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URBAN FIRE PROTECTION: Studies of the Operations of the New York City Fire Department

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PREFACE

For nearly three years, beginning with its inception in January 1968, Dr. Edward H. Blum has led the New York City-Rand Institute's Fire Protection project, as well as related research on the deployment of municipal emergency services.

Dr. Blum presented this paper to the Symposium on Urban Fires at the American Association for the Advancement of Science 137th Annual Meeting, Chicago, December 26, 1970.

URBAN FIRE PROTECTION:
STUDIES OF THE OPERATIONS OF THE NEW YORK CITY FIRE DEPARTMENT

This paper describes studies of urban fire protection being conducted jointly by the Fire Department of the City of New York (FDNY) and The New York City-Rand Institute.

Underway now nearly three years, these studies have:

- created the perspectives, methods, approaches, and results of a new analytical field;
- transformed these research products into policies, helped put the policies into practice, and evaluated results;
- helped alter the FDNY's fire-fighting technology, the operation of its dispatching system, and the ways it manages and deploys its men and equipment;
- yielded (and continued to yield) gains in operational effectiveness valued at many million dollars per year -- annual returns more than ten times the studies' cost;
- helped the FDNY develop new problem-solving traditions and capabilities and improve its bases for future decisions and policies.

Sponsored by the FDNY, the work has been carried out by an interdisciplinary team: FDNY chiefs and other officials; engineers; an urban planner specializing in organization theory; applied mathematicians -- including specialists in statistics, operations research, and computer sciences; economists; and a social psychologist. From the outset, most of the work has been done jointly by members from different disciplines.

This joint character has become reinforced as the work has evolved from highly technical analyses of operational questions to synthesis and implementation and basic research on broader issues. On this last, for example, the FDNY has recently assigned high priority to examining social and physical origins of the demands for its services and to looking in detail at its probable future milieu and the forces shaping it.

I would like here to convey some of the style and results of our work. To set the stage, and set later descriptions in context, I would like first to describe some of the fire department milieu and to illustrate some of the problems that most urban fire departments -- including the FDNY -- now face. Then I will describe some of the work and the results it has yielded -- albeit necessarily in brief and without the reams of supporting technical details. Afterward, and finally, I would like to comment briefly on what seem to be the work's more general implications.

FIRE DEPARTMENT PROBLEMS

The fire service's mission is traditional and enduring: to prevent fire from occurring and to respond to those that do occur and put them out. Although most urban fire departments stress the preventive role, all are primarily organized to serve in crisis -- to react promptly and protect the community when parts of the physical or social order break down.

The fire department on which our work focusses is the Fire Department of the City of New York (FDNY), which provides the sole fire protection, most of the alarm communications, and some non-medical emergency services to the land and port of New York City. With roughly 14,700 uniformed men, 1000 civilian employees, and 400 fire units, the FDNY is the world's largest paid fire department. Its organization and operations -- and its problems -- are much like those of its counterparts in other cities, but larger and more extensive.

Men and Management

Perhaps more than any other municipal service, the fire service across the nation is linked by a sense of fraternity and tradition, the keystones of which are reliability, dedication, esprit, heroism, and self-sacrifice. In the contemporary city, however, this tradition is gradually eroding and coming to seem anachronistic. Public adulation and even sympathy for the fire fighter has been waning; serious technological problems are mounting; costs are rising; and in the larger cities demands on the fire service are increasingly becoming conspicuous symptoms of deeper social ills.

This erosion of tradition underlies several of the fire service's most serious problems. Fire fighters are increasingly disturbed because their traditions, and the values they represent, appear to be disintegrating. Changing public attitudes, deteriorating relations with minority communities, and a trend toward bureaucratization have dimmed the luster of the job and shaken and transformed many fire fighters' self-image. In larger cities, imbedded in the general national growth of municipal service unions, these trends have helped accelerate a rise in militancy, which has led to growing demands on wages and working conditions and a growing willingness to strike.

This crisis in public and self-identity has also afflicted fire service management. Recruiting of the most highly qualified men has become more difficult, and labor and community relations have become increasingly important, though unwonted concerns. Costs have been rising, but voter resistance to increased budgets and taxes has stiffened. And management itself has become more difficult and more complex, now that tradition no longer suffices to motivate and guide the skilled manpower on which the fire service depends.

Yet, nearly everywhere, some other traditions still dominate: the only road to the top of larger fire departments is from within, and few training programs are available to teach management and organizational skills. Moreover, even among officers, the acculturation toward putting out fires is so decided that many of the best men prefer field command even to top administrative or staff jobs.

Practices and Equipment

Fire management also faces external problems, which are best illustrated through a brief outline of how the fire service operates. Since fire is inherently a physical and chemical phenomenon, much of the fire service's activity is oriented technologically, from prevention through extinguishment. Urban fire departments, for example, inspect or advise on building plans. This activity helps ensure that materials, wiring, heating units, etc., meet the fire codes and will present firemen as few problems as possible should a fire occur.

They also inspect industrial, commercial, and public buildings -- and residences to which they are invited -- for possible ignition sources, kindling, and fuel, for lack of safe egress, and for other potential hazards. Urban fire departments have special communications networks, both into the department from the public -- to report hazards and fires -- and within the department for contact with mobile units.

When an alarm is reported, the most conspicuous part of the fire service springs into action: fire engines and sirens, pumps, hoses, axes, hooks, and ladders. At a building fire, firemen rescue and evacuate people who are or may be endangered, and put out the fire. Once the fire seems to be out, then the tedious work of overhauling begins -- finding and quenching embers and hot spots from which the fire could reignite, and putting the property in order.

To carry out these activities effectively, the fire service depends heavily upon outside persons and agencies: those who formulate and administer the codes, architects and building contractors, fire insurance companies (whose rating practices influence the private fire protection, such as detectors, sprinklers, or brush clearance that property owners provide), telephone companies, private or auxiliary alarm services, and equipment manufacturers and suppliers. These form important additional parts of the fire protection "system." And when they perform poorly, they impair the fire service's ability to carry out its mission.

Further, as this outline indicates, fire departments are essentially line-operating agencies. And, as students of bureaucracy have noted, even without external pressures such agencies are often ill-equipped in outlook, skills, and organization to undertake novel or significant change. They are usually ill-equipped to undertake efforts that involve more than minimal uncertainty and risk. The rewards for success within the organization -- and its political setting -- are too small, and the price of failure disproportionately high.

This problem is compounded in that the fire service receives little effective support from industry, universities, or the Federal government. It still depends for information and new ideas largely on a few dedicated interest groups and professional associations, which are backed by limited financial resources and next to no research. Most of the research that has been done has either supported existing practices and products or treated subjects that, while important, are peripheral to the main interests and needs of the urban fire service -- such as nuclear blast fire problems, forest fires, and the chemistry of combustion. Congress passed a Fire Research and Safety Act (1968) which set Federal responsibility for urban fire research, but only this year have there been supporting appropriations, and these are minute compared with the need.

As a result of all these influences, even with the advent of motorized equipment and mobile radio communications, basic fire department practices seem to have changed little in the past century. Radio has just begun to replace voice and hand signals and messengers for tactical communications at the fire scene. Power tools have just begun to replace axes and crowbars in ventilating roofs and walls. Command-and-control is hampered by turn-of-the-century technology and procedures. New materials, new protective clothing, new fire detectors, new extinguishing agents, or materials to enhance water, have been introduced agonizingly slowly, in part because of the small and atomized fire service market and a fragmented and reluctant supply industry.

New York City

In New York City, fire problems have additionally been driven by demand. Between 1956 and 1969, fire alarm rates more than tripled -- from 69,000 alarms per year to more than 240,000. The rate for every type of incident, from false alarm to structural fire, has been increasing exponentially. False alarms, rubbish fires, non-fire emergencies, fires in vacant or abandoned buildings, and deliberate fires now outnumber the accidental structural fires that used to be the fire service's main *raison d'etre*. Indeed, false alarms have been increasing more rapidly than any other type. There are now many more false alarms each year than structural fires; in 1969, about 30 percent of the alarms were false alarms, and 20 percent of the alarms were for structural fires.

A disproportionate share of the increase has occurred in slum areas, where fire incidence seems ineluctably tied to deteriorating housing and facilities, continued overcrowding and under-maintenance, and other accumulating social ills. Between 1962 and 1968, for example, one rapidly deteriorating New York neighborhood experienced an average annual rate of increase in alarms of 44 percent; a stable neighborhood barely two miles away saw an average increase less than 5 percent. In 1968, an area in the Brownsville section of Brooklyn -- frequently cited as one of the "worst" in the City -- had an annual rate of over 10,000 alarms per square mile, more than thirteen times the city-wide average. Due to these alarm densities, some fire companies in high-incidence areas responded more than 8000 times a year, and more than 20 times a night many nights of the year.

Costs have been rising nearly as fast as demand. Between fiscal year 1957-58 and fiscal year 1970-71, the FDNY's total budgeted expenditures rose from $99 million to $311 million; even in constant dollars (taking out effects of inflation) the FDNY budget doubled in this period. With expenditures of $35 to $40 per capita, fire is the fifth largest basic service in the City -- after welfare, education, health services, and police. Manpower costs amount to more than 90 percent of the total fire budget.

Command-and-control still must function primarily with equipment installed shortly after the turn of the century. The system worked well for a long time, but in the last few years the numbers of incidents and the volumes of information to be handled have grown much faster than the system's ability to cope with them. And as alarm rates have continued to rise, strain in command-and-control has increasingly been accompanied by strained field operations.

OUR RESEARCH

As the joint FDNY-Rand research began in January 1968, broader efforts were underway within the New York City government to improve the quality of operations and decision-making. Mayoral staff and program planners in the Bureau of the Budget were working to make analysis part of the budgetary process. And, both in line and staff positions, the Fire Department had begun to develop internal analytical interests and skills.

The initial research program was thus both broad and technical. Rand was asked to help the Fire Department with a wide range of its important problems, focussing on those where the Fire Department felt the greatest need for additional technical expertise. The problems jointly specified for research were, on the whole, those that had troubled the Department for some time, but there was a new urgency with which many of them were beginning to be addressed.

The joint FDNY-Rand team quickly began pursuing several different lines of work, as the later examples illustrate. Some involved helping the Department with rather well-defined problems and issues, where the Rand staff supplied an independent point of view and an assortment of tools and expertise to support the Department's own activities. Some involved helping the Department grapple with basic, ill-defined problems, where we were able to help clarify just what the underlying problems were and bring analytical expertise to bear on solving them. And some involved more traditionally creative work -- discovering things that had not been noted before, and bringing to the Department and the fire profession new insights and capabilities.

The team was urged initially to focus on approaches that would help the Department with forthcoming decisions, but would also prepare sound bases for the range of decisions the Department was likely to face in the next several years and in the next decade. Initially, we thus chose to center on issues that were then important to City officials and on which decisions would have to be made, and on areas where leverage existed -- or could be created -- for significant change. In our joint research, this immediate, concrete focus, combined with the mandate to develop the capability for a longer range perspective, has led to a number of major results.

I would like here to discuss examples of our work in four broad, closely related areas: communications, deployment, management information and control systems, and new technology. These examples represent a cross section of research styles, impacts, and progress.

- The work on communications has essentially been completed, and most of its results have been put into practice. As a consequence, for example, the peak-period capacity of the Brooklyn Communications Office has effectively been doubled at a very low cost.

- The deployment research has contributed to several innovative changes in Department policies, many of which are already in operation. Working together, these changes have significantly enhanced the Department's fire protection capabilities.

- The communications and deployment research have both helped provide the basis for the work with which the Department has begun to develop a computer-based management information and control system. Now being specified in detail, the new system will enable the Department to make and sustain major improvements in the quality of the service it provides, using novel techniques that lie beyond its current capability.

- The work on new technology has had two major products -- the concept for a system that might eventually reduce the incidence of both large and fatal fires, and a breakthrough in fire-fighting technology that now is close to use in routine operations.

COMMUNICATIONS

Early in the work, it became apparent -- as some Department officials had already recognized -- that the Department's command-and-control system needed comprehensive modernization, rather than continued incremental improvements. Especially critical were the dispatching centers in the communications system, which form the link between alarms from the public and the Department's fire-fighting response. These centers were operating with antiquated equipment and occasionally experiencing noticeable delays and difficulties. In addition, it appeared they would be hard-pressed or even unable to accomodate the new deployment policies then envisioned.

We examined several broad modernization alternatives, including the application of high-speed computers, which appeared attractive. This early work stimulated key officials to decide to invest in possible computerization.

By mid-1968, we began to focus on the dispatching centers. We wanted to know in detail the performance of the then-current system and to be able to predict the effects of future, increasing loads. We also wanted to be able to evaluate proposed alternative systems. We were especially interested in the dispatching time (the time alarms spend being processed at the centers before fire-fighting units are dispatched) and in understanding when it became significant relative to response times (the times the units take to arrive at the scene once they have been notified).

Dispatching consists of two basic sets of operations: receiving, interpreting, and identifying alarms; and allocating and dispatching fire-fighting units to respond. The first set involves a great deal of noise and activity -- counting telegraphic signals, answering telephones, etc. -- and is so hectic in busy periods that it readily dominates one's view of the system. Indeed, prior improvement plans -- which included new equipment, additional receiving dispatchers, and computer aid for routine tasks -- focussed heavily on this first set of operations.

At the start, Arthur Swersey spent many weeks -- night after night -- in the Brooklyn Communications Office, the busiest in the City, observing both the unusual and the routine and distilling what he saw into a detailed quantitative model of dispatching operations. From these extensive observations, and the discipline imposed by modeling, evolved several important findings. First, Arthur found that the system had a definite bottleneck when busy, not at the point where alarms are received, but at the point where response decisions are made and carried out. Several different men might work at this point at different times, but decisions were essentially made one at a time by one man with the possible aid of another. When the system was busy, its performance was limited by the performance of this single service route.

Moreover, his data showed clearly that the time delay in this bottleneck increased significantly with the number of active incidents, not only because there were more incoming alarms to be processed, but also because service of each additional alarm slowed down as there became more active incidents that had to be considered. These and other results were incorporated into a simulation model, which accurately depicts the system's performance over a wide range of conditions.

That busy periods could strain the system had, of course, been obvious. But the simulation first revealed precisely when and why the system became strained, and how large the delays could become as alarm rates continued to rise. And the model showed that, even though the system then appeared to be performing reasonably well, conditions were rapidly approaching under which the system could come close to breaking down.

The Brooklyn dispatching system performed well at normal alarm rates, routinely dispatching alarms in under a minute. Since the response time for the pumper or ladder closest to an incident typically runs between two and four minutes, these dispatching times seemed tolerable. The model showed, however, that at thirty alarms per hour -- a peak-hour load that rising alarm rates would shortly bring -- dispatching time would average nearly four minutes, and at thirty-five alarms per hour the average time would soar to nearly eleven minutes. Delays that long would clearly be intolerable.

Further, the simulation results established that the key problems were not those on which attention had previously been focussed. For example, the model showed that increasing the number of dispatchers by 50 percent in the first part of the process would reduce five-minute delays by barely a few seconds. Even using high-speed computers for the routine tasks would reduce long delays by barely 10 to 15 percent.

Of the several changes we suggested, the most attractive was to divide operations at the decision point. A live test of the idea was conducted. Using the suggested system one busy evening, the dispatchers handled without strain or delays 27 alarms in 30 minutes, and 43 alarms in an hour -- more than the system had ever been able to handle before. After some further work, Fire Department top management adopted the idea and ordered it put into practice in July 1969. This Brooklyn installation, which cost less than a thousand dollars, has effectively doubled the system's ability to handle peak loads.

Many of the other changes suggested have also been put into practice. These have served to guide, for example, the communications improvements now underway in the Bronx.

This straightforward dispatching analysis which followed from a fresh point of view and anytical skills not previously brought to bear, thus has proved operationally quite effective. It also showed that simply automating the then-current system would not significantly reduce peak-period delays. Indeed, it showed that to handle future peak loads one would need computer assistance for the dispatcher making decisions. As the deployment research began to make computer-assisted decisions possible, and to show what the potential gains would be, the Department adopted this point of view as the basis for all future design.

DEPLOYMENT

An important and difficult set of management issues concerns the allocation of fire-fighting units: how many units to have and how to man and deploy them. How these issues are resolved affects both fire protection effectiveness and the cost of providing it. Most urban fire departments have followed tradition. Paid departments, for example, have had the same number of men and units on duty around the clock, even though demand in the afternoon-evening peak period is several times greater than demand during early morning hours. Similarly, most departments have maintained a uniform "standard response" of men and equipment to alarms in most areas at all times, although fire hazards and the likelihood that an initially indeterminate alarm will turn out to be a serious fire vary greatly with area and time of day. Moreover, this "standard response" varies greatly from city to city. Some fire departments initially send as few as one engine (pumper) and one ladder (hook-and-ladder truck), while others send as many as six engines and four ladders.

For an alarm at a given location, dispatchers consult an "alarm assignment" or "running" card to see which units to send. This card contains a list of the units closest to the site, ordered by proximity. In some cities, including New York, it also lists pre-planned move-ups or "relocations" to cover the area around the site should there be a large fire that draws many units away. These lists implicitly assume that only the one incident is active in the area at the time. In active periods, therefore, following the cards in areas with high alarm densities can quickly deplete coverage and lead to deployment problems that have to be settled by improvisation.

Thus, as early analysis showed, the traditional system forces dispatchers to make ad hoc deployment decisions when the incoming flow of new alarms most presses them for time. And, as the alarm rate rises, it leads increasingly to responses containing fewer units than planned, to improvised relocations, to longer than normal response times, and to unusually imbalanced workloads.

Problems arising from these traditional procedures had become severe in New York by the late 1960s. Busy periods were depleting coverage rapidly, and dispatchers were increasingly hard-pressed to maintain coverage, especially when several large incidents were active simultaneously. Some units were responding more than eight thousand times per year, and even on shifts when many of the runs were unimportant or unnecessary -- minor incidents or false alarms -- the units still felt the strain. Adding more units -- at a cost per unit of over $500,000 per year -- was a possible solution. But new units added earlier had provided less relief than expected, and several had become new high-running units themselves.

Members of the Fire Department had proposed numerous approaches to these problems. Without analysis, however, competing theories seemed more or less equally plausible, so that all but the most conservative ideas tended to lose impetus. The Department needed ways to test ideas that avoided the delays, risks, and costs of trying something new in practice and could distinguish the effects of new policies from the effects of changing circumstances. It also needed ways to help select the best ideas from those that had been put forward, and to help develop new solutions that might be even better.

There existed extremely little prior analysis of fire deployment, and no work on problems as complex as those in New York. Together the FDNY and the Institute thus have had to create, essentially from scratch, the perspectives, methods, approaches, and results of a new analytical field.

We began by creating a wide variety of models that analyze and evaluate Fire Department deployment and suggest new policies. Each model addresses a particular set of policy issues. With the help of the entire team, much of the development work for these models has been done by Jan Chaiken, Edward Ignall, and Grace Carter. Some employ quite complex mathematical analysis; some rely more on the power of the computer to compile, generate, reshape, and analyze large volumes of information; others distill the results of these complex analyses and computer runs into simple rules of thumb.

The choices open to the Fire Department are quite varied. For example, it can embark on a long-range program to reduce the number of fires and other causes of fire alarms. It can add men and equipment, either full- or part-time. It can better allocate men and equipment and match assignments more closely to demand, redistribute work among its men, and reduce the strain and time now called for at incidents of various kinds. The models help the Department examine all these options: some broadly and some in great detail -- even down to the level of individual street corners.

The Fire Department has been intimately involved in developing, testing, and refining these models. And the Department has used these models for a wide range of purposes. Both staff and line officials use them to see how various policies can and do perform, and why, and to see how to reshape and modify them to fit new circumstances. They have found that the models reveal key points of leverage, where actions will have their greatest effects, and thus enable the Department to tighten the linkage between decisions and results. Used iteratively, prescriptive and simulation models have helped to create new policies and to distinguish worthwhile ideas from those that would be ineffectual or even potentially harmful. They have helped fire officials develop and gain acceptance for new programs, and have provided new bases with which to prepare for the future.

I would like here to discuss briefly a few examples of results that have led to changes in Fire Department practice.

Early analysis and projections of fire incidence showed that alarm rates from roughly 3:00 p.m. to 1:00 a.m. were and would remain at least twice as high as the rates for other times of the day. It also showed that in high-incidence areas false alarms, rubbish fires, and other minor incidents are most frequent during these hours. These minor events do not require men and equipment needed for structural fires. Yet the FDNY's standard response policy attempted to send three engines (pumpers) and two ladders to all street box alarms. The models, supported by extensive data, showed quantitatively how, during the peak demand hours, the standard response tended to strip high-incidence areas quickly. So many units, in fact, were tied up responding to and diagnosing early alarms that subsequent alarms received much less than the standard response and, if additional units were needed, received them from relatively far away.

Given these conditions, it seemed logical to consider an adaptive response -- varying the number of men and equipment dispatched, depending on the likelihood of given types of alarms and hazards at various locations and times of day. To those who wondered how quickly the full standard response could reach a site if a street box alarm proved to be a serious fire, extensive analysis showed, paradoxically, that during peak periods the adaptive response policy on the average got the full response to fires faster than the standard response could; the "standard response" often did not dispatch the full complement of equipment initially, and even when it did, it had so stripped the area that the third engine, say, had to come from much farther away.

For a wide spectrum of response policies and performance criteria, various models showed how many additional units would be needed, and showed clearly that important gains in protection and relief would be realized only with different response policies and even then mainly during the peak hours. Both the Fire Department and the fire-fighting unions drew upon these results and the supporting analytical framework during their 1969 negotiations.

From these negotiations emerged a program of innovation, including an adaptive response policy and new fire-fighting units, called Tactical Control Units (TCU's), that operate only during the hours of peak demand. In helping make this new policy work, we assisted the Department in improving the dispatching centers, choosing and designing the adaptive response areas, and selecting sites and dispatching policies for the TCU's and the new full-time units.

Yet another model provided a quite unexpected bonus. The traditional dispatching rule dictates always sending the units closest to an incident. Analysis showed that when nearby units have widely different workloads other dispatching assignments dominate this traditional rule -- by both leveling workload and reducing average response time. Moreover, the gains come essentially free. Accordingly, we have helped the Department put these new rules into practice -- in particular, in redesigning response areas for battalion chiefs.

These deployment innovations have now been in practice, in varying degrees, for more than six months. Evaluations indicate that the benefits for men and equipment have surpassed expectations. Tactical Control Units provide the impact of full-time units, but at 40 percent of the cost. Adaptive response has consistently worked well -- permitting equipment to arrive sooner, with additional units available for immediate dispatch when needed. Fire officials have estimated that the increased effectiveness these innovations provide would have cost an additional five to fifteen million dollars per year if supplied traditionally.

MANAGEMENT INFORMATION AND CONTROL SYSTEM

In the late 1960s, the Fire Department had begun to explore computer aid for its paper work and dispatching. Initial research suggested that these two problems be treated together -- in an integrated management information and control system. Fire Department and other City officials supported this notion and urged the team to proceed in more detail.

The work in communications and deployment helped define such a system. The dispatching simulations showed that simple computer automation of the current system would not pay. The deployment studies revealed attractive new policies that exceeded the capabilities of the present system or of narrowly conceived computer systems. The Fire Department wanted a system that would handle projected future loads with minimum delay, put the new deployment strategies into routine operation, simplify paper work, and strengthen information available for planning and support. After considering previously proposed systems, the Department asked the joint team to prepare a functional definition for a computer-based management information and control system (MICS) that would specifically meet its needs.

Prepared quickly, this functional definition outlined, comprehensively and with detail, what a computer-based MICS should do: the functions it should perform, how it should do them, and why. Following the adoption of these guidelines, we helped the Department and other City agencies involved prepare a detailed invitation for bids on translating the functional definition into detailed system specifications. A large number of companies responded with formal proposals and bids, which we helped the City evaluate.

Rae Archibald, Carol Shanesy, and Warren Walker, among others, are now working closely with the new contractor, supplying the detailed policies, procedures, and computational algorithms that will form the heart of the operating system. These draw upon much of our other work, including extensive deployment analyses that build on the research described above.

Implementation should begin in a year or so. When the system is complete, the FDNY should have the most advanced management information and command-and-control capabilities of any fire department in the world.

NEW TECHNOLOGY

Fire protection has traditionally been viewed as an engineering problem. It should be clear that we view urban fire protection as including much more. Yet, there are some urban fire problems that remain based in technology or for which technology offers potentially attractive solutions. Hence part of our work has been to find new technology that shows promise of enhancing the Fire Department's overall effectiveness; to assess this technology to determine its relevance to Departmental needs and its prospective impact on the City; to devise means of applying it effectively; and to stimulate and, where possible, accelerate development and application of especially promising items.

When this research began, we felt certain of finding "spin-offs" from defense and space programs that would be useful in urban fire protection. Yet, after many months of exploiting contacts in defense and space agencies, we found little new that seemed ready for transfer or even highly promising.

We have thus directed our work toward points where technology appeared to offer particularly important leverage: reducing the gap between the time a fire starts and the time it is reported to the fire department; and enabling firemen to deliver more water through light maneuverable hose.

Under present practice, response to a fire cannot begin until some person reports it to the fire department. Early detection and warning systems (EDWS), usually of the kinds that sense high temperature or smoke, are in fact used in some commercial and industrial buildings. Their wider use is usually dismissed as uneconomical; moreover, existing thermal and smoke detectors are rarely sensitive enough to detect fires before they threaten human life.

More sensitive "ionization" detectors recently have become less expensive and more reliable. We thus became interested in seeing whether they might form the basis for a comprehensive EDWS to save lives and sharply limit the number of serious fires. We examined a potential system which includes the automatic detection of incipient fires and automatic transmission of alarms and alarm information directly to the Fire Department.

The study showed a large-scale EDWS using ionization detectors to be technologically feasible, and to cost -- for amortized installation and operation -- roughly twelve dollars per detector per year. Although difficult to estimate, the potential gains appear to be significant, especially in valuable or hazardous occupancies.

In fighting a fire, the classic weapon is water from a hose. But the friction the water meets in flowing through the hose creates a classic dilemma: it dictates using a large, bulky hose to get enough water to the fire, while firemen prefer and need a small, light hose for speed and maneuverability. This dilemma has now been resolved by a technological breakthrough initiated and catalyzed by the work of Edward H. Blum at the Institute.

This development derives from the fact that dissolving trace amounts of a special chemical -- a long-chain polymer called polyethylene oxide -- in the water reduces the water's turbulent viscosity by about 70 percent. The solution has been termed "slippery water." It permits the Fire Department to increase the flow through a hose at a given pressure by 70 percent or more, and to more than double the reach of the stream.

With slippery water, a fireman can deliver as much water with a 1 1/2-inch hose as he previously could only with a 2 1/2-inch hose. With the lighter hose, fire fighters can climb stairs and reach remote locations more rapidly and with less strain, and put out fires more quickly and effectively. Slippery water also permits delivering large volumes of water over greater distances in conventional size hose.

Principally a laboratory curiosity as late as November 1968, slippery water is now in the last stages of a joint development program aimed at bringing it into routine Fire Department use. Involved in this program are the Fire Department, The New York City-Rand Institute, and the Union Carbide Corporation, which makes the special polymer and has contributed highly significant technical and material resources. The first pumper equipped to use slippery water was activated in October 1969 and used effectively in actual operations. Over one hundred new pumpers equipped to accept slippery water have been ordered. Fire Department officials have estimated that in the next few years, when nearly all pumpers should have been so equipped, an increase in operational effectiveness will have been gained that otherwise would have cost many millions of dollars per year.

In developing slippery water and bringing it into fire department use, we have been "technological brokers," playing a unique role in public management. By having experts with extensive professional and industrial contacts working closely with a municipal agency, we were able to identify both an area where major gains could be made and the means of making them. We were then able to bring together the people with the problems and those with possible answers, and help them develop what was needed -- for both the local problem and a national market. (Union Carbide plans to market the product nationally under the trade-mark Rapid Water.) Both the Fire Department and Union Carbide agree that without our active intervention, the chances of slippery water being developed effectively would have been small -- the full story demands another paper.

SOME BROADER IMPLICATIONS

Most previous efforts to carry out broad-ranging frontier research on real urban problems have not been noted for success. It may thus be useful to note here a few of the reasons why this work appears to have been successful. These reasons include:

- a receptive agency, which recognized the relative obduracy of its problems and resolved to do something about them;

- a young, energetic staff (most of whom left secure faculty positions at top universities) interested far more in doing first-rate, policy-oriented work to help the Fire Department than in simply publishing papers to earn kudos in their disciplines;

- an effective joint research partnership between the agency and the "outside" research staff, conducted at a scale and over a period of time sufficient to do basic research as well as devise stop-gap measures.

This last has been extremely important, as I hope the preceding discussion has made clear. Indeed, at New York City's request, the partnership has now been made formal. A new organization -- The New York City-Rand Institute -- has been constituted as a formal, legal partnership between The Rand Corporation and the City of New York. Half the trustees of this not-for-profit organization are appointed by the City; its charter and mission make it much more a quasi-public agency than a traditional consultant.

This organizational form, preserving necessary objectivity and independence with direct, explicit links to the government, may well have wider applicability, as do the results of the studies described above.