Data Interpretation in Nuclear Forensics

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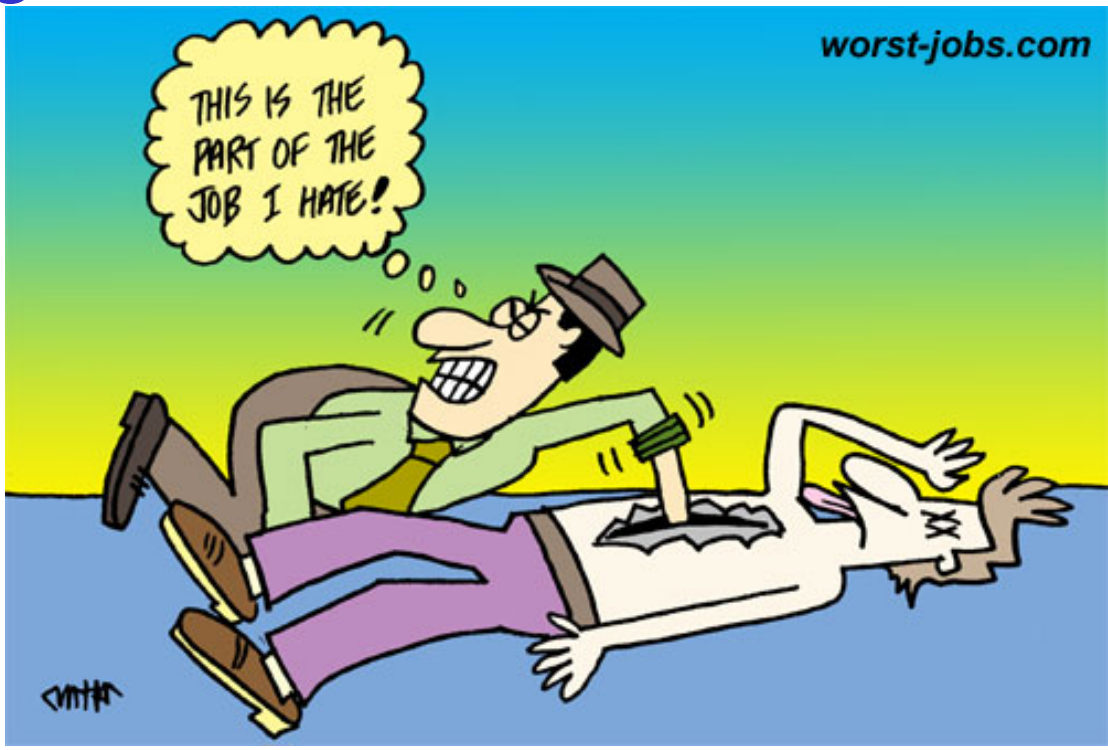
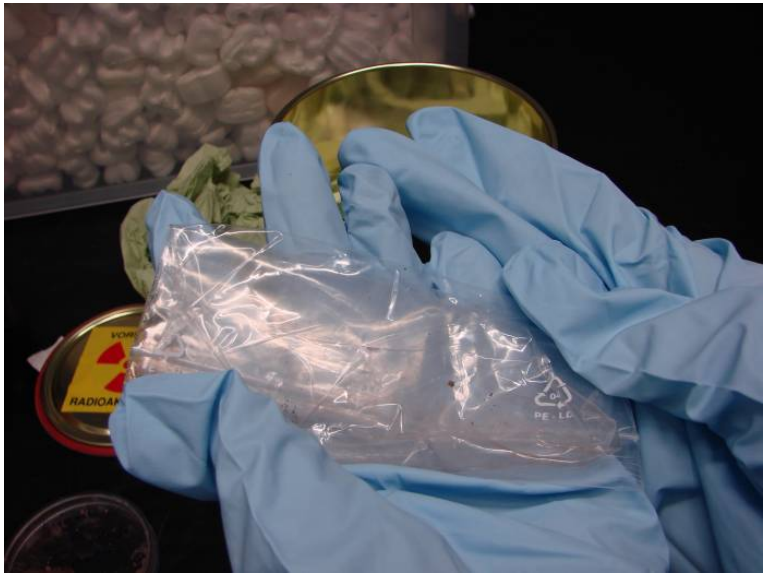
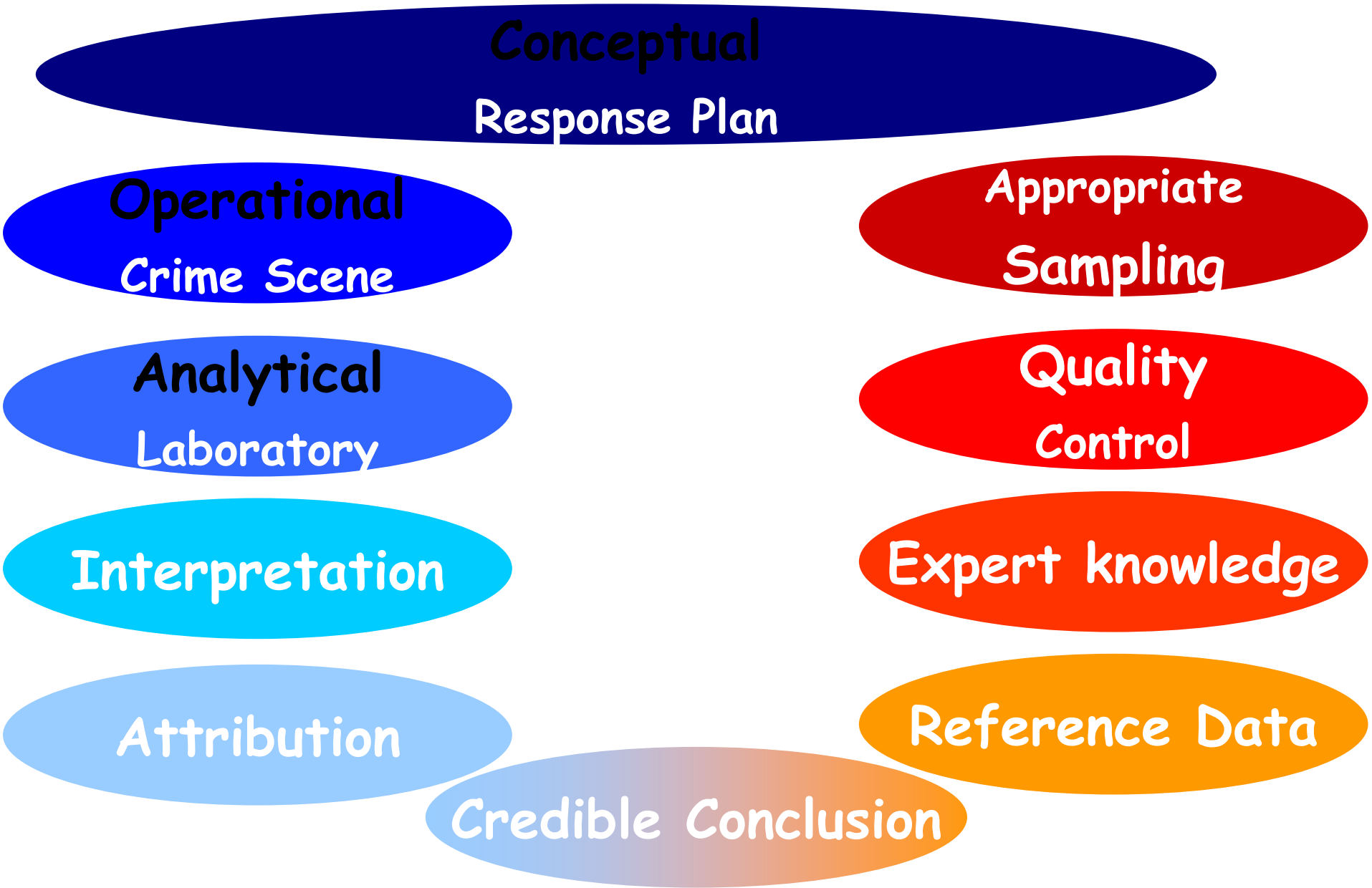


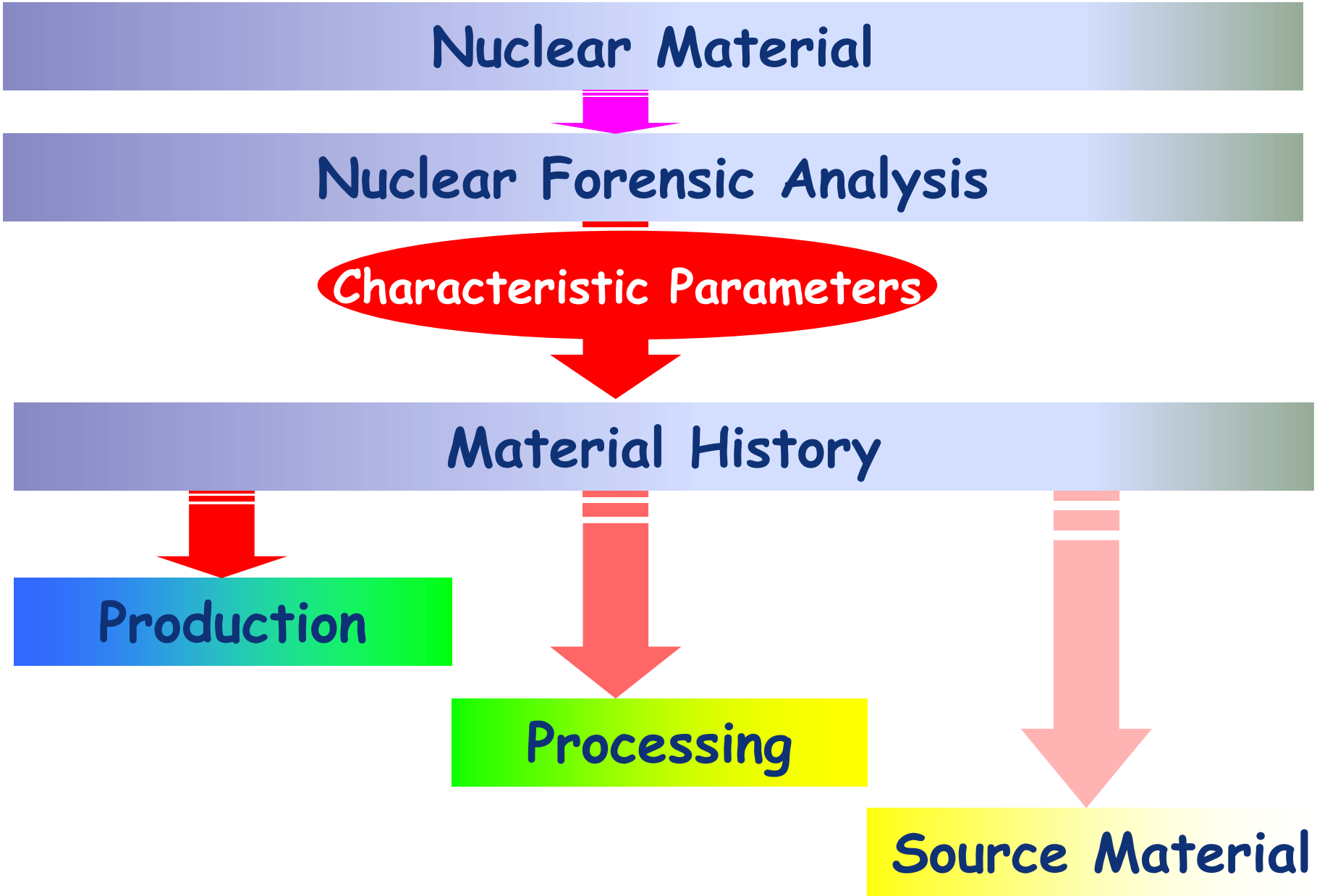
Objectives of Nuclear Forensics

- **Traditional Forensics**
  - Serves Prosecution
  - Relation between
    - Evidence
    - Incident (crime)
    - Individual (criminal)
- **Nuclear Forensics**
  - Serves Nuclear Security
  - Serves Non-Proliferation
  - Relation between
    - Nuclear Material
    - Intended Use
    - Origin (place of theft/diversion)



Nuclear Forensics Approach




Nuclear Material
Nuclear Forensic Analysis
Characteristic Parameters
Material History
Production
Processing
Source Material

Clues on the history of material

Characteristic Parameters

Identification

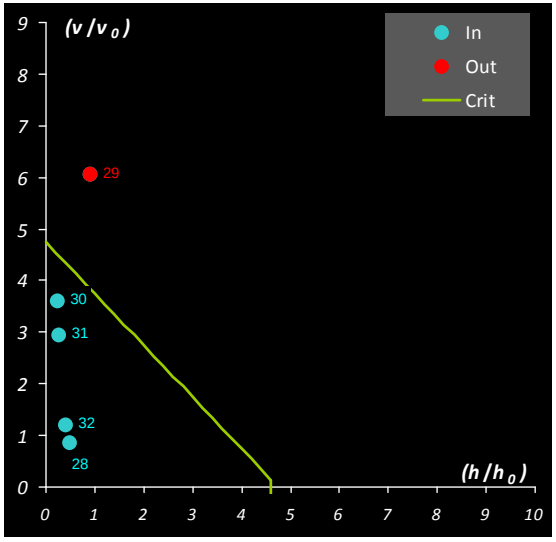
R&D

- Grouping of parameters
- Relating parameters to
  - Source material
  - Processes
  - Application

Application

Case Work

- Classification
  - Statistical Methods
  - Expert knowledge



Statistical Methods

- Cluster analysis
- Principal Component Analysis
- Decision Trees

Expert knowledge

Mechanistic Approach using Comprehensive Data Set

Data Acquisition

- Systematic
- Structured
- Adapted
- Multiple Parameters
- Multi-dimensional data set

Data Interpretation

- Data pre-processing
- Data processing
- Data evaluation
- Attribution
  - Comparison against database
  - Comparison sample

Attribution

Data Interpretation (2)

Iterative Approach using Prioritized Data

Data Acquisition

- Prioritize Parameters
- Measurement of most relevant parameters

- Prioritize Parameters
- Measurement of next relevant parameter(s)

Data Interpretation

- Data evaluation
- Data base query

- Data evaluation
- Data base query

Attribution

Seizure of uranium fuel pellets

1. Origin of the material ?
2. Intended use of the material?

Seizure of uranium fuel pellets

Data Acquisition

- Enrichment
- Diameter

Data Interpretation

- Data evaluation
- Data base query

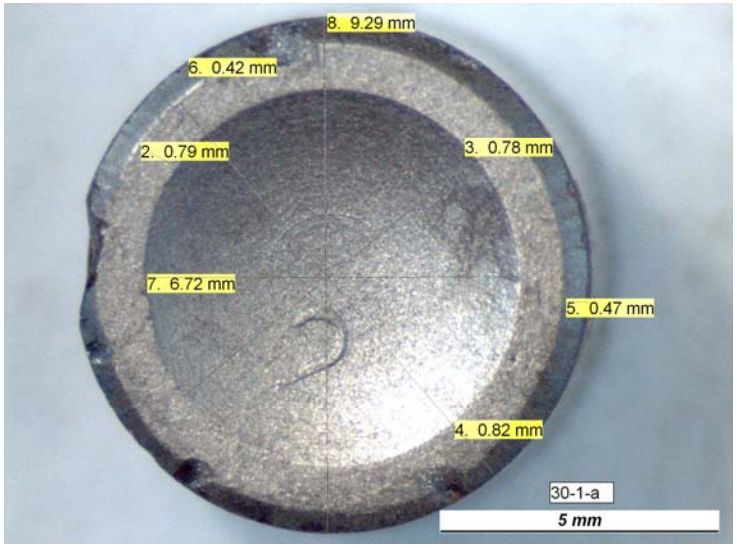
- Exclude all non-matching records
- Identify parameters for subsequent measurement

Data Interpretation (Example 1)

Seizure of uranium fuel pellets

Data Acquisition

- Chamfer
- Dishing
- Land



Data Interpretation

- Data evaluation
- Data base query

- Exclude all non-matching records
- Identify parameters for subsequent measurement

Attribution

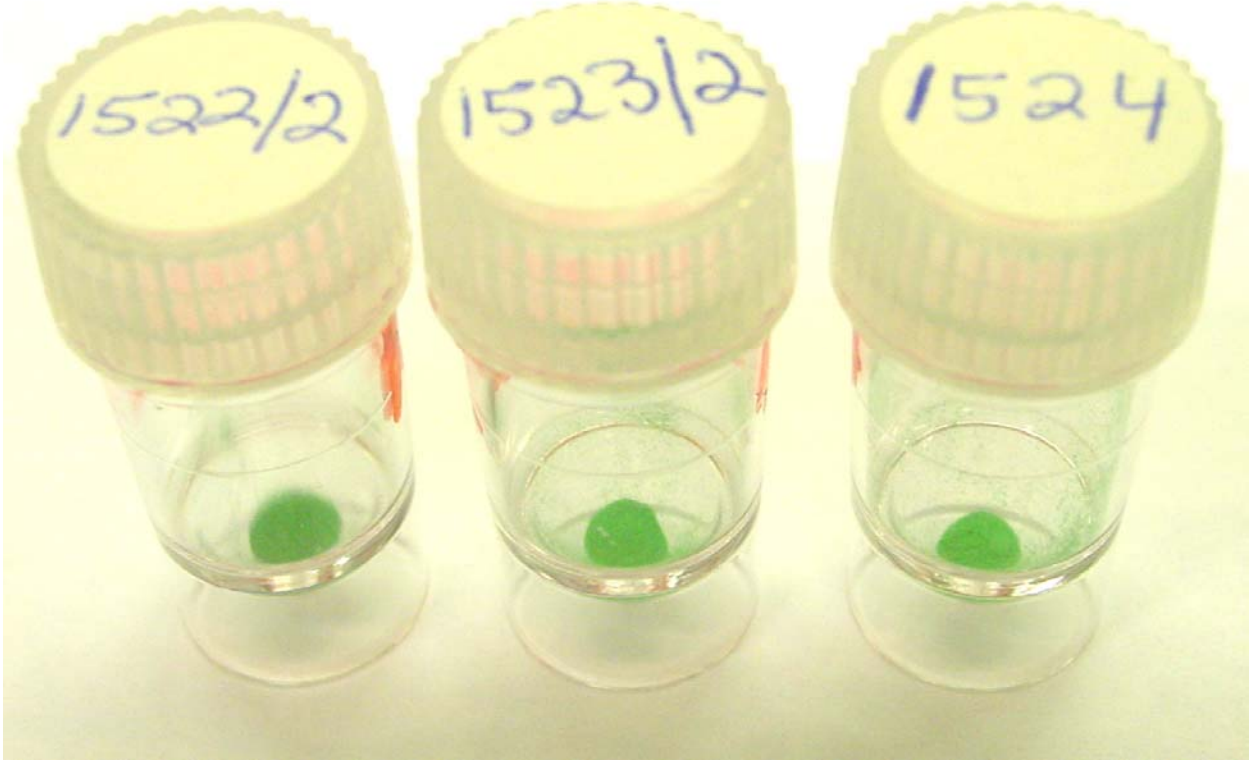
Data Interpretation (Example 1)

		Measured			Database Record [1]		Database Record [2]	
		Average	StDev		Nominal	Tolerance	Nominal	Tolerance
Diameter	mm	9.26	0.02		9.11	0.02	9.11	0.02
Dishing	mm	**6.71**	**0.08**		**6.7***	**0.3***	6.73	0.05
Land	mm	**1.22**	**0.16**		**1.2**	**0.3**	1.2*	0.1*
Chamfer Width	mm	**0.44**	**0.04**		**0.4**	**0.2**	*0.61*	*0.05*

Siemens (RBU) Brennelementfabrik Hanau

Data Interpretation (Example 2)

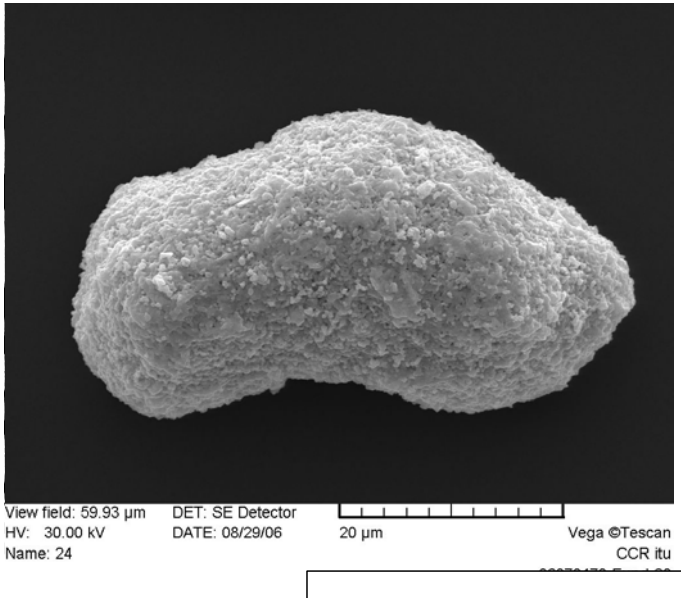
- Absence of Database information
- Non-numeric information

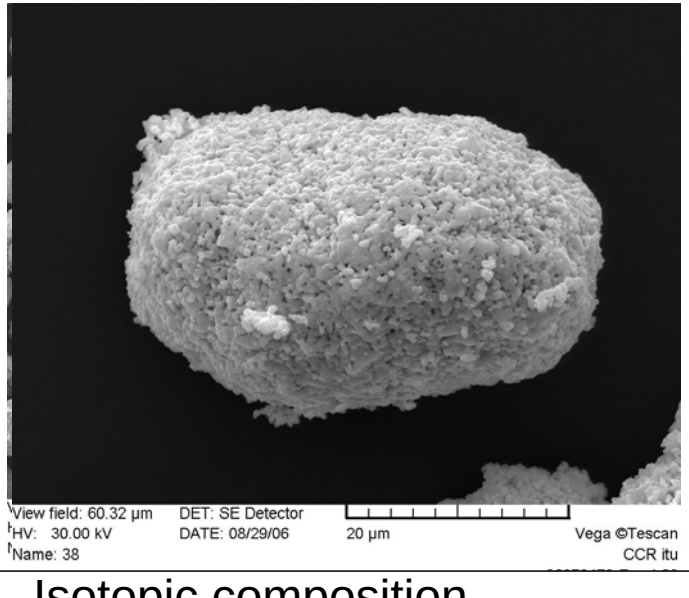


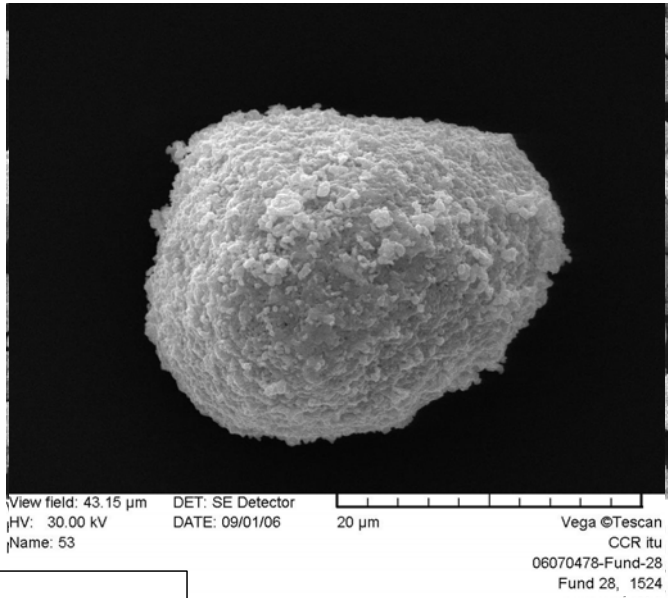
Natural uranium (UF_4)

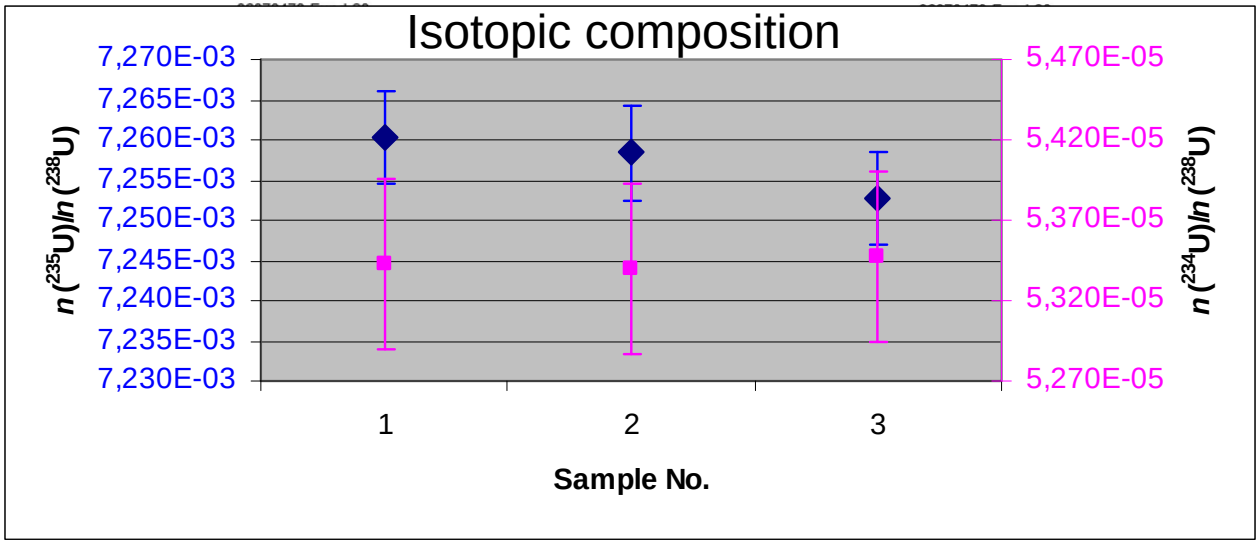
Data Interpretation (Example 2)

Microstructure



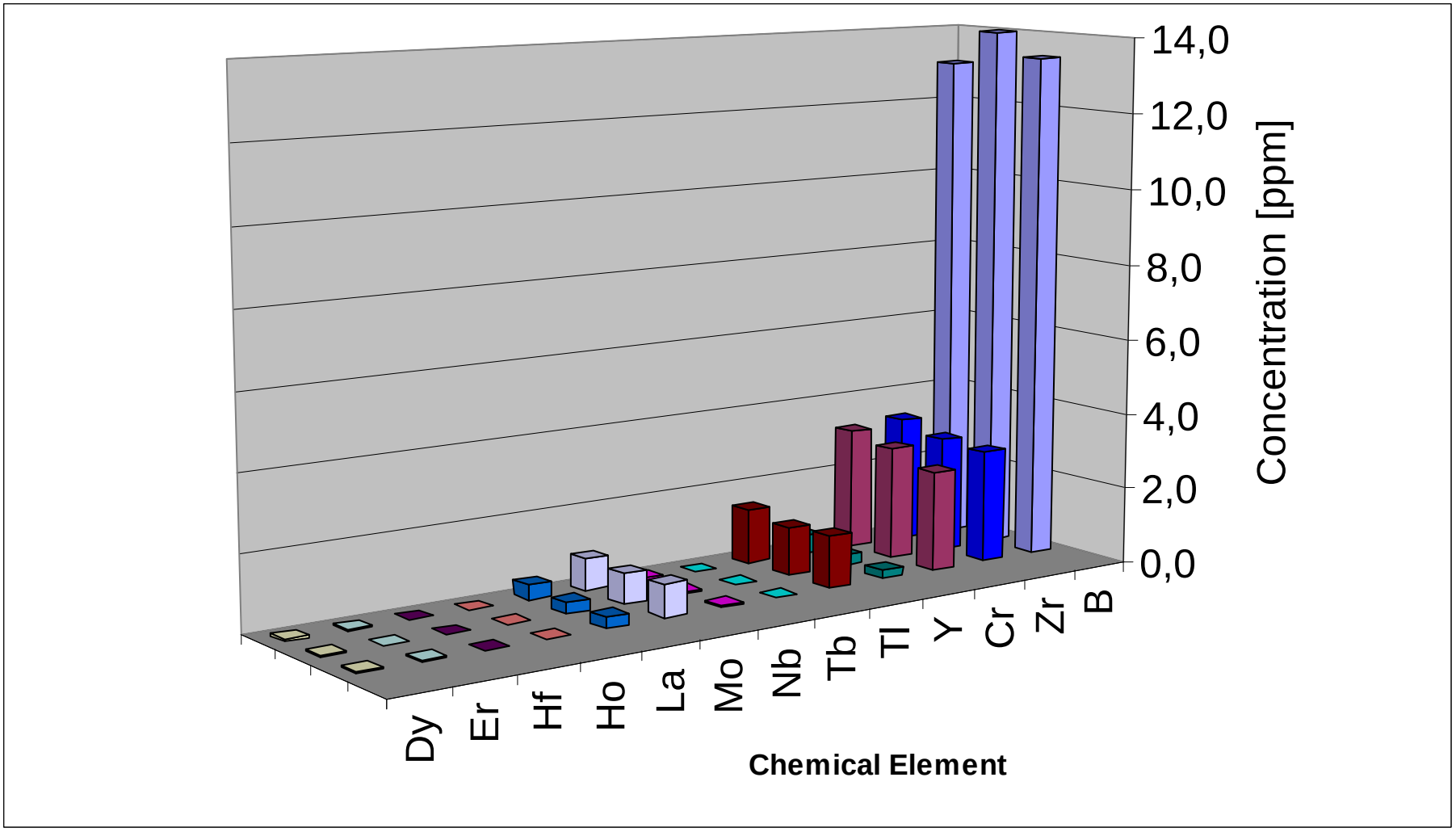






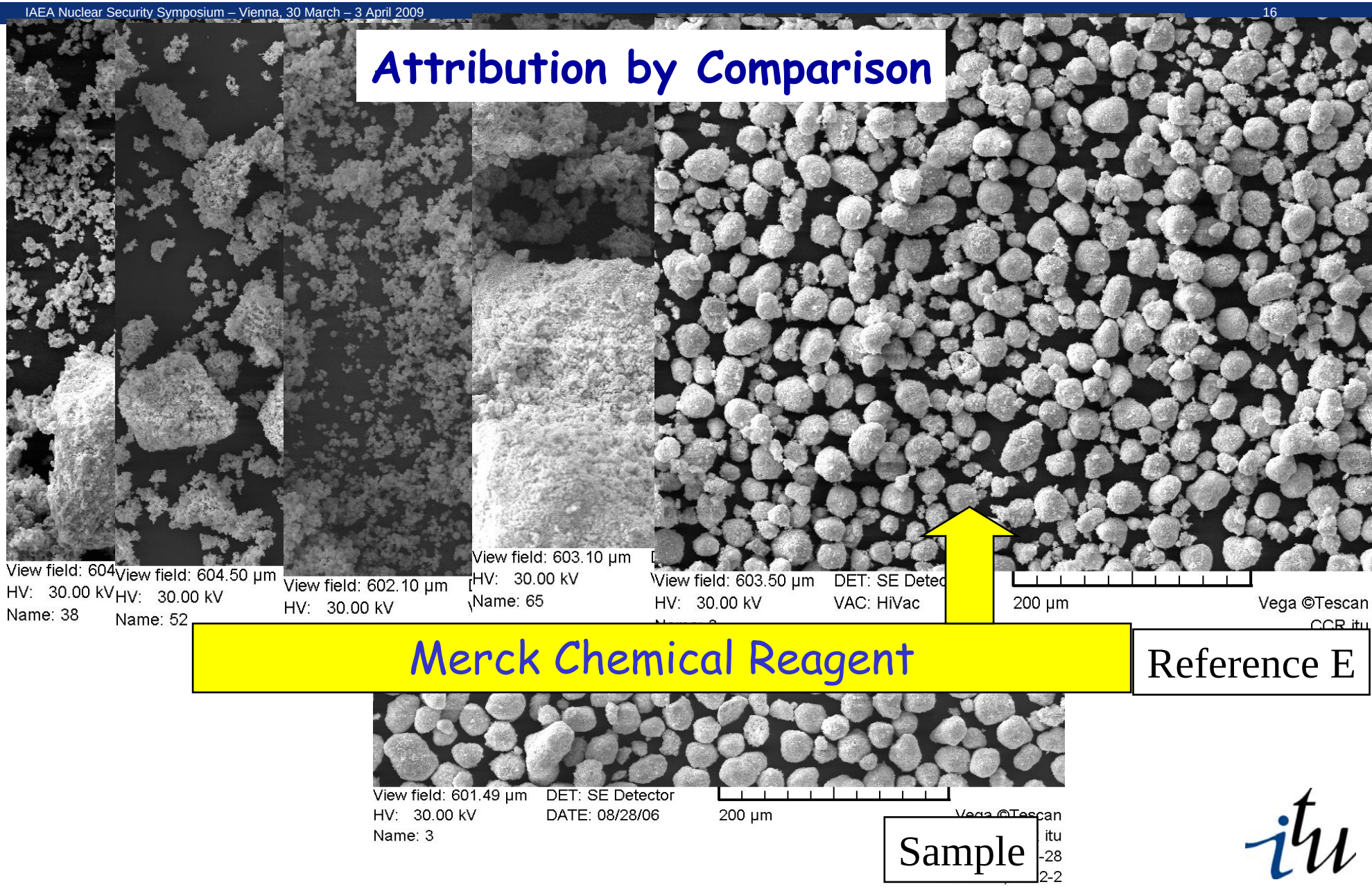
Data Interpretation (Example 2)

Chemical Impurities



Data Interpretation (Example 2)

Attribution by Comparison



Comparative Evaluation

Parameter	Comparison against	Evaluation Method
U isotope ratios	Data base	Simple statistics
Pu isotope ratios	Model calculations	Simple statistics, graphical eval.
	Data base	Simple statistics
Chem. Impurities (concentrations, patterns, ratios)	Process knowledge	Expert judgment, consistency
	Data base, known samples	Advanced statistics
Isotope ratios (of minor constituents)	Data base, known samples	Simple statistics
Macroscopic appearance	Process knowledge	Expert judgment
	Database, known samples	Simple statistics
Microscopic appearance	Process knowledge	Expert judgment, consistency
	Database, known samples	Advanced statistics
Radioisotopes	Model calculations	Simple statistics, graphical eval.

Conclusions (1)

- Nuclear Forensics is a powerful tool providing
  - Sample History or Attribution
  - Sustainability
  - Deterrence
- Credible Nuclear Forensics requires
  - Identification of characteristic parameters
  - Reliable sampling
  - Validated measurements
  - Careful data interpretation

R&D

R&D

Conclusions (2)

- Data interpretation is based upon
  - Tacit Knowledge
  - Access to Reference Data
  - Statistical testing
- International collaboration
  - Enable possibilities for data base queries
  - Access to reference data/comparison samples
  - Exchange expert knowledge
- Training/Exercises

IAEA International Atomic Energy Agency

ITWG Nuclear Forensics