APPENDIX A

PROPOSAL COVER PAGE, REQUIRED DECLARATIONS, AND BUDGET SUMMARY FORM AND INSTRUCTIONS

I. Proposal Cover Page

A. Requirements

A proposal cover page must be part of each proposal, but will not be counted against the page limit. The cover page must be signed by the Principal Investigator and an official, by title, of the investigator's organization authorized to commit the organization. *This authorizing signature also certifies that the proposing institution is in compliance with the three required certifications printed in full in Section II of this appendix.* The three certifications *do not* need to be submitted with the hard copy of the proposal.

Proposal Cover Page

NASA Broad Agency Announcement BAA-01-OES-01

Proposal No. ____________________ (Leave Blank for NASA Use)

Application Theme Area (Please check one or all that apply):
- Resource management __X________
- Environmental assessment __X________
- Community growth ____________
- Disaster management ____________

Title: Development and Implementation of Remote Sensing Techniques to Monitor Invasive Plant Species in the State of Idaho

Principal Investigator: Jeffrey Pettingill

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Co-Investigators:

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Keith T. Weber	Idaho State University webekeit@isu.edu
Dr. Timothy S. Prather	University of Idaho tprather@uidaho.edu
Dr. Lawrence W Lass	University of Idaho llass@uidaho.edu
Dr. Walter S. Snyder	Boise State University wsnyder@boisestate.edu

Budget (by government fiscal year, October 1 through September 30)

1st Fiscal Year:	$373,125
2nd Fiscal Year:	$283,905
3rd Fiscal Year:	$144,665
4th Fiscal Year:	N/A
Total:	$801,695 (includes data costs)

By submitting the proposal identified in this *Cover Page/Proposal Summary* in response to this Broad Agency Announcement, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the three Certifications contained in this BAA [namely, (i*) Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs*,

(ii) Certifications, Disclosures, And Assurances Regarding Lobbying, and, (iii)) Certifications, Disclosures, And Assurances Regarding Debarment & Suspension].

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Title of Authorizing Institutional Official: ____

Signature: ________________________________ Date: ______________________

Name of Proposing Institution: ____

Telephone: __________________ E-mail:______________________ Facsimile: ________________

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Development and Implementation of Remote Sensing Techniques to Monitor Invasive Plant Species in the State of Idaho

PI: Mr. Jeffrey Pettingill

3) Application:

3a. Theme/Characterization: The application to be developed under this proposal will address the NASA BAA themes of *Resource Management* and *Environmental Assessment*. It targets the problem of invasive weeds in both rangeland and/or riparian ecosystems of southern Idaho. This proposal builds on existing research to develop an application/tool to help land managers accurately and reliably map the extent of invasive plants, manage weed invasions, and identify similar habitats where the targeted species (see Section 3c) may occur. The application will be readily transferable to similar areas across the western states. More specifically, the application will use remote sensing imagery to identify, map, and monitor targeted invasive plant species in Bonneville County (map, page 3) and surrounding lands. The proposal is based on an integrated partnership between Bonneville County (the lead agency), Ada County, Fort Hall Indian Reservation, Idaho State University (ISU), Idaho National Engineering and Environmental Laboratory (INEEL, a federal DOE facility), University of Idaho (U of I), Boise State University (BSU), Idaho State Department of Agriculture (ISDA), and USGS Snake River Field Station. The application will utilize imagery from both NASA and commercial (i.e., Positive Systems, Inc.; (3D)i; and Ecoprobe) remote sensing data.

3b. Currrent Situation: The region's ecology and economy are dependent upon riparian and rangeland ecosystems. Maintaining the health of these lands is vital to policy and decision makers at both private concerns and all levels of government. With respect to riparian habitat, the availability and quality of water is always of concern in the arid west (southern Idaho is "high desert"); this is especially true in times of drought (such as the present). Rangeland supports not only abundant and diverse wildlife, but also the state's $1.4 billion/year livestock industry. These ecosystems are inter-related, and informed decision making in one topical area cannot take place without comprehensive knowledge of the other. The challenges caused by invasive plant species are numerous. They impact range site productivity, disturb wildlife habitat, alter the wildland fire regime and fire frequency interval (and subsequent erosion, etc), and reduce biodiversity (by diminishing native habitat). Existing techniques to delimit invasive weeds in Idaho includes the use of:

- color-infrared imagery and photography in southern Idaho (Ada County, Brian Wilbur),
- multispectral and hyperspectral imagery to identify:
  - yellow starthistle (*Centaurea solstitialis*) and St. Johnswort (*Hypericum perforatum*) (Lass et al. 1993);
  - meadow hawkweed (*Hieracium pratense*) (Carson et al. 1995, Lass et al. 1997);
  - and spotted knapweed (*Centaurea maculosa*) (Lass et al. submitted) in northern Idaho.

Predicting occurrence of weed species using both remote sensing data and topographic variables will be a useful management tool, as in the case of common crupina (*Crupina vulgaris*) (Prather and Callihan 1993, Lass and Callihan 1993). In addition to hyperspectral systems, relatively new high spatial resolution sensors such as ADAR (Positive Systems, Inc.) have been utilized in Idaho for invasive plant mapping. Landsat 7 ETM+ and MODIS has also been integrated into a weed-management program with its relatively low cost, high geometric accuracy, and multispectral capabilities for landcover classification.

Bonneville and Ada Counties currently use GPS to record weed locations. Both counties have GIS layers that contain weed locations. Ada County has used aerial photography coupled to ground survey to map rush skeletonweed. Neither county has sufficient resources to conduct extensive GPS-ground survey. Both counties have well-trained personnel capable of implementing and evaluating the proposed application. The county governments are part of a larger program to manage invasive plants. Statewide there are 26 Cooperative Weed Management Areas (CWMA). These are managed for invasive plants across ownership boundaries by land owners and land managers. Membership in CWMAs include public land management (USFS, BLM, IDL, IDFG), tribal, and private owners (cooperative, individual and conservancy group). These CWMA's represent a network of potential users of this proposal's application.

In Idaho, every county participates in their area's CWMA. In Bonneville and Ada Counties, partners in the CWMA do not have the same ability to use GPS to locate plants. Nor do other counties and their participating CWMAs have a low-cost system that is easy to use for mapping with an adequate resolution for weed management (1 to 5 m). The CWMAs need to be able to share information, but currently the partners have a wide range in their expertise with these technologies. No CWMA has the necessary resources to create the application described in this proposal. The CWMA process is ideally suited to a distributed data collection system with central storage of data. The ability for each participant to access and jointly use strategic planning tools will enhance cooperative efforts to manage invasive plants across ownership boundaries.

The development of a successful application will lead to broad systemic change in weed control for Idaho and the CWMAs. For example, the current methods of identifying weeds in Bonneville County are typical of the region, and consist of either notification by landowners, or by "stumbling upon them" during day-to-day operations (e.g., field mapping) of Bonneville County Weed Control. This means the infestations are usually visible from vehicle, horseback or ATV: i.e., by the time they are identified, the weed colony has become large and firmly established. In contrast, the proposed application will allow land managers to identify and control weed sites while they are still small and manageable, and therefore much less expensive to control. The extreme accuracy of GPS/GIS will increase the efficiency of control operations, as managers will know almost exactly where to commit resources for existing invasions, and/or take preventive action in terrains/soils identified as vulnerable to invasion. Further, the species of invasive weeds which can be monitored by the application may be increased as warranted. The impact of a successful application will be revolutionary for regional weed control efforts.

3c. What the Application Will Do: The application will use NASA and commercial remotely sensed data to detect and identify invasive plant species with efficacy and accuracy. This will enable land managers to take corrective action while invasive plant colonies are still small, as well as identify other areas/habitats similar to those already colonizedi by the invasive plant. NASA Landsat 7 ETM+ and MODIS data will be utilized, in conjunction with high resolution hyperspectral (AISA and Probe) and multispectral (ADAR) and IKONOS (Space Imaging) data. The application will also integrate SPOT data (discussed under Section 4), and develop a methodology that will be seamlessly integrated into Bonneville County's weed control and land management programs. The application will also be readily transferable to other counties, CWMAs, and land management agencies in southern Idaho.

The project will initially focus on evaluating soil composition and vegetation growth of downy brome (cheat grass; *Bromus tectorum*), leafy spurge (*Euphorbia esula*), purple loosestrife (*Lythrum salicaria*) and spotted knapweed (*Centaurea maculosa*) in a 10 km x 10 km test site in

Swan Valley, southeastern Idaho. Additional test sites and plant species will be studied in southwestern Idaho (Ada County and/or Birds of Prey Conservation Area; see Fig.1) contingent upon the successful application testing in Bonneville County, and will be approximately the same size.

Figure 1.

Each test site will be determined using input from all participating and user organizations on types and abundance of species, habitat, and economic and ecological importance. Available historical monitoring data will also be used as criteria for test site selection. Ground-truthing of vegetation and soil composition will be accomplished through field surveys performed primarily by Bonneville County and ISU, and with help and input from U of I, BSU, USGS Snake River Field Station, Fort Hall Indian Reservation, INEEL, and Ada County.

More specifically, the application will consist of 4 specific sections: 1) GIS layers of invasive species acquired through remote sensing data analysis and other methods; 2) GPS system and interface for downloading data to GPS, to aid mapping and navigation to infestations/invasions data; 3) Monitoring of control actions, including control method used, effectiveness, number of years successfully treated, change in area of infestation; and 4) Strategic planning module to assist county government and their associated CWMA partners to develop yearly management plans and evaluate the success of current-year efforts.

3d. Users: The users will initially be county (Bonneville County, Ada County, Idaho) and tribal (Fort Hall Indian Reservation) weed managers and land stewards (INEEL, USGS Snake River Field Station), and partners in the CWMAs**.** However, a much larger end-user group is envisioned and includes southern Idaho ranchers, farmers, and watershed advisory groups (e.g., the Teton Regional Land Trust). These latter groups are interested in using the proposed application to understand how changing vegetative cover --and subsequent changes in fire regime (e.g., increased fire frequency with concomitant increases in soil erosion)-- will effect total maximum daily loading of sediment and nutrients into surface waters. Wildlife managers will utilize the tools created by this project to understand where invasive plants may be affecting the habitats of sage grouse, elk, deer, and other species. Groups such as the INEEL and USGS Snake River Field Station are interested in the project's tools for evaluating sagebrush habitat in southern Idaho. Other uses includes mapping of sites similar to those currently containing the invasive species taking into consideration disturbance factors (e.g., fire, grazing) as well as soil characteristics. The Idaho State Department of Agriculture will utilize the project as an informational and training demonstration, leading to its statewide dissemination for invasive plant *prevention* and monitoring.

3e. Mandates/Decision-Making: All the participants are charged with mandates and/or the need to make informed decisions on habitat management/weed control. The described application will facilitate these responsibilities through the means described in Section 3.c. The application's demonstrated improved efficiency and accuracy of weed control with remote sensing will result in interagency cooperation and data sharing.

In Idaho, a number of invasive plant species fall under regulatory jurisdiction and are designated noxious weeds. This designation may be made at either the federal level, the state level, or both. Also, within the State of Idaho, a county government can designate a county-level noxious weed. Plant species with a noxious designation must be prevented from spreading. In addition, federal agencies must evaluate their own activities to consider invasive species under an executive order issued by former President Clinton. Federal land management agencies have been active participants in noxious weed management, along with state agencies, county government and private land owners. The federal mandate for invasive plant management is also represented by funding passed through ISDA to support CWMA weed management activities. These federal dollars are matched by CWMA participants providing in-kind support to the management effort.

As described in Section 3b, current weed control relies upon ground-based identification. However, there are many areas where no roads exist or roads are inaccessible (a portion of Targhee National Forest lies within Bonneville County and is subject to the Inventoried Roadless Areas Initiative); ground-based mapping is not always feasible. Statewide, 69% of all land is owned by the state or federal governments. The State of Idaho is home to a dozen national forests and nearly 70% of Bonneville County is owned by either the USDA FS, BLM, Idaho Fish and Game, or Idaho Department of Lands. These agencies have limited resources, but are willing to build upon strong working relationships, share historical data, and support the implementation of new technology. As an example of this, Ada County has acquired aerial photography over the past four years to map weeds at a cost of approximately $7,000/year. One of Ada's challenges in using this imagery is to design acquisition campaigns and image enhancement techniques to minimize shadowing in the Boise foothills. Ada County is interested in comparing their methodology and costs with the proposed application in Bonneville County. This cooperation is indicative of the high levels of cooperation between the agencies with mandated responsibilities for weed control/land management, and will facilitate dissemination of the application.

The project involves all three of the state's public universities. These universities have mandates to perform research, community service, and educational activities; and are also crucial to building the state's economy. U of I is the state's land grant institution, and operates the state-wide system of cooperative extension offices, with direct responsibility to aid agricultural endeavors. This project is directly connected to all of these purposes. The other participants (i.e., Fort Hall, USFS, other federal/state agencies) all have land stewardship responsibilities .

3f. Public & Private Benefits: Public benefits include better stewardship of public lands and wildlife management (including efforts to maintain bio-diversity); improved cost/labor efficiency and effectiveness in controlling invasive plants; improved coordination and cost-sharing among local, state and federal agencies; broad dissemination of usable information to a broad community of users, and better management tools for regional industry (livestock). Private benefits are much the same, with the economic benefits being perhaps the most important to the individual. For example, rangeland productivity will increase with improved control of invasive plants such as cheat grass (downy brome) (so-called because its little-to-no nutritional value "cheats" grazing livestock.).

4) Information Products, Processes and Services Necessary

4a. Required Data Sets: Several space- and airborne imaging platforms will be employed for this application. Multispectral data products from NASA's Landsat 7 ETM+ and MODIS systems will be acquired directly from the USGS EROS Data Center. High spatial resolution digital multispectral aerial photography (ADAR) will be acquired from Positive Systems, Inc. IKONOS (Space Imaging, Inc.) high spatial resolution multispectral (.4m) imaging may also be used. Hyperspectral remote sensing imagery from (3D)i (AISA sensor) and Ecoprobe (Probe sensor) will also be acquired from airborne mapping of test sites. SPOT imagery will also be utilized for its 10 m panchromatic band and availability (see below).

Landsat is chosen for this study due to its high geometric and radiometric accuracy, ease of use for the end-user, and accessibility. Landsat 7 ETM + images will be used for (1) large-scale vegetation monitoring such as peak greenness and NDVI (normalized difference vegetation index); and (2) support tools to other imagery in discrimination of invasive vegetation with other native vegetation and their host environment by sub-pixel image processing and classification. Level 1G datasets will be utilized and mosaicked as necessary. MODIS data has a much coarser spatial resolution than Landsat; however MODIS provides enhanced vegetation and land products for end-users managing large tracts of land (e.g. INEEL, USGS). The MODIS products which will be utilized include the NDVI and EVI (enhanced vegetation index), LAI (leaf area index), and FPAR (fraction of photosynthetically active radiation).

Statewide SPOT 10 m panchromatic imagery (with the possibility of 5 m data in 2002) is currently being acquired by the State of Idaho and will be available for government and education partners. This availability along with its spatial resolution makes it ideal to integrate into this proposed application. Also, the state is considering additional SPOT data buys, thus offering a long-term data supply at little or no cost to the project participants (i.e., counties).

ADAR airborne imagery will be acquired from Positive Systems, Inc. and will include 0.5 m to 3 m pixel spatial resolution, georectified and registered images in the visible and NIR bands. The ADAR images will be used for plant identification and mapping and will be acquired through direct interaction and guidance from Positive Systems, Inc. The ADAR imagery can also help calibrate the Landsat data and can easily be incorporated into a GIS environment. Hyperspectral imagery from the AISA and Probe sensors will be acquired through (3D)i and Ecoprobe, respectively. The AISA airborne platform is capable of collecting data within a spectral range of 430 to 900 nm and up to 286 spectral channels within this range, however current operational collection configurations range from 10 to 70 spectral bands depending on the aircraft speed, altitude and mission goals.

Ecoprobe's Probe 3, "Next Generation Hyperspectral Sensor," will be used for the study. The Probe 3 has a forward-looking scanner, allowing block capture of 128 data rows and 128 spectral bands with an internal IMU (Internal Mapping Unit) for positioning. The new sensor reduces the positioning error and swirls associated with single line scan systems such as HyMap, AVIRIS, and Probe 1 and 2. The sensor configuration allows the aircraft to fly faster and capture data at spatial resolutions down to 1 meter. Level II digital elevation model data (DEM) from USGS will be used to correctly rectify during the flight. The project will image the study sites two times during the growing season. Hyperspectral data will be classified to detect the invasive species at three foliar cover classes (1% to10%, 10% to 40%, >40%). Procedures for remote sensing will follow standard protocols reported in previous research using multispectral and hyperspectral images to detect plant species based on procedures outlined by Campbell (1996) that have been updated (Ben-Dor and Levin 2000, Cochrane 2000, Zhang et al. 2000).

4b. Data Processing Steps: Ground-based surveys and monitoring by field personnel with GPS equipment will be used. These practices currently take place in Bonneville and Ada Counties, and other participating organizations. A GIS module will be established to integrate the imagery, ground-based surveys, and historical data provided from participating agencies. A GIS monitoring module, which can be customized and distributed, will be developed to ensure end-user access and feasibility. For example, a web-enabled GIS system will be established with customized tool-bars that can be designed for each end-user agency. Image processing and GPS software, including ENVI, ERDAS, Idrisi, ArcInfo, ArcView (with Image Analysis), and Trimble Pathfinder will be used for image processing, classifications and transforms. Unsupervised, supervised, fuzzy-class membership, and regression tree analysis GIS data sets will be developed (in Idrisi, ArcInfo, and ArcView) showing predicted areas of invasive plant species.

Additional sites for hyperspectral analysis will be located in naturally occurring infestations that vary in their % foliar cover with sites selected within each cover class of the invasive weed. These study sites will also vary in the stage of phenological development and often require two image dates to increase detection accuracy based on prior information about the site. Sites will have coordinates measured by a GPS with Wide Area Augmentation System (WAAS) to delimit both invasive weed cover and nearby vegetation not containing the invasive weed (Goodchild and Gopal 1988; http://waas.stanford.edu/metrics.html). Selective availability was turned off on May 1, 2000; thereby removing the need to differentially correct most GPS data. Weed cover for each delimited area will be manipulated with herbicides to obtain the desired cover class. Non-weed features expected to be present on the images such as rock outcrops, buildings, and water will be located with the GPS WAAS unit. Areas represented by non-weed species and other feature classes will not contain the target invasive plant. A cover class will not be assigned to the non-weed species classes to prevent cross tabulation confusion when the class is used for verification. Prior research indicates that each study site should have about 2000 5x5 m validation points for the weed classes and 1500 5x5 m validation points for the non-weed species and other feature classes. In addition, 200 5x5 m points in the highest weed cover classes and each of the non-weed features will be collected for spectral signature development.

Image classification will use the Dempster-Shafer theory of maximum likelihood and other probability classification algorithms to classify the hyperspectral. Data sets will be statistically partitioned into training and validation data prior to modeling. Classification accuracy will be assessed from other locations containing the weed. Detection accuracy will be expressed as omissional and commissional error rates and Bayesian statistic (Price et al. 1998). Establishing "pure" endmembers for each invasive plant species will use the Adaptive Real- Time Endmember Selection and Clutter Suppression (ARES) algorithm (Haskett and Sood 1997) and other weighted linear algorithms (Ashton and Schaum, 1995; Boardman 1999; and Research Sys. 1998). The ARES algorithm generates an overall clutter signature (non-weed) for the image and identifies the target (weed) by assuming the spectral angle between the target weed from the non-weed clutter will vary more widely than the spectral angles between plants that make up the clutter signature (Hasket and Sood 1997). The weighted linear algorithm assumes the spectral signature is a weighted sum of the "pure" endmember where the weighted value at the ith band can be modeled based on the pure signature values for each component in the mixed pixel (Aston and Schaum 1995; Boardman 1999; and Research Sys. 1998). Contrasts between classification with probability, endmember, and traditional classification of both the multispectral and hyperspectral images will be made using Bayesian methodology to assign significance (Price et al.

1998). Results will show if using probability and membership classification will enhance the detection of Idaho's invasive weeds with images from multispectral and hyperspectral sensors.

Fuzzy Classification will be used to aid in classifying multispectral imagery. Fuzzy Classification is considered a soft classifier (cf., hard classifiers such as unsupervised and supervised classification). It operates by assigning membership proportions to each class of interest (e.g., cheat grass, an invasive plant; and sagebrush and bluebunch wheatgrass, two native plant classes) and produces one dataset for each class and an uncertainty dataset. This technique has the potential to reliably identify sub-pixel elements and discriminate mixed signatures. To effectively utilize fuzzy systems, the project will acquire training sites where target species are dominant and homogeneus over a relatively large area (i.e., 30 x 30 m for use with Landsat 7 imaging). These training sites will then be used in Idrisi's and ENVI's fuzzy class module.

Error/accuracy contingency tables, reports, and manuscripts describing the efficacy of these platforms with management implications will also be produced. In addition, maps will be printed and distributed to the collaborating user organizations. A standard error matrix (i.e., confusion matrix) and Kappa chance correction statistics will be prepared and modulated to compare accuracy among remote sensing platforms and remote sensing data and ground surveys. These data products will be generated from input by local agencies and generated under the supervision of Bonneville County at ISU, U of I, INEEL, and BSU.

Remote sensing data products will also be generated with help from data processing experts from Positive Systems, (3D)i and ESSI. These commercial remote sensing groups can provide atmospherically corrected, georectified, and mosaicked data. Because scientists at three universities and INEEL are involved in this project's application, many of these image processing steps will take place in their respective laboratories. If time does not permit or it is more economically feasible, these steps will be performed by the commercial participants.

The data products will be generated using existing software at ISU (ENVI, Idrisi, and Arcview Image Analysis), BSU (ERMapper), INEEL (ERMapper) and U of I (Idrisi). Positive Systems DIME software will also be utilized if necessary, as well as (3D)i's CaliGeo. The types of data products will include atmospherically corrected, georectified data for integration with GPS field data. The data products will include select bands of imagery to generate pure endmembers in the wavelength range most effective for delineating reflectances of leafy spurge, spotted knapweed, purple loosestrife, and cheat grass. Images of vegetation indices will be produced to indicate ideal times for collecting airborne imagery and for weed management (i.e. spraying).

5) Software, Data Processing Algorithms, etc.

Existing software (see Section 4b) will be utilized in this study for image processing and geographic mapping. Particular emphasis will be placed on utilizing software that end-users already have or can cost-effectively acquire (such as ERMapper or ArcView with Image Analysis). Data processing algorithms will need to be developed for georectification, atmospheric corrections, and accurate mapping of reflectance in the use of hyperspectral imagery. These algorithms will be developed based on existing algorithms in ENVI routines, and other software used by the commercial participants (See Section 4b).

The accuracy of Landsat 7 ETM+ will be evaluated by performing sub-pixel processing and comparing it against other remote sensing platforms (e.g., SPOT, IKONOS and ADAR) using standard contingency tables, the Kappa statistic, as well as newer statistics that utilize omissional and commissional error (Price et al. 1998). Accurate delineation and detection of early weed invasions are extremely important. These areas are most treatable and tend to have the highest probability of success compared with the treatment of large infestations. For this reason, the acquisition of relatively small area (<25m2) invasion patches using GPS is a critical part of this study. We propose to utilize Mapping grade Trimble ProXR GPS receivers (owned by GIS TReC and to be obtained by Bonneville County) to acquire and attribute small area weed invasions as they are located in the field. These area features will be post-process differentially corrected using either the ISU GIS TReC Community Base Station (CBS)(which operates 24-hours/day, 365 days/year) or other locally available CBS. The resulting small area invasions will have a horizontal positional accuracy of approximately +/0.5 m. These areas will then be used as training sites to locate similar invasions within the extent of our acquired imagery. To validate this portion of the study we will randomly select 30 predicted invasion sites and ground-truth that area to determine the accuracy and reliability of the various classification methods and imagery platforms used in this project.

One important aspect of this application is the user's capability to continue to use the methodology developed in this project after the project term is over. For example, the need to address the issues of 1) intensity of processing hyperspectral imagery; 2) costs of acquiring commercial imagery; and 3) advantage of using NASA products with the disadvantage of data format complexity (e.g. MODIS). An accuracy assessment of high resolution multispectral imagery versus hyperspectral imagery will be studied in detail, as well as uses of coarser resolution NASA products. A study of the cost and long-term rigorous use of hyperspectral imagery for the end-user will be explored prior to implementation of this type of imagery.

A schedule for development, testing, and implementation is noted in Section 11. The data and information products to be distributed will include:

- Feasibility study of high resolution multispectral and hyperspectral remote sensing imagery. The study will include a detailed methodology of image processing, results and accuracy of classifications.
- Detailed methodology of implementing remote sensing in weed management.
- Development of a GIS-based management system to incorporate remote sensing data into on-going invasive plant management activities

6) **Organizations, Agencies and Companies**

6a. Names, Addresses, Roles/Responsibilities: The following list highlights participating organizations with a point of contact who will serve as project manager for their respective organizations.

- **Bonneville County**, Mr. Jeffrey Pettingill, Bonneville County Weed Manager, Weed Management Office, 605 N. Capitol, Idaho Falls, ID 83402, 208-529-1397, Email: **Jpettingill@co.bonneville.id.us** Pettingill ***(Proposal PI)*** will head ground-based surveys and data compilation for Bonneville County. Pettingill will also facilitate communications between end-user groups; he has extensive interaction with southern Idaho county weed managers, ISDA, ISU, U of I, and INEEL.
- **Idaho State University** Dr. Nancy F. Glenn, Assistant Research Professor, Department of Geology, Campus Box 8072,, 208-282-2949, **glennanc@isu.edu**, and Mr. Keith

Weber, Director of GIS Training and Research Center (GIS TReC), Campus Box 8130, 208-282-2757 **webekeit@isu.edu**; Pocatello, Idaho, 83209-8130. ***(Co-PIs)*** Glenn will provide remote sensing expertise in image processing and validation, and help Pettingill oversee the project's schedule and timeline, and facilitate communication between the universities and state/local agencies. Weber will coordinate GIS activities, integration of field and digital data, and oversee all activities taking place in the GIS center. Weber will also provide his expertise in range and wildlife ecology.

- **University of Idaho**, Drs. Timothy S. Prather and Larry Lass ***(Co-PIs)***, Assistant Professor/Extension Specialist-Weed Ecology and Scientific Support Staff III. Department of Plant, Soil and Entomological Sciences, College of Agriculture, P.O. Box 442339, Moscow, Idaho 83844-2339, 208-885-9246 and 885-7802, tprather@uidaho.edu and llass@uidaho.edu Prather and Lass have extensive research expertise in remote sensing of invasive plants and experience in invasive plant ecology. They will provide expertise in designing test-bed sites, implementing hyperspectral image acquisition through Ecoprobe, and interpretation of remote sensing images. Prather currently acts as Assistant Professor and Extension Specialist in Weed Ecology and interacts frequently with weed/land managers in various levels of state agencies. This facilitates communication and outreach for the application. Lass will analyze the hyperspectral data collected for the Probe 3 and develop website interactive map functions.
- **Boise State University**, Dr. Walter S. Snyder, ***(Co-PI)***, Professor, Department of Geosciences, 1910 University Drive, Boise, Idaho 83725, 208-426-3645, Email: **wsnyder@boisestate.edu**. Snyder will coordinate project activities in southwestern Idaho, including training and outreach activities at BSU and test sites for field and aerial surveys. BSU will provide a central training facility for outreach to end-users and act as a liaison for training with the ISDA. Current activities in the BSU Geospatial Research Facility include interaction between GIS and remote sensing experts and state agencies (see Section 8).
- **Bureau of Indian Affairs**, Mr. Norman Bird Soil Conservation Office located at the Fort Hall Indian Reservation, Idaho, 208-238-2305. Bird will participate in Year 3, when he will integrate existing plant community studies at Fort Hall Indian Reservation with results of this application. Bird will also aid in application evaluation and participate in training on how to integrate remote sensing into weed control at Fort Hall.
- **Idaho National Engineering and Environmental Laboratory** Mr. Ron Rope, 208-526-9491 and Mr. John Beller, 208-526-1205; PO Box 1625, Idaho Falls, Idaho 83415. Rope and Beller will help manage application development, in particular, test site selection, GPS field surveys, collecting historical data, and image interpretation.
- **Idaho State Department of Agriculture**, Ms. Danielle Bruno, Data Coordinator, PO Box 790, Boise, ID 83701, 208-332-8529, **dbruno@agri.state.id.us** Bruno will provide links with other organizations that will assist with collection of grand truthing data and monitoring sites; helping to disseminate project results, including providing training in use of the application to other organizations.
- **Ada County** Mr. Brian Wilbur, Ada County Weed and Pest Control Director, Weed Management Office, Boise, ID 83706, 208-888-2316 **wpwilbbk@adaweb.net** Wilbur will facilitate evaluation of the project through comparison of results with Ada County's

infrared photography and low-level flight remote sensing. Ada County is also a possible secondary test site (along with the Birds of Prey Conservation Area) for the application.

- **USGS Forest and Rangeland Ecosystem Science Center**, Dr. Steve Knick, USGS, Snake River Field Station, 970 Lusk Street, Boise, ID 83706, 208-426-5208, **sknick@eagle.boisestate.edu** Dr. Knick will provide existing invasive weed data and expertise in southwestern Idaho and facilitate test-site use at/of the Snake River Birds of Prey Conservation Area. Dr. Knick will provide the Snake River Field Station as a portal for dissemination of data for weed information and provide expertise in sagebrush habitat.
- **Positive Systems, Inc.**, Mr. Brad Stoltz, Acquisition Manager, 223 Baker Ave., Whitefish, Montana, 59937, 406-862-7745, **bstoltz@possys.com** Stoltz will acquire/ provide commercial data from high resolution color-infared digital aerial photography. Positive Systems has expertise in acquiring and processing data for imaging invasive plants, and has previously worked on NASA projects.
- **(3D)i LLC**, Mr. Bill Bernard, Director of Business Development, 28969 Information Lane, Easton, MD 21601, 410-770-6001, **Wbernard@3DiLLC.com** Bernard will acquire/provide commercial hyperspectral remote sensing imagery with the AISA platform. Bernard has previously worked with ISU to provide information for data acquisition, and has demonstrated the use of AISA imagery for applications in invasive plants with a variety of agencies, including USDA, NASA, and universities.
- **Ecoprobe**, Mr. Chuck Eubank, 1729 Montana Highway 35, Kalispell, MT 59901 406-755-5001 **aquiavision.aol.com** Eubank, Chaiman and CEO of the company that owns the Probe 3 “Next Generation” hyperspectral sensor, will be a subcontractor for the data.

6b. Project Management: Bonneville County will serve as lead agency for the project. Sub-contracts will be entered into with each major sub-recepient: BSU, ISU, and U of I.

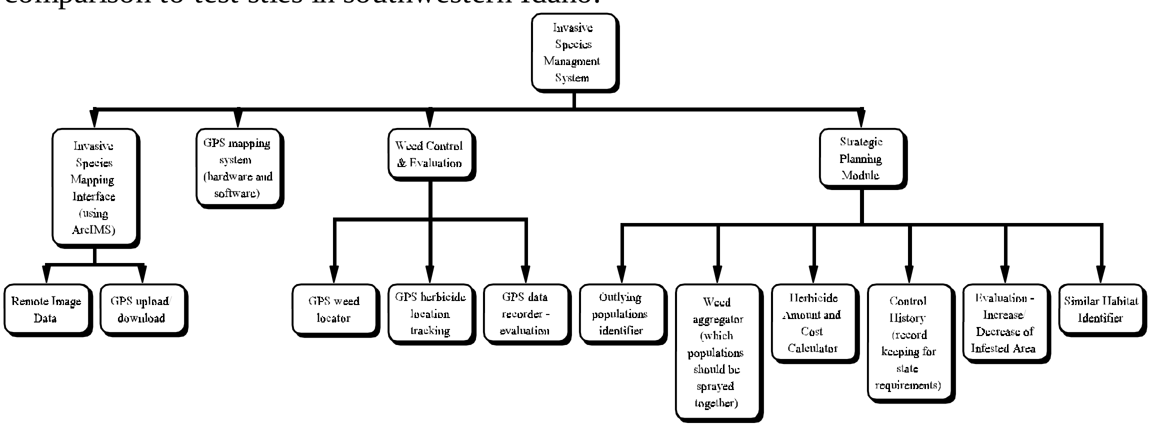
General project oversight will be the responsibility of Mr. Pettingill (Principal Investigator/PI). Pettingill will also manage field operations, including GPS surveys. He will be responsible for all reporting to NASA and related data collection, and will serve as liaison for the project with other county/federal/state agencies. He has strong working relationships with the other participating organizations. He will ensure adequate coordination/communication between the partners, using a regularly scheduled meetings (teleconference, phone and/or face-to-face; currently planned to be held monthly), list serves and Internet web pages, as appropriate.

Pettingill will be assisted in the project’s execution by a total of five Co-PI’s. Each of the three sub-recipients (BSU, ISU, and U of I) will have a primary Co-PI, who will be responsible for the internal management of their portion of the project, as delineated in their respective contracts. These primary Co-PI’s are Drs. Snyder (BSU), Glenn (ISU) and Prather (U of I). Each of these individuals (and their institutions) is experienced in grant management, and have served as PI and/or Co-PI of other federal grants.

Two additional Co-PIs, Mr. Weber and Dr. Lass, will lend their technical expertise to the project. They will be subordinate to the Primary Co-PI at their respective institutions. Drs. Glenn, Prather and Lass, with Mr. Weber, will manage application development, image processing and GIS activities. Mr. Pettingill and Dr. Glenn will oversee agency collaboration and user participation. Bonneville County has been involved in various local projects in Idaho, including research, data sharing and/or training at ISU’s GIS TreC. Sub-tasks are provided in Section 11.

7) Assimilation into On-going Operations

The successful integration of this project's application into on-going operations is an integral component of this proposal. For the near-term, the project's partners will incorporate the application into daily operations by: (1) disseminating data and data modules; (2) developing a long-term plan for remote sensing image acquisition needs (temporal, spatial, and spectral resolutions) and prevention and monitoring (test sites, field surveys, accuracy thresholds); (3) training personnel of various skill levels; (4) working with personnel from different systems and agencies; and (5) developing a mandate for incorporating remote sensing in weed control. Specifically, Bonneville County Weed Control, with the help of contributing organizations, will: (a) map the extent of invasive plant species and their host environment in the Snake River Plain, southeastern Idaho; (b) identify similar conditions between known infestations and potentially infested areas; c) identify the anthropogenic sources which produce the environment and host soil composition for invasive plants; and (d) utilize most efficient, cost effective findings for comparison to test sties in southwestern Idaho.



Assimilation into on-going operations will be accomplished by integrating the remote sensing data into other aspects of weed management where the county and their associated CWMA partners are collaborating. The remote sensing data and the addition of data from GPS survey forms a common, shared data layer that the CWMA can use. Implementing data sharing using ArcIMS allows easy access to each participant, increasing assimilation into daily work. The GPS mapping system must function easily with the ArcIMS and with other associated GIS software like ArcView and ArcInfo. The emphasis should be on function rather than accuracy of the instrument. An error of several meters should not impact the application of herbicide since the operator will be able to see the plants. However, if the system is difficult to use, even if it is accurate, it will stay in the office. The development of such a system will be accomplished by collaboration among the PI and Co-PI's. The GPS mapping system will allow controlled navigation to the plants and also allow for tracking the area that received weed control. Collection of tracking data assists in meeting State of Idaho requirements on herbicide applications data storage. Evaluating the effectiveness of control using the GPS linked system will aid strategic planning when assessing if changes are required to the method of control. Planning is a key activity of a county weed program and it is key to proper functioning of the CWMA. Building an application that facilitates joint planning will increase the likelihood of its adoption and incorporation into on-going weed management activities.

An important aspect of the operational concept includes determining schedules of when and how often (temporal resolution) remote sensing imagery will need to be acquired. A long-term plan will need to be developed to acquire imagery at a temporal resolution that is cost-effective while maximizing the amount of information collected. For example, overlapping stages in development of knapweed and leafy spurge may allow simultaneous image acquisition; however, timing in peak development of cheat grass could require image acquisition from a different date. This application study will focus on the feasibility of acquiring imagery for baseline information, followed by implementation of management practices, and subsequently acquiring test data to assess/monitor these management practices.

Note that the proposed application also has broad applicability, beyond the direct participants. Indirectly, this project will allow the application to be incorporated into the daily operations of many other organizations. The many direct participants provide multiple regional/national dissemination avenues through their various "networking" groups: e.g., ISDA can help spread a successful application throughout Idaho's CWMAs, as well as to the Agriculture Departments of other states; Fort Hall can share project findings through appropriate Native American organizations, etc. The PI has direct access to his own network of colleagues; he and others will take all appropriate measures to share the final application with other counties and organizations. The university researchers involved will submit papers to appropriate peer-reviewed journals, teach CWMA participants on the use of this application utilizing Cooperative Extension and CWMA training opportunities, etc.

This proposal will provide the necessary start-up funds for the application and demonstrate its usefulness. In the long-term, retaining the application as part of daily operations ultimately depends on the ability to demonstrate its efficiency and cost-effectiveness. The entire premise for this project is founded on these attributes. The impact and cost data collected during the grant period will be vital to the project's evaluation process. Once demonstrated, the funding for acquisition of remote sensing data needed for this application will be through an Idaho State Department of Agriculture (ISDA) cost-share grant program that emphasizes detection of invasive plants and strategic planning. The ISDA program allocated over $2 million dollars to CWMA's statewide in 2001. It is reasonable to assume managers and decision makers will favor technology that increases program effectiveness and/or reduces costs. In addition, because the application benefits so many organizations, including strengthened communication and other ties between existing agencies (such as Bonneville County and INEEL), the cost to any one organization of data buys and sharing may be minimized.

8) List of Facilities, Equipment, Resources

8a) Facilities at Bonneville County: Bonneville County Weed Control, as a county agency, has considerable resources available through its linkages with other Bonneville agencies, as well as with CWMAs and peer units of other counties. These latter networks will be invaluable in the ultimate dissemination of the project/application.

The Weed Control office itself includes an assistant and secretary. Office computers are recent and up-to-date; a Trimble Geo Explorer 3; software includes Pathfinder. Equipment includes 8 trucks, 2 trailers and an arctic cat, various sprayers (truck- and backpack-mounted) and supporting/ miscellaneous tools (e.g, weed trimmers, shovels, etc.). These vehicles and tools provide the necessary mobility for application testing: i.e., verifying the presence of the targeted invasive plants, assessing the level of infestation (is it identifying sites before the invasive plants become firmly established?), and treating the area as appropriate (allowing the application long-term monitoring of the effectiveness of the weed control and thereby the application itself). Specifics of the major items of equipment are:

All trucks are equipped with an amber rotating beacon light, at least one shovel, 12 gallon emergency clean water tank, extra fuel container, two-way radio, county road map, waterless hand cleaner, roll of paper towels, one-way CPR safety mask, First Aid Kit, extra spray gloves and misc. tools.

A. **W-1** 1992 Chevy 1-Ton 4X4 Dual rear wheels, 454 V-8 engine, automatic transmission, 54,000 miles

Sprayer

2 – 200 gallon FMC stainless steel tanks (age unknown)
1 - 8 horsepower electric start Honda Motor (1999)
1 - 140 gallon per minute, 60 p.s.i. Ace centrifugal pump (1999)
1 – Boombuster Nozzle sprayer system – each system contains:

1- 265R, 20 foot spray nozzle
1- 180-10, 10 foot spray nozzle
1 – 120-5, 5 foot spray nozzle
1 – 6 inch electric ram, for adjusting slope of spray pattern
1 – customized metal spray boom system that was developed to be inserted into a 2” receiver mounted under the front of the vehicle. This allows interchangeability of booms from each vehicle as well as the ability to be removed when towing or in the off-season.

1 - Calc-N-Acre monitor - For keeping track of the speed of vehicle as well as the ability to measure accurate distance and amount of area covered from nozzles.) (age unknown)

1– spray nozzle control console - for controlling individual nozzles and regulating spray pressure.
2 – 200 foot hoses with electric hose reel and Spray System handgun (age unknown)

Use – This sprayer is mainly used for roadside applications of herbicides and when necessary as additional help for pasture and rangeland applications. In addition, we use this truck for bare ground residual herbicide (sterilant) applications in the fall and early spring.

B. **W-2** 1989 Chevy ¾ ton 4x4, Flatbed, with Line-X lining on top deck, 350 V-8 engine, automatic transmission, 120,300 miles

Sprayer

1 – 300 gallon plastic tank (age unknown)

1 – 8 horsepower electric start Honda Motor (1999)
1 – 140 gallon per minute, 60 p.s.i., Ace centrifugal pump (1999)
1 – Boombuster nozzle sprayer system (1999)
1 - Calc-N-Acre Monitor (1999)
1 – Spray Systems Spray nozzle control console (age unknown)
1 – 200 foot electric hose reel with Spray System handgun (age unknown)

Use – This sprayer is utilized as one of our main pasture and rangeland application equipment. It is ideal for off-road applications due to its size. We will use this truck for roadside herbicide applications when necessary.

C. **W-3** 1994 Dodge Dakota Mid-Size Extended Cab Pickup, V-6 engine, standard transmission, 65,000 miles

Use - For shuttling of crew to sprayers as well as for chasing parts and going to places where no spraying is required. Not sprayer equipped

D. **W-5** 1993 Chevy 1-Ton 4x4, dual rear wheels, automatic transmission, 454 V-8 engine, 35,900 miles

Sprayer
1- 500 poly leg tank (purchased 1999)
1 - 8 horsepower electric start Honda motor (1999)
1 – 140 gallon per minute, 60 p.s.i., Ace Pump (1999)
1 – Boombuster Nozzle Spray System (1999)
1 – Calc-N-Acre Monitor (age unknown)
1 – Spray System Nozzle Monitor (age unknown)
2 – 200 foot hoses with electric hose reels and Spray Systems handguns (age unknown)

Use – This sprayer is primarily used for off road applications such as pasture and rangeland. We will also use it for roadside applications as well as for bare ground herbicide applications in the fall and early spring.

E. **W-4** 1991 Chevrolet 1 ton 4x4, 4 speed transmission, 454 V-8 engine, 67,300 miles.

Sprayer
1 – 300 gallon plastic tank (age unknown)
1 – 8 horsepower Honda electric start (1999)
1 – 120 gallon per minute Hypro centrifugal pump (1999)
1 – 200 foot electric hose reel equipped with Spray Systems handgun (age unknown)
1 – Boombuster spray system as on the other trucks as well as a rear-spraying nozzle.

The flat bed on this truck has been sprayed with polymer coating to protect the bed and helps as a non-slick surface.

Use: This is our primary pasture and rangeland application vehicle. And is generally used by the Assistant Weed Control Supervisor. Also this vehicle is the primary snow plowing vehicle during the winter

G. **W-8** 1991 Chevy 1 ton 4X4, dual rear wheels, automatic transmission, 454 V-8 engine, 58,500 miles

Sprayer

This truck is set up with a state-of-the-art Norstar Spray System. This system has two 30 gallon and one 15 gallon chemical injection tanks with a small roller pump attached to each. It is equipped with a 750-gallon water tank (too large to use efficiently due to gross vehicle weight maximum limits for truck). It has a hydraulically driven centrifugal pump. A computer in the cab regulates all functions of the sprayer and speed is monitored by radar attached to the underside of the truck. As one sprays along the road way the computer automatically adjusts for speed variances and rate changes. This sprayer has two 14 nozzle spray heads, which is operated from the cab to spray a distance of 1.5 feet up to 26 feet for each spray head. This is most efficient truck in the fleet (1991)

Use – Primarily our main roadside herbicide application sprayer. This truck can cover twice the miles the other traditional sprayers can. When necessary we can use this for pasture applications.

H. **W-9 2000 GMC 4X4 ¾ ton extended cab truck.** The County Weed supervisor uses this truck. The extended cab is utilized for shuttling the applicators to and from the spray rigs as well as housing literature. The truck has a 12,000 Warn winch mounted on the front and is used to recover stuck vehicles.

I. **W-20** 1998 20 foot, 12,000 G.V.W. bumper-pull trailer, tandem axel.

Use - This trailer is equipped with a 1,500 gallon plastic tank. It has a 5 horsepower Briggs and Stratton motor with a 2" banjo centrifugal pump. This trailer can be pulled behind any of the sprayers for additional water when working remotely from the shop, with the capability of obtaining water from the hydrants or from a creek or canal. The spray trucks can then tender off of it for faster turn around of mixing spray materials. The larger trucks can also pull this trailer behind them as they spray and have enough water for four additional loads, thus not having to return to the shop for water.

J. **W-21** 2000 Suzuki King Quad 4X4 four-wheeler ATV. 300 cc

Sprayer

3 – 12 gallon tanks, one mounted on front rack and 2 mounted on rear rack.
1 – 5.0 gallon per minute diaphragm electric pump
30 feet of hose with a spray center hand gun

1 – 125R, 15 foot Boombuster nozzle

Use - This is used for all off-road applications where the trucks cannot reach the larger weed patches. Utilization of this Four Wheeler saves much wear and tear on the larger trucks. It also cuts down on manpower due to its ability to haul much more water than a backpack sprayer.

K. **W-22** Single axel tilting, flat bed trailer for hauling ATV's.

L. **W-23** 2001 4x4 Artic Cat ATV. 400cc

3 – 12 gallon tank

1 – 5 gpm electric flomax pump

50 foot hose with spray systems hand gun

125 boombuster nozzle mounted on adjustable bar

M. **W-24** ATV trailer, single axel, This trailer will be used to put on a sprayer then it will be used as a rental.

N. **Solo and Field King Backpack Sprayers**, 8 each. 4-gallon capacity

Use – Utilized in remote areas or when a specific small area needs treated with a particular herbicide. The operators will carry one per truck and have product available that will be of better use of a herbicide when the product mixed in truck sprayer is not adequate for a given weed.

8b) Facilities at Idaho State University: ISU is the only public university in southeastern Idaho, and has close working relationships with INEEL, Fort Hall, the universities, and other partners. It shares a branch campus with U of I in Idaho Falls, the county seat for Bonneville County, and thus has easy access to the lead agency.

ISU's GIS Training and Research Center (GIS TReC) was the first, and is still the most comprehensive, GIS facility in southeastern Idaho. Its mission is to provide GIS instruction and research capability to the region; it was established with grants from the State of Idaho and from the National Science Foundation's Major Research Instrumentation grant program. In carrying out its mission, it has established close working relationships with many local, state and federal agencies, and often completes GIS and remote sensing research projects for faculty, agencies, institutions, and corporations that do not have the facilities or expertise to do so. These relationships, along with the facilities and reputation of GIS TReC, are indispensable resources for this project. GIS TReC is also the recipient of NASA funding. GIS TReC is an ESRI Authorized Learning Center (one of only two in Idaho) and Weber, its Director, is an ESRI certified ArcView Instructor. GIS TReC was recently awarded the prestigious ESRI Special Achievements in GIS award. This honor was bestowed upon only 150 sites (chosen from among over 300,000 user sites worldwide) in 2000.

GIS TReC will provide training and outreach for sites in southeastern Idaho, as well as performing the bulk of the application development. GIS TREC has a staff of four besides the director, and places student internships as well. The Center expects to shortly be hiring an Assistant Director. The GIS Training and Research Center includes:

Hardware:

1. 15 Pentium Pro 200mHz MMX computers with Windows NT 4.0 Workstation and 64 MB RAM.
2. A Pentium II 233mHz MMX Windows NT 4.0 Server with 128 MB RAM with 18GB SCSI Hard drives. This is our primary server and our web server.
3. A 266 mHz MMX Micron Millennia NT workstation with 19” Hitachi monitor and 96M of RAM.
4. A 400 mHz Pentium II MMX Micron Millennia Cartographic workstation with 21” Hitachi monitor, SCSI hard drives, and 400M RAM
5. A 500 mHz Pentium III MMX Silicon Graphics 320 NT workstation with flat panel digital monitor, 120M of RAM and 64M of video RAM.
6. 2 500 mHz Pentium III MMX Micron Millennia NT Workstations with 19” Trinitron monitors and 120M of RAM.
7. A 450 mHz Pentium III MMX Micron ClientPro XKU full tower Windows NT Server with 128M RAM and 45GB Hard drives. This server is our GPS Community Base Station server.
8. 15 CalComp digitizing tablets
9. 1 Altek Large format digitizing table with adjustable back lighting and power tilt and elevation adjustments (accuracy = 0.001”).
10. 36” color drum scanner (800dpi)
11. Internal PCI-SCSI 100 MB Iomega ZIP drives
12. ENCAD NovaJet Pro 600e 42” wide color inkjet printer (600dpi) with 64M of RAM.
13. Hewlett Packard Laser (18M of RAM) and color inkjet printers.
14. Hewlett Packard Office Jet 720 capable of scanning, faxing, color copying and printing.
15. Hewlett Packard 2400 dpi 45-bit flat bed color scanner.
16. Integral campus connectivity at 100 MB/Sec.
17. 8 ft. screen and full color ViewSonic LCD projector; 550 Lumens, 1:200 contrast ratio
18. Memorex CD-ROM writer for write-able and re-write CD’s using fast SCSI-2 hardware.
19. 8 Trimble GeoExplorer II hand held GPS receivers.
20. 3 Trimble ProXR mapping grade GPS receivers
21. A Trimble 4800 Total base station GPS receiver with Real-time Kinematic differential correction capable of 1cm accuracy.
22. A Trimble ProXR Pathfinder Community Base Station phase corrected GPS receiver. This receiver has been permanently mounted and is continuously running.

Software:

1. ESRI's Arc/Info 7.2.1 and ArcView 3.1 (including Spatial Analyst, 3D Analyst, Network Analyst, Kriging Interpolation extension, and MapObjects 1.2)
2. ESRI's ArcView Internet Map Server (IMS) and MapObjects IMS
3. Clark University Lab's Idrisi GIS ver. 2.01 for Windows
4. Pacific Meridian's LUCCAS (Land Use Cover Change Analysis Software)
5. Able Software's R2V (Raster to Vector conversion software)
6. World Construction Set 4 Landscape Simulation GIS software
7. Trimble Office software
8. Trimble Pathfinder Office software
9. Trimble Pathfinder Community Base Station software (ver. 2.68)
10. Stat-Box statistical tools for MS Excel
11. Frag-Stats landscape fragmentation software
12. MS Office 97 Professional
13. MS Visual Basic version 6.0 Professional edition.
14. Internet access using Microsoft's Internet Explorer 4.01
15. Proctor! digital testing software
16. Metadata Profile Builder version 1.01
17. ESRI Spatial Database Engine (SDE) for MS SQL Server ver. 7.0
18. ESRI State wide site license
19. ENVI

Data:

1. Full DEM and DRG coverage for Area of Concern (AOC, cf. http://giscenter.isu.edu/data)
2. Over 2,000 DOQQ's
3. Landsat TM imagery for 1987 and 1997 for our AOC
4. Landsat TM imagery for 1985, 1992, and 1998 for the Palcazu River valley, Peru
5. Idaho State University GIS data sets
6. Lower Portneuf River Valley aquifer GIS data sets
7. Digital Chart of the World GIS data sets
8. 1:1 million, 2 million, and 3 million world data sets
9. ESRI street data sets for the entire US
10. STATSGO soils coverage for most of the western US
11. SSURGO soils coverage for parts of Bannock, Power, and Oneida counties, Idaho.

To be acquired: RADSARSAT, IKONOS, AISA, ADAR, PROBE 1 (from INEEL) for Snake River Plain

8c) Facilities at University of Idaho: The U of I is the state's land grant institution, and is based in Idaho's northern panhandle. It shares the branch campus with ISU in Idaho Falls. The resources it brings to the project include the statewide system of cooperative extension offices, which facilitates networking and dissemination of application/project information to potential end-users (i.e., ranchers, etc.).

The College of Agriculture at the University of Idaho has allotted space to a weed mapping laboratory in the Agricultural Science Building. The laboratory is a charter member of the Idaho Chapter of UCGIS and a cooperator with NASA's Center of Excellence in Applications of Remote Sensing to Regional and Global Integrated Environmental Assessment, located in the Department of Forestry at the University of Idaho. The weed mapping laboratory provides cartographic and remote sensing support in the area of weed science. Experienced full-time professional staff and students with GIS training work in the lab. Previous hyperspectral projects include detecting weeds in wheat, pea, lentil, and chickpea fields; detection of yellow starthistle, spotted knapweed, and rush skeletonweed in rangeland; the detection of food sources for mountain gorillas in Rwanda, Africa; and of Brazilian Pepper in Florida's Everglades National Park. Other projects include mapping common crupina in the USA; mapping yellow starthistle in Idaho; remote sensing yellow starthistle, yellow hawkweed, and poison hemlock with multispectral sensors; and several local and regional weed surveys.

Equipment available for use by the Idaho Weed Mapping Laboratory includes:

Global positioning equipment (3 DGPS units and 3 GPS units).
Portable spectroradiometer (350 to 850 nm).
Semi-portable spectroradiometer (440 to 2500 nm).
Workstations, servers and portables
0.5 TB data storage space, plotters, digitizer, large format scanner and software (ARC/Info, ARC/View, Idrisi32, ENVI, EasyCAD, and other general software).
1-4X4 truck, 1 van, and other specialized vehicles under University lease.
Field research equipment (tractors, sprayers, tape measures, pressure bomb, light measuring devices, and ATVs.)
Cartographic data on roads, rivers, streams, soil types, slope, aspect, and weed surveys. Remote sensing data includes over 0.4 TB hyperspectal data of Idaho, 0.8 TB of Florida and 0.9 TB of other sensor data of Idaho.

8d) Facilities at Boise State University: BSU is located in the state's capital, in southwestern Idaho. It is the largest university (i.e., in enrollment) in the state. It has easy access to state agency offices and political centers, facilitating dissemination of project results.

The Geospatial Research Facility (GRF) at BSU will be utilized in this project for application development for test sites in Southwestern Idaho, and for training and outreach. For example, the lab will be used to process GPS field and ground-truth data for the test site in southwestern Idaho. An undergraduate student under the direction of Drs. Snyder and Knick will collect this data. The lab will also be used to train county weed managers in using imagery with field collected data. The ISDA will also be able to utilize the facilities for dissemination of data through demonstration of project methodology. The GRF offers several GIS training courses to state agencies and provides facilities for teacher training and outreach. The lab includes:

Teaching Lab: 10 Pentium III 866 Mhz PC's with 256 Mb ram, and 19" monitors.

Research & Development Lab**:** 4 Pentium III 866 Mhz PC's with 512 Mb Ram, 21" monitors; two HP servers. Hewlett Packard 750C 36 inch inkjet plotter. Hewlett Packard 5M laser jet printer, and HP 1220 C ink jet printer (with 11x17 capabilities).

***Software*:** Fully networked department of research facilities. Specific software includes the latest versions of: Arc/Info (Windows NT Intel Platform); Arc View, Image Analyst, ArcIMS, etc; the GRF's ESRI license includes unlimited copies of all ESRI software.
Other GIS software includes: AutoCad Map; ERDAS image analysis (remote sensing) software
Microsoft: Windows NT 4.0 Server; Windows NT 4.0 Workstation;
Miscellaneous Software Available: Corel Photo Paint, Draw 9.0; Adobe Illustrator 6.0, PhotoShop 6.0; Canvas; Netscape Navigator; Lan Work Place Pro (FTP, X Serer, Telnet clients), and other productivity software.

Other Resources:

The GRF can also offer:
1) Technical advice and participation from: Tyson Taylor (GIS Lab Manager) and Charlla Adams (GIS Analyst) of the Geospatial Research Facility.
2) workshops and training sessions at any time because of the dedicated teaching lab.
3) Working relationships with the USGS Snake River Field Station, established during past landscape ecology projects.
4) Working relations ships with the Bureau of Land Management, Forest Service and state agencies particularly with respect to research projects in southwestern Idaho.

9) NASA Contributions

9a. Science NASA scientists and scientists previously funded through NASA grants can provide technical review of the proposed application. Remote sensing invasive plants is not a new application of imagery and this application will build on previous NASA science and remote sensing research. This will include the data and expertise developed from the NASA Commercial Remote Sensing Programs (1) EOCAP (Positive Systems, Inc.) and (2) Affiliated Research Centers (Utah State University).

Timing of flights of fixed wing aircraft will be aided by analysis of satellite imagery, generating existing vegetation indices. Phenological stage will be important to address as it may influence spectral signature so utilization of satellite data will allow better prediction of flight schedules.

NASA has aided in sensor calibration of private companies involved in this grant. Privatization of technology through NASA contributions has improved our ability to acquire high resolution data.

9b. Verification/Validation. Hyperspectral data is being used in this application to find small infestations. The application is dependent upon finer-resolution imagery (working in tandem with NASA images) than that provided by NASA platforms.

9c. Technology This application will use NASA's Landsat 7 ETM+ and if available, data from Landsat continuity missions (e.g. EO-1).

Fall 2002/Winter 2002:

- Disseminating preliminary results to other Idaho counties and state agencies
- Completion of image processing/classifications
- Determining schedule for upcoming Spring image acquisition and evaluating most cost-effective implementation for southwestern Idaho site
- Developing plan for long-term integration of methodology
- Success criteria includes 1) feedback from end-users; 2) accurate classifications based on ground-truth data; 3) determining necessary data acquisition for southeastern Idaho site based on classification results; 4) feedback from policy makers

Spring 2003/Summer 2003:

- Acquisition of imagery for southwestern Idaho site
- Field work and ground-truthing for site
- Monitoring of southeastern Idaho site
- Continue dissemination and outreach
- Success criteria includes 1) collaboration of end-users in southwest Idaho; 2) data sampling modeled after first test site; 3) feedback from policy makers and end-users

Fall 2003/Winter 2004:

- Completion of classifications/results from southwestern Idaho site
- Implement strategy for long-term funding
- Success criteria includes 1) future funding sources; 2) monitoring of test sites

12) Evaluation and Outreach

The project may be evaluated both quantitatively and qualitatively. Quantitatively, the actual results of the project may be compared to the above timeline of tasks. Where the tasks conducted as scheduled? Did the results of each task provide the necessary/specified data to perform the next step? Where the proper quantities mentioned throughout the text (e.g., # of hyperspectral images) obtained? Etc. The project may be assessed in terms of its accuracy/ usefulness in locating invasive plant infestations at early stages of development. Remote sensing classification accuracy will be determined using: 1) previous methods (Price et al. 1998) and 2) invasive plant management using GPS to navigate to reported infestations. Utilizing a test area where % plant cover has been manipulated will allow investigators to evaluate classification from each platform across a range of plant cover classes.

Primary evaluation of the application will take place through assessment of the system by Bonneville and Ada County Weed programs. ISU and UI will work to train participants in CWMAs on use of the system and on evaluation of various remote sensing platforms to consider for their own invasive plant species detection requirements. Participation in training session will indicate interest in adoption of the system. Secondary evaluation will be through UI's tracking (through cooperative extension) of the level of adoption of the GIS system by other county weed supervisors and other participants in the training session. This – the ultimate use of the application by other entities – is key to the evaluation process.

Outreach is therefore an integral part of the Tasks above, starting in Fall/Winter 2002. Dr. Prather has educational responsibility for invasive plant species at University of Idaho. He will work through the CWMA network to teach CWMA members (i.e., including public, tribal and private sectors) how to use the application once it is developed. In Southeastern Idaho, educational outreach will be coordinated between Co-PI's at UI and ISU. Three regional educational events will be conducted in the final year of the project, located in Pocatello, Boise, and Moscow, Idaho. Training sessions will be hands-on events that include all aspects of use of the application developed through this proposal. Levels of participation in sessions will also be used as an evaluation criteria. Our target attendance is a minimum of 20 participants per session, for a minimum total of 60. This based on there being 26 CWMAs in Idaho (5 of which cross state lines, thereby including Oregon, Washington, Utah and Wyoming); and a probable average of about 3 per CWMA, covering all the various government/private sectors. Note that as the state and federal governments own about 70% of Idaho, penetrating these audiences will have particularly broad impact, and a special effort will be made to recruit attendees from such agencies.

References:

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13. Letters of Commitment

Letters of Commitment have been included in the paper copies of this proposal, but omitted from this electronic version. The paper copy includes letters (in order) from the following:

Ecoprobe
Bureau of Indian Affairs, Fort Hall Agency
Idaho National Engineering and Environmental Laboratory
Ada County
University of Idaho (2 letters)
Idaho State University
Positive Systems
US Geological Survey, Biological Resources Division
(3D)i
Boise State University
State of Idaho Department of Agriculture

14. Appendices

Vita from the following individuals are included in the paper copies of this proposal, but omitted from the electronic version:

Jeffery Alan Pettingill (PI, Bonneville County)
Dr. Nancy F. Glenn (Primary Co-PI, Idaho State University)
Keith T. Weber (Co-PI, Idaho State University)
Dr. Timothy S. Prather (Primary Co-PI, University of Idaho)
Dr. Lawrence Lass (Co-PI, University of Idaho)
Dr. Walter S. Snyder (Primary Co-PI, Bosie State University)