

Study of "Fukushima" and Discussion Exploring Future Presentations

Shuichi Iwata

The University of Tokyo

Abstract:

An international collaboration agenda for creating a new paradigm triggered from many troubles of the Fukushima Daiichi Nuclear Power Plant "FUKUSHIMA" is proposed. The agenda consists of two main aspects: One aspect concerns a way to reorganize our engineering knowledge on safety beyond experience-based engineering, targeting to establish robust enough engineering against the next big risk and disaster, and the second aspect concerns how to create a human-oriented society of perfect individual care. Sharing of reliable scientific data is the key starting point for this big challenge. Challenges to realize data-centric individual cares and data- and scenario-driven collaborative design approaches together are expected to follow as remedies to get our future perspectives.

By any means, we must be prepared against the next big earthquake and tsunami, and nuclear accidents based on not only reliable data and knowledge acquired from "FUKUSHIMA" but also on restructuring our domain-differentiated disciplines and knowledge into a tough, robust, flexible and basic discipline of perseverance. Almost every day, we have seen reports about changes at "FUKUSHIMA" and have experienced large aftershocks of magnitudes around 4 to 7, but there has been no chance of a big tsunami after March 11. Our land is not stable. The nuclear reactors require a long time to become stable, and we are going forward step by step with trial and errors. We must derive solutions to control nuclear energy under the worst "Multiple organ dysfunction syndrome" at the end. And in parallel we need to establish robust engineering against future risks and disasters based on our research from the biggest disaster during these one thousand years.

1. Introduction

In order to overcome the disaster and accident of the Tohoku/North Kanto Earthquake, Tsunami and Nuclear Reactors, on-site experts have been struggling together to deal with many troubles of the Fukushima Daiichi Nuclear Power Plant (“FUKUSHIMA”), by trying to make the reactors more stable and with less release of radioactive materials. Our common mission is to optimize strategies to minimize health risks and hazards to all the affected people.

Just after the Earthquake/Tsunami/Nuclear Accident, our society had not been stable due to bad information-a kind of “Information Tsunami” which passed rapidly through different media types and the Internet together with the right information on the facts. But recently thanks to reliable scientific and technical data reported by the media, Japanese society has become calm and regained reason, as imaginable by “Special vegetable sale direct to Fukushima”. The customers in Tokyo have confidence in the safety of Fukushima vegetables and want to support Fukushima farmers by buying vegetables produced in Fukushima.

Thus, our Japanese society hopefully converges into a steady status through joint fact finding by knowledgeable citizens. However we need to be well prepared against the next big disaster and also ready for initiating new actions with future perspectives. The new initiative is designed not by excluding variables through educated guessing, as were the former cases, but by bringing to bear powerful and complex analysis & synthesis inclusively based on data commons of “FUKUSHIMA”, reconsidering all safety and risk issues of man-made and natural complexities. In this paper, a preliminary work along this direction is given following data-centric approach.

2. Efforts for Joint Fact Finding

During the chaotic confusions just after Earthquake/Tsunami/Nuclear Accident, it was not easy to report fresh, accurate, useful and consistent information by rapidly identifying and evaluating the very wide spectrum of accidents in the station blackout. Emergency planning did not cover this

kind of accident. Reactor status reports were given in an old-fashioned delayed and top-down way from different organizations, which has not only frustrated journalists but also required extra-works for on-site experts. In order to solve this issue, we need to make a good plan on how to disseminate available data and clear explanations for the public to grasp the on-time reactor status by summarizing the data. Precise and detailed raw data with explicit descriptions on each set of data are helpful to gather support from knowledgeable experts in the outside. It should not make confusion due to ambiguous expressions on data.

Even a simple fact sheet of reliable scientific data accompanied with enough metadata inspires outside experts to work together for solutions. We need to avoid “chaos begets further chaos” through “copy & paste with exaggerated speculations of false data”. So it is important to inform people of each measurement condition, how they can evaluate raw data, and express uncertainty on the public announcement. To enable spokespeople to provide essential raw data so that they will reach the population in a timely and proper manner is the key point to be noticed and kept in mind. We again and again need to avoid “chaos begets further chaos”, and through active disseminations of reliable scientific data it can be avoided properly.

In the end of this paper a part of available information sources are listed. They are prepared by different organizations committed to “FUKUSHIMA” and from such works we can make a summary report on “FUKUSHIMA” by ourselves as shown below as an example.

【Station Blackout and Data Blackout 】

The 14-metre-high tsunami after the magnitude 9 earthquake of 11 March 2011 severely damaged the Fukushima Daiichi Nuclear Power Plant of the Tokyo Electric Power Utility Company (TEPCO), in particular, the plant's principal power supply. The wave also took out the backup electricity sources, leaving four reactor buildings — including four pools containing spent fuel elements without power. Consequently the earthquake and tsunami caused the station blackout, which has resulted in a kind of “multiple organ system failure” of the Plant bereft of coolant. We had no light, we could not cool the reactor core and spent fuel pool actively, and we

could not measure the exact status of the plant by taking advantage of a set of advanced instruments and tools to do so. Available tools to measure radiation doses have been given priority for the ongoing emergency and to workers health management. Without enough sensors and “powerful hands,” careful and coordinated efforts have been continued with perseverance to make each unit more stable and safer in a step-by-step manner by TEPCO and other experts. We had no “CPU” and no “Intensive Care Unit” to support and restore damaged parts in the beginning.

Reports on the plant and site have become publicly open just after the Earthquake. Presently we can see the immediate status of the plant through the latest data measurements and the compilation and explanation of the data by experts from periodical reports (see details at “Status of Nuclear Reactors” in Information Sources at the end of this paper) from TEPCO, NISA (Nuclear and Industrial Safety Agency), and JAIF (Japan Atomic Industrial Forum, Inc.). In short, the nuclear reactor systems were damaged mechanically and chemically, but they shut down perfectly with respect to nuclear chain reactions. Therefore, the Fukushima Plant is different from the accident at Chernobyl. It will take time to control, namely cool down and confine almost all hazardous materials in the site, a large and complex object of decay heat and radioactive elements, but this should be done with minimal radiation exposures to workers.

At Fukushima, ranging fuel burn-up (averaged for each fuel assembly) from 3,200 to 41,100 MWd/t, 1,498 fuel assemblies in Unit 1-3 reactor cores, 2,724 fuel assemblies in spent fuel storage pools are producing decay heat, and at high temperature a part of cladding materials zircaloy of the fuel assemblies had reacted with steam/water to produce hydrogen. Three buildings were severely damaged due to the hydrogen explosion. Radioactive materials have been released from containment vessels on several occasions after the Tsunami, and this was the result of deliberate venting in an attempt to reduce gas pressure in each containment vessels and/or spent fuel exposures due to dry out. The radiation dose rate at one location between reactor units 3 and 4 was measured very high at 400 mSv/h, at 10:22 JST, on the 13th of March. This was most probably a spike due to a fragment of

strong radioactive materials being released after the hydrogen explosion. This fact led experts to urge rapid rotation of emergency crews as a method of limiting exposure to radiation. Measured high doses and accidental or uncontrolled events have been associated with one or a few pre-events in the beginning as reported in the information sources as mentioned above. Perhaps as a result of a chemical explosion, some particles with a rather large amount of radioactive material became airborne and, by chance, must have fallen near the detector at that time. However, the size of particle was much smaller than one millimeter in diameter. Workers at the plant are strictly monitored so as not to exceed the upper limit of acceptable radiation exposure.

【Notice in Reporting Data to Public 】

It is important for all to recognize that there are different observers, instruments, sampling methods and time of observations and time when observations are made. The reported raw data will have scatters and spikes and sometimes errors due to the ongoing complex event, so that it is important to evaluate the reported data independently and scientifically if possible with other scientists, and if possible by digital logic filters prepared by experts before. In our information society, various voluntary experts of different disciplines in the world can carry out evaluations of reported data, so that exaggerating biased reports and mistakes will be phased out gradually. An important prerequisite to make it happen is that we scientists need to communicate with each other by a common language beyond each scientific domain without using specialized technical terms Shibboleth, hopefully, through facts/objects and accessible scientific data in the beginning.

In case of calculated data, we need to know at least functionality and correctness of the program, valid range and domain, input data, computational parameters, accuracy and uncertainty of calculated data, and objectives of estimation, for example, best estimate or conservative estimate, phenomenological or first principles, deterministic or probabilistic, etc. So we need to be very careful in using calculated data without reference data

and/or reference programs. Just a collection of calculated data without explicit explanations has brought confusions to the society also in this occasion.

【Preparation against the Next Big Risk】

In short we do not know about the earth perfectly, so that we cannot predict the next earthquake/tsunami accurately enough with respect to the magnitude, time and place for preparation. What we can do now is to make our engineering for safety robust enough against any big risks in the future. Defense-in-depth and/or fault-tolerant design approaches do not work if we follow experience-based design staying within one specialized academic domain. We need to prepare an open environment-data commons for "FUKUSHIMA" for example to collect various advices and remedies to make the nuclear plant sites in the world safer. Some proactive works we can do now are to make all nuclear reactors safer referring lessons in the past from scratch, which should be summarized in the data commons, especially as recommendations of practical and emergent actions against the next earthquake/tsunami. Working together with the world based on reliable scientific data is the best way to fight with this kind of big disasters, solving each trouble carefully one by one to reach a steady status of cooling and confining of radioactive materials.

Establishing robust enough engineering against the next big risk and disaster is a very challenging subject, but can be done by resolving all ideas into a set of knowledge and meta-knowledge. In this context "FUKUSHIMA" can be articulated as a strategic procedure to derive local and global control of a complex, heterogeneous, non-linear and dynamic multi-component system by identifying the status of the system with limited data. It is a very tough problem we have left as it is since the end of 19th century.

3. Fundamental Human Right for Knowing Risk

Each individual has a fundamental human right to know his/her own risk rather than ambiguous indices of his/her place. And it looks more practical to carry out health care of each individual who may have a risk suffered from the release of radioactive materials, rather than of an unspecified large number of people with a poor statistics. By taking advantage of human genome database and digitized clinical chart, we can maintain the health of the public as individual care perfectly rather than depending on the sophisticated epidemiological data of large uncertainties in the low dose range. As the current regulation of radiation protection has been established as a result of health physics in the high dose range, which can be identified by area, time and shield. We need careful and scientifically reasonable risk evaluation for each individual. Some experts say that stress and fear to each individual who is declared as an inhabitant living in a risky area defined officially may make the individual worse than the low dose radiation. Scientific research is required to maintain the public health focusing on individual care, which may explore another dimension for the public care. In case of Chernobyl, a holistic approach by combining tele-medicine and human genome database has been under discussion for practical solutions, and it could be a good reference for "FUKUSHIMA". Reliable scientific data and individual care policy can be the basis for reasonable solutions. In this context, calculated data requires careful evaluation on their reliability and we need to use calculated data in a proper way with reliable references.

How safe is safe enough? It is a question concerning not only science but also sociology, which requires powerful and elaborate analysis on interplay of science and society back and forth in both qualitative and quantitative way. The government's role of informing the public of the risks is not easy. The person to provide this information must speak with knowledge and authority taking into account uncertainties of the risks. Obviously there's a lot of concern about food and water contamination, and it seems uncertain about the pathways and contamination. Methods and/or procedures to evaluate risks and uncertainties are to be explained explicitly in a global context

when the risk information is given to the public. If it is not possible, an individual care approach is more promising of rich implications for the future. Media people must be competent to understand and report the risk information properly with conscience. They must be able to distinguish fact and informed opinion from speculation.

【Risk of Each Individual】

Practical monitoring data such as “List of nationwide activity concentration”, “Radioactive material level in tap water in Tokyo/day” are available through the Internet, and medical experts in Japanese Society of Nuclear Medicine and Science Council of Japan have declared their opinion to public. However it is not easy for the public to understand such explanation in the context of their risk and safety. Scientific research and detailed regulations do not assure that “the reported dose is not dangerous and safe enough”. Massive written articles and snowballing massive explanations on each data set in the Internet produced the status “chaos begets further chaos”. To reduce unnecessary stress/fear and untold suffering due to health risks for workers from radioactive materials, experts must work together to explicitly explain the complex procedures of the ongoing nuclear accidents - what we know, what we do not know, what we expect to happen, and what we need to take care of based on timely and proper compilations of each set of raw data. The key to relieving the invisible stresses and fears of the general public living in the vicinity of “FUKUSHIMA” is to release reports made through the proper compilation and reporting of measured data with a perspective to normal. These reports should explain the complexity of partly mechanically and chemically damaged nuclear reactor systems and reassure the public that the systems shut down perfectly with respect to nuclear chain reactions. In order to confirm this continuously, experts of the sites have been measuring important data seriously to manage doses of workers in Fukushima I Site as well as to evaluate diffusion of radioactive materials in the local district as accurately as they can.

Bad news travels quickly even if false. One newspaper reported: “10million times norm-Massive iodine-134 live in No.2 reactor turbine bldg.”

Another media reported later:“Wild radiation spike in No.2 proves false.” The first report spread through the Internet and the consequent bad impressions have been snowballing and returned to Japanese SNS giving people unnecessary stress and fear. Invisible radioactive materials reported in digits by the media together with sudden hydrogen explosions have given stress and fears to public anyway even if biophysical effects due to radiation are small. This aspect implies ethical issues beyond classical scientific deterministic frameworks, on which human beings have been discussing continuously in the history.

To enable spokespeople to provide essential raw data that will reach the population in a timely and proper manner, key points must be noticed and kept in mind. We again and again need to avoid “chaos begets further chaos.” However, in spite of confusions in the first phase, recently as described above Japanese society has listened to reason.

【Public Service and SNS】

Both public service and private service played an important role for individual care. National Police Agency of Japan periodically reported Damage Situation and Police Countermeasures after 2011 Tohoku district - off the Pacific Ocean Earthquake and Tsunami. The agency reported on March 30th we have lost 11,232 people and in addition 16,361 are missing. There are over 100,000 crashed or damaged houses and consequently many refugees in Tohoku and North Kanto District. Because of the Fukushima Nuclear Emergency, food, drinking water, bedding, medicine, and other emergency relief supplies fail to reach the stricken areas promptly, and the sufferers are afflicted with cold, hunger, and illness. There is a need for good governance, openness and transparency in passing necessary information onto the population to maintain the public trust. It is important to repeat our first priority “minimizing damages to each individual” again and again so as to allocate available manpower and resources properly, especially to the people who are suffering now.

As for this aspect, many SNSs organized by grassroots voluntary groups as well as private sectors have been playing important roles to establish various service channels to each individual, complementing official channels

in parallel. However in the aged society, elderly persons do not use SNS and the originals of a family register were lost due to the Tsunami. So official governmental services have importance for the society even if the official data are prepared following official procedure and do not reflect the reality perfectly. In order to take care of latent effects of radiation exposure, continuous follow-ups are expected. This kind of care should be proactive enough as preventive medicine. The objective is to make the suffered public healthier than before.

【 Global Risk Managements 】

Contamination of the sea by release of radioactive materials implies very sensitive, ethical and international issues and we need careful scientific surveys on the effects to the sea, which should be followed up by international open discussions. As for our long-term future, we need to prepare reference data for making decisions and organize global discussions open for public. We are now learning a big social risk of nuclear technology, and economic risks and environmental risks are waiting. Proliferation risks exist every time. If nuclear power spreads to less developed countries without deep repositories of expertise, we should consider a regulatory role for the International Atomic Energy Authority, instead of its current role of helping countries upgrade their safety and prepare for emergencies. Potential natural disasters for each region are definitely to be taken into account now, and all the paradigms that have driven our modern society should be critically reviewed from scratch by global collaborations. On the contrary it is not reasonable to link the Fukushima naively to the TMI and the Chernobyl and say that Nuclear should be phased out in favor of other energy sources.

We need to consider also risks of other energy sources. The truth is that all energy choices carry risks, and serious and continuous evaluations are required. Climate changes due to greenhouse gas emissions may be more invisible, uncontrollable and complex. Sharing reliable data and having productive global discussions transparent to the public are prerequisites to ensuring our future. More and more transparency and objective reasoning on nuclear issues must be organized, while always taking into account the

extremely important issue of security.

It seems that continuous individual care and reports on health evaluation are the only promising way to verify “safety”. So, data-centric approaches with transparent evaluation procedures are the key to overcome the chaos, which is suggesting a necessity for new paradigm on our society as well as sciences. It is a challenge to make our society thoughtful and tough.

4. International Collaboration from “FUKUSHIMA”

Big Earthquake, Big Tsunami and Big Accident, which may happen once in a millennium, have forced us to reconfirm the weakness of our modern society mainly supported by oil and also the weakness of our technology before the nature. Our history to apply mechanics is just 500 years, our history to apply the thermodynamics to learn the earth and technology “cooling based on theory” is just 200 years in age, and our history to use nuclear energy is just half a century. It depends on our work on “FUKUSHIMA” whether the public will accept nuclear or not. In this context I will try to list up possibilities of international collaborations.

In order to carry out proactive and practical actions in collaboration with international experts having excellent knowledge and diagnostic ability, our information society has prepared an infrastructure to make it happen. However, some barriers to this do exist. These will be thoroughly discussed and reevaluated in the future. Immediate global actions that we can do together now in the outside of “FUKUSHIMA” are:

(1) Simulation of Sever Core Damage to Find Possibilities of Recycling

For a moment the total release of radioactive materials from the Fukushima Site is not certain, and recently it is estimated about 10% of Chernobyl Case. The difference is due to the first barrier “materials” are working and other barriers “pressure vessels” and “containment vessels” partly working although it is going on about one month. Due the burning of graphite, the Chernobyl Case had no barriers against radioactive material release for two weeks.

It is important to evaluate potentialities to confine radioactive materials in the fuel pellet, the damaged reactor cores, the spent fuel storage pool and

the plant site with respect to different time-space scales. For example, the solubility of radioactive materials in different mixtures of nuclear fuels and components called “corium” in the case of the TMI (Three Mile Island) Accident, and release rate estimation from the damaged plant for different scenarios including the best and worst cases based on the reported and above mentioned data on the number of fuel assemblies and burn-ups. Restructuring of the damaged areas and subsequent mass transfers are expected to be modeled with a proper robustness and balance of details to get a holistic and dynamic view of the estimated event. Several computer codes exist that estimate the severe core damages that have occurred throughout the world, which along with a kind of grid computing that evaluates various scenarios, should be helpful for better decision making including recycling of the fuels.

(2) Quality Control of Data for High Reliability

Good data takes time to produce, and it is not so easy to maintain a set of good data, which are easily contaminated by bad data. Strange data have a very high breeding ratio-copied & pasted with exaggeration in the Internet, and they are breeding very rapidly in media and SNS. Only reliable data and truthful information may enlighten the darkness of “unknown” to overcome the disaster. One of important issues we need to consider intensively is how to deal with collective knowledge in the cloud for the quality control.

(3) Dissemination of Data and Utilization of Data

Valuable lessons learned during and after the TMI and Chernobyl accidents should be reevaluated in order to prepare a set of remedies for Fukushima with different time scales and different radiation exposures, in particular paying attention to socio-psychological aspects. We now have a variety of information channels and contents that must be used to maximum advantage. The dissemination of data and knowledge is far faster and wider than when TMI and Chernobyl occurred, which has various unexpected side effects as well as benefits. The accuracy, timing, and context of the disseminated data must be observed carefully, and advice for timely improvements will become lessons for the future. What general public and

active people can add is an analysis of reaction of people to disaster and behavior in critical situation. Reaction and behavior of Japanese people and international friendships and sympathy on disaster of 11 March and Fukushima accidents are to be studied and lessons used around world as an example of peoples behavior. Supports from socio-psychologists are necessary. And it is important to observe that a new feature of the society where we have increased number of sensors, increased number of data sources, meta-language/knowledge/infrastructure for data sharing and exchange, evaluation of data reliability in an era of real-time and near real-time observation and reporting. Diffusion of data, quality of data, semantics of data and contexts of data are interacting each other far more dynamically in our information society that makes changes in public behavior and perceptions.

We are now observing data-driven-real-time-immediate effects on people in emergency situations, which requires us a very careful and deep consideration on its path for the future. A part of the tragedy is some of the media reports, which are somewhat unnecessarily and essentially articulate the fears of the “unknown” and “unexpected”. However, scientific analysis is to be based on reliable data and proactive explanations.

(4) Utilization of Outsiders Views

Worst-case scenarios are better prepared by the off-site independent experts who have time to think and are calm enough to get a holistic view. They can examine potential interactions between risks, nonlinear responses and feedbacks, common mode failures, and response strategies during extreme events. Moreover, a coastal storm or another large quake could disrupt current containment and stabilization efforts. If in situ data are prepared for open access, we can expect more useful contributions.

(5) Conversion into A Closed Cyclic System

We need to make a plan for mid-term decontamination works of waters and longer-term waste managements of huge amount of contaminated materials with radioactivity. Not only on-site closed cycles for cooling and decontamination, but also sustainability issues with larger design windows are to be solved on the basis of joint “fact” findings by all stakeholders.

Inherent technologies to make each reactor safer and robust enough for any kind of disaster need to be implemented for the next disaster that may happen in the future. Necessary actions are to be taken from now at each site

5. Preparation for “Beyond FUKUSHIMA”

Our history to utilize nuclear energy is relatively short, and we need to reevaluate the nuclear technology intensively from scratch. After a short excerpt in 1939 “Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle” by Otto Hahn and Frits Strassmann, the era of “nuclear” has evolved making not only good stories but also bad stories. Japanese network of power systems has been developed by introducing nuclear reactors and created a culture of large socio-technical systems and an engine to develop an advanced industrialized society of Japan. We have pursued, in general, a strategy of building larger, more efficient, centralized powerful systems of a minimum redundancy in our modernized society.

I have been learning many lessons from this accident as one of researchers in nuclear engineering. Tasks to cool down and stabilize the reactor cores and spent fuel storage pools, and confine nuclear substances, nuclear fuels and contaminated waters have been going on to prevent their diffusions from the plant. Medical and livelihood services are carried out for workers and residents near the plant. Individual care is the first priority and efforts focusing on it are going on. The results of these efforts have not yet been collated after 30 days, but it is our duty and mission to stabilize this nuclear crisis as soon as possible. We appreciate the global support very much and ask for cooperation from all fields around the world. I believe that the world needs nuclear energy. Therefore, we must show the world that we are able to control nuclear energy under the worst “Multiple organ dysfunction syndrome”.

Transparency and data sharing between industry, government, academia, and nongovernmental stakeholders are the keys for productive discussions, which will help in the long run to prevent future catastrophe, which will evoke something productive through international collaborations as

described above.

Acknowledgement

I would like to express my sincere gratitude to all my data colleagues in the world for their advice to write this article. Their suggestions and discussions have been encouraging me a lot and I would like to work with them to supply the world with reliable scientific data. And the existence of varieties of voluntary people who have been working together to overcome the disaster and accident has been giving me energies to go ahead. I have been lazy to think risks deeply and to go beyond experience-based engineering. I am happy if I can express my sincere gratitude by returning something good to the society.

Information Sources (in English)

<Earthquakes and Tsunami>

*Japan Meteorological Agency

<http://www.jma.go.jp/jma/indexe.html>

http://www.jma.go.jp/jma/en/2011_Earthquake.html

*Geospacial Information Authority of Japan(partially in Japanese)

http://www.gsi.go.jp/BOUSAI/h23_tohoku.html

<Status of Nuclear Reactors>

<http://www.nisa.meti.go.jp/english/index.html>

<http://www.jaif.or.jp/english/>

<http://www.tepco.co.jp/en/press/corp-com/release/index-e.html>

<Radiation Levels> Radiation Levels around the plant

http://www.mext.go.jp/english/radioactivity_level/index.htm

http://www.mext.go.jp/english/radioactivity_level/detail/1303962.htm

<Assistances>

*NHK Radio provides quake-related broadcast in 18 languages

<http://www3.nhk.or.jp/nhkworld/english/radio/program/index.html>

*Assistance Manual for Foreigners in Times of Disaster by TICC

<http://www.tokyo-icc.jp/english/information/howto.html>

*Transportation

http://www.mlit.go.jp/page/kanbo01_hy_001411.html

*Damage Situation and Police Countermeasures associated with 2011Tohoku district - off the Pacific Ocean Earthquake

http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf

*Health Guidance

<http://www.bloomberg.com/news/2011-03-14/understanding-risk-of-radiation-poisoning-in-japan-questions-and-answers.html>

*List of nationwide activity concentration

<http://atmc.jp/>

*Radioactive material level in tap water in Tokyo/day

http://ftp.jaist.ac.jp/pub/emergency/monitoring.tokyo-eiken.go.jp/monitoring/w-past_data.html

*Japanese Society of Nuclear Medicine

<http://www.jsnm.org/japanese/11-03-28>

<http://www.scj.go.jp/ja/info/jishin/pdf/m-110325.pdf>

<http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-21-kanji-2e.pdf>

<Information Service>

<http://cryptome.org/eyeball/daiichi-npp/daiichi-photos.htm>