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Research on Assurance System of Nuclear Fuel Supply

(Contract Research)

Naoki KOBAYASHI, Yosuke NAOI, Shuji WAKABAYASHI, Makiko TAZAKI and Masao SENZAKI

Nuclear Nonproliferation Science and Technology Center

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Assurance of supply (AOS) of nuclear fuel is a special arrangement in case of nuclear fuel supply disruption caused by political reasons other than nonproliferation. It aims to support a stable supply of nuclear fuel while avoiding spread of sensitive enrichment technology. Current discussions on AOS have been initiated by the IAEA Director-General's article published in The Economist entitled "Towards a Safer World" Oct. 2003. Since then, various proposals on AOS have been presented.

In order to facilitate international discussions on AOS, authors have conducted studies of AOS system based on Japanese Government's proposal "IAEA Standby Arrangement System (INFCIRC/683)".

In this paper, we have been able to discuss feasibility of AOS system more specifically by including additional costs and period required for AOS, and to present a system which could work as a practical system.

Issues we have tried to tackle here include definitions of AOS, and roles of consumer States, supplier States, IAEA and nuclear industries. We present some solutions including broadening coverage of AOS, declaration by supplier States on AOS, establishing advisory committee in the IAEA on the actual application of AOS, and setting up an IAEA fund for AOS.

Keywords : Assurance of Supply of Nuclear Fuel, Fuel Bank, IAEA, NPT, Reliable Access to Nuclear Fuel(RANF), IAEA Standby Arrangement System, IAEA Director General's Report, NTI Proposal, Angarsk International Uranium Enrichment Center (IUEC), Multilateral Enrichment Sanctuary Project (MESP)

This report is based on the results of "System improvement plan research on strengthening the international nonproliferation regime" in "the Scientific and Research Projects", entrusted to JAEA by the Cabinet Office, from 2006 to 2008, and revised according to the latest trends.
(JAEA: Japan Atomic Energy Agency)

* Lead author: July 2009～ Overseas Reprocessing Committee

核燃料供給保証システムについての調査

(受託研究)

日本原子力研究開発機構
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(2010 年 2 月 4 日受理)

核燃料供給保証(以下、供給保証)は、核不拡散以外の政治的な理由により核燃料の供給が途絶された場合に対する特別な備えであり、機微なウラン濃縮技術の拡散を防止しつつ、核燃料の安定な供給を支援することを目指している。現在の供給保証に関する議論は、2003 年 10 月に IAEA 事務局長がエコノミスト誌に投稿した論文「安全な世界を目指して」を発端としており、その後、多くの提案がなされている。

著者らは、供給保証に関する国際的な議論に資するために、日本国政府の「IAEA 核燃料供給登録システム提案」(INFCIRC/683)をベースとした供給保証システムについて検討した。

本稿では、供給保証に必要な追加的なコストと所要期間の想定を行うなど、より現実的なシステムとして実現可能な供給保証メカニズム全体のシステム提案を試みた。

供給保証システムにおける供給保証の定義や消費国、供給国、IAEA と原子力産業界の役割など関連する課題を整理し、幾つかの解決策、供給保証の対象事由の拡大、「供給保証に関する供給国の宣言」、IAEA での「供給保証発動諮問委員会」の設置、「供給保証基金」の設置等を示した。

本報告書は、内閣府の科学技術基礎調査等委託事業として、日本原子力研究開発機構が平成 18～20 年度に受託した「国際的な核不拡散体制強化に関する制度整備構想の調査」報告書を最新の動向を踏まえ加筆、修正したものである。

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1. Preface

Nuclear power generation is being reevaluated worldwide and its use is anticipated to be established and expanded not only because of the pressing need for States to augment energy security, but its low carbon footprint appears attractive for mitigating the effects of global warming. On the other hand, there is growing apprehension about the spread of nuclear proliferation, as seen by the notable current examples of North Korea and Iran. In the context of these and other issues there is an ongoing international discussion concerning the assurance of supply (AOS) of nuclear fuel as part of a new framework called for by the IAEA Director General in The Economist in 2003[1)] to increase the availability of nuclear energy to States desiring it and whether it can successfully satisfy goals of peaceful uses of nuclear energy and nuclear non-proliferation. The AOS would be, so to speak, an insurance system managed by the IAEA, which would provide temporary supply of nuclear fuel in the case of political disruption of the normal fuel market mechanisms. A motivation for establishing the AOS is to encourage the emergence of new States having nuclear power by assuring them a secure and stable backup access to fuel so they will not need to develop indigenous enrichment or reprocessing capabilities.

The present discussion on AOS, initiated by the IAEA Director General's article and other communication has continued to be fed by reports including the IAEA-commissioned expert group report for multilateral approaches[2)]. Subsequent proposals include the six-country proposal for a multilateral mechanism for reliable access to nuclear fuel [3)], the U.S. proposal to down-blend 17.4 tons of highly enriched uranium and provide them for the assurance of supply[4)], pledge of funds from the Nuclear Threat Initiative (NTI) [5)], the Japanese Government's proposal (Japan's proposal) for an IAEA nuclear fuel supply registration system [6)], the British proposal for enrichment bonds[7)], the Russian proposal for the International Uranium Enrichment Center (IUEC) [8)], the German proposal for the Multilateral Enrichment Sanctuary Project (MESP) [9)] and the World Nuclear Association Report by the nuclear fuel industry experts[10)]. The IAEA held a special event on the AOS at its general meeting in September 2006 [11)], and later issued an IAEA Director General's report [12)] in June 2007 about a proposed framework for establishing AOS.

To maintain this momentum of substantial international discussions on AOS, it is necessary and important to step forward with some concrete details of how to embody the AOS system and its mechanisms. In the following sections we present our views of how this can be done and make recommendations for some of the challenges to constructing a practical system.

2. The Purpose of Assurance of Nuclear Fuel Supply (AOS)

2.1 The purpose of AOS in Main Proposals

The purpose of nuclear fuel supply assurance (supply assurance) has been taken up differently in previous discussions. Previous major reports, speeches, and the like have expressed it in Table 2-1 and Table 2-2.

As seen in the IAEA Director General El Baradei's article in The Economist in 2003 [1)], which initiated the present discussion on AOS, and in the U.S., President Bush's speech at the National Defense University in 2004 [13)], the purpose of AOS is to supplement the NPT system and assurethe supply of nuclear fuel for peaceful uses to non-nuclear weapon states which have renounced uranium enrichment and reprocessing to ensure the non-proliferation of nuclear weapons.

In contrast to the past discussion in the International Nuclear Fuel Cycle Evaluation (INFCE) [a)] and the Committee on Assurance of Supply (CAS) [b)], which covered the ordinary supply of nuclear fuel at normal times, the present discussion covers exclusively the assurance of supply at times of supply disruption for political reasons [c)].

(1) This purpose has been shared in the main proposals for AOS, including the expert group's report to the IAEA Director General El Baradei (MNA proposal) [2)], the report by a private sector organization, the World Nuclear Association (WNA) [10)], the six-country proposal mentioned above, and the IAEA Director General's report as shown in Table 2-1.

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a) It should be noted that, in previous INFCE and CAS processes, they were discussion on the ordinary supply of nuclear fuel at normal times from the viewpoint of nuclear non-proliferation, but not on the supply as an insurance exclusively at times of "supply disruption for political reasons" as in the present discussion on the assurance of supply. A general description of INFCE was given in the White Paper on Nuclear Energy 1980 (in Japanese).
(http://www.aec.go.jp/jicst/NC/about/hakusho/wp1980/sb2040301.htm)

b) CAS was a committee set up in the IAEA, and operated actively in 1980-1987.
(http://www.iaea.org/NewsCenter/Focus/FuelCycle/key_events.shtml)

c) The Russian proposal for the IUEC centers on the provision of an enrichment services at normal times, and the German proposal for multilateral sanctuary project is a proposal to establish a new multilateral enrichment facility in which the IAEA is also involved. Neither of them has clarified the final contents, such as those of an agreement with the IAEA. Basically, however, they cover not only the approaches to cope with the supply disruption for political reasons, but also the general supply of nuclear fuel. In the United States, there are discussions about the RANF (Reliable Access to Nuclear Fuel) (please see President Bush's speech in 2004, in which the President stated "reliable access at reasonable cost to fuel") and about the "reliable supply of nuclear fuel." Although these discussions use the term "assurance of supply," it is necessary to note whether they cover the assurance of supply at times of supply disruption for political reasons (in a narrow sense) or general assurance of supply regardless of reasons (in a broad sense). In this respect, confusion arises sometimes in the present discussion. Further, in the United States, though not actually institutionalized, the Nuclear Non-Proliferation Act of 1978 stipulates (in Sec. 101) "a reliable supply of nuclear fuel," which may be said to be the assurance of supply (in a broad sense), and (in Sec. 104) the basic outline of the system of assurance of supply (in a broad sense), centering on the establishment of an international nuclear fuel authority (INFA).
(http://www.nrc.gov/about-nrc/governing-laws.html)

Table 2-1 Purposes of nuclear fuel supply assuranceas expressed in major reports and others made public in and before June 2006

Proposals and others	Purpose as expressed
President Bush's speech at the US National Defense University (February 2004)[13]	Under the NPT, nuclear-weapon countries agree to support non-nuclear-weapon countries in their peaceful utilization of nuclear energy, on the condition that the latter will abandon the development of nuclear weapons. However, there are loopholes in the NPT, and in order to close them it is necessary to ensure reliable access to nuclear fuel to those countries that have renounced nuclear enrichment and reprocessing.
Multilateral Nuclear Approaches to the Nuclear Fuel Cycle (MNA) (February 2005)[2]	Gradual adoption of the MNA will make it possible to ensure the worldwide supply of nuclear fuel and related services, while also preventing nuclear proliferation associated with the civilian use of nuclear cycles (such as the diversion and theft of nuclear material, proliferation of sensitive technologies, and clandestine development)
US proposal: Reserve of low enriched uranium (LEU) from diluted 17.4-ton HEU derived from nuclear dismantling [4]	Support for the reliable access to nuclear fuel to countries that are not pursuing enrichment or reprocessing.
US GNEP (February 2006)	Along with the development of proliferation-resistant technology in order to reduce nuclear waste and minimize the risk of proliferation, price-competitive nuclear fuel services are provided concurrently from the market with the aim of promoting increased nuclear power generation without the possession of sensitive nuclear fuel cycle technologies.
World Nuclear Association (WNA) report (May 2006)[10]	The goal of the MNA report can be achieved by limiting the spread of sensitive nuclear technologies by providing additional assurances of supply to countries that volunteer to forego the development of indigenous capabilities.
Six-Country proposal (June 2006)[3]	An assurance for reliable supply of enrichment services or enriched uranium is an important factor in non-proliferation. The supply mechanism endorsed by low-enriched uranium reserve takes the needs of consumer countries into account, reduces the need for expensive and sensitive enrichment and for the nuclear fuel cycle for reprocessing. It promotes the safe, reliable, and peaceful utilization of nuclear energy in accordance with Article IV of the NPT, and reduces the risk of non-proliferation.

(2) At the IAEA Board of Governors meeting in June 2006, there were strong oppositions from developing countries, arguing that the AOS would deprive the right provided for in the Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). In the main proposals thereafter, the wording of the purpose of AOS has been changing from a strong expression of "renunciation of enrichment and reprocessing" to a softer expression such as "support for the states which have opted not to construct nuclear fuel cycle facilities" (in the NTI proposal). The United States, too, has changed its wording to avoid provoking opposition from emerging countries, from "renunciation" of sensitive

technology to “not to pursue” sensitive technology. In the present-day discussion about AOS, the focus is on the front-end enrichment among the sensitive enrichment and reprocessing technologies.

Table 2-2 Purposes of supply assurance as expressed in major reports and others made public since September 2006

Proposals and others	Purpose as expressed
NTI proposal: IAEA nuclear fuel bank (September 2006)[5]	Support for those countries that have chosen not to build nuclear fuel cycle facilities in their territories
Japan's proposal: IAEA Standby Arrangements System for the Assurance of Nuclear Fuel Supply (September 2006) [6]	Improved transparency/projectability of the nuclear fuel supply market; avoidance of a dichotomy between “have” and “have-not” countries (the possibility of evolving from the latter to the former)
UK proposal: Enrichment bond (June 2007)[7]	Support for the supply of enriched uranium
Germany’s proposal: Multilateral management of the nuclear fuel cycle (later MESP) (May 2007)[9]	Multilateral management of the nuclear fuel cycle with the aim of establishing non-proliferation and reliable access to nuclear fuel
Austria’s proposal: For the multilateral management of the nuclear fuel cycle (May 2007) [14]	Recover the confidence in an international nuclear fuel cycle
Russian proposal: International Uranium Enrichment Center at Angarsk (IUEC) (June 2007) [8]	Creation of an international center for the provision of nuclear fuel cycle services, including enrichment

2.2 The Role of AOS in Preventing the Spread of Sensitive Technologies (Enrichment and Reprocessing)

The assurance of supply (AOS) is considered helpful to reduce the incentive for states to develop or possess enrichment technologies in their own territories, to prevent sensitive technologies spreading to any state other than the nuclear weapon states and the non-nuclear weapon states possessing sensitive technologies (such as Japan, Germany and the Netherlands in the case of enrichment technologies), and to contribute to nuclear non-proliferation. However, limiting the possession of sensitive technologies to the states presently possessing sensitive technologies has been opposed by developing countries, as mentioned above, which has become a major cause of stagnation in the discussion on the AOS. The states intending to possess enrichment technologies may be broadly classified into three groups: 1) a group purely seeking the peaceful use of nuclear energy, 2) a group ostensibly advocating the peaceful use of nuclear energy, and 3) a group intending to develop nuclear weapons. The AOS has the significance of existence in its contribution to preventing an increase in the number of states transferring from group 2) to group 3) and intending to develop nuclear weapons. However, it should be understood that the AOS will not directly prevent nuclear proliferation, but has a limited function to help nuclear non-proliferation indirectly by preventing the spread of sensitive technologies.

Further, as an educational aspect other than the intrinsic purpose mentioned above, the AOS has a realistic and secondary effect for emerging countries to understand that the spread of sensitive technologies fuels leads to a potential development of nuclear weapons and the fact that the IAEA

safeguards and bilateral nuclear agreements are important for them to avoid being suspected. On the one hand, states possessing enrichment technologies would find it difficult in international politics to cause a supply disruption by themselves while discussing matters at times of supply disruption, hence the AOS may help deter a supply disruption stemming from political reasons. Further, if the AOS can be institutionalized, there will be no further supply disruption, and it would be meaningless to exert political pressure to disrupt the supply of nuclear fuel.

3. Proposal for the AOS System

JAEA proposal concerning a nuclear fuel supply assurance system (JAEA Proposal) is based on both the Japanese Government's proposal, herein called "Japan's Proposal" entitled "IAEA Standby Arrangements System for the Assurance of Nuclear Fuel Supply (INFCIRC/683)"[6] and the IAEA Director General's report of June 2007[12]. It is inclusive of other proposals and is also based on the experience of past discussions at INFCE (International Nuclear Fuel Cycle Evaluation) and CAS (Committee on Assurance of Supply). It proposes the overall image of an IAEA-centered nuclear fuel supply assurance system. Based on Japan's proposal, this proposal extends objects of supply assurance to the entire front-end of nuclear fuel cycle, and consequently, reorganizes Levels 1 to 3 in the IAEA Director General's report as Modes 1 to 3. The proposal further adds to items of the registered information defined by Japan's proposal, the quantities of materials and services that can be provided and the period of time required before making an offer.

3.1 The Basis for JAEA's AOS System Design

The Proposal has been created on the basis of the basic concepts described in Sections 3.1.1 to 3.1.4 below.

3.1.1 Non-Disturbance of Market Mechanisms

It has frequently been pointed out in international discussions on this matter that the nuclear fuel market has been consistently performing a normal supply function. Nuclear fuel supply was never interrupted in the past due to political reasons in terms of the recent supply assurance discussion.[d] Similarly, in the future, we must strictly refrain from politically motivated market intervention, which would disturb the market. Nuclear fuel supplier and utilities are always cautious about this.

Along with the danger of diversion to nuclear weapons, it must be remembered that nuclear fuel is a special commodity that creates extraordinary political interest and that the nuclear fuel market is a unique one that consists of a very small number of suppliers and few specific customers. In a market with such a limited number of participants, information is passed instantly between those concerned, with any new move in the market affecting it greatly.

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[d] Examples of supply disruption for fear of nuclear proliferation include: the case where the United States stopped the supply of nuclear fuel because India had not met the requirement of comprehensive safeguards in the U.S. Nuclear Non-proliferation Act (in 1980), the case where, in response to the intention of Brazil to obtain a nuclear fuel cycle, the United States cancelled the subsequent contract to supply enriched uranium to Brazil (in 1973), and the case where the Western nations ceased their cooperation for Iranian nuclear development following the Iranian revolution in 1979.

The supply of nuclear fuel is usually carried out on a long-term contract basis. However, even in a case where supply is disrupted, the consumer countries should first seek alternative sources of supply, including the spot market, and the supply assurance system should be their last recourse, only after all other means are exhausted.

3.1.2 To be Based on a Realistic System Design

As mentioned, JAEA proposal is based on the Japan's proposal and the IAEA Director General's report. The purpose of Japan's proposal is to avoid disturbing the nuclear fuel market through securing transparency and Japan's proposal intends to an information registration system for that purpose.

The Director General's report, based on the discussions contained in the MNA report, the Six-Country Proposal, and the special event concerning the assurances of nuclear supply and non-proliferation (September 2006), includes many other proposals, compiling an overall system based on the fundamental framework of the Six-Country Proposal. For this reason, the current international trend is for supply assurance discussions to be carried out on the basis of this Director General's report.

In addition, there are only a few realistic steps to their realization. These include an International Uranium Enrichment Center (IUEC) at Angarsk (Russian proposal), an IAEA LEU bank (NTI proposal), and a LEU reserve initiative based on the downblending of 17.4 tons of highly enriched uranium (HEU), as proposed by the United States (this is considered to form part of the Six-Country Proposal).

Although JAEA Proposal is based on Japan's proposal and the Director General's report, it incorporates the abovementioned concrete proposals, with the aim of structuring a realistic system around the IAEA.

Regarding the international management of nuclear fuel cycle facilities, several discussions similar to those on supply assurance have been repeated on a number of occasions. These include, in chronological order, the 1946 Baruch Plan, which proposed the transfer of all nuclear-related activities to an international organization (the International Atomic Development Authority); the Atoms for Peace speech by President Eisenhower and the subsequent establishment of the IAEA; the INFCE, established under the leadership of the United States in the late 1970s with the aim of the international management of nuclear fuel; and the CAS, established within the IAEA in the 1980s, which examined a nuclear fuel backup system similar to the supply assurance system that is currently being discussed.

In the current discussion of supply assurance, it is necessary to design a realistic system in which, on the basis of the experience and problems presented by these past discussions, challenges are foreseen and measures to solve them are examined. Such experience suggests that it is necessary to establish a realistic system as quickly as possible in order to achieve a multilateral system on the basis of actual international relations and the current nuclear fuel market situation through international discussions. A substantial change in the current circumstances surrounding supply assurance would make it difficult not only to create such a system, as in the past, but also to advance discussions. In order to create a system in which developing countries can comfortably participate, our experience with the CAS has taught us that we should not only conduct discussions among developed countries but also exchange opinions with developing countries.

3.1.3 To Create a Supply Assurance System in which the Participating Countries and the IAEA Play the Principal Roles

Nuclear fuel supply assurance is expected to contribute to an important target for the international politics of nuclear non-proliferation, the founders and the main operating body of the system should be the governments of the countries concerned and the IAEA. In the case of Level 2, mentioned in the Director General's report, enrichers must be requested to cooperate, but without having economic burdens forced upon them.

As with the Director General's report, JAEA Proposal assumes that the IAEA is the main operating body of the system and the supplier of the nuclear fuel. The same assumption applies to cases in which the IAEA operates a nuclear fuel bank directly and to cases in which supplier countries have reserves of actual fuel until a supply assurance system is triggered. It also applies to cases in which fuel is provided from the virtual fuel reserves of the countries concerned or when services are provided from them.

In connection to the possibility of IAEA playing the role of system operator, IAEA member states have strong anxiety about excessive expansion of the IAEA’s authority and organization, and an increase of financial burden to them.Although the IAEA, as the system operator, will have more roles to play, and an increase in expenses should be minimized in view of the rarity of the expected to trigger of the system.

3.1.4 To Extend the Objects to the Entire Front-End of Nuclear Fuel Cycle through Japan's Proposal

The objects to be covered by nuclear fuel supply assurance should be extended to the entire front-end of nuclear fuel cycle. They should include not only the supply of LEU and the provision of fuel fabrication services but also the supply of uranium concentrate and conversion services through the implementation of Japan's proposal. It is important to link the objects to the actual supply as a result of such extension.

Furthermore, in order to secure the diversification of supply sources and the reliability of the system, it is important to extend the objects as mentioned above and to keep the door open to uranium producing countries and those providing other services. The conditions that should be examined in order for a country to become a supplier include a sufficiently reliable supply capacity and qualifications for non-proliferation that should be examined in the same way as they would be examined for a consumer country.

In addition, there are politically difficult problems associated with Article IV of the NPT. Limiting supplier countries to current nuclear fuel suppliers will invite strong opposition from emerging nuclear energy countries, as well as from Canada and Australia, which do not perform enrichment and reprocessing but provid uranium ore and conversion services. With this in mind, it is necessary to establish a system that does not limit the number of supplier countries as far as possible.

It is important to avoid dividing countries into 'countries having nuclear fuel cycle technology and countries not having it', especially in enrichment technology, as "nuclear weapon states and non nuclear weapon states" in NPT, and to keep the possibility to participate in for as many countries as in NPT in some ways.

3.2 Registration of Information Based on Japan's Proposal

3.2.1 Information Registration System Based on Japan's Proposal

Fig. 3-1 shows the process steps in the front-end of the nuclear fuel cycle. The uranium extracted from mines undergoes conversion, enrichment and fuel fabrication in preparation for use in power reactors.

The Japan's Proposal states that Member States shall voluntarily register their nuclear fuel related information with the IAEA, including uranium concentrate, conversion capacity, enrichment capacity, fuel fabrication capacity, uranium reserves in the entire front-end, and also specify the current status of availability at the following three levels: Level 1 (not providing products/services to foreign countries on a commercial basis), Level 2 (providing products/services to foreign countries on a commercial basis), and Level 3 (having reserves that can be provided in a short time). By including the entire front-end of the fuel cycle more countries will be able to participate in the market as supplier States and transparency in the fuel market will be enhanced, even for normal commercial operations.

The details of JAEA Proposal, which utilizes the strong points of Japan's proposal, will be developed so that the system that the Director General's report aims toward may be further developed in specific detail.

The Fig. 3-1 shows objects to be covered by the registration system put forth in Japan's proposal and the descriptions concerning them.

- Member States voluntarily register their supply capacity in the following areas to the IAEA:
  - Uranium concentrate supply
  - Uranium reserve supply
  - Uranium conversion
  - Uranium enrichment
  - Fuel fabrication

- A participating States notifies the availability of its capacity at three levels:
  - Level1: providing products/ services domestically but not to foreign countries on a commercial basis;
  - Level2: exporting products/ services to foreign countries on a commercial basis;
  - Level3: reserve can be exported at a short-term notice

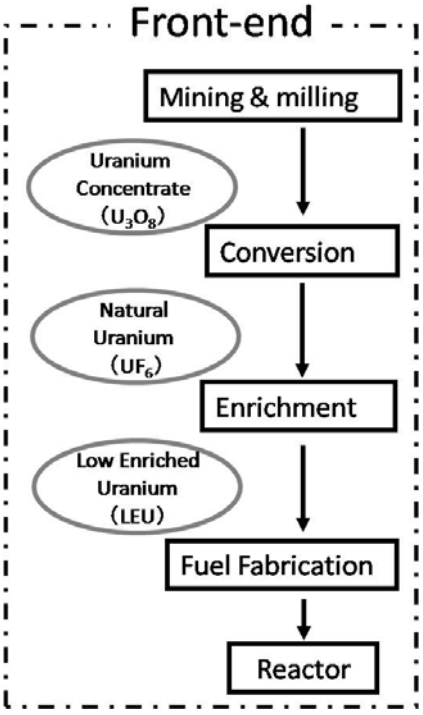

Fig. 3-1 Registrating information and flowchart of the fuel cycle for uranium

3.2.2 Items to be Made in the Registration System According to Japan's Proposal

In order to make supply registration system of the Japan's Proposal more robust and feasible, we propose that, in addition to the above, the following contents should also be registered with the IAEA under the system proposed in this paper:

- Approximate quantity of nuclear materials/services available for supply/provision
- Shape, composition, other information of nuclear materials
- Approximate period of time required from the agreement with consumer States to the supply/provision of nuclear materials/services

3.2.3 AOS Registration Relationships; Operators, States and the IAEA

As shown in Fig. 3-2, for the registration of nuclear fuel information, coordination shall initially be made between each supplier State and its operators (shown in dotted lines), whereupon each supplier State shall inform the IAEA of the data of the quantity of nuclear fuel available for supply determined through coordination with its domestic operators (shown in solid lines).

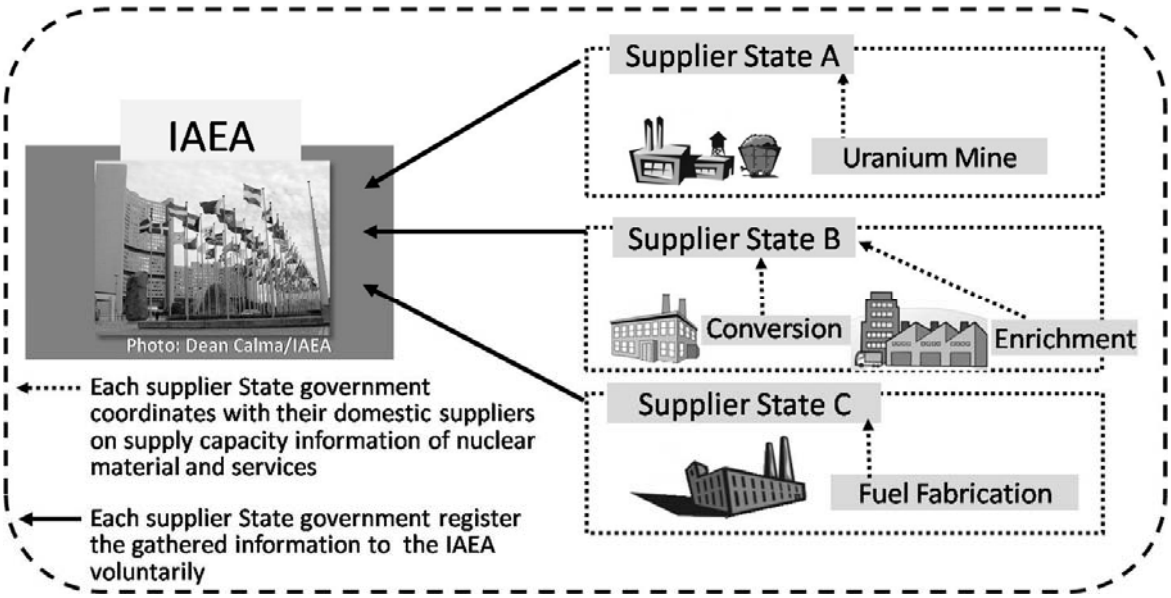

Fig. 3-2 The image of the "IAEA nuclear fuel supply registration system"

Firstly, the supplier states (A to C in Fig. 3-2) coordinate with their domestic nuclear suppliers regarding the contents of information on supply capacity of nuclear materials and services for the purpose of supply assurance, then they determine the contents to be registered. In order for this system to run smoothly and to avoid placing a burden on domestic suppliers, the states provide them with regulatory assistance and subsidies if necessary.

Next, the states notify the IAEA of the gathered information that they have finalized following coordination with their domestic suppliers, as well as the capacity of their facilities.

Duplication of work can be avoided if the data collection at the IAEA is implemented in conjunction with the data collection for the Nuclear Fuel Cycle Information System already

implemented by the IAEA and for the nuclear energy data book commonly known as the "Brown Book" issued by the OECD/NEA(Organization for Economic Co-operation and Development/ Nuclear Energy Agency). The IAEA would register the supplied data informed and make it publicly available every year.

3.2.4 Registered Information from Virtual Country X for the Year 20XX

In Table 3-1 we give an example of registration information from one hypothetical supplier State.

Table 3-1 An example of information registered for virtual states X for the year 20XX

Registration Materials & Services / Registration Level	Uranium Concentrate (U_3O_8) Natural Uranium (UF_6) <*Fuel Bank*>	Conversion Service 【Design capacity: 5,000tU/y】 <*Supply Capacity*>	Enrichment Service 【Design capacity: 10,000tSWU/y】 <*Supply Capacity*>	Low Enriched Uranium (LEU) (UF_6 or UO_2) <*Fuel Bank*>	Fuel Fabrication Service 【Design capacity: BWR 500tU/y, PWR 1,000tU/y】 <*Supply Capacity*>
(Level 1) Not exporting but willing to cooperate. Quantity would be limited and considerable time would be needed	U_3O_8 200～300tU (12 months)	----	----	----	----
(Level 2) Exporting and willing to cooperate as much/soon as it can.	----	----	----	UF_6 30～50tU (9 months) *(Virtual Reserve)*	----
(Level 3) Exporting and willing to cooperate through reserve/supply capacity in a short period of time.	----	100tU (3months)	200tSWU (3 months)	UO_2: 30tU* (1 month)	BWR: 20tU PWR: 50tU (6～9 months)

* State X has its own nuclear fuel bank and stores 30tU of LEU in the form of UO_2 for AOS.

(1) Uranium Concentrate

State X is not an exporting uranium concentrate. However, for the year 20XX, the state has some surplus uranium concentrate in reserve, about 200-300tU of which the state can provide for the AOS within a period of about 12 months after the supply agreement is concluded.

(2) Conversion Service

State X is engaged in the conversion operations for overseas. For the year 20XX, the state has some margin in its contract situation and can provide conversion service of 100tU or so for the AOS within a period of about three months after the provision agreement is concluded.

(3) Enrichment Service

State X is engaged in enrichment operations for overseas. For the year 20XX, the state has some margin in its contract situation, and can provide an enrichment service of 200tSWU or so for the AOS within a period of about six months after the provision agreement is concluded.

(4) Low Enriched Uranium

State X has a reserve of 30tU of enriched uranium (UO_2) in its nuclear fuel bank and can provide them for the AOS in about a month. Adding to this, judging from its contract situation for enrichment operations, the state can provide 30-50tU of enriched uranium (UF_6) for the AOS in about nine months for this year.

(5) Fuel Fabrication Service

State X is engaged in fuel fabrication operations for overseas. For the year 20XX, the state has some margin in its contract situation and can provide services including the fabrication of about 20tU and 50tU of BWR and PWR fuel respectively, for the AOS within a period of about 6 to 9 months after the provision agreement is concluded.

3.3 JAEA Revised AOS System

3.3.1 Dividing Objectives of AOS into Modes 1, 2, 3

As earlier stated, JAEA authors propose a reorganized AOS system, as described and depicted in Table 3-2 below. We include the entire nuclear fuel cycle front-end, and thus the proposed system can be used in the event of supply disruptions in any process; from the procurement of uranium concentrate to the arrangement of fuel fabrication.

Mode 1 in this paper refers to the supply in the ordinary nuclear fuel market and corresponds to Level 1 in the Director General's Report.

In the Director General's report, there is a coexistence of supply/provision by two different entities (operators or States) in Level 2 - one of which is the supply of low enriched uranium by enrichment operators and the other is the provision of services committed by States and implemented by fuel fabrication operators. This hampers understanding of the system. Further, the difference between the two levels (Levels 2 and 3) is not clear, especially in the provision of a fuel fabrication services. Level 3 in the Director General's Report covers the actual and/or virtual reserves held by supplier States, and the supply from a nuclear fuel bank managed by the IAEA. The reserve includes the supply of low enriched uranium, and the provision of fuel fabrication services, which is an expansion of Level 2.

Therefore, in this paper, to make the system more comprehensible, we define Mode 2 to be limited to all virtual fuel supply and service provision. The term "virtual fuel supply" means the supply of nuclear fuel from an ordinary supply process or facility by a temporary increase in production or provision, but without specifically storing nuclear fuel for the AOS, as would be the case of a nuclear fuel bank or establishment of AOS-specific service facilities. We define Mode 3 as the supply of natural uranium (uranium concentrate or UF_6) and low enriched uranium from the nuclear fuel banks of supplier

States and the IAEA[e]. The Director General's Report covers the provision of a fuel fabrication service in Level 3, but this paper proposes it to be covered in Mode 2 only, as shown in Table 3-2. Modes 2 and 3 are both means of implementing the AOS through the IAEA. The AOS system response would be optimised according to the type of supply disruption; however, there is no order of priority to indicate which of the two modes should be used first.

Table 3-2 Levels and modes in the nuclear fuel supply assurance system (in comparison)

<table>
<tr><th colspan="3">Modes 1-3
(JAEA Approach)</th><th colspan="2">Levels 1-3
(IAEA Director - General's Report)</th></tr>
<tr><td>Fuel/
Services
to be
assured</td><td colspan="2">U_3O_8、LEU、
conversion・enrichment・
fuel-fabrication service</td><td>LEU、fuel assembly</td><td>Fuel/
Services
to be
assured</td></tr>
<tr><td>Mode 1</td><td colspan="2">Commercial market</td><td>Commercial market</td><td>Level 1</td></tr>
<tr><td colspan="2">Mode 2</td><td>Mode 3</td><td rowspan="2">●LEU：Backup commitments by suppliers and their respective Governments

●Fuel fabrication: commitments by supplier States</td><td rowspan="2">Level 2</td></tr>
<tr><td colspan="2">Virtual fuel reserve/
Virtual services

Backup commitments by suppliers' respective governments

Supply of
U_3O_8
UF_6
LEU
conversion service
enrichment service
fuel fabrication service</td><td>Fuel bank/
a physical reserve

Supply of
U_3O_8
UF_6
LEU</td><td>●LEU：a physical LEU reserve, stored in one or several separate locations

●Fuel fabrication：a set of agreements between fuel manufacturers and owners of relevant intellectual property rights</td><td>Level 3</td></tr>
</table>

(1) Mode 1: Procurement of Nuclear Fuel and Services from the Market

Mode 1 refers to the supply from the ordinary nuclear fuel market, as in the case of Level 1 in the Director General's report.

(2) Mode 2: System of Nuclear Fuel Supply through the Virtual Fuel Reserve and Service Provision

In the Director General's report, Level 2 covers the supply of low enriched uranium with the backup of enrichment operators after a supply disruption is identified by the Director General, and the provision of a fuel fabrication service through commitment by respective states.

Mode 2 covers all virtual fuel supplies and service provisions. The term "virtual fuel supply" means

[e] Nuclear fuel banks as covered in Mode 3, the establishment plans of which are currently embodied, are the IAEA nuclear fuel bank proposed by the NTI, the U.S. nuclear fuel bank to store LEU for downblending 17.4tHEU, and the Russian nuclear fuel bank within the IUEC, the setup of which is planned in Angarsk.

the supply of nuclear fuel from an ordinary supply process or facility by a temporary increase in production or provision, but without specifically storing nuclear fuel for the AOS, as would be the case of a nuclear fuel bank or establishing AOS-specific service facilities. The assurance in Mode 2 covers the supply of uranium concentrate through virtual reserves, the provision of a conversion service, the provision of an enrichment service, the supply of low enriched uranium through virtual reserve and the provision of a fuel fabrication service, and therefore the scope of coverage is expanded from that in the Director General's report.

(3) Mode 3: System of Supply from the Nuclear Fuel Bank

Level 3 in the Director General's report covers the actual and/or virtual reserves held by supplier States, and the supply from a nuclear fuel bank managed by the IAEA. The reserve includes the supply of low enriched uranium, and the provision of fuel fabrication services, which is an expansion of Level 2. In Mode 3, AOS coverage is simplified to cover the supply of natural uranium (uranium concentrate or UF_6) and low enriched uranium from the nuclear fuel banks of supplier States and the IAEA. The Director General's report covers the provision of a fuel fabrication service in Level 3, but this paper proposes it to be covered in Mode 2 only, as shown in Table 3-2.

3.3.2 "Modes 1 to 3" and the AOS Flowchart

Fig. 3-3 demonstrates the AOS process flow with the JAEA model using Modes 1, 2, and 3.

Mode 1 refers to the ordinary nuclear fuel market and the situation before the AOS is triggered. Modes 2 and 3 refer to the situation after the AOS is triggered.

In Mode 1, if the supply of nuclear fuel is disrupted, the consumer State would first seek alternative procurement from the nuclear fuel market. This system of the normal fuel and fuel services market is shown in Fig. 4. The information registration system proposed in the Japan's Proposal would facilitate the research for alternative procurement. If the alternative procurement cannot be realized, the consumer State would request AOS from the IAEA and the IAEA would decide whether or not to implement the request.

As shown in Modes 2 and 3, if the IAEA decides to implement the AOS, it would request services or provision of fuel from States with registered information. The registered States would notify the IAEA of quantities available for supply and the required time period. The IAEA would then present this information to the consumer State, which would review the quantities and supply conditions, select a supplier State and inform the IAEA of its selection. After concluding the necessary agreements and contracts between the IAEA and consumer and supplier States, the consumer State would receive the supply through the IAEA.

Although the IAEA has proposed it would temporarily or conceptually acquire the ownership of the nuclear material, the method of transferring the ownership directly from the supplier State to the consumer State is also worth considering because it would simplify and shorten the supply acquisition process. It is necessary to examine the issues of which parties should be signatories of the AOS contracts to provide and receive services of enrichment, conversion, and fuel fabrication.

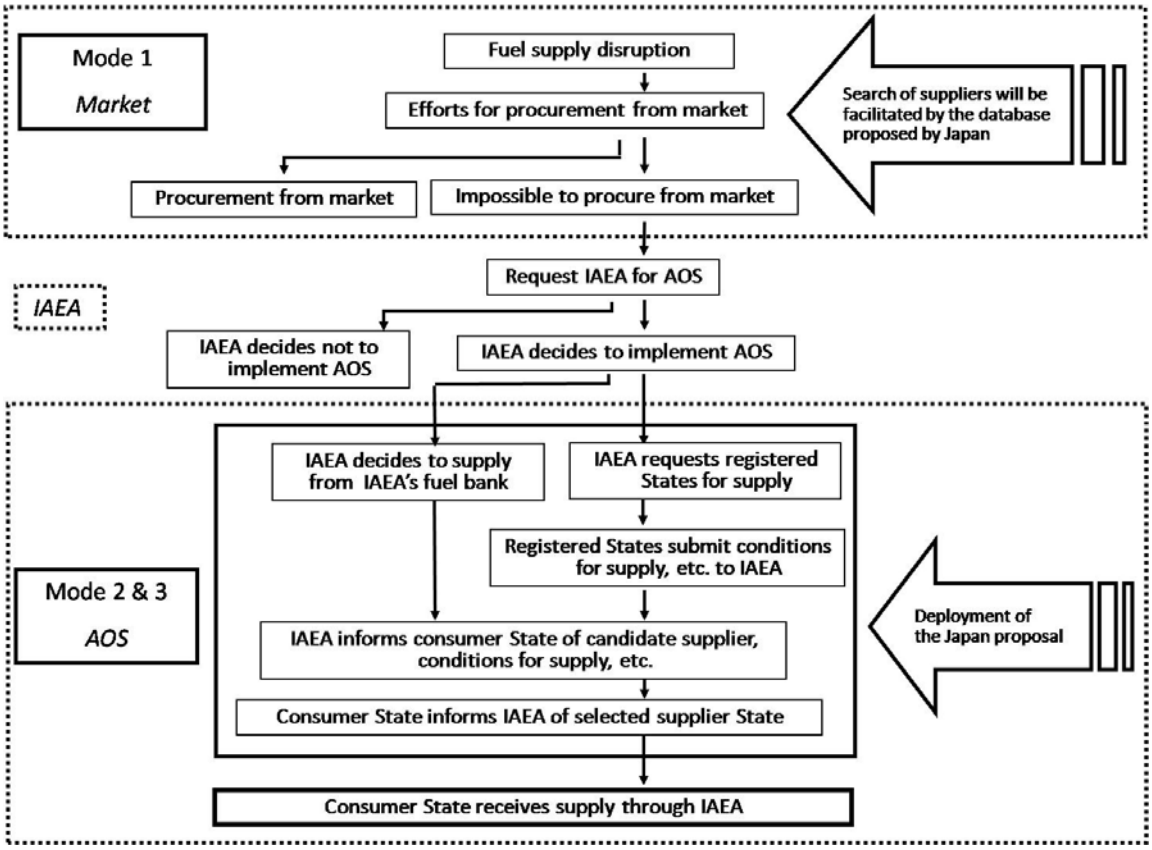

Fig. 3-3 The AOS flowchart

When the IAEA decides to trigger the supply assurance system, it requests the supply from countries that have registered their supply capacity information (according to Japan's proposal).

Registered countries submit the conditions for supply, such as the quantities which they can supply and the time required, to the IAEA which in turn presents the information to the consumer country.

The consumer country studies the proposed quantities and supply conditions, selects the supplier country, and notifies the IAEA of its selection.

After the necessary agreements and contracts have been concluded between the consumer country, the supplier country and the IAEA, the consumer country receives an alternative supply through the IAEA.

3.4 Mode 1: Procurement of Nuclear Fuel and Services from the Market

Fig. 3-4 shows the concept of the processes for the procurement of nuclear fuel and services before the trigger of the supply assurance system, that is, through the existing nuclear fuel market. The light green portion represents the market of front-end of nuclear fuel cycle.

The fuel procurement sources and procedures vary, depending on states/electric power companies. There is a wide variation ranging from the states with resources and nuclear fuel facilities within their own territories to those depending 100% on overseas. As for the procedures for procurement, too, some states/electric power companies are directly engaged in procurement by themselves, and others depend largely on the manufacturers who constructed their power plants. Despite such differences, Fig. 3-4 assumes, briefly, that the "consumer state" procures nuclear fuel from supplier states A to D.

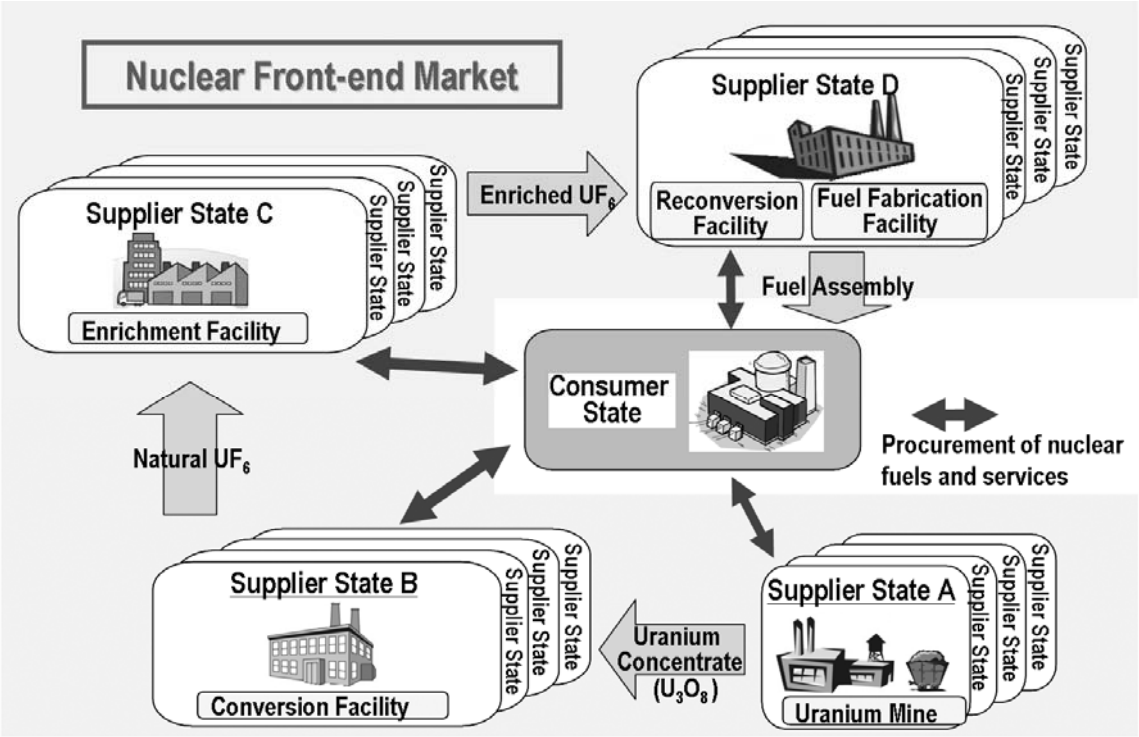

Fig. 3-4 [Mode 1]Procurement of nuclear fuel and services from the market

3.5 Mode 2: System of Nuclear Fuel Supply through Virtual Reserve and Service Provision

3.5.1 Nuclear Fuel Supply/Service Provision System Based on a Virtual Fuel Reserve

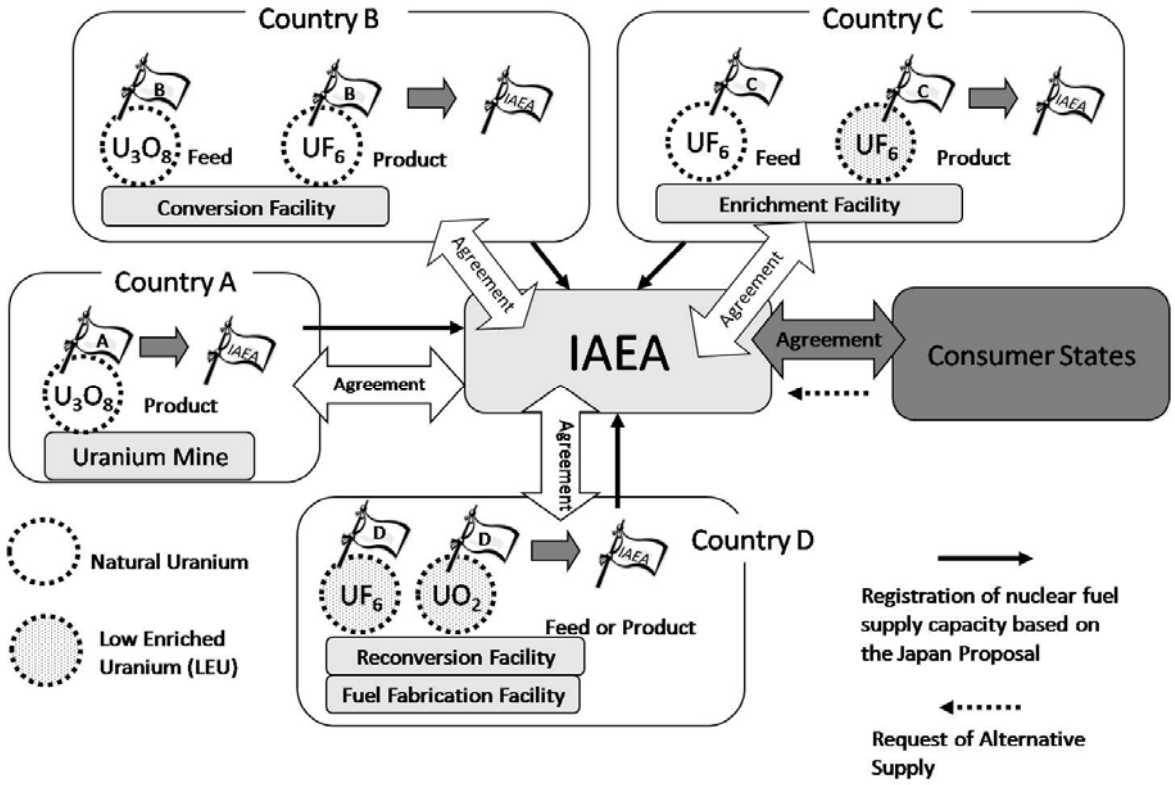

Fig. 3-5 [Mode 2] System of nuclear fuel supply through a virtual fuel reserve and service provision

(1) Overview of the System

In Mode 2, the necessary nuclear fuel and services will be supplied and provided through the IAEA from reserves and service providers that are registered in the AOS system by their respective States, Fig. 3-5.

Information on the nuclear fuel and the services available for supply and provision is registered, based on the Japan's proposal, and in Mode 2, the necessary nuclear fuel and services will be supplied and provided through the IAEA according to the events actually having taken place. State A has uranium mines, and registers the quantity of U_3O_8 as a product available for supply and the period of time required with the IAEA. When the AOS is implemented, State A will supply uranium product from its virtual reserve. Likewise, State B has conversion facilities, State C has enrichment facilities and State D has fuel fabrication facilities, and they register their capacity with the IAEA just like State A and they provide nuclear fuel and services for the AOS. It is advised to predetermine the pricing formula for nuclear fuel supply prices, by using publicly available spot prices for that purpose. It may be difficult to calculate the service provision prices, but it is desirable to predetermine and agree to a pricing formula as well.

In a virtual service provision, there is commitment of operator and the government in advance without uranium storage. When supply disruption occurred, they should supply the low enriched uranium and service based on their commitment.

At the uranium enrichment facility of centrifugal method, centrifuges should be turn continuously, they operate plant continuously deliberately. Normally, cut in processing is difficult. We examined the feasibility of virtual service provision of continuously and deliberately operating uranium enrichment and the fuel fabrication facility, in the view point of method, cost and period.

In JAEA Proposal, the supplier country is required to make a supplier country declaration, as described later, concerning supply assurance. (The supplier country promptly grants the authorization to provide alternative supply from its domestic suppliers and export permits for transportation through the country. It transfers its flag right to the IAEA concerning the nuclear material to be supplied, and the country that has provided the cause of the trigger of supply assurance shall not perform any activities that may hinder supply assurance.) This will contribute to a smooth supply in the event of a supply interruption.

(2) Overview of the System Flow

(a) Registration of Nuclear Fuel Information with the IAEA According to Japan's Proposal

The arrow in Fig. 3-5 represents the supply capacity registration with the IAEA, according to Japan's proposal. According to the proposal, countries A to D in the illustration register their supply capacity information with the IAEA.

Country A, which has a uranium mine, registers the quantities of U_3O_8 it can supply as a product and the period of time required for supply with the IAEA. This is a virtual fuel reserve; therefore, country A does not set U_3O_8 apart as a reserve for supply assurance, but it supplies existing uranium in the form of a product for the purpose of supply assurance when such assurance system is triggered.

Country B, which has a primary conversion facility, registers the quantities it can supply in terms of conversion services and the period of time required for such conversion with the IAEA. This is the provision of conversion services. In addition, depending on the circumstances, country B can register a quantity of U_3O_8 as feed or UF_6 as a product for the purpose of supply assurance.

Country C, which has an enrichment facility, registers the quantities it can supply in terms of enrichment services and the period of time required for enrichment with the IAEA. This is the provision of enrichment services.

Depending on the circumstances, country C can register a quantity of UF_6 as the feed for enrichment or UF_6 after enrichment for the purpose of supply assurance.

Country D, which has a fuel fabrication facility, registers the quantities it can supply in terms of fuel fabrication services, and the period of time required for such services, with the IAEA. This is the provision of fuel fabrication services. In addition, depending on the circumstances, country D can register the UF_6 it has as feed for reconversion or UO_2 after reconversion for the purpose of supply assurance.

(b) Conclusion of Nuclear Fuel/Services Provision Agreements between Countries and the IAEA

The left-to-right double arrows in Fig.3-5 show the agreements concluded between the IAEA and the countries concerned, respectively.

The participating countries in these agreements have agreed to a model agreement in advance. When actual supply becomes necessary, an individual agreement based on the advance agreement allows a supplier country to supply LEU or services like enrichment from its virtual fuel reserve.

(c) Occurrence of a Supply Interruption

When a supply interruption occurs and an alternative supply becomes impossible, even after all other commercial means have been exhausted, the consumer country may ask the IAEA to trigger the supply assurance system.

(d) Recognition of Supply Interruption

In consideration of advice from the Advisory Committee on the Supply Assurance System, based on the predetermined criteria, the IAEA Director General decides whether to trigger such supply assurance system. At the time that the trigger is determined, the consumer country concludes agreements with the IAEA according to the model agreement prepared by the IAEA beforehand.

(e) Request from the IAEA for Supplier Countries to Provide Supply / Services through the Supply Assurance System

When an interruption of supply is identified, the IAEA, on the basis of information registered by various countries according to Japan's proposal, asks these countries to provide a supply proposal. This proposal indicates the quantities and timeframes concerning the provision of uranium concentrate, conversion services, enrichment services, LEU, and fabrication services.

The IAEA asks those countries to supply LEU or to provide enrichment services based on their commitments. At the same time, the IAEA asks individual governments to provide cooperation based on their commitments.

(f) Submission of a Supply Proposal to the IAEA and Its Delivery to the Consumer Country

In any case of supply interruption, the countries concerned submit a supply proposal to the IAEA, which then delivers it to the consumer country.

At this point, while the consumer country is selecting a supplier country, the IAEA acts only as an intermediary. Since the proposal includes the period of time necessary for the supply, and the price is calculated using a predetermined calculation formula, there is no need for a bid, with the selection of a supplier country being left to the consumer country. This simplifies the procedure and hastens the commencement of supply, without unduly increasing the IAEA’s role.

(g) Determination of the Supplier Country by the Consumer Country

The consumer country, of its own free will, selects the supplier country.

(h) Supply

Upon the selection by the consumer country, the IAEA asks the supplier country for the supply. The supplier country should transfer the flag right to the IAEA.

According to a draft that is currently under review at the IAEA, it will acquire the ownership of the nuclear material on a temporary basis. Matters concerning the principal parties who will be in the case of the provision of enrichment, conversion, and fuel fabrication services (it is deemed proper for the consumer country to conclude an agreement directly) will require deliberation.

3.5.2 Case Study 1: Specific Methods for AOS in the Event of Enrichment Service Disruptions

In the event of enrichment service disruptions, we have examined how other operators would provide supply services for the AOS. The backup by operators premised in the six-country proposal and the IAEA Director General's report is supposed to be made in a similar way.

(1) Premises

There are various factors concerned in enrichment, such as the separation method used, and the contracts based on the quantity of service or the quantity of enriched uranium received. We operate on the following premises:

- Company A's PWR (1.1 GW) suffered an enrichment service disruption. The company replaces one-third of it fuel core (about 30tU) every 13 months.
- For this single replacement of fuel, the enrichment service of 194tSWU is required.
- Company A identifies an alternative service provided by Enrichment Plant N with an annual production capacity of 3,000tSWU by the gas centrifuge separation method.
- Enrichment Plant N will allow a "cut in" of existing processing contracts to accommodate Company A's need.
- Company A will bring natural UF_6 into the enrichment plant N.
- The enrichment plant shall procure the natural UF_6 (232tU) necessary for a "cut in"
- Delivery dates in existing contracts at Enrichment Plant N shall not be delayed.

(2) Method to Cope with Enrichment Service Disruption

Fig. 3-6 shows an example of how Enrichment Plant N might cope with enrichment service disruption. We assume Enrichment Plant N increases its feed quantity and tails assay to allow a "cut in" or additional production of 194tSWU for Company A.

It should be noted that some conditions in existing contracts might be specified, e.g., specifications of tails assay. These situations must be anticipated and coordinated with contracting parties before an AOS service can be provided.

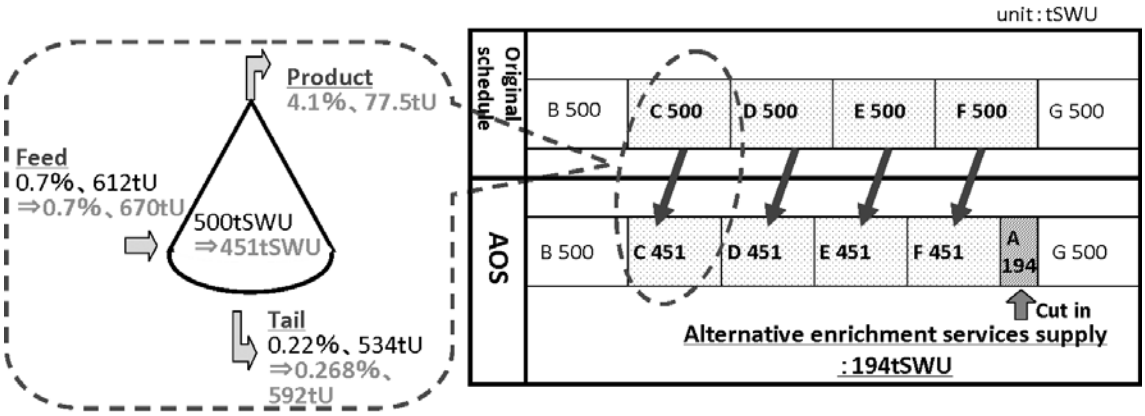

Fig. 3-6 Example of coping with enrichment service disruption

(3) Calculation of the Additional Cost

Based on the spot price from April 2009, the cost for Enrichment Plant N to procure natural UF_6 (232tU) for the AOS will be about 3.5 billion yen (including transport costs), while the enrichment service revenue will increase by 3.1 billion yen as revenue from Company A. Therefore, the additional cost for the AOS will be about 400 million yen, which should be provided by the AOS mechanism. Company N should be compensated by AOS system such as the fund for AOS which we touch on later in this paper.

(4) Service Provision Schedule

Fig. 3-7 shows an example of an enrichment service provision schedules one operating normally and the other after a disruption that leads to request of AOS. It is assumed that a certain period of time, perhaps many months will be required to go through the steps of seeking alternative sources from the market, triggering AOS and its review and approval process, and ending with a contract with the selected supplier. The AOS process should be designed to be as streamlined as possible, understanding that a good balance must be struck between good system governance and minimizing to the extent possible any delays to the consumer State's facility.

The upper part represents the original schedule, while the lower part shows the schedule for the period of time that starts with the consumer country's effort to secure supply from the market through the trigger of the supply assurance system. The schedule for the fuel fabrication (including transportation and reconversion) is represented in the bottom of each part.

In the initial plan, nine months were required from the time of delivery of natural UF_6 through the enrichment services to the delivery of enriched UF_6. Nine months were needed for fuel fabrication (including transportation and reconversion), and two months from the completion of fuel to its loading in the reactor. This is a total of 20 months.

It is assumed that an interruption of supply occurs at the point in time of the delivery of natural UF_6 to the enricher. It is also assumed that the consumer country's efforts to procure alternative fuel and the procedure to trigger the supply assurance system by the IAEA require five months.

The time required to carry out the supply assurance procedure is assumed to consist of two months for procurement from the consumer country's market, one month for the IAEA's decision to trigger the supply assurance system, one month for the supplier countries to express their intention to supply, and about one month for the consumer country to select a supplier country and for the subsequent conclusion of an enrichment service provision agreement through the IAEA. It is also assumed that eight months are required for the enrichment operation to be completed, including the adjustment of cutting into the normal operations. As a result, the drawing of enriched UF_6 and its loading will be five months behind the initial plan. (However, this five-month delay is purely an assumption, based on the result of the case study.)

Generally, fuel fabrication is ordered and completed fuel assemblies are shipped to the nuclear reactors in accordance with the reactor operation schedule. In other words, fuel assemblies are not carried in stock in the nuclear power station. Because of this, it may require further consideration on prompt activation of the supply assurance system and on shortening the time required to take measures.

Though not detailed here in this paper, the transportation of nuclear materials is a special issue, and it currently takes considerable time to prepare the transportation of nuclear materials amid the trend of strengthening nuclear security in recent years. It should be noted that any supply from either a virtual or actual fuel bank would require new safety and security authorizations for transporting and delivering fuel by new routes. This could incur a major delay in the service provision schedule.

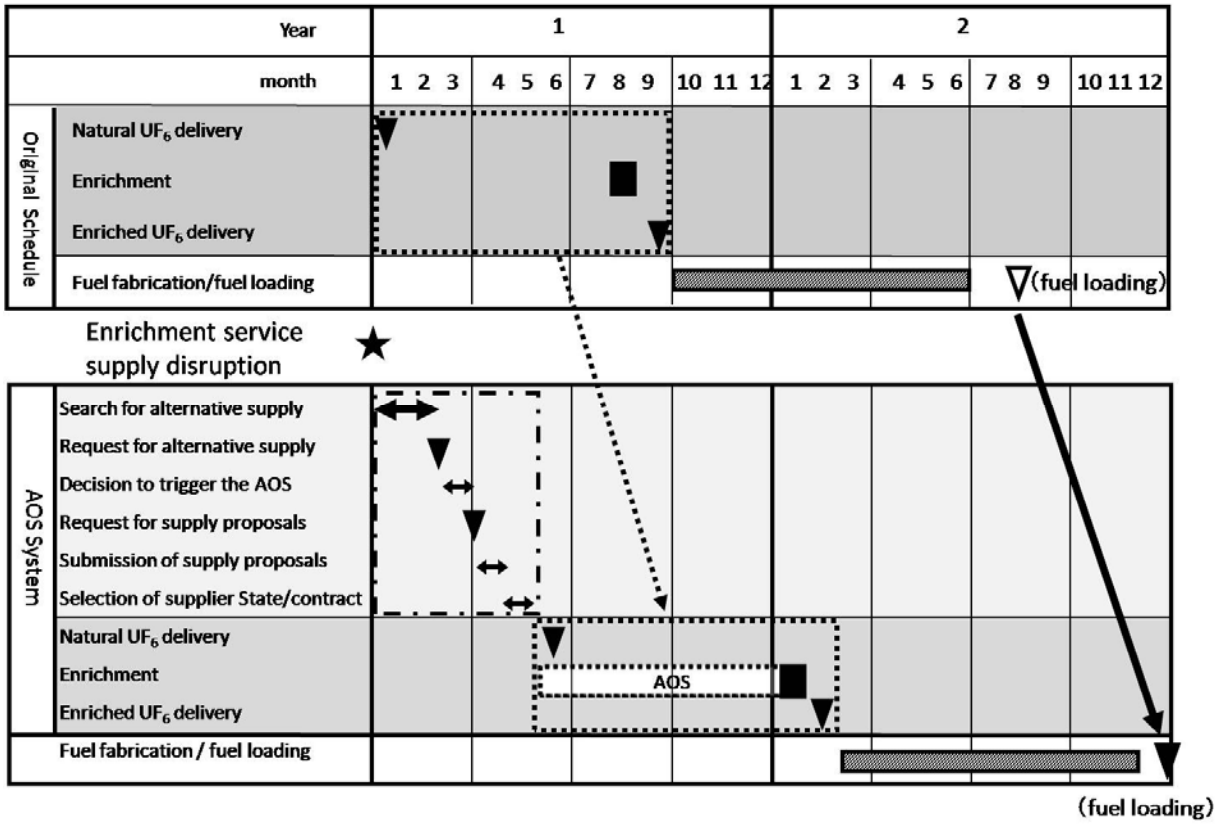

Fig. 3-7 Example of schedule to cope with enrichment service disruption

3.5.3 Example of AOS for Fuel Fabrication Service Disruptions

We discuss below is how the operator (fuel fabricator) would make alternative fuel supplies under AOS if the fuel fabrication were disrupted.

(1) Premises

We assume the disruption affects the fuel fabrication plant that supplies fuel for Company A's PWR. Its annual fabrication capacity is 400tU (850 assemblies). To supply one-third of the fuel core for Company A requires 65 assemblies, or about 30tU.

Note that, basically in fuel fabrication, PWR and BWR fuels require different processing conditions, which could possibly be major limiting factors for the AOS. For the purposes of this example, we assume that these conditions exist:

- No special components or materials are required in the fuel.
- The fabrication plant is able to obtain fuel design information promptly.
- The fabrication plant is able to produce the fuel satisfying the safety regulations of Company A's State.
- No large-scale modifications to plant facilities are required to fabricate the fuel.
- In the event of accidents due to the fuel supplied, the fuel fabricator shall be exempted from liability[f].

To supply alternatively in the fuel fabrication stage, there are various conditions depending upon the reactor type and the fuel design. There is a possibility when it is difficult to fabricate in short period.

(2) Example of Addressing an Interruption

Under various premises as mentioned above, we assumed that to cope with a supply disruption, the fuel fabricator allowed "cut in" on the existing contracts of fuel production for company A by raising the plant utilization rate, for example by operating on holidays. Fig. 3-8 shows an example of this method.Fuel fabrication plants are supposed to interrupt alternative services into the line of a fuel fabrication services under existing contracts by raising the plant utilization rate, for example by operating on holidays.

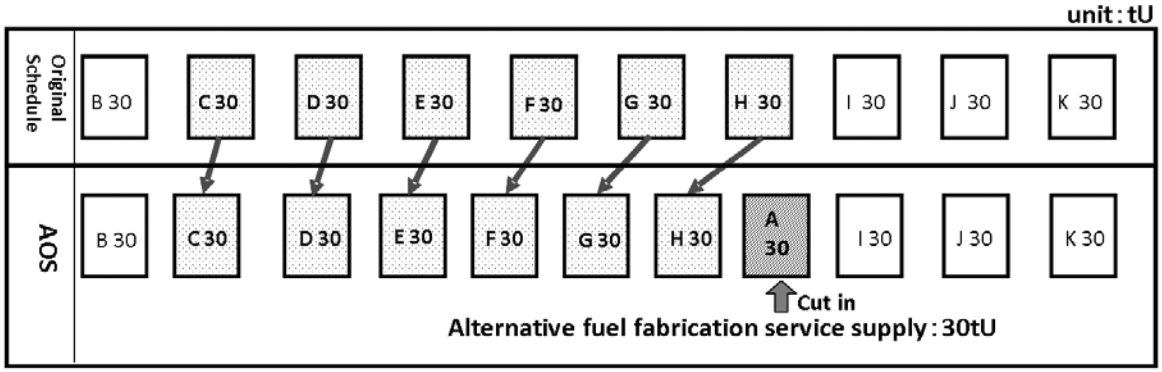

Fig. 3-8 Example of coping with fuel fabrication service disruptions

[f] This point should be examined carefully. As a minimum, fuel fabricators will be required to have fabricated the fuel in accordance with the information they received for fuel fabrication, and the prerequisite will be no willful or gross negligence on the part of fuel fabricators.

(3) Calculation of the Additional Cost

The cost for the AOS is that of raising the plant utilization rate, which will be basically the surcharge for company A's fuel fabrication service. The incremental fuel fabrication service cost is supposed to be a product of [the ordinary fuel fabrication service unit cost ($275/kgU[g]) x the interrupted quantity] (800 million yen) multiplied by a surcharge rate (supposed to be 50 - 100 %). According to a provisional calculation, ensuring supply for a single replacement of fuel for PWR (1.1 million kW) will require an additional cost of approximately 400 million yen (at a surcharge rate of 50%) to 800 million yen (at a surcharge rate of 100%) in addition to the 800 million yen payable originally.

(4) Service Provision Schedule

The schedule for providing the fuel fabrication service assumes that fuel loading will be five months delay compared with originally scheduled, as in the case of an enrichment service. Needless to say, it is necessary to try to bring the schedule as close as possible to the original schedule by shortening respective processes.

The upper part represents the original schedule, while the lower part shows the schedule for the period of time that starts with the consumer country's effort to secure supply from the market through the trigger of the supply assurance system. The schedule for the fuel fabrication (including transportation and reconversion) is represented in the bottom of each part.

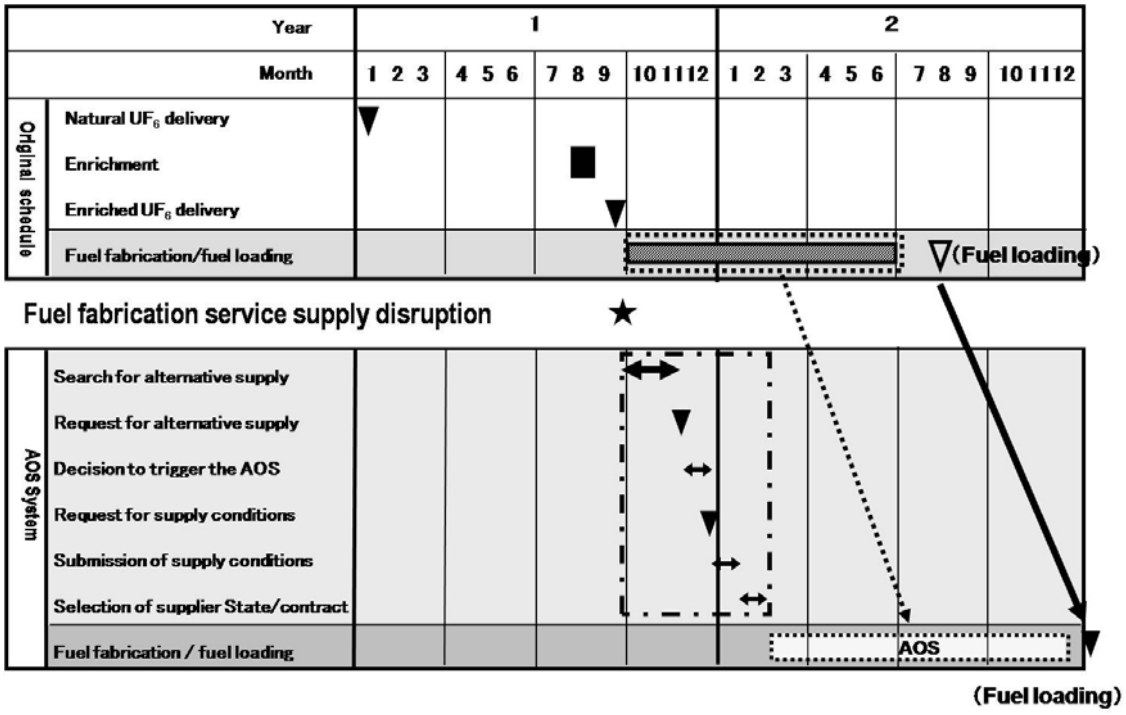

Fig. 3-9 Example of schedule to cope with fuel fabrication service disruption

g) The unit price is based on the MIT report "The Future of Nuclear Power, 2003." The exchange rate between the U.S. dollar and yen is as of the end of April 2009.

In the original plan, a total of 11 months were considered: nine months from the delivery of enriched UF_6 to fuel fabrication (including transportation and reconversion) and two months before loading into the reactor.

Suppose that a supply interruption occurs at the time of the delivery of UF_6, immediately before fuel fabrication. As with the schedule for addressing an interruption of enrichment services, assume that five months are required by the consumer country's effort to procure alternative fuel and the IAEA's procedure to trigger the supply assurance system. Assume about 10 months, instead of the normal nine months, for fuel fabrication because of the adjustment for cutting into the normal production. Further, assume that one month as the result of an effort to roughly halve the original plan, is required by the processes from the completion of fuel to the loading. Even after all these steps have been taken, the loading of fuel assemblies will still be approximately five months behind the original schedule. However, this five-month delay is purely an assumption based on the result of the case study.

There is an additional special situation in fuel fabrication. It involves the consideration of design requirements varying from reactor to reactor as well as of intellectual property rights. For these reasons, the more time the IAEA takes to trigger the supply assurance system, the longer will be the delay in the loading of fuel assemblies onto the reactor.

Fuel fabrication processes are controlled to match the power reactors' operating schedule; fuel is not stored as inventory there. For this reason, it is deemed necessary to create a supply assurance system that will allow more expedient actions to be taken in the case of an interruption of supply.

3.5.4 Feasibility of Virtual Nuclear Fuel Supply and Service Provision

The issue of how much quantity is available for the AOS is a key factor. We have examined the specific methods of providing an enrichment service and fuel fabrication service, supposing the disruption of fuel supply for a single replacement of fuel for a PWR with a power output capacity of 1.1 GW. The quantity required in this case will be 30 tons of enriched uranium, about 200tSWU of an enrichment service, or about 230tUF_6 of natural uranium. This number is equal to 0.3% of the production capacity in the world, which was reported to be 59,650t-SWU in 2006[15]. It is highly possible that there is a plant that can accommodate this level of additional processing without unduly perturbing existing contracts. However, for this type of arrangement to succeed, it will be important to secure operators' cooperation through a fair and attractive compensation program, with a predetermined pricing formula for alternative fuel supply, and some reasonable arrangement for a release of liability.

Considering that supply disruption would happen rarely if ever, virtual fuel reserves and service provisions are considered to have significant advantages in that no reserve for the AOS is maintained and no cost incurred until the AOS is actually implemented. We have examined specific methods and assessed costs of a virtual service provision, and, as a result, we believe virtual reserve and service provision are worth considering.

On the other hand, it is necessary to ensure the certainty of provision as a system and to examine the measures that would shorten the period of time required to provide an alternative supply.

3.6 Mode 3: Nuclear-fuel-bank-based Supply Assurance System

3.6.1 Nuclear-fuel-bank-based Supply Assurance System

(1) Overview of the System

In Mode 3, as proposed in this paper, the supply commodities are natural uranium (uranium concentrate or UF_6) and low enriched uranium, all of which will be supplied from the nuclear fuel banks of IAEA and registered under the system proposed in the Japan's Proposal, Fig. 3-10.

Basically, States A to D, which have virtual fuel reserves in Mode 2 as shown in Fig. 3-5, have changed to have an actual nuclear fuel bank, and the IAEA nuclear fuel bank in State X has also joined the system.

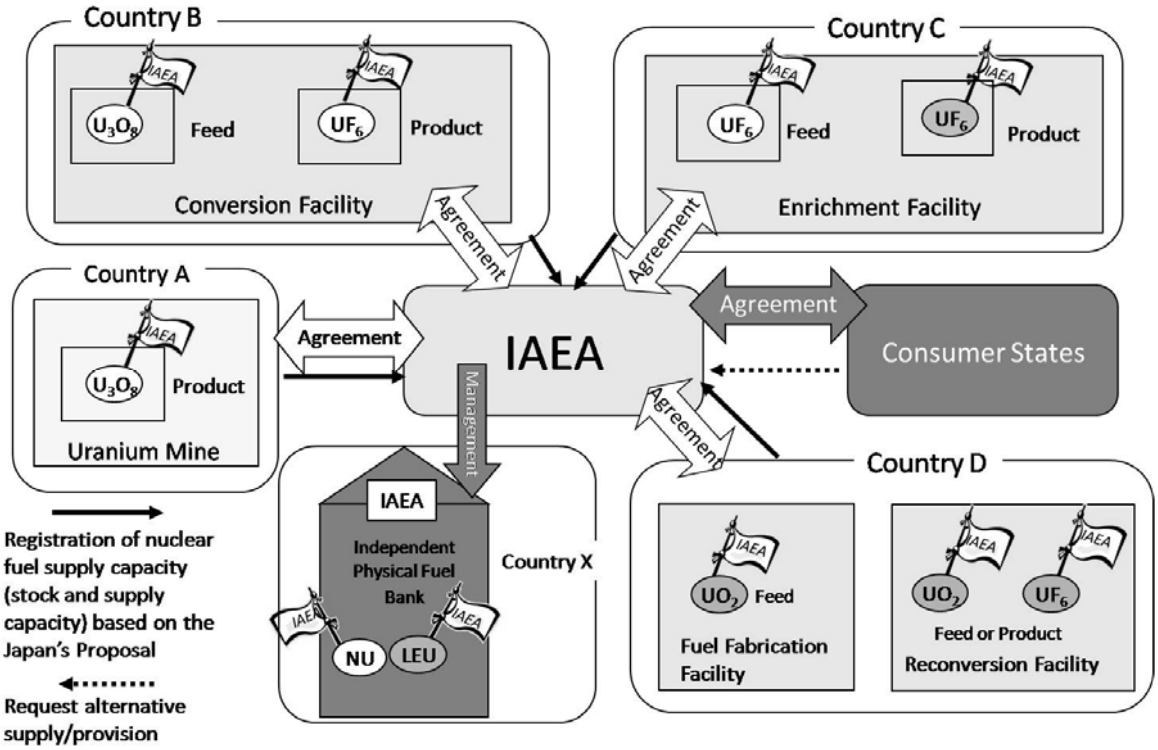

Fig. 3-10 [Mode 3] System of supply through a nuclear fuel bank

In Level 3, according to the Director General's report, the objects to be covered by the supply are LEU and nuclear fuel fabrication. The Proposal, however, specifies LEU and uranium concentrate as the objects to be covered by the system.

On the basis of the supply capacity registered information, in Mode 3, the IAEA sounds out countries that have registered the approximate quantity and the required period of time concerning physical uranium concentrate and LEU on the possibility of supply, using the supply capacity registration system based on Japan's proposal. As described above, two nuclear fuel banks have been established, one in the United States and the other in Angarsk, Russia.

In order to supply natural uranium and low enriched uranium in response to a request, the IAEA

shall decide whether it will supply from its own fuel bank or request Member States for supply, considering the situation of its own fuel bank and other conditions. If both the IAEA and Member States have fuel banks, it is desirable to determine the order of priority in advance. The IAEA shall send the consumer State its own supply proposal, including the quantity available and the period required for supply from its own fuel bank, and/or the supply proposals from registered supplier States. If there are two or more proposals, the consumer State shall select one of them. The supply will be performed if an agreement is reached between the parties concerned. As for the supply price, it is necessary to prepare the pricing formula based on the spot price beforehand. Further, in order to limit the cost of storage of a nuclear fuel bank, one conceivable method is to entrust the storage as a running stock to any private operator's facility.

The supplier country is required to make a declaration concerning supply assurance. The supplier country will promptly grant authorizations of supply from its domestic suppliers and export permits for transportation through the country; it transfers its flag right to the IAEA concerning the nuclear material to be supplied, and the country that has provided the cause of the trigger of supply assurance shall not perform any activities that might hinder supply assurance. This will contribute to a smooth supply process at the time of a supply interruption.

(2) Overview of the System Flow

(a) Registration of Nuclear Fuel Information with the IAEA Based on Japan's Proposal

The arrow in Fig. 3-10 denotes the processes of providing the IAEA with information regarding nuclear fuel and of registering such information with the IAEA in the same way as in the case of virtual fuel reserve/service provision described in Paragraph 3.5.1(2)(a). Country X reserves the uranium for the supply assurance (NU and LEU) that is owned by the IAEA.

Country A with a uranium mine reserves U_3O_8 as a product for the supply assurance. It notifies the IAEA of the quantity it can supply and the period of time required for such supply, and registers such information with the IAEA. As shown in the illustration, it is desirable that the flag right to the uranium is transferred to the IAEA. The same principle concerning the flag right applies to the countries mentioned below.

Country B reserves U_3O_8 as feed for the primary conversion facility and/or UF_6 in the form of a product for the purpose of the supply assurance. It notifies the IAEA of the quantity it can supply and the period of time required for such supply, and registers such information with the IAEA.

Country C, which has an enrichment facility, reserves UF_6 as feed for enrichment or UF_6 after enrichment for the purpose of the supply assurance. It notifies the IAEA of the quantity it can supply and the period of time required for such supply, and registers such information with the IAEA.

Country D, which has a fuel fabrication facility, reserves UO_2 as feed for reconversion or UF_6 in the form of a product or UO_2 for feed for the fuel fabrication facility for the purpose of the supply assurance. It notifies the IAEA of the quantity it can supply and the period of time required for such supply, and registers such information with the IAEA.

(b) Conclusion of a Nuclear Fuel/Service Provision Agreement with the Countries Concerned

The left–right double arrows in Fig. 3-10 show the agreements concluded between the IAEA and the countries concerned, respectively. As in the case of the virtual reserve/service provision in Mode 2 above, agreements and the like enable nuclear fuel to be provided from the physical reserve of the IAEA or supplier countries.

(c) Occurrence of Interruption of Supply

When an interruption of supply occurs and the supply cannot be secured, even with all other commercial means having been exhausted, the consumer country requests that the IAEA trigger the supply assurance system.

(d) Recognition of Interruption of Supply

An interruption of supply is recognized in the same way as in the case of the virtual reserve/service provision in Mode 2, described above.

(e) Supply from the IAEA or a Request to Countries for the Offer of Supply

In consideration of the condition of its physical fuel bank, the IAEA decides whether it will supply the required items or ask the countries concerned for supply, sending the supply proposal to the consumer country. A formula for the supply price on the basis of the spot market price and the like must be predetermined.

For cases in which the IAEA asks the countries concerned for supply, it will study the possibility of temporarily acquiring ownership of the items to be supplied to the consumer country.

(f) When One of Signatory Countries Supplies the Items Required, the Consumer Country Selects the Country from which the Supply will be Received.

The consumer country freely selects the supplier country.

(g) Supply

According to the decision made in advance, the IAEA supplies the required items on its own initiative or asks a country with a reserve to supply the required items to the consumer country.

3.6.2 Schedule of Supply from the Nuclear Fuel Bank

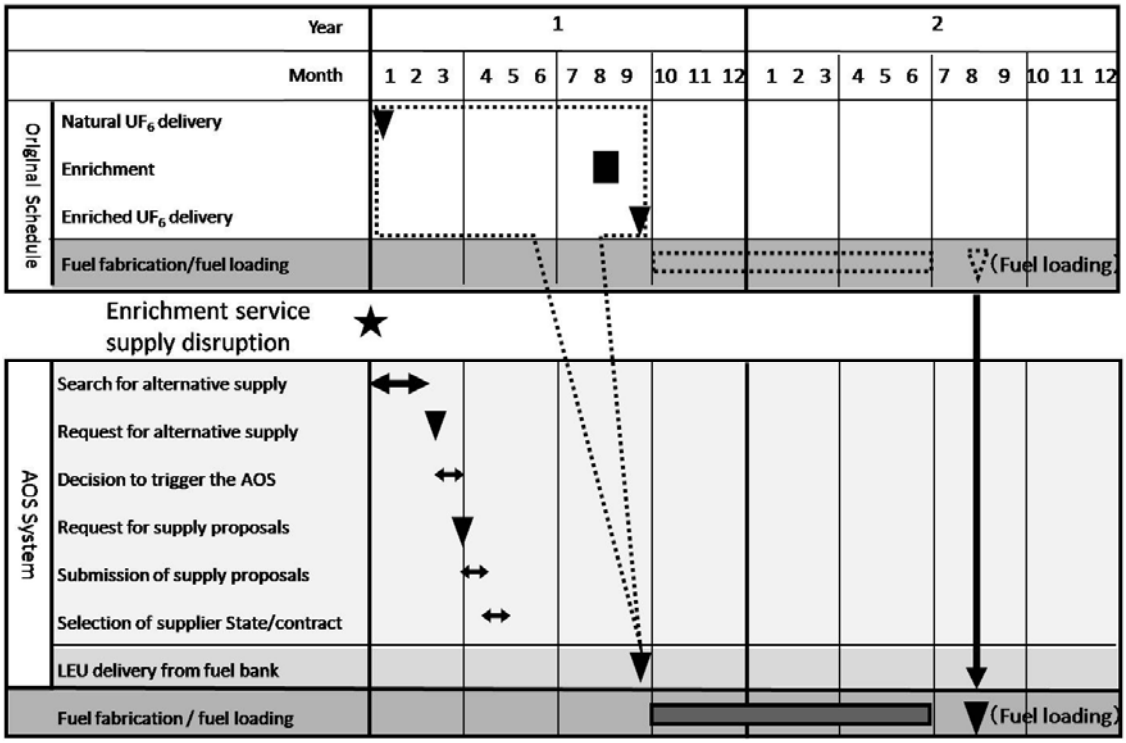

Fig. 3-11 Schedule of supply from the nuclear fuel bank

Fig. 3-11 shows an example of the schedule of supply from the nuclear fuel bank in Mode 3. In this case, the IAEA does not seek a supplier of alternative enrichment services. Instead, enriched UF_6 is supplied from the physical fuel bank. This scheme assumes that the enriched UF_6 is delivered as initially scheduled which enables the nuclear fuel to be loaded.

The upper part represents the original schedule, while the lower part shows the schedule for the period of time that starts with the consumer country's effort to secure supply from the market through the trigger of the supply assurance system, until the conclusion of an enriched LEU supply agreement, and the schedule for the period of time until the enriched UF_6 is drawn from the nuclear fuel bank. The schedule for the fuel fabrication (including transportation and reconversion) is represented in the bottom of each part.

Even though, various procedures are required in the AOS mechanism, nuclear fuel may be loaded as originally scheduled.This schedule could be made possible, largely because no enrichment service is required in the case of supply from the nuclear fuel bank in Mode 3, hence the existence of a nuclear fuel bank will give a great sense of ease to consumer states.

3.6.3 Trial Calculation of the Reserve Cost of a Nuclear Fuel Bank (Low Enriched Uranium)

A trial calculation of the reserve cost has been made on the assumption that 50 tons of low enriched uranium UF_6 at 4.9% enrichment would be bought, the land and sea transport would be in 36- 30B cylinders, 1,000 square meters of space would be leased in Japan, and 450 square meters (25m x 18m)

of reserve facilities would be built there (with no plans for construction of a repacking facility).

Based on the trial calculation, the total initial cost would be 12.6 billion yen, the breakdown of which is as follows: 12.2 billion yen[h)] for the purchase of low enriched uranium, 210 million yen for transportation, and 160 million yen for the construction of reserve facilities. The post-construction maintenance cost would be small, as compared with the initial cost, at about 10 million yen (annually, not including the cost of measures against deterioration of the uranium).

4. Considerations for the Structuring of the AOS System

4.1 Preventing the Spread of Sensitive Technologies (Enrichment and Reprocessing)

As with previous discussions on INFCE and CAS, Director General ElBaradai's paper (printed by The Economist magazine in 2003 [1)]) and President Bush's speech (mentioned above) are both intended to convey the idea that preventing the proliferation of sensitive technologies is one of the purposes of nuclear fuel supply assurance.

While the term "proliferation" can be interpreted in several ways, it seems to be basically understood as the spread of sensitive technologies out of nuclear-weapon countries, and from non-nuclear-weapon countries with sensitive technologies (Japan, Germany, Netherlands, and others in terms of enrichment technology). However, this definition would inspire discussions. For example, Japan's Rokkasho enrichment/reprocessing facility can be said to have sensitive technologies in terms of "enrichment". Meanwhile "reprocessing" might have a possibility to become a slightly delicate issue. Director General ElBaradai's paper in The Economist magazine and his mention at the Carnegie International Non-Proliferation Conference (held in November 2005) of a five-to-ten-year moratorium[16)] on the construction of new enrichment/reprocessing facilities created misgivings among some people in Japan at that time. It will become necessary to consider to the way in which certain countries are evaluated. These include Brazil, which has started operating an enrichment facility to meet its domestic demand, Argentina, which has declared its development of an enrichment facility in cooperation with Brazil, Australia, which has its own enrichment technology, and Canada, which has expressed its interest in future enrichment. Needless to say, there is a problem how we evaluate the enrichment in Iran. And there will be a problem in North Korea in the future.

In addition, limiting possession of sensitive technology to the countries that already own the technology would raise not only criticism of NPT but also strong opposition from developing countries, as described above. This would form one of the serious causes of the current stagnation of discussions on nuclear fuel supply assurance. In reality, the Nuclear Suppliers Group Guidelines (NSG Guidelines), which form the regulatory framework for the export of nuclear equipment and technology to non-nuclear-weapon countries, will serve as reference. Regarding the "proliferation" of sensitive technologies in connection with supply assurance, however, more convincing grounds or incentives to prevent the spread will be needed, as stated below, more than for the problems of nuclear weapons related to the NPT.

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h) Based on the UxC spot price (as of the end of April 2009).

4.1.1 Reason why Different Countries Wish to Have Enrichment Facilities

The possible reasons as to why certain countries wish to have enrichment facilities can be categorized roughly as follows:

(a) Pursuit of Purely Peaceful Utilization of Nuclear Energy

(b) Superficial Profession of Peaceful Utilization of Nuclear Energy

(c) Pursuit of Nuclear Weapons Development

In terms of the motivation to own enrichment facilities, most countries seem to fall into category (a) or a position between categories (a) and (b). Probably there are countries on position between categories (a) and (b). Those countries have decided on the peaceful utilization of nuclear energy formally and in terms of domestic politics, but allow some political forces to act with an eye toward the possibility of the future ownership of nuclear weapons.

Iran is, currently, probably in the state of a country that does not acknowledge the development of nuclear weapons formally but takes a position as described in category (b), close to (c).

Countries that declare their position as category (c), or are engaged in the development of nuclear weapons, are India, Pakistan, Israel, and probably North Korea, in addition to the countries with nuclear weapons known as the P5 countries.

Regardless of whether the fuel supply assurance system functions effectively and even if it is limited to IAEA members, the effect of the system in nuclear non-proliferation varies greatly depending on how certain countries take certain positions on items (a) to (c). The supply assurance system design will vary depending on how a country is defined in terms of being covered by such assurance.

The relationship between reasons (a) to (c) and nuclear fuel supply assurance system are considered below.

(a) Pursuit of Purely Peaceful Utilization of Nuclear Energy

Countries pursuit of purely peaceful utilization of nuclear energy are believed to be studying the startup of enrichment operations in the hope of eliminating uncertainty related to fuel procurement or fostering the operation of nuclear fuel cycling as an industry, or in the hope that having an enrichment facility provides proof of their qualification to join the ranks of the developed countries.

These countries will be dissuaded relatively easily from having their own facilities by the following reasons: The nuclear fuel market functions soundly and steadily; importing nuclear fuel is economically preferable to a country having its own enrichment facility; and support from supplier countries is given through supply assurance. It is inconceivable that an emerging nuclear energy country would construct the number of nuclear power reactors required to allow its own enrichment facility to be run on a paying basis. Furthermore, it is extremely difficult for such a country to have an enough enrichment facility all at once like an export industry.

For these reasons, the development of enrichment facilities in such a country is neither rational nor persuasive. Supply assurance, therefore, should be effective todissuade a country from developing such facilities.

Countries that closely relate the development of nuclear fuel cycle facilities (such as enrichment facilities) to national pride, or that strongly assert the right to peaceful utilization of nuclear energy under

Article IV of the NPT, the effect of supply assurance will be limited.

Furthermore, it gives rise to a difficult issue on how we should respond to a country making 'Non-nuclear weapon use'(peaceful use) of nuclear power as for propulsion of a non-strategic military nuclear submarines, like Brazil or one of the emerging nuclear energy countries.

(b) Superficial Profession of Peaceful Utilization of Nuclear Energy

This stance is adopted by countries that superficially claim the peaceful utilization of nuclear energy but have a strong awareness of the option to have nuclear weapons in future. These countries are more difficult to address than those that take the position in item (a).

For such countries, however, a supply assurance system is believed to have some effect. One effect is that the smooth procurement of enriched uranium through the supply assurance system will be a persuasive tool with which to trigger political pressure against a potential act that conflicts with the assertion of peaceful utilization. On the other hand, the smooth procurement of enriched uranium through the system will make it possible to ask an emerging nuclear energy country that is about to start enrichment why it needs to do so.

(c) Pursuit of Development of Nuclear Weapons

The nuclear fuel supply assurance system cannot be effective with regard to a country that has made clear its desire for developing nuclear weapons, either by a definite expression of will or through concrete actions such as the production of HEU and the development of rockets. Such a case is basically an issue for the United Nations Security Council, as it is not covered by the discussion of the supply assurance system around the IAEA.

Neither the stability of the nuclear fuel market nor the economy of overseas procurement would dissuade such a country from abandoning the idea of building an enrichment facility. In addition, persuasion based on the supply assurance system would only be criticized as an infringement of the rights given by the NPT.

4.1.2 Effectiveness of the Nuclear Fuel Supply Assurance System in Preventing Sensitive Technologies from Proliferation

The aim of a supply assurance system is to indirectly prevent the proliferation of sensitive technologies, through the assured supply of nuclear fuel. In other words, it aims to create an environment for non-proliferation. In fact, the importance of preventing spread of sensitive technologies through the supply assurance system was mentioned in the G8 Heiligendamm Summit[17] in 2007. The Heiligendamm Statement on Non-proliferation mentioned "…We also stress the importance of developing and implementing mechanisms of multilateral approaches to the nuclear fuel cycle as a possible alternative to pursuing national enrichment and reprocessing activities…"

As described above, however, emerging nuclear energy countries strongly object to the idea of the supply assurance system, with which the goal of non-proliferation is becoming difficult.

As described below, the supply assurance will be somewhat effective for countries pursuing purely peaceful utilization of nuclear energy. This will happen with the achievement of either an economic

incentive or a sense of ease in terms of nuclear fuel supply that can be regarded as justifying the abandonment of sensitive technologies. However, the supply assurance cannot be effective towards a country that has an eye on the development of nuclear weapons. In a similar way, the supply assurance can have only a limited effect on a country that stakes its dignity and honor on the establishment of a nuclear fuel cycle.

4.1.3 Realistic Effect of Discussions on Nuclear Fuel Supply Assurance

The supply assurance has a number of problems that need to be solved in its establishment. If it were not for an incentive such as the US's "illustrative offer," described above, it might be difficult to structure an effective system.

However, the subject of such assurance has its meaning also just in being discussed continuously. It would have a certain effect as described below.

In terms of what supply assurance means to emerging nuclear energy countries, it is hoped that they will understand the concerns that sensitive technologies could lead to the development of nuclear weapons and that, to avoid suspicion, these countries need the IAEA's safeguards, bilateral nuclear cooperation agreements, and the like. It should be also understood that with the acquisition of sensitive technologies comes accountability. Understanding these concerns and responsibility would be able to dissuade them from acquiring sensitive technologies.

For a developed country, a contradiction will arise if it discusses measures against a supply interruption on one hand, yet causes the supply of nuclear fuel to be interrupted on the other. Discussions on supply assurance would act as a deterrent against political pressure regarding an interruption of supply. Furthermore, the creation of a supply assurance system will prevent supply interruptions, which would lead to the meaning of putting pressure on supply being lost.

4.2 Incentives for States to Participate AOS

Countries such as Bahrain, the United Arab Emirates and Saudi Arabia have announced that they are not pursuing sensitive technologies, on the basis of memorandum and agreements of nuclear cooperation with the United States. The United Arab Emirates has announced the contribution of a 10 million dollar fund to the NTI proposed IAEA nuclear fuel bank. However, most emerging nuclear energy countries seem to be unwilling to join a supply assurance system, so far as the system requires them to limit their rights for the peaceful use nuclear energy, including enrichment and reprocessing.

In order to create an environment in which emerging countries join the supply assurance system to eliminate the need (or to make it difficult) for them to have their own enrichment facilities, the question should be asked as to whether it is necessary to prepare incentives to join the system and to make arrangements to increase the number of such countries.

In 2007 the United States studied the Illustrative Offer, a plan intended to provide incentives to emerging nuclear energy countries. The Illustrative Offer is a comprehensive nuclear energy cooperation agreement under which the consumer country is provided with proliferation-resistant reactors, ensured fuel supply, management of spent fuel, assistance for infrastructure, cooperation in safety culture, financial assistance, and so forth, on the condition that they sign the additional protocol, refrain from

enrichment and reprocessing, and take safety and physical protection into consideration. In addition, there seemed to be a move to insist that the World Bank assist emerging countries in their nuclear efforts.

Although the Illustrative Offer's effectiveness is uncertain, the nuclear energy cooperation agreements that Bahrain and the United Arab Emirates have concluded with the United States appear to have partly embodied elements of the Illustrative Offer. One method of realizing a supply assurance system would be to implement a de facto supply assurance system between two countries in the first place, instead of a comprehensive international system, and then expand it into a multilateral framework.

Although there have not been any moves similar to that of the United Arab Emirates since then, a system such as this, through which supply assurance plans to prevent sensitive technologies from spreading, is likely to become necessary. Financial assistance will be particularly important in nuclear power generation that requires huge amounts of capital in its initial construction phase.

The declaration issued on the occasion of the G8 Hokkaido Toyako Summit, held in July of 2008, expressed a desire for international cooperation regarding nuclear infrastructures based on 3S, namely Safeguards (nonproliferation), Safety, and Security.

The situation being different from that surrounding the supply assurance approach, negotiations for an agreement were settled between India, a non-participant in the NPT, and the United States on civilian nuclear energy cooperation in July 2007. In October of 2008, the NSG approved the treatment of India as an exceptional case on the condition that comprehensive safeguards should be applied to the recipient.

4.2.1 Expansion of the Causes to be Covered

In order to raise incentives for States contemplating the use of nuclear energy to participate in the system, it would be useful to expand the scope of the causes allowed to prompt the use the AOS system, which is limited in the current discussion to "supply disruption for political reasons". For example, it would be appropriate to cover supply difficulties due to force majeure, such as large-scale disasters.

The fact that the past discussion, such as in INFCE, covered the overall nuclear fuel supply and that the present discussion covers only the supply disruption "for political reasons" is supposed to be one of the reasons for a growing sense of reluctance among emerging states using nuclear energy. It is better to expand the events to be covered, considering that supply disruption for political reasons has never previously occurred and that it is an event expected to happen rarely.

4.3 Problems Associated with the Definition of AOS

The term "supply assurance" is used as if its meaning is self-explanatory. In the past, however, the term has been used with different meanings in similar discussions. It is therefore necessary to note that this term is used differently than it may have been elsewhere.

In discussions held at INFCE and CAS the 1970s and 1980s, the use of the term was seemingly not limited to an interruption of supply due to political reasons but was used in the same way as "Reliable Access to Nuclear Fuel (RANF)," is used by the United States today. Even in the present day discussions, the terms "stable supply" and "supply assurance" are used without clear distinction. In the IAEA Director General's report of June 2006, supply assurance is defined as a means to address an interruption, "due to political reasons." However, the meaning of "political" is defined merely as "not due to technical

or commercial reasons," and what constitutes a "political" reason is not defined in concrete terms.

The term "supply assurance" is defined below and each element is examined.

(a) When, due to political reasons other than nuclear non-proliferation (excluding technical or commercial reasons),

(b) the supply of nuclear fuel is interrupted,

(c) from a system centered on the IAEA,

(d) a temporary supply of nuclear fuel is provided.

(a) Political Reasons Other than Nuclear Non-Proliferation (Excluding Technical or Commercial Reasons)

An interruption of supply due to a problem of nuclear non-proliferation is outside the definition of supply assurance. The presence of a problem of nuclear non-proliferation means that nuclear non-proliferation, a purpose of the NPT, could not be realized. This can be considered as a problem for discussion at the United Nations Security Council. This point may appear to be self-explanatory, but actual judgment is accompanied by great difficulties. The general perception is one of human rights violations, serious environmental pollution, and so forth in the consumer country. These problems are also thorny issues for the operating organization (for example, the IAEA). In particular, the operating organization will be urged to pass political judgment on intermediate–level political problems that are not referred to the United Nations.

When the reason is serious (such as a massacre of political prisoners by a dictatorial political power, or an extreme human rights violation against a minority races), the issue becomes a matter for discussion at the United Nations Security Council. Moreover, there could be a situation that U.N. Security Council prohibits "supply assurance" itself, when important and serious "political reason" exists. (refer to the Charter of the United Nations Article 103)

Passing judgment on whether a problem of nuclear non-proliferation exists is not an easy task. If this point cannot be judged, then it is also not possible to judge whether the situation can be included in the scope of conditions for supply assurance. For example, it is clearly difficult to determine the facts concerning the presence of nuclear facilities in Syria, and the difficulty determining intentions related to nuclear development is easy to understand, considering the difficulty in assessing Iran's enrichment activities. With regard to the existence of violations against safeguards, the extent to which a certain violation constitutes a problem of nuclear non-proliferation is a difficult question for which even the IAEA has not drawn a conclusion.

The same can be said regarding "technical or commercial reasons" outside the scope of supply assurance. For example, if an event similar to the interruption of Russia's gas supply to Ukraine starting in late 2008 were to occur in respect of nuclear fuel, it would be a very difficult judgment as to whether it was purely due to commercial reasons, such as unpaid gas charges, or due to political reasons resulting from Ukraine's Western-leaning policies.

The question remains as to whether the limitation of supply assurance to "political reasons" is one of the causes of objections among emerging countries. Other discussions worth consideration include the question of whether limiting supply assurance to "political reasons" contributes to the purpose of nuclear

non-proliferation, and whether the scope can be extended to include inevitable force such as natural disasters.

(b) The Supply of Nuclear Fuel is Interrupted

Although this point may appear simpler than others, it does present some problems that need to be solved.

The first of these is whether, after the supply is interrupted, the consumer country believes that it has an obligation to make an effort to procure an alternative supply in the existing market before it asks the IAEA for a trigger of the supply assurance system. If doing so is an obligation, it is then obliged to procure alternative supply in the spot market, and the country to which supply has been interrupted is forced to buy expensive nuclear fuel.

In addition, it is difficult for the IAEA to acknowledge a situation as “an interruption of supply” in terms of methodology. It would be impossible to rely on the unilateral declaration of the consumer country. It would be necessary, at least, to verify the situation from both the supplier and consumer countries. In any case, it would be necessary to determine the facts, and to implement legal-type procedures.

(c) From a System Centered on the IAEA

Although the idea of structuring a supply assurance system with the IAEA at the center is unlikely to meet with objections, there is no clear consensus on the actual role of the IAEA (which will be described in detail below). The role of the IAEA, as presently conceived, is to be the facilitator of a supply assurance system. According to its Statute, the IAEA is allowed to provide services associated with nuclear fuel services. It will become a virtual or real facilitator of the fuel bank, joining the international nuclear fuel centers or operating on its own to be the last resort supplier.

The Board determines the conditions to trigger the supply assurance system, and the Director General passes judgment on whether it can be triggered.

In order for a supply assurance to become a concrete system, detailed discussions are needed regarding the role of the IAEA and, in particular, whether the Director General can actually pass judgment on the advisability of the trigger of the supply assurance system. The relationship with the provisions of the IAEA Statute is described below.

(d) A temporary Supply of Nuclear Fuel is Provided.

Will the supply assurance be provided only once for each interruption due to a political reason, or will it be continued as long as the particular political reason persists?

In reality, the supply assurance would continue to be required until the reason that caused it is eliminated and a smooth settlement is reached between the supplier and the consumer country. If it persists until the next fuel replacement (or the fuel replacement for another plant in the same country), it is arguable whether a second supply assurance would be needed.

Or as a result of consultation with the supplier, there may be the possibility of changing suppliers. However, when the changing of suppliers is considered, such an assumption would be necessary for

suppliers based on the supply assurance.

This leads to the question of how the follow-up for the supply assurance would be carried out.

When the supply assurance system is triggered, matters concerning the follow-up of the original agreement will arise. The type of follow-up that will be required differs depending on the stage at which an interruption occurs. In terms of enrichment, for example, it needs to be determined whether the receipt of the natural uranium was refused at the stage when the uranium was delivered, whether the enrichment services were rejected after the natural uranium was received, or whether the delivery of enriched uranium was refused after the completion of the services.

Depending on these factors, the follow-up transactions between the party that asked for enrichment and the enrichment operator, including the presence or absence of uranium to be returned, the form in which uranium is to be returned, and the need to pay the fee, may differ. These may be the liabilities for the country to which the supply has been interrupted, or the IAEA may play a role something like that of a mediator.

All of these points should be discussed.

4.4 Supplier of Nuclear Fuel

4.4.1 Main Operating Body for the Supply of Nuclear Fuel

The main operating body for the supply of nuclear fuel provides nuclear fuel according to the decision of the IAEA, the operating organization of the supply assurance mechanism. The IAEA, supplier countries, and other involved parties could be this main operating body. When the reserve of nuclear fuel, either physical or virtual, is assumed in the supply assurance, the main operating body of supply must be predetermined in order to increase the reliability of the institution and ensure the timely functioning of the mechanism. Two or more main operating bodies of supply must be predetermined and roles assigned to them beforehand, either the provision of actual material or enrichment services, so that the institution can function reliably should an interruption of supply occur.

4.4.2 Roles of the Countries Concerned

In order for the supply assurance mechanism to function effectively, it should be noted that the countries concerned study adequate budgetary measures and that they have the following roles to play.

Firstly, in order to improve the situation of interrupted supply generation, the countries concerned should follow the decision of the supply assurance mechanism quickly.

Secondly, in order to improve the situation of interrupted supply, the countries concerned should handle formalities such as licensing for the transfer of nuclear material to the operators concerned in an expedient manner. In particular, the countries concerned must maintain an adequate cooperative relationship with the operators under its jurisdiction, and urge the operators with which a particular country is involved to respond without undue delay.

In addition to the third item, in order for the supply assurance to run smoothly, it is preferable for the supplier country to waive the regulatory right (the right to prior consent) over the materials to be provided.

In terms of the relationship with a country that has made a political intervention that could

constitute a reason for the supply assurance system to be triggered, it is necessary to prevent that country, a supplier country, from intervening in the operation of the supply assurance system.

4.4.3 Conditions for Supplier Countries to Join the Supply Assurance System

Limiting supplier countries to the current nuclear fuel supplier countries may invite opposition from emerging nuclear energy countries. It is therefore necessary to define conditions so that supplier countries may not be limited in their choice.

It should also be noted that, ideally, the objects to be covered by the supply assurance would include the entire front-end of nuclear fuel cycle. For this reason, in order to ensure the diversity of supply sources and the reliability of the mechanism, it is necessary to open the door to uranium producing countries and future nuclear fuel supplying countries.

As a condition for a particular country to become a supplier country, it would need to be determined whether it has a sufficiently reliable supply capability and, at the same time, whether it meets the same non-proliferation qualification as the consumer country.

4.4.4 Declaration on AOS by Supplier States

Supply disruptions requiring AOS are caused by supplier States in the first place. In order to ensure that the AOS system may function effectively, we propose that supplier States contribute positively to the system-building and make a “declaration of AOS” as shown below. This will give consumer States a greater sense of confidence in an AOS system.

In the proposed “declaration on AOS,” supplier States should declare in advance not only to supply in AOS but also to permit promptly and to resign the flag-right on nuclear material. And they should commit to not obstructing the provision of supply and to cooperating with international transportation for AOS even when they are not performing a supplier role. Supplier states shall declare the following purposes, and inform the IAEA of such declaration together with information concerning the supply of nuclear fuel. The IAEA shall then publicize them in an INFCIRC document. Specifically, the following contents are conceivable:

In the case of AOS supply:

(a) Supplier states shall promptly grant permits and licenses, such as export permits, for the supply by domestic operators or the transit of nuclear fuel in their own countries.
(b) Supplier states shall transfer their flag right to the supplied nuclear materials to the IAEA.
(c) The state causing the AOS to be initiated or any other state shall not engage in any activity preventing the AOS.
(d) Cooperation for the smooth international transportation of nuclear materials.

Making this declaration, registering it with the IAEA and publishing it as an INFCIRC document would help heighten the consumer states’ sense of security on the system.

4.5 Conditions for Consumer States to Participate

4.5.1 Need for Equality, Freedom from Being Political, and Similar Quality

Article IV of the NPT stipulates that the development of research, production and use of nuclear

energy for peaceful purposes is the "inalienable right of all the Parties to the Treaty." Regarding the functions to be achieved by the IAEA, Article 3 (Functions) B of the IAEA Statute states that it should: "Allocate its resources in such a manner as to secure efficient utilization and the greatest possible general benefit in all areas of the world, bearing in mind the special needs of the under-developed areas of the world." In other words, the qualifications for joining this supply assurance mechanism as a consumer country must not limit the right to use and develop nuclear energy for peaceful purposes. In connection with this, as already considered in Section 4.1, it should be noted that some countries believe that the requirement to commit to waive sensitive technologies and related facilities from the consumer country limits their right as stated in Article IV of the NPT.

In addition, it should be noted that it is necessary to consider freedom from being political as a qualification of the consumer country, as stated in Article 3 (functions) C, which stipulates that "In carrying out its functions, the Agency shall not provide assistance to members subject to any political, economic, military, or other conditions incompatible with the provisions of this Statute."

4.5.2 Prerequisites for a Consumer Country and Measures against Violation of the Consent to Non-Proliferation

(1) Consent to Nuclear Non-Proliferation

As a condition for a consumer country to join this supply assurance system, it is considered necessary for that country to express its intention concerning nuclear non-proliferation. Such a country is also expected to conclude an agreement stipulating the safeguards to the nuclear activities of the country concerned with the aim of ensuring that nuclear energy is not diverted from peaceful purposes to military purposes such as weapons production.

In particular, Article III, Paragraph 1 of the Non-Proliferation Treaty (NPT) stipulates that, "Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Furthermore, it is stipulated that, "The safeguards required by this article shall be applied to all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere."

Furthermore, in addition to the above comprehensive safeguards agreement, it is considered that a consumer country must agree to a protocol that contains policies that cannot be implemented within the scope of that agreement. These are: (a) to declare any nuclear activities that are not declared in that agreement; and (b) to grant the IAEA complementary access to locations for which no access was granted in that agreement.

As a qualification for a consumer country to join, it is considered necessary for them to obtain consent of some kind concerning the transfer of nuclear material to a third party country (for example, the observance of the NSG guidelines).

(2) Measures to beTtaken against a Violation

Article 12 (Agency safeguards), Paragraph A 7 of the IAEA Statute stipulates that IAEA shall have the right and responsibility to the extent relevant to the project or arrangement"to suspend or terminate assistance and withdraw any materials and equipment made available by the Agency or a member in furtherance of the project, in the event of non-compliance and failure by the consumer State or States to take requested corrective steps within a reasonable time"

Paragraph B of the same article, stipulates that, "The Agency shall take remedial action forthwith to correct any non-compliance or failure to take adequate measures."

In addition, Paragraph C of the same article stipulates that, "The Board shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members and to the Security Council and General Assembly of the United Nations. In the event of failure of the consumer State or States to take fully corrective action within a reasonable time, the Board may take one or both of the following measures: direct curtailment or suspension of assistance being provided by the Agency or by a member, and call for the return of materials and equipment made available to the consumer member or group of members. The Agency may also, in accordance with Article XIX, suspend any non-complying member from the exercise of the privileges and rights of membership."

In connection with this, Article 19 (Suspension of Privileges), Paragraph B of the IAEA Statute stipulates that, "A member which has persistently violated the provisions of this Statute or of any agreement entered into by it pursuant to this Statute may be suspended from the exercise of the privileges and rights of membership by the General Conference acting by a two-thirds majority of the members present and voting upon recommendation by the Board of Governors."

When the IAEA is considered to be functioning as the organization operating the institution, it is necessary to consider the actions that are to be taken against violations in the supply assurance, while taking into consideration the descriptions in the IAEA Statute above. In particular, it is necessary to study the need to establish a third party organization (like the International Court of Justice) that would apply sanctions against a non-conforming recipient as well as concrete sanctions methods (the divestiture of rights to the consumer country (definite or indefinite terms) or a stay of execution for a certain period of time (several years)). In this case, it is also necessary to study ways of handling past violations of safeguard obligations and international commitments (such as the imposition of new international commitments as a condition for a country with past cases of violations to become a recipient).

(3) New Possibility of Dichotomy

If the qualifications for a country to join this supply assurance system as a recipient are strictly limited, a demerit will arise of inviting a difficulty in winning the very countries to be put under an international surveillance, the original purpose of the institution, (the countries very likely to become second North Korea). Firstly, countries that will consent to these qualifications are those that require less international control. For this reason, the degree to which the qualifications for joining should be

moderated can be one of the prerequisites for pushing ahead with international non-proliferation through this supply assurance system.

In this sense, the institution must be operated in such a way that prevents bifurcation, and one of the decisions to be made is the type of institution that should be created.

(4) Other Conditions

The following factors, among others, must be taken into consideration: The safety regulation scheme (Convention on Nuclear Safety), radioactive waste regulation (London Convention (sea dumping ban)), actions to be taken when an accident occurs (Convention on Early Notification of a Nuclear Accident; Convention on Assistance in the Case of a Nuclear Accident), trade insurance, and measures for physical protection/nuclear security, nuclear damage compensation systems.

4.6 Roles of the IAEA as the Organization Operating the Mechanism

4.6.1 Becoming the Administering Authority of the System

As the operator of the supply assurance system, the IAEA should:

- Determine the conditions for both a supplier country and a consumer country to join the mechanism,
- Determine the prerequisites for exercising the mechanism,
- Pass judgment on whether the prerequisites for the trigger of the supply assurance system have been met,
- Prepare a model agreement with a participating country and conclude an agreement,
- Manage the mechanism.

The following provisions of the IAEA Statute have already granted IAEA the authority to be the operator of the supply assurance system.

(a) Article 3, Paragraph A 1 of the IAEA Statute: “The Agency is authorized, if requested to do so, to act as an intermediary for the purposes of securing the performance of services or the supplying of materials, equipment, or facilities by one member of the Agency for another; and to perform any operation or service useful in research on, or development or practical application of, atomic energy for peaceful purposes.”

(b) Article 9: “Members may make available to the Agency such quantities of special fissionable materials as they deem advisable and on such terms as shall be agreed with the Agency. The materials made available to the Agency may, at the discretion of the member making them available, be stored either by the member concerned or, with the agreement of the Agency, in the Agency's depots.”

(c) Article 10: “Members may make available to the Agency services, equipment, and facilities that may be of assistance in fulfilling the Agency's objectives and functions.”

(d) Article 11, Paragraph A: “Any member or group of members of the Agency desiring to set up any project for research on, or development or practical application of, atomic energy for peaceful purposes may request the assistance of the Agency in securing special fissionable and other materials, services, equipment, and facilities necessary for this purpose.”

(e) Article 11, Paragraph C: “The Agency may arrange for the supplying of any materials, services, equipment, and facilities necessary for the project by one or more members or may itself undertake to

provide any or all of these directly, taking into consideration the wishes of the member or members making the request."

Furthermore, Article 11, Paragraph E stipulates seven matters that require adequate consideration before the IAEA Board can approve a plan based on the provisions of Article 11. Paragraph F of Article 11 stipulates seven matters that are to be decided in an agreement to be concluded with a member country or a group thereof when the IAEA approves the plan (to be described later).

An actual example of this was when Japan concluded an agreement (INFCIRC/3) with the IAEA in 1959, and received a supply of three tons of Canadian-produced natural uranium as fuel for its first domestically made reactor (JRR-3 of the then Japan Atomic Energy Research Institute).

On the other hand, allowing the IAEA to play the role of the operator of the supply assurance mechanism has led to serious concerns regarding a possible increase in the IAEA's authority, the scale of its organization, the number of personnel, and contributions from the members as well as the overgrowth of the IAEA itself. There have been moves to create an international organization made up of nuclear energy operators that will not only conduct ordinary business operations but also activities as an operating organization of the supply assurance system. However, a number of difficulties are anticipated in the creation of a new operating organization to replace the IAEA. Since the supply assurance mechanism is a scheme that should be utilized only rarely (and, ideally, not at all), it would be realistic for an existing organization to be used, regardless of who the operator of the system would be. Even if a new organization is to be created, it should be on a minimum scale, with its clerical work entrusted to a law firm, for example.

4.6.2 Determination of Fulfillment of the Conditions for the System to be Triggered

It is necessary to predetermine the parties responsible for determining the fulfillment of the conditions for the trigger the supply assurance system, and in what manner, when a country from which the supply of nuclear fuel has been interrupted requests the trigger of the system from the IAEA, the operator of the system.

Article 11, Paragraph E of the IAEA Statute, described above, stipulates that the Board should take the following matters into consideration before approving a plan for research, development, or the commercialization of nuclear energy for peaceful purposes by a member or a group of members:

(a) Usefulness of the plan (including its scientific and technical feasibilities)
(b) Validity of the planning, funding, and technical personnel to ensure the effective implementation of the plan
(c) Validity of the health and safety criteria proposed for the handling and storage of the materials and for the operation of facilities
(d) The abilities of the member or group of members that requested the trigger of the system to secure the necessary funding, materials, facilities, installations, and services
(e) Fair distribution of materials and other resources that the Agency can utilize
(f) Special needs in areas of low development areas
(g) Other related matters

The IAEA Board consists of a total of 35 countries, 13 of which are designated by the Board as the

most advanced in nuclear technology and 22 of which are countries elected at the General Assembly (Article 6, Paragraph A of the Statute). The IAEA budget is determined by a two-thirds majority of those present and voting, and other matters are decided by a majority of those present and voting (Article 6, Paragraph E).

When the Board determines the criteria for a trigger of the supply assurance system in the manner currently contemplated by the IAEA, this provision will be applicable. According to these criteria, the Director General will pass judgment on whether the supply assurance system can be triggered for an individual case for which the trigger of the system has been requested.

4.6.3 Drafting and Signing a Model Agreement with Participating States and the IAEA

After finalizing the implementation of the AOS system, it will be necessary for supplier States, consumer States and the IAEA to conclude an agreement stipulating the contents, quantities and conditions for supply.

Considering the urgency surrounding an event that would trigger the AOS and the period of time required to conclude the agreement, it would be practical for all parties concerned to conclude a model agreement beforehand in preparation for potential supply disruptions.

It would be desirable to specify in the model agreement the renunciation of flag right, the contents of supplies and services, supply quantity, period, pricing method, delivery method, use for peaceful purposes only and acceptance of safeguards, treatment of intellectual property, dispute settlement methods and so on. [i)]

Article 11, Paragraph F of the IAEA Statute, described above, stipulates that if the IAEA approves the project submitted by the country or the group of countries that requested the trigger of the system, it shall conclude an agreement with the country or the group of countries that submitted the project. According to Paragraph F, the contents of the agreement are as follows:

(a) Allocation to the project of any special fissionable materials required, or other materials;
(b) Transfer of special fissionable materials from their place of custody to the member or group of members submitting the project, under conditions that ensure the safety of any shipment required and meet applicable health and safety standards;
(c) Terms and conditions, including charges, on which any materials, services, equipment, and facilities are to be provided by the Agency itself, and, if any such materials, services, equipment, and facilities are to be provided by a member, the terms and conditions as arranged by the member or group of members submitting the project and the supplying member;
(d) Undertakings by the member or group of members submitting the project: (a) that the assistance provided shall not be used in such a way as to further any military purpose; and (b) that the project shall be subject to the safeguards provided for in Article XII, the relevant safeguards being specified

i) According to the Article XI (F) of the IAEA Constitution, the IAEA shall enter into an agreement with any requesting member or group of members, providing for the allocation of any required nuclear materials to the project, the conditions for securing the safety of shipment, the terms and conditions for the provision of materials and services, including charges, the use for peaceful purposes and the application of safeguards, the rights and interests in patents, and the settlement of disputes.

in the agreement;

(e) Appropriate provision regarding the rights and interests of the Agency and the member or members concerned in any inventions or discoveries, or any patents therein, arising from the project;

(f) Appropriate provision regarding the settlement of disputes; and

(g) Other such provisions as may be appropriate.

4.6.4 Management of the System

The possible roles to be played by the IAEA, as the operator of the supply assurance system for nuclear fuel (a physical fuel bank, virtual fuel reserve, the provision of enrichment services, and a supply assurance fund), are as follows:

(1) Physical Fuel Bank

As for the IAEA's own possession of actual nuclear fuel, Article IX (A) of the IAEA Statute provides that the IAEA has the option to store the fuel for itself.

It may be more practical to store nuclear materials with established enrichment or fuel fabrication operators, rather than in an independent AOS storage. Proper planning and execution of storage, operations, including construction, packaging, transportation, and managing age-related deterioration must be performed by experienced, skilled, and licensed personnel.

As a system similar to the nuclear fuel bank, there is an oil reserve system. However, it should be noted that there are many differences between the two systems, including the fact that the purpose of the nuclear fuel bank is nuclear non-proliferation rather than energy security, and that the nuclear fuel bank is used under the extremely rare limited conditions.

Regarding the physical locations of the banks, at the 2006 Special Event of the IAEA on Nuclear Fuel and Non-Proliferation, German Foreign Minister Steinmeier expressed the idea of setting non-sovereign zones to build uranium enrichment/fuel supply facilities. From a realistic point of view, however, this could create substantial difficulties.

(2) Provision of Enrichment Services and Virtual Fuel Reserve

In order for the supply assurance system to operate efficiently, it is necessary for the countries concerned to register their supply capacity for the provision of enrichment services and that for the supply of uranium concentrate, conversion, and fuel fabrication available for a definite period of time, respectively, with the mechanism operator. The operator should convert the registered details into a database form and update it each year. When the system is triggered, the operator uses the database to recruit suppliers, selecting a supplier by means of tendering or otherwise.

4.7 Cooperation in the Nuclear Energy Industry

4.7.1 Necessity of Industry Cooperation

The supply assurance system is based on the premise that the existing commercial market is functioning well. Given that the actual trigger of the supply assurance system involves the cooperation of the nuclear industry, the cooperation with the industry is indispensable for the effective and efficient operation of the supply assurance system.

The supply assurance system aims to solve the political challenge of preventing the proliferation of sensitive technology. Therefore, the main operating bodies in the structuring and operation of the system are the governments of the countries concerned and the IAEA.

Because of this, the parties with which the nuclear energy industry cooperates are basically the governments of the countries to which the industry belong. When the IAEA is the system operator, the industry cooperates with it through the governments of the countries to which they belong. However, when a multinational enterprise like URENCO is involved, special agreements between the countries involved would be required.

4.7.2 Concrete Objects for Cooperation

Once the system for the provision of enrichment and other services has been structured, the virtual fuel has been stored, and physical fuel banks have been installed in the supply assurance system, the objects for which the industry cooperates will vary, depending on what matters are requested by a country of its industry. Basically, a country will survey the type of cooperation can be offered by the nuclear industry in that country according to the supply system to be implemented. On the basis of that survey, the country will request cooperation from its industry.

If providing information in order to increase market transparency, which is the basis of Japan's proposal, is to be a prerequisite for or part of the supply assurance system, the countries concerned will provide information about their operators.

In this case, the level of information that can be provided becomes important. Each nuclear operator may be reluctant to disclose sensitive corporate information about business management, such as the quantity of received orders at a specific time of the year. However, the question should be asked as to whether it is possible to register, as the supply capacity reserve, the portion that can be offered to the supply assurance system out of the capacity of an operator’s facilities, minus the capacity of facilities used on the basis of existing agreements/the capacities of facilities at rest for inspection.

A careful examination is required of the information that can be offered depending on the actual situation of individual operators.

The registration of such supply capacity reserves with the IAEA by individual operators through their governments would help enhance the transparency of the nuclear fuel market and simplify the functioning of the provision of enrichment services and virtual fuel reserve.

4.7.3 Creation of an Environment to Obtain Cooperation

Because the supply assurance system is basically handled by the governments of the countries concerned and the IAEA, incentives of some kind are necessary to obtain the cooperation of the industry. While each nuclear operator is obliged to comply with the legal obligations associated with nuclear non-proliferation, it is not part of business management to consider the enhancement of the non-proliferation system through the supply assurance system. For this reason, cooperation with the system is not considered to be an inherent activity of each operator , but rather an activity outside the operator’s core business, such as corporate social responsibility (CSR) and social contribution activities.

The conditions for the operator to join the supply assurance system would basically be absence of

any cost. For this reason, if an operator does incur special costs, one of the conditions would be that such costs must be covered by the government or a similar organization. This has frequently been pointed out by operators, both in Japan and overseas. Even virtual fuel reserve incurs concrete expenses to the operator involved.

4.8 Fund for AOS

4.8.1 System for a Fund

In addition to fuel purchase costs, a nuclear fuel bank requires inter alia funding for storage including costs for safeguards, physical protection and regular anti-deterioration measures. On the other hand, procurement of the virtual services as conversion, enrichment and fuel fabrication would also require funds to temporarily cover expenses. We propose the establishment of a fund for AOS (the AOS Fund) to cope with these problems. In the least, it will be necessary to manage funds in some account or other for the period from the time when funds are provided by states and other entity to the IAEA until the purchase of the nuclear fuel is made.

After the establishment of the AOS fund, it will be necessary to manage the fund in a special account (escrow account). The fund shall be managed by the IAEA to cover various costs related to service disruption and incidental expenses. It is expected that funds from the NTI and others would be at least partly included in the AOS fund and that it is expected that other member states would also contribute to the AOS fund. As in the case of a nuclear fuel bank, consumer states shall repay the costs to the IAEA after nuclear fuel supplies and service provisions are implemented.

4.8.2 Merits of the Supply Assurance Fund

The fund has many advantages because it is in cash, and can respond flexibly to the costs of various services, as mentioned above. Further, it should be noted that supply disruption has never previously occurred and the possibility of occurrence of supply disruption will remain extremely low in future.

On the other hand, no such problem would happen with the fund. Of course, there are problems, such as the safety of financial organizations where the fund is deposited and variable interest rates. However, basically the fund will increase with interest and its scale will grow year by year.

4.9 Advisory Committee for the Implementation of AOS

It is a difficult task to specify the conditions for implementing the AOS system. Under the draft definition currently under consideration by the IAEA, which provides for supply disruptions “for political reasons, but not by contractual reasons or nuclear non-proliferation reasons,” semi-judicial judgment would be required to actually implement the AOS. The possible causes for implementing the AOS would include a violation of human rights, a serious environmental pollution. However, grave and serious causes (such as massacres of ethnic minorities, extreme human rights violations of the freedom of speech,) would be a matter of the discussion in the U.N. Security Council, going beyond the category of causes to be handled by the IAEA. It should be noted that the AOS assumes international political issues of such kind, but to the extent that they are not referred to the United Nations.

The system under consideration by the IAEA is going to give the IAEA Director General the

authority to judge whether or not specific conditions have been fulfilled. For example, if the same event as in the case of the Russia's gas supply to Ukraine, happened in the winter of 2008 to 2009, were to occur with the supply of nuclear fuel, the IAEA Director General would be forced to make a judgment, an extremely difficult one, so that it is supposed that the Director General actually cannot make judgment.

We propose the establishment of an "advisory committee for the implementation of AOS", composed of several subject matter experts. The IAEA shall empower the expert committee with the role of decision maker in order to minimize to the extent possible politicalisation of the AOS decision process and its outcome. On receipt of a request for the implementation of AOS, the IAEA Director General shall activate the committee for deliberation. The committee shall make a recommendation to the IAEA Director General to implement the AOS if it judges the conditions are fulfilled, and the Director General shall defer to the committee's recommendation.

The committee shall release the IAEA from the role as a decision-maker on political issues, and the committee's judgment is assumed to be more persuasive, as compared with the sole judgment by the IAEA Director General or internal IAEA process.

5. Future Challenges

5.1 Discussions on the Realization of the AOS System

The deadline for fulfilling the conditions for the NTI proposal has been extended by one year from September 2008 to September 2009, and the condition for fund contribution of $100 million has been fulfilled by the contribution of $10 million by Kuwait in March 2009 (in addition to $50 million by the U.S., $5 million by Norway, $10 million by the UAE, and $25 million by the EU). The next focus is how the IAEA and its member states would deal with another condition, which requires the IAEA to take the required actions to establish a nuclear fuel bank, at the meetings of the Board of Governors, the General Conference in September 2009.

As for the IUEC in Angarsk, Russia, the conclusion of an agreement on safeguards and the assurance of supply with the IAEA is expected to materialize.

In the context of the NPT, Mr. Javier Solana, EU High Representative for the Common Foreign and Security Policy, said on the day following the EU's announcement of fund contribution to the NTI that the EU hoped for the early establishment of the nuclear fuel bank; possibly before the NPT Review Conference in spring 2010.

The new Obama administration in the United States is showing it is well placed to tackle nuclear disarmament and nuclear non-proliferation positively, and is expected to stress the safety and long-term waste management while conceding the role of nuclear power generation. The Obama administration is also referring to its intention to positively tackle the issue of nuclear fuel supply assurance and strengthening the IAEA.

It is also necessary to focus on trends in the U.K., where an international conference on the AOS was held in March 2009 and in Germany proposing the MESP, and the influence the successor of the IAEA Director General Mohamed El Baradei, the advocate of the AOS, would have on future AOS

discussions. Further, attention should be paid to how the emerging countries using nuclear energy would respond to the AOS amid new trends, such as the materialization of a new nuclear power plant project in Vietnam and the planned investment of advanced countries into uranium operators in Kazakhstan and new bilateral nuclear cooperation treaty between U.S. and Gulf countries such as Quwait.

5.2 Measures to Achieve Nuclear Non-Proliferation and AOS

IAEA Director General ElBaradai and President Bush leading current discussion, have seen that preventing the spread of sensitive technology as the goal of the supply assurance system for the purpose of nuclear non-proliferation.

Non-proliferation of enrichment and reprocessing technology is fraught with difficulties, such as how we should interpret the intention of having the technology and the relationship between the possession of the technology and the right to peaceful utilization of nuclear energy provided for in Article IV of the NPT. An effective supply assurance system must be structured while these problems are dealt with. To this end, a concrete system would need to be designed, which considered incentives for the countries joining the system as consumer countries, and also interacted sufficiently with emerging nuclear energy countries.

5.3 Relationship with Multilateral Approaches [18)]

The IAEA Director General El Baradei often referred to the Multilateral Approach, and in September 2006 when a special event on the AOS was held at the IAEA headquarters, he said roughly as follows:

In order to cope with an increase in worldwide energy demand and an increase in nuclear proliferation risk due to the spread of sensitive technology, the following step-by-step approach is effective:

(1) To build a system of the AOS of nuclear fuel necessary for nuclear power plants.

(2) To start an international project on nuclear fuel and reactor technology in order not to divide supplier and consumer states.

(3) To change the existing enrichment and reprocessing facilities from unilateral to multilateral ones (under multilateral management).

These points are emphasized in other reports and proposals. The report on multilateral nuclear approaches (MNA) submitted by the expert group in 2005, the German proposal for the Multilateral Enrichment Sanctuary project (MESP), the Russian proposal for the IUEC in Angarsk, and the British proposal for enrichment bond are also referring to the multilateral management.

As for the definition of “multilateral,” however, no specific description is given other than “management by many states.”

Presumably “multilateral” generally refers to the facilities invested by multiple states. However, in order for such facilities to be recognized as multilateral, discussions should be made on specific standards on management involvement, such as what percentage of investment from foreign countries is required and whether or not the right to elect directors should be given to foreign countries and so on. It

is assumed that sensitive technology, such as enrichment, is secured in black boxes and not accessible by any country other than that possessing the technology concerned.

5.4 Back-End in AOS

As pointed out by NTI President Charles Curtis, who chaired the IAEA Special Event in September 2006 [19], it was only within the first phase period that the AOS was focused on the front-end enrichment, and in the medium and long term of the next phase, efforts will be made to establish a multilateral framework, including the provision of power plant technologies, fuel supply and waste disposal.

Previously also, the International Plutonium Storage (IPS) has been discussed, and at the start of the recent discussion over the AOS, the purpose of the discussion was to prevent the spread of both of the sensitive enrichment and reprocessing technologies. The back-end was also considered an important issue as part of the nuclear fuel cycle in IAEA Director General El Baradei's paper carried in The Economist in 2003 [1], and in other past discussions over the INFCE and the International Spent Fuel Management (ISFM) [j]. Also in the report published on September 30, 2008 by the joint committee of the U.S. National Academy of Sciences and the Russian Academy of Sciences [20], attention was paid to the establishment of multilateral management of the back-end in view of the potential advantages of nuclear non-proliferation.

As shown above, the back-end has generally attracted growing interest, and considerable discussion over the back-end will be made with the progress of the discussion on the AOS of nuclear fuel.

The problem of the treatment and disposal of spent fuel, including intermediate storage as a transitional technique, is also a major issue to be solved within the context of the AOS.

6. Summary

Based on the IAEA nuclear fuel supply registration system proposed by Japanese Government, this paper has proposed a more concrete form to the AOS system outlined by the Director General's report.

First, this paper has proposed a system in which more States can participate by expanding the coverage of the AOS to include the whole range from uranium concentrate to fuel fabrication services. Also, the expansion of the coverage of the AOS will enable the use of the AOS mechanism at any point in the supply chain.

Second, this paper has proposed adding approximate quantities of materials and services available for supply, the period required to the contents of supply registration proposed by Japan, and examined more concrete contents.

Third, this paper has reorganized and replaced the categories of Levels 2 and 3 in the IAEA Director General's report with the categories of Modes 2 and 3, and further clarified and elaborated on

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[j] The ISFM concept was designed to store and manage the spent fuel in bulk under the international cooperation from the perspective of nuclear non-proliferation, because the quantity of spent fuel from reactors is expected to exceed the global storage capacity in future. The conference for review started in June 1979, and the result was finalized in July 1982 as a final report (Source: Nuclear Power Encyclopedia ATOMICA).

the AOS system with respect to organizational roles and service provisions of the respective States and operators.

Fourth, this paper has presented practical details of implementing the AOS system by explaining that additional costs and waiting periods are necessary for the AOS for enrichment and fuel fabrication services in Mode 2. In addition, we have shown that Mode 3 requires a larger initial cost for implementation of the nuclear fuel bank, but is more advantageous for the alternative supply schedule at times of disruption, as compared with Mode 2.

Fifth, this paper assumes that the AOS system will be implemented mainly by respective States and the IAEA, considering that the AOS will contribute to the nuclear non-proliferation, an important task in international politics and that the fundamental responsibility for the system lies with the respective States and the IAEA. Regrettably, cooperation and relationship of enrichment operators with host States, are not clear in the IAEA Director General's report. However, the system proposed by this paper is considered to promote more peace of mind in this respect because it specifies that respective States shall also play a key role.

Finally, this paper has made proposals and suggestions for the AOS system on the following points: the expansion of use to include natural disasters, the declaration of the AOS by supplier States, the establishment of an AOS implementation advisory committee, the development and conclusion of a model agreement with participating States, the entrustment of actual nuclear fuel bank management to operators, and the financial support for the AOS.

Discussions and actions that encourage consensus building in the IAEA for the materialization of the AOS mechanisms are being actively carried out. Funding for an IAEA fuel bank pledged by NTI with matching contributions from many States has been raised. As Russia finished preparation for IUEC fuel bank in Angarsk, two model agreements were approved in the IAEA　Board of Governors will allow the IUEC fuel bank to become operational. It is expected that the proposals in this paper can be used effectively in such discussions.

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国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m^{-1}
密度，質量密度	キログラム毎立方メートル	kg/m^3
面積密度	キログラム毎平方メートル	kg/m^2
比体積	立方メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
量濃度(a)，濃度	モル毎立方メートル	mol/m^3
質量濃度	キログラム毎立法メートル	kg/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率(b)	（数字の） 1	1
比透磁率(b)	（数字の） 1	1

(a) 量濃度（amount concentration）は臨床化学の分野では物質濃度（substance concentration）ともよばれる。
(b) これらは無次元量あるいは次元１をもつ量であるが、そのことを表す単位記号である数字の１は通常は表記しない。

表３．固有の名称と記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン(b)	rad	1 (b)	m/m
立体角	ステラジアン(b)	sr(c)	1 (b)	m^2/m^2
周波数	ヘルツ(d)	Hz		s^{-1}
力	ニュートン	N		m kg s^{-2}
圧力，応力	パスカル	Pa	N/m^2	m^{-1} kg s^{-2}
エネルギー，仕事，熱量	ジュール	J	N m	m^2 kg s^{-2}
仕事率，工率，放射束	ワット	W	J/s	m^2 kg s^{-3}
電荷，電気量	クーロン	C		s A
電位差（電圧），起電力	ボルト	V	W/A	m^2 kg s^{-3} A^{-1}
静電容量	ファラド	F	C/V	m^{-2} kg^{-1} s^4 A^2
電気抵抗	オーム	Ω	V/A	m^2 kg s^{-3} A^{-2}
コンダクタンス	ジーメンス	S	A/V	m^{-2} kg^{-1} s^3 A^2
磁束	ウエーバ	Wb	Vs	m^2 kg s^{-2} A^{-1}
磁束密度	テスラ	T	Wb/m^2	kg s^{-2} A^{-1}
インダクタンス	ヘンリー	H	Wb/A	m^2 kg s^{-2} A^{-2}
セルシウス温度	セルシウス度(e)	℃		K
光束	ルーメン	lm	cd sr(c)	cd
照度	ルクス	lx	lm/m^2	m^{-2} cd
放射性核種の放射能(f)	ベクレル(d)	Bq		s^{-1}
吸収線量, 比エネルギー分与, カーマ	グレイ	Gy	J/kg	m^2 s^{-2}
線量当量, 周辺線量当量, 方向性線量当量, 個人線量当量	シーベルト(g)	Sv	J/kg	m^2 s^{-2}
酸素活性	カタール	kat		s^{-1} mol

(a)SI接頭語は固有の名称と記号を持つ組立単位と組み合わせても使用できる。しかし接頭語を付した単位はもはやコヒーレントではない。
(b)ラジアンとステラジアンは数字の１に対する単位の特別な名称で、量についての情報をつたえるために使われる。実際には、使用する時には記号radおよびsrが用いられるが、習慣として組立単位としての記号である数字の１は明示されない。
(c)測光学ではステラジアンという名称と記号srを単位の表し方の中に、そのまま維持している。
(d)ヘルツは周期現象についてのみ、ベクレルは放射性核種の統計的過程についてのみ使用される。
(e)セルシウス度はケルビンの特別な名称で、セルシウス温度を表すために使用される。セルシウス度とケルビンの単位の大きさは同一である。したがって、温度差や温度間隔を表す数値はどちらの単位で表しても同じである。
(f)放射性核種の放射能（activity referred to a radionuclide）は、しばしば誤った用語で"radioactivity"と記される。
(g)単位シーベルト（PV,2002,70,205）についてはCIPM勧告2（CI-2002）を参照。

表４．単位の中に固有の名称と記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa s	m^{-1} kg s^{-1}
力のモーメント	ニュートンメートル	N m	m^2 kg s^{-2}
表面張力	ニュートン毎メートル	N/m	kg s^{-2}
角速度	ラジアン毎秒	rad/s	m m^{-1} s^{-1}=s^{-1}
角加速度	ラジアン毎秒毎秒	rad/s^2	m m^{-1} s^{-2}=s^{-2}
熱流密度，放射照度	ワット毎平方メートル	W/m^2	kg s^{-3}
熱容量，エントロピー	ジュール毎ケルビン	J/K	m^2 kg s^{-2} K^{-1}
比熱容量，比エントロピー	ジュール毎キログラム毎ケルビン	J/(kg K)	m^2 s^{-2} K^{-1}
比エネルギー	ジュール毎キログラム	J/kg	m^2 s^{-2}
熱伝導率	ワット毎メートル毎ケルビン	W/(m K)	m kg s^{-3} K^{-1}
体積エネルギー	ジュール毎立方メートル	J/m^3	m^{-1} kg s^{-2}
電界の強さ	ボルト毎メートル	V/m	m kg s^{-3} A^{-1}
電荷密度	クーロン毎立方メートル	C/m^3	m^{-3} sA
表面電荷	クーロン毎平方メートル	C/m^2	m^{-2} sA
電束密度，電気変位	クーロン毎平方メートル	C/m^2	m^{-2} sA
誘電率	ファラド毎メートル	F/m	m^{-3} kg^{-1} s^4 A^2
透磁率	ヘンリー毎メートル	H/m	m kg s^{-2} A^{-2}
モルエネルギー	ジュール毎モル	J/mol	m^2 kg s^{-2} mol^{-1}
モルエントロピー, モル熱容量	ジュール毎モル毎ケルビン	J/(mol K)	m^2 kg s^{-2} K^{-1} mol^{-1}
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	kg^{-1} sA
吸収線量率	グレイ毎秒	Gy/s	m^2 s^{-3}
放射強度	ワット毎ステラジアン	W/sr	m^4 m^{-2} kg s^{-3}=m^2 kg s^{-3}
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2$ sr)	m^2 m^{-2} kg s^{-3}=kg s^{-3}
酵素活性濃度	カタール毎立方メートル	kat/m^3	m^{-3} s^{-1} mol

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	μ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^9	ギガ	G	10^{-12}	ピコ	p
10^6	メガ	M	10^{-15}	フェムト	f
10^3	キロ	k	10^{-18}	アト	a
10^2	ヘクト	h	10^{-21}	ゼプト	z
10^1	デカ	da	10^{-24}	ヨクト	y

表６．SIに属さないが、SIと併用される単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86 400 s
度	°	1°=(π/180) rad
分	’	1’=(1/60)°=(π/10800) rad
秒	”	1”=(1/60)’=(π/648000) rad
ヘクタール	ha	$1ha=1hm^2=10^4m^2$
リットル	L, l	$1L=11=1dm^3=10^3cm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg

表７．SIに属さないが、SIと併用される単位で、SI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位で表される数値
電子ボルト	eV	$1eV=1.602\ 176\ 53(14)\times10^{-19}J$
ダルトン	Da	$1Da=1.660\ 538\ 86(28)\times10^{-27}kg$
統一原子質量単位	u	1u=1 Da
天文単位	ua	$1ua=1.495\ 978\ 706\ 91(6)\times10^{11}m$

表８．SIに属さないが、SIと併用されるその他の単位

名称	記号	SI 単位で表される数値
バール	bar	1 bar=0.1MPa=100kPa=10^5Pa
水銀柱ミリメートル	mmHg	1mmHg=133.322Pa
オングストローム	Å	1 Å=0.1nm=100pm=10^{-10}m
海里	M	1 M=1852m
バーン	b	$1\ b=100fm^2=(10^{-12}cm)2=10^{-28}m^2$
ノット	kn	1 kn=(1852/3600)m/s
ネーパ	Np	SI単位との数値的な関係は、対数量の定義に依存。
ベル	B	
デジベル	dB	

表９．固有の名称をもつCGS組立単位

名称	記号	SI 単位で表される数値
エルグ	erg	$1\ erg=10^{-7}$ J
ダイン	dyn	$1\ dyn=10^{-5}$N
ポアズ	P	1 P=1 dyn s cm^{-2}=0.1Pa s
ストークス	St	1 St =$1cm^2$ s^{-1}=$10^{-4}m^2$ s^{-1}
スチルブ	sb	1 sb =1cd cm^{-2}=10^4cd m^{-2}
フォト	ph	1 ph=1cd sr cm^{-2} 10^4lx
ガル	Gal	1 Gal =1cm s^{-2}=$10^{-2}ms^{-2}$
マクスウェル	Mx	1 Mx = 1G cm^2=10^{-8}Wb
ガウス	G	1 G =1Mx cm^{-2} =10^{-4}T
エルステッド(c)	Oe	1 Oe≙ $(10^3/4\pi)$A m^{-1}

(c) ３元系のCGS単位系とSIでは直接比較できないため、等号「 ≙ 」は対応関係を示すものである。

表10．SIに属さないその他の単位の例

名称	記号	SI 単位で表される数値
キュリー	Ci	$1\ Ci=3.7\times10^{10}Bq$
レントゲン	R	$1\ R = 2.58\times10^{-4}C/kg$
ラド	rad	$1\ rad=1cGy=10^{-2}Gy$
レム	rem	$1\ rem=1\ cSv=10^{-2}Sv$
ガンマ	γ	1γ=1 nT=10-9T
フェルミ		1フェルミ=1 fm=10-15m
メートル系カラット		1メートル系カラット = 200 mg = 2×10-4kg
トル	Torr	1 Torr = (101 325/760) Pa
標準大気圧	atm	1 atm = 101 325 Pa
カロリー	cal	1cal=4.1858J（「15℃」カロリー），4.1868J（「IT」カロリー）4.184J（「熱化学」カロリー）
ミクロン	μ	1 μ =1μm=10^{-6}m

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