Underwater Photogrammetric Verification Of Nuclear Fuel Assemblies Via Natural Feature Measurement

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GANCELL

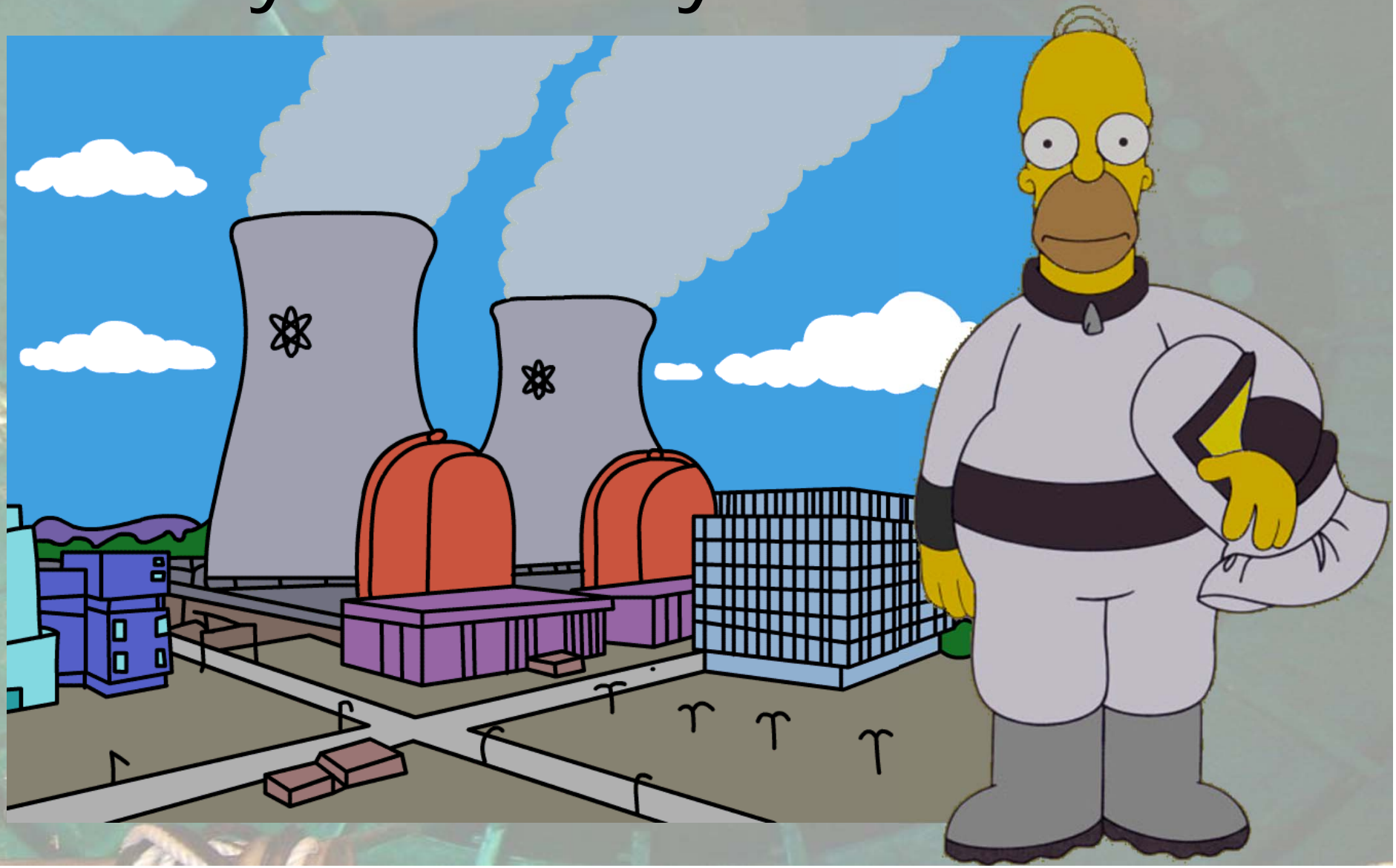
A few warnings...

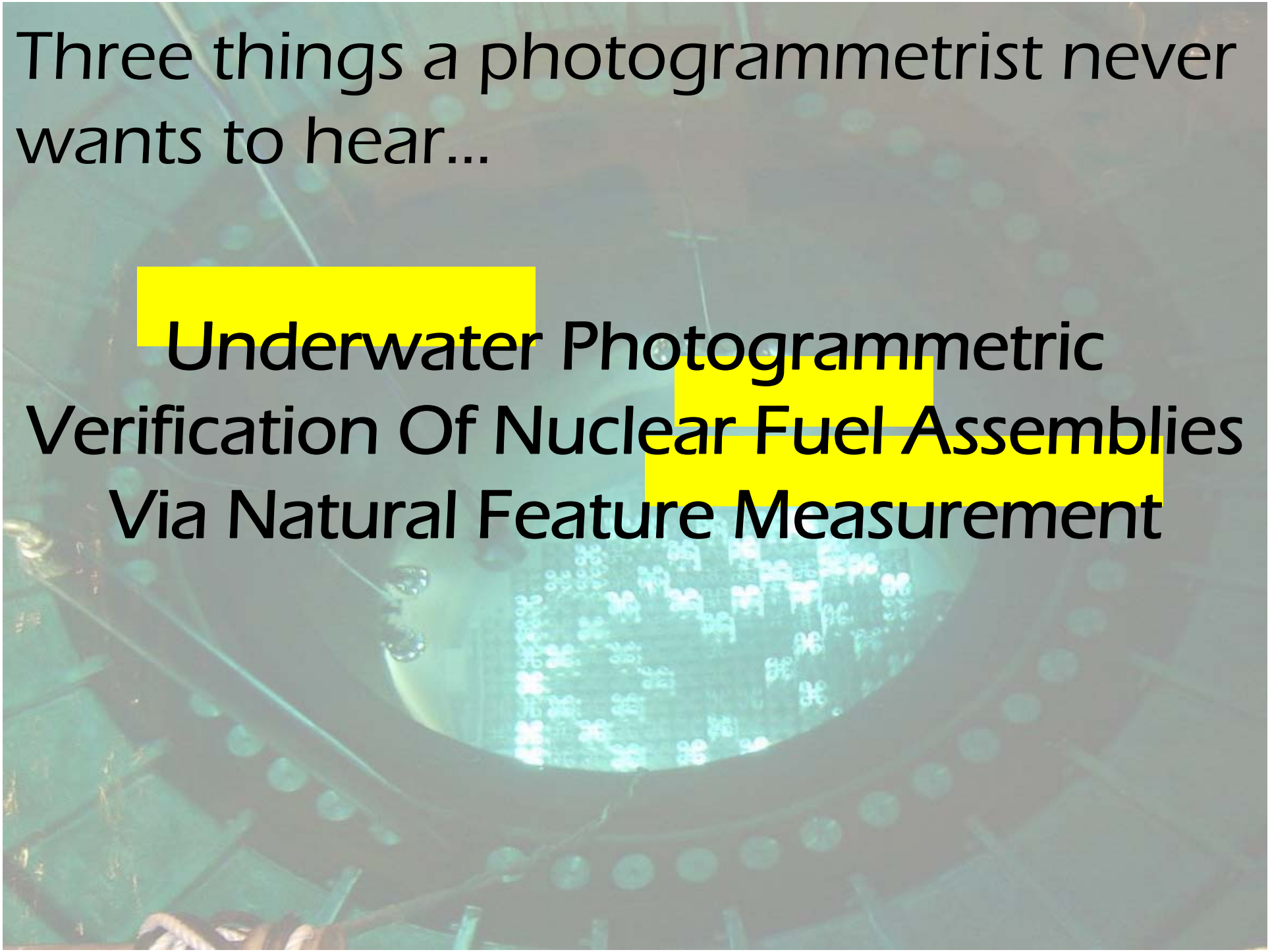
- This presentation may cause cancer in the state of California
- There will be some blatant copyright infringements
- Presentation may digress at times
- Some animated nudity may offend younger audience members, may excite older audience members (Rick)
- Questionable content

Who is the North Korean Nuclear Industry Poster Boy?

Who is the North Korean Nuclear Industry Poster Boy?

Who is the American Nuclear Industry Poster Boy?





Three things a photogrammetrist never wants to hear...

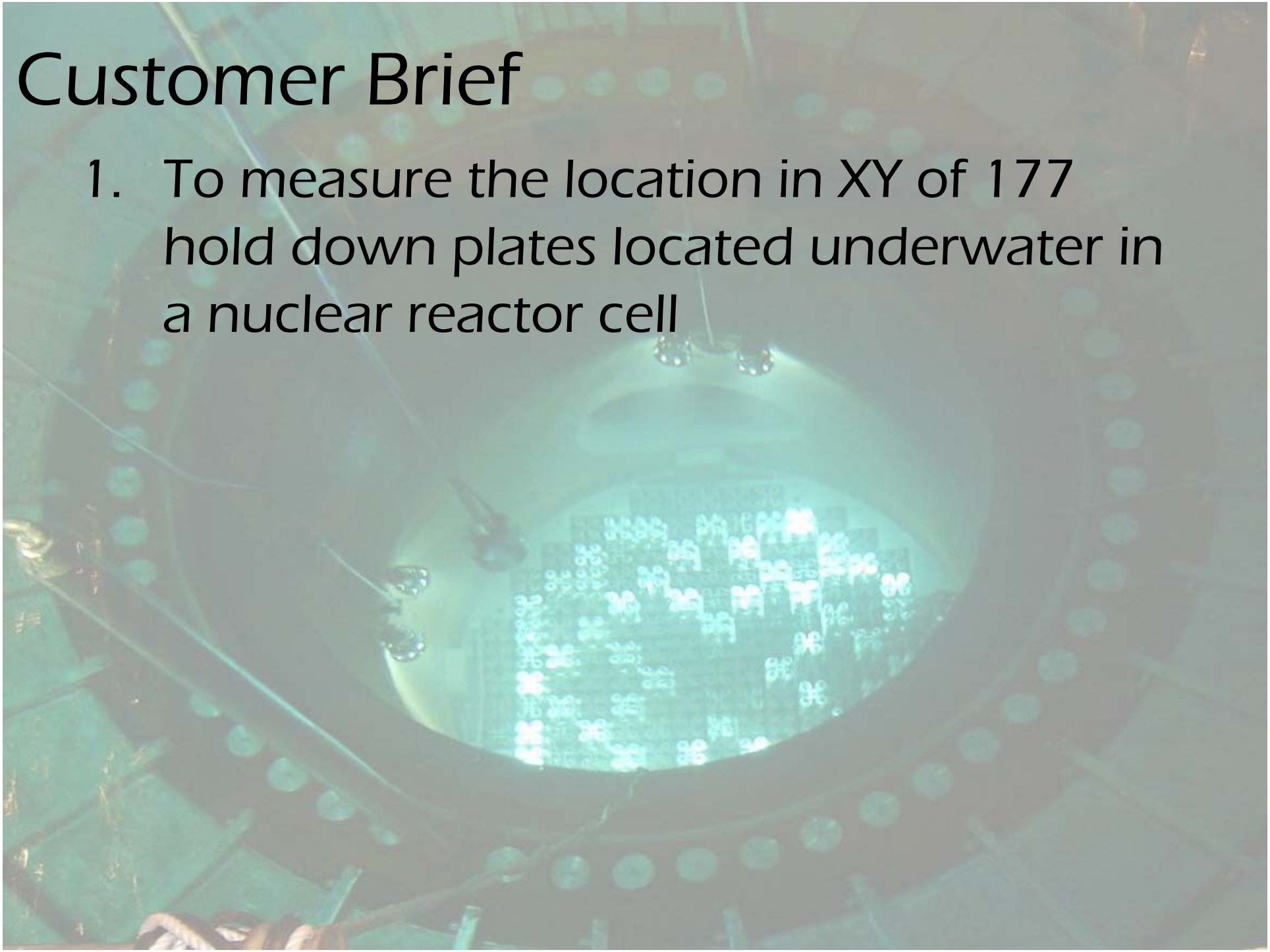
Underwater Photogrammetric Verification Of Nuclear Fuel Assemblies Via Natural Feature Measurement

Three things a photogrammetrist never wants to hear...

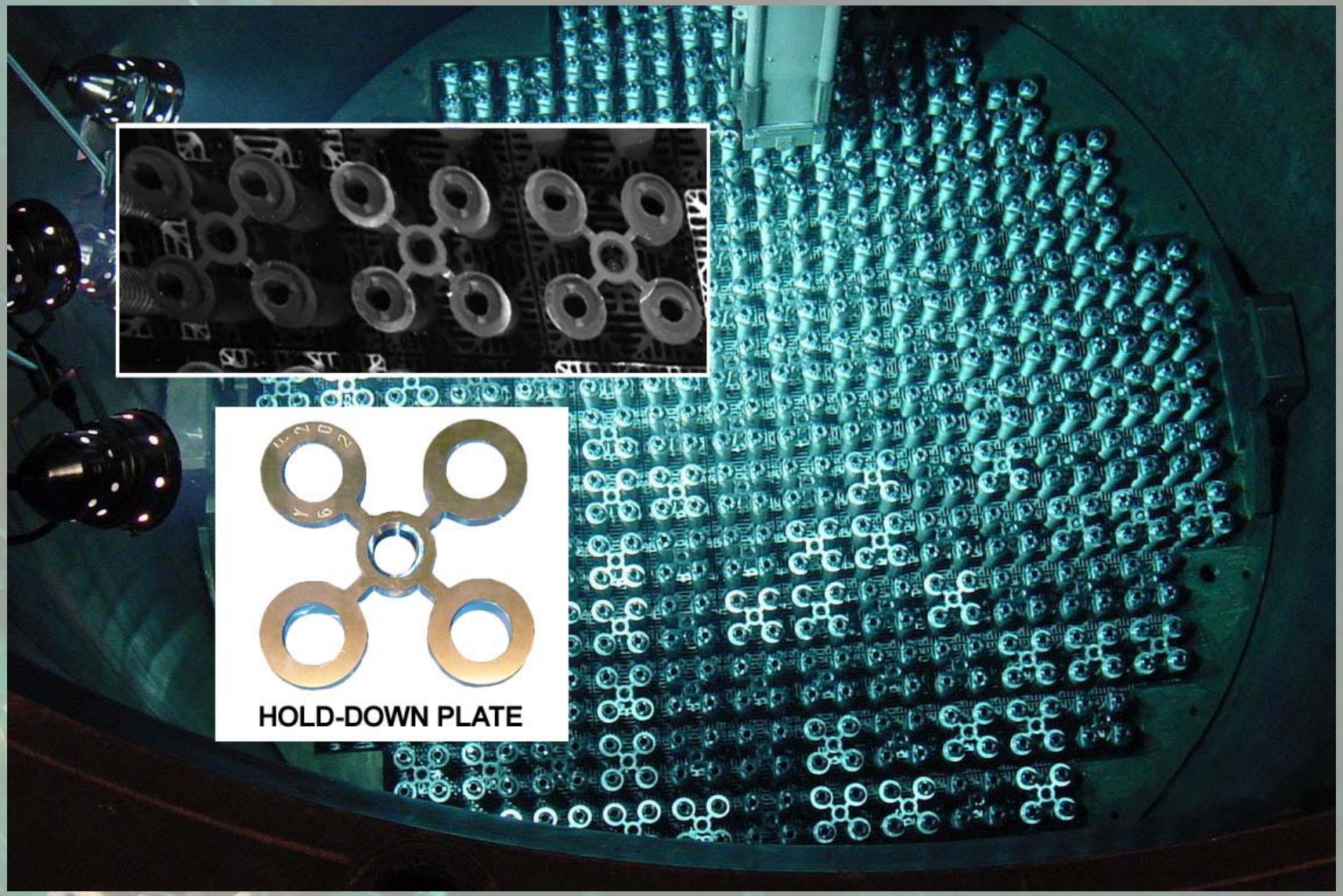
1. Underwater
   i. Lots of water
   ii. Need to protect camera
   iii. Standard calibration model not as suited
2. Nuclear
   i. Radioactivity
   ii. Potential to damage electronics
3. Natural Feature
   i. No target to define point of interest
   ii. Lower accuracy
   iii. Limited measurement automation

Customer Brief

1. To measure the location in XY of 177 hold down plates located underwater in a nuclear reactor cell



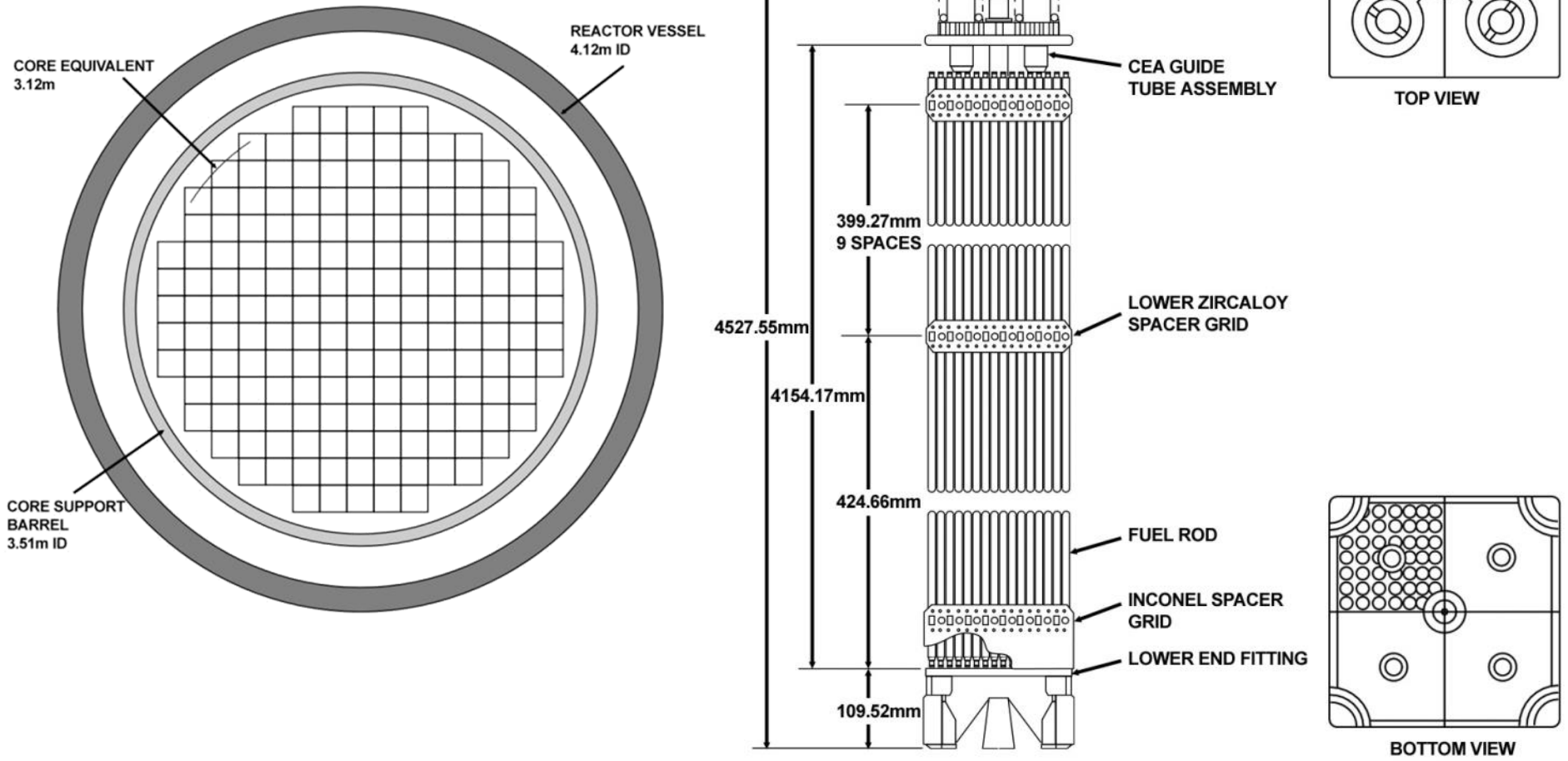
Chamber Overview



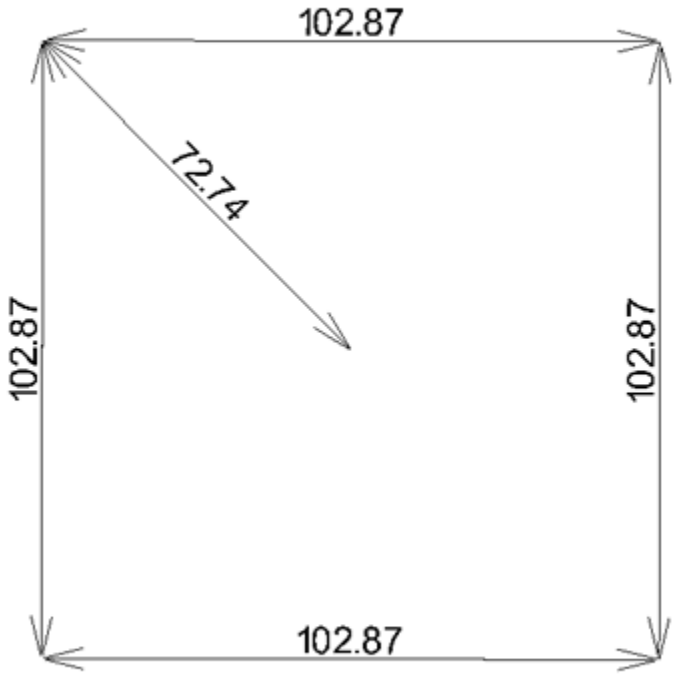
Customer Brief

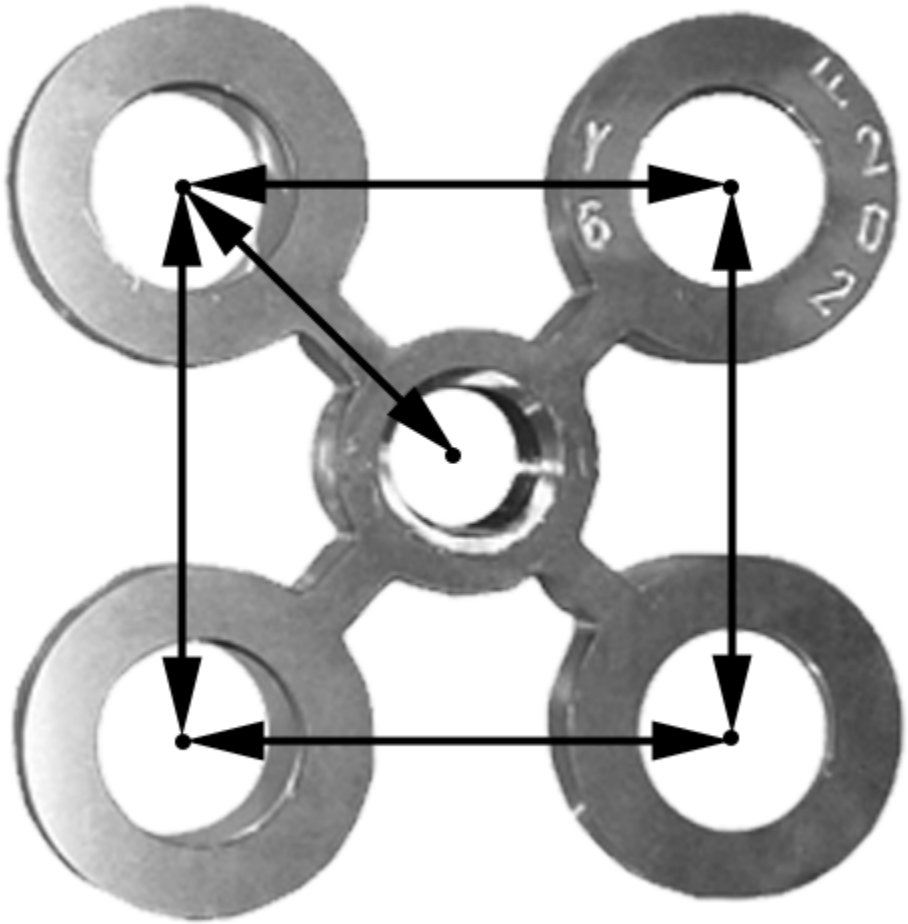
1. To measure the location in XY of 177 hold down plates located underwater in a nuclear reactor cell
2. To measure in XY the location of a further 708 circular features on the hold down plates
3. To measure the location of fixed concrete points around the cell
4. To compute deviations from design value for the 805 points (177 + 708)
5. Point-to-point accuracy requirement of 0.76 mm (one-sigma) in X and Y

Chamber Overview



Chamber Overview





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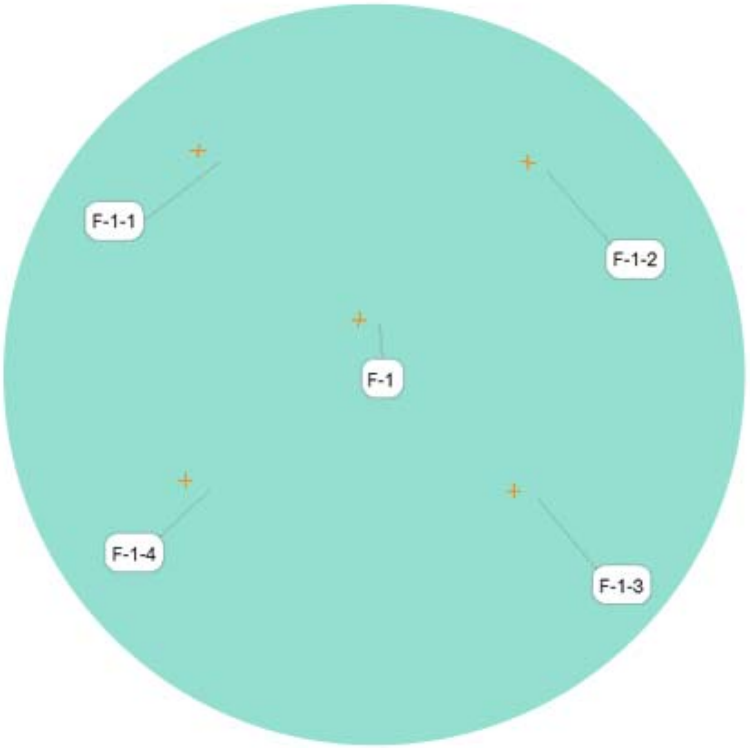

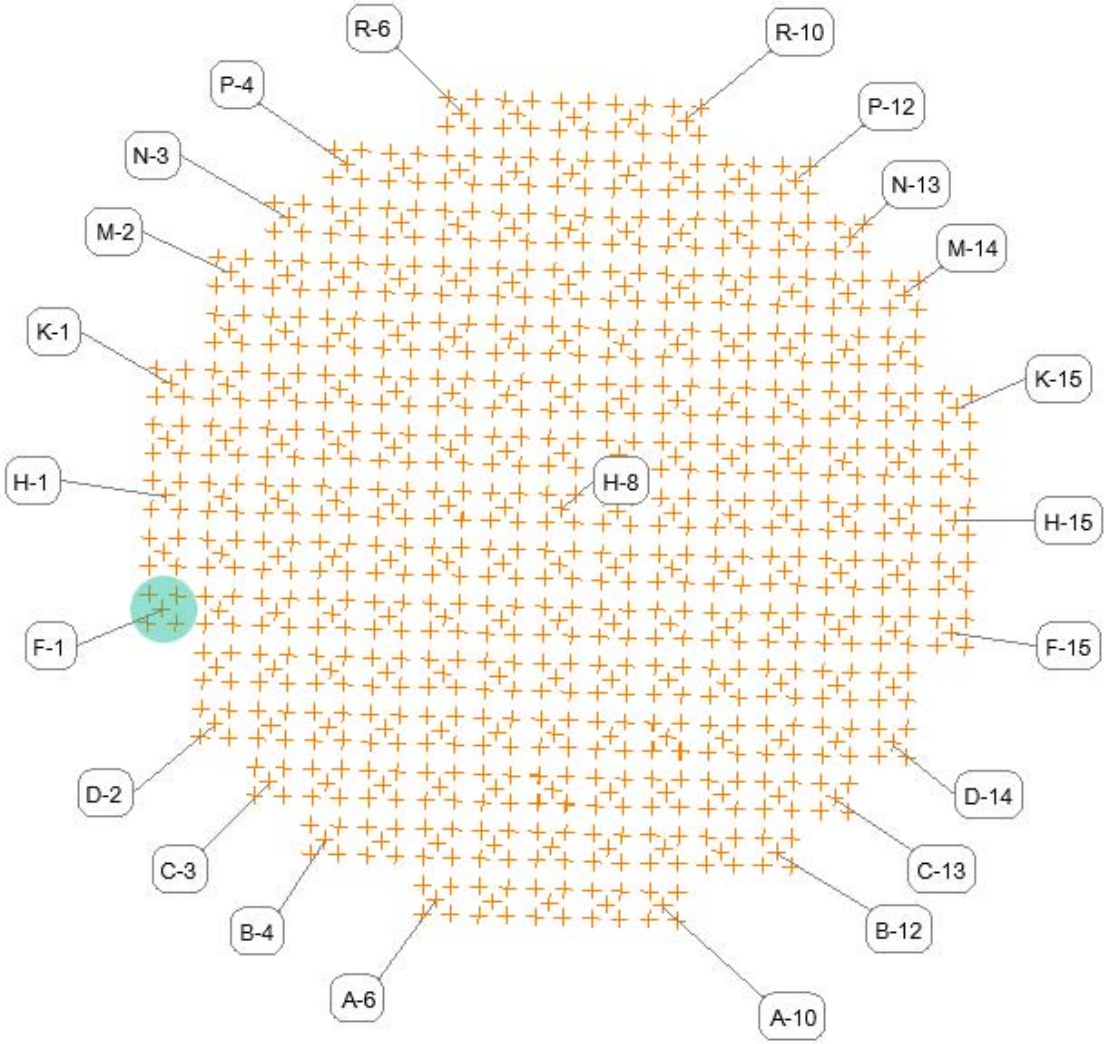

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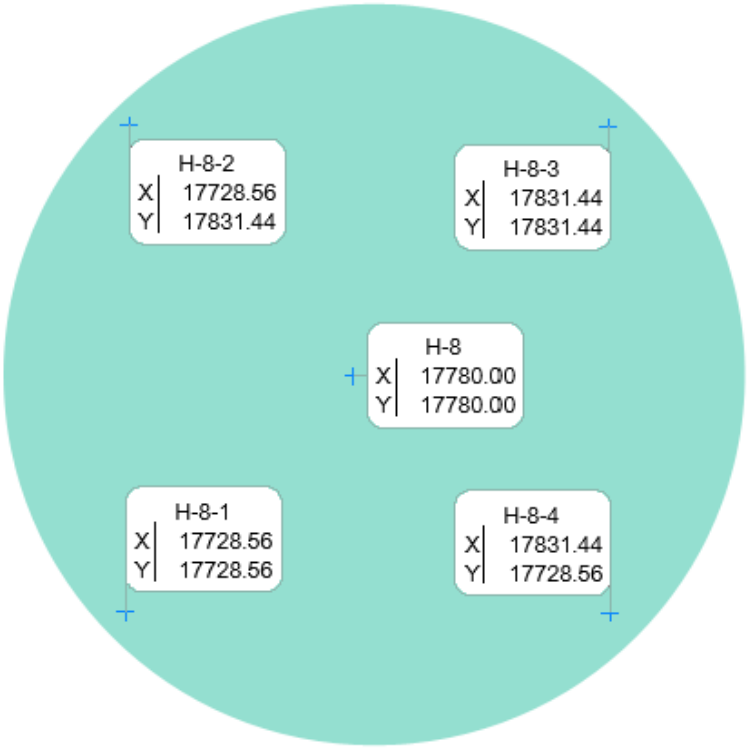
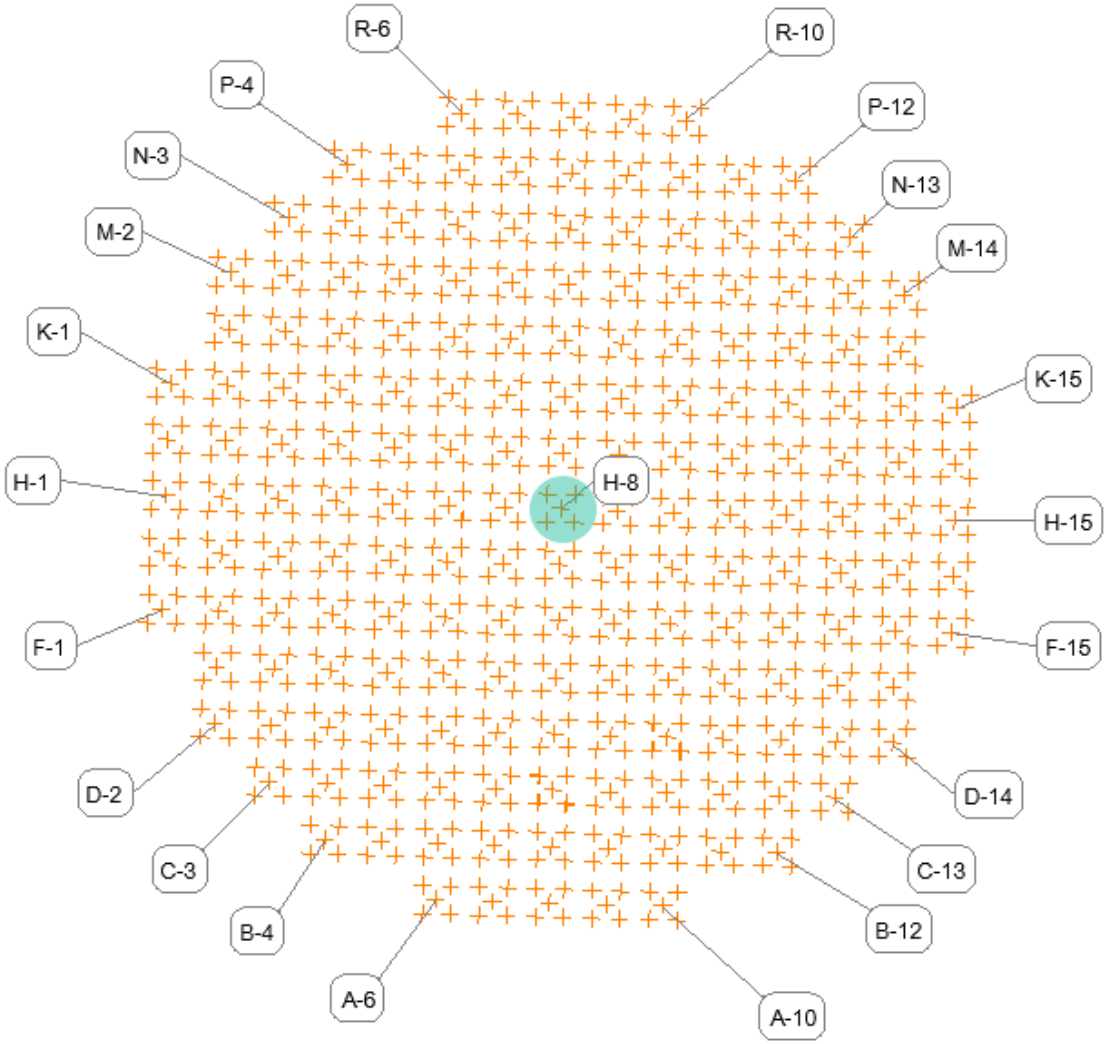




Measurement Constraints

1. No targeting in the cell area
2. No exterior orientation (EO) devices, no coded targets
3. No external scale artifacts for scale
4. Limited measurement window
5. Automated measurement of the hold down plate circles
6. Only some of the fuel bundles are changed during the refueling, which mean some of the plates are new and shiny whilst other are dull

Project Requirement Checklist

1. High accuracy camera with remote operation functionality
2. Underwater canister
3. Pan and tilt mechanism
4. Software development to detect edges and then compute best-fit ellipse of center points. SA to plot residuals and report
5. Pilot project measurements to verify system performance

Photogrammetric Exorcism Checklist

1. One priest
2. Holy water
3. Wooden stakes
4. and a bottle of chea

Hardware - camera

- Geodetic Systems Inc. INCA3 was selected for this project
- Camera has proven track record in canister environments (thermal chambers)
- Camera can be powered and networked for remote operation
- Camera has an integrated flash
- Camera capable of producing accurate results (5μm + 5μm/m)

Hardware - canister

- It was necessary to design a canister suitable of housing the INCA3
- No suitable off the shelf canister was available, so one was designed
- Development time limited by customer outage schedule
- In addition to a waterproof environment, some mechanism was needed to rotate and tilt the housing

Hardware – canister early attempts

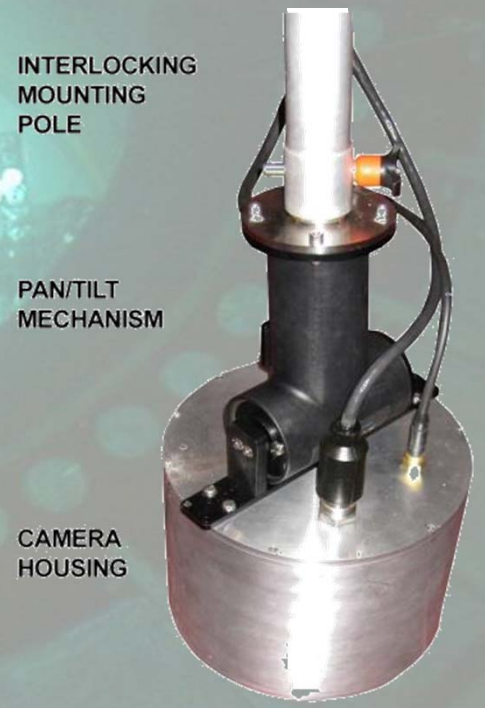
Hardware - canister early attempts

Hardware - canister

- Housing made out of rolled aluminum and two end plates.
- One end plate housed the non-browning quartz window.
- The other plate included a mount for the camera

Hardware – pan and tilt mechanism

- For self-calibration purposes it is necessary to roll the camera during the data collection
- This was achieved by hanging the camera vertically and using the "pan" function as a "roll"
- The "tilt" was used to help point the canister towards the center of the field

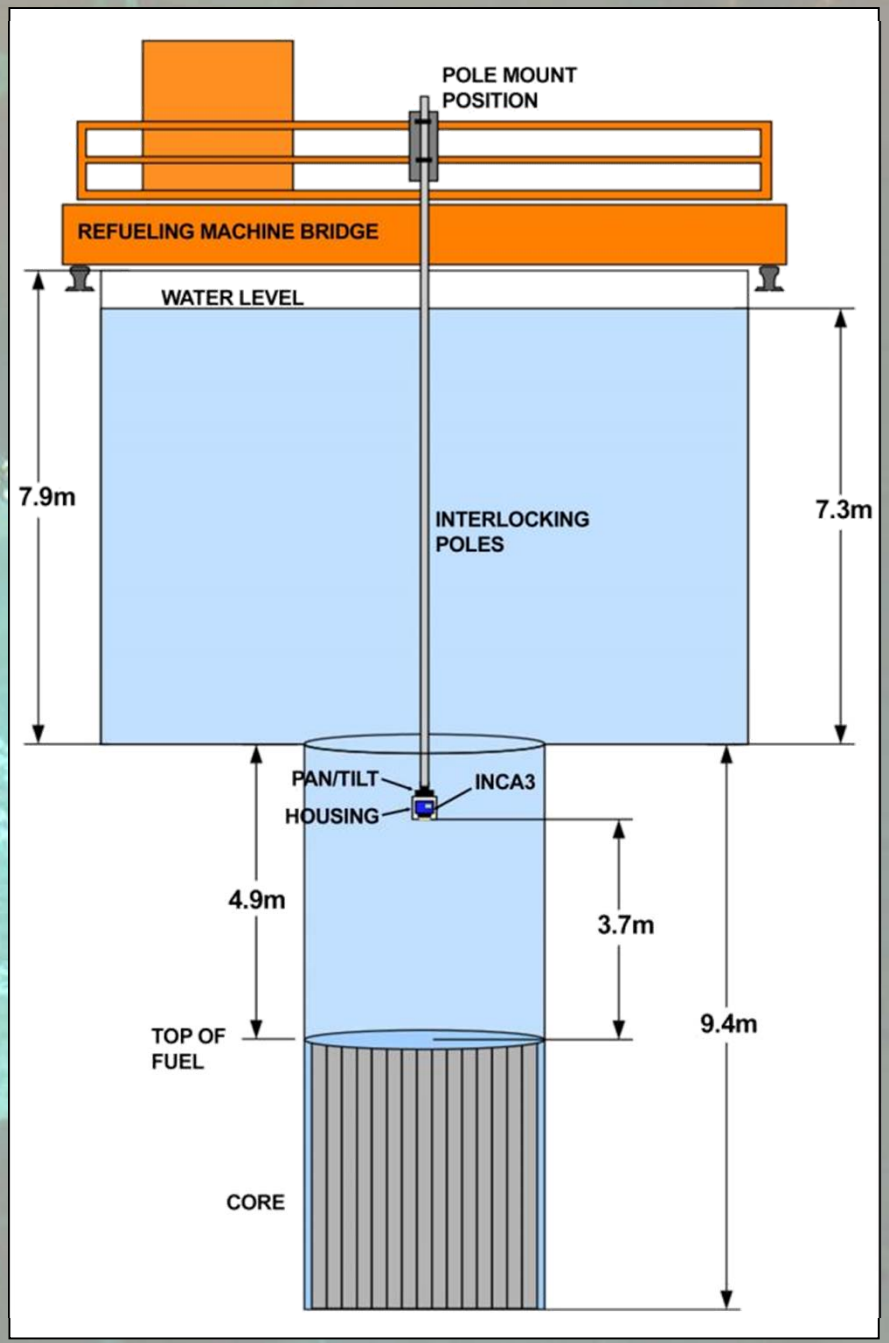


Hardware - test

- Once the hardware aspects of the test were resolved a live test was scheduled
- The aim of the live test was to collect images that could be used to guide the software development
- The results of the test would also indicate what level of accuracy was achievable using this method of measurement

Hardware - test

- The overhead refueling crane was used to shuttle the camera around the cell
- Lights lowered into cell to illuminate area
- Images at different exposure were collected to find the optimal measurement conditions
- The pole mount position was moved to three position on the overhead crane



Before entering containment area…

- Need to strip down to underwear and change into approved clothing

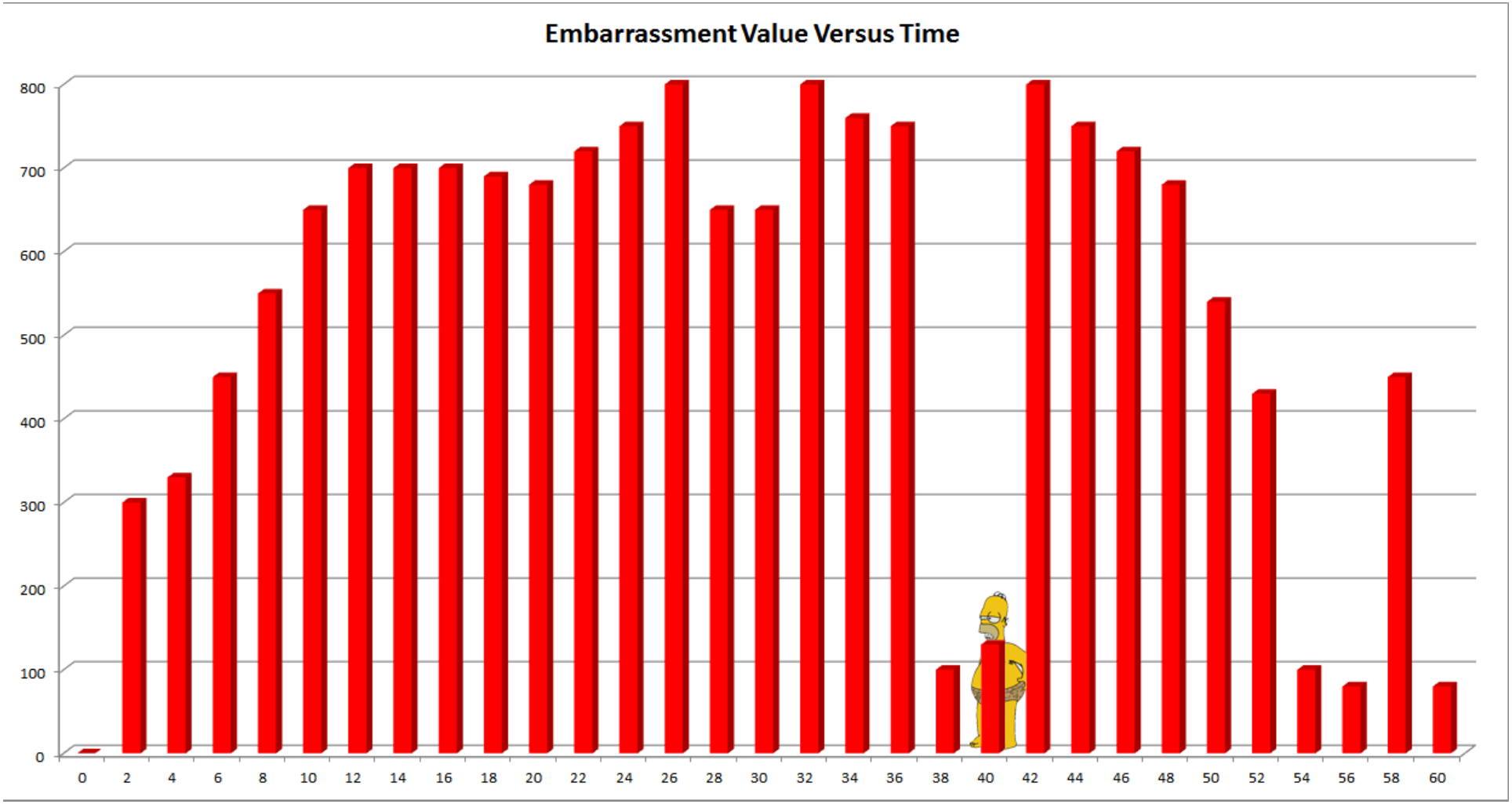
Two things crossed my mind…

- Am I even wearing underwear today?
- Is that underwear clean?

Before entering containment area...

- Once nearly naked, stand around for 60 minutes in a public area hiding behind laptop bag

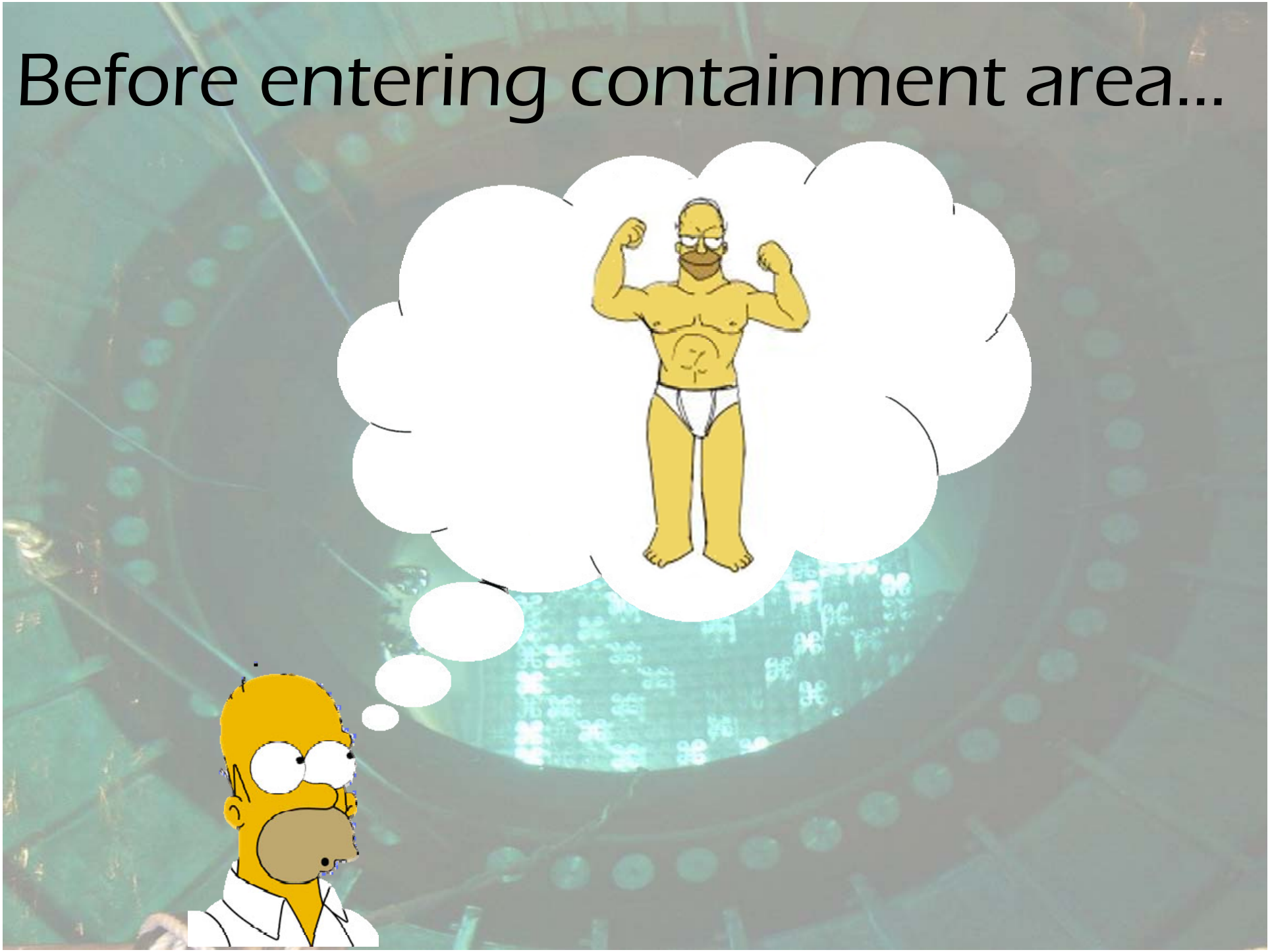
Before entering containment area...



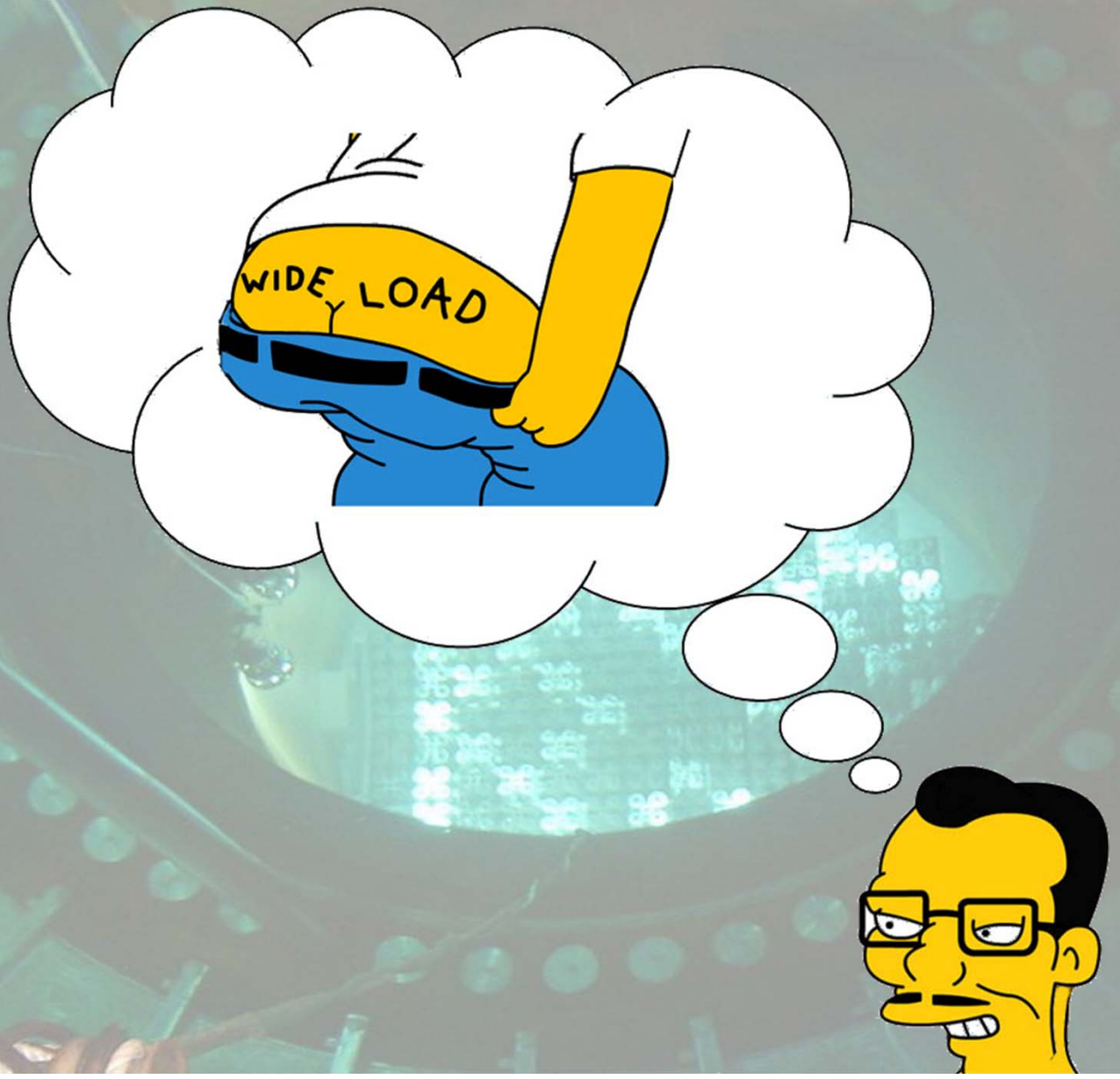
Before entering containment area…

- There was much animated discussion and I saw many of my Korean counterparts with their arms apart

Before entering containment area...



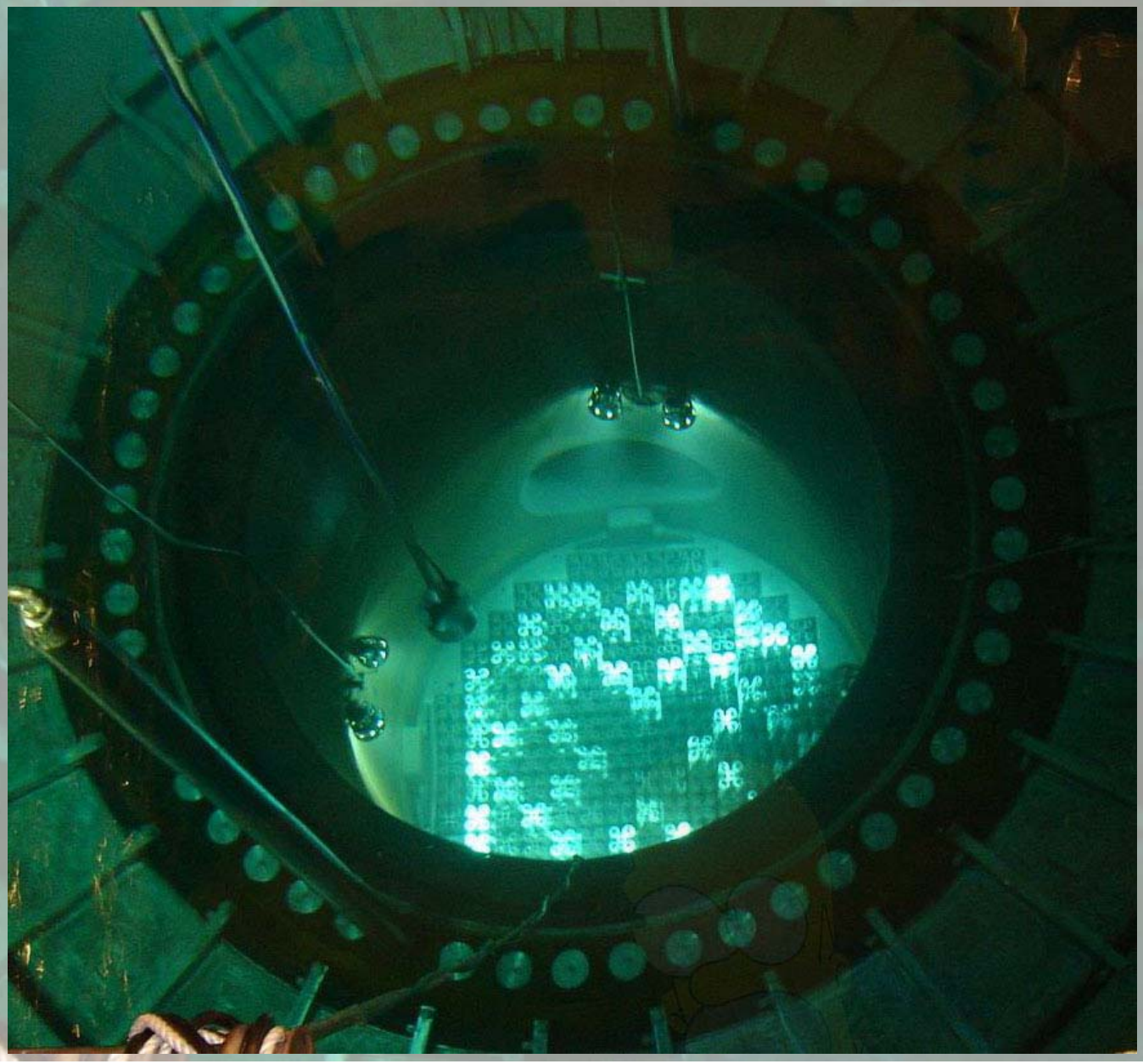
Before entering containment area...



Hardware – test

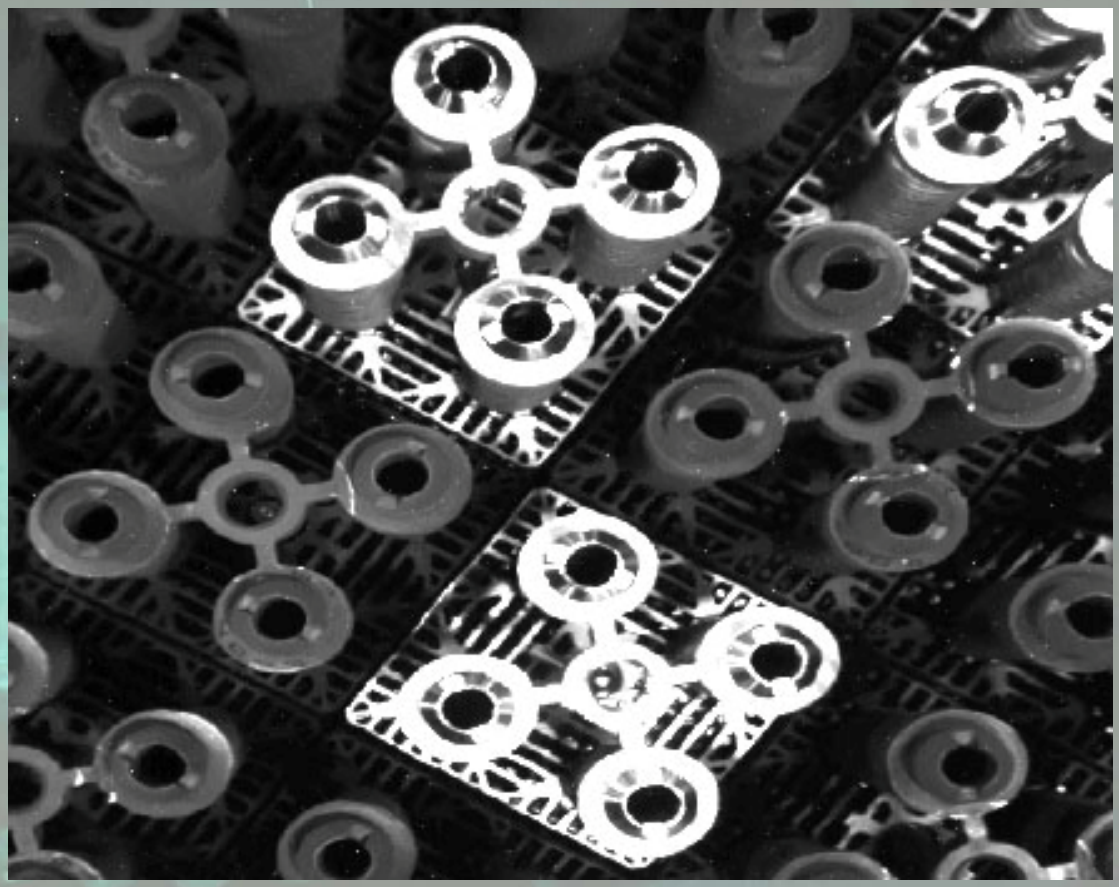
Hardware – test

Hardware - test



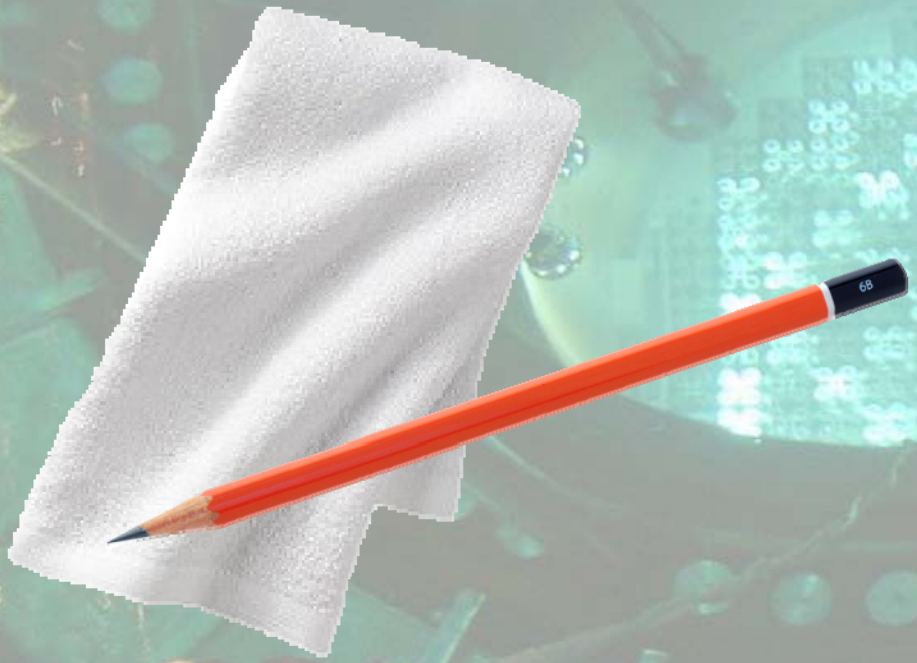
Hardware - test

- Underwater lights were essential, but they caused reflections off the new plates.
- A balance in shutter time was needed as the new plates were significantly brighter than the older ones
- 1000ms was used for most of the test



Cleaning up…

- After the test we were escorted to change rooms and instructed to shower
- Presented with a towel and taken to the "prisoner" showers



Cleaning up...

If you can read this you
may have dropped the soap
You may experience some d

Cleaning up…

- After dressing we returned to the screening area for final radiation dosage testing
- I failed my test due to the presence of Cobalt gamma radiation
- Their explanation? Hairy arms!
- Search tip?

Radioactive...who knew?

Got Radiation?

- Excerpt of conversation whilst walking back to showers…

“Do you have spare panties?”

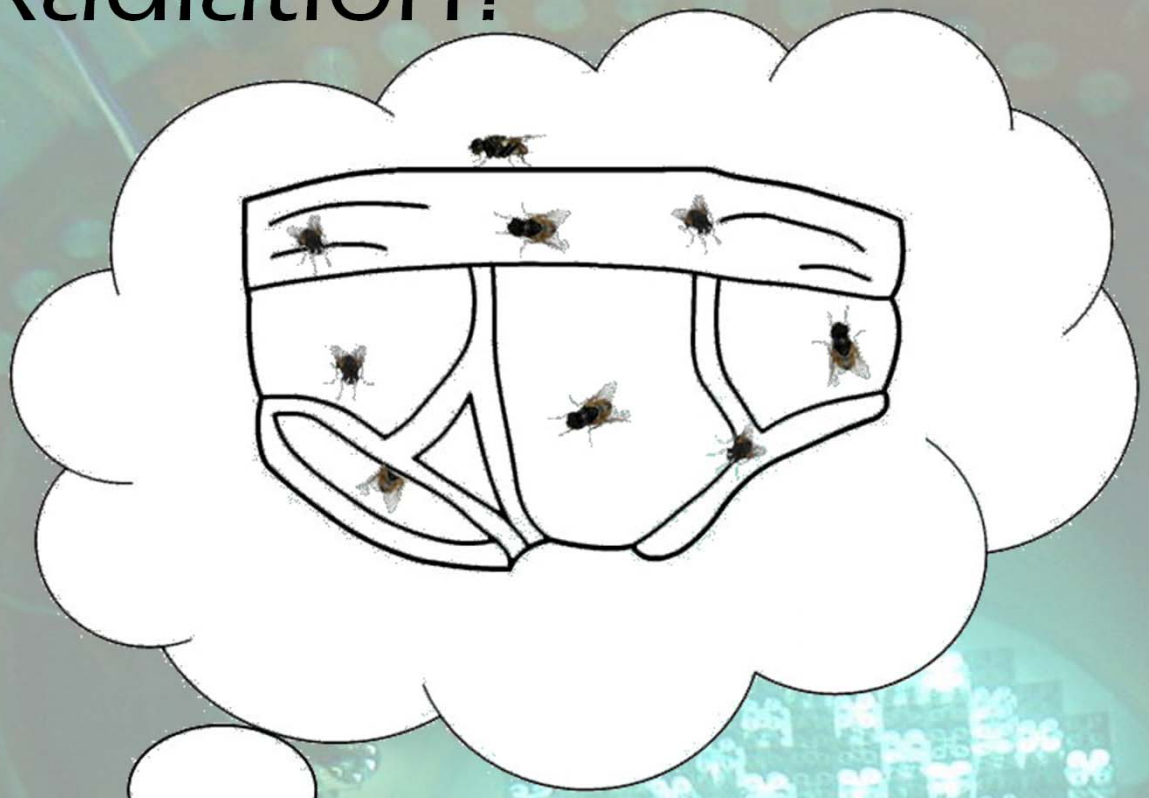
Got Radiation?

“Panties?”

Got Radiation?

“Yes, maybe your panties are contaminated.”

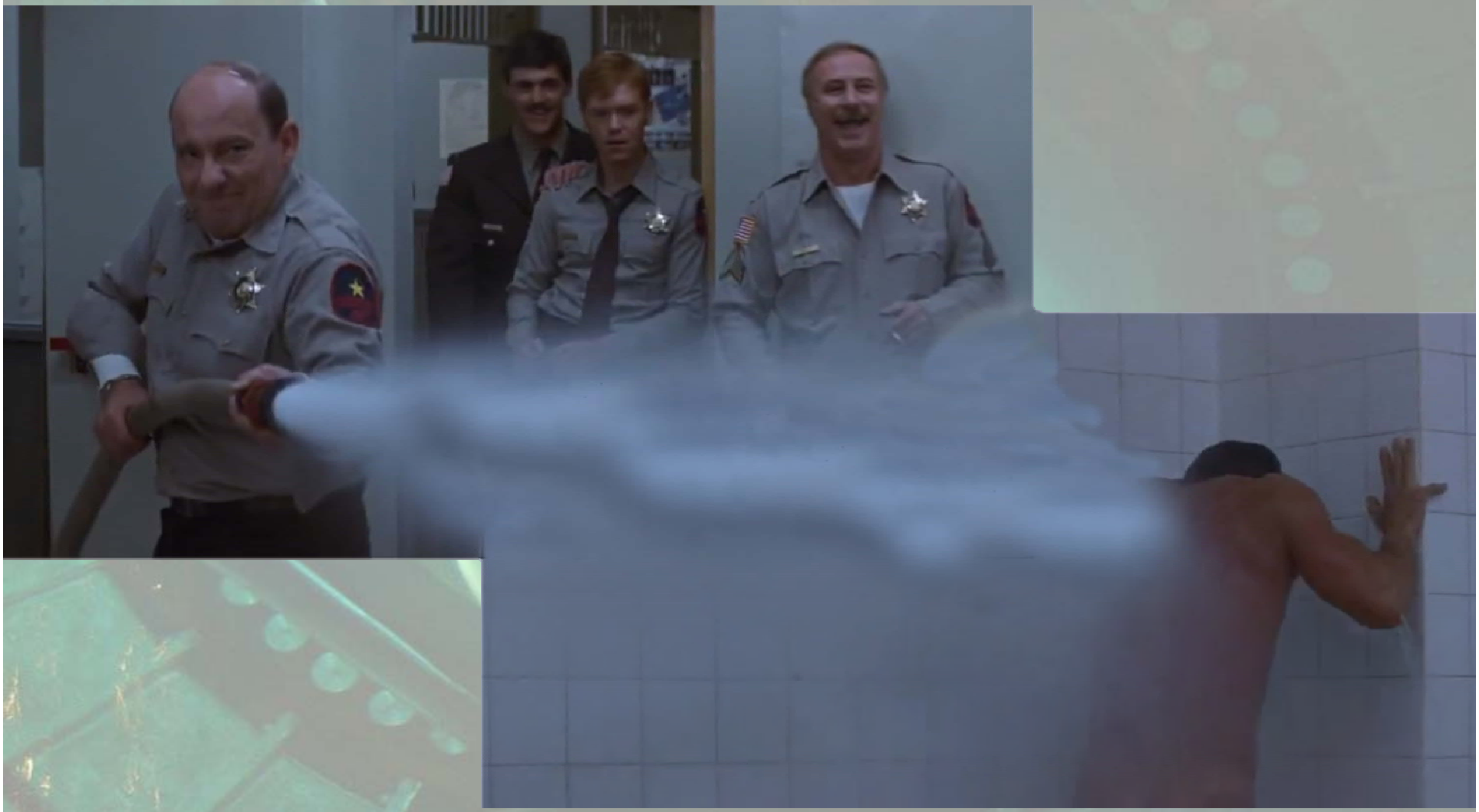
Got Radiation?



“but they are only a couple of days old.”

Got Radiation?

Need a hard core shower!



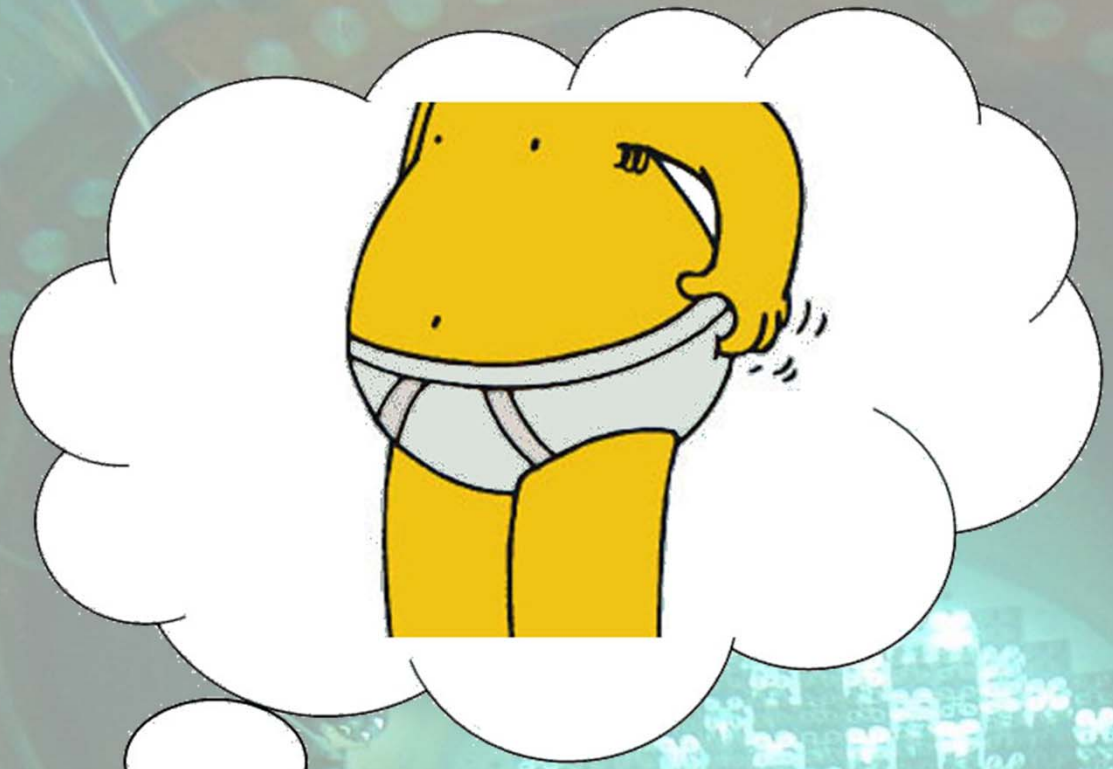
Rambo First Blood – Jail shower scene

Got Radiation?

- Excerpt of conversation whilst returning from showers…

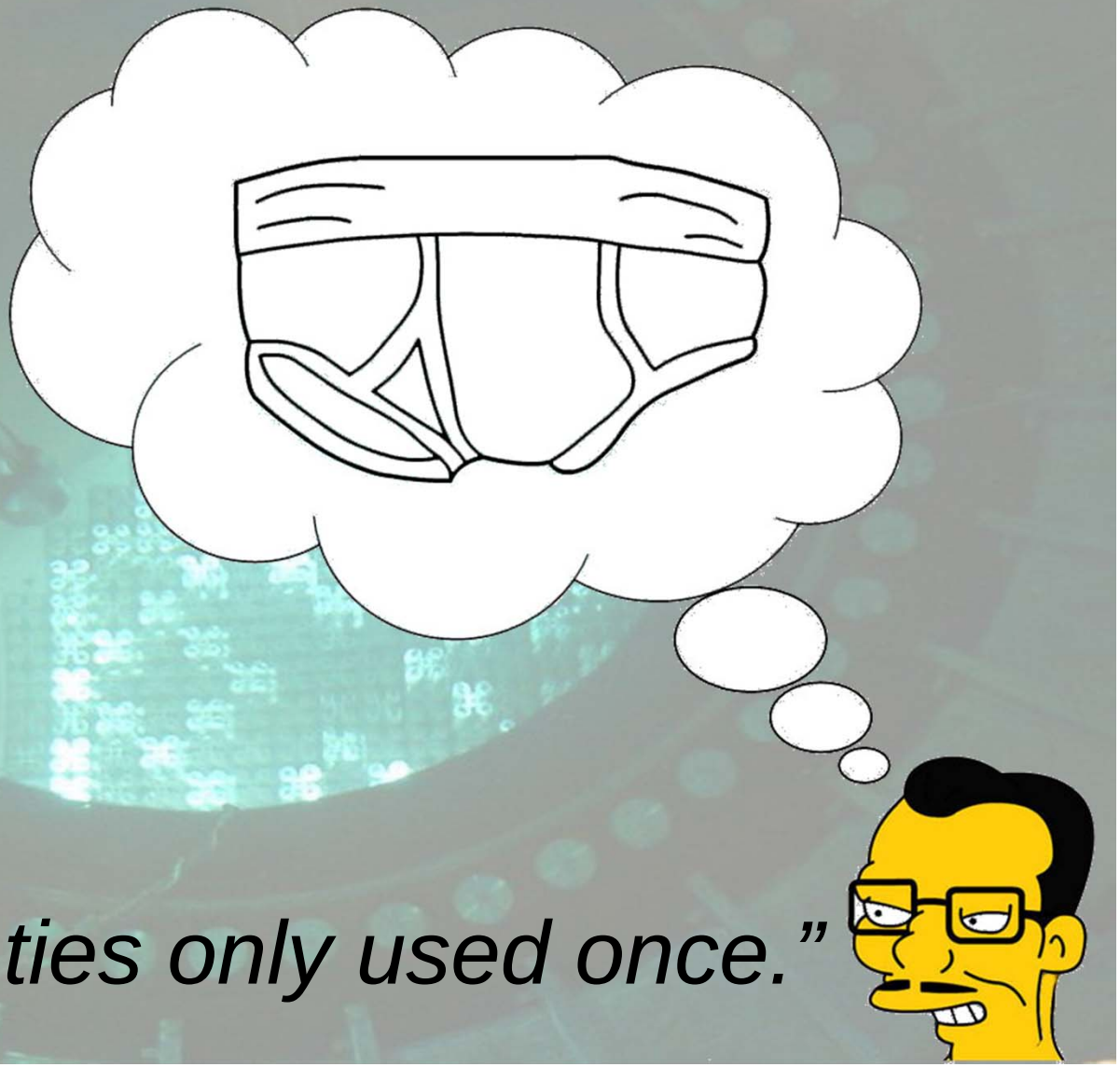
*"Did you put the **panties** on?"*

Got Radiation?



“Yes, I put the panties on.”

Got Radiation?



“Good, panties only used once.”

Got Radiation?

“ONCE!?”

Got Radiation?

eBay: 3 LARGE CELLULAR MENS WHITE Y- FRONT (OR 6 FOR £6.75) (item 220001314896 end time Jul-04-06 13:40:18 PDT) - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://cgi.ebay.com/3-LARGE-CELLULAR-MENS-WHITE-Y-FRONT-OR-6-FOR-6-75_W0QQitemZ220001314896QQihZ012QQcategoryZ122401QQrdZ1QQcmdZViewItem

exchange

1 PAIR of USED XL Y-FRONT UNDERWEAR

Item number: 220001314896

Buyer or seller of this item? Sign in for your status

Watch this item in My eBay | Email to a friend

View larger picture

Buy It Now price: **$2.00** Buy It Now >

End time: **Jul-04-06 13:40:18 PDT** (1 day)

Shipping costs: **$20.00**

Ships to:

Item location:

You can also: **Watch this item**

Get SMS alert | Get IM alert | Sell one like this

Listing and payment details: Show

Description

One white pair low mileage jocks. Excellent condition and definitely no "skids". Suit as new buyer. Regretful sale, owner moving to bigger underwear.

Meet the seller

Seller: qwadduk (2085) Power Seller

Feedback: **99.8% Positive**

Member: since Aug-27-04 in United Kingdom

- Read feedback comments
- Ask seller a question
- Add to Favorite Sellers
- View seller's other items: Store | List
- Visit seller's Store: waddo's

Buy safely

1. **Check the seller's reputation**
   Score: 2085 | 99.8% Positive
   Read feedback comments
2. **Learn how you are protected**
   PayPal Free PayPal Buyer Protection.
   See eligibility
   Returns: Seller accepts returns.
   7 Days of receipt

Listing and payment details: Show

Description

One white pair low mileage jocks. Excellent condition and definitely no "skids". Suit as new buyer. Regretful sale, owner moving to bigger underwear.

Plate measurement

- Having collected a network of test images, work could commence on developing a suitable algorithm to measure the center of each circle
- After examining different methods, an edge detection method coupled with ellipse fitting was implemented

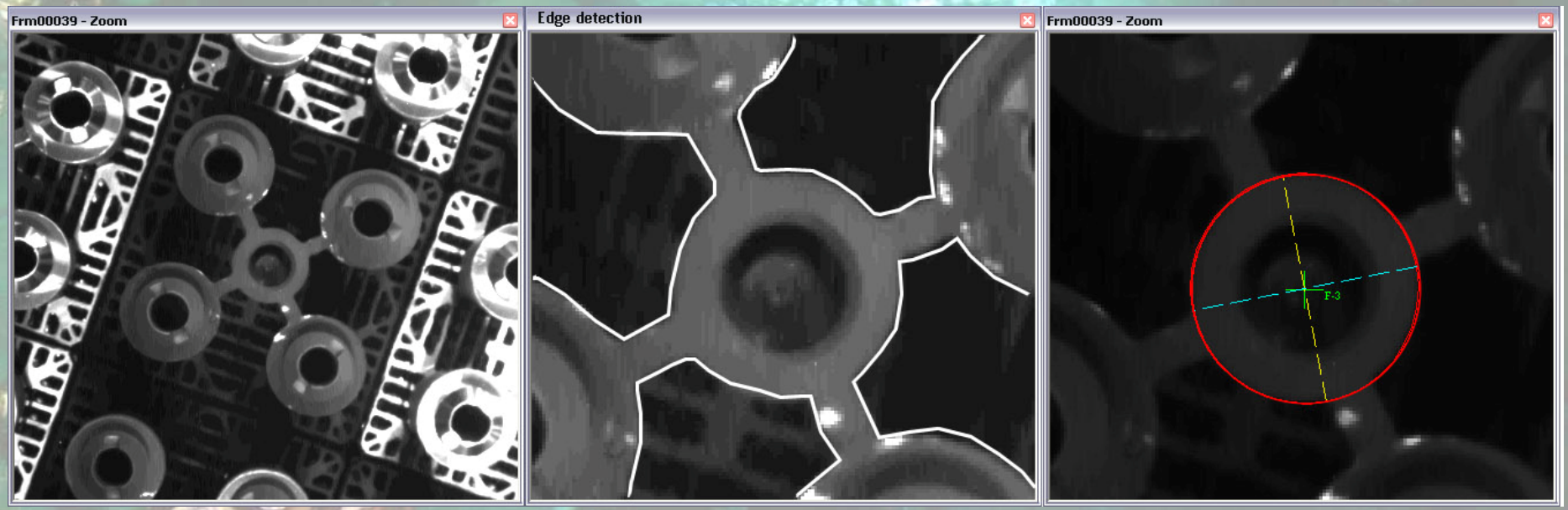


Plate measurement

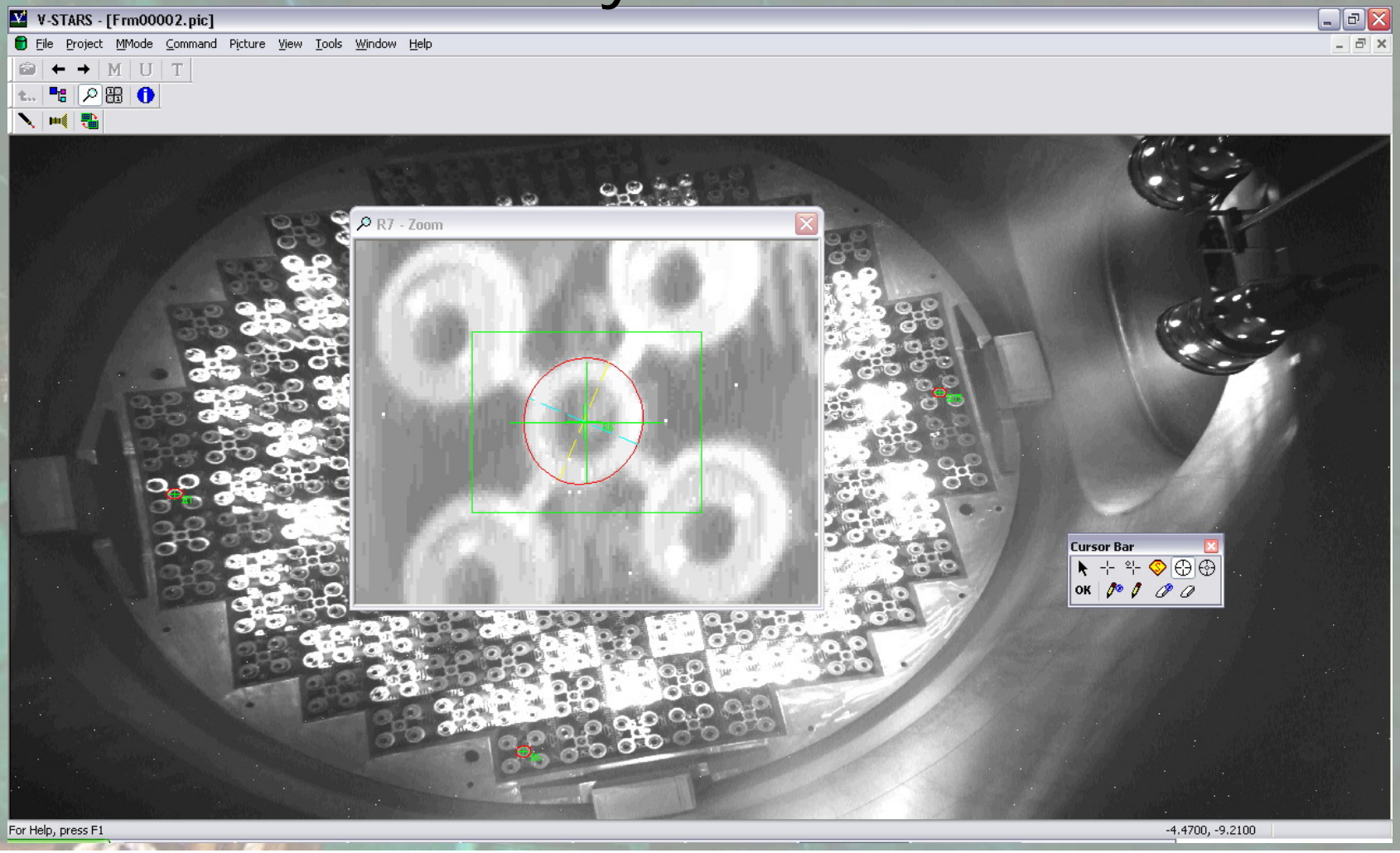
- As the hold down plate is a precisely engineered item, apriori information about the radii and approximate image center could be used to guide the solution
- Without the assistance of EO devices it is necessary to manually locate at least four well distributed points in each image
- Once this has been done, the design XY values and the radii are used to measure the remaining circles
- This data is then bundled to produce the required XY data

Test Measurement

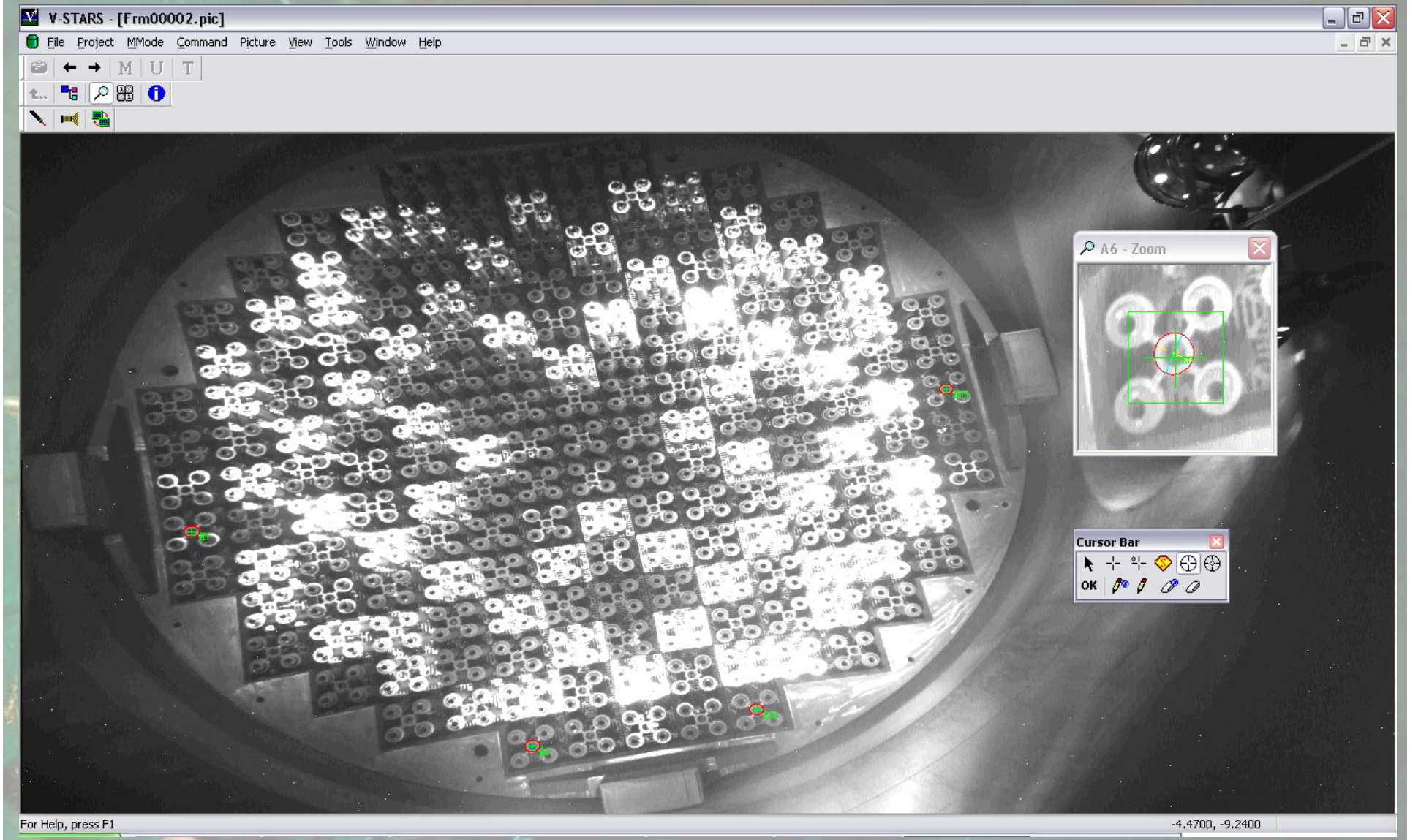
- A test measurement was scheduled to coincide with the next refueling outage
- The aim of this test was to test the software and verify that the objectives outlined could be met
- The test was carried out and approximately 45 images were collected
- A typical image is measured in 30-60 seconds

Test Measurement

For each image, four points well distributed points were manually measured

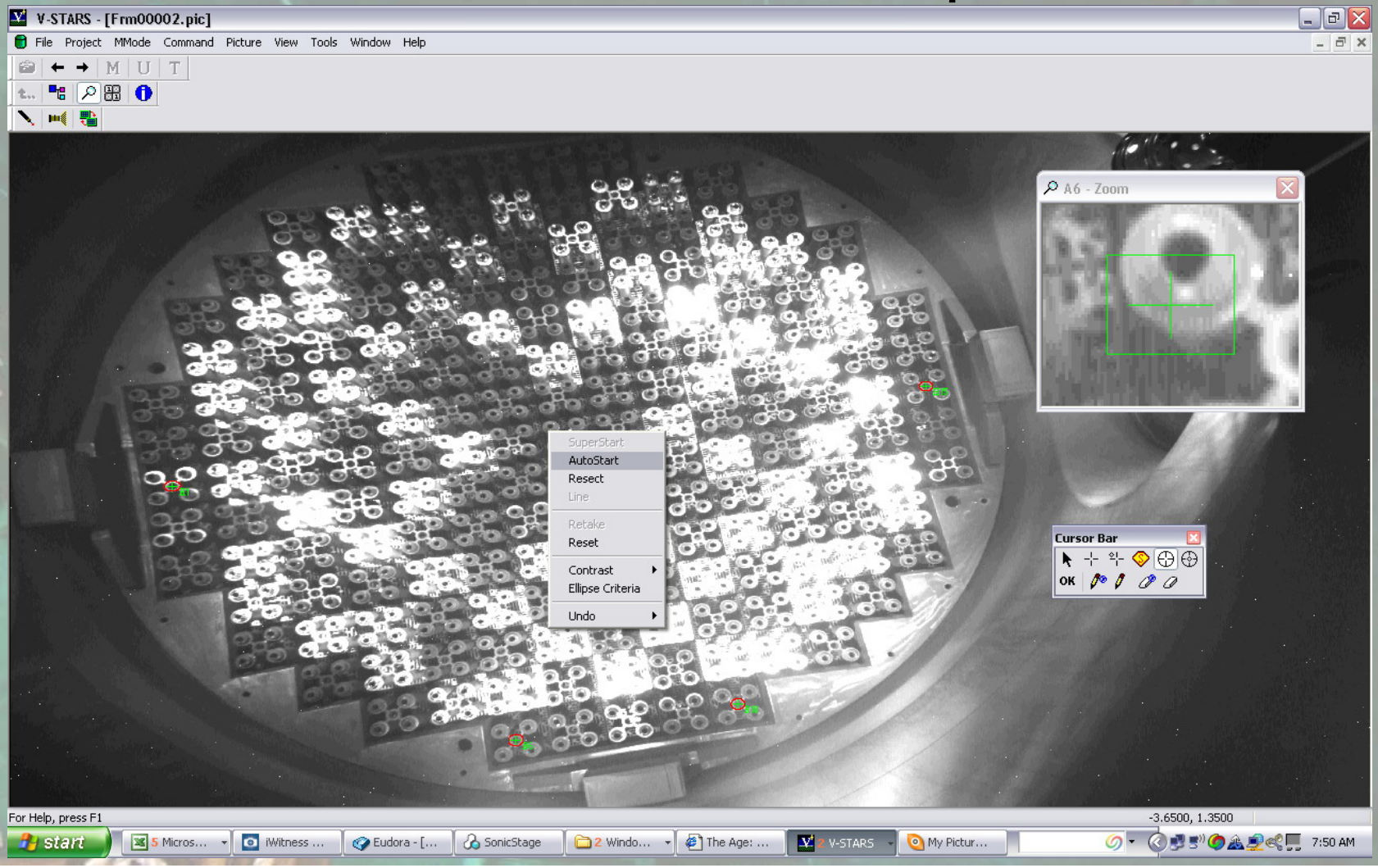


Test Measurement



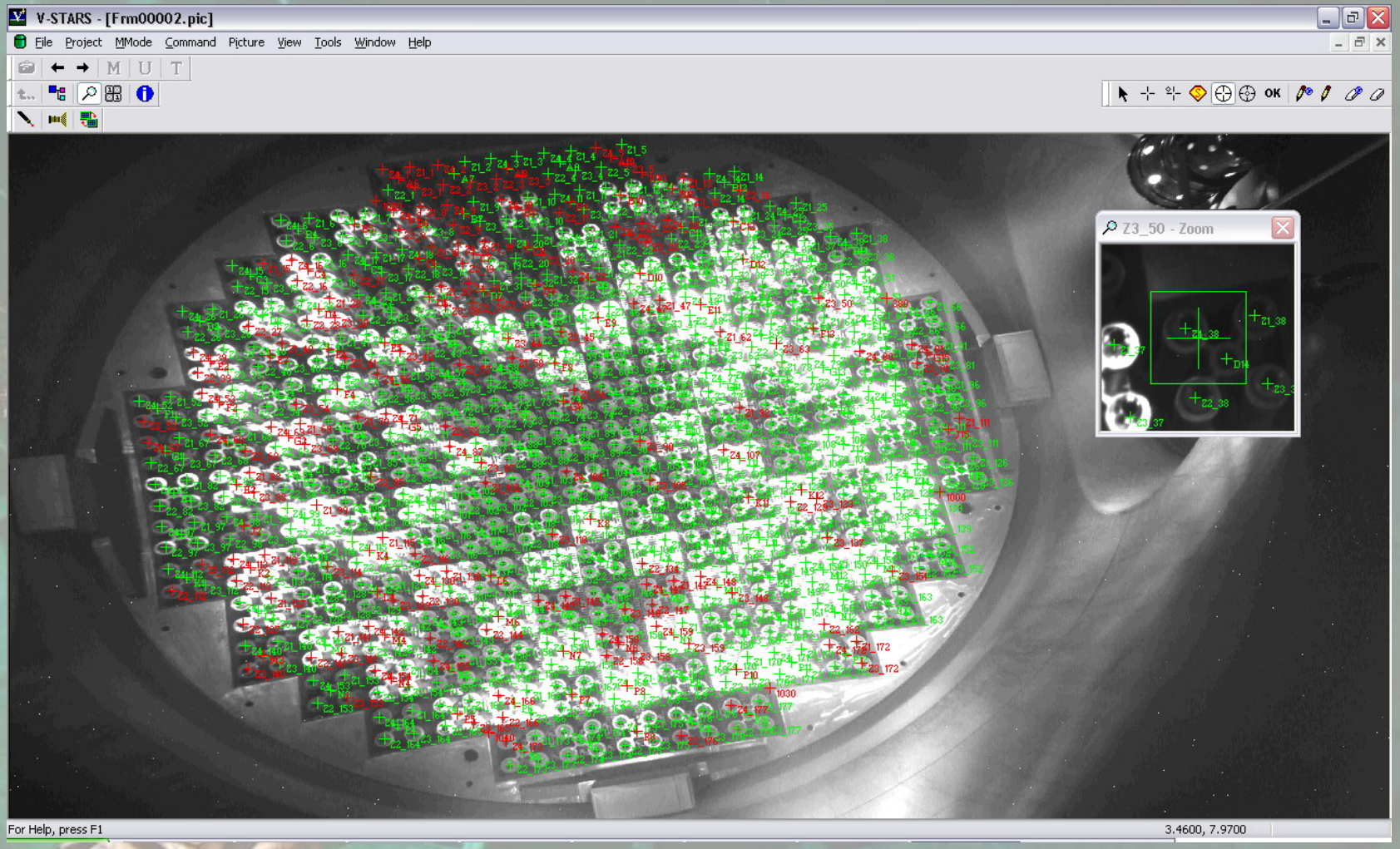
Test Measurement

The exterior orientation (camera location) was then determined from the four points

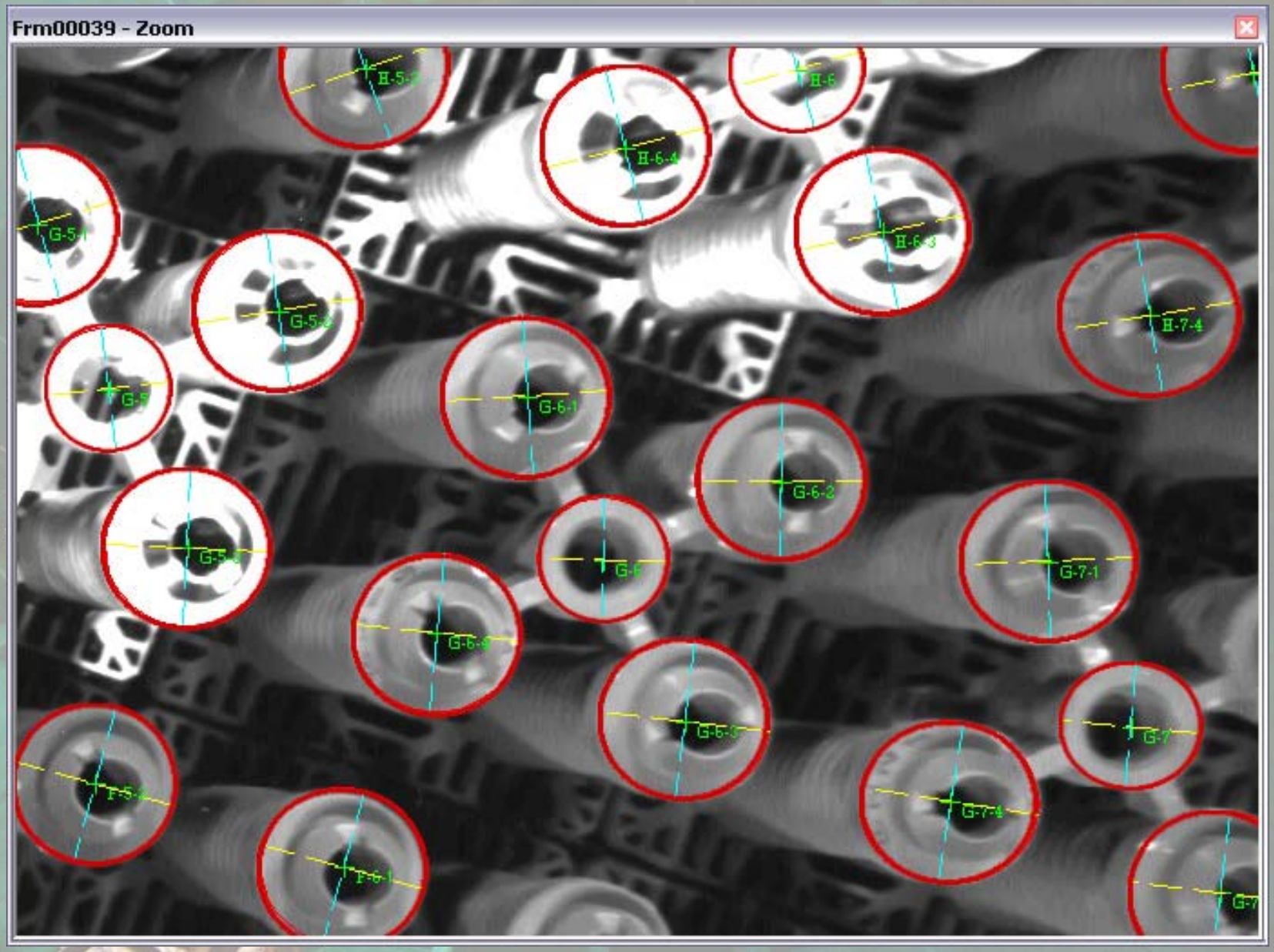


Test Measurement

The design coordinates were then used to guide the measurement of the remaining points

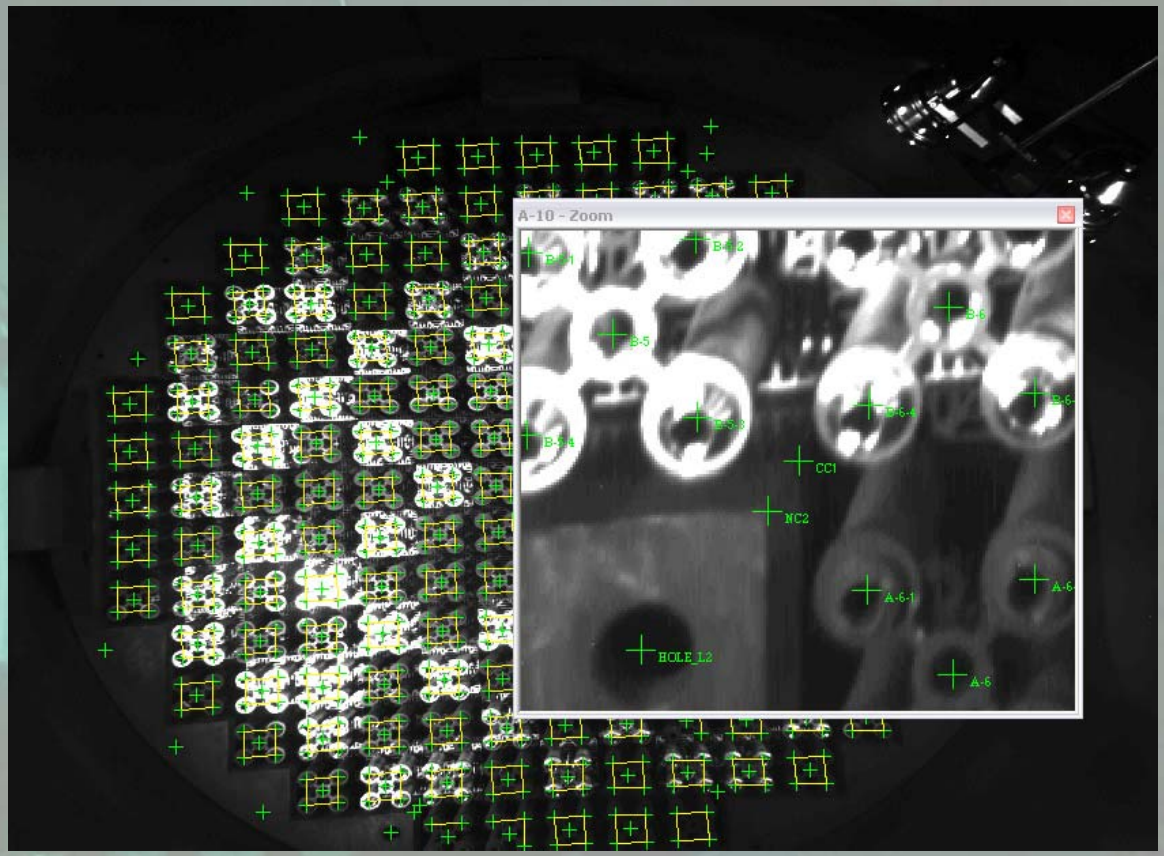


Test Measurement



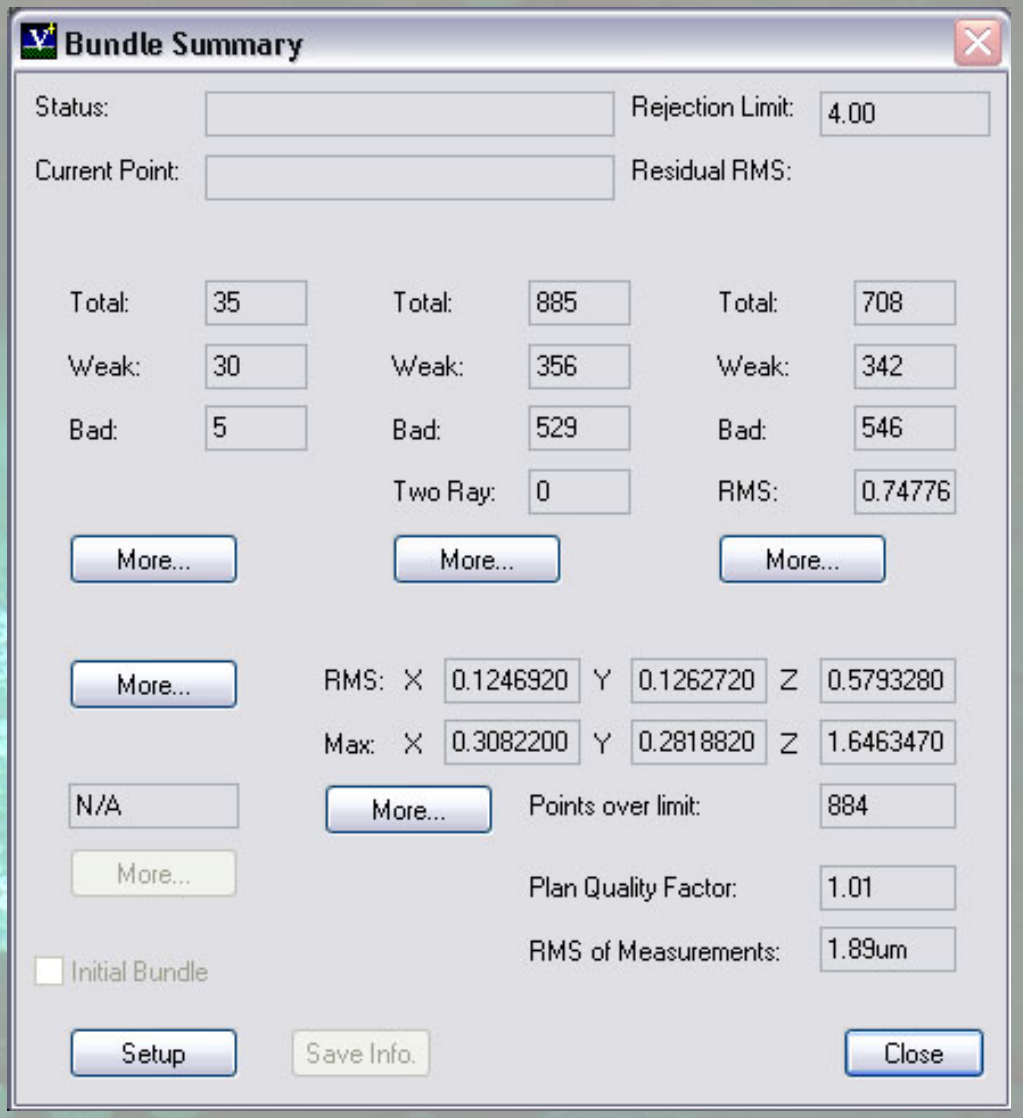
Test Measurement

- Corners and holes in the concrete surrounding the cell were measured to provide an external reference frame
- The accuracy of these points in lower as they are "manual" measurements



Test Measurement

- Once XY locations are available, the images are bundled like any normal photogrammetry network



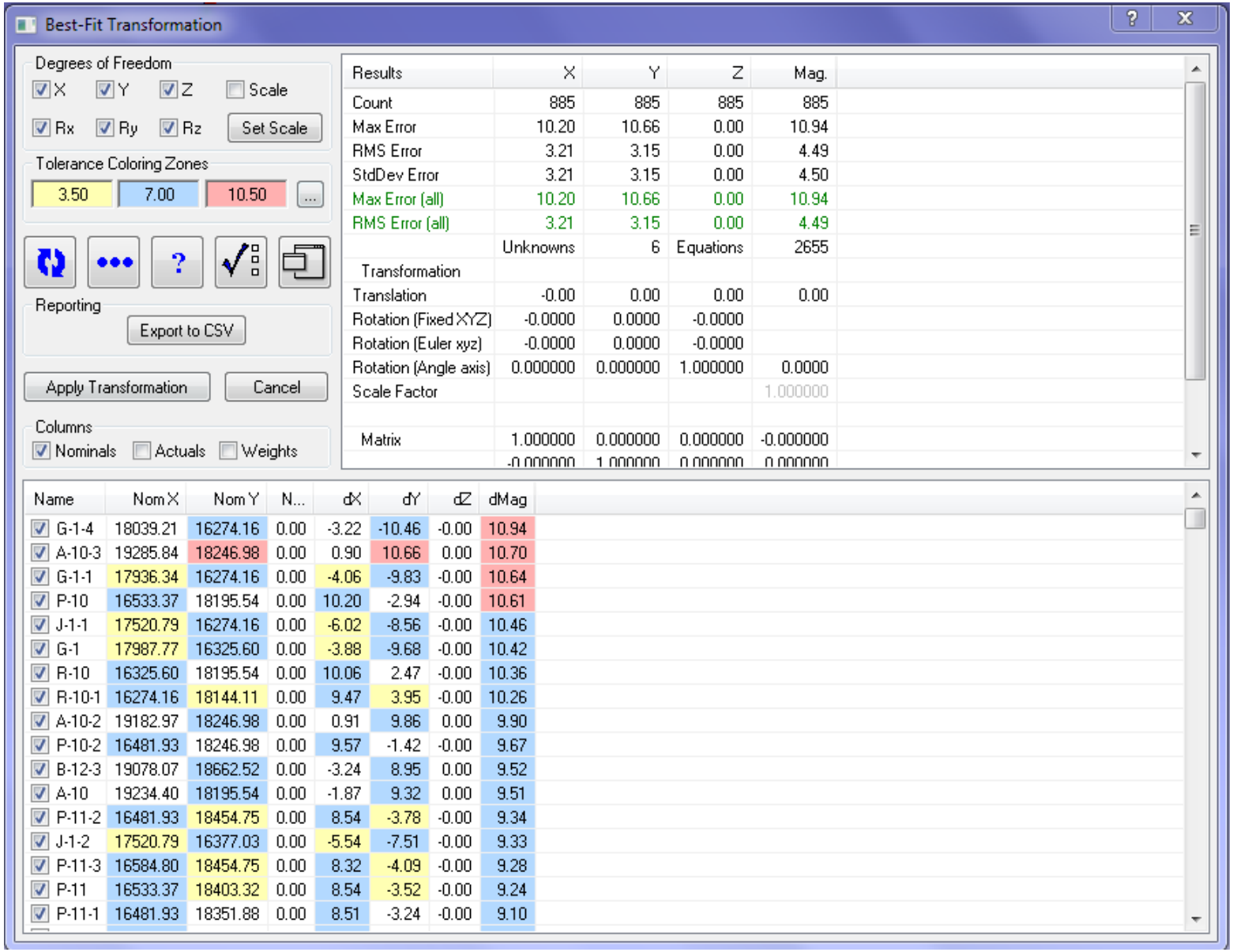
Test Measurement

- The geometry used for the network is shown in the adjacent image
- The physical conditions restrict the network geometry
- Accepted observations are shown as green lines. Rejected observations are shown as red lines

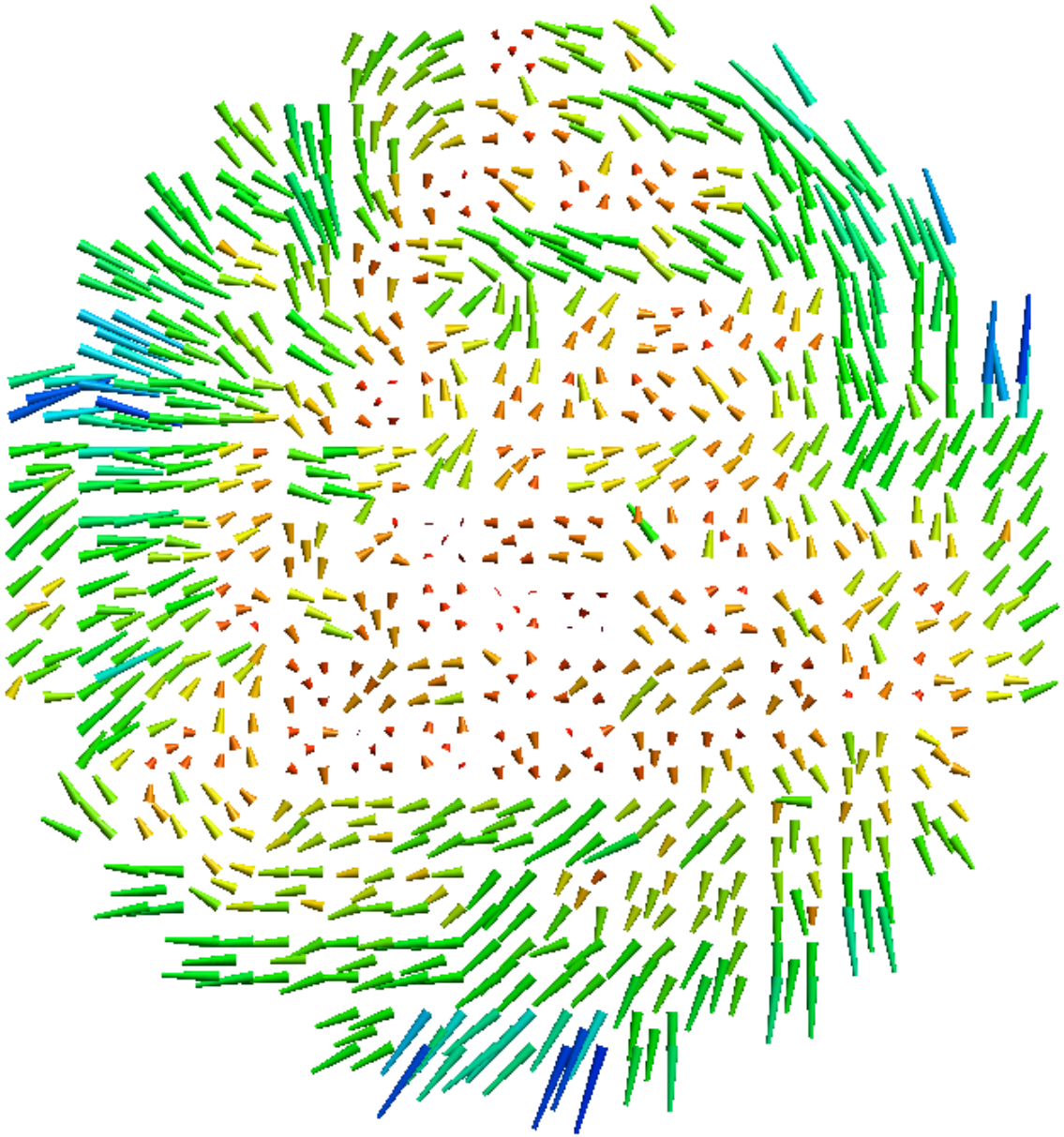
Test Measurement

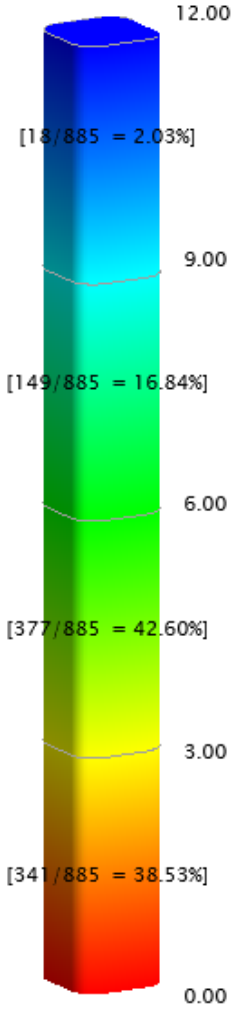
- The measured corner data was referenced against the supplied design data for the corners using a best-fit transformation. All points treated equally
- Based on this alignment, the deviation for each point could be computed

Test Measurement

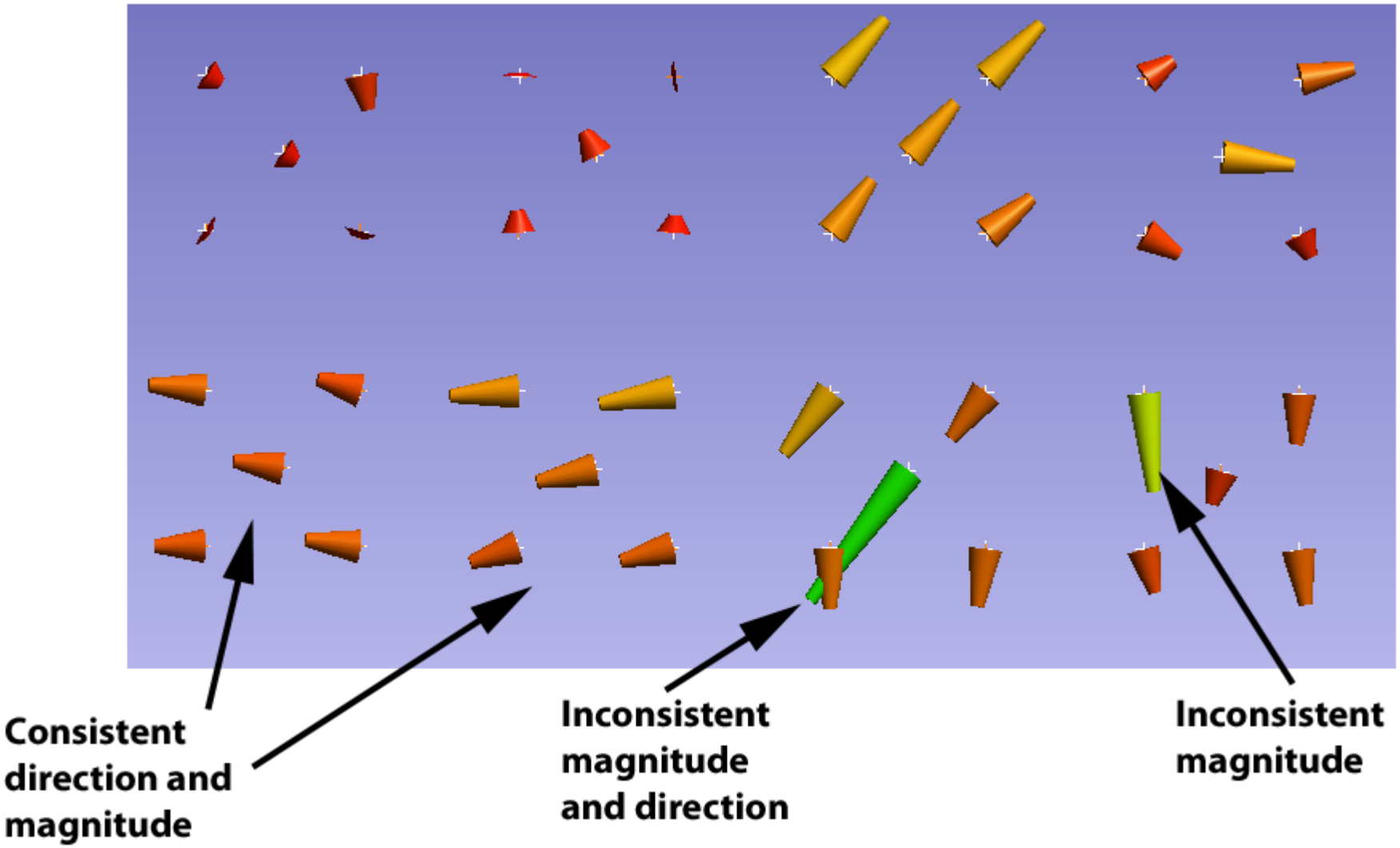


Test Measurement

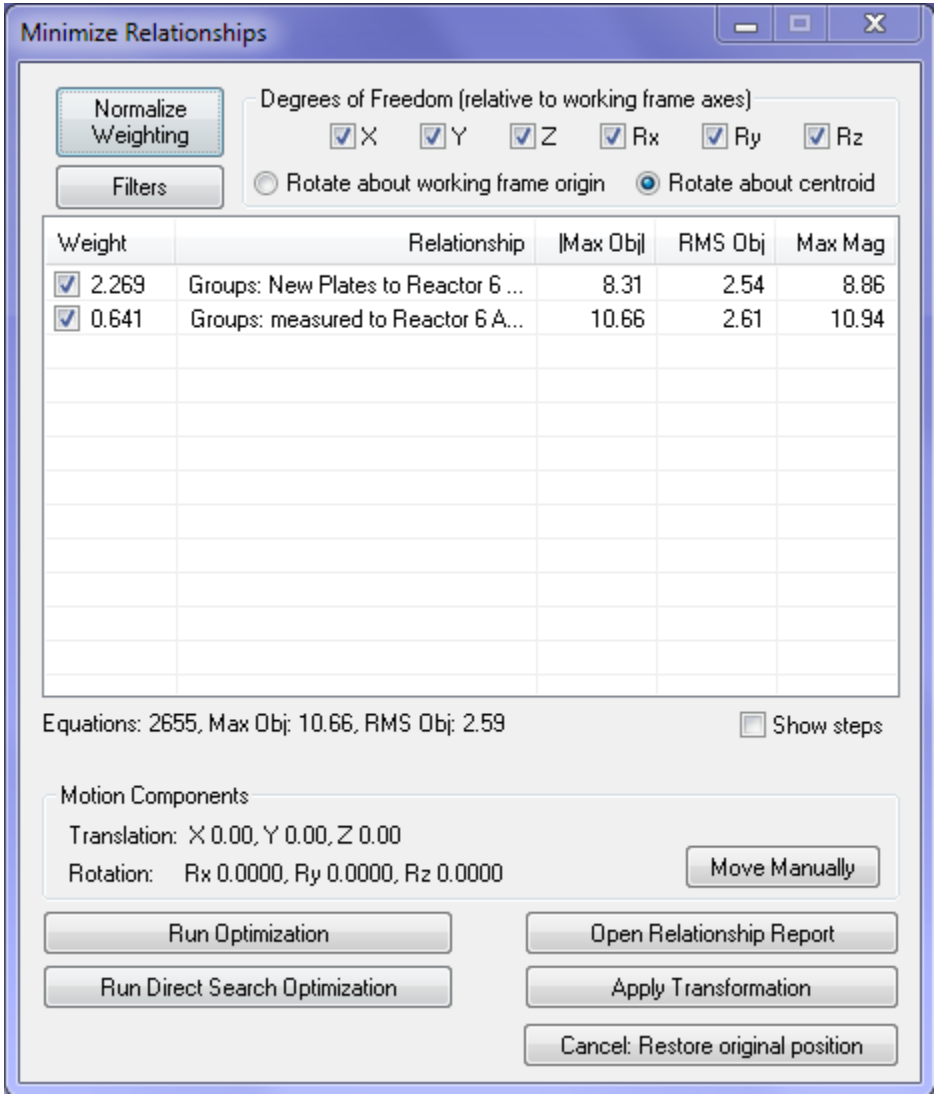




Test Measurement



Test Measurement

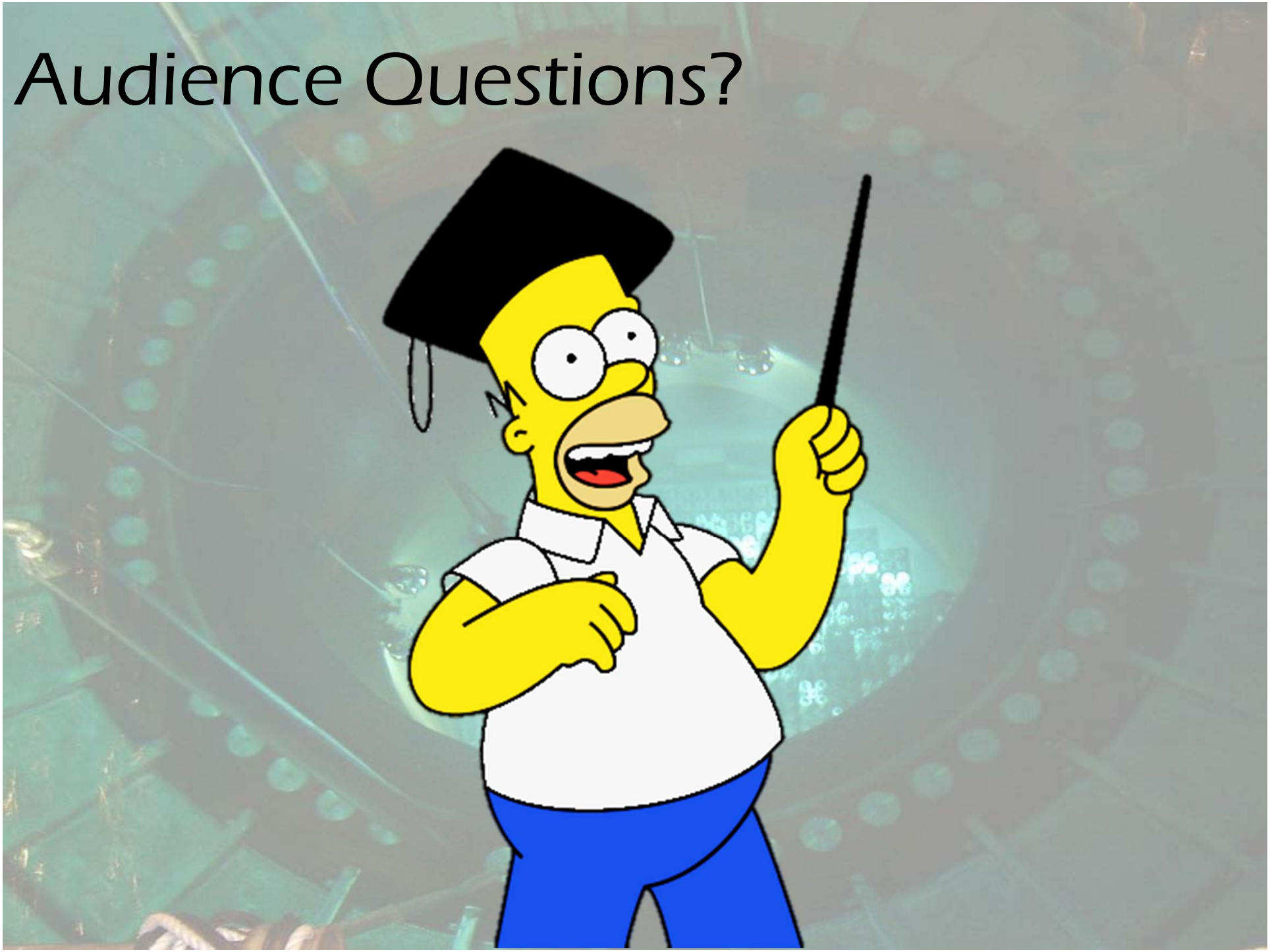


- Can use Relationships to alter weights and tolerance between new and old plates
- Old plates given more weight as their location is assumed to be within tolerance

Concluding Remarks

- Despite the difficulties related to working in an underwater, radioactive environment a successful feature based measurement technique was developed
- Further work could be undertaken to evaluate underwater measurement on actual retro targets
- The lessons learnt on this project will be used to facilitate other underwater measurements in both nuclear and non-nuclear environments

Audience Questions?



Thank You