The Future of Safeguards Technology

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• No known forecasts to date either in the areas of technology, politics or economics have proved to be really successful.
• None of the major events or technological breakthroughs defining the current environment were ever successfully foreseen or even properly evaluated at the time of their emergence.
• Examples are numerous, and in general, all of these detract from classical concepts of “smooth” extrapolation and probability assessment.
Nevertheless, attempts to form a vision of the future should never be abandoned as they help:

- To structure current efforts
- To establish priorities
- To provide a focus for short-term planning.

While being prepared for unavoidable adjustments or even radical changes

The history of international safeguards currently covers about five decades and one may identify illustrative examples of patterns in the evolution of different technologies.
“Conservative” pattern:
- Many radiation detectors, NaI(Tl) being the most striking example, have for decades remained the backbone of numerous applications, without significant changes.
- Advancement of the respective systems is mainly attributable to progress at the “back-end” (in data processing/storage/evaluation).

“Explosive” behavior:
- Information and Communication technologies demonstrate this type of behavior since approximately the mid 1970s.
- ICT-based safeguards applications generally follow this trend, with some inherent delay due to certain inertia in developing concepts and changing system architecture.
Looking backwards (2)

- **“Breakthroughs”:**
  - There are a few technological innovations, which have enabled real “Quantum Leaps” in some safeguard applications, examples being global networking, satellite imagery and, to a lesser extent, global positioning systems (GPS).

- **“Oscillators” and “Die-away(s)”**
  - Among technologies demonstrating this type of evolution pattern, one can notice certain types of neutron detectors (boron detectors as alternative to helium-3), film cameras (completely gone) and others

- Combinations of such different types of evolution patterns certainly make any forecasting effort based on simple extrapolation and trend analysis at the very least doubtful
Defining the Scope (1)

• “Safeguards technology” in a wide sense includes a variety of techniques and methodologies used in the process of obtaining the final product, i.e. Safeguard Conclusions:
  – Methods addressing statistical and integrated data analysis;
  – Laboratory analytical techniques;
  – Information technologies affecting all areas from everyday office activities to processing of digitized satellite images and establishing geoinformatic systems;
  – Measurement and other techniques available to the inspectors in the field;
  – Knowledge management and resource planning tools, etc.

• As this range is too broad for a single review, the scope of the current presentation will be limited to technologies addressing the needs of safeguard inspectors in the field.
Defining the Scope (2)

• Pursuant to the defined scope, the current presentation will mainly address:
  – Attended and unattended measurement techniques to be either installed permanently at facilities or brought there by Agency inspectors;
  – Technologies preserving continuity of knowledge about either nuclear material or the characteristics of related processes;
  – Instrumentation allowing the detection in real time during various types of inspections of indicators and signatures of NFC-related processes.

• A variety of other “Safeguards Technologies” will thus remain outside the focus of the current presentation and will be addressed elsewhere in the course of the meeting.

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Role of the Safeguards [Inspection] Technologies

• The general trend in the evolution of the overall international safeguard system is currently characterized by striving to implement coherently:
  – An “objectives based” state-level approach;
  – The full use of all available information for drawing safeguard conclusions;
  – Adaptable and dynamic safeguards implementation plans for different states based on state-level factors and the outcome of integrated information analysis

• The role of information obtained by safeguards instrumentation is unique in this sense as being, alongside the observations of inspectors in the field, the only type of knowledge directly obtained and authenticated by the Agency itself.

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The Snapshot of the Current Status

• After several decades of extensive evolution, the Safeguards instrumentation pool currently includes more than 200 systems capable of addressing the majority of inspection tasks.

• Taking into account the ever increasing scale of safeguards activities both at international, regional and national levels, the majority of these instruments have *de facto* become international standards, are rather well known, and hardly deserve detailed presentation to this audience.

• Therefore, it might be more productive to concentrate not on the successes and achievements, but rather on those features, which may be considered as far from optimal:
What is Wrong with the Current System?

• Extensive mode of evolution (new task → new instrument):
  – Pros: Responsiveness to innovations worldwide; flexible approach to customized solutions.
  – Cons: Lack of attention to standardization, maintainability, versatility of application, reliability and user friendliness; a slightly “chaotic” equipment categorization scheme.

• Prevailing reliance on the results of external R&D (commercial and/or sponsored by Member States):
  – Pros: economic efficiencies, flexibility, broad coverage of tasks;
  – Cons: ever-growing equipment pool, dependence on proprietary technical solutions and on availability of a diverse range of spare parts and components.
Other Challenges (1)

• The potential political importance and sensitivity of safeguards conclusions forces the Agency to establish a comprehensive system of equipment authorization for use in inspections:
  – Thorough elaboration of end-user and technical requirements;
  – Extensive testing both in laboratory and field environments;
  – Adequate training of inspectors;
  – Reliable support and logistical infrastructure.

• At the same time this results in:
  – A lack of flexibility in addressing ad hoc inspection tasks;
  – Disproportionate efforts in support for routinely and rarely used instrumentation;
  – The existence of “gray” areas for certain equipment classes.
Other Challenges (2)

• The diverse origins of instruments and simultaneous maintenance of different standards has led to an absence of adequate standardization in data review software;

• The wide introduction of unattended and remotely operating instruments emphasizes the need for data protection/encryption, which currently results in the necessity for inspectors to memorize dozens of passwords and/or use several security dongles addressing different data security protocols.

• The existing infrastructure mainly reflects “traditional” safeguard tasks targeted at verification of declared data, prescriptively defined by rigid criteria, and lacks flexibility to address the expanded scope of the verification mission.
Other Challenges (3)

• Irrespective of either benefits or deficiencies of the current system, there are certain permanently acting factors, which define the dynamics of further developments:
  – The need to establish balance between the “scientific perfection” and practicality of field applications – among a variety of technically sound technologies, only those providing tolerance to a lack of specialized expertise on the part of the operator, which are insensitive to unknown variations in the operating environment, capable of withstanding harsh environmental conditions, and economically feasible, eventually become part of safeguards instrumentation toolkit.
  – The need to achieve balance between reasonable conservatism in maintaining the existing toolkit and innovation in introducing cutting-edge technical solutions.
Drivers for Structural Change

• **Effectiveness:** Evolution of the Safeguards System:
  – Expansion of information base
  – Technology role outside “traditional” SG (CA, special inspections)
  – Verification missions beyond NPT.

• **Economics:** Expected Nuclear Renaissance (??)
  – Volume of NFC activities vs. available SG resources

• **Technological:** Existing and future gaps:
  – New reactor generations (fast breeders, liquid core, etc.)
  – Innovations in fuel cycle (pyro-processing, laser enrichment, etc.)
  – Actual start of long term storage/disposal
  – Spent fuel characterization, on-line enrichment monitoring

• **Ambitions:** From exploiting opportunities to managing the development process …
Elements of Vision for Future

- Defined in the series of documents:
  - The Agency Mid-Term Strategy
  - Department of Safeguards Long-Term Strategic Plan
  - Long-Term R&D Plan (under development)
  - Mid-Term Strategy of the Division of Scientific and Technical Services (being finalized)
  - Biennial R&D Programme (under preparation for 2012-13)

- May be presented and analyzed from different perspectives
Three Different Perspectives

1. Evolution pattern for instrumentation depending on prevailing application mode:
   - Equipment permanently installed in the field and operating in unattended and/or remote mode
   - Inspector’s toolkit addressing “standard” [declarations] verification tasks
   - Expert systems applied to complicated, rare, *ad hoc* and unique verification tasks
   - Inspector’s toolkit for CA and similar verification tasks (revealing undeclared activities/material)

2. Evolution pattern for traditionally defined technology groups, i.e. NDA, C/S; [DA]

3. Expectations regarding the introduction of technology innovations
1. Prevailing Mode of Application

• The most noticeable difference in application mode refers to “traditional” safeguards, i.e. verification of state/operator declarations, as compared with [instrumental] “search for” undeclared materials/activities:
  – Predefined measurement/surveillance scope vs. addressing ad hoc needs;
  – Upfront known operational environment vs. following the circumstances;
  – Confined set of expected verification results vs. “open-end” investigation

• Assignment to a respective class/category will affect:
  – Level of standardization/customization
  – Requirements for automation, reliability, maintainability, data security
  – Certification/authorization requirements
  – Approach to training of inspectors
  – Documentation requirements
  – Modes of technical support provided to field inspectors

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1.1. Unattended and Remote Equipment

• Mission:
  – To essentially replace inspector in standard and routine operations.

• Features:
  – Customized for concrete operational environment
  – Using “building blocks” design concept.

• Priorities in development and implementation:
  – Low maintenance solutions → automation, standardization at component level, reliability, redundancy, maintainability+, remote connectivity
  – Uniform user interface and data review platform.

• Reduced inspector training program
• Examples: surveillance, in-process monitors

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1.2. Standard Verification Toolkit

• Mission:
  – To be available for all inspectors upon demand.

• Features:
  – Standard equipment units (portable and transportable)
  – Fully integrated solutions.

• Priorities in development and implementation:
  – Versatility of applications (“workhorses”), transportability
  – User friendliness, uniform and highly automated data review software.

• Extensive, full-scale training program, detailed user documentation, in-house technical support.

• Examples: Gamma spectrometers, Neutron Counters.
1.3. Expert Systems

- **Mission:**
  - To address complicated (rare, special) verification scenarios

- **Features:**
  - Flexible equipment configurations, addressing concrete tasks
  - Direct participation of technical experts in inspection exercises
  - Availability of “one-for-a-case” authorization process (experts board).

- **Priorities in development and implementation:**
  - Maintaining in-house expertise and modeling capabilities
  - Access to unique instruments (COTS, lease from Member States).

- **Minimal training for inspectors (awareness campaigns).**

- **Examples: Tomographic scanners, 3D Laser rangers, GPR.**
1.4. CA Toolkit

• Mission:
  – Field support for activities under CA (visual/radiation/samples).

• Features:
  – Multipurpose equipment sets for uncertain detection scenarios.

• Priorities in development and implementation:
  – Preference to COTS instruments
  – Highest priority for portability and user friendliness:
    ➢ Hand-held, pocket-size, backpacks, vests/belts
    ➢ “Push-a-button”, “switch-on and forget”, concepts
  – Use of wireless communications, data streaming, GPS.

• Streamlined training procedures (automated instruments).

• Examples: LIBS, RAMAN, radiation “BackPacks”, misc.
2.1 NDA Technology Evolution (1)

- **Radiation sensors:**
  - Marginal improvements are expected
  - Availability of currently “expensive” sensors (LaBr, CdZnTe, etc.) to be improved → possible replacement for NaI(Tl)
  - Alternatives to $^3$He to be gradually introduced (boron-based, scintillators with PSD, etc.), depending mainly on economic factors
  - Further progress in electrically cooled HPGe detectors is expected
  - IAEA strategy: to closely monitor/evaluate outside developments, limited in-house developments (front-end electronics).

- **Other sensors:**
  - Adequately addressed within the worldwide industrial community (weight, pressure, temperature, light, etc.)
  - IAEA strategy: to rely completely on COTS solutions.
2.1 NDA Technology Evolution (2)

- Data acquisition platforms (unattended apps.):
  - From current diversity to (ideally) “one-for-all” standard.
  - The Agency is currently pursuing UNAP concept, however it is premature to make definite conclusions.
  - Market availability of outdated equipment becomes a real issue (MiniGrands, JSR’s, ADAM).
  - IAEA Strategy: reliance on UNAP success, while being prepared for backup solutions.

- Data processing/review software
  - Current situation in IAEA is far from optimum (diversity, immaturity, version control issues, different security protocols)
  - Mismatch in dynamics with hardware progress
  - IAEA Strategy: to promote uniform modular approach using, inter alia, EURATOM experience (RADAR, CRISP).
2.2 Surveillance Technology Evolution

- From inspector’s film cameras to digital networked solutions

- Next Generation Surveillance System (NGSS):
  - Supposed to be a solution for at least a decade
  - Implementation already started at the facilities in test mode
  - “One-for-all” building block
  - Scalable, direct networking
  - Modern security protocol considered to become a wider applicable standard (UMS, Sealing)
  - Low-maintenance, including partial serviceability by third parties.

- IAEA strategy: extending NGSS operative modes (underwater), concentrate on developing image post-/pre-processing algorithms; consider non-optical surveillance.
2.3 Sealing Technology Evolution

- Diversified but limited range of designs:
  - Standard cheap passive seal (CAP) – outdated
    - To be replaced by in-situ verifiable design (glass)
  - Fiber optics COBRA seal
    - continued to be used after upgrades and replacing reader
  - Active seals (VACOSS → EOSS)
    - Strong economic motivation for replacement (search for COTS, R&D)
    - Consider merging with remotely monitored sealing arrays
  - Special seals (ultrasonic bolts, etc.) → to maintain
  - Surface identification techniques, tamper indicating enclosures → R&D

- IAEA strategy: “one-for-all” hand-held reader; security protocols coherent with those in NDA and Surveillance.

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3.1 Awaited Innovations

- Spent fuel characterization (long-standing “gap”):
  - Intensive research program in USA (one of NGSI priorities)
  - Still far from expecting field applications
  - Low probability of identifying a universal solution.

- One-line Enrichment monitoring

- Analytical chemistry in the field:
  - Laser spectroscopy → dependent on progress in tunable lasers
  - Express sampling on-site → COMPUCEA as prototype.
  - Remarkable progress (not SG-driven) from heavy laboratory equipment to hand-held fully automated devices:
    - LIBS – available as BackPack (US) and briefcase (CA) formats
  - “Laboratory on the chip” concepts.

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Potential Innovations (TBD)

- Wireless inter-instrument communications:
  - Potential value for data security (replacing cable conduits)
  - Integrating elements of CA toolkit(s).
- Remote sensing (lidars, etc.):
  - Demand-driven vs. technology-push analysis still pending.
- Underground (inertial) navigation
  - DIV at underground and heavily protected facilities.
- “Physics” signatures (radiation, seismic, acoustic, etc.):
  - May be viewed as reasonable alternative to classical C/S for stable NM configurations, structural features, fixed designs, etc.
- Active interrogation (neutron, gamma) → niche still to be defined
- Minor actinides, Deuterium, Tritium → to be policy driven
- Portable mass-spectrometry → Ever-lasting “dream” that may outweigh all of the above expectations!

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THANK YOU!