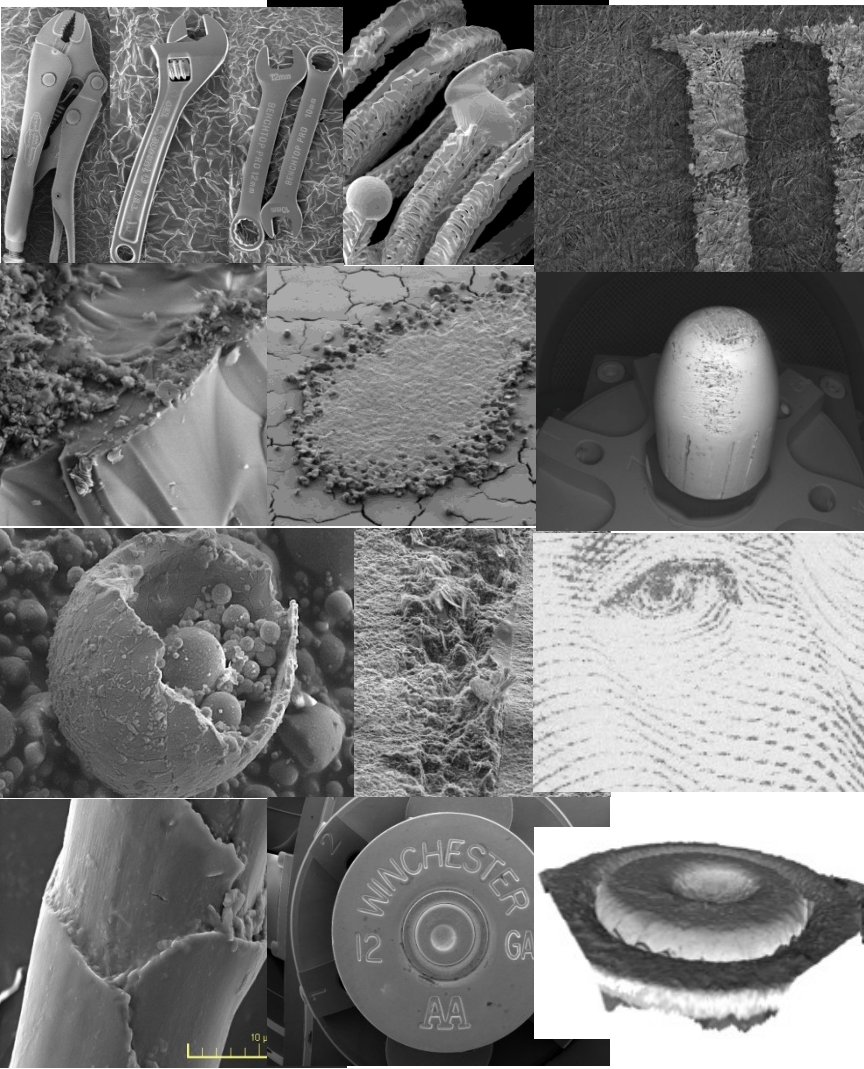


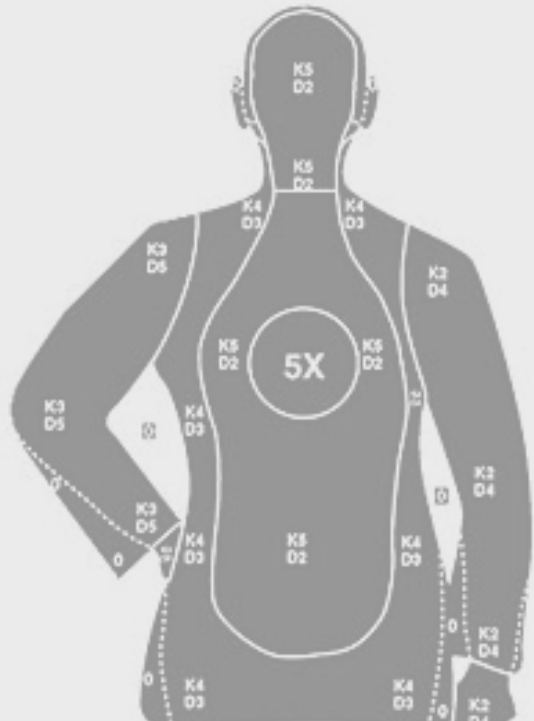
FYZIKA VE FIRMĚ

Martin Zadražil, 9.11.2011



Forensic Applications in SEM :

- Gun shot residue analysis (GSR)
- Bullets and cartridge investigation
- After car crash filament and bulb investigation
- Tool marks investigation
- Analysis of hairs, textiles and papers
- Paints, prints and ink analysis
- Counterfeit signatures, bank notes
- Minerals, soils and metals analysis
- and many others...



Gunshot Residuum analysis.

- Identification of the shooter
- According GSR particles on hands/clothes
 - Typical size, shape
 - Typical composition: Pb, Sb, Ba.

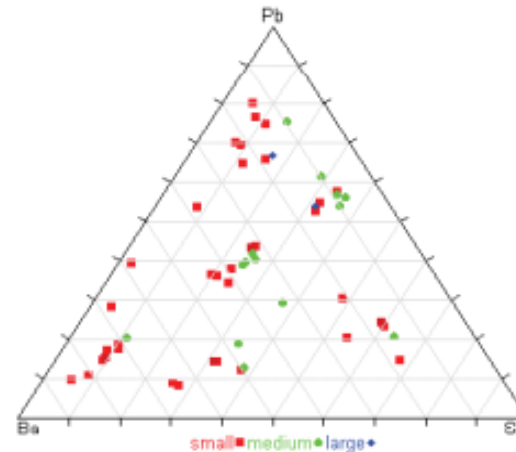
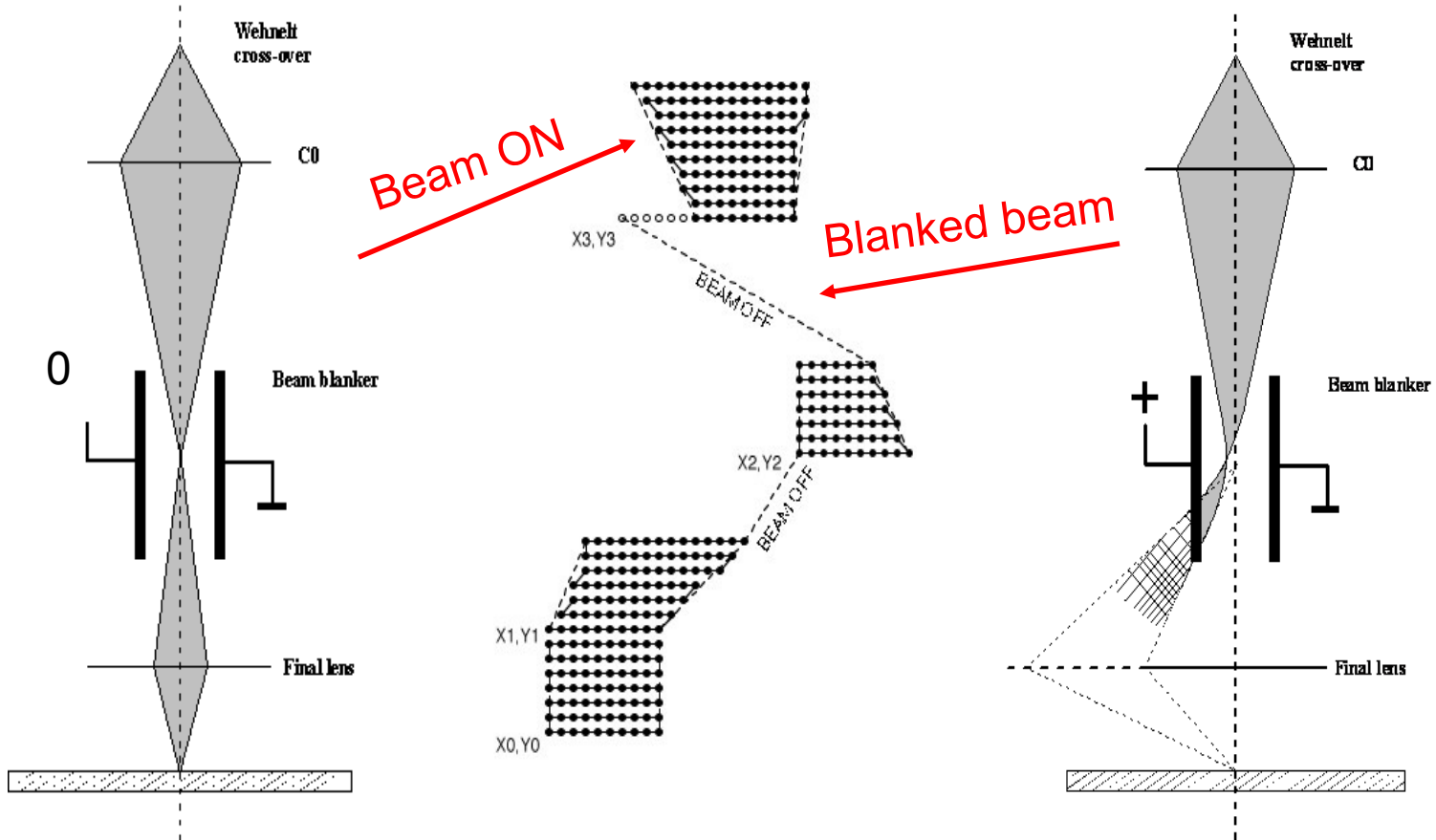
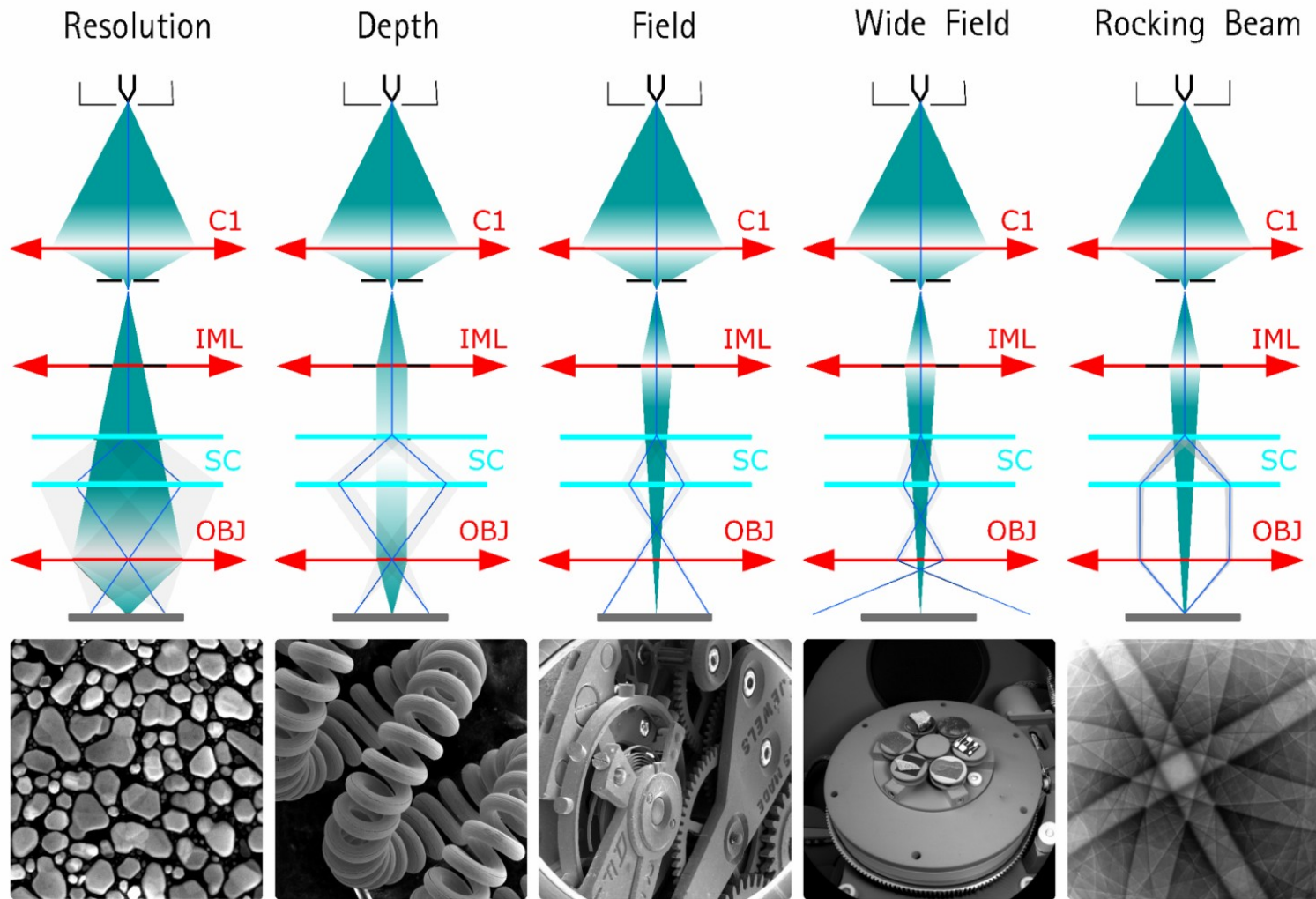


Fig. GSR Particles composition in ternary chart

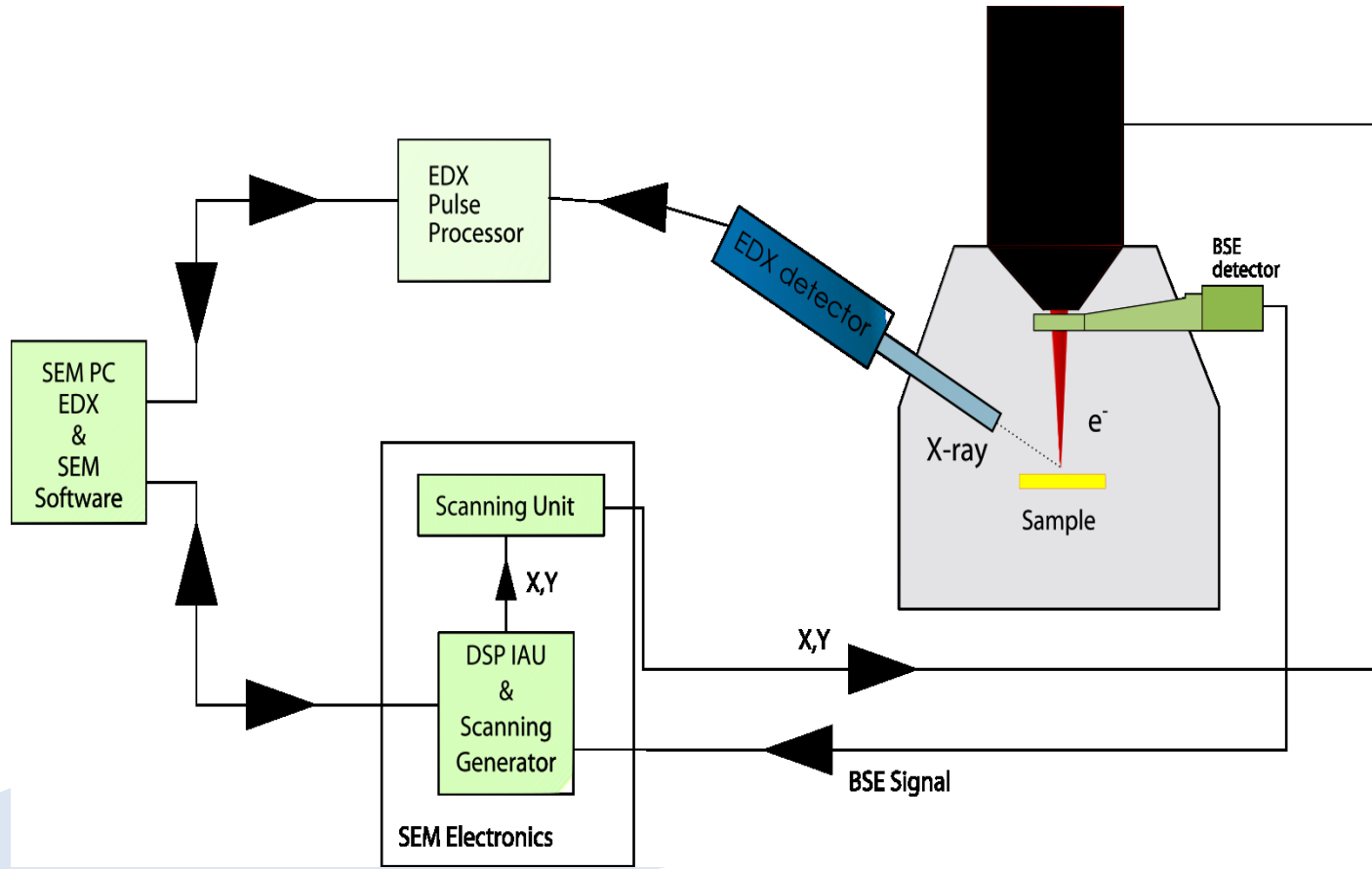
Beam interruption – Beam blanker



- Beam blanker electro-statically deflects the electron beam

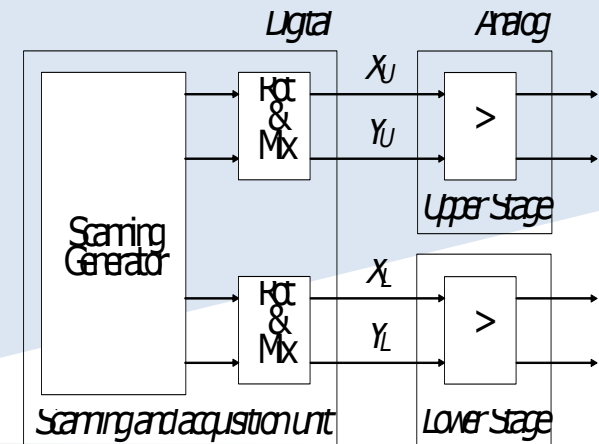
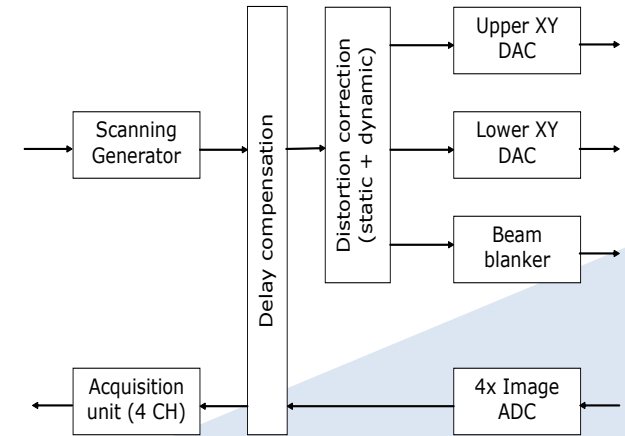


TESCAN TRACE GSR Hardware Integration



Scanning Generator

- Powerful 50 MHz internal Pattern Generator
- 2 x DAC for each stage of deflection coils (X, Y)
- 16-bit scanning ramp DACs
(65,536 x 65,536 virtual write field)
- Variable dwell time
- Static and dynamic distortion correction
- Digital compensation of field errors
- Automatic control of electrostatic beam blanker (10 MHz)



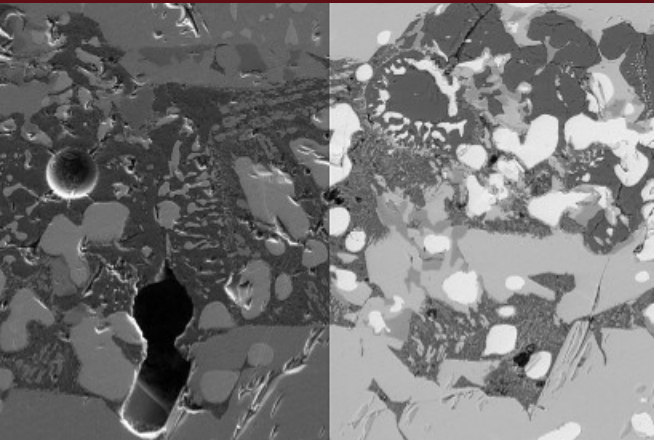


Fig. On-line SE/BSE signal mixing

Dwell/pix	1Mpix	100 fields analysis
50 us	50 s	> 1 hour
100 ns	0.2 s	< 3 min

Fast detectors save time!!

Synthetic YAG crystal

- High efficiency – low noise
- Fast response
- Unlimited lifetime
- Suitable for high vacuum



SE – Everhardt-Thornley type with YAG

Fast imaging rate (20ns/pix)

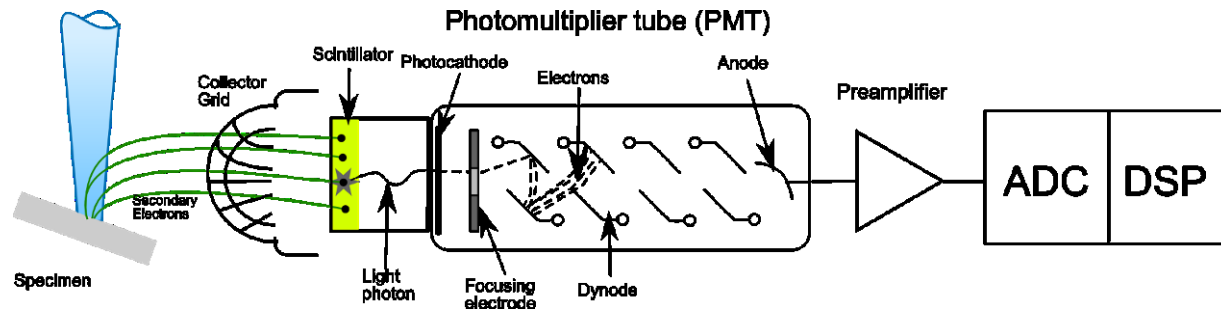
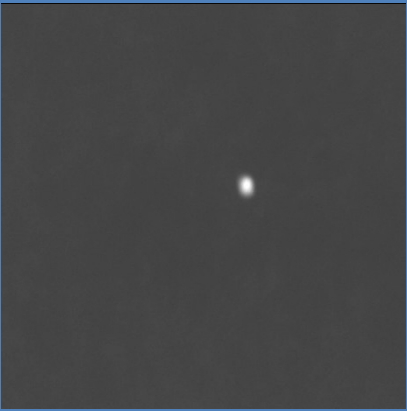


Fig. Everhart-Thornley SE Detector



*Fig. Phase identification by material contrast
Used for GSR particles location*

Backscattered Electron Detector

- Crucial for GSR applications
- Detection of particles containing heavy elements



Tescan R-BSE detector

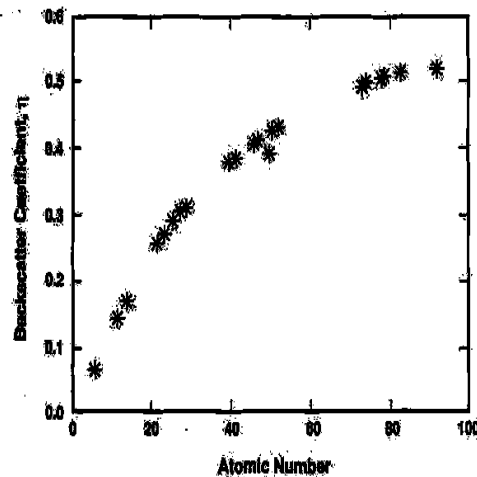


Fig. Dependency of BSE intensity on Atomic number

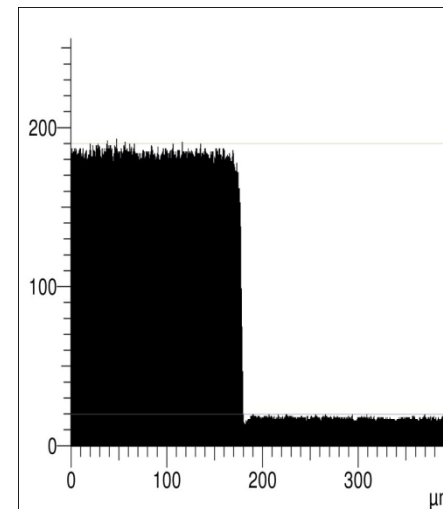
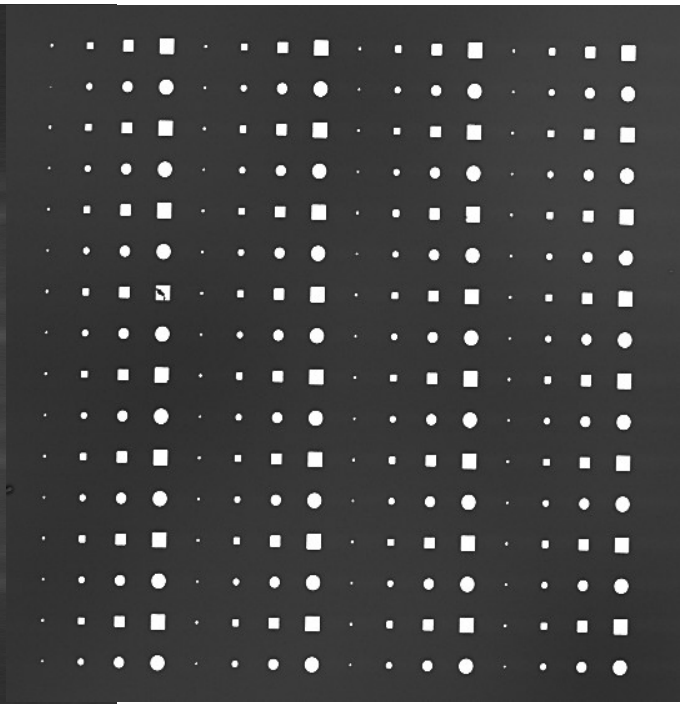
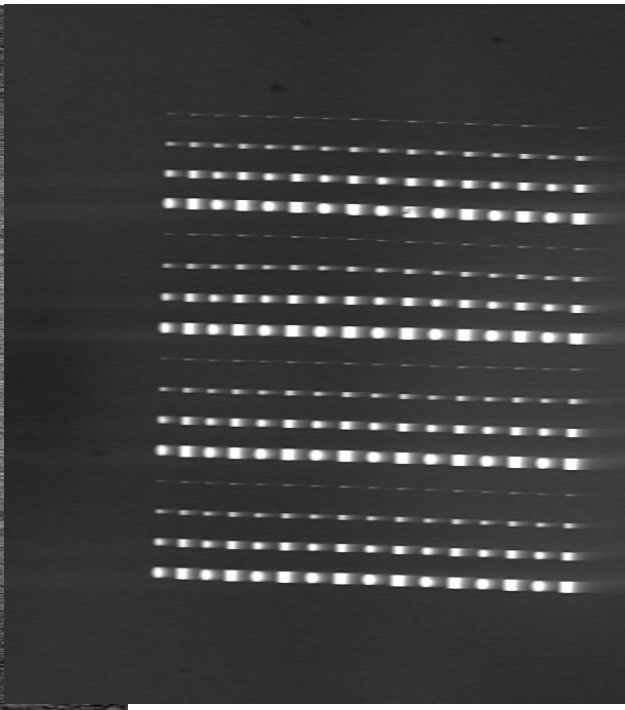
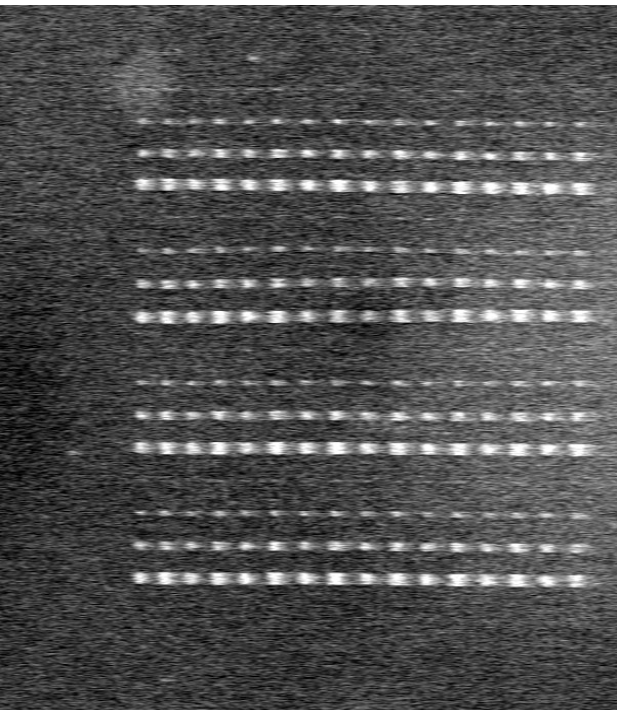


Fig. Thresholding on a calibration sample

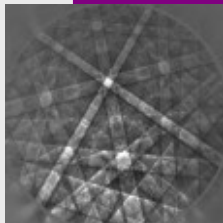
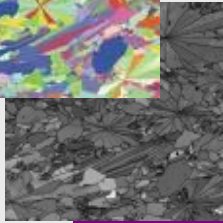
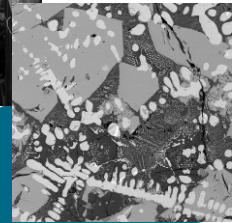
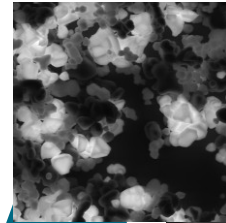
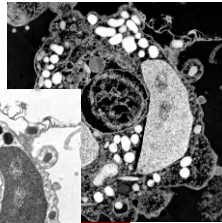
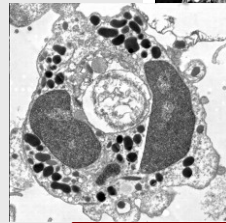
Testing sample: Gold on Si imaging standard



*Low-end solid-state BSE
detector
1us/ pixel*

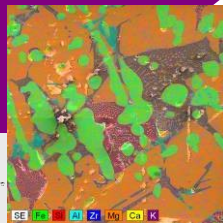
*Middle-class scintillation BSE
detector
500ns /pxl*

*Latest generation
Tescan YAG scintillation BSE
100ns /pxl*



**EDX-1s

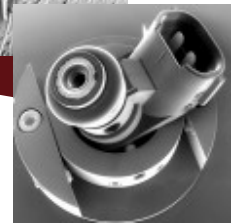
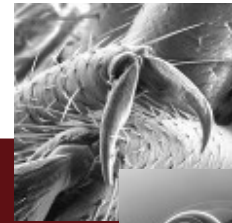
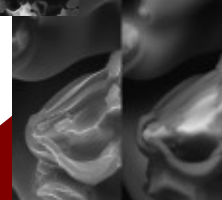
EDX/WDX



SE Mg Al Zn Mo Cu K

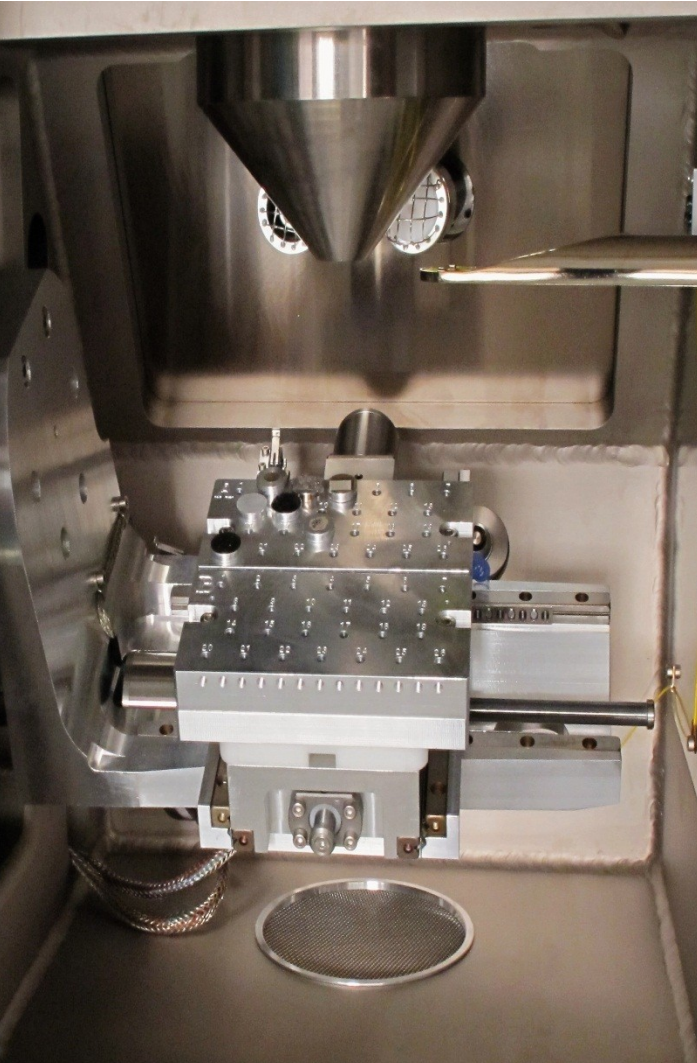
TEI

CL



Other accessories

EBIC, Absorbed current measurement, IR chamber view camera and many other



Stage movements

During GSR analysis the sample is divided into individual fields. Location and analysis of the particles is done field-by-field using stage movements.

Positioning accuracy is critical parameter for GSR analysis.

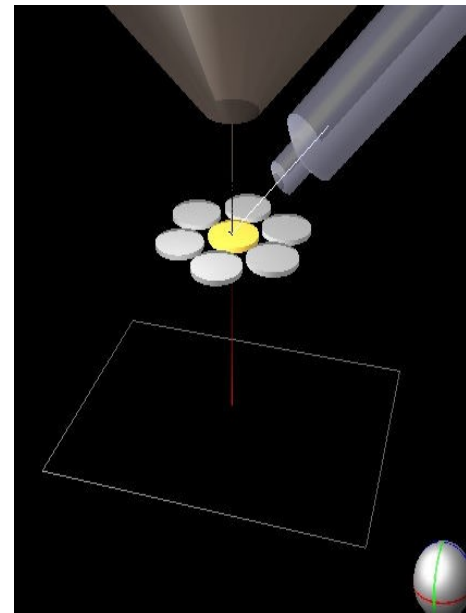
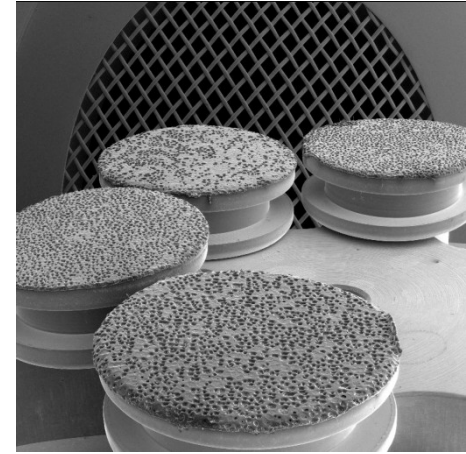
Tescan XM Stage:

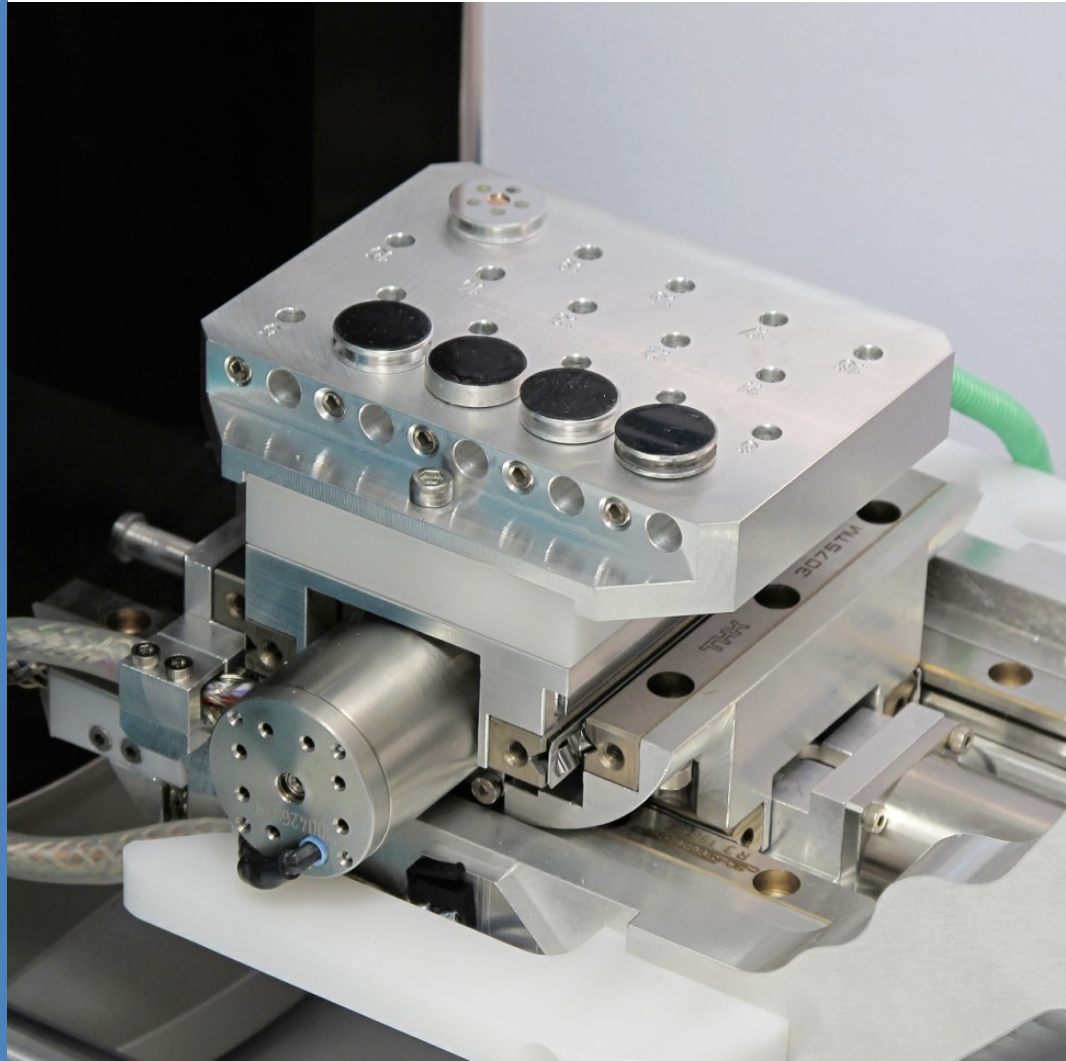
XY Range : 130 x 130 mm

Min. Step : 300 nm

Relocation accuracy: < 2µm
guaranteed

Speed: 5 mm/s





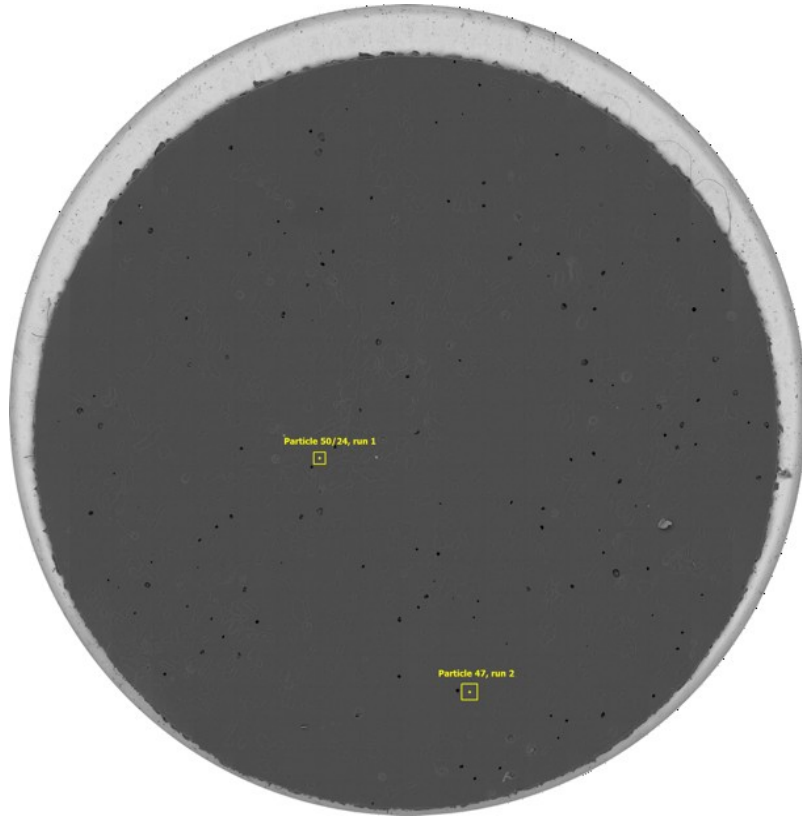
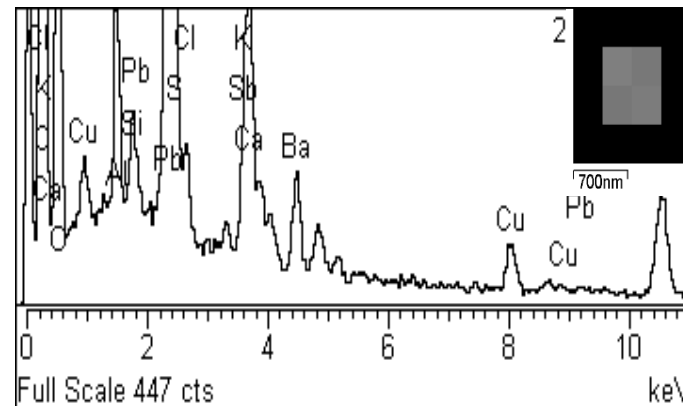
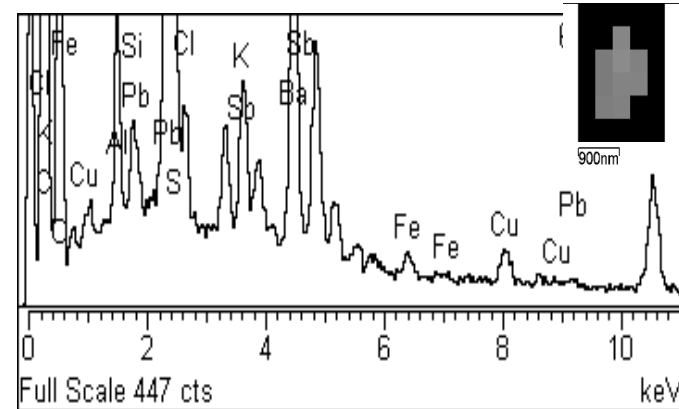


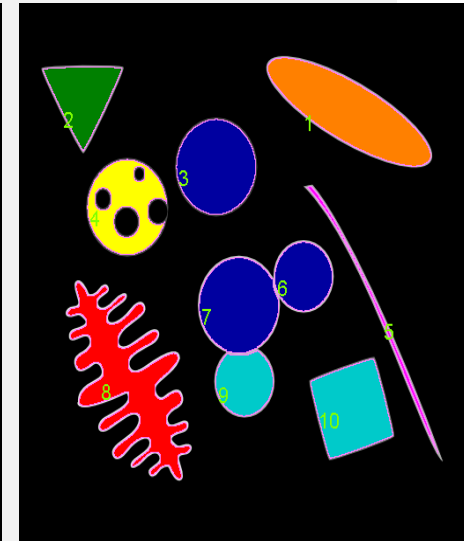
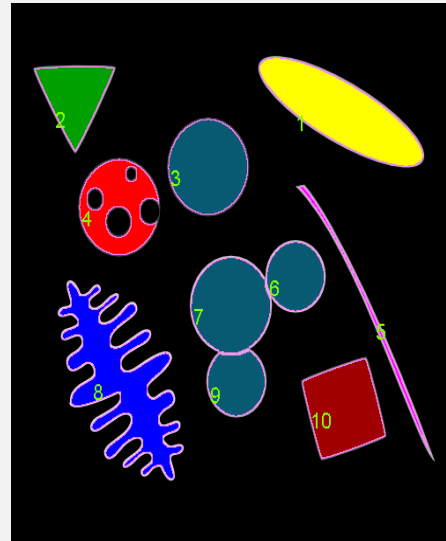
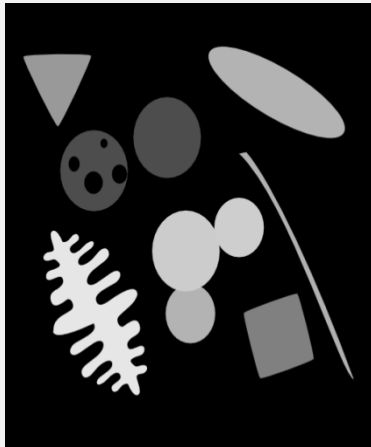
Image montage from 1048 BSE image fields with two submicron GSR particles found from totally 48 detected particles.



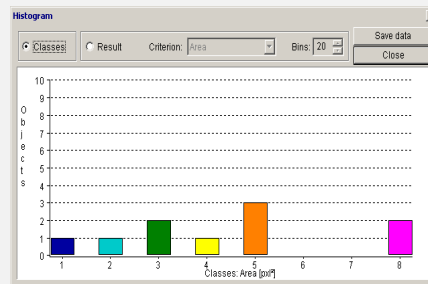
Classification by Area

Classification by Roundness

Classification by Extension (Compactness)



- Object size and shape classification
- Over 40 parameters
- Object filtering
- Statistical output



Roundness:

$$R^2 / (4 * d * Area)$$

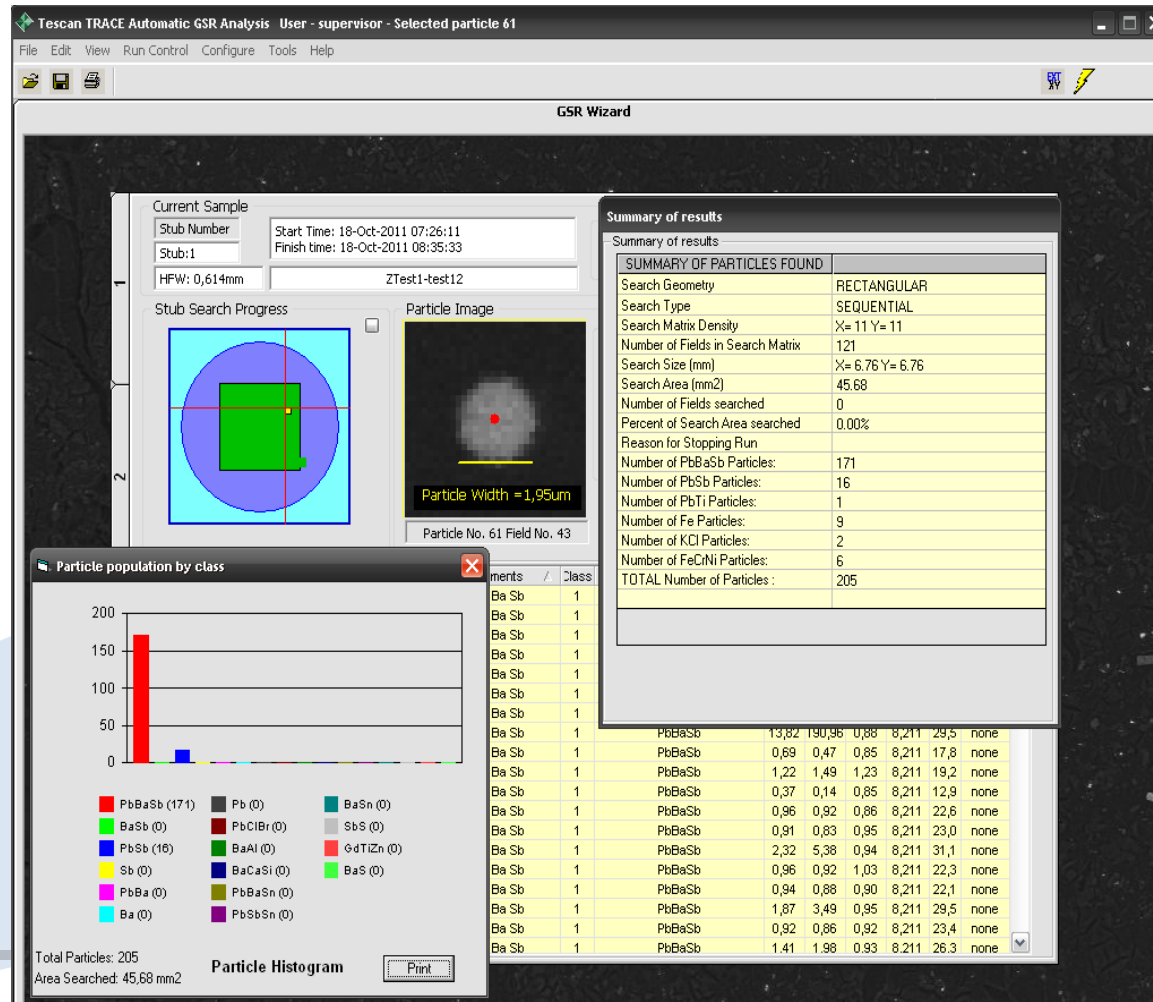
- Circle = 1
- Square = 1.3
- Triangle = 1.5
- Ellipse = 2
- Dendrite ~ 15
- Thread ~ 25

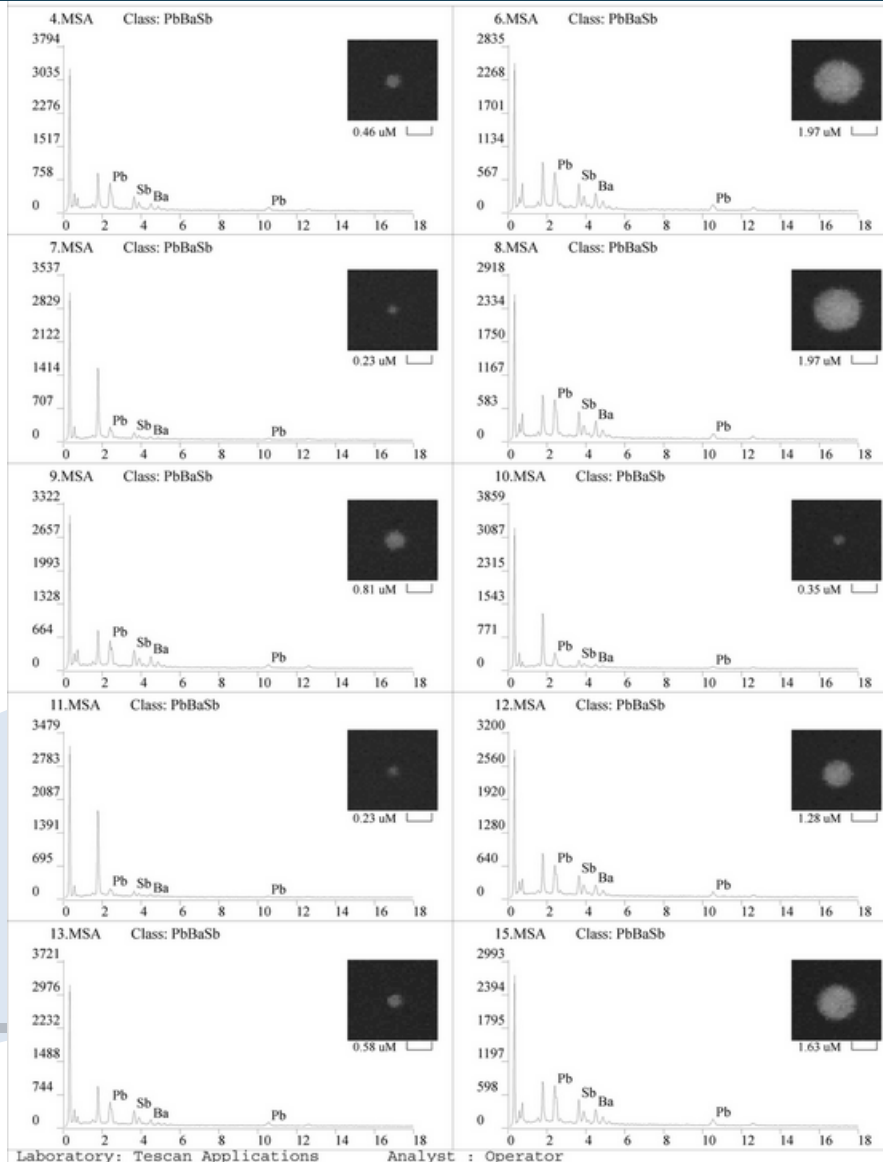
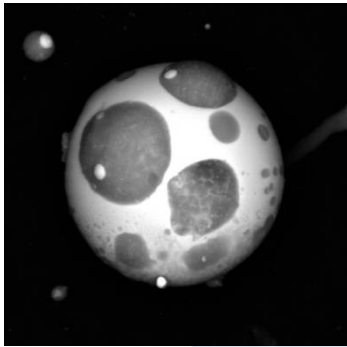
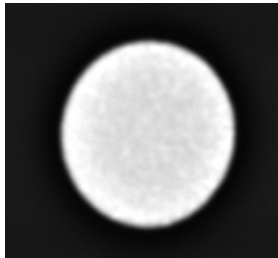
Extension:

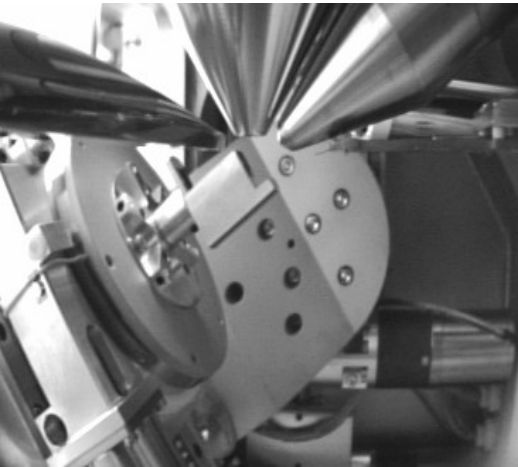
- Circle = 0
- Square = 0.3
- Triangle = 0.5
- Ellipse = 2.5
- Dendrite ~ 4
- Thread ~ 14

TRACE GSR Results

	Plano GmbH	TESCAN, a.s.
10/15/20 μm	3	3
0,5 μm	38	36
0,7 μm	30	29
1 μm	33	32
1,5 μm	32	30
2 μm	27	27
2,5 μm	27	27
total no.	190	185







Nanomanipulators

E-Beam Blanker

SE

FEG SEM

FIB

EDS

GIS

BSE

EBSD



Fig. Tescan LYRA Demo as installed on EMC Aachen 2009

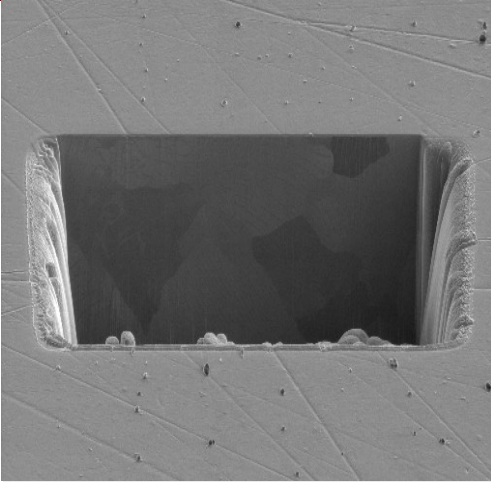
SEM objective lens

One Coincidence Point for All Parts

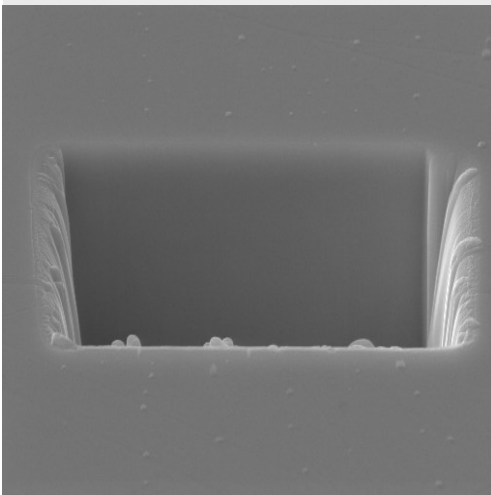
FIB column nose

GIS stage with
nozzles





SE imaging FIB ▲, SEM ▼



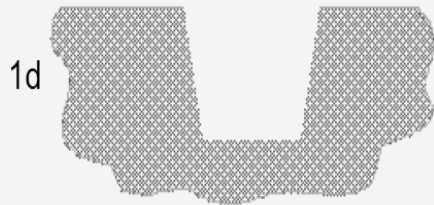
Ion Beam Imaging

- SE generated by ions
- Ion imaging resolution < 5 nm
- ✓ High surface sensitivity with ions
- ✓ High channeling effect contrast
- Ion imaging is destructive!

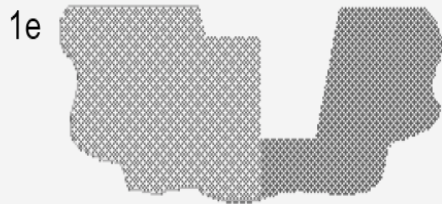
Electron Beam Imaging

- SE generated by electrons
- High Electron Imaging Resolution
- Lower surface sensitivity especially for light elements
- ✓ Nondestructive - reason for “dual beam” systems

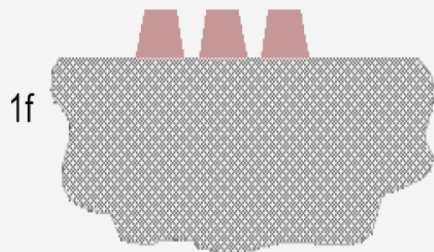
FIB + GIS



Enhanced Milling (Etching)



Selective etching



Material deposition (*)

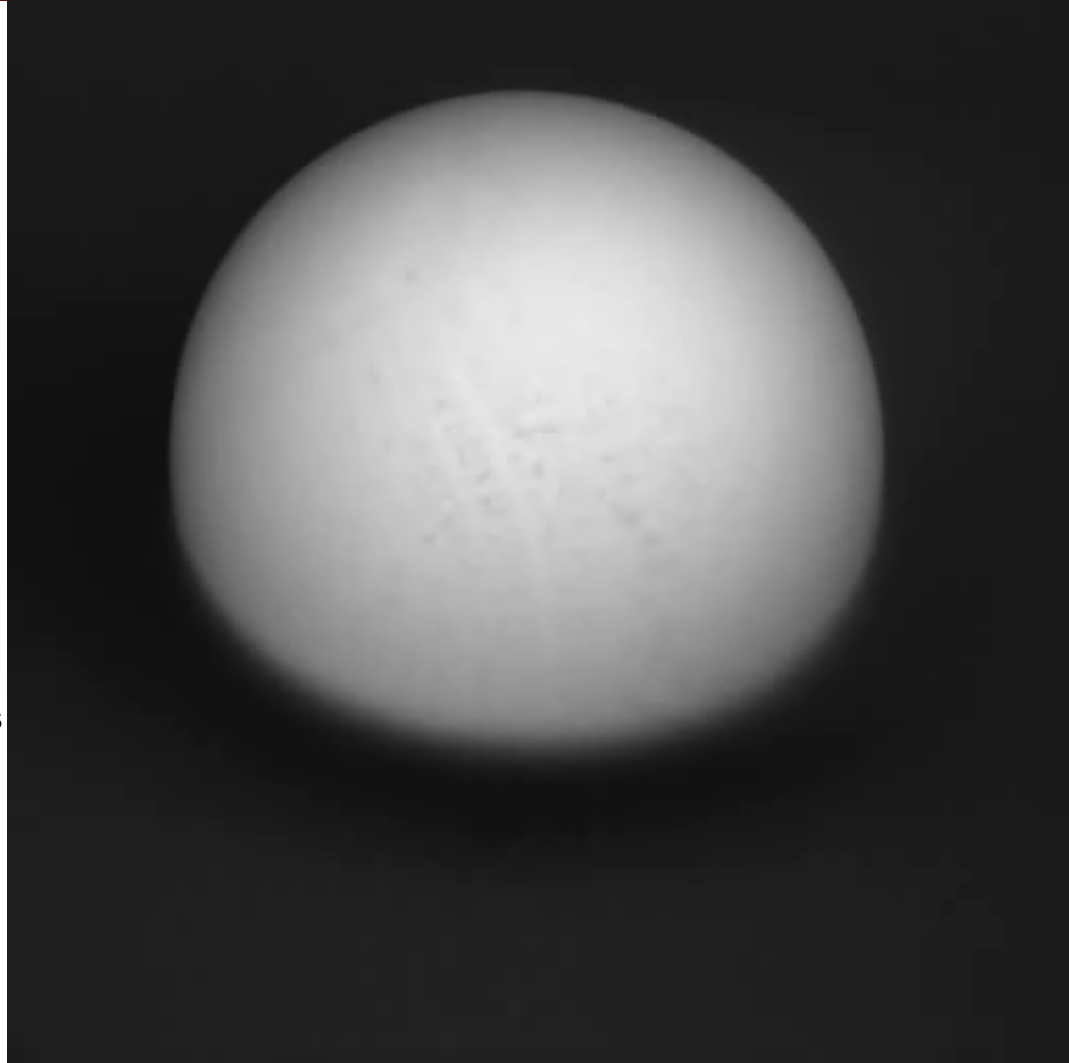
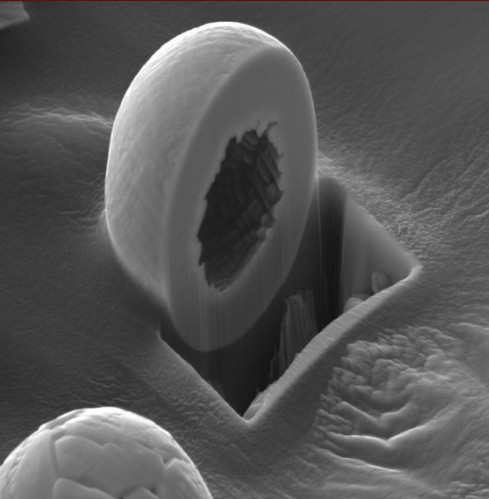
FIB + GIS Capabilities

- Enhanced Milling (Etching) – examples: XeF_2 enhances Si, SiO_2 and W etching by factor of 5-100 times; H_2O of PMMA and diamond 10-20 times
- Selective Milling (Etching) – combination of enhanced and reduced milling. Examples: H_2O greatly reduces etching of Al, Si and SiO_2 ; XeF_2 of Al.
- Material deposition – Adsorption of the precursor molecules on the surface, ion beam (or e-beam) induced dissociation of the gas molecules, deposition of the material atoms (e.g. Pt, W, C, SiO_x).



Common SEM+FIB Applications

- Nano-structuring
- IC process inspection and failure analysis
- Nano-tomography
- Local cross-sectioning, thin film thickness measurement
- TEM sample preparation
- Biology
- Materials science
- Mineralogy
- Fossils analysis
- Forensic applications



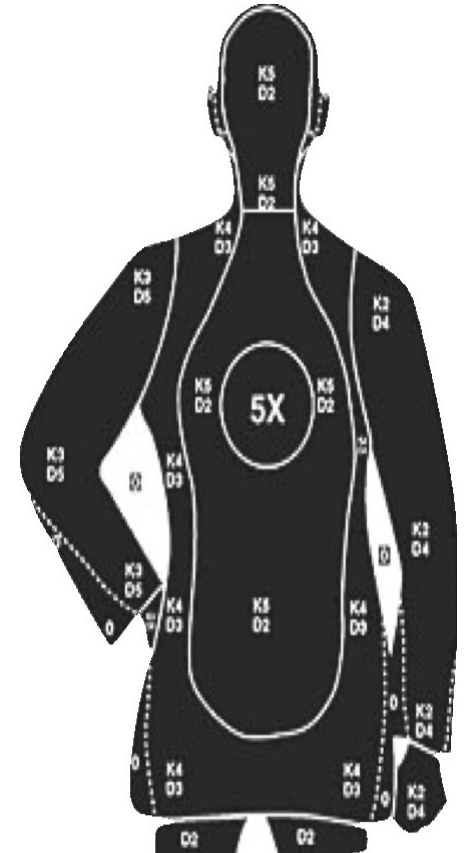
Forensic Application

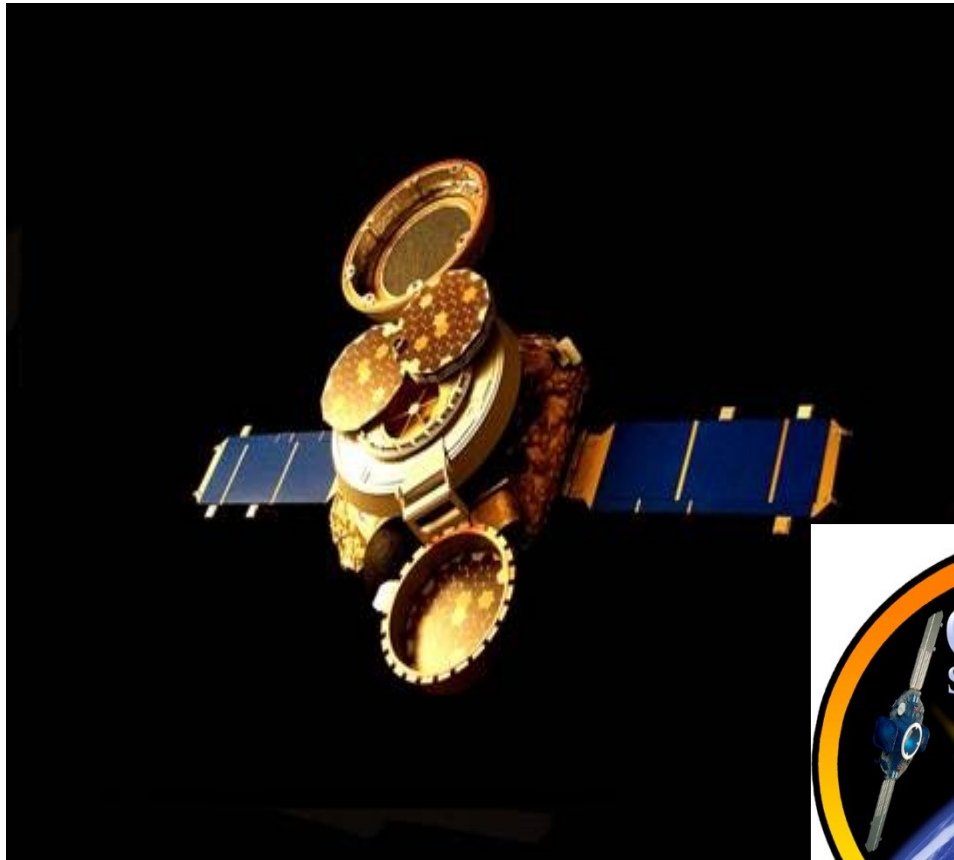
Gun Shot Residue Volume Analysis

**Simultaneous
imaging** of the milling
process.



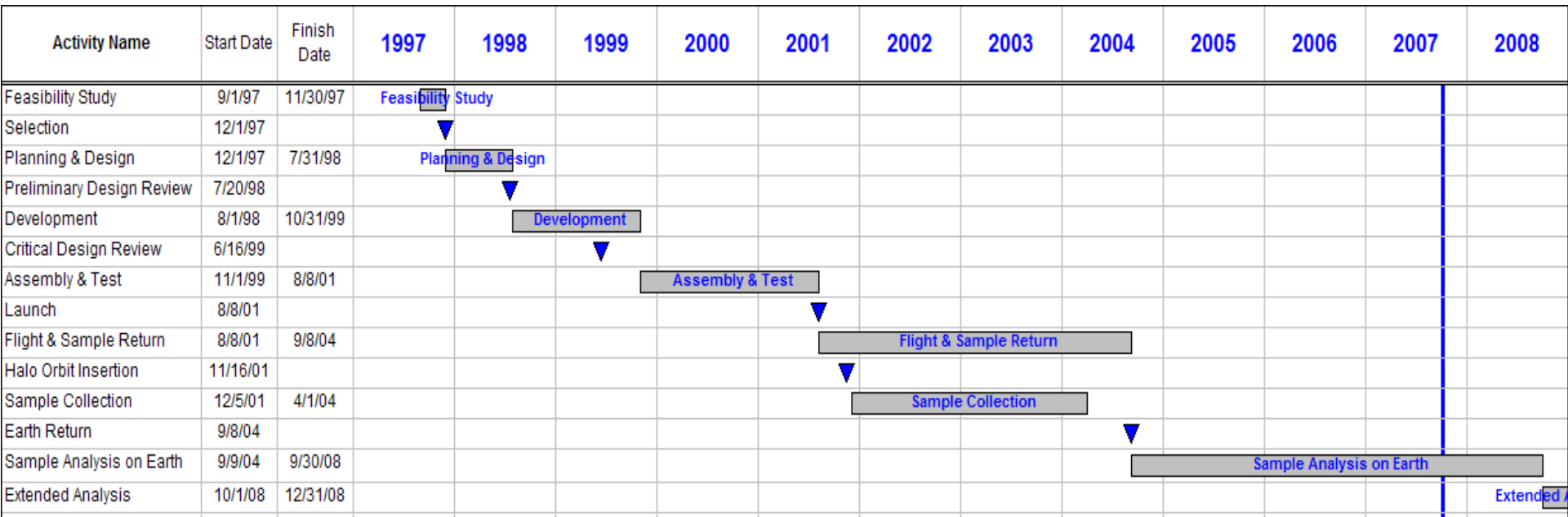
Questions ?



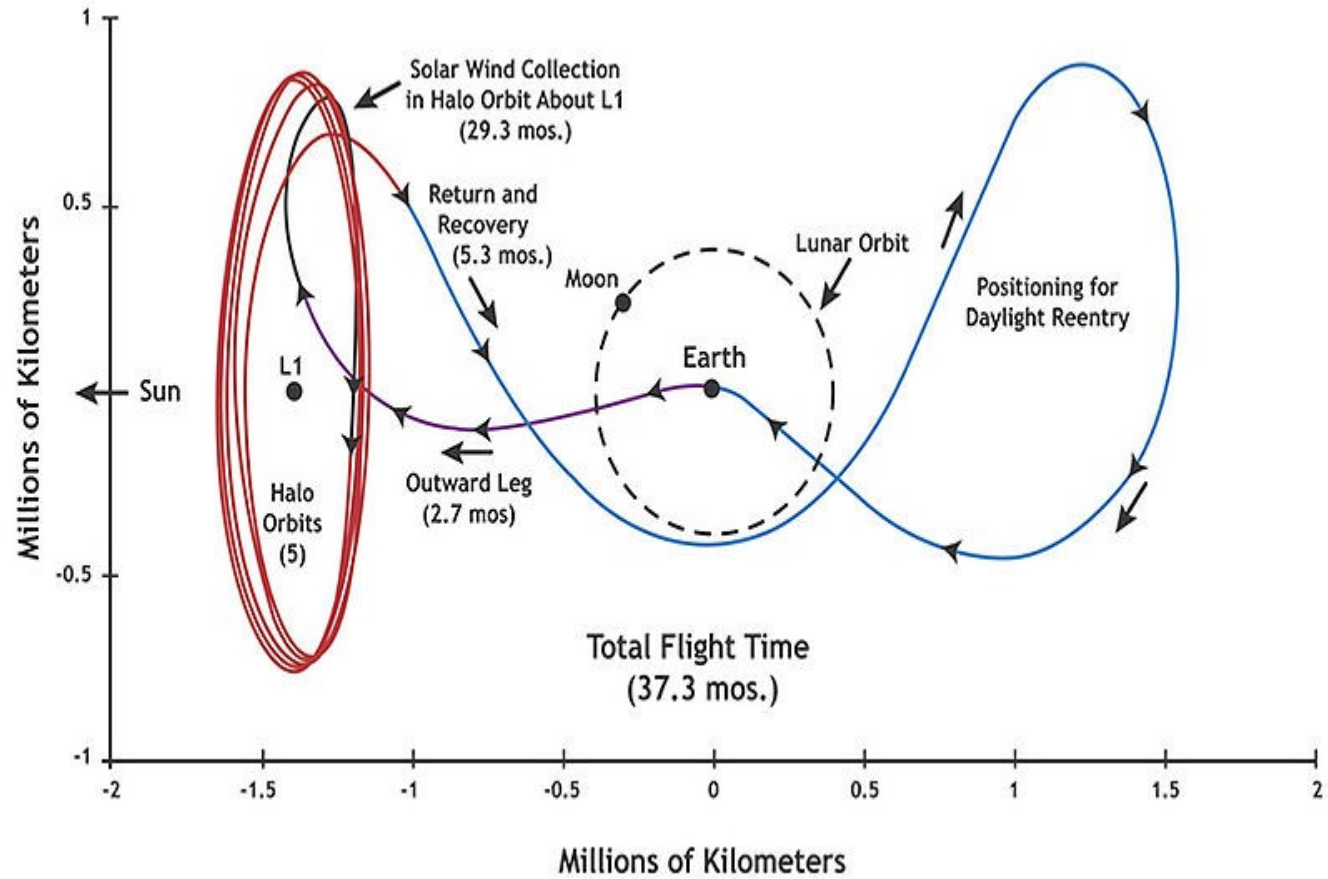


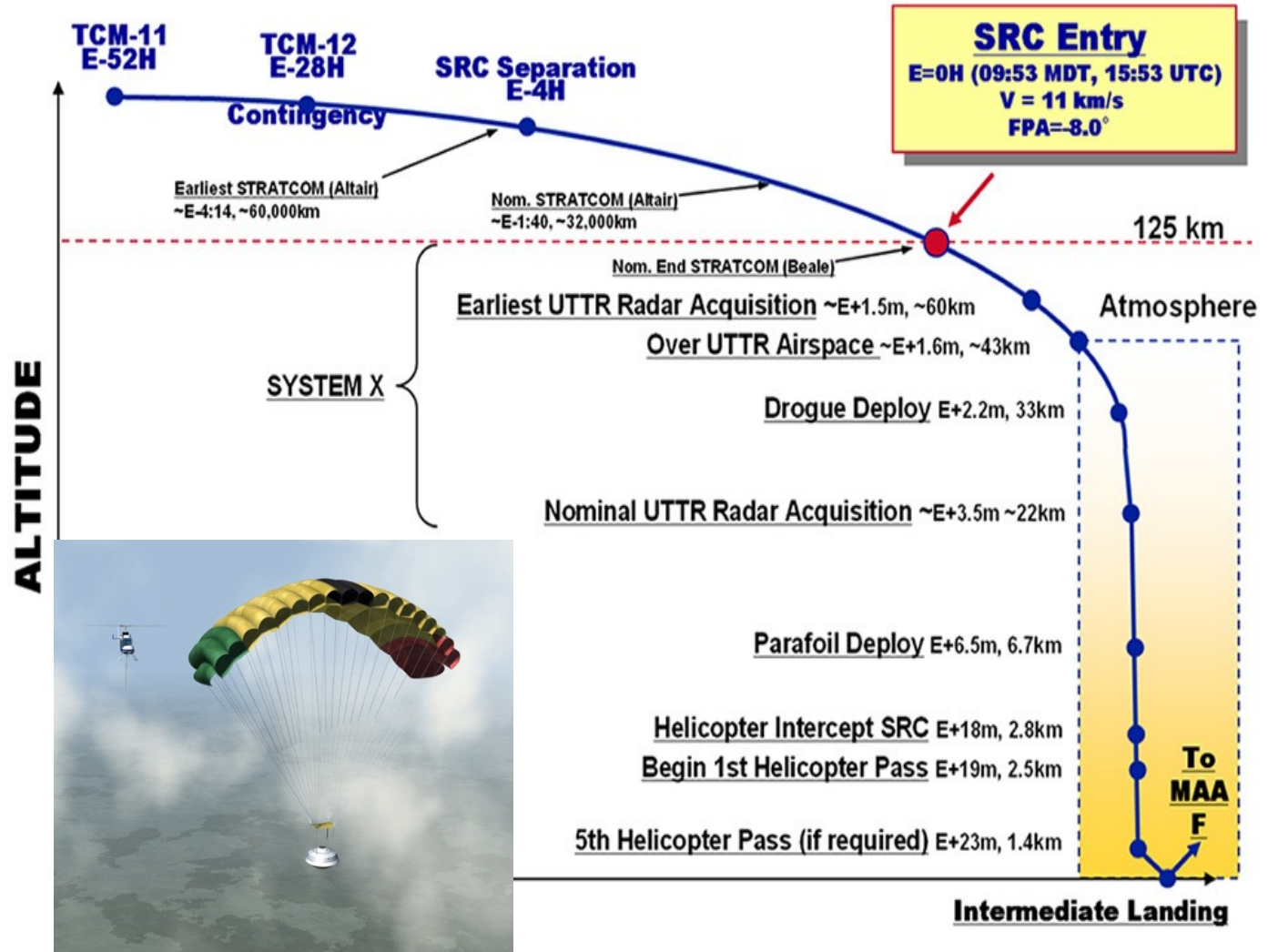
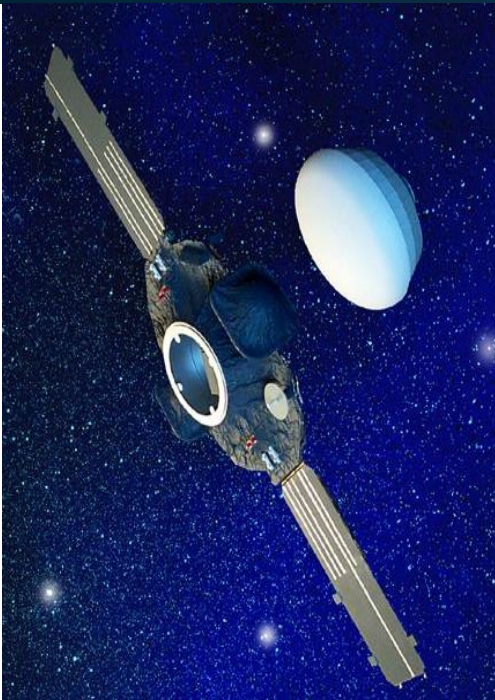


The collectors after assembly on Earth before flight



Genesis Timeline







Although the mission was a success with solar wind atoms implanted into the collectors, the return to Earth was **'non-optimal'** with the parachutes failing to open.



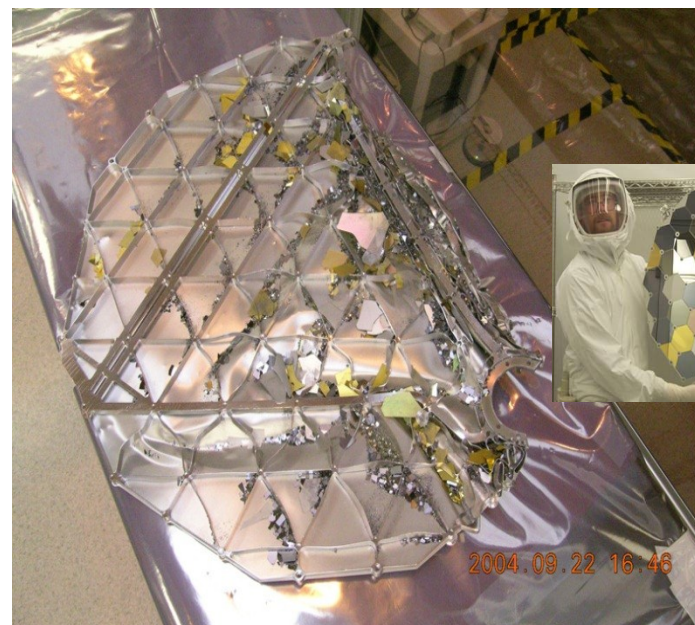
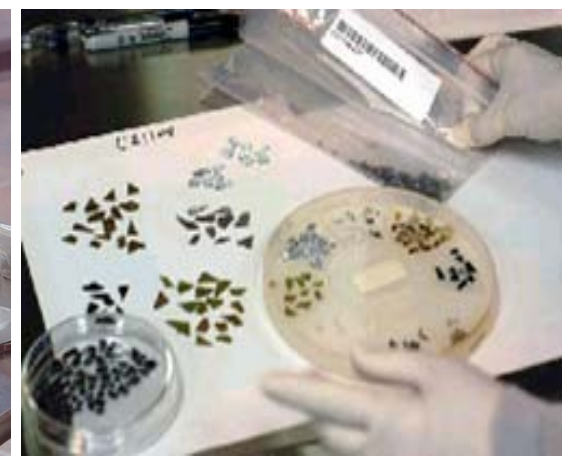
Gravity switch



Monument
purchased and
designed by
Genesis team
members to
commemorate the
return to Earth



Hundreds of collector fragments were retrieved

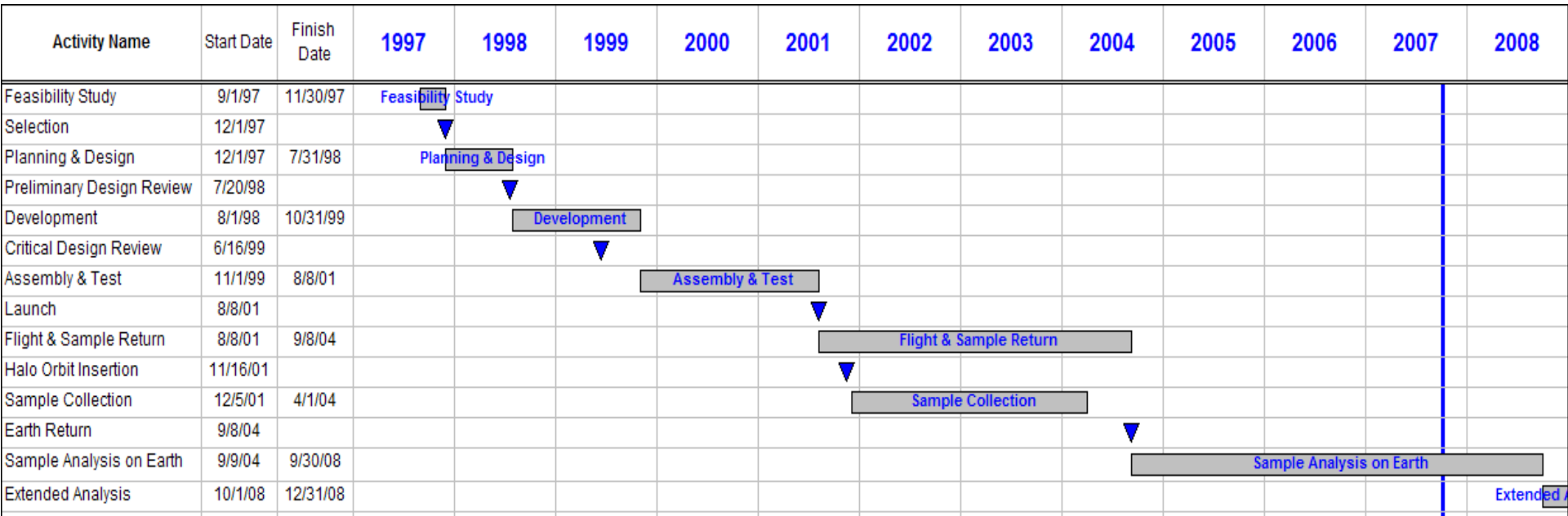


Backside of
Collector Array



Gold Foil Collector –
post landing





Genesis Timeline

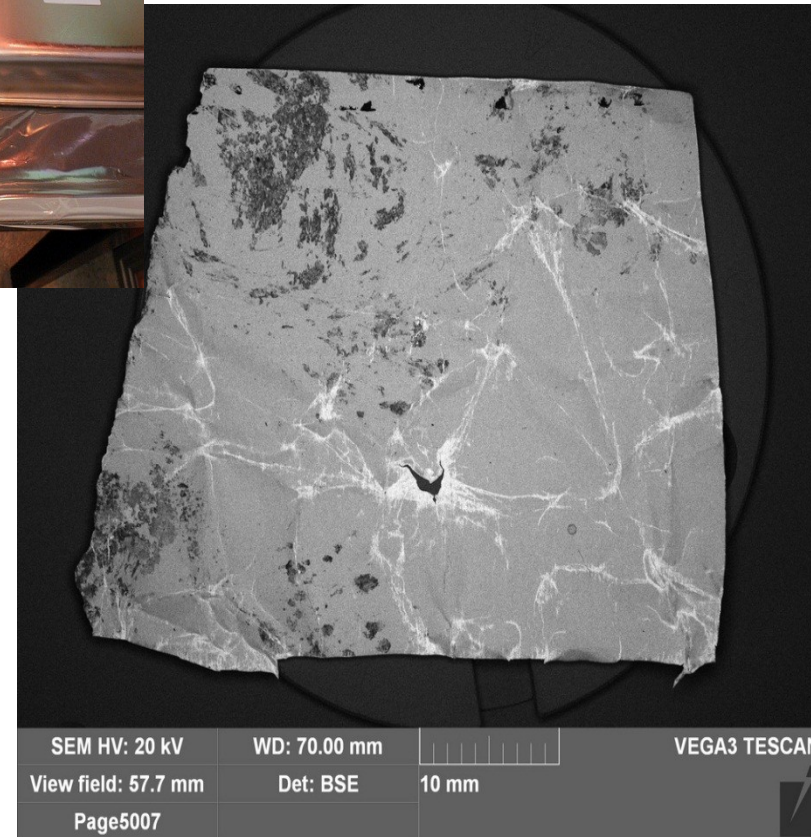
Value & Excellence in SEMs



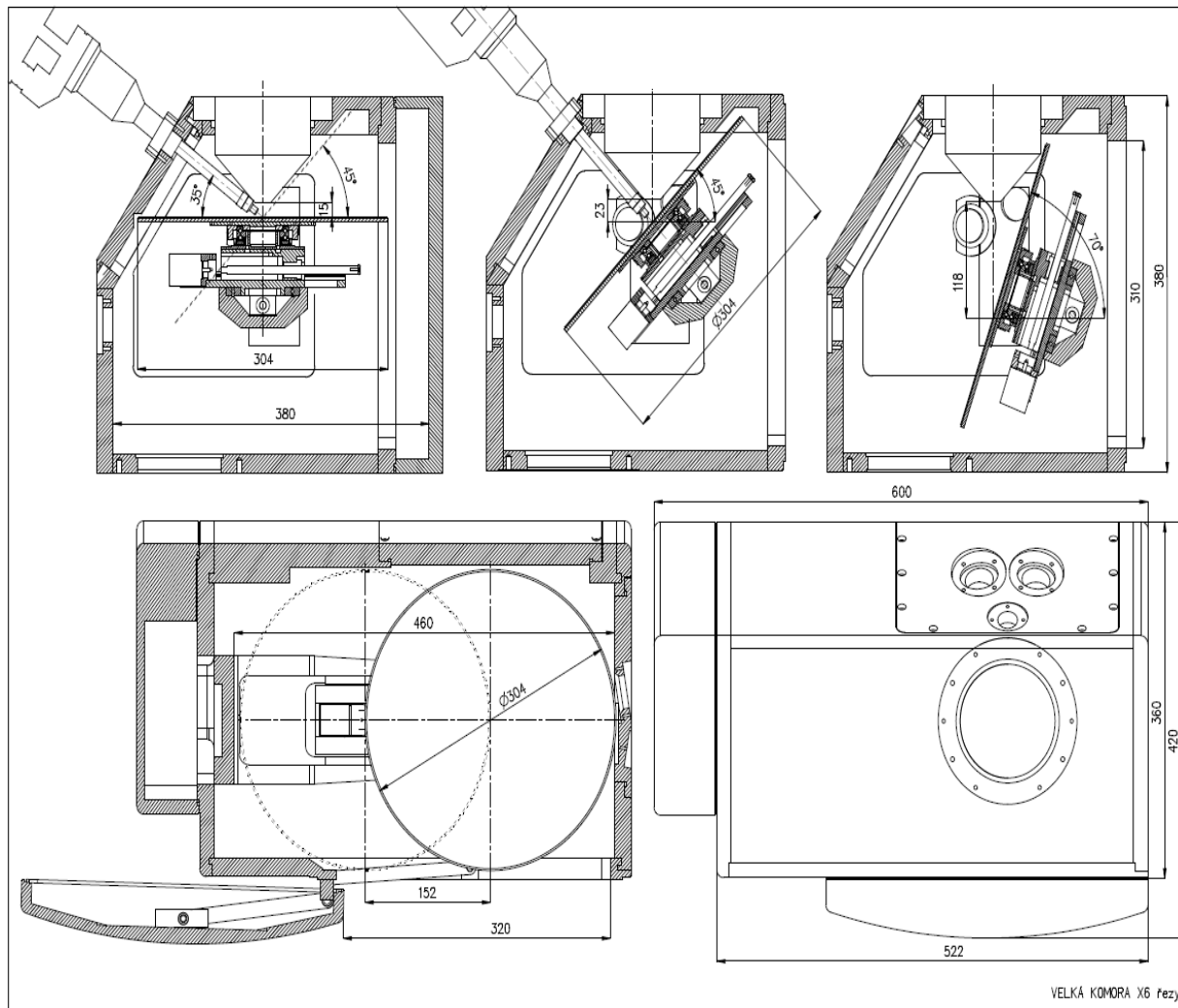
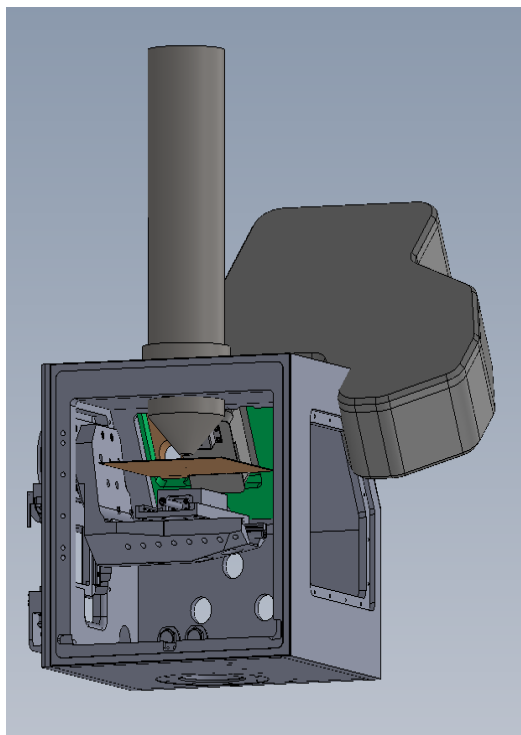


< Gold Foil Collector – post landing

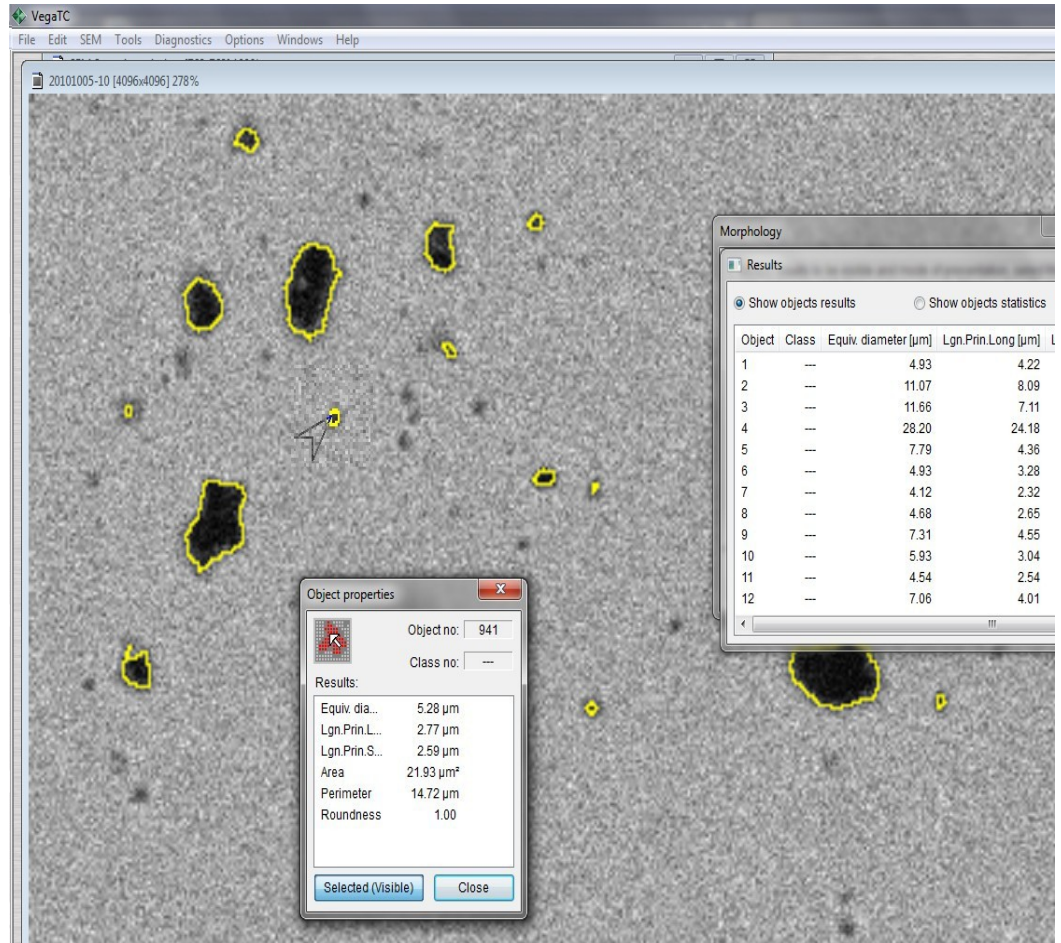
REQUIREMENT> SEM-EDS instrument with the ability to perform fast, automated detection, location and quantification of 10- μ m clay-based dirt particles, molybdenum coating and platinum substrate over the entire area of minimum 16 cm x 16 cm square) crumpled Pt-Mo foils. Approximately 8000 cm² Pt-Mo foils will be imaged in total. **Gold Foil Post-landing**



VEGA 3 XMU – X8M5



VELKÁ KOMORA X6 řezy



TESCAN's automated particle analysis