Wildland fire phenomenology experiments: 2001 - 2002

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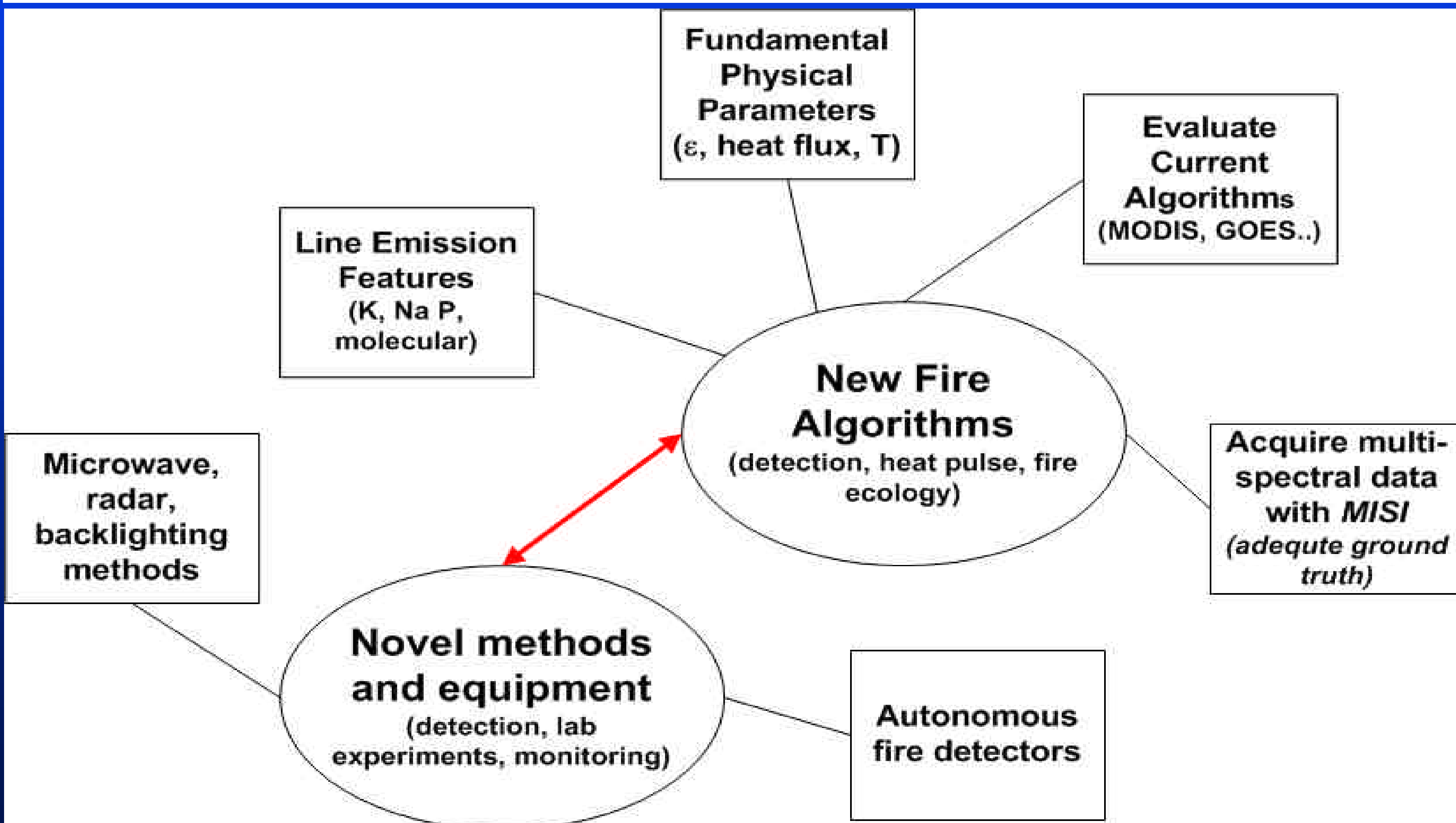
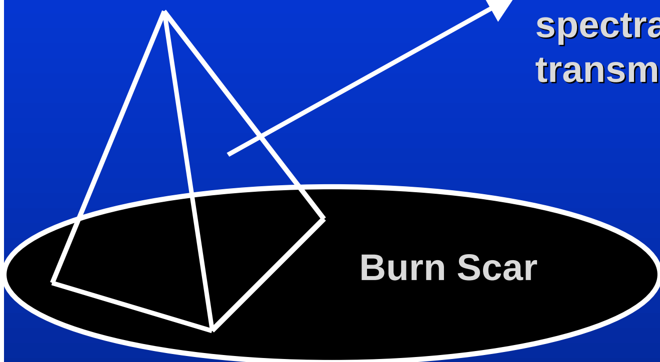
We plan to measure unknown fire physical parameters (mostly) relevant to remote sensing of fires



The parameters required are the basic inputs to a scene simulator using tools like DIRSIG

Emissivity, total flux, spectra, reflectance, transmission, temperature



DIRSIG Fire Element

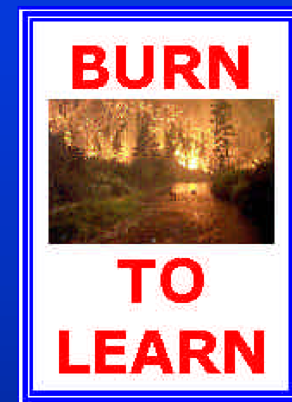
Gaseous emission products

Flame emissivity, temperature, emission line structure

Burn Scar Temperature vs. time, emissivity

Experimental campaigns during July 2001 and August 2002 gathered valuable data and provide a jumping off points for more complete characterization

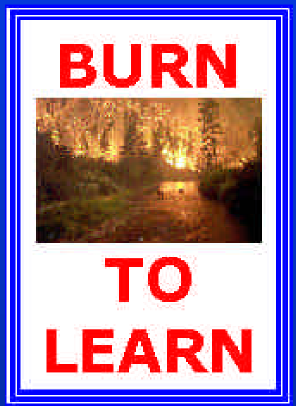
- **Data summary 2001:**
  - Acquire detailed spectra in the visible using ASD spectrometer
  - Gained valuable experience on fire behavior and experimentation



- **Data summary 2002:**
  - Good measurement of fire temperature field at 1 second resolution
  - Good measurement of average emissivity as a function of flame depth in the 8 - 14 μm region
  - Valuable experience in narrowband (10 nm FWHM) transmission measurements of flames

Experimental campaigns during July 2001 and August 2002 gathered valuable data and provide a jumping off points for more complete characterization

- **Lessons learned 2001:**
  - ASD difficult to optimize (0.3 - .95 mm OK)
  - Need to measure temperature field more accurately
  - Time synchronization of data very important
  - Repeatability of fires in question when no using 'prepared' fuels



- **Lessons learned 2002:**
  - Can't 'slap together' an experiment at the last minute
  - Experiments appear quite reproducible
  - Experimental complexity is an asset - must measure multiple related parameters to fit data models
  - This is difficult!

The 2001 experiments were designed to measure fire radiant temperature and spectral signatures from 0.3 - 11 μm

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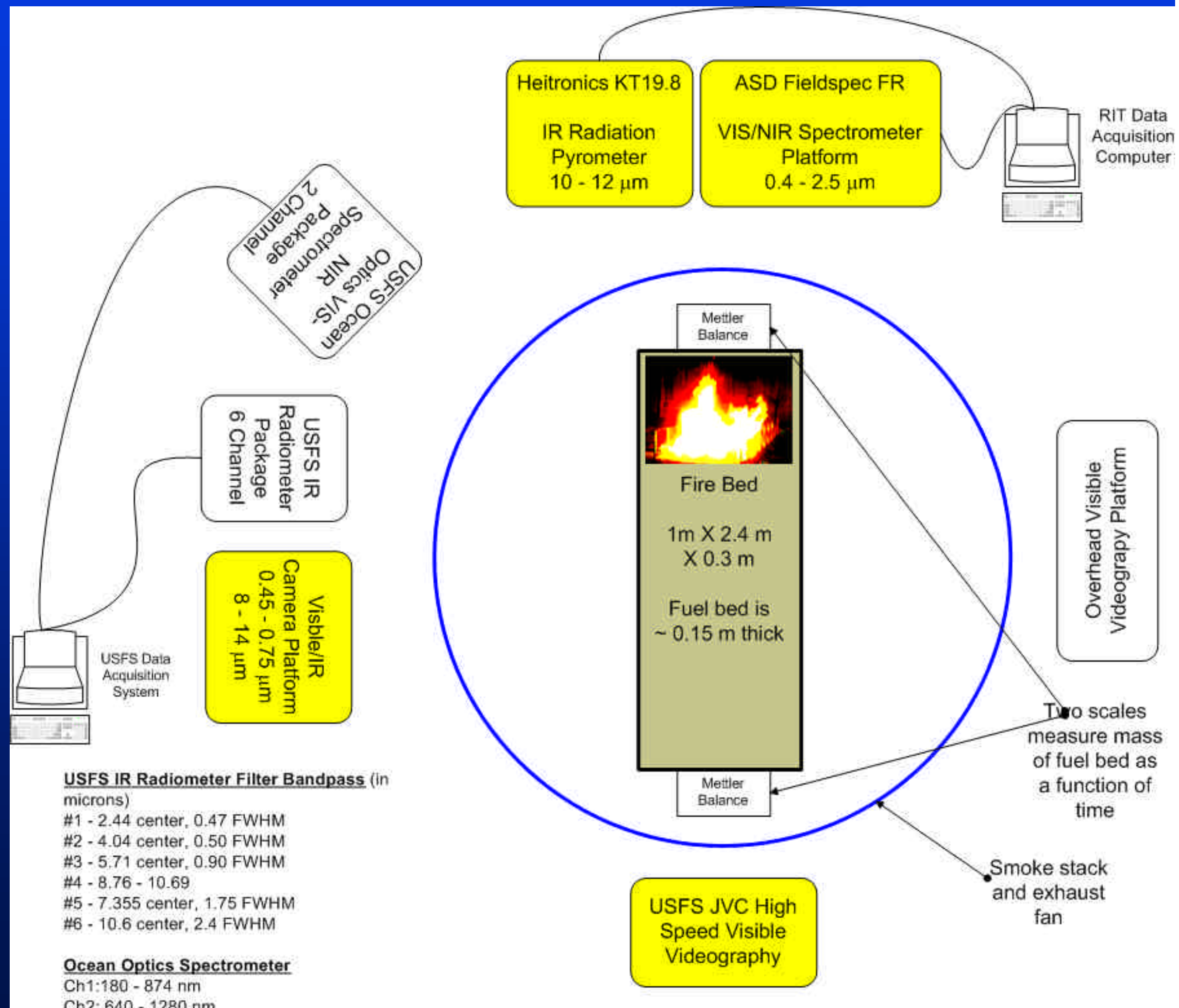
- **Status:**
  - Visible (350-990 nm) data analyzed, strong spectral features observed
  - IR data awaits completion of calibration of IR filter spectrometer
  - Analysis of high speed movies show spatial variability of fire and help in design of future experiments
  - Potassium line strength analysis still underway



We believe we need other measurements of flame temperatures to accurately model potassium emission

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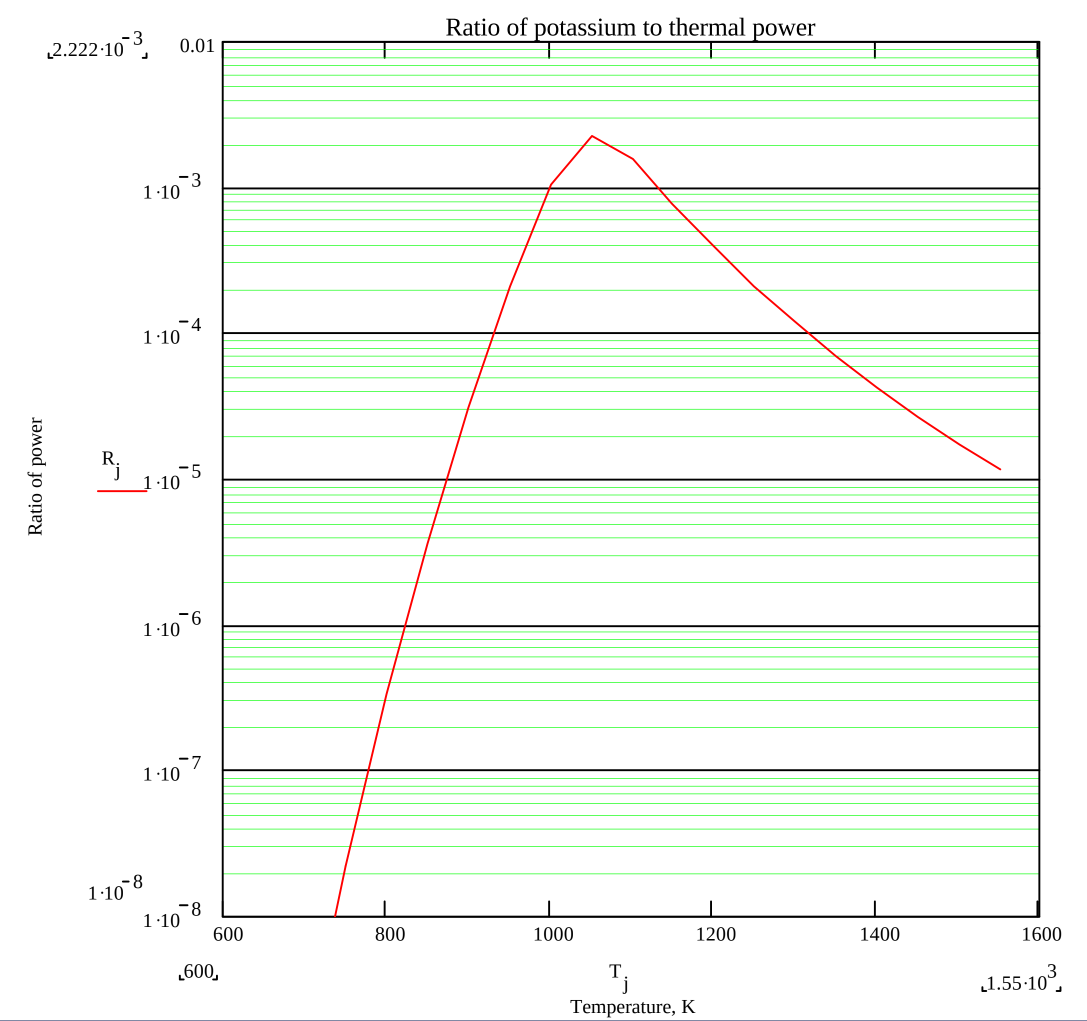
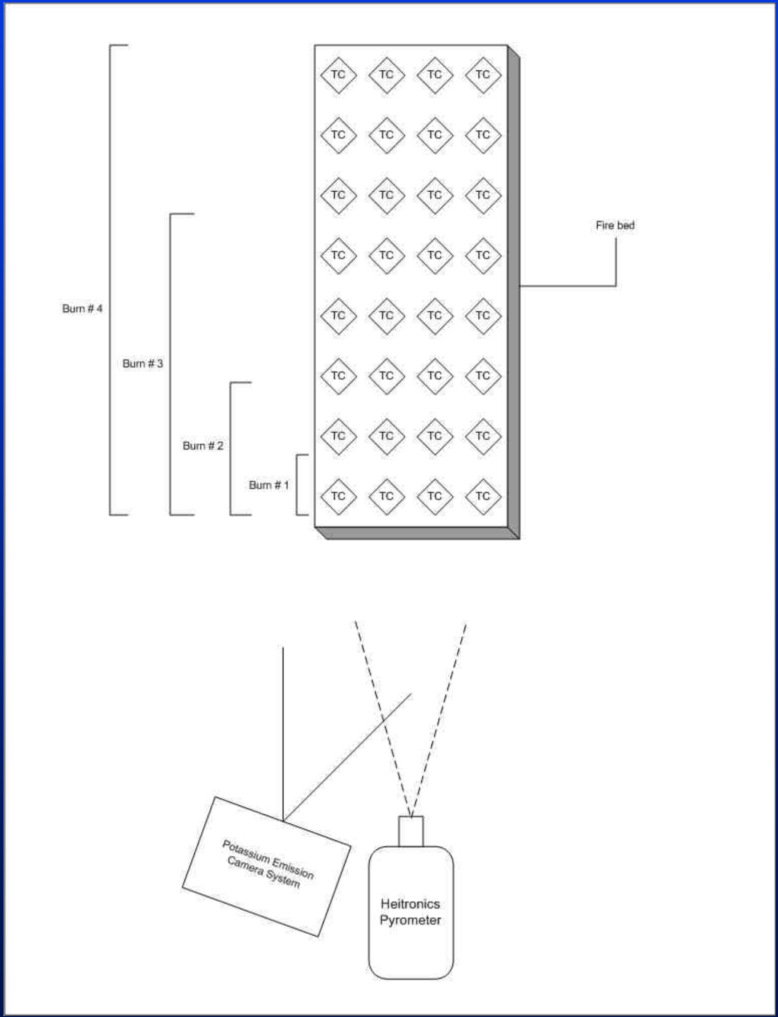
- Initial model worked out by Pete Gee off by an order of magnitude or more. (Measurement is too high compared to model)
- Possible sources of error:
  - Incorrect temperate measurement
    - » Obtained T by fit to ASD data - no good???
  - Absorption/opacity unknown for fire in this waveband - assume = 0
  - Lousy model?
  - Duh?



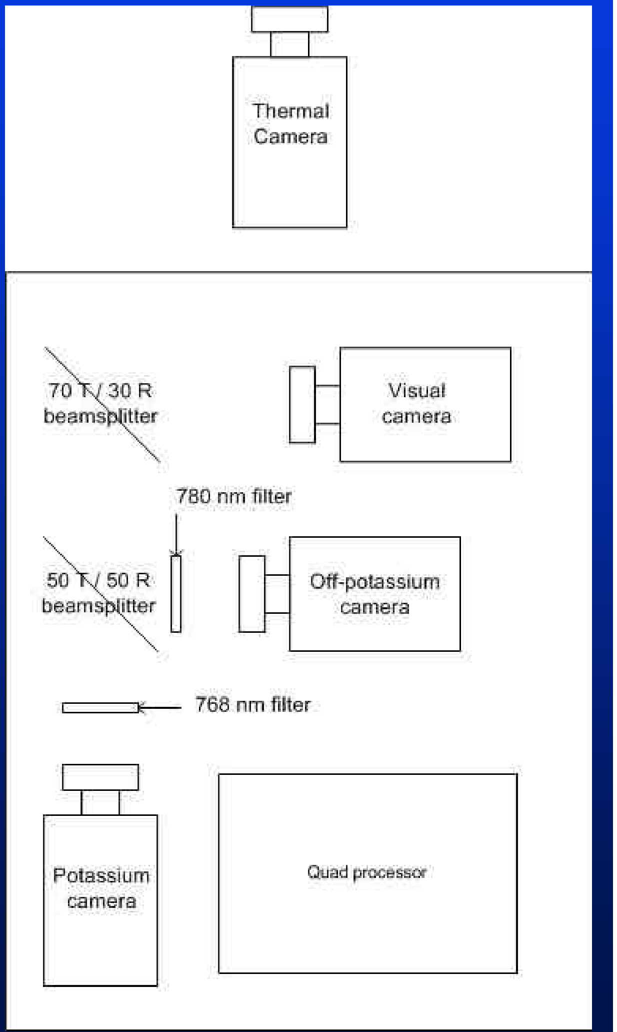
The 2002 experiments were designed to measure emissivity and image potassium line emission

- The fire kinetic temperature was monitored by an array of thermocouples in the fire bed
- The length of the ignited flame bed was varied to study the change in emissivity and K line emission on flame length
- The Heitronics radiant thermometer was used to measure the radiant emission from the fire. This was compared to the emission expected from the measured fire temperature to determine the emissivity



The emission from excited potassium resonance lines was imaged using a 3-band camera

- Camera developed during senior thesis
- Simultaneous imaging of 766 nm, 780 nm and panchromatic (silicon CCD response)
- Temperature along observation path measured by thermocouple array
- Attempt to correlate temperature and potassium emission line strength without doping or other invasive probing
- Camera output recorded to digital video tape for subsequent analysis
- Cameras, thermocouple loggers, computer data acquisition all time-synchronized



We need to measure many more parameters in self-consistent ways to understand fire phenomenology

- **Burn scar temperature as a function of time**
  - Montana, Spring 2004, Jason-O-Tron
- **Transmission/absorption measurements at critical wavelengths**
  - Emission lines* + samples in visible through LWIR. Laser/bright source and receiver
- **Emissivity measurements as a function of flame depth at a number of wavelengths**
  - 8-14 μm in hand: need 3-5 μm and visible (0.3 - 1 μm) at least. Radiometer in several bands.
- **Self-consistent temperature measure for line emission**
  - Potassium 'thermometer' using Ocean Optics spectrometer (RMSC) or filter/detector packages
- **Test of AFD in prescribed burn scenario**
  - Montana, Spring 2004
- **Possibility of radioactive release during fires**
  - High volume air sampler and radioactive analysis with SUNY Geneseo

Some of the characterization is funded under a USFS Joint Venture agreement

- **Some of the measurements described are funded by USFS**
- **Motion analysis of flamelets begs a student project**
- **Open ended invitation to field data collection or burn chamber experiments**
- **Heat pulse modeling with ME department**

D. THE COOPERATOR SHALL:

1. Perform the following tasks for Phase One (date last signed through Feb. 15, 2004):

   a. Perform optical radiation characterizations of wildland fuel material flames, with particular attention to remote detection of heat pulse as it may be used to predict 1st-order fire effects such as damage to trees or organic material adjacent to the fire. This effort may include, but is not limited to, measurement of flame emissivity, optical depth of the flame envelope, particle density and emissivities and heat flux from fuels.

   b. Perform motion analysis of high-speed movies (250 - 500 frames per second) taken in the Forest Service's combustion chamber to produce velocity profiles of active flames.

   c. Support field and laboratory data acquisition with Cooperator and Forest Service instruments, including data analysis and recording. Support will be provided on 2-3 prescribed and/or wildland fires in remote locations in the Western United States. Support may also include deployment of the autonomous environmental sensor (AES) for remote ground-based data acquisition.

   d. Examine the feasibility of modeling the heat pulse using simple transport models.

   e. Initiate the preparation and submittal of 1-2 refereed journal articles, participating as co-author(s) on relevant papers and reports with Forest Service scientist(s).

2. Collaborate with the Forest Service in the preparation of a mutually acceptable, detailed work plan, submit a copy of the plan to the Forest Service by Dec. 15, 2002, and conduct this study in compliance with the work plan as well as the provisions of this agreement.

Both field and laboratory experiments will be required to understand these critical fire parameters

- **Future Burn 200X:**
  - **November 2002:**
    - » Chamber experiment, varied flame bed length
    - » Re-measure emissivity at 8-14 μm and attempt measurement at 3-5 μm
      - Need to develop 3-5 radiometer *post haste*
    - » Instrument fire with 4-channel thermocouple field boxes for test/shakedown
    - » Measure transmission as a function of flame depth for potassium line
    - » Measure relative emissions from potassium lines at 766nm and other lines for independent temperature measurement.
      - Seed fire with aqueous KCl solution
  - **November-December 2002**
    - » Analyze radioactivity of wood samples from Firelab (ponerosa pine, Douglas fir, aspen)
    - » Continue analysis of all experiments
  - **Spring 2003**
    - » Field measurement of burn scar temperature as a function of time using 2 X 4-channel position-aware thermocouple boxes

Both field and laboratory experiments will be required to understand these critical fire parameters

- **Future Burn 200X:**
  - **Spring 2003**
    - » Prescribed burn field measurement of burn scar temperature as a function of time using 2 X 4-channel position aware thermocouple boxes
    - » Based on preliminary radioactivity studies, make more sample collections and measurements over a wider geographic area and deploy high volume air sampler on prescribed burn
    - » Continue emissivity measurements as a function of fuel bed length at visible/near infrared wavelengths