

## Part III

### Conclusions and Options

I think all of us have to acknowledge somewhere that while having safety legislated is not the ideal way to go, the fact .\*. that Congress set a deadline has been a very significant piece of this program, and . . . for that,

I think we owe the Congress a thanks.

— Robert Buley, Northwest Airlines, OTA Workshop

### THE ISSUES

The basic issues associated with TCAS II legislation include the safety, technical, and economic consequences of rapid installation — by 1992 — in the Nation% commercial fleet. All three are interrelated; however the safety and technical issues are so closely connected that they will be summarized together. A fourth issue is the impact on international relations.

#### Safety and Technical Issues

The safety concerns related to TCAS II are twofold: 1) the as-yet-unknown effect of full TCAS II implementation on system safety, and 2) the possibility of reduced safety because resources are strained or diverted from other maintenance needs in order to implement TCAS II by December 30, 1991. FAA has not developed a well-defined plan for evaluating operational performance in a setting that includes a substantial portion of the Nation's fleet equipped with TCAS II. The limited installation programs undertaken to date have involved no more than two commercial aircraft and did not provide an adequate assessment of the effects of a fully-equipped fleet on the air traffic system. TCAS II technology is now well developed, and a more widespread operational evaluation is justified to determine whether software or hardware modifications are called for or whether pilot or air traffic control procedures must be changed. Without such a

program, a worst case scenario is that the airlines would completely outfit their fleets only to learn that a technical problem requires major modification of TCAS II equipment. A structured evaluation program would allow most problems to be identified quickly, preventing further installation of flawed units and permitting equipment modifications to be made early in the installation program.

A successful operational evaluation would require a critical mass of aircraft to be outfitted with TCAS II at an early date. Operations under the evaluation should cover the full spectrum of geographical locations and aircraft and airspace types, including sufficient numbers at hubs to address high-density issues and assess the impact on air traffic controllers in heavily used airspace. The effects of TCAS II on pilot and controller performance are still unknown and must be carefully analyzed during the evaluation.

Regardless of the results of an evaluation period, airlines are aware that some upgrades to TCAS II will probably occur over the next 30 months, and they may postpone taking delivery of TCAS II equipment until near the installation deadline. This would permit airlines to avoid possible costs associated with removing TCAS and installing a modified version, but it would confront equipment manufacturers with serious cash flow problems. Moreover, this also means the air traffic system could suddenly be saturated with new equipment, and the resulting effects on the system are virtually impossible to predict.

Supplies of skilled labor, as well as ramp and hangar space, are limited. Thus, airlines may need to divert maintenance attention from other programs to install TCAS II on time. These strains on resources could degrade the quality of both TCAS II installations and other important maintenance and safety activities, such as those associated with aging aircraft.

## **Economics**

The economic consequences of the implementation deadline will affect each airline differently. TCAS II installation would be least disruptive for airlines if it could be accomplished during the normal heavy maintenance cycle that occurs about every 4 years for each aircraft. However, the December 1991 deadline leaves the airlines only 2 years for fleetwide implementation, because production equipment of TCAS II will not be available until December 1989. To complete the work in 2 rather than 4 years will require airlines to hire additional labor, schedule more overtime, and take more aircraft out-of-service time. The increased workload may cause sequencing problems with other programs, such as aging aircraft requirements and windshear equipment installation. Airlines that are financially healthy are much better able to meet these demands than airlines with cash flow or labor problems.

Out-of-service time for aircraft raises equity issues for the various airlines. Some of these equity issues are separate from the direct costs of installing TCAS II. Airlines without any extra aircraft may have to eliminate some flights for short periods. These airlines are likely to lose passengers to other airlines, whereas companies that have extra aircraft in their fleets or the resources to lease them can avoid canceling any service. In addition, some communities served by airlines without extra aircraft may be inconvenienced during down time for the aircraft that normally serve them. Finally, the costs associated with the multiple maintenance requirements now in place may cause some airlines with older fleets to retire aircraft rather than complete the programs, further compounding out-of-service problems.

Airlines that do not meet the deadline for any reason will be penalized severely if unequipped aircraft are not permitted to fly in U.S. airspace in 1992. However, airlines that complete TCAS II installations on time will face substantial indirect cost penalties if their competitors do not commit similar resources and are granted extensions. If

problems occur in early 1992 and TCAS equipment should need to be modified, all airlines will face substantial costs.

The TCAS II installation requirement has a different effect on the various U.S. TCAS manufacturers. Expecting over 6,000 orders from domestic and foreign airlines by the end of 1991, these companies have invested accordingly.<sup>50</sup> Under the current schedule, airlines may postpone taking delivery of equipment until late in 1991 to allow modifications to be made before their purchases are effective. Equipment manufacturers that were not early supporters of TCAS II development may reap benefits from such postponements, while those that invested heavily in development and testing programs will face cash flow problems as they gear up for production. A simple extension of the deadline could heighten cash flow problems by further postponing purchases.

### **International Issues**

Foreign airlines contend that the installation of collision avoidance systems in international air transports should occur on the basis of agreed international standards and recommended practices. Such standards are under consideration in the International Civil Aviation Organization and are currently scheduled for adoption in 1990. Many question the appropriateness of the United States action in including foreign carriers within the scope of its TCAS II requirements, claiming this undermines the basic objectives of ICAO in producing international standards. Moreover, critics claim the United States may have abrogated Article 37 of the Convention on International Civil Aviation by its actions.<sup>51</sup>

An extended TCAS II implementation schedule could help ensure that U.S. and ICAO standards are compatible. If international airborne collision avoidance standards

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50. Joe Wilson, Bendix/King, personal communication, Feb. 7, 1989.

51. Office of Technology Assessment, op. cit., footnote 7.

are completed and approved as expected by mid-1990, an international implementation schedule can then be established.<sup>52</sup>

## CONCLUSIONS AND OPTIONS

**OTA concludes that the TCAS II compliance deadline established in Public Law 100-223 (TCAS section) has some safety, economic, and international consequences not fully foreseen at the time of enactment.** The TCAS II requirement is unique in the combination of technological complexity, rapid implementation, and the number of aircraft affected. Moreover, the extensive maintenance requirements associated with the aging of the national fleet were not anticipated when the legislation was enacted. Maintenance for aging aircraft will place severe demands on airline personnel and facilities resources concurrently with those needed for TCAS II.

Different groups concerned with aviation matters recognized some or many of the issues summarized in this report several months ago. Three possible congressional approaches were being discussed as OTA began this study in October 1988. The tradeoffs associated with each option are discussed below and summarized in Table 1 at the end of this section.

**The first option was a signal from the congressional leadership that Public Law 100-223 would remain unchanged, thus ensuring rapid implementation of TCAS II.** The signal would be necessary because uncertainty over whether Congress will make any change has led some airlines to postpone planning and committing resources to TCAS II. These airlines are likely to find that facilities and personnel are unavailable once they do begin to prepare for TCAS II, since both types of resources have already been committed. An early decision by Congress not to reconsider the legislation can minimize, but not eliminate economic penalties for some of the industry groups. If the

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52. M. Parkes, Civil Air Attache, British Embassy, in *ibid.*

current deadline is clearly confirmed, airlines will not gamble on an extension and delay implementing TCAS II.

However, **OTA finds a critical and immediate need for FAA and the airlines to define and undertake an operational evaluation program.** The current deadline does not appear to allow adequate time for this, given the constraints on certification, production, and installation capabilities.

**The second option included explicit indication by congressional leaders that the deadline in the law was not going to be changed and that Congress encourages FAA's vague plans for a TCAS II transition program.** However, even if FAA and industry tried to undertake a more well-defined transition program during late-1990 and early-1991, the deadline under this option does not allow time for adequate evaluation. Delays are likely during the certification process, which is complicated enough that it is likely to strain both industry and FAA resources, limiting the capabilities for evaluation. Further, since some airlines may fail to meet the current deadline, FAA would have to exercise its authority to grant exemptions under this option as well as under option one.

Moreover, under any circumstances, **OTA finds that the input of air traffic control personnel to the TCAS II program must be stepped up considerably from its level to date.** Full participation by FAA air traffic control personnel is an essential component of any evaluation. The effects on the air traffic system must be assessed, including the reactions of pilots and controllers to TCAS II, and any initial problems resolved, so that the full benefits can be realized.

Furthermore, and regardless of any decision on the deadline, Congress may wish to ensure that FAA has adequate resources for the installation period. These will be necessary for the Agency to evaluate TCAS and maintain adequate oversight of other airline maintenance and modification programs to prevent possible safety diminution indirectly related to TCAS II requirements.

**The third option included amending the law to extend the deadline and encouraging an unspecified operational evaluation.** (This was basically the airline industry's position.) In the view of both domestic and foreign airlines, the implementation deadline is the most pressing TCAS II issue. **However, OTA concludes that if the deadline is extended with no other specific, required actions, most TCAS II safety benefits will be delayed, and equipment manufacturers will be severely penalized.**

**Yet, the present TCAS II implementation requirement is** extremely difficult for some segments of the industry. Aircraft that cannot easily be fitted with TCAS II because of technical problems, such as some older commuter turboprops, would probably require extensions without a longer installation period. Moreover, the unilateral U.S. action in requiring TCAS II equipment of foreign airlines has created ill feelings around the world. Many foreign carriers are likely to install TCAS II voluntarily for safety and competitive reasons, once ICAO standards are established. **Extending the deadline could ease international concerns and help synchronize ICAO's activities with U.S. requirements.**

**As OTA's study neared completion, a fourth option emerged — amending Public Law 100-223 to require a phased implementation schedule beginning in 1990 (to ensure early equiptage of a substantial portion of the fleet) and a structured operational evaluation program, as well as extending the deadline.** This would allow manufacturers to incorporate any necessary modifications before airlines took delivery of the balance of their orders. Sufficient airline resource limitations, economic inequities, and international implications stem from the present deadline for Congress to consider extending the installation schedule. **OTA finds that the fourth option is the best choice and that aviation safety will be best served by introducing TCAS II on commercial aircraft as soon as possible, by requiring a phased implementation schedule, and by providing for a structured evaluation program carried out jointly by industry and FAA to oversee the first year of operation.**

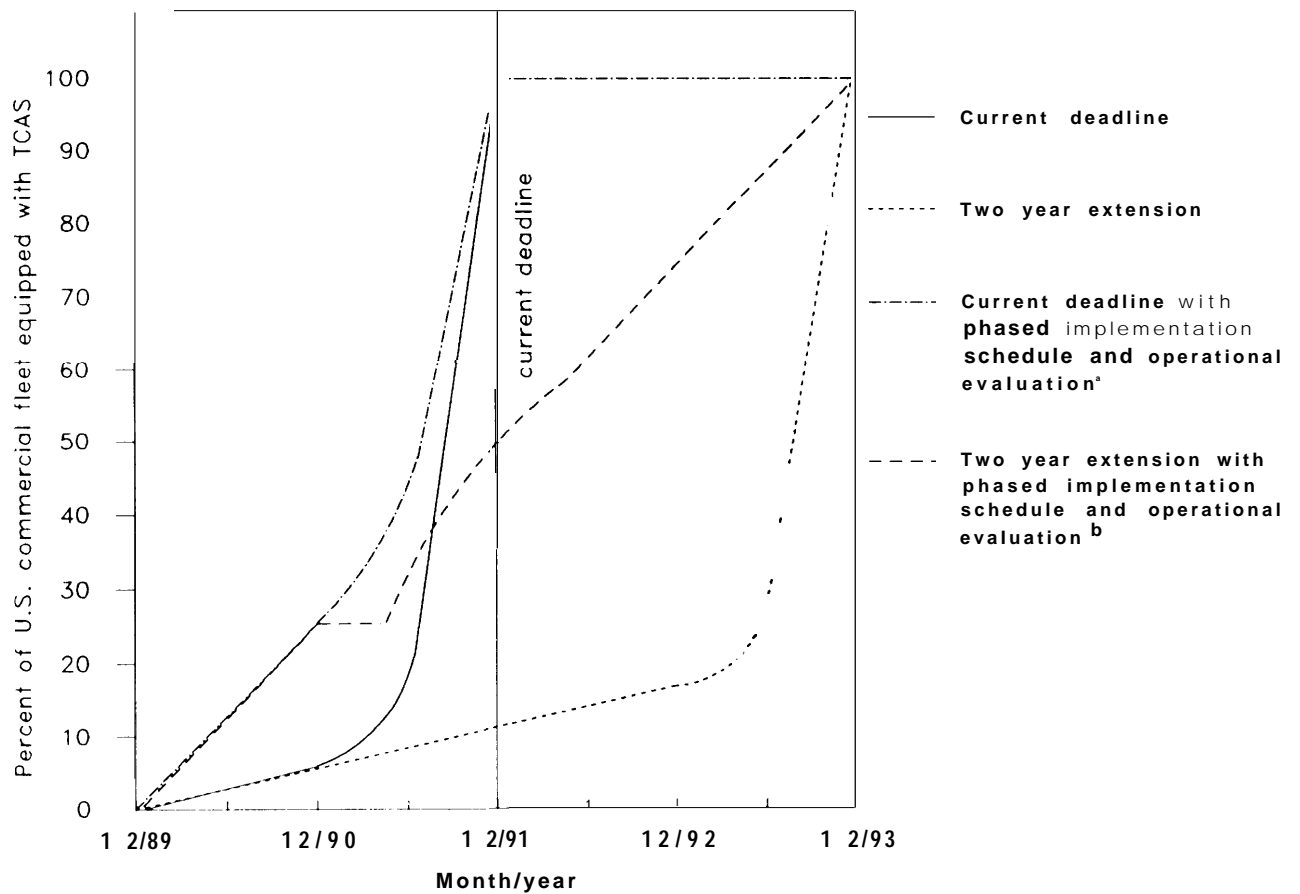
Prompt congressional consideration of any change to the law is important. OTA finds no reason to delay initial TCAS II implementation; yet, the forcing effect of legislation may well be necessary to ensure maximum safety benefits as early as possible and allow airlines to make appropriate plans for investments in personnel and equipment. Requiring and linking an operational evaluation program, a phased compliance schedule, and an extended deadline (the fourth option) will place additional responsibilities on each affected party, but it spreads the burdens more equitably than the other options.

OTA concludes that introducing TCAS early into a substantial portion of the commercial fleet and requiring a structured evaluation program conducted jointly between FAA and industry could ensure early safety benefits. Industry officials at OTA's workshop indicated that such an evaluation program might include a requirement that airlines purchase and install TCAS II equipment in 15 to 30 percent of the national fleet (600 to 1,200 aircraft) as soon as possible after production equipment is available (probably over the period from late spring to the end of 1990). The operational evaluation would be conducted over this time period, with the specific details and responsibilities to be worked out jointly under industry leadership. Congress could further require that 50 to 60 percent of the national fleet be equipped by the end of 1991 and fully equipped by the end of 1992 or sometime 1993. For an indication of the percent of the U.S. commercial fleet equipped with TCAS II over different time period options, see figure 7.

This combination of requirements and an extended deadline offers the opportunity for early identification of any technical and human factors problems during the operational evaluation. It also addresses economic and international issues more completely than simply extending the deadline. A phased compliance schedule balances greater safety from more TCAS II-equipped aircraft early in the program against a more lengthy period for full implementation. It minimizes the downside of a more flexible



Figure 7.- U.S. Fleet Equipped with TCAS and Possible Timing Options



<sup>a</sup> Time constraints with a 12/91 implementation deadline do not permit an installation level off during the operational evaluation and analysis.

<sup>b</sup> This curve suggests only one of several possibilities.

SOURCE: Office of Technology Assessment.

deadline for the TCAS II manufacturers by ensuring more early orders and permits identification of system safety effects and timely corrective actions.

An operational evaluation program also offers the airlines the equivalent of an insurance policy. For the relatively modest extra cost of early installation in portions of the fleet and analytical support, the industry and public gain peace of mind if TCAS II works well, and avert financial and safety penalties if TCAS II should need to be modified. Regardless of how well TCAS II works, early implementation and evaluation bring the most TCAS safety quickly to the public.

TABLE 1: EFFECTS OF TCAS OPTIONS

TCAS issues	TCAS IMPLEMENTATION OPTIONS				Phased implementation schedule, operational evaluation program, and deadline extension
	No new legislative action	Same deadline and transition program	Deadline only	Extension	
<p>f TCAS performs adequately:</p> <p>(1) Level of TCAS safety benefits before 1992</p> <p>If TCAS equipment requires modification after implementation</p> <p>2 Level of TCAS safety benefits before 1992</p> <p>3 Economic impact on industry</p>	+	+			+/- <sup>a</sup>
<p>Regardless of total TCAS performance:</p> <p>4 System safety effects from TCAS identified by 1992</p> <p>(5) Level of safety in other areas</p> <p>6 Economic impact on airlines</p> <p>(7) Economic impact on TCAS manufacturers</p> <p>(8) Availability of TCAS component options and support equipment</p> <p>(9) FAA certification resources</p> <p>(10) International relations</p>	-	+	-	+	+
	-?	-?	-	+	+/- <sup>b</sup>

KEY: (+) positive effect  
 - negative effect

<sup>a</sup> early implementation benefits +, but delayed full benefits -  
<sup>b</sup> more early orders +, but extended product on run of same number of systems -

## LIST OF ACRONYMS

AC	Advisory Circular
ACO	Aircraft Certification Offices
ALPA	Air Line Pilots Association
ARINC	Aeronautical Radio, Inc.
ATC	air traffic control
BCAS	beacon-based collision avoidance system
CAS	collision avoidance system
CFIT	controlled flight into terrain
CRT	cathode ray tube
FAA	Federal Aviation Administration
GPWS	ground proximity warning system
ICAO	International Civil Aviation Organization
<b>IVSI</b>	instantaneous vertical speed indicator
LIP	limited installation program
MOPS	minimum operational performance standards
NASA	National Aeronautics and Space Administration
NPRM	Notice of Proposed Rulemaking
RA	resolution advisory
RTCA	Radio Technical Commission for Aeronautics
STC	Supplemental Type Certificate
TA	traffic advisory
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TSO	Technical Standard Order