USDA FOREST SERVICE (FS) INFRARED (IR) NEEDS AND PLANS

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ABSTRACT

The USDA Forest Service has used thermal IR remote sensing for nearly 30 years. There have been few changes in the basic way that the airborne IR line scanners are used and in the products that they provide. Within the past 10 years there have been significant advances in some technologies which could pave the way for major improvements in the IR line scanner systems and their products. Also small forward looking infrared (FLIR) systems have been in use for about 15 years. The technology advances can also be applied to FLIR systems. The Fire Mouse Trap* represents a way that new technologies can be systems engineered to improve a basic technology. There are other possibilities open now to further improvements. A list of technology applications is included which could be applied to present Forest Service IR systems needs. For a baseline, the present status of Forest Service IR systems, activities and plans for 1994 is included.

INTRODUCTION

The current status of USDA Forest Service (FS) thermal InfraRed (IR) remote sensing capabilities as of 1994 are discussed and a list of current and future needs of FS IR systems is presented. Planned activities for 1994 are also included.

BACKGROUND

The USDA Forest Service (FS) has used airborne thermal infrared (IR) line scanning systems for nearly 30 years for fire detection and mapping missions. (Warren, 1991) Forward looking infrared (FLIR) systems have been used for about 15 years, and the Fire Mouse Trap (FMT) was conceived 10 years ago. (Warren, 1991) The initial IR line scanners used were military line scanners, modified for fire detection and mapping needs. The initial FLIR's were hand-held units which were procured about as soon as they became commercially available. The initial FMT was systems engineered from a combination of new technologies and equipment, such as FLIR, laptop then notebook computers, LORAN then GPS navigation receivers, small video caption generators, packet radio modems, and the applications software to tie them all together into a useful fire (or other area) mapping system.

* **F**lying **I**nfraRed **E**nhanced **M**aneuverable **O**perational **U**ser **S**imple **E**lectronic **T**actical **R**econnaisance **A**nd **P**atrol. A complex but "catching" acronym, originally suggested by John Chambers, Asst. Director, FS Fire & Aviation Management, Washington Office.

The Firefly (FF) program was an attempt to do similar systems engineering to the IR line scanners and a combination of technologies, such as GPS, stored digital terrain elevation data, digital signal processing, and satellite data communications. Two FF systems were delivered to the FS with major accuracy problems and some inherent deficiencies, in Sept., 1992. There have been only minor changes, primarily to upgrade the Daedalus commercial line scanner to its originally intended configuration. (It was procured without some of its capability for use as the FF front end sensor.) Meanwhile, over the last (nearly) six years since FF was started, there have been some significant advances in some technologies (image processing and compression), while other anticipated capabilities (satellite data communications and wide-spread real-time differential GPS corrections) have lagged behind. So where does that leave us now?

STATUS

The FS has two operational IR line scanner aircraft: A King Air 200 and a Sabreliner jet. One of the two FF systems is installed in the Sabre and the other is being used as a shop system for trouble-shooting and a source of spares. The FLAME (traditional type) IR line scanner is installed in the KA. It is now 11 years old. The venerable RS-25 line scanner is on stand-by. The IR line scanners, pilots, and IR technicians are stationed at Boise. There are no known equivalent commercial airborne IR line scanner systems available.

The FS has 5 hand-held FLIR systems and one turret-mount FLIR system. One or two more turret-mount FLIR systems are expected to be procured this year. The turret-mount FLIRs are intended for use on Air Attack Aircraft to determine their operational feasibility in the Air Attack Operations. Technical feasibility and the potential for more effective results in air tanker operations was shown several years ago, during the Operational Retardant Effectiveness (ORE) Research Project. (George, 1989) The FS also has a few hand-held pyro-electric vidicons (PEV's), which are simpler and less expensive, but lower quality IR imaging units.

The FS has several trained FMT operators and these systems can be used with any hand-held or turret-mount FLIR's or PEV's. They require a GPS (or may use LORAN in some areas), a notebook PC, and a plotter. The FMT is easy to use and very effective for a variety of fire, or other area mapping/detection tasks. (Scott, 1991)

The FS has two FLIR image transmission systems, one in R5 So. Zone, used with L. A. County FD, and one in R5 No. Zone, on the Eldorado NF. These were originally developed for use with the FS IR line scanners, but have been adapted for the microwave transmission, from aircraft to ground, of live FLIR video. They are installed in aircraft, fixed wing or helicopter, and are used with a ground receiving van. Line-of-sight is required between the aircraft and ground for live transmissions, or a video tape can be delivered later.

There are no known USA companies with airborne IR line scanner capabilities suitable for fire use. There are 2 Canadian companies, both using Daedalus line scanners, which have roughly the equivalent capability and products of the Firefly system in its present (1994) configuration.

There are several USA companies with FLIR capability in helicopters. The companies do a good job and are available through Regional FS contracts. They are available for FLIR, FMT, or FLIR/Air Attack services. They all have fire experience and can provide the entire IR service for fires or other applications.

Infrared provides information which is necessary for the successful management of wildfires or prescription fires. IR can provide information about the location and intensity of fires or hot areas or spots that may become fires. IR systems can provide this information, day or night, and through smoke. The IR systems sense radiation in the thermal IR bands, 3-5 and 8-12 micrometers, which cannot be detected by our eyes in the visible spectrum.

FS IR NEEDS

There are IR line scanners, turret-mount FLIRs, hand-held FLIRs, and less expensive hand-held IR imaging systems available which do a creditable job. In general, the higher quality sytems cost more. But it is basically true, that an IR system can be procured from industry sources which will meet basic FS requirements for IR information. What more, then, is needed?

There is a variety of technology which is available, or is becoming available, (or at least being considered) which can make the IR systems more effective in delivering information to the user. These technologies will accept the basic outputs of the various IR systems and process, transmit, display, print, or otherwise operate on them to make them more useful, and available sooner, or more often than they have been in the past.

Technology applications needed are:

- Image geo-referencing (to remove terrain and other distortions).
- Image fusion (to allow merging, to scale, of images from various sources).
- Image overlay (to allow image overlay, to scale, on maps or GIS layers).
- Image compression (to reduce the image data required to be stored/ transmitted).
- Image transmission (from a moving aircraft to ground, via satellite).
- Image recorders or printers (with color, which are good, fast, cheap, and small).
- GIS compatibility (of IR images or other products, along with other attributes pertinent to fire management).
- GPS (P-Code or real time differential GPS over remote areas for better accuracy).
- IR focal plane arrays (IR-FPA) (for better, cheaper IR imaging).
- Expert systems (for aiding in the selection of the type of IR system needed to provide the required information on a variety of fire sizes and various conditions).
- IR in Air Attack, and maybe other operational aircraft, (to improve the effectiveness and efficiency of retardant drops and other operations).
- IR and night vision systems (for implementation of night-time fire operations).

The above list is substantial, but not all-inclusive. Some of the needs could be implemented right away, and some are not quite realizable, at least at the right price. Others need to have more research and development of the right approach. Some are in work, and some have not been recognized as a real need as yet. Suffice to say that there is ample opportunity for extensive improvements to be accomplished in FS thermal IR systems and their products in the next 5-10 years. Un-doubtedly before these can be implemented, there will be other new technologies or applications of technologies which will be available for investigation. "A Look At The Future", might provide some ideas. (Warren, 1989)

PLANS FOR FS IR IN 1994

The 1994 plans are fairly modest. The Daedalus line scanner used for the Firefly IR system has been up-graded, to add back items which were intentionally omitted when it was ordered by the Firefly developer. These include a strip-film image recorder, which will produce the traditional FS IR line scanner product; V/H compensation, moving window display, and an Exabyte digital cassette recorder. The FS also installed a color dye-sublimation image recorder to produce hard-copies of the FF freeze-frame images which are shown on the FF main computer monitor (images from the Daedalus line scanner output). The FF system will be used as one of the two FS airborne IR line scanning systems operationally this year, with the Daedalus (strip-film image) and the FF (freeze-frame image) hard copy products this year. Both will require physical delivery and manual interpretation, the same as the traditional line scanners always have.

Meanwhile, the Army Missile Command at Huntsville, AL is completing a FF Systems Engineering Analysis to determine: what is the accuracy of the FF system as-delivered; what can the potential accuracy be with improvements in navigation gyros, P-code GPS, faster computing, and better software/ algorithms; and, what could we do now to provide better products such as completely geo-referenced and scaled images. (The FF product originally proposed was a file containing the latitude, longitude, and intensity number of every ground pixel in the field-of-view which exceeded a threshold, and would therefore be defined as "hot". The file could then be transmitted to the ground from the aircraft, by satellite when that became economically available. The inherent problems with that product are: the relative position of the "hot spots/areas" to other features such as roads and fire breaks are not determinable within the required accuracy, and the burned area perimeter cannot be established). With image compression programs now available, it is possible to transmit entire image frames within the same time and bandwidth that just the data files would take. For 1994, some operational experience will be gained with the Daedalus line scanner in the FF system and the results of the Systems Engineering Analysis will help determine what the future holds for FF. The outcome could be doing major modifications to improve the accuracy to "acceptable levels" or changing the system substantially and producing a better product, such as geo-referenced image frames with hot-spots or areas shown in different color levels proportional to the "heat intensity", and overlaid in hard-copy on stored USGS quad sheets, ready for entry into FS GIS.

FLIR will be installed in Air Attack Aircraft (AAA) for use operationally by the Air Tactical Group Supervisors for evaluation of logistics and operational methods. The technology and advantages have already been researched and document-

ed by the Operational Retardant Evaluation reseach project. Canada and California Department of Forestry have also used FLIR successfully for this purpose and are planning further implementation. Besides the advantage of being able to improve retardant drop operations, there will be other uses of FLIR for acquiring fire information around going fires.

FLIR evaluations have been completed for the FS by the Army Missile Command at Huntsville, AL of a variety of commercially available FLIRs for future reference. Also a couple of the newer focal plane array IR systems were evaluated. There appears to be a high potential for these to improve image quality and reduce cost over the traditional FLIRs.

The FS is participating with BLM, DOD, and other agencies in the evaluation of DOD satellite based systems for remote area fire detection, as part of the Redsky Program. FS participants include F&AM, NFAP, Engineering/RS and the Fire Sciences Laboratory (Missoula). This will determine whether such systems could replace other detection means or augment existing detection means.

In summary, 1994 is sort of an investigative year, with some areas being analyzed (Firefly); some informational IR tools being tried out operationally (FLIR in AAA); some new systems being evaluated (FPA's); and, some joint venture investigations being performed (Redsky). One could certainly postulate some major advances in thermal infrared remote sensing for fire and other applications if these all turned out positive and showed achievable results which could then be implemented.

CONCLUSION

The Forest Service has a solid background and a unique current capability in IR systems for fire detection and mapping. However there is a variety of new or un-tapped (for FS fire management) technologies which could greatly enhance and improve the FS systems and methods. The research, development, and subsequent implementation of these technologies will be on-going for several years, even though much is basically available right now. Ultimately, we may approach that optimum condition of all wildland fires burning only within safe "prescribed" conditions and boundaries, with IR and other information coupled with a host of other stored and dynamic data inputs so that the situation is monitored and controlled.

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