CHAPTER ONE

Introduction

The U.S. Forest Service, an agency of the U.S. Department of Agriculture, has an aging fleet of contracted fixed-wing airtankers to assist in fighting wildfires. Tragically, there were two fatal crashes of Forest Service–contracted airtankers in 2002. On June 17, 2002, a C-130A experienced an in-flight breakup initiated by the separation of the right wing, followed by the separation of the left wing, while executing a fire retardant drop over a forest fire near Walker, California. All three flight crewmembers were killed, and the airplane was destroyed. On July 18, 2002, a Forest Service–contracted P4Y aircraft experienced an in-flight separation of the left wing while maneuvering to deliver fire retardant over a forest fire near Estes Park, Colorado. Both flight crewmembers were killed, and the airplane was destroyed.[1]

After these crashes, the remainder of the Forest Service's contracted airtanker fleet was grounded. Ultimately, fewer than half of the fleet of 44 2,000- to 3,000-gallon airtankers returned to service. These remaining 19 contracted airtankers have a limited remaining service life, and the Forest Service plans to replace them over the next few years.

The Office of Management and Budget (OMB) rejected an earlier Forest Service proposal to replace the aircraft on the grounds it lacked both an acquisition plan and a sufficient cost-benefit analysis justifying the need for airtankers. The U.S. Department of Agriculture's Office

1 A more detailed account of the crashes can be found in National Transportation Safety Board (2004).

of the Inspector General (2009) stated that the subsequent cost-benefit analysis required a more persuasive justification for new aircraft.

In response, the Forest Service asked the RAND Corporation for assistance in determining the composition of a mix of airtankers, scoopers,[2] and helicopters that would minimize the total costs of wildfires, including the cost of large fires and the cost of aircraft.

One might view our study as a total cost minimization exercise. The goal is to choose the portfolio of firefighting aircraft, *a*, that minimizes the total cost. The total cost consists of the sum of fire-related costs, C_F, and aircraft-related costs, C_A. The cost of fires, C_F, is a function of the wildfires that occur, *f*. But *f* itself is a function of a variety of independent variables (e.g., weather, pre-suppression tactics), including the number of aircraft: Having more aircraft reduces the number and costs of wildfires. Of course, having more aircraft also increases aircraft costs. The overall objective is to choose the number of aircraft to minimize the sum of costs of fires and aircraft. These values trade off on one another, i.e., a large portfolio of aircraft would reduce fire costs but would imply large aircraft costs.

We can express this exercise in mathematical notation, where *f* is a function of a variety of variables, including *a*, where having more aircraft reduces the number and cost of wildfires but increases the cost of the fleet. The overall objective function is to choose *a* to minimize $C_F\left(f(a)\right)+C_A(a)$, recognizing that a large portfolio, *a*, reduces fire costs but increases aircraft costs.

Other researchers have examined the value of aviation in fighting wildfires. For example, Countryman (1969) presented a case study of airtanker efficacy in fighting a 1967 fire in the Los Padres National Forest in Southern California. He found that airtankers increased suppression costs, but this was justified by reduced acres burnt and, hence, reduced damages. Martell et al. (1984) evaluated initial attack resources in forest fires in Ontario, Canada, and Loane and Gould (1986) undertook a detailed cost-benefit study for the Australian state of Victoria on the aerial suppression of bushfires.

2 Scoopers, as the name implies, scoop water out of lakes, rivers, or the ocean and then drop it on fires. Scoopers, unlike rotary-wing helicopters, are fixed-wing aircraft.

The Forest Service found that the primary need for both Type I (large) and Type II (medium-sized) helicopters is in supporting large fire suppression operations (U.S. Department of Agriculture, Forest Service, 1992).[3] In 1995, the Forest Service and the U.S. Department of the Interior (DOI) recommended a national fleet size of 41 large airtankers (U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, 1995). A follow-up study by the two agencies (1996) recommended the procurement of excess military aircraft, suggesting a fleet composed of 20 P-3A aircraft, ten C-130B aircraft, and 11 C-130E aircraft. Fire Program Solutions (2005) found that airtanker platforms of 3,000–5,000 gallons were significantly more cost-effective than smaller-capacity platforms. Its study suggested that airtankers are more efficient than helicopters in building the fire line in an initial attack on small fires but that helicopters are preferred for large fire support.

There has been considerable modeling, research, and evidence collection related to the value of aircraft in the initial attack phase.[4] *Initial attack* refers to fighting fires while they are small to prevent them from becoming large and much more costly. There is far less evidence of the benefits of aircraft against already-large fires. Therefore, we approached the task of determining the optimal mix of large aircraft in two phases. In the first phase, we modeled the effects of alternative fleet mixes in an initial attack. In the second phase, the results of which are presented at the end of Chapter Six, we considered the benefits that must be assumed to accrue from a large fire attack to warrant the acquisition of additional aircraft beyond those selected for the initial attack.

This report presents the results of two models that we call the RAND National Model and the RAND Local Resources Model. The National Model is an optimization model that views aircraft allocation as a national problem, with aircraft allocated at the national level

[3] Personal communication with Paul Linse, U.S. Forest Service, July 17, 2012, defined a Type I helicopter as one that can lift 5,000 or more pounds, a Type II helicopter as one that can lift 2,500–4,999 pounds, and a Type III helicopter as one that can lift 1,200–2,499 pounds.

[4] See, for example, Bradstock, Sanders, and Tegart (1987); U.S. Department of Agriculture, Forest Service (1992); U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior (1995); Fried and Fried (1996); and McCarthy (2003).

to stop as many small fires as possible from becoming large and costly. The National Model trades off the cost of aircraft (having more aircraft increases costs) against the costs of large fires (having more aircraft results in fewer large fires).

Our greatest concern about the National Model is that it does not account for differential local firefighting resources. Some parts of the country (e.g., Los Angeles County) have considerable local firefighting resources, but other areas (e.g., eastern Nevada) have relatively few. The marginal impact of a Forest Service firefighting aircraft would therefore be different in different areas. Of course, there are good reasons for greater firefighting resources in Los Angeles County: The area at risk is much more densely populated and has high-value buildings and infrastructure. Ideally, an aircraft optimization model would account for differences in both the local firefighting resources available and the value at risk.

We developed the Local Resources Model to address the lack of local resource consideration in the National Model. The Local Resources Model uses data on local firefighting resources in the Forest Service's Fire Program Analysis (FPA) system. FPA simulates fires and the resulting initial attack outcomes given local firefighting resources with or without Forest Service large firefighting aircraft. The Local Resources Model uses the FPA simulation results to determine optimal initial attack aircraft fleet sizes and locations, trading off the costs of large aircraft against the costs of large fires.

The Local Resources Model is not without concerns. Most centrally, it is dependent on the validity of the FPA simulations. Forest Service personnel raised concerns about latent assumptions in the system. For instance, FPA attributes as much efficacy to a gallon of water dropped from a scooper as to a gallon of retardant dropped from an airtanker. This assumption is contrary to a traditional assumption that retardant is twice as effective as water on a per-gallon basis,[5] but

---

[5] Fire Program Solutions (2005, p. 16) highlights the traditional two-to-one retardant-to-water efficacy assumption. The assumption is supported by performance results in a standard burn test dated January 16, 2008, provided to RAND in personal communication from Tory Henderson of the Forest Service on April 26, 2010.

we were not able to modify FPA's inherent parameters. Instead, the Local Resources Model sits astride FPA, with FPA being, de facto, a "black box" from an analysis perspective. We were, however, able to use the more flexible National Model to assess the impact of different assumptions of retardant-to-water efficacy.

Not surprisingly, the National Model and the Local Resources Model provide different point estimates as to the Forest Service's optimal initial attack aviation fleet. Rather than assessing which model is "better" or "right," we think it is more constructive to consider some of their broader lessons and consistencies:

- Both models suggest that scoopers have the central role in initial attack, even though water dropped from a scooper is half as effective as retardant dropped from a fixed-wing airtanker in the National Model (appropriately, in our view). The key virtue of scoopers is that they can drop far more water per hour on most fires than airtankers can drop retardant. Our analysis of geographic information system data shows that most high-risk fires occur near water sources, precisely because most human settlement is near water.
- Access to fixed-wing airtankers is also valuable in the minority of fires that are not proximate to water sources. Furthermore, some airtanker availability is a useful hedge against a scenario in which scoopers may lack permission to draw off a proximate water source.
- There is a trade-off between the number of aircraft needed (of any type) and the prescience with which those aircraft are used. If the Forest Service used firefighting aircraft only when the aircraft would be most effective in preventing a large, costly fire, only a small fleet would be needed. But dispatchers lack such perfect information. We cannot expect aircraft dispatchers to know exactly which small fires will benefit from aircraft and which will not. As aircraft dispatch becomes less prescient, more aircraft are needed. This phenomenon suggests an opportunity for better strategic decisions about aircraft locations (e.g., where to preposition firefighting aircraft) and better tactical decisions about

aircraft usage (e.g., fires to which aircraft should be sent) to reduce required investments in firefighting aircraft.

Neither the National Model nor the Local Resources Model considers aircraft usage against already-large fires. As mentioned earlier, there is a paucity of evidence as to the benefits of aircraft against already-large fires. If, however, one is willing to make an assumption of the daily value of such aircraft against large fires, one can then calculate an appropriate augmentation to the initial attack fleets suggested by the National Model and the Local Resources Model.

The remainder of this report is structured as follows: Chapter Two provides background information on wildfires and firefighting. Chapter Three discusses the social costs of large fires. Chapter Four discusses the estimated costs of acquiring, operating, and maintaining a national fleet of large aircraft. Chapter Five and Chapter Six then present findings from our minimization explorations: Chapter Five presents results from the National Model and its estimation of the optimal initial attack fleet, and Chapter Six presents the results from the Local Resources Model. We also discuss how the Local Resources Model's findings compare with those from the National Model. Chapter Seven presents concluding remarks. Two appendixes provide additional detail on the analyses underlying the cost estimates in Chapter Three and future trends in the use of aviation assets to fight wildfires, respectively.