# 5.3 Airborne and Ground-Based Laser-Induced Fluorescence Imaging

## Technology Need

Laser-induced fluorescence (LIF) addresses the need for rapid survey tools for monitoring sites remotely, identifying contaminant "hot spots," assisting in cleanup activities, and monitoring remedial progress. Future efforts may include verification of site cleanup if regulatory sensitivity can be achieved and verified through field tests. Development and field testing of an airborne survey tool for fluorescence and reflectance signature detection promises area coverage of sites that are either spread out geographically, such as uranium firing sites, or sites that have poor access, such as clay cap areas. The concept of detecting plant stress as an indication of subsurface contamination is an active area of research at a number of federal agencies, as well as many universities. The EPCOT Land Pavilion research and development (R&D) work brings researchers together from many institutions in an effort to better understand and scope the applicability of LIF as a remote sensing tool. Laser-induced fluorescence imaging (LIFI) applications include the detection of: uranium (as uranyl oxides) during Decontamination and Decommissioning (D&D) activities; surficial heavy metals and volatile organic compounds (VOCs) (solvents, polyaromatics, and fuels) associated with landfills; and vegetation stress as an indicator of subsurface contaminant plumes.

## Technology Description

LIF is an optical technique that exploits the detection of fluorescent compounds irradiated with laser light or filtered conventional light sources. Fluorescence is the prompt luminescence of a material caused by an external stimulus — in this case, a laser. When the stimulus ceases, so does the fluorescence. Common compounds which fluoresce include such organics as chlorophyll in plants and hydrocarbon fuels. When uranium is excited by a UV laser, however, its peak fluorescence is persistent (phosphorescent), lasting well longer than the laser pulse. Operationally, the prompt fluorescence of compounds which may mask the presence of uranium can be removed by delaying the activation of a photon detector 60 nsec after a laser pulse. This precise delay ensures the extinction of prompt fluorescence, effectively isolating the presence of uranium.

The scope of this TTP includes a variety of techniques to exploit LIF in several environmental applications, including aerial remote sensing (Figure 5.3-1) and hand-held portable survey tools (Figure 5.3-2) for detecting uranium on surfaces and subsurface contaminants via vegetation stress. This task has required the development of hardware, software, and analysis methods for ground-based and airborne LIFI systems. The current LIFI configurations

include UV and visible laser source (355 nm and 532 nm wavelength), intensified Charged-Coupled Device (CCD) cameras, and video monitors for instantaneous viewing. Video images can also be electronically stored for further analysis and display.

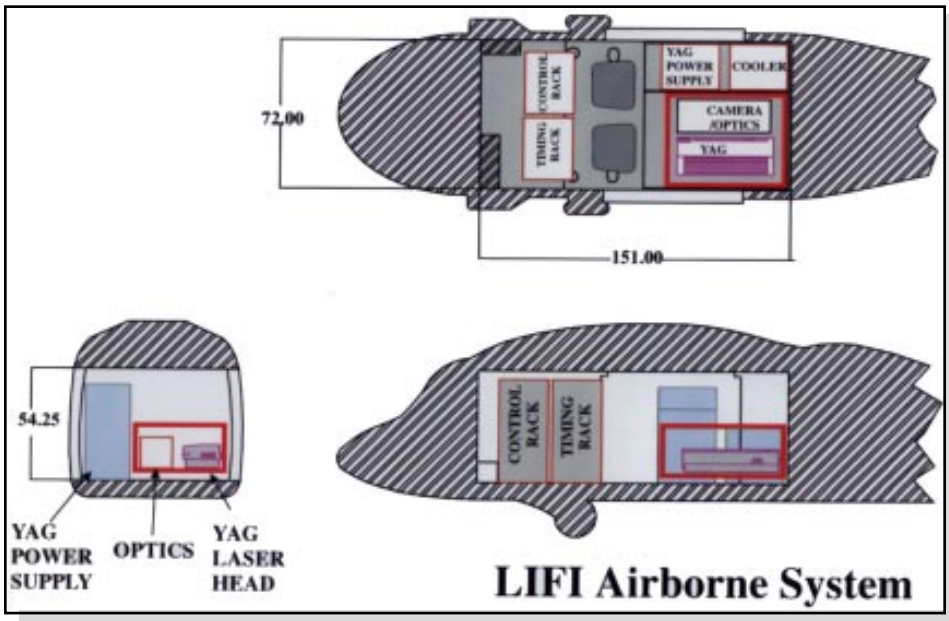


**Figure 5.3-1** Blackhawk Helicopter System

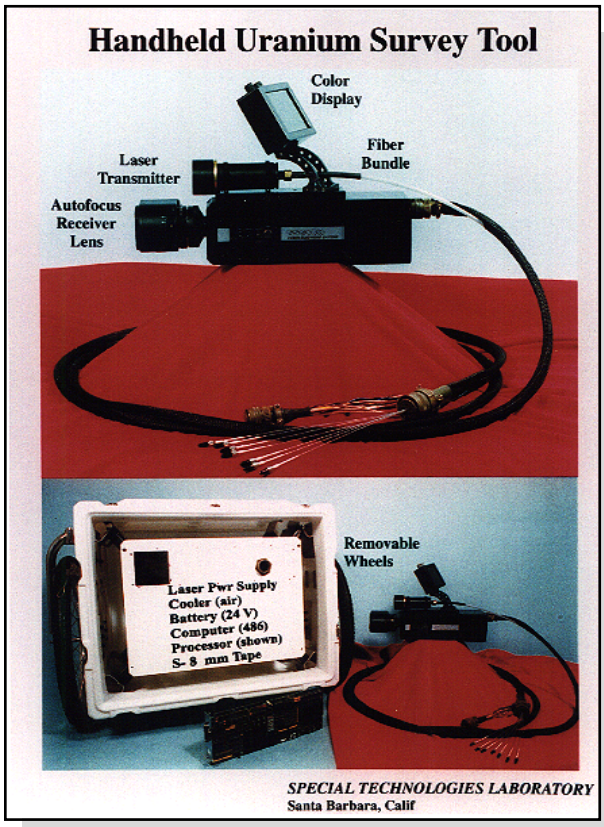


**Figure 5.3-2** Hand-Held LIFI System

This year's scope of work includes: (1) the completion of customer requested upgrades and fielding of the portable uranium survey tool at DOE sites for characterizing facility walls, floors, equipment, and surface soils; and (2) the completion and flight testing of the airborne LIFI system. The hand-held uranium survey tool will be fielded in cooperation with EM-40 personnel for D&D applications at the Oak Ridge Gaseous Diffusion Facility (K-25) and the Fernald Facility. It will also be deployed at EPCOT Center's Land Pavilion to collect data on plant stress.

The airborne LIFI system was configured last year for the DOE Convair 580T aircraft. The system has been reconfigured for helicopter usage, so that deployment is now possible on a variety of platforms, including the U-60 class (Blackhawk, Seahawk, Pavehawk), Chinooks, and SH-3s.

## Benefits

Fluorescence techniques have the ability to detect signatures that are not observable by traditional remote sensing methods. The high spatial resolution of intensified CCD cameras and the time-resolved phosphorescence emission characteristic of the uranyl ion allow one to obtain a digital picture of the extent of surface contamination. This allows mitigation efforts to be focused on specific areas, which speeds the survey and lowers overall costs. The real-time image processing of the data into a false color composite on gray scale background allows the operator to quickly distinguish the uranium signature. Since the data is recorded on video tape, they can be reviewed for planning and evaluation of D&D activities.

The advantages of airborne systems for remote sensing are well documented. Airborne operations allow one to survey large areas in a cost-effective manner. Many DOE sites are located in remote areas, with practical access obtained only from the air. An aerial view allows identification of subtle changes and patterns that are not apparent from ground-based operations. High resolution imaging techniques under development allow one to obtain a picture of the extent and location of surface contamination. This allows mitigation efforts to be concentrated on specific local areas.

Participation with EPCOT Center in plant studies affords the opportunity to collaborate with world class plant physiologists to study the effects of plant pathogens and contamination. A variety of sensors will be used and compared to evaluate the concept of plant stress. EPCOT Center will act as a focal point for collaboration across agency boundaries and act as a site for continued collaboration. The development of robotic systems will provide platforms for testing the concept of LIF on sites of agricultural interests.

## Collaboration/Technology Transfer

The LIF project has often used the leverage of collaboration to control costs, especially in joint agency field exercises. Efforts with EPCOT scientists have involved scientists from the DOE Remote Sensing Laboratory, DOE Special Technologies Laboratory, Army Topographic Engineering Lab (Army Corps of Engineers), and Rochester Institute of Technology. Field tests have been performed in collaboration with the above-mentioned federal agencies, members of EM-50 and EM-40 at the Oak Ridge reservation, and EM-50 personnel at Savannah River. FY96 field tests at the Oak Ridge Gaseous Diffusion Facility will be completed in collaboration with EM-40 at K-25.

An agreement to conduct sensor R&D for plant stress detection at EPCOT with a NASA-funded company, Aerodyne, has been developed. FY96 technology transfer activities include the commercialization of a disk interface card with SYSTEMWARE, a disk manufacturer in Westlake Village, CA.

## Accomplishments

- The hand-held LIFI system has been deployed at the K-25 Gaseous Diffusion Facility in Oak Ridge, TN, to detect uranium during D&D operations; the K-25 uranium cylinder storage yards (E and K) to detect uranium on surfaces; and EPCOT Land Pavilion to detect chromium induced stress in plants. The system will also be deployed at the Fernald Facility for a D&D demonstration this year.
- Significant improvements have been made to the hand-held system, including the addition of removable hard drives for increased data storage, expansion of digital LIFI data to 16 bits for greater radiometric resolution, integration of a companion analysis system for rapid data evaluation, and addition of a variable gate and delay laser control for greater flexibility of adjustments by the user.
- The airborne LIFI system has been reconfigured for flight testing on a U.S. Army Blackhawk helicopter at the Yuma Proving Grounds and the Los Alamos National Laboratory late in 1996. All equipment pallets have passed preliminary flight approval from the Army. A lidar system has been added for altitude correction measurements. The final camera configuration is in progress and will be completed prior to the flight tests.
- At the EPCOT Land Pavilion, laboratory facilities have been completed and plant experiments have begun. A DOE scientist is at EPCOT full-time conducting experiments. The hand-held LIFI system was deployed at EPCOT in March, with a second data collection scheduled for April. Plans were approved for a robotic system to automatically detect plant stress in the Land Pavilion. The robot has been selected and ordered and the initial sensor suite has been determined.

## TTP Information

Airborne and Ground-based Laser Induced Fluorescence for Environmental Monitoring technology development activities are funded under the following technical task plan (TTP):

TTP No. NVO5C253 "Airborne and Ground-based Laser Induced Fluorescence for Environmental Monitoring"

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## Bibliography of Key Publications

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DiBenedetto, J., R. Abbott, G. Capellel, G. Chavez, S. Lutz, and J. Tesar. "Airborne and Ground Based Laser Induced Fluorescence Imaging (LIFI)," *Optical Remote Sensing for Environmental and Process Monitoring*, AWMA Symp. (September 1995).