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U.S.-ROK COOPERATION FOR GLOBAL NUCLEAR GOVERNANCE

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SESSION II. FUTURE DIRECTIONS FOR U.S.–ROK NUCLEAR COOPERATION PAPERS AND PRESENTATIONS

- *U.S.–ROK Partnership for the Peaceful Use of Nuclear Energy and Non-proliferation* by Bong-geun Jun, Korea National Diplomatic Academy

- *Possible Future Directions for U.S.–ROK Nuclear Energy* Cooperation by Man-Sung Yim, Korea Advanced Institute of Science and Technology

The ROK-U.S. Nuclear Partnership for the Peaceful Use and Nonproliferation

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1. Needs of Nuclear Energy in South Korea

Nuclear energy has increasingly gained the limelight over the past few years in the Republic of Korea (hereafter 'ROK, 'South Korea' or 'Korea') for the following reasons:

First, in the era of energy 'insecurity' due to high and volatile oil prices, nuclear energy is considered as the most reliable semi-domestic energy source in South Korea, providing about 35 percent of its total electricity generation.

South Koreans have been sensitive to energy security since its energy self-sufficiency rate is about 3%, probably the lowest among industrialized countries.[1] When including nuclear energy, Korea's energy self-sufficiency rate jumps to 19%.[2] Since Korea has no domestic oil and gas production, it spent about USD 170 billion in 2011 for energy imports, accounting for one third of total imports. It is also estimated that the nuclear power generation in Korea saves about USD 20 billion a year that could otherwise be used for importing additional fossil fuels.

South Korea's total electricity consumption ranks the 10th in the world. However, unit price of electricity in Korea is one of the lowest, about 70% of the U.S. and 40% of Japan. Therefore, despite the 2011 Fukushima nuclear accident and a few recent safety accidents at Korean nuclear power plants, Koreans tend to accept nuclear power as necessary.

Second, in the era of climate change, nuclear energy is the only realistic low-carbon energy source in South Korea, where solar, wind and other renewable energy sources are too unreliable and expensive to produce due to geographical, meteorological and topographic restrictions. In Korea, the unit electricity generation/sale price of nuclear power is the lowest, about 70% of coal-burning, 28% of gas, 17% of oil, 10% of solar, etc.

Third, Korea has become a major global nuclear supplier exporting nuclear power plants to the United Arab Emirates and a research reactor to Jordan. Korea is committed to utilize the global wave of nuclear renaissance, a boom in nuclear power plants construction. The Korean government designated nuclear power plants as one of the next-

1 Energy self-sufficiency of other industrialized countries are as follows: Japan 4%, France 8%, Germany 28%, England 74%, and the U.S. 65%. 『Energy Balances of OECD Countries 2011』 International Energy Agency(2011)

2 Nuclear energy also helps increase energy self-sufficiency of Japan up to 20%, France 51%, and the U.S. 78% respectively.

generation 'strategic exporting items,' followed by Korea's other successful exporting items such as ships, semiconductors, LCD TVs and smart phones. The Korean government also announced the nuclear power industry a key pillar of its "green growth" strategy that enables environment-friendly and sustainable economic growth.

In order to both accelerate its green growth strategy and strengthen its energy security, the Korean Nuclear Energy Committee, led by the Prime Minister, announced "the Long-term Implementation Plan for Research and Development of the Future Nuclear Energy System" in late 2008. The Implementation Plan asks for, among others, accelerating the development of the sodium fast reactor (SFR) and pyroprocessing technology to utilize the full potential of nuclear energy.

According to the Plan, pyroprocessing is necessary not only to produce nuclear fuels for the SFR in the future, but also to manage spent fuel. “Dry” pyroprocessing is considered as a proliferation-resistant alternative to the existing and proliferation-prone “wet” reprocessing.

Despite the apparent economic, industrial and energy-security needs for sustainable and expanded use of nuclear energy, its implementation is often challenged for various reasons, including technical, safety, nonproliferation and political ones.

Against this backdrop, this report argues that an expanded and upgraded Korea-US nuclear cooperation would contribute to securer and safer global nuclear governance as well as commercial and energy-security interests of both countries. This report discusses a common vision and strategic goals of the new Korea-US nuclear partnership for the peaceful use and nonproliferation.

2. A Vision of the New ROK-U.S. Nuclear Partnership for the 21st Century

The new Korea-U.S. nuclear partnership aims to build a cooperative and mutually beneficial relationship between the two countries that could accommodate and accelerate expanded nuclear cooperation for the peaceful use of nuclear energy and nonproliferation.

The new partnership will be different from the old one where the United States both sponsored and controlled the Korean nuclear activities unilaterally under the 1974 U.S.-ROK nuclear cooperation agreement.

In fact, the U.S. sponsorship of the peaceful use of nuclear energy programs in Korea in early years was very successful. South Korea’s first nuclear cooperation agreement with the U.S. was concluded in 1956. The first research reactor, TRIGA Mark II, was provided by the U.S. in 1962. The first nuclear power plants were provided by an American company, Westinghouse, in 1978. The ROK-US nuclear cooperation had been so successful that it now asks for an upgraded and expanded cooperative relationship.

The new partnership asks for enhancement of the peaceful use of nuclear energy and nonproliferation, bilaterally and globally. This demand was echoed at the Joint Vision for the Alliance, adopted by President Lee Myung Bak and President Barack Obama on June 16, 2009: "We aim to make low-carbon green growth into a new engine for sustainable economic prosperity and will closely cooperate in this regard. We will strengthen civil space cooperation, and work closely together on clean energy research and the peaceful uses of nuclear energy."[3]

This Joint Vision is regarded as a landmark policy statement between the two countries that declares a new 'strategic alliance' that is both reciprocal and global. Traditionally the alliance was narrowly-focused one-way sponsorship by the U.S. against North Korean military attack and its scope was limited to the Korean peninsula.

This new partnership is necessary and possible due to the recent rise of South Korea as a responsible and capable middle power.[4] Korea is now one of four active nuclear power plant supplier states, including France, Russia and the U.S. Korea also ranks the fourth in nuclear power generation, after the U.S., France and Russia. If we could combine Korea's nuclear manufacturing and construction capabilities with the U.S. technology and global marketing outreach, we could further strengthen our joint competitiveness in the global nuclear plants market. Otherwise, this nuclear plants market could be dominated by the French, Russian or possibly Chinese reactors in the near future.

More importantly, the new partnership will also be possible as Korea, a newly rising and prosperous middle power, is prepared and eager to contribute to nonproliferation and world peace and prosperity. Korea has demonstrated its will and capability to contribute to global peace and prosperity by successfully hosting the 2009 G-20 Summit and the 2012 Seoul Nuclear Security Summit.

Korea, relying heavily on exports and imports with very little domestic resources, knows the vital importance of maintaining world and regional peace and stability for uninterrupted trade by strengthening global nuclear nonproliferation and security regimes. Under direct nuclear threats from its neighboring country, South Koreans are also keenly aware of the value of nuclear nonproliferation. The new US-ROK nuclear partnership would enable both countries to enhance their common commercial, technological, energy security and nonproliferation interests, bilaterally and globally

3 A similar agreement was also made between President Lee and President Bush on August 6, 2008: "The two Presidents agreed to actively promote close cooperation in the fields of civil space exploration, and space science and in the peaceful use of nuclear energy."

4 Here are a few notable world ranking and statistics of South Korea showing its size, characteristics and activities: GDP 15th, total export 8th, total import 10th, population 25th, oil consumption 5th, electricity production 6th, electricity consumption/per capita 3th, nuclear power capacity 5th, a member of Development Assistance Committee (24 states), 620 to UN Peacekeeping Operation and 670 to US-led multi-national forces, etc.

again.

3. Strategic Goals of the New ROK-U.S. Nuclear Partnership

a. Enhancing Common Commercial Interests and Competitiveness

During the global economic crisis, manufacturing industries and exports play critical roles in facilitating job creation and economic growth, which are the key issues of the 2012 presidential elections in both Korea and the U.S. In this regard, construction and exports of nuclear power plants could help achieve some of these goals.

As Korea is committed to export more nuclear power plants to the global market, Korean and American companies could team up to strengthen their joint competitiveness. Since the U.S. stopped building nuclear power plants three decades ago, it has lost its capability to compete alone against the French or Russian companies. Korean companies could be a natural partner for American companies, since they use U.S.-origin nuclear technologies and have a long and excellent history of cooperation with each other.

Three areas of cooperation for mutual benefits are noted by an American nuclear industry: U.S. exports to Korea, U.S. exports to the third countries to supply Korean or U.S.- Korean joint projects, imports of Korean products to supply U.S. projects.[5]

First, the U.S. can export nuclear components such as control and instrumentation equipment and cooling pumps to power plants in Korea. Second, U.S. companies can participate in Korean-led or ROK-US joint construction projects in a third country. For example, to KEPCO (Korea Electric Power Corporation)'s USD 20 billion LWR construction projects in UAE alone, American exports exceed USD 1.5 billion. Third, Korean companies participate in U.S. construction projects. For example, Korean firms supply major nuclear components to Westinghouse's AP1000 reactors under construction in the U.S. and China.

b. Utilizing Sustainable Nuclear Energy for a Stronger Energy Security

The utilization of nuclear energy in a sustainable way becomes imperative especially in the current era of energy insecurity and climate change.[6] As major producers of nuclear power-generated electricity, the U.S. and Korea, ranking the first and fourth in the world,

5 Daniel S. Lipman, Senior Vice President, Westinghouse Electric Company, House Committee on Foreign Affairs, Subcommittee on Asia and the Pacific Hearing: What's Next for the U.S.-Korea Alliance? June 6, 2012. KEPCO says that US firms would make over USD 2 billion from the UAE project alone.

6 Ernest Monitz, "Why We Still Need Nuclear Power: Making Clean Energy Safe and Affordable" Foreign Affairs, Vol. 90 No. 6, (2011)

are already beneficiaries of nuclear energy. In order to sustain such a benefit, however, both countries have to solve their nuclear spent fuel problem as soon as possible.

The cancellation of the Yucca Mountain nuclear waste repository project in 2011 in the U.S. shows the volatility and difficulty of the spent fuel management problem. Korea could not even start a governmental process to find a repository in consideration of public sensitivity to the issue, even if some of the on-site spent fuel storage pools will be full by 2025.

Three other top-ranked major nuclear energy producers - France, Japan and Russia - rely on reprocessing to manage their spent fuel problem. On the other hand, the U.S. voluntarily gave up reprocessing due to its nonproliferation policy. Korea also stays away from reprocessing for various nonproliferation and political reasons. Therefore, among major nuclear energy producers, only two states, the U.S. and South Korea, do not reprocess their spent fuels, and thus share serious spent fuel storage and disposal problems. As nuclear renaissance proceeds, more countries in other parts of the world will face the same problems sooner or later.

Korea's solution to the spent fuel issue was to develop a new and advanced spent fuel processing technology, called pyroprocessing, with built-in nonproliferation characteristics. Pyroprocessing extracts plutonium and other minor actinides together, unlike the current "wet" reprocessing technology to separate pure plutonium that could be used as bomb material.

Korea wants to develop the pyroprocessing technology jointly with the U.S. for several good reasons. First, once developed, this new technology could help solve spent fuel disposal problem in both countries. Pyroprocessing could drastically reduce the volume of high level wastes and increase storage volume in a given space, by reducing toxicity, heat and waste volumes to a great deal. Second, it provides a proliferation-resistant spent fuel management alternative to traditional reprocessing. Since pyroprocessing doesn't separate pure plutonium, it would also help reduce nuclear terrorism risks. Both small and big nuclear power producing countries could get these benefits. For example, big nuclear energy countries could provide pyroprocessing services to smaller ones so that the latter stays away from seeking their own reprocessing capability.

Pyroprocessing in Korea is also an essential part of a bigger nuclear energy research program to provide nuclear fuels to the fourth generation nuclear energy system, based on fast reactor. As an energy resource poor country, South Korea cannot stand idle in the middle of global competition to tap the full potential of nuclear energy for a greater energy security. In the U.S., skepticism on the feasibility of the fourth generation fast reactor systems runs high. On the other hand, France, Belgium, China, Russia, India and Japan continue to expand their fast reactor development programs. Despite technical difficulties yet, the fast reactor system is expected not only to strengthen energy security but also to help solve the spent fuel problem by recycling LWR spent fuels continuously. This new system, once realized, also helps ease nuclear security and nonproliferation concerns by burning nuclear fuel to the full.

South Korea now runs 23 nuclear power plants and will have about 10 more in a decade. As South Korea's reliance on nuclear energy increases, the economical and stable supply of nuclear fuel becomes a critical energy security issue. As South Korea enters global nuclear power plants export market, it learns that it is the only country without enrichment capability, among nuclear plants suppliers. South Korea was handicapped in the market, since it cannot make a fuel supply guarantee while most other suppliers can do.

There are now increasing demands in South Korea to own enrichment facility to supply domestic fuel in a stable way and to provide a fuel supply guarantee to plants importing countries. These demands were raised by South Korean nuclear businesses and utilities for commercial and economic reasons. In this case, multinational and/or black-box approach to an enrichment facility in South Korea or in the region could be considered to meet nonproliferation and transparency concerns.

As South Korea's nuclear research and industry make progresses, there are growing demands for nuclear fuel cycle research and commercialization to make nuclear energy sustainable and economical. The U.S. shares same goals and problems. As South Korea and the U.S. have somewhat disparate and complementary strengths in their nuclear research and industrial capabilities, these two countries are natural partners for nuclear cooperation. This cooperation would enable technological advancement to solve the spent fuel waste management problem and to accelerate the fast reactor research program for future energy security. It would also strengthen our joint competitiveness of civilian nuclear products in the global market for greater commercial benefits to the people of both countries.

c. Strengthening Global Nonproliferation, Security and Safety Regimes

Nuclear energy cannot remain in the hands of only a few countries, but will be available to all qualified and capable states for economic development and welfare of mankind. In coming decades, nuclear energy would spread to more developing countries as entry barriers for having nuclear energy become lower.

In this regard, Korea and the United States are sharing a common responsibility to make more economical, safer, and securer nuclear energy system with strong nonproliferation characters. A significant consequence of such joint efforts would be stronger global nonproliferation, security and safety regimes.

"Nuclear accidents anywhere are nuclear accidents everywhere." So are nuclear incidents. Any nuclear accidents or incidents could damage nuclear energy program and exports seriously. They could also hurt or even paralyze every lives and international trade. As South Korea and the U.S. are major nuclear energy producers and global traders, both states share high stakes for the world free from nuclear accidents, terrorism

and proliferation. The stronger the global nuclear safety, security and nonproliferation regimes become, the better for Korea and the U.S.'s sustainable and expanded use of nuclear energy and exports of nuclear plants will be. Korea and the U.S. must strategically cooperate to achieve these goals.

To maintain strong global nuclear safety, security and nonproliferation regimes, the U.S. relies on bilateral nuclear cooperation agreements as well as related international agreements and regimes. As U.S. civilian nuclear capabilities declined and U.S. firms stopped exporting nuclear plants for decades, however, its bilateral and global nuclear influences were also declining.

Korea and U.S. nuclear cooperation in the fields of nuclear plants exports and advanced fuel cycle research programs could help to rebuild stronger U.S. positions, bilaterally and globally. Again, Korea will be the best partner when the U.S. strives to maintain its influence in bilateral relations. Unlike other major plants exporters like France and Russia, Korean nuclear plants have imbedded U.S.-origin nuclear technology. This means that the U.S. government can exercise its right of (re)export control licensing in accordance with its own regulations and ask for bilateral nuclear cooperation agreements with importers of South Korean power plants.

Russia traditionally does not ask for higher standards of nuclear control when exporting nuclear plants as was witnessed in Iran. China is also insensitive to such demands as was seen its nuclear export to Pakistan. China is conjectured to enter global nuclear power plants export market with very cheap power plants possibly within a decade. These trends could undermine not only commercial interests of Korean and American firms, but also global nuclear nonproliferation, security and safety regimes.

d. Presenting a Model for the Emerging and Middle Nuclear Energy States

South Korea has one of the best performing nuclear power programs in the world. To newcomers, South Korea shows how it could succeed in utilizing peaceful nuclear energy for its fast economic growth. Here are a few of the success factors of the Korean nuclear energy program: state-led strategic planning and investment, nuclear cooperation agreement with the U.S., technical support from the IAEA, focus on peaceful civilian nuclear program only and excellent human resources. South Korea shows also to newcomer states that they do not need enrichment and reprocessing capabilities for a long while.

Among the top five nuclear power generation states, South Korea is the only one without enrichment and reprocessing capabilities. With 23 nuclear power plants running and about 10 more under construction or planning, South Korea is already a major nuclear energy state. However, instead of seeking national enrichment and reprocessing capacities like most predecessors, South Korea seeks after new institutional and technological solutions to deal with its fuel supply and spent fuel problems in cooperation with the U.S. and international society.

Institutional and technological innovations such as multilateral approach and pyroprocessing could be alternatives to both national ownership of sensitive technology and traditional reprocessing. If South Korea and the U.S. could work out to develop such a formula, they could help dissuade following middle nuclear energy states from seeking national enrichment and reprocessing programs.

4. Suggestion: Holding the Korea-US High-level Strategic Dialogue on Peaceful Nuclear Energy and Nonproliferation and Adopting a Joint Vision Statement

As mentioned above, leaders from South Korea and the U.S. adopted the Joint Vision for the Alliance in 2009 and agreed to work closely together on clean energy research and the peaceful uses of nuclear energy. However, there were no high-level meetings to translate this agreement into actionable programs. In addition, as global nuclear renaissance continues, a strategic cooperation between the U.S and Korea becomes urgent to enhance both common economic and nonproliferation interests.

Therefore this report proposes to hold ROK-U.S. ‘2+2’ minister-level strategic dialogues on nuclear energy and nonproliferation and to adopt a vision statement in 2013. This high-level vision statement would provide guidelines to the negotiators of the Korea-U.S. 123 agreement. The high-level strategic dialogue should be headed jointly by the foreign and science-technology ministers: Ministers of Foreign Affairs and Science and Technology from South Korea and Secretaries of State and Energy from the U.S. We could also add heads of nuclear regulatory bodies to make it ‘3+3’ dialogue.

Possible Future Directions for U.S.–ROK Nuclear Energy Cooperation

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1. Introduction

Nuclear power is an important part of energy security in many countries. Although the Fukushima accidents presented a major challenge, nuclear power continues to be the choice for electricity generation in many countries. Although a few countries such as Germany, Japan, Switzerland, and few others, are changing the course of their nuclear development, demands for new nuclear power plants in the world are continuing to rise. As of August of this year, there are 63 new reactors under construction (including 26 reactors in China, 11 in Russia, 7 in India, and 4 in the Republic of Korea), According to the latest IAEA report[1], the projected demand for new nuclear power capacity in 2030 is 450 GWe (under low scenario) and 740 GWe (under high scenario). There also remains a strong interest in nuclear power in the developing world. The United State of America (U.S.) and Republic of Korea (ROK), both a nuclear plant supplier country, want to be a major player in the global market for nuclear export. Close cooperation between the US and ROK may turn out to be beneficial for both countries.

2. The ROK Nuclear Power Situation

The ROK presents an impressive case of industrial development. In 1950, the ROK was one of the poorest countries in the world. Right after regaining independence after the WWII, the country went through one of the bloodiest civil war. About 60 years later, on June 23rd 2012, South Korea is landmarked to become the 7th member of the 20-50 club (with the population surpassing 50 million and maintaining per capita income of U.S.$20,000) after Japan, United States of America (U.S.A), France, Italy, Germany and United Kingdom. Korea remains the only country to date to have transitioned from aid recipient to aid donor (in 2009). It is the 7th largest exporter and 10th largest importer in the world in 2010. The country was the host of 2010 G20 Summit and then the host of 2012 Nuclear Security Summit. The country is the world's 6^{th} exporter of nuclear steam supply system (NSSS). The country has been very successful in exporting its commercial goods along with its popular culture such as Korean pop music, drama, and movies. With these successes, the ROK's soft power in the global stage continues to rise. The ROK is also one of the major success stories of U.S. foreign policy. With relatively short history of modern political development, the country emerged as a defender of liberal democracy with highly transparent culture backed by popular information technology. It forms common front in the campaign against terrorism and WMD with the U.S. Through the recent U.S.-ROK free trade agreement, the country also solidified economic interdependence with the U.S. The country is committed to universal values in human rights, environmental protection, non-proliferation, and the rule of law as promulgated in the UN Charter. In particular, the military relationship with the U.S. is essential for national security of the country. In this regard, pursuing cooperation with the U.S. in nuclear power program is also quite natural.

[1] Ahmed Irej Jalal, "Long-term Nuclear Energy Outlook: IAEA's Estimates for Nuclear Power Development in the World," *INPRO Dialogue Forum on Global Nuclear Energy Sustainability*, Seoul, ROK, August 27-31, 2012.

The ROK has a very high dependence on foreign energy import with lack of domestic natural resources. The country's energy self-sufficiency is only at 3 percent. This demands long-term energy security. Out of this necessity, the country started nuclear power development in 1974 through a turn-key contract with Westinghouse of the U.S. Now the country has a very mature civilian nuclear power program.

Since its initial effort to build commercial nuclear power plants, the ROK has emerged as one of the largest nuclear power states. The country boasts one of the best records of safe nuclear power plant operations with the highest capacity factors among nuclear suppliers. The nuclear power plants built by Koreans features highest cost effectiveness among the current NSSS vendors. Also as the country's economy is export-driven, there is a natural drive for nuclear export at the government level. The Korean nuclear industry successfully standardized their plants with the development of OPR-1000 and APR-1400 units. The APR-1400 model is being built in the UAE through the recent export deal in 2009. The Korean nuclear industry maintains a stable domestic supply chain for NSSS component manufacturing. It is 100% self-sufficient in NSSS design and manufacturing. They have also successfully developed a small size reactor, called the SMART reactor. They also have the experience of developing the DUPIC technology as one of the innovative ways of handling light water reactor spent fuels for reuse in CANDU reactors.

Another interesting development related to ROK's nuclear export ambition is the perception by the developing world. During the Nuclear Power Asia conference in Malaysia in 2012, the participants were asked to answer the following question by an on-line poll: "Which country will lead the way in 2012 and beyond for nuclear power export?" Twenty seven percent of the respondents chose Russia to be the leader. Ten and twelve percent of the respondents picked France and the U.S.A, respectively. Only five percent of them said Japan. In contrast, forty six percent of the respondents answered that the ROK would lead future global nuclear export.

While the ROK's civilian nuclear power program features various successes as enumerated above, it also faces a number of challenges. Under the current once-though fuel cycle policy, all of the nation's spent nuclear fuels are stored at the reactor sites. With very limited reserve capacity, the continuing accumulation of spent nuclear fuel is quite burdensome. There is no confirmed plan for centralized interim storage or final disposal of spent nuclear fuels. While the country is eager to pursue alternative approaches to spent fuel management, such as reprocessing, to reduce the toxicity of the materials and to reduce the burden for repository disposal, any dialogues involving ROK's new fuel cycle capability development are challenged by the U.S. according to the 1974 123 agreement, by the 1991 Joint Declaration for Denuclearization of Korean Peninsula, and by the presence of North Korean nuclear weapons program. The country has been prevented from pursuing the option of overseas reprocessing as well.

As to nuclear export, the ROK need U.S. approval whenever the ROK wins a contract for nuclear export. This is because the ROK's nuclear capability involves the use of U.S. license. Also, even if all of the ROK's nuclear export dreams are realized, the size of nuclear infrastructure in the ROK is not large enough to meet the demand.

Lack of domestic uranium supply or enrichment also presents a major limitation both domestically and in nuclear export. It will eventually work against ROK's competitiveness in the global nuclear export market as several of other vendors (such as Rosatom and Areva) can guarantee fuel supply. In the case of Rosatom, they are ready to offer the spent fuel take-back service as well.

Although the ROK's nuclear program is well supported by domestic licensing infrastructure, the current expertise is for the pressurized water reactor technology. As the country plans to develop fast reactor technology or other advanced reactor technologies, the necessary experience in reviewing safety issues of fast reactors or other advanced reactor is weak. Cooperation with the U.S. would be beneficial in this regard.

3. The U.S. Nuclear Power Situation

The U.S. is the origin of civilian nuclear power technology. With 103 operating nuclear reactors in its fleet, the U.S. has the largest civilian nuclear power program in the world. With the experiences and expertise developed over the years, the U.S. is still the powerhouse of nuclear know-how in all fields of nuclear technology. This includes reactor licensing experiences and overseeing the development of global nuclear safety infrastructure. The U.S. is not only the leader in the use of light water reactor technology, but also maintains extensive know-how of alternative reactor technologies such as sodium fast reactors, molten salt reactors, high temperature gas cooled reactors, and small/compact reactors from its nuclear navy programs. Also from its inception, the U.S. nuclear power program grew with a strong nuclear nonproliferation culture. With the opening of the Atoms for Peace period, the U.S. established and maintained global nuclear nonproliferation regime under its influence. Today, the U.S. maintains global leadership as the guardian of global nuclear safety, security, safeguards, and nonproliferation.

In contrast to this global leadership, the domestic developments of nuclear power program in the U.S. have had ups and downs. After starting with high hopes, the domestic nuclear power industry in the U.S. struggled during the 1980s and 1990s.By mid 2000s, the U.S. nuclear industry was able to make a comeback by performance improvements and reduction in operating/production cost along with popular concern over global warming and greenhouse gas emissions from the use of fossil fuel technologies. This trend grew into the expectation for nuclear renaissance. But recently nuclear renaissance is an unfulfilled dream in the U.S. as the industry is hit by low cost natural gas production. Moreover, the recent Fukushima accidents in Japan also dampened the prospects for global developments. The nuclear industry in the U.S. continues to face uncertain future with continuing low cost trend of natural gas. This has slowed down the renewed efforts of developing U.S. nuclear manufacturing infrastructure. Nevertheless, the public's support for nuclear power is rising again even after the Fukushima accidents. This is according to the latest NEI poll this year.

Another reality that faces the U.S. nuclear industry is that many domestic NPPs in the U.S. will go through decommissioning in the next several decades. This will vacate more than 100GWe nuclear electric generating capacity. Whether nuclear or not, the U.S. has to build new electric generating capacity. Also the U.S. industry needs to address spent fuel management challenges under the current once-though fuel cycle policy. While all of the U.S. spent nuclear fuels from commercial operations are stored on site waiting for permanent disposal, the U.S. government is under its legal obligations to take title of spent nuclear fuels from 1998. As the government was unable to meet this obligation, penalties from lawsuits have exceeded $1 billion to date. Also the Yucca Mountain repository, the only HLW repository site approved by the U.S. congress, let alone the project is currently cancelled, has the capacity of only 70,000 MTU. The projected inventory of U.S. spent fuels will far exceed this value based on existing nuclear generating capacity. Even if the Yucca Mountain repository could be expanded in its footprint size, the repository will not be able to accommodate all of the domestic spent fuels unless advanced fuel cycle is adopted. Various research work performed by the U.S. national laboratories indicated that the capacity of the repository could be enough to handle all of the nation's spent nuclear fuels if partitioning and transmutation of nuclear waste can be performed. This requires the capability of spent nuclear fuel reprocessing. Without reprocessing, the U.S. nuclear industry needs to find multiple geologic repositories. But the U.S. is presently unsure to commit to "closing" the nuclear fuel cycle. There is no commercial interest among the utilities for spent fuel treatment under the current policy structure. At the same time, the U.S. government has decided not to use the current state-of-the art, the PUREX technology, the technology domestically available. With lack of economic and political incentives, there is a very slim chance of realizing the vision of advanced fuel cycles in the U.S. This leaves the U.S. spent fuel management challenges unresolved at least in the foreseeable future.

The U.S. is also actively building new enrichment capacity. These new facilities were built under the premise of global and domestic nuclear renaissance. These facilities include the U.S.EC –American

Centrifuge Plant (ACP) in Portsmouth, Ohio, the URECO-New Enrichment Facility (NEF) in New Mexico, the AREVA centrifuge facility in Eagle Rock, Idaho (construction delayed to 2013), and the GE Silex laser enrichment plant in Wilmington, North Carolina. However, as the expected nuclear renaissance in the U.S. is not realized, there is potentially an over-supply of enrichment capacity. The U.S. is in need of a strategic partner to maintain this infrastructure.

Another challenge that faces the future of U.S. nuclear power industry is knowledge loss management. As the majority of workforce in the U.S. nuclear industry is aging with the expected near-term turnover of highly experienced personnel, maintaining the nation's existing nuclear know-how is an important task to maintain global leadership. The industry has hired young generation of workforce in recent years (with the expectation for nuclear renaissance). But recent slowing down of the industry may mean overcapacity of the workforce.

One important agenda that the U.S. has to grasp as a global leader in the use of civilian nuclear power is to shift its focus from "domestic energy option" to "international safety and security imperative"[2]. The current global regime of nuclear safety and nonproliferation could become weakened with the decline of U.S. industrial leadership. This trend is certainly not conducive to enhancing global nuclear safety and security, in particular with the expected rise of Russia or China. The U.S. needs better market penetration to maintain lion share of the market. This demands the U.S. nuclear power industry to regain economic competitiveness over other suppliers. The U.S. industry also needs stable supply chain for the manufacturing of components. Currently, the U.S. is incapable of providing the NSSS with domestic capability. This is even true for Westinghouse with Toshiba as owner as Toshiba capabilities are only for boiling water reactors. Thus the U.S. nuclear industry needs a partner. The ROK appears to be a very good candidate for the role. Even today, in the construction of current AP1000 units in China and the U.S., Westinghouse is relying on ROK manufacturing capabilities for the supply of reactor pressure vessels, steam generators, condensers, demineralizers, and valves. Even the engineering design work of AP1000 was supported by Korean nuclear power company (KEPCO E&C).

Depending upon how the collaboration is weaved, the collaboration could lead into mutual benefits. The timing of cooperation is significant to slow down wide-spreading influence of Russia or China in global nuclear arena. The bilateral cooperation could cover activities in the front-end nuclear fuel cycle, the back-end fuel cycle, domestic and international civilian nuclear power development, nuclear licensing, and global stewardship. Thus under the cooperation, it is possible to cover complete spectrum of civilian nuclear power program such as science and technology, nuclear safety and security, and safeguards and nonproliferation. In the following sections, possible scopes and details of the U.S.-ROK nuclear cooperation are presented in two parts, i.e., industrial cooperation and the cooperation in basic R&D.

4. The U.S.-ROK Nuclear Industrial Cooperation

One of the main goals of industrial cooperation between the U.S. and ROK is to increase the market share in nuclear export. For this goal to be met, this cooperation needs to be structured to provide economic competitiveness. The scope of this industrial cooperation could include engineering design, construction, manufacturing, operation, nuclear services, fuel supply services, and even spent fuel management services. The cooperation should take advantage of the respective strengths of both countries to meet global market demand.

Let's take an example. Certain nuclear import countries may prefer large nuclear units (e.g., 1000 MWe or 1400 MWe units) for economy of scale. Other countries have to select smaller units (e.g., 600 MWe or even 100 or 200 MWe) as the nation's electricity grid is not capable of handling a large generating

[2] Craig Piercy, "The Evolving U.S. Role in the International Nuclear Arena," FAS/GABI 2012 Workshop on *The United States and Korea Cooperation in World Nuclear Market*, July 26, 2012

capacity. The U.S. nuclear supply capacity is mainly based on 600 MWe or 1000 MWe units while the ROK capacity is with larger units such as 1000 MWe or 1400 MWe units. Also the ROK has developed a small reactor technology called SMART, which is at 100 MWe. The SMART reactor's licensing review is at its final stage in Korea. The U.S. also has a variety of small modular reactors (SMRs) under development based on early nuclear navy reactor experiences. Collaboratively, the U.S. and ROK can offer strong products of nuclear reactors at various sizes to the global market.

Both countries could also work together in licensing activities. This will be very useful for safety reviews of new SMRS or advanced reactors. The U.S. has accumulated a large body of expertise in reactor licensing based on its domestic nuclear history. However, with lack of licensing activities for new advanced reactors, the U.S. may be losing this capability. The ROK will benefit from the cooperation as the country lacks experiences in advanced reactor licensing.

Collaboration in nuclear fuel supply or spent fuel management will also enhance the competitiveness in nuclear export. In terms of fuel supply, the ROK could participate in U.S. enrichment as a partner. Alternatively the ROK could build its own enrichment facility through a bilateral or multilateral arrangement with strong U.S. participation. The ROK could even earn enrichment capability through a separate international arrangement. But this capability would be leveraged for mutual benefits in nuclear exports. In any case, the resulting capability would help both countries through increased market share.

As to the spent fuel management capability, developing pyroprocessing technology is a national agenda in the ROK. South Koreans have to rely on the prospect of the technology to solve their nuclear waste management problem. The U.S. can rely on ROK efforts to pave the way to demonstrate the feasibility of commercial utilization of pyroprocessing. The resulting capability can be shared for domestic spent fuel treatment or international services. Eventually both countries need to carefully explore the possibility of offering spent fuel take-back services in nuclear export. As both countries are in need of developing interim spent fuel storage or final disposal, these facilities could be utilized to provide such services.

The two countries should also work together to address the issue of knowledge loss management. With the differences in the age group distributions in the respective workforce between the two countries, joint man-power training and workforce utilization would reduce the risk of age gap-induced knowledge loss.

5. The U.S.-ROK Collaboration in Basic Nuclear R&D

In terms of collaboration in basic R&D, the areas of collaboration should be selected based on national needs and strategic importance for global nuclear leadership. Six areas of collaboration can be considered for this purpose: 1) Fast reactor technology development; 2) Pyroprocessing technology development, 3) Geologic disposal technology development; 4) Global nuclear safety enhancement; 5) Global nuclear safeguards enhancement, and; 6) Global nuclear security enhancement. The first three areas are to address national needs. The remaining three are for global nuclear leadership. The collaboration could also include education and training activities in support of basic R&D.

5.1 Collaboration in fast reactor technology development

Basic R&D in fast reactor development can be envisioned in three different areas: 1) R&D to improve existing sodium fast reactors (SFR); 2) R&D to develop very long-lifetime fast reactors, and; 3) Research for fast reactor licensing.

Major problems with the existing SFR technology are safety concerns with sodium leakage and sodium and water interactions, potential proliferation concerns with the fissile materials used, and high cost of the new reactor build. The R&D activities to improve existing SFR could include: 1) Optimization of LEU core with no blanket; 2) Developing standardized design methodology to reduce engineering cost; 3)

Design changes in intermediate heat transfer system; 4) Optimization of passive residual heat removal system, and 5) Optimization of power conversion system.

Development of very long-lifetime reactor requires new core design with the concept of breeder and burner reactor along with safety optimization. New advanced nuclear fuels are also needed in this development to minimize the impact of fission product buildup and fuel cladding interactions due to the implementation of long burnup.

The research to support licensing of new fast reactor development could be based on examination of previous fast reactor licensing experiences in the U.S., France, and Japan. Differences between light water reactors and fast reactors should also be analyzed. Any institutional or technical issues in the current licensing system that hinder new technology development should be identified.

5.2 Collaboration in pyroprocessing technology development

Collaboration in pyroprocessing technology development is already underway between the U.S. and ROK under “ROK-U.S. Joint Fuel Cycle Study”. The study currently consists of 7 areas[3]: 1) Safeguards technical direction and analysis; 2) Safeguards testing with irradiated material; 3) Technology for nuclear material accountancy; 4) Technology for containment and surveillance; 5) Safeguards and security by design; 6) Modeling and simulation for analysis of safeguards performance, and 7) Safeguards for dry storage and repositories (as fuel cycle alternatives).

The ROK is also making parallel efforts to enhance the technology. These efforts are to increase throughput, process efficiency and scale-up, and to reduce waste volume, and to enhance remote operability and inter-connection between unit processes.

Additional efforts can be made jointly between the U.S. and ROK to develop a so-called “breakout” barrier. This barrier is to prevent any future diversion attempt by a state actor through a breakout scenario. Success in developing such a barrier could be combined with a black-boxed pyroprocessing technology as a standard technology of spent fuel treatment for the future.

5.3 Collaboration in geologic disposal technology development

Development of geologic repository is a must for both countries. Although the recent efforts in the U.S. were focused on Yucca Mountain repository as an unsaturated system, new needs are arising to explore alternative rock systems for future repository development. These alternative rock systems are most likely located in a saturated system. Although the rock types of these systems may not be the same in the ROK, the experiences in underground system development, site characterization, hydrogeological model development, performance assessment, repository design and construction, and long-term monitoring and institutional control of geologic repository can be shared between the countries to strength each other’s efforts.

5.4 Collaboration in global nuclear safety enhancement

After the Fukushima accidents in Japan, the global nuclear industry once again realizes that any accident in any region is a global accident. With the prospects for global deployment of each country’s nuclear reactor technology, the U.S. and ROK should actively work together to enhance the safety of future nuclear reactor builds. These efforts are complementary as the two countries’ directions in approaching the future of nuclear safety are somewhat different. The U.S. is more focused on holistic approach under

[3] Seong Won Park, “ROK’s Fuel Cycle Development,” Georgia Tech-KAIST Workshop on *Nuclear Energy and Fuel Cycle Activities: From Impasses to Opportunity for U.S.-ROK Cooperation*, Atlanta, GA, October 7-9, 2012

the theme of risk-based nuclear safety against severe accidents. The ROK is emphasizing actual system development and implementation to effectively address the beyond design basis accident scenarios.

5.5 Collaboration in global nuclear safeguards enhancement

Major technical issues that need to be addressed to enhance global nuclear safeguards include[4]: 1) Misuse of gas centrifuge enrichment plants; 2) Real-time accountancy at large bulk handling facilities; 3) Remote monitoring of facilities to enhance transparency; 4) Maintaining continuity of knowledge at storage facilities; 5) Accountancy measurements for pyroprocessing; 6) Direct measurement of plutonium in spent fuel, and; 7) Detection of undeclared activities. Some of these issues present major challenges in technology development. The U.S. and ROK should actively work together to develop capabilities against these challenges.

5.6 Collaboration in global nuclear security enhancement.

The U.S. and ROK collaboration could also address the remaining challenges in global nuclear security[5] through basic R&D. The R&D should examine the following issues: 1) Quantitative risk analysis for security systems; 2) Assessment of security risk from low and medium consequence targets; 3) State-level nuclear security measures and assessment methods; 4) Enhanced border monitoring capability against shielded SNM; 5) Rapid forensics and attribution; 6) Aerial measurement capabilities, and 7) Systems for managing consequences following a radiological event.

6. Concluding Remarks

This review outlined the rationale for U.S.-ROK nuclear cooperation. The details of the proposed cooperation are based on respective strengths of both countries. Through careful coordination and planning, the U.S. and ROK nuclear cooperation could be a ‘Win-Win’ by taking advantage of each other’s strengths and meeting each other’s needs. The cooperation could present a new global collaboration model to promote Atoms for Peace Initiative as was originally envisioned by President Eisenhower. The ultimate goal of the cooperation is to strengthen global nuclear governance for safer world. The cooperation will strengthen the U.S. leadership to enhance for global nuclear security, safeguards, and nonproliferation under the support by the ROK.

[4] William Charlton, “Enhancing Global Nuclear Security Through U.S.-ROK Technical Cooperation,” Georgia Tech-KAIST Workshop on *Nuclear Energy and Fuel Cycle Activities: From Impasses to Opportunity for U.S.-ROK Cooperation*, Atlanta, GA, October 7-9, 2012

[5] Ibid, 4.