SEMIANNUAL RESEARCH PROGRESS SUMMARY

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EARTH OBSERVATIONAL RESEARCH USING MULTISTAGE EOS-LIKE DATA

Principal Investigators

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INTRODUCTION

Work under this grant is directed at preparation for the EOS era and, in particular, high spectral resolution data such as that from the imaging spectrometers HIRIS and MODIS. The objectives of the work are (a) to prepare suitable means for analyzing data from high spectral resolution sensors and (b) to advance the fundamental understanding of the manner in which soils and vegetative materials reflect high spectral resolution optical wavelengths. The work thus involves basic Earth science research and information system technique understanding and development in a mutually supportive way.

Some key factors influencing remote sensing information extraction in the new context of imaging spectrometry are (a) there will be a very much larger number of spectral bands available than in the past, (b) this should lead to the possibility of discriminating between a larger number of more detailed ground classes, (c) there is, in remote sensing, inherently a paucity in the size of training sets available by which to quantitatively define classes to be discriminated between, and (d) there is also an inherent impreciseness in the knowledge of values of some of the analysis parameters (e.g. class prior probabilities, class statistics, loss functions, etc.).

Research Directions and Previous Results

In the face of these factors, work during this multi-year effort has been divided into the following thrust areas[1]:

- **Feature Design or Selection.** Create a calculation procedure which would allow one to determine the best mission-specific spectral feature set for discriminating between a given set of Earth surface materials, given the location, time of season, and raw high resolution spectral samples to be available from a given sensor. The feature set may be realized either in terms of a linear combination of the original sensor bands or by selecting an optimal subset of them. [2,4,6,8,20,21]

- **Analysis Algorithm Design.** Determine a set of analysis algorithms which are well matched to the EOS era high dimensional data to be available and a list of classes presumably larger in number and more detailed in character than have traditionally been possible to use. Hierarchical analysis schemes were selected for study as an effective means for dealing optimally with large numbers and/or quite detailed classes; other methods under study relate to fundamentals of inference and decision-making in the face of imprecise or partial knowledge. [1,7,10,12,13,14,15,17,23]

- **System Simulation.** Create a capability to simulate an entire remote sensing system, including the ground scene, atmosphere, sensor system, and analysis procedure, so that it is possible to study the interrelated effects of various system parameter settings and noise sources across the entire system, including the functioning of the algorithms produced by the above

[1] Numbers in brackets refer to papers and reports listed in the Bibliography of Previous Results below.

research efforts. Here the definition of noise is taken to be any deleterious effect that occurs in such systems. The motivation for this study, which is more basic in character, stems from the fact that as the information to be derived from such systems becomes more detailed, the interrelated effects between various system parameter selections and degrading influences within such systems will need to become more fully understood if the full potential of such systems is to be realized. The simulator should also be useful for simulating data sets and analysis situations which are not yet available, but which will be in the future. [3,9,11,16,18,22]

- **Earth Science Studies.** Develop the fundamental understanding of the variations of physical and chemical properties of soils and vegetation and their influence on high spectral resolution optical wavelengths. Effects of a human dominated landscape on soils and vegetation are a major emphasis. These studies provide a means for first-level testing of the new information extraction technology which results from the other research areas. [5,19,21,24,25,26, 27].

- **Analysis System Implementation.** Create a data analysis system implementation which has the power and flexibility needed in the future research environment, but which is economical to acquire and use and has greater emphasis on ease of use than has been the case in past implementations.

This latter area of work is motivated by the observation from previous land-oriented satellite programs that it is important, especially for analysis algorithms that are new and at all complex or require significant study in order for users to adopt them and realize there full potential, that there be a convenient means available for Earth scientists to try the algorithms on their own problem. Here, "convenient" means that the implementation hardware must be inexpensive or readily available and the software must be easy to learn and use, even for the occasional user.

This work has been begun by building a software system on a personal computer workstation which contains a system of algorithms suitable for the analysis of multispectral data sets. The particular system implementation, originally called MacLARSYS, has been renamed MultiSpec in order that its name better convey what it does rather than where it originated. A first draft of it is nearing completion and versions at various previous stages of development of it have been made available to approximately 35 researchers at various institutions in order to provide some feedback on the implementation and the ideas used in it. A document entitled "An Introduction to MacLARSYS" is distributed with it to assist in learning how to use it; here again, feedback on the users' reaction to this documentation assists in improving it.

BIBLIOGRAPHY OF PREVIOUS RESULTS

Following is a bibliography of papers, reports, theses, published abstracts, and presentations produced previously by work supported at least in part by this grant.

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Results Appearing During the Current Reporting Period

A bibliography of papers, theses, and reports appearing during the current 6-month reporting period is given below. These results correspond to the above-listed thrust areas in the following fashion:

- **Feature Design or Selection.** [31]
- **Analysis Algorithm Design.** [28,29,30,32,33,34,35,36,37,38,39,40,41]

Reference [31] describes a new means for predicting the optimal number of features to use in a given classification in the face of training sets of very limited size.

References [28] and [37] report on a study of the use of neural networks on high dimensional data. Reference [29] describes some first results in attempting to find an effective classifier which will identify a single class within a data set without requiring representation of the entire data set. References [30] and [36] describe a scheme for designing heirarchcial classifiers. Reference [32] describes a scheme which materially reduces the computational resources needed for a maximum likelihood classifier. Reference [33] provides some new information on mapping multispectral data to the color space of a video display. References [34], [40], and [41] document some more fundamental background studies done in conjunction with this work. References [35] and [38] report on a classification procedure which accounts for uncertainty in ones knowledge of some classifier parameters. Reference [39] describes a filtering technique which is effective against speckle in radar imagy.

In addition to these results, substantial progress was made in the **System Implementation** research area. A several new capabilities were added to the system during this reporting period, and its testing and debugging continued.

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