093075

QUARTERLY REPORT

Reporting Period: June 1, 1975 - September 30, 1975
Contract Number: NAS9-14016
Title of Investigation:

Research in Remote Sensing of Agriculture, Earth Resources, and Man's Environment

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Mark for: Contract NAS9-14016

2.1 Layered Classifier Adapted to Multitemporal Data Sets

The objective of this activity is to develop and test a layered classifier applicable to multitemporal data sets from LANDSAT in which the training data from different passes comes from different training segments. As the result of previous research at LARS, a general approach to the layered classifier concept has been developed and research software has been written. During the present contract year, it is intended to apply the layered classifier to the multitemporal/multisegment problem, upgrade the software to improve its utility, and investigate potential methods for more effectively designing layered classifiers. Since June 1, 1975, attention has focused primarily on the first two of these three areas with two exceptions. Early in June, a paper based on work carried out during the previous contract period was presented at NASA's Earth Resources Survey Symposium in Houston, Texas. Also during June, a task analysis was performed in accord with section 4.0 of the contract work statement, Exhibit D. This was submitted in mid-July.

The Multitemporal/Multisegment Problem. As reported at the Houston symposium, multitemporal data can be used with the layered classifier to fill in "holes" in LANDSAT data caused by clouds, provided a valid training set is available for each of the satellite passes involved. A similar procedure can also be used to alleviate some forms of electronic data anomalies.

The most difficult situation to handle, however, is that in which it is necessary to draw training data from a combination of passes and segments. The problems encountered in such circumstances are closely related to the general signature extension problem, since extrapolation of training data sets over either time or space (or both) is required.

Initially we are concentrating on extrapolation over time, since a separate SR&T task is dealing with the spatial problem. A few candidate strategies have been proposed and will be cast into layered classifier logic and tested. In addition to the formulation of these strategies, efforts have been directed toward the assembly of appropriate LACIE data sets for the purpose of carrying out the necessary test and evaluation. We anticipate meeting the December 31, 1975, milestone which calls for completing the development of the single-segment layered classifier logic.

Layered Classifier Software Improvement. An initial assessment of the effort required to make the research software for layered classification compatible with LARSYS was completed in August, 1975. Some serious questions must be addressed before the programming can procede, largely as a result of the radically different form of the pattern classifier and the need to document, for each area classified, the detailed definition of the classifier used. We hope to be able to resolve these questions shortly and procede with the program development. Availability of the upgraded basic classifier software by the December 31, 1975, milestone date will greatly facilitate progress in the other aspects of this task.

<u>Optimal Classifier Design Procedures</u>. Due to unavailability of appropriate personnel to pursue this aspect of the layered classifier task, no work has yet been carried out during the contract period. However, an offer has been extended and accepted for a post-doctoral research position related to this task and we anticipate resumption of this effort during October, 1975.

2.2 Development of Spectral Strata from Clustering Techniques

Major Activities. Six procedures utilizing clustering techniques for determining spectral strata have been defined. A description of the characteristics of each procedure was submitted to JSC/EOD in early July. Three of the procedures have been implemented and possible spectral strata maps have been produced for two LANDSAT scenes, 1583-16525 and 1689-16382. We are now in the process of evaluating these preliminary maps in terms of classification accuracy and correlation with physical factor maps.

During the first quarter, programming of the procedures has been a major activity. Some of the steps in the proposed procedures use existing LARSYS algorithms, while other steps required additional programming. The procedure involving a non-parametric representation of data distributions required the development of a new processor. Programming was completed for this processor during the period. For three of the procedures, a parameter-space clustering is used. A program already existed to do this, but a new initialization method was developed and programmed.

A second activity has been prepared to evaluate the products of the clustering procedures. Acquiring suitable test sets and converting them to suitable formats has required more time and effort than anticipated. Field coordinates from the LACIE operational system were received from JSC on July 14. Programming to convert these cards to a LARSYS compatible format has been completed. Field coordinates determined by ERIM for SRS sites were received September 2. Programming to convert these cards to a LARSYS compatible format has begun.

The third area of activity this quarter has been to define the physical factors which can be expected to determine spectral strata boundaries in LANDSAT data. The physical factors selected are: soil association, soil color, crop calendar, temperature and precipitation patterns, and agricultural land use. We are now in the process of breaking each of these factors into a reasonable number of classes or levels and compiling available data and maps in formats compatible with LARSYS LANDSAT data products. A procedure for digitization of physical factor maps has been defined and is being used for digitizing soils maps.

Technical Problems Encountered and Solutions. The initialization procedure originally incorporated in the parameter-space clustering program depended on the order in which classes appeared in the input statistics. In order to remove this dependency, a new initialization method based on the distribution in the parameter space of the mean vectors and covariance matrices of the input classes has been implemented. Due to this difficulty, possible spectral strata have not yet been obtained for the remaining three procedures.

The tapes containing crop type data for use in evaluation of strata arrived in universal format, necessitating the development of a program to reformat the tapes. Programming is in progress.

2.3 Field Measurements for Remote Sensing of Wheat

Field measurements activities during this quarter included data acquisition missions, preparation of data analysis and processing software, data processing, data analysis, and project leadership and coordination.

Data Acquisition. Seven one-week data acquisition missions were performed at Williston, North Dakota between June 1 and August 31. The missions covered the planting-preemergence to mature-harvested stages of spring wheat development. Data were collected using the LARS spectroradiometer system for: (1) 60 spring wheat and other small grain plots, plus 10 plots of other crops and cover types, (2) an intensive study of the emissive characteristics of spring wheat canopies, (3) a study of the effect of view and solar angle of the reflective and emissive characteristics of wheat canopies, and (4) measurement of the reflectance of canvas panels used for calibration of the S-191 and 24 channel MSS data. In addition, data were periodically obtained with a tripod-mounted radiometer in support of LACIE/SR&T wheat canopy modeling studies.

Detailed agronomic data including leaf area index, dry matter production of leaves, stems, and heads, soil moisture, and grain yield were obtained. Supporting meteorological measurements included: cloud cover and type, wet and dry bulb temperature, barometric pressure, sky brightness, total irradiance, wind speed and direction, and soil and canopy temperature measurements of selected plots.

A special effort was added to the mid-July mission to carefully evaluate the ERL spectroradiometer system when it was identified that the system was producing data with higher reflectances than the LARS system was for identical targets. A report describing the tests made and results was prepared and submitted to ERL with copies to JSC personnel. A copy of this report is attached as Appendix A.

Data Processing. Data processing activities during the period were directed toward developing and implementing the data processing system to receive as inputs the measurements and data from various sensor and data acquisition systems and producing data products with comparable units of reflectance and data formats. Data for six missions from the helicopter S-191 system have been received and three missions have been processed. Data from three of LARS field spectroradiometer missions have been processed. No data have been received for the ERL field system due to technical difficulties in the field this summer, nor from the JSC VISS and MSS systems.

EXOSYS, the user data handling system, has been upgraded during the summer and the capability to perform statistical tests of data has been improved. And, a program for multivariate analysis of variance is currently being implemented to improve the data analysis capabilities.

Data Analysis. A preliminary comparison of data collected over the same wheat field by the LARS truck-mounted spectroradiometer and the helicopter-borne S-191 systems has shown that the two systems are producing similar responses. In addition, as time permitted during the summer, analysis of variance and multiple regression analyses were performed on the data collected for several corn and soybean experiments during 1972-1974. These analyses have served as a test of data analysis procedures which will be applied to the wheat data. The analyses have been completed and are ready to be written-up.

Project Leadership and Coordination. The field measurements project plan was revised and additional material added to make it current and accurate. A meeting of experiment participants from USDA/ASCS, NASA/JSC, Texas A&M Univ., Colorado State Univ., ERIM, and Purdue/LARS was held at Purdue, September 9-11, 1975, to review the first year of the project and finalize plans for the second year beginning in September. Discussions of progress, problems, and plans of the project were held with JSC personnel during two trips to JSC in August and in early September a trip was made to Garden City, Kansas to set-up experiments on the Agriculture Experiment Station for the 1975-76 crop year.

2.4 Scanner System Parameter Selection

Major Activities. A milestone plan that describes the proposed plan for the first year activities in the task was prepared and submitted to NASA/JSC. The project has been broken down into three major sub-tasks for work during FY76. They are:

1. Assembly of spectral data ensembles.

2. Development of scheme to represent spectral data in a generalized multivariant fashion through functional expansion coefficient characteristics.

3. Development of a scanner simulation and simulated digital data array.

A preliminary decision has been made to rely principally upon the spectral data being produced by the Field Measurements Remote Sensing Research Task. It is essential that well calibrated, fully annotated data be used in the formulation of the spectral data ensemble. Personnel are being trained to manipulate the software system to assemble the data ensemble. A small ensemble to illustrate the general characteristics of the data is being prepared first for use by the personnel working on the data expansion subtask.

Personnel assignments have been made to each subtask and background studies in the data expansion and scanner modeling subtasks have been initiated.

Technical Problems and Solutions. No significant technical problems have yet been encountered in this task.

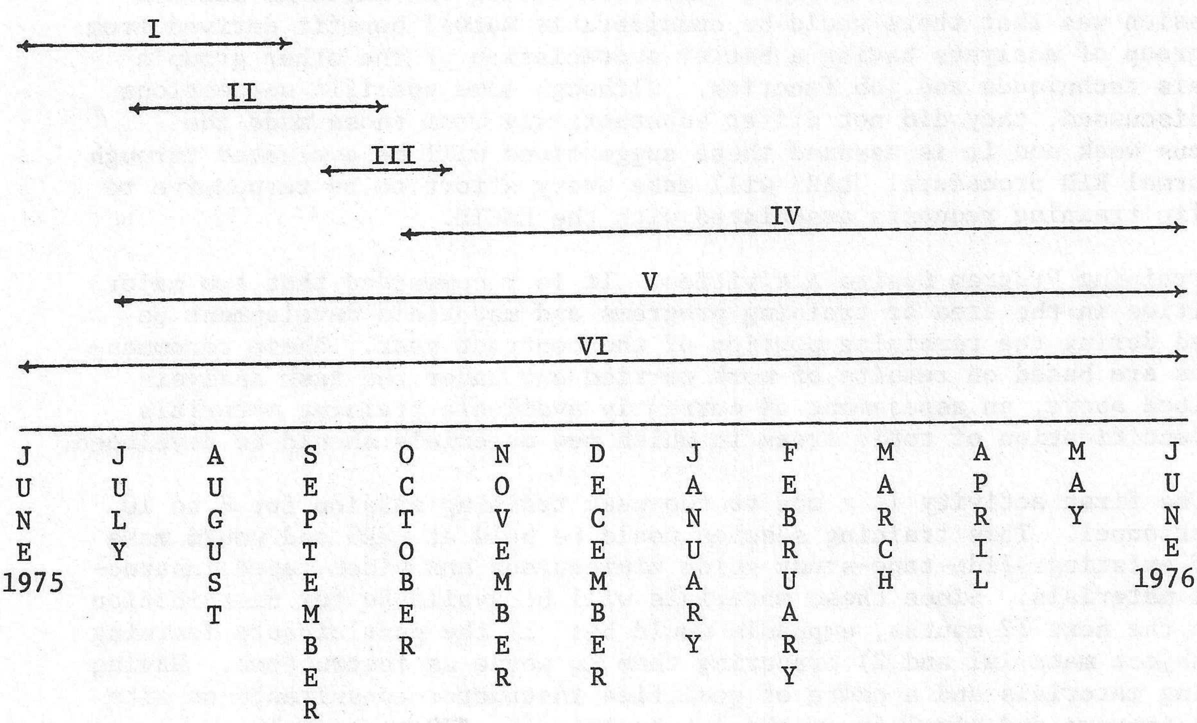
Data Analysis. Some data from the field spectral system has been preprocessed. Preliminary analysis will depend upon scene definition. A small trial set of spectra is being assembled for testing and evaluation. Preliminary work on scene definition has been instituted.

Plans for Next Quarter. The assembly and trial spectral data ensemble will be completed. Work on the data expansion phase of the study will be initiated. A definition of a complete scene upon which a complete ensemble will be based will be completed. The background study on scanner modeling will continue.

2.5 Transfer of Computer Image Analysis Techniques (Remote Terminal)

Activities under this section of the work statement include continued support of the JSC remote terminal and the development of technology transfer concepts and materials. During the first quarter, milestones for those activities were submitted to NASA along with the milestones for the other tasks under this contract. Discussion of the work carried out under this task during the June 1 - September 30, 1975 period parallels the milestone statements. For convenience the technology transfer milestones are summarized in the table below.

Key:
- I. Task Analysis (with JSC)
- II. Training Program Design
- III. Development Priority Assignment (with JSC)
- IV. Materials Development
- V. Interim Training Programs
- VI. Remote Terminal Support



Summary of Technology Transfer Milestones

Task Analysis Activities. On June 12, Ms. Shirley Davis and Ms. Tina Cary visited JSC and met with Mr. Donald Hay. The work statement and preliminary milestones for this task were reviewed at that time. On August 19 and 20, Dr. John Lindenlaub visited JSC to meet with Mr. Hay to discuss training needs, determine typical entry levels of trainees and survey presently available training materials (milestone 1). A series of meetings between Dr. Lindenlaub and Building 17 personnel was arranged by Mr. John Sargent. Most of the discussions were on a one-to-one basis with personnel working on specific projects. The exception was a group discussion organized by Mr. Tom Minter which centered around LACIE Analyst Interpretors (AI) and Data Processing Analyst (DPA) training.

The following observations were made as a result of the one-to-one conversations. The individuals talked to were for the most part working within a relatively small group (less than 8 individuals). The individuals had a wide diversity of backgrounds reflecting the interdisciplinary nature of remote sensing technology ranged from none to minimal with most of the people learning through on-the-job training.

Perhaps the strongest feeling expressed during the LACIE AI and DPA discussion was that there would be considerable mutual benefit derived from each group of analysts having a better appreciation of the other group's analysis techniques and job function. Although some specific suggestions were discussed, they did not differ substantially from those made the previous week and it is assumed these suggestions will be evaluated through the normal RID procedure. LARS will make every effort to be responsive to specific training requests associated with the LACIE.

Training Program Design Activities. It is recommended that two major activities in the area of training programs and materials development be pursued during the remaining portion of the contract year. These recommendations are based on results of work carried out under the task analysis described above, an assessment of currently available training materials and identification of topic areas in which new materials should be developed.

The first activity is a one to two week training session for 8 to 10 JSC personnel. This training session would be held at LARS and would make use of existing slide-tape-study guide minicourses and video taped instructional materials. Since these materials will be available for distribution within the next 12 months, emphasis would be: 1) the participants learning the subject material and 2) preparing them to serve as instructors. Having training materials and a cadre of qualified instructor-consultants on site should improve and simplify on-the-job training of JSC personnel.

The second activity proposed for the remaining portion of the contract year is the development of some additional training materials. Simulation exercises centered around the forestry applications project (FAP) and regional applications project (RAP) and additional titles in the FOCUS series are specifically recommended. Simulation exercises are designed to lead the reader through the professional thought and decision-making processes typical of those required of a remote sensing analyst. The FOCUS series is a set of pamphlets which contain one page of text and one page of supporting figures.

Priority Assignment Activities. The following priorities are recommended for the training program and materials development work during the remaining portion of the contract period:

1. Development of a forestry applications (FAP) simulation exercise.
2. Training 8-10 JSC personnel at LARS as described in the previous section.
3. Produce additional titles in the FOCUS series.
4. Development of a simulation exercise for the RAP program.

These priority assignments will be assumed to be agreeable to NASA unless notified to the contrary.

Materials Development Activities. Although there were no materials development activities scheduled for the first quarter of the contract period preliminary preparations have been made for the development of a FAP analysis simulation exercise and a request for the purchase of a video tape recorder/playback unit to be used for the training of JSC personnel at LARS has been made.

Interim Training Programs. No requests for interim training programs were received from JSC during the June 1 - September 30, 1975 time period.

Remote Terminal Support. Support of the JSC remote terminal has continued during the first quarter of the contract period. The only reported problem was a modem failure on September 5. The service people were called and the power supply in the modem at LARS was replaced on September 10, 1975. The terminal is now operating properly.

Problems. Written approval for the purchase of a video tape recorder/ playback has not been received from JSC. Lack of approval will impede the development of new training materials and limit the scope of training materials that can be presented to JSC personnel.

Summary. Work under the Transfer of Computer Image Analysis Techniques (Remote Terminal) task has progressed as documented in the work statement. All milestones for this reporting period have been achieved.

2.6 Research in Remote Sensing

Ancillary Data Registration. The primary activities during the period were completion of the image to image registration research conducted in CY75 and analysis of a modified Computer Sciences Corp algorithm revealed at the Purdue Symposium in June. Analysis of the new algorithm will be included in the final report on the project which should be finished soon after September 30. Work on the CY76 task "Registration of Ancillary Data" was pursued via a literature survey of all techniques for registration of both image and non-image (ancillary) data sets. This will form a basis for the research throughout the remainder of the year.

LANDSAT Imagery Enhancement. In addition to the Ancillary Data Overlay task a continuing image enhancement task was included in the milestones. Work on this task included program refinement for carrying out the enhancement and obtaining reproductions of enhanced data on the Optronics film writer system. A program will be delivered to JSC in October as defined in the milestone plan along with some further enhancement examples.

An evaluation subtask is also continuing as a part of the enhancement task. Enhanced and unaltered data is being classified for the Dekalb, Illinois test site used in the ERTS Wabash Valley Study. Test field results and total county crop area results will be compared to determine if the enhancement inprocess classification and area estimation accuracy.

Soil Reflectance Investigation. At the present time, the research on this task is proceeding as scheduled. The present state of the project spans three of the proposed sections (A, B, C) previously mentioned in the milestones. The progress in each area is discussed below.

A. Data Collection and Refinement

Approximately seventy-five percent of the raw data to be used throughout the study has been collected or refined from existing data. A brief examination of the digital data under the "Exosys" format, has indicated that the quality of the data is very high. The data not yet obtained pertains to the study of organic constituents. Samples have been sent to Dr. Flaig in Germany and we are anxiously awaiting the results of his analysis.

B. Clay Samples

Samples representative of the 1:1 and 2:1 clay types have been collected and analyzed for their spectral character after different heat treatments. This section of the study is aimed at determining the source of moisture in the absorption bands so as to allow for a more conventional interpretation of the spectral data for soils. Several clay mineralogists have agreed to evaluate this data.

C. Organic Constituents Analysis

As previously stated this portion of the study is at a pause in that the physio-chemical data required for its completion has not been received by the lab. Upon reception of this data, analysis will continue.

Inquiries to John Dietrich at JSC revealed that Mr. Dietrich will monitor the enhancement portion of Task 2.6 only and he does not know that any monitor has been assigned for the other research tasks in 2.6. This situation must be corrected if JSC is to be cognizant of the work on the ancillary data registration and soil reflectance tasks.

2.7 Forestry Applications of Computer Aided Analysis Techniques

Introduction. Work at LARS is supporting the FAP by documenting and refining computer-aided analysis techniques for forestry applications. Under this broad objective, specific subtasks of 1) defining training procedures, 2) statistically evaluating results, 3) selecting optimum wavelength combinations, 4) analyzing multitemporal data and 5) evaluating change detection methods have been defined. Work during this first quarter has been aimed at documenting these subtasks.

Accomplishments to Date. The major effort during the first month of the contract period was spent defining milestones and time lines. Before we made any attempt at drafting procedures for the appropriate subtasks, we felt that it was necessary to draft our mapping criteria. These criteria, based on USFS definitions, define a minimum unit on the ground that we will attempt to map with satellite data. The Level II (U.S.G.S. Circular #671) minimum unit that we are defining equals a homogenous area of ten acres or larger. Areas five acres or larger will be defined for Level III. Results for these levels of classification will take into account the minimum units in the display of the output product. Therefore, the final map product should be a more reasonable representation of maps produced by standard techniques.

The greatest emphasis has been placed on documenting procedures for statistically evaluating results of analysis. We feel that the classic means of evaluating MSS results, by their nature, introduces analyst bias. Furthermore, characteristics of LANDSAT data make exact location of test and training fields for forest sites difficult. For these reasons, we feel, and have reported to FAP, the necessity of developing a statistically valid means of sampling the results. A draft of a statistical method has been written and is currently being reviewed.

Drafts are also being developed for the "modified or interactive clustering" procedure, wavelength band selection, and multitemporal analysis. The clustering procedure has previously been documented in:

- "Computer-Aided Analysis of LANDSAT-1 MSS Data: A Comparison of Three Approaches, Including 'Modified Clustering' Approach", M. D. Fleming, J. S. Berkebile, R. M. Hoffer. Machine Processing of Remotely Sensed Data, Purdue University, June 3-5, 1975 and
- "A Case Study Using LARSYS For Analysis of LANDSAT Data"; T. K. Cary, J. C. Lindenlaub; LARS Information Note 050575.

Presently being drafted is a version which defines the specific step-by-step approach necessary to apply this technique. The approach being defined simplifies the approach described in the second reference.

Prior to identifying the so-called optimum wavelength bands or regions for forestry applications, one must have a reasonable data set available. Such a data set is not available at LARS for the Sam Houston National Forest. Therefore, work being accomplished in part for a SKYLAB contract involving the San Juan National Forest will be the basis for this study. Both SKYLAB and NC130 aircraft data exist for this test site along with sufficient ground reference data to insure that the study undertaken will be valid.

The ability to digitally overlay and analyze LANDSAT data collected at different growth points in the year has been assumed to yield an increase in the classification accuracy. The question concerning which dates, which channels(s) per date, and how many dates quickly arises when one deals with multitemporal data. Procedures are being developed to answer these questions for a 7-date LANDSAT data set collected over the Hoosier National Forest. A visual method of data selection is being considered together with a machine-aided technique.

Development of this procedure is being accomplished for data on the Hoosier rather than the San Houston National Forest. This is being done because there is more scene variability for the Hoosier, and because the data set for the Sam Houston is of somewhat poorer quality (figure 1).

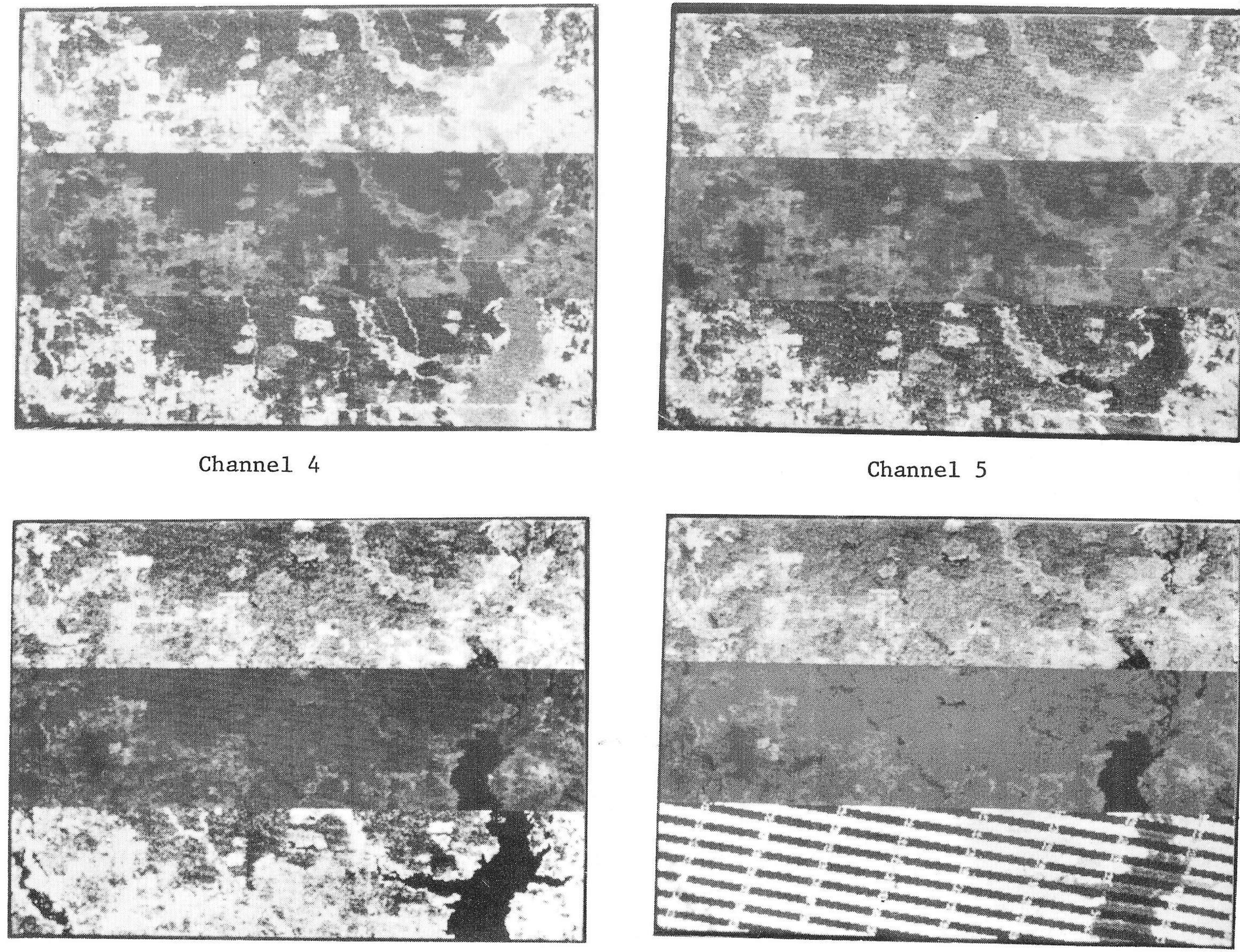
Projected Accomplishments. Draft documents outlining procedures to implement; "modified or interactive clustering"; statistical evaluation of results; wavelength band selection; and approach to multitemporal analysis. Application of some of the above techniques to data from the Sam Houston National Forest. Testing the statistical evaluation approach on an analysis of the Hoosier National Forest.

Figure 1 Illustrates the multitemporal LANDSAT data overlay available for the Sam Houston National Forest test site. A coincident area has been replicated for each of the three dates available for each channel. A quick visual comparison indicates the quality of this data set.

Nov 27, 72

Feb 25, 73

May 8, 73



Channel 4

Channel 5

Channel 6

Channel 7

2.8 Regional Applications Project

The two major objectives of the RAP, SR&T effort are

(1) Develop a procedure for classifying the Texas Coastal Zone into categories approximating the Bureau of Economics Geology (BE6) environmental planning units and

(2) Develop a procedure to detect change within the Texas Coastal Zone.

Objective (1) was addressed during CY75 and objective (2) constitutes the statement of work described for CY76.

Major Activity. With the knowledge and approval of the NASA/JSC RAP project manager, the majority of the work conducted during the first quarter of CY76 was directed towards completing the CY75 objective. The following activities were addressed:

1. Final, supervised classifications of the nine quadrangles of the Matagorda Bay area were completed.

2. Statistics on the ratio's used for the various classifications were compiled.

3. Precision geometric corrections of the three date temporal overlay of the Port O'Connor, Austwell and Port Lavara quadrangles were completed and a classification of these quadrangles was completed.

4. Compilation of histograms, means, and co-variance correlation matrics of the training fields of all nine quadrangles. All materials generated in No.'s 1 - 4 were forwarded to NASA/JSC for evaluation and study.

5. In September, Dr. Kristof spent one week at NASA/JSC working with RAP personnel on grouping informational classes to allow the resulting classification map to more closely approximate the BEG Environmental Geology maps.

6. In addition to the above efforts Dr. Kristof is and will continue to work on the grouping of informational classes and also will supply NASA/JSC with more documentation on the classification procedures used in the original classification of the nine quadrangle areas.

The following tasks were directed towards completing the FY76 effort:

1. Development of an RAP milestone schedule and submission to NASA/JSC.

2. Development of an RAP implementation plan (not yet completed).

3. Receipt of LANDSAT II February 25, 1975 data.

4. Precision geometric connection and development of a four date temporal overlay for the Port O'Conner, Port Lavaca, Austwell and Pass Cavallo quadrangles, includes the February 25, 1975 data.

5. Program development to allow for detecting change using a post classification comparison technique.

Technical Problems Encountered. No serious technical problems were encountered. The level of work directed towards the FY76 objective is expected to increase greatly during the next quarter. Receipt of the aerial photography taken concurrent with the February 25, 1975 LANDSAT II pass will greatly aid in the progress of the FY76 effort.

SUMMARY OF TESTS, RESULTS AND CONCLUSIONS FOR THE ERL DATA COMPARISON STUDY AT WILLISTON, N. D. JULY 16, 17, and 18, 1975

Purpose: To determine the comparability of data gathered by the Model 20C and 20D spectroradiometers.

Personnel: Morgan McIntosh, LEC
Jim Jones, LEC
Jim Shaffer, LEC
B.F. Robinson, Purdue/LARS
L.L. Biehl, Purdue/LARS
L.F. Silva, Purdue/LARS

I. Introduction

Preliminary investigation of reflectance spectra computed from data gathered by the Model 20C and 20D indicated the following:

> The computed reflectance values based on data from the ERL 20D were significantly greater than the computer reflectance values based on data from the LARS 20C for identical targets.
>
> Reflectance spectra of the Model 20D exhibited considerable offset between the reflectance values of the silicon detector and the lead sulfide detector.

As a result of these differences, it was felt that some form data comparison study was necessary. It was decided that the ERL instruments, vehicles and crew, having completed data taking activities at Garden City, Kansas, would join the LARS instruments, vehicles and crew which were operating at Williston, N.D. The requirement of LARS test facilities, suitable buildings, and typical field conditions obviated the choice of Williston, N.D. as a site for the comparisons. The opportunity for side-by-side measurements of the NASA canvas reflectance panels and recency of the data taking activities indicated that July, 1975 would be the optimum time for the comparisons.

II. General Procedures

In order to isolate possible causes for the differences in the data, work proceeded according to the following plan:

A. Comparison of Procedures

It was affirmed that both ERL and Purdue used the painted barium sulfate surfaces to calibrate their instruments from a distance of 8 feet. This verified previous observations of the operations of both instruments which indicated that the reflectance standards were viewed and positioned properly.

Procedures for pointing the instruments were examined and it was found that they could be geometrically pointed at targets and standards with sufficient accuracy. However, an operator trained in interpreting the level indicator located in the ERL instrument van was required. This was felt not to be a serious difficulty as all operators are aware of the procedures and a TV camera (which went out of service during the ferry) is normally used to view the target area.

It was also reviewed that repeatable procedures involving the use of plumb bobs were used to ascertain the altitudes of the instruments.

To ensure the correct machine processing of the ERL data, four data runs were recorded to measure the reflectance of sunlit grass. The second incident observation was accomplished with half of the solar port covered. This should produce a reflectance spectra having roughly twice the reflectance of the spectra obtained using the full solar port. Purdue had previously run similar tests on their system.

B. Evaluation of Instrument Performance

Since the Model 20C had the most recent routine instrument performance tests, it was decided to run the same tests on the Model 20D. These tests consisted of examination of the electronic signals and optical behavior of the instrument.

It was found that the chopping frequency was satisfactory and that the noise level on the system signals was acceptable.

A shift in signal "zero level" was experienced when the tape recorder was turned on. After verifying and investigating this, all measurements of the system's static behavior were made with the tape recorder "on". It was determined that the tape recorder status did affect the data. See Table I.

The only instrument signals which indicated faulty electronic processing were the synchronously demodulated signals for the lead sulfide and silicon detectors (before filtering). This originated with assymetric reference signals due to the phasing network. Tests of the gain coefficients for the electronic processing proved them to be accurate to within the uncertainty of the measurement procedure. It is certain that the gain coefficients do not cause any appreciable error. See Table I and II.

Tests performed using a high intensity source of radiation indicated that the output voltage versus irradiance for the silicon channel was linear; however, the lead sulfide channel was not linear for intensities near to typical solar conditions. (See Figure 1 and Table III). Spectral scans were recorded for several relative intensities. The source of the non-linearity was not determined.

Tests performed on the incident optics indicated that the Incident/Target mirror was not perfectly adjusted to reflect the full solar port radiation into the detectors. Since the stray radiation under severe circumstances was very low and the mirror position was judged to be highly repeatable, it is probable that the incident radiant power was measured with satisfactory consistency.

Tests performed on the telescope optics indicates that the primary mirror for the $3/4^{o}$ field of view was securely mounted and smoothly adjustable. The size and shape of the $3/4^{o}$ field of view indicate that <u>after</u> other system adjustments the focal distance adjustment may need to be recalibrated. The location of the $3/4^{o}$ and 15^{o} FOV with respect to the geometrical center indicated that the field of view selecting mirror needs to be adjusted. (See Figure 2). In view of the number of times this mirror was flipped and its apparent repeatability, it is probable that this is a stable condition of the mirror.

C. Comparison of Instruments Using Large Diffuse Targets

1. Dynamic Tests

Both systems were taken to the helicopter calibration site where data were taken over the five canvas panels following normal procedures. The ERL Model 20D was carefully positioned to ensure the reflectance standard was filling the 15° field of view. On the next to darkest panel an instrument-to-reflectance-standard distance of six feet was used for one series of observations.

The instruments were placed side-by-side and data were taken over a uniform patch of grass. The instruments were positioned to ensure that they were viewing the same area.

The instruments each took calibration data over their calibration panels and then the panels were switched and treated as targets.

2. Static Tests

Using a helium pluecker tube having a distinct line at 1.014µm, the circular variable filters for the lead sulfide detectors both instruments were stopped at approximately that wavelength. Then, each system, using its own reflectance standard, measured the reflectance of the patch of grass using a digital volt meter. See Table IV. The results indicate that the computed reflectivities agree favorably when identical procedures are followed.

Following the comparison above, the CVF for the silicon detector of the ERL Model 20D was stopped at approximately 1.014µm. Data was taken over the patch of grass. Due to the low signal level available from the silicon detector it was not possible to measure the reflectivity of the grass. However, the calibration panel to solar port ratios were determined to be within 3%.

D. Irradiance and Wavelength Calibration

A helium pluecker tube was used to irradiate the solar port to provide helium lines for the ERL 20D. The spectrum was scanned and the response recorded. The response can be treated as a data run to produce a digital graph of the observation. Then the actual wavelength of the spectral lines can be compared to the wavelength scale. This procedure was followed for the LARS 20C about July 10, 1975.

Irradiance calibration was performed about July 10, 1975 at Williston, ND for the 20C. However, it was decided that ERL would perform the irradiance calibration in its laboratory.

III. Conclusions

Based on the results given above, the following conclusions may be drawn:

Optical mis-alignment probably caused the Model 20D to miss some portion of the calibration panel during operations at Garden City. This would cause a sizeable increase in the apparent reflectance of the target.

The assymetry in the synchronous demodulation process of the lead sulfide detector signal would cause a slight decrease in the apparent reflectance of the target and tend to make the infrared reflectance appear to be a few percent less than the visible and near infrared reflectance. The effect appears as a small "offset" in the spectrum.

The nonlinear responsivity function for the lead sulfide channel would cause an increase in the apparent reflectance of the target and, as well, an offset in the spectrum.

The distribution of sensitivity over the fields of view for the two detectors is different (this is normal). However, when some parts of the field of view miss the barium sulfate standard, an "offset" in spectrum may be produced.

IV. Recommendations

Samples of the data gathered over the summer at Garden City, Kansas should be examined for the following items:

(i) solar port response minus cover-on response corrected for sun angle (ie : ÷ cos θ)

(ii) 15^{o} FOV response to canvas panels minus cover-on response. Corrected for sun angle.

The purpose of (i) is to track the responsivity of the solar port over the period of the summer. The purpose of (ii) is similar for the 15^{o} FOV. The canvas panels are suggested because they provide a stable reflectance large enough to fill the FOV of the instrument.

If the responsivity of the solar port and the responsivity of the 15^{o} FOV are determined to be constant, then the barium sulfate versus solar port calibrations performed on July 18 may be used for the summer's data for sun angles above 40^{o} with an estimated uncertainty of 11% to 16% of reflectance value for a lambertian target.

$$\rho = \pi \frac{L}{E} = \left(\frac{R_{TGT}}{R_{SP}}\right) \times \left(\frac{R_{SP}}{R_{BaSo4}}\right) \times \left(\rho_{BaSo4}\right)$$

$$\frac{\Delta\rho}{\rho} = 3\% + 10\% + 3\%$$

- 3%: Based on Repeatability of $\frac{R_{TGT}}{R_{SP}}$ from past years
- 10%: Estimate of maximum effect of non-lambertion behaviour for solar port for $\theta_E > 40^{o}$
- 3%: Based on last measurements of Barium Sulfate Paint at LARS using Model 20C. (Probably a low estimate of actual uncertainty because of the field condition of 4' x 4' reflectance standards)

For sun angles less than 40° the uncertainty will be greater. Subsequent tests can be made by comparing reflectance values (ERL corrected values) measured for the canvas panels by both instruments. These tests can indicate the measured difference between the reflectances measured by both systems and provide a measure of the uncertainty.

It is possible that the canvas panels can be used to improve the comparibility of the data in case either the solar port or the 15° FOV should prove to be unstable over the summer. This would require further study of the data.

One problem which must be yet considered is the possibility that the field of view of the Model 20D was not always filled with the desired target. The line-up procedures used by ERL will enable an evaluation at each plot. Since three spectra were taken at each plot it is probable that two spectra will be satisfactory and certain that at least one will be on target.

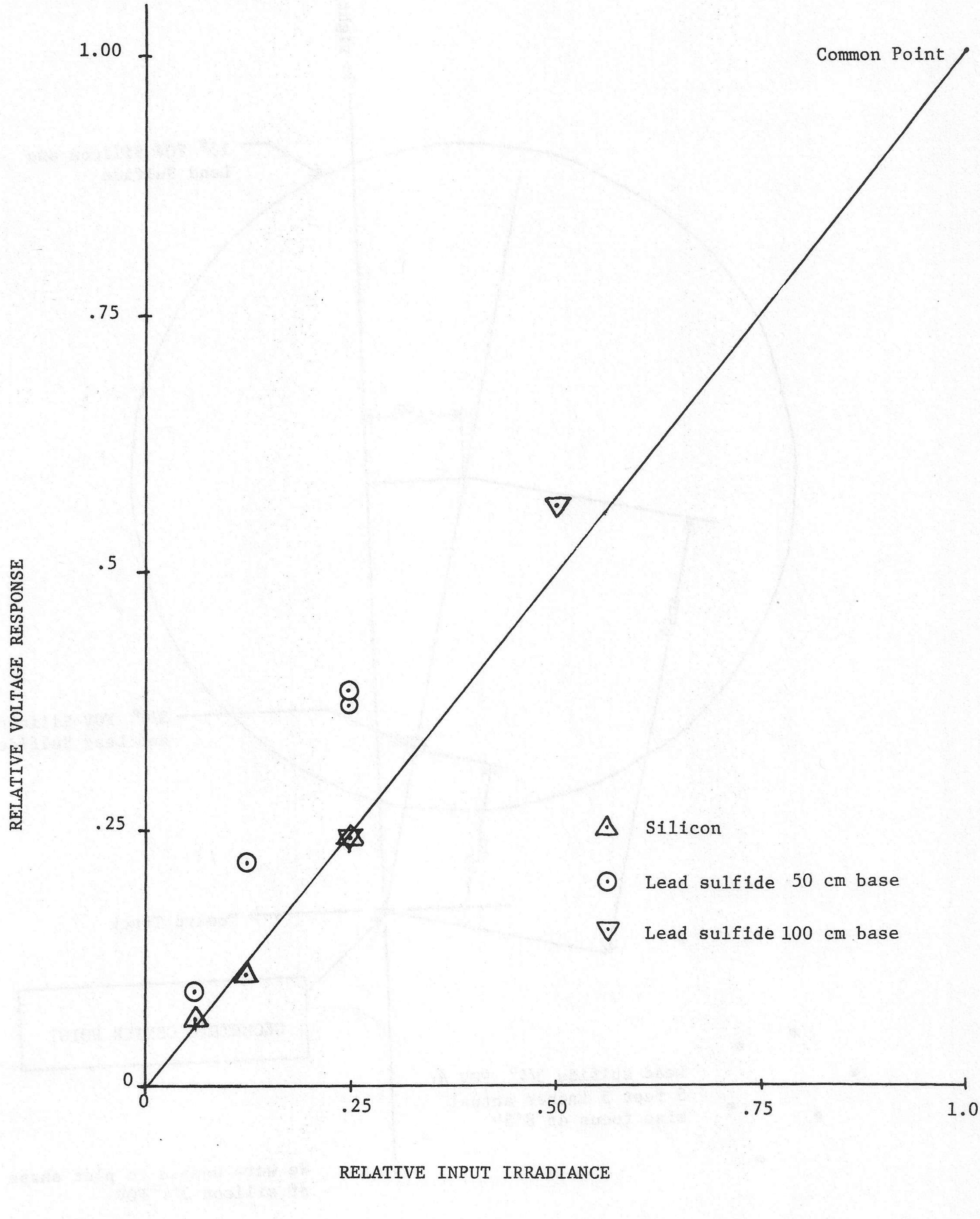


Figure 1. Responsivity Functions

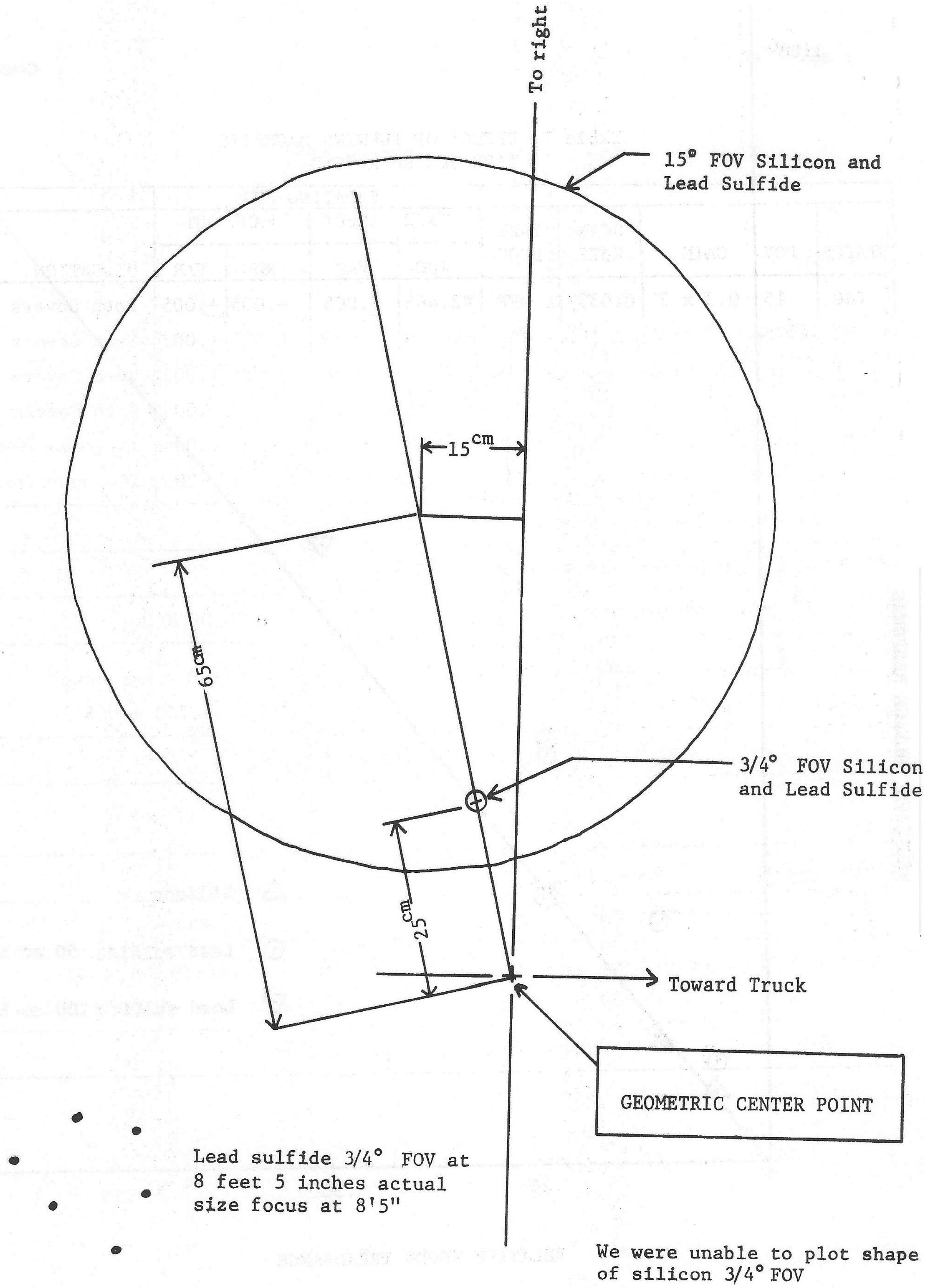


Figure 2. Field of View Maps (½ Power Points).

Table I EFFECT OF TURNING MAGNETIC TAPE RECORDER "ON"

					FLOATING DUN				
					TAPE INPUT		PANL OUT		
STATUS	FOV	GAIN	SCAN RATE	TAPE DECK	RDG	VAR	RDG	VAR	SITUATION
INC	15	0.3 x 2	0.033	OFF	*2.465	±.005	-.005	±.005	Both Covers on
INC	15	0.3 x 2	0.033	ON	*2.440	±.006	-.005	±.005	Both Covers on
TGT	15	0.3 x 2	0	OFF	2.462	±.006	-.005	±.003	Both Covers on
TGT	15	0.3 x 2	0	ON	2.435	±.006	-.005	±.005	Both Covers on
INC	15	0.3 x 2	0	OFF	.647	±.006	-3.113	±.004	INC open (sunlit)
INC	15	0.3 x 2	0	ON	.675	±.005	-3.123	±.006	INC open (sunlit)

*Average value for several revolutions

Table 1A Signal Difference Measured at tape deck	
TAPE DECK OFF	TAPE DECK ON
Reading - Zero Ref = Response .47-2.462 = -1.815 ± .007	Reading - Zero Ref = Response .675 - 2.435 = -1.760 ±.008
Average Difference = 3%	

Table 1B Signal Difference Measured at Front Panel	
TAPE DECK OFF	TAPE DECK ON
Reading - Zero Ref = Response -3.113 -(-0.005) = -3.108 ±.007	Reading - Zero Ref = Response -3.123 -(-0.005) = -3.118 ±.007
Average Difference = 0.3%	

Table II GAIN CALIBRATION

PbS	HIGH INTENSITY IRRADIATION				LOW INTENSITY IRRADIATION			
GAIN	RAW RESP	OCCULT	*DIFF	RATIO	RAW RESP	OCCULT	*DIFF	RATIO
1.0	+1.694±.002	+2.431	-0.737	.1664				
1.0 x 2	+.951±.002	+2.431	-1.480	.3341				
0.3	+.213±.003	+2.423	-2.21	.4989	+1.703	+2.429±.001	-.726	.1506
0.3 x 2	-2.004±.006	+2.425	-4.429	1	+.970±.003	+2.419±.001	-1.449	.3007
0.1					-0.000±.001	+2.412±.001	-2.412	.5005
0.1 x 2					-2.435±.005	+2.384±.001	-4.819	1
Closed	+2.436							

* The lead sulfide signal is synchronously demodulated for an output having negative polarity.

SILICON	LOW INTENSITY IRRADIATION				HIGH INTENSITY IRRADIATION			
GAIN	RAW RESP	OCCULT	DIFF	RATIO	RAW RESPONSE	OCCULT	DIFF	RATIO
1.0					-2.314±.001	-2.478±.001	.164	.0502
1.0 x 2					-2.153±.001	-2.480	.327	.1001
.3					-1.989±.002	-2.475	.486	.1488
.3 x 2					-1.500±.002	-2.474±.001	.974	.2981
.1	-1.957±.002	-2.474	.499	.1634	-0.832±.002	-2.466±.001	1.634	.5002
.1mx 2	-1.438±.002	-2.472±.002	1.034	.3387	+0.810±.005	-2.457±.001	3.267	1
.03	-0.930±.002	-2463±.002	1.533	.5021				
.03 x 2	+0.600±.003	-2.453±.003	3.053	1				
Closed	-2.481±.003							

Table III $1/R^2$ CALIBRATION

III A LEAD SULFIDE - CVF STOPPED (DVM at INPUT TO AMPEX)						
SOLAR PORT STATUS	TRIAL #1				TRIAL #2	
	LAMP TO PORT DISTANCE (CM)				LAMP TO PORT DISTANCE (CM)	
	50	100	150	200	50	100
CLOSED		2.436				
OPEN	-.545±.006	+1.285±.001	+1.778±.002	+2.162±.001	-.438±.004	+1.349±.002
OCCULT	+2.426±.001	+2.429±.001	+2.431±.001	+2.425±.001	+2.425±.001	+2.430±.001
Δ	-2.971±.006	-1.144±.002	-0.65±.002	-0.273±.002	-2.886±.004	-1.081±.00
RATIO #1	*1.0	.385	.219	.092	1.0	.375
RATIO #2		*1.0	.569	.240		

* Ratio 1 is based on 50 cm responses; Ratio 2, 100 cm.

IIIBB SILICON CVF STOPPED (DVM at INPUT to AMPEX)				
SOLAR PORT STATUS	LAMP TO PORT DISTANCE (CM)			
	50	100	150	200
CLOSED		2.481	±.003	
OPEN	+.198±.004	-1.826±.003	-2.184±.003	-2.304±.002
OCCULT	-2.420±.003	-2.460±.003	-2.471±.003	-2.471±.003
Δ	+2.618±.005	+.634±.004	.287±.004	.167±.004
RATIO	1.0	.242	.110	.064

TABLE IV. COMPARATIVE STUDY OF
REFLECTIVITIES MEASURED AT 1.014μm
BY THE SPECTRORADIOMETER SYSTEMS

Model 20C PbS (Using LARS Reflectance Panel)

SUBJECT	INCIDENT	TARGET	GAIN
Covers on	0.006 ± .006	0.006 ± .006	0.3
Covers on	0.008 ± .002	0.006 ± .002	1.0
Cal. Panel	0.840 ± .002	2.935 ± .005	1.0
Grass	2.670 ± .005	4.500 ± .006	0.3
COMPUTED REFLECTIVITY = .476			

Model 20D PbS (Using ERL Reflectance Panel)

SUBJECT	INCIDENT	TARGET	GAIN
Covers on	2.470	2.460	.01
Cal. Panel	1.030	-.835	.01
Grass	+.915	+.725	.01
COMPUTED REFLECTIVITY = .488			
Cal. Panel to Solar Port Response = 2.288			

Model 20D Si (Using ERL Reflectance Panel)

SUBJECT	INCIDENT	TARGET	GAIN
Covers on	-2.460	-2.460	.003
Cal. Panel	.480	1.920	.003
Cal. Panel to Solar Port Response = 2.212			