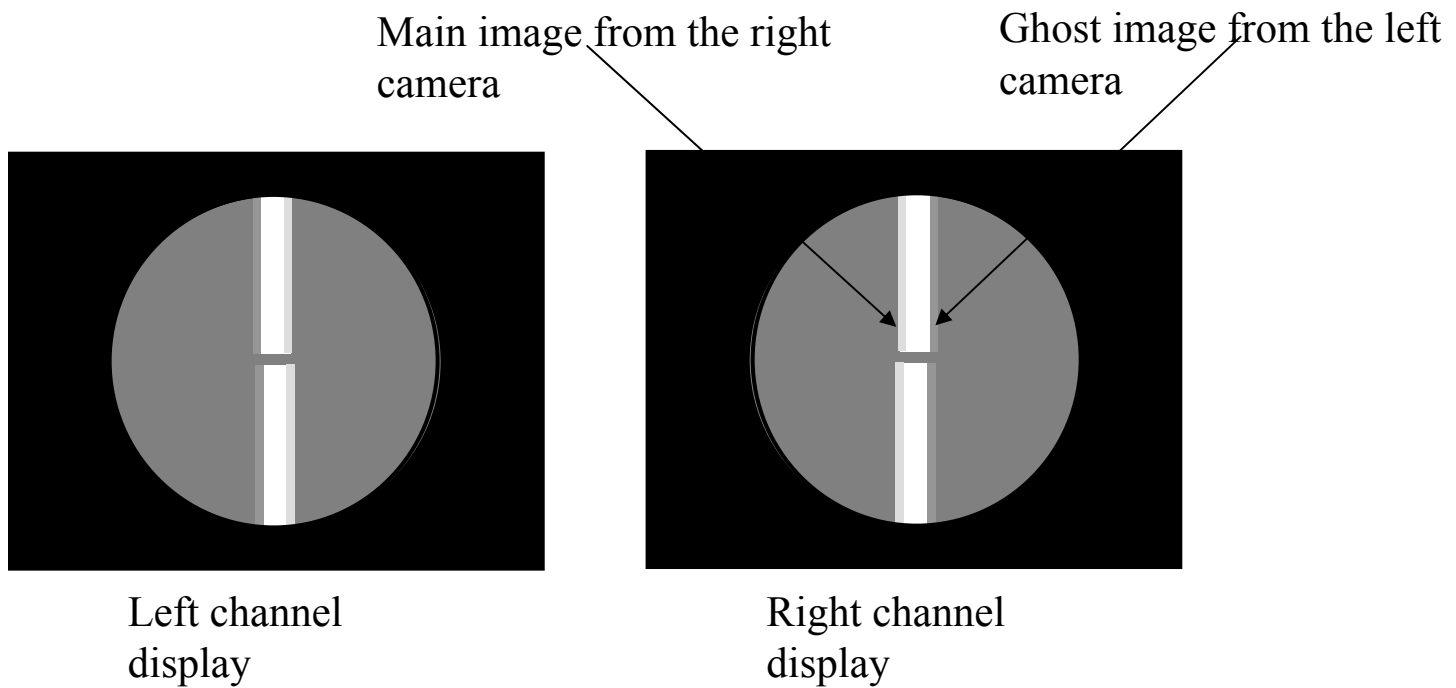
# Capture and Task Region



# Introducing Crosstalk



# Crosstalk Images



## Capabilities of Photon Counting System

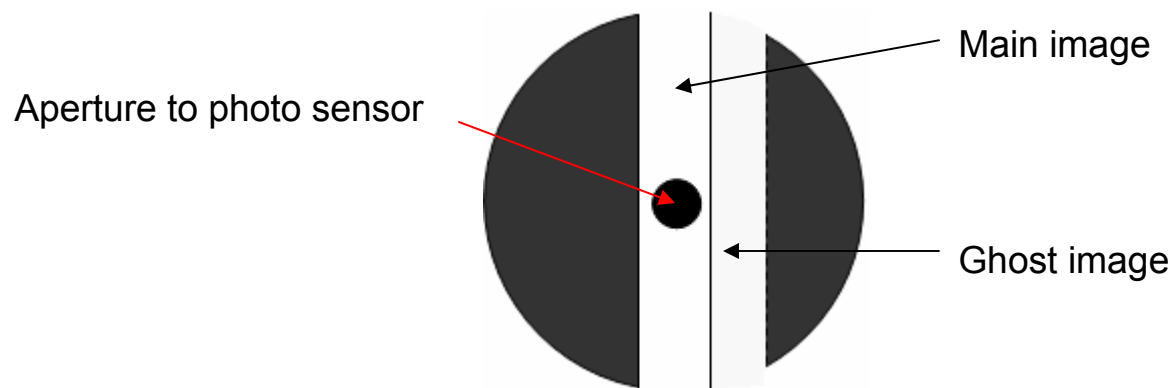
- The photon counting system allows us to make accurate and repeatable measurements at the very low light levels present
- Typical luminance values:
  - 2% Crosstalk < 3 Cdm<sup>-2</sup>
  - Comparison of different black levels ~ 0.2 Cdm<sup>-2</sup>
- These measurements are not possible using any commercially available system

# Definition of Crosstalk

Calculation of crosstalk:

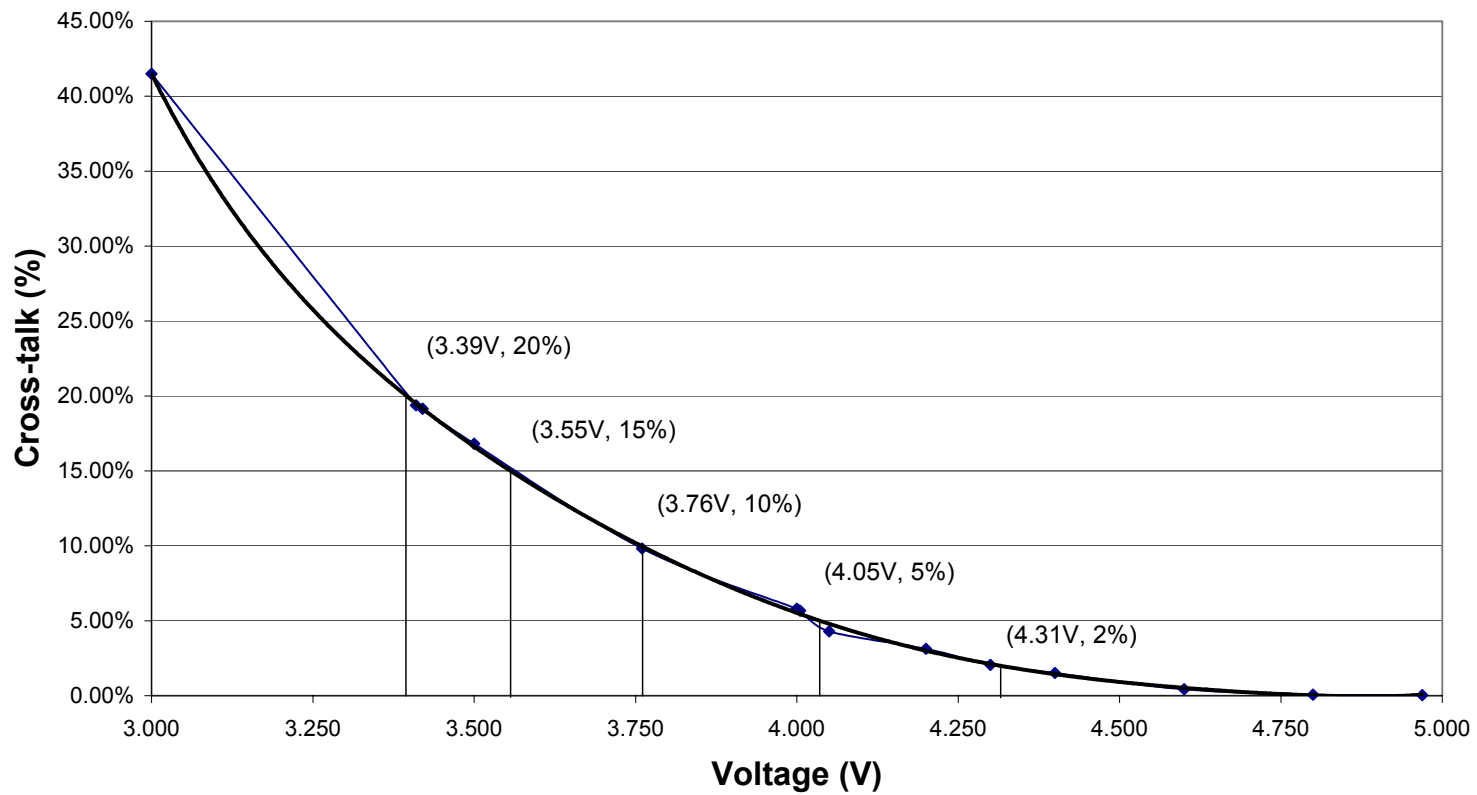
$$C = \frac{L_G - L_{BL}}{L_M - L_{BL}}$$

Where,  $L_M$  = Luminance of Main image,  $L_G$  = Luminance of Ghost image,  $L_{BL}$  = LCD background luminance



# Calibration of system for Crosstalk

Mixer Voltage vs Cross-talk for Left Channel



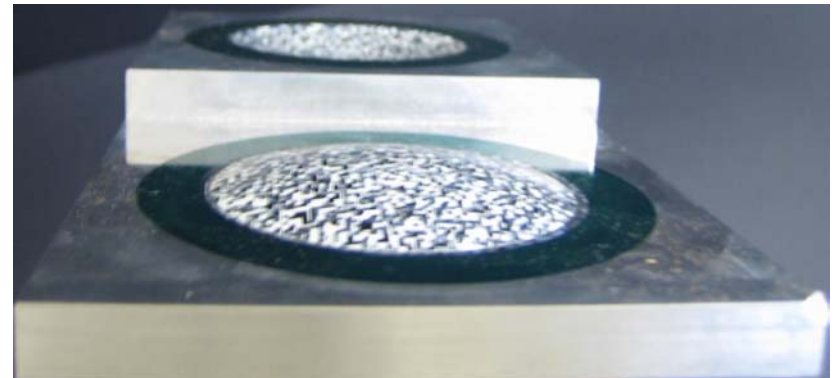
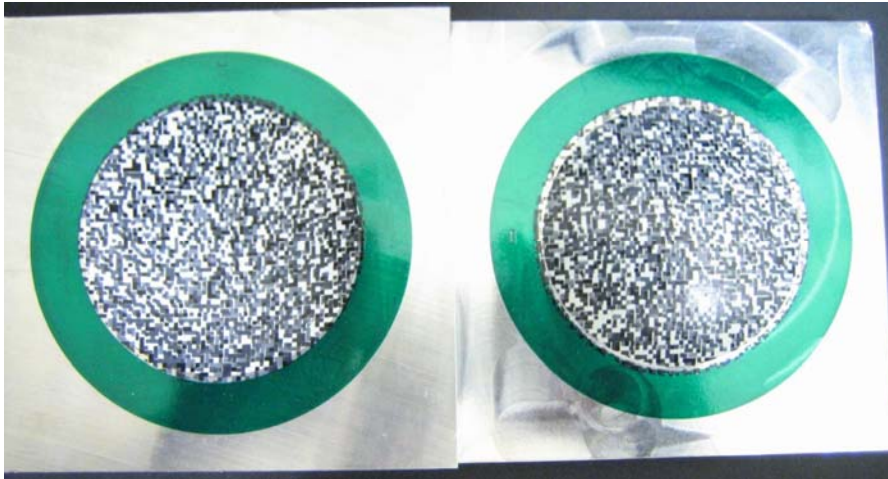


## Criteria

- Task Criteria
  - Simple enough to be of equal challenge to all users
  - Worst case scenario when crosstalk is introduced
- Subject Selection
  - Tested for near vision acuity, distance acuity, stereo acuity and colour vision
  - Questionnaire to probe how frequently subject uses 3D displays, computers, experiences headaches/eyestrain/nausea, and enthusiasm for new technology

## Depth Object

- An artefact with a simple convex/concave profile with a random patterned surface was engineered



# Ergonomics

- External factors of discomfort had to be reduced to a minimum
- Dimensions were configured to suit 97% of the population
- Adjustments to the chair and table height are easily controlled by the user electronically

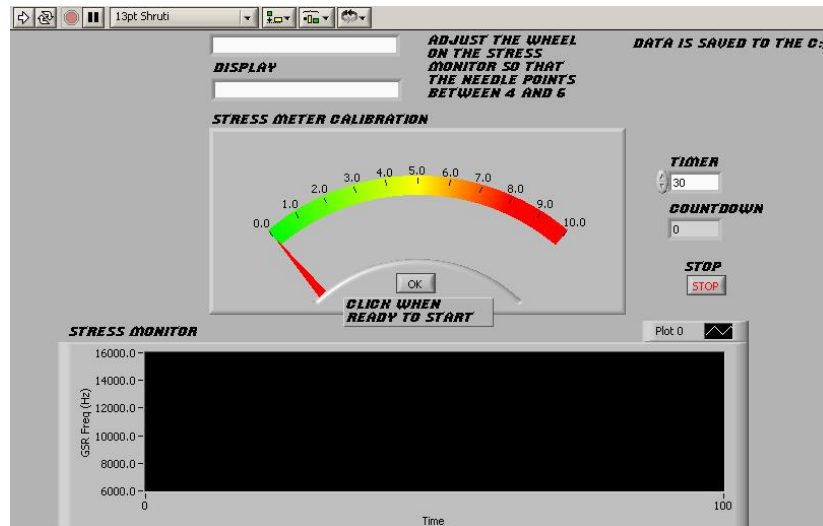


## Measurement Techniques

- Depth Object – we change both disparity and crosstalk
  - Can the user identify the convex/concave profile
  - Is there any hesitation in deciding the profile
- Aligning Rods – Set disparity to 10% and vary crosstalk
  - Can the user identify the relative start positions of the rods
  - Time taken to complete the alignment to user's satisfaction
  - Galvanic Skin Resistance (GSR)
  - NASA Task Load Index (TLX) Questionnaire
  - Error in final alignment

# Galvanic Skin Resistance

## GSR software interface



Example of a user's GSR reading. Region A is a period of relaxation and region B is a period of induced stress



Further consultation is planned with a psychologist to interpret this data

# Depth Object Results 1

Score	Evaluation
0	Could not tell
1	Difficult ( $> 4$ seconds)
2	Hesitation ( $\leq 4$ seconds)
3	No hesitation (less than one second)

Disparity	Total scores across all crosstalk levels	Ratio of correct answers across all crosstalk levels
25%	148	0.92
50%	135	0.80
75%	143	0.88

## Depth Object Results 2

<b>Crosstalk</b>	<b>Total scores across all disparity levels</b>	<b>Ratio of correct answers across all disparity levels</b>
0%	143	0.98
5%	108	0.90
10%	102	0.87
15%	73	0.70



## Rod Alignment Results

<b>Crosstalk</b>	<b>Average correct judgement of start positions</b>	<b>Average modulus of alignment error (mm)</b>	<b>Average completion time (s)</b>	<b>Average TLX Score</b>
0%	3.00	0.87	48.5	38
2%	3.00	1.15	33.1	47
5%	3.00	1.11	42.5	51
10%	2.57	1.60	43.3	57
15%	2.28	2.68	41.7	58

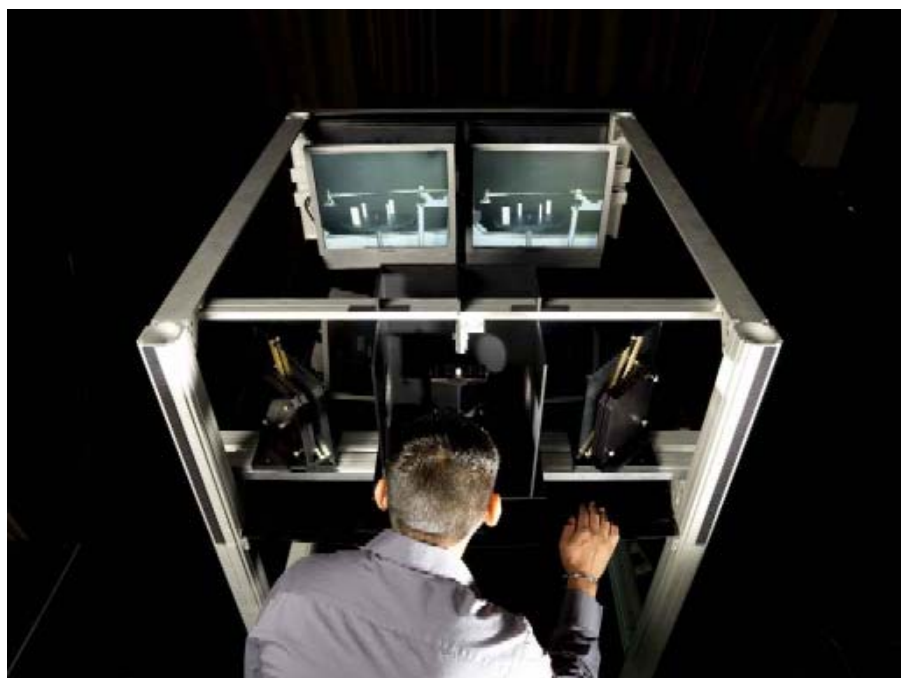
## Conclusions

- We have developed a robust system for making traceable measurements of crosstalk on 3D images
- We have not yet found any clear trend that varying the disparity affected the users' judgement of depth in a predictable way
- In these trials a decrease in task performance and increased workload was observed as crosstalk was increased

## Further Work

- Carry out a pilot study with surgeons and develop new tasks that both address the needs of a surgeon and better emulate a real scenario
- Test the importance of the background when crosstalk is introduced

# Latest Set Up





# Thank You

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