

involving at least one cargo airplane under the following circumstances:

1. The current situation—no requirement for collision avoidance systems on cargo airplanes, and

2. The reduction in risk with the implementation of this final rule.

To do this, the FAA combined the risk reduction estimates developed by MITRE, with the FAA's estimate of risks.

#### *Assumptions*

The estimates derived by Mitre depend on a number of simplifying assumptions. These assumptions are believed to be consistent with the level of accuracy that can be achieved when estimating the probabilities of such rare events as midair collisions or NMACs.

The two major assumptions are:

1. Exposure to a possible midair or near-midair collision is assumed to be approximately proportional to the number of airplane pairs flying through the same airspace at about the same time. The number of pairs increases in proportion to the square of the number of airplanes.

2. The NMAC risk reduction estimates documented in the Safety Analysis of TCAS II Version 7, which were derived from airplane track data collected at major terminal areas for passenger flights, also apply to cargo airplanes.

#### *Pre-TCAS II Accident Rates*

This section discusses the risk of cargo airplane midair collisions (MAC)s. The risk is the expected number of cargo airplane MACs with another cargo airplane, a commercial passenger airplane, or a general aviation airplane. Due to general aviation data limitations and the fact that passenger airplanes are presently equipped with TCAS, this assessment of risk is limited to that of cargo/cargo MAC. While to date there has not been a MAC involving a cargo airplane in the United States, there were two near midair collisions (NMAC) with cargo airplanes in 1999. The FAA believes there is a small, but significant, risk. Several methodologies are presented below which provide an approximation of the number of cargo airplane MACs that may occur in the future if cargo airplanes are not equipped with collision avoidance devices.

Passenger midair accidents have occurred. In the FAA's 1988 regulatory analysis of TCAS on passenger airplanes, it was noted that during the 15 years before the use of TCAS on airplanes, two midair collisions occurred, each of which involved at least one large air carrier passenger airplane. Accordingly, at that time the

rate of 2 MACs per 15 years was used as the estimate of future incidence in the absence of TCAS. By extending the time period to 20 years to coincide with the cost-analysis reference period of this analysis, the rate increased to 2.67. Because there are substantially fewer cargo airplanes than passenger airplanes operating in the United States, a rate of 2.67 defines the upper bound as the rate of MAC involving cargo airplanes. The actual rate is probably substantially less than this upper bound. The FAA has used this figure, however, as a basis for several different methods to approximate the actual risk. These methods include a direct ratio of numbers of aircraft, and proportions of pairs of both cargo aircraft and cargo operations. Taken together, the agency believes that the results of these methods define a reasonable approximation of the range of the actual risk.

In the next 15 years the average number of operating cargo airplanes is projected to be about 1,545, or nearly 50 percent of the average number of passenger airplanes (3,230) that operated between 1973 and 1987. If the MAC risk were solely a function of the number of airplanes, then the cargo MAC risk in the next 15 years could be considered to be 1.0 MAC (50 percent of 2.0). This approximation however is likely to overstate the actual risk, as cargo operations per airplane are lower than that of passenger airplanes. If the ratio of cargo to passenger departures-per-airplane remains roughly that of today (between .33 and .40), then multiplying the value of the departure-per-airplane ratios by 1.0 accidents results in range of .33 to .40 MACs for 15 years, or nearly .44 to .53 MACs over 20 years.

From a slightly different perspective, another approximation can be derived from information on the number of airplane pairs (a collision potential). As the number of years, and as the number of airplane pairs increase, the likelihood of a collision increases. The number of pairs can be calculated for the relevant period.<sup>2</sup> Over the 1973 to 1987 time period, the average annual number of in-service passenger airplanes was approximately 3,230. Over the fifteen-year period 2000 through 2014, the average number of cargo airplanes is projected to be about 1,545. Based upon the assumption that risk is a function of

<sup>2</sup> The number of pairs involving airplanes from the same population (cargo/cargo) can be calculated using the formula:  $N = n(n - 1)/2$ . For large numbers this formula can be approximated by:  $N = nn/2$  for comparisons among different assumptions of the number of airplane pairs involved.

the number of aircraft squared, the estimate of a MAC risk to cargo airplanes not equipped with collision avoidance equipment is estimated as  $2.0 * (1,545)^2 / (3,230)^2 = 0.45$  accidents in 15 years, or approximately 0.60 accidents in 20 years.

A different application based on numbers of operations provides an effective lower bound of the likely range of risk for a cargo MAC. Total revenue departures summed from 1974 through 1988 (1973 data are not available) are 79.1 million. For a 15-year period from 2000 through 2014 total cargo airplane departures are assumed for this analysis to grow at a 5 percent annual rate on an estimated base of 645,000 departures in 1999. These total cargo departures sum to 14.6 million. Based upon the assumption that risk is a function of the number of operations squared, the estimate of a cargo MAC is approximated as  $2.0 * (14.6)^2 / (79.1)^2 = 0.07$  accidents in fifteen years. An additional five years raises this risk to nearly 0.1 accidents.

The above methodologies provide a range from 0.1 to 0.6 mid air collision involving a cargo airplane over twenty years. Admittedly, these models are simplified representations of complex interactions of many other excluded factors such as the time of day, weather, airway congestion, hub concentration, and perhaps pilot error or malfunctioning airplanes. It is clear, regardless of methodology that the risk is low, but it is not zero.

The Poisson probability distribution is often used to analyze rare and random events, and may be useful here. If 0.1 is assumed as the mean of a Poisson distribution, there is a 10 percent chance that there will be one or more mid air collisions involving a cargo airplane during the twenty-year period. If the actual risk rate is 0.6 MACs over 20 years, there is nearly a 50 percent probability that there will be at least one MAC, and slightly more than a 10 percent chance there will be two or more. Such a level of risk is unacceptable.

The benefit sensitivity section will show the potential range of outcomes reflecting the above accident rate variation discussion. For the purpose of the analysis and to ease presentation, the FAA uses a single estimated rate of 0.5 MACs involving a cargo airplane over the next 20 years if they are not equipped with collision avoidance devices.

#### *Risk Reduction—Cargo Airplane Perspective*

The following table (Table 4–11 of the MITRE report) shows the MITRE