Lessons from Major Accidents

A comparison of the Three Mile Island nuclear core overheat and the North Sea Platform Bravo blowout

Executive Report 6, based on work done by David W. Fischer
at the International Institute for Applied Systems Analysis (IIASA)

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Preface

In January 1980, a workshop on "Procedural and Organizational Measures for Accident Management: Nuclear Reactors," was held at the International Institute for Applied Systems Analysis in Laxenburg, Austria, just south of Vienna. The opening paper, presented by David W. Fischer, formerly of IIASA and now continuing his work at the Institute for Industrial Economics at Bergen, Norway, was on *Organizing for Large-Scale Accidents: Experiences from the Bravo and Three Mile Island Accidents*; it is summarized in this Executive Report as a means of bringing its findings to a wider readership of decision makers in government and industry.

This Executive Report draws on the Fischer paper to make comparisons of two large-scale accidents that have occurred in recent times – the oil blowout in the North Sea in the spring of 1977 (Bravo), and the nuclear reactor accident at Three Mile Island, Pennsylvania, USA, in the spring of 1979 (TMI). The remarkable similarity of these two unrelated events in different technological fields provides a rare and perhaps unique opportunity to identify some key organizational issues of accident prevention and accident management.

Fischer has capitalized on this opportunity by briefly describing and comparing the organizations involved and by exploring some of the organizational issues thus raised. As a basis for discussion and comparison of major accidents, he identifies six types of actors (individuals or agencies) involved in the events of Bravo and TMI; they would be present in any large-scale accident involving the production of resources.

He then shows how these actors came to play their roles at Bravo and at TMI, and how roles – and even responsibilities –

changed during the crucial periods of both accidents. Next he compares the accidents, and finally he presents the lessons they offer us, including the areas they suggest where accident prevention and accident management as practiced today need a lot more hard thinking.

This concise report should be of particular value to decision makers who are involved in any way in the various aspects of pre-accident planning and accident response, a readership that David Fischer sees as a very important one.

ALEC LEE
Chairman
Management and Technology Area

1

Two "Impossible" Accidents

At 10 pm on April 22, 1977, an oil well went out of control in the North Sea off Norway. By the time it was finally capped off eight days later, the blowout at platform Bravo had spewed some 12,700 tons of oil over the surface of the water.

It was the first blowout of an offshore oil rig in the North Sea, and it came as a shock to the North Sea oil industry and to the governments of several countries in the vicinity. All had been assured that such an event was impossible.

The Royal (Norwegian) Commission of Inquiry created to investigate the accident concluded that "The organizational and administrative systems were on this occasion inadequate to assure safe operations." And it had more pointed words, saying that the "accident to a large degree was due to human errors," and that while "certain technical weaknesses were present," they were of "peripheral significance for the course of events."

Nearly two years later, at 4 am on March 28, 1979, a series of events culminated in a nuclear plant accident at Three Mile Island (TMI) in the eastern United States. The plant's uranium core became seriously overheated within a short period. By the time the initial danger had subsided six days later, an unspecified but probably low amount of radiation had been released into the environment.

It was the first major nuclear accident in the US, and it captured worldwide attention, signaling to the nuclear industry and governments everywhere that nuclear accidents caused by human error were not just things that happened in fiction. Prior to TMI, such accidents were also considered impossible by many decision makers of industry and government involved in nuclear energy development.

Events at Bravo

Time	22 April 1977
22:15	Well 14, production platform 2/4 B (Bravo) goes out of control. Phillips receives notice at its Norway head office and in turn begins its notification plan.
22:20	Phillips notifies the Petroleum Directorate.
22:30	Phillips requests assistance from the Texas-based Red Adair Company.
	Phillips notifies the Minister of Environment and the Director of State Pollution Control.
	23 April
02:30	The *Seaway Falcon*, a fire-fighting vessel, begins to pump water at the Bravo Platform.
	The Director of State Pollution Control arrives in the area and immediately holds a meeting to set up a provisional Action Command. He serves as chairman; other members are the Stavanger Chief of Police, a naval captain from the Maritime Operation Center, and a section head from the Petroleum Directorate.
04:00	The Minister of Environment agrees by telephone to give Action Command authority to control the blowout and clean up the oilspill.
05:00	Action Command issues its first press release.
11:00	Action Command holds its first press conference with representation from Phillips.
15:00	Prime Minister Odvar Nordli arrives in the area with the ministers of Industry and Environment. They confirm authority of Action Command and approve the actions being taken.
18:45	Two advance representatives of the Red Adair Company arrive in the area (20 hours and 15 minutes after being notified of the accident).
	24 April
05:21	All oil production in the area is stopped.
10:00	A group is appointed for an on-going assessment of whether chemicals should be used to dissolve the spill.
	26 April
10:00	Phillips submits supplementary plan for capping the blowout, which is approved by Action Command.
20:00	The Council-in-State passes a royal decree giving authority to Action Command and establishing regulations governing it.
	27 April
10:30	Action Command decides to bring in equipment from Britain and the US Coast Guard.
14:45	All preparations for stopping the blowout are made.
	28 April
06:30	First attempt to cap the blowout fails.
06:40	Second attempt fails.
10:21	Third attempt fails.
20:00	Phillips is notified that the decision not to use chemicals still applies.
	29 April
12:15	The oilspill reaches its maximum extent.
	Fourth attempt to cap the blowout fails.
15:00	Paul "Red" Adair arrives in the area.
20:00	Altogether, 330 tons of oil have now been collected from the sea.
	30 April
11:02	Fifth attempt to cap the blowout is successful and the oilspill is stopped.

Events at TMI

Time	28 March 1979
04:01	Several water pumps stop pumping at Unit 2 of the Three Mile Island nuclear power plant. Pressure in the reactor cooling system begins to increase.
06:00	The station manager has a telephone conference from his home with experts from the operator (Metropolitan Edison) and the manufacturer (Babcock & Wilcox).
06:40	A coolant sample indicates that radioactivity is about 250 times greater than normal.
06:56	Readings indicate that the nuclear core of the plant has been damaged.
	The shift supervisor declares a site emergency and begins calling outside agencies: the Pennsylvania Emergency Management Agency (PEMA), the Pennsylvania State Police, and others. PEMA calls the State Bureau of Radiation Protection (BRP) and civil defense authorities.
07:05	The station manager arrives at the plant and forms an emergency command team. He serves as leader; other members are supervisors and operators of the 7 am outgoing and incoming shifts.
07:23	A general emergency is declared and the earlier calls are repeated. A telephone line is opened between the control room and BRP in Harrisburg.
07:50	The duty officers of the Nuclear Regulatory Commission's regional office arive at work and are notified, the NRC's first word of the event.
09:00	A task force convenes at Babcock & Wilcox headquarters in Virginia and decides to fly three engineers to the TMI site.
17:00	The NRC issues a press release that is misconstrued on 7 pm national television newscasts.
	29 March
10:00	Met-Ed holds its first formal press conference and provides an optimistic assessment of the accident, predicting that releases to the environment will end in about two days.
16:15	A reading shows a high concentration of radioactive material (10 percent of the core's radioactivity) has been released to the coolant system. Unaware of this, NRC representatives have informed Governor Thornburgh that potential danger from the site has virtually ended.
	30 March
10:25	The Governor speaks on a local radio station to deny reports that the TMI area is to be evacuated. Other conflicting reports are publicized.
10:45	US President Carter asks the NRC to put a senior official in charge at the site. Harold Denton, the Director of Nuclear Reactor Regulation of the NRC, is then sent to TMI.
20:00	At a press conference held by the governor and presidential representative Denton, the public is told that there is no need for evacuation at that time and that the possibility of a core melt down is remote.
	31 March
14:45	The chairman of the NRC holds a press conference and expresses serious concern about the possibility of an explosion of the hydrogen bubble.
21:00	Denton and the Governor hold a press conference stressing that there is no immediate danger. The Governor notes that President Carter will soon come to the site.
	April 1
13:30	The President tours the plant and tells local citizens that the reactor is stable, but that further precautionary measures could yet be required of them.
19:00	The hydrogen bubble is down to 350 cubic feet and obviously disappearing, due to the efforts of Met-Ed, Babcock & Wilcox, and outside experts.

The Report of the (US) President's Commission on the Accident at TMI, the "Kemeny report," concluded that "fundamental changes will be necessary in the organization, procedures, and practices, and – above all – in the attitudes of the Nuclear Regulatory Commission, and, to the extent that the institutions we investigated are typical, of the nuclear industry."

Two major accidents had occurred in different types of energy development, and both had been officially considered impossible. Understandably, concern was great in both cases, despite the fact that in neither case was there significant off-site damage, so far as is now known. Bravo's oil slick evidently caused little damage to marine life, and no oil reached shore. The radiation at TMI was largely contained, and overall health effects of the accident have been judged minimal.

"Despite less-than-catastrophic damages, both accidents resulted in moratoriums on energy development in an energy-short world."

Despite less-than-catastrophic damages, both accidents resulted in moratoriums on energy development in an energy-short world. (Both moratoriums have since been lifted.) Such stringent measures were probably taken by the governments involved for several reasons. Growing awareness of the need for safety, governmental emphasis on safety regulations, environmental awareness, a reaction to the reassuring safety claims of manufacturers, lack of experience with such accidents, and concern about the spread of large-scale energy production facilities, all may have influenced the decisions to stop offshore oil drilling plans in the North Sea and nuclear plant construction in the US.

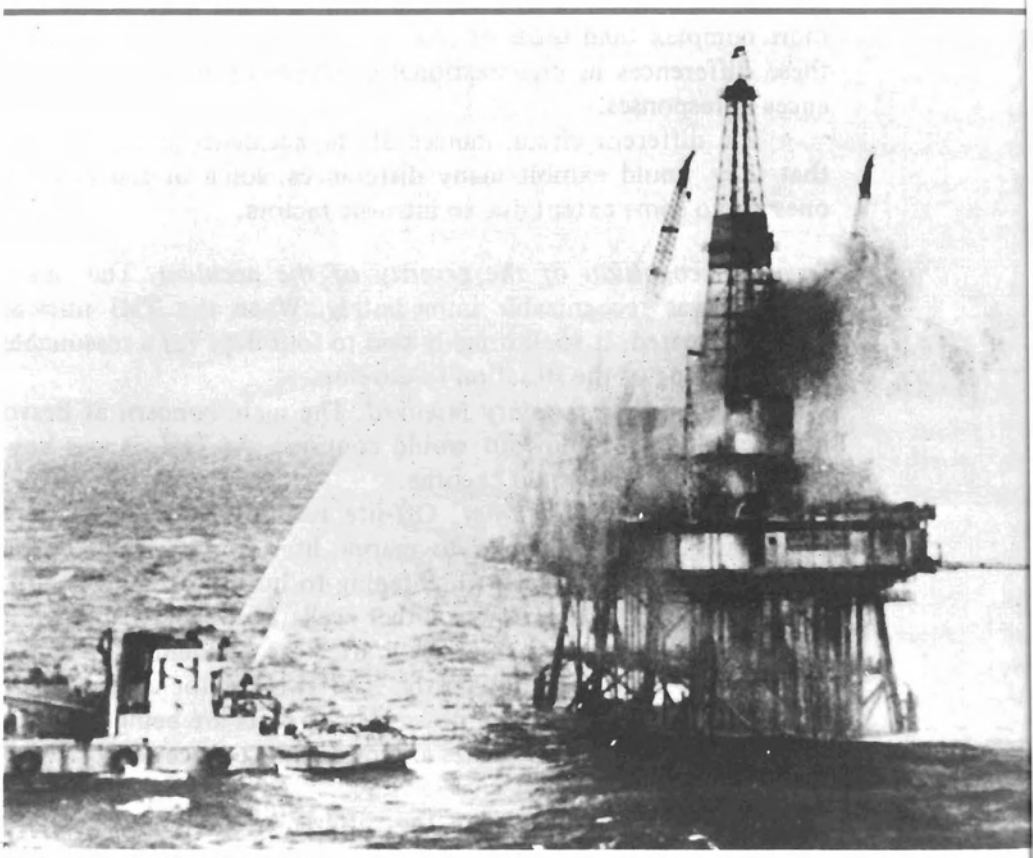
Since both accidents had similar and far-reaching repercussions, it is useful to compare them, particularly as to the organizational and administrative issues involved. A paper recently presented at the International Institute for Applied Systems Analysis (IIASA) makes such a comparison. In *Organizing for Large-Scale Accidents: Experiences from the Bravo and Three*

"The organizational similarities of Bravo and TMI suggest that there are lessons to be learned about large-scale accidents in general."

Mile Island Accidents, David W. Fischer, now at the Institute for Industrial Economics, Bergen, Norway, looked at possible lessons to be learned from a comparison of the organizational responses to these two accidents. This IIASA Executive Report summarizes Fischer's findings.

The obvious differences

By juxtaposing the two accidents, Fischer illustrates that each major accident is not necessarily unique. On the contrary, the organizational similarities of Bravo and TMI suggest that there are lessons to be learned about large-scale accidents in general.



Early arrival. The fire-fighting vessel Seaway Falcon began pumping water over North Sea oil platform Bravo at 02:30 hours on Saturday, April 24, 1977, 4½ hours after the accident occurred and 1½ hours before Action Command was created to stop the blowing well and combat its effects. Here the vessel is still pumping at midmorning. (Photo courtesy of Associated Press.)

The obvious similarities of Bravo and TMI (as outlined on the inside front cover of this report for easy reference) facilitate Fischer's quest for general accident responses. However, it is also important to note the important differences in the two accidents.

Bravo was a self-contained offshore oil drilling platform of some danger to its marine environment but little threat to human life, provided its crew observed good safety procedures. TMI was a complex nuclear power generating plant of potential hazard to a large, densely populated area. As might be expected, accident prevention and management varied in two such different situations.

Accident prevention and management at Bravo were readily organized under central authority. A far greater number of organizations were involved at TMI, and their linkages were necessarily more complex than those of Bravo. As the two incidents evolved, these differences in organizational involvement influenced differences in responses.

The different circumstances of the accidents predetermined that they would exhibit many differences; some of the obvious ones are to some extent due to intrinsic factors.

- *Recognition of the severity of the accident.* The Bravo blowout was recognizable immediately. When the TMI nuclear core overheated, it took roughly two to four days for a reasonable understanding of the situation to develop.
- *Type of uncertainty involved.* The main concern at Bravo was how long the blowout would continue. At TMI, it was how severe the accident would become.
- *Nature of the threat.* Off-site releases from Bravo were visible and threatening only to marine life. At TMI, the releases were invisible and directly threatening to human life and health.
- *Nature of breakdown.* Other wells at the Bravo platform were able to continue pumping oil after the accident. Repairs to the blowing well were not costly. The two reactor units at TMI were shut down and remain down. Major costs are being incurred to remove contaminated wastes and replace lost power.

Both the similarities and the differences noted thus far are obvious. In comparing the two accidents, Fischer looks beyond these immediately apparent similarities and differences and finds weaknesses in major accident prevention and management as they are generally organized and executed. His aim is to identify common defects in accident planning as a first step toward reducing the risk of such accidents happening again.

2

Large-Scale Safety Systems

An attempt to appraise the organizational responses to major accidents must consider the overall system from preventive planning through accident control to changes made in the system as a result of the accident. Any safety system designed to prevent large-scale accidents consists of three distinct but closely related phases: pre-accident planning, accident control, and post-accident recovery. The recovery phase includes applying the lessons learned to the pre-accident phase.

"Sound allocation of resources will assure that the whole system can respond to anything from near-accidents to catastrophes."

Seeing large-scale safety systems as a three-phase process helps to identify the linkages of organizations and individuals that develop and change during the course of events. For instance, available resources must be organized for each of the three accident phases. Sound allocation of resources will assure that the whole system can respond to anything from near-accidents to catastrophes. For accident response to be quick and effective, accident management must be designed as part of a highly integrated system.

The development of events at Bravo and TMI, as briefly summarized in Chapters 3 and 4 of this report, suggests that at both sites the overall safety systems for preventing and managing accidents were concentrated too much in the pre-accident phase. Despite the emphasis on prevention, neither accident was anticipated or prevented.

It appears, in both cases, that those in charge were overly optimistic. By assuming that the accidents could be made impossible, they allocated too much of their safety resources to accident prevention and too little to accident management.

The following summaries of the two accidents also illustrate another weakness that is significant to the design of large-scale safety systems in general. At both Bravo and TMI, an early warning went insufficiently heeded. The event that marked a departure from normal operations could have been controlled.

At TMI, alarms and responses were designed for near-accidents, but the response to the alarm failed to prevent the accident, and it took two to three days after the initiating event to recognize that a serious accident had taken place. At Bravo, the accident itself was recognized immediately, but the earlier events that combined to cause it were not recognized.

If large-scale safety systems are seen as highly integrated three-phase processes, the experiences at Bravo and TMI suggest clearly that in both cases greater emphasis should have been placed on understanding a multi-faceted accident *as it develops*. Before either accident occurred, resources could have been shifted from the preventive planning phase to the accident control phase. In this middle phase greater attention could then have been paid to recognizing developing accidents.

The actors

Both accidents were unexpected despite safety programs, and they were managed in a largely impromptu manner. Each actor – individuals or groups involved or wanting to be involved – had a unique perception of safety and accident management, which included communication and linkage to other actors. This appears to be an important determinant of the adequacy of organized responses to large-scale accidents.

Any technology has a core of support from actors linked together by a common ideology or set of oversimplications of shared knowledge and interests. This ideology results from technical expertise and gives power to organized technical experts in private and public bureaucracies. The ideology is communicated to other actors, including rivals and groups that may suffer from it as well as those who may benefit.

For example, while setting a safety standard directly involves the industry or group of industries designing, manufacturing, supplying, using, and servicing the technology, as well as the regu-

lator, it also involves many other actors – unions, politicians, local governments, area residents, consumers, rival technologists, other government agencies, and research experts. These other actors will be influenced by the information provided them, which is meant to promote the ideology that has grown up around the technology. At the same time, these actors may generate conflict because of their differing perspectives, and in some cases because of their own particular technological ideologies.

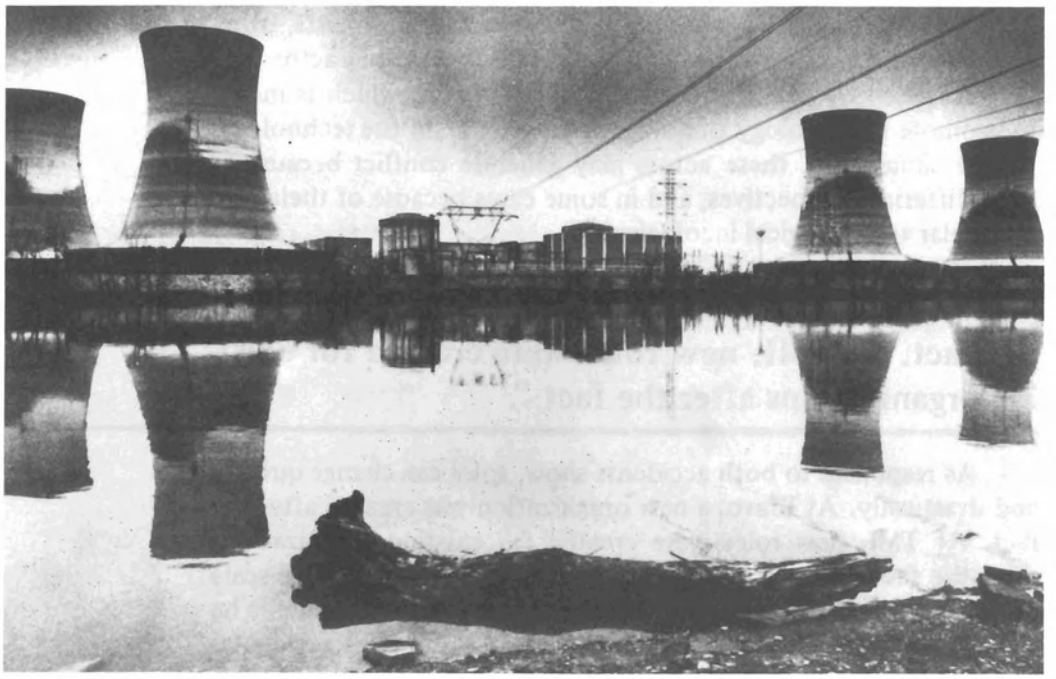
"At Bravo, a new organization was created after the fact. At TMI, new roles were created for existing organizations after the fact."

As responses to both accidents show, roles can change quickly and drastically. At Bravo, a new organization was created after the fact. At TMI, new roles were created for existing organizations after the fact. Fischer identifies the major actors in any large-scale accident and characterizes their responses in the two accidents he compares. These six types of actors played roles in both accidents:

- *Accident response groups*. The agencies managing emergency situations and accidents.
- *Normal regulators*. The government agencies regulating the technology.
- *Operators*. The companies owning, operating, and servicing the technology.
- *Inside experts*. Technical experts from government agencies, research institutes, companies, and universities.
- *Affected groups*. Heterogeneous social groups affected for better or worse by the technology and the accident.
- *Outsiders*. Unorganized but influential individuals or factions affected by the accident – politicians, outside experts, media representatives, and others.

In addition, Fischer notes that associate actors may be called in by any of these major actors. Outside ministries, technical experts, research agencies, foreign colleagues and observers, and others played parts at Bravo and at TMI.

The various actors may have different ideologies, which influence their goals, incentives, perceptions of facts, and preferred choices. They are bound together by the linked management responses to the accident. Since no organizational form including



Nuclear tombstones. The four cooling towers at Three Mile Island, Pennsylvania, as seen in March, 1980, just one year after the accident. Now, more than two years after the accident, there is no indication that the plant will ever be put back into service. (Photo courtesy of International Communication Agency.)

all these actors existed before the accident, form and function tended to evolve on an *ad hoc* basis after the accident, both at Bravo and at TMI. Responses were based largely on experiences during the emergency period rather than on the pre-established organizational and administrative responses.

The relations of the actors involved in any serious large-scale accident are highly complex and at times highly informal. Dealings and decisions take place under conditions of urgency, around-the-clock activity, exhaustion, and frayed nerves, so that conflicts are likely. To shed light on the questions of who will be involved and in what ways, what linkages will occur among the actors, and how information will be given and acted upon to control the on-site accident and mitigate its off-site effects, the next two chapters of this report deal with what actually happened at Bravo and at TMI. The remainder of the report compares the two accidents and offers some conclusions that may be drawn from them.

3

Bravo Roles and Performances

When the blowout occurred at Platform Bravo, the central accident management role was given to Action Command, a new body created for the occasion. Although legislative authority for such a group existed, appointments had not yet been made. Therefore, its links to other major actors at Bravo were new and untried.

As the accident response group, Action Command played a supervisory role at Bravo. It answered directly to the Norwegian government, and it had representation from the Oil Directorate (supervising well control), the Pollution Control Agency, the Navy (providing support vessels, aircraft, and personnel), and the police (handling rescue and relief).

Responding to the accident

Primary responsibility for responding to the accident remained throughout with the owner of the oil drilling platform, the Phillips Petroleum Company. Phillips acted immediately to fulfill its obligations, which included notifying the rescue center and the regulatory agency, rescuing personnel, securing the platform, calling in capping experts, and attempting to contain the oil pollution. At the time of the accident, Phillips had no contingency plan for dealing with an uncontrolled blowing well, nor did it have the organization and resources needed to manage the accident and its consequences.

Despite the lack of preparation, Phillips shut down the other wells of the platform successfully and quickly evacuated it with no loss of life. It then sprayed chemicals near the platform to reduce further risk of fire. The company notified the required authorities

an hour after the accident, and it then hired Red Adair, an independent well-control expert from the US, to control the blowout. Efforts to cap the well were greatly hindered because a blowout preventer valve had been fitted to the wellhead upside down.

While the main accident management role was undertaken by Phillips, Action Command played both supplementary and supervisory roles. It helped Phillips combat the oil slick, got oil pollution control equipment and personnel from foreign governments, and provided information for elected officials and for the press.

Action Command assessed, directed, and observed the company's plans and efforts to cap the well while ensuring that the entire operation functioned as effectively as possible. It had the authority to take over management of the accident if its director thought such a step was necessary.

Phillips was represented at twice-daily meetings of the Action Command. In addition, the Oil Directorate, which as part of the Action Command was responsible for supervising the company's efforts to stop the flow of oil at the wellhead, carried on constant discussions with Phillips on these efforts. Oil Directorate personnel were not allowed on the platform during capping operations.

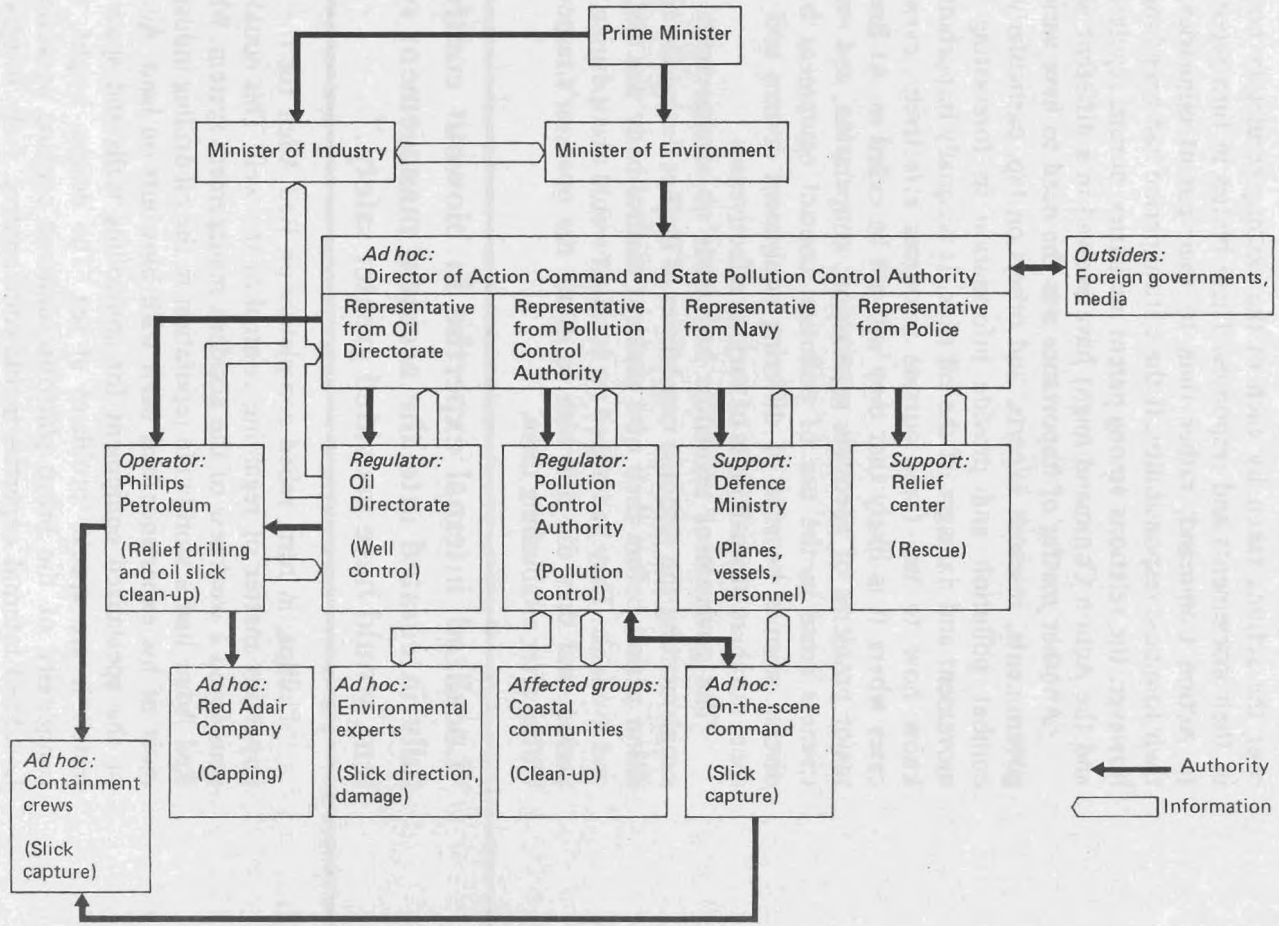
The role of elected government officials was not significant during the management of the accident. The Prime Minister and two other ministers visited Action Command headquarters, expressing full confidence in the group at that time. In addition, the Minister for Environment participated in some internal Action Command discussions of alternative measures, such as mechanical collection of oil versus chemical dispersion. The Oil Directorate also kept the Minister of Industry informed of the accident management efforts by telephone.

The only decision related to the accident that was taken without the knowledge of the Action Command was an order to shut down all other offshore wells in the Ekofisk area. This action was not considered necessary on technical grounds either by the Oil Directorate or by Action Command. The government called a moratorium on oil production in the area for its own reasons.

Evaluating Bravo

The most significant aspect of accident management at Platform Bravo, according to Fischer, was the integrated approach to large-scale accident management taken by Norway. This was achieved effectively despite the hasty formation of Action Command. Rather than continuing to function independently, the

The Actors at Bravo



existing regulatory bodies then coordinated operations and co-operated with other actors who were within the command.

The director of the Action Command had final authority over the actions taken by each of the existing regulatory bodies in their assessments and responses. These bodies in turn reported to Action Command, rather than to their parent ministries, as their foremost responsibility. If the critical period had been longer, however, the relations among parent ministries, normal regulators, and the Action Command might have evolved in a different way.

Another matter of importance was the need to have various governments, research experts, and others on tap, particularly to combat pollution and provide information in forecasting the movement and damages of the oil slick. It is equally important to know how to use these outside resources effectively, even in cases where it is likely that they will not be called in. At Bravo, major problems of adequate supervision, cooperation, and effectiveness arose in the use of pollution control equipment from diverse sources because of differing equipment designs and the sheer numbers of small units of varying effectiveness.

The government regulators had made no arrangements for supplementing the response capabilities of Phillips during the transition period before their own accident control body was staffed and available. They had hoped no accident would occur during the period, and they did not wish to dilute the operator's responsibilities after establishing them.

"Localized internal expertise in blowout control, fully integrated into the accident management system, would have provided greater safety."

Phillips, in turn, relied completely on Red Adair for the all-important matter of regaining control of the well. This could be considered a weakness of the accident management system. While Red Adair had a worldwide reputation in the oil drilling industry, most of his experience had been with blowouts on land. Access of the specialized equipment for controlling wells and space to install it are special problems at sea. The design, height, and complexity of the Bravo platform hindered capping operations. Localized internal expertise in blowout control, fully integrated into the accident management system, would have provided greater safety.

What barring chemicals meant

Action Command insisted that Phillips pursue two approaches to blowout control simultaneously – capping, and drilling relief wells to reduce pressure. Also, it demanded that the company mount a full-scale effort to control the pollution by mechanical means and not use chemicals that Phillips had available to emulsify the slick. Phillips had not been prepared to combat the pollution by mechanical means. Significant delays resulted from locating, transporting, and applying the required mechanical equipment. Additional equipment had to be manufactured on an emergency basis, and some equipment was not effective.

The Action Command felt bound to set a precedent in accident management by accepting Norway's political decision to use only mechanical devices to control the pollution. If the accident had been prolonged, more severe, or closer to shore, adherence to a politically determined principle might not have been the most effective course for controlling it. In the Bravo case, the strong fishing and environmental interests played an important role. The government felt they could affect public opinion on the question of continuing oil development. Therefore chemicals were ruled out, even though the chemical products available at the time disperse oil effectively in water and are far less toxic than those applied after the Torrey Canyon oil spill off the southwest shore of England.

"Other oil companies held back aid for fear their involvement at Bravo would in some way affect future government responses to oil development."

Other oil companies operating in the Norwegian sector of the North Sea did not come to the aid of Phillips in this accident. A cooperative plan existed among the area's oil operators, but it was not followed. However, an offer from an oil company operating in the British sector of the North Sea was accepted.

The oil companies held back for fear their involvement at Bravo would in some way affect future government responses to oil development. Also, the only effective control measures these companies could offer quickly were based on using chemicals, which had been ruled out. This situation has now been improved. Requirements for inter-company responses to drilling accidents

off the shore of Norway have been established, and they include mechanical means of pollution control.

Handling the communications media was a problem for Bravo accident management. Information was given from a central source, with Action Command and Phillips authorities available at one time and place for questioning.

The difficulties arose from poor local facilities for accommodating the press, advance information being released by Norwegian media from their own sources, early preference on flights being given to Norwegian media, and a lack of prepared technical background information on the problems of capping the well and controlling the slick. Attempts by representatives of the media to gain information interfered with the Action Command's management of the accident in the frantic early days of the blowout.

Adair affair. Paul "Red" Adair directs high-pressure water spray with help from his son, James Adair. The internationally acclaimed oil well blowout expert was first contacted in Texas by the platform Bravo operator just after the accident occurred and later given full responsibility for capping the well. (Photo courtesy of International Communication Agency.)

4

TMI Roles and Performances

The nuclear plant accident at Three Mile Island came in four stages. The first three occurred within a week, the fourth lasted much longer.

The first stage was a loss of cooling capability, an on-site emergency that escalated into an accident with potential for catastrophic off-site consequences. Failure to interpret this initiating event properly led to the second stage – several releases of radioactivity into the atmosphere. At this stage, responses concentrated on attempts to cool the core of the plant and on the potentially greater off-site emergency, which did not develop.

Stage three was the formation of a hydrogen bubble in the cooling system. The bubble, which had not been foreseen, blocked coolant flow and was considered the potential source of an explosion that could affect hundreds of thousands of people. The fourth stage was the gradual cooling of the plant to a safe shutdown, and subsequent decontamination efforts.

Responding to the accident

As was the case at Bravo, the accident management process at TMI developed largely after the accident took place. By the end of the six-day critical period, an array of organizations were involved, and many other actor groupings appeared later on, as the emergency diminished. As more was learned about the accident and its different aspects, the accident management actors and their relations changed quickly in an *ad hoc* manner.

At the time of the TMI accident, neither the operator of the plant, Metropolitan-Edison Company (Met-Ed), nor the US Nuclear

Regulatory Commission (NRC) had anything more than very general plans for multi-event emergencies, noncontained accidents, and providing public information on such events.

Both the operator and the NRC had to improvise responses to the accident and its consequences, including decisions on bringing in outside experts to supplement their efforts. Met-Ed relied on the designer and manufacturer of the reactor cooling systems, Babcock & Wilcox Inc., and on other expertise available from the nuclear industry. The NRC relied on the nuclear industry and on the US Department of Energy's national research laboratories. The NRC played a dual role. As regulator, it supervised Met-Ed's accident management responses. As a source of expertise, it also supplemented the responses.

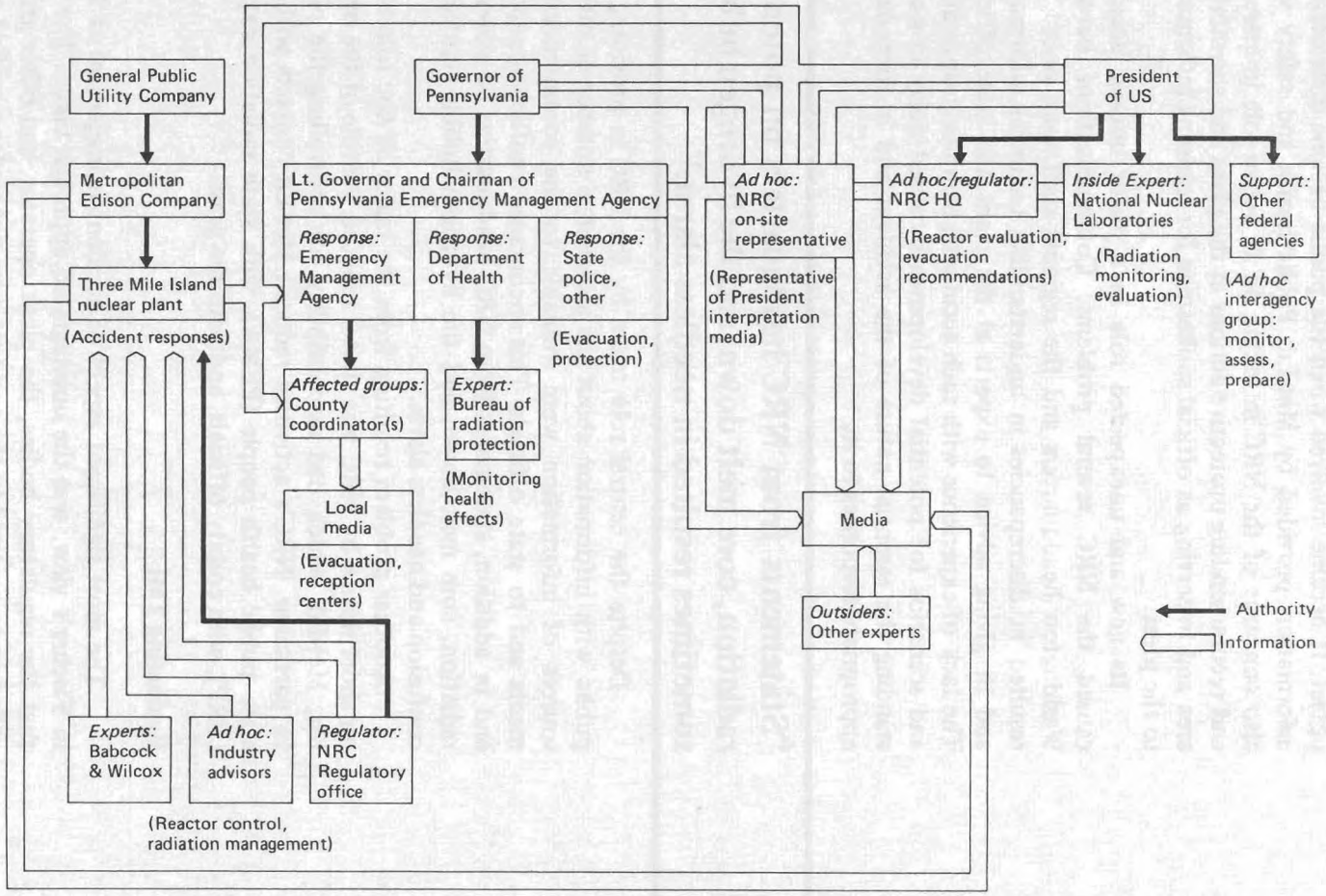
The Pennsylvania Emergency Management Agency (PEMA) and the Pennsylvania Bureau of Radiological Protection (BRP) became part of the off-site accident management organization upon declaration of an emergency by Met-Ed. The efforts of these state agencies were supplemented by requested help from several federal agencies having greater resources for transportation, communications, and radiation monitoring. The US Department of Energy monitored atmospheric radiation from the accident and used a computer model to predict affected areas and possible damage.

For all the actors at TMI, gaining accurate, adequate, and timely information was a major problem. The problem was made worse by the communications media, which besieged officials at the site, at Harrisburg (the state capital), and at Washington for information that sometimes proved conflicting or alarming. Generally, reporting at the site by local media was more accurate than by national and international media throughout the course of the accident.

Faced with varying technical interpretations of the severity of the accident, conflicting information on radiation releases, and a recommendation from the NRC in Washington to evacuate the area, the governor of Pennsylvania asked the President of the US for clarification of technical information and public health and safety implications.

As in the case of Bravo, the operator had primary responsibility for controlling the reactor. Responsibility for evacuation and monitoring off-site radiation rested with the state. The NRC was drawn in as concern over the severity of the accident grew and more information was sought from the commission, and as the potential effects on public health in the plant area became apparent.

The Actors at TMI



The NRC did not have an accident management role at the outset. It became involved when the public became distrustful of information provided by Met-Ed. Public health and safety were also concerns of the NRC in taking on an active role in assessing and recommending protective actions at the plant and surrounding area and in serving as official spokesman for releasing information to the press.

Its new and unexpected role in a major nuclear accident caused the NRC several problems. Communications between Washington headquarters and the regional staff were poor. This resulted in discrepancies in understanding technical information and in giving advice to experts at the plant and state officials. The lack of experience with such accidents, technical information, and scenarios for potential developments caused delay in understanding the essential nature of the accident and in formulating appropriate responses to it.

"Statements from NRC headquarters on potential radiation, core melt down, and the hydrogen bubble sometimes resulted in needless alarm."

Despite the central role taken by the NRC in providing the public with information about the accident, a number of official sources of information were available to the communications media and to state officials. This encouraged conflicting reports, and in addition, statements from NRC headquarters on potential radiation, core melt down, and the hydrogen bubble resulted in confusion and needless alarm.

Another problem resulting from the major *ad hoc* role taken on short notice by NRC was that it reduced the role of the operator, Met-Ed, which had responsibility for controlling the plant. In particular, NRC's activities reduced Met-Ed contacts with the state public health people (PEMA), with state radiation experts (BRP), with county officials, and with the press.

Evaluating TMI

The most significant aspect of accident management at TMI, in Fischer's view, was the unintegrated approach taken. The fact that the regulatory bodies, the plant operator, and other groups called in to respond to the accident were not under a unified command contributed to many of the problems and difficulties that arose.

The NRC headquarters in Washington did not make use fully of the on-site knowledge gained by its own regional office. It then contributed to confusion and anxiety among actors and the public by issuing statements to the Governor of Pennsylvania and the press that overstated the need for evacuation and the explosive potential of the hydrogen bubble.

At the outset, no one appeared to have final authority, and this prompted the Governor to ask the President to direct one man to take responsibility for on-site activities. The arrangements that thus evolved, as outlined above, might have been difficult to maintain if the accident had been more severe or more prolonged and had required evacuation of a large area.

Clearly, there was a need for predetermined roles. Accident management responses should be based on research that has been carried out before the fact. Regulators, experts, and support people should know how they will be used and how they will fit into the organization hierarchy before an emergency occurs. Release of information should be planned so that it has desirable effects and does not cause unnecessary anxiety and confusion.

The nuclear-industry accident-management plans are based on taking no chances, with emphasis on reactor shutdown, emergency cooling, and containment capabilities. While these safety measures were provided for at TMI, it was also possible for the operator to override the system. This puts the whole safety system into question.

A similar accident occurred at the Davis-Besse nuclear plant a year before TMI, and though early warning signs were ignored, no serious accident resulted. The NRC could have learned from that accident and passed on valuable knowledge to the TMI operator, but did not do so in time to help prevent the accident that took place.

The confusing information and recommendations from a variety of sources and the uncertain links between actors were potentially serious shortcomings of the system at the start. Only the swift and strong action of the governor to put himself in charge of state information sources remedied the worst of the problem.

Politicians thus had significant direct and supportive roles. The combined appearances of the US President, the Governor, and the NRC accident manager demonstrated a meeting of the minds on the nature of the accident and the appropriate responses. This served to counteract the confusion and anxiety that had developed over the event.

It is true that the results of prolonged releases of large amounts of radiation at TMI could have been catastrophic. How-

ever, such releases did not take place, and a hydrogen explosion was never even a possibility. If the accident had been more severe, the evacuation plans that were underway would no doubt have reduced radiation effects on residents of the surrounding area. However, if evacuation of a 20-mile radius had proved necessary, 650,000 people would have been involved, and achieving an evacuation of this scale would have been extremely difficult with the resources readily available.

What off-site implications meant

Of considerable significance in the TMI accident was the fact that the electric utility operating the plant, Met-Ed, had primary responsibility for responding to an accident confined to the perimeter of the plant site. As soon as the accident was recognized, the plant staff summoned technical engineers from its parent company to help with the containment effort. Also, the plant supervisor brought in representatives of Babcock & Wilcox, the company that designed and constructed the reactor cooling systems, their controls, and their instrumentation.

"At a later stage the nuclear industry set up an *ad hoc* advisory group consisting of representatives from nuclear industry."

At a later stage in the accident, Met-Ed asked for and got help from the nuclear industry, which set up an *ad hoc* advisory group consisting of representatives from several nuclear utilities and suppliers. Then, since the consequences of the accident went beyond the plant itself and into the adjacent environment, and even beyond, the plant supervisor also notified PEMA, BRP, the regional office of NRC, the local county, General Public Utility Company (Met-Ed's parent company), the Brookhaven National Laboratory, and the Pennsylvania State Police.

The responsibilities of some of these actors are worth noting briefly. The state of Pennsylvania bears primary responsibility for the health and protection of its citizens. Its agency for responding to the emergency was PEMA, a group created in 1978 from an existing body called the Civil Defense Council. This agency has long been concerned with evacuation planning and execution, and in fact has had some experience with it.

BRP, the state bureau responsible for radiation protection, including responses to any nuclear accidents, also monitors off-site

The risks of haste. The Pennsylvania State Governor's Emergency Control Center, seen here, was hastily set up in the sub-basement of the State Capitol in Harrisburg to coordinate all state and federal responses. While this center was the source of information on evacuation, the Pennsylvania Emergency Management Agency (PEMA) was responsible for executing evacuation. For a crucial period, PEMA was cut off from the Emergency Control Center and had to rely on the press for its information. (Photo courtesy of Associated Press.)

radiation. It must recommend protective measures including evacuation. Monitoring actually became a three-actor response. BRP kept contact with Met-Ed's monitoring efforts, but because of a lack of monitoring and radio equipment, a federal monitoring team was called in from Brookhaven.

The similarity to events nearly two years earlier at Platform Bravo does not extend to the organizational structure. The difficulties that arose at TMI can largely be attributed to the fact that accident management was split among several actors.

There was the on-site accident center established at the TMI plant run by Met-Ed and supplemented by an NRC staff that included one man who became the source of all technical and on-site information. In addition, an off-site accident management center in the Governor's office coordinated all state and federal responses. This center was the source of information on evacuation and other protective measures. Finally, the President's office coordinated federal agency responses for emergency relief and provided information on these efforts.

This three-way split in accident management served to coordinate responses and to consolidate information sources from many to merely three. However, the new arrangements failed to bring information on off-site radiation under one of its three information centers. So the main sources of information on any consequences adverse to local and area residents remained BRP, NRC, and other state and federal monitoring groups – all of whom continued to maintain ready contact with the press.

The three-headed approach had another important weakness. It left out three key actors, at least to some extent. The utility (Met-Ed) and its industrial advisors, who collectively represented primary responsibility and the most experience with matters at hand, ended with a reduced role and no contact with the press. Washington headquarters of the NRC, which was a source of regulatory and safety expertise despite also being the source of misinformation and alarming scenarios, was also cut off from the press.

Even less desirable was PEMA's situation. Headquarters for evacuation planning, preparation, and execution found itself cut off, not only from the press, but from the Governor's office.

Undoubtedly, had the accident grown more severe and been prolonged, all three of these somewhat neglected actors would have had very important roles. Met-Ed, the nuclear industry, and NRC headquarters would have become increasingly involved with accident management and with the media, and if evacuation had been necessary, PEMA would have had primary responsibility.

5

Comparing the Responses

The similarities and differences in the ways the actors responded at Bravo and at TMI throw light on accident prevention and management in general. The similarities of the two accidents make the comparison easier. However, some important differences in the two accidents account in significant measure for the differences in responses. Also, there were successes and failures in both cases, so that neither accident can be seen as a model of how accident management should or should not proceed.

Unquestionably, the regulation, operation, and safety needs of a nuclear power plant in a densely populated sector of the US are a much larger and more complex responsibility overall than responsibility for an offshore drilling platform in the North Sea. Because of the greater scope of responsibility, authority necessarily had to be more divided at TMI than at Bravo.

Fischer recognizes the important differences in scope of the two accidents, but he nevertheless draws the conclusion that an integrated system of accident prevention and management works best. He demonstrates the need for integration by comparing the responses of his six major types of actors at each accident.

"At Bravo a virtually on-the-spot decision was made to put all regulatory and supportive actors into Action Command under a single leader."

Accident response groups. There was a big difference in the way authority to act evolved in the two cases, which related to the differences in scope. At Bravo a virtually on-the-spot decision was

made by the Minister for Environment to put all major regulatory and supportive actors into Action Command under a single leader.

This response had in fact been part of an outline plan, but it had never been implemented. Implementation was oral, coming within hours of the accident itself. All on-site and off-site responses – including release of information to the public – then came from Action Command, which was the direct representative of the government. This meant that no political officials had to participate in management decisions directly.

Action Command worked closely with the governmental regulatory agencies and allowed primary responsibility for managing on-site control (capping the well) and off-site control (containing the spreading oil slick) to remain with the operator of the offshore drilling platform.

All official statements released to the press came from Action Command. This eliminated any possibility of conflicting reports and alarming speculations from government or other sources.

It had been clearly established before the accident took place that the operator was responsible for accident control. It was also clear that Action Command had authority to take over management from the operator if this was considered to be necessary in the public interest.

At TMI, the original plan had been to keep accident control centralized. The operator's loss of credibility and the growing apprehensions of the public forced the NRC in. Responsibility for on-site accident management was then delegated to an NRC man, Harold Denton, while off-site responsibility rested largely with the Governor.

The organizational form was decentralized in three separate headquarters. Each had responsibilities reflecting their normal jurisdictions. For these three organizations, understanding the accident and communicating clearly became crucial, particularly for actors responding at a distance from the site.

The two individuals directing on-site and off-site activities – the Governor and the designated representative of the NRC – held joint press conferences to provide information to the media. PEMA, the state agency responsible for evacuation, did not receive needed information from the Governor's office during the latter stage of the accident.

Direct responsibility for on-site management of the accident became unclear during the course of events as the NRC became increasingly involved in cooling the reactor. No predetermined authority allowed this federal agency to take over management of

the accident from the public utility it had licensed to operate the plant. The operator's evolving background role extended to being requested by NRC not to attend press briefings or issue information to the press.

Normal regulators. The NRC first took an impromptu role in managing the accident from Washington and soon assigned a man in charge on the site (on the direction of the President). The NRC role at the site contributed to effective management and improved the quality of public information. Its role was partly active (managing the release of information) and partly passive (supervising the operator's efforts to control the accident).

Postmortem begins. Three US congressmen, James Weaver of Oregon, Morris Udall of Arizona, and Austin Murphy of Pennsylvania, view the control room of the TMI plant six weeks after the accident. They were members of the House Subcommittee on Energy that later held hearings on nuclear power. (Photo courtesy of Associated Press.)

During the Bravo accident, by contrast, the on-site governmental regulator, the Oil Directorate, played only a passive role, checking and assessing the prospective plans for controlling the accident. The regulating agency for off-site responses was the Pollution Control Authority, which played a supplementary role by requiring the operator of the platform to use mechanical pollution control devices and by helping to acquire and apply them.

Operators. At both accidents, Bravo and TMI, the operators had primary responsibility for preventing and responding to accidents. Phillips Petroleum Company, the owner and operator of the Bravo oil production rig, and Metropolitan Edison Company, the operator of the TMI nuclear plant, proceeded in similar ways. They protected their employees at the site, called in industrial experts to supplement their accident-control efforts, and notified and cooperated with government regulators and accident managers. Both operators complied with the wishes of government officials in releasing information to the press.

Once the accidents had occurred, experts from elsewhere in the industry assumed key roles in bringing each of them under control."

Neither operator relied on previously developed assessments of alternatives for the events confronting them. In both cases, the supervisory and operational staffs did not respond correctly while the accident was still preventable. Once the accidents had occurred, experts from elsewhere in the industry assumed key roles in bringing them under control.

Inside experts. Specialized inside experts had similar tasks at both accidents. These included assisting on-site and off-site control and tracking and predicting off-site effects. At Bravo no roles for experts had been developed ahead of time, so they had to be initiated on the spot.

Bravo scientists generally agreed on the seriousness of the threat posed by the accident and on predictions concerning it. At TMI considerable disagreement arose over the nature and consequences of the accident and its radioactive emissions. Integrated roles had not been developed.

Affected groups. A destructive oil slick produced at Bravo threatened marine life and the residents of nearby coastal communities. An invisible radioactive cloud threatened residents of the TMI area, and a more serious accident would have expanded the

threat to a large heavily populated area of the eastern US. However, neither accident resulted in major adverse effects on workers, residents, or the biological environment.

At Bravo and at TMI no public information roles or facilities had been planned ahead of time. Information from a variety of sources, some of it inaccurate, caused confusion at both accidents. This was a greater problem at TMI, where the scope and implications of the accident were also greater. In both cases, press representatives for the most part lacked technical knowledge for judging the information they received or for asking accident managers appropriate and answerable questions.

Outsiders. Outside experts used both occasions as opportunities for airing their personal views of the respective energy technologies and their implications for the environment and mankind. These views contributed to public alarm during both accidents and influenced the decisions in both cases to declare moratoriums on further energy production of the type involved.

Foreign observers at each accident demanded extensive information because of the potential consequences in their countries. At Bravo, foreign observers were present throughout the accident. They observed the deliberations of Action Command firsthand, tracked the direction and extent of the oil slick from aircraft, and played essential roles in efforts to contain the slick. The Bravo accident led to closer cooperation between Norway and the United Kingdom on matters relating to accident management.

At TMI, foreign observers were present at the NRC Washington office during and after the accident, and afterward at the plant location. In addition to sending observers to both accidents, various international agencies have deliberated over the implications of the accidents. The discussion has been based to a large measure on the information about the two accidents generated during the first hectic crisis days.

The *ad hoc* nature of accident management in both cases has the advantage of allowing outsiders – actors affected by the accidents, useful experts, and others – to come into the system. But this could lead to interference with the system and to wrong interpretations of events, both within the system and for the public.

A well-planned accident management system should allow for including external actors, such as influential involved groups. These actors should be identified, contacted, and integrated in the system where this can be done without provoking controversy unnecessarily.

6

Lessons and Suggestions

It can be seen from the experiences at Bravo and at TMI that, from the organizational point of view, accidents are not necessarily unique. There are similarities that suggest lessons applicable to accidents in general. Fischer's paper brings out several possible lessons to be learned from Bravo and TMI:

- A central organization is critical to smooth management of accidents.
- An overly optimistic predisposition can cause excessive allocation of safety resources to accident prevention at the expense of accident management.
- All potentially participating individuals and organizations should have clear, preplanned roles.
- Accident management plans can be more flexible and better designed to deal with rare contingencies if they are developed through a dialectic process with all affected parties involved.

Some common weaknesses

Fischer draws several more-specific conclusions from his comparison of the two accidents. They are not meant to be definitive and final, but merely interpretations of the official responses to the two events that warrant further consideration by those concerned with large-scale accident prevention and management.

In each case, predetermined, *a priori* roles in accident management were lacking for most of the actors involved. The accident response actors were not prepared for immediate active involvement at or away from the site. A major Norwegian response sys-

tem had been legislated and was being prepared, but there was no plan for the interim until the system could be completed. The US NRC had no plan for active involvement in an uncontained nuclear accident.

Lack of predetermined roles extended in both cases to the normal regulatory agencies of the government, the operators of the facilities, industry and government experts, scientific experts, outside experts, high political officials, the press, and representatives of groups of people who might be affected by the accident.

"The need here is to plan for the unexpected, to take into consideration the fact that preventable accidents can nonetheless occur."

It appears from both experiences that accident planning is not extensive for accidents that are considered preventable. Both accidents were later found to be wholly preventable, and yet both of them did happen. The need here is to plan for the unexpected, to take into consideration the fact that preventable accidents can nonetheless occur.

The transition period at Bravo also provides a lesson. Since such periods are inevitable, effective responses should be planned for them. Accidents, if anything, are more likely during such times, because integrated prevention and accident management roles are then unclear and safety procedures may not be fully articulated.

After both accidents occurred, substitute decision makers came on the scene. At Bravo, the new Action Command took over and Red Adair and other experts were called on the scene without any preplanning to handle well-capping and pollution-control operations. The void at TMI was filled by the two highest level politicians with jurisdiction over the geographical area, and also by industry experts and an administrator from the highest governmental agency with jurisdiction, all of whom played roles at TMI for which they had had no forewarning.

Using substitute decision makers raises questions of authority, responsibility, liability, appropriate alternatives for management, and the effects on future working patterns at the two facilities, and in particular the relations between the operator and the normal regulator. Once the accident is over and under control, the substitute actor has completed his task, which leaves the normal regulator and operator to cope with and adjust to the consequences of someone else's actions.

Another complication of authority relations occurred after both accidents, when temporary investigatory actors came on the scene at Bravo and TMI. This further altered the relations between the regulators and the operators of each facility.

A more effective arrangement would be to have such substitute actors as accident managers and accident investigators work through or with the normal regulators and operators. This would reinforce the assumption that accident management requires special attention by both regulator and operator. This would not only smooth the transition to the post-accident phase, but also strengthen the pre-accident phase, which is concerned with prevention.

In neither accident were the roles of outside actors anticipated. Politicians, the press, outside experts, foreign observers, and representatives of threatened groups all played important roles during and after the two accidents. To the extent that such actors can be expected to become involved, they should be included in accident planning.

A centralized organizational form, with accident headquarters near the accident, proved advantageous at Bravo, particularly because it allowed for the consolidation of information sources. Despite the far greater complexity of events at TMI, central control from the outset would appear to have been able to avoid the difficulties with information flow that were resolved later.

Some broader implications

The damage sustained in the accidents at Bravo and at TMI was not, in Fischer's view, the most significant result of the events. Bravo caused a halt in offshore oil drilling plans in the northern part of the North Sea. TMI stopped the construction and licensing of nuclear power plants in the US. Both moratoriums have since been lifted despite the fact that provisions for accident prevention and management of both types of energy production have not been drastically altered since the accidents took place.

Technical means for containing the consequences of an accident in any case appear to reduce only the immediate effects on the threatened environment and people. Politicians, the press, and the general public can cause long-range effects without regard for their full consequences. The question of whether to continue to develop nuclear power or to extract offshore oil without interruption, for example, should not be resolved as a response to public concern over a single accident that caused little damage. Therefore,

a wider range of consultations is needed, particularly with interested groups outside the direct accident management circle, to reduce the possibility of inappropriate political responses to accidents that occur.

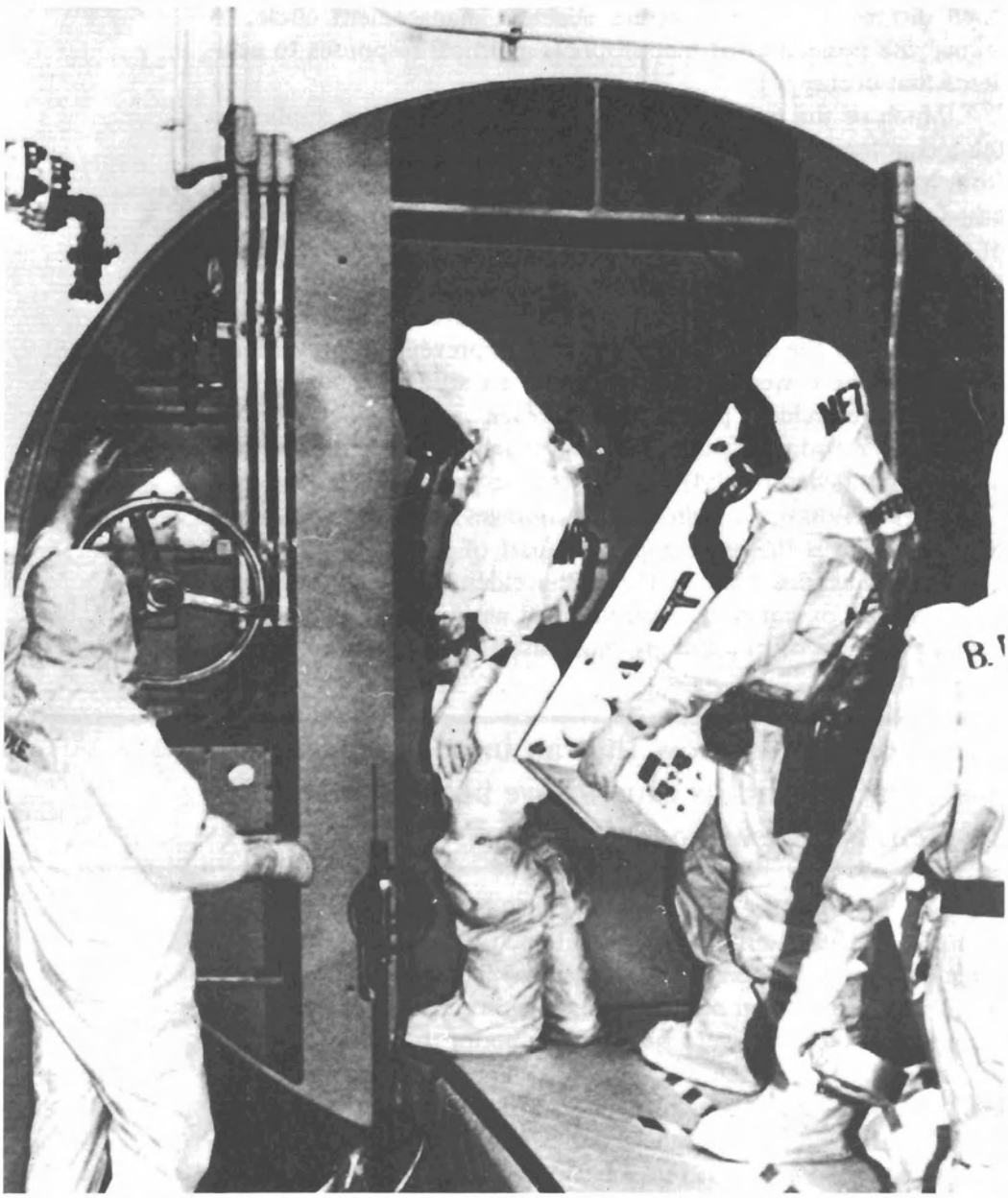
Much of the available research resources has been applied to the technological aspects of accident prevention. Fischer concludes from his overview of Bravo and TMI that there is need for research based on systems analysis, using social scientists as an integral part of the research process. Accident-management systems such as the two cases in point are based on individual actors and organizational actors. Investigators have attributed both Bravo and TMI to weaknesses among the actors responsible for preventing preventable accidents. These weaknesses had not been studied or accounted for in the pre-accident phases of either event.

Fischer also wants a broader approach to accidents to eliminate oversights that result from adherence to professional ideologies. Collective wisdom, or mindset, discourages questioning assumptions – which is the most important part of accident prevention. The hard questions came in the post-accident phase of these accidents, which of course is essential. But an imaginative and deep-probing process of questioning must also be structured in the pre-accident phase.

"To some actors, now that an impossible accident has occurred and its causes have been corrected, an accident is once again impossible."

In preparing the paper from which this executive report is derived, Fischer found that regulators, operators, experts, and other actors often referred to the accident in question as "unique." Each accident was thought impossible because in-depth safety technologies applied were generally superior to those of other industries or those used in the past. The accidents that nevertheless occurred were seen as one-time configurations of weaknesses.

These assumptions lead to others. Since the one-time combination of weaknesses had now been accounted for and corrected, it could never happen again. To some actors, now that an impossible accident has occurred and its causes have been corrected, an accident is once again impossible. The similarity of these two accidents shows that uniqueness is a myth, and it also suggests that further comparative studies of other accident-prevention and accident-management systems would prove useful.



For some the risk remains. Two years after the accident, protective suits and other precautions are needed within the building housing the damaged TMI reactor. Here technicians enter the Unit Two reactor containment building in February 1981 with one of eight cameras in a closed-circuit TV system that now monitors the activities of anyone inside the building. (Photo courtesy of Associated Press.)

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