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Fukushima Daiichi Nuclear Power Station (NPS)[1]

"Dad, I place my son and wife in your care; please look after them," entreated an operator at Fukushima Daiichi's Central Control Room, via SMS, on March 12, 2011 – a day after the site had been flooded by the tsunami resulting from the East Japan Earthquake.[2] That day, the building lodging the Unit 1 reactor was destroyed by a hydrogen explosion. At the time of the earthquake there were 24 operators scared to death and lost in the blacked-out control room, without any data from the reactors in Units 1 and 2.

When instructed by Prime Minister Naoto Kan to coordinate the police, fire authorities and Self Defense Forces, General Toshinobu Miyajima, the then head of the CRF (Central Readiness Force) – a group specialized in dealing with terrorism and natural disaster emergencies at Japan's Self Defense Ministry – felt desolate at the prospect that eastern Japan, including the Tokyo Metropolitan Area, might be affected irreparably by the nuclear radiation. Simulations personally conducted by him in secret suggested the need for an ever-expanding evacuation zone.[3]

In fact, two weeks after the accident, on March 25, a report was submitted to the prime minister estimating the worst-case scenario (see **Exhibit 1**). In his 20-page report on Fukushima Daiichi, Shunsuke Kondo, the author and head of the Atomic Power Committee at the Cabinet Office, identified the loss of cooling capability at the Unit 1 reactor as being caused by a lack of electricity, hydrogen explosions in the Unit 1, 3 and 4 reactors, and a meltdown in the Unit 2 reactor. The cooling of the reactors was being carried out through the injection of seawater.

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[1] Unless otherwise indicated, this case study draws on the report by the Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident – abbreviated as the "Independent Panel" (2012). The Independent Panel was organized by the Rebuild Japan Initiative Foundation.

[2] http://www.asahi.com, accessed on December 28, 2011.

[3] http://www.mainichi.jp, accessed on December 31, 2011.

This case was prepared by Professor Kimio Kase, Professor Ikujiro Nonaka from Hitotsubashi University, and Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident, as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation. May 2012.
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In the worst-case scenario, it was believed that further hydrogen explosions in any of the Unit 1 to 3 reactors would cause the radiation level inside the power station to shoot up, and the fuel bars inside the Unit 4 reactor pool would melt due to the cooling operations being interrupted. This would: (1) increase the level of radiation in soil within a 170 km radius from the station to 1.48 million Bq (becquerels[4]) per square meter – equivalent to the evacuation standard in the case of Chernobyl; and (2) consequently make it necessary to evacuate all inhabitants of Tokyo, as well as those of Yokohama, located within a 250 km radius of Fukushima.[5]

Media around the world, initially shocked at the magnitude of the catastrophe brought on by the earthquake that hit eastern Japan on March 11, 2011, kept the world on tenterhooks by broadcasting the increasingly alarming news that a nuclear power station[6] in the affected area had been flooded, and that an immeasurable disaster was taking place on the site.

What happened? And how did Japan and its people attempt to cope with this unprecedented catastrophe?

Fukushima Daiichi NPS

The Fukushima Daiichi NPS[7] consists of six light water boiling water reactors (BWR[8],[9]), driving electrical generators with a combined power of 4.7 GW, making it one of the 25 largest nuclear power stations in the world.

Unit 1 is a 439 MWe-type [...] reactor [...]. It commenced commercial electrical production on March 26, 1971 [...], designed for a peak ground acceleration of 0.18 g (1.74 m/s^2), and a response spectrum based on the 1952 Kern County earthquake. Units 2 and 3 are both 784 MWe-type BWR-4 reactors [...] [commissioned] in July 1974 and [...] in March 1976 [respectively]. The earthquake design basis [...] ranged from 0.42 g (4.12 m/s^2) to 0.46 g (4.52 m/s^2)[...].

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[4] The SI unit of radioactivity, equal to one disintegration per second (symbol Bq) (Shorter Oxford Dictionary).

[5] http://www.maichin.jp, accessed on December 24, 2011.

[6] Japan has 17 commercial-use nuclear power stations totaling 54 reactors (48.85 million kW), of which 30 are BWR-type and 24 are PWR-type (Kamoshita, 2011).

[7] Based on the Investigation Committee (2012) and http://en.www.wikipedia.org/wiki/fukushima_daiichi_nuclear_disaster, accessed on January 21, 2012.

[8] "The boiling water reactor (BWR) is a type of light water nuclear reactor used for the generation of electrical power. It is the second most common type of electricity-generating nuclear reactor after the pressurized water reactor (PWR), also a type of light water nuclear reactor. The main difference between a BWR and PWR is that in a BWR, the reactor core heats water, which turns to steam and then drives a steam turbine. In a PWR, the reactor core heats water, which does not boil. This hot water then exchanges heat with a lower pressure water system, which turns to steam and drives the turbine. The BWR was developed by the Idaho National Laboratory and General Electric in the mid-1950s. The main present manufacturer is GE Hitachi Nuclear Energy, which specializes in the design and construction of this type of reactor."
http://en.wikipedia.org/wiki/Boiling_water_reactor, accessed on April 16, 2012.

[9] Whereas BWR-type reactors have a simpler structure, driving turbines within the reactors make the handling of radioactive materials more difficult, since the turbines and their vicinity are contaminated by radiation; PWR, on the other hand, drives turbines outside the reactor vessel, which means that handling of radiation is easier, but its structure is more complicated because of the need to supply a steam generator for the secondary cooling water.

> Units 1 - 5 have a Mark 1-type [...] containment structure; Unit 6 has a Mark 2-type [...] containment structure [...].[10]

These details are shown in Table 1.

Table 1
Units at Fukushima Daiichi NPS

			Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
	Output (thousand kW)		460	784	784	784	784	110
	Construction started in		xi-1967	v-1969	x-1970	ix-1972	xii-1971	v-1973
	Commissioned in		iii-1971	vii-1974	iii-1976	x-1978	iv-1978	x-1979
	Reactor type		BWR-3			MWR-4		
	Main contractor		GE	GE-Toshiba	Toshiba	Hitachi	Toshiba	GE-Toshiba
Nuclear	Heat output (thousand kW)		1,380	2,381				
Reactor	No. of fuel rod sets		400	548				
		kPa gage	427			427		310
		°C	140	140	140	140	138	D/W 171
								S/C 105

Source: Independent Panel (2012), p. 23.

March 11

The Earthquake

On March 11, 2011, at 2:46 p.m., the Pacific Coast area of northeastern Japan was hit by an earthquake with a magnitude of 9.0 – the largest ever recorded in Japan. Afterwards, tsunamis struck that part of Japan in a series of seven waves inundating 561 km^2. According to reports, as of June 2011, 25,000 people have been killed or are missing on account of the earthquake and tsunamis.[11]

Tsunami Hit

On the day the earthquake hit,

> "a total of six external power supply sources had been connected to the Daiichi Power Station [...]. However, all power supplied from these six lines stopped due to the damage to the breakers, etc., [...] due to the earthquake" (Nuclear Emergency Response Headquarters, 2011).

In Units 1 - 6 the external power supply was lost after the earthquake, which made the fail-safe mechanism work. This closed the steam isolation valve, which enabled the isolation of the nuclear reactors from turbines.

After control rods were inserted and the main steam isolation valve shut, water was injected into Units 1 - 3.

[10] Investigating Committee on the Accidents at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (2011).

[11] Wikipedia, http://en.wikipedia.org, accessed 2012.

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