SIGGRAPH 2010

Terminators and Iron Men: Image-based lighting and physical shading at ILM

Ben Snow - Industrial Light and Magic

The 90‘s - Light Probes, Textures and Environment Maps

- Grey Sphere
  - –Known Object
  - –18% Grey
  - –Can (somewhat) easily reproduce on computer.
    - Evaluate how closely our lighting matches.

The 90‘s - Light Probes, Textures and Environment Maps

- Chrome Sphere
  - –Lets us look at the lighting that was there on set.
  - –Can extract environment maps.

The 90‘s - Light Probes, Textures and Environment Maps

- Chrome Sphere
  - –Maps derived are low resolution.
  - –Can use cubic map instead but clunkier, problems with seams.

The 90‘s - Light Probes, Textures and Environment Maps

- Heavy use of texture maps.
  - –Great painters, rich textures helped the realism despite the materials and lighting.
  - –Can end up with painted in highlights and shadows, particularly when based on photos.
- Cook-Torrance specular.
- Light rig - reflection environments, ambient light, spots and directional lights.

The 90‘s - Light Probes, Textures and Environment Maps

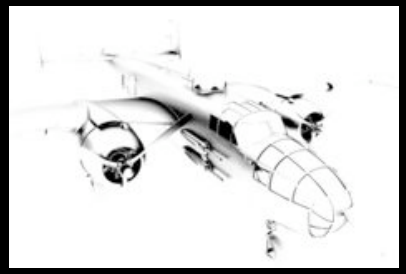
- Cheats for lighting
  - –Replacing ambient with multiple spot lights.
  - –Turn down the shadow opacity (eek!)

Pearl Harbor and “production ready” IBL

- Ray tracing and Global Illumination not practical for our scenes.
- And we loved Renderman which didn’t do either.
- Partial solution:
  - –Reflection Occlusion
  - –Ambient Occlusion
  - –Ambient Environments

Reflection Occlusion

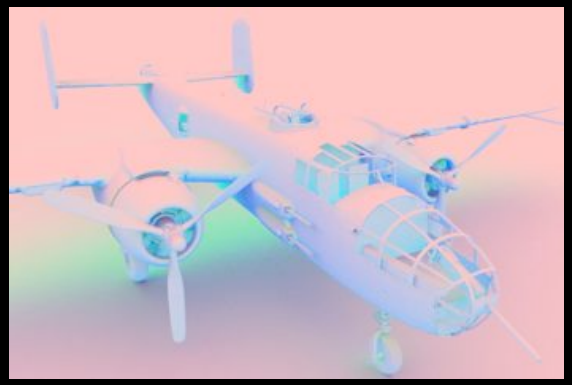
- Addresses problem of reflections not being occluded when you use an all encompassing reflection environment.



Ambient Environments

- Developed on Pearl Harbor as a way of getting diffuse fill illumination more like GI.
- Uses a blurred version of the environment map for ambient light color and intensity.
- Uses a pre-rendered occlusion map accessed at render time to give the scene a realistic shadowing.

Ambient Environments



- Rays cast in a hemisphere around the surface normal.
- # Rays hitting other surfaces dictates occlusion.
- Pre-pass done to calculate average direction of light
  - –Weighted with the surface normal to bend the direction of the lookup: “bent normals”

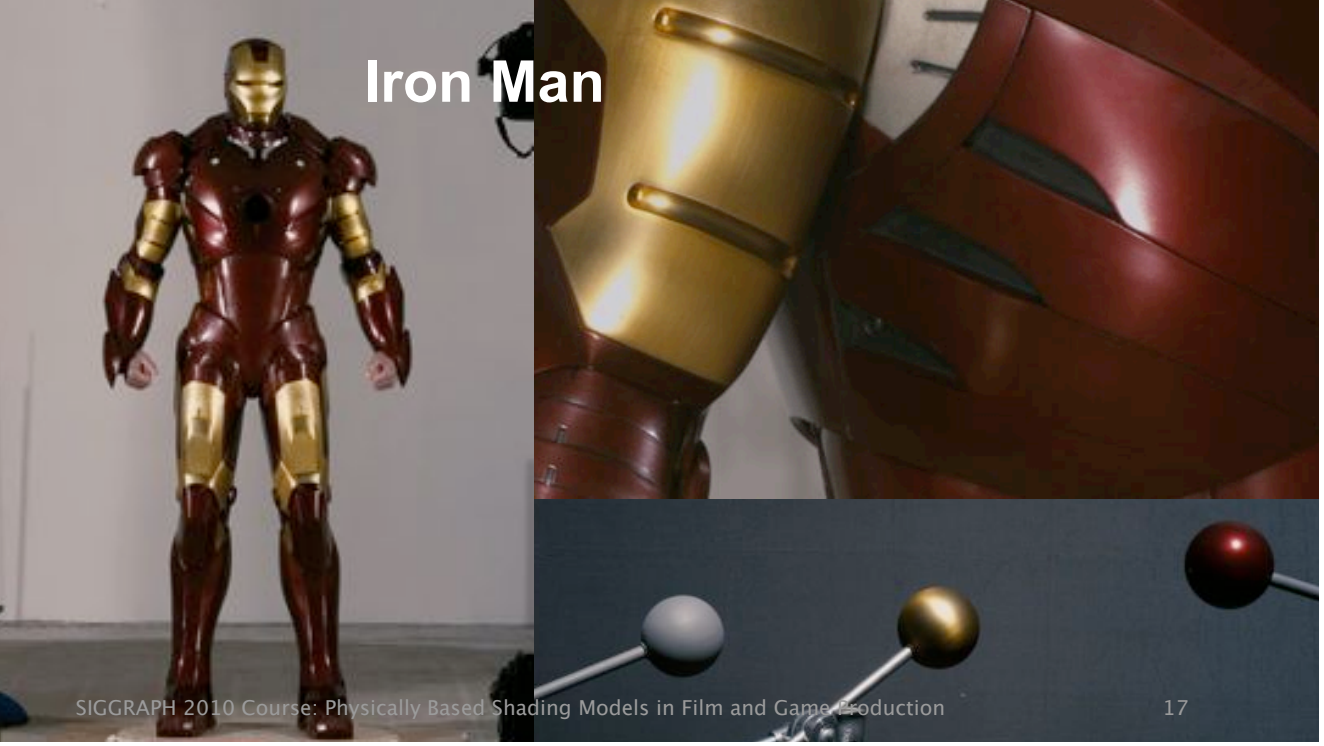
Ambient Environments

Post Pearl Harbor

- Dynamic range of image data improved with introduction of openExr format.
- Use of pano-scan for High resolution HDRIs
- Projection of HDRI data on geometry for Hulk
- Introduction of point based methods, first for subsurface scattering, then occlusion and indirect diffuse illumination.

Iron Man and better metals

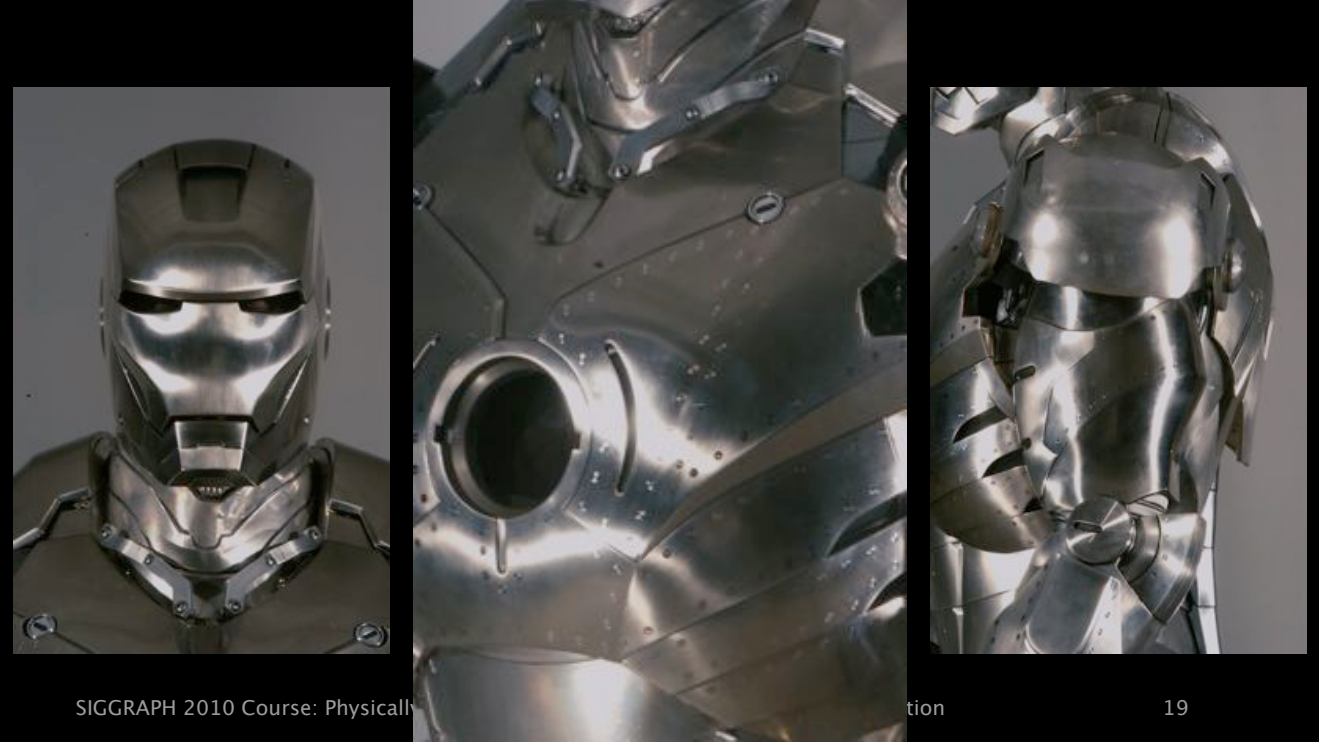
- High (ish) dynamic range images captured on set.
- Able to leverage car finish materials from Transformers.
- Need to match practical suits; brushed metal
- Raw metal materials lacking.
- Try to acquire sampled BRDFs



Winston/Legacy suit on left.

Looking at real red and gold materials: narrower/whiter central hilight, a wider/ colored glow around it.

- sent swatches out to measure the BRDF
- Decided to approximate BRDF using functions: sum 2 different spec functions to simulate the complex response. Big adv. of shading model over measured BRDF is tweakability.

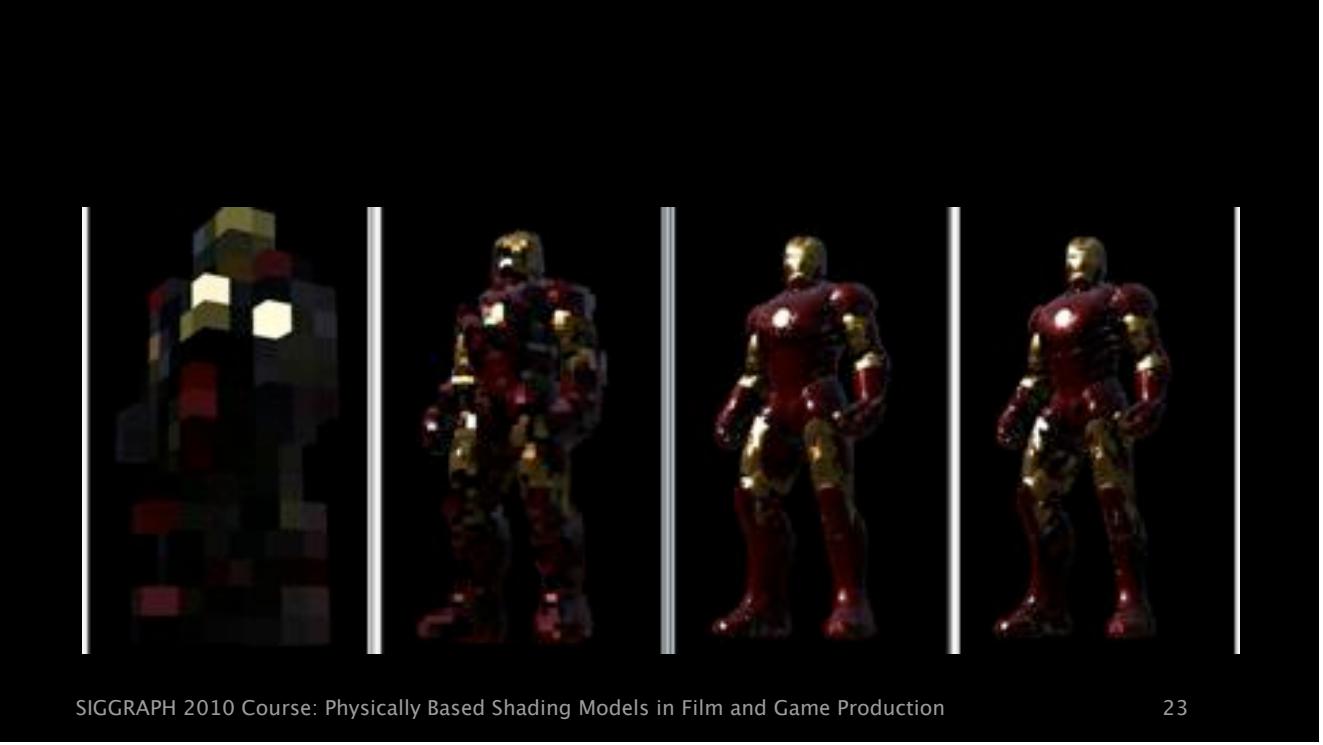


- One tell-tale sign the anisotropy is working is "spinny bowties" on circularly-brushed surfaces. Without it, circles are more solid-colored.
- We also see a very complex colored fringe around the hot core of the highlights which we would like to replicate.

- Our first attempt was to match situation physically with a very fine "scratched surface" bump map: way too noisy and aliases and slow. And even if we got it looking good without aliasing at one size in frame, when we shrank Ironman in frame, the aliasing problem would reappear at a different scale.

Here is a render showing that attempted methodology: the scratches are aliased, and we don't get spinny bowties.

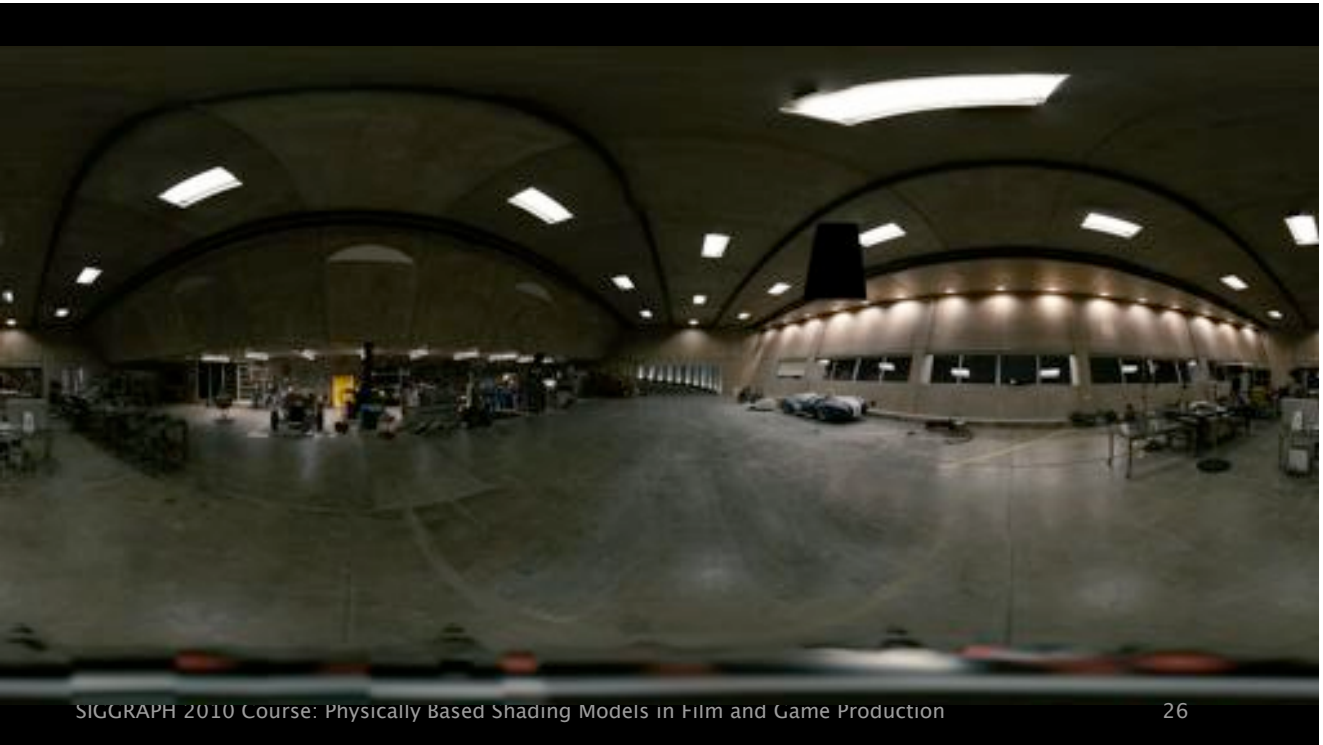
- Seperate X and Y specular components along with a scratch direction.
- also allowed seperate expondent for each color channel to add the fringe I pointed out earlier.
- Meshes were UV laid out so primary brushing direction was vertical in the texture and the UV could be used as brush direction.



-Need for speed - use Renderman Brick Maps for cacheing surface data for ray traced self reflections.

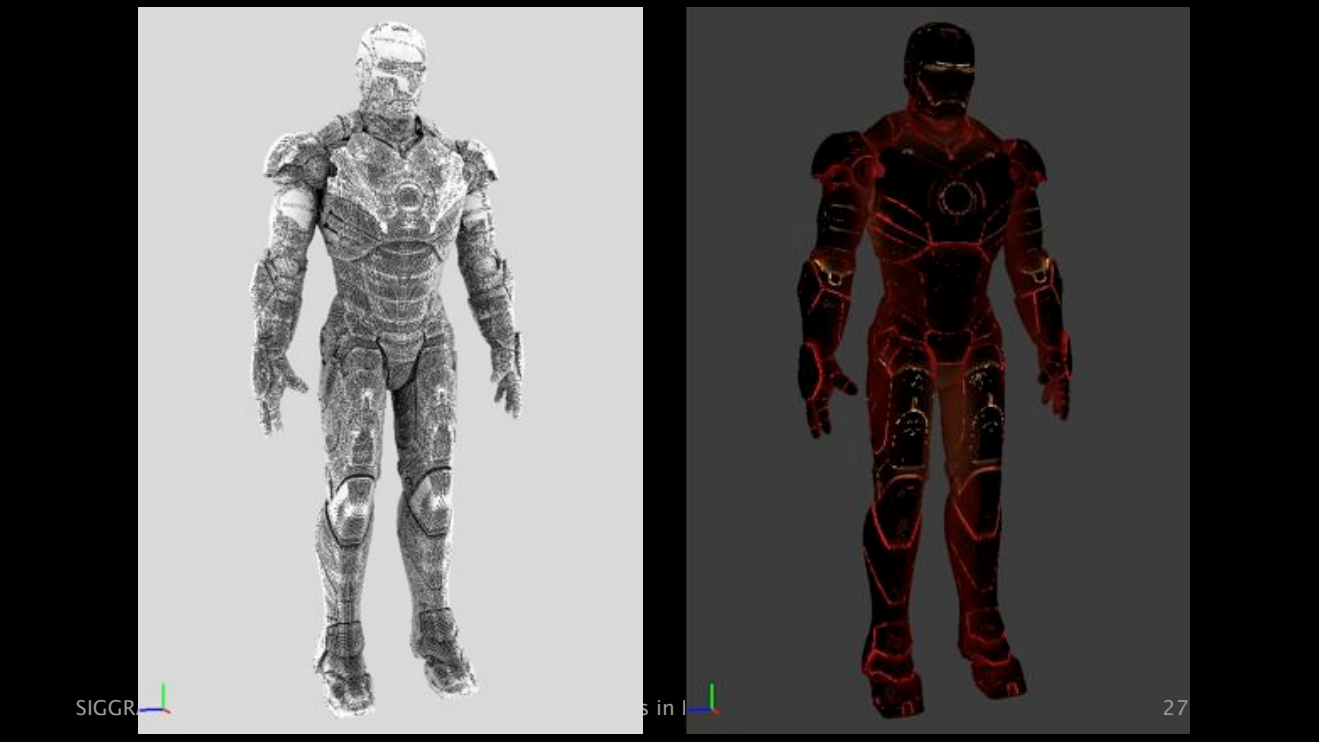
-Brick Map is volumetric texture map Instead of 2-D texture that you project or map onto UVs, brick map defines color at each voxel that was occupied by some geom at time map was created.

To generate our environment, the multiple-exposure images mentioned earlier were aligned and merged into an HDR exr image per-direction using in-house software, then stitched into a single 360-degree environment texture.



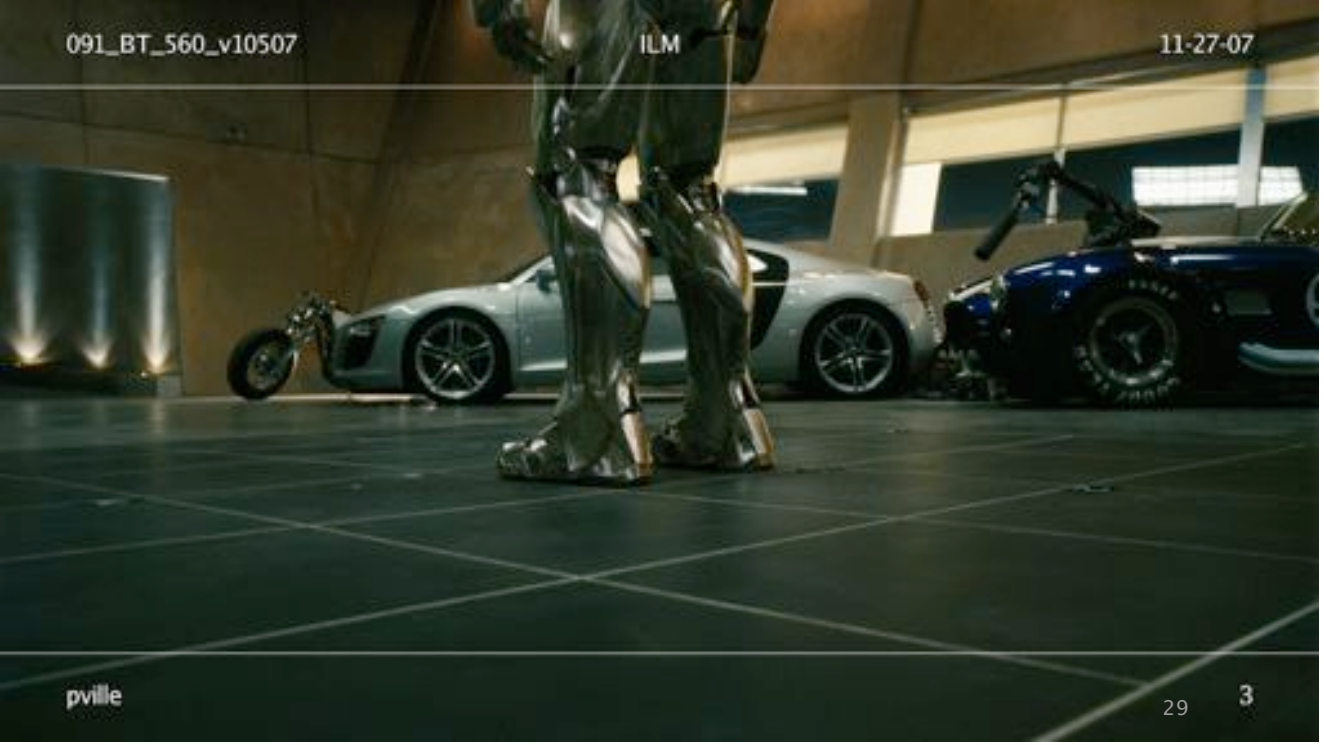
Resulting stitched image was painted on to remove remaining artifacts and fill in holes from bad or missing tiles. Particular attention must be paid at the top and bottom to remove spurious bright spots.

- This stitched image can then be used as an environment for CG lighting. We often supplemented bright lights in the environment with CG lights to efficiently get complex surface material properties.



Another optimization we used is that ambient occlusion and diffuse illumination are sampled only at lower density on all surfaces and baked into a cloud of point data, used in the final render when gathering indirect diffuse illumination as well as ambient shadowing.

Practical suit (which includes some plastic components - eg abdomen) on left, final CG version (all brushed chrome) on right.



problems:

- possible to create unbalanced lighting because of all the components being balanced across and between models.
- spec and refl are same, diffuse and ambient are same, but would drift out of alignment.
- lighting strategy - mix of cards and lights - arbritray and up to artist - no consistency

Example frame from the final film - suit up sequence.

Terminator salvation and physically based shaders in Renderman

- Terminator Challenges and Aims
  - –Many raw metal and shiny metal surfaces for Terminators.
  - –Tight budget, wanted faster good-looking take on shots.
  - –Dynamic environments filled with practical effects
  - –Harsh Desert exteriors and a harsh DI look for the release.
    - Want to be sure our renders reflect the dynamic range of the photography.
  - –Improve and simplify look development and lighting

Terminator salvation and physically based shaders in Renderman

- Solution - move to a new, physically-based materials and lighting paradigm.
  - –Energy conserving materials.
  - –Normalized specular.
  - –More physically plausible specular falloff.
  - –More heavily image-based.
  - –Importance sampled ray-tracing.
- Goal: A simpler, more intuitive and physically based system of lighting and rendering.

Terminator Salvation: Energy Conservation

- The amount of light that reflects or bounces off a surface should never be more than the amount hitting the surface.
- Specular and reflection combined into one component called specular.
- Ambient and Diffuse combined into one component called diffuse.
- One importance sampled environment light.

"Traditional" setup for reflection

- 3 spheres reflected in 3 ground planes, each with a different reflection blur.
- As we increase reflection blur the image of the sphere gets darker.
  - –we're gathering light from a wider cone of directions.

Traditional setup for specular.

- 3 lights illuminating 3 ground planes, each with a different specsize.
- As we increase specsize the highlight doesn't get darker.
  - –with the old specular model it can even get brighter at grazing angles so specular values are hard to predict (!)

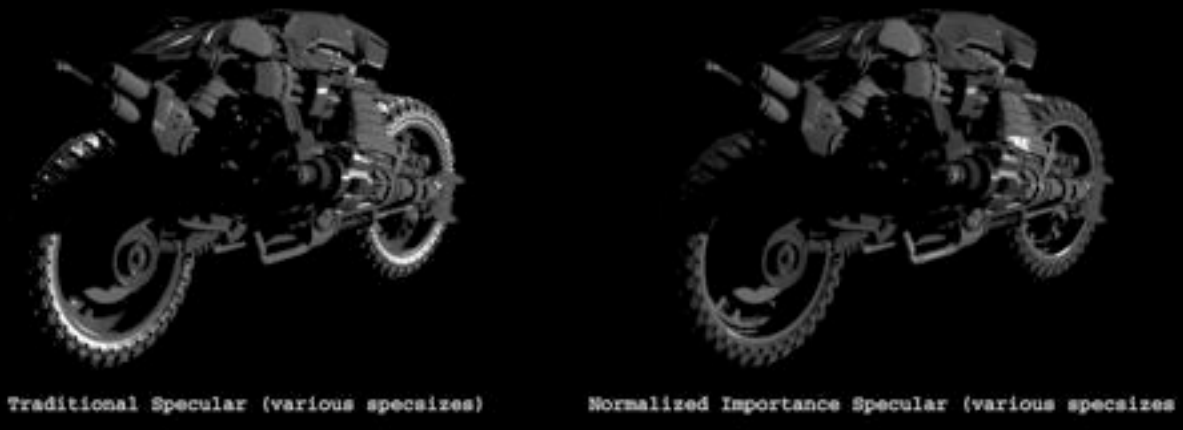
Traditional setup for specular - problems

- Adjusting the gain of the specular to make it look correct for different sizes was left to the look develoment artist.
- The way surfaces respond to specular was inconsistent with the way it corresponded to reflection.
- Objects with different materials could behave differently to one another in different lighting - ie more artist time spent tweaking materials and lights.

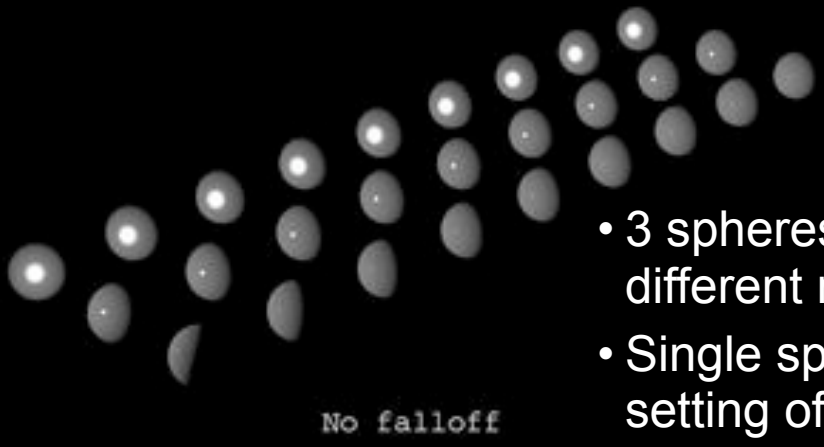
Terminator Salvation: Normalized Specular

- 3 lights illuminating 3 ground planes, each with a different specsize.
- Specular works the way reflection does. As specsize increases, intensity reduces.
- The area under the specular lobe always sums to 1.0

Terminator Salvation: Normalized Specular - old vs new on a mototerminator



Traditional Light Falloff



- 3 spheres, each with different roughness.
- Single spot light withi default setting of no falloff.

Traditional Light Falloff

- Controls allowed1/r2 falloff or smoothstep falloff.
- Falloff affected both diffuse and specular, but specular separately controlled.
- Falloff didn't account for roughness

Terminator Salvation: Normalized importance falloff.

- Intensity of highlight falls off on rougher surfaces
- For tight speculars like chrome or mirrors, the light source has to get a long way away before dimming.
- For broad speculars it will dim more quickly.
- For this to work the light needs to have a physical size in the system.
- Initial implementation on Terminator allowed us to decouple diffuse sparking a Holy war.

Terminator Salvation: Importance Sampled Raytracing.

- Aim is to sample your scene as efficiently as possible.
- Concentrate samples around the brightest points of any images used for lighting.
- Sample the specular function to determine which ray directions will provide most lighting contribution.
- Reflections from objects and specular lights are treated in the same way.

Terminator Salvation: Importance Sampled Raytracing.

- More on this in course notes
- Refer also to Phary and Humphrey's "Physically Based Rendering"
- Tuesday morning course "Importance Sampling for production rendering"

Terminator Salvation: Switching to the normalized importance materials.

Towtruck turntable with references - also comparing practical, old and new materials on spheres.

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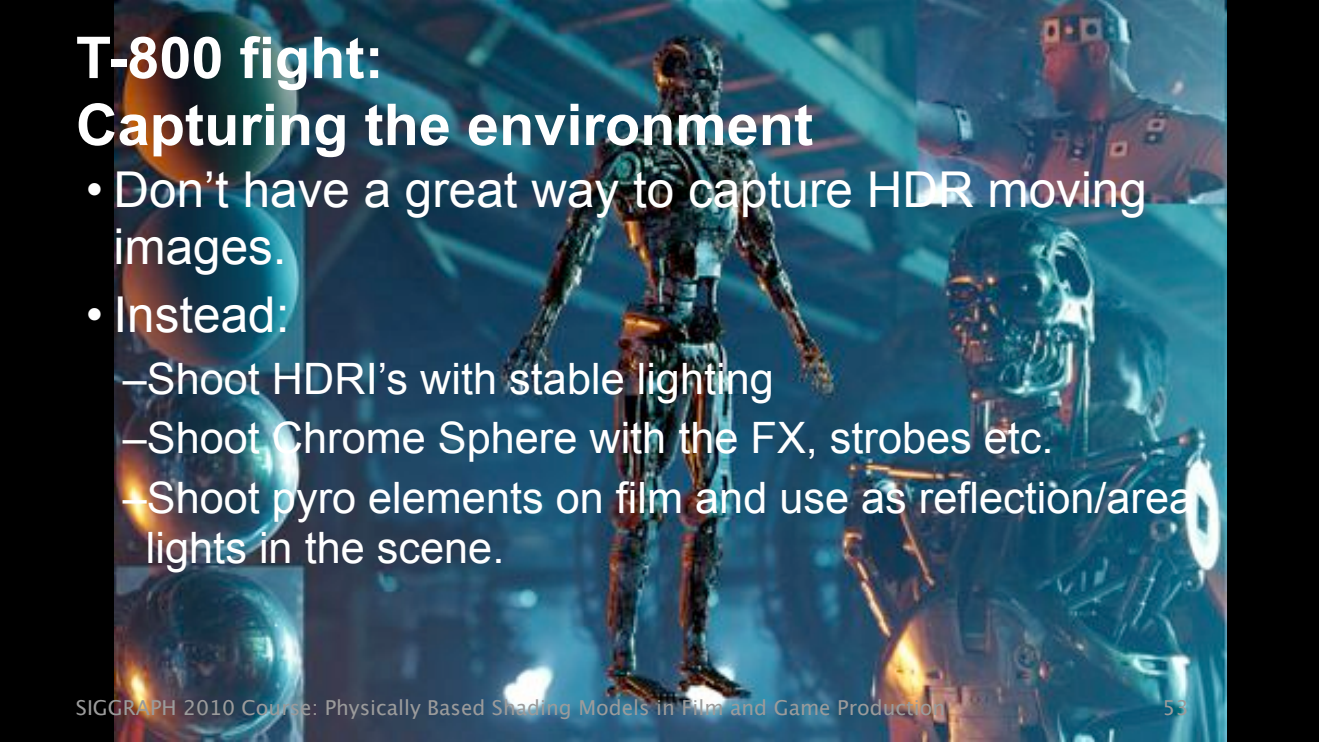
T-600 endoskeleton CG turntable.

"Before"

Terminator Salvation: T-600 fight - renders

"After"

Terminator Salvation: The T-800 fight



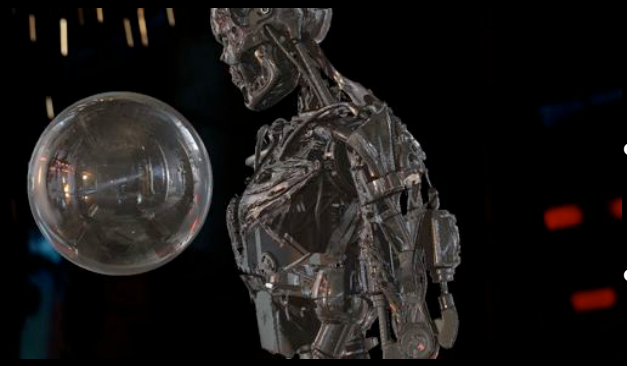
T-800 fight: Capturing the environment

- Don't have a great way to capture HDR moving images.
- Instead:
  - –Shoot HDRI's with stable lighting
  - –Shoot Chrome Sphere with the FX, strobes etc.
  - –Shoot pyro elements on film and use as reflection/area lights in the scene.

T-800 fight: Creating the sequence foundation.

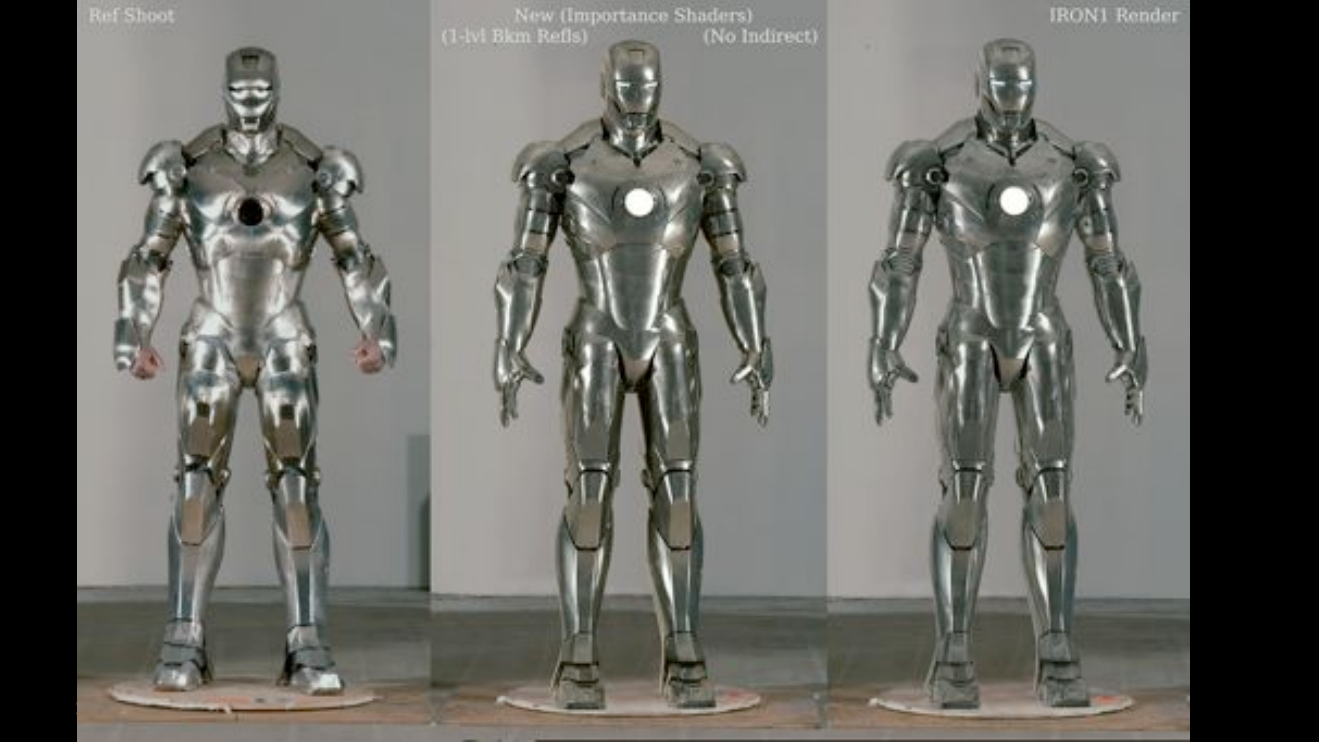
- Sequence leads set up environment maps and lighting instruments for sequence.
- Sequence leads run first take for each shot.
  - –Shot set up for TD so they start right into lighting.
  - –Can run quick takes for animation reviews if needed.
- Start with hero HDR image set stitched into sphere
  - –Paint out bright lights and use images of lights and pyro events on cards to light scene.
  - –Document the different environment maps and lights.

T-800 fight: Choreography of the lights



- TDs needed fast render tool to sync the lights to the BG by hand.
- Solution: “Layer cake” an internal GL lighting tool.
- Overnight renders set up to generate sphere renders that were auto-composited into dailies movies.

Iron Man 2:
Putting Normalized Importance to work



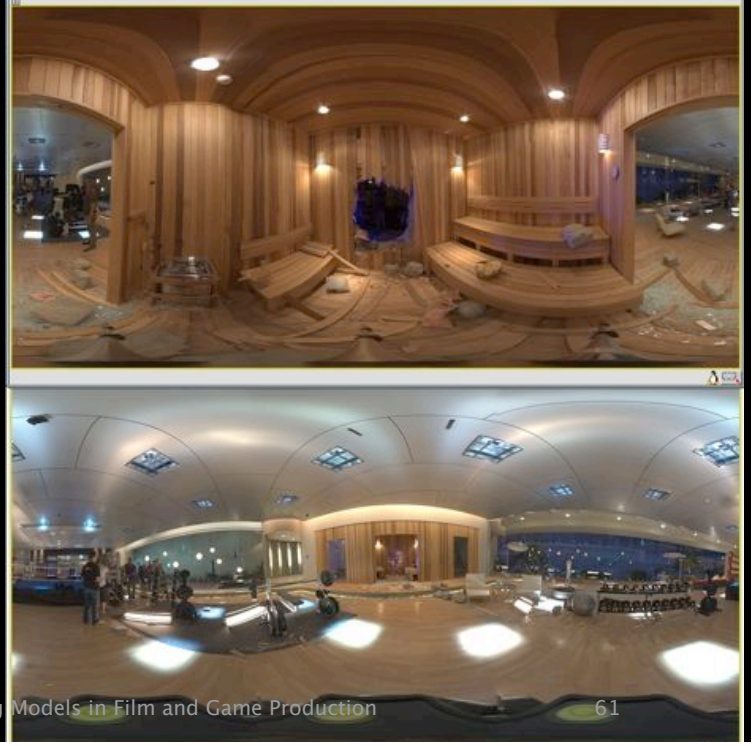
Practical suit; Normalized Importance materials on CG suit; Iron 1 materials on CG suit.

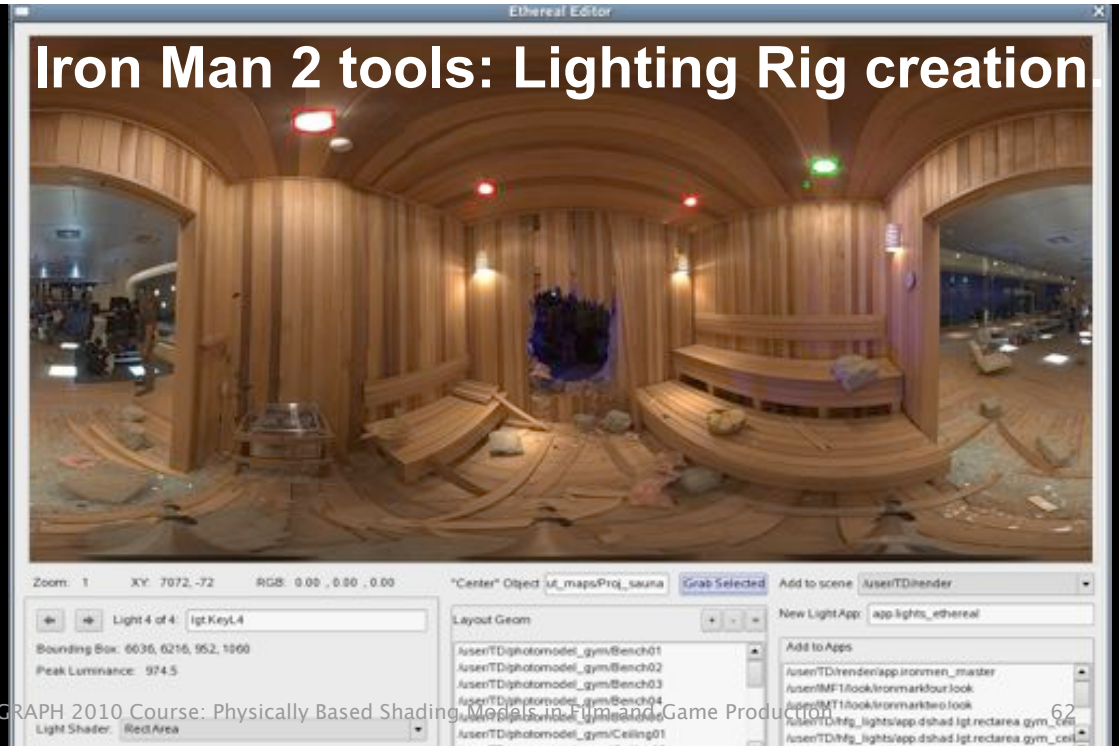
SIC

Practical suit; Normalized Importance materials on CG suit; Iron 1 materials on CG suit.

Iron Man 2 tools for image-based lighting: Environments browser

Iron Man 2 tools for image-based lighting: Environments browser



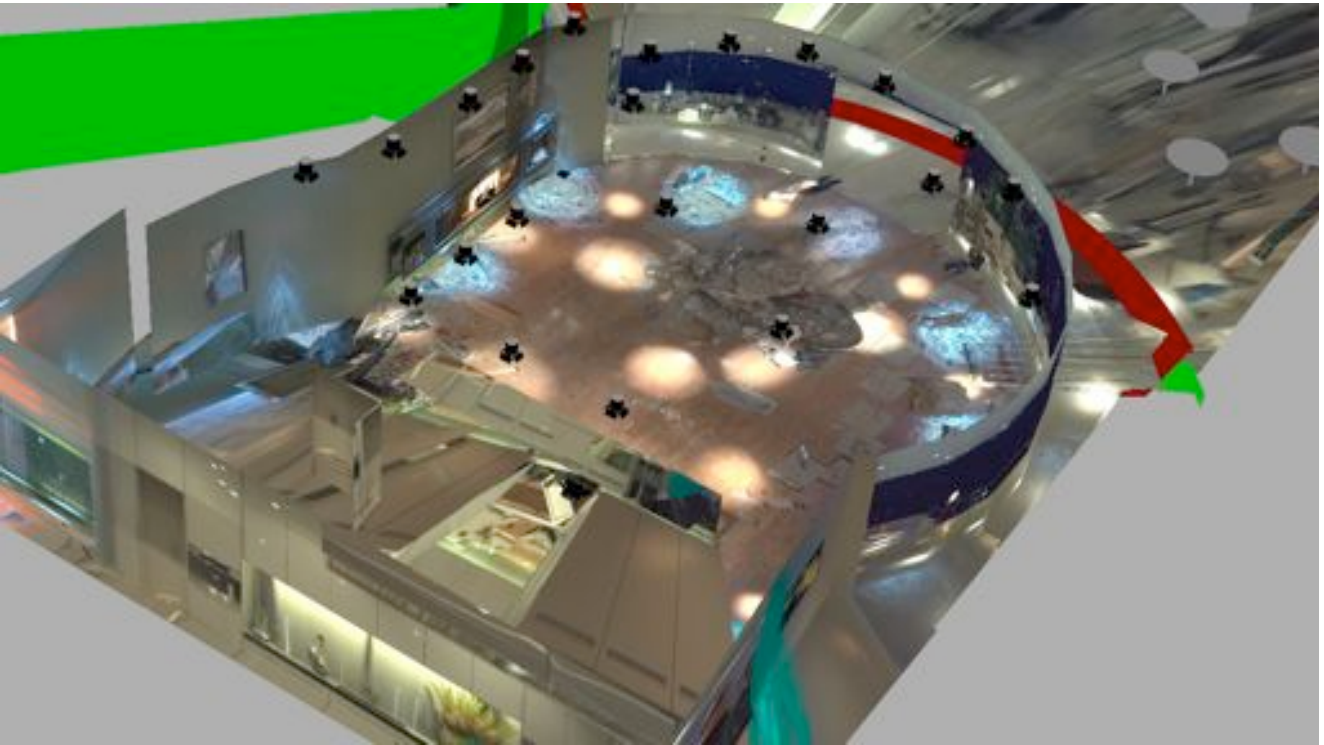


- Ethereal: loads the env sphere image and semi-automatically creates a lighting rig. Artist can draw rectangles around lights, tool converts them to CG textured area lights, and "raytraces" from the probe position out to the matchmove set geometry to put CG light at correct initial distance/position in set. Also removes the bright lights from the HDRI texture.

Example final frame from movie.

Stunt reference

Animation pass.

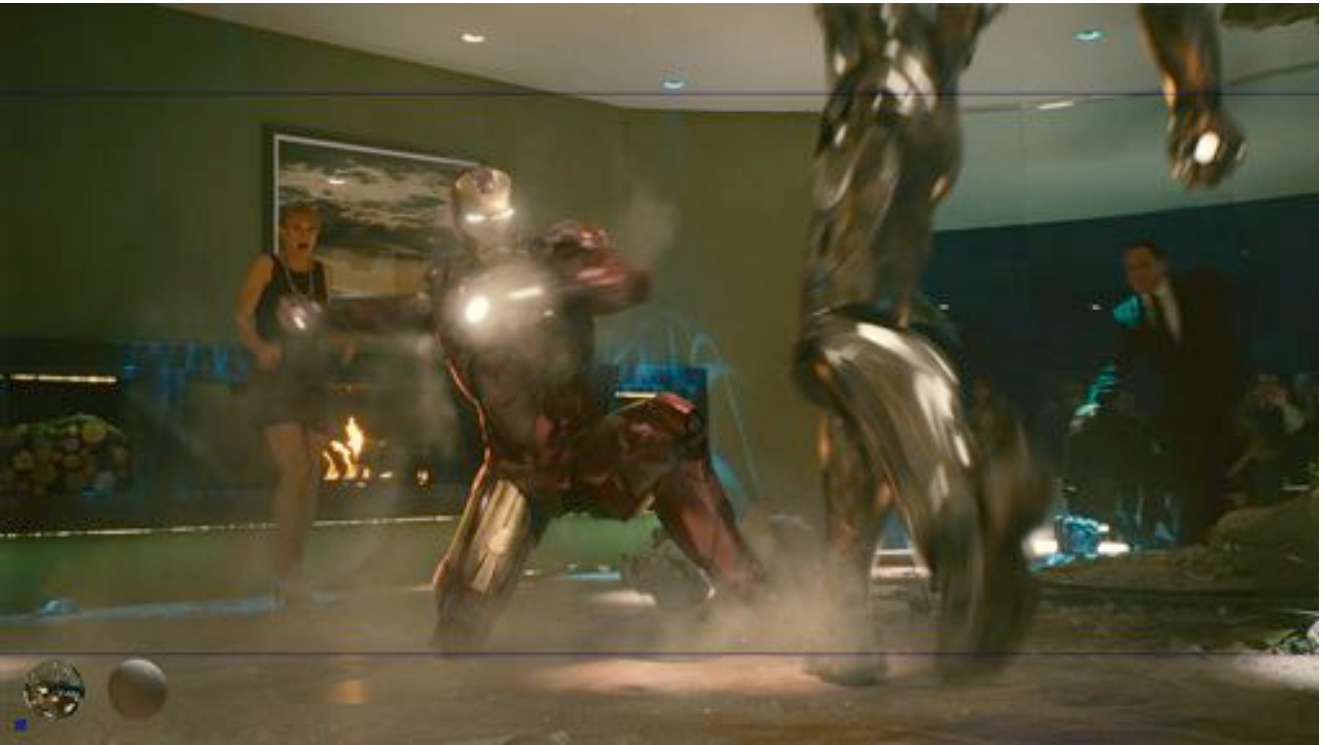


Simple matchmove set geometry built and HDRIs projected on.

- Textures are projected from multiple HDRI sphere photography positions to fill in spots hidden from other views. The red cones represent the positions of the the three

Aim is to get positionally-accurate colors in all directions from where the action is (as it moves through set). Here's view from center of room.

Render the virtual scene from the characters position, including shadowing from the character and others.

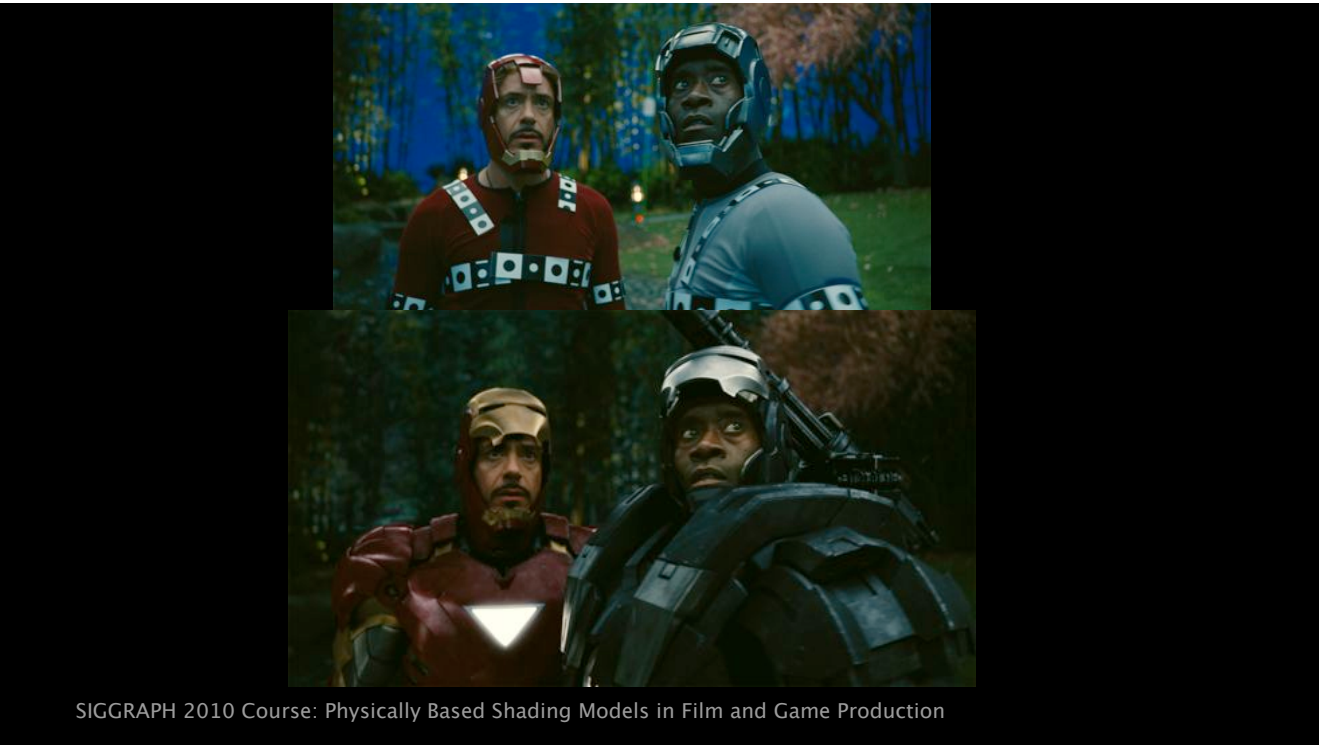


Final frame example.

WIP render - note the practical spheres against our automatically generated CG reference spheres.

The final version

By reproducing lighting instruments like this Kino we could extrapolate lighting to sets where D.P. hadn't necessarily lit with suits in mind.



Before/After

Issues with Image Based

- Infinite environment.
- Learning curve.
- Important to get good environment HDRIs on set.
- Need to be sure you don't lose range when editing HDRIs.

Capturing Image data on set

- Chrome/Grey spheres and references.
  - –get the crew into the habit.
  - –Make sure the lighting is consistent with the plate photography.
  - –Make sure the spheres are as big as possible in frame.
  - –Make sure the spheres are in the right spot.
  - –Don't shadow or be reflected in the spheres.
  - –Move the spheres like the object but have some static chrome sphere footage.

Capturing Image data on set

- Be ready to zoom in and get the references.
- When in doubt, shoot the references.
- Don’t be sloppy about it.

How we capture HDRIs

- Canon 1Ds mk3 w Sigma 8mm fisheye lens
- Nodal Ninja & Tripod
- Remote shutter trigger
- 0.6 ND (2-stop) filter.
- 7 exposures, 3 stops apart.
- Direct sun f/16, ISO 100, centre exposure 1/32sec