# INTERDISCIPLINARY DISASTER RESEARCH

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Disaster research is asking scientific questions about Acts of God. During the last ten years efforts have been made to understand the causes of natural and man-made disasters, to determine how people are affected, and how material and mental relief can aid recovery. Such research as has so far been carried out in isolation, has followed the old academic tradition of investigating separate disciplinary problems. Yet to come, and urgently needed, is the interdisciplinary investigation of disasters, where for example seismologists, social scientists and civil engineers work together as a team to study earthquakes in general and together make an in-depth hindsight review of a particular seismological event. This paper will attempt to point the way to more interdisciplinary disaster research.

## DEFINITIONS OF DISASTER

Asking scientific questions about Acts of God is hardly an adequate definition of the subject. I have defined interdisciplinary work elsewhere as originating from the joint and continuously integrated effort of two or more specialists of different disciplinary background and training. Research is easy to define and it appears as: "a course of critical or scientific inquiry" in the Shorter Oxford English Dictionary, Third Edition, 1977. It is only when we come to Disasters that our difficulties begin as there is no agreed definition, nor is there a scale of magnitude. In a previous paper I gave on this subject (Disasters Past and Future, 1972) I suggested the following definitions :

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| ACCIDENTS | 1 - 1000 people dead or in immediate danger of death. |
| DISASTERS | 1000 - 1 million people dead or in immediate danger of death. |
| CATASTROPHES | More than 1 million people dead or in immediate danger of death. |

These definitions are by no means adequate. Consider for example the destruction of the City of Darwin by Cyclone Tracy in December 1974. Only 65 people died and there was no imminent danger of death to the population of 45,000; this danger would only have occurred if a lethal epidemic had broken out. Yet it was undoubtedly a real disaster in terms of the total destruction of a city and the suffering it caused to its inhabitants.

Harold D. Foster of the University of Victoria, BC, has so far given the most comprehensive definition of disasters and their magnitude. (Professional Geographer 28, No 3, 241, 1976). His scale is built around a social stress rating, derived from an individual's loss, or change subsequent to being involved in a disaster. He derived a number of formulae, allowing for the differences between developed and under-developed countries, to arrive at the total stress caused during a disaster. The terms in his formulae included the number of fatalities, of seriously injured, the stress values and the number of the total population affected. He derived a logarithmic magnitude scale for a number of famous disaster events, for example: Black Hole of Calcutta of 1756, magnitude 5.0; Titanic sunk 1912, magnitude 6.1; World War I, 10.5; World War II, 11.1; Atomic Bomb, Hiroshima 1945, 8.2; Earthquake, Managua 1972, 7.9; Cyclone Tracy, Darwin 1974, 6.6. These magnitudes on Foster's logarithmic scale, as derived from his formulae, are directly correlated with the total number of stress units, in the hundreds of millions.

I am not aware that the Foster scale of disasters has found universal acceptance as it neglects the difficult-to-assess damage to structures and environment. Yet a universal scale of disaster magnitude would be most valuable both for researchers in this field and for those in charge of relief operations. It might well become as universal as the logarithmic Richter scale for earthquakes.

In this paper, having inadequately defined disasters, I shall attempt to review such systematic disaster research as has occurred and mention some of the results. Again this can by no means be definitive and can only point others in the right direction. After that I want to talk about two types of natural disasters, before coming to man-made disasters and what I would call nuclear accidents. Finally I shall arrive at some conclusions about disaster research by suggesting the need for an International Disaster Research Laboratory.

## WHY NO RESEARCH

Disasters, both natural and man-made, are unpredictable but inevitable. We might now know where they could occur but not when. Each disaster appears to differ from its predecessor, and hence a lack of incentive to carry out research may appear understandable. And who is to fund such research? There is no industrial and profitable infrastructure to encourage it, nor are the academic and scientific communities keen to consider disaster research a subject of pure knowledge, worthy of investigation *per se*. Would insurance companies not make larger profits if they had to pay smaller indemnities to those who had applied the results of disaster research? For example, adherence to building codes for earthquake-proof buildings is rewarded by lower insurance premiums in California.

Another reason for the lack of disaster research is the impossibility of creating artificial disasters for experimental purposes. Yet model experiments are undertaken routinely where macro-engineering projects are involved. For example, elaborate hydrodynamic flow tests were carried out before the Thames Barrage was built. Mathematical computer models should prove of great value in disaster research, but so far few have apparently been carried out and reported in the literature. Other scientific disciplines are also difficult to study by experiment, as for instance astronomy. Yet great knowledge of the planets and the stars has been obtained by observation, hypothesis, and renewed observation, refining the instruments for each successive examination.

## INTERNATIONAL LABORATORY

There appears to be no theoretical reason why an International Disaster Research Laboratory should not be set up and supported by rich insurance companies. There interdisciplinary research on earthquakes, floods, fires, volcanic eruptions, tsunamis, drought, hurricanes, frost and other meteorological phenomena, landslides and erosion, could be studied in depth by all the many scientific disciplines which must contribute to progress in this field. I shall outline a research programme for such a laboratory a little later on.

## INTERDISCIPLINARY PLANNING

Pre-disaster planning is so far the best example of interdisciplinary work in this field, and a considerable literature on disaster planning has accumulated. *Advanced Planning for Disaster Relief* (Pergamon 1979) a small book by Barbara J. Brown, was a detailed project undertaken for the United Nations Institute for Training and Research, UNITAR. It contained much sound advice for planning before disaster strikes, particularly for the Third World and also for Donor Countries. For the richer and more developed disaster-prone areas in the US and in Canada Professor H.D. Foster of the University of Victoria, BC, has contributed an excellent research effort in his book Disaster Planning, The Preservation of Life and Property (Springer Verlag, 1980). Each of his chapters contains extensive lists of references and the work is highly recommended to all concerned with pre-planning, be it safer design of structures, the prediction and prevention of disasters, and disaster warning systems. Both Brown and Foster have done much research for their surveys. If their advice were only half followed, innumerable lives would be saved in the next disaster. At present, on an average, there are each year 250,000 deaths and $ 15 thousand million damage due to disasters.

## INTERDISCIPLINARY SOCIAL SCIENCES

A very wide-ranging, large-scale survey of natural disasters, in their interdisciplinary relation to human populations and demography, was begun in 1981, and still continues, by J.F. Coates Inc., a consulting firm in Washington; they received a grant from the National Science Foundation for this work. A massive literature search of the social sciences in relation to disasters accompanied the survey; it can only briefly be summarised here. A total of 17 hazards was considered, ranging from earthquakes to bush fires, from tsunamis to drought and snow avalanches. It was found that Disaster Research at various levels was now being carried out at Ohio State, Clark, Toronto, Chicago and Colorado Universities. The well-known newsletter, Unscheduled Events, founded in 1963, will in future be published by the Research Committee on Disasters; other publications in this field include the International Journal of Mass Emergencies, the Hazard Monthly, in its third year in 1981 and the Natural Hazard Observer then in its seventh year.

Coates found that overall migration of the US population affected the likely future of disasters. With people moving into the Sunbelt of Texas, California and Florida, well known high hazard areas, future disasters may have much higher mortality figures. On the other hand, deaths from snow, lightning, frost and tornadoes in the North Central States would diminish, simply because people had moved away from these areas.

In more general terms, Coates stated that man ignores, forgets and discounts hazards from natural disasters. Without any real experience of them, the risks from hurricanes and earthquakes seem uncertain, indefinite and even unlikely. Compared to our many other pressing concerns, of immediate attention demand, natural hazards receive low priority.

Coates and his team of researchers maintained that, at least in the US, people did not panic after a disaster and that looting was only a minor problem, although such behaviour was widely believed to occur. Rich and poor had widely different reactions to disasters and saved themselves in totally opposite manner. People always converged on disaster sites, either to watch or to help, and hindering rescue workers. Most disasters have no long term effects, either social or economic, on communities; elderly people do not always agree to be evacuated, and if they remain, they can have a major effect on the morale of disaster victims. Coates pleaded for three kinds of social science research on natural disasters: long-term studies, lasting years and decades, of the same topic and of the same region; more cross-cultural and international studies, and particularly a vastly increased amount of field research after disasters.

INTERDISCIPLINARY TECHNOLOGY

If the Coates Survey confined itself to the interdisciplinary aspects of human behaviour before and after disasters, then another Washington investigation in March 1977 considered The Role of Technology in International Disaster Assistance from an equally broad and interdisciplinary point of view. This workshop created by the US National Academy of Sciences, which also published its Proceedings, underlined the fact that no technology related to disasters is an economically profitable field, and if it is funded, then only erratically, if at all. It is well known that, whatever the disaster, any rescue equipment brought to the scene is of standard manufacture and must be adapted at the site to the special needs of the occasion. Some of the conclusions and recommendations of the workshop may not be well enough known and should be repeated here.

For immediate disaster rescue, heavy gear is essential, be it helicopters, boats or simply gin poles to lift heavy rubble, or parts of destroyed buildings. In pre-planning operations for disaster-prone areas, it should be borne in mind that military surplus is ideal, as it can be bought at a fraction of the normal cost from commercial sources. Care and maintenance of tractors, assault boats, power-shovels and other items so acquired, can be arranged with nearby military establishments. Training in its use should have top priority for the community, as after a disaster there will always be unaffected volunteers anxious to help. Furthermore, official aid can thus be saved for major aspects of rescue.

Many other ingenious adaptations of readily available goods were suggested; for example large plastic garbage bags can give an instant shelter for people to protect them from wind and rain. Torches, and audible distress signals can be distributed or airdropped before or during floods, and particularly valuable are small radio receivers; these proved essential during the Darwin disaster.

## DISASTER COMMUNICATIONS

Communication equipment puts control into the hands of the decision makers. General Alan Stretton's The Furious Days (Collins, Sydney 1976) should be read by any disaster planner as it is the best available account of dealing with a disaster situation - the case of Darwin destroyed by cyclone in 1974 - that has yet to come to my notice. Over 3,000 radio receivers were air-lifted into Darwin and proved vital to keep up morale; Stretton broadcast regularly twice daily after their arrival. Equally important are communicative facilities for the press and the media, who will inevitably flock to the site of any disaster; nothing can be more frustrating for the press than to be unable to transmit their reports back to their home base. During large scale disasters, foreign Governments and International Aid Organisations often send aid for prestige purposes, and their prestige as well as further aid will vanish if media reports do not describe in glowing terms what their help has achieved.

## SATELLITES

If satellite systems are available they will of course be most valuable for international traffic. The plan much discussed by the International Telecommunication Union, the United Nations Agency responsible for all telecommunications, to have small portable antennae for underdeveloped countries for disaster communications via satellites, has apparently not yet been used. A booklet on this subject, entitled Space Radiocommunications System for Aid Following Disasters was published by the I T U in 1975.

The first Satellite for Emergencies, SAFE, was proposed by H S Wolff in September 1964. From a hand-held and hand-cranked transponder an interrogation signal from a satellite in polar orbit would be re-transmitted to a ground station. This would give knowledge of the existence of an emergency, and if two such satellites were available, also its location. In his pioneering publication on the subject, Wolff called it a "Technologically feasible pipe dream".

NASA's first Applications Technology Satellite, ATS-1, launched in 1966, transmitted 800 to 900 emergency medical calls per year during its 10 year life, linking doctors with remote villages. A natural technological development from "Flying Doctor" to "Space Doctor"!

One of the first uses of satellite communications during a disaster occurred in July 1977 when Johnstown, Pennsylvania, was flooded. A portable 4-foot (1.2m) antenna was set up at a local school and allowed Red Cross officials to communicate with their headquarters in Washington; the satellite used was NASA's Communications Technology Satellite, CTS, launched in January 1976 into a synchronous orbit and stationed just west of South America over the equator.

Today there are many communication systems available in developed countries and some even in less fortunate areas, be they troposcatter links, cable systems when telephones have been restored, microwave radio, VHF and UHF frequency modulated radio. Small portable intercom-radio equipment will allow those in charge of operations to keep in constant touch with headquarters. All communication in a disaster area should be tied together to establish a total emergency communication system.

But to return to the Washington Workshop on Disaster Technology and one of its final recommendations when considering Search and Rescue: after a disaster, a physical point of orientation is a vital necessity for people who have lost their normal orientation, for receiving of services and advice, for them to be counted and identified, for collecting families and possessions, and as a staging point. This would be necessary for any evacuation, as was the case in the Darwin disaster when in five days 25,000 people were airlifted to the Southern Capitals of Australia.

## DISASTER RESEARCH HISTORY

Disaster research, often highly interdisciplinary, has of course also been carried out in other countries, although I am only aware of such work in England and in Australia. It was undoubtedly stimulated, if not started, by one of the greatest disasters in modern history, the cyclone and tidal waves in East Pakistan during November 1970. It was also the worst example of disaster relief. An estimated 500,000 people died as a direct consequence of the event, but had the relief been organised and co-ordinated, thousands would have been spared. The Archdeacon of Westminster, the Venerable Edward Carpenter voiced the thoughts of many who had followed the incredible bungling, the corruption and delays, the deficiencies and scandals, which attended the events in East Pakistan: "The feeling of guilt of the affluent West that in our highly technological age, capable of putting a man on the Moon, forces, so age-old and elemental, could bring about such a disaster". Yet, 14 years later, it appears that half a million Pakistanis did not die in vain.

Two years after Pakistan, in October 1972, the Royal Army Medical Corps held Exercise Helping Hand in Hampshire, England, to which representatives of all the Army Medical Corps of the West had been invited to consider in what manner their Medical Corps might contribute to disaster relief, more efficiently and more cost-effectively, than had been the case in East Pakistan. I was greatly honoured on that occasion by an invitation to give the key-note address Disasters Past and Future in which I pleaded for the establishment of an International Rescue Organisation - it still does not exist.

A few months earlier, in March 1972, the United Nations set up in Geneva an Office for its Disaster Relief Coordinator, generally referred to as UNDRO. It has a communication room in the United Nations in Geneva with telephones and telexes. The funds allocated to fulfil its true function of co-ordination have been woefully inadequate and its own review report in 1980 was generally considered a disaster itself. (London Times, 11 November 1980).

It was also in 1972, though probably not as a consequence of the Pakistan disaster, that the Civil Defence Directorate of the Commonwealth of Australia was relocated and that its function changed from Civil Defence to Counter-Disaster activities; these activities were formalised on 1 January 1975 and the College received its present name, the Australian Counter Disaster College on 1 January 1978.

Perhaps more directly traceable to the Pakistan disaster is the British Disaster Unit set up in 1974 as part of the Ministry of Overseas Development. Regrettably, like UNDRO, the funds and organisation at its disposal are quite insufficient to make a major impact on relief, although small sums are regularly dispatched to overseas governments when disasters occur.

In England it was the Disaster Research Unit of the University of Bradford which started in December 1973 in order to increase awareness of pre-disaster planning, including research on precautions to be taken before the event. Their team went to the Bahama Islands for field research to study pre-planning and, after two years' existence in 1975 seven occasional papers had been published. Parallel to the Bradford Group, the London Technical Group started work in 1972 on disaster research as a direct consequence of the Pakistan cyclone and in 1978, the International Disaster Institute developed from the London Group. It had extreme financial difficulties in starting its work, as it was attacked by the voluntary disaster relief agencies who feared that some of their work might be critically analysed. The prime aim of the Institute is to make disaster relief more effective through research.

An outstanding example was their investigation of the effectiveness of large scale vaccination in developing countries following a breakdown of normal life after a disaster. In the past it had never proved possible to vaccinate a complete population at risk, and if a small proportion only can be vaccinated at random, the epidemic cannot be contained. Much better, LTG concluded, to conserve the available supply, watch for outbreaks, then vaccinate and thus contain the epidemic; this of course depends on local conditions and the particular disease. Similarly the distribution of vitamin supplements was found to be a waste, as deficiency diseases appear only after long periods of deprivation.

END OF METHODOLOGY

So far I have reviewed what might be called the methodology of disaster research, I have pointed to the inadequacy of interdisciplinary research and the preponderance of pre-disaster planning advice. The need for an International Disaster Research Laboratory appears to me overwhelming. And this is particularly so as disasters are on the increase world wide. The reasons are not only the population explosion in the underdeveloped countries, but also the steady movement of populations into cities, increasing living standard and hence greater loss during a disaster, and in the last decade the location of industries in disaster areas. For example off-shore oil platforms in the North Sea, exposed to the dreaded winter storms, and in the Gulf of Mexico, exposed to cyclones; also the erection of high-rise hotels along hurricane exposed coasts.

Similarly it appears that after the relative quiet of 1950-1980, earthquakes are again becoming more frequent; however, there is a lack of historical research, only in China and in Italy are records available extending over 2,000 years. We need to know the 'repetition period', the 10, 100, 1000 year event, as present accurate knowledge extends at most over a 30-50 year period.

HISTORICAL EARTHQUAKES

I would now like to turn to a more detailed consideration of earthquakes. Here there is one splendid example of historical disaster research, the in-depth hindsight review which is so much needed for all types of disasters. It was Professor N.N. Ambraseys of Imperial College, London, who made a profound study of the history of earthquakes and reported some of his results in 1976 (UNESCO Courier vol. 29, May p. 24). Using all possible human documentation during the last 2,000 years, he found for example that after the earthquake in 25AD which destroyed the town of Taxila in Northern Pakistan, stronger houses were built with special foundations, going down to as much as 5m. Elsewhere, builders learnt after destructive earthquakes to reduce the heights of new houses from three and four stories to only one or two. Grids of wooden beams were also used to strengthen foundations.

On a more historical basis, he found that areas free from earthquakes at present were previously the centres of such events, and conversely. He also found that single large earthquakes during the last 25 centuries had little or no effect on a stable and developed community. Personal, political, religious and particularly economic interests seemed to overshadow the lessons to be learnt from earthquakes. As an example, Ambraseys mentioned Antiochia in Turkey: in 115 AD, the city was almost totally destroyed but was rebuilt on the same site, to be destroyed again in 458 AD, but was again rebuilt on the same spot. A generation later a further earthquake led to the death of 200,000 lives, yet the city was once again rebuilt in the same place, finally to be destroyed in 540 AD by the Persians. However, should the affected community be poor and politically unstable, earthquakes may bring about great social

changes, such as population movements, emigration and conquests by enemies.
Earthquake prediction also has a venerable history, Ambraseys discovered; soothsayers, astrologers and various prophets all tried their hand. There was for example the Cadi (judge) in Eastern Persia who in 1549 predicted an earthquake in his city. In vain did he try to persuade his friends to spend the night in the open, away from their houses. His pleading was fruitless and for a time he was alone in the open during the bitterly cold night. Eventually, not being too sure of his own prediction, he returned to his house, only to be engulfed together with the 3,000 people who perished in the earthquake.

PREDICTIONS AND PATTERNS

After more than 500 years and in spite of some recent scientific research we are still quite unable to predict earthquakes. A Panel on Earthquake prediction set up by the US National Academy of Sciences, Washington DC, concluded in 1976 that "imminent routine prediction of earthquakes is not warranted". A program of reliable, routine prediction may be 10 or more years away, and even then there might be "unavoidable errors and false alarms". Even the Chinese claims for earthquake prediction cannot be fully accepted on a strictly scientific basis and much further research will be required.

Earthquakes appear to follow certain patterns, but so far their analysis has hardly yet begun. Charles Richter who in 1932 originated the Richter Scale of earthquake magnitudes, gave in 1976, a year of great tectonic activity an outline of earthquake patterns. From 1896, when the first accurate measurements were made, to 1906 there was high activity, with 1906 being particularly notable with five earthquakes of magnitude 8, including of course the San Francisco event. In the following years there were on average only one or two events a year of such magnitude, until 1950, when there was again great activity. From 1953 to 1964 there was again a respite, until the great earthquake in 1964 in Alaska. After further years of relative absence, the year 1976 was once again one of great activity with major earthquakes in Mexico, Iceland, Italy and Turkey, China, Bali and Japan, the Philippines and New Guinea. Correlations of these patterns with other geophysical and possibly astronomical events presents a great challenge to disaster research, which may only now be possible by powerful computers.

NAPLES EARTHQUAKE

Let us now turn to a recent earthquake, the one that hit Southern Italy on 23 November 1980 which exemplified the worst possible human behaviour. It struck not far from Naples one of the poorest districts of the country, a mountainous, isolated region where peasants obtained a meagre living from olive trees and a few cattle. The number of dead has never been officially stated, the figures ranged from 4,000 to 5,000. Like all disaster victims, the local peasants were stricken with terror and at first quite unable to help themselves. It was at that stage that all outside aid was lacking and for four days after the earthquake, hardly any constructive help reached them, except the criminal elements to exploit the situation. Contemporary newspaper accounts (London Times and Frankfurter Allgemeine Zeitung) were full of ghastly stories which one cannot dismiss. Amongst the bus loads of sightseers, eager to photograph the events, were smart cars with well-dressed persons. They did not come for pictures, but left with babies and young children, perhaps only stolen for themselves, but likely to be sold for adoption. Others were satisfied with simply stealing relief goods and selling them on the black market, a type of behaviour not unknown after most disasters in developing countries. There is a saying in Turkey that each earthquake makes one millionaire, the bad ones several.

In Italy, in November 1980, there was a total lack of command structure, locally as well as from central Government in Rome. In fact the disaster had severe political repercussions, as politicians accused each other of mismanagement and corruption leading to resignations. Worst was the opposition to evacuation of the most seriously damaged towns, as local politicians feared that this would lead to the loss of their electorate at the next election. Undoubtedly, as in all disasters, there must have been many acts of heroism and utterly unselfish behaviour; so for example a group of German volunteers with their specially trained dogs flew to the area and the dogs discovered at least some victims under the rubble. It was also reported that 13,000 soldiers were brought to the disaster area, but as they only carried their rifles and had no picks or shovels, they only added to the need for food, housing and transport which should have been reserved for the disaster victims. And all this in spite of strict laws which had been passed by the Italian parliament a few years previously to set up a Disaster Relief and Command Organisation; the laws were simply not implemented.

INSURANCE

Finally a word about earthquake insurance. If there was to be a repeat in Japan of the Kanto earthquake of 1 September 1923 with 143,000 dead, the present total damage would amount to $\$250 \times 10^9$. This has led to a country-wide Japanese insurance scheme but covering only 30 per cent of damage. It is therefore only a minimal help to start rebuilding. However, the Chemical industry can only be insured for 15 per cent. Similar calculations for damage of San Francisco and Los Angeles reach for each city the sums of $\$50 \times 10^9$; Insurance against earthquakes, however, is hardly more than 10 per cent. There are far too few instances of insurance companies demanding earthquake-proof constructions to decrease their premiums.

## HURRICANES, FLOODS

The second major type of disaster to be considered concerns tropical circular winds and the floods often caused by them. The worst in recent history, the East Pakistan near-catastrophe, has already been mentioned. A potentially equally dangerous situation exists along the whole east coast of the United States, and although many separate analyses have been made, there appears to be as yet no interdisciplinary assessment of what might lie ahead. During this century many tropical storms have hit the east and south coasts of the United States, including the worst disaster in US history, the drowning of over 6,000 people after a hurricane struck Galveston on 8 September 1900. Since then windspeeds of up to 135 m.p.h. and tides 15 to 20 feet above normal have occurred in the same area ten times, yet the death toll has steadily decreased and thus brought a feeling of false security to the 300,000 people now living permanently below the 20 foot elevation in that area. During the holiday season, this number may double and similar dangers exist the whole way along the Gulf Coast and the eastern areas of the United States.

In addition, large demands for ground water, both industrial and residential, have lowered the ground level, and erosion of sand dunes and beaches has increased the danger. Much has been written, yet little can be done to reduce the real danger if a major hurricane should strike again. Advance warning, from satellites and computer forecasting, has been responsible for lowering the death toll, yet the maximum prediction time which can be broadcast is 10-12 hours, leaving a 50 mile error on either side. Evacuation is beginning to be countered by forecasts of massive jamming of traffic, even if roads are not flooded or otherwise damaged.

Protection against hurricanes along exposed coastal areas has cost Miami $64 million, recreating a 300 foot wide strip of new sand, 12 miles long. In other areas further north the building codes are not strict enough and timber houses replace those destroyed during the previous tropical storm. Galveston after the storm of 1900 constructed a huge sea wall facing outwards to the Gulf, but has failed to protect its shores facing inwards. When on 2 September 1981 nearly a foot of rain fell during 24 hours and four small tornados hit the town, the damage was estimated at nearly $ 5 million, but not a single person was hurt. Yet it is doubtful if Galveston can survive another 1900 hurricane without a death toll in the tens of thousands. It is simply called the irreducible residue of risk, shrugged off by saying "it may not happen to me".

In comparison with the east coast of the United States, Australia may perhaps call herself fortunate that Cyclone Tracy has given Australian Disaster Planners a lesson which will be remembered for decades. Hardly had the Natural Disaster Organisation been set up in Canberra and Major-

General Alan B. Stretton been appointed its Director-General, than Cyclone Tracy devastated Darwin on 25 December 1974. During the following seven days Stretton was appointed by the Australian Government to act in complete command of all relief operations, being himself stationed in Darwin. After the historical evacuation of three-quarters of the inhabitants and restoring major faciities in the town, General Stretton summed up the following lessons to be learnt: Apathy syndrome, communications breakdown, failure of local radio stations, convergence of visitors to disaster area, legislation needed, lack of co-ordination of relief stores, registration and tracing of disaster victims, first aid instruction at secondary school level in disaster-prone areas, the requirement for centralised control of all disaster areas.

"Disasters caused by enemy attacks are possible, but disasters caused by natural phenomena are certain", Stretton concluded. It does happen in the history of science that one exceptional individual can combine knowledge of one or more disciplines and can thus greatly contribute to interdisciplinary progress. In the history of disaster research General Stretton deserves such a place.

LONDON FLOOD BARRIER

Like Darwin, the story of the London Flood Barrier is equally instructive. Had any interdisciplinary research been carried out in connection with the real danger of a London disaster, the preventative measure of building the largest movable flood barrier in the world could have been avoided. London, like many other towns situated on rivers and near their estuaries, has been flooded many times in its history. But only research in recent decades has determined the particular dangers threatening London. There was the gradual sinking of the southeast of England, about 2.5 cm per century, as an after-effect of the last ice-age. Then the existence of the North Sea storm surges was recognised when a meteorological anti-cyclone to the east and a cyclonic depression to the west of England combined to rush masses of oceanic water around Scotland into the funnel between Denmark and England. A further factor was the dredging of the sandbanks lying in the estuary to allow bigger ships to enter the Port of London. Thus in January 1953 a storm surge coincided with high spring tides and more than 300 people were drowned along the East coast; in the Netherlands the same floods killed 1,400 people. Fortunately the flood of 1953 did not coincide precisely with the Thames high tide, and London itself was spared. London was not so lucky in January 1928 when tides and storm coincided and 14 people died. It was then that the proposals for a flood barrier were first considered and the 1953 events strengthened the demand. However it took precisely 30 years before the barrage was completed at Woolwich and was first used in earnest on 1 February 1983. In those 30 years there had been innumerable reports, warning of the catastrophic consequences if 45 square miles of London had been flooded, with 50 underground railway stations, 35 hospitals as well as the heart of Government in Whitehall inundated. Damage was estimated at thousands of millions of pounds sterling, casualty figures in the tens of thousands.

Elaborate rescue plans code-named "Operation Giraffe" had been formulated by the Armed Services, with forward and rear command posts, with hundreds of assault boats and helicopters on standby. Fortunately these often rehearsed plans have never had to be implemented. But the most extraordinary aspects of the London Flood was the barrier itself. From bank to bank, over half a kilometer long, the barrage consists of four main navigation spans, each 61 m wide. These can be closed in 30 minutes by vertically rising steel sectors, which normally lie below the river bed to allow free navigation. This macro-engineering project cost more than five hundred million pounds and was demanded by the influential shipping interests of the City of London. It will be the biggest movable flood barrier in the world until the Delta Plan of the Netherlands is completed.

What nobody had foreseen, inspite of years of engineering research on the Thames Flood Barrier, was the complete change in social and economic forces during the 30 years from 1953 to 1983. Shipborn container traffic had concentrated at the Tilbury Docks, 20 km downstream from the barrier, and the docks above the barrier, for which navigational access had been requested, had become derelict and abandoned. A much simpler dam with one or two standard locks would now seem perfectly adequate for the few small ships steaming up to the higher reaches of the Thames. Was this totally unforeseeable?

## MAN-MADE DISASTERS

Let us now turn to man-made accidents and disasters. By definition, accidents are unforeseen contingencies, and unpredictable. But that they are also inevitable, is only now slowly being realized. Nothing, but absolutely nothing, made by man is perfect and therefore everything will have inherent faults, be they in design, materials or manufacture. All that the best of engineers can aspire to achieve is to reduce the number of accidents, to accumulate sufficient experience, allow a large enough safety factor and include one or more back-up systems to continue operations when a component fails. And most important of all, where humans are involved, provide for their utmost training by the simulation of all kinds of accidents and supply the operators with instruments of simplicity, clarity and reliability.

## TANKER DISASTERS

Accident statistics for the operation of large tankers make unhappy reading, not only for the owners and operators, but for all concerned with past and potential future disasters. So for example in 1978, the Amoco Cadiz spilled 220,000 tons of oil onto the coast of Brittany in Northern France; but the number of dead during that year was only 29. In the following year, the total spillage of oil during all accidents was only 105,000 tons, but 177 died, and four tankers exploded. In a wide-ranging interdisciplinary review of tanker safety Captain R. Maybourne (J. Roy. Soc. Arts, July 1980) admitted that accidents occurred because of human error, slackness in obeying operating procedures, and because of the irreducible residue of risk; better training was the most promising answer in his opinion.

However, Captain Maybourne only dealt with the transportation of oil, not of liquefied gases, either natural gases LNG, or refined petroleum gases LPG. Their flammability and the necessity to carry them in highly compressed and liquified state at -175°C makes them certainly the most dangerous cargo carried at sea. On 16 December 1980, the LNG tanker Taurus, capacity 125,000 cubic metres ran aground off the west coast of Japan while carrying its cargo from Indonesia to Japan. Fortunately no serious consequences arose unlike the fictional story of the LPG Tanker Prometheus, whose fate was described a year earlier by Terence Moan in his disaster fiction book The Deadly Frost (Ballantine Books). Prometheus struck a submerged but uncharted obstacle inside New York harbour, ripped her hull and part of her cargo escaped onto the surface of the water; her capacity was 123,000 $m^3$. A weather inversion at first prevented dispersion of the gases, later they penetrated the New York subway, finally they ignited and the ship exploded. Damage and loss of life were great, as can be expected if such a scenario should ever become reality. Meticulous research had been carried out by the author to describe the disaster and the tale is highly recommended to any port authority contemplating the dangers arising from the transport of liquified gases.

So far the worst accident caused by an LPG explosion occurred on 11 July 1978 when a road tanker carrying 23.5 tons propylene exploded near a holiday camp on a road running parallel to the north east coast of Spain; 200 people were killed instantly, over 150 suffered severe burns. The causes for the explosion were variously attributed to overloading, lack of a pressure relief valve, corrosion, as the tanker had been occasionally used to transport ammonia. and the high summer temperature of 28°C; most likely it was a combination of several factors that led to this accident.

## CHEMICALS AND OIL INDUSTRY

Some of the worst man-made accidents have occurred in the chemical industry. In Ludwigshafen, West Germany, 550 people were killed in 1921 during an explosion and subsequent fires, and in 1948 a similar accident in the same town killed 184, 70 were missing and 6,000 were injured. When two cargo ships carrying ammonium nitrate collided in the port of Texas City, Texas, in 1947, exploding and setting on fire an oil refinery plant, 561 people were killed and 3,000 injured. Much less severe was the explosion of cyclo-hexane at Flixborough, England, in June 1974; 28 people died. Then in the 1970s a new industrial risk arose, the production of oil from the sea. It had of course been carried out in the offshore regions of the Gulfs of Arabia and of Mexico for some time, but never before in such dangerous waters as the North Sea.

## OIL RIGS

By 1981, more than 100 divers and workers on offshore oil rigs in the North Sea had lost their lives, a loss registered by the oil industry as nothing more than a statistic in oil production economics. Only when on 27 March 1980 the Keilland platform sank in the Ekofisk oil field with the loss of 123 men aboard was there a major investigation. It was concluded that serious flaws in both design and construction were responsible. A 70 mm long crack in one of the welds had existed since the rig was manufactured; this led to the development of a fatigue crack in one of the bracing columns which failed in a North Sea storm. A similar disaster overtook the Ocean Ranger off the east coast of Canada in February 1982 with the loss of 84 men during a fierce storm; structural failure was considered the reason for the disaster. These were by no means the only disasters which occurred on oil rigs. In November 1979 an oil rig off China collapsed and 79 men died; others, fortunately with a much smaller loss of life had occurred in January of the same year when a new rig sank while being towed from Scotland to Brazil; in May 1979 another rig collapsed in the Mexican Gulf, off Galveston. Deadly accidents to divers operating from oil rigs and their attending control ships are too numerous to be considered here and unfortunately little research has been undertaken to improve their working conditions.

The safety of oil rigs and their crews became a highly political question, with human lives balanced against the profits of operators and their many sub-contractors. A highly critical book, The Other Price of Britain's Oil was published in 1981 by W. G. Carson of the University of Edinburgh; his main argument was that the Government Agency responsible for production of oil was also responsible for safety, two objectives fundamentally contradictory. Disaster research is powerless when such conflicts are involved.

## COMPUTER AIRSAFETY

The situation is even worse for disaster research when relevant facts are deliberately hidden. Such is the case for certain investigations of air crashes demanding disaster research of a very special nature; this is particularly so nowadays when flight path control is computer predetermined. Two examples might be briefly considered. The Air New Zealand DC-10 which crashed into Mount Erebus, Antarctica, in November 1979, with the total loss of 257 passengers and crew, the third fatal disaster of a DC-10 that year. And secondly the total loss of the Korean airliner, KAL-007 a Boeing 747 in September 1983 with the deaths of 269 passengers and crew, when it was shot down by a Russian fighter. In both cases the position of the aircraft was not the one intended and both had their flight paths computer predetermined. Subsequent official and unofficial enquiries into both disasters left many doubts and it is unlikely that the full facts will ever be known. What research can answer these questions where facts remain secret and when the pilots are dead?

ATOMIC ACCIDENTS

The last type of man-made disasters to be considered is also the worst, the possibility of a malfunction at an atomic reactor leading to the release of very large amounts of radioactivity. Much of the debate about the safety of nuclear power focusses on the large number of fatalities that could be caused by an extremely unlikely, but imaginable, reactor accident. Sir Walter Marshall, FRS, until recently chairman of the UK Atomic Energy Authority, discussed in October 1982 (Atom 312 p.210) the vocabulary used by the media - for example 104,000 killed - compared to the technical description of such an accident. He did not specify what such an accident might involve, for example a melt-down of the core, nor did he mention the direct number of people killed by lethal radiation received in the neighbourhood of the disaster. He did, however, state the increased average probability of cancer for people exposed to 1 rem: a loss of 20 hours in their life expectancy of 70 years. If such a gigantic hypothetical accident should occur in London, with an assumed population of 10 million, it would result in a potential long-term death toll of 1,250 persons. It is doubtful if such figures would assuage public concern, particularly when films like The China Syndrome with their horrific, but not impossible scenario, are given such wide publicity.

WINDSCALE

The first accident to an atomic reactor which received world-wide attention occurred on Friday 11 October 1957, when the graphite moderator in the air-cooled nuclear reactor at Windscale in Cumbria caught fire. It had been built to produce plutonium for British bombs. No-one had ever seen or experienced such a fire or anything like it, and the only solution to the emergency was to put out the fire by drowning the reactor in water. A small quantity of radioactive iodine escaped, and found its way from the surrounding fields, through grass eaten by cows, into milk, which was declared unsafe and was confiscated.

No lasting disaster occurred and no-one was hurt, yet the effect of the accident was widespread, the first ever to be made public. A sister reactor was also shut down for good and the two giant concrete structures with their huge overhanging chimneys stand today, after a quarter of a century, as "monuments to our ignorance" as Lord Hinton described them. The full details of the fire were described 25 years later by Roy Herbert, present at the accident, in New Scientist of 14 October 1982, page 84.

URAL ACCIDENT

Much worse, but not revealed to the west until 20 years after its occurrence, was the accident in the USSR, described in a most interesting piece of disaster research. Dr. Z. Medvedev proved that a large explosion of nuclear waste in the South Ural mountains had occurred in late 1957 or early 1958 (New Scientist 30 June 1977, p. 761). He made a systematic search of the Russian biological literature and found a large number of scientific research reports describing amongst many other facts the behaviour of many different species, from single cell algae to carp, living in highly radioactive contaminated areas. In only one of the papers he found was a location given, obviously a slip in censorship. From the number of generations, up to 30, who had lived in contaminated areas, it was easy to calculate the date of the accident. No loss of human life has ever been revealed.

THREE MILE ISLAND

So far the most serious potential disaster occurred at Three Mile Island. Let me quote the official report:

"On Wednesday, 28 March 1979, 36 seconds after the hour of 4.00 am several water pumps stopped working in the Unit 2 nuclear power plant on Three Mile Island, 10 miles south-east of Harrisburg, Pennsylvania, USA. Thus began the accident at Three Mile Island. In the minutes, hours and days that followed, a series of events - compounded by equipment failures, inappropriate procedures and human errors and ignorance - escalated into the worst crisis yet experienced by the nation's nuclear power industry." (The President's Commission on the Accident at TMI, John G. Kemeny Chairman, published Washington, DC, 31 October 1979.) That such an accident was to occur sooner or later, was brilliantly forecast by Thomas N. Scortia and Frank M. Robinson in their disaster fiction book The Prometheus Crisis, published in 1976; it was made into the film The China Syndrome two years later.

One reads in the Kemeny report "that training did not adequately prepare them (the operators) to cope with the accident at TMI-2" (p. 91) and "the fact that they failed to realize that these conditions resulted from a LOCA (Loss of Coolant Accident) indicates a severe deficiency in their training to identify the symptoms of such an accident" (p.96). Also on page 91:

"Frederick and Faust (two reactor operators) were in the Control Room when the first alarm sounded, followed by a cascade of alarms that numbered 100 within minutes. The operators reacted quickly as trained to counter the turbine trip and reactor scram. Later Faust would recall for the Commission his reaction to the incessant alarms: "I would have liked to have thrown away the alarm panel. It wasn't giving us any useful information".

These must be the interdisciplinary lessons of the Three Mile Island accident:

* Accidents will inevitably happen at nuclear power stations as anywhere else and they will always be unpredictable.

* To keep accidents to minor inconveniences, it will be essential to have in the control rooms operators trained to astronaut standards, and to accord to the best of them salaries and status equivalent to captains of a jet aircraft.

* Only the most modern electronic computer aided instruments and executive controls can find a place in the high technology operation rooms of nuclear power stations.

* And finally, when the inevitable and unpredictable has happened, as unfortunately it must, a highly efficient aid and rescue service should be available; they will have had frequent rehearsals and thus have become near perfect.

DISASTER REHEARSALS

Apparently once a year, each British nuclear power station holds an emergency exercise. Little of these exercises is made public and the general population is never involved; thus little can be said about the effectiveness of such emergency drills. However, one of these was described in full in The Sunday Times of London on 18 May 1980, but giving little detail of what would have happened in the case of a real disaster. All actions and reactions within the atomic power station, Dungeness, went according to plan: the incident assessment team donned protective gear, the local fire brigade extinguished a fire, and a much delayed damage control team finally cleared the way to an emergency valve which was closed and thus brought the "incident" to a close. The exercise was considered successful by those who had planned it and who had prepared the 50 page document setting it out.

In the Federal Republic of Germany, two weeks earlier, a similar emergency drill had been held near the nuclear power station at Biblis. At least theoretically the population in the neighbourhood was to have been warned 30 minutes after the incident, but what would have happened if 60,000 people had been told of it and it was not rehearsed. Buses and trucks would have been made available, but what the private motorist would have done and whether he would have followed the emergency evacuation routes was much in dispute. (Hessische/Niedersachsische ALLGEMEINE 5 May 1980). A real evacuation of any modern large city is generally considered impossible, once panic has been created when a disaster has occurred. One may well doubt if soothing announcements over the radio and television from official sources would have any credence; they would only contribute to the general confusion, as the accident at Three Mile Island so clearly demonstrated.

DISASTER RELIEF

A few final words about disaster relief, a subject that should have the highest priority for interdisciplinary research, when the International Disaster Research Laboratory is established. Today, disaster relief is basically similar to what it has always been - a voluntary, highly uncoordinated affair. Disasters are still too often considered as Acts of God and are dealt with as local resources permit. If luck is on their side, victims receive medicines, food and blankets from their own government, if they are unlucky, their deaths are statistics. Foreign aid, although generously given, is probably the worst cost-effective operation ever mounted, and very rarely reaches the victims in time. Only an International Rescue Organisation with its own stockpiles and experts flown to the scene, can here offer a final and appropriate solution. I pleaded for it repeatedly during the last decade, but have been unsuccessful so far.

IDRL

Let me now sum up the need for interdisciplinary disaster research by giving some details of what an International Disaster Research Laboratory might do. The establishment might not prove as difficult as it appears, as during the last decade a considerable number of disaster fiction novels have been published. Apart from frightening people in general, especially in the nuclear field, this disaster literature has also informed the politicians of the Western world of what natural and man-made disasters might lie in store for us. As a concrete example, R. Doyle's Deluge (Arlington, London 1976), the story of the flooding of London, was considered an important factor in speeding up the completion of the barrage which now protects the metropolis. When politicians are frightened, action can be taken swiftly to prevent disasters, or at least minimise the irreducible residue of risk in man's affairs.

Here then are some of the research areas which might engage the attention of an I D R L, not necessarily in this order of priorities:

* Human behaviour, before, during and after a disaster, including the role of the media, unwelcome visitors and the needs of special groups.

* Pre-planning, warning systems, meteorological forecasting and apathy of populations.

* Demographic trends affecting disasters.

* State of art and science of disaster prediction.

* In-depth hindsight reviews of natural and man-made disasters, with laboratory staff members sent to site for direct observations.

* In-depth literature surveys with particular reference to lessons from historical research (Coates Survey and Ambraseys).

* Constant review of new technology and its possible effects, positive and negative, on disaster situations.

* Develop a simple disaster scale of magnitude.

* Disaster communications analysis, especially role of satellites, disposable radios air-dropped, emergency broadcasting facilities.

* World-wide co-operation with existing accident and terrorist investigation authorities, for example air and sea transportation.

* Training and education of people in disaster areas, rescue rehearsals and emphasis on First Aid teaching in schools.

* Investigate possibility of individual household in disaster areas holding emergency food and water supplies as was done in Switzerland.

* Triage and other medical aspects unique to disaster situations.

* Psychological and physiological endurance of workers and victims on disaster sites.

* Evaluation of satellite imagery before, during and after disasters.

* Relief priorities for various types of disasters, value of vaccination.

* Development of simple rescue gear, airdrop of inflatable lifebelts, gin poles.

* Investigate possibility of model experiments of disasters and their prevention, particularly by mathematical models using computers.

* Theoretical investigation of safety factor concept, comparison of its application in various industries.

* Co-operation with Insurance Companies, research and support.

* Best involvement of Armed Services in disaster relief in different countries, especially their Medical Services.

* Legislative aspects of state of emergency and Natural Disaster Acts in various countries.

* and above all develop better rehabilitation, physical and mental, for recovery of disaster victims, carried out by themselves.

Some of the above research areas are already being investigated by Australian and other universities and particularly by the Australian Counter Disaster College and co-ordinated by the Australian Natural Disaster Organisation. But are their resources sufficient to extend their pioneering work internationally and in an interdisciplinary manner to all the research programs outlined above?

## TRIBUTE TO NOAH

I want to finish by once more going back in history, to the first recorded great disaster, the Great Flood described in Genesis. Noah was in fact the first search and rescue coordinator. He analysed the risk and trained his sons. Ignoring the ridicule of those whose visions were less keen than his, he constructed his rescue vehicle; gathered the family; searched out the animals to perpetuate all kinds; and when the flood came he set sail. While we may lack Noah's direct communication with the Lord, the lessons of the Ark - analysis, equipment and training - are as valid today as they were in Noah's time.