High-capacity data storage The declining cost of memory storage combined with specific technical advances may soon increase the storage capacity of small machines by a factor of several hundred, and possibly much more.
Cheap micro-sensors A major set of innovations are imminent in the development of cheap micro-sensors, including digital cameras, sensors for pollution monitoring, medical diagnostic equipment, fingerprint readers and a range of security devices.
Narrow casting via telecommunications networks As bandwidth increases, so more information-intensive applications are possible, including transmission of high-quality video to individual machines on networks. This is currently known as 'narrowcasting' and provides a television-like service tailored to small audiences, potentially on a global basis.
'Smart cards' These are credit card-sized devices with embedded memory and computing capacity. They can already hold large quantities of personal medical, financial and other data, and can act as an instrument for electronic cash transactions and beneficiary registration.
Mobile wireless Personal Digital Assistants (PDAs) These are essentially combinations of very small computers and portable cellular telephones, some of which are likely within about five years to use low-Earth orbit (LEO) satellite links for voice and some limited data services.
High-performance computing Large computers, including distributed networks of computers working in parallel, are increasing in performance also, and massively powerful clusters of machines are already available. These are particularly useful for their simulation and modelling facilities, which may become more readily available.
Remote high-resolution surveillance technology Satellites have provided ground images for many years, but a new generation of civilian systems can produce higher-resolution pictures essentially on demand. Small remote-piloted surveillance platforms are also likely to decline significantly in cost, and may become more widely available for humanitarian programmes.

General trends

The pace of development of information management systems continues to accelerate, and some new and potentially important developments are beginning to have a significant impact. However, the existing pattern of very patchy and diverse application of information technology in emergencies is likely to continue for some time. In the short term, the application of innovative technologies generally tends to lag, and in some elements of the international humanitarian relief community these delays can be long What is very clear from the historical record is that some groups have always been years or even decades ahead of others.

Four general trends are well established: continuing miniaturisation of components; increasing processing power; increasing bandwidth; and increasing mobility. Concomitant trends include declining costs of some equipment, reduction in weight, increased ruggedness in some cases and reduced dependence on mains electric power.

Industry forecasts suggest that the computing performance of the microprocessors which are used in common desktop equipment will continue to double every 12 to 18 months. This gives somewhere between a 200-fold and a 1,000-fold increase in performance every decade or so. But it also suggests that really radical changes will

not occur before the end of this decade. In the medium term, what is more likely to affect capabilities is the expected emergence of a wider variety of specialised microprocessors and micro-sensors, and greater linkages between machines. There is also likely to be a real advance in the use of dedicated multimedia equipment, and various opportunities for inexpensive remote monitoring and data collection.

There are other factors likely to have a marked impact on the way information is stored and handled. The cost of storage of digital information (including video) is likely to fall radically with the introduction of new compact disks with very high capacity and further increases in the capacity of other inexpensive storage devices. A further radical shift towards widespread networking of information systems will have a profound impact on organisational structures, and on the ability of individuals to obtain information from a wide range of sources.

Telecommunications bandwidth is likely to become abundant in many places, and at least not too limiting in almost all others. Nodes on major backbone communications routes will have access to very high-capacity communications links, certainly enough for routine video conferencing and for extensive transport of digital documents. Documents themselves are likely increasingly to become assemblies of various multimedia components. A problem at this stage will be the variation in styles of operation and content of communications between staff with routine access to high bandwidth, or 'thick' routes, and those who normally access only the 'thin' ones — those in remote areas, and those generally using mobile equipment. None the less, emergency-related organisations in most major cities almost everywhere will soon have the possibility of an acceptable level of global Internet e-mail and access to the Worldwide Web (or its successor) for information searching and basic document transfer.

Communication with mobile units will continue to improve, with increasingly ubiquitous use of satellite connections in relief operations, and further incremental improvements in digital wireless technology. There will probably be a gradual increase in transmissions of digitised still-pictures from the field over these wireless links, but the main advance may be the numbers of teams using this equipment rather than any radical improvement in data-carrying capacity in most settings.

The five-year horizon

If we look five years ahead, certain outcomes seem very probable. Convergence of the various types of media used for information delivery will continue. Television sets will look more like computers and vice versa. Digital phones will take on many of the characteristics of pocket computers. New information appliances combining several features will also appear

Convergence in technologies will be accompanied by convergence in the economic sphere, with mergers of media, computer and telecommunication companies, nationally and internationally. Free trade and competition in these sectors will increasingly become issues for national debate. There may also be fewer public debates and discussions about the emergency-related implications at national level of these commercial realignments.

Information overload is likely to become a crucial problem, and a range of software to cope with this can be expected. Probably the involvement of so-called 'agent'

technologies will be needed. This is a file-searching software which can be 'trained' to recognise relatively complex patterns of text and other data of interest to individual users. Search agents can be released on to networks to seek out information on many different machines. In addition, the presentation of detailed material is likely to improve with new display software.

More-powerful equipment may paradoxically become more simple to use. Emergency managers will increasingly be drawn into using information technology of all kinds. The interfaces will improve somewhat, probably with more voice interaction and responses to spoken commands. A model of computing originally described at the pioneering Xerox Parc research laboratory currently looks likely, with three wireless-networked levels of equipment: small, shirt pocket-sized, highly portable communications and data-carrying devices, or 'Tabs'; inexpensive A4-sized writing screens, or 'Pads', which can be strewn around an area for general use; and metre-sized or larger wall-mounted panels, or 'Screens', for groupwork. But, of course, all sorts of new configurations could also emerge.

Support for group working is likely to grow rapidly. The same protocols and software which have driven the growth of the Internet are being applied within many organisations to improve the flow of information, ensure easier access to organisational databases and allow much higher levels of intra- and inter-group collaboration. These 'intranets' are likely to emerge within government in many countries, as well as in commercial organisations. At both national and particularly at local government level, they may start to have a significant impact on the way both mitigation planning and emergency planning can be promoted and co-ordinated.

A range of new technologies will probably grow as a result of this focus on the network model. In some organisations, the internal (and externally linked) network will become a pipe into the desktop computer, with characteristics that begin to resemble broadcasting. There may in some cases also be a major substitution of bandwidth for processing, with what in many ways could be a return to a mainframe-terminal type of arrangement, albeit with a much more sophisticated interface than the 1970s examples. Gradually, the network itself will become a prime focus for those who need to protect systems against natural and other hazards. While the details of the components will still be of crucial concern to operations managers, the approach and attitude of users is likely to change. To quote one telecommunications authority:

> The next wave of IT development will focus on the delivery of information and experience on demand, in the right form, at the right time, at the right price, to fixed or mobile terminals anywhere, over networks of optical fiber, radio, satellite, and optical wireless Bandwidth, distance, and time will no longer be significant cost elements as service and access become the dominant features of the changing demands of an information focused society.

There is a wide range of other implications for disaster managers. One major one is the impact of the reduction in bandwidth scarcity and distance-related telecommunications costs. In both national and international organisations, there may be a blurring of existing distinctions between headquarters and the field offices. Improvements in bandwidth could also influence the way field activity is widely perceived. New Internet technologies, combined with good wide bandwidth communications allow almost any group rapidly to assemble and deliver audio and

video reports directly to interested recipients. Media relationships will become even more complex. Technologies and standards such as Asynchronous Transfer Mode (ATM) and bandwidth-on-demand may play increasingly important roles during this period.

A shift towards widespread storage and communication of digitised multimedia documents is also likely to affect both research and the design of training programmes; real-time mentoring, simulation and distance learning would all be enhanced. It would also generate opportunities for the design of new types of interactive manuals, and new requirements for library provision However, operational application may lag far behind the emerging technology because of cost, copyright and other factors.

The increasing importance (and potentially the vulnerability) of interlinked networks will also have implications for mitigation in places where hitherto this has been of little concern. Furthermore, societies experimenting with extensive information technology for the first time are likely to experience some serious problems with system failures, generating new and unexpected types of emergency. Training for emergency network management will become an increasingly important issue, especially where a wide range of new, inexpensive hazard warning sensors begins to be built into urban and other networks.

The longer term

Beyond the next five years, it is increasingly difficult to make useful detailed estimates. Some outcomes are foreseeable and may be of particular interest to those contemplating longer careers in disaster management. Many surprises can also be expected; there are likely to be just too many unexpected synergies of emerging technologies. In addition, structural changes, such as more extensive use of military-related information technology in humanitarian relief, or greater involvement in privatised relief by the information consultancy industry could have a significant impact. Growing emphasis on emergency preparedness and IT in rapidly developing countries such as China and India could also alter the course of application of appropriate information technologies in the Third World.

Systems are likely to become increasingly transparent, reliable, invisible — and ubiquitous. Over the next decade there will probably be about a thousandfold increase in both the overall performance of individual computing devices and in the amount of data that can be transmitted down office communication links. The distinction between the place of storage and the place of use of information will continue to break down

Some forecasts suggest that network backbone links supporting the Internet will carry at least 500 to 5,000Gb/sec within 10 years. Some estimates imply that there may be almost infinite bandwidth available On a more practical basis, efforts are under way now to develop 1Gb/sec end-to-end connectivity on academic research networks, as part of the Next Generation Internet Program co-ordinated by the US National Science and Technology Council (NSTC).

On this basis, several telecommunications company research laboratories are confidently forecasting that communications are likely to have an immersive quality, with a strong perception of shared space. Video links of all kinds would become routine. A few commentators go much further, and suggest that a new 'fibersphere' of

interlinked optical communications will fundamentally change the architecture of IT, with the location of processing equipment determined largely by the form of the network. Processing may routinely be thousands of miles from the point of data capture — a possibility with profound implications for emergency preparedness in some areas.

Remote data acquisition of all kinds will grow in importance. High-resolution satellite photography and mapping may be accessible more widely, as will relatively inexpensive automated low-altitude aerial-monitoring platforms. The importance of GIS is also likely to grow, but its technology may also become incorporated relatively invisibly into other applications The combination of remote sensing, improved communications and possibly tracking technologies, may eventually be used more in complex emergencies to assist with security planning, and provide more rapid emergency assistance to relief workers.

Integration of computer systems will continue, particularly in the larger cities in developed nations, to the point where the matrix of communications and computing power will, in theory at least, have the resources to assess autonomously and respond to shocks and disruption. Other related improvements may include much more precisely tailored public information and warning systems, and the expansion of 'real-time' hazard warning and response scheduling. The impact of advanced computer networks may also be very extensive. A detailed review of possible crisis management applications of very high-performance computing is included in a US National Academy of Sciences study (United States, 1996). Some other possible implications are described in a visionary paper, 'Intelligent cities' and metropolitan area networks (Stalberg, 1994).

The vulnerability of complex networked systems, together with potential ways of using data resources to speed up recovery almost certainly will increasingly preoccupy emergency planning staff in some areas. The survival and recovery of networks for electronic commerce in particular will continue to grow in importance.

Data quantity has the prospect of being completely overwhelming. There will also probably be much more emphasis on sophisticated software tools that help to select, organise and structure information and knowledge. Products could have names like electronic secretaries, electronic information agents and 'digital representatives'. Co-ordination and scheduling of resources will become increasingly automated. Further problems for information location could be introduced at some later stage as new technologies of very high-density storage based on biotechnology begin to emerge

There are many implications for mitigation, planning and response management. We can only touch upon a few, and many will not be clear for years. There may be a profusion of so-called network agents capable of very rapidly seeking required emergency information without the necessity for close supervision. and perhaps in the end making autonomous emergency decisions. Other possibilities include very large, globally accessible data libraries, including random-access video collections; extensive sensor networks for natural hazard prediction, and the capacity for real-time simulation on a very large scale

Educational requirements will also be affected. Many teaching and training institutions, including universities, will need to change their structure significantly to make use of the new opportunities, and various 'virtual' universities may appear quite quickly. Specialist emergency-focused universities, linked through distributed networks into a new culture of quality control and certification are entirely feasible within this model.

Table 1 The information technology revolution: development in progress

	Ultra-broadband networks	Network commerce	Network agents	Digital libraries	High-capacity data storage	Cheap micro-sensors
1. Staff recruitment	Video interviews.	Virtual recruitment networks.	Staff search agents.		Video records	
2. Staff training	Global interactive simulations Remote mentoring.	Global purchase of training packages.	Registration systems Interactive simulators.	Global access to training materials.	Portable interactive audio-visual courses. Access to video record of training sessions.	
3. Early warning–sudden emergencies	Emergency digital information systems Video monitoring and remote sensing. Public warning broadcasts	Purchase of remote-sensing data.		Monitoring databases and archives. Mission reports Satellite images.		Reduced cost of extensive seismic monitoring networks for real-time warning.
4. Early warning–long onset	Video monitoring and remote sensing	Purchase of remote-sensing data.	Network discovery. Automated news analysis.	Remote sensing–hydrological and crop data. Mission reports.		
5. Emergency assessment	Remote video interviews and inspection. Real-time exchange of GIS datasets. Damage/impact images			More rapid access to baseline information.		Inexpensive wireless video surveillance of remote facilities.

	'Narrow-casting' via telecommunications networks	'Smart cards'	Mobile wireless PDAs	High-performance computing	Remote high-resolution surveillance technology
1. Staff recruitment		Portable staff records	Video records of field performance.	More extensive use of simulation for testing applicants.	
2. Staff training	Specialist humanitarian training channels. Televised conferences.		Remote mentoring.	Complex real-time simulation. VR for some training.	
3. Early warning–sudden emergencies	Direct 'tailored' broadcast warnings to affected populations.		Cheap real-time rapid earthquake warning to dispersed groups.	Hydrological modelling Real-time earthquake and cyclone impact modelling.	Possible use of satellites and aerial platforms to support rapid flood mapping
4. Early warning–long onset	Broadcast appeals by affected populations.			Possible extension of drought forecasting and modelling	Possible extension of drought forecasting.
5. Emergency assessment					Inexpensive unmanned air-reconnaissance.

	Ultra-broadband networks	Network commerce	Network agents	Digital libraries	High-capacity data storage	Cheap micro-sensors
6. Emergency decision-making	Shift towards virtual Emergency Operations Centres More extensive use of graphics and video in group decision support systems. AI/ GIS interfaces.			Manuals, emergency plans, humanitarian and emergency law.		
7. Emergency communications	Video conferencing. Remote telepresence Integrated, addressable multi-media systems.		Automated status monitoring Database search engines Trunking of communication channels	Directories Archives of message traffic		
8. Raising funds	Complex multimedia sites for public and corporate fund-raising by NGOs. More integrated links to government donors.	Pressures for marketing charitable activities via electronic media. Highly personalised fund-raising initiatives.	Pledge forms and electronic payment systems	Appeals databases. Donor lists. Financial records and contributions tracking.		
9. Project formulation and reporting	Re-engineering of project formulation process to include wider range of participants.			Multimedia records of project activities.		
10. Purchasing and procurement	Video negotiations with suppliers	Electronic tendering and purchase.	Autonomous electronic purchasing and negotiation agents.			

	'Narrow-casting' via telecommunications networks	'Smart cards'	Mobile wireless PDAs	High-performance computing	Remote high-resolution surveillance technology
6. Emergency decision-making				'Intelligent' group decision support tools. More extensive use of visualisation tools Wider use of GIS.	
7. Emergency communications			On-demand access to global information resources from most remote locations.		
8. Raising funds	Direct TV marketing – charitable fund raising channels.			Wider use of 'data warehouses' and data-visualisation techniques in NGO marketing planning.	
9. Project formulation and reporting					
10. Purchasing and procurement					

	Ultra-broadband networks	Network commerce	Network agents	Digital libraries	High-capacity data storage	Cheap micro-sensors
11. Transport and logistics	Integrated logistics management information systems. Real-time tracking of supply movements	Electronic document interchange (i e customs manifests). Reservation systems.				Cheap tagging and tracking of individual consignments.
12. Relief distribution	Conferencing between co-ordination centres, warehouses and field operations				Real-time region-wide access to detailed beneficiary records	Biometrics methods of recipient identification.
13. Emergency settlements	Potential for direct dialogue between agency HQ and beneficiaries	Electronic marketing of produce from income-generating projects.		Access to wider range of school and university educational media Vulnerability analysis and mapping.		
14. Community health and nutrition	Global access to multimedia documentation.			Global access to scientific literature. Travel and immunisation information Prevention guidelines.	Extensive local digital library storage.	
15. Clinical medical care	Remote medical consultation Global access to multimedia documentation. X-ray and other image exchange		E-mail document retrieval Medical alerts.	Global access to scientific literature.	Extensive local digital library storage.	Inexpensive diagnostic equipment.

	'Narrow-casting' via telecommunications networks	'Smart cards'	Mobile wireless PDAs	High-performance computing	Remote high-resolution surveillance technology
11. Transport and logistics					
12. Relief distribution	Electronic distribution records. Wider use of electronic cash				Use of aerial platforms or commercial satellite photography for early estimates of beneficiary numbers and locations
13. Emergency settlements			Extension of wireless telephone services to some emergency settlements.		Possible use of commercial satellite surveillance for site identification
14. Community health and nutrition	More extensive health educational television		Probable improvement of communications to smaller remote clinics in some areas		Commercial satellite surveillance for identification of locations of dispersed groups
15. Clinical medical care	More extensive specialist medical educational television.			More extensive simulations of patient care on personal computers.	

	Ultra-broadband networks	Network commerce	Network agents	Digital libraries	High-capacity data storage	Cheap micro-sensors
16. Security	Dependence on network prompts wider electronic security measures			Travel advisories.		Full automatic video records of incidents
17. Rescue	Remote cameras and robotics			Building and infrastructure plans and images.		Inexpensive sensors for finding trapped people.
18. Infrastructure recovery	Extensive network redundancy and diverse routing				Detailed local facilities mapping. Wider use of GIS.	
19. Public information	Global access to educational simulations. Emergency digital information systems. Integrated but addressable emergency broadcasting systems	Wider access to commercially marketed public information material.	Broadcasting all channel alert systems. Automated e-mail distribution and document retrieval systems.	Global access to multimedia documentation		
20. Community-level recovery	'Horizontal' community to community conferencing					

	'Narrow-casting' via telecommunications networks	'Smart cards'	Mobile wireless PDAs	High-performance computing	Remote high-resolution surveillance technology
16. Security			Personal emergency alerting and tracking devices for relief workers.	More extensive simulations for security training.	
17. Rescue		Smart cards as locator devices.		Use of real-time simulation to identify priority areas for rescue activity	
18. Infrastructure recovery				Further trend towards network simulation in recovery planning. 'Intelligent' self-re-adjusting integrated urban infrastructures	
19. Public information	Specialist emergency preparedness channels	Smart cards with emergency advice expert systems.	Emergency support/ first aid expert system software for PDAs.	More extensive use of simulation and immersive technologies (VR) in public information and education.	
20. Community-level recovery	'Recovery television' channels via telecom networks.		Community-level recovery wireless telecommunications network.		

In conclusion

Application of information technologies in emergency management still has a very long road to travel. What we have so far witnessed are simply the preparations for the journey. It may be a while yet before the real implications of these technologies are clear. In the examples and forecasts given here, we are well aware of the risks both of overestimating shorter-term impacts, and of underestimating longer-term consequences. Overall, it does seem very likely that some profound changes will occur in the skills, the organisational design, the management styles and the learning processes of emergency planning and management.

Many of the possible outcomes are only vaguely perceived, and many may seem very remote to many readers at present, especially those in countries where this technology has not yet penetrated. None the less, IT futures need to be given much closer attention now in planning large-scale mitigation projects and in the choice and design of formal education programmes for the next generation of professional emergency managers worldwide.

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