
GameDevelopers Conference
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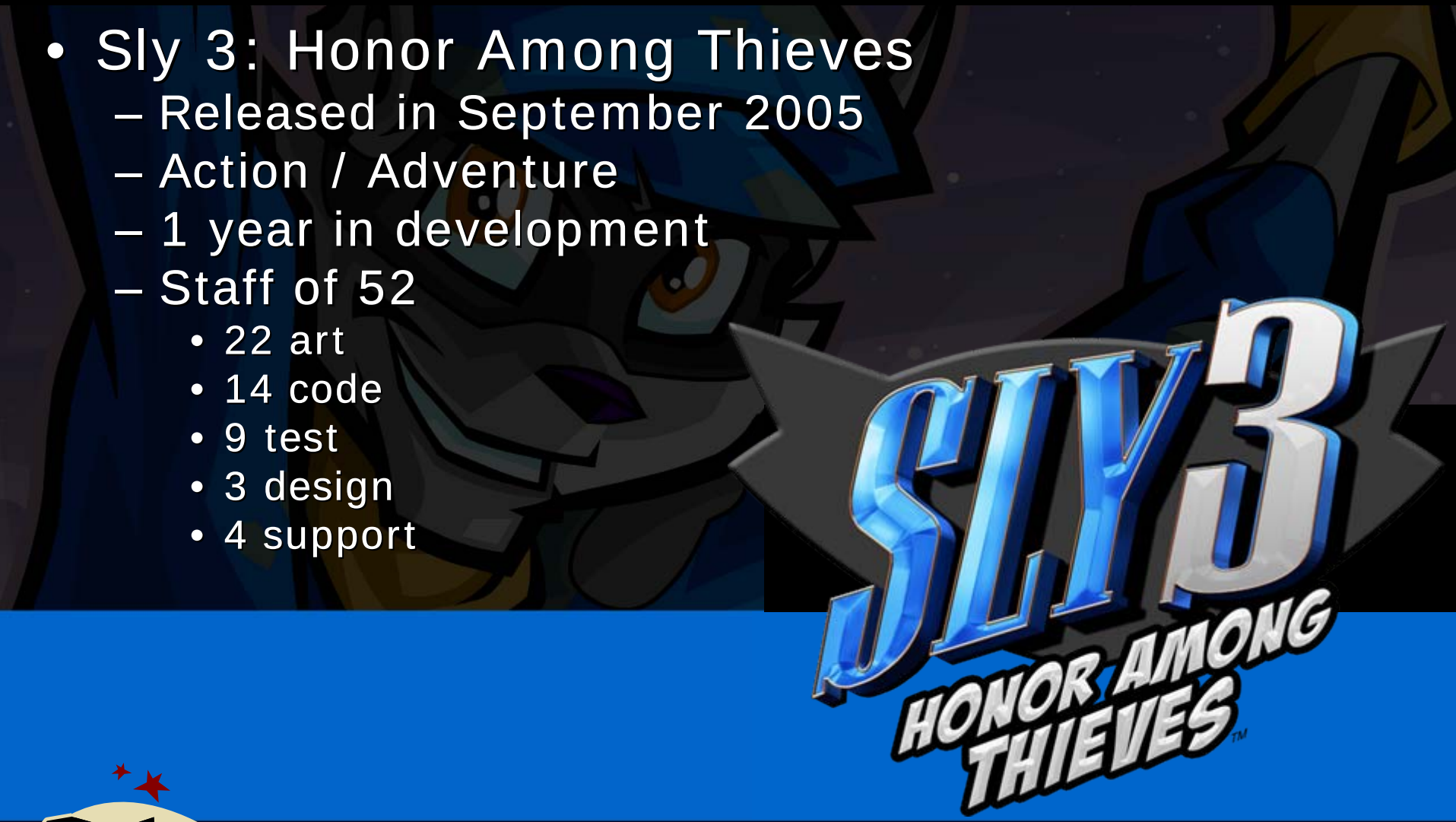
SAN FRANCISCO
3D in 3D:
Rendering anaglyph stereographics in real-time
Bruce Oberg,
Programming Lead
SUCKER PUNCH
Sucker Punch Productions

The Project

- Sly 3: Honor Among Thieves
  - Released in September 2005
  - Action / Adventure
  - 1 year in development
  - Staff of 52
    - 22 art
    - 14 code
    - 9 test
    - 3 design
    - 4 support



Anaglyph Stereography

- Each eye gets an image from a slightly different perspective
- Left eye image drawn in red, Right eye drawn in cyan
- Red/Cyan Glasses included in box
- Use not required (7%-10% population has inadequate depth or color perception)
- Designed into some missions, an unlockable replay mode for others

Real Time Anaglyphs in Sly 3

- Single display list built
  - Frustum culling via standard camera
- Display list submitted twice
  - L/R Camera matrix patched
  - R/GB Color masking activated
- Effectively halved GPU frame rate

How to do Stereography right

- Cameras
  - Frustums and positioning
- Colors
  - Working with Red/Cyan separation
- Content
  - What works in a scene
- Cables
  - Our big mistake

Cameras

- Two cameras pointing exactly in parallel
- Separated horizontally (the “eye distance”)
- Frustums skewed to produce a “stereo window” at the “window distance”

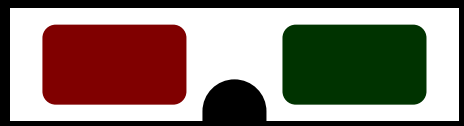
Classic Two Camera Stereography

- Take two pictures from different positions, but pointed in parallel
  - Trivially pairing these is usually bad
- Stereographers line up some significant figure in the pair, then trim off excess
- Result establishes a “stereo window”
- Anaglyph Examples, but principals hold for other viewing methods

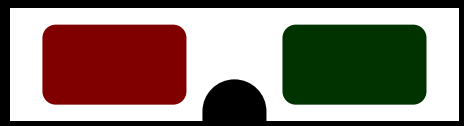
A Simple Stereo Pair

Red/Cyan filtered

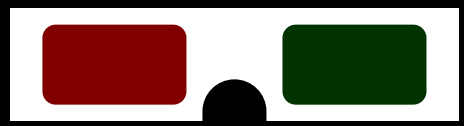
Naïve pairing



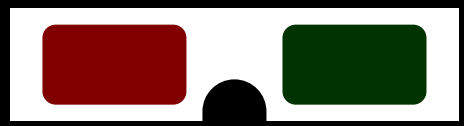
Aligned



Aligned and Cropped



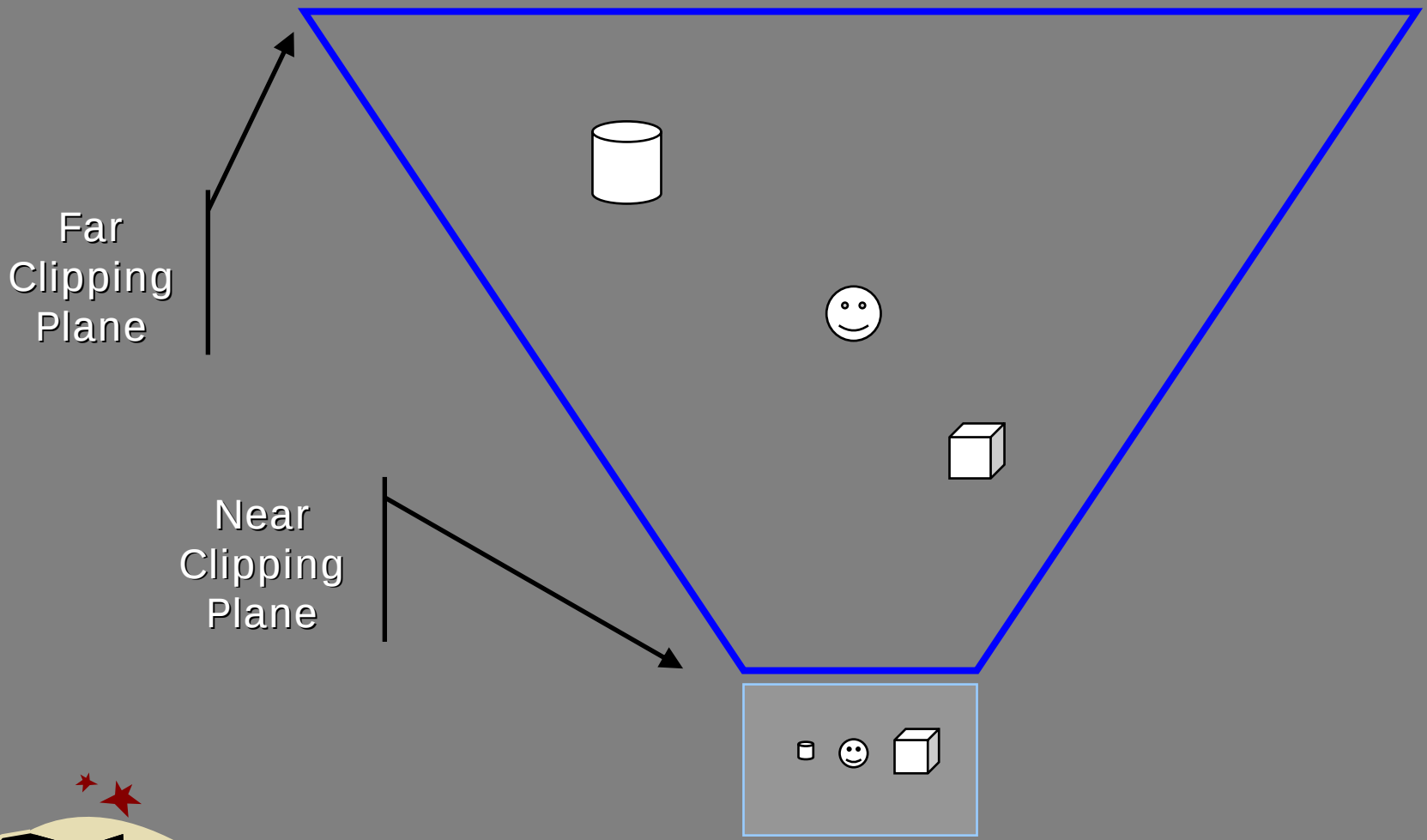
Naïve vs Aligned



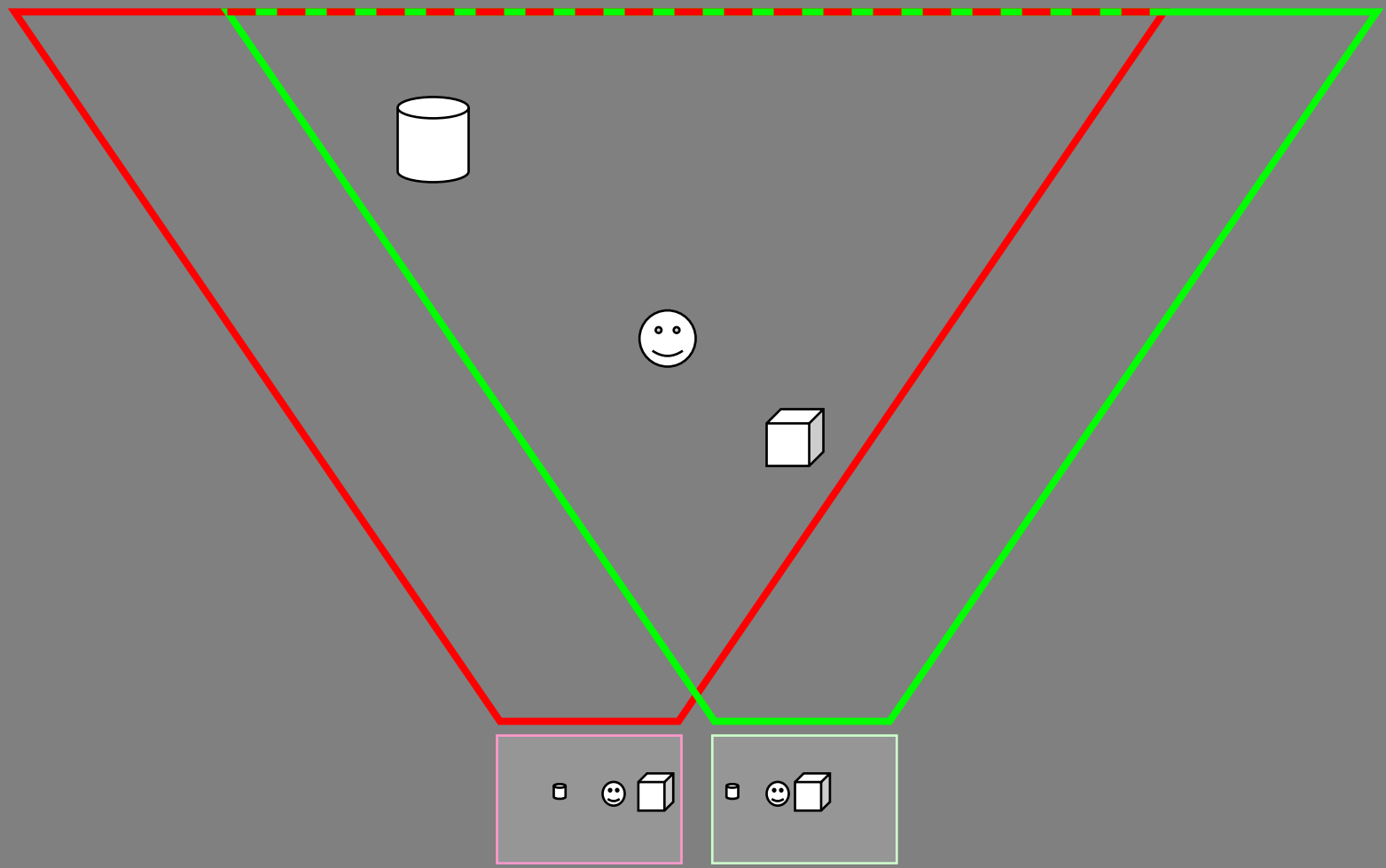
What about Frustums?

- “Stereo Window” cropping effectively skews each Frustum in opposite directions
- This skewing establishes a “window distance” from the cameras, where drawn objects have no parallax

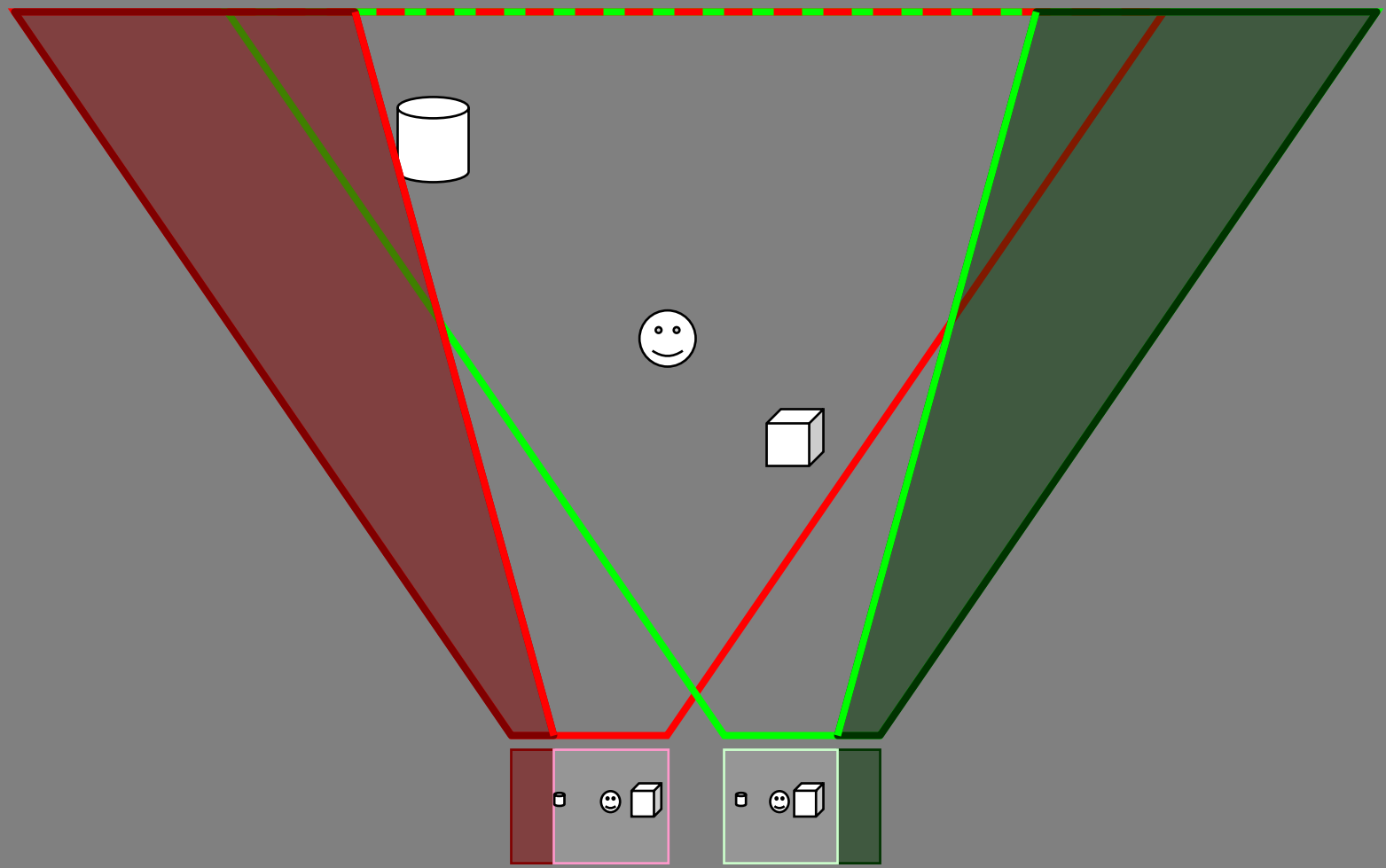
The frustum from above



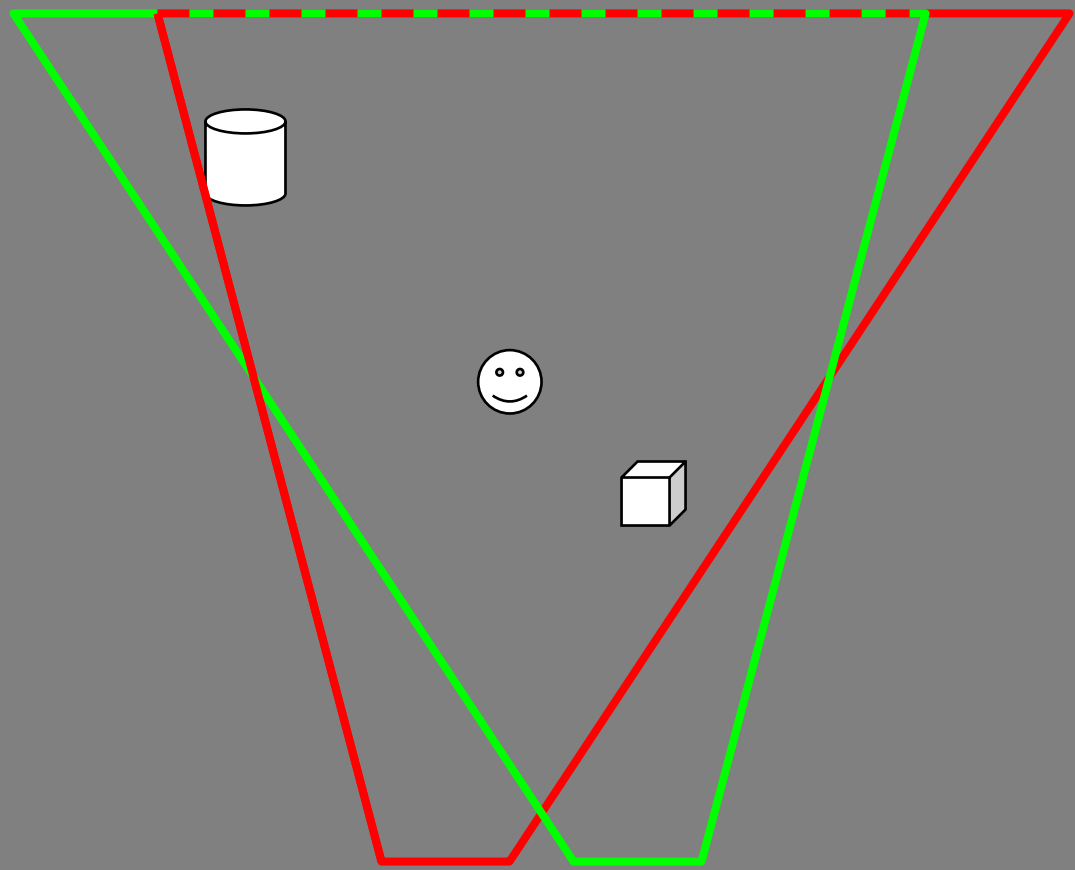
Naïve Frustum Pair



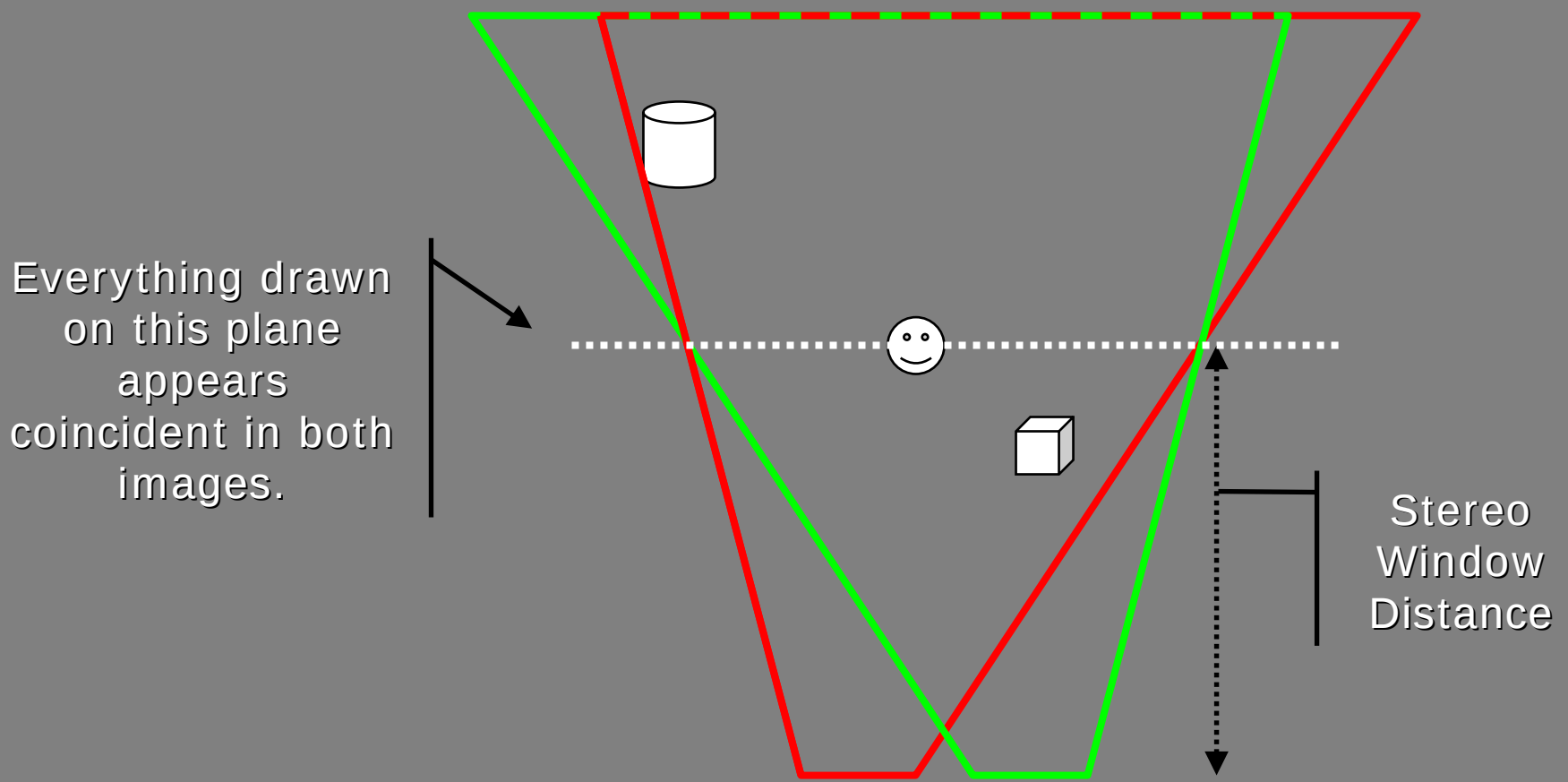
Cropping pair trims frustum



Skewed Frustums from Cropping



The “Stereo Window” revealed



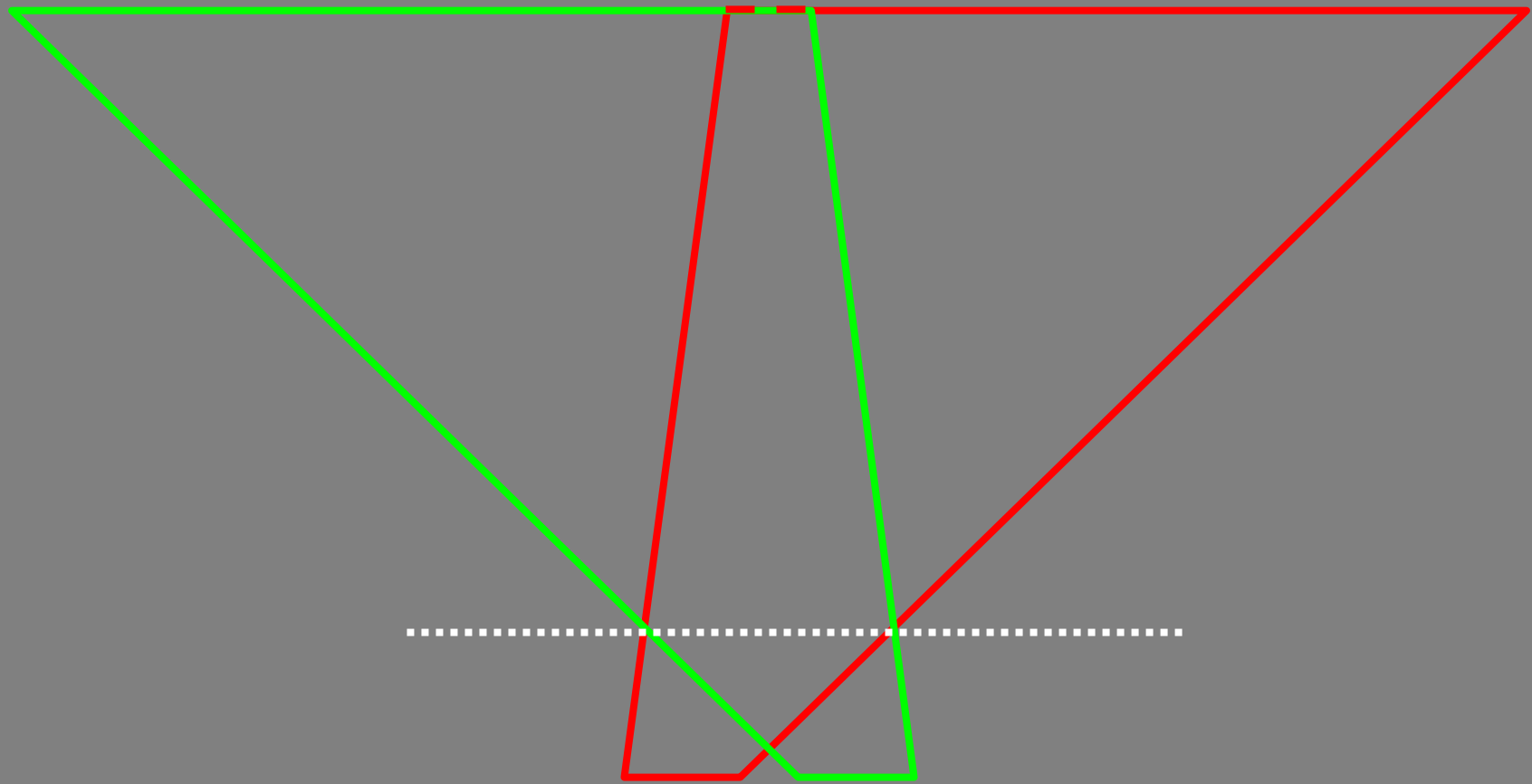
Building Frustums in Sly 3

- Pick a stereo window distance (usually the main character's head)
- Pick an eye distance (more on this later)
- Translate and skew projection matrix in two directions, one for each eye

Sly 3 Stereo Matrix Code

```
void CCm::StereoMatrices(STEREO stereo, MATRIX4 * pmatWorldToClip)
{
	// new eye position is to the left or right

	float	sStereo = 0.0f;

	switch (stereo)
	{
	case STEREO_Left:
		sStereo = m_sStereoEye;
		break;

	case STEREO_Right:
		sStereo = -m_sStereoEye;
		break;
	}

	//	build skew matrix for this eye offset and the “stereo window” distance

	MATRIX4 matSkew = MAT_Identity;

	matSkew.aag[2][0] = -sStereo / m_sStereoFocus;
	matSkew.aag[3][0] = sStereo;

	//	folding the skew matrix into the projection matrix

	MATRIX4 matProjSkewed = m_matProj * matSkew;

	//	Combine world and skewed projection matrix

	CombineEyeProj(MatWorld(), matProjSkewed, pmatWorldToClip);
}
```

Close Window == Strong Parallax



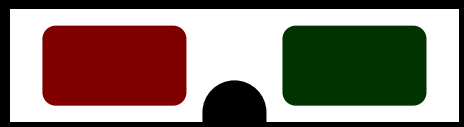
Minimizing the puke factor

- Too much parallax makes 3D effect harder to see (and may make people sick)
- Solution: change eye separation to compensate for large parallax
- Smoothing all transitions keeps the effect from begin jarring

Colors

- Any color with too much red or green/blue will cause retinal rivalry
- Whites, grays, yellows, magentas work best
- Sly 3 reloaded levels when entering 3D mode, desaturating and brightening colors at load time
- Result: greyer and brighter levels, ensuring color content for both eyes
- Color adjustments were tweakable

One color problem



Content

- Vertical Edges
  - Our most effective level was a forest of thin trees
- Near and far objects
  - Objects on both sides of stereo window reinforce stereo effect
- High resolution textures and models
  - Stereography can show details and subtleties… ask the Mars Rover team
- NOT: Racing scenarios
  - Depth cues moving too fast?

Cables

- Video bandwidth matters
  - RF and Composite (single yellow RCA) compress image, distorting colors and brightness (your frame buffer RGB does not survive)
  - S-Video cables better
  - Composite cables the best
- Our biggest error
  - Not including in-game cable information or display calibration (Spy Kids DVD does this)
- Result: Many customers had a so-so experience

What we've learned

- Cameras Matter
  - Both stereo window and parallax angle should be determined carefully
- Colors Matter
  - Grayscales, yellows, magentas are best
- Content Matters
  - Vertical edges, near/far objects, and *detail*
- Cables Matter
  - Educate your customers

Questions? Answers!

www.suckerpunch.com

local.wasp.uwa.edu.au/~pbourke/projection