EXHIBIT 5

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MISSION REPORT

THE GREAT EAST JAPAN EARTHQUAKE EXPERT MISSION

IAEA INTERNATIONAL FACT FINDING EXPERT MISSION OF THE FUKUSHIMA DAI-ICHI NPP ACCIDENT FOLLOWING THE GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP, Japan

24 May – 2 June 2011

IAEA MISSION REPORT

DIVISION OF NUCLEAR INSTALLATION SAFETY

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY

REPORT

THE GREAT EAST JAPAN EARTHQUAKE
EXPERT MISSION

IAEA INTERNATIONAL FACT FINDING EXPERT MISSION OF THE FUKUSHIMA DAI-ICHI NPP ACCIDENT FOLLOWING THE GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

REPORT TO
THE IAEA MEMBER STATES

Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP, Japan

24 May – 2 June 2011

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Mission date: 24 May – 2 June 2011

Location: Tokyo, Fukushima Dai-ichi, Fukushima Dai-ni and Tokai Dai-ni, Japan

Facility: Fukushima and Tokai nuclear power plants

Organized by: International Atomic Energy Agency (IAEA)

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Issue Date: 16 June 2011

REPORT

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CONTENTS

ACRONYMS

AC	Alternate Current
BAF	Bottom of Active Fuel
BWR	Boiling Water Reactor
DC	Direct Current
EDG	Emergency Diesel Generator
EPR	Emergency Preparedness and Response
EPREV	Emergency Preparedness Review
FAO	Food and Agriculture Organization
HPCI	High Pressure Coolant Injection
IAEA	International Atomic Energy Agency
IC	Isolation Condenser
ICRP	International Commission on Radiation Protection
IEC	Incident and Emergency Centre
IRRS	Integrated Regulatory Review Service
ISSC	International Seismic Safety Centre
LPCI	Low Pressure Coolant Injection
MAAP	Modular Accident Analysis Programme
MUWC	Makeup Water Condensate
NISA	Nuclear Industrial Safety Agency
NPP	Nuclear Power Plant
NSC	Nuclear Safety Commission
OECC	On-site Emergency Control Centre
PSA	Probabilistic Safety Assessment
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel
SAMG	Severe Accident Management Guidelines
SFP	Spent Fuel Pool
SRV	Safety Relief Valve
SSC	Structures, Systems and Components
TAF	Top of Active Fuel
TEPCO	Tokyo Electric Power Company

1. INTRODUCTION

1.1. BACKGROUND

The “2011 Off the Pacific Coast of Tohoku Earthquake” occurred at 05:46 UTC (14:46 JST) on 11 March 2011. The magnitude (M_w) of the earthquake was 9.0. Extreme vibratory ground motion and tsunami were generated from this large earthquake. These caused massive devastation with 15 391 lives lost and 8 171 people still missing.

Because of the widespread disaster caused by this large earthquake, it is called the Great East Japan Earthquake. The hazard of severe vibratory ground motion and tsunami hit five nuclear power plant (NPP) sites in the North Eastern coast of Japan — Higashi Dori, Onagawa, Fukushima Dai-ichi (1F), Fukushima Dai-ni (2F) and Tokai Dai-ni. A sequence of events initiated by the earthquake led to the severe accident at the Fukushima Dai-ichi NPP site.

The epicentre of the earthquake was located at 38.1N and 142.9E (130 km ESE off Ojika Peninsula), at a focal depth of 24 km on the subduction zone between the North American plate and the Pacific plate. The earthquake is estimated to have originated from the rupture of a subduction zone area having a length of more than 400 km and width of about 200 km. The main shock was preceded by a strong motion foreshock and followed by a number of aftershocks over a long period. Table 1.1 contains information on the foreshock and some of the aftershocks (magnitude greater than or equal to 7.0) that occurred shortly after the main shock. Large tsunamis were created by the earthquake. Tsunamis were observed to be more than 8.5 m at Miyako, 8.0 m at Ofunato and 9.3 m at Soma. The maximum tsunami height was 38.9 m in Aneyoshi, Miyako.

The location of the five power plants site vis-à-vis the epicentre of earthquake is shown in Fig. 1.1. All sites have NPPs of the boiling water reactor (BWR) type. There is one BWR-5 reactor of 110 MW(e) in Higashi Dori. The Onagawa site has one BWR-4 reactor of 524 MW(e) capacity and two BWR-5 of 825 MW(e) capacity. Fukushima Dai-ichi has the largest number of reactors among the five sites. Six reactors are located on this site: Unit 1 (BWR3) 460 MW(e), Units 2, 3, 4 and 5 (4-BWR4) 784 MW(e), and Unit 6 (BWR5) 1100 MW(e). There are four units of BWR5 reactors each having 1100 MW(e) capacity at the Fukushima

Dai-ni site. Tokai Dai-ni has one operating BWR-5 unit of 1100 MW(e) capacity. Pictorial views of Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP are given in Figs 1.2, 1.3 and 1.4 respectively.

At the time of the earthquake, all the reactors were in operation except the one unit of Higashi Dori and Units 4, 5 and 6 of Fukushima Dai-ichi NPP. The earthquake caused automatic shutdown of all the operating units. Large tsunamis caused by this earthquake hit all the five sites within an hour of the main shock and caused damage at several sites. The status of the NPP reactors is summarized in Table 1.2.

The worst affected sites were Fukushima Dai-ichi and Fukushima Dai-ni. Fukushima Dai-ni lost some safety related equipment but off-site and on-site power remained available albeit somewhat degraded. On the other hand, Fukushima Dai-ichi lost much of its safety related equipment from the tsunami and all off-site and on-site power except for one diesel serving Unit 6. This led to a loss of cooling for the reactors of Units 1, 2 and 3 and the spent fuel pools (SFP) of Unit 4. In addition, cooling for other safety related equipment was unavailable or inaccessible. All these resulted in accident conditions at four units of Fukushima Dai-ichi NPP.

The International Seismic Safety Centre (ISSC) of the International Atomic Energy Agency (IAEA) received information about the earthquake on 11 March 2011 through its “External Event Notification System” within about half an hour. The ISSC promptly conveyed the information to the IAEA Incident and Emergency Centre (IEC).

The Japanese authorities subsequently informed the IAEA about the event. The IAEA has been in constant contact with the Government of Japan and disseminating information to Member States on a regular basis since that time. The IAEA Director General, Yukiya Amano, called for a robust follow-up action. The IAEA has been collaborating with the Government of Japan in sharing information about the status of the damage at the nuclear power plants and its effect on the surrounding areas. As immediate assistance, the IAEA sent seven expert teams to Japan, including a joint IAEA/FAO team on food monitoring to coordinate information sharing on radiation and environmental monitoring, on boiling water reactors and on marine environment monitoring.

Since late March 2011, the Government of Japan and the IAEA were engaged in consultations over sending a fact finding expert mission to explore the impact of the earthquake and tsunami on several of Japan's NPPs, including Fukushima-Dai-ichi. The Government of Japan and the IAEA agreed to send to Japan a mission comprising international experts together with IAEA staff in order to provide a preliminary assessment of the accident at Fukushima Dai-ichi and recommend areas that need further exploration. The Mission was one of the initial activities of the IAEA and would be followed by other missions as well as relevant international cooperative activities including further information exchange. These future activities may include facilities not covered by the scope of the present Mission and would comprise technical studies, discussions with the participation of relevant Member State institutions, and the organization of international, regional and national workshops and training courses. Covering the areas of external hazards and structural response, safety assessment and management of severe accidents, and monitoring, emergency preparedness and response, the IAEA could support the development and incorporation of the lessons learned from different issues identified by this and subsequent relevant missions.

The findings of the Mission are being shared with the international community to assist in identifying the lessons learned and their incorporation into the global nuclear safety structure. In this connection, the Director General informed IAEA Member States that an IAEA Ministerial Conference on Nuclear Safety will be held from 20 to 24 June 2011, in Vienna. The more specific objectives of the Conference are the following:

- To provide a preliminary assessment of the Fukushima Dai-ichi NPP accident;
- To assess national and international emergency preparedness and response levels in light of the Fukushima Dai-ichi NPP accident, with a view to strengthening them;
- To discuss safety implications and identify those areas of safety which may be reviewed with the aim of strengthening them through launching a process to that effect;
- To identify lessons learned and possible future actions.

The findings of the Mission will be reported to the Ministerial Conference.

TABLE 1.1. FORESHOCK, MAIN SHOCK, AFTERSHOCKS AND ASSOCIATED EVENTS OF THE 2011 OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE

Shock	Date	Location		Magnitude
		Epicentre	depth	
Foreshock	9 Mar. 11:45 (JST)	N38d20m, E143d17m	8 km	M7.3
Main shock	11 Mar. 14:46 (JST)	N38d06m, E142d52m	24 km	M9.0
Aftershocks	11 Mar. 15:08 (JST)	N39d50m, E142d47m	32 km	M7.4
	11 Mar. 15:15 (JST)	N36d06m, E141d16m	43 km	M7.7
Associated events	11 Mar. 15:25 (JST)	N37d50m, E144d54m	34 km	M7.5
	7 Apr. 23:32 (JST)	N38d12m, E141d55m	66 km	M7.1
	11 Apr. 17:16 (JST)	N36d57m, E140d40m	6 km	M7.0

TABLE 1.2. STATUS OF NPPS AFFECTED BY THE 2011 OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE

NPP	Unit	Type		Capacity (MW(e))	Status		
		CV** type	Safety system		Before earthquake	After earthquake	After tsunami
Higashi Dori	1	Mark I R	BWR-5	1,100	Outage	Cold Shutdown	Cold Shutdown
Onagawa	1	Mark I	BWR-4	524	Operating	Automatic Scram	Cold Shutdown
	2	Mark I	BWR-5	825	Reactor Start	Automatic Scram	Cold Shutdown
	3	Mark I	BWR-5	825	Operating	Automatic Scram	Cold Shutdown
Fukushima Dai-ichi	1	Mark I	BWR-3	460	Operating	Automatic Scram	Loss of Cooling
	2	Mark I	BWR-4	784	Operating	Automatic Scram	Loss of Cooling
	3	Mark I	BWR-4	784	Operating	Automatic Scram	Loss of Cooling
	4	Mark I	BWR-4	784	Outage	Cold Shutdown	Loss of SFP* cooling
	5	Mark I	BWR-4	784	Outage	Cold Shutdown	Cold Shutdown
	6	Mark II	BWR-5	1,100	Outage	Cold Shutdown	Cold Shutdown
Fukushima Dai-ni	1	Mark II	BWR-5	1,100	Operating	Automatic Scram	Cold Shutdown
	2	Mark II R	BWR-5	1,100	Operating	Automatic Scram	Cold Shutdown
	3	Mark II R	BWR-5	1,100	Operating	Automatic Scram	Cold Shutdown
	4	Mark II R	BWR-5	1,100	Operating	Automatic Scram	Cold Shutdown
Tokai Dai-ni	-	Mark II	BWR-5	1,100	Operating	Automatic Scram	Cold Shutdown

*: Spent Fuel Pool
**: Containment Vessel

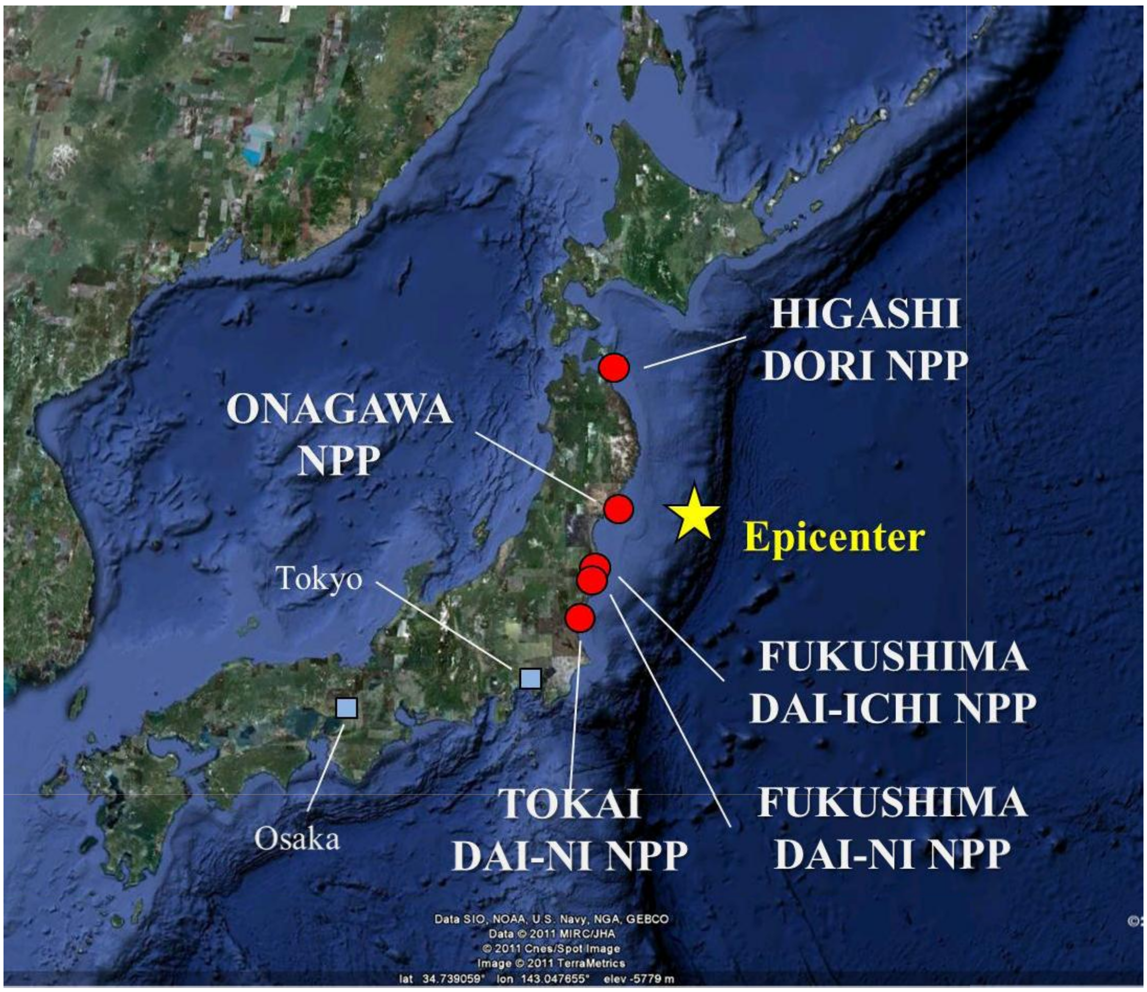
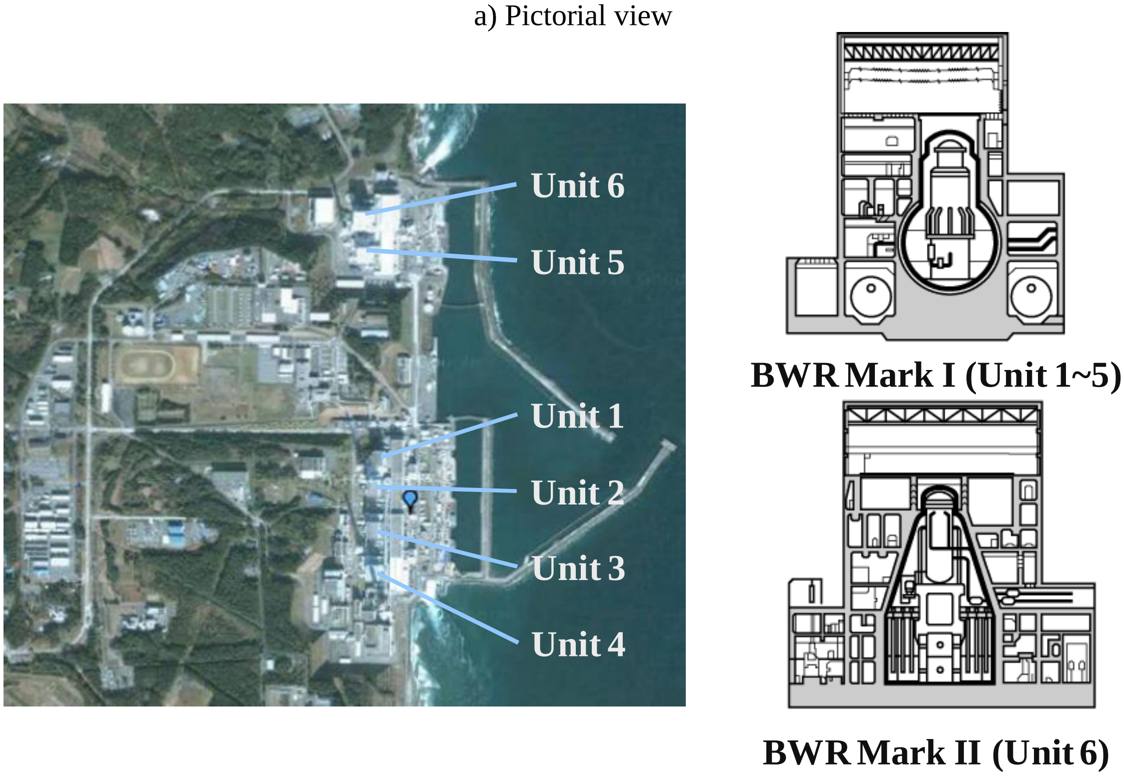


FIG. 1.1. NPP sites affected by the "2011 Off the Pacific Coast of Tohoku Earthquake".

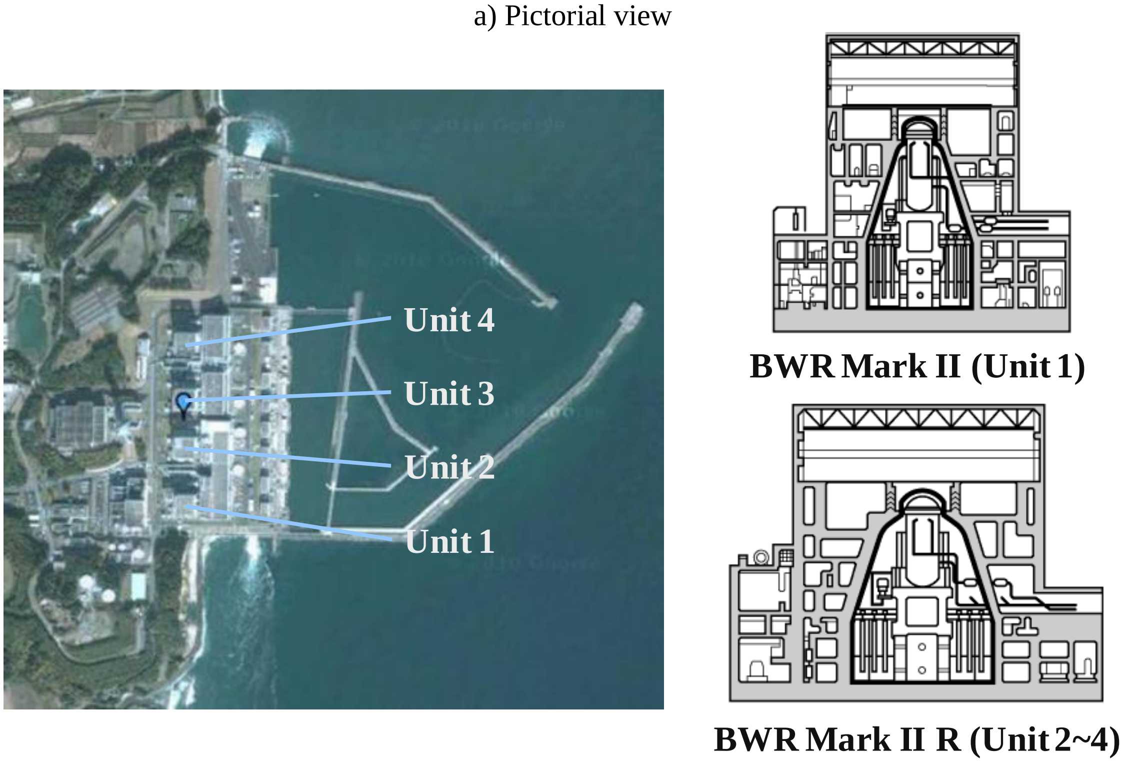
a) Pictorial view



b) Layout

FIG. 1.2. Fukushima Dai-ichi NPP.

a) Pictorial view

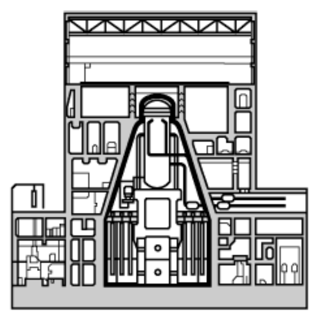


b) Layout

FIG. 1.3. Fukushima Dai-ni NPP.

a) Pictorial view

b) Layout



BWR Mark II (Unit 1)

FIG. 1.4. Tokai Dai-ni NPP.

1.2. OBJECTIVE OF THE MISSION

The Mission conducted a fact finding activity for a preliminary assessment of the accident (in particular at the Fukushima Dai-ichi NPP (1F)). The Mission also collected information on the Fukushima Dai-ni (2F) and Tokai Dai-ni (T2) NPP sites located in Fukushima Prefecture and in Ibaraki Prefecture respectively to make a preliminary assessment of the generic safety issues associated with the natural events and the identification of issues that need further exploration or assessment based on IAEA Safety Standards.

The Mission received information on the progress reached to date on the Japanese assessment of the accident and discussed specific technical issues to develop an informed assessment of the accident for sharing with the international nuclear community.

1.3. SCOPE OF THE MISSION

The scope of the Mission, while focusing on overall nuclear safety issues, covered the following specific areas:

a. External events of natural origin;

b. Plant safety assessment and defence-in-depth;

c. Plant response after an earthquake and tsunami;

d. Severe accident;

e. Spent fuel management under severe facility degradation;

f. Emergency preparedness and response; and

g. Radiological consequences.

The Government of Japan provided the Mission Team with all relevant information it had readily available at the time of the Mission.

1.4. CONDUCT OF THE MISSION

The Mission was conducted through discussions with the counterparts and observations made during the visit to the sites.

The official language of the Mission was English and Mission documents were prepared and finalized in English. The documents summarize the studies and inspections performed and the results obtained, and recommend future actions.

The Mission consisted of meetings at offices in Tokyo and a two-day visit to the Fukushima Dai-ichi, Fukushima Dai-ni and Tokai Dai-ni sites.

Courtesy visits were paid to various Ministers.

The meetings over the first two days in Tokyo addressed the general safety issues listed under Section 1.3. Presentations by the Japanese counterparts during these meetings included the requirements, regulations and procedures pertaining to the issues addressed in this report.

The visits to the sites included question and answer sessions in which the Japanese counterparts provided detailed answers to the questions of the Mission Team.

The Mission Team was divided into the three following groups:

1. External Hazards Group — comprising experts on the assessment of external hazards of natural origin and plant response. They interacted with the Japanese experts on assessment of hazards of natural origin and their incorporation in design, and on the response of the plants, including structures, systems and components, against the hazards.

2. Safety Assessment and Management Group — comprising experts in the area of safety assessment, of severe accident and management, and defence-in-depth analysis. The team held discussions with the Japanese experts on the response of plant systems after the events, severe accident management, defence-in-depth and fuel pool cooling after severe plant degradation.

3. Monitoring, Emergency Preparedness and Response Group — comprising experts in the areas of emergency preparedness and response (EPR), and of radiological consequences. They addressed the plant specific protective actions taken and reviewed the details of the governmental infrastructure and communication along with the radiological consequences of the accident.

The experts attended multiple presentations to address cross-cutting issues. The meetings of the groups were held in parallel following the site visits in order to gain as much information as possible from the Japanese experts prior to the finalization of the Mission Report, including the development of conclusions and lessons learned. Press contacts with the Mission leader were arranged, as appropriate. The Mission was conducted by a team of international experts and IAEA staff. The list is given on page iii and iv of this report.

2. SEQUENCE LEADING TO THE FUKUSHIMA DAI-ICHI NPP ACCIDENT

2.1 FUKUSHIMA DAI-ICHI NUCLEAR POWER STATION

The Fukushima Dai-ichi site NPP has six BWR reactor units. Unit 1 is a BWR-3 reactor with a Mark I containment, Units 2–5 are BWR-4 reactors with Mark I containments, and Unit 6 is a BWR-5 reactor with a Mark II containment. At the time of the earthquake, Units 1–3 were operating and Units 4–6 were in refuelling/maintenance outages. In response to the earthquake, Units 1–3 automatically scrammed (shutdown). All six off-site power lines were lost as a result of the earthquake and all 12 of the available plant's emergency diesel generators (EDG) started. The site has 13 EDGs but one had been taken out of service for maintenance. About 46 minutes after the earthquake, the first tsunami wave hit the site. It was followed by several additional tsunami waves leading to the inundation of the site. The resulting ground acceleration at Units 1, 4 and 6 did not exceed the standard seismic ground motion, whereas at Units 2, 3 and 5, the resulting ground acceleration did exceed the standard seismic ground motion. The tsunami exceeded the design basis at all units. The standard seismic ground motion was established for each unit for the purpose of a seismic back check based on the Seismic Design Review Guideline revised in 2006.

The extent of flooding was extensive, completely surrounding all of the reactor buildings at the Fukushima Dai-ichi site. The tsunami caused the loss of all nine available EDGs cooled by sea water and the loss of all but one of the three EDGs cooled by air. The air-cooled EDG at Unit 6 was the remaining source of AC power at the six-unit site. Workers were temporarily evacuated from the site as a result of several after-shocks and accompanying tsunami alerts. On the entire site, no means of communication between the On-site Emergency Control Centre (OECC) and on-site personnel executing recovery actions was available. Only one wired telephone was available between the OECC and each control room. The seawater pumps and motors located at the intake were totally destroyed so the ultimate heat sink was lost.

Core Damage Progression of Units 1–3

With the loss of all AC power, all safety and non-safety systems driven by AC power became unavailable. At Units 1 and 2, the 125 V DC batteries were flooded, so no instrumentation and control was available, thereby hampering the ability of the operators to manage the plant conditions. No lighting was available in the main control rooms in either unit. At Unit 3, DC power and, in turn, main control room lighting and instrumentation and control systems, were available for 30 hours but were lost once the batteries drained, as the battery charger was flooded and AC power was not available. During the initial response, work was conducted in extremely poor conditions, with uncovered manholes and cracks and depressions in the ground. Work at night was conducted in the dark. There were many obstacles blocking access to the road such as debris from the tsunami and rubble that was produced by the explosions that occurred in Units 1, 3 and 4. All work was conducted with respirators and protective clothing and mostly in high radiation fields. All three units experienced severe core damage but during the Mission no further detail was provided. The system response described below is preliminary and lacks a number of details in many areas. It is likely that the description will be changed once TEPCO can obtain more information and analyse it.

Some systems were available to cool the cores in Units 1–3 after the earthquake. In Unit 1, the Isolation Condenser (IC) is designed to operate through gravity driven natural circulation of coolant from the reactor pressure vessel (RPV) through a heat exchanger immersed into a large tank of water in the reactor building at an elevation above the core. The Unit 1 IC was designed to have a decay heat removal capacity of about 8 hours. A valve must be manipulated to bring the IC into service. It was started at 14:52 on 11 March after the earthquake. Although unconfirmed it appears to have operated for about 11 minutes and was then manually shutdown at 15:03 because the RPV temperature was dropping rapidly. This action is consistent with the plant operating procedures which direct the operator to control the IC so that the RPV temperature reduction rate does not exceed 55°C per hour. After the tsunami, at about 18:18, the IC was started by manually opening the DC powered valve as it is located outside of containment. At about 18:25 the valve was closed. It was then reopened at 21:30. Steam generation was confirmed in the IC pool after the valve was opened at 18:18 and 21:30, so it appears that heat was being removed from the core to the IC pool during these periods. The IC was the only system available to cool the core during this period and it eventually failed. TEPCO is further investigating the failure of the IC and operator actions related to its operation during this period.

As designed, the Reactor Core Isolation Cooling (RCIC) systems in Units 2 and 3 utilize a pump which is driven by a turbine that takes steam from the RPV. The turbine exhaust steam is discharged to the suppression pool. The RCIC systems are limited to operation when the steam pressure in the RPV is above a certain pressure rating. In order to start the RCIC systems, valves must be realigned. Some are operated with AC power and some are operated with DC power. After the earthquake at Fukushima Dai-ichi, the RCIC systems in Units 2 and 3 were manually started and then tripped on a high RPV water level automatically before the tsunami. After the tsunami, the RCIC systems were started at 15:39 and 16:03 in Units 2 and 3, respectively. Conditions indicate that the RCIC system of Unit 2 operated as designed for about three days until 14 March at 13:25, although the actual status could not be confirmed in the control room. The RCIC system in Unit 3 stopped after about 19.5 hours, on 12 March at 11:36, and after an approximately 1 hour delay the turbine-driven high pressure coolant injection (HPCI) system started automatically on a low RPV water level signal and remained operable for about 14 hours. Their failures will be investigated by TEPCO once stable conditions are achieved.

Once the IC in Unit 1, the RCIC system in Unit 2, and the RCIC and HPCI systems in Unit 3 were unavailable, an alternative cooling process had to be established. In Unit 1, the alternate process involved injecting feed from a low discharge pressure fire engine pump through the fire protection and makeup water condensate (MUWC) lines connected to the core spray line. On 11 March at approximately 20:00, the reactor pressure was 6.9 MPa. Once the pressure reading could be taken again on 12 March at 2:45 (the lack of DC power for instrumentation required the use of car batteries so only intermittent readings were available), the pressure was 0.8 MPa. The cause of the depressurization will be investigated once conditions are stable. As a result, the fire engine pump could begin to inject freshwater into the core, and it was initiated at 5:46 on 12 March. Over the next nine hours, approximately 80 tonnes of water was supplied to the core until the water supply ran out. As steam was bled from the RPV to the containment through an unconfirmed pathway, the containment pressure increased and it became necessary to align the valves in order to vent the containment and reduce pressure. Venting requires instrument air as well as AC power. High radiation levels in the reactor building impeded the work. Beginning on the morning of 12 March, the operators attempted to open the valves manually. In the afternoon, an engine driven air compressor (typically used for construction work) and an engine-generator to provide AC power to a solenoid valve were used. At approximately 14:30 on 12 March, the operators confirmed a decrease in the dry well pressure, providing some indication that venting had been successful. Approximately an hour later, the first hydrogen explosion occurred at the site in the Unit 1 reactor building at 15:36 on 12 March. About 3.5 hours after the explosion a means to inject sea water (borated intermittently to ensure subcriticality of the core) was established. This was discontinued on 25 March, once a source of fresh water was secured. Injection using fresh water is now provided through a pump taking suction from a filtered water tank and injecting into the feedwater line. Fresh water is obtained via a piping system that connects the site to a dam located approximately 10 km away. Measures have been taken to inert the containment with nitrogen.

The alternative cooling process used in Units 2 and 3 involved feeding water to the RPV using a fire engine pump injecting sea water, which was borated intermittently, and bleeding the steam to the suppression pool through the safety relief valves (SRVs). This "feed and bleed" process essentially moves heat from the core to the containment and therefore the suppression pool temperature increases as does the pressure of the wet well. Since the ultimate heat sink was lost, venting from the containment was used to reduce pressure, as discussed below.

After RCIC failed in Unit 2, approximately six hours elapsed until an alternative injection source could be established using a fire engine pump injecting sea water. The RPV pressure was reduced using the SRVs to allow injection, due to the low discharge pressure of the fire engine pump. Several attempts were made to open the SRVs, which require both DC power and adequate nitrogen pressure in the valves' accumulators to assist in the manipulation of the valve. The operators tried to open several valves using a car battery as the DC power source but the nitrogen pressure in the valves' accumulators was insufficient to either open the valves or keep them open. A valve was eventually opened and the RPV pressure was reduced. A nitrogen cylinder was used to maintain a vent path through the SRVs. About 9197 tonnes of sea water was injected between 14 March and 26 March through the fire protection and MUWC lines connected to the low pressure coolant injection (LPCI) lines. LPCI is one mode of the residual heat removal (RHR) system. At one point, the injection was temporarily discontinued when the truck ran out of fuel. After 26 March, a fresh water source was established similar to that of Unit 1.

Alignment of the valves to vent the Unit 2 containment was carried out on 13 March by opening an air operated valve using an air cylinder and another valve with AC power supplied by an engine generator. After the Unit 3 explosion, discussed below, the valve was rendered inoperable. The operators then attempted to open another air operated valve to establish the vent path. An engine driven air compressor and AC power supplied by an engine generator were used and the valve appeared to open slightly. However, the successful venting of the Unit 2 containment could not be verified.

After the HPCI failed in Unit 3 on 13 March, approximately seven hours elapsed until an alternative injection source could be established. The RPV pressure was reduced through steam discharge through one of the SRVs into the suppression pool. The accumulator of the SRV contained adequate nitrogen pressure so the SRV could be opened with car batteries. Once pressure was reduced, injection of water was established using a fire engine pump injecting through the fire protection and MUWC lines connected to the LPCI (one mode of the RHR system) lines. Boron was added intermittently. The suction of the pump was changed to a pit filled with sea water at one point temporarily interrupting injection for a short time, on the order of minutes. A further interruption occurred for two hours. Once restarted, a total of 4495 tonnes of sea water was injected from 13 March until 25 March, at which time a fresh water source was established similar to that of Unit 1.

Alignment of valves to vent the Unit 3 containment was begun on 13 March at approximately 8:41 using air cylinders and an engine generator. Several attempts were made to open the valves and at 9:20 successful venting was confirmed by the decrease in dry well pressure; however, due to the leakage of air, an engine driven air compressor was finally used to provide the required air pressure. At 11:01 on 14 March, a hydrogen explosion occurred in the Unit 3 reactor building resulting in substantial damage. At approximately 6:00 on 15 March, an explosion occurred in the Unit 4 reactor building. Since the spent fuel in the Unit 4 spent fuel pool appears to have been covered with water precluding the generation of hydrogen, the source of flammable gas is unclear. A potential source is hydrogen in the Unit 4 reactor building backflowing from the Unit 3 standby gas system lines through the vent lines of Unit 4. Units 3 and 4 share a common header that vents to the exhaust stack. This is not confirmed. Plans have been made to inert the Unit 3 containment with nitrogen in the future.

MAAP Calculations of the Unit 1-3 Core Degradation Sequence

TEPCO has performed a simulation of the accident using the Modular Accident Analysis Programme (MAAP) code. The information below is only an estimate of the core behaviour.

Based on the calculation, assuming an estimated injection rate, the top of active fuel (TAF) was reached in Unit 1 about three hours after the plant trip. The core was completely uncovered two hours later. Core damage is calculated to have begun four hours after the trip and a majority of the fuel in the central region of the core was melted at 5.3 hours after the trip. At 14.3 hours after the trip, the core was completely damaged with a central molten pool and at 15 hours after the trip, all fuel had slumped to the bottom of the vessel. Although the calculation shows that the RPV is severely damaged, measured data show much cooler temperatures. Due to the uncertainty in the instrumentation at Dai-ichi, the state of the vessel is unknown.

The calculation of the accident progression of Unit 2 is based on an assumed seawater injection rate such that the reactor water level was maintained at about the midpoint of the active fuel as measured by the instrumentation available during the event. The calculation shows that when the RCIC system was available, the water level was maintained well above the TAF. Once RCIC was lost and the system was depressurized the water level dropped to the bottom of active fuel (BAF) about 76 hours after the trip. Seawater injection was initiated and according to the instrumentation, the water level remained at the midpoint of the active fuel region, leading to a rapid increase in core temperature, reaching the melting point. A molten pool existed in the central region of the core with melted fuel surrounding it at 87 hours after the trip. The molten pool was shown to grow larger by 96 hours and then begin to cool at 120 hours. At one week after the trip, there was a small molten pool surrounded by melted fuel. Due to the uncertainties in instrumentation which gave information about the selection of seawater injection rate, another calculation was performed using a reduced rate. This model shows that the fuel has slumped and in turn the RPV is extremely damaged at 109 hours after the trip. Although the calculation shows that the RPV is severely damaged, measured data show much cooler temperatures. Due to the uncertainty in the instrumentation at Dai-ichi, the state of the vessel is unknown.

The calculation of the accident progression at Unit 3 is based on an assumed seawater injection rate such that the reactor water level was maintained at about 3 m below the TAF, as measured by the instrumentation available during the event. The calculation shows that the core was covered until the RCIC and HPCI systems failed. Once seawater injection was initiated and the water level stayed at around 3 m below the TAF, the temperature of the core increased quickly, reaching the melting point. The extent of fuel melting is less than that of Unit 1. This is presumed to be because the time between failure of the RCIC and start of the HPCI system was smaller than the time of no injection in Unit 1. At 64 hours after the trip, a molten pool smaller than Unit 1 was surrounded by melted fuel, and a week after the scram the molten pool had cooled somewhat. No slumping of the fuel to the bottom of the RPV was predicted. Due to uncertainties in instrumentation which gave information about the selection of the seawater injection rate used in the calculation, another calculation was performed using a reduced injection rate. This case predicts that slumping of the fuel occurs at 62 hours after the scram. Although the calculation of this scenario shows that the RPV is severely damaged, measured data show much cooler temperatures. Due to the uncertainty in the instrumentation at Dai-ichi, the state of the vessel is unknown.

Response of Units 5 – 6 and Site Spent Fuel Storage

Units 5 and 6 are located a distance from Units 1–4, and are at a higher elevation than Units 1–4. They suffered less damage than Units 1–4, although the damage was still severe. As a result of the earthquake all off-site power was lost. As in Units 1–4, the seawater ultimate heat sink was lost as a result of the tsunami, and in Unit 5, all EDGs were lost due to flooding. One air cooled EDG was available at Unit 6 because the air intake louvers were located above the tsunami inundation height. Units 5 and 6 had been shutdown since January 2011 and August 2010, respectively, and the fuel had been reloaded into the core recently, awaiting startup. Though decay heat was much lower than the operating plants, cooling the fuel in the cores was necessary and action was taken to restore the seawater cooling system.

On 12 March, measures were successful to provide AC power to important components of Unit 5 using the Unit 6 EDG. On 13 March, the MUWC system was used to inject coolant into the core, and steam was discharged through the SRVs to the suppression pool. Due to the low decay heat of the fuel, venting of the containment was not necessary. On 19 March, an alternate cooling path to cool the RHR system was established. The RHR pump was powered from the Unit 6 EDG. A temporary pump provided sea water to the RHR heat exchangers using an engine-generator to provide AC power. On 20 March, the core was cooled to cold shutdown levels. Plans are underway to provide more heat removal capacity.

There are seven spent fuel pools (SFPs) at the Fukushima Dai-ichi site. One at each unit and a common SFP located behind Unit 4, which contains older fuel removed from the Units' SFPs. SFPs have a large inventory of water above the TAF, approximately 7–8 m, although at Fukushima some of the water inventory could have been lost as the result of the sloshing from the earthquake. Although dependent on the heat load of the fuel stored in the pool, the large inventory of water typically allows many days before the pool would boil to a level below the TAF. Therefore, immediate action to cool the SFPs was not necessary. Because of the lack of instrumentation and high radiation levels, the water levels in the SFPs of Units 1–4 could not be determined in the first several days of the accident. However, the explosions at the site destroyed the reactor building roofs of Units 1, 3 and 4, providing access to the SFPs. Several options were considered to provide coolant to the SFPs periodically. Both fresh and sea water were used. Two techniques involved the use of a water cannon and dropping a water supply from a helicopter. These techniques were used on the Unit 3 SFP beginning 17 March, and then on the Unit 4 SFP beginning 20 March. The success of these techniques could not be verified. Another technique which involved utilizing existing fuel pool cooling system lines and temporary pumps was used on the Unit 2 SFP beginning 20 March and on the Unit 3 SFP beginning 23 May. Beginning 22, 27 and 31 March, coolant was provided to the Unit 4, 3 and 1 SFPs, respectively, using a concrete pumping truck with a hose secured to a boom lifted to the appropriate height. To determine the status of the SFPs, images were taken of the Unit 3 and 4 SFPs remotely. The images verified the presence of a water level and showed that the fuel appeared to be intact. An extensive amount of debris generated by the explosion in Unit 3 had fallen into the Unit 3 SFP, so that the structural integrity of the racks could not be confirmed. There was some debris in the Unit 4 SFP, likely due to the explosion at Unit 4, but the status of the racks and the fuel is reported to be near normal on the basis of present information. At this stage, the concrete pumping truck and boom technique is being applied to the Unit 1 and 4 SFPs. Inventory is being provided to the Unit 2 and 3 SFPs via the fuel pool cooling system lines. Both techniques connect to a header that is fed by a pump taking suction from a large water tank. Fresh water is pumped to the tank from the nearby dam.

Forced cooling was used at the site to cool the Unit 5 and 6 SFPs, using the AC power from the Unit 6 EDG. Forced cooling was established in the common SFP once AC power was provided to the site in late March. Because of its low heat load, no action was necessary earlier in the event.

A dry cask storage building is located adjacent to the Unit 5 turbine building. The building was damaged by the tsunami but the casks appear to be intact. Radioactivity monitoring has been used to determine the status of the fuel. Because no radioactivity release has been detected, the dry casks appear to be unaffected.

2.2 FUKUSHIMA DAI-NI NUCLEAR POWER STATION

The Fukushima Dai-ni site has four BWR-5 reactors with Mark II containments. At the time of the earthquake, all four units at Fukushima Dai-ni were operating. In response to the earthquake, all four units automatically scrammed (shutdown). One off-site power source remained operable, while the other three off-site power sources were either lost or in scheduled maintenance. About 37 minutes after the earthquake, the first tsunami wave hit the site followed by several additional tsunami waves, leading to the inundation of the site. Workers were temporarily evacuated from the site as a result of several aftershocks and accompanying tsunami alerts, which hindered recovery actions. The maximum acceleration of the earthquake was less than the standard seismic ground motion for each unit. However, the tsunami was much greater (inundation height of approximately 6.5–7 m) than the reference tsunami level of 5.2 m. The reactor buildings and the turbine buildings are at an elevation of 12 m, and although the run-up wave of the tsunami that reached this elevation caused partial flooding of these buildings, the extent of flooding was less than at Fukushima Dai-ichi.

The tsunami waves flooded the heat exchanger building, the seawater pumps and electric power centres, which caused the loss of core cooling functions and pressure suppression functions in three of the four units. The run-up wave that reached the reactor building of Unit 1 flooded its EDGs. Unit 3 was the least affected and was able to reach cold shutdown the day after the earthquake.

Because the extent of damage caused by the tsunami was not as great as at Fukushima Dai-ichi, the plant superintendent had more options for dealing with the effects of the tsunami. The plant operators were able to continue to provide water to the reactor cores with the RCIC and MUWC system, and to manually depressurize the reactors. The plant superintendent called for mobile power trucks and mobilized the workers on site to lay more than 9 km of temporary power cables in 16 hours. In addition, replacement motors were procured for some of the flooded pumps. This allowed the normal RHR systems to be returned to service three