The Responsive Workbench

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Display Systems

Immersive stereo displays

- HMD
- BOOM

Augmented stereo displays

- See-through HMD
- CAVE
- *Responsive Workbench*
- Holographic displays
- "Volumetric Hyper-Reality" (Gavin Miller)

Total Immersion: BOOM

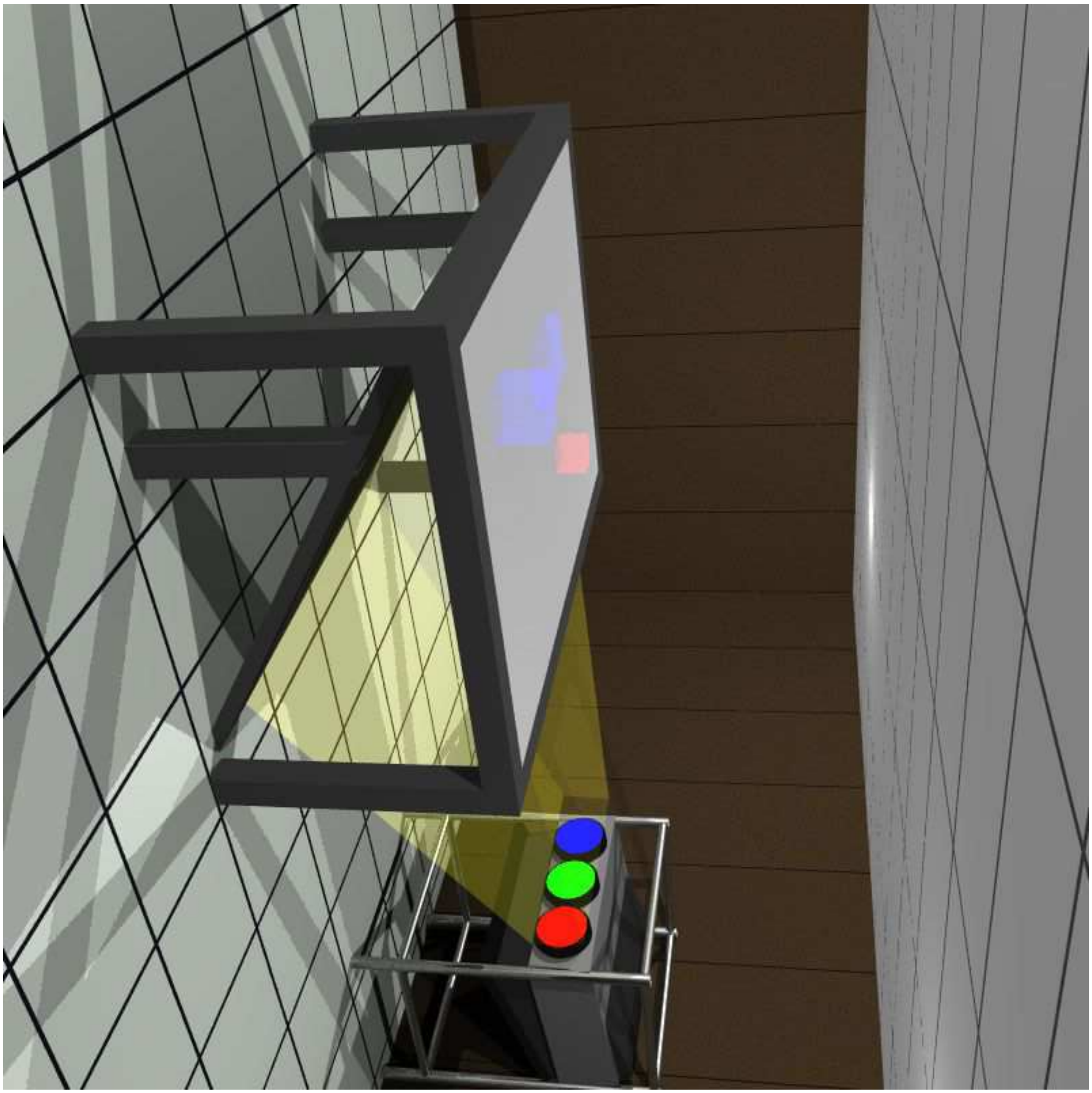
Photograph courtesy W. Krueger

Total Immersion: HMD

Photograph courtesy W. Krueger

Responsive Workbench

A high resolution table-top stereo display system with real-time head and hand tracking to support natural interaction with 3D environments



Components

Hardware

Output: 1025x768 96Hz (48Hz per eye)

- High performance 3d graphics engine (SGI RE2)
- High scan rate projector (Electrohome 8000)
- Shutter glasses for stereo (Crystal Eyes)

Input

- Head and hand 6d trackers (Polhemus FASTRAK)
- PinchGlove (Fakespace) and stylus (Polhemus)

Software

- Performer 2.0
- RWB library and drivers

Design Motivation

Targetted applications

- Urban and campus planning (architects)
- Surgical simulation (doctors)
- Scientific visualization (engineers and scientists)
- Museum exhibit space

Task-driven

- Workbench metaphor
- Collaborative group situations

Specific Applications

Architecture

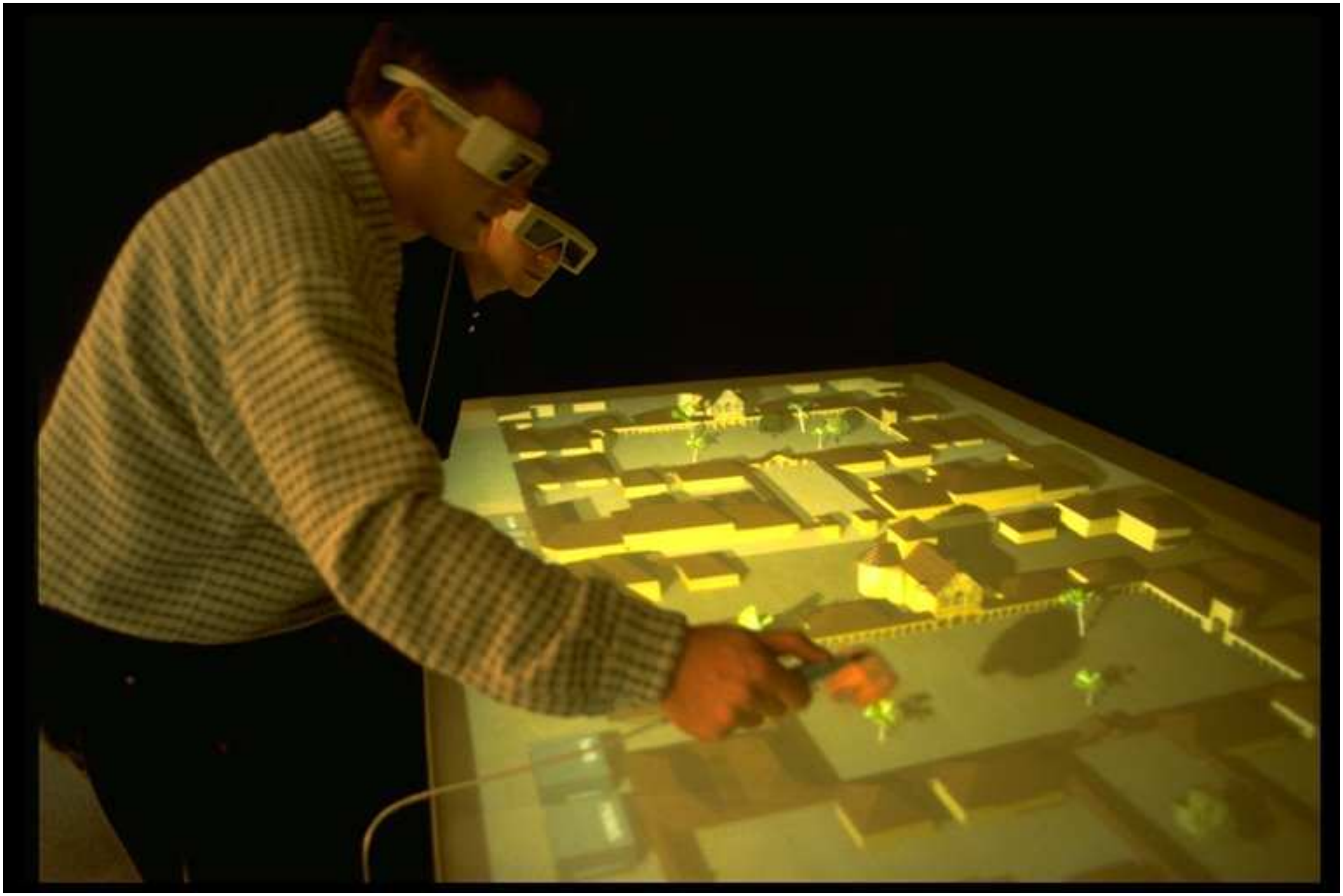
- Virtual site model (GMD, Stanford)
- 4D-Cad (Fischer)
- Kit of parts

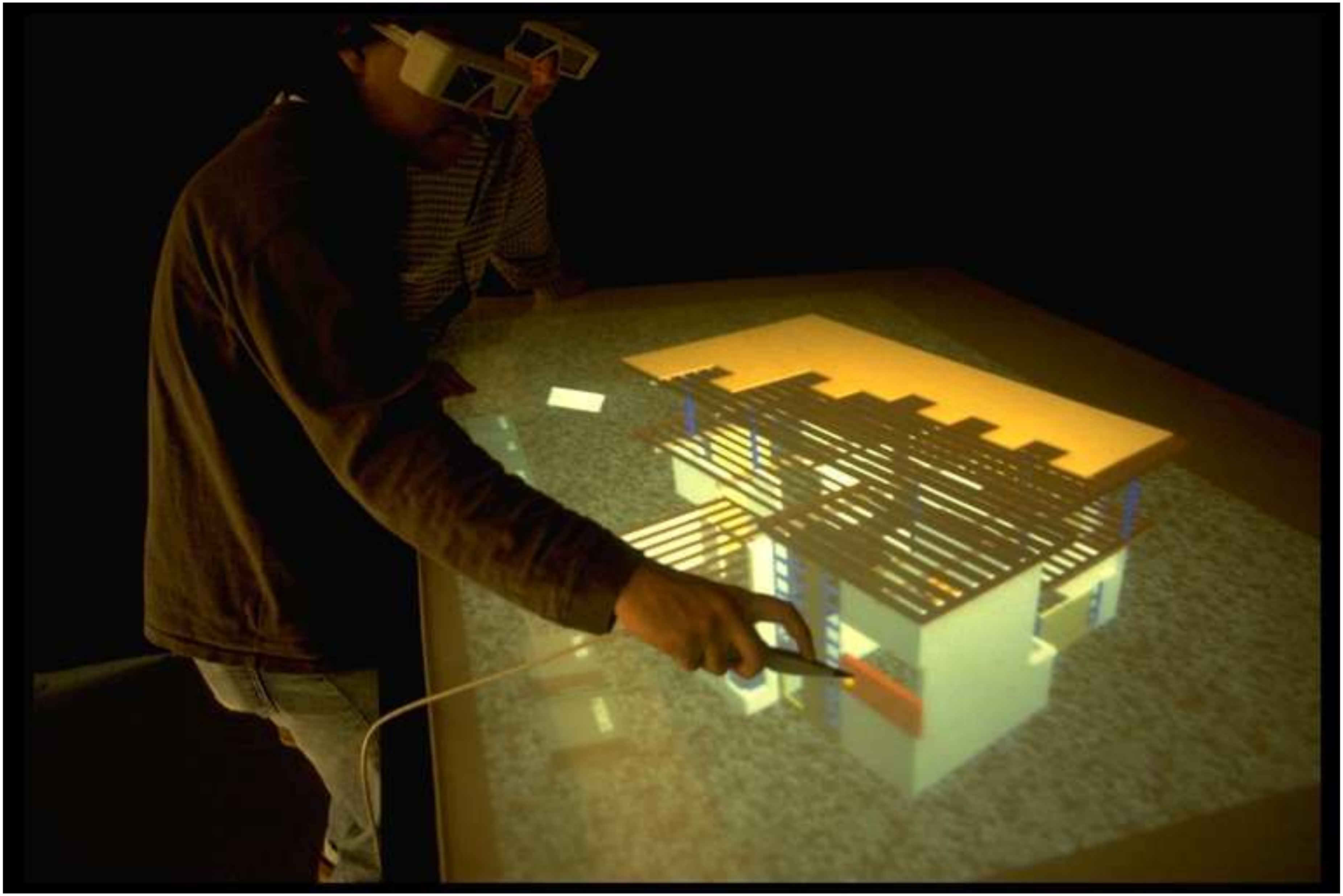
Geographic information visualization

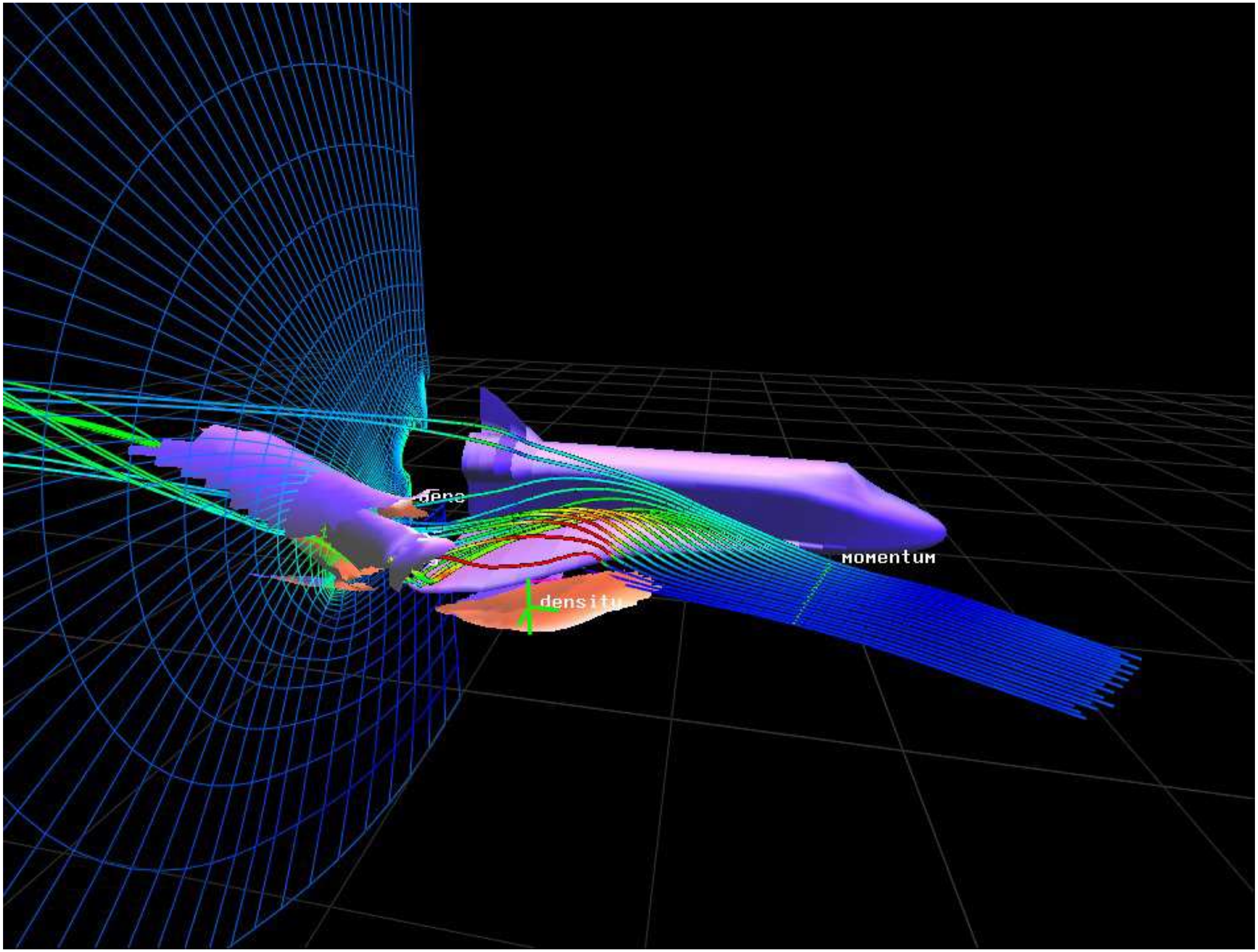
- Dynamic maps
- Air traffic patterns (Bill Eddy)

Scientific visualization

- Virtual windtunnel (NASA)
- Engine combustion (Daimler Benz)
- Virtual patient





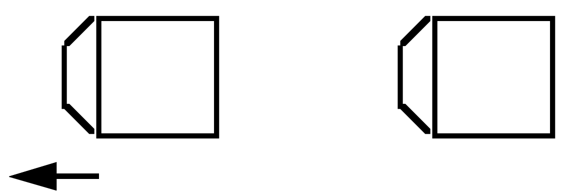

momentum
density

Effective 3D

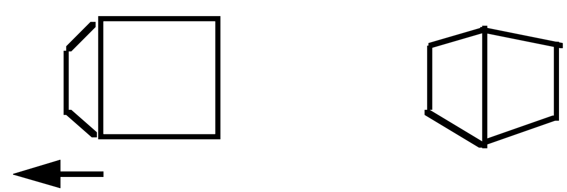
- Workbench cues
  - Objects resting on surface
  - Textured polygon at table surface
  - Cast shadows
  - Gravity defines up, table defines orientation
- Perceptual cues
  - High resolution (14 dpi) / flicker-free
  - No motion sickness
  - Human scale
  - Wide field of view
  - Uses stereo at effective distance (hands)

Synergy between 3 Visual Cues

1. Binocular stereo
2. Motion parallax
3. Accomodation and convergence



stereo, without tracking



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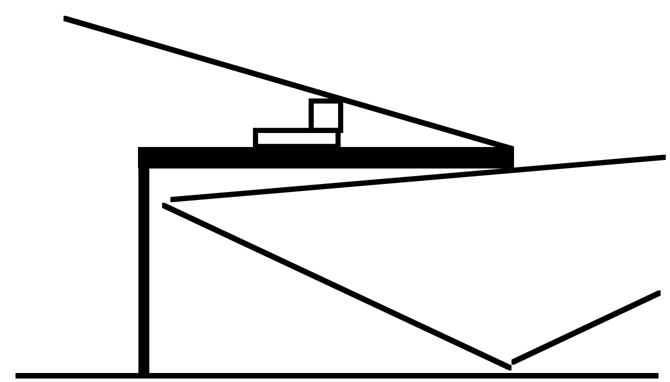
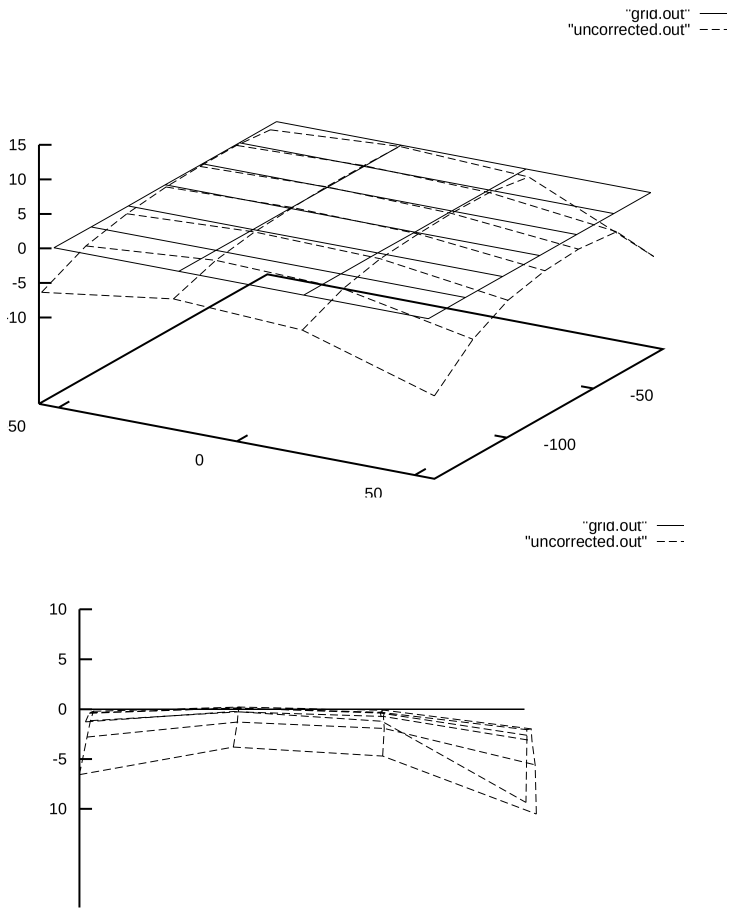


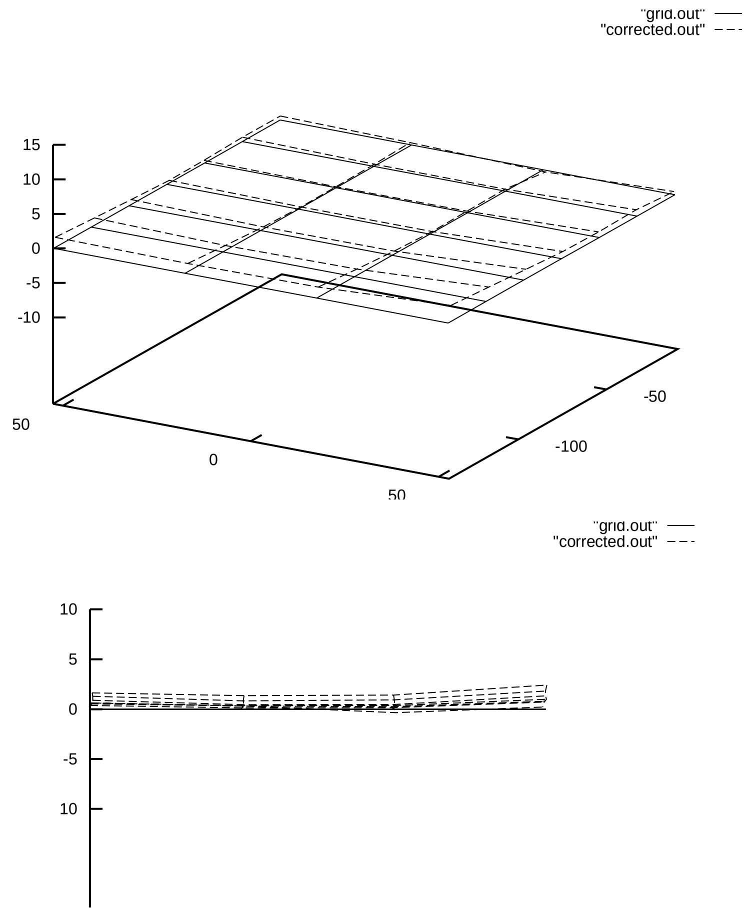
Registration of Real and Virtual

Error	Magnitude	Effect
Head tracking	up to 10cm +	View may distort
Hand tracking	up to 10cm +	Interaction difficult
CRT distortions	a few cm	Image non-linearities
Optical path	a few cm	Keystoning
Glasses position	up to 2-3cm	Misalignment of real/virtual
Eye separation	about 1cm	Perceived distances
Screen refraction	about 1mm	Apparent location of pixels
Screen sag	0.5-1.5cm	Apparent location of pixels

Calibration



Uncalibrated



Calibrated

Two-Handed Interaction

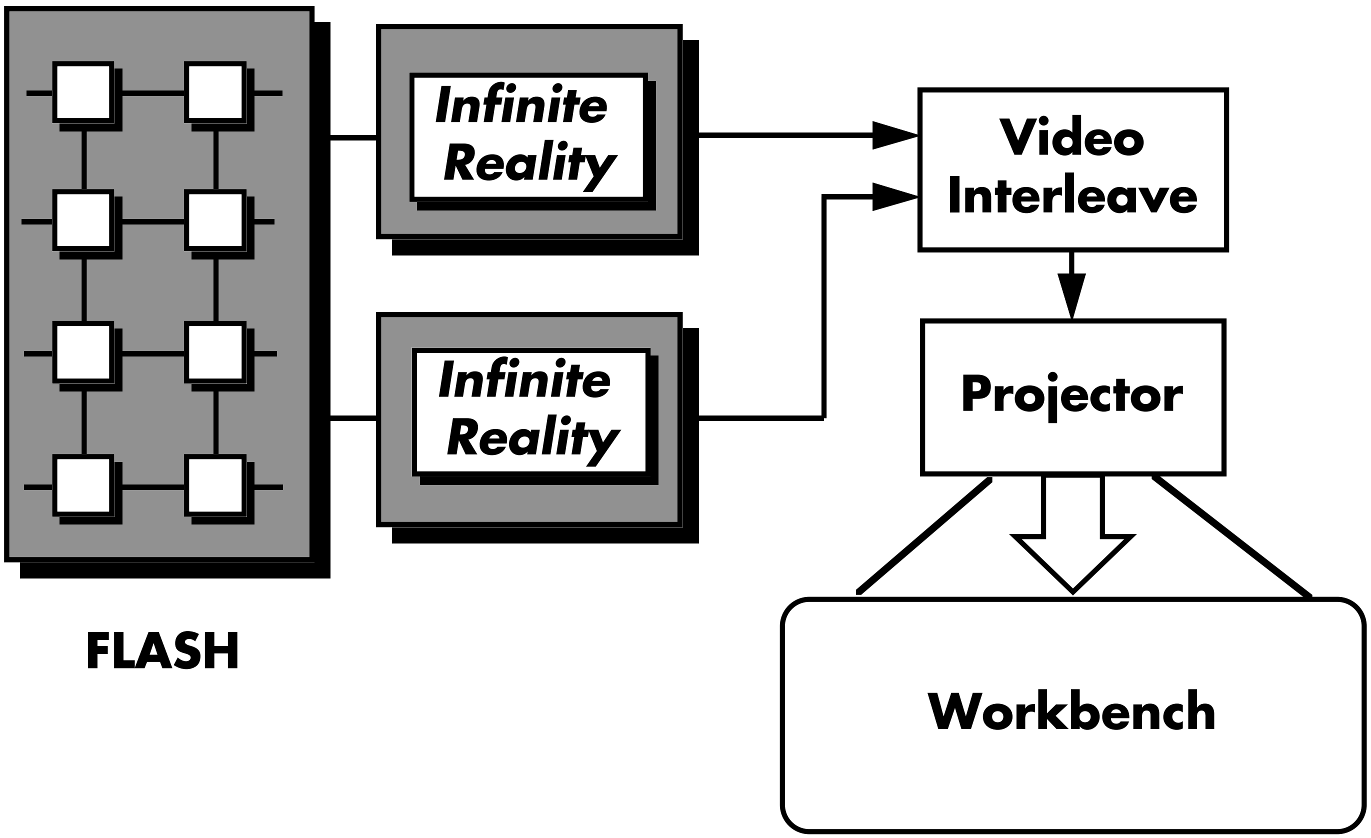
Guiard framework

- Unimanual
- Bimanual symmetric
- Bimanual asymmetric (dominance)
  - LH moves, RH acts
  - LH coarse, RH fine
  - LH first, RH second

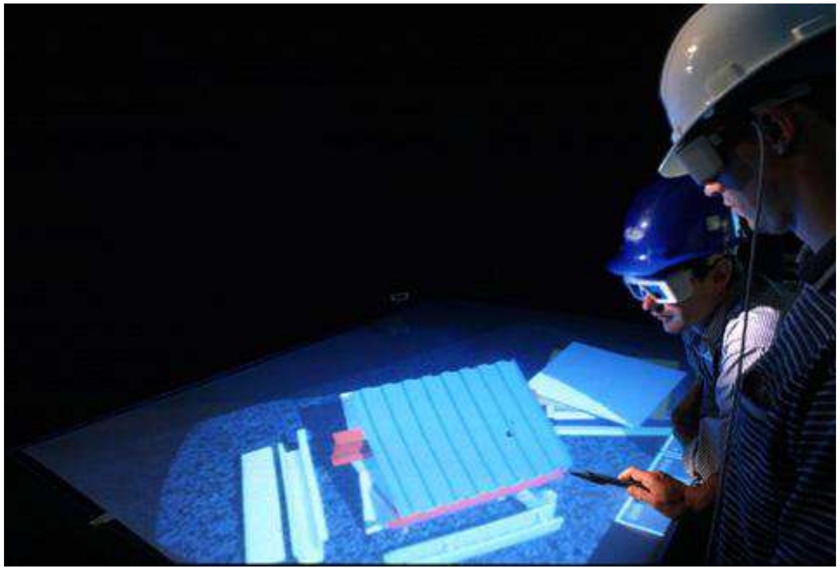
Widgets

- Symmetric: move and turntable
- Asymmetric: centered zoom and rotate

2-Person Responsive Workbench



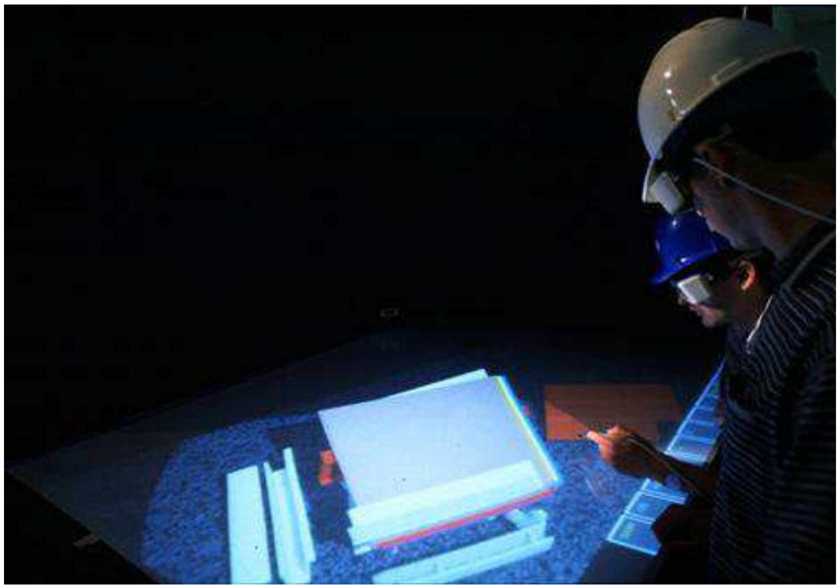
Roof-Gutter Scenario



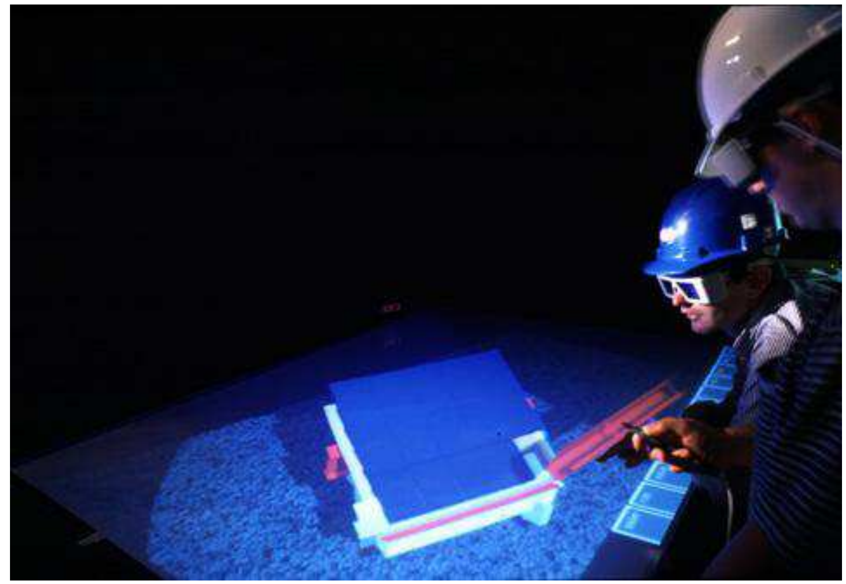
Step 1: Steel has been erected (part of the roof steel can be seen in the model on the table in red), and the metal deck has been installed. The work of the stucco contractor, the sheet metal contractor, and the roofing contractor now need to be coordinated. To the left of the model, the stucco soffit is shown in white, in the front the model of the double gutter, and on the right various other elements. Martin Fischer (white hardhat) and Chris Marolf (blue hardhat) are now trying out an assembly sequence.

Step 2: The roof insulation and the ice and water shield have been placed on the metal deck. Using the wand (Polhemus stylus), Chris is picking up a strip of metal which will act as a kicker for the first row of tiles (the component that is touched or moved turns red). In front of Chris, one can see the menu-driven interface (in light blue) that allows users to move and rotate the model, and to zoom in and out.

Roof-Gutter Scenario

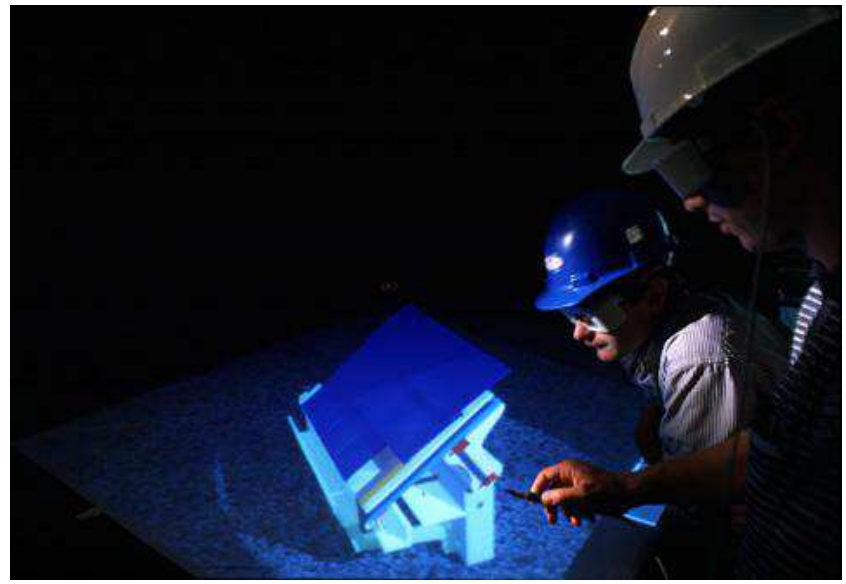


Step 3: Chris has "installed" the kicker and the gutter assembly piece at the roof edge. He is getting ready to place the roof tiles (which have turned red since Chris is touching them with the wand).



Step 4: The tiles have been placed, and have reverted from red back to their model color blue. The stucco has also been placed. Martin is moving the gutter into place.

Roof-Gutter Scenario



Step 5: The roof is fully assembled. The whole assembly took just a few minutes and can be repeated easily, or an alternate sequence can be tried until agreement about the best assembly and installation sequence between all contractors has been reached.

Step 6: Chris and Martin have rotated the model to inspect and discuss the roof assembly plus the supporting structure and fireproofing.

Concept by Martin Fischer, Civil Eng., Stanford

Summary

Task-driven system design

Augment, not replace, surrounding environment

RWB effectively provides *extra* visual cues

Enables interaction/collaboration - the *key*

Acknowledgements:

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GMD Bonn