Chapter 5

Conclusions Regarding Current Research and Development Into Detection of Explosives

A large number of detection systems are currently being developed. In addition to SAIC (developers of the thermal neutron analysis [TNA] method), several vendors have produced prototypes that, they claim, can usefully detect small quantities of plastic explosives. Some of these use vapor detection and some use x-ray imaging techniques. Among the vendors making such claims are Barringer, Inc. (vapor), Ion Track Instruments (vapor), Thermedics, Inc. (vapor), AS&E (backscatter x-ray), and Imatron (x-ray, using computerized tomography). The x-ray and vapor systems are significantly smaller and cheaper than the current TNA device. Further, other companies, such as EG&G Astrophysics and Siemann-Heimann, have commercial x-ray systems available that they claim are useful for explosives detection at airports.

After reviewing the current state-of-the-art, OTA sees no evidence that any device, currently at the prototype stage, is capable by itself of ***reliably***[1] detecting small quantities of plastic explosives in checked baggage. There are many technologies, including TNA, that have limited capabilities; however, all have serious flaws. Table 5-1 provides a summary of the qualities of the principal types of detectors.

Since each device has serious weaknesses, the best solution for a security system would be a combination of different technologies, if this could be made economically and operationally feasible. This would exploit the advantages of each technique while compensating for its weaknesses. As a hypothetical example (not a definitive prescription), a first step in screening might sequentially employ vapor detection and x-ray imaging devices, which are smaller and less expensive than TNA. Those bags that produced alarms in both systems would go to TNA and computerized tomography for a further look. This would reduce the number of heavy, expensive detectors at each airport, and, if false-alarm rates in the frost step were low enough, the cost and operational feasibility could be practical.[2]

Greater attention should be paid to passenger screening, which could provide a filter that would greatly reduce the number of bags that the technical tools would have to examine. If, say, 90 percent of passengers could be eliminated as likely carriers of explosives through a combination of profiles, interviews, and matching of passengers with baggage, the number of bags that required inspection would be reduced by a factor of 10. This would reduce the requirements for the explosives detection equipment with regard to number, size, and speed of throughput. This "human factors"-oriented security approach is highly labor-intensive, but has been used in Israel and by El Al Airlines worldwide to provide security with a good measure of success.

Many have criticized the suggestion that this approach be applied to the United States, on the grounds that the size of El Al's operation is minute compared to U.S. traffic. However, it would be a mistake to conclude that none of these techniques and procedures can be adapted from the Israeli experience for application on U.S. carriers. Further, where machines are used to aid human decision-making, there may be economies of scale in the United States.[3]

[1]That is, With a high (at least 90 percent) detection probability and a low (at most 5 percent and preferably much less) false-alarm rate. A significantly lower detection probability may not be sufficient to deter attacks by terrorists who are willing to risk the arrest of several operatives in order to achieve one spectacular success. Regarding false-alarrnrates, at least one foreign country has found that intensive scrutiny of about 3 percent of checked baggage is feasible without introducing more than a 2-hour delay between check-in and departure. This implies that a false-alarm rate of this order may be acceptable, at least in some settings.

[2]If the first step had a false-alarm rate of, say, 2 percent, only 1 bag in 50 would have to be examined by the following step. Then, instead of requiring that each TNA machine handle a flow of 600 bags per hour, as is currently specified in the FAA rule, published in September 1989 (see below), it would only be necessary for it to handle 12 bags per hour. This would mean that the number of TNA devices needed at a large airport would be 1 or 2, rather than 10 to 20.

[3]Our final report will examine this issue further.

Table 5-l-Advantages and Disadvantages of Available (or nearly available) Explosives Detection Techniques

Type	Advantages	Disadvantages
Chemiluminescence	Cost; size; sees plastics; specificity (determines molecular compounds with low rate of misidentification).	Slow; needs vapor or residues.
Electron capture	Cost very low; size;, may see plastics.	Slow; no specificity; needs vapor or residues
Ion mobility	Cost; size; may see plastics.	Needs substantial development; needs vapor or residues.
TNA	Sees plastics; prototype exists and being tested in airports; automated. No vapor needed.	Large; expensive; sensitivity currently inadequate; false-alarm rates high.
X-ray, dual energy, or backscatter.	In commercial production; high spatial resolution; may see sheets or small quantities of explosives; does some discrimination on atomic number, but only roughly; cost and size relatively small; can see other weapons; vapor not an issue.	Not specific to explosives; sensitivity to small or thin quantities uncertain; not yet automated.
Computerized tomography	Very high 3-D spatial resolution, good for small quantities of explosives or other contraband; prototype exists. Vapor not an issue.	Only looks at density; not specific to explosives; slow; large; expensive.

SOURCE: Office of Technology Assessment, 1991.

TESTING AND EVALUATION

With a potential market that could reach hundreds of millions of dollars within the next few years, it is to be expected that there will be a multitude of conflicting and highly optimistic claims made on behalf of many different products. Consequently, a credible, objective, official evaluation and certification procedure is badly needed. For this function, the government may wish to turn to an independent agency or body that is widely respected for integrity, scientific and technical expertise, and neutrality.

An independent testing authority, *outside the Federal Aviation Administration (FAA), is* urgently needed to provide a neutral testing protocol and to carry out such evaluations. It would be useful, if not essential, if this were to be accomplished and potential devices certified before rules requiring massive and expensive purchases of equipment are established. The FAA is on record as welcoming the establishment of such a body.[4] Following criticism from public officials and the Victims of Pan Am 103 organization, the FAA has also recently constituted an independent advisory panel that is to provide outside recommendations on testing protocols. The TNA equipment should be retested using new protocols.

Establishment of an independent testing panel would help the FAA avoid future allegations of conflict of interest. Some observers have criticized the agency for a perceived lack of objectivity in the past. These accusations were based primarily on two facts. First, specific technologies have been funded by the FAA for several years, creating the possibility of institutional bias in favor of those approaches. Second, serious questions were raised about the procedures used in the San Francisco Airport and Los Angeles Airport testing of the TNA device.

One possible agency for testing is the National Institute of Science and Technology (NIST), formerly the National Bureau of Standards. Not having participated to any important degree in the development of explosives detectors (although it recently tested a number of vapor detectors for the National Institute of Justice), it has no perceived “axe to grind”; it has a well-deserved reputation for scientific and engineering competence, and has performed, as part of its mission, evaluations of a multitude of engineering and measuring devices. Another institution with much experience is Sandia National Laboratory, which has worked in this area for over a decade. However, Sandia might be handicapped by the fact that it has worked assiduously on a few technical approaches for a number of years, and thus may be perceived as having a stake in developing them at the expense of others. Another possibility, the National Research Council of the National Academy of Sciences (NAS), which has concluded a study of the problem of explosives detectors for the FAA, is a respected body with the required technical capability. However, the NAS is not interested in being a testing laboratory, and, indeed, is not setup to perform this sort of task.

[4] Testimony of Monte Belger before the President’s Commission on Airline Security and Terrorism, Feb. 2, 1990.

Any of the above institutions, however, would be excellent choices to develop appropriate protocols for the testing and evaluation of explosives detection equipment. In fact, the FAA has contracted with the National Research Council to develop some testing protocols for nuclear-based explosives detection methods.

A further alternative would be to contract with other outside sources, such as academic institutions, military laboratories, or private laboratories, to write protocols and perform the testing. In all cases, it would be useful to establish an advisory board, consisting of technical experts from several government agencies (e.g., the FAA, the Departments of Defense, State, and Energy), academia, and, possibly, the private sector, to oversee the testing and evaluation process.

MANAGING RESEARCH

Cooperation

A few Federal agencies are funding the major share of research into detectors for explosives. These include, of course, the FAA, which, in addition to working on vapor detectors and TNA, is pursuing a number of advanced technologies, described elsewhere in this chapter and in appendixes A through C. As another example, the State Department is funding Thermedics' chemiluminescent technology for detection of explosives in packages. A small amount of other work is scattered among other agencies.

Several specific examples have persuaded OTA staff that coordination among the agencies, both regarding cooperation and exchange of information, is in need of improvement. In recent months there have been signs of better interagency communication, but more needs to be done.[5]

Time From Laboratory To Deployment

A major problem is the length of time needed to go from laboratory work to deployment in the field. Although many Americans would like to have immediately a set of new, devastatingly effective tools to fight terrorism, the reality is that the time required to research, develop, prototype, and, finally, to field a particular device is often considerable. It can frequently take as long as 10 years to bring a new, complex technology to the commercial market. The first 2 or 3 years are usually spent in research, making fundamental measurements to determine the feasibility of an idea. Another 2 years are typically required to demonstrate the feasibility of a process or equipment. Two more years are often needed to develop a prototype, and as much as another 2 to 3 years are frequently spent in so-called "beta test sites" where the engineered hardware is rigorously tested in a realistic environment.[6] These lengths of time are rough estimates and not absolute rules that apply to every case. However, they are consistent with the experience with TNA.

This process may be shortened somewhat, but rarely to less than 5 years. The developmental time depends on the urgency of the project, whether the initial research is funded sufficiently to allow concurrent approaches to solutions of problems, the complexity of the hardware, and, most of all, the relation of the hardware to other existing, preferably commercial, equipment.

The time to produce a prototype can be reduced in the case where only a minor rnodification of existing commercial hardware, rather than a brand new class, is required. Modifications of existing commercial x-ray scanners fall into this category. Another major advantage of modifying existing hardware is that the manufacturing capability is likely to exist already.

To maximize the likelihood of success, long-term research often must incorporate different avenues of approach. In some cases, it may be advisable to back different groups working on similar technologies. Much basic research is a high-risk, high-payoff procedure. Coupling high-risk research with small studies that evaluate how a particular technical approach would fit into an integrated security system would be a useful approach in guiding long-range funding decisions and in determining which technologies to support. One especially important topic to study would be the definition of requirements for an integrated system, as opposed to requirements for component devices.

The FAA is pursuing a dual-track program. On the one hand, it is looking for devices that, while limited in effectiveness, have the advantage of being avail-

[5]The final OTA report will discuss this issue in detail.

[6]For a discussion of why it takes so long to field the results of government-funded R&D, see U.S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, DC: U.S. Government Printing Office, April 1989), ch. 8.

able soon. On the other hand, it sponsors technology that is not yet mature, but has the promise of producing superior equipment in the long run. The FAA's funding has increased substantially in the last 2 years, as Congress has urged increased research efforts in hopes of providing a near-term solution.

The FAA's work in sponsoring research appears to be improving, in part due to increased funding, which makes it possible to take more research risks. But there is a need to decide with some firmness on a date, preferably within 2 years, by which time competing technologies for near-term application should provide detectors to be tested in realistic settings. This would allow the winnowing out of unpromising lines of research. If testing is successful, a rule requiring widespread acquisition of the detectors could be promulgated. This action would presumably stimulate the market to produce more competing instrumentation of the same type. If testing in a given area is unsuccessful, this may indicate that R&D should no longer be actively supported along that particular direction.

If such a restriction is not imposed on research that is on the near-term track, there is a danger that technologies may continue to develop, but without ever producing workable prototypes. It is a cliche, but true, that the better becomes the enemy of the good.

One difficult task is to formulate a reasonable set of performance standards to judge the products of research. The standards will have to be acceptable to Congress, as guardian of the public interest.[7] If this had been done in the TNA case, much controversy and many political difficulties could have been avoided. There are, however, problems in setting standards, particularly for vapor detectors, because the performance of the machines is so affectedly the scenario in which they are used and, thus, a terrorist scenario must be specified in order to set the standards. Efforts have been made in developing such scenarios, e.g., by the American Society for Testing and Materials, but little in the way of progress has yet been achieved. Nevertheless, a logical basis for standards must be developed and set so that credible testing and evaluation may begin.

Analysis is needed to determine how much effort should be devoted to developing near-term solutions, how much to longer term technologies, and how much to accelerating work on the more promising longer term technologies so that they may be developed more quickly.

FAA RULEMAKING FOR EXPLOSIVES DETECTION SYSTEMS

The FAA accepted a TNA prototype in fulfillment of an R&D contract following a series of tests run in 1987 and 1988 at Los Angeles and San Francisco Airports. These tests have been criticized by a number of groups.[8] They were not double-blind and they used explosive simulants equivalent to the amount then thought required to cause a large commercial aircraft to crash. Unfortunately, after Lockerbie, the world discovered that a much smaller quantity could destroy an aircraft. Further, the explosives were attached to the outside of test items of luggage, not a likely geometric configuration to be found in practice.[9]

As part of Public Law 101-45, which became effective on June 30, 1989, Congress ordered FAA to develop a rule that required:

> . . . the use of explosive detection equipment that meets minimum performance standards requiring application of technology equivalent to or better than thermal neutron analysis technology. . . as the Administrator determines that the installation and use of such equipment is necessary to ensure the safety of air commerce. The Administrator shall complete these actions within sixty days of enactment of this Act. . . .

The FAA then issued a proposed rule, published in the Federal Register as a Notice of Proposed Rulemaking, to amend part 108 of the Federal

[7] The specific details probably should be kept secret from the public to avoid tipping Off terrorists as to the limitations of the accepted systems.

[8] For example, seethe testimony of Ref. Lee Grodzins before the Presidential Commission on Airline Security and Terrorism, Washington DC, Feb. 9, 1990.

[9] This is another serious defect, since the TNA system is supposed to ''learn,'' through an artificial intelligence technology known as ''neural networks," to detect a bomb in a suitcase through experience in evaluating data (stimulated gamma ray counts from the suitcase, together with the rough location of the gamma rays' origins) and comparing it with the knowledge of whether the suitcase actually had a simulated explosive or not. If the samples on which the device learned were not realistic, there would be no guarantee that, when inspecting realistically packed bags containing explosives, the machine would have the same rate of detection or false alarms.

Aviation Regulations to require an explosives detection system (EDS) for screening checked baggage (but not carry-on baggage) on international (but not domestic) flights.[10] Ironically, TNA might work better for carry-on than for checked baggage because the weight of carry-on luggage is generally less than the weight of checked luggage. Thus, for carry-on luggage, the nitrogen signal from the explosive would be easier to see above the background from other nitrogen in the bag than would be the case for checked luggage. About half of recent successful airline bombings have resulted from explosives placed in the passenger compartment, and half from explosives in the cargo hold.

The EDS was supposed to alarm automatically. This feature was designed to eliminate reliance on security personnel for a rapid determination of what was suspicious and what was not. Many security personnel are not highly paid, trained, or motivated, and reliance on their alertness under these constraints was not considered to be reasonable.

The Final Rule was published in early September 1989.[11] The FAA felt that it was feasible to promulgate and enforce the rule since the tests at the two airports showed that at least one technology was available. In the discussion accompanying the Final Rule, the FAA referred to TNA as "the only existing, proven system. ' The goal, as stated in the Final Rule, was to require 860 such systems by 1999. An alternative possibility was to install 200 within 3 years and 300 by 1999.

In further tests carried out at JFK Airport in New York since September 1989, the TNA system has performed significantly worse than in the earlier tests. In addition to frequent calibration tests done with simulated explosives on the outside of luggage, the JFK tests are also occasionally performed with explosives placed within bags taken from a set belonging to the FAA for test purposes. This latter test is claimed to have been carried out in a double-blind manner.

Whereas detection probabilities of 95 percent with false alarm rates of 5 percent were cited from the earlier tests, more recent results quote significantly higher false alarm rates. Further, at least one common explosive used by terrorists was not simulated and **used for testing the device. The** false alarm level was reduced by adding a two-beam x-ray device to the equipment. However, the rate was still high enough to clog airport operations, if the device were to be used to screen every piece of baggage.[12] Automated decisionmaking was not used for the x-ray part of the equipment. In any case, for a Lockerbie-sized bomb, which was smaller than equivalent explosive quantities used in the initial tests, the detection rate is likely to be much worse, or the false alarm rate higher (or both) than the figures cited above.

Based on the testing results up to the present, the TNA device by itself does not currently appear to be an adequate **system for screening baggage at airports for small but deadly quantities of explosives. On the** positive side, the experience gained by installing an explosives detector in an operational environment has been extremely valuable and has provided the FAA with important lessons that will help in developing performance criteria as well as evaluation standards and procedures for future EDS devices.

Attention should be given to developing means (TNA-based or other) of screening carry-on baggage. TNA may work better in this mode than for checked baggage.

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[10] Federal Register, 54, p. 28985, July 101989.

[11] Federal Register, 54, p. 36938, Sept. 5, 1989.

[12] It is difficult to say without a detailed analysis what an acceptablefalse-alarm rate would be. Some estimates, however, may be made. A false-alarm rate of 5 percent is required by the FM rule. However, even this rate maybe marginal at busy airports, in that long queues maybe generated. A recent study for the Air Transport Association gives support to this view (Practicability of Screening International Checked Baggage for U.S. Airlines, Geoffrey D. Gosling and MarkM. Hansen, Institute of Transportation Studies University of California at Berkeley, UCB-ITS-RR-90-14, July 1990). As mentioned in an earlier footnote, one foreign country has found it possible to operate if about 3 percent of checked baggage is carefully inspected, so a false-alarm rate of this level would be tolerable in at least some circumstances.