IAEA SAFEGUARDS EQUIPMENT

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Department of Safeguards

IAEA

Atoms for Peace: The First Half Century
1957–2007

Technical Objectives

- **Satisfy needs in the area of Traditional Safeguards, Additional Protocol and Integrated Safeguards (IS) by providing equipment, technology and expertise able to verify nuclear material and detect undeclared material and activities in a timely manner.**
- **Possess new or improved equipment/technology that will address present deficiencies, have higher reliability, enhance the efficiency and effectiveness of verification activities and ensure the security of information.**

IAEA SG equipment/techniques in use

Wide variety of SG equipment/ techniques *(~ 150 different routine equipment types!)* such as:

- **Non Destructive Analysis (NDA)**
  - **attended (portable and resident)**
  - **unattended (radiation monitoring systems)**
- **Destructive Analysis (DA)**
- **Environmental Sampling (ES)**
- **Containment and Surveillance (C/S)**
  - **seals**
  - **cameras**

Nuclear Material Verification

The basic verification method
used by the IAEA is

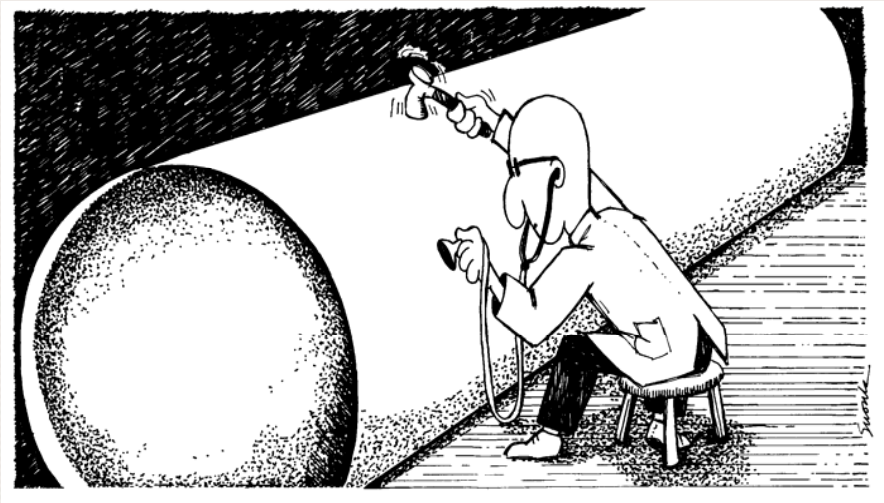
Nuclear material accountancy (NMA)

With

Containment and surveillance (C/S)

As important complementary measures

Nuclear Material Verification

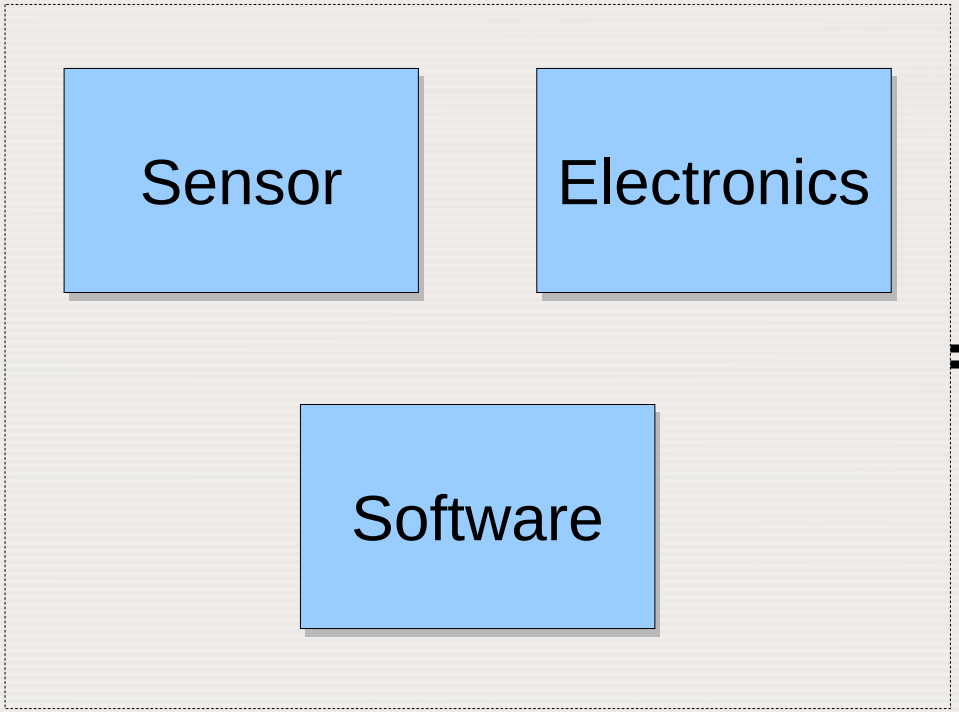


IAEA inspectors have to make **independent measurements** to verify declared material quantities

Materials Measured

- Uranium and Plutonium in:
  - feed materials
  - fresh fuel
  - spent fuel

Components of NDA Instruments



Gamma Systems
Neutron Counters
Physical Measurements

Gamma-Ray Measurements

- Nuclear materials emit γ and x rays
- *Gamma-ray Energy* identifies *what* material
- *Gamma-ray Intensity* tells *how much* material
- Gamma systems usually measure energy and intensity simultaneously

Gamma-Ray Instruments

Code	Instrument	Typical Application
HM-5	Hand-held assay probe (NaI based)	Attribute Tester for U, Pu, enrichment, active length, NM detection
MMCA,MMCN	MiniMCA, MMCA + NaI	Attribute tester for U, Pu and U-Enrichment
MMCC	MMCA + CdZnTe	Attribute tester for U, Pu
MMCG	MMCA + Ge	U-Enrichment (mainly for UF6)
IMCA,IMCN	Inspector 2000, IMCA + NAI	As above
IMCC	IMCA + CdZnTe	As above
IMCG	IMCA + Germanium	U-Enrichment, Pu-isotopics

HM-5 Hand-Held Assay Probe

Portable hand-held gamma detectors for detecting presence and identifying nuclear and other radioactive materials

Mini MCA (MMCA)

+ NaI ⇒ MMCN; + Cd ZnTe ⇒ MMCC

Mini-multi-channel Analyzer systems for spectral analysis of gamma rays with NaI detector or CdZnTe (small, compact and easy to use)

NMA of Fresh Fuel at a Reactor

InSpector-2000 MCA

Multi-channel Analyzer system with Ge detector for isotopic analysis of Uranium enrichment and Plutonium isotopics

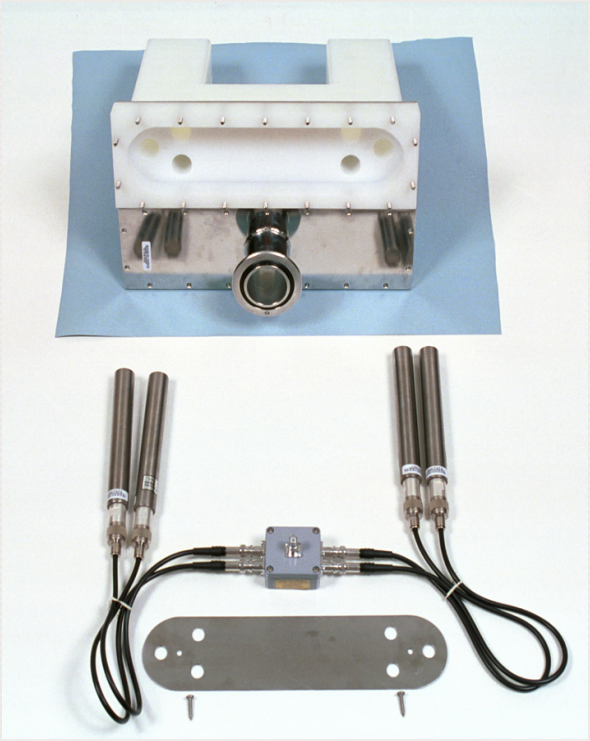
Gamma-Ray Instruments (cont'd)

Code	Instrument	Typical Application
SFAT, IRAT	MMCA + CdZnTe with Customized colimator/shielding	SF verifier (presence/absence of Cs-137)
FMAT	MMCA + CdZnTe with Customized colimator/shielding	Attribute Tester for Pu in fresh MOX fuel (under water)
NGAT	MMCAs + CdZnTe chamber + FC or He-3	SF verifier (Gamma + Neutron) MOX fuel (under water)
FDET	Grand III + Ionization chamber + FC	SF verifier (Gamma + Neutron) burnup verification

Irradiated Item Attribute Tester - IRAT

Spent Fuel Measurements

Fork Detector (FDET)



Spent Fuel Attribute Tester (SFAT)

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Neutron Measurements

- Nuclear materials emit neutrons
- Neutron energy does not readily identify the material
- Neutron *intensity* tells *how much* material
- Neutrons penetrate dense matter better than γ 's
- Two categories:
  - Passive methods
  - Active methods

High Level Neutron Coincidence Counter - HLNC

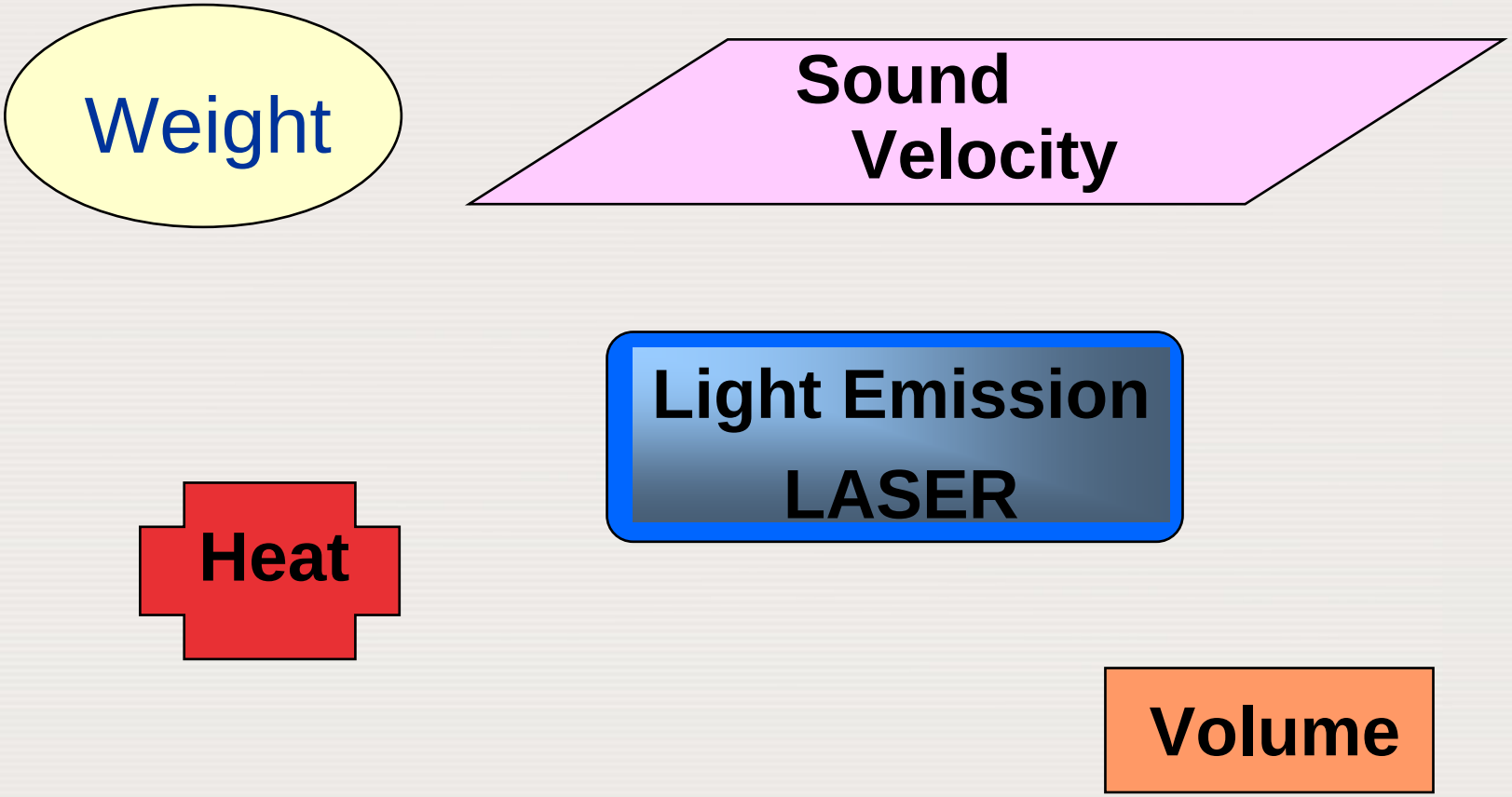
Neutron Coincidence Counter, with He-3 detectors and coincidence counter electronics for verification of Pu bearing materials

Hand-held Neutron Monitor - HHNM

HHNM:- a modern and efficient tool for primary search (detection) and localization of neutron radiation sources as well as verification of neutron alarms by installed radiation monitors.

Active Well Coincidence Counter - AWCC

Physical Measurements



Cerenkov Viewing Device (ICVD)

Load-Cell Based Weighing System (LCBS)

Load cell being used to weigh a UF_6 cylinder

Future Functionality and Needs

- Miniaturization bulky -> smart portable
- High level of integration of sensors and instruments
- Robust with multipurpose detection functions
- Secure and wireless transmission
- Enhanced mobility for the inspector
- Continuous gamma/neutron screening function with positioning information
- Ability to receive early feedback from HQ

Improved NDA Capabilities

New generations of NDA equipment using:

- **Advanced information technology**
  - *Location stamped information*
  - *Imbedded databases for nuclear material identification*
  - *Pattern recognition for URM*
- **New detector technology**
  - *Increase in resolution and efficiency (CdZnTe, $LaBr_3$, HPGe)*
  - *Fast signal processing*
  - *HRGS systems at room temperature?*

Future Inspection Schemes

Implementation of IS:

- Optimum combination of all SG measures available to the Agency
- Reduced number of routine inspections incl. PIVs
- Increased number of unannounced inspections and Complementary Access (CA) visits
- Instrumentation to be available at very short notice
- Multipurpose oriented, easy to operate and portable
- New plant designs require new, design specific SG systems
- Search for undeclared nuclear materials and activities

Complementary Access activities may include:

- Visual observation (including taking photographs)
- Collection of environmental samples
- Use of radiation detection and measurement devices
- Sampling for DA
- Application of seals and other identifying and tamper indicating devices
- Examination of relevant records regarding material, production or shipping (limited applicability)
- Other objective measures (agreed by the Board of Governors)

Tools for Detection of Undeclared Materials and Activities

Confirm absence of undeclared nuclear materials and activities:

- **Non traditional elements/isotopes in CA inspections (tritium, beryllium, americium, neptunium etc.)**
- **For enrichment and reprocessing (HF gas monitoring)**
- **Tunable Laser Diode systems**
- **Differential LIDAR (light detection and ranging)**

Tools for Detection of Undeclared Materials and Activities

DIV activities confirm that existing facilities are used as declared:

- **Past and present usage of NM by ES**
- **Laser Ablation spectroscopy (LIBS)**
- **Optical Stimulated Luminescence (OSL)**
- **Ground penetration radar (GPR) to detect hidden objects/structures**

What is available in the CAI-Kit ?

Swipe Sampling Kit

IAEA Clean Laboratory, Seibersdorf

Thermal Ionization Mass Spectrometry

Scanning Electron Microscopy

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Improved Verification Techniques for Enrichment Plants

- **Development of in-line NDA instrumentation**
  - ***Check of enrichment levels***
  - ***Confirm absence of HEU***
- **NDA instrumentation to quantify all materials in various process stages to verify undeclared material overproduction**
- **Continuous flow verification of UF6 cylinders by Laser item identification system (LIIS)**
- **TDLS spectroscopy could analyze UF_6 and reduce DA samples**

Conclusions

- **Continuous R&D required to meet emerging challenges to verify and detect NM**
- **Special attention to development of new, alternative technologies for searching undeclared material, activities and facilities**
- **Compromises between operational use and safeguards requirements to optimize detection capability.**
- **Improvement of equipment is a continuous challenge >> importance of collaboration with Member States.**
- **Need to include R&D operating outside the traditional "safeguards world"**

Containment and Surveillance (C/S) A Complementary Measure with NMA

The C/S combination:

- **Reduces effort required to carry out Nuclear Material Accountancy (NMA) verification**
- **Provides diversion detection capability for some strategies not covered by NMA verification**

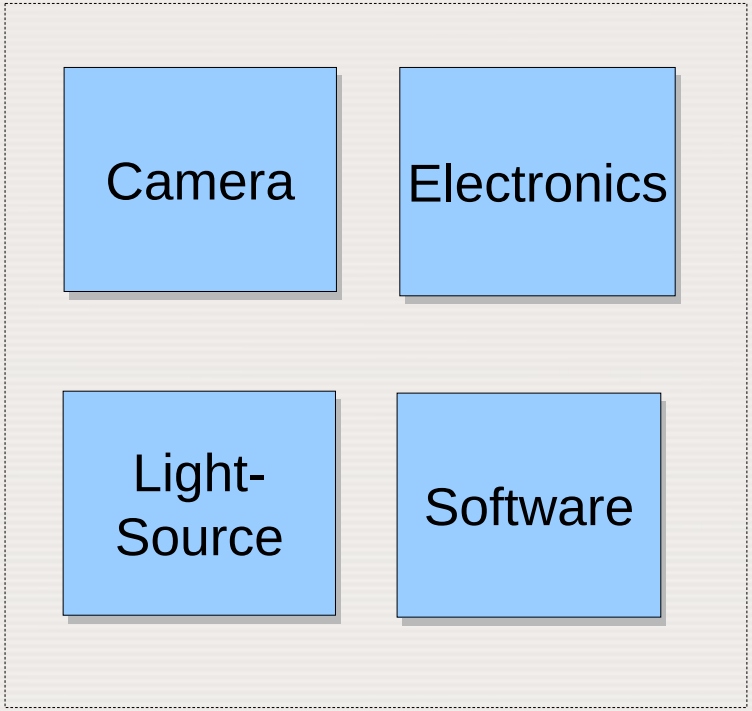
Containment & Surveillance (C/S) Devices

- **Optical surveillance systems**
- **Sealing systems**
- **Others (Examples: Radiation Monitor, Process Monitor)**

Surveillance is Used to:

- Detect and/or confirm all movements of nuclear material and spent fuel containers
- Confirm that containment is maintained
- Confirm that information related to locations and quantities of nuclear material is valid
- Confirm IAEA devices are not tampered with
- Ensure the absence of undeclared operations
- Continuously monitor a specific activity for a short period of time

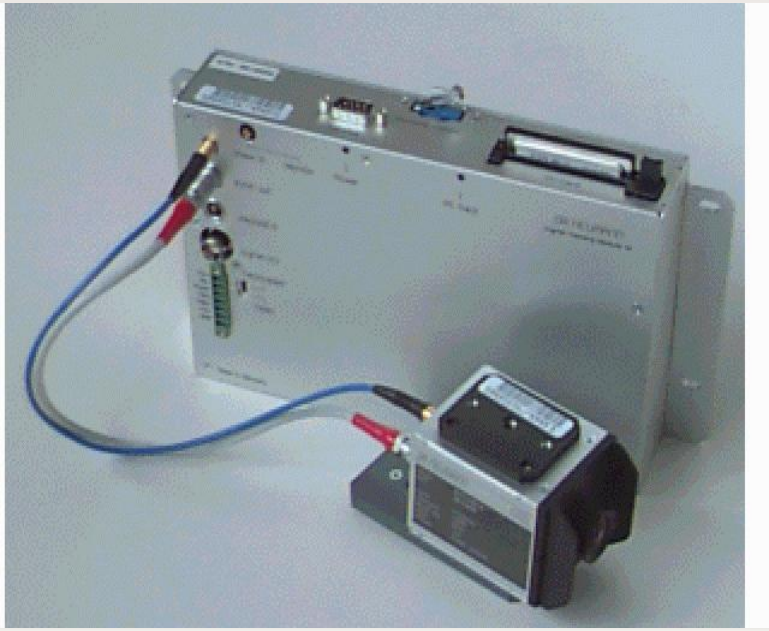
Surveillance System Components



- Single and multi-camera systems
- Radiation tolerant systems
- Underwater systems
- Laser systems
- Lighting systems
  (visible and infrared)

Most Commonly Used IAEA Surveillance Systems

Current IAEA surveillance systems are based on the DCM14 digital camera module



- **Digital image**
- **Scene change detection**
- **Image compression**
- **Image/data authentication**
- **Image/data encryption**
- **Power management**
- **Battery back-up**
- **External triggers**
- **State of health**
- **Removable image and data recording media**

ALIS

(All-In-One-Surveillance)

For single camera applications where the cameras are located in easy to access positions

ALIP

(All-In-One-Surveillance Portable)

Portable, battery-powered single camera, for single camera applications where the cameras are located in easy to access positions

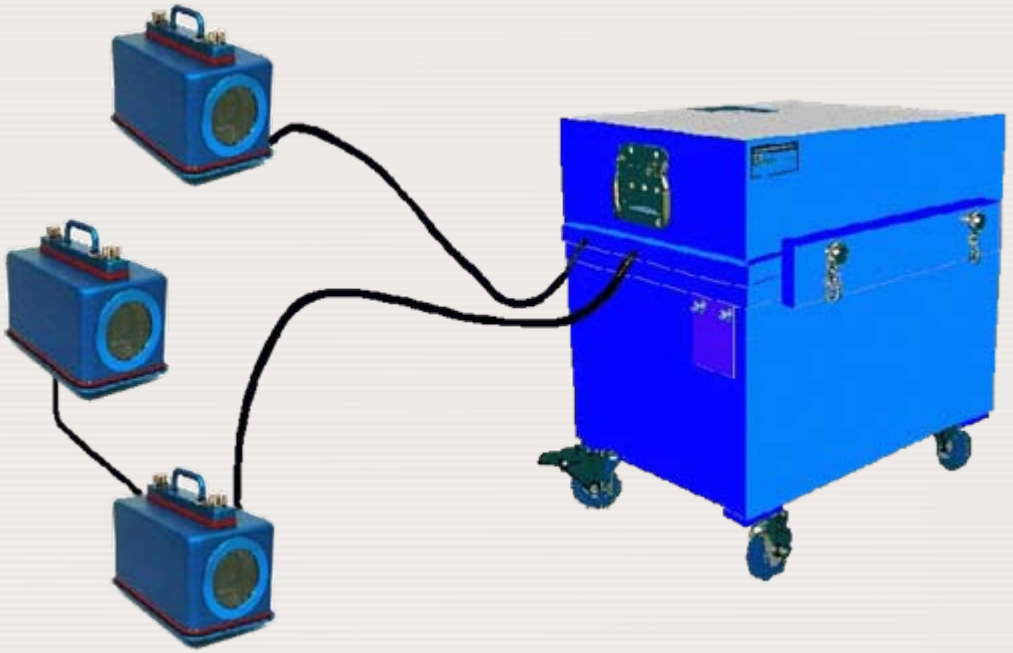
DSOS

(Digital Single Camera Optical Surveillance)

For single camera applications where it is difficult to access the camera position

SDIS

(Server Digital Image Surveillance)



For RM and UM applications in complex facilities requiring multiple (up to 6) cameras

DMOS

(Digital Multi-Camera Optical Surveillance)

For RM and UM applications in complex facilities requiring multiple (up to 16) cameras

HDIS

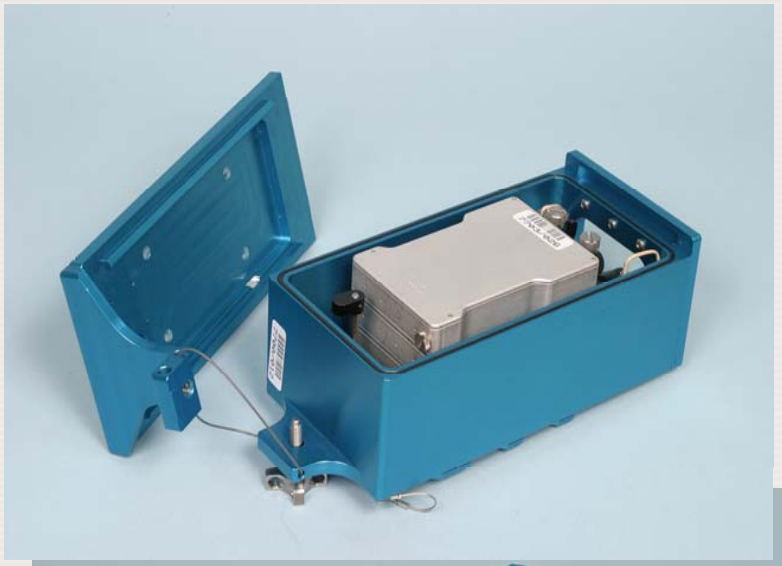
- Portable battery operated camera
- Up to 3 months operation on one battery set
- 1 sec PTIs
- Two USB cameras
- 32 Gb image storage

- No authentication
- No image transmission

HDIS

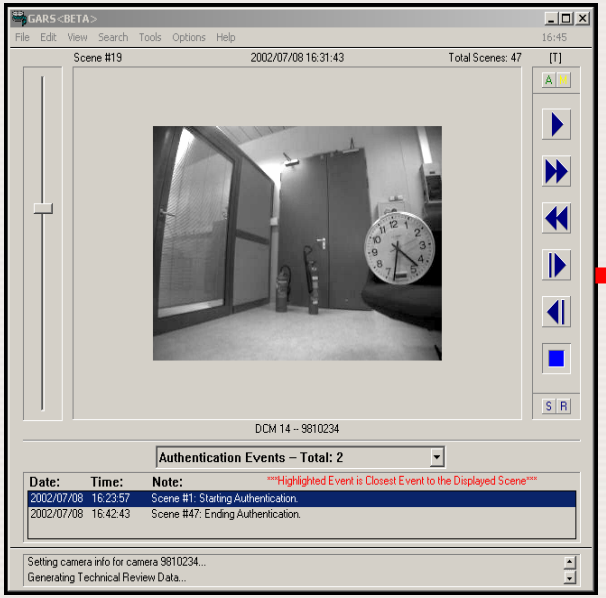
DCM14 based ALIP

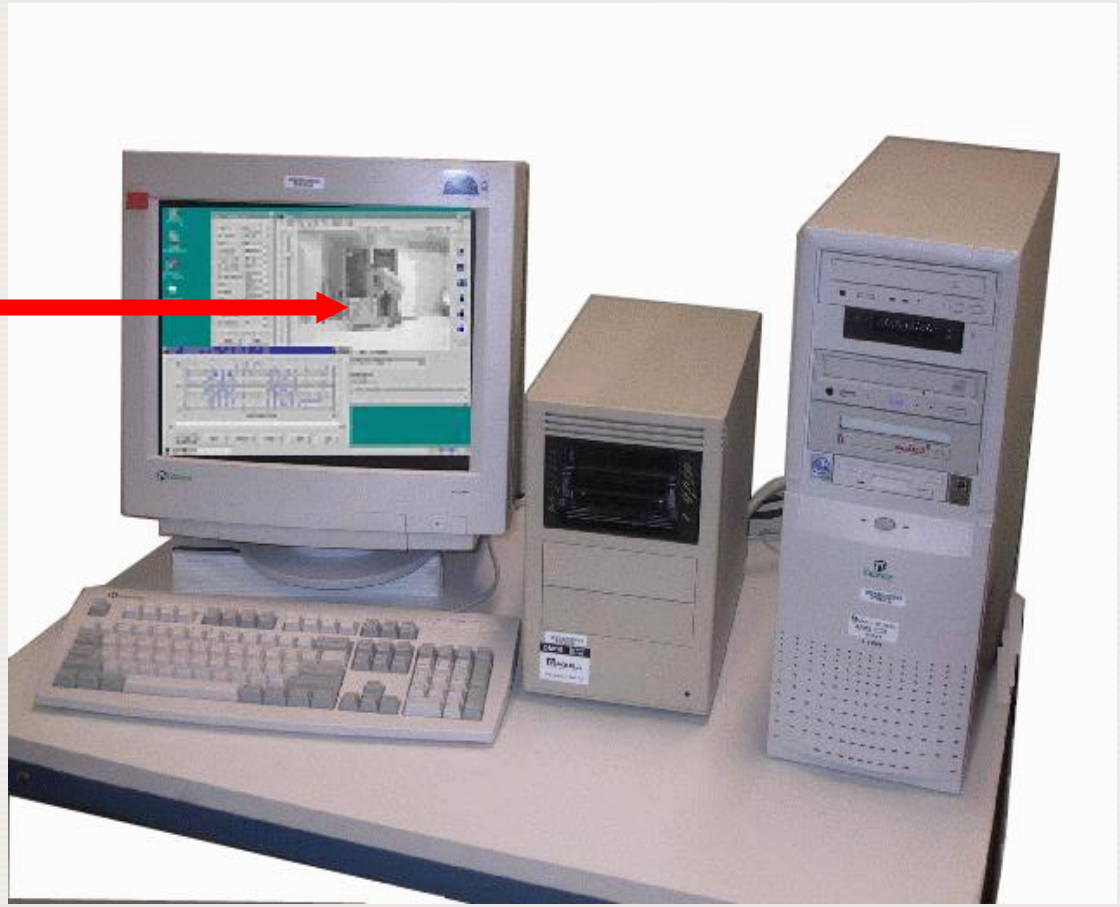
HDIS (continued)



GARS

(General Advanced Review Software)





For the review of ALIS, ALIP, DMOS, DSOS, GDTV, SDIS images and data. Also for the review of VACOSS seal data when connected

3DLRFD Laser DIV Tool

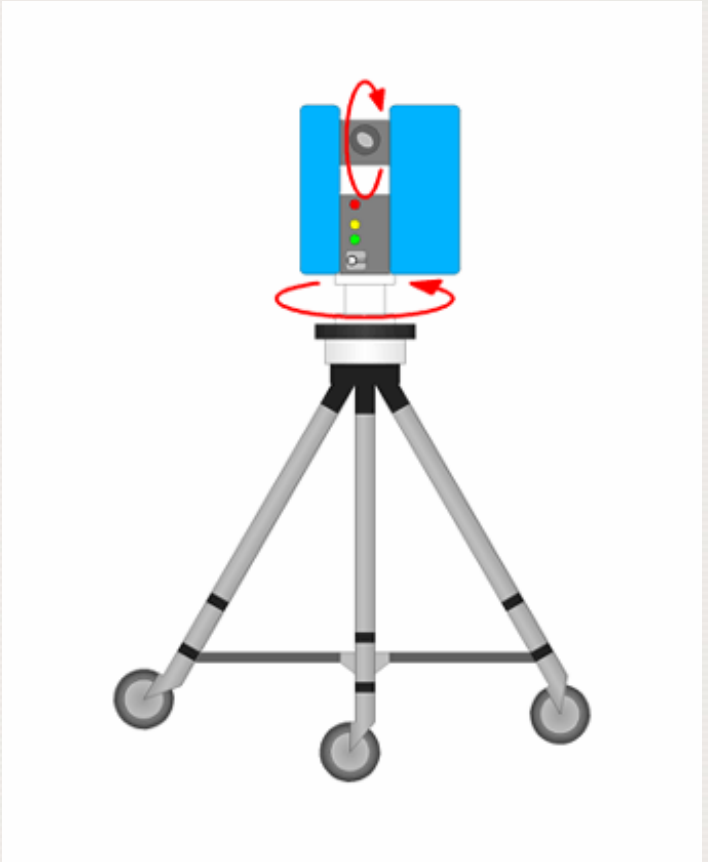
Laser Range Scanner

Portable Computer

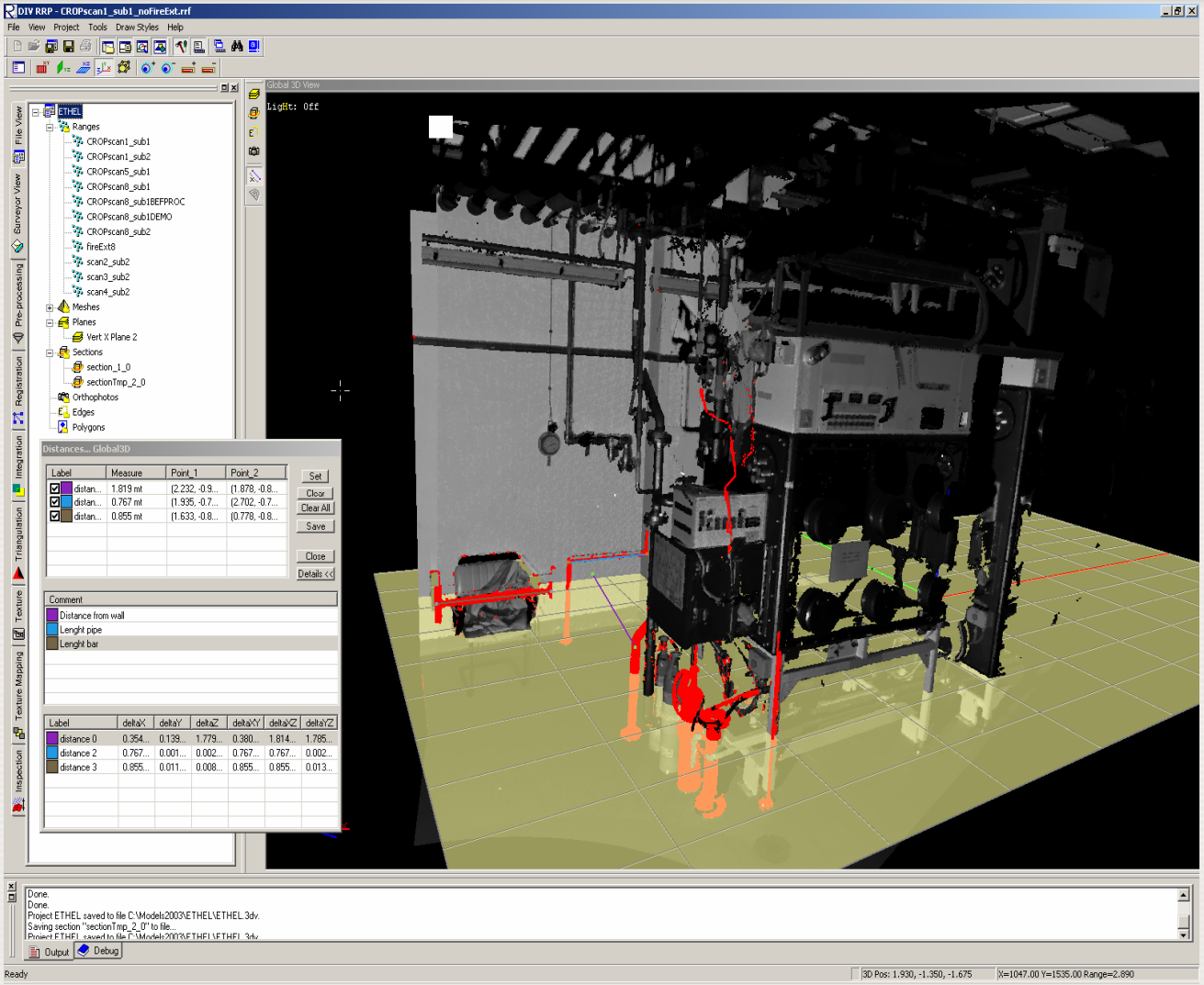
Tripod

Batteries

Dolly



3DLRFD Laser DIV Tool



Conclusions

- Surveillance is an effective inspection tool and is required for the IAEA to meet its safeguards objectives
- Current trend is to continue the use of surveillance in both classical and future safeguards applications
- Current generation surveillance systems use digital technologies that support remote monitoring
- Next generation surveillance systems will provide the inspector additional capabilities and will include features required for the implementation of Integrated Safeguards approaches

Containment Devices

- **Sealing systems**
- **Containment Verification devices**

Containment Devices : Sealing Systems

Metallic Seals	**(CAPS)**
Type-E	
Type-X	
Advanced Seals	
Fiber-optic (COBRA)	**(FBOS)**
Fiber-optic (VACOSS)	**(VCOS)**
Ultrasonic (ARC)	**(ULCS)**

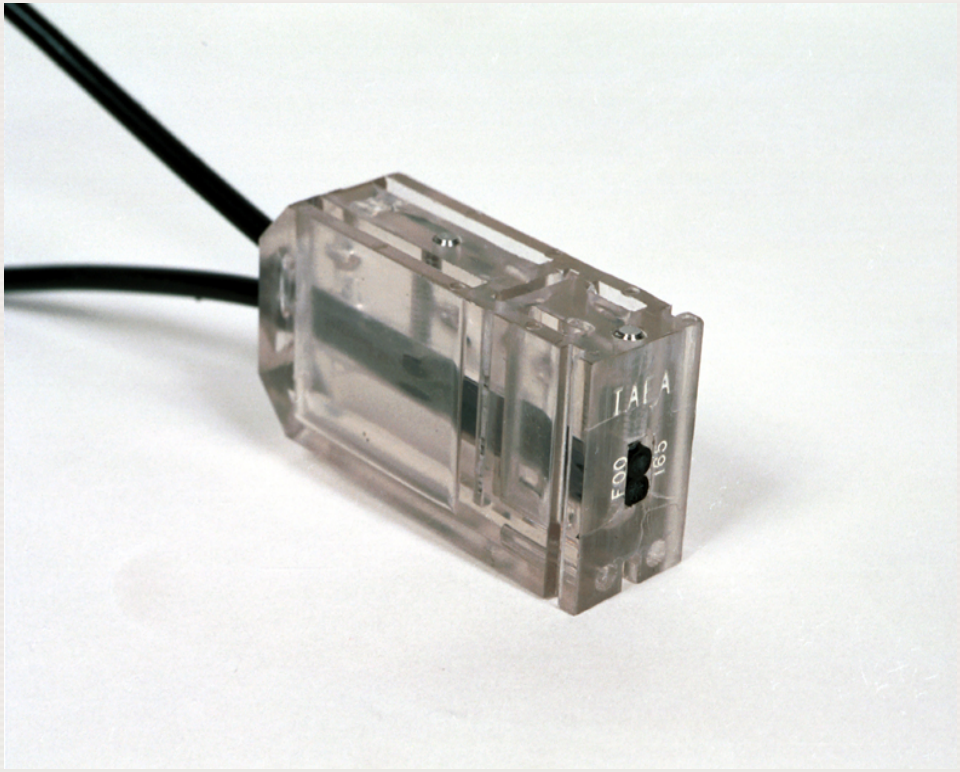
Containment Devices : Sealing Systems

- Temporary Seals
  - Paper adhesive (ADPS)
- New-Generation Seals
  - Electro-Optical Sealing System (EOSS)

Note: Seals are only a part of “containment systems”. The container itself is important.

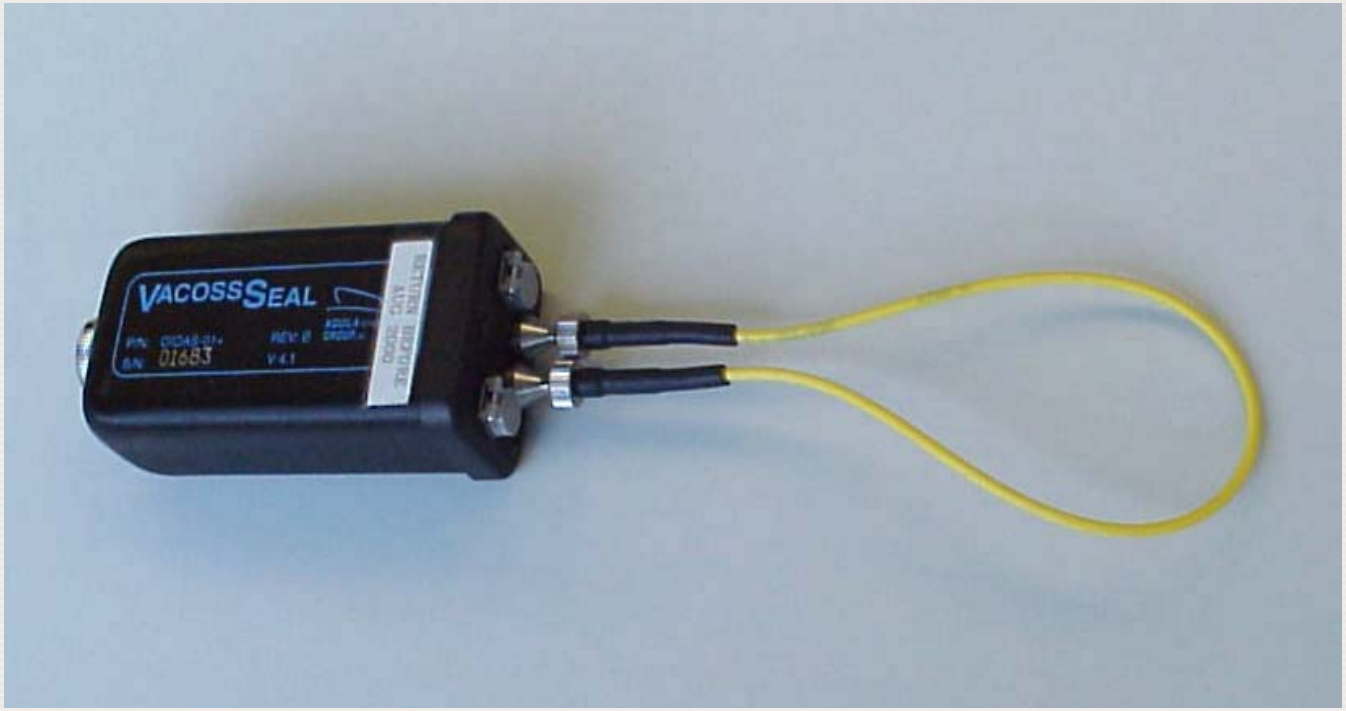
Type-E Metal Seal

Cobra Seal Body and Fiber Optic Cable



Cobra III Verifier

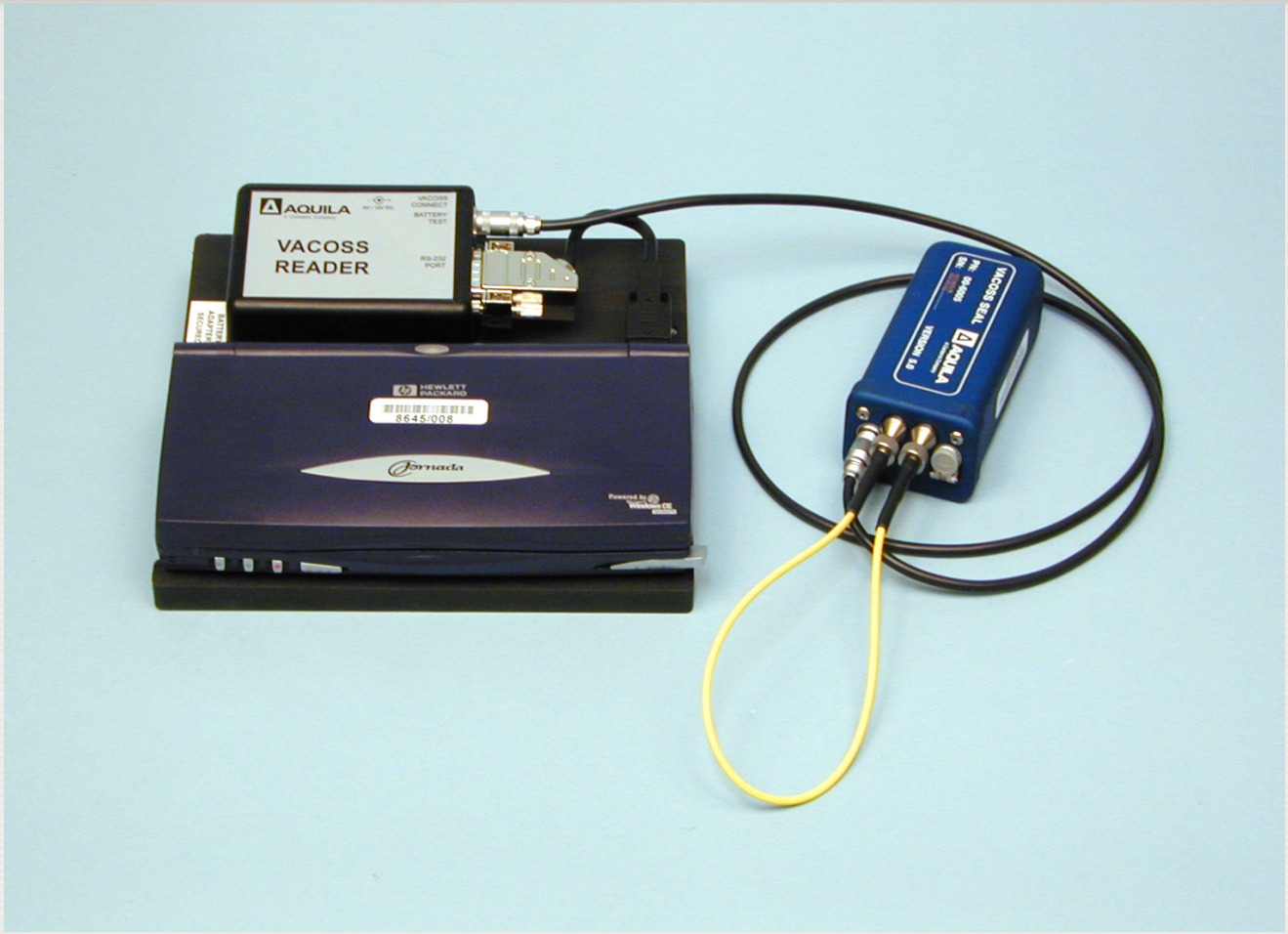
VACOSS Seal and Fiber Optic Cable



VACOSS Seal

Palmtop Computer and Interface Box with VACOSS Seal

VACOSS 5 Sealing System



EOSS Sealing System

Conclusions

- Containment is required for the IAEA to meet its safeguards objectives
- Current trend is for more extensive use of Containment in future safeguards applications
- New-generation systems for Containment will use digital technologies that will support the role of remote monitoring as part of the new Integrated Safeguards concept

Remote Monitoring Communication Modes

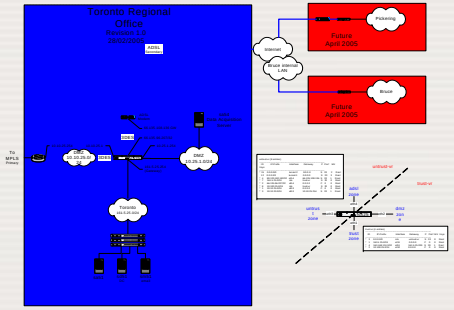
- Public switched telephone network (PSTN)

- Integrated Services Digital Network (ISDN)

- Very small aperture terminal (VSAT) satellite network

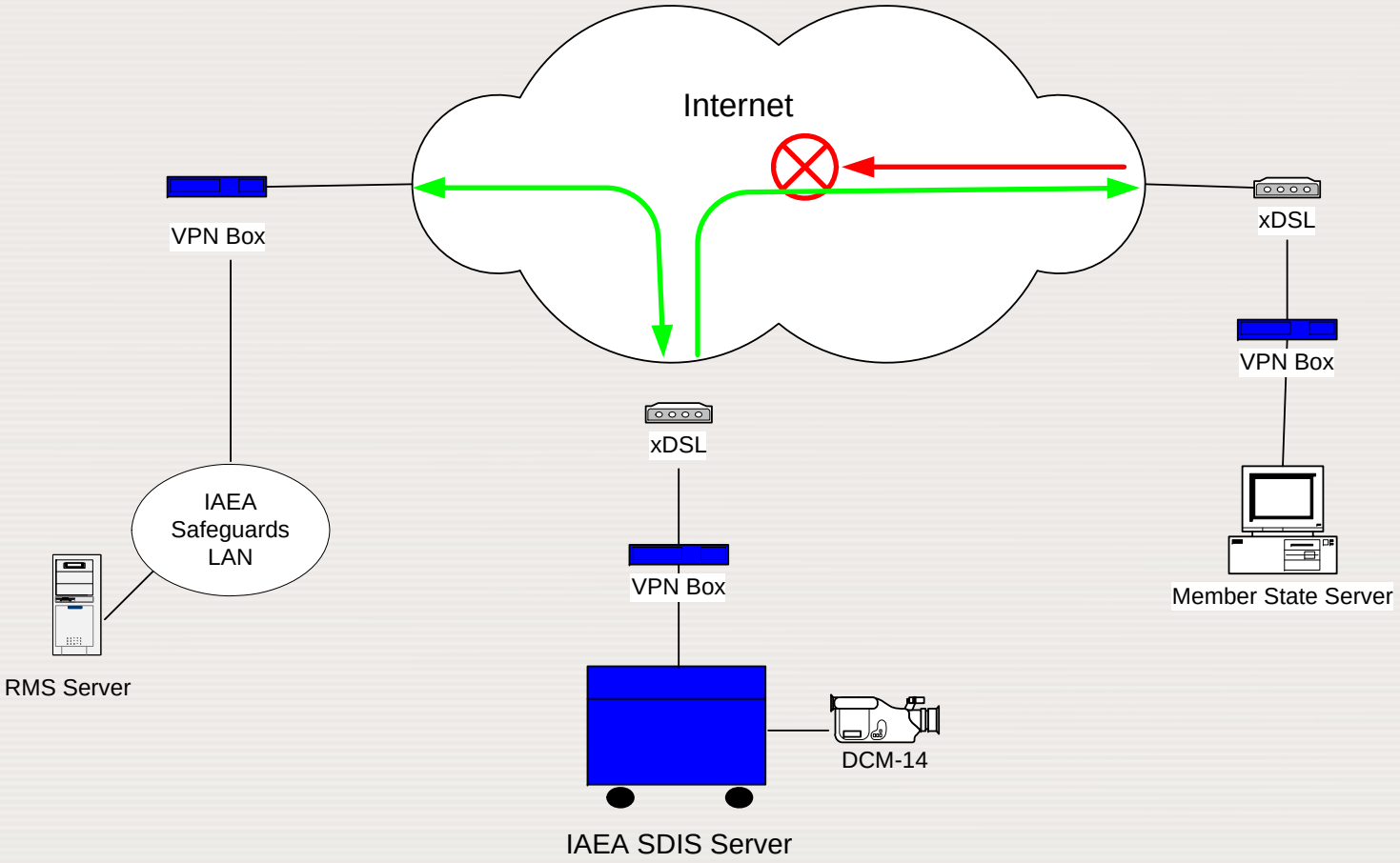
- Asynchronous Data Subscriber Line (xDSL)

- International Maritime Satellite (INMARSAT) network



- LAN-Sharing

RM over Virtual Private Network (VPN) with Data Sharing



What are the advantages of RM?

- Surveillance can be reviewed anytime
  - You can verify positive C/S before you leave on inspection
    - Results in better inspection planning (for instance, you know if you need to re-verify the SF pond before you go)
    - Less follow up visits
    - Less impact on operator
  - If you find an issue in the field, you can ask someone at HQ to look at the surveillance to see if it is positive
- Inspections are faster (no surveillance systems to service)
- Better quality reviews
  - Images are clear and scenes are rarely missed
  - You know what events to ask about before you go
- Failures can be identified and corrected sooner

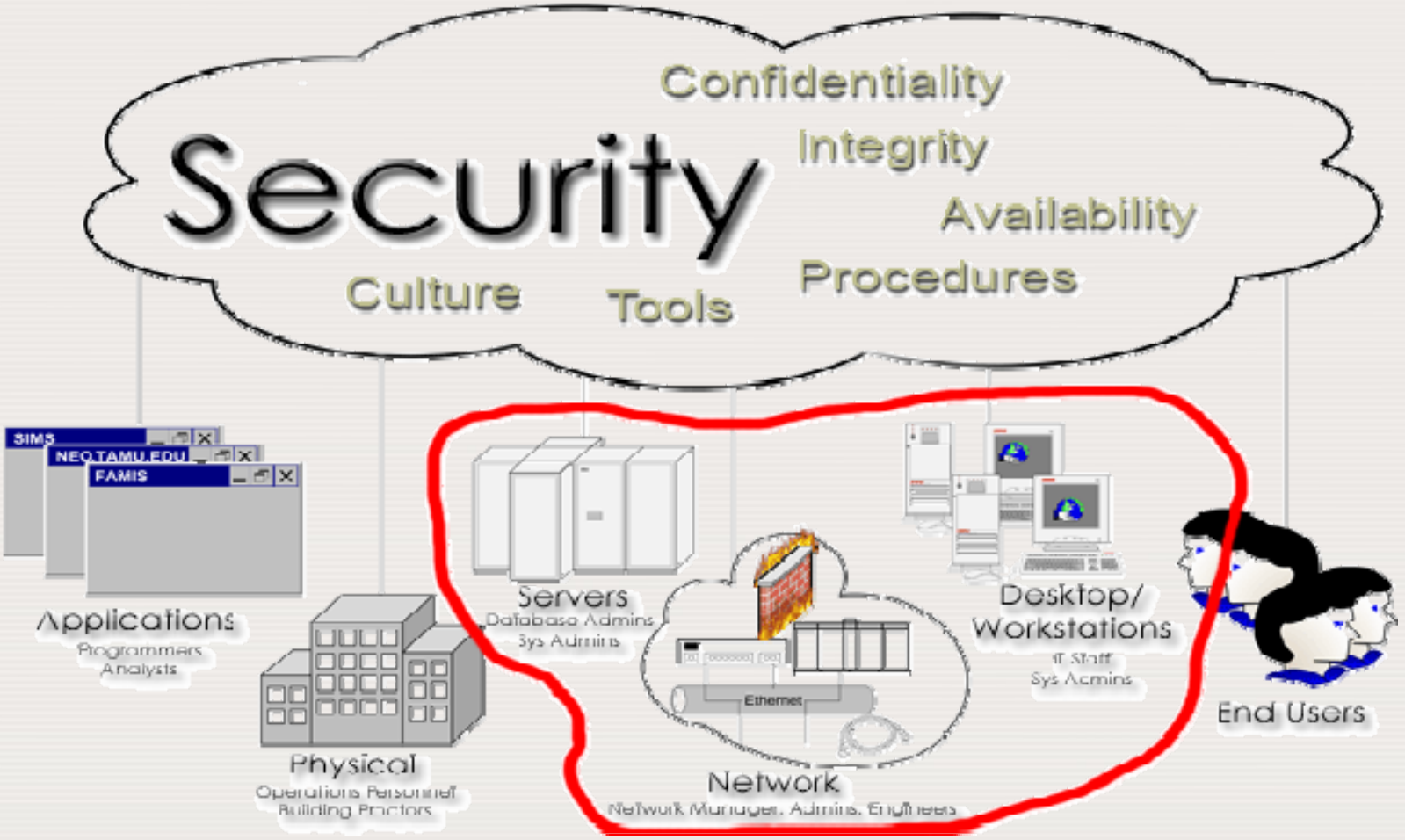
Conclusions

- RM works
- RM is reliable
- RM improves the safeguards approach
- RM saves time and money
  - For the Agency
  - For the Operator

Security Risks

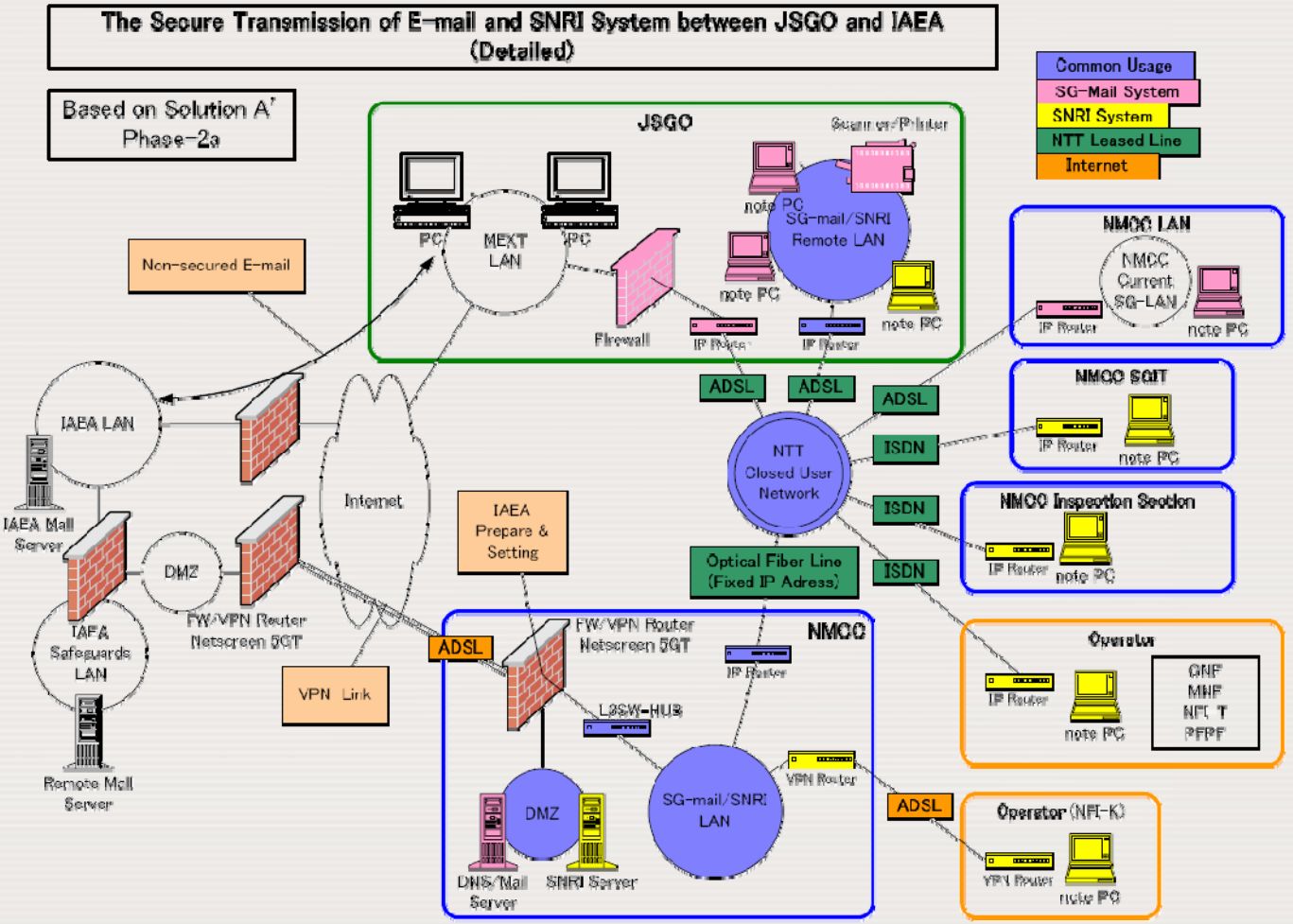
- Confidentiality – loss of trust
  - Insider Threat
  - Theft of Member State Information
  - Knowledge of our intentions
- Integrity – leading to inaccurate conclusions
  - Corruption of data
  - Spoofing time stamps, data, sources
  - Authenticity of information – esp. Open Source
- Availability
  - Prevention of inspection planning
  - Prevention of timely detection

Security has many aspects



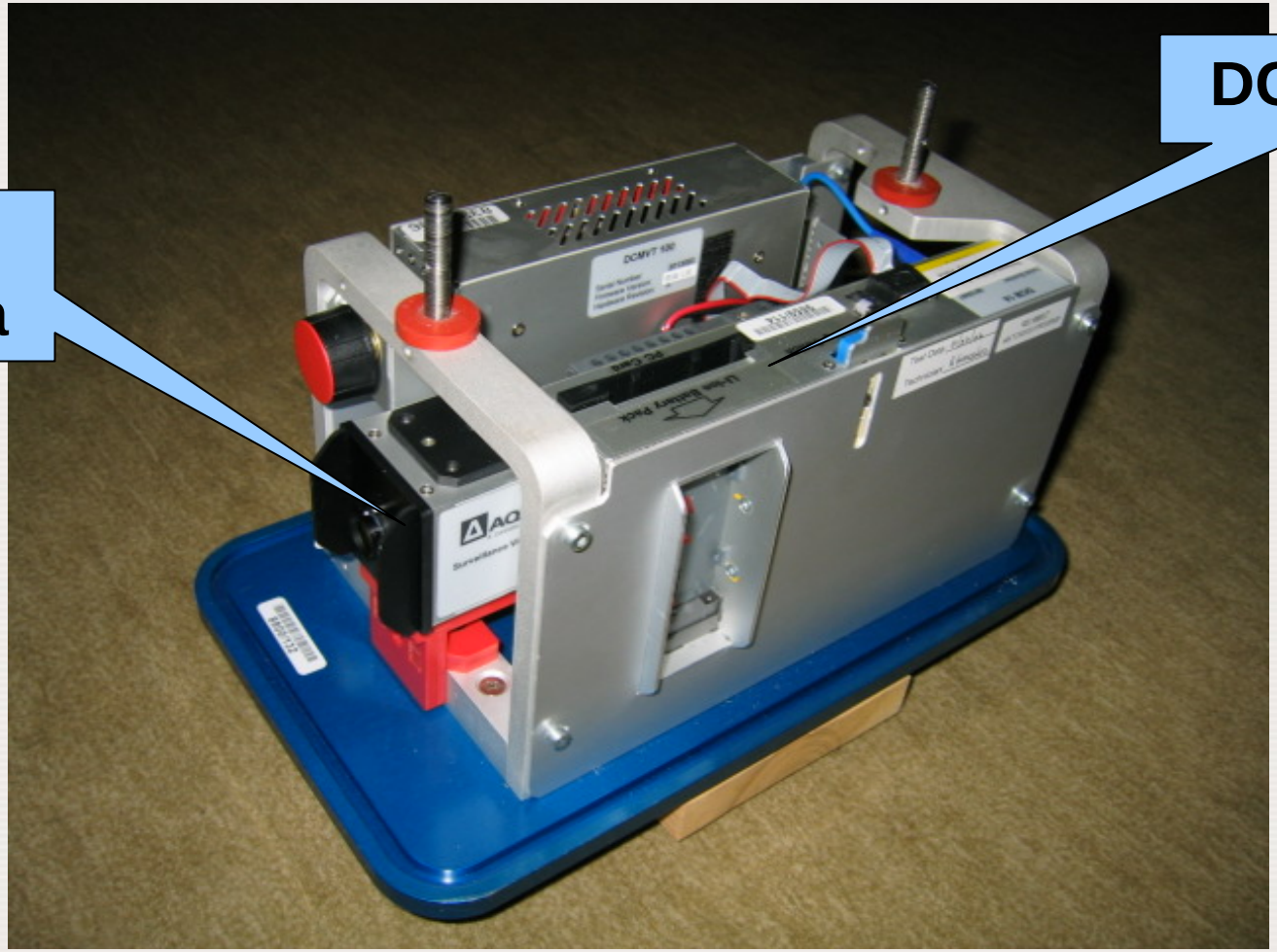
Confidentiality and Integrity

- PGP and PKI
- VPN

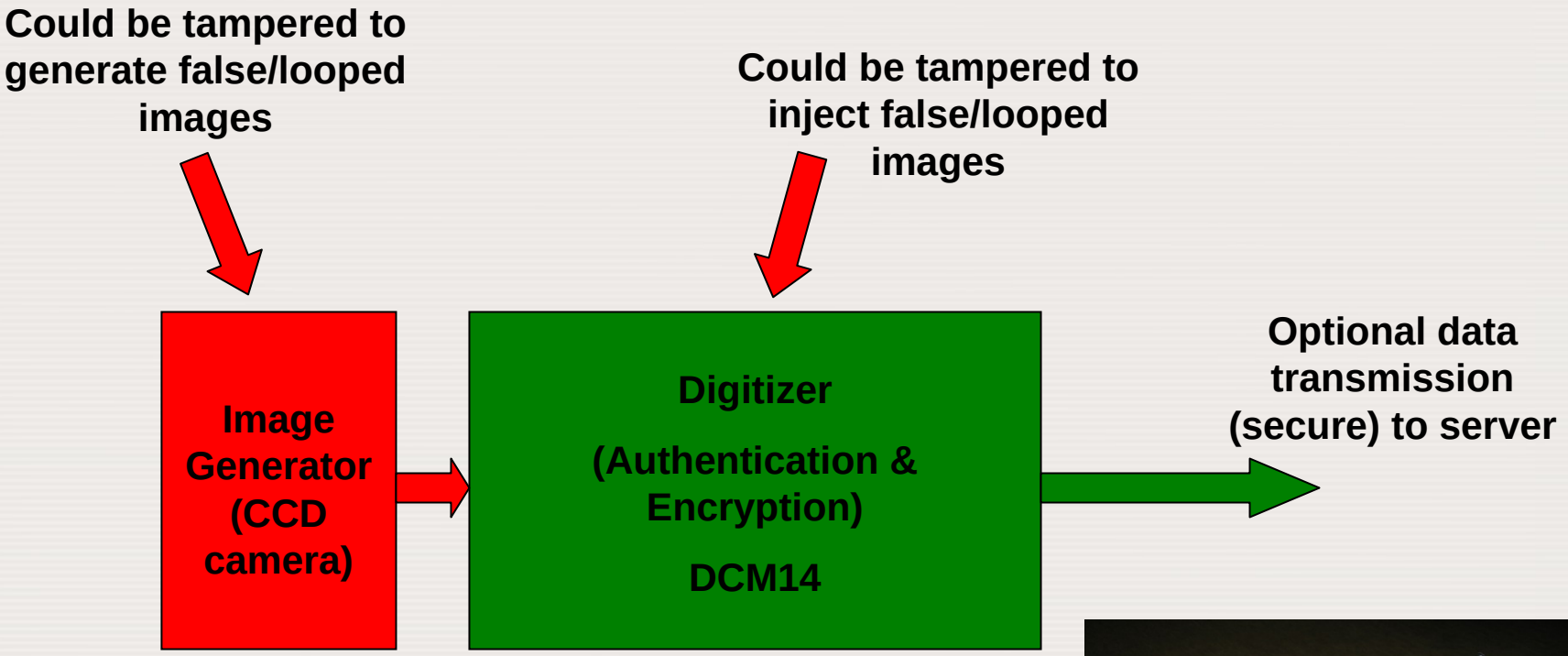


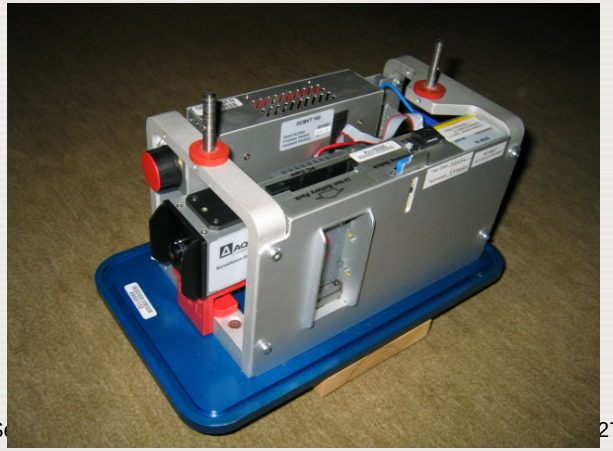
DIS camera example

DIS camera example



Potential DIS vulnerability





Potential DIS vulnerability (cont.)

- If unsupervised/unauthorized access is granted to a DIS on a component level then the image authentication potentially could be compromised.

Conclusion

- Future C&S devices must be tamper indicating at the service component level
- Data encapsulation (authentication and encryption) algorithms must be implemented according to “state of the art” technology at the time of equipment development, or equipment must be designed to support an upgrade to future encapsulation techniques.