CHANGES IN INFRARED USE FOR FIRE MANAGEMENT

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Introduction:

Infrared (IR) systems have been used by the USDA Forest Service (FS) for over 25 years. (1) The airborne IR line scanning systems remotely sense temperature differences. Very small temperature differences result in a thermogram of the terrain features. Large temperature differences indicate fire or hot spots. Trained IR interpreters can locate the fire & hot spots on USGS or other maps, by matching the terrain features in the IR images to their map locations. The FS IR systems have several unique design features that are not usually found in military or general purpose IR line scanning systems. (See Appendix 1). The two IR line scanners owned and operated by the FS are the only ones known, in the world, that were specified, designed, and built especially for fire management tasks. There are two manual tasks involved in the use of these current systems. One is the physical delivery of the IR images, produced on film, to the Incident Command Post (ICP). The other is the location and plotting of fire perimeters and hot spots from the film to the map by trained IR interpreters. Both can be time-consuming tasks. (Note: the IR image signals are produced by sensors in the two thermal IR bands (3 to 5 and 8 to 12 micrometers) and then processed for display on black and white film. The images are NOT produced from cameras by direct exposure of near-IR film.)

Within roughly the last ten years, technology advances have developed which are now being applied to the FS IR needs for fire managers. Also numerous private contractors have acquired an IR capability with either IR line scanners or forward looking infrared (FLIR), and are now available, contractually for fire management tasks. Fire managers are becoming increasingly aware of the "other" IR systems that are available, after some 25 years where IR has meant only the two FS line scanner aircraft in most cases. Finally, IR systems using advanced digital signal processing techniques are in development to replace the two traditional FS line scanner systems.

These changes to the long-standing FS means and methods of using IR for protecting natural resources from fire will be addressed in this paper.

Problem:

The problem of IR intelligence availability for fire managment has long been known but never addressed in a satisfactory manner. The (lack of) IR availability, when needed, on fires has been identified as the #1 problem with IR. That is, an Incident Staff cannot depend on having IR flights when it wants them. It is

easy to see that with only two FS IR line scanning systems, that problem was virtually unsolvable. During the last 5 (1985-1989) "unusually busy" fire seasons, it became increasingly evident that the IR practices of the previous 20 years must be changed if IR is to be a dependable and effective source of intelligence for the Incident Command Staffs. A detailed review of the IR performance during 1988, which included the Yellowstone Fires, determined that the FS IR systems worked fine. But, it was evident that two systems are not enough to cover all the fire needs during most fire seasons. (It is generally agreed that the IR shortage is worse than the records would indicate. There are no records made of the number of IR requests which go unfilled. Also, when the two IR systems are being used at other locations, they will simply not be ordered unless the local situation is so severe that it would out-prioritize the existing assignment.) Basically the fire community has only recognized the FS systems contained in the King Air and Merlin, twin engine turbo-prop fixed-wing aircraft. When IR is mentioned, those are usually the only systems that have come to mind. Thus the problem has been lack of availability, because only two systems were available. There is still a lack of awareness of availability of other systems (most of which were not available in the past). The recognition that other types of systems are now available and the understanding of the capabilities and limitations of all the types of IR systems is just getting started. It is difficult to change long-established methods and ways of thinking, but some of the progressive fire staffs are already applying the new technologies and alternate capabilities. It is reasonable to expect that the basic problem of IR (lack of) availability will be resolved within a few years as the new means and methods are understood, tried, and accepted by the fire staffs.

Solutions:

1. New methods using new technologies have been conceived and developed into effective fire mapping/detection tools. (2), (3). These involve the reduction in size and weight of IR sensors, navigation receivers and computers; increased interfacing capability of some of those components; development of new concepts; and adapting new technologies.

2. Numerous private contractors have been identified with a variety of capabilities in both traditional airborne IR line scanners, FLIR's and new technologies. Prior to the Yellowstone fires (of 1988) there was little interest shown in using other sources of IR intelligence than the two FS line scanners. As a result of the Yellowstone IR usage review, contractors are now placed on national or regional contracts and

are available any place in the country, during fire season, for fire management and suppression needs.

3. Fire managers are increasingly aware of new methods and of how to determine which type of IR system may be best, satisfactory, or unsuitable for various situations, conditions, and IR information needs. As the awareness progresses, IR may be ordered based on what the real needs are, which system can do an adequate job, and other situation concerns, rather than on simply whether or not one of the two FS IR aircraft can be made available.

Characteristics of IR Systems for Fire Management:

Airborne IR Line Scanners.

Airborne IR line scanning systems usually produce an IR image on film. (See Figure 1.) The film must then be physically delivered to a trained IR interpreter. The interpreter transposes the fire/hot spot information from the film to a map, typically a USGS 7&1/2 minute quad. By the nature of the process of placing the 3D location information onto a 2D film, the film image cross-track scale is continuously non-linear. The scale is not even constant across a single scanned line--unless the terrain is at a constant elevation, seldom the case where wildland fires occur the most. (See Figure 2.) Sometimes the images may be dropped in a special canister, which speeds the delivery process but that is not often available because of safety considerations. Spot fires (hot spots) are usually automatically marked on the IR images. That is, the spots are marked so that the operator or interpreter does not need to visually identify them in the image on the film. The two FS line scanners have far better detection capability than any other line scanners including the military. The two thermal IR bands (3-5 and 8-12 micrometers) are combined in some unique signal processing circuitry which gives about a 10 to 1 improvement in detection capability. The processing also effectively eliminates "false targets" by a line-to-line store and compare method.

In summary, the FS IR line scanners cover large areas in a relatively short time. They have excellent small hot-spot detection capabilities. They can provide an overall IR "view" of a large area displayed on film. But, there are only two of them so availability may be a problem. The time from actual flight over the fire area til time of delivery of the final product may be long, 2-6 hours. They are used mostly at night. They are mainly a stategic information system, not real time nor tactical.

FLIR with Fire Mouse Trap (FMT) capability.

INFRARED FIRE SURVEILLANCE SYSTEM

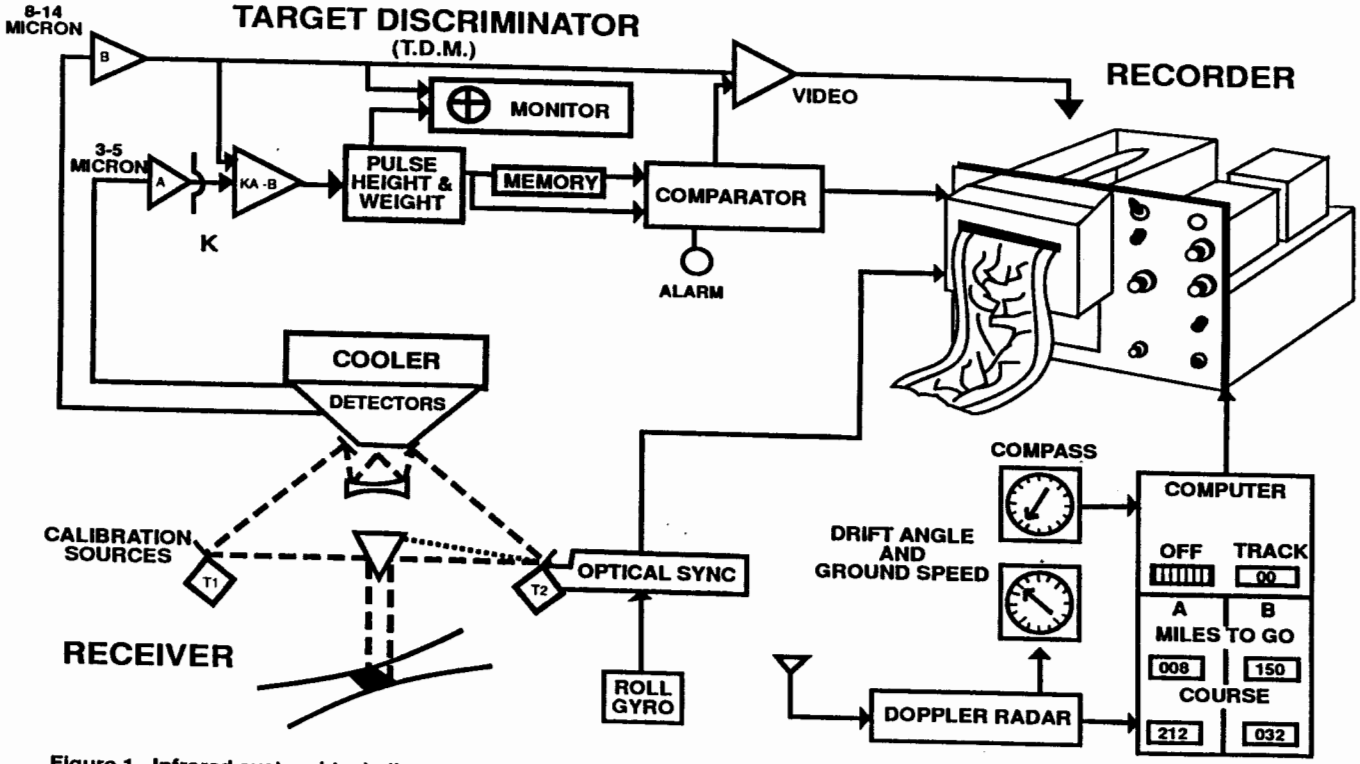


Figure 1. Infrared system block diagram.

FLIR combined with FMT capability (Figure 3) provides a viable alternate method for mapping fires of any size. The mapping is done in a direct manner by flying a helicopter (or light fixed-wing) around the fire perimeter while storing the position of the aircraft every few seconds. These latitude & longitude position points are stored in a laptop computer. Upon landing the laptop is connected to a small plotter, two scaling points are entered, and the fire perimeter and hot-spot location points are plotted on a map or transparent overlay, to scale. Because the points are taken directly over the fire perimeter or hot spots of interest, the inherent displacements and non-linearities caused by terrain altitude variations in line scanners, do not appear and manual interpretation is not necessary. The aircraft position is automatically updated for storing, by a LORAN-C navigation receiver. Planning is under way to utilize the Global Positioning System (GPS) when it is available 24 hours a day. A FLIR videotape on standard 1/2 inch VHS of the fire perimeter and hot spots is available for more detailed analysis of any area of interest. The latitude and longitude is continuously displayed on the bottom of the monitor to facilitate locating the area of interest during playback.

In summary, a FLIR/FMT system is usually readily available, at the disposal of the local fire managers, when assigned to a fire or area, rather that needing to be scheduled in as available and allowing for other fires' priorities. Much more detail can be gathered about designated areas through the versatility and lower altitudes of the helicopter. A videotape is available for subsequent re-viewing. But, they are not appropriate for large area (over 1200 A. or so) detection missions because of their smaller total field of view and lack of automatic target marking capability. Initial mapping of large fires may be difficult because of the smaller field of view, although subsequent update mapping is very appropriate. They can "map" fire perimeters of any size providing IR information all around the perimeter, but not necessarily deep inside of the perimeter, unless that area is also flown. The FLIR/FMT is essentially a versatile tactical near real-time system, which can be over the area(s) of interest in a hurry and provide a lot of detail. Because of FS restrictions on helicopter night operations, they are mainly used from dawn to dusk.

A new use of FLIR systems, with or without FMT, has been identified by the Operational Retardant Evaluation (ORE) Research Group. The use of FLIR in coordinating, directing, monitoring, and evaluation of effectiveness of retardant drops can greatly improve the efficient and effective use of those resources. (4)

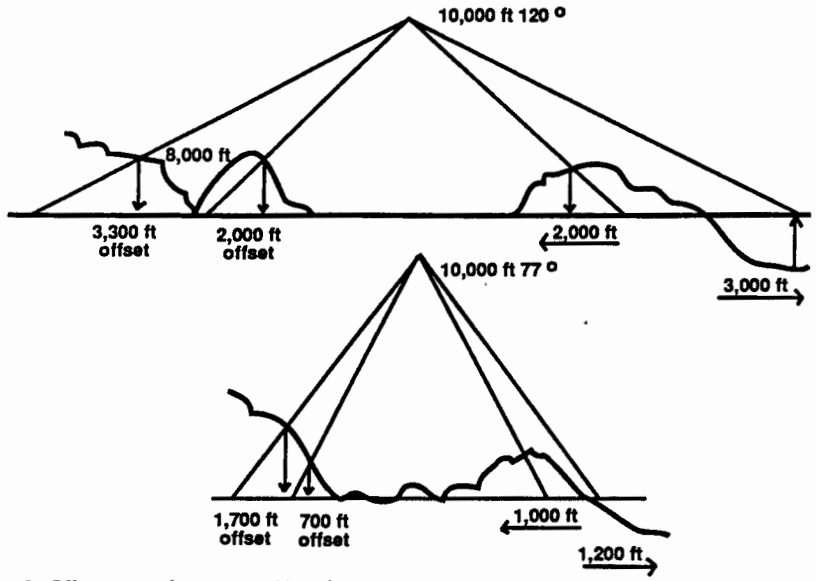


Figure 2. Offset errors from unlevel terrain

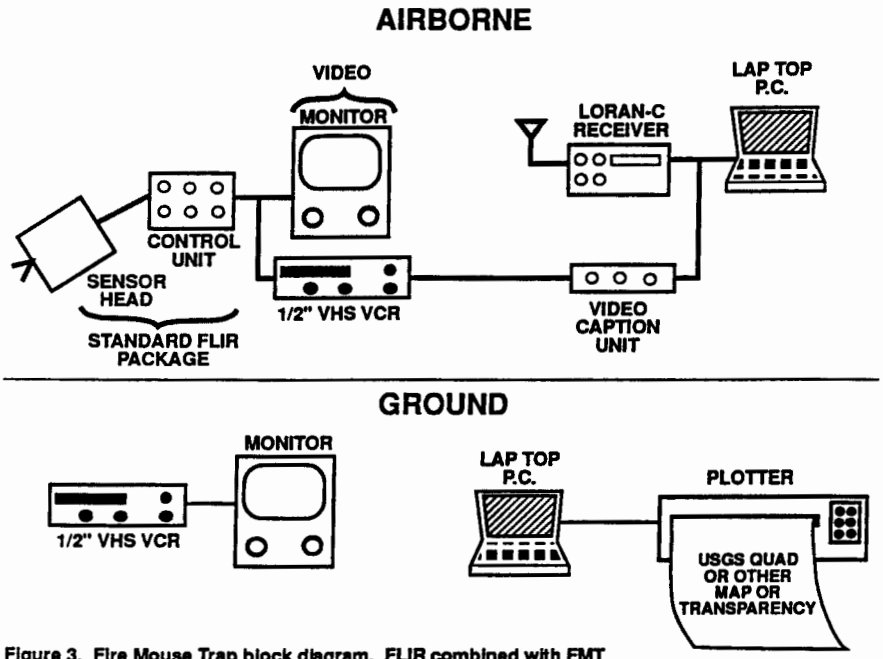


Figure 3. Fire Mouse Trap block diagram. FLIR combined with FMT capability provides a way to accurately map fires of any size.

Selection of IR Systems:

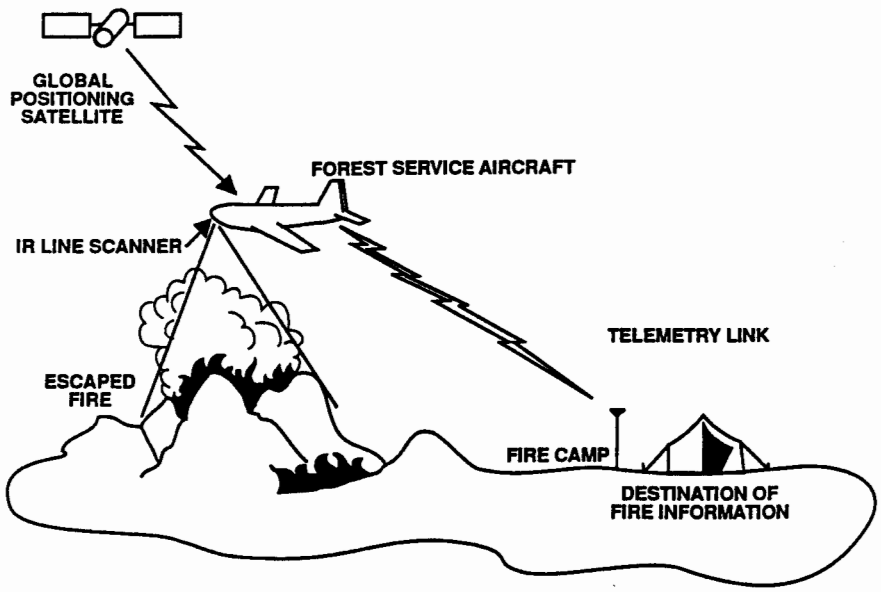
A list of the various functions usually performed by IR, both fire and non-fire, was reviewed by experienced Class I Incident Commanders (and the author) see Appendix 2. The types of IR which could perform the functions, under the conditions described were graded by their ability. The results clearly show that reliance upon only one type of IR system is not necessary or even reasonable. It is expected that by a careful review of the situation, conditions, and timing that IR intelligence capabilities can always be made available even in the busier fire seasons. This can only happen if fire managers are knowledgable in the selection and ordering of the types of IR systems which are suited for their unique needs. That will then free up the FS line scanners for those applications which they can do best--large area detection; first-time large fire mapping. Other systems will be available by contract to do other jobs adequately and in many cases better than the line scanners would have done those same jobs.

Note: Helicopter use on fires is usually restricted to daylight hours. The line scanners are usually used at nite to avoid solar reflection/heating indications that may not be resolvable from film.

FireFly in the Future For Forest Fire-Fighting Forces:

The Jet Propulsion Laboratory (JPL), the folks that remote-sense interesting planets from anyplace in our solar system, are developing new airborne IR systems, named Firefly, for the FS. (Figure 4) The two Firefly systems are planned to take the place of the existing FS airborne IR line scanners beginning operation in 1993. Firefly will take advantage of newly developed or developing technologies in digital signal processing, data bases, satellite navigation systems, and mobile satellite communications. Although commercial IR line scanners, rather than higher performance military type line scanners will be used, the signal processing from the scanner outputs will be advanced. The Firefly signal processing will use Digital Terrain Elevation Data (DTED) from USGS, aircraft location from GPS, and other sensed data, to geo-locate the hot areas in and around a fire, on board the aircraft. The pertinent fire data will then be transmitted to the ICP or any other ground receiving location via the mobile communications satellite(s), being developed for commercial use. This will eliminate the two manual tasks (physical delivery and transposing fire data from film to maps) that are inherent in the traditional line scanner methods. Without the need to use up most of the available thermal resolution to show terrain features for the interpreters using the limited gray-scale range of

FIREFLY
SYSTEM CONCEPT



- AIRBORNE REMOTE SENSING SYSTEM DETERMINES FIRE PERIMETER AND HOT SPOT LOCATIONS
- GEOREFERENCED PLOTS ARE TRANSMITTED TO THE FIRE COORDINATION CAMP IN NEAR REAL TIME

Figure 4. Firefly is a new airborne infrared system under development by the jet propulsion laboratory.

film, the fire "energy output" levels can be transmitted which may help determine the equivalent fire intensity level of the fire.

Various means of transmitting IR images to the ground have been successfully developed and explored since 1974. These all required the higher transmission bandwidths associated with active video. They have also required establishing line-of-sight RF transmission links between the aircraft and ICP receiving station. The bandwidth/power/gain/time trade-offs have never been favorable for transmission via satellite. Fire managers in the past have felt there was a need to have the full image available for viewing and there are some advantages. However, most folks are much more comfortable with computer-generated outputs now, and usually only the interpreter did any detailed analysis of the film anyway. The FMT plots have been readily accepted where they have been used. If the additional detail provided by a film or video output is necessary, FLIR/FMT flights could provide it in a timely manner, usually in more detail than the line scanner IR film does anyway. The delivery of the Firefly product, hot spots/areas plotted on maps or overlays with intensity-related levels, without the time-comsuming physical delivery and manual interpretation will make these new systems valuable intelligence sources.

Remote Sensing of Fires by Satellites.

This subject inevitably comes up, especially in discussions of future or advanced technology systems. See appendix 3--written several years ago, it is still fairly accurate today and for the forseeable future.

Summary:

Changes are underway in FS means and methods for remote sensing of fire information by thermal IR systems. The traditional means and methods, in use for about 25 years are being supplemented by new technologies and new applications of integrated-technologies. Most of what is being done could not have been accomplished ten years ago, some not even five years ago, and some is dependent upon still developing technology. Changes don't always come easy and it may be difficult for some to abandon the tried-and-true methods, but just about everyone has done that on and off the job during the past several years. The FS and other agencies' fire managers will recognize the advantages, and if there are failings, identify those in a positive manner so that they can be corrected, with the new systems now available, with contractor-provided IR services, and with new systems in the future.

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