law enforcement equipment, of which some 51 will be in the form of standards (the other being informational reports). To date, however, only 4 standards have been publicly issued.

One of these is a standard for metal weapons detectors used in airports and other public places; another is for the breath analyzer devices which police use to measure illegal drunkenness in drivers. Both these standards will put some current models off the market or force their redesign. But only the breath analyzer one, which will be promulgated by the Department of Transportation and not by LEAA, will be mandatory and have the force of law. For the rest, the local police purchasing agent must obtain the relevant LESL documents† and copies of the standards, and compare the specifications they state with those offered by the vendor. It is a clumsy process, some NBS officials say, and the police and other users of this equipment would be better protected against poorly designed and unsafe equipment if the standards LEAA issues were mandatory.

The Carnahan meeting also offered other presentations which indicated the extent of R&D going on in crime technology and the range of clients and institutions involved. Lawrence Livermore Laboratory is performing a $1.8 million study for the Pentagon's Advanced Research Projects Agency (ARPA) which examines the seven major computer manufacturers' system designs to find where their operating systems or "brains" are vulnerable to illegal access. Jet Propulsion Laboratory reported on a study prepared for the National Science Foundation on standards, of all things, for AVM systems. An entire morning was given over to the international side of crime technology field, when the British, Canadian, and other foreign experts spoke.

And, for those who feel that the police have gotten the lion's share of new technology, the "Courtroom of the Future" was displayed one evening in a film. The Courtroom of the Future is located at the McGeorge School of Law at the University of the Pacific, in California. In the film, television's courtroom virtuoso, Raymond Burr, who starred as Perry Mason on TV, described how the room's circular shape and special acoustic ceiling, eight-track sound recorders, and, ironically, its 14 television monitors, could help the ends of justice be served.

Vendors, military engineers—even the experts from universities and federal laboratories—at the meeting all spoke as though technology really would bring a better future to the police and result in substantial improvements in their operations. But the police themselves, who as Zannes pointed out are the "ultimate users" of the technology, aren't so sure. In a talk given at the 1973 meeting and distributed again this year, the Chief of Police of Miami, Bernard L. Garmire, wondered aloud how Miami was going to spend a $20 million bond issue it raised to modernize its police force.

Like most police institutions, Garmire said, the Miami department lives "in an experiential vacuum" with respect to technology.

> I have often been given to wonder if the police have not been exploited, particularly by the manufacturers and vendors of technical services and hardware. Is the hardware really designed for police use, or is it simply adapted . . . ? Is the hardware constructed with the durability to withstand 24 hours a day, seven days a week usage, or is the standard obsolescence built in? . . .
>
> That the police are so grossly inexperienced in technology that they are easily victimized is, I suspect, well known in some circles.

Douglass Lee, a lawyer with the American Civil Liberties Union's Privacy Project, pointed to another problem. Summarizing what he had seen and heard at the Kentucky meeting, Lee explained the "chilling" effect all this technology could have on citizens' habits once it comes, slowly and invisibly, into general use. Lee noted that when the day comes when average people have to pull switches to enter or leave their houses without setting off an alarm, when vehicles can be tagged electronically, unknown to a driver as he travels down the highway, and when employees are fingerprinted in order to get into their place of work (not to mention telephone tapping and computerized banking) people will feel watched. Whether we really are on the road to George Orwell's *1984*, of course, cannot be foreseen. At least the Carnahan conferences offer some signposts along the way.

—DEBORAH SHAPLEY

† Documentation and copies of the LESL-developed standards may be obtained from the National Criminal Justice Reference Service, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D.C. 20530. Questions about standards for law enforcement equipment may be addressed to Lester D. Shubin, Manager, Standards Program, LEAA.

Airlines: Half-Empty Planes Keep Profits Low, Waste Fuel

Since the mid-1960's the U.S. airline industry has, on the whole, been in the anomalous situation of suffering from overcapacity and low profits at the very time that passenger traffic has generally been rising. Moreover, even while many commercial aircraft have been flying half empty, state and local authorities across the nation have been planning or undertaking costly and sometimes environmentally questionable projects to relieve airport congestion. If only from the standpoint of energy conservation alone, the inefficient use of aircraft and airport facilities is serious because of the waste of fuel.

For the outsider looking in, the management and regulation of the airlines and the airports have been puzzling indeed. Joseph L. Sax, a University of Michigan Law School professor who has been interested in the problems of commercial aviation for some time, has described the situation as "bizarre." Commenting on its conservation aspects, Sax observes:

> To put it as bluntly as possible, redundant planes with lots of empty seats are one significant piece of the energy crisis. And, to make matters worse, the more planes there are—full or empty—the more congested the airports are. And airports that suffer congestion . . . undertake development and enlargement programs that, of course, use more energy and cost vast sums of money. In short, a whirlwind of energy wastefulness.

This strange and paradoxical situation has been principally the result of a regulatory system that has fostered an intense but limited kind of competition that seems counterproductive, both for the airlines and for the public. Only in very recent years has the system shown signs that it may evolve toward something that is at least a bit more rational, even if not fully responsive to the public interest. The present scarcity and rising cost of fuel have perhaps made such an evolution inevitable.

Since fuel shortages began last fall, the airlines have been increasing their passenger load factors by cutting some flights unilaterally and, in some cases, eliminating others through mutual "capacity reduction agreements" approved by the Civil Aeronautics Board (CAB). These actions, coupled with increasing passenger traffic (many people, afraid they may be stranded without gasoline, are flying instead of driving), have given a number of the airlines the best first-quarter profits that they have ever had. On the other hand, the industry's crisis-induced response could well prove only temporary. Before long, many of the airlines may again find themselves competing fiercely for business with half-empty planes, although rising fuel costs could make this practice ruinous unless the CAB allows further fare increases.

The airline industry has been regulated ever since its infancy in the 1930's. The Civil Aeronautics Act of 1938 gave the CAB, which was created under the act, authority to set air fares and award "certificates of public convenience and necessity" for transporting passengers, cargo, and mail route by route.

"Grandfather provisions" contained in the act allowed existing air carriers, which were for the most part the original mail contractors, to continue flying their accustomed routes. The "trunk line" operators of today—that is, the airlines conducting long-haul flights on the principal domestic air routes—are in fact the grandfather carriers.

The original route awards did not themselves result in the kind of highly competitive situation that was eventually to develop. During World War II demand for air travel was so much greater than existing capacity that load factors rose as high as 88 percent, with only the traveler who could claim priority status being assured of a seat. Later, during the late 1940's and the 1950's, load factors were to range from about 58 percent to about 65 percent (and occasionally a little higher), levels quite sufficient for profitable operations.

At various times during the 1950's and 1960's, however, the CAB made numerous route awards which, taken altogether, made for stiff competition on the busier routes within the trunk-line system. The grandfather carriers were allowed to extend their historic route systems, and local service carriers were permitted to share in some of the trunk-line business.

The growth of air travel during the 1960's was such as to encourage the mistaken belief that, if there was a potential problem of airline overcapacity, it was not imminent. Jet aircraft, introduced in the late 1950's, were making the airlines the overwhelmingly dominant common carrier for intercity travel. As late as 1962, buses and trains still carried more than half of the intercity travelers who relied on public transportation (about 90 percent of all travelers went by private automobile, a proportion that would hold steady over the next 10 years but now may be beginning to decline). By 1972, the airlines claimed almost 80 percent of the travelers using public transportation, with the 200 million revenue passengers emplaned for domestic travel that year representing a nearly threefold increase over the number emplaned a decade earlier.

Defective Regulation

Given this phenomenal growth in the number of paying passengers, perhaps only a grossly defective regulatory policy could have contrived to make commercial aviation a sick industry. The CAB's freehanded policy of awarding routes proved equal to the challenge. The upshot of that policy was that, after 1966, when the load factor for trunk lines stood at 58.4 percent, load factors dropped markedly, even falling to a low of 48.7 percent in 1971. It must be borne in mind, moreover, that the figures cited are those applying to the entire trunk-line system, which means that on many individual routes the load factor was much lower still.

Although the CAB had brought about this situation by its route awards, it could not initiate corrective measures because it had no authority to fix flight schedules or limit flight frequencies. The agency is, by law, forbidden to intervene in such matters. And, as for the airlines themselves, they often found it difficult to cope rationally with the competitive pressures.

Because price competition is largely precluded under the CAB's regulation of air fares, the airlines were forced to compete principally on the basis of flight frequencies and such frills as the thickness of the steaks served and the height of the stewardesses' hemlines. The number of flights offered and the convenience of schedules were deemed the critical things, for experience showed that the airline that gained the advantage here reaped a disproportionate reward. If, say, two-thirds of all the flights on a particular route were offered by one airline, that airline would be likely to enjoy substantially more than two-thirds of the total business available.

Each of the airlines serving a heavily competitive route could see the need for less redundancy of flights and higher load factors, but, then, which company would be willing to reduce its flights? Surely not the airline enjoying the competitive edge. And, as for the others, were they to allow the leader to grab a still larger share of the business?

The situation that developed on the Chicago–Los Angeles route represents a classic case of unproductive competition. On this route—served by American, Continental, TWA, and United—the average load factor has been about 44 percent. As of last 1 October, before the onset of the energy crisis and the subsequent capacity reduction agreement by the four airlines, there was a total of 55 daily flights (counting both eastbound and westbound) serving this market, with jumbo jets capable of carrying more than 300 passengers used on many. Just how excessive such frequency of service really was is evident from the fact that, as of 1 May, with the capacity reduction agreement in effect, the total number of flights had been reduced to 41—14 fewer than before—and, even with that, the average load factor was not expected to exceed 60 percent.

A number of the airlines have made the problem of low load factors still worse by investing heavily in jumbo jets. These aircraft, by virtue of their great seating capacities, can make for troublesome inflexibility when introduced under conditions of uncontrolled competition as to scheduling and flight frequency. As of 1 February, American Airlines had ten Boeing 747's—planes that cost $25 million apiece—grounded as a result of the fuel shortage, and Continental Airlines had four in the same status. Yet, with proper

control over flight frequencies and load factors, these jumbos could actually have proved an asset in coping with fuel shortages. Compared to the Boeing 707, the 747 uses only about half as much fuel per passenger seat mile.

Only since the start of the jet era have the domestic trunk lines approached the 12 percent rate of return on investment that the CAB now regards as fair. That was in 1965, when the trunk lines had a return of 11.2 percent. Profitability is of course influenced by other things besides load factors, and the rate of return happened to decline to 6.7 percent by 1967 even though the load factor actually increased from about 55 percent to approximately 57 percent. After that, however, both profits and load factors declined markedly, and the correlation between them, while imperfect, was clear.

In 1970 and 1971, when the load factor for the domestic trunk lines was below 50 percent, the rates of return were down to 1.4 and 3.3 percent, respectively. The situation has since improved somewhat, but 1973 profits were no better than half the CAB guideline figure of 12 percent. Throughout, the most profitable of the trunk lines have been those (such as Delta, National, and Northwest) that have been blessed with less competitive route systems as well as strong management.

Fares up 35 Percent

Responding to the airlines' pleas, the CAB has allowed periodic fare increases, such as those of 1970 and 1971 and the two granted within the last six months (one of 5 percent in December and another—to offset the rising cost of fuel—of 6 percent in March). Clearly, however, fare increases cannot make up for low load factors. Indeed, if carried much further —the price of a coach ticket already has increased by about 35 percent over the past 5½ years—they could reverse what has been a trend toward a broadening passenger market.

Business travelers, who represented 85 percent of all passengers a decade or so ago, now account for only about half because a mass market of people traveling for personal reasons has developed. Today, to fly coach on a New York–San Francisco round trip costs $374 (including an 8 percent federal transportation tax). If the fare goes up by another third before the end of the decade, many of the grandmothers, the tourists, and others who have become part of the market may give up flying. What the airlines need is more such travelers rather than fewer.

The CAB regulatory policy has, over the past several years, become somewhat more responsive to the problem of low load factors. For one thing, there has been a virtual moratorium on route awards that would increase competition on the trunk lines. In fact, as recently as 3 May, the CAB reversed the decision of an administrative law judge that would have allowed Eastern to enter the Detroit-to-Cincinnati market and Delta to enter the Atlanta-to-Cleveland market.

In so doing, the board pointed out that average load factors on these routes during the last several years have been not more than marginally higher than the 55 percent load factor standard adopted in 1971. By this standard, the CAB is supposed to fix passenger fares at levels that permit the desired 12 percent return on investment only if, on the average, 55 percent of all seats are filled.

Although the CAB lacks authority to regulate flight frequencies, the airlines are not allowed to collaborate in adjusting schedules and frequencies without its approval. Therefore, the agency's role in the capacity reduction agreements initiated by some of the airlines has been a key one. Several such agreements were approved during fiscal 1972; these came well before the energy crisis and had greater economic efficiency as their sole motivation. The most important was an agreement by the three largest domestic trunk line carriers—American, TWA, and United—to reduce flights on several intensely competitive transcontinental routes.

Then, last fall and early this year, the CAB approved temporary capacity reductions on more than a score of competitive routes in the interest of conserving fuel. Again, the most important of these involved the big three carriers and their east-west routes. Actually, with their fuel allocation reduced to 95 percent of 1972 levels—and with much uncertainty as to whether even the allocated amounts would be available when needed—all of the air carriers simply had no choice but to reduce flight schedules drastically, and this they did largely by independent management decisions requiring no CAB review. Altogether, at the height of the energy crisis last winter some 2000 domestic flights had been eliminated.

Together with such energy conservation measures as reducing flight speeds, using fewer engines to taxi, and using simulators instead of aircraft for many pilot training activities, the flight reductions have been expected to produce large fuel savings. Barring an early return to the wasteful practices of the past, the fuel consumed by the total U.S. scheduled airline industry (domestic and international) this year could be about 1 billion gallons less than the 10.3 billion gallons used in 1972.

Passenger Traffic Rises

Even with all the fuel savings and flight reductions, no less than 12,000 daily departures have been available through the late winter and spring. Passenger traffic, far from declining, has substantially increased over that for the same period in 1973—it was up 5 percent in January, 7½ percent in February, and more than 8 percent in March, and seemed to be going even higher in April.

The load factor for the trunk lines is now about 60 percent, which means that there would still be plenty of room for more passengers even without increasing flights. But, with an apparent easing of the fuel shortages and the growth of traffic demand, flights are in fact being restored. For instance, American has announced that, by 15 June, seven of the ten Boeing 747's which it has grounded will be back in operation and some 170 additional daily flights will be offered in anticipation of a seasonal increase in traffic. Other airlines will no doubt be following suit, and a new round of frantic competition for business may be close at hand.

Now would seem to be the time for a thoroughgoing inquiry by Congress, the CAB, and the Department of Transportation into how best to put the regulation and promotion of commercial aviation on a more rational basis. It should take into account the need for a fuel conservation ethic, an economically sound airline system, and a system capable of accommodating a mass market at attractive fares, especially for long flights.

Properly conducted, such an inquiry would be wide-ranging, with no possibilities excluded a priori. The polar extremes are nationalization on the one hand and complete deregulation on the other. Distasteful as the idea of nationalization is to the industry, it cannot be dismissed as fanciful. A combi-

nation of low profits and high capital costs could lead to a situation where the trunk lines cannot survive without government subsidy. Already, fears are being expressed that the industry will not be able to raise the huge sums (some estimates have been as high as $27 billion) that must be spent before the end of this decade for new aircraft and ground equipment.

Heavy subsidization could lead to politically compelling demands for an increasingly large role for the government in airline management, with nationalization to be the eventual outcome. It is entirely conceivable of course that some form of nationalization would produce excellent results. The nationalized foreign airlines generally have a reputation of offering relatively limited and costly service, but circumstances in the United States might be much more favorable to air service to a mass market at reasonable fares.

Deregulation of the airlines would produce a major upheaval within the industry, and it is probably the alternative least likely ever to be adopted. Moreover, J. C. Constantz, chief of the CAB's economics analysis division, believes that deregulation would lead finally to an inadequate system dominated by a few big carriers. On the other hand, even at the CAB there are knowledgeable people who suspect that a deregulated system would work at least as well as the existing one.

A promising middle way that would avoid the uncertainties and pitfalls of nationalization and deregulation would be to modify the present regulatory system. The CAB could be directed by Congress to regulate airline schedules in such a manner as to ensure satisfactory load factors. The agency regards load factors of 60 to 65 percent as "reasonable," and even this may be conservative. Some students of the problem have concluded that the average load factor could be raised to 70 percent without substantially reducing the availability of service.

A truly efficient air service will of course be one that is planned as part of a well-integrated national network of intermodal transportation systems, with the air mode devoted primarily to long-haul service (at present, half of all domestic airplane hops are for distances under 260 miles). But the planning and development of such a system is a problem for the long term. Raising load factors for the existing domestic air service is a problem that cries out for early solution.—LUTHER J. CARTER

RESEARCH NEWS

Energy Storage (II): Developing Advanced Technologies

The concept of energy storage—storing energy generated when demand is low for use when it is needed later on—is rapidly coming of age (*Science*, 17 May, p. 785). Electric power utilities, faced with a demand for electricity which fluctuates with the time of day and season of the year, estimate that, by the end of the century, up to 25 percent of the total power generated during the day could be stored and subsequently used. One spokesman rated energy storage as the best technological and economic investment after advanced nuclear power. In addition to serving the needs of utilities, energy storage is needed for electric vehicles. While experiments with vehicles powered by storage batteries, one alternative to petroleum-fueled internal combustion engines, are well under way, advanced energy storage systems could make such vehicles much more useful than they are now. And energy storage will be essential to the development of presently unexploited energy sources, such as the sun, the wind, or the tides, which are intermittent in character.

A number of proposed storage technologies are emerging from the stage of preliminary feasibility studies and entering the stage of engineering study and prototype development. For example, energy can be stored in a magnetic field. In the familiar electromagnet, however, the resistance of the magnet windings results in power losses, and power must be constantly supplied in order to maintain the field. If the windings lacked resistance—that is, if they were superconducting—then once the desired magnetic field was obtained, it would require no further power, and the energy originally supplied to the magnet would be stored in the magnetic field. Later the stored energy (proportional to the square of the current) could be recovered by drawing off some of the current in the magnet. The storage efficiency (the fraction of stored energy that is recoverable) could be about 95 percent.

Such an idea for storing electrical energy has been advocated by researchers at the University of Wisconsin, Madison (*1*), and at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico (*2*). Both groups have pointed out that storing energy for utilities via superconductors is economically thinkable only for large storage capacities, in the range 1,000 to 10,000 megawatt-hours (1 watt-hour equals 3600 joules). A typical magnet might be a solenoid with a radius of 50 meters and a height of 50 meters, and would probably be set in bedrock in order to contain the large forces on the conductors of such an immense magnet. Because of the relatively low energy density (measured in watt-hours per cubic meter) of superconducting magnetic storage, this type is inappropriate for vehicles.

Both the Madison and Los Alamos groups have made preliminary engineering and economic studies of the feasibility of storing energy in this way, and are hoping to build model systems from which to obtain data for extensive analysis. The Wisconsin group is aiming for a 10–megawatt-hour model (in the form of a solenoid) to be completed by 1980 or 1981. The solenoid would be made of niobium-titanium composite superconductors (*Science*, 25 January, p. 294) and would operate at 1.8°K with a field of 0.5 tesla. The Los Alamos researchers are planning first on a 30–kilowatt-hour model (in the shape of a torus), to be followed by a 10–megawatt-hour prototype later on. The largest superconducting magnets now operating (in terms of energy storage capacity, not magnetic field strength) are those used in bubble chambers, such as the big European bubble chamber (BEBC) magnet at CERN in Geneva. The BEBC magnet has a storage capacity of about 220 kilowatt-hours.

The large size of the superconduct-