aLIGO Contamination Control & Analysis

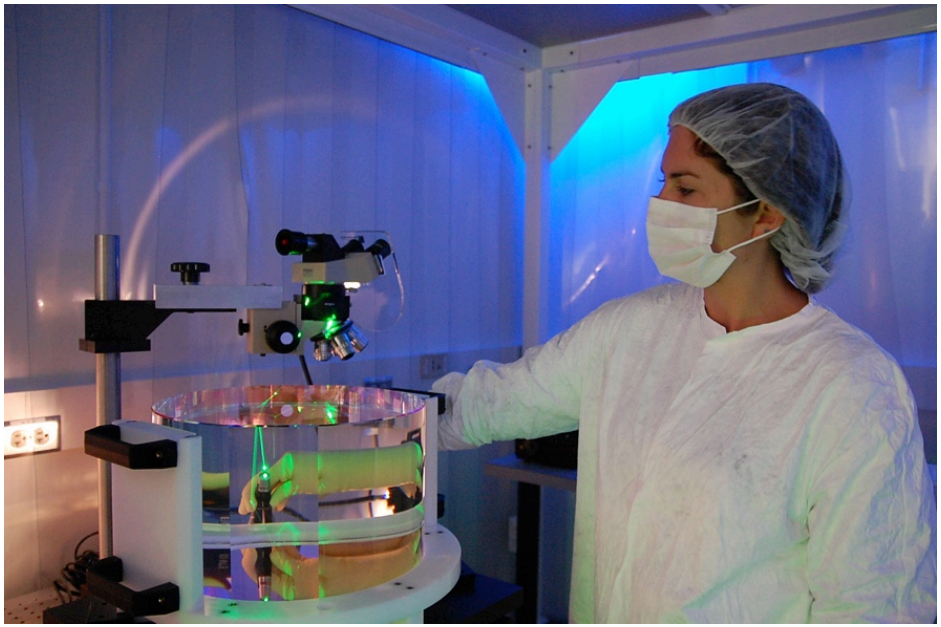
Kate Gushwa
For the Contamination Control Working Group
LVC Meeting Hannover – September 24, 2013

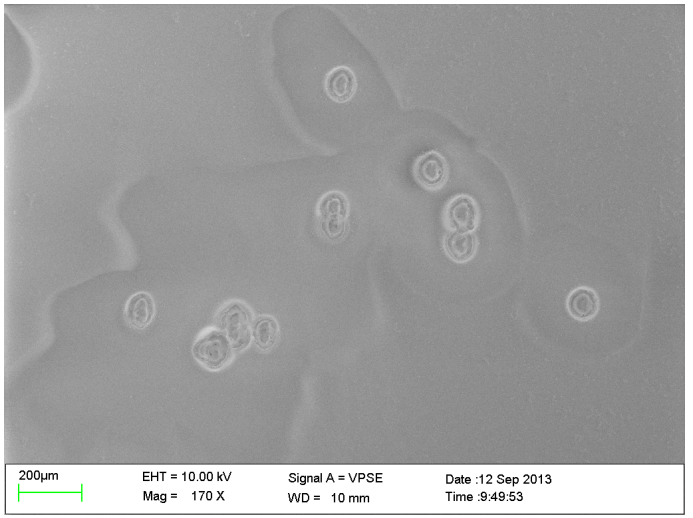
Outline

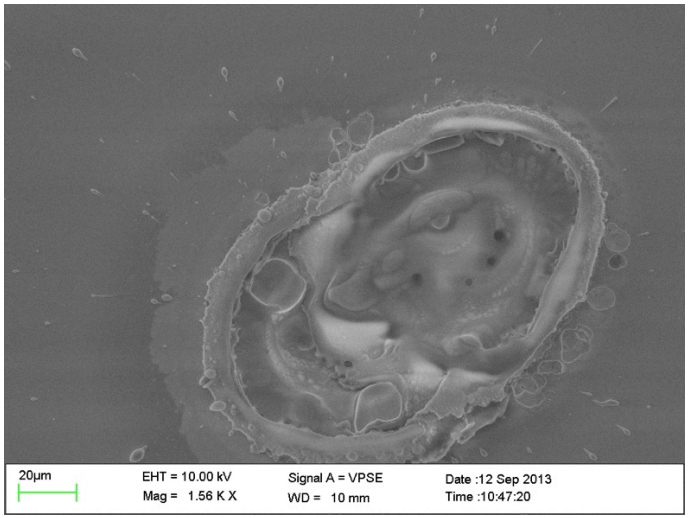
- Why do we care about contamination?
- Diagnostic Tools
  - How bad is it?
  - Where is it coming from?
- Mitigation & Protection

It's All About Optics

- Performance limited by core optics
- Cavity loss budget: **70 ppm total**
- If optics are dirty…



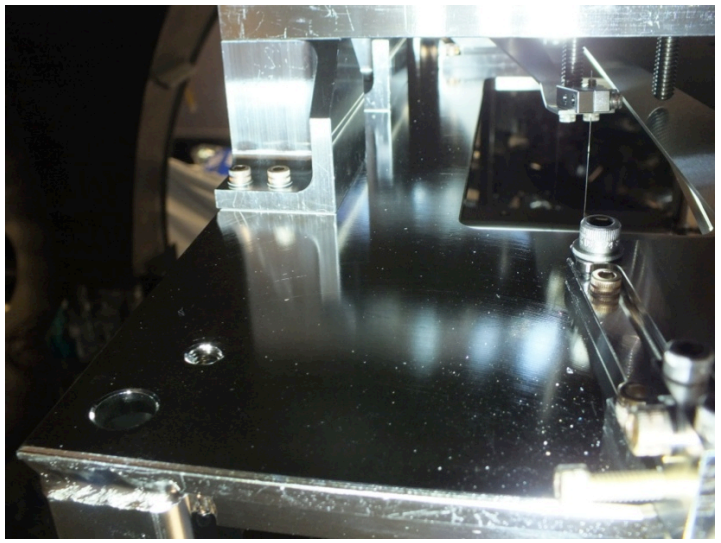


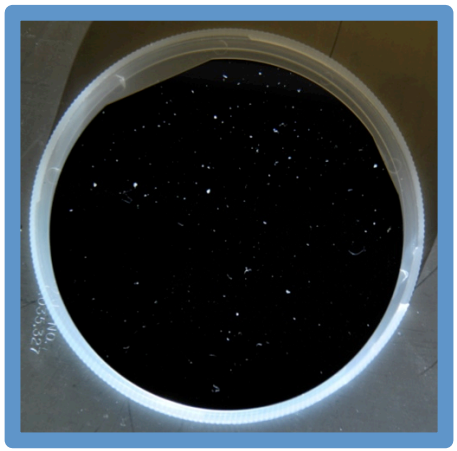


Defining Clean

Defining Clean

	Cleanroom Class	**Particulate Cleanliness Level (PCL)**
Particles per:	Volume of air	Area of surface
Requirement:	ISO 5 (Class 100)	Level 65 (at full power)
Standard:	ISO 14644-1	IEST-STD-1246D
Tool:	Particle counter	Not specified

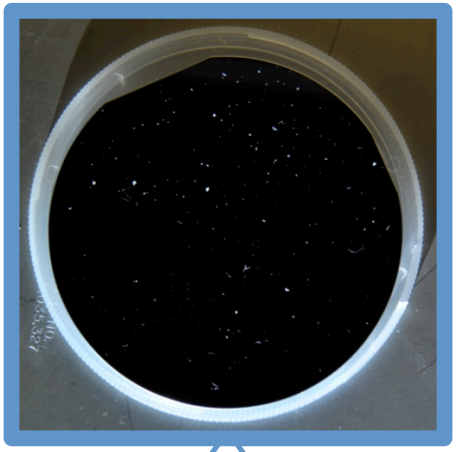


DIAGNOSTIC TOOLS

FBI Samples

4” Wafers



1” Optics

Swipe Tool

Scanning Electron Microscope
(Caltech)

Elemental analysis
High res images

Nikon Counting Microscope
(Caltech)

PCL

Metrology Lab
(Caltech)

Absorption measurements

AmScope Digital Microscope
(Caltech, observatories)

PCL

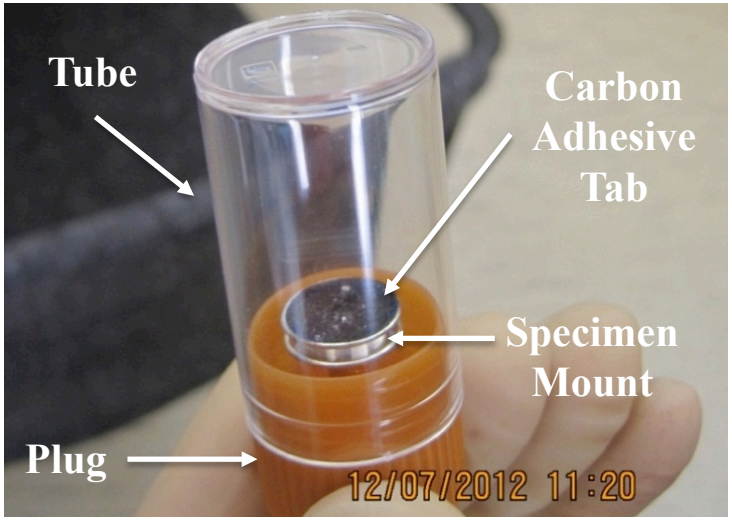
Jet Propulsion Laboratory

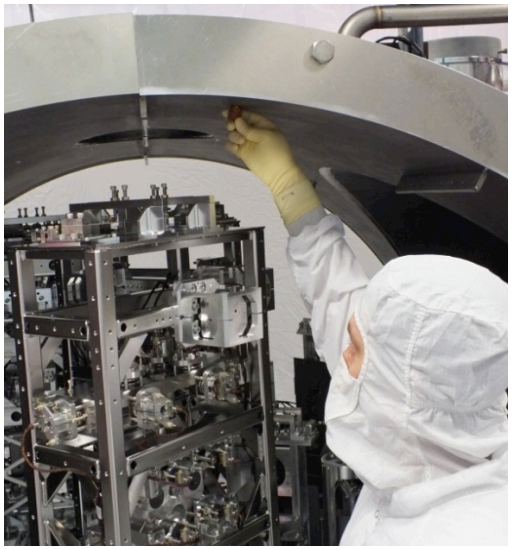
Automated microscope → PCL

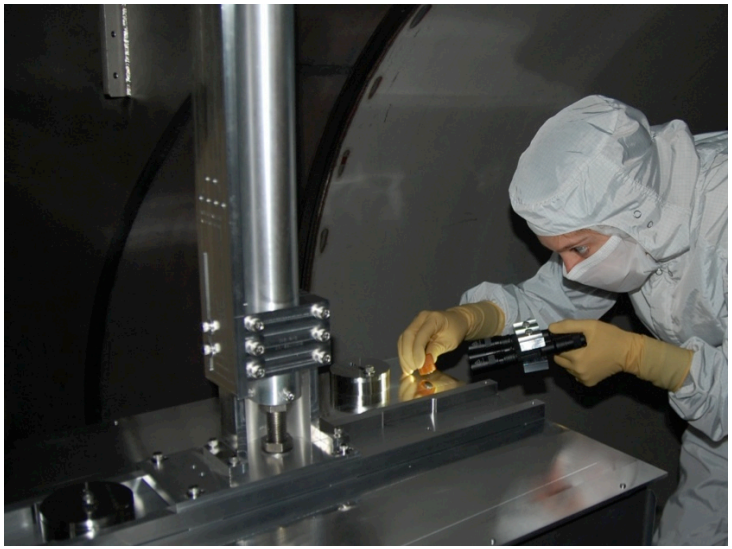
Spectroscopy → Chemical function group

FBI Samples

- Sample small area of interest
- “Criminals”
- “Known Suspects”



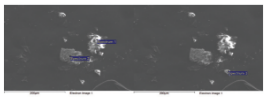


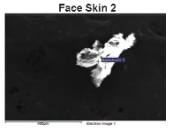


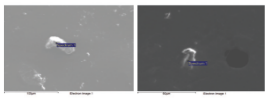
LIGO-T1300165-V5

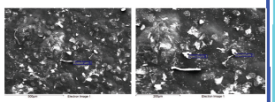
KNOWN SUSPECTS

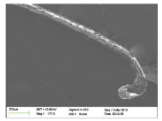
PEOPLE

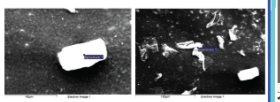
Sweat


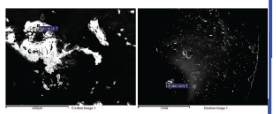
Face Skin 2


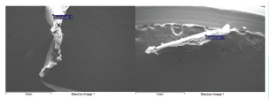
Saliva


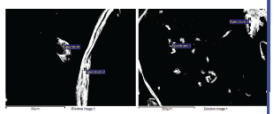
Human Sweat AND Saliva


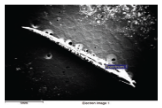
Eyebrow Hair


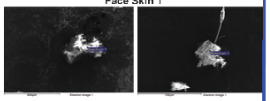
Human Sweat AND Saliva


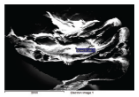
Skin


Viton


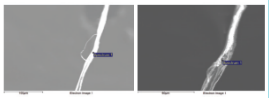
Skin


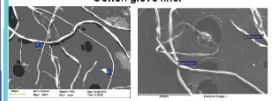
Ameristat Bag (New)


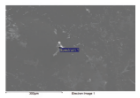
Face Skin 1


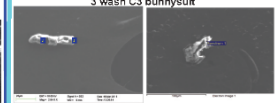
Teflon


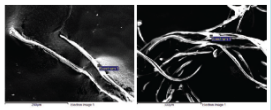
FIBERS

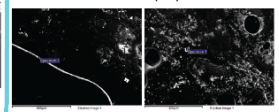
Jeans


Cotton glove liner


Particle from Jeans


3 wash C3 bunnysuit


Alpha 10 Wipe


C3 Frock (Old)


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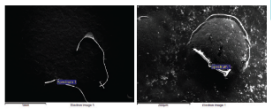
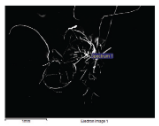
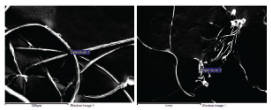
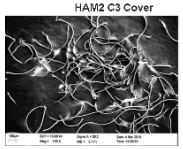
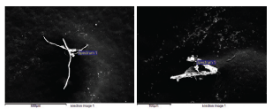


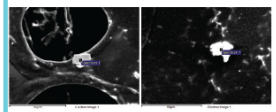
C3 Frock (Old)


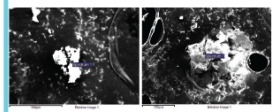
Contec Wipe


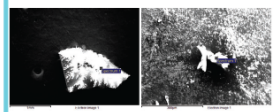
HAM2 C3 Cover


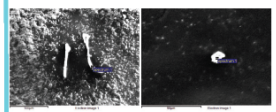
Berkshire Wipe


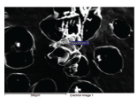
METALS

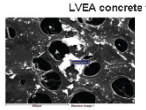
Glove Print


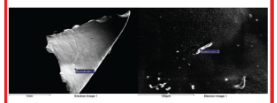
Glove Print


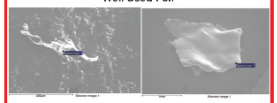
Glove Piece


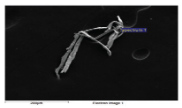
Glove Piece


LVEA Cleanroom curtain


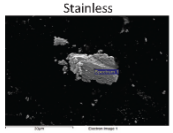
LVEA concrete floor dust


Aluminum Foil (New)


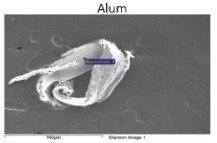
Well Used Foil


Silver


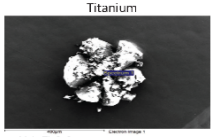
Main: Ag, C
Trace: N/A

Stainless


Main: Fe, Cr, Ni, C
Trace: Si, Mn

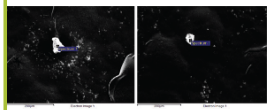
Alum


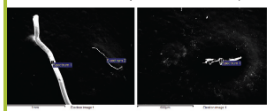
Main: Al
Trace: C, O, Mg, Si

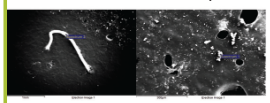
Titanium


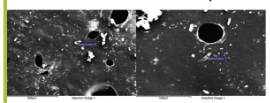
Main:Ti, C, O
Trace: Si

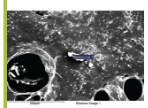
CABLES

Cut Section of Over-temp Bake Teflon Quadrapuss


Cut Section of Over-temp Bake Teflon Quadrapuss


Cleaned and Baked Teflon Quadrapuss


Cleaned and Baked Teflon Quadrapuss


Cleaned and Baked Teflon Quadrapuss (3)


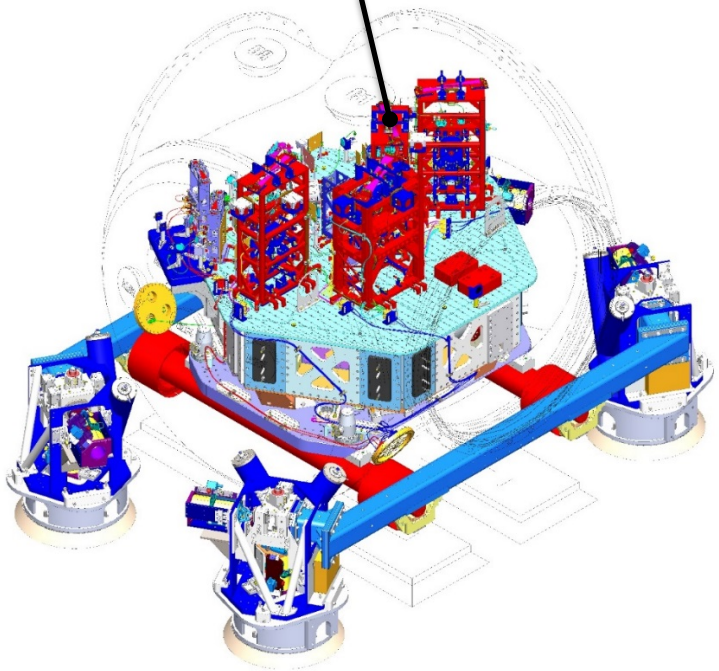
MORE TO FOLLOW

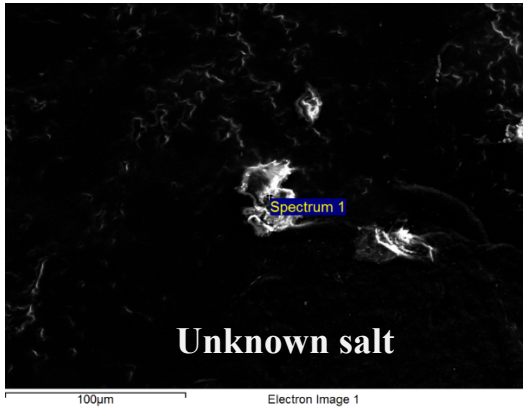
TO GET ADDED TO THE LIST
CONTACT CALUM TORRIE,
MARGOT PHELPS OR KATE GUSHWA

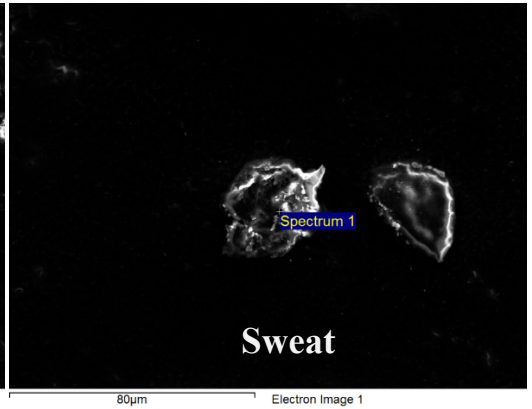
LIGO-T1300165-V5

SEM Analysis – LHAM2

Location: Top of MC1
Date: Feb 2013
Guess: C3

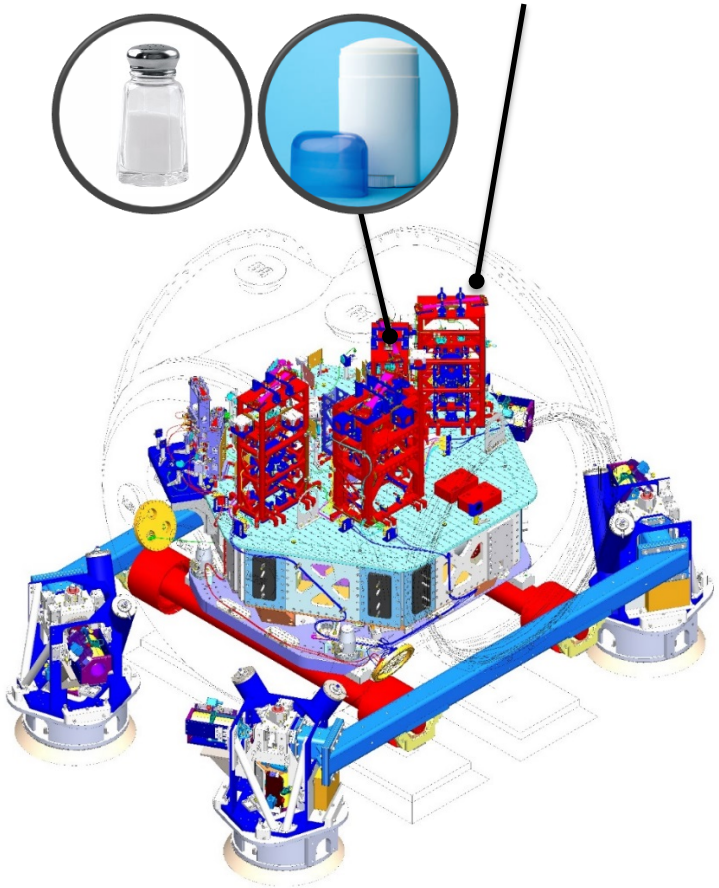






SEM Analysis – LHAM2

Location: Ceiling above MC3
Date: Dec 2012
Guess: Metal

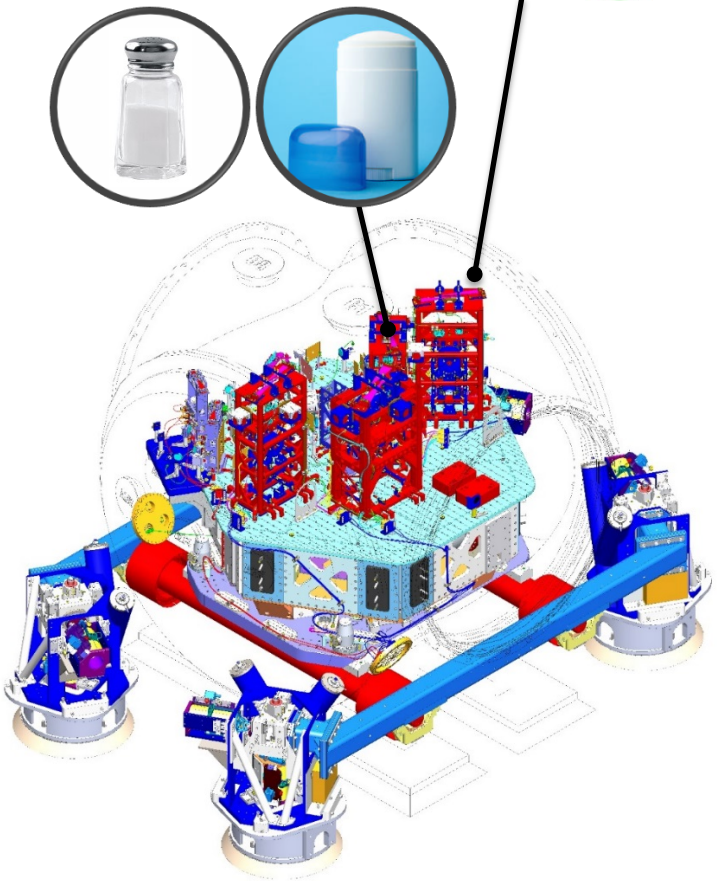


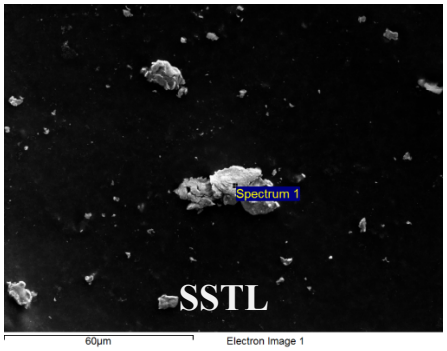
SEM Analysis – LHAM2

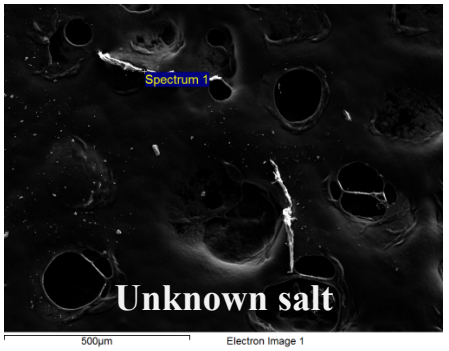
Location: Ceiling above MC3

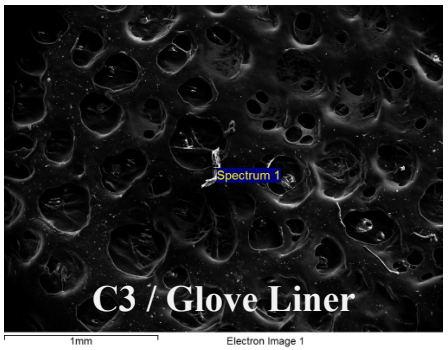
Date: Dec 2012

Guess: Metal

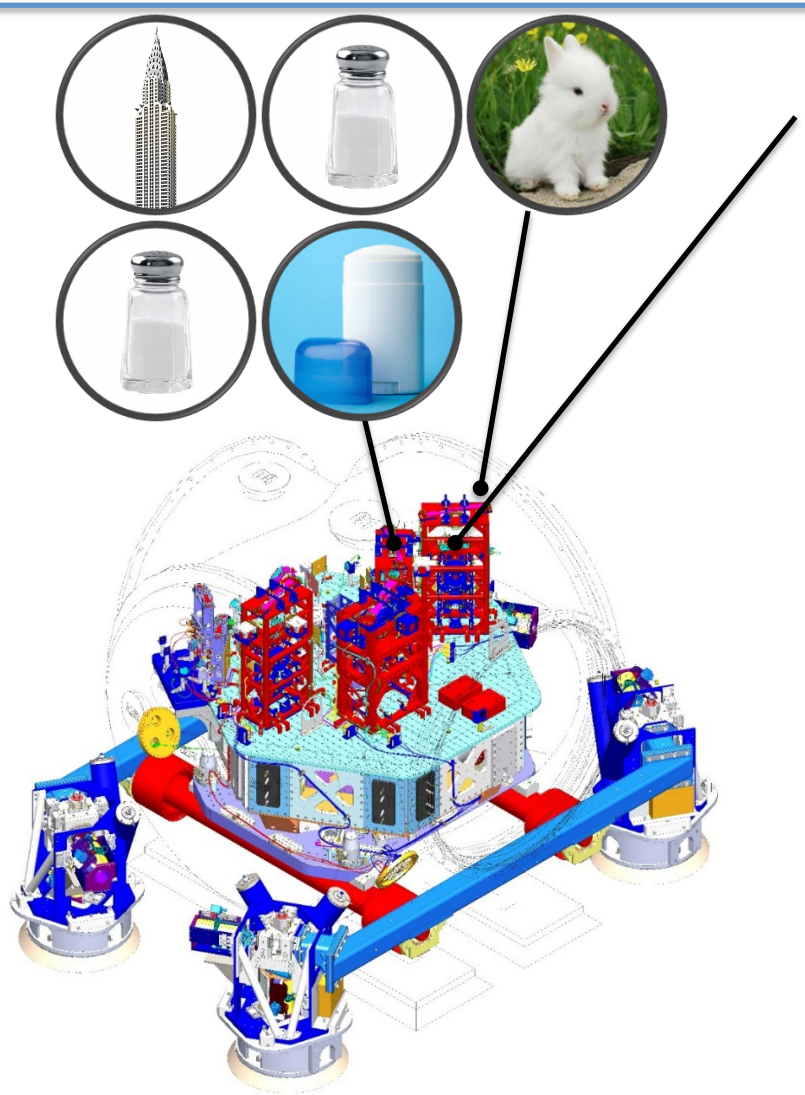








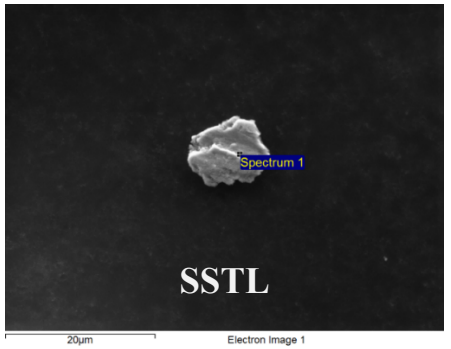
SEM Analysis – LHAM2

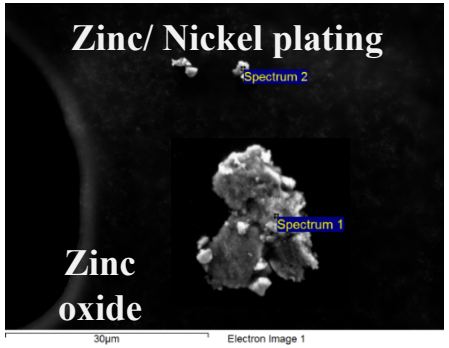


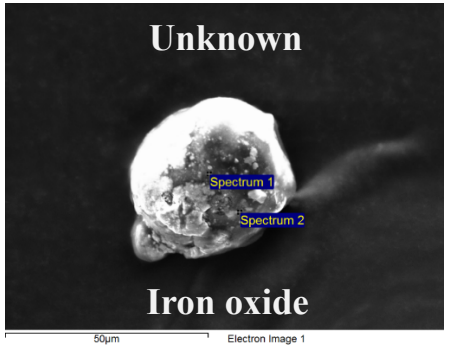
Location: MC3 tablecloth

Date: Dec 2012

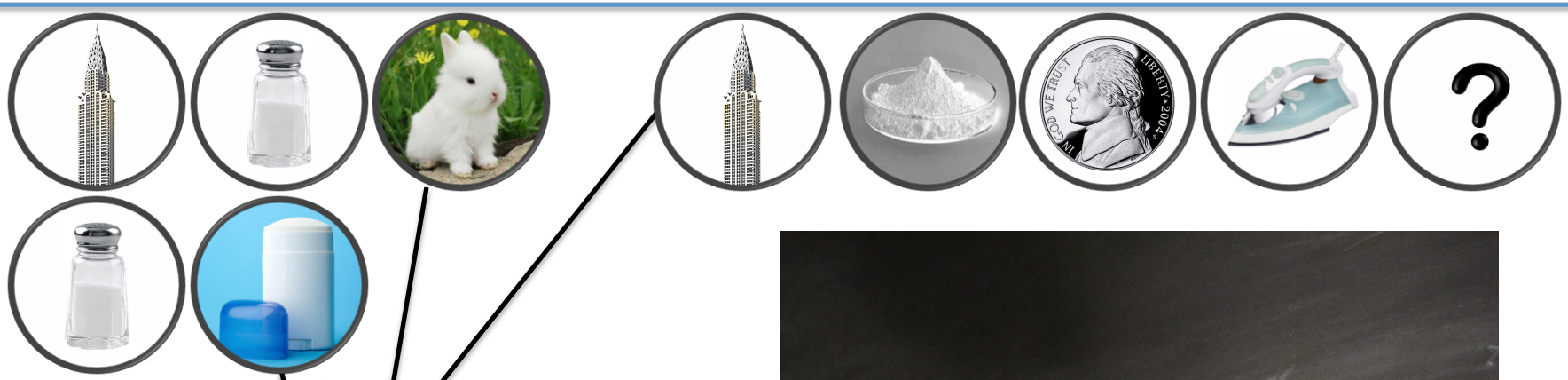
Guess: Metal & C3

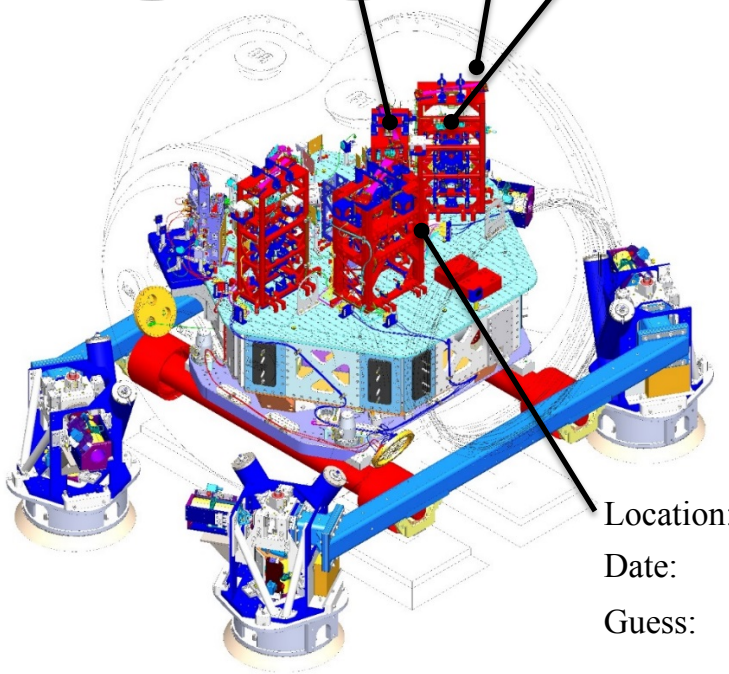






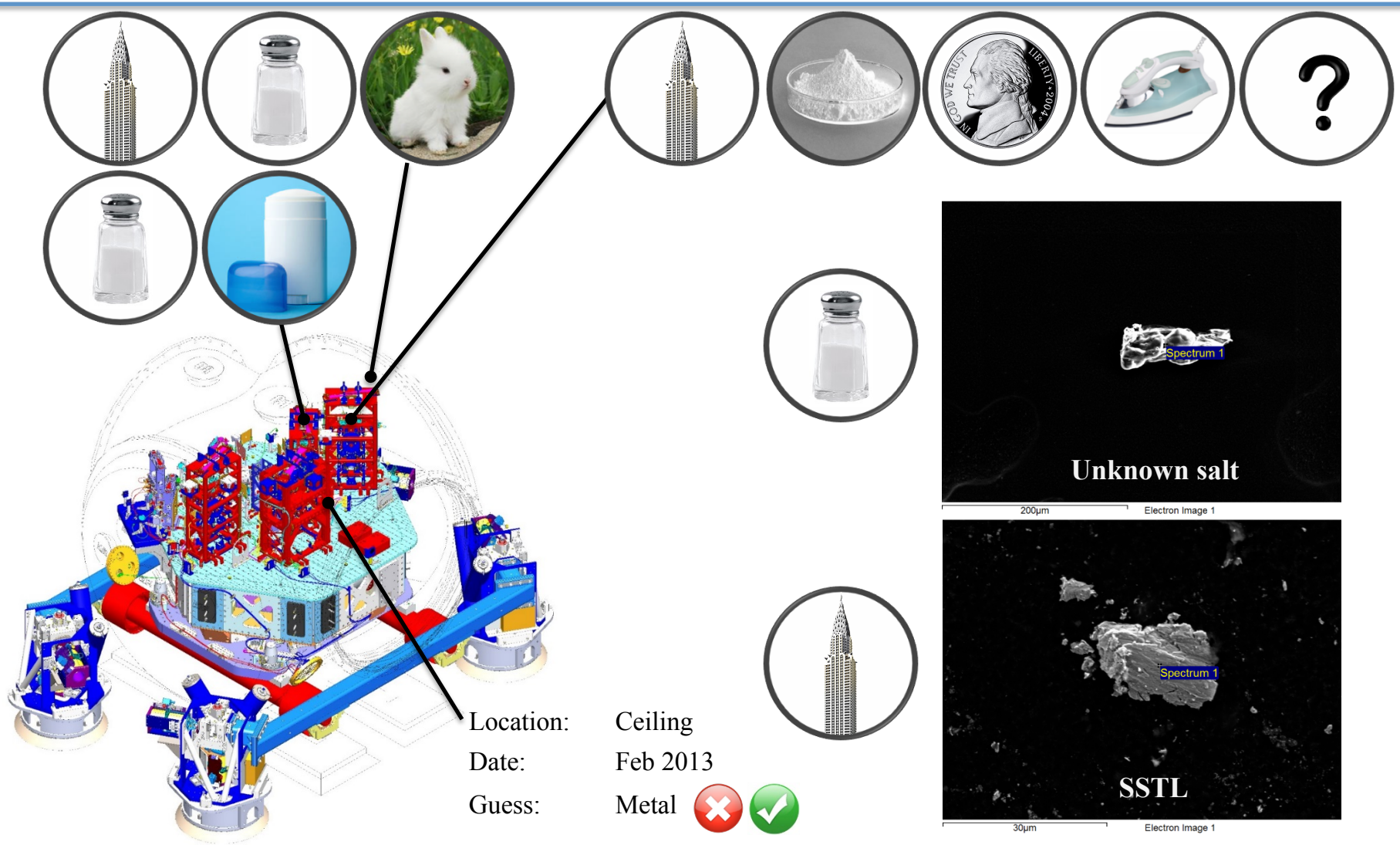
SEM Analysis – LHAM2



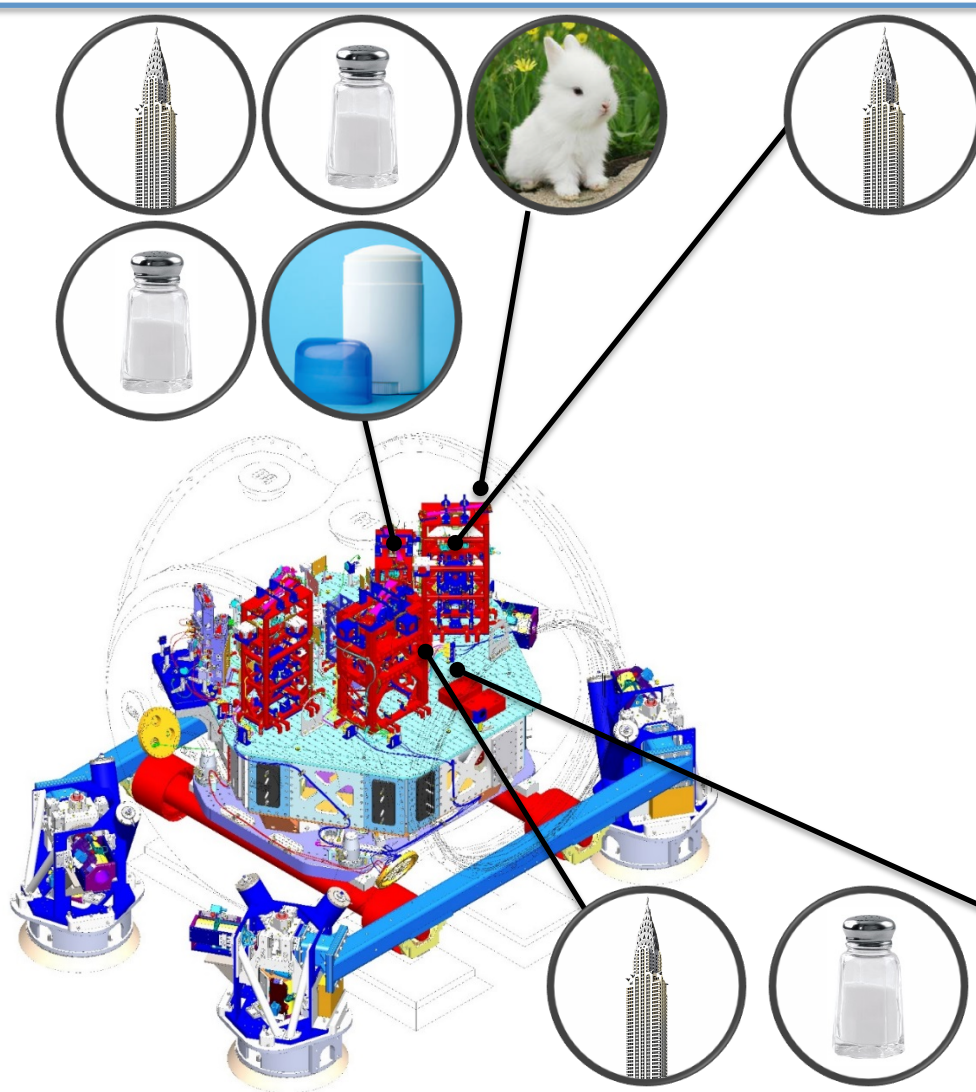


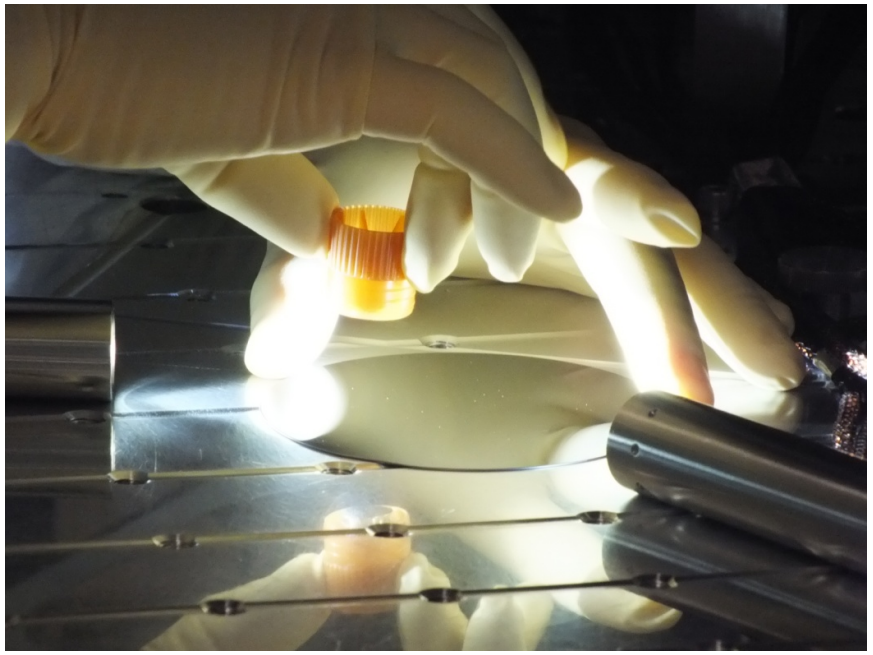
Location: Ceiling
Date: Feb 2013
Guess: Metal

SEM Analysis – LHAM2



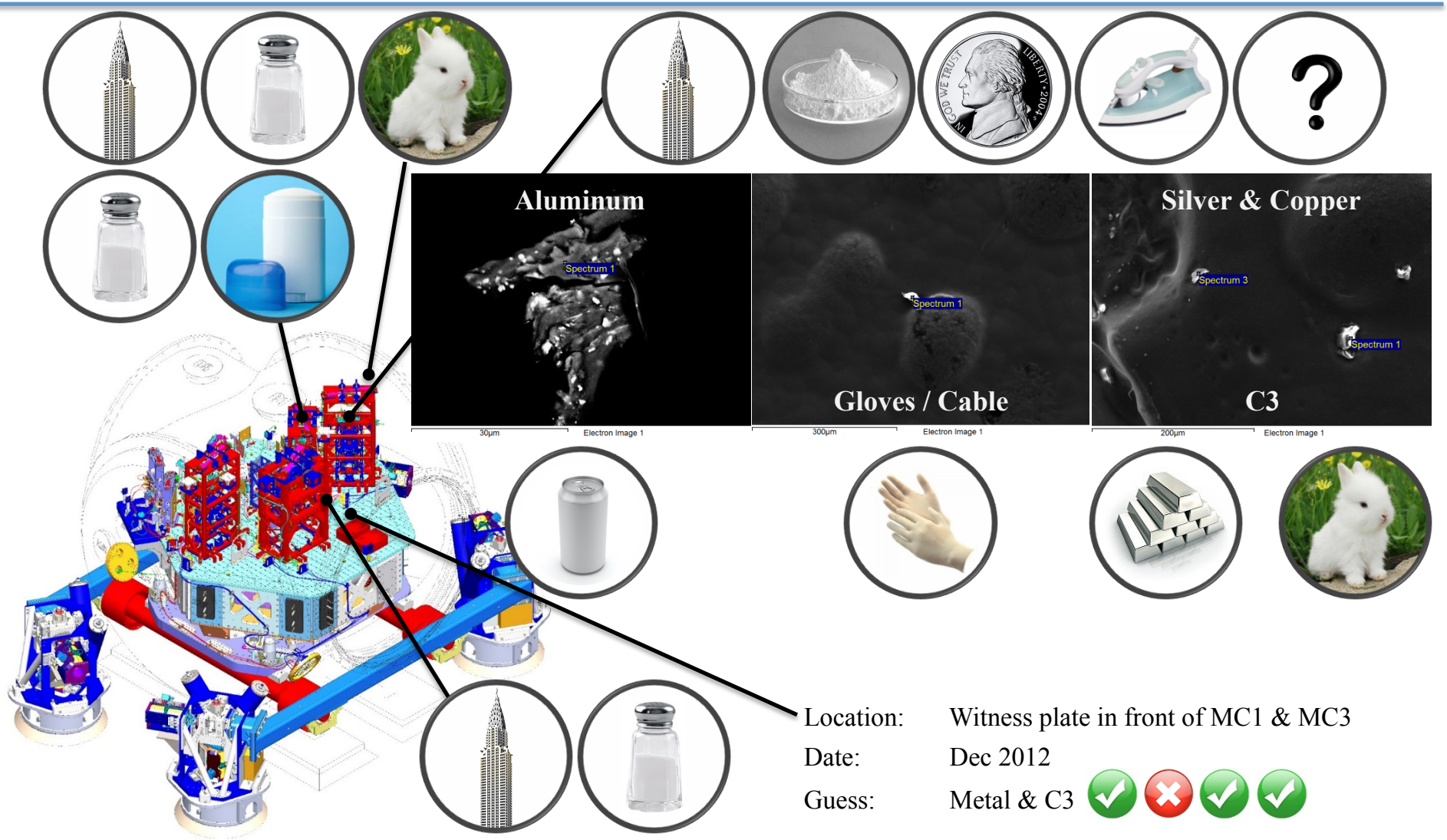
SEM Analysis – LHAM2





Location: Witness plate in front of MC1 & MC3
Date: Dec 2012
Guess: Metal & C3

SEM Analysis – LHAM2

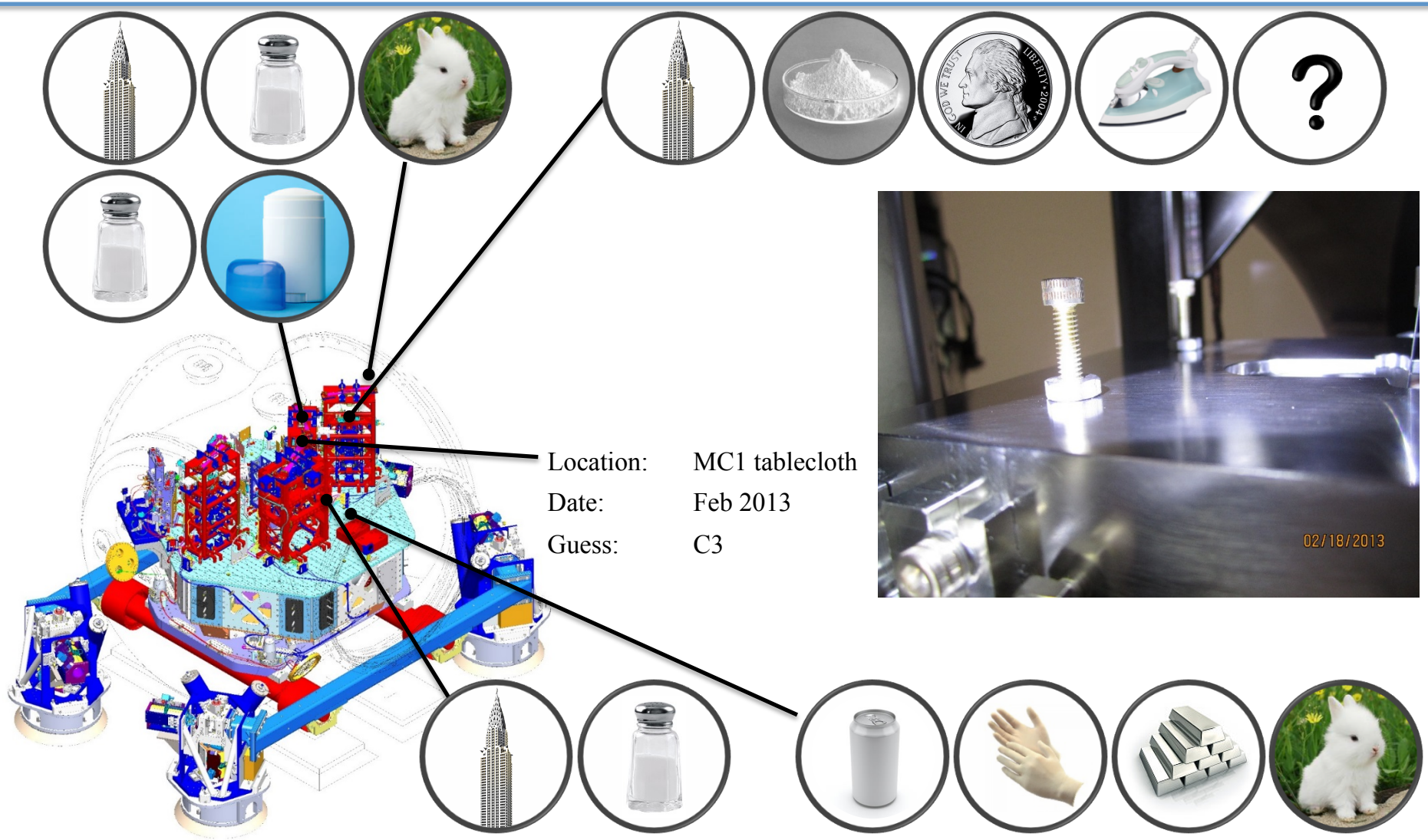


Location: Witness plate in front of MC1 & MC3

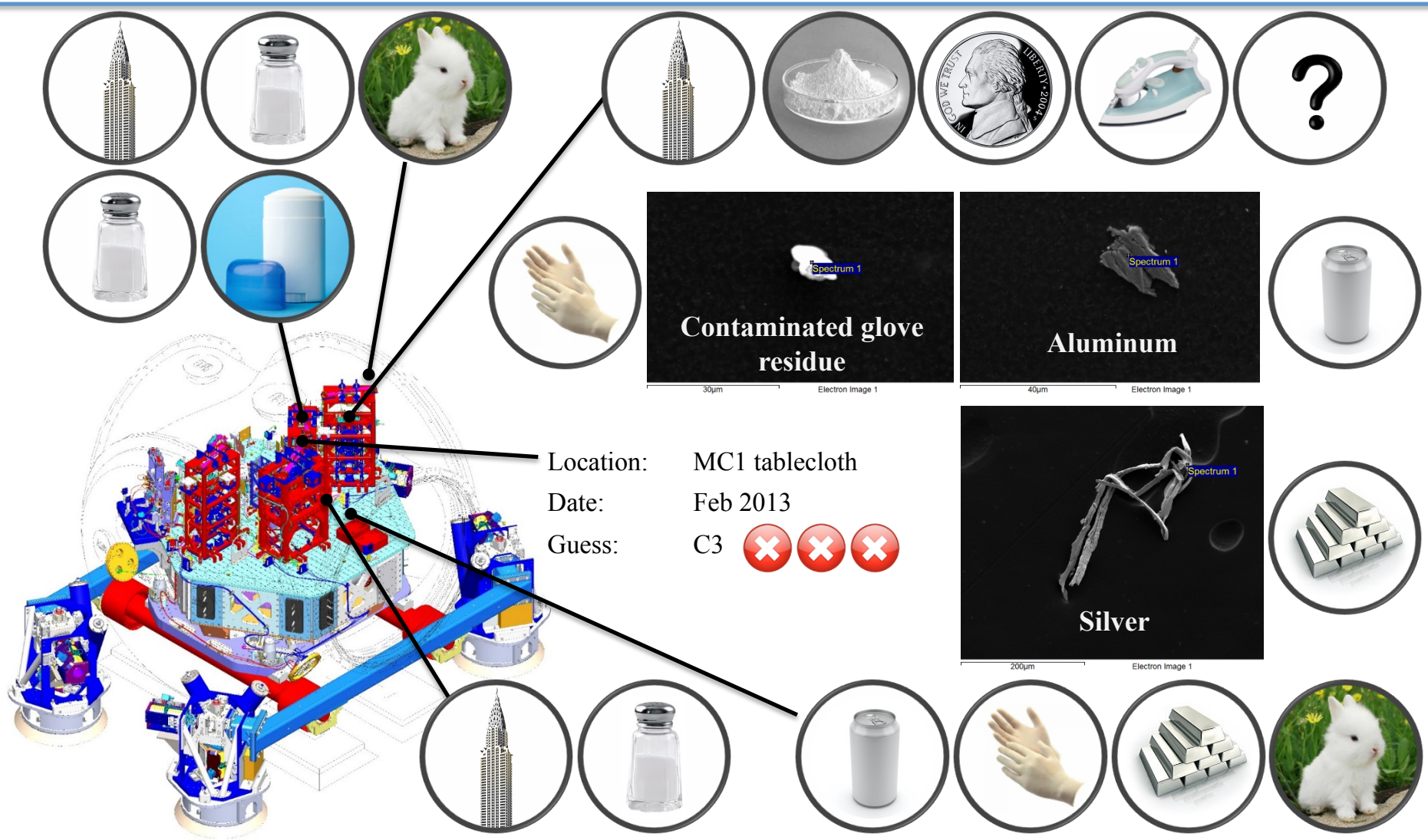
Date: Dec 2012

Guess: Metal & C3

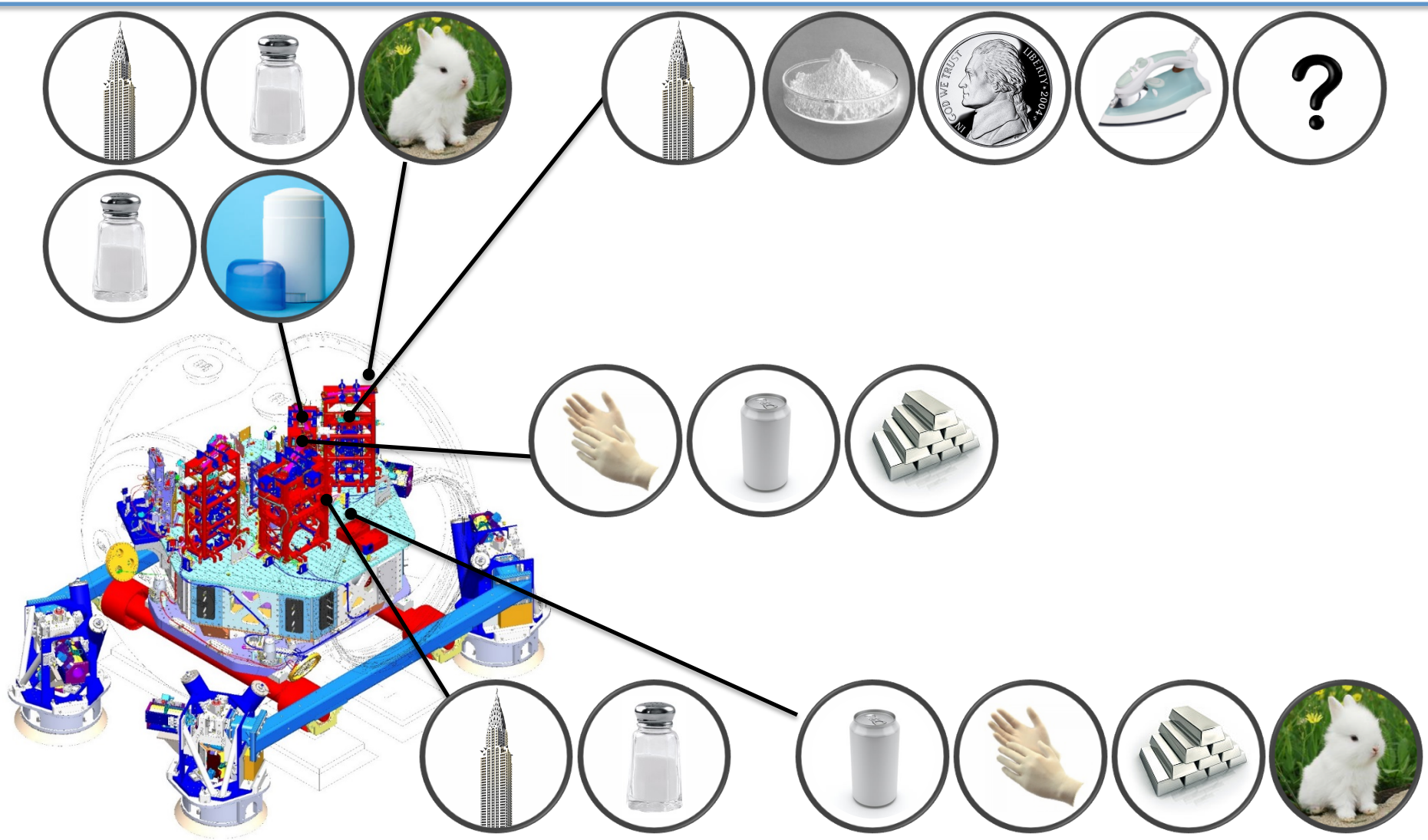
SEM Analysis – LHAM2



SEM Analysis – LHAM2

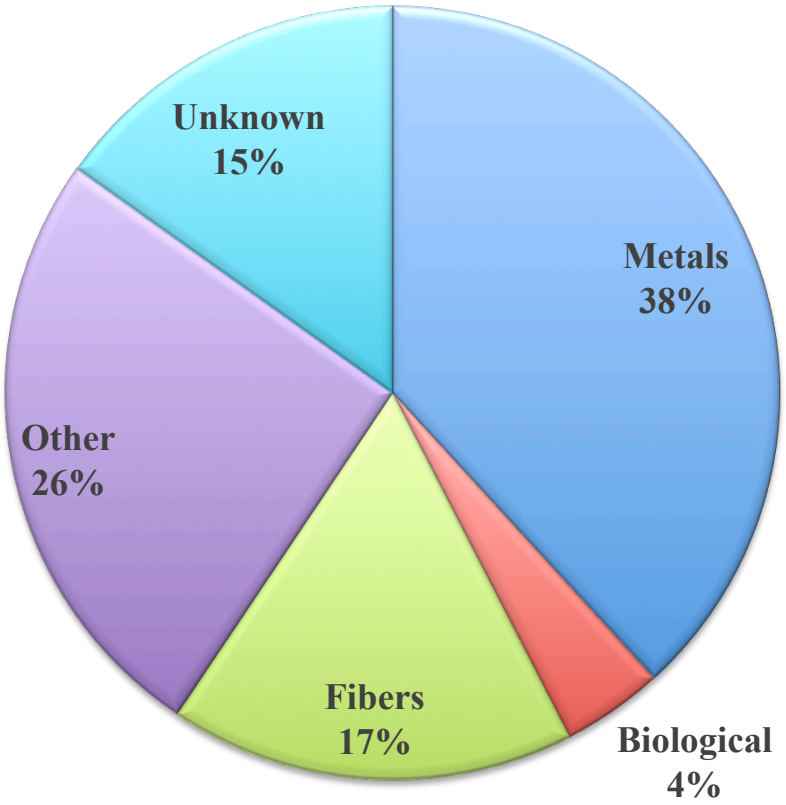


SEM Analysis – LHAM2



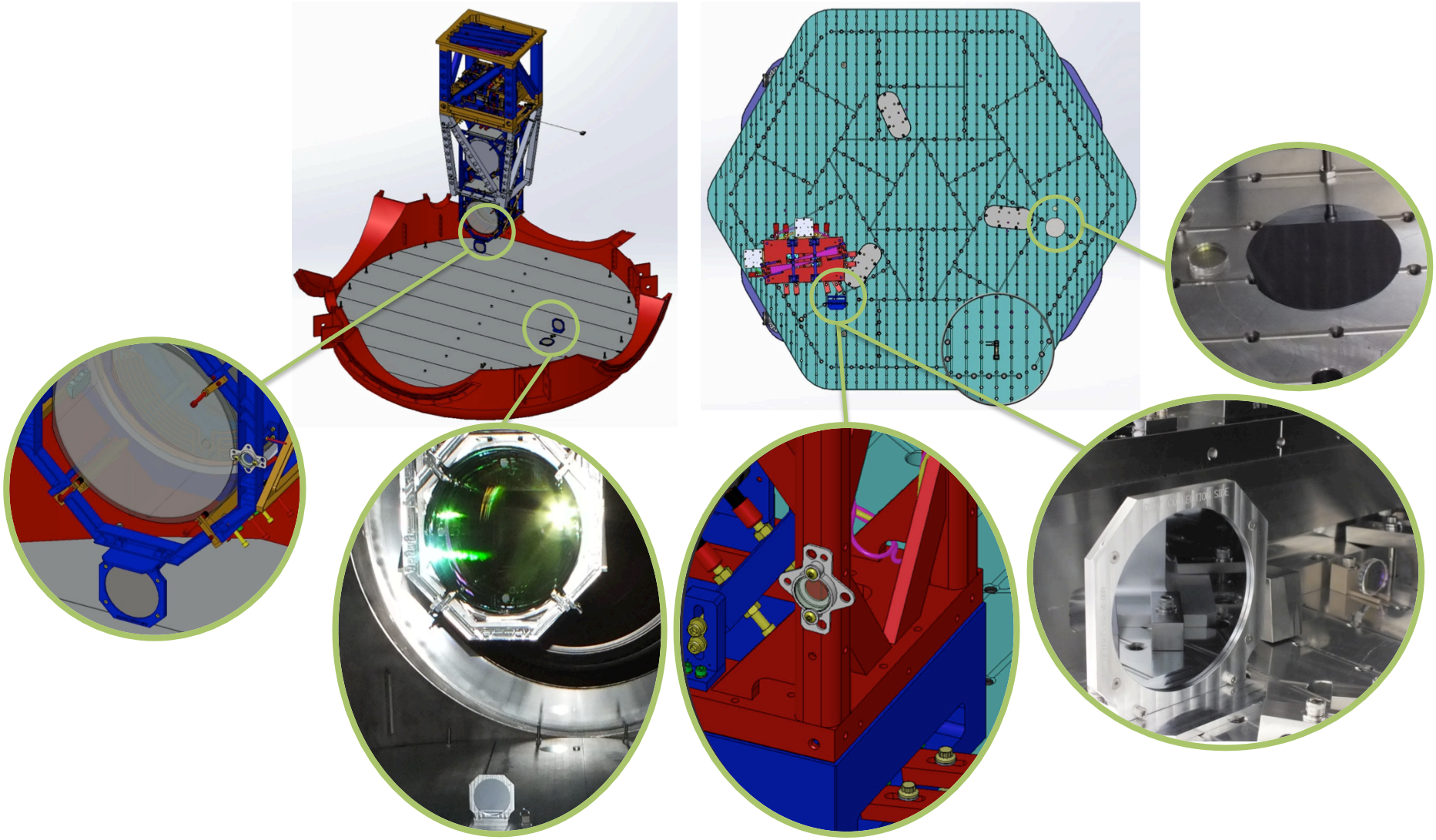
FBI Samples on Instrument Surfaces

➢ *Finding: no smoking gun*



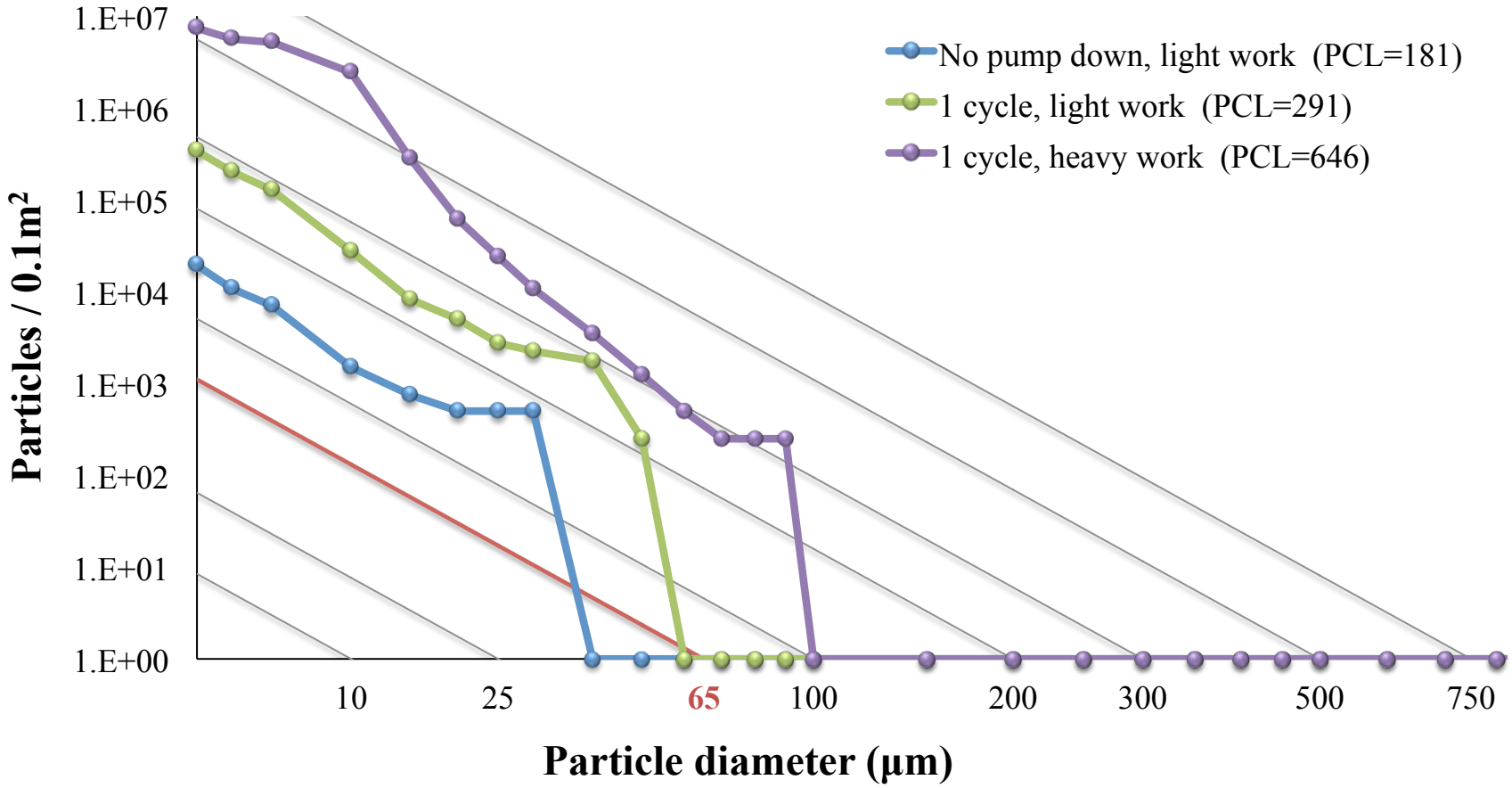
Group	Material	Specimen	Total
Metals	Any Metal	63	63
Biological	Hair	1	7
	Skin, Sweat, Saliva	6	
Fibers	C3	9	28
	Glove Liner	2	
	Jeans	1	
	Unknown Fiber	4	
	Wipe	12	
Other	In-Vacuum Cable	2	42
	Carbon	21	
	Fused Silica	4	
	Glove	15	
Unknown	Unknown	25	25

4” Wafers & 1” Optics



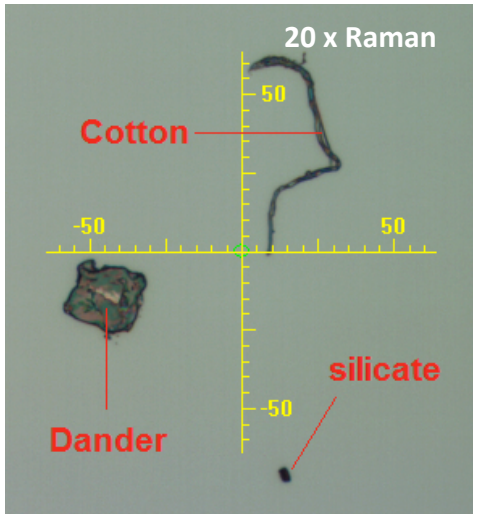
Wafer PCLs – WHAM2 ISI Table

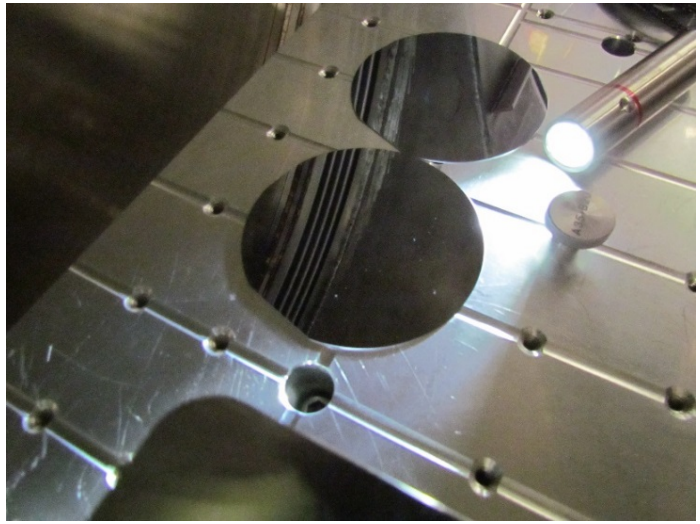
- On the right track – Caltech and JPL PCLs matched.

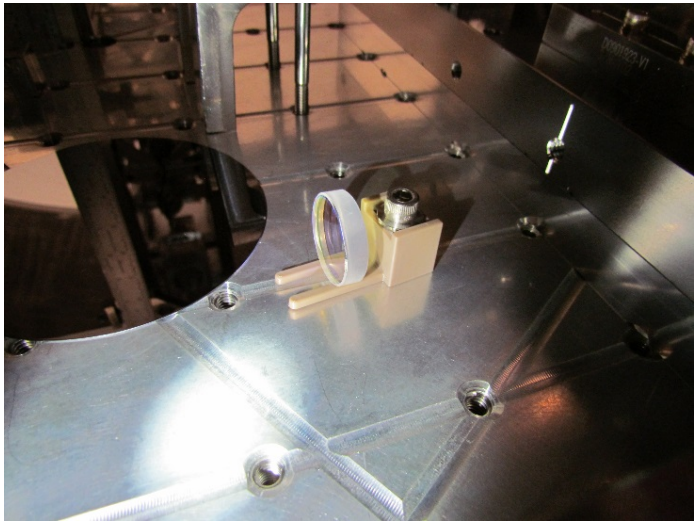


Materials on Wafers and Optics

- Special cases – JPL organic material identification
- Example: LLO HAM3 (pump & vent)
  - Mixed silicates (soil)
  - Complex mix of hydrocarbons
  - Skin dander
  - Polyester & cotton fibers

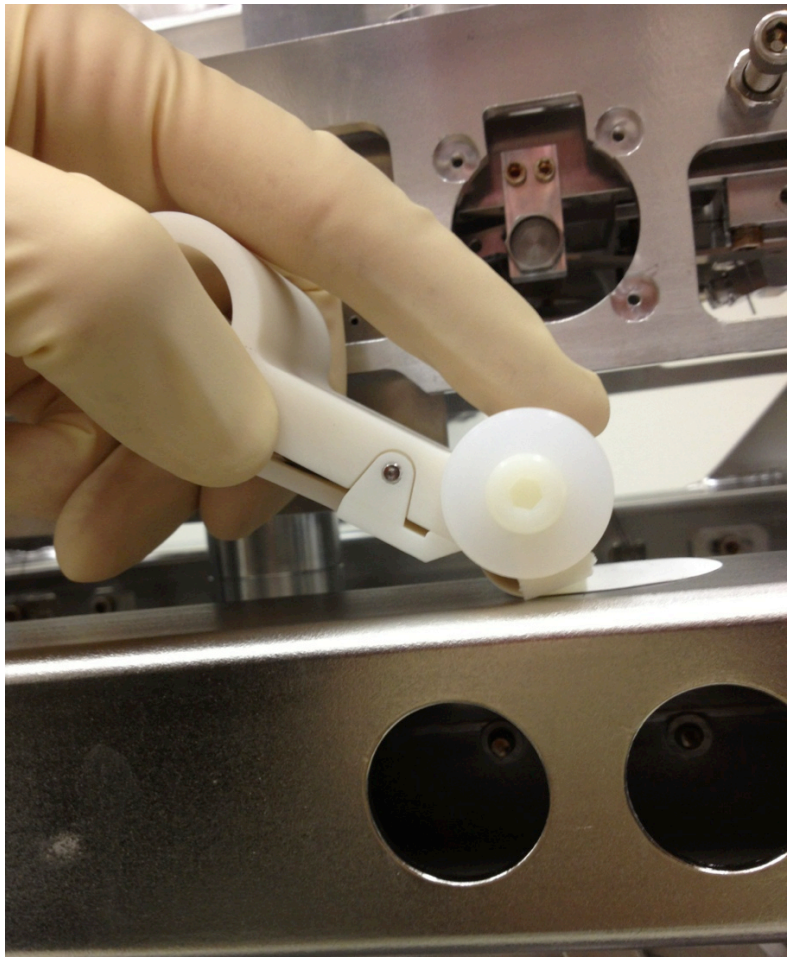






Particle Cleanliness Validation System (PCVS) aka Swipe Tool

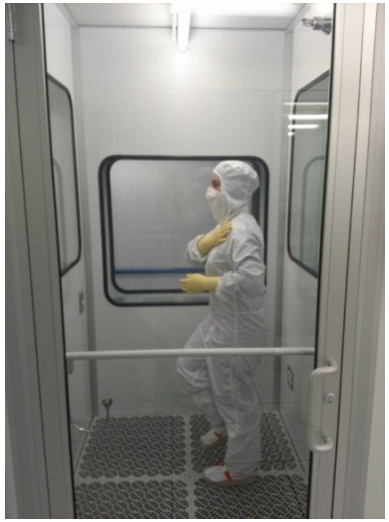
- Visited Nation Ignition Facility (NIF)
- New swipe tool based on NIF design
- Quick PCL calculation
- To be implemented soon



MITIGATION & PROTECTION

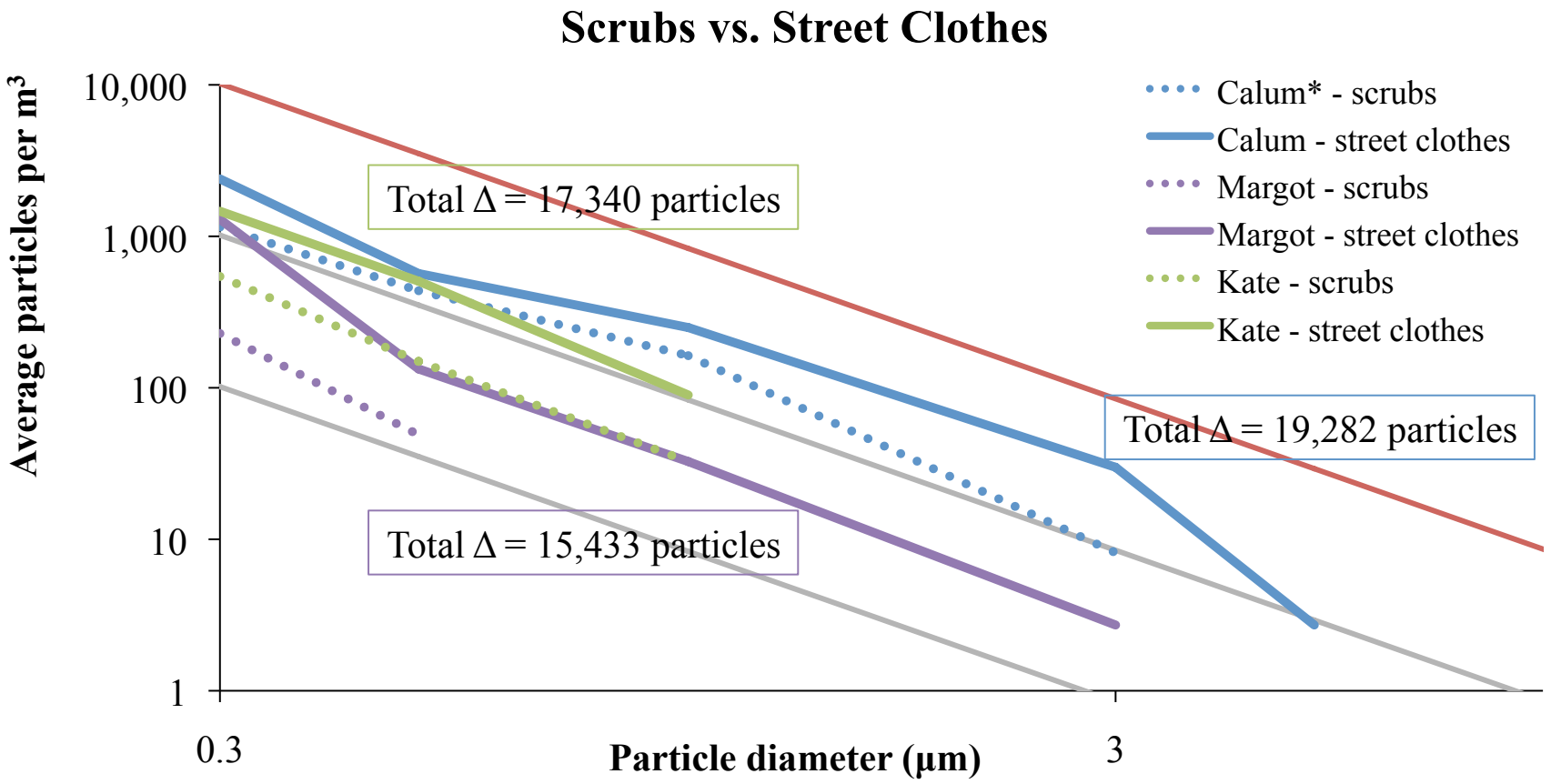
The Human Factor

- Body Box testing



The Human Factor

- Body Box testing
  - *Finding: At least ½ class improvement with scrubs*



The Human Factor

- Body Box testing
  - *Finding: At least ½ class improvement with scrubs*
- Implemented:
  - Scrubs
  - Dedicated shoes
- Future research:
  - New garb options

Facilities

- Implemented:
  - Optimized transition area

Facilities

- Implemented:
  - Optimized transition area
  - Dycem flooring outside VEA

Facilities

- Implemented:
  - Optimized transition area
  - Dycem flooring outside VEA
  - Double buckets
  - Nova Clean

Facilities

- Implemented:
  - Optimized transition area
  - Dycem flooring outside VEA
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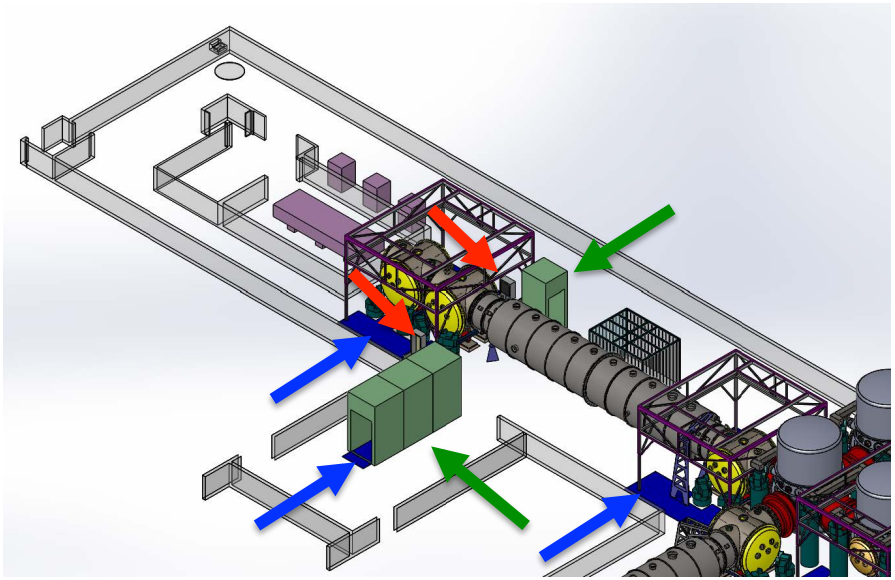
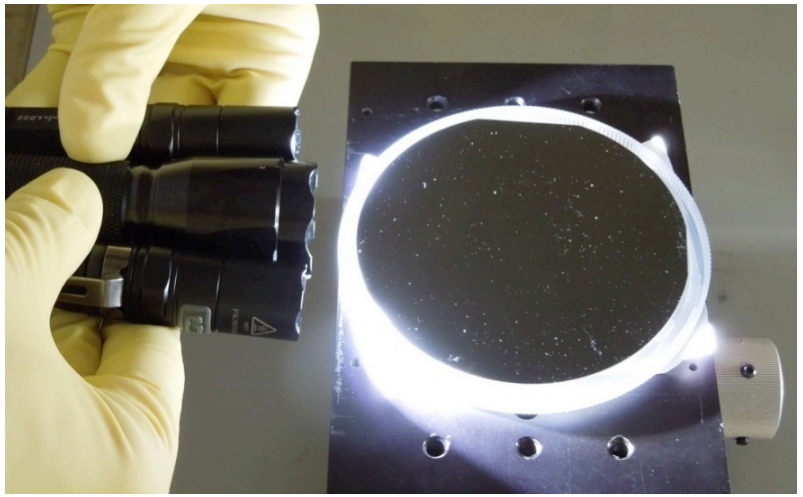


- Future (all portable):
  - Dycem flooring in VEA
  - Air showers
  - Cross-flow system with ionization
  - Particulate monitoring system

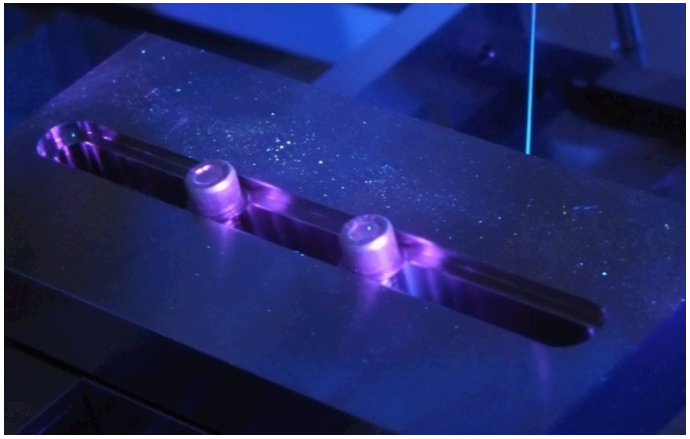
Mitigation Tools and Methods

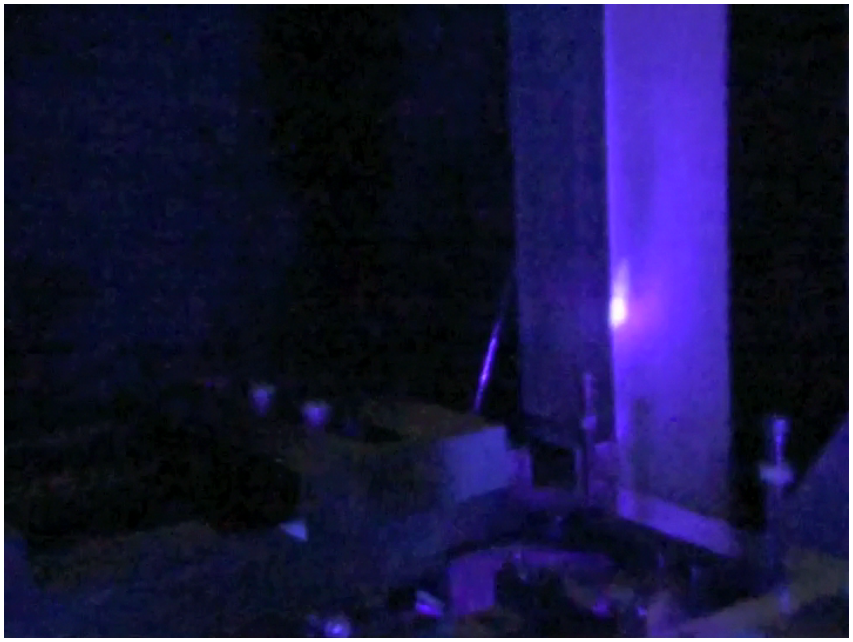
- Implemented:
  - Cleaning on the go:
    - Flashlight arrays



Mitigation Tools and Methods

- Implemented:
  - Cleaning on the go:
    - Flashlight arrays
    - UV-A blacklights

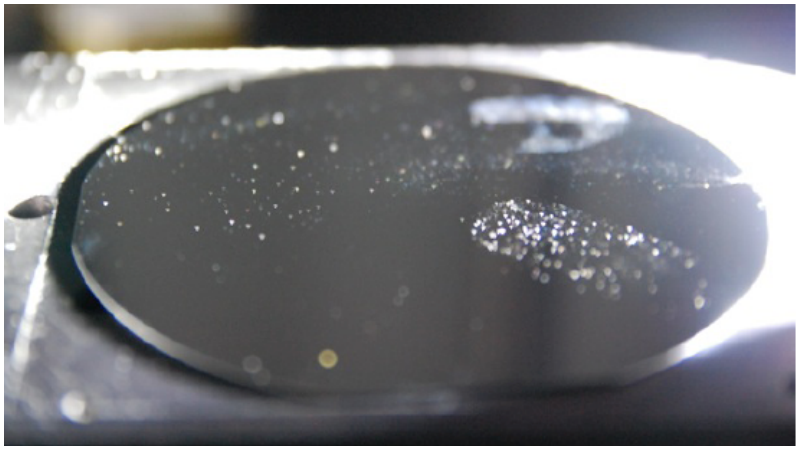




Mitigation Tools and Methods

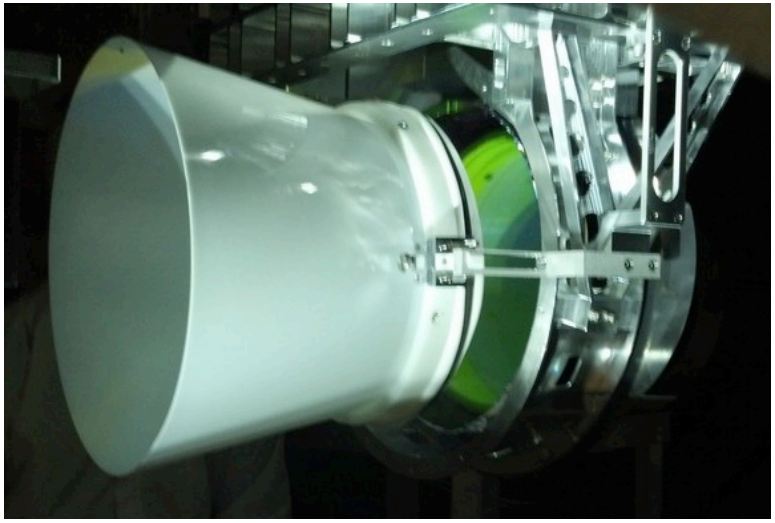
- Implemented:
  - Cleaning on the go:
    - Flashlight arrays
    - UV-A blacklights
    - Custom vacuum cleaners
    - Wet wipes
  - Glove wash with IPA

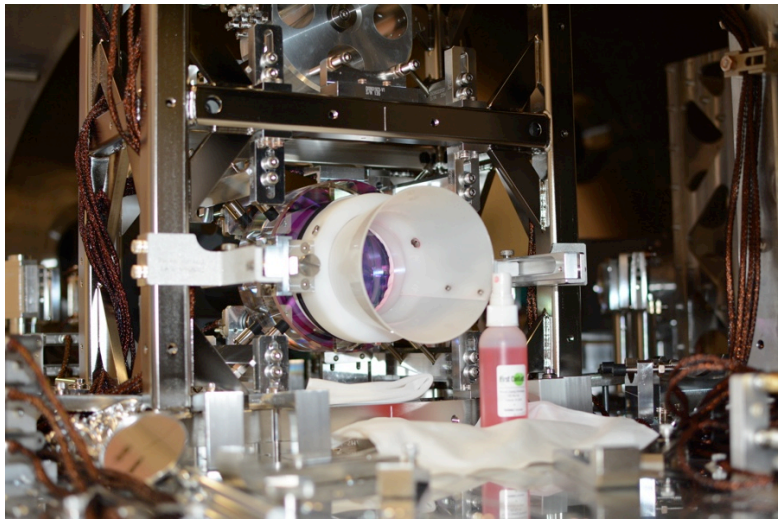
- Currently testing gloves & wipes:
  - Non-volatile residue
  - Particles and fibers
  - Particle removal efficiency



Cleaning & Protecting Suspended Optics

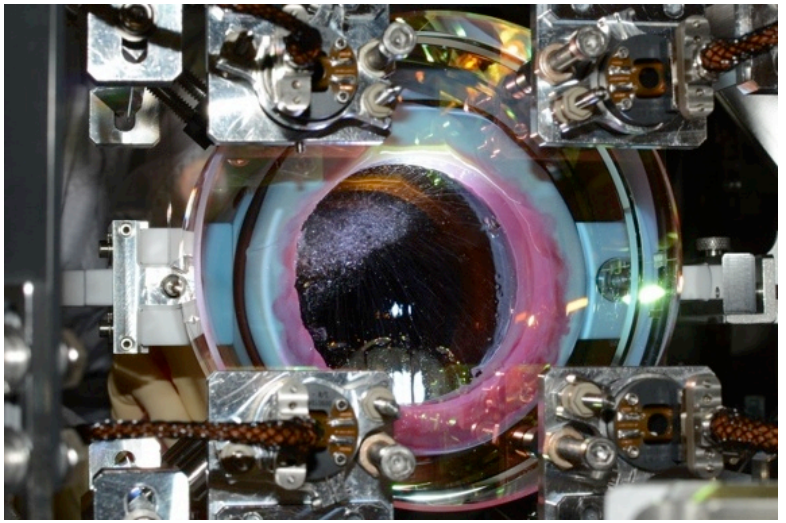
- No-contact cleaning approach aka cone of shame
  - Protective device for spray application of First Contact
  - Custom brushes

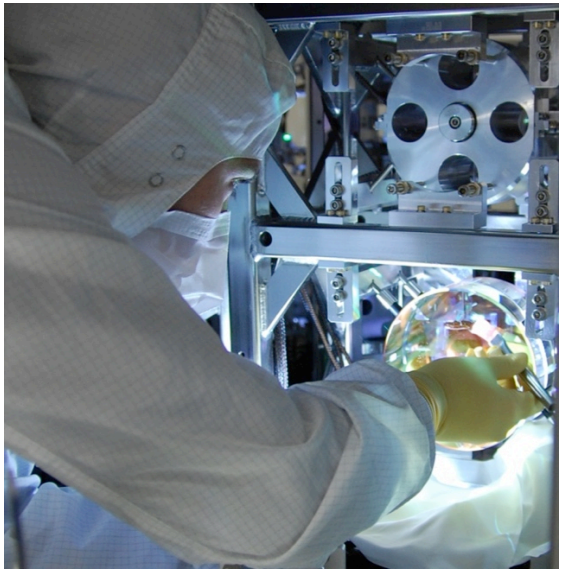


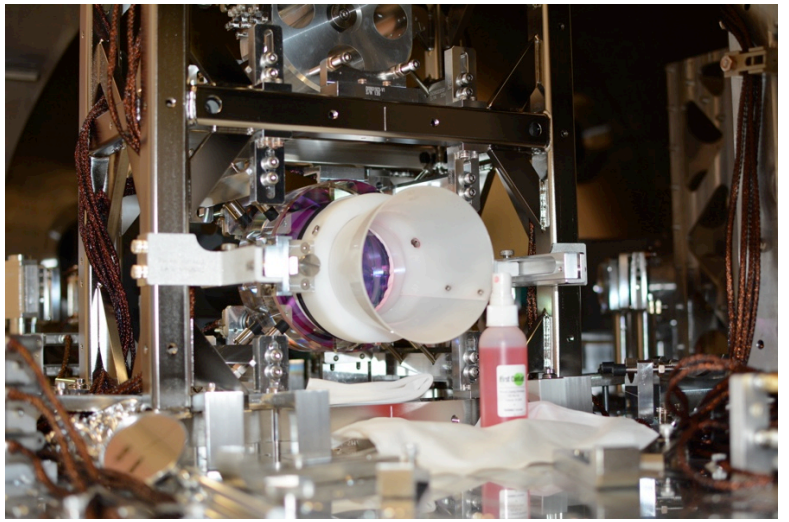


Cleaning & Protecting Suspended Optics

- No-contact cleaning approach aka cone of shame
  - Protective device for spray application of First Contact
  - Custom brushes
  - Successful application to MC







Cleaning & Protecting Suspended Optics

- No-contact cleaning approach aka cone of shame
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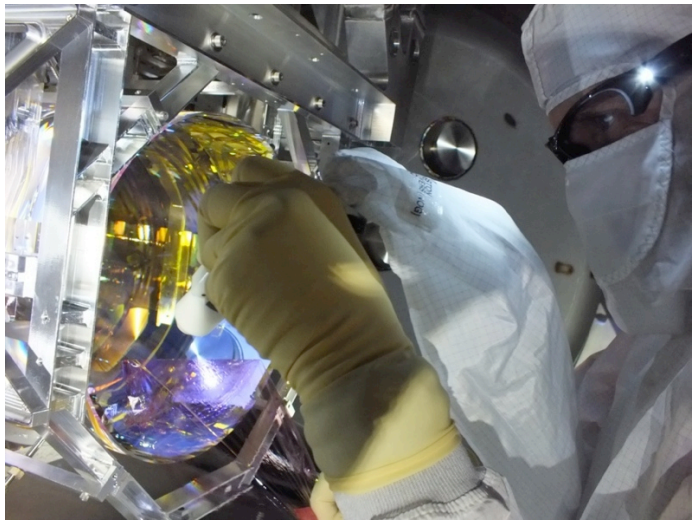
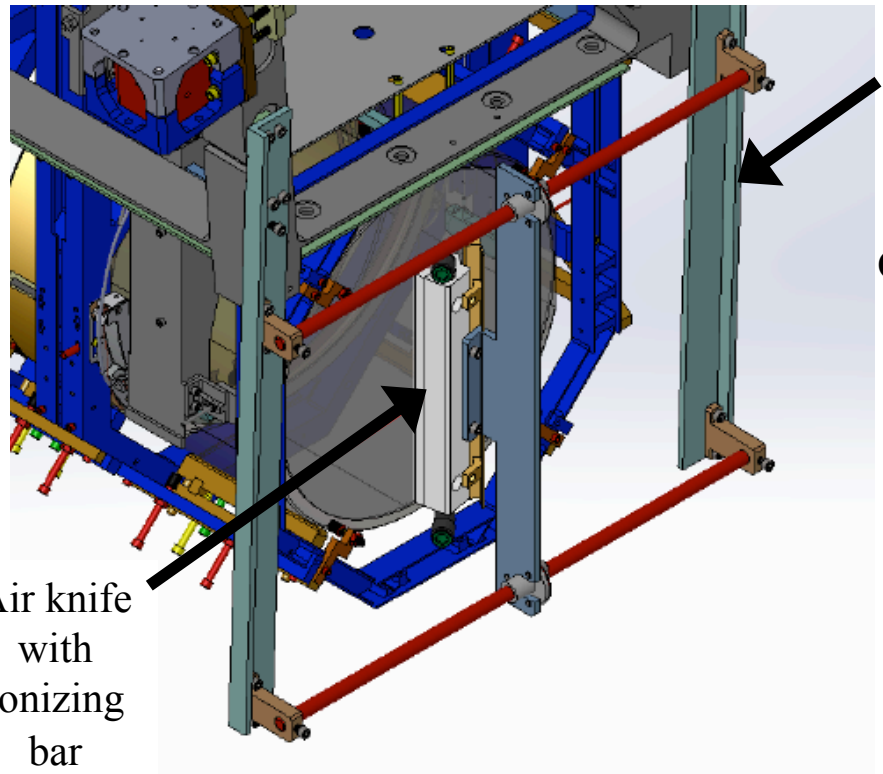
  - Custom brushes
  - Successful application to MC

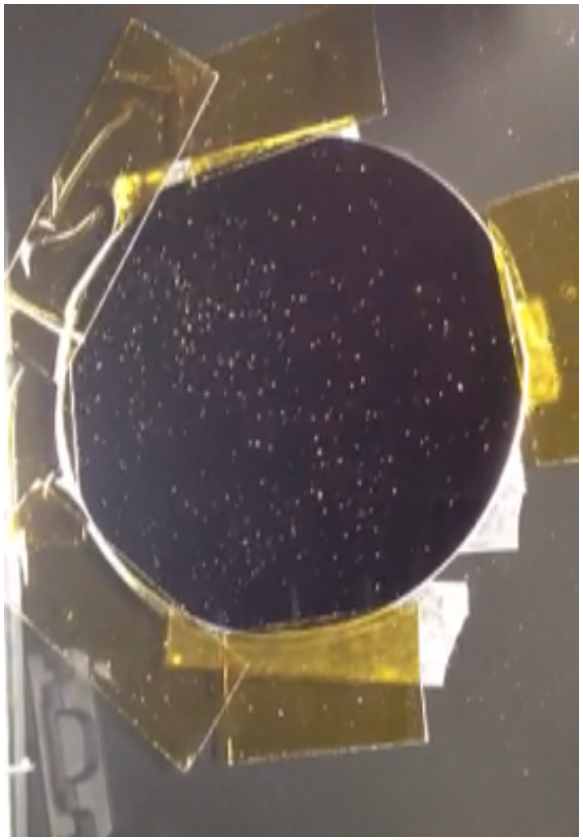


- Ionization gun aka Top Gun
  - Efficient cleaning
  - Rapid static discharge

Cleaning & Protecting Suspended Optics

- Currently researching:
  - Ionized air knife system
  - Delivers 1 sec pulses up to 250 psi





Conclusions

- Contamination is a problem without an quick, easy solution.
- There are many sources and causes of contamination.
- We should re-evaluate reasons for old practices and purchases.
- A lot can be learned from industry.
- We are taking steps in the right direction.

Contamination Control Working Group

Caltech – Calum Torrie, Margot Phelps, Kate Gushwa, and Jeff Lewis along with GariLynn Billingsley, Norna Robertson and Dennis Coyne

LHO – Betsy Weaver, Cheryl Vorvik, Jodi Fauver, Mike Landry, and John Worden

LLO – Bryan Smith, Danny Sellers, Gary Traylor, Matt Heintze, Brian O'Reilly, and Richard Oram

References

- **LIGO-T1300511-v1 Some thoughts regarding Particulate Contamination Requirements**
- LIGO-T080067-v1 Protecting Installed Optics from Particulates
- Contamination Control wiki
- LIGO-E0900047 aLIGO Contamination Control Plan
- LIGO-T1300093-v7 Prudential Body Box Results
- LIGO-G1300777-v2 Contamination Control Requirements – Gloves, Cleaning on the Go and The Plan (past, present, and future)
- LIGO-G1300427-v3 Slides for Contamination Control
- LIGO-T1300493-v1 "Known" Particulate Sample Poster
- LIGO-E1201096-v4 Contamination Sample Handling – How to receive, use, send, buy and store samples.