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Title: JOINT DOE-PNC RESEARCH ON THE USE OF TRANSPARENCY IN SUPPORT OF NUCLEAR NONPROLIFERATION

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JOINT DOE–PNC RESEARCH ON THE USE OF TRANSPARENCY IN SUPPORT OF NUCLEAR NONPROLIFERATION

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Disclaimer:

The views presented in this paper represent only the personal views of the authors. They do not necessarily represent the views of PNC, LANL, DOE or the University of California. All discussions were from the nuclear nonproliferation viewpoint, so information considered for release for enhancing transparency does not always mean that operators can actually release this information due to requirements to protect both nuclear materials and sensitive nuclear technology (SNT). In case of actual information release, more consideration and discussion are definitely needed from many viewpoints.

Remarks:

This paper was written in September 1998. From October 1, 1998 PNC will officially change its name from PNC to JNC, Japan Nuclear Cycle Development Institute.

The paper was originally written in English. A tentative Japanese translation is also available.

Introduction

PNC and LANL collaborated in research on the concept of transparency in nuclear nonproliferation. The research was based on the Action Sheet #21, which was signed in February 1996, "The Joint Research on 'Transparency' in Nuclear Nonproliferation" under the "Agreement between the Power Reactor and Nuclear Fuel Development Corporation of Japan (PNC) and the US Department of Energy (DOE) for Cooperation in Research and Development Concerning Nuclear Material Control and Accounting Measures for Safeguards and Nonproliferation."

The purpose of Action Sheet 21 is to provide a fundamental study on "Transparency" to clarify the means to improve worldwide acceptability for the nuclear energy from the nuclear

nonproliferation point of view. This project consists of independent research and then joint discussion at workshops that address a series of topics and issues in transparency.

The activities covered in Action Sheet 21 took place over a period of 18 months. Three workshops were held; the first and the third hosted by PNC in Tokyo, Japan and the second hosted by LANL in Los Alamos, New Mexico, U.S.A.

The following is a summary of the three workshops.

I. First Workshop

The first workshop, held March 10-11, 1997, in Tokyo, addressed the policy environment of transparency. Each side presented its perspective on the following issues: 1) *a definition of transparency*, 2) *reasons for transparency*, 3) *detailed goals of transparency* and 4) *obstacles to transparency*.

A. Determine Different Definitions of Transparency

PNC felt that the definition of transparency could change depending upon the audience, the timing requirements of the activities, the location of the effort (country or facility where activity takes place), and changes in the international environment, and therefore a broad definition would be best. Culture also has an impact on the definition of transparency. Cultural characteristics and beliefs will affect how the definition is interpreted. Also, it is difficult to determine what constitutes transparency and what activities actually demonstrate transparency.

Another problem for PNC stems from the words 'openness' and 'transparency' themselves. Sometimes these words seem to be used interchangeably. Openness is sometimes used to mean allowing increased access to facilities, providing additional documentation, and increasing participation in international forums in the nuclear field. Transparency is more of a general desire to share information about the day-to-day activities at PNC nuclear facilities. To be open is just to allow more access, but to be transparent encourages trust.

As a general definition, PNC submitted the following definition: *"Transparency is the effort to promote mutual trust, improve credibility, and establish working relationships between countries, international agencies, other nuclear entities and citizens through the sharing of information with respect to nuclear activities, both in the areas of nuclear disarmament and the peaceful use of nuclear energy."*

The LANL representatives also felt that transparency must be flexible enough to meet the demands of a variety of situations, locations, and needs. Indeed, each transparency effort will depend upon the situation and the target audience, but, in general, it involves documenting nuclear activities in such a way that an outside observer can form an accurate picture of those activities. Therefore, the definition should be seen as flexible and can be used in a variety of ways to accomplish a variety of tasks.

In addition, LANL felt that the voluntary release of information was the true measure of transparency. Transparency goes beyond what are traditionally thought of as required activities, such as reporting to regulatory bodies. This distinction is evident in LANL's definition of transparency: *"Transparency is the voluntary release of information for the purpose of reassuring outside parties that one is engaging only in announced activities."*

The most important difference between the two sides seemed to be the concept of voluntary transparency versus required transparency. LANL believed that transparency is the result of the voluntary release of information, over and above what is specified by previously existing requirements or undertakings. However, PNC felt that obligatory and voluntary documentation both were included in transparency and that, perhaps, of the two, voluntary might be inferior to obligatory activities because the voluntary information is not formally verified. This difference may be due to the fact that the US is a nuclear weapon state, where Japan is not. Nuclear weapon states and non-nuclear weapon states have different responsibilities in the international nonproliferation regime.

B. Determine Reasons for Transparency

PNC organized its reasons for transparency into three main areas: 1) the need for nuclear energy, 2) safety concerns, and 3) nonproliferation.

Japan needs nuclear energy due to its limited natural resources, and the country has adopted a recycling program as its long-term energy strategy. In addition, the demand for energy will continue to grow since both the population and the economies in the Asian region are increasing. Many Asian countries are interested in pursuing nuclear energy to satisfy their growing energy needs.

Citizens around the world are becoming more and more concerned about nuclear activities, not only in issues of nuclear disarmament, but also in the use of nuclear energy in general. Of particular concern is the safe and environmentally friendly operation of nuclear facilities. PNC feels that by becoming more transparent about its nuclear activities to citizens, it will create an atmosphere of trust and support among the population.

In the area of nonproliferation, PNC would like to use transparency as a way to confirm that it is indeed a peaceful user of nuclear materials as well as to ease regional concerns.

It is desirable to give the public and other countries additional assurances that nonproliferation obligations are being met. It is believed by LANL that International Atomic Energy Agency (IAEA) safeguards are completely adequate for verification of obligations under the Nuclear Nonproliferation Treaty (NPT), but extra steps beyond the requirements of IAEA promote a higher level of trust.

C. Determine the Detailed Goals of Transparency

As for PNC, the goal of transparency is to become as transparent as possible to a variety of audiences; however, 100% transparency to everyone is impossible. There are always inevitable, but reasonable and acceptable, obstacles to transparency. Because of the differences in target audiences, the details of transparency measures will vary. Therefore, the ultimate goal of

transparency is to show a satisfactory level of transparency to each target. To achieve this goal, some descriptions such as at the "Mechanism of Transparency" (Table 1) are useful as a preliminary step for developing transparency options.

MECHANISMS OF TRANSPARENCY	
Who	To whom should one be transparent? (general public, foreign government, local government, mass media, international organizations, etc.)
Which	Which facility needs to become more transparent? (enrichment plant, reprocessing plant, fuel fabrication plant, etc.)
What	What aspects (peaceful use of nuclear energy, nuclear nonproliferation, operation safety, etc.) and what contents (technology, people, materials, etc.) need to be more transparent?
When	When (timing) should transparency efforts be implemented? (immediately, step-by-step)
How	How (what measures) can one show transparency? (share more information, facility visits, education/training, web sites, etc.)

Table 1

LANL takes a similar approach to the goals of transparency. Although LANL is also interested in becoming as transparent as possible, the goal of U.S. transparency efforts is to assure the audience that non-proliferation obligations are being met. To accomplish this, LANL tailors each transparency measure according to the appropriate audience.

D. Determine Obstacles to Transparency

For both sides the complications of both domestic and international agreements/laws are an impediment to transparency. However, these obstacles are derived from SNT and physical protection requirements so they are seen as acceptable obstacles.

PNC is focused on existing international, multilateral, and bilateral agreements, such as the NPT; the London Guidelines, and "Agreement for Cooperation between the U.S. and Japan Concerning Civil Use of Atomic Energy." Ensuring that PNC adheres to all the requirements and guidelines of the myriad of agreements can be both time consuming and costly. It will also be difficult to create new transparency initiatives without reviewing how they will interact with the existing agreements.

Of primary concern to PNC was the lack of a Japanese equivalent to the Freedom of Information Act of the United States. At the time of the first workshop, Japan did not have a law with regards to the release of information, but an information disclosure act was being drafted and was making its way through the Japanese legal system.

PNC is in the process of becoming more transparent. On June 30, 1997, new guidelines for information disclosure for PNC procedures were released to the public and took effect on July 1, 1997. The underlying principle of these guidelines is that PNC's operations must be performed in an open, transparent manner, except in cases where Japan's nonproliferation obligations, physical protection concerns, and the like require that limited pieces of information be kept confidential.

The U.S. side is affected by national security concerns, a delicate and complicated topic. Unlike Japan, the U.S. has the added dimension of being a nuclear weapons state. Due to the classified nature of much of the information, many additional steps are needed before the information can be released.

Questions regarding the protection of proprietary rights are also a concern. Companies under contract to the U.S. government want to stay in control of their technology and maintain a competitive edge. LANL also discussed the additional burdens of environmental, safety and health legislation.

A major concern of both sides is the cost of transparency efforts. It seems that the more transparency that is requested, the more it cost. The challenge for both sides is to increase transparency without adding to the escalating cost of these activities. However, both realized that some transparency measures would have to be maintained even if the cost is high.

Through this section, both sides learned more about the obstacles the other side faces. By learning each other's obstacles, it will be easier for PNC and LANL to understand each other. There is the possibility that one side has experience with a similar obstacle and can help the other side work through it.

II. Second Workshop

The topic of the second workshop was "Development of Transparency Options." The activities accomplished were 1) *identify type of facilities where transparency might be applied*, 2) *define criteria for applying transparency*, and 3) *delineate applicable transparency options*.

A. Identify Type of Facilities Where Transparency Might Be Applied

The first step taken by PNC in identifying potential facilities for transparency activities was to review the nuclear fuel cycle (Figure 1). PNC concluded that in order to receive the most benefit from transparency activities, it is important to select facilities from the nuclear fuel cycle where non-proliferation concerns exist. This means that facilities that manufacture, store, or use any form of nuclear material that might be converted to weapons use should become more transparent.

As widely known, plutonium and highly enriched uranium (HEU, defined as uranium containing more than 20 percent ^{235}U) are said to be two favorable materials to make nuclear weapons and explosion devices. Therefore, the facilities in which these two materials are handled or the facilities where these materials can be produced or extracted should incorporate transparency activities in order to promote nuclear non-proliferation.

In the Japanese nuclear fuel cycle, enrichment plants, MOX fuel fabrication facilities, and reprocessing facilities are of the highest priority for transparency activities.

Non-weapons states, such as Japan, do not use HEU in their civil fuel cycle. It is possible to technically modify an enrichment plant in order to produce HEU. Therefore, transparency at enrichment plants would be used to demonstrate that all enrichment activities produce only LEU.

MOX fuel fabrication plants store large quantities of MOX powder. Due to the presence of this material, proliferation is a concern. Reprocessing plants handle a large quantity of nuclear materials, including plutonium, and are therefore a proliferation concern.

The approach by LANL to the selection of generic nuclear facility types for the application of transparency measure to demonstrate that a country is complying with its nonproliferation obligations begins with a few assumptions. First, it is assumed that the country in question has complied with all obligations under the NPT, including inspections by the IAEA. Second, the country seeks to provide further assurances to others of its commitment to nonproliferation. In particular, the country wants to demonstrate that its civil nuclear program is only to be used to produce nuclear material for further peaceful civil purposes.

In Figure 2, LANL also refers to the nuclear fuel cycle. The figure highlights areas where LANL feels diversion would be particularly attractive.

Since the U.S. is a weapons-state and Japan is a non-weapons state, LANL briefly discussed a few reasons for transparency measures in a weapons state plus the connections of the civil and military portions of the fuel cycle. The civil fuel cycle can be found in both weapons and non-weapons states, but any use for military purposes is proscribed for non-weapons states. A weapons state may choose to employ transparency measures on some portion of their military cycle in order to demonstrate a commitment to arms reduction. It could also employ transparency measures at civil facilities to demonstrate that they are not being used for military

purposes. There are two possible connections between the civil and military portions of the fuel cycle. These involve the diversion of either HEU or Pu.

For all but a few research reactors, there is no need for a nation to have HEU in its civil cycle. When necessary, HEU is usually obtained from weapons countries, but nations with enrichment capability have the potential to produce HEU indigenously.

In a civil fuel cycle, weapons usable Pu is available as spent reactor fuel, as oxides separated from uranium and fission products, or as unirradiated MOX. Pu is more readily available in the latter two forms because it is not protected by highly radioactive fission products. It is found at reactors, reprocessing plants, storage facilities, and MOX fuel fabrication facilities. Spent fuel can be found at reactors, reprocessing plants, or in separate storage facilities.

LANL believes that on the basis of the ready availability (or potential availability) of material that is easily used for nuclear weapons, the facility types of greatest proliferation concern are research reactors with unirradiated HEU fuel, enrichment plants, reprocessing plants, reactors with unirradiated MOX fuel, MOX fuel fabrication facilities, and storage sites for bulk HEU and MOX. Among these facilities, those that handle material in bulk form (outside of sealed containers) are of particular interest because of the greater difficulty in performing safeguards. These facilities would be reprocessing plants, enrichment plants, and MOX fuel fabrication facilities. Of somewhat less concern because of the high radiation fields are storage locations for spent fuel. This conclusion is similar to the IAEA emphasis on the protection of "direct use material." This is nuclear material that is usable for nuclear weapons purposes without further isotopic enrichment or transmutation in a reactor.

Comparing the two viewpoints of PNC and LANL on which facilities are of particular concern with respect to non-proliferation, both sides agree that due to the presence of weapons usable material (HEU or Pu), enrichment plants, reprocessing plants, and plutonium (MOX) fuel fabrication facilities could benefit from transparency activities.

B. Define Criteria For Applying Transparency

The next step is to create some basic criteria for the evaluation of different transparency options. PNC believes that for ease of use and flexibility purposes, transparency criteria should be created that can be applied at a general level to all nuclear facilities. Of course, each facility has specific needs and concerns, but those will be addressed once an activity has passed a basic review.

Before evaluating a transparency option/activity against a set of criteria, PNC would require that all information to be released undergo an initial review for quality, quantity and ownership. As mentioned in the first workshop, transparency measures depend highly upon the target audience. Concerning quality, information should be in a format that is easy to understand and be most beneficial to the target market. In order to avoid releasing too much similar information, the quantity of information already available should be reviewed. If an activity is well documented, it may be more beneficial to choose another activity or facility. The most critical part of this review is determining the ownership of the information. Due to existing agreements with local, national, and international governments/agencies, some information might not be released with out first consulting the owner.

Upon examination, PNC established five main criteria categories: confidence building, protection, disruption, time, and cost.

The goal of confidence building is to release information through transparency activities that will corroborate that there are no clandestine activities taking place, bolster the validity of material accountancy, confirm that nuclear materials are adequately protected, and verify that non-proliferation obligations are being met.

Regarding protection, detailed information concerning (SNT), physical protection of nuclear materials, and proprietary information should not be released. It is also important to review all information already released. Individual pieces of information may not be a problem, but the combination of all those pieces might inadvertently reveal sensitive information.

The disruption category is primarily concerned with the set up and maintenance of a transparency activity. When transparency equipment is being set up, both the facility operations and employee activities may be disrupted. This might be a temporary inconvenience, or it may cause permanent changes. Either way, too much disruption can make the project infeasible.

Every activity will be affected by several time constraints, such as time for negotiation of time of information to be released and time for the development and installation of systems. These constraints will impact the effectiveness of the transparency activity. Cost is always a factor. Therefore a balance must be sought between the effectiveness of the transparency activity, the time involved, and its various costs.

LANL's discussion on defining criteria for applying transparency had several important themes. First and most important is the theme that transparency activities should be undertaken as part of a rational, coordinated plan to achieve clear objectives. For example, one objective might be to convince another government that one's nuclear activities are consistent with declared nonproliferation obligations. Of course, this potential objective relies heavily on the second theme of the LANL presentation: the idea that each transparency activity should have a clearly defined target audience or audiences. Third, the combination of the target audience and transparency goals will help determine and constrain acceptable transparency options. And finally, each option must be reviewed in detail on a case-by-case basis to assure that the transparency objectives are being achieved.

Common to all transparency methods, however, should be the notion that the particular means are chosen to accomplish clearly conceived ends. That is to say that transparency should be thought of as a carefully designed strategy rather than as a collection of ad hoc activities.

Based on the above themes, LANL established the following criteria categories: support for transparency objectives, release of appropriate information, confidence gained, and costs.

Whatever means of transparency that are ultimately selected for use in a given facility, they should be designed to support carefully considered transparency or non-proliferation goals. As discussed in the first workshop, these goals depend critically on the target audience for transparency. Non-governmental organizations, the public, or other governments are all potential target audiences. The transparency or non-proliferation goals may differ depending upon the target audience, but, in general, only activities that support the overall goals should be pursued. This is the strategy that should be followed.

Transparency is primarily about information: what information to release, to whom, and when. As part of our transparency strategy, the information released should be thoughtfully designed to achieve some understood goal. In considering various transparency options, it is also necessary to understand what information should not be released to a given target audience. There are several general guidelines that should be followed.

First, the transparency measure should not release information that could be damaging to the very non-proliferation interests it seeks to promote. Release of proprietary or other forms of sensitive information should be avoided. The desire to avoid releasing trade secrets is a legitimate cause for concern in a competitive industry. Although the release of general information concerning material shipments or plant throughputs could be a useful transparency measure, one would want to avoid releasing detailed information that might put the physical protection and security of materials in jeopardy.

Confidence gained is another criteria. It serves no purpose to release information if it does not result in increased confidence in your established transparency goals. Information of no interest to the target audience will not result in increased confidence.

Because any facility at which transparency methods may be applied may have various operating costs associated with it, it will be important to carry out the transparency measure in such a way as to minimize the impact on the facility's operations. In particular, one would strive for transparency methods that minimize interference with the process line or the facility's personnel.

It should be realized that transparency is not cost free. Transparency is best viewed as a strategy designed to advance certain goals, e.g., to continue operations relatively unimpeded while providing important information to the public or to political entities. The value of these objectives, and the efficacy of transparency methods in attaining them, will determine how big a price one should reasonably be willing to pay.

CRITERIA FOR APPLYING TRANSPARENCY	
PNC	**LANL**
• Confidence building • Protection of information • Disruption from transparency activities • Time • Cost Initial review required (quality, quantity, & ownership)	• Support for transparency objectives • Release of appropriate information • Confidence gained • Costs

Table 2

Table 2 summarizes the criteria for both sides. Although the titles of the criteria are somewhat different, the concepts are very similar. One primary difference is that LANL stresses that transparency should be thought of as a carefully designed strategy rather than as a collection of ad hoc activities.

C. Delineate Applicable Transparency Options

From the PNC viewpoint, in order to develop transparency options, the first step is to review the type of information that, if released, could result in increased trust and understanding between nuclear operators and local and foreign governments and agencies, as well as between the nuclear

operators and the general public. In creating this list, PNC tried to catalogue the types of information that a variety of audiences might be interested in and not necessarily information that can be released.

The three general categories of information PNC has created are facility functions, operations, and IAEA activities. Table 3 below describes, in general, the type of information sought in each of the categories. All information, including the contents and quantity to be released, will depend upon the target audience.

TYPES OF INFORMATION OF INTEREST
Facility Function • General facility information (operations, operations plan/schedule) • General safeguards information (summary of safeguards inspection efforts, safeguard technology R&D) • General information on the physical protection of nuclear materials (summary of the physical protection systems, physical protection technology R&D)
Operations • Accounting information (type of material used, amount used, amount stored) • Transportation (type of material, to where, how much, purpose, who is notified)
IAEA Activities • General information on IAEA activities

Table 3

Now that PNC has identified the types of information of interest, the next step is to look at devices that could be used to release this information. In general, the information release mechanisms are the following:

1. **promotional materials**, such as videotapes, brochures, tours, news releases.

   This type of information could be used to explain both the nature of the facility and its complicated processes. Sometimes, the combination of a written and visual description of an activity makes it easier to understand and perhaps more interesting. Tours can allow

people to see first hand what is going on in a facility. News releases can be used to advertise a new project or a research breakthrough.

2. **remote monitoring**, where a target audience can see activity in a specified area.
   A remote monitoring system, perhaps in a storage unit, could confirm that only declared activities are taking place in the monitored location.
3. **environmental monitoring**, samples taken from outside, inside, or both.
   Environmental monitoring, perhaps at a facility under suspicion, could be used to confirm that only declared activities are taking place at the facility.
4. **satellite monitoring**, shipments between facilities.
   This type of monitoring could be used in two ways: to confirm that shipments between facilities happen as declared and to demonstrate that the shipments are adequately protected.
5. **independent inspectors**, target audience participants.
   Allowing inspections of a facility could decrease suspicions that something other than declared activities is taking place at the facility.

In order to pull together the three elements of the second workshop, identifying types of facilities where transparency might be applied, defining criteria for applying transparency, and delineating applicable transparency options, PNC created a model chart (Figure 3). This chart should allow an operator to do a quick initial review with respect to a target facility and a target audience by matching the type of information against the basic criteria. Then the operator can identify which information might be opened and which transparency options might be applied to the facility.

The chart provides an initial estimate and guides the information collection efforts for a more in-depth research and review. In order to come to a final decision, a variety of detailed research will be needed with respect to the target audience, the criteria, the type of information, and the facility being reviewed.

LANL took a facility-by-facility approach towards selecting transparency measures. The facilities were organized into two categories: 1) bulk-handling facilities and 2) reactors and

storage sites with unirradiated HEU or MOX fuels. Table 4 below lists the transparency options available in each facility category.

Although PNC and LANL took a slightly different approach to listing potential transparency options, the lists created by both sides are similar. In conclusion, the options currently available to increase transparency are facility tours, increased information dissemination, monitoring (remote, environmental, and satellite), and independent inspection.

POTENTIAL OPTIONS AT CANDIDATE FACILITIES	
FACILITY	**TRANSPARENCY OPTIONS**
Bulk-Handling Facilities (enrichment, reprocessing plants)	• Regular facility tours to the public, visiting dignitaries, etc.; • General information on facility material throughputs, radiation releases, operational characteristics, etc.; • General information on material shipments to and from enrichment and reprocessing plants; • Environmental monitoring of enrichment levels in or around an enrichment facility; and • In-stack environmental monitoring of effluents to determine burnup of spent fuel being reprocessed.
Reactors and Storage Sites with Unirradiated HEU or MOX Fuels	• Regular facility tours to the public, visiting dignitaries, etc.; • Regular dissemination of environmental data in and around facilities; • Release of general information on material shipments, quantities, and locations; • Remote monitoring of incoming unirradiated fuels; • Remote monitoring of stored material; and • Independent inspection of tags and seals on stored or unirradiated materials.

Table 4

III. Final Workshop

The goal of the third workshop, "Technical Options for Transparency," was to 1) *identify conceptual options for transparency system design*; 2) identify instrumentation, measurement, data collection and data processing options; 3) *identify data display options*; and 4) *identify technical options for reprocessing, enrichment, and MOX fuel fabrication facilities.* LANL introduced existing proven technology as transparency options for each facility.

For this workshop, the facilities to be discussed were narrowed to enrichment, reprocessing, and fuel fabrication plants. The target audience for this workshop was limited to foreign governments and/or international agencies.

This section will differ from the preceding sections. Instead of alternating between PNC and LANL, the paper will first discuss PNC's systems design research followed by short summaries of the technologies demonstrated by LANL.

PNC-A. Identify conceptual options for transparency system design

The purpose of this activity is to create a methodology, a strategy, that can be applied to every transparency systems design project.

The first step towards the goal of building trust is to identify the proliferation concerns. Since each facility is unique, the concept for identifying options for transparency system design will be to first identify proliferation concerns at the facilities of greatest proliferation concern, reprocessing plants, enrichment plants, and MOX fuel fabrication plants. Table 5 illustrates the major proliferation concern at each facility.

TYPE OF FACILITY	PROLIFERATION CONCERN
Reprocessing	— Extraction and Purification of Plutonium — Large Quantities of Plutonium Present
Enrichment	— HEU Production
MOX Fuel Fabrication	— Presence of MOX Powder

Table 5

The second step in the methodology is to review the material accounting, monitoring, and tracking systems currently in use at the facilities. The goal of this research would be to discover what information is gathered by the current systems and if the information could be used to decrease proliferation concerns at the facility.

From an operations safety and nuclear material management point of view, the current material accounting, monitoring and tracking systems collect a variety of information. However, from a nonproliferation viewpoint, these systems may not collect suitable information or the systems might not collect all information needed. So either adding onto the existing system or creating a completely new system or a combination of both must be considered.

The third step is to apply the five main criteria categories for applying transparency, which were established in the second workshop to the system information. These criteria are confidence building, protection, disruption, time, and cost.

The final step in our methodology would be to build the transparency system. This could be done by accessing the current system, building a completely new system, or using a combination of the current system and a new system.

PNC-B. Identify instrumentation and measurement, data collection, and data processing options

Every facility, whether it's an enrichment plant, or a reprocessing plant, or a fuel fabrication plant, has to track the materials being used in order to ensure the efficient, safe operation of the equipment. From a nuclear material management and operation safety viewpoint, all facilities have operations systems that collect a variety of information, such as accounting data and measurements as the material flows throughout the facility.

Since a facility most likely already collects, in one format or another, the necessary information regarding the materials, the best means to reduce time and cost would be to utilize the facilities existing system. Once the information gathered in the existing operation system is reviewed it can be determined whether or not the existing system collects all the targeted information, if the system could be altered to collect the missing information, or if a new system will need to be created.

There are, however, several reasons why a new system may need to be created. One reason might be due to concerns from the facility operators, such as fear of inadvertent release of both facility information and sensitive nuclear information or the obstruction of facility operations, access to existing systems may be denied. Another reason may be that the existing system may not collect all the measurements of interest from a non-proliferation point of view. A new measurement device and a new system might need to be developed. Also, it might be impossible to access the IAEA safeguards equipment for transparency purposes. In this case, it might prove easier to duplicate this system or create a scaled-down version of the system.

Table 6 summarizes this section.

INSTRUMENTATION AND MEASUREMENT, DATA COLLECTION AND DATA PROCESSING OPTIONS
• **Use existing facility operations systems** • **If system does not collect all target information:** — add new measurements or data collection devices to system — create a separate system to collect missing information • **Create a completely independent duplicate or a scaled down version of facility systems** • **Use a combination of the facility system and a new system**

Table 6

Whether or not the existing facility systems can be used or if a new system is created or if some combination of the two is needed, the new information should be stored in a separate system. The main reason for this is to protect the facility system from things such as unauthorized access, data contamination, or the inadvertent release of protected information. Plus, storing the data in a new system would allow this information to be freely manipulated without affecting the facility.

The independent transparency system needs to be accessed by the staff in charge of transparency activities, who are not located at the facility. Therefore, the independent system should include the ability to transfer the data, via telephone lines, local area networks, or some other method, from the facility to an office location and/or to a separate monitoring location.

PNC-C. Identify data display options

Like the data processing options, there also are several options available for displaying the data collected from a facility as shown in Table 7. The display option(s) relies heavily on the goals of transparency and the needs of the target audience, but the system should be flexible and allow for the possibility of using the same data in different displays for different target audiences.

The primary display options are printing a report for distribution, posting information to a web site, providing the target audience with a remote monitor station, or providing the target audience with direct access to the data.

DATA DISPLAY OPTIONS
• **Printing a report for distribution**
• **Posting information to a web site**
• **Remote monitoring of a facility/site**
• **Direct access to information**

Table 7

The display option(s) selected would depend on whether the goal is for the target audience to simply view the information or if the goal is for the target audience to have the ability to create custom reports, tailored to their needs, by allowing the target audience direct access to the information. For example, if you wish only to release the information in a visual format, one data display option would be to print a paper report for distribution. Another option would be to display the information on a web site where both historical and current information can be viewed.

If the target audience were allowed direct access to the information, the data could be manipulated as the target saw fit. Allowing the target audience to create its own reports provides a great deal of flexibility in reporting and sharing the information, but this type of access would require a large amount of mutual trust.

In order for a camera system in storage locations to be most useful, the picture should be displayed via a remote monitoring system or posted directly to a web site. Using a remote

monitoring location, several display options could be available. Those pictures taken at regular intervals could be stored and accessed as desired by the parties at the remote location, or a picture could be triggered at random from the remote location, thus providing a near-real-time image.

PNC-D. Identify technical transparency options for reprocessing, enrichment and MOX fuel fabrication facilities.

PNC-D-1. Identify technical transparency options for reprocessing facilities.

The following are types of information that may be valuable from a transparency viewpoint: 1) quantity of plutonium (inputs, outputs, and waste), 2) the plutonium isotopic value in the adjustment vessel, 3) inventory of stored materials, and 4) storage monitoring activities.

The measurements taken at the start and at the end of a reprocessing campaign could be correlated to demonstrate that all the material in the campaign resulted in final products within an appropriate manufacturing range. It should be noted that the figures could only be compared at the completion of the campaign. Then comparisons will be needed from campaign to campaign. It is also valuable to confirm that the reactor supplying the spent fuel was not producing weapons-grade plutonium.

The reason for sharing information regarding storage materials is to confirm efficient materials management. In addition to accounting measures, monitoring of the facility's via a camera system could also be used to confirm that materials have not been stolen. One possibility would be the use of an infrared camera in the plutonium storage vault. An image from an infrared camera can confirm whether or not the storage container actually contains the declared material by displaying the type of heat emitting from the container.

PNC-D-2. Identify technical transparency options for enrichment facilities.

The following are types of information that may be valuable from a transparency viewpoint: 1) quantity of feed material, 2) quantity of product (low-enriched UF-6), 3) quantity of tail (depleted UF-6), and 4) enrichment range.

It would be useful from a transparency standpoint to compare the amount of feed materials presented for enrichment with the amount of product and tail produced after the enrichment procedure is completed. These measurements would be correlated to confirm that the nuclear material flows and inventories are in accordance with the facilities declaration. Of primary importance is measuring of the enrichment range of the fuel in order to confirm that no HEU is being produced. Such an enrichment pipe monitor could prove that the enrichment range stays consistently within the LEU level. This monitor might be a useful technology for transparency purposes.

PNC-D-3. Identify technical transparency options for MOX fuel fabrication facilities.

The following are types of information that may be valuable from a transparency viewpoint: 1) MOX powder located in feed material, scrap material, and in the fuel assemblies; 2) inventory of stored materials; and 3) storage monitoring activities.

It would be valuable to compare the amount of plutonium within the feed, scrap material, and the assemblies produced. As for the feed storage, it would also be valuable to allow a target audience to independently monitor the storage facilities via a camera system. This would provide independent confirmation that materials have not been stolen.

LANL: Available technologies for transparency activities

LANL-A. Technology Options for Reprocessing Facilities: On-Stack Stable Noble Gas Monitoring

The burnup of fuel being reprocessed is a key indicator of compliance with nonproliferation obligations. Spent fuel from power reactors typically has burnups as high as 35,000 MWd/tU or greater. Fuel that is to be reprocessed for potential military applications has a nominal burnup on the order of 1000 MWd/tU or less. An independent, nonintrusive measure of burnup that would confirm that the fuel being reprocessed has a burnup consistent with the declared value would be of great utility in the context of transparency.

The heavier stable isotopes of the noble gas xenon (namely, ^{131}Xe, ^{132}Xe, ^{134}Xe, and ^{136}Xe) are produced in substantial quantities as byproducts of the thermal fission of ^{235}U and ^{239}Pu during reactor operations. These fission gases are retained within the cladded fuel rods, while the fuel is in the reactor and in cooling ponds. However, they are volatilized when the fuel is dissolved prior to separation of actinides from fission products. The dissolver off-gases are then routed through the plant stack and emitted into the atmosphere.

Because the natural atmospheric isotopic abundance of the heavy xenon isotopes are well known and do not appear to vary significantly over the globe, it is a relatively simple matter to isolate the component due to fission gas production. Using this approach in experiments conducted within the United States, Los Alamos National Laboratory has demonstrated that analysis of the relative abundance of stable xenon isotopes in whole-air stack samples is valuable for fuel burnup determinations. LANL has demonstrated the ability to distinguish between the reprocessing of civil power reactor fuel with high-burnup (about 35,000 MWd/tU) and low-burnup fuels (1000 MWd/tU). The approach uses air samples taken from the stack of the reprocessing facility. The xenon isotopic abundance in the samples is then analyzed using mass spectrometry. After subtracting out the background component, the burnup can then be estimated from the isotopic data using a variety of statistical techniques. On the basis of this experience, it is expected that this concept could confirm declared burnups to an accuracy of roughly ten percent, which is sufficient to distinguish between high- and low-burnup fuels.

Los Alamos believes on-stack noble gas monitoring is a well defined, proven technology that has a clear transparency application.

LANL-B. Environmental Sampling

Environmental Sampling (ES) is a technology option that can be applied to transparency in nuclear nonproliferation. The basic process is to take a sample from the environment, e.g., soil, water, vegetation, or dust and debris from a surface, and through very careful sample preparation and analysis, determine the types, elemental concentration, and isotopic composition of actinides

in the sample. The sample is prepared and the analysis performed in a clear chemistry laboratory (CCL). This ES capability is part of the IAEA Strengthened Safeguards System. Such a laboratory is planned to be built by the Japan Atomic Energy Research Institute (JAERI) at Tokai and will give Japan an intrinsic ES capability.

The focus of ES in this application is on isotopes with half-lives greater than 1000 years, primarily the actinides. For lesser half-lives, radiation counting techniques provide the analytical information needed to determine the composition of a sample. However, for longer half-life isotopes, such as uranium and plutonium, mass spectrometry sensitivities are required. Mass spectrometry can provide both the elemental abundance and the isotopic ratios when isotopes are present at very low levels, far below any levels that might pose any health hazard. Elemental abundance measures the total amount of the material in the sample, and the isotopic ratios provide information about the source or use of the material. In uranium, these isotopic ratios can let us distinguish between depleted, natural, low-enriched (<20% U^{235}) and high-enriched uranium. In plutonium, the isotopic ratios can let us determine the source process by which the plutonium was produced (e.g., worldwide fallout or domestic activities) and verify that the plutonium is consistent with the declaration from high-burnup reactor fuel.

To understand the levels of sensitivity of ES analysis, consider that worldwide fallout of plutonium, primarily from atmospheric nuclear testing, is about 8 femtograms ($8 * 10^{-15}$ grams) of Pu in each gram of surface soil. Or expressed another way, to obtain a sample with about $5 * 10^8$ atoms of fallout Pu, which is sufficient for determination of the isotopic ratio, a soil sample of ~6 grams is required. Picture the Tokyo Dome stadium filled with ping-pong balls and let three of the balls be colored red. If the ping-pong balls represented the atoms in the total sample, then the analysis is sufficiently sensitive to detect the three red balls and determine their isotopic ratio.

In order to perform such sampling and analysis, several key building blocks are required. In all of these building blocks, the focus is on the integrity of the sample to assure that the sample can

never get contaminated with any material that does not represent the true sample. These key building blocks are

- the protocols and procedures that define how samples are obtained and handled during transfer to a laboratory;
- the facility (a building with the proper construction and air flow);
- the equipment within the building that can handle the samples, do the chemical separations, and perform the mass spectrometry analysis;
- the protocols that define the fundamental approaches to the facility operation;
- the procedures that will be used throughout the facility, including quality assurance (QA) and quality control (QC); and
- the training of the personnel who will operate the facility.

These building blocks, and their details, have been developed over the last several decades as the technology in ES has been pushed to the 100 million-atom level achievable today.

The US Department of Energy (DOE) and LANL are working with JAERI under the Agreement for Cooperation in Safeguards to provide the technical expertise to support the construction of a CLL at Tokai, Japan. The CCL will have the capability to perform the ES analysis that has been demonstrated in the US and throughout the world.

As the IAEA implements the Strengthened Safeguards Systems, it is investigating the use of new technologies, such as ES, to enhance some existing safeguards techniques. Japanese technologists will be at the leading edge for these applications when they have their ES capability.

The ultimate goal would be to show through environmental sampling and analysis that the country is adhering to her commitments to nonproliferation. The result of the sampling and analysis would show that all activities were consistent with the country's declared activities and commitments under the NPT.

However, this does not happen simply by taking some samples and having them analyzed. All samples must be referenced to a pre-existing status. For example, uranium is naturally present in the crust of the earth. So how does a new sample taken near a facility compare to what is naturally present? The use of environmental sampling must start with establishing a baseline showing the present existing conditions by taking many samples both near and away from a nuclear facility. Any organization interested in ES must consider this a decade-long process, and this part of the process will involve the technical facility operators, the public (including the press), and political leaders. One must remember that the levels of detection are so low that all samples will see plutonium and uranium far below health hazard levels. The education process is making the public, press, and political leaders aware of that fact and helping them to gain a much needed recognition of the natural environment and levels of hazards. However, there is a downside. An organization will release environmental sampling results that will indicate the levels of actinides in the environment. There will be people and organizations that will use the information against the organization, and indeed some past statements may have to be corrected. In the long run, an organization will establish a baseline of the environment around its nuclear facilities, and it is from that baseline that future environmental sampling will demonstrate, to IAEA and other States, the organization's commitment to nonproliferation. The IAEA will not release any results, so it is the discretion of the State and the operator that makes the results available to the desired audiences.

Environmental sampling can be a very powerful technical option in demonstrating an organization's commitment to nonproliferation. However, it entails a long-term commitment (one Japan may have already made) and will require the involvement of the technical community, the public, and political leaders. LANL has been performing environmental surveillance and analysis for the last 15 years and has characterized the environment around Los Alamos in very great detail. This activity has served LANL well in clearly identifying what is in the environment and thereby eliminating many accusations, which often come from rumors rather than fact. Experience has shown that one must perform the analysis, present the facts in an open and honest forum, and do any cleanup where it is warranted; then support will increase for the activities being carried out by the operator. The annually published LANL Environmental Surveillance

report is one example of the way in which frank, open, scientific dissemination of environmental sampling information can strengthen an operator while enhancing public trust.

LANL-C. NTvision

NTvision is a state-of-the-art video monitoring system to observe changes as they occur (in "real time") using Internet technologies. NTvision is low cost, easy to use, and simple to maintain. It can also be used in a secure mode and can interface with other sensor technologies. Figure 4 is an example of a set of images from an event. Shown is the beginning reference image, the event image, the post reference image, and the difference, indicating what changes have been made in the field of view. LANL showed examples of events that add or take away something in the image, or simply change the configuration in the scene. For transparency applications NTvision can be used in much the same way. The uniqueness of the system is the use of embedded HTTP server technology that creates an event table that can be accessed using Internet browser technology, such as Netscape. Restricting access to authorized users is easy and intuitive because NTvision uses the Netscape FastTrack Server with a browser interface. This can provide secure, worldwide access to event data within seconds of an occurrence using Internet technologies. A summary of the key features of NTvision include:

- it acquires and provides scene analysis in real time;
- it can provide secure Intranet / Internet camera access using a wide range of a media including telephone and secured or unsecured Internet;
- raw data is processed, filtered, and stored for user review;
- the user scans and selects data of interest with a commercial Web Browser available from Microsoft or Netscape;
- NTvision uses almost entirely commercial hardware and software building blocks.

LANL pointed out that with the Internet technology approach using web browers, the data from an event is available within seconds, and the user only accesses the data necessary to resolve a given event rather than having to download all data from the event. LANL demonstrated the

system in Japan by accessing, via a web browser, an event calendar of a test system at LANL in New Mexico. PNC was supplied with a user name and password to use in evaluating the system.

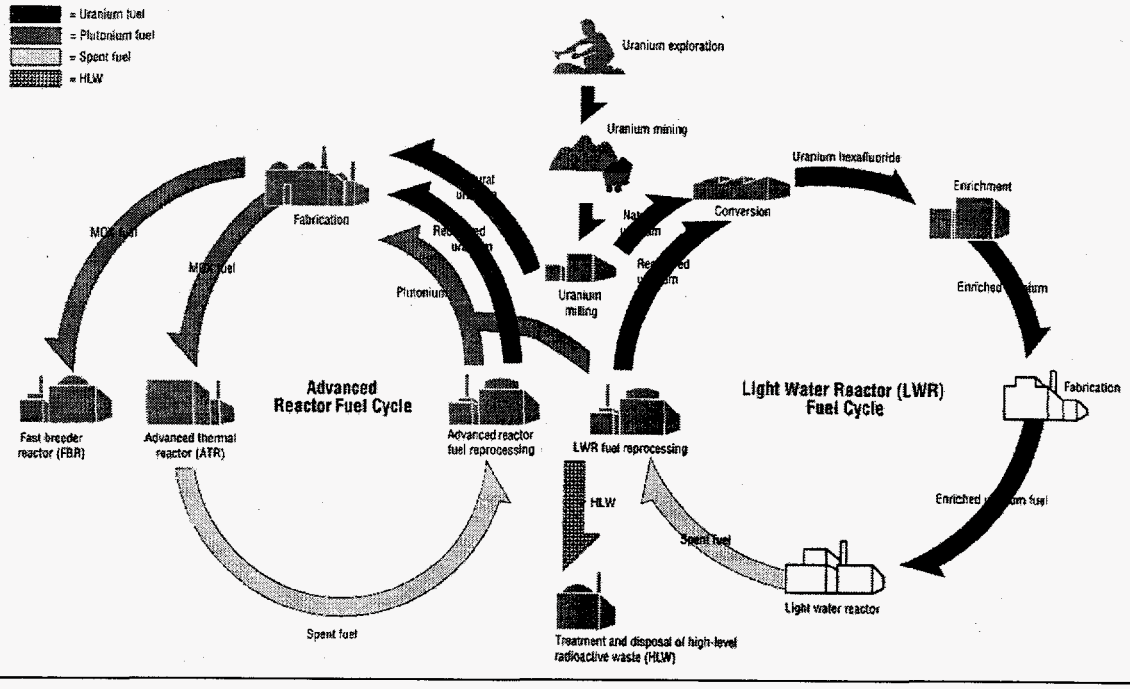
Finally LANL informed PNC that the NTvision team was looking for qualified beta testers for the system. The requirements for a beta tester were outlined and names and phone numbers were supplied.

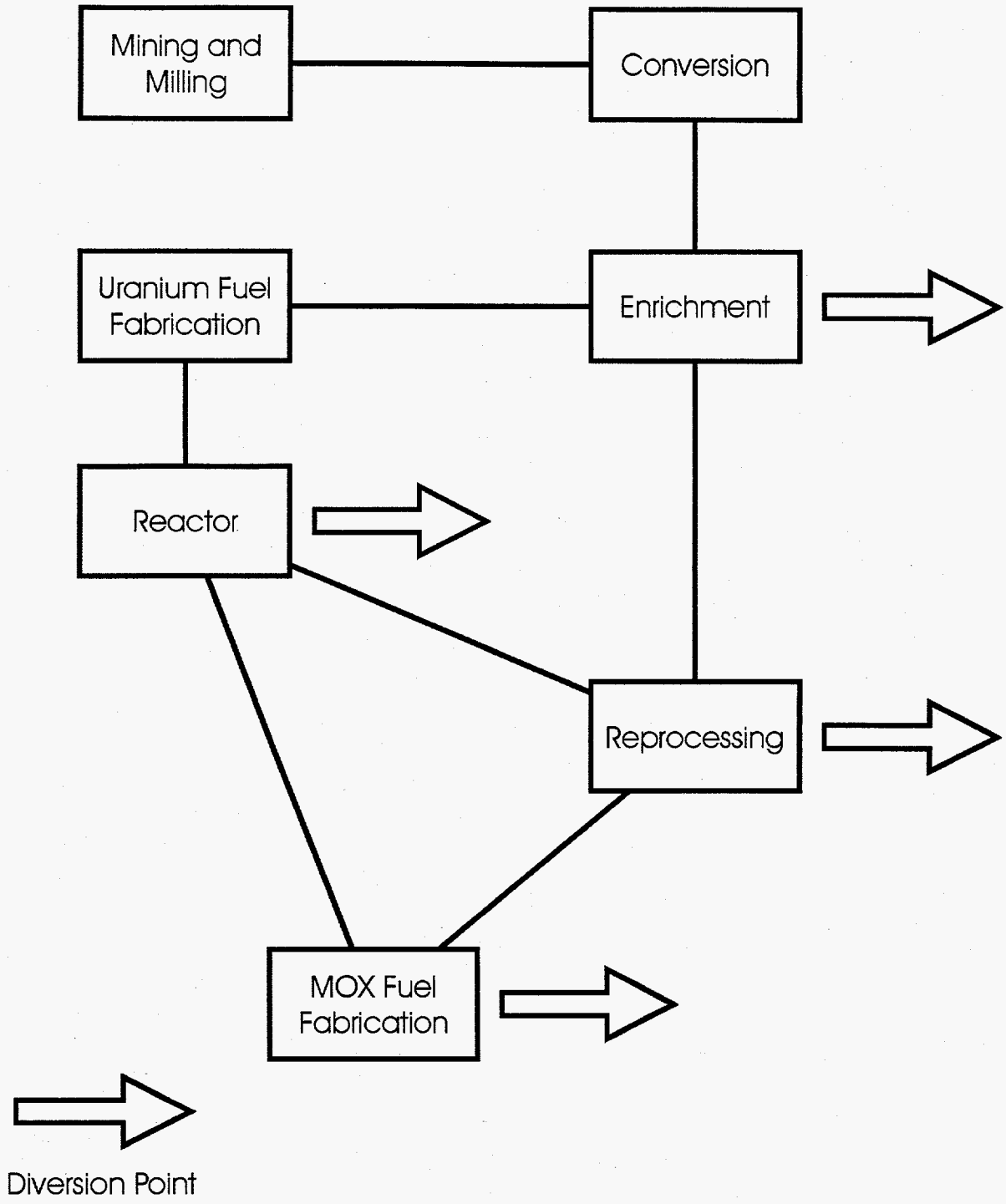
Summary Section

With PNC's and LANL's independent studies and exchange of information and views in the transparency workshops, this fundamental research on "Transparency in Nuclear Nonproliferation" was completed in June 1998. This was a basic study where both sides could learn more about the other and more about transparency issues.

This research will form an excellent base for future transparency collaborations. PNC and LANL are now investigating candidate subjects as a follow-on to this transparency study. One possible future subject could be the introduction of actual technical transparency measures into facilities where transparency is desired. Whatever the subject of the next project, PNC and LANL have formed a working relationship that both sides would like to continue.

Figure 1:
Nuclear Fuel Cycle




Mining and Milling
Conversion
Uranium Fuel Fabrication
Enrichment
Reactor
Reprocessing
MOX Fuel Fabrication
Diversion Point

Type of Facility: Reprocessing Plant

Audience: Non-Governmental Organization

Types of Information of Interest / Criteria		Transparency Options	Criteria														
			Confidence Building				Protection		Disruption		Time			Cost			
		PR: Promotion Materials **RM:** Remote Monitoring **EM:** Environmental Sampling **SM:** Satellite Sampling **R:** Reports **II:** Independent Inspection **O:** Other	**Declared** (Can information confirm that there are no clandestine activities taking place?)	**Accuracy** (Can information bolster the validity of material accountancy?)	**Protection** (Can information confirm that nuclear materials are adequately protected?)	**Obligations** (Can information verify that nonproliferation obligations are being met?)	**Review** (Does information include SNT or information on physical protection of nuclear materials?)	**After Release** (Does the combination of all information released result in the inadvertent release of SNT and/or physical protection information?)	**Operations** (Will transparency options disrupt facility operations?)	**Employees** (Will transparency options disrupt employees?)	**Negotiation** (Will negotiations for transparency options take much time?)	**Development** (Will the development of transparency options take much time?)	**Installation** (Will the installation of transparency options take much time?)	**Development** (Will the development of transparency options be expensive?)	**Labor/Training** (Will labor and training costs for transparency options be expensive?)	**Installation** (Will the installation of transparency options be expensive?)
Facility Function	General Information on Facility	R (Report)	YES	YES	YES	YES	NO	NO	NO	NO	NO	—	—	—	—	—
	General Information on Safeguards															
	General Information on Physical Protection of Nuclear Materials															
Facility Operations	Accounting Information															
	Transportation															
IAEA	General Information on IAEA Activities															

Legend:

Y: YES

N: NO

—: Not Applicable

EXAMPLE: Type of facility: Reprocessing Plant, Target audience: NGO, Transparency Option: Report

RESULTS: As for the Confidence Building criteria releasing a report would result in a favorable response (YES). However, for the Protection, Disruption, Time and Cost criteria, the result of releasing a report would be unfavorable (NO).

GOAL: This chart allows an operator to do a quick, initial review with respect to a target facility and a target audience by matching the type of information against the basic criteria. Then, the operator can identify which information might be opened and which transparency options might be applied to the facility.

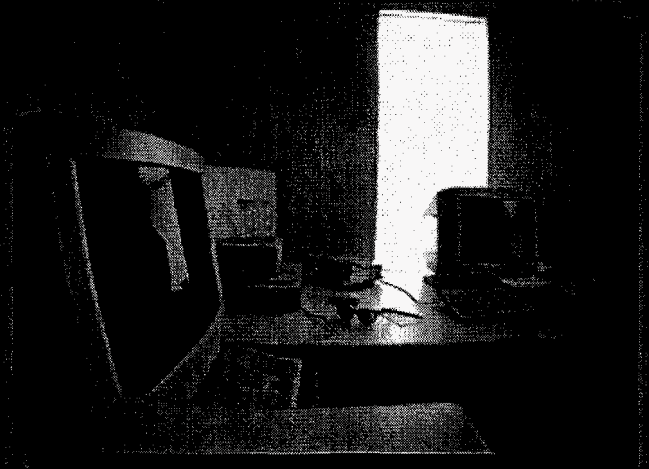
Figure 3

Four images are used to summarize the event

Reference

Event

Post Event



Object Key