ONE

Station Blackout

"WE'RE IN TROUBLE! WE'RE BEING INUNDATED WITH SEAWATER!"

2:46 P.M., MARCH 11, 2011. The Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Station.

At the time, there were twenty-four employees in the Central Control Room that managed the Unit 1 and Unit 2 reactors. The Central Control Room was the size of about two classrooms. The stainless steel, moss-green walls were crammed with instrumentation.

"460,000 kilowatts."

That number was displayed on a large digital panel on the Unit 1 side. It was the output generated by Unit 1.

The Central Control Room was situated in the Control Wing, which was attached in hinge-like fashion to the Unit 1 and Unit 2 turbine buildings. Outside were the reactor buildings. Behind them were the radioactive waste treatment buildings for the Unit 1 and Unit 2 reactors.

There was not a single window connecting the room to the outside world. The instruments lining the wall shook with a creaking sound.

"Is that an earthquake?!"

The shaking became even stronger. The operations manual and documents flew from the desk of Ikuo Izawa (age 52), the duty manager of Unit 1 and Unit 2 Central Control Room, and scattered all over the floor.

The operators could not remain on their feet. They held on to the levers attached to the control panel. The levers were mounted so that they could still be operated and not shaken loose by an earthquake. Some of the operators sat down on the floor still clinging to the levers.

The shaking stopped after a little while. Red alarm lights started to

flash. It was not just the red lights. White lights, orange lights, everything started to light up like a Christmas tree. Next came the fire alarm.

Izawa remembered an operator who worked in the control room of the TEPCO Kashiwazaki-Kariwa Station at the time of the 2007 Chuetsu earthquake, who said the fire alarm had been triggered by a mere flurry of dust in the control room.

"Try resetting it."

The alarm stopped ringing when one of the staff reset it. Apparently, there was no fire.

The loud voice of Izawa rang out, "Everyone, calm down! First, check the SCRAM! Don't operate the plant. Don't do anything until the quaking calms down."[1]

When an earthquake strikes, the first thing that has to be done is stopping the fission reaction of the reactor. If this is not stopped, the temperature in the reactor would rise, the fuel would melt, and a large amount of radioactive material would leak out.

In order to stop the fission reaction, rod-like devices called "control rods" were inserted into the reactor. Each control rod was about four meters long. They contained boron. They were inserted between the fuel rods in the reactor to allow the boron to absorb the neutrons and stop a nuclear fission chain reaction.

Following the assistant shift supervisor's instructions, the control panel workers started checking the situation in Units 1 and 2. They were able to ascertain that all control rods had been fully inserted and the two reactors had been automatically scrammed (SCRAM).

Finally, the tremors subsided. An alarm was ringing loudly. After a short time, one of the operators cried out, "Shift supervisor, we've lost external power!"

"Emergency power check." Izawa gave the instruction immediately.

The emergency power was a diesel generator (D/G) that ran on heavy fuel oil in an emergency. Nuclear power plants generated electricity, but several hundred of the devices in the facilities were powered by electricity provided by external transmission lines. This was what had been hit.

"The MSIV is off!"

"Roger, MSIV off!"

The main steam isolation valve (MSIV) was the valve that isolated the main steam going to the turbines from the reactors. Turning it off prevents any radioactive main steam from reaching the turbines and leaking.

Already a loss of electricity meant there was no external power coming in. An operator was soon heard to say, "We've started the D/G! Both A and B are firing up."

They felt a low reverberation inside the Central Control Room. The

emergency diesel generator had started to operate. Up until this point, everything was going according to the operation manual. But it was a very short-lived moment of peace.

A young worker in the Central Control Room shouted out, "D/G trip!"

"What?"

"The D/G has tripped!"

The emergency diesel generator had gone offline. Alternating current (AC) power had already been lost from the quake. If the D/G was down, it meant that they had lost the power to cool the reactors down. If that was so, it meant the situation was hopeless.

One of the workers whispered, "The lights are flickering." The lights on the control room's power panel blinked, then, one by one, went out. The only light that remained was the emergency light for Unit 1. The alarms could no longer be heard and the room was enveloped in a bottomless silence.

The voice of Izawa, the duty manager, rang out, cutting the silence.

"SBO!"

Station blackout—that is, the total loss of AC power. One after the other, the workers all repeated, "SBO! SBO!"

Izawa placed a call to the operational manager at the Emergency Response Center.

"We have SBO. The D/G has failed. The emergency generator is down."

"This makes it a Special Measures [Act on Special Measures Concerning Nuclear Emergency Preparedness] article 10 event. We are currently checking what is functioning."

Izawa was surprised himself at how matter-of-fact he sounded when declaring an article 10 event.

I'm much calmer than during the training drill.

However, the person on the other end of the phone could not say anything but "Ahh!" He appeared to be thoroughly shaken and stunned.[2]

Immediately after that the four operators who had been outside to check the situation came back into the control room in two pairs, shouting at the top of their voices:

"We're in trouble! We're being flooded with seawater!"

"The basement of the turbine building is flooded up to around waist-height!"

"I heard a roaring growl from afar! I'd never heard such a noise before!"

"Seawater came flooding into the basement from the first floor! I managed to come up against the flow!"

All of them were soaked to the skin.

Is it a tsunami? Could a tsunami make it up to here?

This was something they had never imagined.[3]

The first tsunami hit the Fukushima Daiichi Station at 3:27 p.m., and the second and larger sometime between 3:35–3:37 p.m.[4] Ten and thirteen meter–high waves hit the reactor and turbine buildings. The emergency seawater pump installed at four meters above sea level was swallowed up.

The staff who went to see if the Service Building had electricity tried to enter the building, but were trapped in the entrance area. They tried to contact site security, but could not get through.

Water started seeping in from below. They thought it was all over, but an older member of the staff broke the glass from outside and they escaped with their lives just as the water was already up to their chins.

Staff who had gone to the site to restore the electric motor at Unit 2 ran up the stairs in a hurry. From below the ground came a roaring sound the likes of which they had never heard before. Water came suddenly pouring in from the entrance of the Service Building.

For some reason, the door connecting Units 1 and 2 closed, and one person could no longer open it; it required two people pushing on it. The moment it opened, a huge volume of water came surging in. They walked up to their waists in water.

That was when they realized for the first time: *It's a tsunami.*

Another member of the staff emerging from the Service Building saw a tsunami rolling in from the direction of the Unit 4 reactor. It was crashing violently into the steel plates of the water inlet in front of Unit 4, sending up columns of water. It looked like it was higher than ten meters. He froze in his tracks. Looking over to the sea, he saw the breakwaters tumbling down like a pack of dominoes. A construction crane was impaled on one of the pumps. He could hear the endless ringing of car horns below.

The Anti-Seismic Building and the various control rooms were separated by several hundred meters as the crow flies. The twenty- or thirty-meter flight of stairs linked to the Anti-Seismic Building, built on high ground, had been destroyed by a landslide and could not be used. Pipes above the ground had ruptured and water was spewing out in fountains.

The tsunami pounded in. It could well continue its attack. Izawa gathered the operators inside the Central Control Room. Only the emergency light on the Unit 1 side was dimly lit.

"Everyone, listen up. I have no idea what's happening onsite. From now on, we'll follow the rules when going to the site."

Izawa spoke looking them in the eye, one by one.

"You're to get my permission when going to the site, and I'm imposing a two-hour limit. You're not to go alone but in pairs; meaning, you're to move in twos. I want you to stick to this. If you're not back in two hours, I'll send out a rescue. Even if you don't make it to your destination, check

the time, and if it looks like going over two hours, turn back then. And write on the whiteboard the time you set out."

Izawa then looked around at everyone and said, "If you don't follow these rules, then it's your lives on the line. So make sure of it. You've got that, right?"

"Roger that."

"Understood."[5]

Two of the workers headed to Unit 1 and another two to Unit 2 to check for damage to the emergency diesel generators in the turbine building basement. They took the stairs, but by the time they reached the first floor, another tsunami wave had hit. The workers just about managed to run back to the control room soaking wet. Two other young workers in the Unit 4 turbine buildings were not as lucky. They drowned as the waves came crashing in through the parking lot, seeping into all of the surrounding buildings.[6]

The Fukushima Daiichi Nuclear Power Station (NPS) had a two-stage structure from the sea level. The seawater intake and emergency seawater pumps were four meters above the sea level. The reactor buildings, turbine buildings, control buildings, and radioactive waste treatment buildings were located ten meters above sea level.

The operators called them the "4 disk" and "10 disk," respectively. They used to be called the "4M board" and the "10M board," but over time this had evolved into "disk."[7]

Site Superintendent Masao Yoshida had been in his onsite office. Although he could not stay on his feet when the quake struck, he thought, *The plant can withstand it*. He then ran immediately to the Anti-Seismic Building.[8]

The turbine buildings were on the seaside and the reactors toward the hillside. Units 1 through 4 on the Okuma site were painted blue in a seascape motif, while Units 5 and 6 on the Futaba site were decorated in a green mosaic. Blue represented the sea and green the hills. The sales pitch was: "A nuclear plant at one with its environment."

To the southern side of the Unit 4 reactor was a disposal complex for both handling radioactive liquid waste and incinerating solid waste. The entire station with its six reactor units was capable of generating 4.696 gigawatts of electricity (GWe).

There were two unit managers and three deputy site superintendents working under Masao Yoshida, the site superintendent. The operation of the reactor facilities was handled by the TEPCO shift supervisor. Shift supervisor was a career post. Training a full-fledged shift supervisor was said to cost 60 million yen. The shift supervisor acted something like the facility's pilot. Shift supervisors, who reported to the operational manager, were

separated into those in charge of Units 1 and 2, 3 and 4, and 5 and 6. Each shift team consisted of eleven members: a shift supervisor, two assistant shift supervisors, two senior operators, one assistant senior operator, two main equipment shift operators, and four auxiliary equipment shift operators. There were five such teams rostered to operate the reactors around the clock. This meant a nucleus of fifty to fifty-five key personnel.

TEPCO had some 1,100 workers in operations at Fukushima Daiichi NPS. There were a further 2,000 workers from TEPCO-associated companies, who looked after plant manufacturing, fire protection, and site security. At the time of the quake, there was a total of 5,600 workers onsite, of whom 750 were TEPCO employees. The number of associated workers was so large because the quake coincided with a periodical inspection of Units 4, 5, and 6 reactors.

The emergency response center (ERC) was on the second floor of the Anti-Seismic Building. With the earthquake, the room's lights had gone out, only the glowing red light indicating the emergency exit. There were no windows overlooking the site in this room. There were no surveillance cameras, either.

3:37 P.M. One or two minutes had passed since the second tsunami hit.

A report came in via the hotline from the Units 1 and 2 Central Control Room.

"Both the Unit 1 emergency diesel generator and the DC power supply have stopped. We've lost all power! The tsunami is rapidly flooding the building."

Around 3:38 p.m., a hotline report was received, this time from the Units 3 and 4 Central Control Room.

"Both Units 3 and 4 have lost power!"

Around 3:41 p.m., emergency contact was again received from the Units 1 and 2 Central Control Room. A woeful voice reported:

"Unit 2 has also lost all power."[9] Four reactors had now all lost power.

Yoshida was at a loss for words.

What? The D/G is not working?

This is not good. This could be a severe accident. Isn't there any way to get the D/G to function properly again? If that is impossible, it might take hours for the IC and RCIC to cool. If we can't do that, what else can be done . . . ?

The DC power. We will be waiting eight hours for it. Even having said that, because DC power runs on batteries, there is only that capacity. When it does run out, will we be able to charge it? This could well fall under an article 15 for DC power.

Yoshida's thoughts spun around and around the possible scenarios that could unfold.[10]

The operators took out the emergency operating procedures manual that TEPCO had prepared in-house and started to read it by portable battery lights and LED torches.

"Event-based?"

"State-based?"

None of this corresponded to what they were directly facing. An outage of both AC and DC power had not been foreseen.

In the first place, the manuals all assumed that plant information could be ascertained via the instrumentation in the respective control rooms. But those very control rooms were currently in the dark. None of the instruments were showing anything.[11]

Still, the veteran shift supervisor and his team had a mental picture of where everything was on the power panel. They knew by instinct which meter was where even in the dark. In the words of a Toshiba engineer, "They were fellows who knew where even the mouse holes were."[12]

Even for such old hands as these, a total power outage was unimaginable. What's more, a total loss of DC power—also known as a station blackout—had never been conducted in training scenarios. The drills always ended before reaching such a severe point, with an instructor calling out, "Freeze!" Despite all the mayhem, one of the operators turned to Izawa and said, "Isn't this where the instructors say, 'Freeze'?" They both laughed.[13]

3:42 P.M. In accordance with section 1, article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (NEPA), Yoshida reported to the government that a specific event requiring notification (the total loss of all AC power sources) had occurred.[14] This measure was taken after receiving the report from Izawa in the Central Control Room. When Izawa called, he reported that the loss of power supplies and emergency core cooling systems mandated an article 15. Upon hearing this, the person on the other end of the phone in the ERC began to mumble and then fell speechless, Izawa recalls.[15] It had taken staff in the ERC somewhere between thirty minutes to an hour to decide whether to report an article 10 or 15, with article 15 representing the most serious condition: red. Although they had chosen to go with article 10, it was only one hour and three minutes later, at 4:45 p.m., that they would upgrade the incident to an article 15.[16]

By around 3:50 p.m., they were no longer able to read the reactor water level or pressure meters. What was happening inside the reactors? Was the cooling equipment working? They had lost their parameters for identifying this.

The control rooms had lost their five senses.

THE ISOLATION CONDENSER

2:52 P.M., MARCH 11. Let us turn back the clock an hour or so. Units 1 and 2 Central Control Room.

A loud voice reverberated.

"The IC is online."

Unit 1 was equipped with two isolation condenser systems (IC) as an emergency reactor cooling mechanism. This was an appendix-like object attached only to the early types of light-water boiling water reactors (BWR), but in Japan it had been left in Unit 1.

High temperature steam generated in the reactor was cooled by passing through a pipe coil in the IC's cooling water tank located on the fourth floor of the reactor building and condensed into a liquid, flowing back as water into the reactor. The fact that the IC had automatically started meant that steam could now be returned to the reactor as cool water.

After SCRAM took place, the cooling of the reactor core went smoothly. All the operators had to do now was keep switching the IC on and off to gradually lower the temperature of the reactor. The reason it was not left on was to avoid cooling the reactor too rapidly.

Keeping a close eye on the instrument indicating the temperature of the reactor, the operators kept opening and closing the valve of the IC using a lever. The reactor temperature began to fall slowly. Forty minutes after the reactor shutdown, the reactor temperature, which had been close to 300 degrees Celsius when operating, had dropped to about 180 degrees.

The operators were relieved.[17]

However, flooding by the tsunami changed everything. This was because it robbed the plant of both its AC and DC power.

The lever on the IC operation panel was designed to always return to a central position when released after operation. If the valve was open, a red light came on; if it was closed, a green light. Since they had to use the operation lever time and again, they determined its status by the different colored lights.

Those lights had disappeared.

Was the IC valve open or closed, which was it?

The operators could no longer remember. Was the IC working? What about it? Nobody knew.

We can't operate the valve without the display light.

The operators were completely shaken up.[18]

4:44 P.M. Izawa, duty manager in the Central Control Room, was contacted from the Anti-Seismic Building.

"There's steam coming out of the Pig's Nose."

"How much?"

"A puff."

"A puff?"

The Pig's Nose was the two exhaust pipes twenty meters high on the west wall of the Unit 1 Reactor Building. When the IC was working, part of its job was to discharge the steam generated from the IC outside.

Uncertain if the IC was working, Izawa had asked the ERC in the Anti-Seismic Building to check whether steam was coming out of the Pig's Nose. He had heard stories from older operators that when the IC was activated, white steam would gush out of the Pig's Nose.

A worker from the ERC's power generation team had gone out into the parking lot of the Anti-Seismic Building and confirmed steam was coming out of the Pig's Nose.

"The steam's coming out hazily." This was what he had reported.

The ERC interpreted this as "steam is coming out." But Izawa was adamant that the IC was *not* working, because he could not hear the release of steam, which, he had learned in training, was a crucial marker of a working IC. Regardless of this insight, Yoshida and personnel in the ERC were so engrossed in starting the water injection that the IC stoppage failed to catch their attention and remained uncommunicated to senior managers throughout the evening.[19]

The ERC continued to be at the center of communication problems that further strained onsite relations. Tasked with micromanaging onsite conditions and operations, the ERC demanded that all information be passed on to them. Izawa was simply overwhelmed with the sheer volume of data he now had to communicate to the ERC while managing reactor operations at the same time. At one point, an ERC worker questioned Izawa over the phone on how much battery power was left in the control room. "I f****** told you already that we don't have any batteries! I told you that we've lost electrical power! What's wrong with you?" Izawa shouted.[20]

4:56 P.M. The water level in the reactor fell down to 1.9 meters above the top of active fuel (TAF). Top of active fuel serves as the reference point for water-level readings in a reactor; it is the uppermost point in a fuel rod that contains uranium. A few minutes later, the water level gauge again was no longer visible. In the fifteen minutes that the water level gauge had been visible, this worked out to a sixty-centimeter drop.

At 5:15 p.m., in a videoconference connecting TEPCO's Tokyo Head Office and the Anti-Seismic Building, the voice of the person in charge of the technical crew rang out.

"If the Unit 1 drawdown continues at this pace, one hour to TAF!"

It was a shocking prediction. The exposed active fuel would melt, releasing radioactive material.

Is the information about steam coming out of the Pig's Nose a mistake?

Perhaps the IC isn't functioning.

It was only natural to harbor such doubts. However, it had only just been reported by workers from the power generation team that steam was coming out of the Pig's Nose. If steam was coming out, the IC was probably working. But they could not be sure. It was just a guess; it might be just barely working. That was the general conception. Yoshida shared this as well.[21]

No questions were asked about the status of the IC in the videoconference, and no links were made between the falling water level and the IC. Someone took the microphone and shouted, "Entering the Office Building is prohibited!"

Other officials interrupted in rapid succession.

"We can't go to help because seawater has flooded in as far as the seaside bus stop!"

"Suspected fire behind Unit 4 in the light water tank. Smoke has risen about five meters!"

Information on the drop in the water level at Unit 1 had been buried in the avalanche of other reports flooding in.[22]

Izawa sent operators to the field to check if the IC was working. Although he had received a report that steam was coming out of the Pig's Nose, he still was not convinced. It was at this time that the information on the decrease in the Unit 1 water level came in. The only way they could confirm whether the IC was working or not was to verify it directly.

The two ICs, A System and B System, were lined up together on the fourth floor of the reactor building. They decided to examine the water gauge attached to the side of the condensate tank to check the amount of cooling water to see whether it was sufficient. The door of the reactor building was a double door.

5:50 P.M. When the operators tried to open the door, the needle on their dosimeter went off the scale. It was over the 2.5 microsieverts (0.0025 millisieverts) maximum value. They had never seen this high a dose measured outside the double doors. Giving up on going inside, they returned to the Central Control Room.[23]

6:18 P.M. The operators had gathered in front of the control panel in the Central Control Room. The light indicating the status of the IC valve in Unit 1 was dimly lit up. For some reason, some of the batteries flooded by seawater had recovered and some of the instrumentation and lights were once again visible.

"Green."

"Closed."

The IC light was green. The valve was closed. If the valve in the IC piping was closed, that meant that the steam had stopped flowing and the IC was not moving.

"It's not moving. Can we start it up?" Izawa instructed the operator in charge to open the valve using the control panel lever.

"The valve is open. IsoCon startup confirmed."

"Roger that. The time is 18:18."

The operators here referred to the isolation condenser (IC) as IsoCon.

The light had changed from green to red. The IC to cool the Unit 1 reactor had at last started. Approximately two and a half hours had passed since the total power outage at 3:37 p.m.

Izawa ordered the operators to go outside and confirm whether steam was coming out of the Pig's Nose. The operators who had gone out to check came back in a hurry.

"It was billowing out at first, but started to peter out, then disappeared."

Apparently, the cooling water level in the IC tank had dropped and was not generating much steam. This was Izawa's assessment. When the cooling water in the tank ran out, it would fall into a boil-dry state, incurring a risk of damaging the IC piping and releasing radioactive material outside.

"Do you want to continue running the IC?"

After thinking a little, Izawa said:

"It can't be helped. Let's stop the IC. For now, let's close the 3A valve."

6:25 P.M. Izawa ordered the IC valve closed. The control panel light changed from red to green. After a mere seven minutes, the IC had been stopped again.[24]

However, the fact that they had closed the IC valve was not precisely transmitted to the ERC in the Anti-Seismic Building. From Site Superintendent Masao Yoshida down to senior managers in the ERC, even after this, they still believed that the IC was working and continued to respond to the emergency on that basis.

Why was there such a miscalculation? Why were mistakes made? What was happening onsite?

According to an investigation conducted by Niigata Prefecture, the operators and deputy director in charge of operating the IC in the Central Control Room understood that "the IC was not working." After all, electrical supply had been lost; they firmly believed they had closed the valves themselves; and with data up until that point lost from the power outage, their memory was the only gauge they could use.

In fact, the IC had not been working at that time, and their understanding was correct. However, when Izawa asked the onsite director about the condition of the IC, the answer was, "I don't know." The operator and the deputy director's understanding that the IC was not working had not been conveyed to the onsite director. Had Izawa asked the operator of the main reactor directly, he would have been aware of their assumptions on the condition of the IC. This was the first misunderstanding.

Later on, a second misunderstanding emerged as a result of this communication breakdown between the Central Control Room, the Anti-Seismic Building, and the Emergency Response Headquarters. Although Izawa made sure to constantly report to the power generation team leader in the Anti-Seismic Building, information on the condition of the IC had failed to reach Izawa himself, and therefore the Anti-Seismic Building, too. The power generation team leader continued to believe that "since we lost all power supply while the IC was running, it should still be working." In a chain of miscommunication, the fact that the IC had stopped working never reached Yoshida.

By 6:18 p.m., some of the power in the Central Control Room had been restored. The light showing the condition of the IC valves now indicated "closed." Izawa promptly reported this to the Anti-Seismic Building and began to operate the IC while the onsite director opened the valves. However, even this turn of events had been miscommunicated. The report was vague and simply indicated that "the IC is working" rather than communicating that it was working *because* "a valve had been opened that was closed before."

At 6:25 p.m., the onsite director judged that the effect of the IC had been limited and shut down the IC, but even this operation failed to reach the Anti-Seismic Building. By eleven p.m., however, the radiation dose in the turbine building of Unit 1 had risen, and the pressure on the storage container now exceeded the maximum that it was designed to endure. It was at this point that Yoshida became suspicious and realized that the IC might not actually be working. "The IC is working, the water level has a surplus, but something is strange. I started to realize that the situation inside is probably terrible," Yoshida recalled to the Government Investigation Commission.

The misunderstanding on whether the IC was working or not also appeared in TEPCO's official announcement. During the late evening hours of March 11 and early morning of March 12, TEPCO Head Office announced that they were "cooling the steam inside the nuclear reactor using the IC." But it was only after four a.m. on March 12 that TEPCO revealed that the IC had stopped working.

In domino-style, miscommunication had occurred at three different levels. First, between the operator in the Central Control Room and the onsite director; second, between the Central Control Room and the Anti-Seismic Building; and third, between the team leader and the director of the Anti-Seismic Building. This produced "a chain of misunderstanding." On this point, Yoshida later testified the following:

"As far as the IC is concerned, there was a certain water level being shown, so I was under the impression that the IC was still working. . . . That was because no mechanism had been set up for the shift supervisor

to call me at that time. I know I should have made sure many times at that point whether the IC was really functional or not. . . . I've been intensely reflecting upon the fact that I didn't question that then, but at that time an SOS signal from the site had not reached me."[25]

To make matters worse, those at the Anti-Seismic Building, including Yoshida, and operators in the Central Control Room, including Izawa, did not accurately understand the IC itself. In theory, when power supply is lost, the system to detect failure in devices stops functioning and the IC automatically closes the valves. This is what is called "fail-safe function." If a common understanding of this function had existed, the misunderstanding that "the IC is still working" could have been avoided. Yoshida testified to the Government Investigation Commission on this point that "no one besides the onsite operators at Units 1 and 2 knew about it . . . the IC is an extremely unusual system, so, to be honest, I don't know myself."[26]

There was not a single operator onsite who had experience in actually operating the IC, including the operators at Units 1 and 2. According to a 2015 report that TEPCO submitted to Niigata Prefecture, the last time the IC had been operated at Fukushima Daiichi was on June 29, 1992.

However, it was not only the status of the IC that the ERC was wrong about. The water level gauge also fooled Yoshida. He was concerned that the water in the IC tank, which was the only means of cooling, would be gone, but it turned out that even after ten hours, it still contained water. After being stopped for three hours, the IC was restarted. However, at this point, the meltdown had already progressed to a state where the IC could no longer be cooled.[27]

THE WATER LEVEL GAUGE

4:46 P.M. Yoshida reported to the Nuclear and Industrial Safety Agency (NISA) and others that a specific event (inoperable emergency reactor core cooling equipment), as stipulated in Section 1, article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (NEPA), had taken place. At the time, he wrote: "We don't know what is happening with the cooling operations due to an inability to monitor the water levels in Units 1 and 2."

NINE MINUTES LATER, AT 4:55 P.M. This time, Yoshida contacted NISA to cancel his emergency report, because they had "recovered water level observation" in Unit 1. However, just before five p.m., the water level indicator once again could no longer be seen.

The Central Control Room was unable to confirm water levels in either Unit 1 or Unit 2. Nor could they confirm whether the isolation condenser (IC) in Unit 1 or the reactor core isolation cooling system (RCIC) in Unit 2 were working.

It was reported, "If the water level keeps dropping at this pace, the fuel rods in Unit 1 will start to be exposed by 6:15 p.m." Yoshida merely answered, "Roger that."

5:12 P.M. With just the aid of emergency lighting, the shift supervisor recorded the water level shown on the reactor water gauge (broadband = 1500 mm to –4000 mm). The water level was falling steadily. The time and measurement on the power panel next to the water indicator were recorded by hand, then reported to the station ERC. They were no longer able to use the Personal Handy-Phone System they had been using, so the power plant office at the Anti-Seismic Building and the shift supervisor at the control room were using a hotline. Yoshida once again filed a "state of emergency" to NISA.

Just when the Station Emergency Response Center received a report from onsite that "We are able to see the water level," they received another call, saying, "Once again we have lost the ability to assess the water level." Every time Yoshida received a figure, he checked with the reporting official, "Are those numbers really correct?" The answer he got was, "Umm, we aren't sure."[28]

At the mercy of the figures on the water level gauge, the site was in a state of utter disarray. Maintenance Manager Takeyuki Inagaki recalls that "we were quite doubtful about the IC status, but we hoped that the isolation condenser was still partially working on Unit 1. Because it was the only information we got after getting SBO, we wanted to believe the signal, though we knew the water level must be going down."[29] Ultimately, they were flying blind and wanted to believe any signal of hope.

QUITE SOME TIME AFTER SEVEN P.M. Staff from the control room reported that they could see, with a flashlight, billows of white steam on the far side of the glass of the double doors of the reactor building. It was also reported that radioactive material had been detected as far as outside of the control room and non-controlled areas.[30]

"It looks like there's a raw steam leak."

On hearing people whispering these words, one of the subcontracted workers in the Anti-Seismic Building thought to himself, *That's the end of nuclear power. TEPCO is finished.*[31]

In order to get the water indicator and other instruments back online, they needed to restore power via batteries or small generators, but Fukushima Daiichi NPS had nothing like this prepared at all.[32]

The restoration team at Response Headquarters stripped batteries from several buses onsite, delivering a total of five to the control room. Lining them up two abreast, they hooked them up to the water gauge on the power panel.[33]

9:19 P.M. The restoration team managed to reconnect the water gauge for

Unit 1 after four hours without it. They reported to the Tokyo Head Office, "We have confirmation of the reactor water level. TAF +200 via battery hookup."[34]

This meant the water was twenty centimeters above the top of active fuel. The report of TAF +200 shocked everyone in the ERC.

"It's awash."

"This isn't normal."

Takeyuki Inagaki, the recovery team leader, felt his body tremble.[35]

9:47 P.M. A report reconfirming the reactor water level was sent to the Tokyo Head Office. Around the same time, it was reported that the radiation dose in the Unit 1 Reactor Building had started to climb. The dosimeter of the TEPCO workers, who were entering the reactor building to check the water level, rose to 0.8 millisieverts in a short time.

9:51 P.M. The Unit 1 Reactor Building was put on "restricted access."[36]

It looked like the fuel had started to melt. Commensurately, a large volume of hydrogen was being generated and the pressure was mounting in the containment vessel. Radioactive material may have started to leak out of the containment vessel . . .

9:52 P.M. The power plant ERC reported to the authorities, concerned that the "water level is 450 mm from top of fuel," that the reactor water level was above top of active fuel (TAF).[37]

The water gauge continued to show the reactor water level was above TAF.

10:00 P.M. "TAF +550 mm."

10:35 P.M. "TAF +590 mm."[38]

The operators had started to realize, however, that "something's not right." They recorded the rising water level figures on a whiteboard in the control room, then scrawled next to them, "the water gauge is unreliable."[39]

Izawa sent two operators to the scene to check whether the IC was working. Yoshida was also thinking, *Something's up*. The first time he shook his head was when he received a report saying that the dose of Unit 1 reactor building had increased, before ten p.m.

The IC is moving, the water level is at a plus, why is the dosage going up? Something is wrong.

Is the water level wrong or is it a problem with something else?

At 11:50 p.m., the pressure of the dry well of Unit 1 was recorded to be at the high figure of 600 kPa. This exceeded the maximum working pressure of 427 kPa.

The cooling water must be missing.

Hasn't the IC stopped yet?[40]

With the reactor pressure now high, depressurizing the reactors was no longer an option. Their only strategy left was to cool the reactors through restoring high-pressure water systems.[41]

THE ANTI-SEISMIC BUILDING

Masao Yoshida (age 56) was in his ninth month as site superintendent at Fukushima Daiichi NPS. A graduate of mechanical physics at the Tokyo Institute of Technology, he had gone on to graduate school in nuclear power engineering at the same institution, and joined TEPCO in 1980. According to an old acquaintance, Yoshida had also been offered a position as a senior engineer by the Ministry of International Trade and Industry (MITI), but had chosen TEPCO.[42]

He had been transferred many times between the nuclear power stations at Fukushima Daiichi, Fukushima Daini, Kashiwazaki, and the Nuclear Energy Division at Head Office. He got married when working at Fukushima Daini NPS. Hamadori, the easternmost part of Fukushima Prefecture, was like a second home to him.

At 184 cm, Yoshida was tall for a Japanese. The first impression Charles Casto, the head of Japanese site support operations sent by the U.S. Nuclear Regulatory Commission (NRC), had of Yoshida was his height. "A slender gentleman" was his impression.

Getting Yoshida's permission, Casto took a commemorative photo. Yoshida was holding a bag of rice and a bottle of water. Yoshida told Casto, "This is enough for a meal."[43]

They were on the second floor of the Anti-Seismic Building. During the crisis, there was a round-the-clock video link with the emergency response team at Head Office. From the perspective of the Head Office video screen, Yoshida sat plumb in the middle-left seat at the round table, from morning till night and sometimes into the wee hours of the morning. He ran operations from there.

The Anti-Seismic Building had been newly built the previous year as a base for accident response. Based on the damage experienced from the 2007 Chuetsu earthquake, it was a robust design, built to withstand earthquakes of seismic intensity levels of 7 on the Japanese scale. The construction workers bragged, "It won't budge even if you fire missiles into it."[44]

The building had its own gas turbine generator, a videoconference system, and filtered ventilators. In order to prevent radioactive contamination, the entrance had double doors. The opening and closing of the doors operated on a round-the-clock system. When one door was opened, the other closed to prevent outside air infiltrating. When entering the Anti-Seismic Building from outside, workers removed their protective clothing in the space between the doors and immediately carried out contamination checks and decontamination.[45]

The Anti-Seismic Building was the command tower where Yoshida and

the shift team set up camp. This was the only place onsite where protective masks could be removed.[46]

However, they were operating under atrocious conditions. The worst problem was inadequate filtering of radioactive material. Radioactive material was billowing out of the vents and core welding. Its entrance had been twisted by the force of the hydrogen explosion. Radioactive material was seeping into the Anti-Seismic Building from outside. After the explosion, radiation reached 120 microsieverts (0.12 millisieverts) per hour at one stage. They frantically decontaminated the mud on workers' boots.[47]

The radiation dose one of the female workers suffered was over the legal limit.[48] Late at night on March 12, the onsite safety team reported via videoconference link to TEPCO Head Office:

"For those people taking a rest, in order to minimize doses, the northwest corner of this room seems to have the lowest level . . . The room as a whole is about 70 microsieverts (0.07 millisieverts)."[49]

The occupational physicians at the Anti-Seismic Building had evacuated and were absent from March 11 until March 18. Resident physicians did not start examinations until March 19.[50]

Although they were inundated with problems, the Anti-Seismic Building was irreplaceable. It was here that the squad, composed of TEPCO workers under Yoshida's leadership, later on known as the "Fukushima 50," fought on to manage the situation.

After the tsunami warning sounded, Yoshida advised the workers of related companies to evacuate, and again, in the evening, gave the order, "Personnel who are not engaged in work, please evacuate." The allocation of cars began.[51] The workers of the associate companies began returning to their homes and hometowns.

In case of an emergency, there are twelve teams in place under the command of the director general (nuclear power plant site superintendent) of the power plant. Regardless of whether it was a holiday or midnight, the members of these teams had to gather. There were 406 such personnel. They fought night and day throughout the crisis in the Anti-Seismic Building.[52]

Yoshida told the deputy director general of defense, Hideo Suzuki, when Suzuki visited the site in the summer of 2011, "All of the glass shattered in the office building, but the Anti-Seismic Building escaped the impact of the earthquake. It was contaminated, but we decontaminated it. The hotline stayed up, and the videoconference link with Head Office continued to work. The Anti-Seistmic Building saved us. We would have been totally lost without it."[53]

Kazuma Yokota (age 40), head of the local NISA inspectors at the site, said exactly the same thing:

"It would have been total annihilation without it. I think there would have been six explosions. The quake had put the office building out of operation. If the Emergency Response Center had been in the office building, as before, we wouldn't have been able to use it. We couldn't have operated or issued directions. We were able to do that in the Anti-Seismic Building. Everyone says we were saved by the skin of our teeth."[54]

Unit 1 at Fukushima Daiichi NPS was the first nuclear power station TEPCO had built. Yokota remembers Yoshida saying, "It's small and problematic, but it's still a cute little unit."[55]

On that day, the cute little unit bared its fangs and went on the attack.

THE NUCLEAR SAFETY AGENCY INSPECTORS CUT AND RUN

The quake hit just after Yokota had finished an interview for the periodic inspection report in an office in the Training Building at Fukushima Daiichi NPS. Although he could barely stand, he made his way to the door, opened it, then hid under a desk. Someone had taught him that "the first thing to do in an earthquake is to open the door."

Yokota was the designated disaster expert. Under the Act on Special Measures Concerning Nuclear Emergency Preparedness, during the time of a nuclear emergency, it was a legal requirement to establish an offsite center (emergency response facility) to act as a base for measuring radiation levels and a collection point for all nuclear disaster information.[56]

The offsite center idea was born from the 1999 JCO criticality accident in Tokaimura, Naka District, Ibaraki Prefecture. This accident took place in the uranium reprocessing facility of JCO, a subsidiary of Sumitomo Metal Mining, and resulted in two deaths and one serious injury. Residents within a 350-meter radius from the conversion building were evacuated, an evacuation warning released for those within a 500-meter radius, and residents within a ten-kilometer radius were asked to remain indoors. The accident was classed as a Level 4 event (accident with local consequences) on the International Nuclear Event Scale (INES).

It was the need in hindsight for a government-wide, coordinated response, including resident evacuation and local accident response, which led to the promulgation of the Act on Special Measures Concerning Nuclear Emergency Preparedness (NEPA) and the requirement to establish an offsite center.

The offsite center had its own communications system, radiation measuring equipment, and a support system to respond to nuclear accidents, as well as a decontamination room in the case of radiation exposure. The joint offsite center for Fukushima Daiichi and Daini stations was set up in Okuma, Futaba District, Fukushima Prefecture. It was some five kilometers from Daiichi and twelve kilometers from Daini.[57]

At the time of the earthquake, all seven inspectors from the Fukushima Daiichi Nuclear Safety Inspectors' Office and one chief inspector from NISA in Tokyo were onsite, conducting their periodic inspection. After reporting an article 10 event, Yokota and three other inspectors headed to the offsite center. The remaining inspectors stayed behind in the Anti-Seismic Building to collect information and report to NISA.[58]

When Yokota and the others arrived at the offsite center, the local part-time worker minding the facility opened the doors for them. They were double doors.

"Are you all right?"

"Are you all right, too?"

After this kind of exchange with the woman, and learning that she had children, Yokota sent her home.

The entire building was in a blackout. Even the emergency power was not working. Communications were in a state of paralysis as well. There was one phone/fax line working, but nothing else. The mobile phone connections were down. There was no way to contact NISA in Tokyo. They could not videoconference, there was no water, and the toilets were out of order.

The first workers to arrive were from Kandenko, a TEPCO-affiliated company, and they immediately started trying to restore the emergency power. It had been decided with TEPCO that these workers should gather at the offsite center in case of an emergency. That night, the only people who had made it to the offsite center were six NISA inspectors, including Yokota (three from Daiichi, three from Daini), eight TEPCO employees, and a public servant from Okuma Town. (It was stipulated in the disaster plan that forty workers from thirteen ministries and agencies should gather there, but in reality only twenty-one from three ministries and agencies turned up.)[59]

A telephone and fax were connected to the Fukushima Prefectural Office, but it took an hour to send a fax over the line.

The four inspectors left behind onsite at Fukushima Daiichi were growing increasingly nervous. Radiation levels started climbing onsite in the early hours of March 12, and going in or out of the Anti-Seismic Building was becoming more restricted. At the time, they did not have any Tyvek suits or full-face masks. They were able to contact NISA in Tokyo via the satellite phone in the safety inspection's disaster vehicle parked outside, but it was becoming more difficult to exit the building, as radiation levels grew. At around five p.m. on March 12, they decided to evacuate from Fukushima Daiichi to the offsite center.[60]

Their reasoning was, "They gave us a room in the Anti-Seismic Building, but it was impossible to work with everyone coming and going."

In the evening of the same day, after the Kantei (the prime minister's

office) had decided on seawater injection, Banri Kaieda, minister for the economy, trade, and industry, asked Eiji Hiraoka, deputy director general of NISA, "Doesn't NISA also need to directly witness the seawater injection onsite?"[61]

Kaieda was wondering, "What's happening on the ground? Aren't there any NISA inspectors there?" Upon checking with NISA, he learned, "There are none onsite."

"That's no good."

Kaieda had not been informed that the NISA inspectors had evacuated from Fukushima Daiichi. Hiraoka conveyed Kaieda's criticisms to Tetsuya Yamamoto, head of the NISA Inspection Division, who, as in a game of telephone, relayed the message to Yokota.

"Don't you think it's bad that no one is onsite? It's no good having all the inspectors at the offsite center. We want you to go back, all of you except the disaster expert."[62]

Around six a.m. on March 13, Yokota ordered four inspectors "to go to Fukushima Daiichi to observe operations, since they are going to start injecting seawater . . . I want the four of you to split up into two teams and contact the plant team with changes in the parameters every hour." Although he said "observe operations," no specific directives were issued.

"Do you mean go to the site and visually check if they are pumping the water in?"

"Contamination levels are high, so all you have to do is be at the Emergency Response Center checking the situation at the plant regularly and letting us know."[63]

The main point of the matter was to get the inspectors back onsite.

7:00 A.M., MARCH 13. Four inspectors left the offsite center and returned to the Anti-Seismic Building some forty minutes later. Their job was to "work twelve-hour shifts and make hourly reports on the plant data such as the reactor water."[64] Although they stayed on the job there until five p.m., they did not provide any live observations.

With the loss of power, the building was pitch-black. Instruments had to be read by the light of flashlights. In the end, all they did was receive plant status check sheets from TEPCO employees and convey their content via the in-house wireless phone system to the Local Nuclear Response Headquarters (NERHQ) in the offsite center.[65]

One of the four inspectors was a smoking buddy of Yoshida's. They were on easy speaking terms, but at this point everything was being dictated by the Kantei. They had a strong sense that "this isn't a situation for a lowly inspector to butt in."[66]

In the afternoon of March 14, one of them contacted Yokota via a TEPCO mobile phone.

"There's been a hydrogen explosion at Unit 3. I feel I'm in danger."

"I want you to hang in there somehow or other."

Yokota denied the request to leave, telling the four of them to work from the Emergency Response Center. The conversation by TEPCO workers at the Emergency Response Center roundtable could be overhead.

"If Unit 2 blows, this important [Anti-Seismic] Building won't escape either."

A short time later, another report came in.

"Site superintendent, if it does blow, it won't be safe here. There's a strong chance of Unit 2 exploding if pressure keeps mounting in the pressure vessel and venting operations don't make headway."

"Sir, the situation is critical. We can't stay here any longer. If there's trouble with the Unit 4 fuel pool, it'll undergo recriticality. If that happens, then no one here will be saved."

A specialist nuclear power engineer from the manufacturing side, who knew a lot about reactors, spoke up. With a quiet voice, he desperately appealed, "Please let us evacuate for the time being to the offsite center. I'll report the details to you at the offsite center."

He was ringing via mobile phone, but was probably surrounded by lots of workers from TEPCO and its associates. No doubt, they were all listening hard to what the inspectors were talking about with Yokota. He could not go into specifics. Nor was it easy to clearly say "come back" or "stay." The inspector at the end of the line said, "Chief, we're coming back."[67]

He could not say "fine," but then again, he could not say "don't." Yokota hung up with a simple "understood." The four inspectors returned to the offsite center in the disaster vehicle on the evening of March 14, 2011.[68]

THE OFFSITE CENTER

Motohisa Ikeda, senior vice minister of economy, trade, and industry, left the main building of the ministry at five p.m. on March 11. He got in the car with some disaster gear, hardhat, and boots in hand. He was heading to the offsite center in Okuma.

It was stipulated in article 17 of NEPA that a local nuclear response headquarters (NERHQ) should be set up at the offsite center in the case of a nuclear emergency. The vice minister (or the ministerial secretary) was designated to head NERHQ.

Shinichi Kuroki, NISA deputy director general, and Tetsuya Yamamoto, chief of the NISA inspection unit, were traveling with Ikeda. NISA had initially considered sending a senior management team to the Tohoku Electric Power Company's Onagawa nuclear station, which seemed to have been hit the hardest, but as the situation in Fukushima escalated, they decided to set up their NERHQ at the Fukushima offsite center and sent Yamamoto there.[69]

Due to traffic congestion, they failed to link up with the patrol car that was to escort them. They were shortly caught up in the whirlpool of Tokyoites trying to get home. It took them two hours to reach Ueno. It would be impossible for them to travel to Fukushima by car.

Ikeda phoned Kazuo Matsunaga, METI permanent secretary, from the car and asked for a Self-Defense Forces helicopter to be readied.

I mean to say, it's ridiculous to expect the head of a nuclear emergency response team to reach the site by car in the first place. Why did NISA create such an unrealistic rule?

Ikeda was unable to keep his anger under control, but was forced to smile bitterly when he reconsidered: *Isn't it also the responsibility of the politicians who allowed such a rule?*

They finally got their police car escort and headed to the Ministry of Defense (MOD) and Self-Defense Forces (SDF) headquarters at Ichigaya. The only way to get to the site was to board the helicopter on the rooftop helipad and fly. It emerged, however, that this was not so easy, with the whole nuclear station area in blackout. He, therefore, flew to the Japan Air Self-Defense Force (JASDF) Ohtakineyama Sub-Base (a radar base), atop the Abukuma Mountains.

The base was covered in thick snow. Ikeda drove down the mountain. In the town at the foot of the mountains, there were cracks in the road, and some of the houses were leaning. The blackout enveloped the area, with no light to be seen anywhere.[70]

At around eleven p.m., he learned from Tokyo that the wind at the site had changed and was now blowing toward the Pacific Ocean.

If they're going to vent, now would be the time . . .

Kuroki thought as much when he heard this. Kuroki was originally a technical official in charge of examining test furnaces at the former Science and Technology Agency (STA). One of NISA's deputy director general seats was "reserved" for good old STA boys. Kuroki himself was on secondment from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT).

It was the middle of the night when they reached the site. Asked by Ikeda to "check the time of arrival," Kuroki emphasized to Tokyo that they had "arrived on the night of March 11, at 12:00." This was his attempt to prevent the press from writing that they arrived the following day, but NISA's press release said, "They arrived at 00:00 on March 12."

The government officials who made it to the site during the night were the senior vice minister of economy, trade, and industry; Fukushima Prefecture vice governor Masao Uchibori; NISA inspectors from Fukushima Daiichi and Daini stations; NSA staff members; MEXT staff; and staff from Okuma Town. Ikeda was immediately briefed by Yokota about the situation at the plant. Due to instrument failure, they were unable to mea-

sure any key parameters, including the temperature, pressure, or water level inside the reactors. Additionally, of the twenty-four monitoring posts in Fukushima Prefecture, twenty-three were out of action.[71]

Ikeda was then briefed by the TEPCO unit chief. In the early hours of the morning, TEPCO vice president Sakae Muto arrived.

By March 12, staff from the SDF, the Japan Atomic Energy Agency (JAEA), the National Institute of Radiological Sciences, and the Nuclear Safety Technology Center had all assembled. However, members from the Nuclear Safety Commission and the Emergency Response Measures Committee, who were to be dispatched to the scene in line with the Basic Disaster Plan, never showed up. The Nuclear Safety Commission had contemplated dispatching a member of the commission and a few staff members, but only dispatched one staff member when told that "the helicopter is full, make it one person."[72]

Staff were also to be dispatched to the offsite center from the surrounding towns of Okuma, Futaba, Tomioka, and Namie, but only staff from Okuma made it to the center. The other towns needed all of their staff helping to evacuate their residents.

At around three a.m. on March 12, power was restored to the offsite center and everyone moved back from their temporary quarters at the Nuclear Power Center. The television was now working.

They received an alert that Minister Banri Kaieda of the METI was about to give a press conference on the implementation of venting. With things as far gone as they were, venting could not be helped. If they did vent, however, it would have a huge impact on the local residents due to the release of radioactive material. Ikeda directed the TEPCO team chief and Yokota to get as accurate data as they could as soon as possible.

4:00 A.M. They were told that Prime Minister Naoto Kan was coming to visit the site. Grouping around Ikeda, the overall coordinators discussed the matter.

"What if the prime minister suffers radiation exposure? Can that be explained externally?"

"Won't a visit at this busy time slow down the accident response efforts?"

"I expect it'll be all right since the wind's blowing out to the Pacific."[73]

Ikeda, at this stage, was opposed to a prime ministerial visit.

I understand the PM wants to see the site for himself since it's an unprecedented nuclear accident. But the quake is not just about the nuclear plants. There have been huge tidal waves and aftershocks. In a disaster like this, the first seventy-two hours, when people still have a good chance of survival, are critical. The leader should stay at the headquarters and do his utmost to save lives, as well as monitor the nuclear accident response . . . Still, if he really wants to visit the site, we can't allow anything to happen

to our commander-in-chief (the prime minister), so he should visit the offsite center and not Daiichi Station.

Ikeda ordered Kuroki to convey these thoughts to Tokyo. Later, on returning to Tokyo, Ikeda learned that his directive had only gone as far as NISA and did not reach the Kantei.[74]

The local NERHQ comprised seven teams with different areas of responsibility, including a residents' safety team and a medical team. At 10:30 a.m. on March 12, the first general meeting with all team leaders was held. They decided on a course of action for the offsite center, including preparing for the distribution of stable iodine, assessing the status of resident evacuation, and implementing emergency monitoring. On the basis of this plan of action, orders were issued to the surrounding localities.

Given this ragtag assembly of ministerial, institutional, and regional public servants, as well as private sector workers, job descriptions were unclear. To compound the troubles, the phones were not working, or if they were, what was being said could not be heard.

Kuroki had been in charge of gathering information at the Science and Technology Agency (STA) at the time of the 1986 Chernobyl accident. He subsequently spent two years at the Japanese embassy in Moscow. During that time, he witnessed the collapse of the Soviet Union and cooperated with the now three separate countries of Ukraine, Belarus, and Russia in the use and management of radioactive material. Communication between them was poor; they did not know their counterparts' names; they could not get through to each other on the phone; if they did, line interference meant they could not hear each other. Kuroki was remembering how tough it had been then.[75]

By noon on March 12, all communications, bar the satellite communication lines, were down. The emergency battery at the telecommunication company's base station had run out. The government video conference system, the Emergency Response Support System (ERSS), the System for Prediction of Environment Emergency Dose Information (SPEEDI), e-mail, the Internet, phones and faxes using landlines—all of them were out. Contact between the offsite center and NISA's Emergency Response Center (ERC) was limited to external communications via satellite phone lines.[76]

As a result, TEPCO's video conference system became a key medium. Kuroki had "believed that NISA's ERC had the same kind of video conference system as TEPCO," but, having later learned that they did not, thought to himself, *Damn it.*

From time to time, Ikeda would go over to the TEPCO booth and listen to the exchange between Head Office and the Fukushima Daiichi response team. After a while, the booth became crowded. A little after 3:30 p.m.,

someone said they had heard a loud noise from the direction of Fukushima Daiichi.

Maybe a hydrogen explosion?

Tension ran through the offsite center.

At 3:41 p.m., the videoconference linking TEPCO Head Office and the site showed everyone in the Fukushima Daiichi ERC and the offsite center jumping to their feet in the same way and staring at something. It was the moment of the explosion that was being broadcast by Fukushima Central Television.

Just before four p.m., the SDF reported an explosion at Fukushima Daiichi NPS. This was reported to NISA's ERC. After that, everyone was glued to the television screens.

THE RADIATION EMERGENCY MEDICAL ASSISTANCE TEAM

At eight a.m. on March 12, Takako Tominaga (age 33), a doctor at the National Institute of Radiological Sciences (NIRS) located in Inage, Chiba, boarded an SDF helicopter. She was accompanied by two colleagues. The surrounding area was covered in high-voltage electrical power lines. Threading its way through the power lines, the helicopter headed to Fukushima.

Tominaga was an expert in emergency medicine. She had also worked for a year at the International Atomic Energy Agency (IAEA) in Vienna. She had been working for NIRS since 2009 and was a member of its Radiation Emergency Medical Assistance Team (REMAT), made up of emergency medical experts. On her jacket was the red REMAT logo against a navy, gray, and white background. She was wearing navy pants.

They were loaded up with measuring equipment, medical supplies, five hundred stable iodine tablets and forty boxes of Prussian blue. The stable iodine acts to lower levels of radioactive iodine, and the Prussian blue reduces the effect of radioactive exposure due to cesium.

Just before ten a.m., the helicopter landed in a baseball field near the offsite center. They were met by some NISA staff, but they could not open the fence, because it was locked. They climbed over the netting to get out. She had expected someone from the government or prefectural medical team to be there, but no one came.

The medical team on the second floor of the offsite center comprised the head of the Sousou Healthcare Center (South Soma), a liaison official from TEPCO, and a member of staff from the Japan Chemical Analysis Center. Tominaga joined them.

There was an initial radiation exposure medical facility nearby, namely the Ohno Prefectural Hospital (designated by the prefecture for Okuma

Town, Futaba District). They heard that staff were still there accepting outpatients. When they checked it out, however, they found it was not functioning at all.

THE EVENING OF MARCH 12. An inquiry came in from Fukushima Daiichi that a worker had been exposed to "more than 100 millisieverts, what should we do?" The exact figure was 106.30 millisieverts. On further questioning, there did not seem to be an acute disorder.

"All you can do is get them to go to the emergency response center."

A little later, the worker turned up.[77] He had been to the Ohno Hospital, but since there were no doctors there, he had come here. He said he was really worried. He was examined, but did not show any acute exposure symptoms, such as vomiting. It was likely that he was completely exhausted.

"Would you like to rest here?"

"No, I'll go back to my post."

They heard later that he was resting in the Anti-Seismic Building. The radiation levels of which were on the rise when venting.[78]

The two colleagues who had flown in via helicopter with Tominaga were measurement specialists. They said dosage started to rise from four p.m. on March 12 into the night. This was a little after the Unit 1 explosion.

"The air dose rate indoors isn't rising yet, but it's climbing steadily outside."

Contamination of the TEPCO, SDF, and police personnel traveling to Fukushima Daiichi and back was getting steadily worse. Five SDF officers came to the offsite center after they had finished pumping water, which took place before and after the explosion at Unit 1. While their levels were "normal" when measured onsite before they came, a screening test found 30,000 count per minute (cpm) before decontamination and 5,000–10,000 cpm after decontamination.[79]

A screening test involves measuring the amount of radioactive material found on clothes or the body. Everyone had to be screened and decontaminated before entering the offsite center. The decontamination line was set at 600 cpm, but that meant everyone would be over it. Count per minute represented the amount of radiation measured in a minute. Since the type and strength of radiation cannot be measured, it was necessary to make different calculations according to the type of instrument in order to estimate the amount of radiation a person has suffered.

Where should the decontamination line be set? The Nuclear Emergency Plan was unclear on that point also. The medical team and monitoring teams got together and decided to set 40 becquerel/cm^2—or, alternatively, 6,000 cpm—as the standard, which is the equivalent of the typical dosage received by Chernobyl workers who died within a month. They confirmed this with the NSC and NISA's ERC and had a notification issued and sent to neighboring towns under the name of the local NERHQ director.

2:20 P.M., MARCH 13. Ikeda instructed the heads of Fukushima Prefecture, Okuma Town, Futaba Town, Tomioka Town, Namie Town, Naruha Town, Hirono Town, Katsurao Village, South Soma City, Kawauchi Village, and Tamura City that the screening level was to be set at 40 becquerel/cm^2—or, alternatively, 6,000 cpm.

After issuing an order for residents to evacuate in a ten-kilometer radius in the early hours of March 12, people in the daycare centers and old people's facilities in Futaba evacuated to Kawamata. Some of these were said to have been exposed to radiation while evacuating. They had to be screened. That job fell to Tominaga and her team.

"Please go to Kawamata."

That was what they were told, but no one had any idea of where in Kawamata they were to go.

From the night of March 13 to the morning of March 14, Tominaga rode to Kawamata separately from her team in SDF trucks. On the way, the road was cut off by water. They were told it was too dangerous for the trucks and that they were to walk across. When they went to the police in Kawamata, no one knew who had evacuated to where. Guessing that they might learn something at the local gym, they headed there. They found the mayor of Futaba and his staff freezing in the sub-zero cold. They had fled with just the clothes on their backs. They had nothing to change into and their clothes were filthy.

They screened and decontaminated some eighty people from the town hall and daycare center. There were approximately a hundred people asleep in the adjacent building. They were all people who could not move on their own. They went there and screened them as well. Most of them were over 10,000 cpm. Their hair was up to 40,000–50,000 cpm. There were two people over 100,000 cpm.

Returning to the offsite center, they heard a thunderous noise as they were getting out of the truck. It was Unit 3 exploding. They hurried inside the building.

On the evening of March 14, the NIRS measurement experts identified cesium in their nuclide analysis of the airborne radioactive material.

"The core must be in meltdown."

The fact that cesium had been found suggested that the fuel was melting and the containment vessel had been breached. The stable iodine they had brought quickly proved to be useful. Since the SDF unit that was carrying out the water pumping operations onsite at Fukushima Daiichi had not brought any with them, the medical team gave them enough for eight people.[80]