International Cooperative Monitoring for Reactors

Applied Antineutrino Physics Workshop

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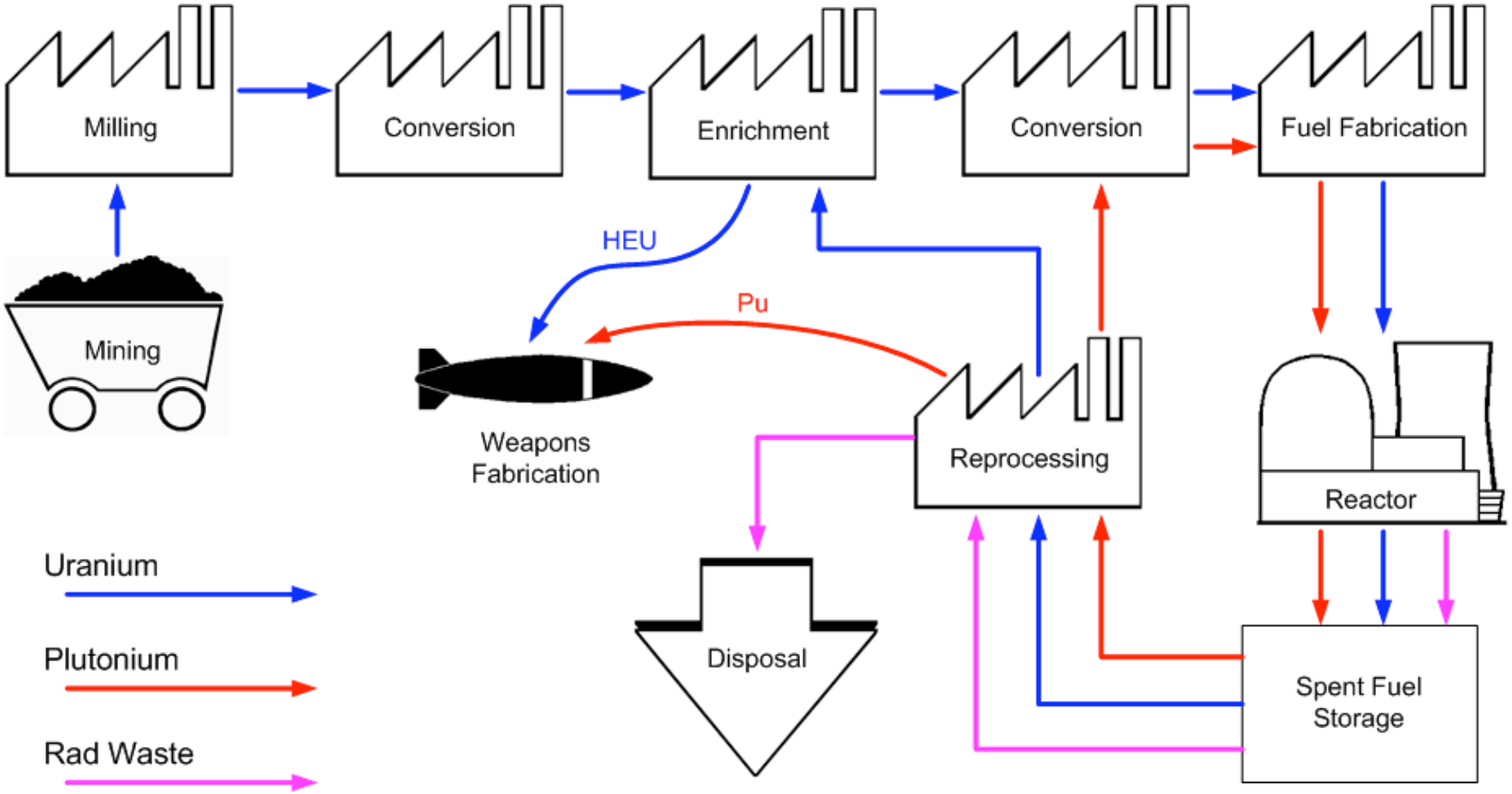
Albuquerque, NM USA

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

- Establish the scope and context for this presentation
- Describe the concept of cooperative monitoring
- Cite examples of cooperative monitoring applied to reactors
- Draw conclusions with implications for antineutrino detection

Reactors comprise only part of the overall fuel cycle.



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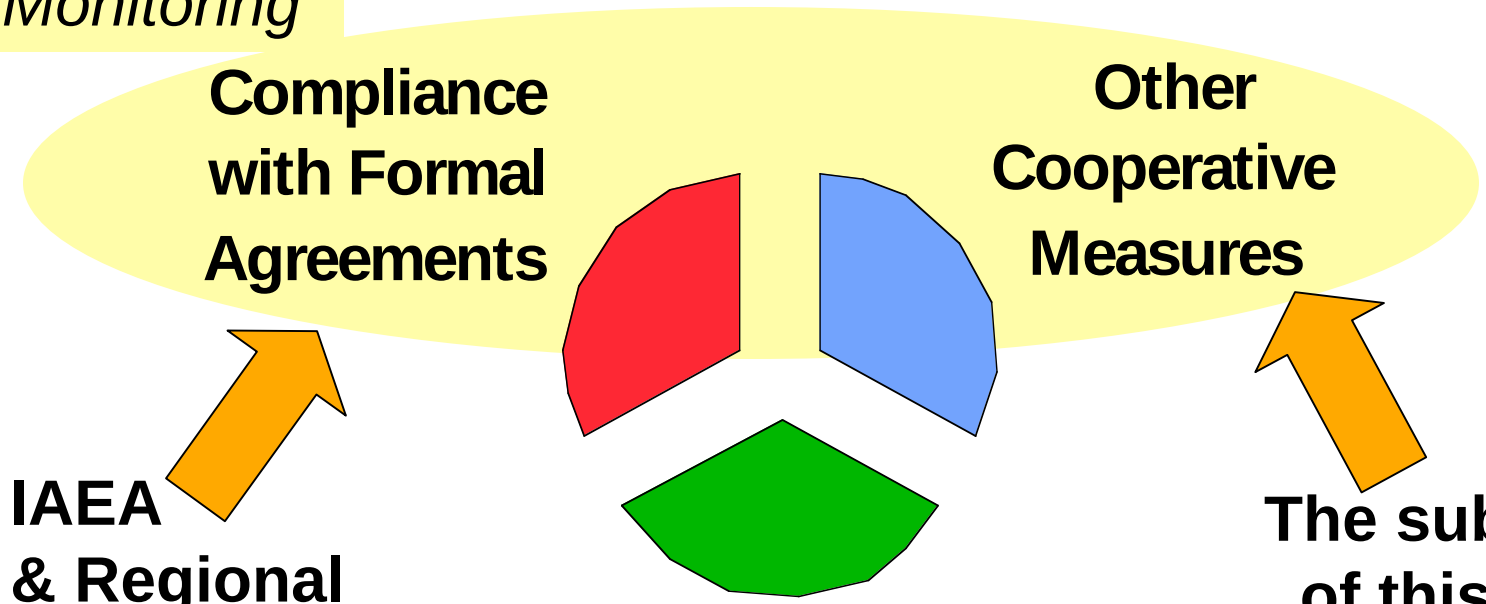
A comprehensive approach to international security issues is multidimensional.

Cooperative Monitoring

Our context: *nuclear nonproliferation*



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Why would I want to do anything beyond compliance? Isn't compliance sufficient?

- Compliance with the "letter of the law" often isn't enough to make judgments about *intent*
- There may be a lack of trust or confidence that the compliance-based approach is fully effective
- Promote our business: we're responsible and open about our use of nuclear technology
  - As a state, the target audience = other states
  - As a business, the target audience = public, suppliers, customers, neighbors
- Set a precedent, expectation or norm for others
- Avoid surprises
- Facilitate entry into a compliance regime

<u>Cooperative Monitoring (CM):</u> The obtaining and sharing of agreed information among parties.

- **Cooperation: requires consent of the monitored party**
  - **Not always "public": group that shares may be exclusive**
  - **Has specific, limited scope: it's not "everything"**
- **Nuclear transparency is an example of CM:**

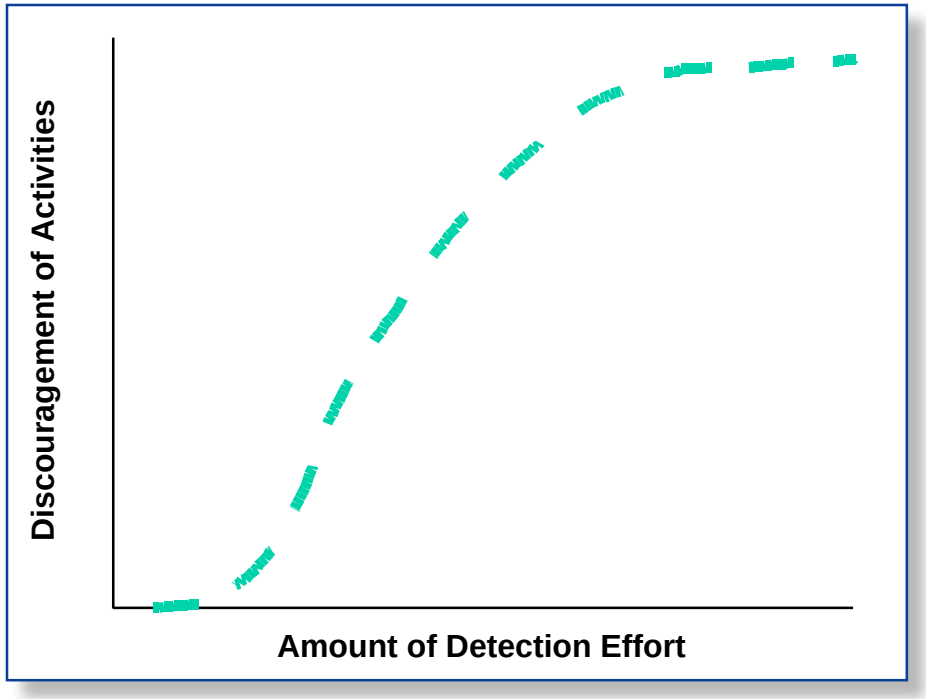
  "a cooperative process of providing information to outside parties so that they can independently assess the safety, security, and legitimate management of nuclear materials."
- **Establish that nuclear activities pose no threat:**
  - **Either our neighbor's nuclear activities, or our own**
  - **Whether intentionally or unintentionally**
- **Complements—does not replace—national capabilities**

Issues for Cooperative Monitoring

- Policy
  - Context
  - Objectives
  - Constraints
  - Risk
- Supporting Infrastructure
  - Institutional
  - Technical
- Security
  - Information protection
  - Technical means
  - Protecting unrelated information
- Technical
  - Parameters / Observables
  - Method
  - Reliability
  - Redundancy
  - Trustable
  - Workability
  - Sharable
- Results & Anomalies
  - what to do if the system works?
  - What if it doesn't?
  - Procedures...!

Cooperative measures put undeclared nuclear activities at risk for detection.

- Assumption
  - Undeclared activity would not want to be discovered
- Conclusions
  - Detection measures may not have to be perfect to discourage undeclared activities
  - States are unlikely to cheat if they accept cooperative monitoring of their nuclear activities



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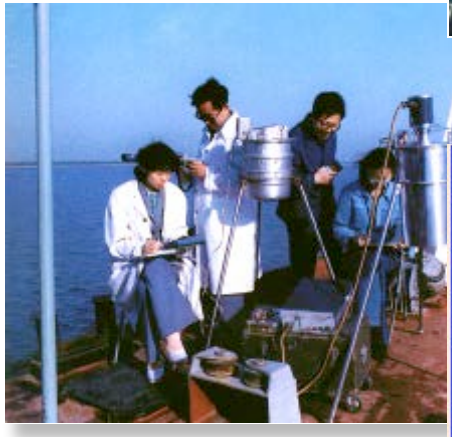
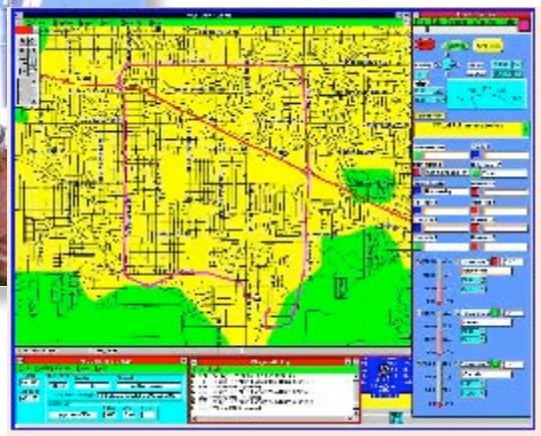
Cooperative monitoring of reactors: What are we interested in knowing?

- Reactor design
- Reactor status
  - Construction / Operation / Shutdown / Decommissioned
- Facility operation
  - Potential for undeclared / other activities?
  - Deviation from expected practice
- Non-diversion of nuclear material
  - Especially direct-use: fresh MOX; spent fuel
- Physical protection
- Production of nuclear material and waste products
- Existence of an undeclared reactor

Cooperative monitoring may address more than nonproliferation.





- Nuclear safety
  - Assurance that danger of an accident is minimal
- Environmental impact
  - Check for contamination of vegetation, groundwater, soil, etc.
  - Assess the radiation exposure risk to public
- Transportation of nuclear materials
  - Minimize hazards to those near the route of material shipments

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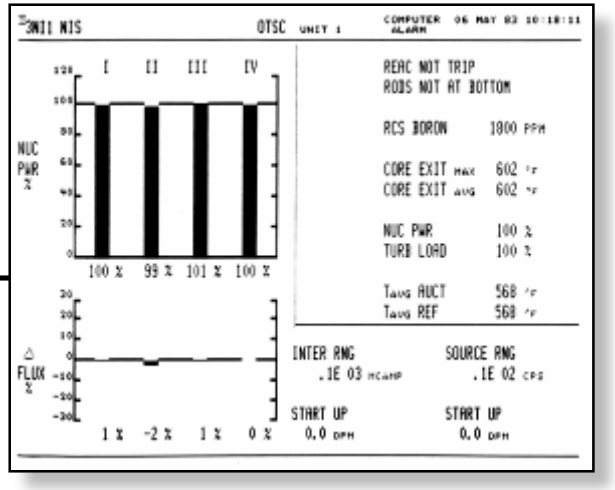
Examples of cooperative monitoring for reactors

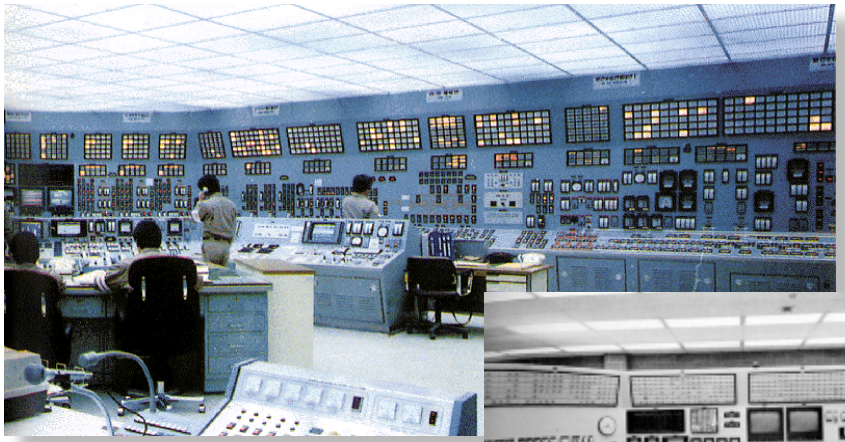
- Sharing operational and other information
  - Declare capabilities
  - Publish operating history, planning documents
  - Exchange or share routine facility data
- Providing access
  - Visits, inspections
  - Allow design verification
  - Access to processes: e.g., site selection, licensing
- Permitting independent (3rd party) monitoring
  - Offsite measurements for radionuclides
  - Portal / perimeter monitoring
  - Onsite monitoring of reactor power

Provision of reactor data

- Many routine measurements are made at reactors
- Facilities already transmit some data to national regulators



- Examples:
  - coolant temperature
  - steam pressure
  - thermal power
  - turbine output
  - containment pressure
  - site radiation
  - radiation in effluent water
  - control rod positions
  - emergency system status



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Cooperative monitoring can facilitate direct interactions.

- Site visits
  - Technical inspections
  - Public relations tours
- Meetings
- Training
- Interactions can be via
  - Foreign ministries
  - Regulatory bodies
  - Professional societies
  - Academic institutions
  - Industrial associations

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Pre-NPT confidence building between Argentina and Brazil employed cooperative monitoring.

ABACC and IAEA inspectors at an inspection mission planning meeting

Inspectors receive practical training during safeguards course

ABACC inspector preparing inspection report

Post inspection review

ABACC:

Brazil-Argentina Agency for the Accounting and Control of Nuclear Materials

Photographs courtesy of ABACC

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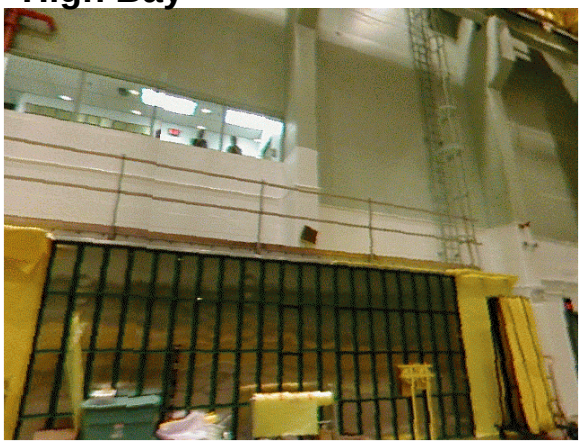
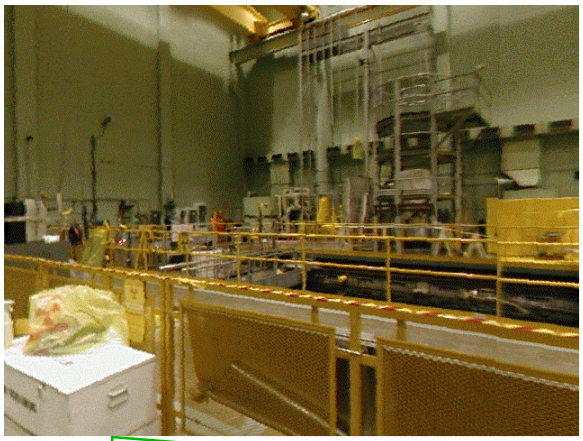
Access can be provided through “virtual” tours: shown here is the High Flux Isotope Reactor.

High Bay

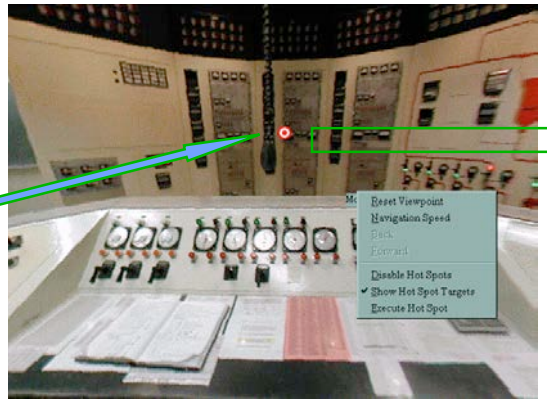


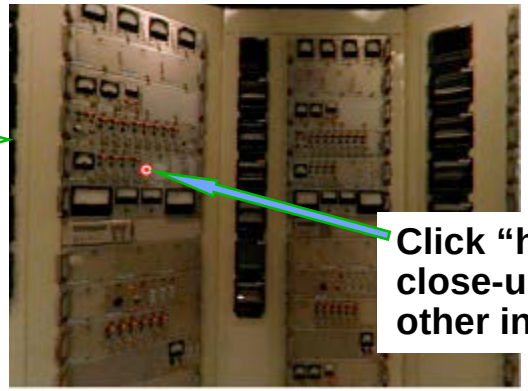


Swing “eyes” around 360º

Control Room

Click “hot spot” to move to linked image





Click “hot spot” to display close-up image or a link to other information

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Cooperative monitoring may rely heavily on technology-based systems.

- **Multinational Technical Project: Enhanced Transparency of Nuclear Material Storage**

- **Remote monitoring**
- **Reports status on demand**
- **Greater redundancy**
- **Less intrusive**
- **Reduced dependence on onsite inspections**

Australia

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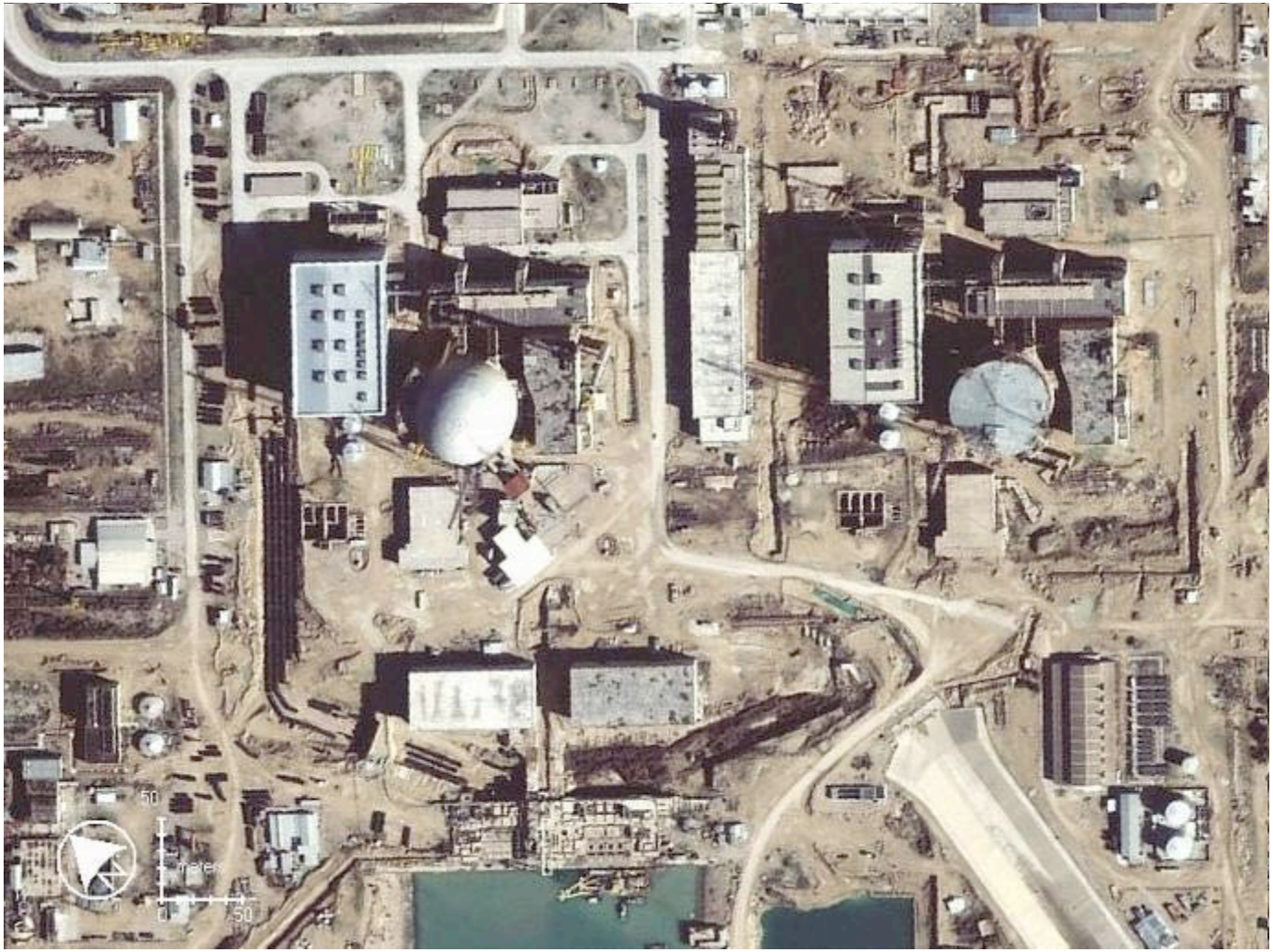
Overhead imagery can reveal status of reactor facility construction: Bushehr, Iran (IKONOS)



(courtesy UNM/EDAC, GlobalSecurity.org, Space Imaging)

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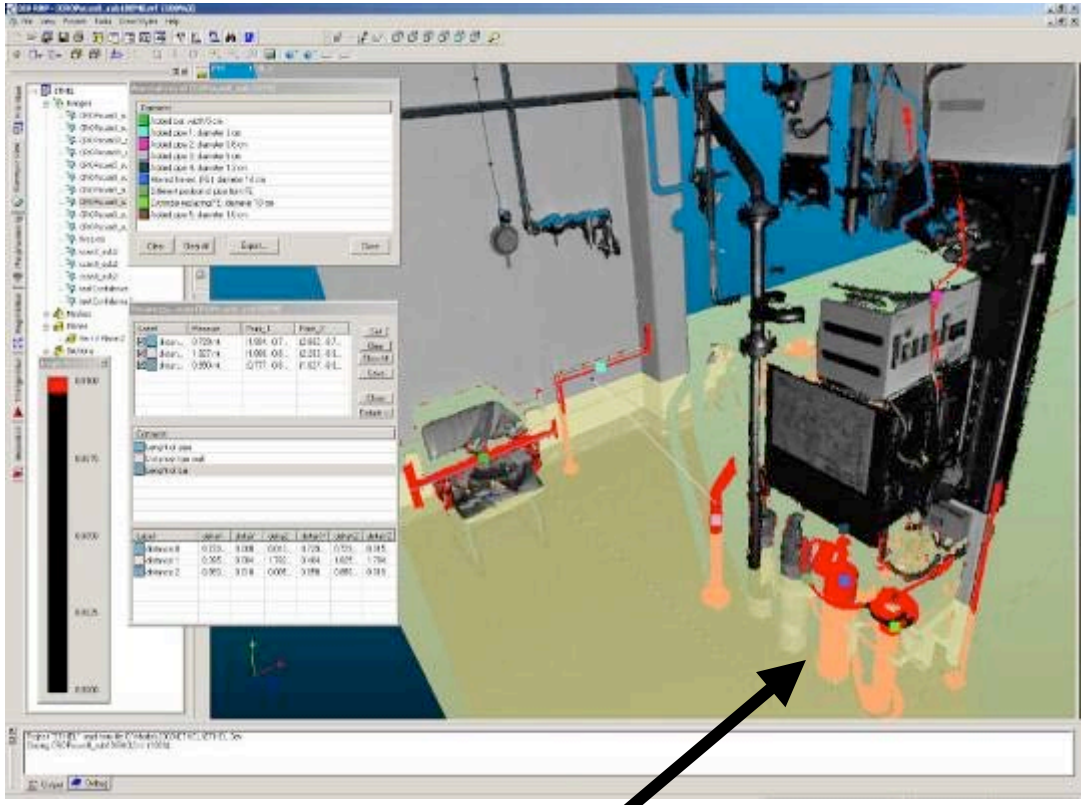
3-D Laser Range Scanning is useful for verifying complicated as-built facility design changes.

Credit:
João G.M. Gonçalves, et al (JRC-Ispra/ IAEA)
"3D Laser Range Scanner for Design Verification"
Proc. INMM 44th Annual Meeting, Phoenix AZ, 13-17 July 2003



Change detection highlights differences from a previous reference image

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Overhead imagery can reveal operational status: Reactor restart at Yong Byon, DPRK (2002—2003)

(courtesy UNM/EDAC, GlobalSecurity.org, DigitalGlobe)

Both spatial and spectral information is useful in overhead sensing by satellite or aircraft.

Merged Landsat/Spot images of Chernobyl reactor site

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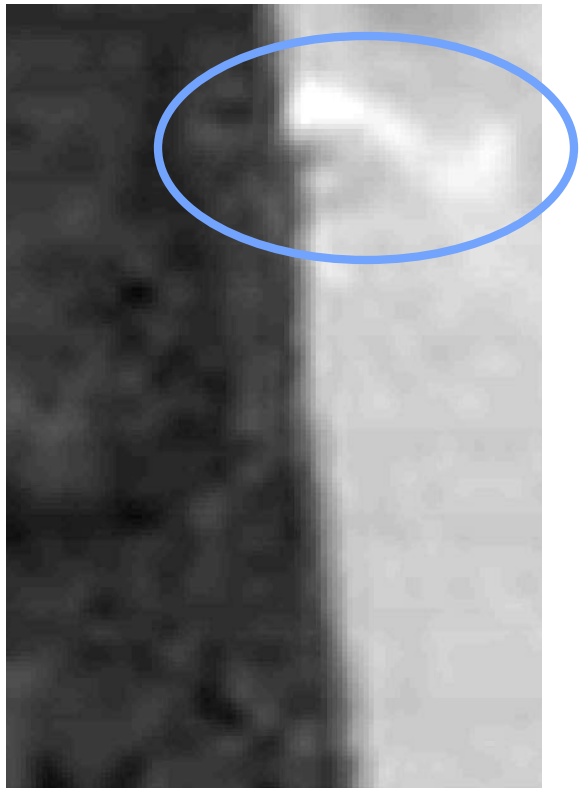
Landsat Thermal Band 6 reveals warm plume from operations at Tokai-Mura, Japan.

Spot: 10 meter

Landsat: IR 30 meter



Landsat: Thermal 120 meter

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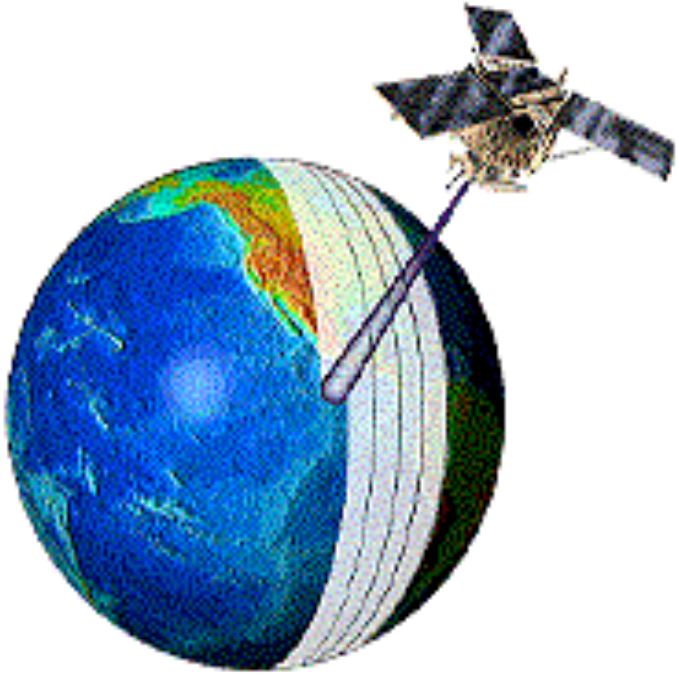
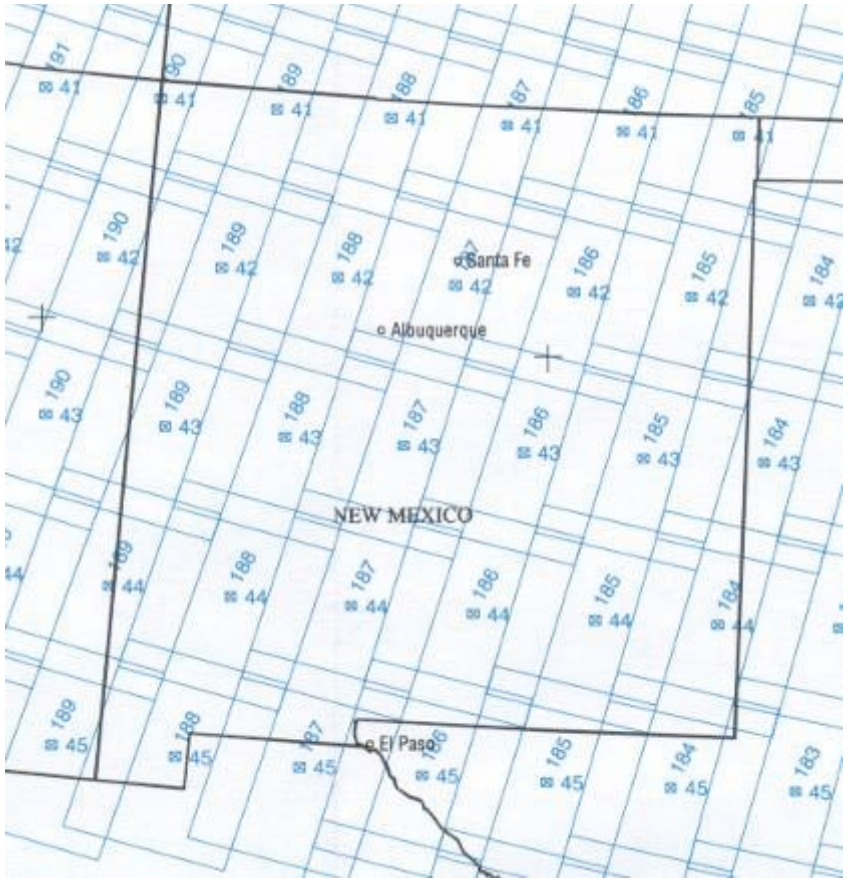
High-resolution satellite imagery is not useful for wide-area detection of undeclared activities.



It is essential for an analyst to know just where to look.



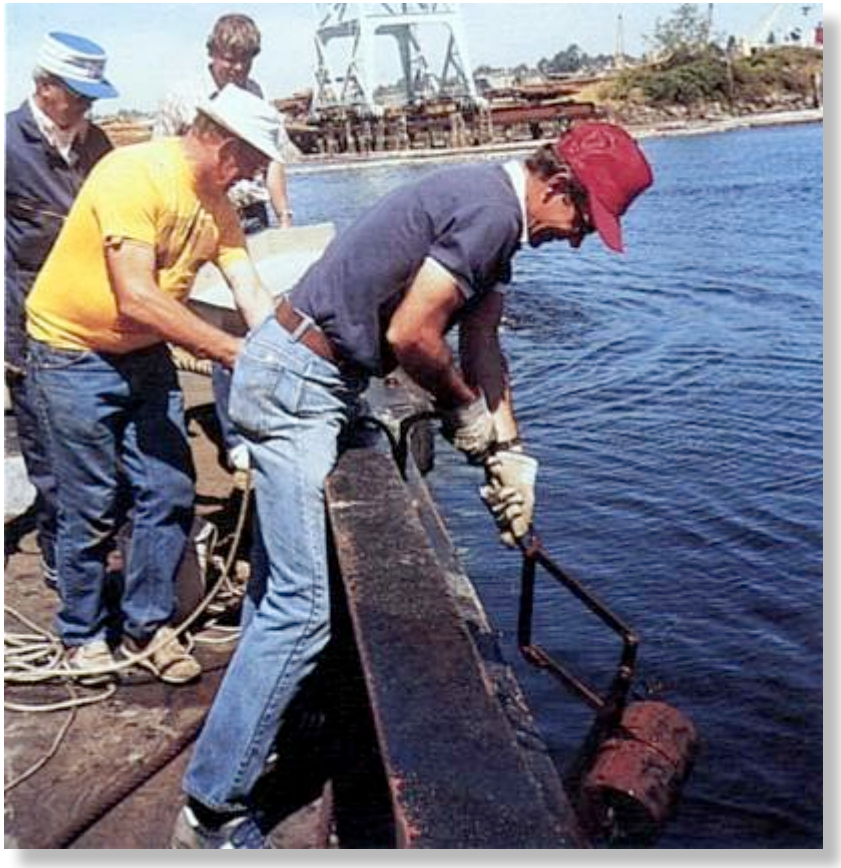
IRS-1 path and row map

All reactors release some radioactivity during normal operation.

- Various radioactive isotopes can be detected
  - Near the reactor site (within a few km)
    - ^{14}C: graphite reactors; ^{3}H: heavy water reactors
    - also short-lived isotopes ^{131}I; ^{41}Ar
  - Distant
    - longer lived isotopes of iodine and various metals deposit in waterways (and their associated plants and animals)
    - evidence lasts many years in river deposits
    - seaweeds and invertebrates can concentrate some isotopes by 10,000-fold or more
- Collection & Analysis methods
  - Soil, water and swipe samples
  - Quantitative gamma spectroscopy

Environmental sampling is an important tool for detecting trace evidence of undeclared activities.

- Natural concentrators - various seaweed and invertebrates
- Long retention of traces - sampling does not have to be prompt or frequent
- Wide area sampling - low intrusiveness reduces sensitivities about losing legitimate industrial secrets
- Thermal Ionization Mass Spectroscopy (TIMS)
- Inductively Coupled Plasma Mass Spectroscopy (ICPMS)



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Nuclear environmental monitoring techniques are already part of several cooperative projects.

- Sampling for radioactive waste in the seas
  - Sea of Japan (RF, Japan, ROK, IAEA)
  - Barents Sea (RF, Norway, IAEA)
- IAEA tests of environmental monitoring techniques for the Additional Protocol
  - Sweden - detected routine reactor radioactivity 20km out to sea
  - Hungary - river sampling for radiation from reactor

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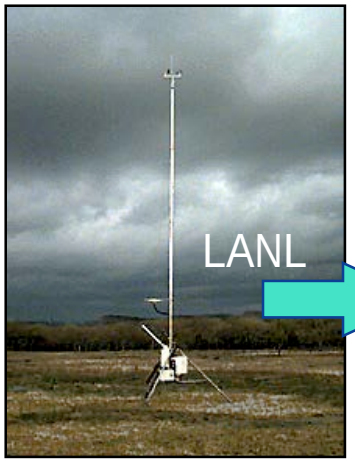
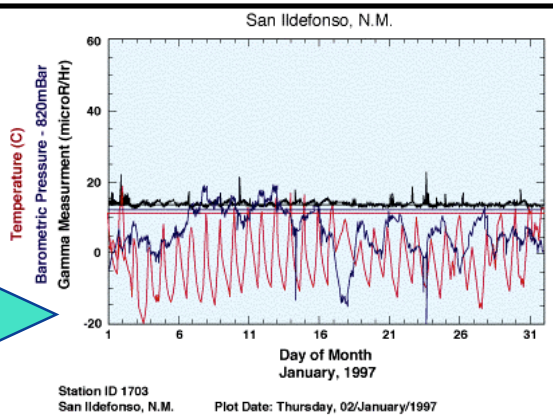
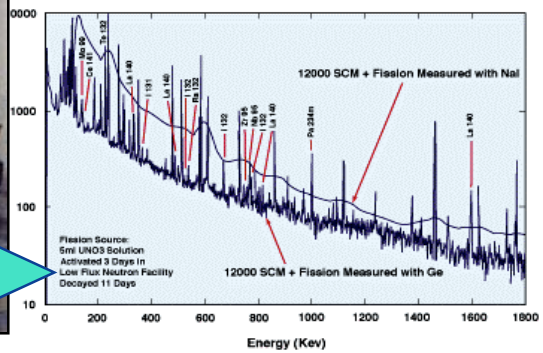
Airborne radionuclide techniques span levels of technical complexity.

- Total Gamma rate
  - measure total airborne radiation
  - useful for emergency warning; public awareness
- Gamma-ray energy analysis
  - gamma decay of isotopes has characteristic energies
  - portable or laboratory tool
- High sensitivity energy analysis (CTBT)
  - faster sampling
  - better sensitivity







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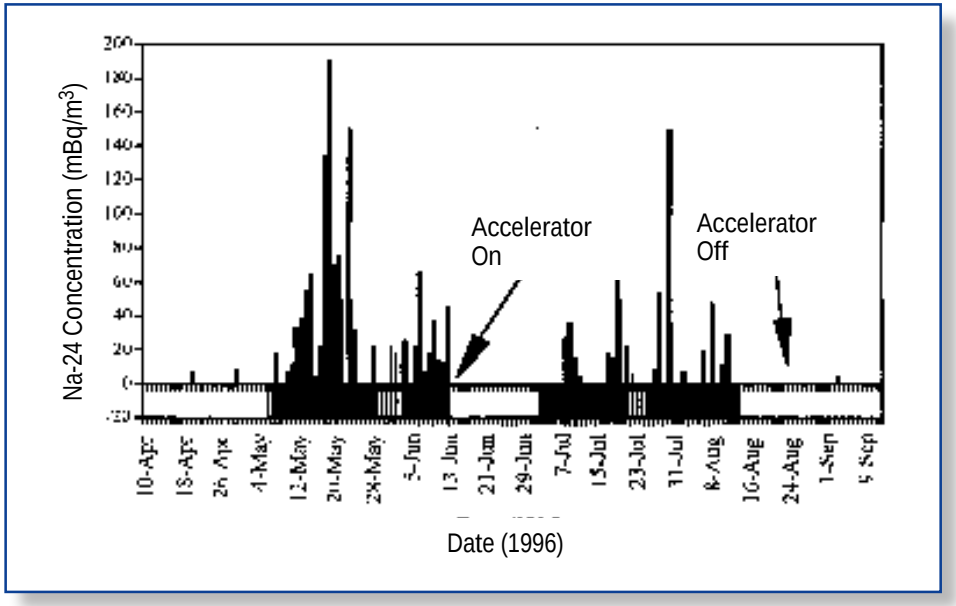
Environmental detection of airborne radioactivity can be complicated by non-reactor sources.

- **Airborne radionuclide monitoring test in Canada was an operational test of CTBT sampling**
- **Unexpected, periodic changes in airborne radioactivity were detected indicating isotopes of sodium and iodine**
- **Eventually traced to a small, nearby industrial cyclotron producing medical isotopes**



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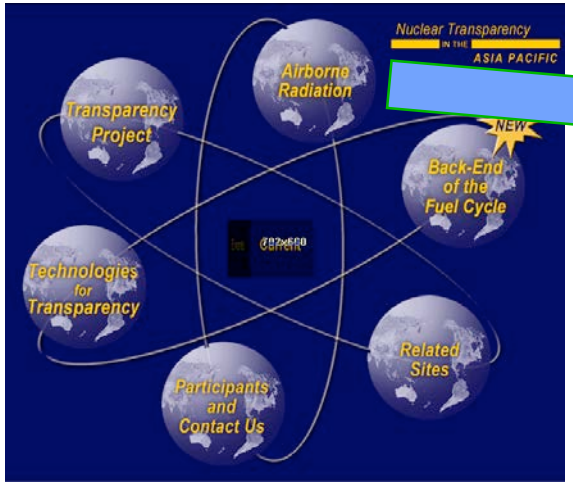
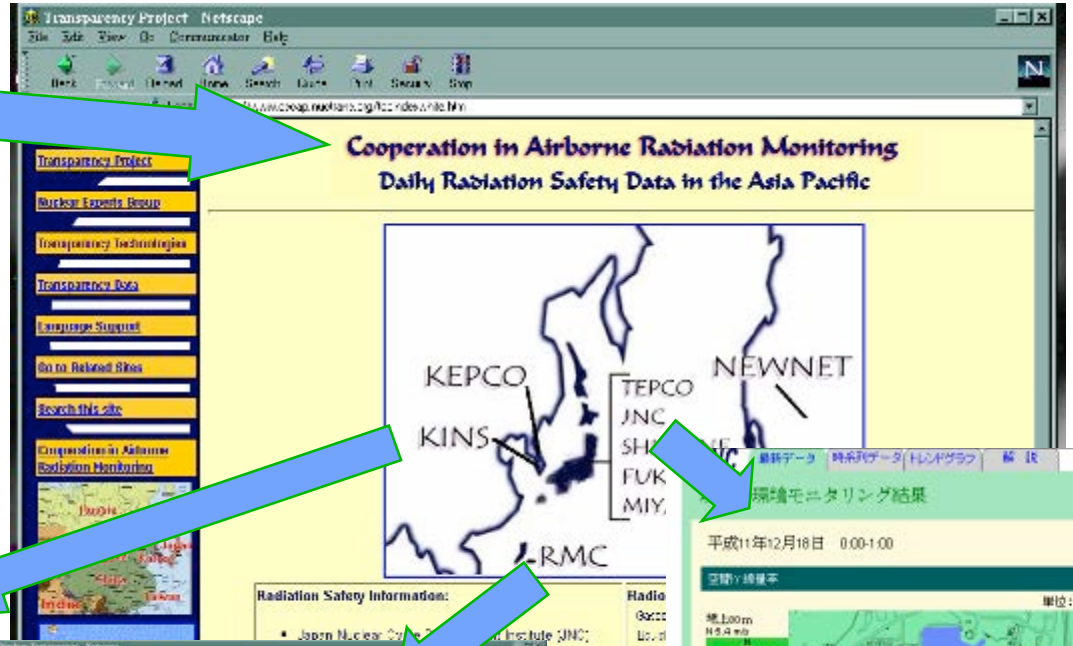
CSCAP Nuclear Transparency Data Website: Airborne Radiation Data

http://www.cscap.nuctrans.org





KINS in Korea

RMC in Taiwan

JNC in Japan

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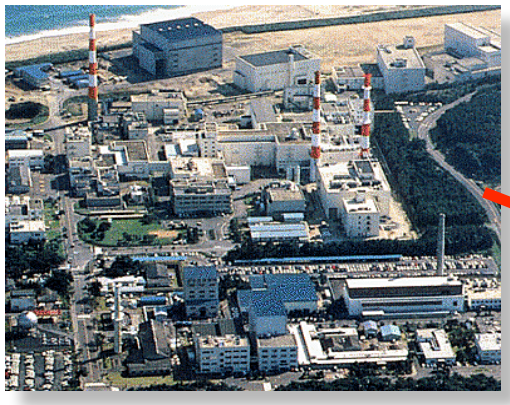
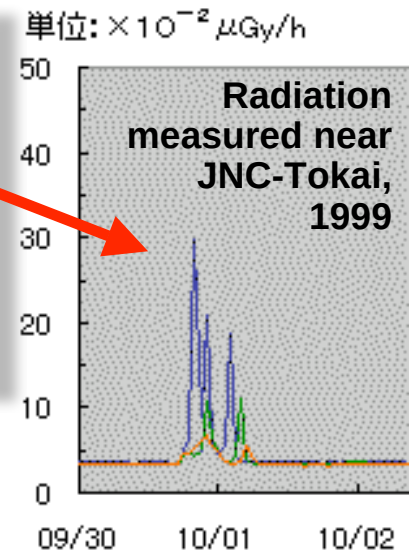
Airborne radionuclide monitoring was particularly useful during two recent events.

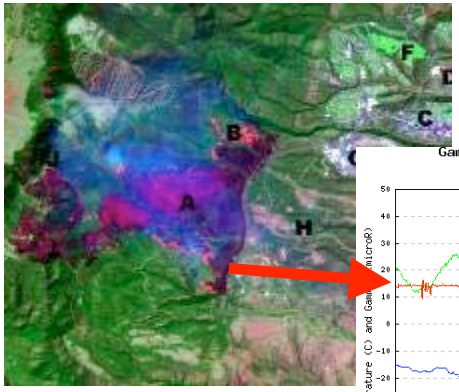
- **Tokai-mura criticality accident**
  - **240,000 people visited JNC-Tokai website in one day**
  - **JNC credited with addressing public fears**

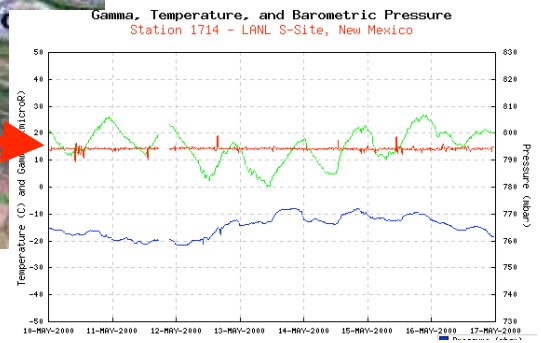
- **Cerro Grande (LANL) forest fire**
  - **Newspapers reported rumors of radiation in smoke**
  - **Los Alamos NEWNET data showed only minor releases**





Radiation measured near JNC-Tokai, 1999





Radiation measured on fire edge at LANL, May 2000

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Conclusions

- There is a universe of information exchange for reactors that exists outside of the safeguards world
- Consideration of potential application for antineutrino detection should also explore this non-Safeguards space
- Needs to be more than just a complicated, high-cost reactor power monitor
- Should exploit unique aspects
  - difficulty to be shielded or otherwise spoofed
  - Can provide isotopic discrimination of the fission source (U/Pu)