FORWARD LOOKING INFRARED (FLIR) UTILIZATION IN AERIAL FIRE SUPPRESSION OPERATIONS

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ABSTRACT

This paper discusses the impact of the adoption of Forward Looking Infrared (FLIR) sensing technology on target identification and retardant drop evaluation tactics, as well as forest fire suppression strategies, within the Alberta Air Attack program. The paper discusses the four main target identification techniques presently in use, and how the use of a FLIR system has modified their execution. It further considers the broader impact upon initial attack and support action missions, viewed from the aerial attack perspective; as well as some necessary modifications to general cockpit organization indicated by the assimilation of this technology. The paper concludes that this technology provides significant benefits in conducting safe, effective, and efficient aerial forest fire suppression operations.

TABLE OF CONTENTS

INTRODUCTION

During the 1991 forest fire season in Alberta, an Alberta Forest Service (now Alberta Land and Forest Services) bird-dog aircraft was equipped with a Forward Looking Infrared (FLIR) scanner in an attempt to improve target visibility in the smoke obscured operating environment associated with its aerial fire suppression program. The technical details of this equipment installation and the results of the initial testing of this system are discussed in the Forestry Canada (now Canadian Forest Service) report **An evaluation of Forward Looking Infrared equipped air attack** by Ogilvie, Lieskovsky, Young, and Jaap (1992). Initial results proved so favourable, that three more systems were added to the Alberta Air Attack program for the 1992 fire season and have seen extensive use since. The equipment has repeatedly proven its worth in a range of related fire fighting activities, and over the three seasons of activity approximately 1200 hours of operational utilization has been logged by FLIR equipped bird-dog aircraft.

The ability to visually monitor an operation that is habitually obscured in smoke has greatly improved the efficiency and effectiveness of airtanker utilization in a comprehensive forest fire suppression strategy. It has also enabled changes in methodology with respect to the targeting and evaluating of airtanker retardant drops that has proven of significance. This paper focuses on the changes in aerial tactics and fire suppression strategies that evolved out of three seasons exposure to FLIR equipped bird-dog aircraft.

FIRE OPERATIONS - TACTICS

While it is commonly known that weather, fuel loading, and terrain interact in the propagation of a forest fire; when viewed from the aerial attack perspective, terrain is perhaps the most important limiting factor in a fire suppression operation. An air attack officer will pay close attention to all factors affecting specific fire behaviour, yet ultimately it is terrain that dictates run orientation, direction and retardant placement possibilities, as well as eventual drop height and speed. These are critical factors in any suppression operation.

The province of Alberta displays a wide range of geographical features including:

- The boreal forest, frequently associated with large muskegs, in essentially flat terrain.
- Spruce / pine / fir stands in rolling terrain and the southern foothills.
- Similar stocking types in the sub-alpine and alpine region of the southwest.

In response to the need to action threatening wildfires, Alberta Land and Forest Services operates a mix of land and water based airtankers as one component in a multi-faceted forest fire management strategy. Each airtanker group operates under the direction of an air attack officer whose job it is to insure that the aerial component of a comprehensive fire containment strategy is undertaken in a safe, efficient, and effective manner.

Four basic techniques for target demonstration and retardant drop evaluation have evolved within the Alberta Air Attack program. These four techniques provide the necessary versatility to attack the majority of wildfires that do occur in the province despite any constraints placed upon the operation by the terrain in which any specific fire may occur. The four techniques presently in use are:

1. Lead-in
2. Dummy run
3. Orbit and direct
4. Called shot

In practice, weather, terrain, target visibility, and technique interact in a given fire scenario to dictate an overall suppression strategy. The introduction of the FLIR technology has impacted upon the demonstration / evaluation tactics in a dramatic fashion, and has in consequence led to some interesting modifications in available aerial fire suppression strategies. In order to fully appreciate these strategic changes, it is necessary to first look at how the FLIR system has enabled changes in operational tactics.

Lead-in

The lead-in is essentially a target demonstration technique which is used in those situations where target visibility is hampered by smoke conditions or terrain. In this situation, the bird-dog aircraft makes a run in front of the airtanker, while on final, pulling up sharply over the target and breaking away in a predetermined direction and into clear air. During this procedure the airtanker and bird-dog pilots maintain constant radio communication sharing relevant visual data regarding line of flight, aircraft visibility and speed, and final target recognition. Since terrain and smoke conditions frequently dictate the direction in which the bird-dog exits after the pull up, a fair evaluation of the drop placement and effectiveness can be difficult to achieve when the bird-dog aircraft is out of position. A FLIR equipped bird-dog enjoys several advantages over a conventionally equipped aircraft when undertaking a lead-in:

- As a preliminary step in the implementation of a lead-in the bird-dog must undertake a reconnaissance run for the heavily loaded airtanker along the exact line of the intended drop. This is to insure the complete safety of the less maneuverable aircraft during the low level operation. Since smoke is frequently present in the drop vicinity and regularly obscures the intended escape route, this run can be undertaken using a FLIR equipped aircraft much more safely and effectively. Snags, hills, and other aircraft stand out clearly when viewed through the smoke with infrared equipment.

- Insuring that the bird-dog is properly aligned when on final for an actual airtanker drop is another feature of this technique that is greatly enhanced through infrared sensing. Active fire areas stand out clearly on the monitor, enabling very precise positioning with respect to the line of attack of the bird-dog and following airtanker.

- Since fire retardant is much cooler than the fuel to which it is applied, it stands out very clearly on the system monitor once released from the airtanker. This image persists for a sufficient period after the drop, greatly enhancing effectiveness evaluations regardless of smoke. Using the FLIR system, it is possible to identify small gaps in retardant lines, identify areas in need of reinforcement due to sudden flare ups, and monitor the ongoing integrity of established firelines as the operation proceeds. All of these parameters are recorded on video tape for later review and analysis, greatly enhancing the debriefing process and training protocols.

Dummy Run

The dummy run is another target identification technique that works well in those situations where terrain constrains aircraft maneuverability allowing only a single flight path to the target. In mountainous terrain, steep sided gullies, particularly in windy situations, or at times when smoke is not a limiting factor, this technique has repeatedly proven advantageous. In a dummy run, with the airtanker in an appropriate position to observe, the bird-dog aircraft makes a simulated fire bombing run on the selected target with the bird-dog pilot or air attack officer calling out reference points, elevations, bearings, hazards, and exit instructions along the flight path. The bird-dog then formates on the airtanker, usually beside and slightly behind it, and observes the drop from an advantageous perspective. The FLIR system has an application in this technique as well.

- The real strength of using the FLIR for dummy runs lies in the evaluation stage of the process. The line chosen by the bird-dog as well as the safety of the selected escape route are essentially similar to the lead-in technique, and the same advantages apply here. However, with a dummy run, once formated on the airtanker, the flight path can be constantly monitored by the air attack officer. In this case slight corrections may be suggested or entire runs may be aborted if the changing situation warrants.

- As with the lead-in, subsequent drop effectiveness evaluations are dramatically enhanced and are recorded for later analysis, discussion, and training.

Orbit and Direct

This technique is commonly employed with skimmer type airtankers and with land based retardant airtankers that are extending an existing retardant line, where the pilots involved have already been exposed to lead-ins and dummy runs along the desired flight path. It entails orbiting the bird-dog aircraft with a good view of the relevant fire area. From this position it is possible for the bird-dog to monitor the theater of activity as a whole and verbally instruct the pilots as to the desired drop locations in an environment that has become quite familiar to them. Again, a FLIR system provides some distinct advantages:

- This approach provides a strategic perspective of the relevant fire behaviour and development. While orbiting, the effect of the airtanker action can be evaluated and documented on the monitor and with the video recorder. Here potential problem areas can readily be identified and possible solutions clearly suggested. If new or differing tactical measures become necessary due to changes in weather or fuel type, it is a simple matter to move back into the attack profile from this perspective.

Called Shot

The called shot technique is much less commonly used in fire operations. This is a method of indicating retardant delivery whereby the bird-dog aircraft flies a parallel track with respect to the airtanker and the bird-dog pilot / air attack officer calls the retardant drop by counting down to the desired drop location. Obviously differences in position, elevation, aircraft attitude, and speed have significant impact upon accuracy in the determination of the trigger point in this technique. Consequently, this technique is only used as a last resort in extremely smoky conditions, or on difficult to identify targets which cannot be adequately attacked in a more precise fashion. The use of a FLIR system can enhance this difficulty somewhat in the following manner:

- If the bird-dog aircraft can be brought to formate on the airtanker in such a manner that it is flying a parallel track directly above it in the same direction, while maintaining a safe degree of separation, then the correctness of line can be checked in the forward looking mode and the camera can then be rotated to look straight down upon the airtanker. This effectively minimizes perceptual difference between the bird-dog aircraft and the airtanker and tends to optimize the possibility of accurately identifying the appropriate trigger point. The author has used this technique very occasionally, and then only with skimmer type airtankers where airspeeds are reduced, yet acceptable results were achieved.

Operationally, these tactical maneuvers are combined, and coordinated with the other components in the fire suppression organizational structure, in the implementation of an overall fire containment strategy. A FLIR equipped bird-dog demonstrates significant advantage over a conventional one at the strategic level of planning as well.

FIRE OPERATIONS - STRATEGY

Strategically, there are two broad classes of airtanker missions generally undertaken. These are:

1. The initial attack mission, which usually occurs early in the fire development, is intended to contain the fire size to the smallest possible area. These missions usually involve attacking fires showing visible flame, substantial amounts of smoke, and the potential for rapid spread. The purpose of the initial attack mission is to slow and contain the fire development until sufficient ground forces can be deployed to undertake suppression action.

2. The support role, which can employ skimmer type airtanker groups and land based airtankers, occurs as a component in the mop-up of a sustained action fire. These missions frequently occur early in the day, and focus upon wetting down potentially threatened areas along the fire perimeter which may create problems later, as the day warms.

Initial Attack Missions

The establishing of control over the head of a fire is usually of high priority on an initial attack mission; and, with greater fire intensity, comes increased difficulty in this regard. If a forest fire gets into the crowns of the trees and begins to roll, the increased smoke and rapid flame propagation makes accurate evaluation of retardant placement and effectiveness almost impossible. In the past, this uncertainty, coupled with an inability to accurately identify problem hot spots and gaps in the retardant line, has indicated a flanking containment strategy with airtankers until a change in fire behaviour permits an opportunity to secure control of the head of the fire. This situation has changed somewhat with the introduction of infrared sensing.

Over the past three fire seasons, successful attacks on what were severe fire situations have been undertaken through closely co-ordinating land based and skimmer airtanker groups with a FLIR equipped bird-dog. It has been possible, using land based airtankers, to lay long-term retardant essentially adjacent to the flame front, usually an area susceptible to rapid burn through; and then quickly suppress the flame by slinging low concentration foam from a skimmer type airtanker over the existing retardant line and onto the flames. Releasing the foam from the airtanker while in a turn effectively "slings" the load across the retardant and onto the flame. Several points emerge from this approach:

- The two types of airtankers must be tightly coordinated when using this attack strategy. The placement of the long-term retardant must be closely monitored and it needs almost immediate backup with low concentration foam. Any success in bringing the fire to ground immediately results in the smoking in of the affected area, so the FLIR becomes essential in effectively evaluating the progress of the action.

- The foam loads must be of low concentration, or even be straight water, to minimize convective dispersion by the flames. This technique is as much a direct attack upon flame as it is a fire proofing of the fuels adjacent to flame, and the FLIR provides interesting insight into the interaction between fire and retardant. High concentration foam drops adjacent to a flame front are visibly dispersed by the associated convective activity and their effectiveness significantly reduced. Interestingly enough the same phenomenon can be observed with unthickened long-term retardant drops from land based airtankers as well. The use of infrared imaging allows an air attack officer to monitor retardant delivery precisely enough to evaluate drop effectiveness, with respect to desired outcome, with precision. This is a major advantage.

- Timing plays a significant role here, and turn-around times for the airtankers are critical. The success of most initial attack actions is dictated as much by aspects of terrain, weather, and distance as by the appropriateness of some technique. When some initial attack action is going to fail, for whatever reason, the first indicator will usually occur in the fire behaviour. When blow-ups occur, the volume of smoke generated may frequently interfere with a realistic assessment of the potential for control. An experienced FLIR operator can monitor the fuel loading adjacent to the fire, identify deciduous stands, wet areas, fuel breaks, clearly see the size of the problem area, and observe the drop frequency and its effect directly. The system is capable of providing immediate indications when situations are not evolving as expected, and consequently enables efficient evaluations, coupled to a video record, of the viability of the mission as a whole.

- The airspace must be well organized and controlled in any such action. One can certainly identify aircraft through the system, and it is frequently convenient to do so; yet it is essential that equipment is used to monitor the situation, not direct it. To be effective with aircraft in such a confined airspace, each pilot involved must understand the mission objective as a whole, as well as the specific role to be played by each individual in part, and this necessarily involves the sharing of information. Once the attack plan has been grasped, the FLIR enables very precise monitoring and documentation of its success. The monitor provides a small, very detailed picture of a portion of a much larger situation; the information made available is certainly of value, but only with respect to a coordinated, consciously controlled airspace. This is a tool, not a technique.

The typical initial attack mission profile is certainly enhanced through the integration of an infrared sensing system with existing air attack techniques. This is similarly the case when considering typical support missions on sustained action fires.

Support Action Missions

Support actions differ from initial attack missions in various ways that also provide a differing venue for the use of infrared scanning systems. A typical mission is usually undertaken at first light when fire behaviour is in a relatively dormant phase. Most commonly, there is little evidence of open flame and smoke lies very close to the ground obscuring the entire fire area. This can be a very frustrating type of operation, since little evidence of combustion is apparent from the air for pilots to aim at; yet critical areas, especially on the fire perimeter, that may create problems later on in the burning period must be identified and dealt with. A FLIR system greatly simplifies this dilemma. With the bird-dog in orbit and direct mode, the skimmers in their established circuit, and with helicopters being directed with respect to this circuit; the infrared system can be used to directly perceive the problematic hot spots. The suppression aircraft are then directed to drop on the areas so identified, with each load dropped acting as a marker load for the next. By proceeding systematically around the fire perimeter in this manner a significant advantage in the mop-up operation is achieved. Of interest here:

- Dryer foam is preferred in this operation more than in initial attack missions. It is desirable that some visible evidence of a foam load persists over the turnaround period of a typical circuit so that the pilots involved can be directed with respect to familiar markers. The foam loads need not be so dry as to persist much beyond the typical turnaround period, however.

- Suppressant can easily be monitored from the moment it leaves the airtanker or bucket with this system. Observing exactly how much product actually arrives as directed from a correctly triggered load is distinctly advantageous. Lower foam concentrations can be used more often with FLIR monitoring than without. The visible evidence of the drop, through the FLIR, persists long after the foam vanishes to the eye, and a wetter foam tends to hang together in the air better, with more product arriving where intended.

- A systematic approach is indicated on missions such as this and the visual aid provided through access to the infrared spectrum is a real asset here. The monitor provides a map of the existing hot-spots as well as a visual indication of the relative condition of previous drops, which facilitates operational planning directly. The entire action can be documented on video and with prints that are conveyed to ground personnel through drop tubes, enabling effective, efficient utilization of resources in such operations. The prints dropped to the fire boss have also proven of real benefit in planning subsequent ground action, showing all problem areas that require further attention clearly with respect to identifiable physical features. By using the FLIR as the primary monitoring device, good results were experienced when directing helicopters ferrying ground crews or overhead personnel to specific locations of interest. This generally assures positive identification of trouble spots from the ground.

- Using the FLIR in these situations greatly reduces redundancy and uncertainty for all concerned. The FLIR allows effective minimization of the number of drops, while providing assurance of the effectiveness of the mission as a whole. This is of real benefit in any cost reduction strategy, yet it also allows decisions regarding mission termination to be made with greater confidence. Both aerial and ground operations benefit from this increased efficiency.

If one area must be identified where the use of infrared sensing can easily and dramatically impact upon overall fire strategy this is surely that area. Various hand held systems have been used by fire suppression agencies for a number of years now with mixed success. The FLIR system is not by any means perfect, but the speed, comfort, convenience, and precision of the fixed wing platform, when coupled with substantial savings in overall operational cost, make a very persuasive argument for its inclusion in any support action.

NECESSARY ADAPTATIONS FOR OPERATIONAL USE

The cockpit of an operationally engaged bird-dog aircraft can be a very busy place indeed. Utilization of the FLIR system entails learning to control a very sophisticated piece of equipment in this already intense environment, and a case certainly could be made that an air attack officer may become distracted by the equipment. Yet, once the operational protocols of using the equipment are fully integrated into normal operating procedures, FLIR directed actions become intrinsically safer, more effective, and more efficient than are conventionally directed ones.

Organization is ever the key to succeeding at complex endeavours. From the air attack perspective, cockpit organization is directly related to overall airspace organization, and ultimately, mission success. Some adjustment must be anticipated when one considers importing new technology into a well established operating environment. The solution to this difficulty lies in re-organizing the cockpit around the presence of the FLIR rather than in trying to graft a new technology onto an existing organizational structure. Total reliance upon remote sensing devices is not being advocated here by any means, but rather the obvious suggestion that being able to see through smoke on a monitor is intrinsically superior to monitoring a situation visually, that is perennially obscured by smoke.

One of the chief difficulties encountered in the early stages of training with the system lies in the acquisition and tracking of relevant targets at speeds and altitudes common in aerial fire suppression operations. Things just happen too fast to properly aim and adjust the orientation of the sensing apparatus to adequately capture relevant information. One generally only operates in this manner while doing lead-ins, dummy runs, or reconnaissance for planned drops. At these times what is directly in front of the aircraft is of principal interest and all that is required of the FLIR is that it be aimed straight forward, and slightly below the horizontal. The aircraft itself then "steers" the unit while the air attack officer monitors the display and the visual situation in exactly the same manner as the pilot monitors the flight instruments and the visual situation in flying the aircraft. More information is made available, for sure, but all that information is immediately relevant to the aircraft's foreseeable orientation. Hot-spots, snags, variations in terrain, and all other aircraft on the relevant flight path are presented in a two dimensional display, providing invaluable assistance in correctly assessing the run. All this is achieved without moving the camera and without controlling the system directly in any other manner; and can be accomplished, given proper monitor placement, with an essentially "heads-up" attitude.

It does become necessary to identify and track specific targets, of course, especially when evaluating drop effectiveness, observing changing fire behaviour, or precisely identifying a specific problem area. This is most readily accomplished while in orbit and direct mode, and from an altitude that gives an overall perspective on the situation. When using the FLIR in this manner, precise control is required and significant concentration unavoidable. Practice is mandatory, and with experience comes fluidity. Yet even in this context, there exists a technique which allows an essentially "heads-up" approach to the task, and again it is the aircraft which becomes the primary aiming agent within the system.

When establishing an orbit with respect to some relevant context, if the sensor is aimed between 45 and 60 degrees of azimuth and 15 to 20 degrees below the horizontal, then the orbit of the aircraft can be maintained in such a manner that the relevant image remains in the center of the monitor and slowly rotates. This enables sustained observation of the chosen target without requiring much more than occasional control input, while the pilot flies the requisite number of orbits in a consistent attitude. Both the pilot and the air attack officer can see the monitor in most situations, and again it is used as simply another flight instrument which is frequently scanned rather than focused upon. There are certainly situations encountered that require sustained focused concentration on the system monitor; scanning for hot-spots in burnt windrows, for example. This orbiting technique is optimal in this context and allows sustained target observation from a safe altitude. Very acceptable results can be expected when scanning windrows from altitudes of 2000 feet A.G.L. because of the image stability provided through using the equipment in this manner.

When properly integrated into normal cockpit procedures the whole system actually demands very little attention from the experienced user. While a very busy time must be anticipated during the initial stages of familiarization, with sustained exposure to this equipment, the very precision it allows when properly utilized entails substantial simplification in an already complex endeavour. When an operator becomes familiar enough with the system and its controls, and comfortable using the aircraft in the manner just described, it becomes possible to aim and interpret almost instinctively whilst talking on the radio, directing the air-space, and monitoring relevant activities visually. One can operate more efficiently and with greater confidence, since smoke no longer plays an obscuring role within the operational environment, and it is possible to monitor and document the mission fully as an aid in the evaluation of immediate tactical objectives as well as providing insight into overall strategic motivation. All this becomes possible only when utilization of a FLIR system is fully incorporated as a central feature of familiar air attack procedures.

CONCLUSION

The author has personally used a FLIR system while bird-dogging for three fire seasons and would feel distinctly disadvantaged by its absence. While this is a complex piece of equipment that requires a certain commitment to master, the added precision brought to aerial fire operations through its effective usage is readily apparent to all who have been exposed to it. In another relevant Canadian Forest Service report, **An economic evaluation of Forward Looking Infrared (FLIR) technology to enhance aerial suppression of forest fires in Alberta** by Woodard, Adamowicz, and Bolster (1993), it is stated:

> One respondent said "FLIR technology is probably the biggest improvement in forest fire control since the 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. (Page 14)

The central topic of this just mentioned study is of course an economic evaluation of system utilization in the fire operations context. Aerial forest fire suppression is a very expensive, if highly effective, endeavor and a FLIR system with its associated global positioning system, video recorder, and printer is a very expensive item. The authors of this report carried out an extensive, full scale economic evaluation of system utilization. They state:

> In conclusion, we recommend this 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....We suspect that if all saving resulting from the use of this technology were known, the economic justification of adopting FLIR scanners would be extremely powerful and overwhelmingly convincing. (Page 16)

From an aerial fire operations perspective, the author of this paper is also convinced. This new component is simply essential in directing a safe, efficient, and effective fire suppression action.

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