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Re: WSU Grant 11763, FY 1997 Progress Report

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Progress Report for FY 97 Enhancing Remote Monitoring and Assessment Capabilities of Agricultural Targets in Support of Nonproliferation (DOE Grant 11763)

FY 1997 Activities

Efforts during the 1997 year were focused on two main areas: 1) the extension of vegetation monitoring capability by use of active radar, and 2) remote characterization of surface parameters (plant stress in particular).

1. Progress on the use of active radar for vegetation monitoring
During 1996 I met with Dr. Susan Moran to discuss her work with relating AMPS radar (Ku band) to Daedalus NDVI values for agricultural crops at the Mericopa Agricultural Center (MAC) near Phoenix AZ. Dr. Moran’s work utilized field averages for the radar backscatter and NDVI; the intent of my work was to establish the same relationships on or near the pixel scale. Unfortunately, two main problems were encountered:
• The Daedalus 3600 DN values appear to be saturated. The maximum values found for the light calibration panel were near or at 255. This presents concerns for the scaling of the Daedalus DNs to reflectance. As a work-around, some in-scene targets (e.g., building roofs) will have to be used to improve the calibration.
• There are problems in co-registering the radar and Daedalus images. Utilizing field averages (as Dr. Moran did), this is not critical; however, working at the pixel basis registration accuracy is critical. There were also problems using triangulation to register the Daedalus imagery to a vector basemap (representing the field boundaries) because of insufficient points. This is a real problem, and future effort will focus on methods to register the Daedalus directly to the radar images (co-registration rather than absolute registration).

Also, communication between Dr. Moran and myself was limited because Dr. Moran was out of the office for much of this period.

2. Progress on remote characterization of surface parameters
The objective of this task is to utilize agricultural targets (crops, bare fields) to detect and quantify the level of impacts from man-made activities associated with the development, testing and deployment of weapons of mass destruction (nuclear, chemical or biological weapons). The idea is to detect subtle changes (disturbances
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to soils and crops) that might indicate proliferation activities (such as development of a new remote test area). For this work, AMPS Mission 4 data dryland wheat field data was examined. The image dataset includes Daedalues 3600 images, CASI (collected in spectral mode), and Ku band radar. The supporting ground truth includes soil characterization (moisture, roughness and residue amount) and micrometer station data from Dr. Hattendorf at WSU, and soil and residue reflectance spectra collected by myself on the overpass date. Evaluation of the imagery has indicated that the Daedalus thermal infrared (channel 10) may be the most sensitive dataset to differences in residue amounts. However, use of the CASI imagery has been limited because of the format of the data. Essentially, no commercial image processing package (e.g., ENVI or Imagine) can read the spectral mode format. Future work will focus on the use of the ground spectral measurements (collected with an ASD Field Spec FR) as a surrogate for the airborne hyperspectral measurements.

Some new and promising work is in the area of characterizing plant status through hyperspectral measurements. During FY 1997 collaborations with USDA-ARS and two private companies were held to develop new capabilities and support real problems from the agricultural side. The research centered on measuring leaf reflectance spectra and relating the spectra to a desired plant characteristic. The two applications were relating leaf reflectance to 1) plant Nitrogen levels in a potato crop, and 2) disease (black leaf) status in Concord grapes. The field spectral measurements were collected at the leaf and canopy levels from June through September, and analysis of the measurements is ongoing. This work has direct application to nonproliferation interests, in developing hyperspectral exploitation methods for detecting subtle changes in plant responses that could be related to the presence of toxic chemicals, new subsurface structures or increased traffic.

**Summaries**

Emphasis on work in FY 1998 will be:

- Continue the work on radar/daedalus co-registration and daedalus calibration to reflectance for the MAC study of vegetation indices from SAR.
- Utilize the datasets for potatoes and grape crops to assess the hyperspectral exploitation for detecting subtle changes in plant response, specifically, 1) how do relationships that are observed at the leaf level extend to the canopy level, 2) what new sensors and platforms will be available for monitoring areas consistent with the scale of the variability seen in the plant response.

Because of technical difficulties and time constraints that have limited efforts on this work, I have requested carryover of FY 1997 funding into 1998, with no additional funding requests.
Summary
This report describes the Department of Energy's Airborne Multisensor Pod System (AMPS) missions which include agricultural targets. The emphasis is on the use of these agricultural targets to improve nuclear non-proliferation assessment capability. Three areas of application of agricultural targets to non-proliferation is introduced: extending vegetation monitoring capability with radar, assessment of soil and crop damage using data fusion, and the use of data fusion for improved plant stress monitoring using hyperspectral data. Also, new algorithm development and future AMPS mission needs are discussed.

1.0 Introduction
Agricultural crops cover a significant proportion of the terrestrial portion of the earth's surface, and for some developing nations (e.g., Republic of China and India), agriculture provides upwards of seventy-five percent of the employment. Agricultural targets may be ideal for non-proliferation monitoring and assessment, allowing remote detection of contamination and assessments of regional economic and political stability.

Since 1994, more than five different agricultural targets have been flown by the DOE/AMPS, one with repeat coverage. These targets include the University of Arizona Maricopa Agricultural Center (MAC) farm, the US Department of Agricultural Beltsville (MD) BARC-East farms, Remington farms in Delaware, and both irrigated and dryland fields (associated with Washington State University and USDA) in south-central Washington state. The climates represented by these targets range from humid mid-latitude mixed forests and fields to high-latitude desert. These targets will provide good opportunities to evaluate the utility of agricultural targets for non-proliferation surveillance and assessment, and to develop and test algorithms for processing and interpreting remotely sensed data for these applications. Research to improve assessment and monitoring capabilities will also have direct application in USDA research, supporting the Memorandum of Understanding between DOE and USDA.

2.0 Summary of Agricultural Targets
This section briefly describes the AMPS collections over agricultural targets. To assess the utility of these datasets, it is important to consider complement of data available (not always complete due to instrument problems, etc.), weather conditions, and the data quality and resolution. Much of this information is available on the PNNL maintained AMPS Web site location (http://info.amps.gov:2080/amps_test.html), but some of the information is available only on the mission reports. Unfortunately, some of the information is lacking because it was not available through either the mission reports or the web site.

2.1 Mission 1
Target: Maricopa Agricultural Center, Maricopa AZ

Pod 1:
Overpass Date: June 24 1994
Start Time: ??
Number of Passes: 4
Elevation: 12500' AGL
Depression Angle = 55 degrees
Ground Resolution: 1 m
Description: complete coverage of MAC with 4 passes, N/S row orientation
Data Quality: good

Pod 2:
Overpass Date: June 24 1994
Overpass Time:
Elevation: 1500' AGL
Number of Passes: 4
Instruments Used: Daedalus 3600, CASI, RC-30
Daedalus
• bands: 3,5,7,8,9,10
• scanrate: 50 scans/sec
• ground resolution: 1 m
CASI
• bands: ?
• scanrate
• ground resolution
Data Quality: Good, no clouds.

Description: Complete coverage of farm with several passes, north/south flight line orientation.

Pod 3: Not used.

2.2 Mission 2A
Target: Maricopa Agricultural Center, Maricopa AZ

Pod 1:
Overpass Date: 27 April 1995
Start Time: ??
Number of Passes: 4
Elevation: 17500' AGL
Depression Angle = ?
Ground Resolution: 1 m
Description: Coverage of MAC farm, N/S flight orientation.
Data Quality: ??

Pod 2: Not used.

Pod 3: Not used.

2.3 Mission 3
Target: USDA-Agricultural Research Service (ARS) Beltsville East area.

POD 1:
Overpass Date: July 9 1994
Start Time: 12:15 LT
Number of Passes: 1
Elevation: 12500' AGL
Depression Angle = 30 degrees

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Ground Resolution: 1 m
Description: 1 flight line over Beltsville East agricultural fields
Data Quality: small clouds

POD2:
Overpass Date: July 9 1994
Overpass Time: 12:24
Elevation: 5000' AGL
Number of Passes: 1
Instruments Used: Daedalus, RC-30 color-IR, color video
Daedalus
- bands: 2,3,5,8,9,10
- scanrate: 25 scans/sec
- ground resolution: 4 m.
Data Quality: ??
Description: ??

Pod 3: Not used.

2.4 Mission 4
Target: Irrigated potato fields near Hermiston OR and instrumented dryland wheat field near Prosser WA.

POD1:
Overpass Date: 28 September 1994
Start Time: 12:24 for Potato fields, 11:33 for wheat field
Number of Passes: 3 for potato circles, 2 for wheat field
Elevation: 17500' AGL
Depression Angle = 30
Ground Resolution: 3 m
Description: Potato fields covered by 1 setup line and collection lines; wheat field has 1 setup line and 1 collection line. Wheat field has 3 met stations, and surface measurements of roughness, soil moisture and wheat residue amounts.
Data Quality: Good, clear skies

Pod 2:
Overpass Date: June 24 1994
Overpass Time: 12:33 for potato fields, 13:05 for wheat field.
Elevation: 2500' AGL
Number of Passes: 1 setup, 2 flight lines for potato fields, 1 setup and 1 flight line for wheat field.
Instruments Used: Daedalus, CASI, Barnes and Stroud, RC-30, color video
Daedalus
- bands: 2,3,5,7,9,10
- scanrate: 50 scans/sec
- ground resolution: 2 m
CASI
- bands: spectral mode
- scanrate: ??
- ground resolution: 2
Data Quality: Good, no clouds.

Pod 3: Not used.
3.0 Potential Applications of AMPS Data Over Agricultural Targets

These AMPS missions and the included agricultural targets will provide excellent test datasets for development of approaches to using agricultural targets for non-proliferation assessment. Three areas we will focus on are extension of biomass monitoring combining radar and optical measurements, improved plant stress monitoring using hyperspectral data, and assessment of soil and crop damage using data fusion. These areas are discussed below.

3.1 Extension of Vegetation Monitoring Relating Radar to Vegetation Indices

Most remotely-sensed assessment of vegetation relies on surface reflectance properties in the visible and near-infrared spectral regions. Clouds, dust and haze can obscure an area and prevent remote evaluation of vegetation. Because of the potential gaps in surveillance, there is a need to develop techniques which extend monitoring capabilities using other sensor data. One such approach is the use of radar combined with visible and near-infrared data. Calibration methods can be developed which calibrate radar backscatter with vegetation indices, allowing the radar to be extrapolated spatially or temporally to areas with poor optical data coverage.

Dr. Moran at the USDA Water Conservation Lab (personal communication) has demonstrated positive correlations between field averages of Ku band backscatter and vegetation indices from AMPs over cotton and alfalfa crops at MAC. As part of the WSU grant, AMPS data over MAC (Mission 1) and in central WA (Mission 3) will be used to develop methods to relate radar backscatter to vegetation indices at or near the pixel level.

3.2 Improved plant stress monitoring using hyperspectral data

Agronomic crops can be used as biological indicators of chemically induced stress, indicating contamination from groundwater, surface water, precipitation, particulates accumulating on leaves. Hyperspectral data can provide leaf and canopy spectra which reveal changes in PAR (Photosynthetically Active Radiation) absorption. Full spectral collected from CASI in the spectral mode, as well as supporting ground-based spectroradiometric measurements, may provide information on the selection of bands optimized for detecting plant stress.

Candidate datasets for this work include Mission 4 CASI data (collected in spectral mode) collected over irrigated potato circles: these circles have had soil and plant characterization by WSU prescription irrigation program.

3.3 Assessment of soil, crop damage using data fusion

The health and status of agronomic crops have implications for the economic and political stability of a nation or region. The availability of multi-sensor data platforms such as AMPS provide data to develop methods for determination of the extent of soil and crop damage using combined reflectance, temperature and radar measurements.

The Mission 4 AMPS data collection includes dryland wheat fields near Prosser, WA. During the AMPS overpass, ground spectra were collected of fields that had varying amounts of residual wheat. In addition, data on soil and surface temperatures, soil roughness, soil moisture and air temperature were collected. This dataset will provide a unique opportunity to develop techniques to assess soil erosion. Radar backscatter will be used to characterize surface roughness. Thermal infrared from the Daedalus radiometer will be used to characterize soil moisture. Visible and hyperspectral data from Daedalus and CASI will be used to characterize the amount of biomass.
4.0 Development/Testing of New Algorithms

These new applications described above will require development of new algorithms, and testing of existing approaches to handle the processing and analysis of data generated by multi-sensor platforms. In addition to the increased volume of data from multi-sensors, data fusion requires accurate image co-registration to combine and analyze the multiple datasets.

4.1 Autoregistration

Autonomous methods are needed to improve co-registration (for data fusion) and to efficiently process the volume of data provided on multi-sensor platforms like AMPS. Semi-automatic registration techniques have been developed as part of DOE NN20 research by Battelle PNNL will be tested on the AMPS data used for agricultural targets research. The Maricopa Agricultural Center (MAC) dataset collection in Mission 1 is an ideal test site because the geometry of the fields is well understood, and a vector overlay exists for the farm down to sub-field level. The imagery to be tested includes Mission 1 radar, Daedalus, and CASI data.

4.2 Algorithms for Relating Radar Backscatter and Optical Vegetation Indices

One of the most promising research areas is potential for using radar data to extend optical assessment of vegetation. To do this, good co-registration between corresponding radar and optical images is crucial, so improved registration techniques are required. Also, methods to empirically relate radar backscatter and optical vegetation index on a pixel by pixel basis are needed: one of the crucial questions is at what scale the radar backscatter can be applied (due to radar noise).

4.3 Algorithms for Detecting Plant Stress

The availability of spectral data from CASI imagery would allow development and testing of algorithms for detecting stress based on the changes in the chlorophyll red-edge (near 720 nm). For example, there are existing derivative techniques for detecting the change in slope of the chlorophyll edge, or to detect subtle shifts. These assessments could shift or shape change in chlorophyll edge. Calculate on pixel basis using spectral mode.

4.4 Testing of Automatic Band Selection Algorithms

The Battelle Pacific Northwest National Lab is in the process of developing automatic band selection algorithms for improved landcover classification; this work is funded through the DOE NN20 office. Application of these techniques to the CASI spectral datasets from Mission 4 could provide insights into how narrow bands might be chosen to improve the detection of plant stress, soil disturbance and other agricultural target applications.

5.0 Improvements For Future AMPS Collections

Based on preliminary analysis of the Mission 4 data, one of the most obvious needs is a direct link to GPS (global positioning system) coordinates to assist in registration of the datasets; this is especially true for the radar backscatter data, which can be extremely difficult to register using the standard manual control point selection.

Another immediate need, based on preliminary inspection of the CASI data from Mission 4 collected in spectral mode, is software for reading, displaying and analyzing this CASI data. The problem is that the CASI spectral mode does not produce a complete 'image cube', only intermittent samples, so this unique format produces real problems with standard image processing software. Full hyperspectral imaging capability would be very useful in order to exploit imaging spectroscopy techniques, so the addition of other hyperspectral sensors (or modification of CASI) to obtain high spectral resolution data would be a major improvement.

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6.0 Conclusions
AMPS missions show great promise for the development of non-proliferation surveillance and assessment capabilities using agricultural targets. The current mission include datasets that should allow the development of algorithms to extend optical vegetation monitoring with radar, the assessment of plant stress, and the assessment of soil conditions. Several recommendations for future missions were sited, including encoded GPS positioning, and improved hyperspectral imaging capabilities. For agricultural targets, repeat coverage over the same crops, and ideally during the same growing season, is often required. Currently, the Arizona MAC site is the only target with repeat coverage.