Enclosure 2

I. Special Technology Development Program New Project Proposal

Complete a copy of this form for: 1) each new project proposal, and 2) each resubmitted but previously unfunded project proposal. Add lines within the form as necessary.

PROJECT NUMBER :R2-2001-02, R4-2001-1

PROJECT TITLE: Landscape scale hazard-rating system for white pine blister rust in the central Rocky Mountains

PROJECT STATUS : New

EXPECTED PROJECT DURATION (total years for project including current fiscal year)**:** 2

EXPECTED COMPLETION DATE OF THE PROJECT : FY 2003

SUBJECT: (mark all that apply using 1 for primary category and 2 for secondary categories): Biological Control___ Invasive Species_2__ Methyl Bromide Alternatives___ Models_1__ Monitoring_2__ Organism Biology___ Pesticides: Microbial ___ Pesticides: Synthetic___ PTIPS___ Population___ Risk and Hazard_1__ Remote Sensing___ Semiochemicals___ Silvicultural Technology___ Social Values___ Spray Technology___ Other_____

STATUS OF SUBJECT SPECIES :non-native

PROJECT OBJECTIVES (question to be answered by the project): We will develop a landscape scale hazard rating system that is linked to a Geographic Information System (GIS) for limber pine (LP)and Colorado bristlecone pine (CBP) using findings and methodologies developed for southwestern white pine (SWWP) and whitebark pine (WBP). Existing plot systems,including PTIPS plots established in Wyoming for LP and Forest Health Monitoring plots, will be utilized, as well as GIS data and supplemental data as needed.

BRIEF DESCRIPTION OF PROJECT: Describe primary activities for each year. This may be a clearly worded bulleted list or graphic of milestone activities.

We will adapt established concepts and techniques for hazard rating stem rusts to the recent discovery of the rust on LP in northern Colorado on the Arapaho and Roosevelt National Forest and adjacent private lands. A rating system will identify areas where LP and CBP are threatened and will indicate which control methods are likely to be effective at any particular site. We will use the current outbreak in southern Wyoming and northern Colorado as a model system; but other areas where the rust could be a serious threat will also be identified. Empirical relations will be determined to predict expected rust severity from epidemiological factors and from site and stand features. Epidemiological factors are those direct influences related to microclimate, Ribes distribution and abundance, and white pine age and size. Because information for these epidemiological factors is not available for most sites, we will relate these direct factors to standard resource management data describing site and stand conditions (e.g., elevation, habitat type, current vegetation, and management history). Using these data, we will generate and evaluate hazard maps for the current outbreak area. We will identify additional areas within the central Rockies, which could be seriously impacted by WPBR; and we will assess the consequences of alternative vegetation management strategies on rust impact.

FHP LEAD CONTACT (FHP person submitting proposal)**:**

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PRINCIPAL INVESTIGATOR(S) (add lines as necessary)**:**

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COOPERATORS (contributing to, but not leading, the project) (add lines as necessary)**:**

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
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COOPERATOR INVOLVEMENT (add lines as necessary)**:**

Name	Role	Time Commitment

JUSTIFICATION (How does the project strengthen FHP program delivery/capability? What is the potential advantage over existing technology?): White pine blister rust is a non-indigenous pest, which has caused significant economic loss and ecological change in other regions. WPBR has been present in lower elevation white pine environments (eastern white pine, western white pine, sugar pine) for many decades and because of their commercial significance, extensive knowledge regarding the rust is available for these pine species. WPBR has spread into higher elevation sites occupied by WBP more recently. Although a significant understanding of these ecosystems has been gained over the past few years, major losses occurred before and during the period when studies have taken place. Because of the lack of commercial value of WBP as a timber resource, information on the ecology and management of this forest type had to be developed as well. Once the ecological significance of WBP was recognized, protection and restoration efforts were initiated.

WPBR has also recently spread into SWWP. It is spreading northward from southern New Mexico into the extensive range of SWWP in Arizona and New Mexico. The rust will likely spread to the white pine forests of southern Colorado and northern Mexico.

In Colorado, the reduction of populations of white pines (LP,CBP,SWWP) could have deleterious effects on dependent wildlife species and secondary effects on forest and watershed health by loss of a valuable tree species. These effects on wildlife and forest health have occurred in the Northern Rockies and could be repeated in Colorado.

The extent of the outbreak needs to be determined by FHP detection surveys. Several trend and damage evaluation plots (PTIPS) have been established in Wyoming. These efforts, however, have not provided a statistical basis for management and assessment, which accounts for the potential loss of an important forest species. Detection surveys indicate that the rust has spread to a new area. However, they can not suggest which areas are at risk and where scouting should be conducted. Without linkage to the Forest Vegetation Simulator and Blister Rust Damage Model, the utility of trend and evaluation plots may be limited. The proposed project would specifically benefit the FHP program by focusing detection, evaluation, and management in those areas with greatest risk and value and by identifying those control techniques and strategies most likely to be effective. The project would benefit forest management and planning by providing needed information on long-term WPBR effects in an appropriate form for assessment (ID) teams and decision-makers.

URGENCY (Does the project address a crisis situation? Would delay result in irreversible loss?):
There is a forest health crisis in the central Rockies. Conversion from a pine forest to a fir forest, increased tree density and fuel loading, recurrent insect outbreaks, abundant dwarf mistletoe, changes in fire regime and now establishment of an aggressive, non-indigenous, tree-killing pathogen, WPBR, constitute a crisis. Although LP is not likely to become

extinct as result of this disease, it is likely to be lost from many stands. The disease is most damaging on regeneration and younger trees causing mortality within just a few years after infection and top-kill and mortality of older trees over longer periods. Not only does this loss diminish economic and aesthetic values, but also reduces the species ecological roles for providing wildlife habitat and buffering other forest pests. Although we have lost the opportunity for early control of the rust in the northern Rockies, early warning of where the rust would be a serious hazard in other areas is possible. This is a particularly appropriate time for the project. Information produced will be used in forest plan revision and in research studies on the impacts of small-scale disturbances. Cooperators from several universities are available to assist with this work.

NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITY (check one):

Priority 1: __ Priority 2: __ Priority 3: __ Priority 4: _X_

TECHNICAL COMMITTEE DEVELOPMENT PRIORITY (check one):

Priority 1: __ Priority 2: X__ Priority 3: __ Priority 4: __

Priority 5: __ Priority 6: __ Priority 7: __ Priority 8: __

SCOPE OF APPLICATION (How widely are results likely to be applied—geographic area, range of pests, length of time?)**:** The benefits of this project extend beyond Colorado. Besides a site specific map of expected rust in northern Colorado, the project will identify site and stand conditions in which WPBR is expected to be a serious forest disturbance agent. Although not a specific goal of this project, results may also be applicable to forests in most of the Rocky Mountain states (portions of Regions 1, 2, 3, and 4). As one set of tools in an adaptive management program, the hazard system and management recommendations could be incrementally corrected, improved, and expanded; and thereby remain relevant and useful as long as there is a need to manage forests with white pines and WPBR.

RESEARCH BASIS (strength of research basis, including publication citations)**:**
White pine blister rust, *Cronartium ribicola* J. C. Fisch., is an introduced pathogen to North America where it causes serious economic and ecological damage to white pines (Anderson 1988, Bingham and Gremmen 1971, Liebhold and others 1995). Because of its importance, blister rust has long been the subject of many research studies and management projects (summarized by McDonald and others 1991, Mielke 1943).

Current interests in blister rust result from its spread to new areas, impacts on ecological values, and new discoveries using molecular techniques (Conklin 1994, Draper and Walla 1993, Hamlin 1996, Krebill and Hoff 1995). Rust hazard models and indices remain the basic and necessary tools for assessing rust severity and evaluating genetic and cultural controls (Catlin and others 1994,McDonald and others 1981, McDonald and others 1990, Rust 1988).

White pine blister rust was first reported in Colorado in 1998 by Johnson and Jacobi (2000) on limber pine (*Pinus flexilis* Engelm.). It most likely spread southward from known infestations in southern Wyoming (Brown 1978). It has also been discovered on southwestern white pine (*Pinus strobiformis* Engelm. by Hawksworth (1990) from the Sacramento Mountains of south-central New Mexico (also see Hawksworth and Conklin 1990). Based on canker distributions and ages, the rust apparently became established in New Mexico circa 1975. A major expansion in distribution and severity of infection occurred about 1985, and significant amounts of new infection have occurred more recently. By the time the disease was discovered, it was already widely distributed throughout the Sacramento and adjoining White Mountains. In 1994, the rust was found for the first time in the Capitan Mountains north of the Sacramento Mountains (Conklin and Schultz, unpublished observations); so far the rust has not been detected in several other southwestern ranges with white pines.

Although the nearest known populations of rust-infected white pine from New Mexico are 800 km north (southern Wyoming, collected by Geils: Forest Pathology Herbarium, Fort Collins #6804C) and 1100 km west (southern California, reported by Kliejunas 1985), these distances might have been bridged by transport of thick-walled, pigmented aeciospores or by successive jumps of repeating urediniospores.

Spread of blister rust to other disjunct pine populations over long distances has been reported (Draper and Walla 1993;

Lundquist and others 1992).

Because of the great risk that this outbreak will cause serious ecological and economic impacts, forest managers are concerned over its ultimate extent and severity (Neuenschwander and others 1999). Although the current Arapaho and Roosevelt National Forest Plan does not specifically mention white pine blister rust, there is general direction to "develop alternatives to prevent or reduce damage [from forest insects and pathogens] to acceptable levels". The realized severity of this outbreak raises uncertainty about the adequacy of present management plans.

Since its discovery in 1998 in northern Colorado, the widespread nature of the outbreak has become much more apparent, with branch flagging, topkill, and small tree mortality appearing in numerous locations. Host and climatic conditions in northern Colorado are favorable for development of a serious epidemic. Both LP and Ribes are common and well-distributed throughout the area. Seedlings of LP and CBP are very susceptible to infection and canker formation (Hoff and others 1980). With concurrence of pathogen, susceptible hosts, and favorable environment, further expansion and intensification of this outbreak is expected similar to the outbreak in New Mexico.

An extensive and severe outbreak of blister rust in northern Colorado will directly impact populations of LP and indirectly affect the surrounding forest ecosystem. Limber pine is a minor component in mixed conifer stands. However, it is a vital biodiversity component and has high aesthetic and wildlife value. The large cones and seeds of white pine trees are vital to several species of wildlife (Benkman 1995, Tomback 1977, Tomback and Linhart 1990, Tomback and others 1995). The cumulative effects of near elimination of LP from the central Rockies or other areas could be detrimental to management objectives for fire and watershed protection, and maintenance of habitat for Threatened and Endangered Species.

Unlike the native insects and pathogens which have evolved in this forest ecosystem and behave as natural regulators, *Cronartium ribicola* is a non-indigenous pathogen and an introduced ecosystem disturbance (Castello and others 1994, Liebhold and others 1995). The consequences of the outbreak could go well beyond its current distribution in southern Wyoming and south-central New Mexico. With a greatly expanded rust population, there would be an opportunity for the rust to improve its epidemiological fitness (McDonald and Andrews 1982). Not only could a new strain develop that would be even better adapted to the central Rockies and southwestern hosts and weather, but that strain might also be able to overcome resistance mechanisms selected in breeding programs for economically important white pines in other regions (see McDonald and others 1984). From a large outbreak in the Sacramento Mountains, the rust would be more likely to spread to the white pine forests of southern Colorado and northern Mexico (Eguiluz Piedra 1991, Shaw and others 1993).

A recent survey of the Intermountain West indicates the disease has also increased substantially in the northern and middle Rocky Mountains since the 1960s (Smith and Hoffman, 2000).

Although the WPBR outbreak in northern Colorado is recent, several efforts have been undertaken to describe its status and to plan appropriate research and management. Several meetings have been held in the last year with interested forest pathologists from the USDA Forest Service, universities and state pest specialists.

The approach to site and landscape hazard rating for WPBR demonstrated by Geils and others (1999) and Van Arsdel (1961, 1962,1964,1965,1967) might be applicable to the central Rockies. This project is the basis for work to adapt McDonald's rust index and simulation model (McDonald and others 1981) and for evaluation of alternative control and management techniques (Hagle and others 1989).

Hazard rating blister rust

A hazard model is a valuable tool for forest planning and management in areas threatened by pathogens such as blister rust (Froelich and Snow 1986, Geils and Jacobi 1991, McDonald and others 1990, Rust 1988, Steele and others 1996, Van Arsdel and others 1961). A general plan for addressing forest health issues related to blister rust in the Southwest (Geils 1993) identifies a hazard model as preliminary to an ecological effects assessment, a genetic evaluation, and an economic analysis. Epidemiological factors of host abundance and proximity and microclimates are well known for determining the incidence and severity of blister rust (Kimmey and Wagener 1961, Van Arsdel and others 1961) as well as other stem rusts including comandra blister rust (Jacobi and others 1993), fusiform rust (Davis and Snow 1968), and sweetfern rust (Gross and others 1983). The distribution of forest diseases can be predicted from forest inventory

data and by using geographic information systems, GIS (Anderson and others 1986, Morse 1986). The basis for relating weather and climate to plant disease, modeling site microclimate, and predicting spore transport are well established (Davis and Monahan 1991, Hungerford and others 1989, Pielke and Avissar 1990, Ryan 1983, Van Arsdel 1965, Wilmot and others 1985). Hazard models and their component functions have been used to address management questions across a range of scales from individual tree, to stand, to an entire landscape (Baker and others 1991, Hunt 1983). For example, hazard information is used to execute the Forest Vegetation Simulator-Disturbance Model for blister rust (McDonald and others 1981). This model allows managers to evaluate various silvicultural options for regeneration, density control, and harvest schedule while taking into account infection, damage, and mortality caused by blister rust. Whether the objective is timber production, wildlife preservation, or fire protection, information on the potential impacts of significant forest disturbances such as blister rust has proven essential for good management (see Monnig and Byler 1992).

METHODS (project design, hypothesis, statistical approach, and QA/QC procedures)**:**
The project will consist of four general tasks completed in two years. The basic hypothesis is that the severity of blister rust depends on the distribution of white pine and Ribes populations and is strongly influenced by microclimate. The fundamental question is where can various cultural and silvicultural practices and forest management strategies be effectively employed to mitigate the impacts of blister rust on desired ecosystem functions and forest values. The hazard rating methods demonstrated in the North Central and Southwestern regions will be adapted and applied in the central Rockies. This will be a multi-scale analysis in which specific sites are evaluated in their landscape context. The development and validation tasks of the project will use southern Wyoming and northern Colorado as a model system with a currently established epidemic of blister rust. The hazard system, however, will be applied as well to other areas in the central Rockies with significant populations of white pines. Local information on Ribes ecology, rust epidemiology, and microclimate will be used to evaluate the feasibility in the central Rockies of various management practices used in other regions at the stand and forest levels. The principle statistical methods used will be correlation and regression (relating rust severity to epidemiological factors directly controlling rust distribution and relating those direct factors to site and stand features in the forest inventory, such as elevation and habitat type). Standardized methods for meteorological and geographic (GIS)(spatial) information will be used. A detailed work plan will be prepared, reviewed, and approved by cooperating research and statistical advisors. This plan will describe each of four general tasks of the project (see Proposal appendix for additional explanation and detail on these tasks):

1) build hypothetical model based on current understanding and data;

2) relate rust severity to direct epidemiological factors, and relate epidemiological factors to site and stand features;

3) validate and revise the initial model with relations developed for central Rockies forests;

4) map potential hazard in areas not yet infested.

MEASURES OF SUCCESS: Standard of Success, Expected Outcomes, and Implementation of Products/methods:
The success of this technology development project depends on both the accuracy and utility of the products. As a component of the Region's detection and evaluation program, we will continue to monitor rust incidence and damage on a series of plots stratified by hazard zone. Plots will include both areas already infested and high hazard areas outside the current outbreak area. Threshold detection and damage levels relative to practical management requirements will be determined and applied as standards for statistically judging system performance. The utility of the products will be assessed by the extent of their use in stand prescriptions, project planning, and Forest Plan revision.

PRODUCTS AND DUE DATES:
Project work will occur during 2001 and 2002. Completed products will be available in 2003.

1. A tested hazard rating system applicable to central Rockies relating rust severity to epidemiological factors and site and stand features.
2. Maps for various forests with white pines delimiting areas of rust hazard.
3. Microclimatological factors for southern Wyoming and northern Colorado(interpolated site conditions as corrected for topography, elevation, and other factors). These factors would also have utility for determining hazards from other forest disturbances such as wildfire, budworm, and bark beetles.
4. Disease control recommendations and vegetation management strategies linked to hazard zones. These include a determination where practices such as Ribes control, pruning, and growing white pines would be feasible.

PUBLICATIONS (how results will be reported)**:**

- A practical guide for identification of blister rust on white pines and of the various species of Ribes in the central Rockies (General Technical Report).
- A series of popular and professional articles informing the public, arborists, and nursery professionals about blister rust in white pines and the danger of transplanting Ribes or natural or horticultural varieties of white pine (Arbor Age, Journal of Arboriculture, etc).
- Several technical, peer reviewed papers describing the hazard rating system and its use (Phytopathology, Western North American Naturalist, Western Journal of Applied Forestry).

TECHNOLOGY TRANSFER (How will products or methods be transferred to users, adapted to other uses, or sustained by continuing technology transfer?)**:** Technology transfer will be accomplished with the publications listed above. We will also consider hosting a symposia on the ecology and effects of white pine blister rust on limber pine in the Rocky Mountains.

LONG-TERM BUDGET REQUEST: (estimates by fiscal year and funding, both monetary and in-kind, excluding FHP base funding) (extend table as necessary)**:**

A.	**Item**	**Requested FHP STDP Funding**	**Other-Source Funding**	**Source**
B. FIRST YEAR 2001				
C. Administration	Salary	20,300.	29,000.	Colorado State University
	Overhead			
	Travel	18,000.		
II. Procurements	Contracting	33,300.	13,000.	Forest Health Technology Enterprise Team
	Equipment	6,000.		
	Supplies	5,500.		
Year Total		83,100.00	42,000.00	

SECOND YEAR - 2002				
A. Administration	Salary	20,300.	29,000	Colorado State University
	Overhead			
	Travel	18,000.		
Procurements	Contracting	33,500.		
	Equipment	6,000.		
	Supplies	3,500.		

B. Year Totals		81,300.00	29,000.00	
C. PROJECT TOTALS		164,400.00	71,000.00	

BENEFIT AND COST: Using the Production Function Handbook (FHTET Publication 97-12, found at http://fsweb.ftcol.wo.fs.fed.us/fhtet/stdp/handbook/pf_handbook.html.), fill out the production function worksheet to capture economic costs and benefits for this project. Attach the worksheet to this application.

ASSUMPTIONS:
Currently, we do not have a way of knowing the likelihood of WPBR infesting sites. Since WPBR will continue to be an element of these ecosystems, studies and inventories can be more efficiently designed by knowing in advance which locations are most at risk.

Assume that benefits will be available to projects and studies in 2005, and that it will be applicable for studies and projects performed over 20 years (2005-2024).

The total cost of the studies and projects is assumed to be $100,000 a year for the 20 year period. This amount is lower than, but based on, the amount spent on whitebark pine studies by the Forest Service (Research, NFS, and S&PF), National Park Service, and USGS, and includes tree and rust inventory and monitoring, seed collection and conservation, and related habitat and ecosystem studies. This is actually a fraction of the amount of current spending on limber pine ecosystem-related research and field studies currently in progress by Forest Service, Park Service, and university researchers in the central Rocky Mountains.

We assume that use of the information produced by our project would be equivalent to a 10% budget increase in field studies and research projects. This benefit would be achieved through an improved allocation of plots and study sites, based on their likelihood of being infested with WPBR.

The relative rarity of white pines in the central Rocky Mountains, and their ability to establish and persist in very dry sites where other trees can not, makes the restoration and protection of these sites of high concern. In the whitebark pine regions, which have already suffered high WPBR-caused mortality, numerous projects are being undertaken on Forest Service and Park Service lands. For ecosystem protection and restoration projects, we assume that $160,000 ($800/acre x 200 acres) a year will be spent for a 20 year period in limber ecosystems for restoration and habitat recovery projects.

We assume that use of the information produced by our project would be equivalent to a 20% budget increase for restoration and recovery projects ($32,000/year, for years 2005-2024). This benefit would be achieved through an improved location of project sites, by being able to avoid failures by choosing sites without a high likelihood of being severely infested with WPBR.

Benefits would potentially be higher if blister rust spreads to other areas in the central Rockies or into Mexico, allowing

the further use of the techniques created from this project.

Background Data:
White pine blister rust has infected and killed extensive areas of white bark pine throughout its range in the northern Rocky Mountains. In response to this infestation, extensive inventory and monitoring and other research projects have taken place to support restoration projects.

Since the studies and restoration/protection projects which project results will support are not necessarily FHP projects and not even Forest Service projects, we are not in a position to estimate their benefits. For the purpose of this exercise, we assume they are equal to their costs. This will have no actual effect on the net present value calculation below, since the cost-savings benefit described in the assumptions section does not consider this portion of the project benefits [Benefit (Change in EOV) Attributable to Project].

Expenditure & Output Values (EOV) Without the Project:
Without the project
Costs = $100,000 x 20 years + $120,000 x 20 years, beginning in year 4 (2005) discounted to present (year 0) at .04 discount rate = $1,161,707+$1,858,730= -$3,020,437.
Benefits = $3,020,437.
Discounted net value, without the project = $0

Expenditure & Output Values (EOV) With the Project:
STDP costs discounted to present at .04 = $156,734
Supported project costs = $100,000 x 20 years + $120,000 x 20 years, beginning in year 4 (2005) discounted to present (year 0) at .04 discount rate = $1,161,707+$1,858,730= -$3,020,437.
Benefits = $3,020,437 + $116,170 + $371,746 = $3,508,353

Benefit (Change in EOV) Attributable to Project:
$3,508,353 - 3,020,437 = $487,916

Benefit/Cost Ratio:
487,916/ 156,734= 3.113 / 1.0

Benefit Attributable to STDP:
3.113 x $156,734 STDP Cost = $487,916

PNV Of Project:
$487,916 - $156,734= $331,182

PNV Of STDP:
$487,916 - $156,734= $331,182

LITERATURE, CITATIONS, ATTACHMENTS, etc.:

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FHP TECHNOLOGY DEVELOPMENT PROJECT PROPOSAL 10/6/00

Project Status: New.

Project number: R2-01-1, R4-01-1

Project title: Landscape scale hazard rating system for white pine blister rust in the central Rocky Mountains.

Subject: white pine blister rust(WPBR), Cronartium ribicola

Project objective:
We will develop a landscape scale hazard rating system that is linked to a Geographic Information System (GIS) for limber pine (LP)and Colorado bristlecone pine (CBP) using findings and methodologies developed for southwestern white pine (SWWP) and whitebark pine (WBP). Existing plot systems,including PTIPS plots established in Wyoming for LP and Forest Health Monitoring plots, will be utilized, as well as GIS data and supplemental data as needed.

Brief description of project:
We will adapt established concepts and techniques for hazard rating stem rusts to the recent discovery of the rust on LP in northern Colorado on the Arapaho and Roosevelt National Forest and adjacent private lands. A rating system will identify areas where LP and CBP are threatened and will indicate which control methods are likely to be effective at any particular site. We will use the current outbreak in southern Wyoming and northern Colorado as a model system; but other areas where the rust could be a serious threat will also be identified. Empirical relations will be determined to predict expected rust severity from epidemiological factors and from site and stand features. Epidemiological factors are those direct influences related to microclimate, Ribes distribution and abundance, and white pine age and size. Because information for these epidemiological factors is not available for most sites, we will relate these direct factors to standard resource management data describing site and stand conditions (e.g., elevation, habitat type, current vegetation, and management history). Using these data, we will generate and evaluate hazard maps for the current outbreak area. We will identify additional areas within the central Rockies, which could be seriously impacted by WPBR; and we will assess the consequences of alternative vegetation management strategies on rust impact.

FHP leads: Dave Johnson, Leader Lakewood Service Center and Jeri Lyn Harris, Plant Pathologist, Lakewood Service Center (R-2), Jim Hoffman, Plant Pathologist (R-4).

Justification:
White pine blister rust is a non-indigenous pest, which has caused significant economic loss and ecological change in other regions. WPBR has been present in lower elevation white pine environments (eastern white pine, western white pine, sugar pine) for many decades and because of their commercial significance, extensive knowledge regarding the rust is available for these pine species. WPBR has spread into higher elevation sites occupied by WBP more recently. Although a significant understanding of these ecosystems has been gained over the past few years, major losses occurred before and during the period when studies have taken place. Because of the lack of commercial value of WBP as a timber resource, information on the ecology and management of this forest type had to be developed as well. Once the ecological significance of WBP was recognized, protection and restoration efforts were initiated.

WPBR has also recently spread into SWWP. It is spreading northward from southern New Mexico into the extensive range of SWWP in Arizona and New Mexico. The rust will likely spread to the white pine forests of southern Colorado and northern Mexico.

In Colorado, the reduction of populations of white pines (LP,CBP,SWWP) could have deleterious effects on dependent wildlife species and secondary effects on forest and watershed health by loss of a valuable tree species. These effects on wildlife and forest health have occurred in the Northern Rockies and could be repeated in Colorado.

The extent of the outbreak needs to be determined by FHP detection surveys. Several trend and damage evaluation plots (PTIPS) have been established in Wyoming. These efforts, however, have not provided a statistical basis for management and assessment, which accounts for the potential loss of an important forest species. Detection surveys indicate that the rust has spread to a new area. However, they can not suggest which areas are at risk and where scouting should be conducted. Without linkage to the Forest Vegetation Simulator and Blister Rust Damage Model, the utility of trend and evaluation plots may be limited. The proposed project would specifically benefit the FHP program by focusing detection, evaluation, and management in those areas with greatest risk and value and by identifying those control techniques and strategies most likely to be effective. The project would benefit forest management and planning by providing needed information on long-term WPBR effects in an appropriate form for assessment (ID) teams and decision-makers.

Urgency:
There is a forest health crisis in the central Rockies. Conversion from a pine forest to a fir forest, increased tree density and fuel loading, recurrent insect outbreaks, abundant dwarf mistletoe, changes in fire regime and now establishment of an aggressive, non-indigenous, tree-killing pathogen, WPBR, constitute a crisis. Although LP is not likely to become extinct as result of this disease, it is likely to be lost from many stands. The disease is most damaging on regeneration and younger trees causing mortality within just a few years after infection and top-kill and mortality of older trees over longer periods. Not only does this loss diminish economic and aesthetic values, but also reduces the species ecological roles for providing wildlife habitat and buffering other forest pests. Although we have lost the opportunity for early control of the rust in the northern Rockies, early warning of where the rust would be a serious hazard in other areas is possible. This is a particularly appropriate time for the project. Information produced will be used in forest plan revision and in research studies on the impacts of small-scale disturbances. Cooperators from several universities are available to assist with this work.

Scope of application:
The benefits of this project extend beyond Colorado. Besides a site specific map of expected rust in northern Colorado, the project will identify site and stand conditions in which WPBR is expected to be a serious forest disturbance agent. Although not a specific goal of this project, results may also be applicable to forests in most of the Rocky Mountain states (portions of Regions 1, 2, 3, and 4). As one set of tools in an adaptive management program, the hazard system and management recommendations could be incrementally corrected, improved, and expanded; and thereby remain relevant and useful as long as there is a need to manage forests with white pines and WPBR.

Measure of success:
The success of this technology development project depends on both the accuracy and utility of the products. As a component of the Region's detection and evaluation program, we will continue to monitor rust incidence and damage on a series of plots stratified by hazard zone. Plots will include both areas already infested and high hazard areas outside the current outbreak area. Threshold detection and damage levels relative to practical management requirements will be determined and applied as standards for statistically judging system performance. The utility of the products will be assessed by the extent of their use in stand prescriptions, project planning, and Forest Plan revision.

Link to national priorities:
This project responds to national priorities identified by the FHM Directors and by steering committees for modeling and western diseases. In anticipation and response to the new and increasing forest health risk from the non-indigenous white pine blister rust, we will develop strategies to prevent, detect, and manage infestations in the central Rockies. This goal will be accomplished by meeting the needs of the modeling committee for WPBR to 1) adapt existing risk rating systems to different host types and forest conditions and 2) extend the site hazard system to the landscape level. The Western Disease Committee lists WPBR as a priority pest and described needs in terms of quantification of hazard/risk and of developing strategies for a variety of management objectives. We will develop a hazard system and set of management strategies for maintaining limber pine under forest planning objectives to maintain watershed functions, reduce fire hazards, and retain viable populations of T&E species and other wildlife.

Research basis:

White pine blister rust and limber pine

White pine blister rust, *Cronartium ribicola* J. C. Fisch., is an introduced pathogen to North America where it causes serious economic and ecological damage to white pines (Anderson 1988, Bingham and Gremmen 1971, Liebhold and others 1995). Because of its importance, blister rust has long been the subject of many research studies and management projects (summarized by McDonald and others 1991, Mielke 1943).

Current interests in blister rust result from its spread to new areas, impacts on ecological values, and new discoveries using molecular techniques (Conklin 1994, Draper and Walla 1993, Hamlin 1996, Krebill and Hoff 1995). Rust hazard models and indices remain the basic and necessary tools for assessing rust severity and evaluating genetic and cultural controls (Catlin and others 1994,McDonald and others 1981, McDonald and others 1990, Rust 1988).

White pine blister rust was first reported in Colorado in 1998 by Johnson and Jacobi (2000) on limber pine (*Pinus flexilis* Engelm.). It most likely spread southward from known infestations in southern Wyoming (Brown 1978). It has also been discovered on southwestern white pine (*Pinus strobiformis* Engelm. by Hawksworth (1990) from the Sacramento Mountains of south-central New Mexico (also see Hawksworth and Conklin 1990). Based on canker distributions and ages, the rust apparently became established in New Mexico circa 1975. A major expansion in distribution and severity of infection occurred about 1985, and significant amounts of new infection have occurred more recently. By the time the disease was discovered, it was already widely distributed throughout the Sacramento and adjoining White Mountains. In 1994, the rust was found for the

first time in the Capitan Mountains north of the Sacramento Mountains (Conklin and Schultz, unpublished observations); so far the rust has not been detected in several other southwestern ranges with white pines.

Although the nearest known populations of rust-infected white pine from New Mexico are 800 km north (southern Wyoming, collected by Geils: Forest Pathology Herbarium, Fort Collins #6804C) and 1100 km west (southern California, reported by Kliejunas 1985), these distances might have been bridged by transport of thick-walled, pigmented aeciospores or by successive jumps of repeating urediniospores.

Spread of blister rust to other disjunct pine populations over long distances has been reported (Draper and Walla 1993; Lundquist and others 1992).

Because of the great risk that this outbreak will cause serious ecological and economic impacts, forest managers are concerned over its ultimate extent and severity (Neuenschwander and others 1999). Although the current Arapaho and Roosevelt National Forest Plan does not specifically mention white pine blister rust, there is general direction to "develop alternatives to prevent or reduce damage [from forest insects and pathogens] to acceptable levels". The realized severity of this outbreak raises uncertainty about the adequacy of present management plans.

Since its discovery in 1998 in northern Colorado, the widespread nature of the outbreak has become much more apparent, with branch flagging, topkill, and small tree mortality appearing in numerous locations. Host and climatic conditions in northern Colorado are favorable for development of a serious epidemic. Both LP and Ribes are common and well-distributed throughout the area. Seedlings of LP and CBP are very susceptible to infection and canker formation (Hoff and others 1980). With concurrence of pathogen, susceptible hosts, and favorable environment, further expansion and intensification of this outbreak is expected similar to the outbreak in New Mexico.

An extensive and severe outbreak of blister rust in northern Colorado will directly impact populations of LP and indirectly affect the surrounding forest ecosystem. Limber pine is a minor component in mixed conifer stands. However, it is a vital biodiversity component and has high aesthetic and wildlife value. The large cones and seeds of white pine trees are vital to several species of wildlife (Benkman 1995, Tomback 1977, Tomback and Linhart 1990, Tomback and others 1995). The cumulative effects of near elimination of LP from the central Rockies or other areas could be detrimental to management objectives for fire and watershed protection, and maintenance of habitat for Threatened and Endangered Species.

Unlike the native insects and pathogens which have evolved in this forest ecosystem and behave as natural regulators, *Cronartium ribicola* is a non-indigenous pathogen and an introduced ecosystem disturbance (Castello and others 1994, Liebhold and others 1995). The consequences of the outbreak could go well beyond its current distribution in southern Wyoming and south-central New Mexico. With a greatly expanded rust population, there would be an opportunity for the rust to improve its epidemiological fitness (McDonald and Andrews 1982). Not only could a new strain develop that would be even better adapted to the central Rockies and southwestern hosts and weather, but that strain might also be able to overcome resistance mechanisms selected in breeding programs for economically important white pines in other regions (see McDonald and others 1984). From a large outbreak in the Sacramento Mountains, the rust would be more likely to spread to the white pine forests of southern Colorado

and northern Mexico (Eguiluz Piedra 1991, Shaw and others 1993).

A recent survey of the Intermountain West indicates the disease has also increased substantially in the northern and middle Rocky Mountains since the 1960s (Smith and Hoffman, 2000).

Although the WPBR outbreak in northern Colorado is recent, several efforts have been undertaken to describe its status and to plan appropriate research and management. Several meetings have been held in the last year with interested forest pathologists from the USDA Forest Service, universities and state pest specialists.

The approach to site and landscape hazard rating for WPBR demonstrated by Geils and others (1999) and Van Arsdel (1961, 1962,1964,1965,1967) might be applicable to the central Rockies. This project is the basis for work to adapt McDonald's rust index and simulation model (McDonald and others 1981) and for evaluation of alternative control and management techniques (Hagle and others 1989).

Hazard rating blister rust

A hazard model is a valuable tool for forest planning and management in areas threatened by pathogens such as blister rust (Froelich and Snow 1986, Geils and Jacobi 1991, McDonald and others 1990, Rust 1988, Steele and others 1996, Van Arsdel and others 1961). A general plan for addressing forest health issues related to blister rust in the Southwest (Geils 1993) identifies a hazard model as preliminary to an ecological effects assessment, a genetic evaluation, and an economic analysis. Epidemiological factors of host abundance and proximity and microclimates are well known for determining the incidence and severity of blister rust (Kimmey and Wagener 1961, Van Arsdel and others 1961) as well as other stem rusts including comandra blister rust (Jacobi and others 1993), fusiform rust (Davis and Snow 1968), and sweetfern rust (Gross and others 1983). The distribution of forest diseases can be predicted from forest inventory data and by using geographic information systems, GIS (Anderson and others 1986, Morse 1986). The basis for relating weather and climate to plant disease, modeling site microclimate, and predicting spore transport are well established (Davis and Monahan 1991, Hungerford and others 1989, Pielke and Avissar 1990, Ryan 1983, Van Arsdel 1965, Wilmot and others 1985). Hazard models and their component functions have been used to address management questions across a range of scales from individual tree, to stand, to an entire landscape (Baker and others 1991, Hunt 1983). For example, hazard information is used to execute the Forest Vegetation Simulator-Disturbance Model for blister rust (McDonald and others 1981). This model allows managers to evaluate various silvicultural options for regeneration, density control, and harvest schedule while taking into account infection, damage, and mortality caused by blister rust. Whether the objective is timber production, wildlife preservation, or fire protection, information on the potential impacts of significant forest disturbances such as blister rust has proven essential for good management (see Monnig and Byler 1992).

Available data:

The forests of the central Rockies already have much of the required site and stand data in their resource and GIS databases (forest stand data from the USDA Forest Service and USDI Bureau of Land Management). On the Medicine Bow National Forest, in southern Wyoming, several PTIPS plots have been established to document rust behavior. Harris is monitoring long-term rust development at several locations on the Medicine Bow National Forest(Harris 1999). In

addition, Forest Health Monitoring plots have been established in Wyoming and Colorado that may provide useful data.

The recently completed analysis of data collected from the STDP (R3 97-1) in the Southwest provides important information on the factors likely to be relevant for construction of a risk-rating system for other white pine-occupied ecosystems.

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Methods:

The project will consist of four general tasks completed in two years. The basic hypothesis is that the severity of blister rust depends on the distribution of white pine and Ribes populations and is strongly influenced by microclimate. The fundamental question is where can various cultural and silvicultural practices and forest management strategies be effectively employed to mitigate the impacts of blister rust on desired ecosystem functions and forest values. The hazard rating methods demonstrated in the North Central and Southwestern regions will be adapted and applied in the central Rockies. This will be a multi-scale analysis in which specific sites are evaluated in their landscape context. The development and validation tasks of the project will use southern Wyoming and northern Colorado as a model system with a currently established epidemic of blister rust. The hazard system, however, will be applied as well to other areas in the central Rockies with significant populations of white pines. Local information on Ribes ecology, rust epidemiology, and microclimate will be used to evaluate the feasibility in the central Rockies of various management practices used in other regions at the stand and forest levels. The principle statistical methods used will be correlation and regression (relating rust severity to epidemiological factors directly controlling rust distribution and relating those direct factors to site and stand features in the forest inventory, such as elevation and habitat type). Standardized methods for meteorological and geographic (GIS)(spatial) information will be used. A detailed work plan will be prepared, reviewed, and approved by cooperating research and statistical advisors. This plan will describe each of four general tasks of the project (see appendix for additional explanation and detail on

these tasks):

1) build hypothetical model based on current understanding and data;

2) relate rust severity to direct epidemiological factors, and relate epidemiological factors to site and stand features;

3) validate and revise the initial model with relations developed for central Rockies forests;

4) map potential hazard in areas not yet infested.

Cooperators:

Brian W. Geils
Rocky Mountain Research Station
forest pathology

William Jacobi
Colorado State University
forest pathology and modeling

Anna Schoettle
Rocky Mountain Research Station
Plant ecology and physiology

Eric Smith
Forest Health Technology Enterprise Team
statistics and modeling

Diana Tomback
University of Colorado, Denver
plant ecology and wildlife uses

Products:

1. A tested hazard rating system applicable to central Rockies relating rust severity to epidemiological factors and site and stand features.

2. Maps for various forests with white pines delimiting areas of rust hazard.

3. Microclimatological factors for southern Wyoming and northern Colorado(interpolated site conditions as corrected for topography, elevation, and other factors). These factors would also have utility for determining hazards from other forest disturbances such as wildfire, budworm, and bark beetles.

4. Disease control recommendations and vegetation management strategies linked to hazard zones. These include a determination where practices such as Ribes control, pruning, and growing white pines would be feasible.

Publications:

1. A practical guide for identification of blister rust on white pines and of the various species of Ribes in the central Rockies (General Technical Report).

2. A series of popular and professional articles informing the public, arborists, and nursery professionals about blister rust in white pines and the danger of transplanting Ribes or natural or horticultural varieties of white pine (Arbor Age, Journal of Arboriculture, etc).

3. Several technical, peer reviewed papers describing the hazard rating system and its use (Phytopathology, Western North American Naturalist, Western Journal of Applied Forestry).

FHP TECHNOLOGY DEVELOPMENT PROJECT PROPOSAL
Continuation for projects not previously funded.

Project duration: 2 years

Long term budget:

	FY 01	FY 02	Total
Equipment (field and computer supplies):	$5,500	3,500	
Salary:			
2 graduate students (9 months)	21,300	21,500	
4 field workers (summer seasonals)	20,300	20,300	
spatial statistics/GIS consulting	12,000	12,000	
Food/lodging for seasonals (12 weeks)	18,000	18,000	
2 Vehicles	6,000	6,000	
Funds needed:	**83,100**	**81,300**	**164,400**

Other contributed funding (value of services):

Colorado State University:		
Primary investigator	12,000	12,000
Graduate students	17,000	17,000
Forest Health Technology Team	13,000	

STDP PRODUCTION FUNCTION

PROJECT NUMBER: R2-01-1, R4-01-1

PROJECT COST: $164,400

PROJECT OBJECTIVE: Develop a landscape scale hazard rating system for white pine blister rust in the central Rocky Mountains. The benefits of this information will be applied to protection and management of sites with limber pines, and possibly other non-commercial white pines (bristlecone pine). The FHP hazard rating system will lead to better planning, silvicultural prescriptions, and cultural practices, resulting in forests with healthier and larger components of these white pine threatened by the non-native white pine blister rust (WPBR) pathogen, than without the system.

White pines are a minor, but essential forest component, particularly to wildlife, for watershed protection, and in highly used alpine recreation sites. As with many FHP protection projects, and consistent with Forest Service priorities, protection of this resource has no direct financial benefit as a commodity. Identifiable benefits are related to more effective management projects and research studies, and lowered management costs, although these are minor benefits relative to protecting this ecologically important resource. *Some Rocky Mountain limber pines are well over a 1000 years old, and bristlecone pines, as is well known, are the oldest trees on earth. Though we understand the need to allocate STDP funds wisely and efficiently, the use of this commodity-based "production function" approach for what are clearly important, but non-commodity, resources, is an irrelevant anachronism. It could easily be misinterpreted by others as evidence that Forest Health Protection's STDP program does not recognize the importance of non-commodity resources and, all other things being equal, gives a higher priority to protecting common harvestable timber resources than rare, non-timber species.*

ASSUMPTIONS:

Currently, we do not have a way of knowing the likelihood of WPBR infesting sites. Since WPBR will continue to be an element of these ecosystems, studies and inventories can be more efficiently designed by knowing in advance which locations are most at risk.

Assume that benefits will be available to projects and studies in 2005, and that it will be applicable for studies and projects performed over 20 years (2005-2024).

The total cost of the studies and projects is assumed to be $100,000 a year for the 20 year period. This amount is lower than, but based on, the amount spent on whitebark pine studies by the Forest Service (Research, NFS, and S&PF), National Park Service, and USGS, and includes tree and rust inventory and monitoring, seed collection and conservation, and related habitat and ecosystem studies. This is actually a fraction of the amount of current spending on limber pine ecosystem-related research and field studies currently in progress by Forest Service, Park Service, and university researchers in the central Rocky Mountains.

We assume that use of the information produced by our project would be equivalent to a 10% budget increase in field studies and research projects.

This benefit would be achieved through an improved allocation of plots and study sites, based on their likelihood of being infested with WPBR.

The relative rarity of white pines in the central Rocky Mountains, and their ability to establish and persist in very dry sites where other trees can not, makes the restoration and protection of these sites of high concern. In the whitebark pine regions, which have already suffered high WPBR-caused mortality, numerous projects are being undertaken on Forest Service and Park Service lands. For ecosystem protection and restoration projects, we assume that $160,000 ($800/acre x 200 acres) a year will be spent for a 20 year period in limber ecosystems for restoration and habitat recovery projects.

We assume that use of the information produced by our project would be equivalent to a 20% budget increase for restoration and recovery projects ($32,000/year, for years 2005-2024). This benefit would be achieved through an improved location of project sites, by being able to avoid failures by choosing sites without a high likelihood of being severely infested with WPBR.

Benefits would potentially be higher if blister rust spreads to other areas in the central Rockies or into Mexico, allowing the further use of the techniques created from this project.

Background Data:

White pine blister rust has infected and killed extensive areas of white bark pine throughout its range in the northern Rocky Mountains. In response to this infestation, extensive inventory and monitoring and other research projects have taken place to support restoration projects.

Since the studies and restoration/protection projects which project results will support are not necessarily FHP projects and not even Forest Service projects, we are not in a position to estimate their benefits. For the purpose of this exercise, we assume they are equal to their costs. This will have no actual effect on the net present value calculation below, since the cost-savings benefit described in the assumptions section does not consider this portion of the project benefits [Benefit (Change in EOV) Attributable to Project].

Expenditure & Output Values (EOV) Without the Project:

Without the project
Costs = $100,000 x 20 years + $120,000 x 20 years, beginning in year 4 (2005) discounted to present (year 0) at .04 discount rate = $1,161,707+$1,858,730= -$3,020,437.
Benefits = $3,020,437.
Discounted net value, without the project = $0

Expenditure & Output Values (EOV) With the Project:
STDP costs discounted to present at .04 = $156,734
Supported project costs = $100,000 x 20 years + $120,000 x 20 years, beginning in year 4 (2005) discounted to present (year 0) at .04 discount rate = $1,161,707+$1,858,730= -$3,020,437.
Benefits = $3,020,437 + $116,170 + $371,746 = $3,508,353

Benefit (Change in EOV) Attributable to Project:
$3,508,353 - 3,020,437 = $487,916

Benefit/Cost Ratio:

487,916/ 156,734= 3.113 / 1.0

Benefit Attributable to STDP:

3.113 x $156,734 STDP Cost = $487,916

PNV Of Project:

$487,916 - $156,734= $331,182

PNV Of STDP:

$487,916 - $156,734= $331,182

Appendix

Methods, Four Tasks

1. Build hypothetical model. Based on personal observations, established research and monitoring plots, and published information from the Southwest, North Central region, and other regions with a history of white pine blister rust, we will construct a hypothetical hazard system that relates rust severity to various forest inventory data describing site and stand features. This system of relations will then be used with a geographic information system to map expected rust hazard across the central Rockies.

2. Determine relations between rust severity and epidemiological factors and relate those factors to site and stand features. Guided by the hypothetical model for site selection, we will identify airsheds in southern Wyoming and northern Colorado for intensive examination. Observations in these airsheds will be used to relate microclimate (temperature and moisture regimes and air flow patterns), Ribes composition and abundance, and white pine density and size to disease severity. Information will be collected on the ecology and susceptibility of Ribes and white pines as well as microclimate at several stations to correlate these epidemiological factors to site and stand features and predict their response to vegetative manipulation.

3. Validate and revise the initial model for the central Rockies. Based on the relations observed during completion of task 2, validate and revise the hypothetical model constructed for task 1. Also, evaluate the likely value of various silvicultural and control practices in each of several hazard zones (severe, moderate, light). For example, observations may suggest that controlled burning does not greatly increase Ribes abundance or that pruning can reduce tree mortality in areas where cankers only establish near to the ground.

4. Map potential hazard in areas not yet infested. Apply the hazard system to map expected rust distribution in other areas of the region with significant populations of white pines and not yet known to be infested. We intend to map potential rust hazard in the central Rockies. The hazard system may be useful to forest managers in adjacent regions, for determining where the greatest risk for white pine blister rust occurs in their territory.