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Air Attack Against Wildfires

Understanding U.S. Forest Service Requirements for Large Aircraft

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Summary

An aging fleet of contracted fixed-wing airtankers and two fatal crashes of these aircraft led the U.S. Forest Service, an agency of the U.S. Department of Agriculture, to investigate the cost of obtaining new airtankers. The Forest Service asked the RAND Corporation for assistance in determining the composition of a fleet of airtankers, scoopers, and helicopters that would minimize the total social costs of wildfires, including the cost of large fires and aircraft costs. RAND was not asked to consider whether the Forest Service should own or contract for its firefighting aircraft.

Background

Wildland fires are among nature's most terrifying and dangerous phenomena. At the same time, periodic wildfires are a natural part of ecosystem dynamics in much of the country. Policymakers therefore face difficult choices as to how, whether, and to what extent to fight wildland fires when they break out.

On-the-ground firefighters can create "fire lines" to contain a blaze. A fire line is a buffer of cleared or treated ground that resists a fire's further growth. When a fire is encircled by a fire line, it is said to be contained. Firefighting aircraft can abet efforts to build a fire line by dropping retardant, suppressant, or water on burning or potential fuel.

While the use of aircraft often garners media attention, there is a dearth of empirical evidence that aircraft are effective against already-large fires. There is much firmer evidence that aircraft can assist in the "initial attack," i.e., support on-the-ground firefighters in containing a potentially costly fire while it is still small.

The focus of this analysis is on large aircraft, a term we use to denote Type I helicopters (those that can lift 5,000 or more pounds), as well as 1,500- to 3,000-gallon airtankers and scoopers. We did not consider the use of military-operated aircraft (e.g., Air Force C-130 cargo aircraft) in firefighting.

The Cost of Large Fires

Large fires can be enormously costly to fight and can result in sizable damages. A successful initial attack saves the public these costs, or at least slows their accumulation. Estimating the cost of large fires requires tabulating the available data on federal suppression expenditures, the state and local suppression costs of fires to which the Forest Service has responded, federal post-fire rehabilitation costs, insured losses, fatalities, and future suppression costs.

We estimated that a large fire has an average social cost of between $2.1 million and $4.5 million. We present this range of values to account for uncertainties in key parameters, including suppression costs and the magnitude of insured losses.

Our baseline estimate is that a successful initial attack that prevents a large fire saves $3.3 million, the average of $2.1 million and $4.5 million.

The Cost of Large Aircraft

Our analysis also involved tabulating the cost of prospective aircraft. We analyzed five candidate aircraft in three categories: 1,500-gallon and 3,000-gallon airtankers, a 1,600-gallon scooper, and 1,200-gallon and 2,700-gallon helicopters.

We estimated aircraft life-cycle costs using information drawn from multiple publicly available sources. Note that they are not "source selection–quality" cost estimates. They are best estimates based on available information, but they have not been verified with the contractors.

We estimate an annualized life-cycle cost per aircraft in the range of $3 million to $8 million, not including retardant costs. Not surprisingly, larger airtankers have higher annualized costs. Retardant costs further increase the cost of airtankers relative to helicopters and scoopers, which do not generally drop retardant.

The RAND National Model

We used two separate but complementary models to estimate the social cost–minimizing portfolio of initial attack aircraft. The RAND National Model is an optimization model that views aircraft allocation as a national problem. It identifies options for relocating aircraft at the national level to stop as many small fires as possible from becoming large and costly.

The National Model's fire simulation is based on data on wildfires in the United States in calendar years 1999–2008. Using the model, an analyst can run different prospective portfolios of aircraft against these historical fires to assess how outcomes might have differed with more or fewer available aircraft. The National Model assumes that a fixed, baseline level of local fire-line production capability is available against any given fire and that aircraft supplement these local resources.

We identified three types of small fires. Category A fires are those that will be contained by local resources, even without aviation support. A Category B fire will become large if only baseline local fire-line production resources are used, but large aircraft can augment those resources to achieve containment. A Category C fire will become large irrespective of large aircraft usage. If aircraft dispatchers had perfect information about every small fire (a condition we refer to as *dispatch prescience*), aircraft would be sent against Category B fires only. However, in the interest of realism, we assumed that aircraft, if they are available, are sent to all Category B fires, as well to all Category C fires and to "close-call" Category A fires (i.e., those that have rates of growth close to that of a Category B fire).

We found that at least two-thirds of historical fires have been within ten miles of a scooper-accessible body of water, and about 80 percent have been within five miles of a helicopter-accessible body of water. These water-proximate fires are the fires against which helicopters and scoopers would be most valuable. Our base assumption, in accordance with findings from Fire Program Solutions (2005), is that water is half as effective as retardant on a per-gallon basis.

Our baseline National Model simulation suggests an optimal initial attack fleet of five 3,000-gallon airtankers and 43 1,600-gallon scoopers.

These results are sensitive to assumptions about the relative effectiveness of water versus retardant. However, we found that it would take a considerable degradation in the efficacy of water relative to retardant for an airtanker-centric, rather than a scooper-centric, portfolio to be preferred in the National Model simulation.

The RAND Local Resources Model

A major concern with regard to the National Model is that it assumes that local firefighting resources are the same across the country. To loosen this assumption, we additionally developed the RAND Local Resources Model. This model uses data on local firefighting resources to characterize the impact of a given mix of aircraft against specific small fires. The Local Resources Model also allows the social costs of large fires to vary by location.

To incorporate information on local firefighting resources, the Local Resources Model relies on data and model results from the Fire Program Analysis (FPA) system, a Forest Service system designed to assist decisionmakers with resource allocation choices. Although FPA's traditional focus has been at the local U.S. Forest Service Fire Planning Unit level, the Local Resources Model uses the system to estimate the outcomes of specific fires in relation to the availability of large aircraft. In the Local Resources Model, it is FPA's algorithms that determine whether an air attack with retardant or water changes a fire's outcome (specifically, from large to small). To these FPA algorithms, the Local

Resources Model adds accounting and optimization algorithms that track the availability of a fixed fleet of aircraft of specified types and known locations. The Local Resources Model dispatches aircraft to fires simulated by the FPA model, calculates aircraft cycle times and fuel endurance, and, in the case of scoopers and helicopters, determines the nearest available water sources. The Local Resources Model can be used to investigate the number of large fires—and the resulting social costs—associated with alternative airtanker fleet sizes and mixes.

Our baseline assessment using the Local Resources Model suggests an optimal initial attack fleet composed of one 3,000-gallon airtanker, two 2,700-gallon helicopters, and 15 1,600-gallon scoopers.

We performed sensitivity analyses for the factors for which limited data were available, including the efficiency with which the Forest Service can pre-position its aircraft and the prescience with which it dispatches aircraft only to the fires that are most likely to be contained (i.e., the small fires that the aircraft can prevent from becoming large fires). If the Forest Service has sufficient insight into where fires will next occur, has the freedom to move its resources to any airport that can optimize an attack, and is precise in sending aircraft only to those fires that require aircraft for containment, the total size of the required fleet would be substantially smaller than if the Forest Service had poorer intelligence on future fires, less flexibility in pre-positioning aircraft, or less insight into which fires were most appropriate for aircraft to fight.

It is important to note that our analysis is subject to the limitations of the Forest Service's FPA model, on which the Local Resources Model is built. Specifically, FPA makes important assumptions about the tactical equivalence of water versus retardant, the tactical role of aircraft in initial response (for instance, that aircraft cannot slow or suppress fires in advance of the arrival of ground resources), and the tactical equivalence of attacking the burning edge of a fire with water or retardant ("direct attack") and building a fire-control line away from the burning edge ("indirect attack"). If these assumptions are invalid or only partially correct, the utility of the results of the Local Resources Model will be correspondingly limited.

Both the National Model and the Local Resources Model analyze aircraft to be used in an initial attack. Unfortunately, little is known about the value of aircraft against already-large fires. However, if assumptions could be made about the daily value of aircraft against an already-large fire, it would be possible to estimate how many additional aircraft should be acquired, beyond those acquired for use in the initial attack phase.

Concluding Remarks

Both models have important limitations due to the unavailability of key data or established science and the need to make sometimes-important assumptions. Given their different underlying assumptions, it is not surprising that the National Model and the Local Resources Model produce different estimates of optimal initial attack aircraft portfolios, as shown in Table S.1. The shaded cells in Table S.1 represent the models' respective base-case estimates.

Rather than trying to adjudicate which (if any) of these findings is "best" or "right," we draw broader insights from the models' different results. These insights may be helpful to the Forest Service's leadership as it considers the fleet mix that is most likely to optimize taxpayer returns on investment.

In each case, scoopers are the central component of the optimal solution. Two factors drive this finding. First, scoopers are considerably less expensive to own and operate than larger helicopters and fixed-wing airtankers. Second, when fires are proximate to water sources, scoopers can drop far more water on a fire than a retardant-bearing aircraft can drop retardant. Because most human settlement is near water, scoopers can be highly effective against many of the most costly fires.

Retardant-bearing airtankers are also valuable, but primarily in the niche role of fighting the minority of fires that are not water-proximate.

In developing both the National Model and the Local Resources Model, we confronted the issue of dispatch prescience and its importance in determining optimal initial attack aircraft portfolios. Greater dispatch prescience can sharply reduce required initial attack air-

Table S.1
Estimates of Optimal Initial Attack Fleets in the National and Local Resources Models

Case	RAND National Model	RAND Local Resources Model
Water-retardant efficacy parity	2 airtankers, 40 scoopers	1 airtanker, 15 scoopers, 2 helicopters
Water half as effective as retardant	5 airtankers, 43 scoopers	X
Water one-quarter as effective as retardant	9 airtankers, 43 scoopers	X
$2.1 million per average large fire	4 airtankers, 36 scoopers	2 airtankers, 14 scoopers, 2 helicopters
$4.5 million per average large fire	6 airtankers, 55 scoopers	1 airtanker, 14 scoopers, 4 helicopters
Geographical constraint	8 airtankers, 48 scoopers	4 airtankers, 25 scoopers, 7 helicopters

NOTE: The National Model geographical constraint case restricts aircraft to operating in a single Forest Service Geographic Area Coordinating Center in a given month. The Local Resources Model geographical constraint case has each aircraft assigned to a given base for at least 20 days. The Local Resources Model does not allow varying water efficacy. The shaded cells represent each model's base-case estimate.

craft portfolios. The importance of prescience suggests the possibility of reducing the required number of aircraft or reducing the number of large, costly fires by improving aircraft assignment and dispatch algorithms.

Given the frequency with which large airtankers are used against already-large fires, we were surprised by the dearth of statistical evidence documenting their value in this role. Better information about the costs and benefits of air assault in large fire operations would help clarify the optimal mix of aircraft required for wildland firefighting operations.

There are several possible extensions of this work, including

- allowing water-efficacy parameter flexibility in FPA and, hence, in the Local Resources Model
- bringing local resource data from FPA into the National Model

- analyzing how Forest Service aircraft have been used, e.g., their patterns of relocation (where and how frequently), the amount of time they spend fighting small versus already-large fires
- assessing, perhaps experimentally, how often aircraft truly change outcomes between small and large fires
- calibrating the frequency and efficacy of direct versus indirect attack in today's airtanker fleet.

Any of these extensions would abet further efforts to understand the Forest Service's requirements for large aircraft.