# Fire Behavior Sensor Package Remote Trigger Design

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***Abstract**—Fire behavior characteristics (such as temperature, radiant and total heat flux, 2- and 3-dimensional velocities, and air flow) are extremely difficult to measure insitu. Although insitu sensor packages are capable of such measurements in realtime, it is also essential to acquire video documentation as a means of better understanding the fire behavior data recorded by individual fire behavior sensor packages. Therefore, coupling each sensor pack with a digital video recorder for simultaneous recording of video and insitu measurements allows viewing of the fire behavior as flames approach, envelope, and disperse past individual sensor packs. The limiting factor in this process is the amount of recordable digital video tape, typically 60 to 90 minutes of record time. This raises both tactical and safety-related concerns, requiring researchers to remain in proximity to the advancing fire in order to activate the fire behavior sensor and video packages. A new remote trigger that eliminates the need for human interaction in order to activate data collection hardware and video equipment has been designed and tested. This trigger system allows the fire behavior and video packages to stay in "sleep" mode until a measurable rise in heat flux is detected. The detection activates the fire behavior sensor package to begin logging data and sends a wireless signal to activate the video package. The setup has been tested for range and interference in open and densely treed plots as well as in fire and nonfire settings, effectively and consistently activating the equipment at distances up to 100 yards.*

## Background

*Insitu* fire behavior measurements are an integral part of fire behavior research (Butler and others 2004). Fire behavior research often starts as an idea that evolves to practical, reproducible experiments in the laboratory setting. Many of the models currently being used by fire managers are tools that were developed in this way.

Models developed in this manner are often calibrated and validated in a controlled environment by changing the key factors that influence fire behavior. Under experimental conditions, air temperature, relative humidity, wind speed, fuel loading, and fuel moisture are systematically changed in order to define and parameterize fire behavior models under various fire conditions. Examples of fire behavior models developed in this manner include Behave (Andrews 1986), Farsite (Finney 1998), and FireStem (Jones and others 2004).

Even though it is possible to manipulate the internal environment within the burning chamber and wind tunnels at the Fire Sciences Lab (Forest Service, Rocky Mountain Research Station), it is often quite different from the outside world. To further calibrate and validate fire behavior models

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developed in the lab, *insitu* measurements are often gathered on prescribed and wildland fires using ruggedized fire behavior sensor packages (FBP). These packages are equipped with heat flux, air temperature, and air flow sensors contained in a compact field setup able to withstand the extreme fire environment (see fig. 1 for FBP details).

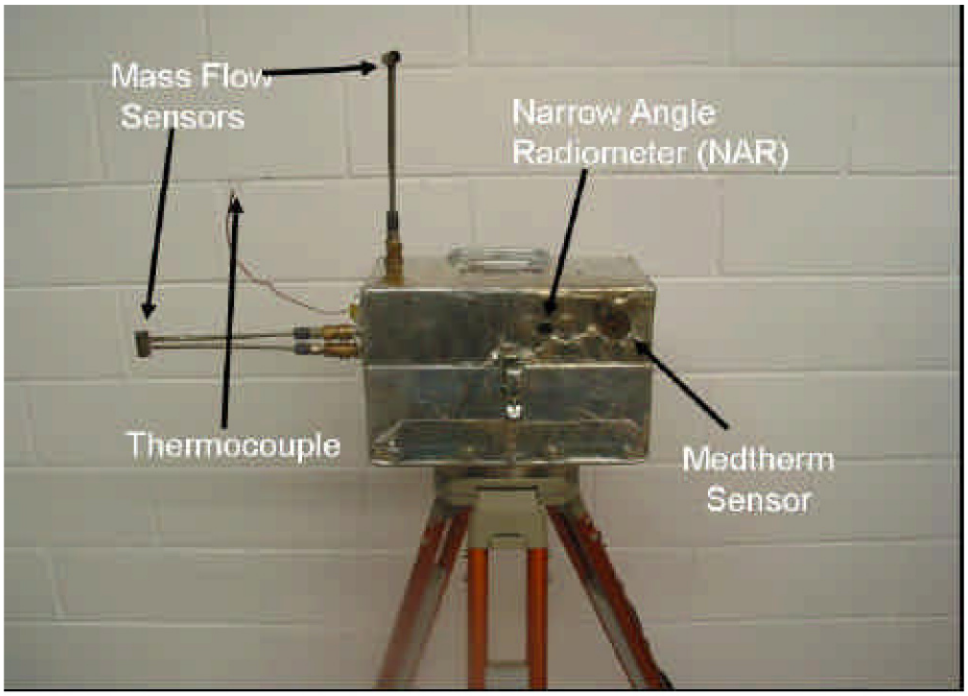


**Figure 1**—View of fire behavior package with sensors labeled.

Although the *insitu* sensor packages are capable of detailed measurements in real time, the researcher's ability to understand and interpret the data is greatly enhanced when digital video footage of the specific fire behavior at the sensor location is provided. Therefore, each FBP sensor pack is typically coupled with a digital video recorder for simultaneous recording of video and *insitu* measurements. This coupling allows researchers to see video footage of the fire behavior as flames approach, envelope, and continue past individual sensor packs (see fig. 2 for video box and camera details). Collection of this field data is vital to the model calibration and validation process.

Unfortunately, the success of field campaigns is often marginal due to the inherent logistical and safety issues and difficulty associated with anticipating the spread of the fire. The limiting factor in most of these efforts is the short record time associated with the digital video tape, which is typically on the order of 60 to 90 minutes. These short record times often make it too risky for researchers to manually turn on the video cameras when the fire is within an hour or less from burning over the sensor locations. This marginal success rate and increased risk to field personnel lead to the design, testing, and development of a wireless triggering system that eliminates the need for human involvement once the equipment is placed.


**Figure 2**—View of digital camera enclosure and camera mounting plate.

# Materials and Methods

A field deployable ground based sensor package and digital video camera provide *insitu* time resolved measurements of radiant and convective energy transfer from the fire, horizontal, and vertical air flow, air temperature, and digital video footage. The data and video are critical to the success of the field experiments. Research efforts have provided the opportunity to improve these sensors through a series of field trials. The result is a system that is not only robust, but also easy to operate, simple to deploy, fire proof, and light weight. Two packages have been developed:

- **Fire Behavior Flux Package (FBP)—**These packages measure 27 cm by 15 cm by 18 cm and provide an insulated protective enclosure for the data logger, sensors, and other electronics. The standard instruments consist of radiometers that measure total and radiant energy fluxes, small-gauge thermocouples (nominally 0.13 mm diameter wire) to sense flame and air temperature, and pitot-static type velocity probes that detect the magnitude and direction of airflow before, during, and after the fire passes. The packages are typically deployed so that the sensors are directed toward the oncoming fire front. The data loggers are capable of logging more than 1 million samples, which translates to a maximum logging duration of 30 hours at a 1 second sampling rate The most recent version of the packages includes a wireless transmitter that allows the data logger to send a signal to turn on a nearby video camera and begin recording.

- **Video Acquisition Box (VID)**—Digital video imagery is an integral component of our field campaigns. Digital video is acquired by camera(s) housed within 10 cm by 18 cm by 19 cm fireproof enclosures. The camera boxes are designed to be lightweight and compact in order to minimize bulk; they are constructed of 1.6 mm aluminum, weigh approximately 1.0 kg. The boxes have a double lens configuration of high temperature Pyrex glass and a second lens of hot mirror coated glass (Edmund Optics). This multilayer dielectric coating reflects harmful infrared radiation (heat), while allowing visible light to pass through. The cameras can either be turned on manually or can be set to trigger and record through a wireless link to the FBP data loggers. The system has been used throughout a full range of fire size and intensity, from slow moving surface fires to full scale crown fires. Analysis of the visual video images provides an objective method for measuring flame height, flame length, flame depth, flame angle, and fire rate of spread.

Currently four of the latest generation fire behavior/digital camera packages have been manufactured to collect *insitu* measurements in wildland fire environments. Table 1 provides details about individual sensors and their engineering specifications.

Recognizing the need to reduce risk to research team members and improve use and reliability of the instrument system, efforts were directed at developing a safe, ruggedized low cost data logger/camera triggering system. The development of this technology was not trivial and required a constant level of effort over a significant amount of time to develop, construct, and test various trigger methods and designs. Some of the options considered included radio frequency, infrared technology, handheld remote, and automatic systems.

The end result was a wireless trigger design based on the SONY proprietary LANC camera control technology (thus, the system is only compatible with SONY cameras). While any digital video camera that meets the size requirements can be used in the VID boxes, presently only SONY cameras are compatible with the automatic trigger system. The preferred model is the SONY PC-1000 HandyCam digital video camera. These cameras were chosen for their relatively high quality construction, image capability, availability, and associated hardware (such as batteries, cables). The system allows users to trigger the recording mechanism of the camcorder remotely by using its own unique internal computer source code. Although the LANC connector is wired directly to the camcorder, by reverse engineering the signals within the LANC system we were able to determine how to remotely trigger the on/off switch using Radio Frequency (RF), much like a remote garage door opener. Radio frequency was chosen over Infra Red (IR) technology due primarily to line-of-sight and interfering reflectance issues. In order to incorporate the wireless technology into our FBP design each package needed to be fitted with a RF transmitter and likewise the video boxes needed to be fitted with a RF receiver. This equipment was designed and assembled in-house using off the shelf supplies (see fig. 3 and 4). The transmitter and receiver operate off the internal 12V battery power sources available in the FBP and VID cases. Once the FBP and VID boxes are deployed the trigger system is armed from readily accessible switches in the respective enclosures.

**Table 1**—*Insitu* fire behavior package (FBP) specifications.

| | |
|---|---|
| **Narrow angle radiometer** | |
| Sensor | Thermopile (Meggett Avionics) |
| Spectral band of sensor | 0.15 – 7.0 µm with sapphire window |
| Field of view | ~4.5° controlled by aperature in sensor housing |
| Transient response | Time constant of sensor nominally 30 m sec |
| Units of measurement | Calibrated to provide emissive power of volume in FOV in $kW\text{-}m^{-2}$ |
| **Total energy sensor** | |
| Sensor | Schmidt-Boelter thermopile |
| Spectral band of sensor | All incident thermal energy |
| Field of view | ~130° controlled by aperature in sensor housing |
| Transient response | < 290 m sec |
| Units of measurement | Total heat flux incident on sensor face in $kW\text{-}m^{-2}$ |
| **Hemispherical radiometer** | |
| Sensor | Schmidt-Boelter thermopile (Medtherm Inc) |
| Spectral band of sensor | 0.15 – 7.0 $\mu$m with sapphire window |
| Field of view | ~130° controlled by window aperature |
| Transient response | < 290 m sec |
| Units of measurement | Radiant energy incident on sensor face in $kW\text{-}m^{-2}$ |
| **Air temperature** | |
| Sensor | Type K bare wire thermocouple, new, shiny, connected to 27ga lead wire |
| Wire diameter | 0.13 mm |
| Bead diameter | ~0.16-0.20 mm |
| Units of measurement | Degrees celsius |
| **Air mass flow** | |
| Sensor | SDXL005D4 temperature compensated differential pressure sensor |
| Pressure range | 0-5 in $H_2O$ |
| Sensor design | Pressure sensor is coupled to custom designed bidirectional probe with ±60° directional sensitivity |
| Units of measurement | Calibrated to convert dynamic pressure to velocity in $m\text{-}s^{-1}$ assuming incompressible flow |
| **Sensor housing dimensions** | 150× 180 × 270 (mm) |
| **Housing weight** | 7.7 kg |
| **Power requirements** | 12V DC |
| **Power supply** | Rechargeable internal battery |
| **Data logging** | Campbell Scientific Model CR10X |
| **Sampling frequency** | Variable but generally set at 1 Hz |
| **File format** | ASCII |

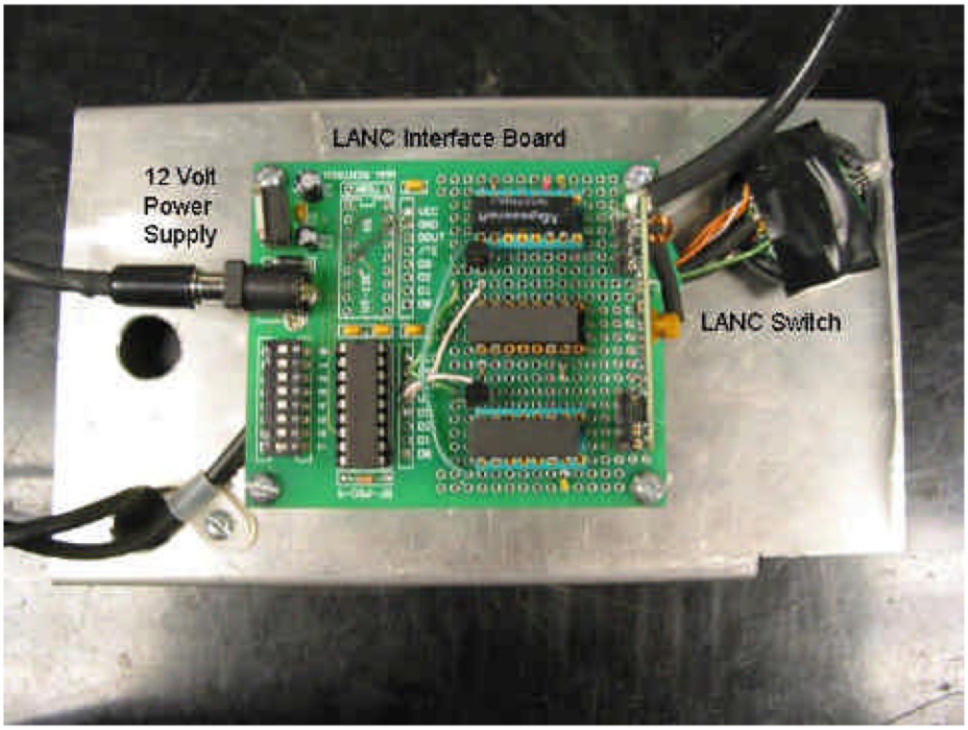


**Figure 3**—View of RF electronics for automatic camera trigger function.

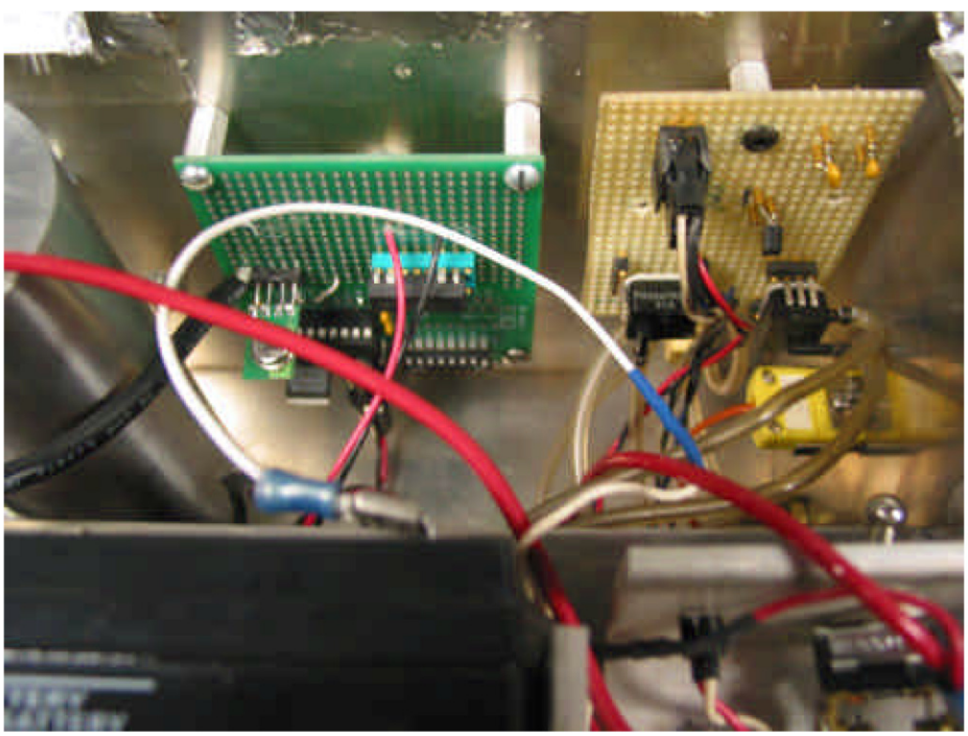

**Figure 4**—View of trigger electronics mounted in fire behavior package.

# Results

This new trigger system allows the fire behavior and video packages to stay in "sleep" mode until a measurable rise in heat flux or air temperature is detected. The detection activates the fire behavior sensor package to begin logging data and sends a wireless signal to activate the video camera package into record mode. The unique capability and hardware have been tested for range and interference over wide range of fire intensities and fuel types in open and densely treed plots as well as in fire and nonfire settings. In all the cases the system effectively and consistently activated the equipment at distances up to 100 yards. The result is a system that is reliable, able to withstand the high temperatures of fires and provides researchers and managers with the capability to quantify fire intensity and behavior safely and effectively. The components required for this conversion cost approximately US$100.

These systems have been used to collect quantitative fire information for support of fire spread models, fire-induced plant and tree mortality studies, firefighter safety zone studies, crown fire transition studies, and for comparing ecosystem management methods and techniques. The systems have been deployed on prescribed and natural fires from Alaska to Florida in the United States, and in Europe and Australia. The designs can be adapted to fit other sensors and data loggers. The FBP enclosures can be constructed for approximately US$300 per box plus cost of data loggers, and sensors. The VID enclosures can be constructed for US$450 per box plus cost of cameras. Users of the hardware and designs include Dr. Bret Butler (Manager of the USDA Forest Service Fire Behavior Team), JoAnn Fites-Kaufman (Manager of the USDA Forest Service Adaptive Management Services Enterprise Team), Dr. Matthew Dickinson (Research Ecologist with the USDA Forest Service Northeastern Research Station), Dr. Miguel Cruz (Research Ecologist with Australian CSIRO Forestry Research Group in Canberra, Australia), Jason Simmons (USDI Bureau of Land Management Fire Ecologist for experiments at Knife-River Village in North Dakota).

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