3D Tower - Display Systems

A Non Expert’s Experience
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What is Micro Nav?

- UK based specialist simulation company
- Delivering ATC simulators for 27 years
- Delivering 3D Tower simulators for more than 20 years
Who am I?

- Mike Male
- Ex Air Traffic Controller (Heathrow)
- Co-Founder of Micro Nav
- 30 plus years experience in ATC simulation
- Involved with many 3D tower systems (> 20 years)
- Not a 3D visual expert by training
The purpose of the presentation

- To explain the basics of 3D tower simulator displays
- Focus more on the user’s perspective and the practical, rather than the low level technical
- Some technical explanation will be required
- Assist potential customers regarding
  - What to ask for?
  - What to watch out for?
Types of Display System
Basic types

- There are 3 basic types of 3D tower display
  - Flat panel displays based upon LCD or LED monitors
  - Displays based upon projectors and screens
    - Projected displays using flat segmented screens
    - Projected display using continuous curved screens

- Examples shown on the following slides are from Micro Nav – there are many other suppliers
Flat Panel Displays
example Shannon
Advantages/Disadvantages

- **Advantages**
  - Generally smaller footprint – fits into a smaller room
  - Lower cost entry point (although prices can climb)
  - Normally good clear image (smaller pixels)

- **Disadvantages**
  - Limited Vertical Field of View – more about that later
  - Can suffer from ‘harsh’ image joins (runways or taxiways appearing broken at the joins)
  - Limited resolution with reasonably priced monitors (HD limited to 1080 pixels vertically)
  - Bezel between images
  - Small physical size makes it difficult to include more than one or two students (large flat panels can help with that)
  - Not good for large Horizontal Field of View
Projector with Flat Segmented Screen
example Oman
Advantages/Disadvantages

- **Advantages**
  - Can be much larger than flat panel and can accommodate more students and instructors
  - Up to 360 degree Horizontal Field of View
  - Normally simple to set up and maintain
  - Can be cost effective
  - No ‘wasted’ pixels (unless keystoned – more later)

- **Disadvantages**
  - Image not as ‘sexy’ as curved screen
  - Can suffer from ‘harsh’ image joins (runways or taxiways appearing broken at the joins)
  - Lamp based systems need regular lamp replacements
  - Colour and brightness matching requires regular attention
Projected with ‘Continuous’ Curved Screen
example Heathrow
Advantages/Disadvantages

- **Advantages**
  - No issues at ‘joins’ - there are none
  - Can be much larger than flat panel and can accommodate more students and instructors
  - Up to 360 degree Horizontal Field of View
  - Seamless image
  - Very good visual effect/impact

- **Disadvantages**
  - Historically more expensive
  - Historically more complex to set up
  - Lamp based systems need regular lamp replacements
  - Historically more complex to maintain
  - Can require regular maintenance
Front or Rear Projection
Front or Rear Projection

- Front Projection – where the projectors are on the same side of the screen as the viewer
- Rear Projection – where the projectors are on the opposite side of the screen and the image is projected onto the back of a partly transparent screen
Front Projection
example Heathrow
Advantages/Disadvantages

- Advantages
  - The image is brighter – rear projection can lose up to 40% of light
  - The overall footprint is smaller – minimum space required behind the screen

- Disadvantages
  - Shadowing is an issue – light path of the projector must not impinge on equipment or occupants
  - Noise and cooling – as the projectors are in the same ‘space’ as the users
Rear Projection
example RNLAF Nieuw Milligen
Advantages/Disadvantages

- **Advantages**
  - No internal shadow problem (example shown even includes built control tower with glass – not possible with front projection)
    - There is a shadow issue behind the screen but easily catered for
  - No noise or heat issues – projectors are separated from users

- **Disadvantages**
  - Footprint – rear projection needs a lot more space
  - Brightness – lose up to 40% of the light passing through the screen
Footprint Example

- The images below show the same projectors used
- Front projection requires 9.75m x 9.75m
- Rear projection requires 18m x 18m
Use of Mirrors

- Mirrors can be used to reduce the ‘throw’ of projectors
- Introduces a more complex set up process (mirrors need exact alignment)
- Mirrors need to be very high quality
- Mirrors must be kept in good condition
- Overall experience not 100% positive at MNL
Rear Projection with Mirrors
example Entry Point North
Rear Projection with Mirrors
example Entry Point North

- Initial issues with mirror quality
- Some maintenance issues with dust
- Successful result in relatively small space
Front Projection and Shadows

- Example of well designed system
- Diagrams from Micro Nav Display Designer
Front Projection and Shadows 2

- Same projector location – modified student and instructor position – now obstruct the light path
Display Designer – Prevention of Errors

- Display Designer tool essential
- Allows problems to be predicted
- White areas on screen are overlaps (good), black areas on screen are shadows (bad)
Field of View
Field of View

- Display system image size can be described as ‘field of view’
- Normally expressed in degrees
- Horizontal Field of View (commonly HFoV) – horizontal angle between the left hand edge to the right edge of ‘the display’
  - 360 degrees means the whole scene is displayed
- Vertical Field of View (commonly VFoV) – the vertical angle from the bottom to the top of ‘the display’
- But...
The Problem with Field of View numbers

- Can be described as the ‘angle of the image’ or ‘the angle from the viewers eye point’
- When described as the angle from the eye point
  - location of eye point controls the reported Field of View
  - but image is unchanged
- Be careful when reading specifications to understand what is being stated
Example

- In the example below, in terms of the eye point of the users, VFoV for student is 29 degrees, for instructor is 21 degrees, yet observable image unchanged
The User’s Required Field of View

- Horizontal field of view must normally be wide enough to see all areas of interest without having to ‘move’ the image.

- Vertical Field of View difficult to define exactly but student must be able to see apron and manoeuvring area and enough ‘sky’ to satisfy the training objective (which can vary between training sessions).

- Note - image can easily be moved during session but:
  - This adds to the workload of the student
  - Is not appropriate with more than one student using the image.
VFoV and Flat Panels 1

- As described earlier, VFoV for flat panels is considered limited.
- Aspect ratio of common large flat panels usually restricted by TV’s HD (1920 x 1080) which is 16:9 aspect ratio.
- Normally maximum image width per flat panel (or flat segmented projected screen) is accepted as 60 degrees to prevent unwanted visual effects.
- That would give VFoV (image, not eye point) of 33.75 degrees if panel is ‘landscape’ (the normal alignment).
- Actual VFoV in real control tower is significantly more than that AND controller can move.
- More typical HFoV per flat panel is 45 degrees which gives VFoV of just over 25 degrees – marginal for effective use.
Example - Landscape

- This is as described in previous slide, 4 flat panels (in this case 65 inch), ‘landscape’
- If used to show HFoV 180 degrees > VFoV 25 degrees
VFoV and Flat Panels 2

- The solution for this is to mount flat panels in ‘portrait’ (vertically)
- Requires more flat panels
- Improves the VFoV
- Increases number of ‘bezel’ joins
Example - Portrait

- In portrait 7 flat panels (again 65 inch) required to cover same physical width
- VFoV > 45 degrees (180 / 7 / 9 x 16) – significantly better but more expensive (more panels, more IG channels)
Bezels and Mullions

- When using flat panels or some flat segmented screens with mullions – there is a border between adjacent screens
- Often thought of as ‘like the pillars between windows in real tower’
Hide Behind Pillar or Not?

- As images are created by Image Generator, user can choose
  - simulate a real pillar (aircraft will disappear behind ‘pillar’)
  - Ignore ‘pillar’ and show a continuous image
- Entirely the customer’s choice
- My advice
  - Have the smallest bezel or mullion you can
  - Do not simulate a real pillar or hide part of the image
  - In a real control tower the controller can move to see behind the pillar
Projectors and Characteristics
Projectors and Image Quality

- There are several ‘types’ of projectors with variants of image creation technologies and light sources.
- Imaging panel technologies suitable for ATC simulation:
  - LCoS – Liquid Crystal on Silicon
  - DLP – Digital Light Processor
  - LCD – Liquid Crystal Display
- LCoS is said to have higher contrast but there are advocates of all types. LCD use seems to be declining.
- Light sources:
  - Lamp
  - LED
  - Laser
  - Laser/LED hybrids
Light Sources – Advantages/Disadvantages 1

- **UHP (Ultra High Performance) Lamps**
  - Traditional technology – reliable, bright
  - Lots of different types available
  - Lamps require replacement regularly (some as low as 1000 hours)
    - Significant lifetime running costs
  - Generate significantly more heat and sound than LED
  - Use more power than LED
Light Sources – Advantages/Disadvantages 2

- **LED**
  - Relatively new technology – solid state, quiet, very little heat
  - Also very reliable
  - Very long LED life - some quoted at 100,000 hours (equating to 50 years of 8 hours/day, 5 days/week)
  - Low lifetime running costs (no lamp replacement, lower power consumption therefore eco friendly)
  - Not as bright as UHP lamp but bright enough (MNL have used them on several projects)
  - More expensive than equivalent UHP lamp based equivalent
Light Sources – Advantages/Disadvantages 3

- **Laser**
  - Solid-state light source (as is LED)
  - Longer life than UHP lamp based systems – comparable or better than LED
  - Potentially very bright.
  - Can be higher initial cost

- **Laser/LED Hybrid**
  - Very little MNL experience
  - Laser seems to be future development path for projectors
Lens Shift and Keystoning 1

- Lens shift is the ability for a projector to show a rectangular image physically above or below the centre of the projector.
- A projector with no lens shift (0 shift) will show as much picture above and below the projector – see below.
Lens Shift and Keystoning 2

- If the projector is capable of lens shift the image can be projected above or below the projector without changing the angle of the projector.
- Image remains rectangular – pixels are constant shape.
- Examples shown below are shift -50 and +50.
Lens Shift and Keystoning 3

- If the projector is not capable of lens shift AND it is necessary to point the projector down (or up) – the image becomes ‘distorted’ – this is referred to as keystone
  - The image on the left below is using lens shift
  - The image on the right is the same projector with no lens shift but pointed down
The Problems with Keystone

- Pixels are bigger at the bottom than the top (assuming the projector is pointed down) – this means the image is not as good at the bottom compared to the top
- If using flat segmented screens, images can spill over onto the next screen
- Projectors commonly have keystone correction but this normally just cuts off the offending triangles (i.e. outside the red lines below) which loses pixels
Use of Keystone

- Keystone should be avoided if possible
  - MNL have not used keystone with our in-house developed systems
- Lens shift is preferred
- To accommodate specific room size and occupancy restrictions, keystone can be required
Double Black

- In all projectors, projected black is not true black (absence of light) - it does have some brightness to it.
- Where two adjacent projectors overlap (either for a continuous image or ‘removed’ triangles with keystone correction) – the projected light is double the black shown where the image is not overlapped.
- This is normally only noticeable in night images.
- This can be corrected by using optical masks or edge blending and colour matching (more later).
Warping and Blending
Warping and Blending

- Image warping is used to correct the optical distortion that occurs when a rectangular image is projected onto a non-flat screen surface.
- The most common non-flat screen surface used in ATC simulation is a cylindrical screen (although the use of other shapes, such as a dome, is possible).
Warping - before

- Before warping the projected desktop image on a cylindrical screen looks like this
Warping - before

- Showing a test pattern – a square grid pattern (referred to as a spherical grid) looks like this before warping
Warping - before

- An airport image would look like this before warping
Warping - after

- After warping the same grid pattern looks like this – lines are now horizontal and vertical and the alignment in the overlap areas is very precise
Edge Blending and Colour Matching

- Projectors of the same type do not produce identical images
- Caused by slight differences in the electrical and optical components
- Each unit has unique colour hue and brightness
- The edge blending produces a soft edge of each projected image in the overlap region
- Colour matching adjusts the colours and brightness of the each projector to give a uniform image colour and brightness over the whole screen
Edge Blending and Colour Matching - before

- This image shows the warped image before edge blending and colour matching
Edge Blending and Colour Matching - after

- This is the result of the process – after both warping and edge blending/colour matching
Warping and Blending – How?

- Warping and blending can be done manually or automatically.
- In the past the majority of the systems we have installed have included manual warping and blending – typically it has taken one or two days by an expert.
- There are now automated systems that use various technologies to allow the process to be carried out in much less time without an expert.
- Our system uses digital cameras and on screen references and takes less than 30 minutes - it does not require any expert knowledge – see demonstration on our stand – Stand 542.
When would you need to do it?

- Obviously the warping and blending process needs to take place when the system is first installed.
- Then needs to take place periodically as even the geometry (the warping) will drift over time causing ‘defocussed’ areas.
- Warp correction will also need to be done when any projector is moved:
  - For example when a projector is replaced or taken down for maintenance or just moved by accident (perhaps when cleaned).
- Edge blending and colour matching will need to be carried out when projectors are replaced and especially with lamp based systems as lamps age or are replaced.
- It should be considered a regular event which returns the display to the ‘just installed’ state.
Flat Panel Warping

- Even flat panels will benefit from some warping
- In the image below the picture is not warped – it is presented as the ‘natural’ flat screen images
- This gives the ‘broken runway’ effect that can be seen
Flat Panel Warping - After

- If the images are warped to get over the broken runway effect, the image straight line objects are warped to give a continuous smooth image
- The images below use a system recently developed at MNL
Image Quality
Image Quality - Summary

- More pixels = more quality, better ability to recognise
- Contrast is important
  - For projected systems the bigger HFoV the more important contrast becomes
- Adequate brightness
- Good ‘black level’ for night scenes
- Good and stable ‘warping’ for curved/edge blended displays
Determining the Optimum Display
Factors to Determine the Optimum Display

The questions MNL ask to advise on the best display to use are as follows:

- How much space is there to accommodate the tower display?
  - To determine the possible types that could be employed
- How many controllers and instructors are to be housed?
  - To again determine the possible display type and projection constraints such as shadowing
- How big is the largest airport to be simulated?
  - To advise on the image quality required for effective recognition and achievement of training objectives
- What is the smallest aircraft to be simulated
- Is there a preference between capital expenditure and running costs?
  - To determine whether LED or other solid state based projectors would be preferable to lamp based systems
Further Information

- Visit the Micro Nav stand – number 542
- Email mikemale@micronav.co.uk – please advise any specific areas of interest or concern

Thank you for your attention