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September 1, 1983

Prepared for

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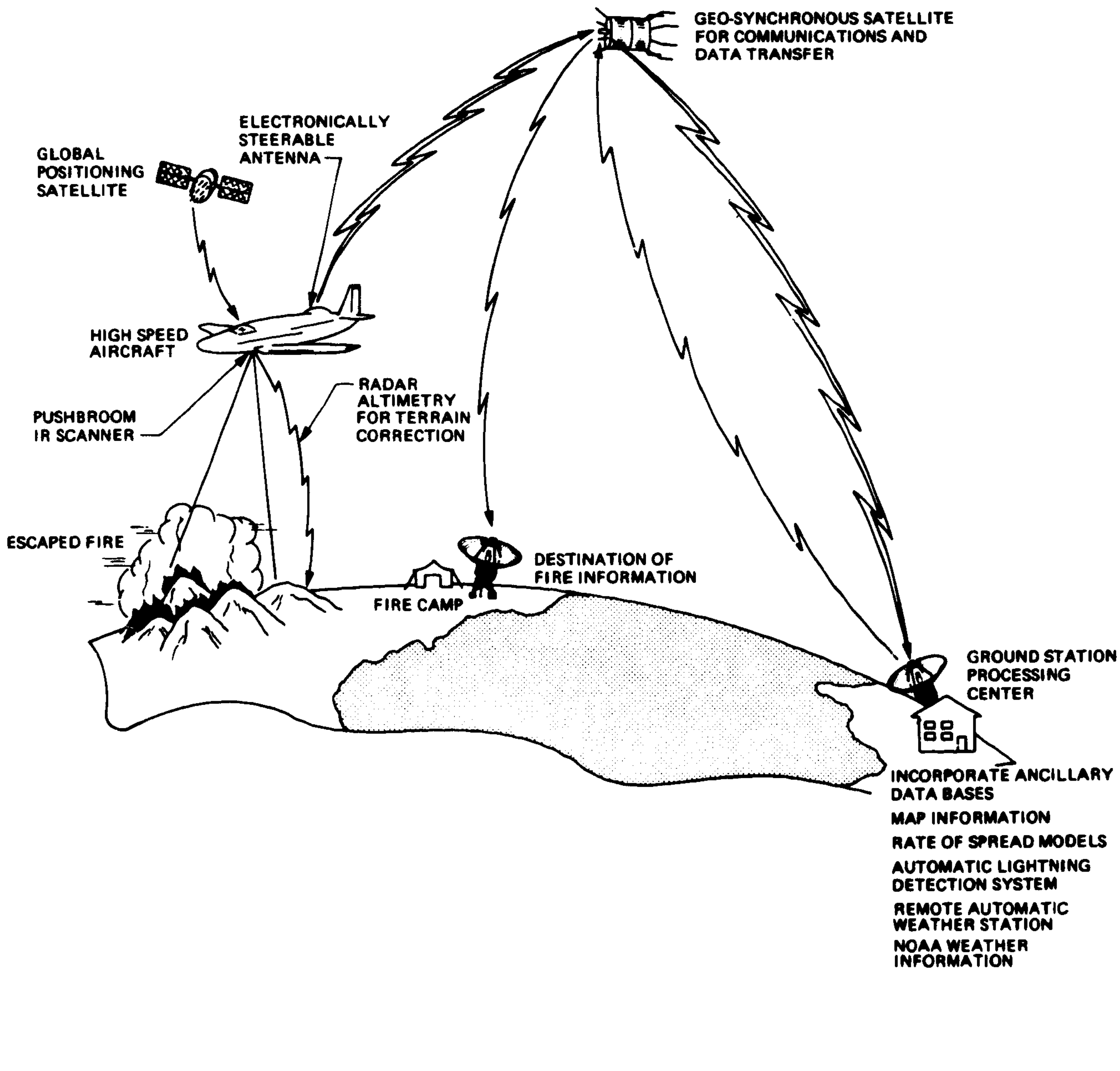
FOREST FIRE ADVANCED SYSTEM TECHNOLOGY
FFAST
STRAWMAN SYSTEM CONFIGURATION



EXECUTIVE SUMMARY

Management of wild and prescribed fires requires timely and accurate information on fire location and behavior. Current methods in use by the United States Department of Agriculture (USDA) Forest Service for determining fire location frequently employ infrared sensing from aircraft. Information pertaining to fire location and intensity is recorded on film and delivered to the fire camp command post to supplement the information needed for tactical fire fighting operations. The infrared sensing systems now in use by the USDA Forest Service are important in fire suppression strategy; however, the sensing units are becoming increasingly difficult to maintain due to the lack of replacement parts. As a result of this, an infrared sensing system is being upgraded at the Jet Propulsion Laboratory under project FLAME.

By the 1990's, additional capabilities of a fire surveillance system will be needed to deal with the complex management task of fire management and suppression. Ancillary information such as general map data, fire rate-of-spread models, and BTU output may be needed to enhance the information base required for allocating resources to fight fires.

In response to the future needs, a joint feasibility study between the United States Department of Agriculture Forest Service and the National Aeronautics and Space Administration/Jet Propulsion Laboratory was undertaken with the goal of examining the potential for applying advanced technology to improve the gathering, integration, and synthesis of information pertaining to forest fire mapping and detection. The objectives of this task were to understand the current and future user needs in information requirements for forest fire management in the 1990's and to survey and identify what technologies may be available to meet these future needs. The results of that study are discussed in this report. In addition, to clearly present the mix of technology and needs, a strawman system is presented and discussed, and a plan for a more detailed, follow-on conceptual design of the strawman system is presented.

The approach of the study was to gather data on current and future information requirements, analyze these user needs, and define a set of functional requirements. In a somewhat concurrent effort, emerging technologies that may meet these requirements were surveyed. The results of matching the technologies and user requirements are presented in a "strawman" system configuration. A plan was then prepared for a detailed, follow-on conceptual design phase.

Officials at various levels in the national and regional offices of the USDA Forest Service, as well as staff members in the federal and provincial branches of the Canadian government, were interviewed over a six month period in 1982-83 to identify user information needs in forest fire suppression and management. The results of the interviews showed that information needs include the following: where the fire is, what is it doing, what is it going to do, and what can and should be done about it. An integrated information gathering and processing system is needed to fulfill these requirements. Particular factors needed for a system are exact location of the fire to within a road width as well as the intensity and areal extent of the burn. Factors influencing the behavior of a fire are needed and include items such as short term weather forecasts (available from National Oceanic and Atmospheric Administration (NOAA) and Remote Automatic

Weather Stations (RAWS)), fuel type, volume and moisture of the fuel, the slope and direction of the terrain, and the material, structures and fuel in the predicted path of the fire. General map data such as roads, land tenure, streams, and lakes are needed as references in pinpointing the location of the fire. Resources at risk must be identified and evaluated in near-real time.

The system to merge the wide varieties of information should

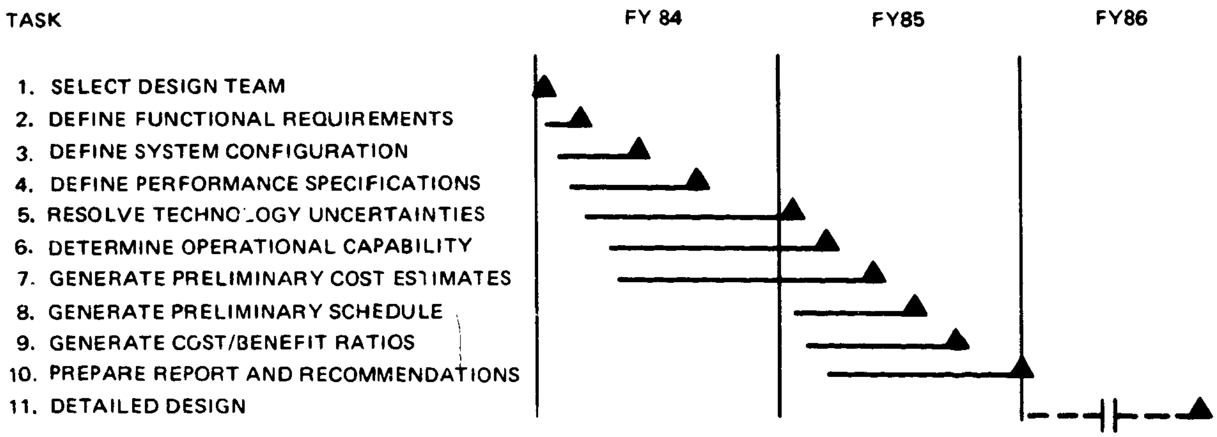
1. Be user friendly;
2. Provide timely information;
3. Incorporate existing data bases;
4. Be accurate;
5. Provide conventional output products;
6. Be of a modular design; and
7. Be reliable and maintainable.

The use of such a system should integrate easily into the practices of the USDA Forest Service and cooperating agencies. The design should incorporate principles of flexibility and keep in mind the need for adaptability to other uses.

Suitable technology surveyed in this study includes sensor platforms, "push broom" sensor arrays, automatic georeferencing, and high speed satellite communications links. For example, the strawman system configuration presented utilizes an aircraft, probably of the turboprop class, and a multiband infrared linear array "push broom" sensor. The raw information on board the aircraft is automatically georeferenced with a central processing unit aided by inertial navigational equipment, the Global Positioning Satellite System, and digital terrain models. Corrections for terrain variations are made with a radar altimeter. The georeferenced data are transmitted via an electronically steerable antenna through a satellite link to a central processing facility where value-added processing is performed to include existing data bases. The reduced information for fire location and intensity is transmitted via satellite link to the fire camp. Additional processing of the data to determine fire rate-of-spread and impact would be performed at the central processing facility utilizing computerized rate-of-spread models.

To look further and in more detail at emerging technologies, a conceptual design phase should be implemented. The conceptual design of a complete system could be prepared over two years in Fiscal Years 1984 and 1985 for an approximate cost of $300,000 (see schedule). Specific tasks in the conceptual design would include the following: 1) definition of functional requirements, 2) definition of performance specifications, 3) selection of the system configuration which best warrants development, 4) locating and filling knowledge gaps regarding emerging technologies, 5) determination of operational capability of the system, 6) generation and analysis of cost/benefit ratios, and 7) preparation of preliminary cost and schedule estimates.

Conceptual Design Phase Schedule



Recommendations

Based upon the support of Aviation and Fire Management Directors at the national meeting in Albuquerque in February, 1983, and the commitment of the USDA Forest Service to keep abreast of the emerging technologies for use in fire management, it is recommended that a conceptual design phase as outlined be undertaken. The strawman system configuration outlined in the study serves to illustrate what can be designed with technologies that currently are under development and that will have matured to the extent that they will be available by the late 1980's. Succeeding phases could involve preparing a detailed plan for engineering design, costs, schedules, and implementation.

ABSTRACT

The National Aeronautics and Space Administration/Jet Propulsion Laboratory and the United States Department of Agriculture Forest Service completed a feasibility study that examined the potential uses of advanced technology in forest fire mapping and detection. The current and future (1990's) information needs in forest fire management were determined through interviews. Analysis shows that integrated information gathering and processing is needed. The emerging technologies that were surveyed and identified as possible candidates for use in an end-to-end system include "push broom" sensor arrays, automatic georeferencing, satellite communication links, near-real or real time image processing, and data integration. Matching the user requirements and the technologies yielded a "strawman" system configuration. The feasibility study recommends and outlines the implementation of the next phase for this project, a two-year, conceptual design phase to define a system that warrants continued development.

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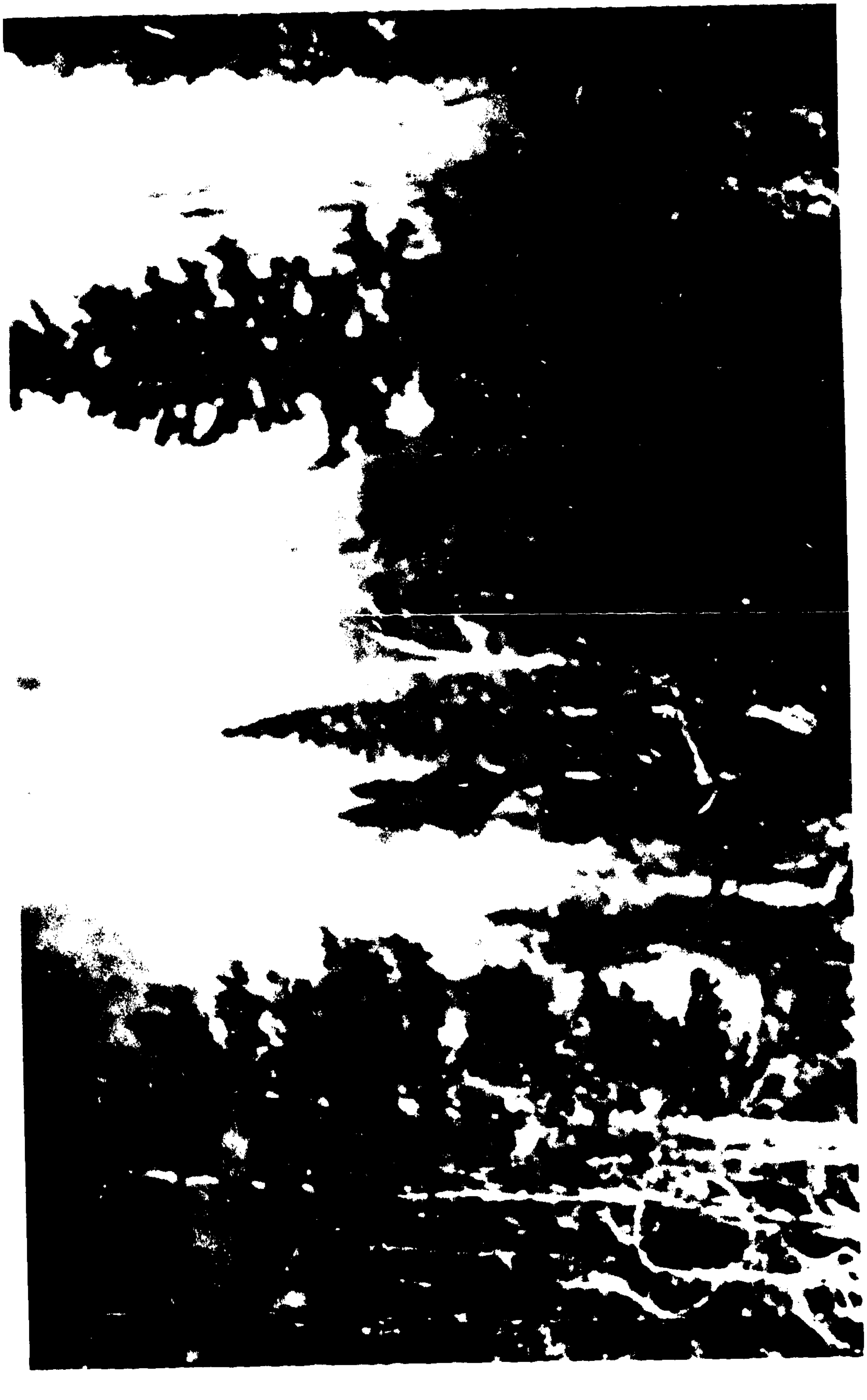

A Typical Fire Storm.

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SECTION 1

INTRODUCTION

Forest fire suppression and management is a complex operation involving trained professionals in many disciplines. A variety of equipment is commonly used, ranging from shovels, pulaskis, and other hand tools to infrared (IR) reconnaissance systems, extensive communications systems, automatic meteorological stations, and computerized fire spread models. As technology becomes available, it is applied, where appropriate, to aid fire management staff manage and suppress fires. It is essential to continue researching and developing new technologies and methods for detecting and monitoring a fire and, when a fire escapes, for mapping to minimize the loss of natural resources, property, and lives.

This document reports the results of a joint National Aeronautics and Space Administration (NASA)/United States Department of Agriculture (USDA) Forest Service sponsored feasibility study to evaluate the application of NASA/Jet Propulsion Laboratory (JPL) technology to forest fire detection and mapping.

1.1 BACKGROUND

The current task resulted from a long history of research and development activities conducted by the United States Department of Agriculture Forest Service in airborne infrared forest fire surveillance, which began with project FIRESCAN [1]. The first research, airborne, infrared line scanner was acquired by the Forest Service in 1962, and research studies were initiated to examine the physical problems of detecting very small heat radiation sources obscured by timber canopy and rugged terrain. Additional items were examined to study and define performance requirements of infrared hardware, to develop optimal fire patrol strategies, and to examine the cost effectiveness of airborne infrared fire detection. Cooperative studies between the USDA Forest Service and the Department of Defense were conducted to examine problems of common interest, to gain access to state-of-the-art equipment, and to augment research funds. In the fall of 1962, the fire mapping capability was discovered. The project soon divided its effort into two independent but technically overlapping fire surveillance capabilities: fire detection and fire mapping.

From 1964 to 1966, a fire-mapping crew was detailed to the FIRESCAN project to expedite development of fire-mapping operational procedures. The fire-mapping system was transferred to the Division of Fire Control in 1966. The system provided a badly needed fire intelligence capability but did not have optimal performance.

The technical requirements for detecting small fires over large areas of terrain were much more difficult to meet. Nevertheless, by 1970 a very sophisticated fire-surveillance system was developed with the capability to patrol 2,000 square miles per hour and to detect small fire targets with high probability. This system also had improved fire-mapping capabilities [2].

The fire surveillance system was operationally tested in 1971 and 1972 with marginal success. In retrospect, the airborne forest fire detection system was conceived of as a strategic fire detection tool rather than a tactical mapping tool. It was designed to have a large payoff in dollar terms or in reduction of numbers of escaped fires. The hardware and operational procedures were developed accordingly. However, fire detection has traditionally been a tactical fire control operation--a fire starts, is detected and initially attacked by fire control personnel. The resources and plans for implementing a new strategic fire detection system proved to be prohibitive.

By 1974 procedures and skill in using the IR mapping equipment were developed, and provision was made to transfer all technical responsibilities to the Aviation and Fire Management located at Boise Interagency Fire Center (BIFC). The fire detecting capability is now available nationally and is used in critical fire danger situations.

The ability to deliver timely IR fire information to fire management personnel has continued to be a serious problem. Image transmission, processing, storage, and display systems using the latest technological advances must be identified and evaluated to meet the critical challenges facing the USDA Forest Service.

In use today are two surveillance and mapping systems, a Texas Instruments RS-7 scanner mounted in a Beechcraft King Air and a modified Texas Instruments RS-25 scanner mounted in a Sweringen Merlin Aircraft. The two systems are based at the Boise Interagency Fire Center.

Obsolescence, coupled with the increasing difficulty in maintaining the scanner units for operational readiness, presents serious problems for the USDA Forest Service. Replacement parts for the units are difficult to find and in some cases have to be custom made. As an interim measure to remedy this situation, a joint effort, the Fire Logistics Airborne Mapping Equipment (FLAME) project, was initiated between JPL and the USDA Forest Service to update the electronics components within one of the line scanning systems. The updated system has a proposed life-cycle of up to 10 years, at which time replacement units may be needed if airborne forest fire detection and mapping are to be maintained.

1.2 FUNDING

The technology generated by NASA programs is an important national resource with great potential. By congressional mandate, one of NASA's tasks is to promote the reuse of aerospace and other technologies by assisting potential users in identifying new ways to employ such technology and assisting them in the transfer process. It is the commitment to technology utilization that led NASA to co-sponsor this study.

Funding for this feasibility study was provided by the Technology Utilization and Industry Affairs Division at NASA Headquarters in Washington, D.C. [3]. The funding was used to support technical, administrative, and management personnel at JPL as well as travel needed to gather user requirements. The USDA Forest Service contributed t· :hnical personnel and expertise to advise and provide direction for the task.

1.3 PURPOSE

The purpose of the phase 0 study was to determine the feasibility of designing and implementing a forest fire detection and mapping system based upon the technology that will be established and available by the 1990's and to assess the expressed needs of the USDA Forest Service in forest fire management. Such a system should meet the following preliminary requirements:

1. Significant improvement in data availability and analysis over the system currently in use;

2. Significant improvement in fire imagery georeferencing and the ability to quickly locate points of interest in the imagery; automatic methods of georeferencing may be indicated here;

3. Improved system reliability and maintainability over the current system;

4. Reduced overall costs through modular design and adaptability to alternate uses.

1.4 APPROACH

Identifying and defining bounds for the forest fire detection and mapping problem were crucial to insure proper direction for this study. (The fundamental approach to this task is shown in Figure 1.) To do this, the information needed by fire personnel in the detection, on-going fire, and mop-up activities had to be presented in clear and concise terms. Information regarding tactical fire suppression could best be obtained from the participants and line management directly involved. To this end, the national and regional offices of the USDA Forest Service were visited. Canada, like the United States, has similar management information requirements with respect to fire suppression; consequently, the forestry agencies in Canada at the federal and provincial level were included in the survey of user needs. Appendix A includes the contacts for each agency visited.

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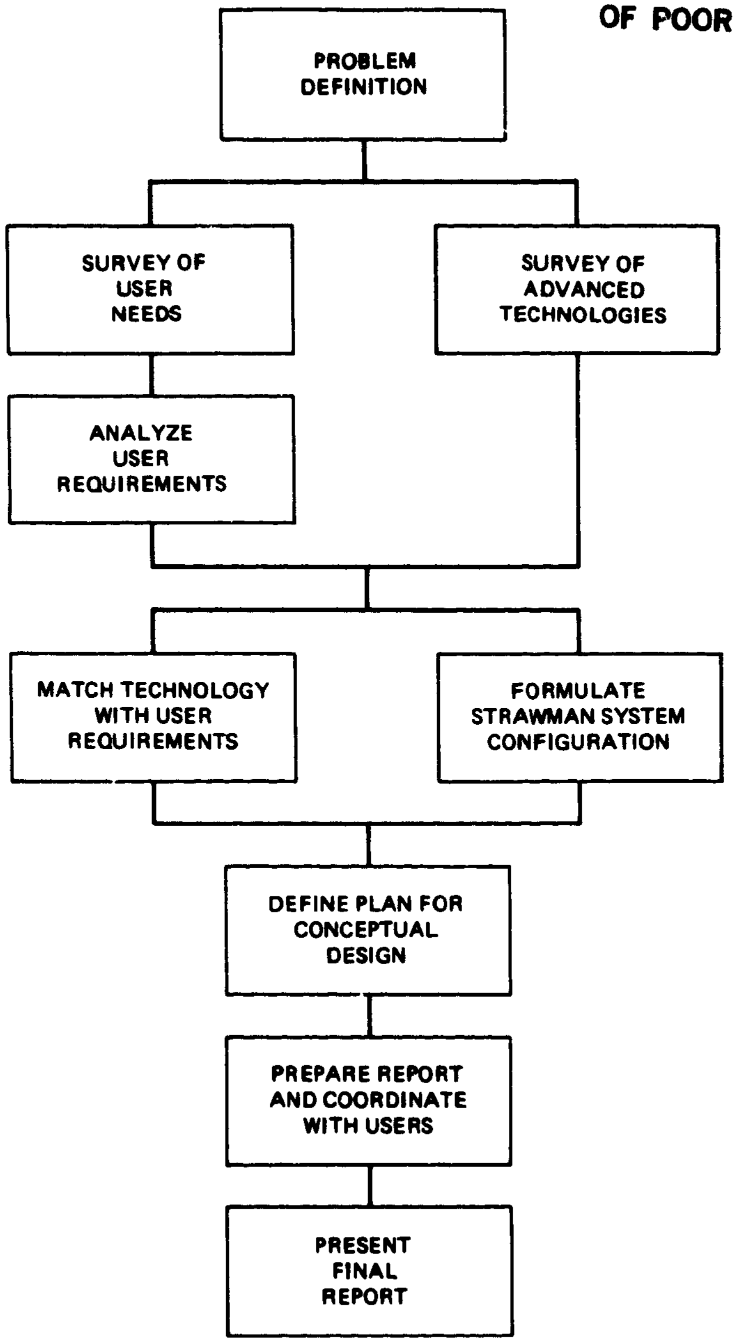

Figure 1. Approach of feasibility study.

SECTION 2

SURVEY OF USER NEEDS AND ADVANCED TECHNOLOGIES

2.1 USER REQUIREMENTS

In understanding the information needs of the user community, several significant points were noted. User requirements for information are stated in terms necessary for fire management and suppression activities. These requirements include information about the following:

1. Fire location and intensity;
2. Current fire behavior, at any given moment, within reason;
3. Predicted fire behavior;
4. Resources available to manage or suppress the fire.

All information must be timely in that the earlier the information is received, the greater the possibility for formulating appropriate management decisions and the larger the number of management alternatives.

2.1.1 Fire Location and Intensity

In managing and suppressing a fire, fire management first needs information about the location and intensity of a fire. Specifically, what is out there: Is a large fire burning or a small fire just getting started? Do holdover fires remain? And where is the fire? Specific locations of the perimeters of both the fire and hot spots ahead and behind the advancing line are needed. This necessarily requires incorporation of general map data.

2.1.2 Current Fire Behavior

A variety of information is needed to ascertain what a fire is doing. These types of information might include the following:

1. Speed of advance or retreat;
2. Fuel type being consumed;
3. BTU output of the fire, which is related to fuel type and moisture;
4. Inhabited areas being threatened;
5. Factors influencing what the fire is doing such as wind speed and direction, relative humidity, and temperature.

2.1.3 Predicted Fire Behavior

Short range forecasts and the forecasts for the remainder of the fire campaign are critically important to suppression activities. Not only do weather factors influence fire behavior, but ambient air temperature can greatly affect the performance and endurance of fire crews out on the line. The prediction of fire behavior is dependent upon the weather, fuel types in the path of the fire, and terrain.

The consideration for weather factors includes relative humidity, temperature, and wind speed and direction.

Combustible materials in the path of the fire greatly influence the rate of spread and the intensity of the burn. Related to the intensity are the fuel types, volume of each fuel type, and moisture content of each fuel type.

An important parameter influencing a fire's behavior is terrain. Individual elements of terrain include elevation, slope aspect (direction in which a slope faces), and, of particular value to the fire strategist, slope gradient (or steepness of slope).

To help the fire boss estimate the fire's behavior, rate-of-spread models utilizing fuels, terrain, other data bases and dynamic weather information could be incorporated into the analyses.

Particular attention must be paid to the urban interface. Because such high value is often placed on structures and associated human safety, there must be sufficient time to obtain and organize suppression resources to insure adequate protection.

2.1.4 Resources Available

The fire personnel must have at their disposal information regarding where the resources are, their availability to fight the fire, and when they can be in place. Such resources might include crews, ground equipment, and aircraft support.

Weather factors must be known because of their impact on air operations and crew safety and performance. Fuel type plays a large role in determining the method by which the fire is attacked and the resources necessary to suppress it. BTU output must be known in order to make best use of fire retardants. The fires that are extremely hot are little influenced by retardants.

Access to a fire is critical to suppression. If there are many roads in the immediate area, then it may be relatively easy to preposition and stage crews and equipment near the fire. Limited access areas generally require air support. Such support requires adequate scheduling and notification.

Given the available resources and knowledge about the fire, a decision then has to be made to either control, confine, or contain each wild fire. Prescribed fires must be monitored to assure that they are within prescription.

Cost/benefits must be examined in near-real time. Many areas have management direction which is available to determine the need for suppression activity. Whether a fire is burning under a prescription or not, surveillance and projection of the fire's future are essential.

2.2 POSSIBLE TECHNOLOGIES

A variety of advanced technologies available in the 1990 time frame could be slated for an advanced fire detection and mapping system. The available technologies may include the following:

1. Sensor platforms;
2. Line and area array sensors;
3. Georeferencing systems;
4. Advanced satellite relay communications;
5. Integration techniques for existing and distributed data bases;
6. Image data processing techniques.

2.2.1 Sensor Platforms

Because satellites are stationed at altitudes much higher than aircraft, they have the ability to cover large areas rapidly with less extreme viewing angles. However, because of the altitude, it is difficult to achieve a high spatial resolution. Either more detectors are required in the instrument focal plane, or more highly powered optics are needed. Satellites also travel in predefined orbits which often preclude coverage of a given target for any given time. Such coverage could be achieved with a geosynchronous orbiting station, but the requirements for spatial resolution could not be met. Because of potential cloud obscuration, it is frequently necessary to fly under the cloud deck to image a target, in which case a satellite platform would not be a viable option.

NASA has flown U-2 aircraft at 65,000 feet to perform color IR photography for a variety of applications, including pest/disease survey [4]. From that altitude, very large areas can be covered in short order. However, the U-2 aircraft are few in number and not necessarily available when needed for an operational task such as fire management.

Sensor platform selection is driven primarily by cost. Cost/benefit analysis will most likely be necessary in determining the final sensor platform. The selection of a high speed aircraft will not adversely influence the overall performance of the faster, more responsive sensor systems of the 1990's. Faster, more responsive sensor systems will be compatible with even faster aircraft than those now in use.

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2.2.2 Line and Area Array Sensors

Currently, the sensing method is infrared line scanners that use a single or dual element detector. The field of view is rapidly swept across the flight line in a direction perpendicular to the aircraft's axis (which is not necessarily the direction of aircraft motion). The scanning mirror must move fast and must be rigidly supported to produce good images. Thus, line scanners tend to be massive. An improvement would be to use detector line arrays, which would sweep out "push broom" images. The line array is oriented perpendicular to the aircraft axis, and each detector traces a separate line on the ground (see Figure 2).

At JPL, a more advanced concept is now being tested in aircraft flights: the use of area arrays in "push broom" imaging. The Airborne Imaging Spectrometer (AIS) uses a 32 x 32 array of detectors sensitive in the 1.2-2.4 micron range [5]. There are 32 detectors in the image focal plane giving 32 spatial locations on the ground (see Figure 3). For each of these, there are 128 spectral bands available. Thus, one can get images 32 picture elements wide in any of 128 wavelength bands. The high degree of spectral information available with AIS is not anticipated to be of direct importance to fire detection. However, the use of area arrays to provide imaging capability over several wavelength bands simultaneously may be of considerable value. The AIS efforts could complement the design team work in subsequent phases of Forest Fire Advanced System Technology (FFAST).

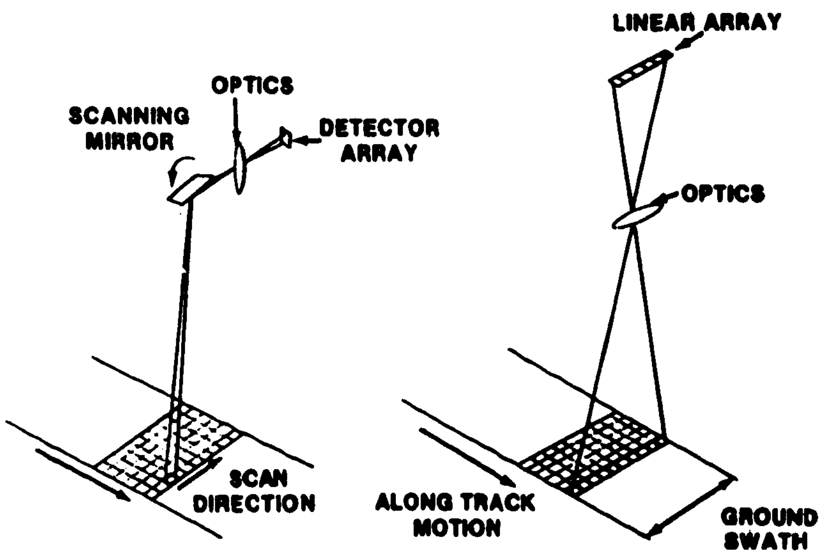

Figure 2. Sensing methods of the line scanner currently in use and an advanced pushbroom scanner. Note lack of mirror in the "push broom" design.

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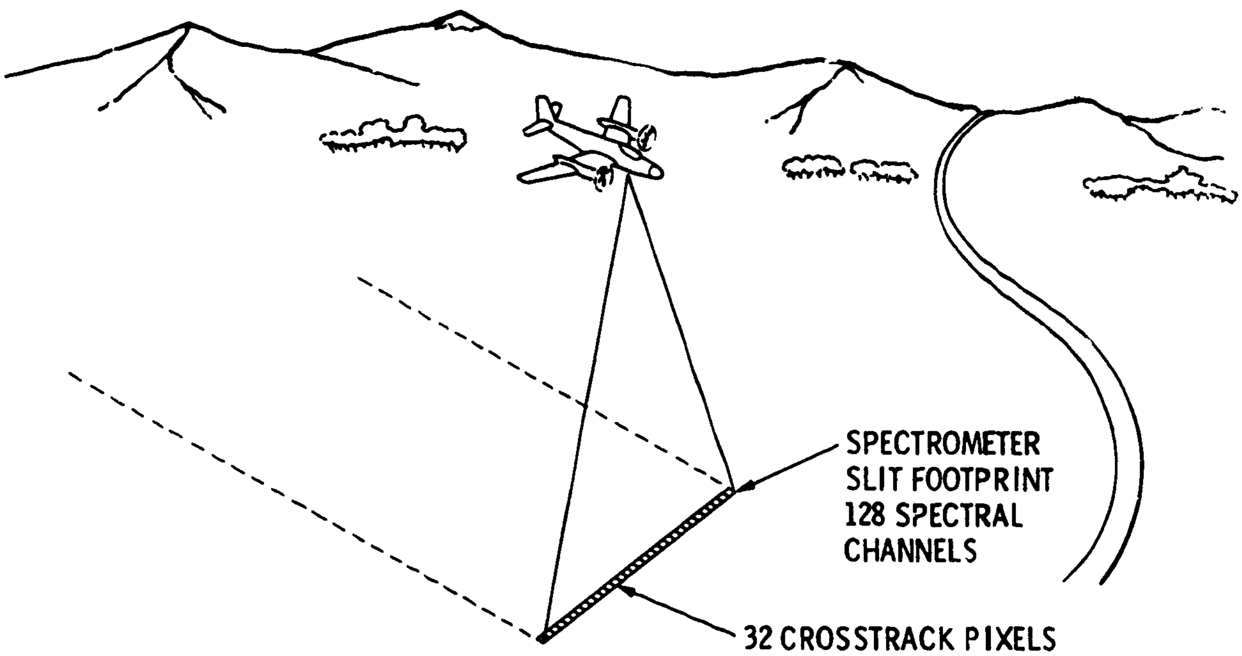

Figure 3. Airborne imaging spectrometer, "push broom" geometry.

Currently, activity is very high in solid-state sensor development. Most of this activity results from real and anticipated military needs. Since the FFAST task is oriented toward the 1990 period, it will be necessary to consider the likely state of the art in the late 1980's. The instruments under discussion here will necessarily be operational and not merely research tools, so it is important to make conservative estimates of future capability.

At present, rather impressive performance is available from silicon charge-coupled devices (CCD's). Pixel arrays of 800 x 800 are being used on the Galileo mission to Jupiter. These have quantum efficiencies near 80%, an intensity accuracy of 1%, and a response out to 1.1 micron (near infrared). CCD's are already capable of replacing film in applications where fields of view are small (several degrees). Large images can be built up with CCD's, and high spatial resolution, the principal advantage of film, can usually be achieved.

The spectral region between 1 and 5 microns of the electromagnetic spectrum is served at present by several developing technologies that include such materials as indium antimonide (InSb), mercury cadmium telluride (HgCdTe), platinum silicide (PtSi), and palladium silicide (PdSi). Both linear and area arrays have been fashioned from these materials. Cut-off wavelength can be tailored in HgCdTe to exclude the thermal IR region if desired. One could expect similar performance from detectors for 1-2.5 microns and for 3-5 microns. Cooling with liquid nitrogen is typically necessary for optimum performance.

The InSb linear arrays of 128 and 512 elements are being made with a multiplexed readout structure (see Figure 4). In scanners, these will produce images of TV-quality resolution. Area arrays have been made up to 32 elements x 32 elements. Approximately the same sophistication exists for HgCdTe, which has somewhat less stringent cooling requirements. It is unclear which detector material will be favored at the end of the decade, but it is safe to assume that area arrays offering TV-quality imaging will be available out to 5 microns.

Existing scanner-type devices producing TV-compatible imagery in the near IR include rotating mirror systems employing single-element HgCdTe detectors and pyroelectric vidicons that operate at room temperature. For some fire-fighting tasks, these have proven valuable and will continue to be of value. The new arrays will probably replace the detectors now in use in a way that is transparent to the buyer and user.

Airborne line scanner technology will probably evolve to make use of many element line arrays, eliminating the need for scanning mirrors. Even now, butting several 512 element arrays together could equal the spatial resolution of the IR line scanners that use one detector.

Infrared detector array technology is the least advanced for those devices sensitive in the 8-12 microns atmospheric window. HgCdTe seems to be the most developed material with linear arrays of 32 elements having been constructed and operating at 77 kelvin with the aid of liquid nitrogen. There is great interest in these detectors, partly because of the existence of the 10.6 micron CO_2 high-powered laser, and much progress is expected by 1990. Certainly we may anticipate that line arrays can be used in airborne scanners. Area arrays are being planned in HgCdTe, tailoring the cut-off wavelength to the 10 micron region and employing technology similar to that used for near-IR cut-off HgCdTe arrays.

In the microwave region, detection techniques are rather different. Antennas are used rather than optics, and spatial resolution is greatly reduced for a given optic (antenna) diameter, relative to the IR. There is no array technology so that images must be built up from scanning, much as the current IR scanners operate. Passive microwave detection is advancing in sensitivity and sophistication at a rapid rate, however; by the late 1980's it may prove feasible to get rough images containing fuel moisture information [6].

Thermal infrared sensing of forest fires and related hot spots is performed in the two prominent atmospheric transmission windows at 3-5 and 8-12 microns. Reflected solar radiation largely can be ignored in the 8-12 micron range but not always for the 3-5 micron range. During the day, highly reflective rocks can produce strong glint near 3 microns. The radiance in the 3-5 micron band is a much stronger function of temperature than at longer wavelengths for hot sources below about 200°C. That means greater contrast exists in the shortwave band. Consequently, if both bands are used simultaneously, hot spots smaller than an instrument's field of view can be detected by comparing the brightness temperatures in the two bands. If there is a mix of temperatures in the field of view, the shortwave channel will always read a higher temperature. This principle is used in current IR airborne scanners and will continue to be an important feature of thermal IR detection systems.

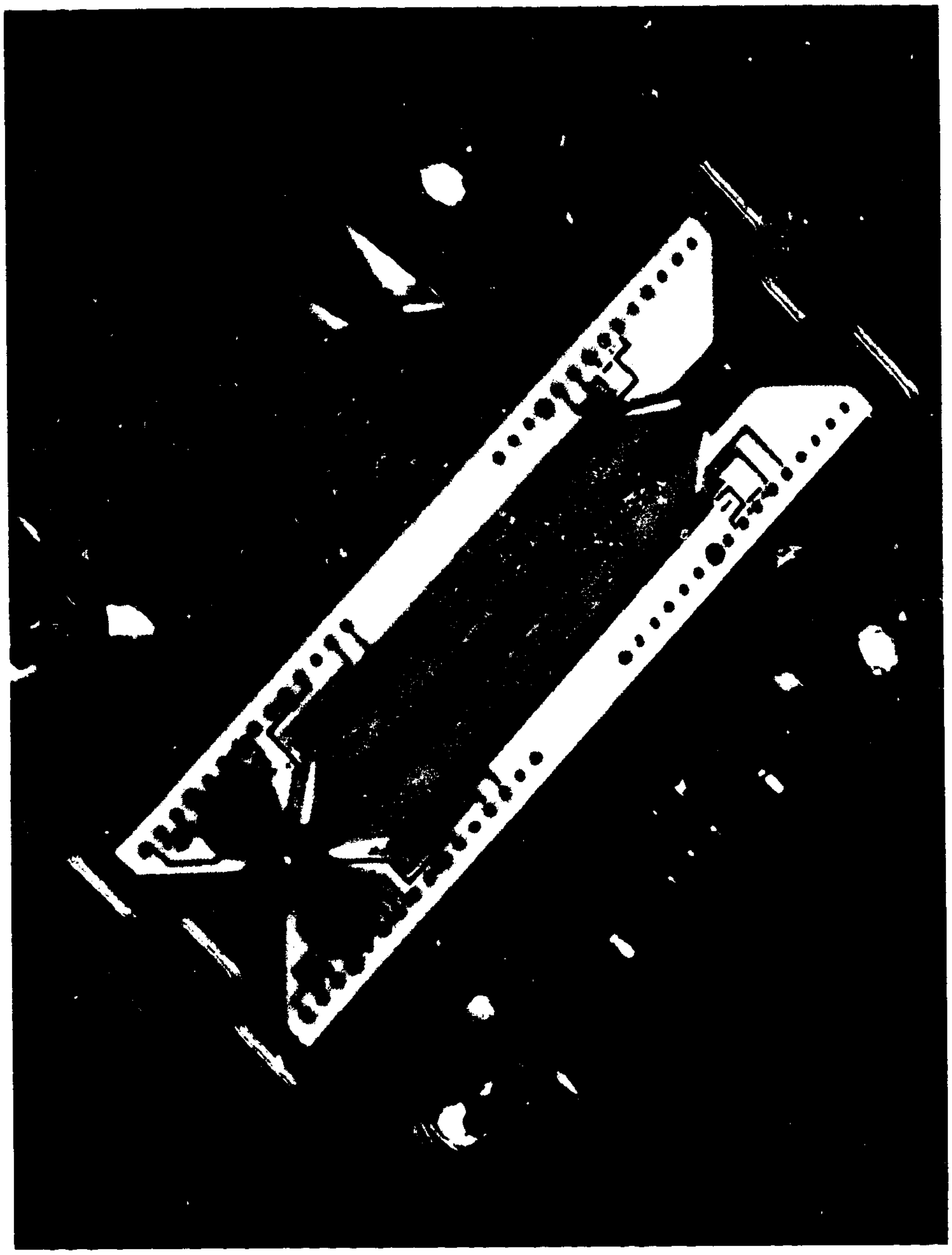

Figure 4. The 512-element linear array of InSb detectors. This 512-element linear array of InSb detectors, made for JPL by Cincinnati Electronics, was developed as a follow-up to the detectors designed for the Galileo mission to Jupiter. Arrays like this one will replace scanning mirror systems and improve sensitivity in many imaging applications.

Hand-held IR viewers operating in both 3-5 and 8-12 micron regions have been found useful for several fire-fighting tasks. They can detect hot spots and fire zones by penetrating smoke and haze, giving the fire fighter and mop-up crew a powerful tool. However, trying to transfer the thermal information to maps can be frustrating, both because the ground is obscured in the visible portion of the spectrum and because the thermal view of terrain offers few familiar landmarks. The latter characteristics are also applicable to the output of airborne IR scanners.

The near-IR region between 1 and 2 microns offers several possibilities relevant to forest fire detection and mapping. In daylight, the surface looks much the same in this spectral range as it does in the visible. However, because of less scattering, penetration of haze and smoke is improved. A near-IR viewer could aid airborne firefighters dealing with active fires (as opposed to holdover fires that warm the surface by only a few degrees).

Although the shortwave region is inaccessible at night, combined near- and thermal-IR viewing may make possible better daytime fire mapping. The shortwave data can eliminate reflective "glint" signals that confuse interpretation of daytime thermal images.

The same near-IR region, 1.0-2.5 microns, is of considerable value both to the forest fire fighting community and the pest/disease personnel because of the presence of surface moisture information in the spectrum. The entire range is dominated by the influence of strong water bands at 1.4 and 1.9 microns. The bands are much broader for water in the liquid phase as in plants, than in the gaseous phase, as in the atmosphere. Water abundance in plants, and even in dead surface material constituting fuels, leads to low reflectivity in the affected spectral regions. As the fuel dries and as the vegetation undergoes water stress, the reflectivity increases. This change enables, in principle, a remote detection of fuel moisture, initially relevant to forest fire prediction and also early diagnosis of water stress induced by or leading to pest/disease damage. However, there are severe problems in the use of near-IR spectra for moisture sensing. The changes in reflectance are easily masked by background or foreground spectra (soil or trees) of different character. Shadows can simulate lower reflectance, and different species differ in their normal spectra. Atmospheric conditions also influence spectra. Moisture information will be forthcoming only when differential measurements are made by comparing adjacent spectral bands and perhaps by comparing spectra obtained for different times and areas.

The microwave region offers potential benefits to the forest manager. First, microwave radiation, with wavelengths greater than several millimeters, penetrates smoke and clouds with minimal attenuation. Like the thermal IR, this radiation depends on surface temperature; thus hot spots and fires can be detected. Fuel moisture sensing is possible because there are water absorption bands present in the microwave range [7].

2.2.3 Georeferencing Systems

In forest fire detection and mapping, the many variables associated with fire behavior must be compared and contrasted. Perhaps the most obvious need is the ability to locate fire targets which appear on IR scanner film output with respect to known geographic positions on the ground. Such comparisons can be made if the image is georeferenced.

Georeferencing involves the adjustment of the fire imagery to a standard geographic base which in turn permits comparisons with ancillary data items provided that they are adjusted to that same base. Difficulties lie in obtaining adequate information on how to adjust the image data. Currently, the raw imagery is examined by a trained photo-interpretation specialist. The interpreter identifies common points between the imagery and a map. A grid is composed based on the selected common points and is overlaid on the map and image. Using the manual information transfer method known as "similar squares," the specialist sketches the fire perimeter on the map using the grid as control.

This method of transfer is precise although time consuming. A particularly difficult part of the procedure is selecting accurate common points between map and image and subsequently composing the translation grid. It is the control point selection process and automatic transformation of the data to a common grid that requires advanced technology.

The Global Positioning Satellite System (GPS) has been developed to provide highly precise position, velocity, and time information to users anywhere in the vicinity of earth and at any time. The GPS, when fully operational, will consist of 18 satellites in six orbital planes. These satellites will be at about 20,000-km altitude and will have a 12-hour period with orbits inclined at 55°. The satellites will transmit L_1 (1575 42-MHz) and L_2 (1227.6-MHz) signals. Navigation information, such as the ephemeris of the satellites and clock model parameters, and the system data are superimposed on these radio signals. By receiving and processing the radio signals from the constellation of satellites any GPS user can instantaneously determine navigation information (position and velocity parameters) to an accuracy of about 15 meters in position and 0.1 meters/second in velocity. This radio navigation system is primarily developed for utilization by the Department of Defense. However, there exists a broad spectrum of civil users who would benefit from the system [8]. While a 15-meter positional accuracy will be available from the GPS system, it may not satisfy the requirement of the USDA Forest Service--an accuracy requirement of one road width (defined as a 15-foot-wide road). However, it may permit the 15-meter error data to be automatically registered with the aid of digital terrain models and radar altimetry information.

The satellite receiver system will provide signals from which range information can be obtained and, simultaneously, from which the position and the bias in the clock relative to the fire fighters can be determined.

There are a number of other radio-based navigation systems available such as LORAN-C, OMEGA, INS, TACAN, TRANSIT. The TRANSIT is probably closer to GPS because it is als itellite based; however, the accuracy degrades in between orbits. GPS provides ∖ same accuracy globally. In other systems, the errors can be large.

2.2.4 Advanced Satellite Relay Communications

A satellite placed in equatorial orbit at an altitude of 22,300 miles will have an orbital period of 24 hours. It will, therefore, appear stationary from any point on earth. Such satellites are called synchronous or geostationary. There are several commercial and special-purpose geostationary satellites now in orbit.

Earth stations may transmit and receive signals to and from a satellite. The signals may be used to convey voice, video, or other types of information. Typically, two or more earth stations work in a duplex mode (simultaneous transmission and reception) using the satellite as a relay.

The electronic components of the earth station can at present be contained in a small van; attached is a trailer containing a power generator and a dish antenna. Telephone links can be accommodated; thus, two-way communications are established from the remote, transportable station via the satellite to the earth station and into the commercial telephone system. Communications can then be achieved from a remote site in a national forest to any place in the country having commercial telephone service. No physical connections at the remote site are required to telephone or powerlines. The terminal is completely independent and self-contained [9].

Satellite communications from the IR sensing aircraft to a central facility may be available by the late 1980's. On-board data processing could reduce the information content and hence the data bandwidth required for use of commercial satellite services. A tracking phased-array antenna would be used on the aircraft to communicate with the relay satellite and in turn a central facility. From the central facility, additional processing could be performed and the results forwarded via a different satellite link to the mobile satellite terminal located at the fire command post. The latter satellite communications capability is commercially available today. The plane to satellite link will require development [10,11].

2.2.5 Integrating Existing Data Bases

Various data bases at different stages of completion are distributed throughout the USDA Forest Service. Many of these data bases represent information on national forests for land ownership and timber attributes (including volume, type, density and fuel capacity) as well as economics and available resources. It would be beneficial to take advantage of existing data bases, wherever they may reside, in order to provide additional and supporting data for forest fire mapping and detection.

Incompatibility of machines and data base formats makes such an undertaking difficult and costly. Communication networks must be established if the data bases are distributed over a wide geographic area. With the advent of distributed computer systems and networks such as the Forest Level Information Processing System (FLIPS), such a task may be less costly and difficult because a majority of the work will have already been accomplished. The general goal in such a system is to make all programs, data, and resources available to anyone on the network without regard to physical location of the resource (data base) or user. Such a system has the potential for providing favorable price/performance ratio, graceful degradation upon failure, and incremental expansion [12].

It is clear that the trend in computer processing and data handling is retreating from the large central computer to a network of smaller independent but linked computers. Developments in networking software will continue to be strong in the years ahead. Much will be learned about the problems of obtaining and processing data such as fuels data from several national forests and districts to be used in real time with fire rate-of-spread models by fire-fighting personnel.

2.2.6 Image Processing Techniques

Image processing was once the domain of only very large institutions with large mainframe computers. Mini-computers and stand-alone image processing systems with fairly sophisticated functions have recently begun to appear in the governmental and private sectors in significant numbers. The increased use of spatial data, particularly those gathered by remote sensing methods for resource inventory and assessment, brought this about.

Several factors combine to indicate a bright future for digital image processing. A major factor is the declining cost of computer equipment. Both processing and storage units are becoming less expensive. A second factor is the increasing availability of equipment for image digitizing and display. Indications are that costs will continue to decline. Several new technology trends promise to further promote digital image processing. These include parallel processing made practical by low cost micro-processors, the use of CCD's for digitizing and storing during processing and display, and large, low-cost storage arrays. Thus, with the increasing availability of reasonably inexpensive hardware and some very important and interesting applications on the horizon, one can expect image processing to continue its growth and play an increasingly important role in the future [13].

SECTION 3

MATCHING TECHNOLOGY AND USER REQUIREMENTS

The technology survey resulted in a wide variety of existing, fundamental and advanced technologies as well as several promising emerging technologies that may be suited to aid the information gathering necessary to meet fire management needs. These technologies range from standard propeller aircraft used as a sensor platform to automatic georeferencing of imagery gathered by highly advanced multiband area arrays. Space communications networks using portable satellite relay stations coupled with advanced ground data processing may be available in the 1990 time frame. Such technology may well fulfill the information requirements of the USDA Forest Service for fire management. Basic user needs and requirements for information include the need to know the location and intensity of fires and the current and forecasted behavior of fires. These needs can be met with the measurement and modeling of the local and regional environment, the functional use of the technology.

A major concern regarding the practical application of advancing technology to fire mapping and detection is the apparent complexity of the system that could result. Complex technology could affect the performance of the entire fire management system in that a high degree of training may be necessary in order to operate the system and to maintain the system. The reliability of the system may be reduced if this training is neglected. Such complexity is clearly not workable in a tactical situation where major decisions would be based on a system that may or may not be up and working. The design of a system should be approached from the fundamental requirement for a "user friendly" system with reliability and maintainability considerations foremost. The advanced technology must translate into cost savings and improved performance if the system is to meet the information needs in fire management of the USDA Forest Service.

Matching technology to user requirements was completed by comparing the capability of each technology to each user need. As an example, timely information was rated as being very important in fire management, as was the ability to receive the information. Past experience has shown that local radio transmissions are often shadowed in mountainous terrain inhibiting information transfer. A portable satellite receiving station that could be set up in a matter of hours would be a likely solution to this problem.

The portable satellite receiving station derives from existing and well-tested technology. Advanced technology may contribute to a solution of delivering the fire imagery to the local fire camp in a matter of minutes after acquisition. Advanced technology may also assist with significant amounts of on-board processing to produce an image or map that has been automatically georeferenced with the aid of navigational and positioning systems.

The strawman system configuration in the following section serves as a sample of the results of matching technology to requirements.

SECTION 4

STRAWMAN SYSTEM CONFIGURATION

The strawman system configuration as shown in Figure 5 was prepared with regard to future information needs and what emerging and available technologies might be present in the 1990's. The strawman configuration is intended as a device upon which a subsequent conceptual design may be based. Each component of the system is discussed in the following.

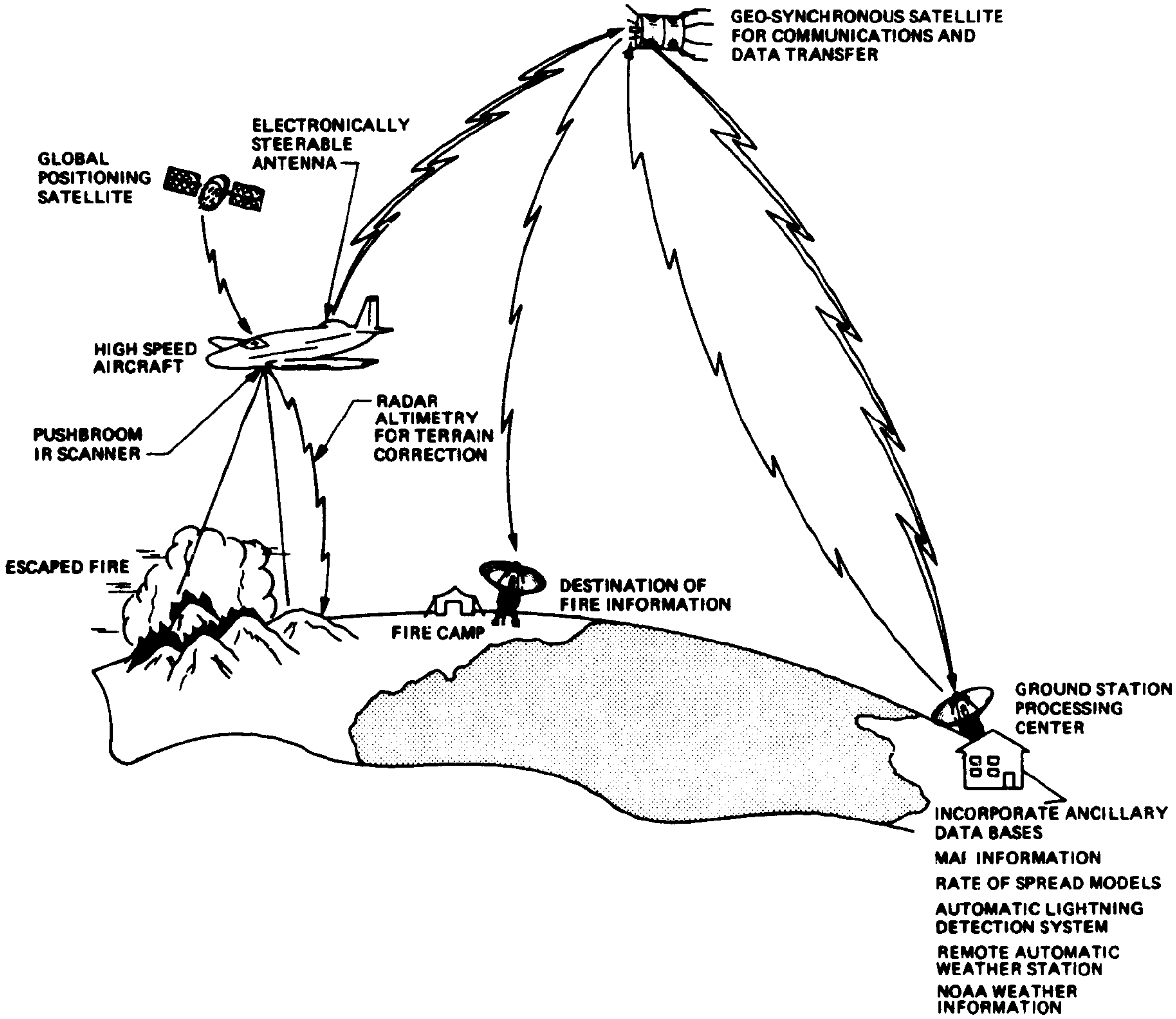

Figure 5. Strawman system configuration (Forest Fire Advanced System Technology--FFAST).

4.1 SENSOR PLATFORM

The likely candidate for a sensing platform will be a turboprop aircraft. Considerations are made here for cost and duty cycle of the aircraft, as well as alternate uses.

4.2 SENSOR TYPE

Using multilinear and area arrays in several wavelength bands will provide basic information on fire and related parameters.

4.3 DATA PROCESSING

4.3.1 On-Board Processing

A variety of functions may be performed with on-board processing. The most significant problem affecting aircraft-gathered imagery is that of geometric distortion. The majority of the distortion can be attributed to aircraft movement during image acquisition. Additional sources of distortion are extreme viewing angles of the sensor and terrain variations which result in non-orthogonal images. A second major problem in acquiring imagery from a moving aircraft is the difficulty in maintaining geographic reference. It may be possible with the aid of inertial navigational equipment, Global Positioning Satellites, and digital terrain models to determine the location of a particular point on the ground accurately enough for Forest Service needs. Current research indicates that advanced computer chips capable of processing large amounts of information in real time or near-real time will be well established and available by 1990. Significant on-board processing may be necessary to reduce the data volume that must be transferred to either a central processing facility or the fire camp.

4.3.2 Ground Processing

To take advantage of archival and existing data bases regarding forest attributes, a variety of processing steps may be necessary at a ground facility.

4.3.2.1 Incorporation of General Map Data. Information contained in standard USGS topographic maps should be used as the convention. Scales at which to display this information would be determined by the conceptual design team.

4.3.2.2 Cost/Benefit Modeling. Information regarding the impending economic loss or advantage could be outlined in a map or graphic form for easy reading. Tables could be generated and updated to show net dollars gained or lost.

4.3.2.3 Fuel Type. Fuel type maps, when available, could be integrated in order to assist the fire boss in prescribing the appropriate action for suppression or management. Information which might be included with a fuel type mapping are fuel volume and moisture control.

4.3.2.4 Fuel Moisture. Information gathered from RAWS would greatly assist in determining fuel moisture by gathering timely meteorological data across a predefined grid.

4.3.2.5 Rate of Spread Models. An important component to fire behavior prediction in the future may be the coordinated use of computer fire rate-of-spread models. Output from developed and well-tested models may be displayed directly on a map facsimile such as a USGS topographic map.

4.3.2.6 Automatic Lightning Detection System (ALDS). Real-time information regarding real and likely fire starts from lightning may be integrated into the processing sequence.

4.3.2.7 Terrain Processing. Information for the United States regarding terrain is available in computer-compatible format. Slope aspect and gradient can be derived from raw elevation points and displayed in map form. Areas of steep slope gradient can be calculated, as well as specific directions of slopes. North facing slopes may contain a higher fuel density than south facing slopes due to the longer water budget cycle.

4.3.2.8 Suppression and Management Resources. Location, quantity, and type of resources available to manage a large fire can be displayed in character and graphic form on a particular map.

4.3.2.9 Sample Output. Figures 6 through 9 depict the sequence of processing steps which might take place in the course of value-added image processing. The sequence of steps entails the initial entry of the thermal imagery into the data base. The requisite maps are obtained, digitized, and readied for input to the computer processor. Common points are selected on an interactive display screen with a trackball cursor by standard photo-interpretation methods and are used to construct a computer deformation grid. The gridded information is then used to geometrically adjust the fire image so that it has a one-to-one correspondence with the map. The final step involves the overlay of the fire image directly on the map base.

Several time consuming steps would be eliminated in the strawman system. These steps would be on the intensive analytic interpretation necessary for selecting common points needed to construct the deformation grid and the digitizing and mosaicking of the fire imagery and map data.

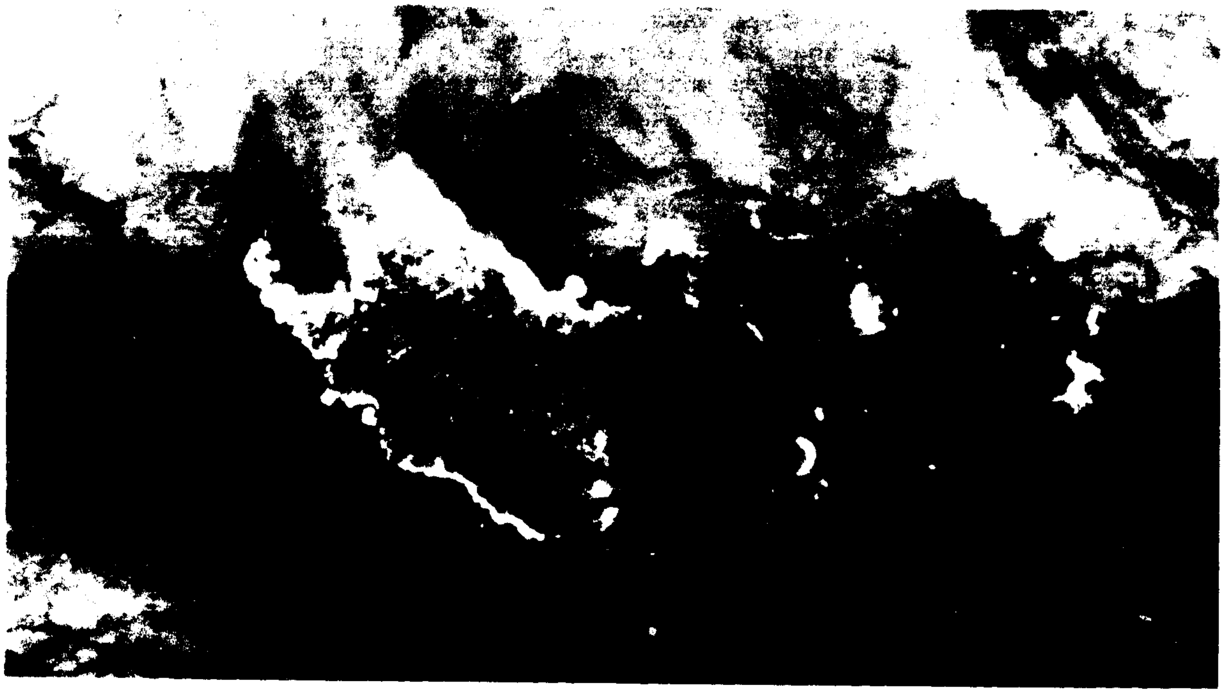

Figure 6. Thermal imagery for Battle Fire, AZ. This thermal imagery of the Battle Fire in Arizona was acquired on May 18, 1972. The image was digitized on a Perkin-Elmer PDS flatbed scanner and formatted for computer processing. Dark tones depict areas of relatively low temperature and light tones depict areas of relatively high temperatures.

4.4 COMMUNICATIONS

Near-real time communication would be accomplished with aid of satellite communication links and highly advanced electronically steerable antennas. The information will be gathered from the ground through the imaging sensor, transmitted via an electronically steerable antenna to a geosynchronous communications satellite, and relayed directly to a ground data processing facility. There, value-added processing would be performed to incorporate fire behavior simulation models and existing data bases. The enhanced data product would then be transmitted directly to the fire camp via the satellite communication link. Voice communication to anywhere in the United States would also be possible.

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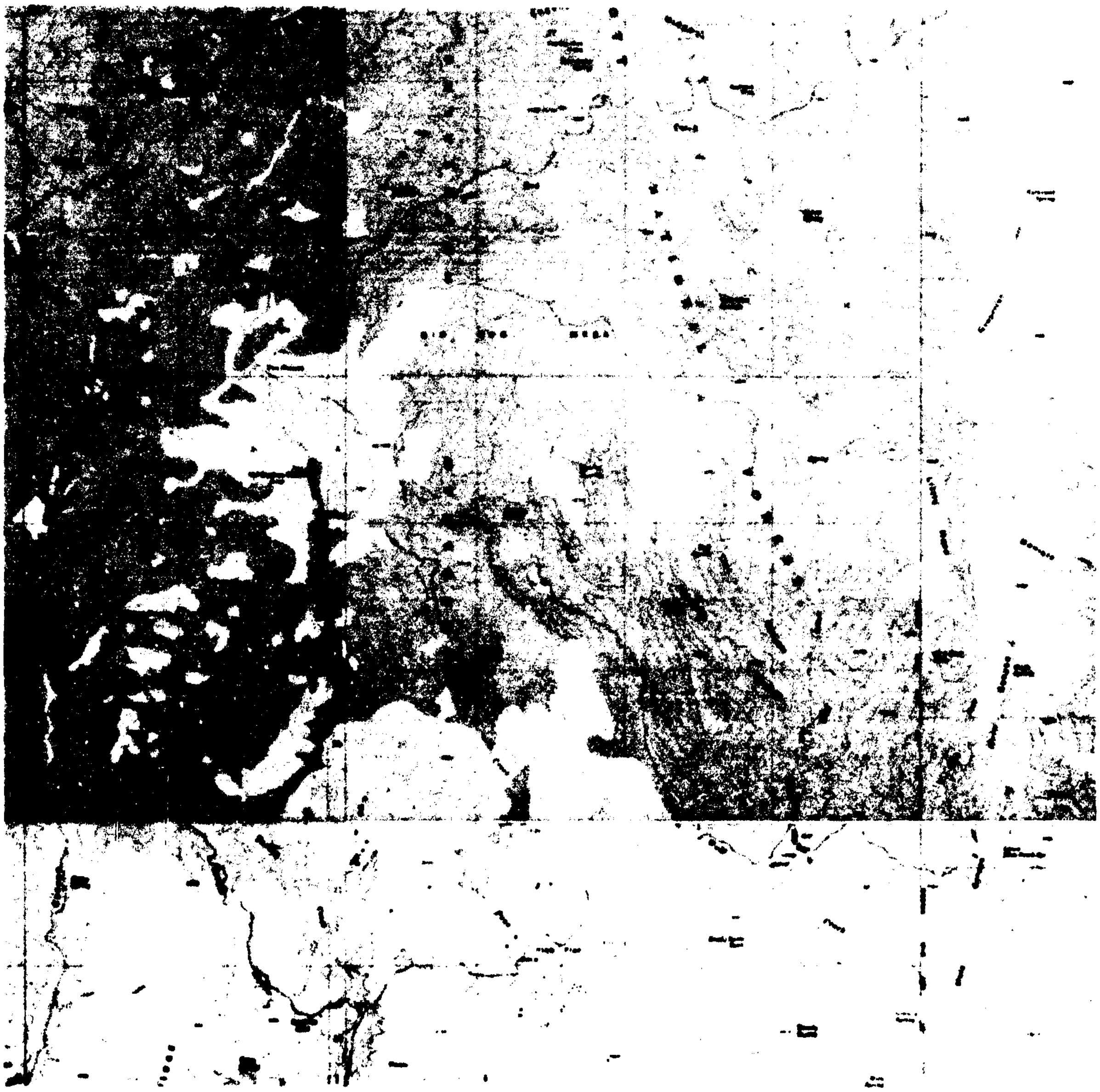

Figure 7. Map base for Battle Fire. The 7-1/2 minute quadrangles which cover the fire area were digitized on a Perkin-Elmer PDS flatbed scanner and digitally mosaicked to provide full coverage. A worst case is shown here where four quadrangle maps are needed to cover the area of interest.

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Figure 8. Thermal imagery for Battle Fire, geometrically adjusted. The thermal imagery was geometrically rectified to the digital map base by using common points selected between the map and image.

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Figure 9. Thermal imagery registered with map base. The thermal image is geometrically rectified and overlaid on the map data base. The sharp brightness difference in the right hand portion of the image is the extent of the thermal imagery coverage.

SECTION 5

CONCEPTUAL DESIGN PHASE

5.1 DIRECTION AND FUNDING

At the February, 1983, Aviation and Fire Director's National Meeting in Albuquerque, the Directors agreed that the Conceptual Design Phase should be accomplished during Fiscal Years (FY) 84 and 85 (see Table 1).

The estimated cost for the conceptual design phase is $150,000 per year for each of the two years. The USDA Forest Service would provide the amount of $75,000 per year and additional funding would be coordinated with interested agencies such as the National Park Service, Bureau of Land Management, and NASA (see Table 2). A suggested participation for each of the nine regions and $12,000 for A&FM, Washington Office (WO) each year was discussed with general acceptance, except for some uncertainty of Regions about any funding being available. The conclusion was that we should proceed and funding would be worked out. Upon completion of the Conceptual Design Phase, the technical report and recommendations, including cost estimates, will be reviewed prior to proceeding into the next phase.

Should the conceptual design lead to detailed design and fabrication, it is envisioned that private industry would participate as subcontractors for supplying components that make up various parts of the total system. Industry would contribute the specialized expertise that results from the privately funded research and development activities. Such expertise may pertain to production processes, both mechanical and chemical, communications problems, and computer hardware manufacturing.

5.2 DEFINITION

The phases of the research, development, test and evaluation cycle are defined in the Advanced Electronics Systems Development Team Missions and Responsibilities document [14]. The conceptual phase is intended to define and select the system which warrants continued development, to identify major uncertainties with recommendations for resolution during subsequent phases, to determine operational capability and characteristics, to provide preliminary cost/schedule estimates, and to examine cost/benefit ratios.

5.3 GOALS

The goals of the conceptual phase primarily will be as defined above, to develop the concept for a total system. The various elements and functions of that system will be reviewed and projections of technology availability made for each. Risk areas and unknowns will be identified. Alternative approaches may be discussed or proposed for additional study where there are high risks or unknowns. At the conclusion of this phase, a viable approach for subsequent phases will be documented.

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Table 1. Conceptual Design Phase Schedule

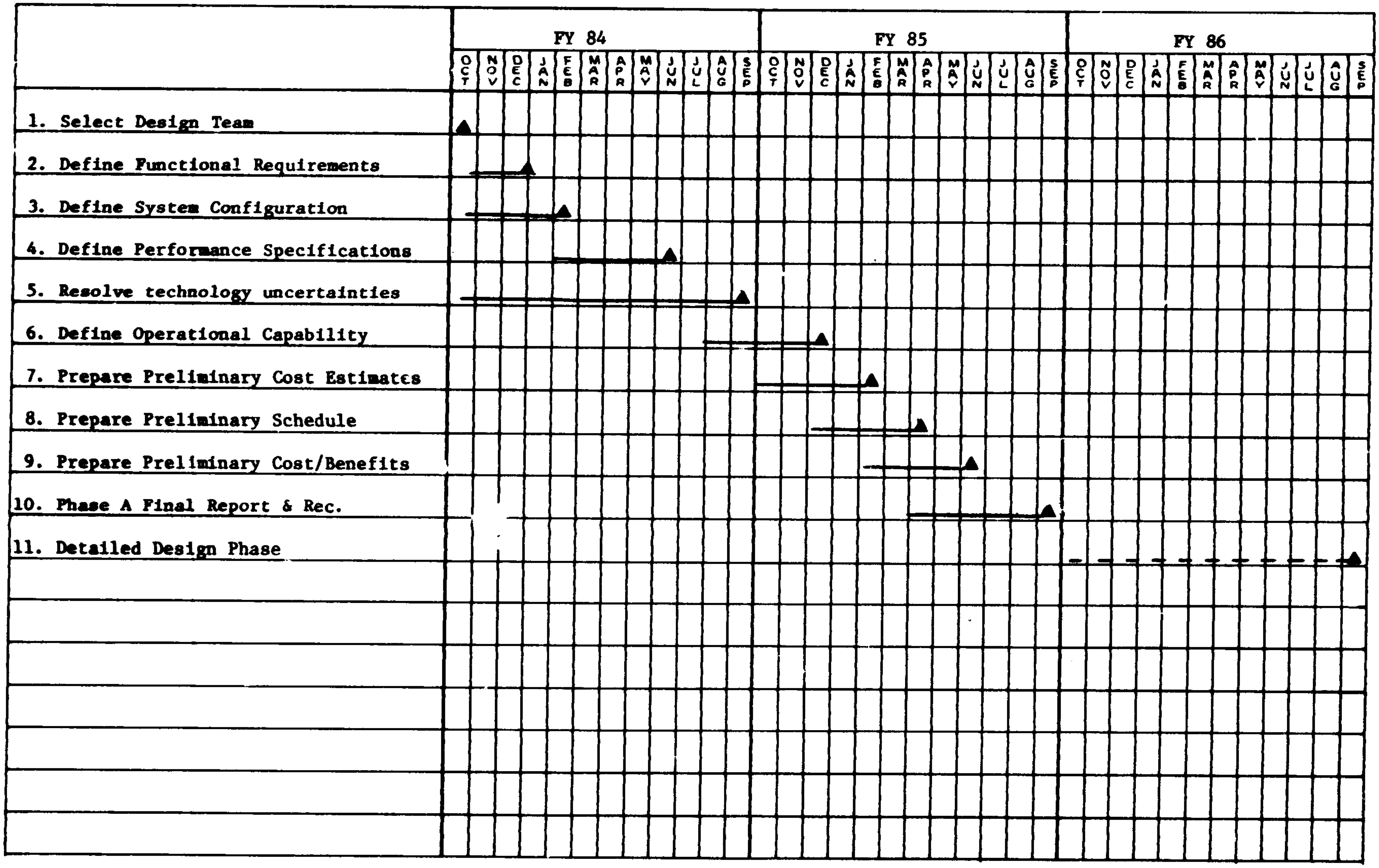

Table 2. Approximate Cost Contributions

Agency	Phase 0 Feasibility Study	Phase A Conceptual Design FY84	Phase A Conceptual Design FY85	Phase 1 Detailed Design
NASA[a]	$ 47K	$ 75K[b]	$ 75K[b]	10%[c]
USDA Forest Service	$ 30K[d]	$ 75K	$ 75K	90%

[a]Technology Utilization and Industry Affairs Division.
[b]Suggested contribution from NASA and other interested agencies.
[c]Suggested percentage contribution to total cost.
[d]Cost incurred as a function of facility use and manpower.

More specifically, the following questions should be addressed during the conceptual design phase:

1. How can the system be modularized to minimize obsolescence and retain capability to use newly developed equipment?
2. What image/digital processing functions can reasonably be done aboard the aircraft and which should be done at a central facility and/or mobile command post unit?
3. What final products are needed by the fire/forest managers?
4. Can the system be made versatile enough for multiple uses (e.g., fire management, insect and disease management, mapping, etc.), through interchangeability of sensor front-ends or multiple band sensors?
5. How can the system provide inputs to existing/developing computer models or utilize existing/developing data bases?
6. What are the milestones, decision points, and general schedule for the succeeding phases?
7. What technologies will be available in the late 1980's, and which should be considered for application?
8. What are the communications needs, and what methods and systems should be used?
9. What contributions (fiscal, technical) could be made by Canada or other cooperating agencies in succeeding phases?

10. What institutional (regulatory, political) issues may be encountered (e.g., frequency allocations)?

11. What system design is recommended for further development?

12. What type and how many aircraft will be needed/available?

13. How should we schedule and phase-in the advanced system?

14. What are the cost/benefit ratios associated with an advanced system?

5.4 DESIGN TEAM

The design team will be composed of John Warren, Electronics Engineer, Advanced Electronics Systems Development Group Leader, A&FM, and members of the Jet Propulsion Laboratory technical staff. Led by Ron McLeod, JPL personnel will provide the specialized expertise in the variety of technical disciplines explored and developed. The team will consult with various Regional Aviation and Fire Management Directors from time to time to obtain user guidance. Coordination will also be maintained with interested Canadian National and Provincial Fire personnel, Research, and other agencies as appropriate. Overall guidance and direction will be provided by John Chambers, Assistant Director, A&FM, WO. The team will prepare an annual report for review at the National Aviation and Fire Management Directors' meetings and interim or specialized reports as needed.

SECTION 6

SUMMARY

In order to assure that the information needs and plans presented here are consistent with the practices of the USDA Forest Service and other agencies, draft copies of this report were sent to those agencies and persons listed in Appendix A for review and comment. A variety of concerns were identified as needed additions and changes to the report. Appendix B includes the correspondence received from the users regarding the suggested changes and additions. As well as the cover letter attached to the draft report, Appendix C includes additional related correspondence.

Planning for the arrival of new technology and the application of existing technology has its obvious advantage. If a two-year planning effort is undertaken that will foresee future develpments, then when those developments mature, the planning process secures a two-year head start and the ability to make use of that technology immediately.

Existing and future technologies promise solutions to fire management information needs. The strawman configuration is a strong possibility and appears feasible. With the current expertise at hand and the benefit of past experience both in fire management and advanced technology, further work in this area is strongly recommended.

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APPENDIX A

AGENCY PERSONNEL INTERVIEWED

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APPENDIX B

CORRESPONDENCE OF USERS REGARDING COMMENTS

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JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
CMS:730/83-950M:mhf

16 June 1983

TO: R. McLeod

FROM: C. M. Stevens

SUBJECT: Review of FFAST Report by NASA/TU

I met with Ray Whitten on Wednesday, 06/15/83, to discuss his comments on the draft report for the FFAST feasibility study. Ray was impressed with the document and had only a few suggestions. The following concerns were identified as needed additions to the document:

1. A paragraph discussing the role invisioned for industry should be included. A brief discussion of who, what and how they would be involved is needed.

2. Copies of the correspondence from users should be included as an appendix.

3. Make a table showing past, present and anticipated future funding incorporating the cost data on page 27.

4. In the interest of clarity, use pie chart format to incorporate information where comparisons are made of funding, RDT&E, user involvement, etc.

Please call me if you have questions concerning these comments.

cc: L. Piasecki
A. Smith

United States Department of Agriculture
Forest Service
Washington Office
12th & Independence SW
P.O. Box 2417
Washington, DC 20013

Reply to 4400

Date May 18, 1983

Ronald G. McLeod
Jet Propulsion Laboratory
4800 Oak Grove Drive, 168-514
Pasadena, California 91109

Dear Mr. McLeod:

Thanks for sending the draft report for the joint NASA/USDA FS sponsored feasibility study. I reviewed it and believe it adequately incorporates or otherwise covers the input we made during our meeting with you and John Warren. We have no concerns you failed to address in the report.

Your report is an excellent reference as to the state of the art and opportunities for advancement. We appreciate your visit and opportunity to comment, and look forward to the final report.

Sincerely,

C. BENTLEY LYON
Staff Fire Control Technologist
Forest Fire and Atmospheric
Sciences Research

Province of
British Columbia

Ministry of
Forests

Ministry of Forests
Protection Branch
1450 Government St.
Victoria, B.C. V8W 3E7

May 18, 1983

File: 720

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California
U.S.A. 91109

Attention: Mr. R.G. McLeod

Dear Mr. McLeod:

Thank you for the opportunity to review JPL Publication 83 - Forest Fire Advanced System Technology, A Feasibility Study. It is an interesting document and I have very few comments to make.

Primarily, I was a little disappointed at the lack of discussion of pest management information needs. Although fire detection and information transfer requirements will have some applications to pest management needs, forest pest problems need further consideration. At our meeting last November I understood that this would be addressed in the feasibility study.

Pest occurrences will also require accurate geographic mapping although accuracy to 15 ft. (3 m) will probably not be necessary. Good estimates of infestation boundaries and intensities will also be required. Growth impact and rate-of-spread models for individual pests are needed. Detection is made more difficult as different pests produce different stress symptoms in affected trees ranging from deformities to outright mortality. A "real-time" capability is not required for pest management due to the time span of their active periods.

Although I realize that many of these concerns are outside the scope of the FFAST study, I would like to see some further discussion of pest management needs within the study. I'm looking forward to seeing further development of this program and again thank you for the opportunity to review the feasibility study.

Yours truly,

Peter M. Hall

Peter M. Hall
Forest Entomologist
Forest Protection Branch

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
324 25th Street
Ogden, UT 84401

5100

Rod McLeod, Task Manager
Forest Fire Advanced System Technology
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

MAY 06 1983

Dear Rod:

Enclosed are my comments on your draft. I have made notations on the copy you sent me. I really have no comments of import; just some minor editorial suggestions. You have done an excellent job.

I hope we can continue to keep in touch. I am very interested in this task and would like to stay abreast of developments as they occur.

Thanks for the opportunity to comment.

Sincerely,

Doug

DOUGLAS M. BIRD
Director
Aviation and Fire Management

Enclosure

6200-11 (1/69)

United States Department of Agriculture

Forest Service

Rocky Mountain Region

11177 W. 8th Avenue
P.O. Box 25127
Lakewood, CO 80225

Reply to 5100

Date May 10, 1983

Mr. Ronald G. McLeod
Jet Propulsion Laboratory
4800 Oak Grove Drive, 168-514
Pasadena, CA 91109

Dear Mr. McLeod:

We have reviewed your enclosed draft report and have made a few minor comments for your consideration.

Thank you for the opportunity to provide this review.

Sincerely,

For JERRY MAUK
Director, Air, Aviation,
and Fire Management

Enclosure

FS-6200-11(8-80)

United States Department of Agriculture

Forest Service

Reply to: 7200

Date: MAY 13 1983

Mr. Ronald G. McLeod
Jet Propulsion Laboratory
4800 Oak Grove Drive, 168-514
Pasadena, California 91109

Dear Ron:

We appreciate the opportunity to review JPL's Phase 0 Report. It was well written and complete. Enclosed is the draft with our suggestions for improvement noted. We look forward to the final report and the decisions necessary at that time.

Sincerely,

John W. Chambers

JOHN W. CHAMBERS
Acting Director of Aviation
and Fire Management

Enclosure

FS-6200 11b (7 81)

United States Department of Agriculture
Forest Service
Regional Office
630 Sansome Street
San Francisco, CA 94111

Reply to 5100

Date June 13, 1983

Mr. Ronald G. McLeod
Jet Propulsion Laboratory
4800 Oak Grove Drive, 168-514
Pasadena, CA 91109

Dear Ron:

In response to your April 15 letter, we have reviewed your Feasability Study for Forest Fire Advanced System Technology (FFAST), and offer our observations for your consideration.

The broad issue of timely gathering, transmitting, processing, display, and applying fire information is a complex one. Your concept is also complex, and ultimately very expensive. To be responsive to fire managers' legitimate needs, it must meet objectives that are not yet clearly defined. The questions you pose on page 28, to be addressed during the Conceptual Design Phase, are a step in defining the objectives. A critical determination is what final products are needed by fire managers? We encourage your team to pursue that base level determination early in the Conceptual Design Phase.

One of the basic frustrations that fire managers experience on major incidents that span several days is how to utilize and apply the wealth of fire intelligence information already available to them in a timely fashion. With the infrared imagery, computer models on fire behavior, fuels and weather, and various other analytical tools presently available, an Incident Commander is still obligated to use intuitive judgment in selecting a suppression strategy in a volatile situation for the next shift, without knowing the actual extent of the success of the current shift's strategy. To wait for more complete information causes unacceptable delays in articulating and reproducing hard copies of the strategy, suppression objectives, assigned resources, and deployed communications equipment. This information is needed by the Operations personnel charged with the suppression assignment for that shift, as well as the Logistics, Safety, Planning, and Finance personnel who must support them in that effort.

In developing your concept, it's worth bearing in mind that more sophisticated methods of gathering and displaying information are of little value unless they lend themselves to easy reproduction into documents that can be distributed to key people at a timely briefing. The timely transition from electronics to usable paper is critical. This transition has been a historical bottleneck.

Mr. Ronald G. McLeod

Another key aspect of the concept is the need for rapid and accurate geo-reference. The emerging geo-loc system offers some potential, but the capability is not yet here. Fire managers involved in the selection of suppression alternatives do not have the time to be making adjustments and corrections in the data they receive.

A usable concept must also minimize the data base development and maintenance chore. We currently lack the capacity to uniformly input and maintain much of the resource data currently available, into existing programs. Fuels data, terrain, fire suppression facilities, and fire history are currently available for virtually all National Forest System lands, but the digitizing of this information for electronic programs that are useful in real time emergency situations has so far proved too formidable for the agency.

These are some observations that you might find useful in development of your final report. They do not directly address the technological aspects of the concept, but rather the practical aspects of application. That perspective is important to your objective of a system that is user friendly, timely, and reasonable to maintain. Within that perspective lies our area of greatest expertise.

Sincerely,

For RICHARD E. MONTAGUE, Director
Aviation and Fire Management

Alberta

ENERGY AND
NATURAL RESOURCES

Alberta Forest Service Depot
10625 - 120 Avenue
Postal Station M, Box 7040
Edmonton, Alberta
T5E 5S9

May 13, 1983

Mr. Ronald G. McLeod
Task Manager
Forest Fire Advanced
Systems Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive,
Pasadena, California 91109

Dear Mr. McLeod:

Thank you for the opportunity to review the joint NASA/USDA Forest Service draft report on forest fire detection and mapping.

The report is very close to the way I see the matter, so very little except a few points can be added.

These are my comments:

Page 6 Section 2.0 User requirements.......
The context of "holdover fire" could be refined. They can be "residual" smouldering heat sources from a previous season or a previous day. They can exist within a large already burned area (wild or prescribed fire) or outside the fire guard of a going fire as smouldering invisible spot fires.

Further, on the same topic, the user requirements have to be met often simultaneously at possibly far distant locations. The alternatives of planning for one or a very limited number of highly versatile systems or a greater number of less sophisticated system may become a consideration.

Also, because of the number of user requirements listed a priorization of requirements seems desireable. Particularly since some requirements can be met by alternate means and not all requirements are important at all times.

Page 15 Section 2.2.2./ Wave length........

The dual wave length or bispectral (or multispectral) approach has definitely its merits but it seems that the current approach leans too much on the assumption that small fires are very hot. Of the over 100 smouldering fires our scanners find each year only a few exceed the ambient surface temperatures by 250°C. Smouldering fires are usually covered with ashes or other insulating substances and the radiation available to the scanner is not unlike the radiation emitted from sun headed rocks, charcoal or other dark substances.

On pages 17 and 22 I noticed some typos which you have likely discovered by now.

On page 28 under subsection 5.2.4. Questions to be addressed......

A question such as:

"What would a fire/forest manager be willing to pay for the services of such a system?"

would add a greater measure of realism to the project.

We are following the development of this project with great interest.

Yours truly

J. Niederleitner, Head
Planning Section

JN/dt

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COUNTRY FIRE AUTHORITY

TELEPHONE 20 2571

All correspondence must be addressed to the Secretary and not to Individual Officers by Name.

MILTON PARADE
MALVERN, VIC., 3144

PLEASE QUOTE
JRB: HJM
(Research Unit)

30th June, 1983.

Mr. Ronald G. McLeod,
Jet Propulsion Laboratory,
4800 Oak Grove Drive, 168-514,
PASADENA, CALIFORNIA 91109.
U.S.A.

Dear Ron,

Thank you for the opportunity to comment on your research project. I apologise for the delay in reply, due to my involvement in fire investigation and reports since the major fires in February, 1983. I have only minor comment to make (pages 6, 7, 8 and 22).

The feasibility study was most interesting, with the operational need to obtain timely and accurate information of a fire's behaviour well set out, and in line with my approach. Our problems here in fire suppression and decision-making are similar, although the concepts you propose would be in advance of what we foresee here in the same time frame, nevertheless our research in remote sensing should be directed along the same lines.

I would therefore appreciate maintaining liaison with you in the research and would be most interested to hear of your future progress in this regard.

Yours sincerely,

J.R. Barber
J.R. Barber
Assistant Chief Officer
in Charge, Research Unit

APPENDIX C

ADDITIONAL RELATED CORRESPONDENCE

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JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91109*

ERA:384-83-RMC37
15 April 1983

Doug Bird
USDA Forest Service
Director - Aviation & Fire Management
Region 4, Intermountain Region
324 Twenty-Fifth Street
Ogden, Utah 84401

Dear Mr. Bird:

Enclosed you will find the draft report for the joint NASA/USDA Forest Service sponsored feasibility study that examines the potential for applying advanced technology to forest fire detection and mapping. The study looks at the information needs for fire management activities as well as exploring future methods of gathering, transmitting, processing and displaying the needed information. The approach to this study was to gather basic data on current and future information requirements by interviewing the professionals involved in fire management activities and analyzing those users' needs so as to prepare a set of functional requirements. In a concurrent effort, future technologies with the potential to meet those needs were surveyed and the result of matching the future technologies with user requirements is presented in a strawman system configuration.

The draft report enclosed is for your review and comment. Please review this draft carefully to insure that our assessment of information needs has been correctly interpreted and presented. Feel free to mark on the draft copy either in the margin or elsewhere. If you feel information has been left out, or too much information is included, please note so.

You may return the draft copy with your comments and corrections up to four weeks after receipt, at which time we will begin incorporating your suggestions. Once your suggestions have been added, we will prepare, publish and distribute the final report.

Telephone (213) 354-4321 Twx 910 588 3269 Twx 910 588 3294 Telex 67 5429

JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91109*

We have been most appreciative of your enthusiasm and response on this task. Keep in mind that your critical review of the draft is very important and we look forward to hearing from you. Should you need additional copies of the draft, please contact Ron McLeod at FTS 792-4994 or Commercial (213) 354-4994.

Sincerely,

John K. Warren
Electronic Engineer
Boise Interagency Fire Center
USDA Forect Service

Ronald G. McLeod
Task Manager
Forest Fire Advanced
System Technology (FFAST)

RMC/df
Enclosure:

Province of
British Columbia

Ministry of
Forests

Forest Service
Ministry of Forests
Protection Branch
1450 Government St.
Victoria, B.C. V8W 3E7

January 11, 1983

File: 780-13

Mr. Gary L. Reisdorf
Technology Applications Manager
Observational Systems Division
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Groove Drive
Pasadena, California
U.S.A.
9109

Dear Mr. Reisdorf:

My staff have advised me of your most recent visit to discuss the FAST PASS system. The potential capabilities of the system would improve our forest fire detection activities, fire control mapping activities and pest assessment and surveillance activities..

We offer our encouragement for this project, as we can foresee benefits in the applications of these technologies to our current and future operational problems.

We would like to be kept informed as to the status of this project and are prepared to offer our comments on future systems design.

Yours truly,

H. G. Doerksen
Director
Forest Protection

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COUNTRY FIRE AUTHORITY

TELEPHONE 20 2571

All correspondence must be addressed to the Secretary and not to Individual Officers by Name

PLEASE QUOTE
JRB:HJM
(Research Unit)

MILTON PARADE
MALVERN, VIC. 3144

12th November, 1982.

Mr. R. McLeod,
Jet Propulsion Laboratory,
4800 Oak Grove Drive,
186-134,
PASADENA, CALIFORNIA 91109.
U.S.A.

Dear Ron,

I was very disappointed to miss your phone call but was pleased that David Nichols was on hand to talk to you.

I have very happy memories of my visit to your establishment and our discussions, which were a valuable part of my overall study tour to America and Canada last year.

I am hopeful that the Authority will approve the Research Unit's participation in your project as requested and I will be looking forward to Mr. Reisdorf's official letter for Authority consideration.

With kind regards,

Yours sincerely,

Jim Barber

J.R. Barber
Assistant Chief Officer

cc: Mr. Ron McLeod
JPL.

JRB:HJM
(Research Unit)
1291 Malvern Road,
MALVERN, Vic. 3144.
Australia.

9th November, 1982.

Mr. Gary Reisdorf,
Task Manager,
Jet Propulsion Laboratory,
4800 Oak Grove Drive,
186-134,
PASADENA, CALIFORNIA 91109.
U.S.A.

Dear Sir,

I was most interested to receive a phone message recently from Mr. Ron McLeod, Jet Propulsion Laboratory, California, regarding Country Fire Authority assistance in your research project relating to remote sensing of fires through the "Advanced Forest Fire Detection Mapping System".

I will be pleased to participate in your research in whatever way possible, but such participation will require initial approval of the Authority. I would therefore appreciate an official letter to the Authority (for attention J.R. Barber) at the above address requesting my participation and setting out the nature of the research, the manner of our participation and the information required.

With kind regards,

Yours faithfully,

J.R. Barber
Assistant Chief Officer
Officer in Charge, Research Unit

END

DATE

FILMED

NOV 25 1983