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Managing Research for Success[1]

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Abstract: Maintaining a proper balance between fundamental and applied research is only one of the important considerations that must be adhered to in the management of Forest Service research. A critical mass of scientists with the necessary professional and technical staff is needed over the long haul for difficult research problems. The project leader must know how he or she intends to reach the user with research products. A conceptual flow of information from problem delineation through basic research to development of models and systems and, finally, testing and transfer to operational units has been shown to be an effective means of getting research into application. Each member of the work unit must understand the role they are playing at any time during the process. Finally, the scientists and project leader must be constantly aware of the hidden manager--the research grade evaluation panel, and make certain that scientists do not become isolated in developmental and applications work without sufficient publications to maintain grade.

Forest Service research is under continuous scrutiny, not only by research managers, but also by all Federal, State, and private agencies that have a vested interest in such research. Research organizations must therefore be particularly concerned about how the actual work units or projects where the research is done are organized and managed. By its very nature, research is difficult to manage. We in Forest Service Research are investigating problems that defy efficient resolution by available techniques. Understandably, such problems often require long and hard study for resolution. Because we are under the scrutiny of such a broad spectrum of both clients and managers, an equally broad spectrum of results is expected. Some want in-depth basic research; others, products that can be "applied in the field."

Individual scientists can survive very nicely by concentrating on-fundamental research. Our grading system has traditionally worked well for scientists doing basic research. Research work units, however, are rated over a much wider range of accomplishment. In simple terms, it often comes down to: "What have they done for us lately?" Therein lies the challenge to the project leader. I am not advocating change in our way of evaluating scientists or work units. I propose that our time is better spent learning to manage research programs that require a sustained effort over a long enough period to be truly effective.

We in Forest Service Research must be prepared to do not only research in the classical sense, but also development, testing, and application. It is imperative that we have in mind the form of the product that will be useful to land managers and organize ourselves to ultimately produce that product. Occasionally, the final product will be new hardware, which we have only a limited capability to produce. Fortunately, most products of our research take the form of either information or an information processor. Our capability to package and distribute information and disperse computer software is excellent.

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Fire research units may be more fortunate than the biologically oriented units because fire is a physical process that is easier to model deterministically. Moreover, many applications, such as long-range planning, prefire planning, and dispatching are well suited to the use of models and information systems that can readily be communicated and implemented through today's computer technology.

By structuring our research work units and our management of those units around this technology, we can not only become effective research managers. but also provide useful results to our clients. This emphasis on modeling and computer technology, of course, calls for strong efforts in both fundamental research and systems development, which, although difficult to maintain, have a synergism that strengthens both.

INFORMATION FLOW

The tasks required for this type of research are reflected in the flow of information within a work unit. The information flow that has worked well for our fire behavior unit at the Intermountain Fire Sciences Laboratory is shown in figure 1. The stages of the process, moving from left to right are:

1. Problem definition
2. Fundamental research
3. Model development
4. System development and packaging
5. Verification and demonstration
6. Handoff and application

Some research units have been successful without going through all of these phases, but the expectations for today's research require that they be considered when the course of a research program is planned.

<u>The first stage, problem definition</u>, must of course be conducted in concert with user groups and managers, including research managers. Problems must be selected very carefully. Priorities must often be set according to what can be done in a reasonable time. The final form of the product should be considered at an early stage. Our clients are often better served with fully developed research products, such as graphic displays or maps of fire-danger levels, rather than traditional publications and tables of numbers.

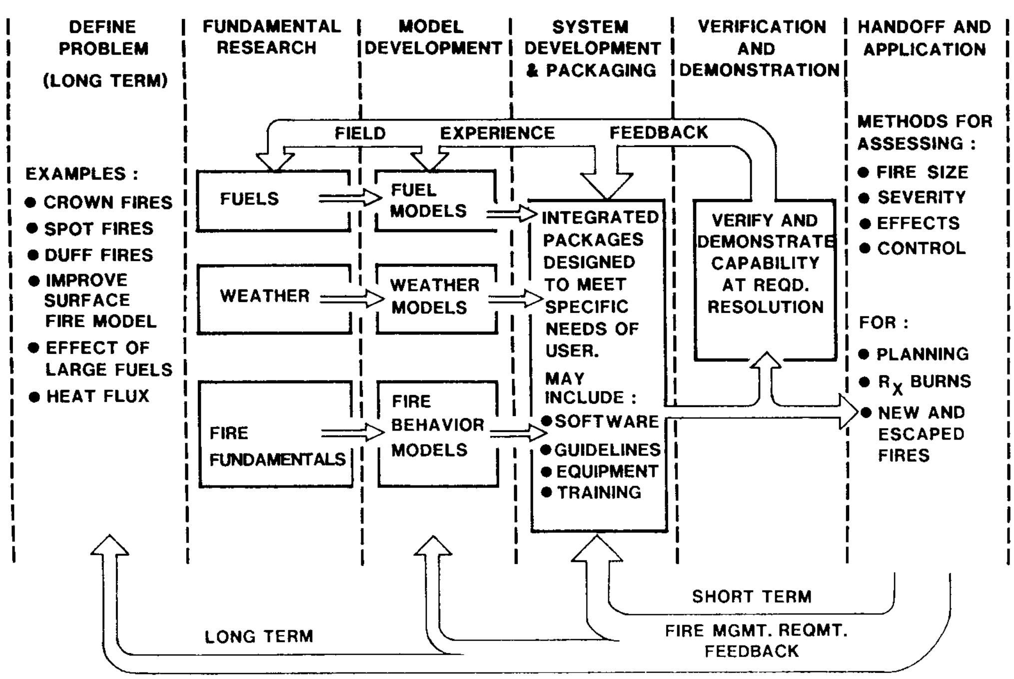

Figure 1--Successful information flow for the fire behavior research unit at the Forest Service's Intermountain Fire Sciences Laboratory, Missoula, Montana.

Problems are usually defined in client's terms, suggesting that only applied research will do the job, but basic research is often necessary before the applied work can begin. The research scientist's problem is usually very different from the client's problem. For example, the client's problem may be "How to predict the fuel moisture of fine dead fuels." The research scientist's problem is to identify the environmental factors that control fuel moisture, understand the processes involved, and develop a model that properly integrates all the variables according to season, time of day, and so on. Packaging the answer in a form the client can readily apply to the original problem lies near the end of the process.

The arrows at the bottom of figure 1 indicate the feedback necessary for problem definition, modeling, and system development.

<u>The second stage, fundamental research</u>, is a critical area that cannot withstand a great deal of introspection or directed management.

> "Research must be unfettered to be productive. Development must be controlled or it will never be productive."
>
> Myron Tribus

One of the primary qualities sought in a project leader is the capacity to provide research leadership.

By its nature, fundamental research can be exasperatingly slow. First attempts often fail. To capitalize on what was learned during initial attempts and proceed to successful discoveries, scientists must often continue their studies beyond traditional planning periods of 5 years or so. Our fundamental research on mechanisms of fire spread, at the lab in Missoula. for example, has continued for 26 years.

Conversely, some work units or "programs" have worked strictly on development and application without conducting any fundamental research whatever. They use results from other units and gleaned from the literature. Unless part of the research unit works at the fundamental level, such units cannot expect to outlive the system development and packaging phase. Research units are sometimes established as term projects with a specific expected lifetime. The National Fire Danger Rating Project, established for 3 years between 1975 and 1978, is an example.

<u>The third stage, model development</u>, is probably the least understood. Modeling can be thought of as a way of making research results usable and applicable over as wide a range as possible. Mathematical models are readily adaptable into today's computer technology. The more fundamental the research base for a model, the wider its applicability. Hence the importance placed on fundamental research and models based on first principles such as the conservation of energy, rather than correlations to locally measured variables. The best models give the most output for the least input. Models can be used independently or in conjunction with others. For instance, the fine-fuel-moisture model can be used directly or as an input to the rate-of-spread model. If properly planned and constructed, models can be linked so that a series of models functions as a system to meet a specific management problems (fig. 2).

<u>The fourth stage, systems development and packaging</u>, requires the services of people who are truly dedicated to producing a useful product. They must have a keen insight into the manager's needs and know how land management agencies operate. Management personnel are often brought into the systems development process. Current systems such as BEHAVE are strictly computer-dependent, thus adding another requirement to the talents needed by a good systems developer. Most of their work is hidden within a computer as an elaborate software package. The client sees "user-friendly" input and output statements and that's about it.

Systems developers fare very poorly in research-grade evaluation panels. This seriously discourages scientists from becoming involved in systems development. There are ways, however, of overcoming this problem. One method is to staff the systems section with personnel such as mathematicians, operations research analysts, or statistician/programmers who are not covered by the research-grade evaluation guide. Such a staff, however, may have trouble understanding the clients' problems or even communicating with the clients.

Happily, I have found strong exceptions to that fear. Another method is to temporarily use scientists normally engaged in basic research within the same unit. They move from basic research, to modeling, to systems development as needed. Such rotations, lasting a few months to a year or more, can be very productive for the unit and stimulating to the individual. For example, we used the talents of a research

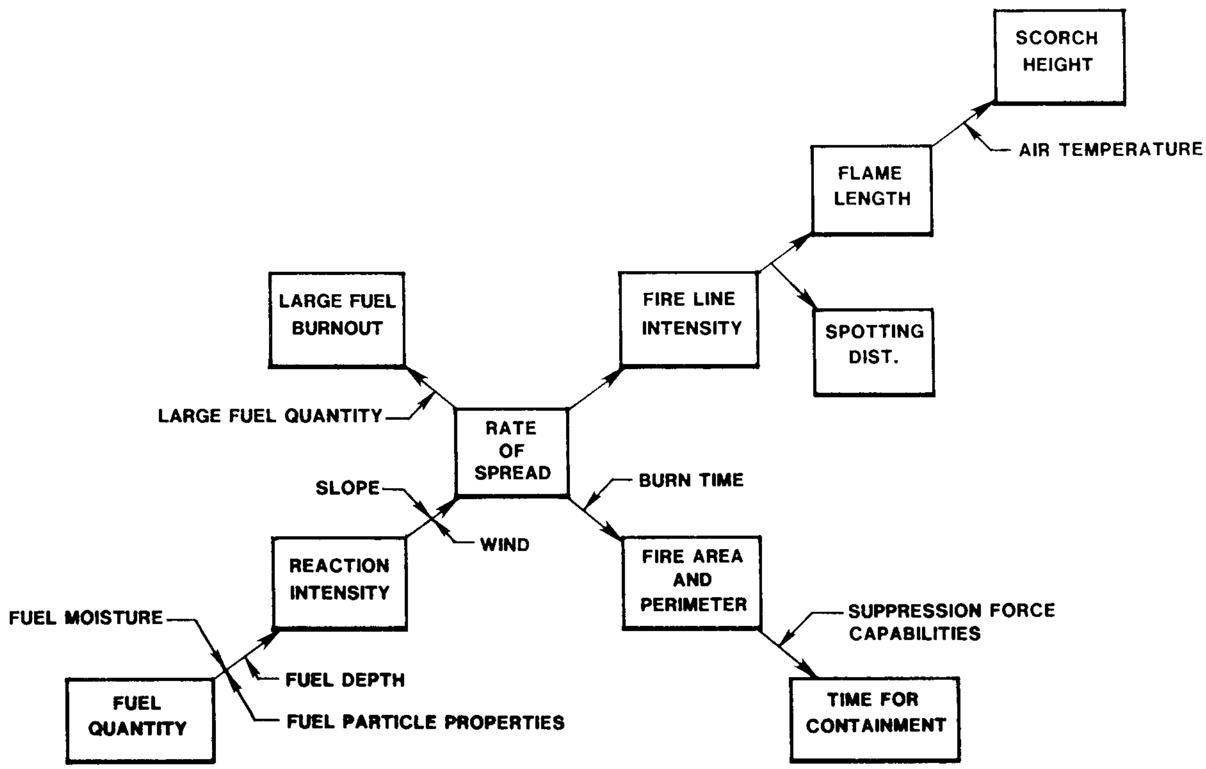

Figure 2--A series of fire models can be linked to meet a specific management problem.

chemist to help develop the computer programs for the HP-71B fire behavior calculator (Susott and Burgan 1986). During the process, about 1 year, the scientist learned a great deal about applying research in the field and the unit benefited by his programming skills and fresh approach.

"A change is as good as a vacation."
Anonymous scientist.

The fifth stage, verification and demonstration is often neglected. It determines how well the modelers and system developers succeeded. The feedback functions shown in figure 1 emphasize the importance of this phase. Testing should determine if the system can be used by others and whether it truly helps them or just adds to their problems. Both users and researchers should be involved in this stage. Often there should be two series of tests: a development test that is closely monitored by research and a pilot test with a fresh set of clients to learn whether the system and its documentation can stand alone. Systems should not be released for pilot testing to individuals untrained in the operation of the system.

The type of testing depends on the system and what it is intended to do. We are not looking for a lot of hard data for regression analysis on prediction capabilities. That should have been done during the modeling stage. Systems developers' time should not be wasted on models that have not been tested. Similarly, systems people should not extend models far beyond their intended use nor should they violate the assumptions under which models were developed. Clients must understand the assumptions behind the system and also its limitations.

The verification testing should reveal how well the programs function in an operational environment, how readily the user can supply the inputs, and whether the outputs are useful to the client. The usefulness of a system is readily apparent by the demand for its implementation by those involved in operational testing.

The sixth stage, handoff and application could be called technology transfer, but that broad term needs to be qualified. Forest Service scientists cannot serve as "county extension agents." There are too few of us for the number of clients. We have overcome that problem by training trainers. Through several consecutive years of instruction in the S-590 Fire Behavior Analyst course at Marana, Arizona, we developed a cadre of fire behavior analysts who were ready receptors for the programs developed for the TI-59 handheld calculator, BEHAVE, and more recently, the HP-71B calculator.

The BEHAVE system development (Andrews 1986, Burgan and Rothermel 1984) provides an excellent example of the concept of training trainers. Users were brought from all Forest Service regions and from other interested agencies to a series of 3-day, hands-on-the-terminal courses at the Intermountain Fire Sciences Laboratory in Missoula. Complete instruction packages were provided to every student. We conducted additional training at training centers in Portland, Oregon; Lone, California; and Anchorage, Alaska. A cascading process, from trainer to trainer, has distributed the system throughout the participating agencies.

An even more extensive travel itinerary was conducted for the TI-59 handheld calculator in 1979 when we conducted training in six cities. It was much easier to implement the HP-71B calculator in 1985. The technology was so well established that after program preparation and chip production, research played only a minor role in training. Detailers from NFS developed the training packages and conducted the training, starting with an agency-wide course in Marana. We have found this stage, especially the training, to be immensely rewarding to us in terms of feedback from users. Some of the students in our early classes have become important participants, and they provide excellent critical review of our proposed plans and system.

WORK UNIT GUIDES

The process I have described requires an adequate staff, facilities, and support. Small units of two or three scientists would be hard pressed to carry out a complete research-to-applications program. A critical mass of people, including scientists, professional support, technicians, and clerical help is required. Based on my experience, I advise against putting all the fundamental research in one unit and the applications work in another. Doing so eliminates flexibility and makes it difficult to obtain special help from a fundamental scientist from time to time. It also makes it difficult for scientists doing application work to move easily back into more fundamental work without rewriting work unit descriptions, transferring money, and instigating the associated personnel actions.

The working group should include a mixture of disciplines whose interactions will enable them to see the problem more broadly and sharply than working in isolation.

Before embarking on a program within this structure, the working unit must define the final form of their product. They must know how they will reach the user--even if application is several years away.

We have been fortunate in the fire behavior work unit to have had sufficient staff to operate in this mode since the middle seventies. It has worked well as evidenced by the influence the work of the unit has had on the fire science and fire management communities. At peak staffing, the fire behavior work unit was composed of:

1 research physical scientist
1 research engineer
3 research physicists
1 research chemist
1 research meteorologist
1 research forester
3 mathematicians
3 technicians
2 clerks

We were organized into two teams: (1) Fire Fundamentals, and (2) Fire Modeling and Systems Development. This was primarily for administrative purposes; we did not try to sharply divide the research. The number of personnel did not prove excessive for supporting the research in the large combustion facilities, wind tunnels, and other labs at IFSL. Surprisingly, the unit can operate effectively on a modest operating budget. Salaries obviously dominate the budget, but with good research facilities and adequate computer capability, operating funds are needed primarily to keep equipment up to date and to provide supplies. This picture is changing, however; we are losing and not replacing key personnel and we are faced with tough research questions that will take considerable time and money to answer. To cope with this situation, more money is going into cooperative agreements for outside research.

The modeling effort, described as stage 3, was not restricted to either team. Almost everyone did some modeling. Similarly, everyone at one time or another did computer programming. We do not think it is inefficient for scientists to program their own work. This is especially true when developing new mathematical models. When tested, proven, and ready for application, models are repackaged as necessary. Of course, routine data reduction, and so on, is better done by programmers and technicians, but we have been careful not to set up a computer czar to oversee all such work.

The work unit I have described evolved over a period of time by assimilation of scientists from disbanding units and key recruitments.

I am not so naive as to suggest that all research should be organized in this way, but I make the following recommendations for managing research for success:

1. Consider the steps shown, in figure 1 when any research unit is established.
2. Consider the form of the product the unit is expected to produce.
3. Allow ample freedom to scientists doing fundamental research.
4. Consider carefully whether your research can be packaged as mathematical models.
5. Carefully plan (control) the development work.
6. Keep the unit flexible so people feel free to occasionally move from fundamental to applied work, and vice versa.
7. Identify the problems of most concern to land managers in your discipline and seek their participation in devising solutions.

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