AN ECONOMIC EVALUATION OF FORWARD LOOKING INFRARED (FLIR) TECHNOLOGY TO ENHANCE AERIAL SUPPRESSION OF FOREST FIRES IN ALBERTA

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ABSTRACT

Previous research suggests infrared technology on aerial platforms enables fire managers to make better forest fire fighting decisions. In 1992-93, we evaluated the costs and benefits of installing Forward Looking Infrared (FLIR) technology on bird-dog planes using cost data provided by the government of Alberta and opinions of experienced users. As part of this study, we asked 11 air-attack officers in Alberta with experience in using FLIRs to estimate the savings to be realized in retardant costs, flying costs, and area burned by employing this technology. Using data from 1988 to 1992, we determined the government of Alberta would have saved over $88,400/yr in retardant costs, over $476,300/yr in variable flying costs, and over 600 ha/yr in area burned. At a 5% discount, we estimate it would take less than 5 years for the government of Alberta to pay off the cost of equipping all 8 of their bird-dog planes with FLIR technology.

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Keywords: Forward Looking Infrared technology, FLIR, air-attack, suppression, fire fighting, protection, Alberta, economics

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INTRODUCTION

Forest fires occur frequently in Alberta. During the period 1988 to 1992, there were 4,942 recorded forest fires in the protection area of Alberta, which is approximately 38,522,237 ha in size. This represents an average annual fire load of over 987 fires per year. The total area disturbed during this period was estimated to be 60,987 ha or about 0.16% of the total protection area. Over this 5-year period, the government of Alberta spent a total of $316,970,503[1] to protect the forests of Alberta from fire. This expenditure includes general operating expenses required to maintain a protection branch, and the costs related to positioning resources in close proximity to areas where the fire danger and values-at-risk are high, as well as suppression costs, which are strictly fire related expenses. Of this total, over $76,601,890 was spent on variable costs associated with the direct suppression of forest fires. This amounts to an average annual expenditure in excess of $15,320,378 per year in fire fighting (non-fixed) cost only (Table 1). The 5-year average cost of suppressing forest fires in Alberta is summarized by fire size class in Table 1.

Table 1. Five-year averages for number of fires, area burned, and cost of fighting fires (in 1992 dollars) by size class based on data from years 1988-1992.

Size Class (ha)[1]	No. of Fires	Avg. Area Burned (ha)	1992 ($)
A (< 0.1)	536	51.7	1,014,209.00
B (0.1 - 4.0)	368	367.2	2,561,567.00
C (4.1 - 40.0)	57	831.7	2,262,820.00
D (40.1 - 200.0)	19	879.4	3,338,310.00
E (> 200.0)	7	9,241.4	6,143,472.00
Sum of All Classes	987	11,371.4	15,320,378.00

[1]The fire size classes (ha) used in this report follow those adopted by the Alberta Forest Service.

The cost of suppressing a forest fire generally increases as the size of the fire increases (Table 1). The importance of this fact, and the fact that losses usually increase with increases in fire size has been known since the early twenties (Chandler *et al.* 1983). In general, most forest management strategies pertaining to forest fire protection are designed to reduce the length of time a fire burns Hence, over the years forest protection strategies have been developed that enable managers to detect, action, and extinguish fires quicker.

Most forest protection decisions pertaining to fire are made using visual cues. Recently, our ability "to see" has been enhanced by technological developments and now many of the decisions made are based on information obtained from remote sensors. For example, the Alberta Forest Service (AFS) is currently using 4 Forward Looking Infrared (FLIR) scanners mounted on bird-dog aircraft (airplanes used in directing airtanker operations) to (1) locate hotspots within smoke-covered wildfires; (2) direct and control airtankers in the process of making retardant deliveries, (3) evaluate the effectiveness of retardant deliveries; (4) safely control suppression resources common to all fire situations; (5) find small wildland fires, which may not be detectable with the

[1]All dollar values in this report are expressed in 1992 dollars unless otherwise stated.

eye; and (6) find hold-over fires resulting from winter burning projects (WBP). These human infrared scanners enable fire suppression personnel to collect fire intelligence information not currently available visually. As a result, the general consensus is that better decisions are made relative to fire control strategies and tactics, and that these decisions significantly reduce suppression costs and losses to values-at-risk.

The goal of this project was to evaluate the costs and benefits associated with using the FLIR scanners, specifically the FLIR System Inc. model 2000 A/B, mounted on fixed wing aircraft to make management decisions as part of protecting the forests of Alberta from fire.

STUDY DESIGN AND METHODS

In accomplishing this goal, we made the following assumptions:

1. The province will continue to use land and skimmer based airtanker groups as they have in the past.

2. Future policies will not significantly change relative to how airtanker groups are used in Alberta.

3. The number of airtanker groups used in Alberta will not change from the historic levels of the last 5-year period. During the period 1988 through 1992, the Province of Alberta has used the same 8 airtanker groups (Appendix I).

4. The province will continue to commit a bird-dog aircraft to an airtanker group and that the fidelity of these groups will remain as strong as in the past. Currently, bird-dog aircraft are always deployed with airtankers even if the tankers are dispatched to fires outside of the province or to another fire in Alberta. We had to assume this policy would not change before we could justify using provincial wide data pertaining to costs associated with the number of hours flown, the volume of retardants dropped, or hectares burned. Failure to accept this condition would make it impossible for us to analyze the situation using the data available.

5. Such variable suppression costs as fuel, oil, and retardants will not decrease significantly in the future.

6. Future air-attack contract fixed costs will not be significantly increased as a result in reducing the number of hours flown because of an increase in suppression efficiency due to FLIR technology.

As part of the economic analysis, we reviewed data maintained by the AFS. Specifically, we reviewed records pertaining to (a) the historical occurrence of fires in Alberta, (b) the costs associated with suppressing these fires, and (c) the levels of damage to public and private resources (values-at-risk) in this province. We identified 3 variable costs, which must be considered in any analysis of the benefits of purchasing FLIR technology for use in wildland fire fighting operations in Alberta. These were (1) the purchase price, installation, maintenance costs, and longevity of presently available FLIRs; (2) the average number of airtanker related delivery hours flown during a representative time period (we selected the 1988 through 1992 fire seasons); and (3) the historical use of fire retardant product used annually as determined from the same 5-year period (1988-1992). We recognize that there are probably other costs that should have been included in our analysis, such as savings in mop-up costs (Nichols *et al.* 1990), but we did not have the data necessary to evaluate savings.

In addition, we spoke to the manager of an aviation company that provides airtankers under contract to the Forest Protection Branch of the Alberta Forest Service and we reviewed the literature pertaining to FLIR systems. Lastly, we developed a questionnaire (Appendix II), which was administered to AFS bird-dog officers who had used the 4 FLIRs as part of their air-attack duties during either the 1991 or 1992 fire seasons or both.

We used 2 approaches to calculate the economic value of FLIR technology. The first approach, the opportunity cost approach, estimates the value of resources (hours flown, retardants dropped, or hectares burned) saved by using FLIR scanners in bird-dog aircraft. Aircraft operating expenses, by type of aircraft, for the period 1988-1992 were obtained from the Alberta Forest Service. These costs were inflated to 1992 dollars using the consumer price index (Appendix III). The cost of the retardant dropped by skimmer and land-based aircraft was also obtained for this 5-year period and these values were inflated to 1992 dollars (Table 2). The percent of the total costs saved by using FLIR technology were determined using responses from the survey participants, which indicated the savings in flying costs and retardant costs by aircraft type (skimmer versus land-based; Questions F-1 and F-2 in Appendix II). We then multiplied the estimated percent of costs saved by the total costs of operating the aircraft. This produced an estimate of the annual cost savings that can be attributed to using FLIR scanners. These annual cost savings were then converted to present values (the sum of discounted annual values

Table 2. The amount of fire retardant used in Alberta by type for the period 1988 to 1992. Also shown is the average cost of these products in 1992 dollars.

	Retardant	
Year	Long-term ($)[1]	Foam Concentrate ($)[2]
1992	2,258,618	24,027
1991	2,558,736	73,536
1990	4,977,345	60,182
1989	2,014,045	18,650
1988	2,571,741	27,714
Total	14,380,485	204,114
Average Use	2,876,097	40,823
Average Cost	519,481[1]	$116,753[2]

[1] We multiplied the average use (in litres) over the 5-year period by $0.1806 (the 1992 average price/l) to obtain estimated yearly cost for long-term retardant.

[2] To calculate the 5-year average cost of foam concentrate used per year, the 1992 product cost of foam at $2.86 per litre was used.

expressed in 1992 dollars) using reasonable estimates of operative life of the scanners (payback period), and representative and reasonable discount rates (the rate of return of alternative investments). The present values of cost savings were calculated using both 5- and 10-year payback periods, which is based on some estimate of the useful life span of the scanners. In addition, we used discount rates of 5% and 10% as some measure of the returns possible from an alternate investment. The discount rates of 5% and 10% were chosen to examine the sensitivity of the results to alternative assumptions on the rate of return of alternative investments. The rate of 5% approximates the current rate of return on risk free investments at financial institutions. The 10% rate, although perhaps still conservative, is considered by some to be a reasonable estimate for the rate of return to be expected for the forecasted life span we are using in our analysis. The cost of equipping all 8 existing airtanker groups currently used in Alberta with FLIR capability ($1,280,000) was then subtracted from the present values of resource cost savings (aircraft operating costs and retardant costs) to obtain the net present value of resource cost savings.

The second approach to estimating the economic value of the technology examined the amount of forest area saved, which is used to determine the present value of forest resource savings attributable to the technology. The survey respondents were asked to estimate the percent of area saved due to the use of the FLIR technology. These percentage savings were then applied to the average area burned per year. The average annual area saved was then multiplied by $887.67/ha, the estimated average value of forest land (Alberta Forest Service pers. comm. 1993). Net present values were calculated based on 5- and 10-year return periods and 5% and 10% discount rates. Note, however, that the use of the estimated value of forest land implies that the burned forest area has no value in the near future. Also, this value is an average over all classes of forest land in Alberta and the actual value in a particular region may differ significantly from this amount.

RESULTS

Using a price quote provided by FLIR Systems Inc., we determined it would cost $160,000 (Cdn) to purchase and install all the equipment necessary to operate a new Forward Looking Infrared scanning system in a bird-dog aircraft. The components of this system include a FLIR System Inc. scanner valued at $156,000; a VHS video recorder, which is used to record imagery of the fire scene, valued at $300; and a thermal printer, which prints the infrared image, valued at $2,500. The remaining expenses are related to installing this equipment in a bird-dog aircraft This estimate is conservative (perhaps a little high), and is based on using the same type of equipment currently being used in the 4 Alberta bird-dogs. We did not include the cost of a Global Positioning System (GPS), which is normally used in conjunction with a FLIR scanner. because all bird-dog aircraft contracted for fire duties in Alberta are equipped with GPS systems as part of the terms and conditions of airtanker contracts.

The AFS has used hand-held infrared scanners well in excess of 10 years. They have determined these systems to be highly reliable and durable. In their opinion, the costs of maintaining these systems are negligible. Therefore, we estimated that the total cost of equipping and maintaining all 8 airtanker groups with a FLIR system would cost $1,280,000, and from previous experience a serviceable life span of 10 years is highly possible.

The non-fixed or operational costs of fighting forest fires with airtankers in Alberta during the 1988 through 1992 fire seasons are presented in Appendix III. These costs do not include contract costs, aircraft basing costs, or other fixed costs; only such operational costs as oil, gas, and other variable expenses related to flying these machines. We assume if the FLIR technology enables airtankers to more accurately deliver retardants then less flying time will be needed, but we do not believe any increase in efficiency will result in a saving in contract price or basing fees. The contractors must return a profit on investment if they are to be economically viable, and aircraft will have to be based even if flying hours are reduced. Hence, we did not include these fixed costs in our analysis. Instead, we determined that over the last 5 years, the province spent an average of $3,558,597 per year on operational expenses associated with retardant delivery (Appendix III). If savings from this technology are to be realized, we believe it must come from reducing these expenses.

During the period 1988 through 1992, the Province of Alberta spent an average of $519,481 per year on long-term retardant and $116,753 per year on foam concentrate for an average annual expense of $636,234 (Table 2). These expenses are simply what was spent on retardant products that were dropped on fires during those 5 years. These costs do not include the dollars paid to store, mix, load, or do the other operations related to using retardants as a suppressant. These "handling" costs are fixed, and this capability must be maintained whether small or large volumes of retardants are used.

Estimates of the percent savings of flying costs for both skimmer and land-based airtanker groups, retardant costs, and area saved are presented in Table 3. Percent savings were calculated using 3 methods: (1) a gross average of the valid responses across respondents (Option A), (2) a

Table 3. Estimates (%) of savings through FLIR use (based on responses from survey participants).

	Option A Percent Saved (gross)[1]	Option B Saved (weighted)[2]	Option C Percent Saved (excl. #2)[3]
Skimmers			
Flying Costs Saved	15.9	7.8	9.6
Retardant Costs Saved	16.6	6.4	10.7
Area Saved	13.2	5.2	9.5
Land-Based			
Flying Costs Saved	12.6	7.1	5.4
Retardant Costs Saved	13.3	7.7	6.3
Area Saved	12.8	5.0	9.3

[1] Average percent savings over all valid responses.
[2] Average savings weighed by amount spent on each fire class (see Table 1).
[3] Average percent savings excluding 1 respondent who provided consistently optimistic percentages.

weighted average (weighted by the expenditures on fires by class; Option B), and (3) an average that excludes 1 respondent's exceptionally high estimate relative to all other respondents (Option C). The 3 methods of calculating the average savings were employed to examine the sensitivity of the results to the percent savings calculation based on the assumptions we adopted. The weighted average approach is employed to incorporate the fact that percent savings on expensive (e.g., E class) fires are likely more important than savings on less expensive fires. For example, the respondents indicated that on A class fires, 23% of retardant costs for skimmer aircraft would be saved using FLIR technology (Appendix II), while only a 10% savings in retardant costs was expected for E class fires. Taking a simple average of these 2 numbers would assume that both types of fires are equally important in terms of costs, which is not true (Table 1). Therefore, since E class fires are more expensive to control than A class fires, we weight the percent savings results by expenditures for fires within the various size classes.

The gross average percent savings for flying costs, retardant costs, and area saved with skimmers are 15.9%, 16.6%, and 13.2%, respectively (Table 3). The weighted averages (Option B) for skimmer type aircraft are lower, reflecting the fact that most respondents felt that the largest percentage in savings occurred on smaller fires. The percent savings calculations (Option C), which excluded the 1 "optimistic" respondent, are also lower than the gross average, as expected.

Percent savings for land-based operations were slightly lower than those for skimmers, but the pattern of savings (gross average highest, weighted average lowest) is consistent between the 2 categories.

The percent savings estimates by skimmer and land-based classes were applied to estimates of flying costs and retardant costs (as presented in Appendix III). These calculations produced the annual savings in flying costs and retardant costs (Table 4). This table contains 12 values, which

Table 4. Present values of cost savings from using FLIR technology under alternative assumptions about (1) operative life of FLIR, (2) discount rate, and (3) option used to estimate percent savings.

	Years of Operation of FLIR			
	5		10	
	Discount Rate			
	5%	10%	5%	10%
Option A	2,445,253	2,141,006	4,361,174	3,470,402
Option B	1,280,320	1,121,017	2,283,484	1,817,081
Option C	1,289,206	1,128,798	2,299,333	1,829,693

Option A= averages of resource savings estimates over respondents.
Option B= averages weighted by expenditures on fires by class.
Option C= averages with the highest reporting respondent removed.
See Table 3 for percent savings.

are the present values (in 1992 dollars) of cost savings under 2 different choices of discount rates (5% and 10%); 2 different assumptions of operative life (5 years and 10 years); and 3 different methods of computing the percent of total costs saved (gross average, weighted average, and the average with 1 "optimistic" respondent removed). These calculations are performed to examine the sensitivity of the cost savings to these various assumptions. We predict the cost savings to be realized will range from $1.1M to $4.3M depending on the discount rate, the payback period, and the percent savings calculations employed. It should be noted that this analysis and the data in this table does not include savings likely to be realized by reducing the amount of area burned.

The net present values (fuel and retardant costs saved less the cost of the FLIR technology) are presented in Table 5. Once again, we do not include any estimate of area likely to be saved by employing this technology. In only 2 cases (for 5-year payback periods, 10% discount rates, and percent savings calculations Options B or C) are the net present values negative. In all other cases, the cost savings from using the FLIR scanners exceed the purchase price of the technology. Since most experts suggest that the technology will be operative (and effective) for at least a 10-year period, it appears that the cost savings could be substantial (up to $3M). The 2 cases that yielded negative net present values (cases in which the cost savings are less than the purchase price of FLIRs) occur when the discount rate is high (10%) and the scanners are assumed to operate for only 5 years. If the FLIR operates for 10 years or if the rate of discount is 5%, the FLIR purchase price is less than the present value of fuel, oil, and retardant costs saved.

Table 5. Net present values of resource costs saved minus the FLIR purchase price under alternative assumptions about (1) operative life of FLIR, (2) discount rate, and (3) option used to estimate percent savings.

	Years of Operation of FLIR			
	5		10	
	Discount Rate			
	5%	10%	5%	10%
Option A	1,165,253	861,006	3,081,174	2,190,402
Option B	320	-158,982	1,003,484	537,081
Option C	9,206	-151,201	1,019,333	549,693

Option A= averages of resource savings estimates over respondents.
Option B= averages weighted by expenditures on fires by class.
Option C= averages with the highest reporting respondent removed.

An alternative method of examining the financial viability of FLIR technology is to determine the number of years required to pay back the purchase price. Using the results presented in Tables 4 and 5, the savings realized will cover the purchase price of 8 FLIR systems in less than 5 years (under a 5% discount rate) and less than 6 years (under a 10% discount rate). Under the most optimistic scenario (a 5% discount rate and the gross average method of computing the cost savings) the FLIR technology payback period is 2.5 years.

Table 6 provides the net present value of forest resources (area) saved less the costs of purchasing 8 FLIR systems. The average area saved, due to FLIR technology, was estimated to be 610 ha/year. The present value of these savings (at a 10% discount rate and a 5-year payback period) is $2M, thus the net present value of the technology is estimated to be approximately $770,000. Employing a discount rate of 10% and a 10-year payback period increases the net present value of savings to over $2M. Forest resource savings also indicate that the technology is economically efficient.

Table 6. Net present values of forested area saved.

Average Area Burned per Year	12,197 ha
Percent Saved (FLIR)	5%
Average Area Saved (5% of 12,197 ha)	610 ha
Annual Value of Savings (610 ha x $887.67/ha)	$541,480
Present Value (5 yr., 10%)	$2,052,634
Net Present Value (Savings - FLIR Costs)	$772,634
Present Value (10 yr., 10%)	$3,327,158
Net Present Value (Savings - FLIR Costs)	$2,047,158

Anecdotal evidence:

We asked 11 air-attack officers, who had used FLIR scanners during the 1991 and/or 1992 fire seasons, to complete a questionnaire (Appendix II), which was designed to evaluate the effectiveness of using this technology for air-attack operations in Alberta. All individuals sampled had been employed by the Forest Protection Branch of the Alberta Forest Service, and all had used this equipment on active forest fires of various sizes. Eleven individuals returned the questionnaires but only 7 of these were used for further analysis. The questionnaires not used were rejected for the following reasons. One respondent had only used FLIR scanners on 2 fires, and we felt this was not enough experience to qualify him as a creditable evaluator. The other 3 respondents either failed to answer all or some of the questions asked or did so in such a way as to make it impossible for us to compare their answers with the others received.

We have annotated this questionnaire in **bolded text** to show the number of respondents (n=), the mean (a larger, bold number), and the range in the responses (as a solid line spanning the range) for each question asked. Also, for the first 2 questions we provide the mean and range. We did not include insufficient operational experience (I/O) responses and the absence of a response when calculating a mean or the range in responses.

In general, most respondents answered all questions. Although, many respondents had insufficient operational experience to assess the questions related to non-fire uses, such as the value of the FLIR system for doing game counts, search and rescue, or monitoring insect or disease infestations (Question D). It was also obvious from the additional comments provided to Question A, that not all individuals had used this equipment to find or map wildfires, but all had used it for operational delivery (Question A-4) because n=7.

This survey uncovered a number of concerns regarding the perceived limitations of the technology. They were:

1. Most respondents thought this was not the tool for identifying fuel types even when visibility is reduced by smoke. The general consensus is that fuel typing is best done using visual cues.

2. Two respondents thought this technology should not be used to search vast areas for fires. In their opinion, this is not a good detection method because the field of view of the scanner is too narrow to make finding unknown fires efficient. Two other respondents said the system worked well when used in conjunction with a tower bearing, or when searching an area where an ignition source was known to exist. These 2 also reported finding fires with the scanners that they could not see with only their eyes.

3. Many respondents thought we should not depend on this system to find ground crews. They commented that although humans can be readily seen from air with the scanner, there was a concern that these individuals would be hidden by the elevated thermal regimes common to forest fire situations and reliance on this method of detection might result in accidents. Two respondents said this technology might prove valuable in search and rescue operations because of the ease of finding humans.

4. There was agreement that we should not rely solely on this tool as our only source to identify aircraft in the vicinity of the fire. Two respondents said that if the smoke was so dense that other aircraft could not be easily seen then air operations should be terminated.

5. Two respondents wrote that the best advantages of the system would not be realized unless the bird-dog pilots and airtanker pilots all had FLIR capability. These individuals felt that "at times a picture is better than a thousand words," but we would add that this is only true if all involved are referring to the same picture and if there are reference marks on the picture or on the display screen that can be used to relate to. We do not argue with this suggestion, but at present it is not feasible to provide all participants in an air-attack operation with the capability of seeing the same picture at the same time. It would also appear that most bird-dog officers have found ways of overcoming this limitation.

Respondents also identified a number of benefits. For example, without exception, the responses to the questionnaire agreed with all of the published literature on this technology. We are not sure if the respondents had read this published material, but it was obvious they all agreed that (a) FLIRs made it easier to see fire perimeters, hotspots, and areas of intense burning activity (Wilson and Noste 1966; Hirsch *et al.* 1968; Wilson *et al.* 1971; George 1985; George *et al.* 1989; Bjornsen 1989); (b) it was easier to see the location and continuity of retardant drops (George 1985; George *et al.* 1989); and (c) all this could be done sooner with a FLIR scanner (Nichols *et al.* 1990).

From the comments provided, it is obvious that the employment of this technology has already enabled some individuals to make changes in the way in which fires are fought. Because of the ability to see through smoke, respondents say they are using fewer "insurance" drops. One respondent said he is "attacking closer to the head of the fire and using a variety of new strategies (2 retardant lines instead of 1, lighter foam concentrations, and a variety of drop heights)." We anticipate these and other kinds of improvements will likely result with this increased visibility.

DISCUSSION AND CONCLUSION

We did not evaluate the policies used in aircraft use nor did we attempt to evaluate the justification for fighting fires. These considerations although important and perhaps necessary were outside the mandate of this contract. Also, as mentioned in the study design and methods section of this report, the value of our analysis is highly dependent on the validity of the assumptions we adopted. These assumptions greatly influence the results provided in this report, but in our opinion all are rational, logical, and consistent with historical approaches to problems of this type.

It should also be noted that there was a reluctance on the part of air-attack officers to provide us with estimates of percent savings by category. Without reservation, all agreed that the technology enabled them to see through the smoke, which enabled them to make better decisions. They also agreed without reservation that because of this increased capability they were able to save money and time, and reduce area burned, but they were not exactly sure how much was saved. One respondent said **"FLIR technology is probably the biggest improvement in forest fire control since adoption of aircraft use"**. The senior author of this report would agree without reservation. This technology is likely to significantly change how fires are fought in the future.

From the results of this survey, we also expect that users will experience improvements in attack strategies, and further that the discovery of better solutions will be rapid in coming. We believe this will be due to the ability of fire fighters to review actual imagery of fire situations even before the fires have been extinguished. As a result, managers will be able to adjust strategies and tactics in real time as a result of better information. In addition, it will be possible to evaluate the situations long after the fires are out and the pressure of making a decision immediately has passed. In group situations, using the same visual cues, protection personnel will be able to review actual fire imagery, which will include topography, fuels, fire size, and pattern, and the known placement of retardants. This information in conjunction with recorded weather data will enable us to brainstorm better solutions. In our opinion, training will be greatly enhanced and efficiency in resource use will be materially improved in a relatively short period of time.

We did not attempt to statistically analyze the information obtained from the bird-dog officers. We calculated mean values only because it was the easiest way of identifying a measure of consensus between respondents, but if all bird-dog officers had responded (n = 11) we would have likely used the mode instead of a mean value. We preferred the mode because in our opinion the sample size was too small to justify calculating a mean and perhaps the usually associated or expected statistics. To do so might have suggested a level of precision that could not be justified.

For Option B, we used a weighted average to account for the differential expenses associated with different size fires (Table 1). This approach seems warranted based on the magnitude of difference in suppression costs associated with fires of different sizes. Yet, this approach masks or discounts the relative effects suppression efforts may have had on keeping Class A, B, C, or D fires from becoming larger. In fact by using this approach it is highly likely that we are underestimating the savings realized by adopting FLIR technology. Nevertheless, without evidence to support this assumption, we have decided to leave this analysis in our report. We would only suggest that there is a strong likelihood that we are underestimating the true savings with this approach.

We did not incorporate the savings likely to result by reducing the area disturbed in our analysis of the net present value. We realize that by keeping fires small, society is likely to experience a cost savings, although the magnitude of those savings will be highly influenced by the level of effort used in restricting fire growth. Also, we were not sure at this time how we should evaluate the magnitude of savings knowing that burned over areas are not really lost from the productive land base, however the value of the resource supported by the land base may be adversely affected. Therefore, in all likelihood, our approach has once again underestimated the savings to be realized by employing this technology. Payback periods are likely to be considerably shorter then we suggest.

In conclusion, we recommend the adoption of this technology without reservation. From our analysis, the use of this equipment is clearly justified based on the data we used in analyzing the costs and benefits. In addition, as suggested earlier, we are sure that all savings to be realized as a result of adopting this technology were not fully assessed because we lacked the data necessary to do so. We suspect that if all savings resulting from the use of this technology were known, the economic justification of adopting FLIR scanners would be extremely powerful and overwhelmingly convincing.

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APPENDIX I

Appendix I. The composition of the 8 airtanker groups used in Alberta during the 1992 fire season to include length of contract.

Group No.	Contract Length (Days)	Airtanker Type and No.	Bird-dog Type
1	123	2-CL 215	Cessna 310
2	93	1-DC-6	Aerostar 600
3	123	2-CL 215	Cessna 310
4	93	1-DC-6	Aerostar 600
5	93	3-B-26	Cessna 310
6	93	4-B-26	Cessna 310
7	93	4-B-26	Cessna 310
8	93	1-DC-6	Aerostar 600

Note: The contracts are staggered to ensure 1 or more groups are available throughout the fire season. During the period April 26 to September 14, at least 1 group is always available. During the core period (June 1 - July 27) all 8 groups are available for fire action.

When fire weather indexes reach the very high to extreme levels, the Alberta Forest Service has the option to hire additional airtankers. This can be done in the following ways:

- Borrow groups from other provinces through the MARS (Mutual Aid Resource Sharing) agreement. These groups come as a self sufficient unit, complete with bird-dog aircraft and a bird-dog officer and until they are FLIR equipped, their addition would not impact this study.

- Hire on a short term basis, an additional tanker(s) and bird-dog aircraft. The department would supply a bird-dog officer from their back-up list. The aircraft are made up from back-up aircraft that all contractors must maintain to support their contracts. At this time, the spare bird-dog would not be FLIR equipped so it would not be relevant to this study.

- Hire additional tankers only and assign to existing groups (e.g., enhance Group 5 from 3 airtankers to 4 airtankers). In this case, it is relevant since the bird-dog aircraft may be already FLIR equipped.

The following costs were not considered since they are fixed costs and would be paid if the aircraft did not fly at all.

- contract basing fees
- crew expenses
- initial purchase price of the CL-215s

At present, the Alberta Forest Service does not levy a surcharge when a FLIR equipped resource is loaned to other agencies. Therefore, no cost recovery can be factored in if the aircraft are being utilized under the MARS agreement.

Appendix II

The questionnaire used to survey individuals who had used FLIR technology in Alberta for enhanced aerial detection and suppression of forest fire.

An Economic Evaluation of the FLIR Technology

Name (optional) ____________________ Experience with FLIR ____________

Date ______________ BDO, Bomber Pilot, etc. ______________________

1. How many retardant missions have you been involved with?

   a. Your career _________ (estimated or actual) **(mean=127 Range: 13 - 250)**

   b. 1992 _______ (estimated or actual) **(mean=18 Range: 13 - 23)**

2. How many of these missions involved FLIR technology?

   a. Your career _______ (estimated or actual) **(mean=15 Range: 8 - 37)**

   b. 1992 _______ (estimated or actual) **(mean=13 Range: 8 - 23)**

SECTION ONE

3. From your personal experience, please use the following values to rate the following questions. Add any additional comments you feel are pertinent to this review.

1	= no value
2	= limited value
3	= moderate value
4	= high value
5	= extremely valuable
I/O	= insufficient operational experience to assess

A. Do you feel this system has been an asset to you in the following areas?

1) detection of spring ground fires	1	2	3	**4**	5	I/O	(n=4)
2) detection of holdover lightning strikes	1	2	**3**	4	5	I/O	(n=5)
3) detection of small surface fires not visible by current detection means (i.e. lookouts or aerial patrol)	1	2	**3**	4	5	I/O	(n=4)
4) operational delivery	1	2	3	4	**5**	I/O	(n=7)
5) mapping of wildfires	1	2	**3**	4	5	I/O	(n=4)

6) other (specify (<u>training</u>))	1	2	3	**4**	5	I/O	(n=4)

Additional comments:

B. On active fires, do you feel the FLIR system enabled you to more readily observe or provide better information on the following?

1) define the fire perimeter	1	2	3	4	**5**	I/O	(n=7)
2) assess the intensity level of the fire	1	2	3	**4**	5	I/O	(n=7)
3) observe and project fire movement	1	2	3	**4**	5	I/O	(n=6)
4) detect spot fires outside existing fire control lines	1	2	3	4	**5**	I/O	(n=7)
5) define portions of the fire perimeter obscured by smoke	1	2	3	4	**5**	I/O	(n=7)
6) aid in determining fuel types	1	**2**	3	4	5	I/O	(n=6)

Additional comments:

C. In your operational role as a bird-dog officer, what value has the FLIR system had in the following?

1) ability to better direct the placement of airtanker drops	1	2	3	**4**	5	I/O	(n=7)
2) ability to more effectively monitor and assess the effectiveness of airtanker drops	1	2	3	4	**5**	I/O	(n=7)

3) ability under limited or obscured visibility due to smoke, to detect and monitor the following:

(a) ground forces (men or equipment)	1	2	**3**	4	5	I/O	(n=5)
(b) rotary wing working fire	1	2	3	**4**	5	I/O	(n=6)
(c) airtankers working fire	1	2	3	**4**	5	I/O	(n=6)
4) ability to pass current, hard copy fire data to fire boss on a real time basis	1	2	3	**4**	5	I/O	(n=6)
5) ability to communicate current fire data to other fire managers	1	2	**3**	4	5	I/O	(n=7)
6) ability to conduct or participate in post fire reviews	1	2	3	**4**	5	I/O	(n=3)
7) ability to aid in the training of pilots or bird-dog officers in strategy	1	2	3	**4**	5	I/O	(n=7)

Additional comments:

D. What value do you feel the FLIR system has for the following?

1) identification and/or monitoring of insect and disease infestations	**1**	2	3	4	5	I/O	(n=2)
2) game counts	1	2	**3**	4	5	I/O	(n=3)
3) search and rescue	1	2	3	**4**	5	I/O	(n=3)

Additional comments:

SECTION TWO

1. Now that you have used the system, has your strategy or tactics changed in the following areas:

	YES	NO
1) in light fuels		
2) in moderate fuels		
3) in heavy fuels		
4) drop sequence		
5) drop height		
6) retardant viscosity		
7) other ______________		

8) What would you estimate this savings to be: _____%?

Comments:

____

____

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____

____

2. If you were given the option of adding another airtanker to your group or another resource to enhance the effectiveness of your group, would you give up the FLIR system to do so? If yes, how many would you give up?

____

____

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APPENDIX III

Appendix III. Actual aircraft operating costs corrected to 1992 dollars by airtanker and bird-dog type for the years 1988-1992.

	No.	Hours	Actual Cost (dry) ($)	Corrected to 1992 Dollars Cost ($)	Fuel ($)	Total ($)	5 YR. AVG. ($)
CL-215							
1992	4	433.90	1,084,750.00	1,084,750.00	185,457.54	1,270,207.54	1,738,051.22
1991	4	807.20	2,018,000.00	2,053,179.08	345,013.42	2,398,192.50	
1990	4	904.90	783,875.00	842,961.06	386,772.36	1,229,733.41	
1989	4	784.50	1,569,000.00	1,767,189.47	335,310.99	2,102,500.46	
1988	4	497.00	1,242,500.00	1,477,194.44	212,427.74	1,689,622.18	
Bird-dog							
1992	2	342.30	68,460.00	68,460.00	26,230.45	94,690.45	87,381.65
1991	2	350.60	70,120.00	71,342.38	26,866.48	98,208.86	
1990	2	449.80	56,225.00	60,463.07	34,468.17	94,931.24	
1989	2	398.60	49,825.00	56,118.68	30,544.72	86,663.40	
1988	2	277.10	34,637.50	41,180.14	21,234.17	62,414.31	
DC-6							
1992	3	195.70	488,662.00	488,662.00	209,359.86	698,021.86	865,487.73
1991	3	478.80	616,788.20	627,540.45	512,220.24	1,139,760.69	
1990	3	266.30	625,867.09	673,043.00	284,887.74	957,930.74	
1989	3	239.60	528,118.90	594,828.66	256,324.08	851,152.74	
1988	3	188.60	402,736.00	478,808.36	201,764.28	680,572.64	
Bird-dog							
1992	3	345.60	59,789.00	59,789.00	26,483.33	86,272.33	79,455.67
1991	3	263.40	49,345.40	50,205.62	20,184.34	70,389.96	
1990	3	340.00	61,290.96	65,910.88	26,054.20	91,965.08	
1989	3	296.30	51,852.50	58,402.29	22,705.47	81,107.76	
1988	3	244.40	41,059.20	48,814.83	18,728.37	67,543.20	
B-26							
1992	11	669.30	378,443.00	378,443.00	318,258.84	696,701.84	721,574.33
1991	11	663.90	351,321.45	357,445.91	315,691.09	673,137.00	
1990	11	918.00	465,971.85	501,095.36	436,518.18	937,613.54	
1989	11	632.60	321,027.80	361,578.68	300,807.63	662,386.31	
1988	11	599.50	296,886.20	352,964.70	285,068.25	638,032.95	
Bird-dog							
1992	3	323.50	46,742.00	46,742.00	24,789.81	71,531.80	66,646.81
1991	3	249.80	30,626.25	31,160.15	19,142.17	50,302.32	
1990	3	297.80	50,331.60	54,125.44	22,820.41	76,945.85	
1989	3	252.20	45,949.00	51,753.08	19,326.09	71,079.17	
1988	3	231.10	38,410.40	45,665.70	17,709.19	63,374.89	
Total							3,558,597.40

NOTE: All costs are converted to 1992 values before computing 5-year averages. Costs are converted using the CPI values: 1992- 128.40, 1991- 126.20, 1990 - 119.40, 1989 - 114.00, and 1988 -108.00.