A REPORT ON

THE ACTIVITIES OF THE EARTH SCIENCES PROGRAM, LARS

BY

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The Laboratory for Applications of Remote Sensing
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1. INTRODUCTION

1.1 This report responds to a request by Marion Baumgardner (Program Leader) to provide a critique of the activities of the Earth Sciences Program Area. In order to achieve these aims, interviews have been conducted with members of the Program and with others who provide a direct input to it (Appendix 1). Additionally, a good cross section of the literature produced by members of the Program and other members of LARS has been reviewed (Appendix 2). Fortunately, I have been able to spend time in the field with three members of the Program (namely, Messrs. Weismiller, Kirschner and Kristof). For the benefit of those who may read the report and whom I have not met, Appendix 3 contains a brief C-V in order that the biases and prejudices of the author may more readily be perceived.

1.2 To maximize the usefulness of this report it is inevitable that statements on changes in the Program outweigh compliments on its performance. It is appropriate, therefore, to state unequivocably that the standards of research in the Program in terms of vigor, originality and substantive contributions to the applications of remote sensing are extremely high.

1.3 It will be a-parent from the index to this report that I have not chosen methodically to review each current individual research project. Rather I have chosen to look at major aspects of the Program's research effort. In the following section, the current approaches to research are reviewed and suggestions made about how improvements could be made. In Section 3, land characteristics that could usefully be studied by members of the Program are discussed, recognizing that only a small proportion of these could in reality be pursued. Since no activity in remote sensing makes any sense unless it is seen in the context of an information system, integration of remote sensing data into such systems is stressed. The contributions of remote sensing to work in developing countries is also emphasized. Finally, in Section 6 the development of connections of the Earth Sciences Program outside of LARS is briefly examined.

1.4 It will be apparent to those from the Program who read this report that some of their own opinions are to be found here. For many of the points, I cannot claim originality, either because I found people expressed similar views to those I already held or because they suggested points which had not occurred to me or they set in train ideas which led onto others and so on. Acknowledgement of everyone's assistance is gratefully given, and I hope people will forgive lack of explicit mention of their contributions which would have created a nightmare complex of referencing for me.

1.5 Finally, may I comment that it has been a pleasure to work with members of the E.S. Program and others from LARS, and that I at least have benefited greatly from the experience. Hopefully, this report will contribute in some small way at least to the future success of the Program. Two relevant maxims come to mind at this stage: "If only we could see ourselves as others see us." This review gives the E.S. Program members a chance to realize that wish. The other maxim is: "Judge not, lest you be judged." I am more than conscious of the latter's relevance to me, but despite this, here follows the review.

2. CURRENT METHODOLOGY AND ITS DEVELOPMENT

Funding for methodological studies has a low priority for most grant-awarding agencies. Despite this, it is important to examine current methodologies and to indicate possible areas of improvement, even though these do not constitute financially attractive research areas.

2.1 Documentation of Research

2.1.1 Until recently the systematic documentation of work and methods of the group as recorded in publications were insufficient to demonstrate properly the true value of the Program's research. For the academic well-being of the Program and its constituent individuals it is desirable that the recent increase in publication rates be maintained. It would be of value both for the Program and more importantly for the outside world if one or two major review papers were produced, explaining in detail how the procedures developed at LARS can be applied to soil studies in general. The brevity of many of the existing publications is to be welcomed given the ever increasing flood of scientific literature, but they are at times so concise and concerned with such relatively narrow topics that their full significance may not be apparent to readers. An expanded review of the type produced for the recent 11th International Soil Science Conference might be appropriate.

2.1.2 Some procedures such as the <u>a priori</u> use of the V/IR ratio and magnitude values are now almost second nature to members of the Program, but I do not recall having seen in any publication both a detailed account of how these values are used and an explanation of why they work in terms of energy-matter interactions.

2.1.3 One aspect which deserves particular attention is the explicit description of the analyst's role in interpreting results, making modifications to spectral maps, re-running programs, etc.

2.2 Ground Data Collection Methods for Correlation of Ground Properties with Spectral Data

2.2.1 As I understand it, there are at present two current approaches for understanding the spectral responses of soils:

(i) Lab-based methods, using radiometers to record the radiation from disturbed soil samples.

(ii) Field checking using an informal procedure to assess whether the spectral maps do delineate soil types or soil properties.

2.2.2 The latter method seems to have substantial validity when carried out or at least field checked by a practicing soil surveyor such as Frank Kirschner. If he finds the spectral map useful for soil survey, then their usefulness has been fairly assessed in as much as it does not really matter why the maps contribute information so long as a soil surveyor is assisted. The "Kirschner" method, although subjective, does certainly seem to be justified if carried out by Kirschner or another experienced soil surveyor. It would seem to me, however, that this approach is dangerous for others to use.

2.2.3 Furthermore, although useful, there does seem to be a gap between the lab approach and the pragmatic "Kirschner" method. This gap is occupied by attempts to identify specifically which properties of soils in the field affect their spectral response recorded by the Landsat sensors. Work on this approach was conducted some years ago, a notable example being the studies at Dieterle Farm, but seems not to be pursued nowadays. It may be that the accumulated wisdom of past years work, which has not yet appeared in print, has established that informal/casual field observation is sufficient to relate the spectral map classes to soil properties. My impression from my field visits was that this was not the case. There would seem to be a need, therefore, to devote more energy to studies of ground data collection.

2.2.4 One possibility would be to carry out radiometric measurements in the field, though this has constraints in terms of high cost, using the present equipment. Thoughts might be devoted to the use of a hand-held instrument. The 4-channel Exotech would provide useful data for interpreting Landsat 1, 2 and 3 MSS data and the proposed field instrument with thematic mapper channels should be available to researchers in the Program.

2.2.5 Ultimately, it is necessary to relate pixels to ground conditions, whereupon the difficulties of precise location of Landsat's large pixels become apparent. Even with Landsat-D the pixels will still be extensive. Ideally for preci~e surface-spectral signal relationships to be understood, one needs to know the precise location of a pixel. This is impossible (as yet) since accuracies are at best ± half a pixel. That sounds reasonable until one faces the fact that this means there is no way of relating any piece of ground on a one-to-one basis with any particular pixel.

2.2.6 A partial solution to this problem is to choose areas which are uniform (extending over at least 3 x 3 pixels). With land cover type, I have found this useful when working in rugged terrain with complex land cover types in southern Italy. Basically, one sets limits for a number of basic parameters (e.g., slope angle, orientation, and basic land cover type), and only 200 meter squares which are "uniform" according to these criteria are chosen. By selecting the numerical value of the central pixel, one can then relate a particular pixel value to the terrain observations which were made. Problems with this method especially for soils include that of defining an area with strict enough parameter limits, since soil properties are much more difficult to observe than land cover and topographic variation. Deciding that an area is sufficiently uniform could take an inordinate amount of time.

2.2.7 A less satisfactory alternative is to locate areas with uniform pixel values or classes and make observations within them. This seems to be the direction in which the field work plan was moving when I was in the field.

2.2.8 Either method requires that field observations are then made at a point. Given the variety of spatial frequencies of soil properties that exist, it is dangerous to rely on single observations. The statistical problems one is likely to meet are substantial (e.g., see Goodspeed, in Land Evaluation, Editor G. A. Stewart).

2.2.9 It would seem of value to examine more soils in the way carried out in Dieterle Farm, but preferably for a less complex area, which should more readily allow comprehension of the way in which assemblages of soils produce individual pixel values. Over a period of time a series of test sites could be developed which could be used as standards for evaluating new sensors and processing algorithms. Having once collected comprehensive ground data, subsequent ground data collection could be minimal. This topic remains of major importance since after all--all pixels are mixed pixels.

2.3 Laboratory Based Experimentation of Spectral Properties of Soils

2.3.1 I am probably least qualified to discuss this topic of all the ones outlined in this report. Certainly the work in progress on soils collected from throughout the U.S. is extremely interesting and should prove very valuable in the future. My one reservation is in the methods of analysis, which in the past several years seem to have relied too exclusively on establishing statistical relationships. Although important, one needs ultimately to understand energy-matter relationships at a more fundamental physical level. The practical importance of this is that prediction of the applicability of remote sensing in soils work must suffer if simply based on statistical relationships since the latter tend only to be valid for the population from which they were sampled.

2.4 Methods of Evaluating Results

2.4.1 Although I found many of the papers of the group very interesting and valuable, several seemed to me to tail off at the end because of a lack of thorough evaluations of their results. This would be helped, in some cases at least, by more quantitative evaluations. By playing around with statistics, it is possible to obtain virtually any answer you want, but I feel that it is equally true that judicious and honest use of statistics can form an important component of an evaluation.

2.4.2 Recent work has shown how confidence limits can be placed around % correct values occurring in contingency tables. Such methods would allow statistics to be used more objectively.

2.4.3 More thought could also be given both to qualitative and quantitative evaluations to laying down criteria as precisely as possible beforehand by which success (or failure) may be judged. These include accuracy levels, improvements in time taken for surveys, cost-effectiveness, etc.

2.5 Classification and Analysis Procedures

2.5.1 Without suggesting that the Program attempt to convert itself into a fully-fledged photointerpretation group, there would seem to be advantages in not relying too exclusively on LARSYS algorithms.

2.5.2 Use of Landsat data is manifestly not the answer to all remote sensing problems, as indeed was shown by the success of the derelict land strip-mining project.

2.5.3 Even if Landsat data are appropriate, this does not necessarily mean that classification by means of LARSYS algorithms is necessarily the best approach. Alternatives of several kinds exist, both analog and digital, which could provide useful information for many purposes.

2.5.4 Such methods may be applicable where final mapping scales are smaller than the present soil survey scales, i.e., where precise location is less important. Usually their costs would be much lower than use of the LARSYS system.

2.5.5 Additional justifications for use of alternatives to LARSYS include the fact that the spectral maps are now regarded as aids to mapping and not as definitive maps of land property classes. Interpretation, therefore, already plays a role in their use, which is not dissimilar in land form traditional image interpretation. With reference to soil surveys in particular, future work may well be in areas with much higher vegetation covers than in Indiana, making the prospects for direct classification of soils difficult and the application of image interpretation to enhanced images more viable. Other application areas such as geological survey, geomorphological survey, engineering materials survey, etc. may well benefit from application of these alternatives.

2.5.6 Suggestions for the use of alternatives to LARSYS are based on the need for applicat'ons scientists to apply methods appropriate to the problem being tackled, taking into account constraints such as cost, scale of final product and type of terrain being investigated. A flexible attitude towards the choice of techniques should be maintained as for example in the derelict land survey. Let the dog wag the tail, and not the tail wag the dog.

2.5.7 Equipment needs for such work would vary with the specific project, and present equipment can cover many needs. A reasonable stereoscope with magnifications up to c. 10 or 15x with a facility for illumination by transmitted as well as reflected light should often prove valuable. Personally, I have found a simple television camera fitted with a macro-lens very valuable for location of sites on Landsat imagery and correlating them with air photographs.

2.5.8 It would also prove useful to have the chance to carry out various simple image transformations and combinations interactively using the digital display unit, which should preferably be in color. Interpretation of imagery could be facilitated in this way, and useful preliminary results could be obtained in this manner, either as an end in themselves or as a basis for more efficient use of LARSYS classification algorithms.

2.6 Potential Conflicts between Long-Term Research Aims and Completing Short-Term Contracts

2.6.1 Several people I have spoken to, felt that the completion of short-term contracts militated against successfully achieving long-term research aims. Nevertheless, in looking at the Program's soils work over the last decade, a clear pattern of progress and achievement is certainly apparent. On the other hand, some projects, e.g., the Texas coastal one, do seem to have been prematurely curtailed based on achievements up to the date of finishing.

2.6.2 Achievement of long-term research aims may affect individuals more than the program as a whole. Nevertheless, there are no indications, for example, of students failing to obtain higher degrees as a result of the program being almost entirely supported by contracts.

2.7 Standards of Higher Degree Work

2.7.1 I have gained a very favorable impression of the standards achieved in the theses of students here (both in and outside the Earth Sciences Program). In several cases, one could wish for a more British-type system whereby good Masters degree work could be developed further and a doctorate awarded. It would appear that LARS is fortunate in the graduate students it attracts and in turn the graduate students clearly benefit from working in this institution. Generally, students felt they were constrained to a relatively small degree by the available facilities. The most common complaint of graduate students in Earth Sciences concerned the registration system; only one student felt that any of the other computer facilities were substantially inadequate. The need for wet-lab space at LARS was thought desirable by some, but very important by only one.

2.8 Use of Available Software

2.8.1 There were relatively few indications that the Program as a whole is not implementing newer algorithms developed by the Data Processing and Analysis Program. Considering the current apparent independence of the two Programs, this is somewhat surprising. Nevertheless, contracts involving both groups should certainly be encouraged, since this will be beneficial in the communication and development of analytical methods.

2.8.2 More complete documentation and attempts at wider dissemination of software developed experimentally by different Programs would apparently reduce duplication of effort according to a number of Program members.

2.8.3 The key problem of the pre-processing area is in obtaining high quality, relatively inexpensive, geometrically corrected registered imagery. Everyone seems to be aware of the problem, so that one hopes a solution is soon found. Unfortunately, no rapid solution is apparent.

3. APPLICATIONS AREAS

3.1 Introduction

3.1.1 Some of these suggested application areas are under active consideration, and in the case of the first application area on "soil survey in different environments" is already part of an existing project. Nevertheless, it seemed worth including it, to emphasize my recognition of its importance.

3.1.2 Comments on several of these areas are predicated on the assumption that the Earth Sciences Program does not necessarily adhere rigidly to the use of the LARSYS pattern recognition for reasons described in Section 2.

3.1.3 A final preliminary comment is that given the range of stated interests of the Program: viz.

Mineral Resource Investigations
Landform Studies
Geology Applications
Agricultural Soils Studies
Land Resources Inventories
Land Use Analyses
International Test Sites (sic)

--the actual range of interests is currently very much narrower. In many respects the advantages of remote sensing are only to be fully realized by adoption of an integrated approach towards the environment, so that this narrowing of the Program's interests could be viewed as undesirable both academically and practically.

3.2 Soil Survey Outside of the Midwest U.S.

3.2.1 Extension of soil survey applications of Landsat data to environments outside of the Midwest (where the large majority of the work has been done) is highly desirable. As already planned, it is intended to work in semi-arid areas. Additionally, efforts should be made to carry out such surveys in all the major North American environments, possibly based on the sort of subdivision already used in the selection of soils for the spectroradiometric measurement program of Eric Stoner. The type of land (including both physiographic and land cover properties) should also be considered since the spatial structure of soil and vegetation assemblages may directly affect both the choice of methods of analysis of MSS data and its success. For example, the diversity of terrain/vegetation assemblages with the semi-arid areas will mean that contrasting areas should be chosen for evaluating Landsat data.

3.2.2 Applications of a rigorous approach to these surveys should permit the laying down of precise guidelines for the use of Landsat data throughout the U.S., in terms of methods of analysis, type of ground survey and so on.

3.2.3 Extrapolation of these methods to evaluate different land types outside of the U.S. especially in developing countries is unlikely to be possible without modifications, emphasizing the need for research overseas (See Section 3.8).

3.3 Surface Materials and Engineering Properties

3.3.1 Work in the engineering properties of surface materials in Indiana and other humid areas is hindered both by vegetation and in some respects by the soils themselves. In this type of environment engineering materials suitable for extraction are usually not directly visible at the surface, though their presence can be inferred by photointerpretation methods. However, in more arid climates the possibilities of direct surface materials investigation by remote sensing become much more feasible. Applications of such work are obviously needed in such regions as the arid southwest of the U.S., where urban and industrial development is particularly dynamic, but similar studies are likely to be important wherever construction of buildings and roads is taking place.

3.3.2 Extension of these activities to the study of surface geology in semi-arid and arid areas also seems feasible (See next section), and consequently surveying of supplies of engineering materials from the regolith should also be aided by application of remote sensing.

3.4 Geological Investigations

3.4.1 The lack of continuing geological investigations carried out in the Earth Sciences Program seems curious to an outsider. In earlier years a number of relatively small studies were conducted, but these seem to have "fizzled out" compared with other activities.

3.4.2 Work on both subsurface and surface geology by the Earth Sciences Program at LARS is favored by the following considerations.

(1) Although difficult in vegetated areas, remote sensing is without doubt a useful tool to geological investigations.

(2) In more arid areas there are clear indications that "direct" mapping of superficial and bedrock geology is feasible.

(3) Generally, bare rock is not exposed at the surface of any but a few areas. Instead, some sort of regolith at least covers the bare rock. Investigation of the spectral properties of such regolith in many respects involves a direct extrapolation of the methods used in the spectral analysis of bare soils. Hence, LARS Earth Sciences Program has experience very relevant to this area.

(4) Methods used should not be restricted to a straightforward classification of scenes, but should also involve use of a variety of image enhancement techniques to aid visual interpretation.

There would also be value in applying the classification algorithms to assess whether the resultant spectral class maps are of use in assisting interpretation. The skills of the Data Analysis Group in overlaying multiple data sets could also be exploited. Applications of this work to developing countries could be substantial.

3.4.3 Applications to Pleistocene and particularly Holocene deposits in currently active areas are likely to prove particularly fruitful. Investigations of landforms would necessarily be a forerunner to such studies and could form an area of study worthwhile in itself in some regions.

3.5 Range Survey and Productivity Studies

3.5.1 This important area of study is apparently not under active consideration at LARS. Given the soils investigations of some western states that are being initiated and current interest in integrating soils into crop yield models, it would seem to be a natural extension to develop interests in this topic.

3.6 Coastal Zone Applications

3.6.1 The earlier work on coastal areas seems now virtually to have stopped. Although the reasons for this were, I understand, in part outside of the control of the Earth Sciences Program personnel, it seems to me a great shame that further work and proposals are not being pursued. An example of current interest is the up-coming Coastal Mapping Symposium, being organized jointly by the ASP, NOAA and the USGS, August 14-16, 1978. The initial work on coastal areas seemed to me to be promising and worth pursuing.

3.7 Monitoring Systems

3.7.1 It is generally recognized that one of the key potentials of remote sensing is in monitoring the biophysical environment. As an outsider I, therefore, find it strange that efforts in this direction are currently limited, though, of course, two or three years ago methodologies were explored for monitoring coastal areas. Areas where monitoring by remote sensing could usefully play a role include rangeland productivity and management, floodplain management, soil management especially with respect to land degradation, i.e., erosion and salinization.

3.7.2 Although Landsat imagery could play a role in several of these areas, it would be advantageous to explore the uses of other sorts of imagery, especially for smaller features where higher resolution is desirable.

3.7.3 Development of methods for incorporating soils information into yield models which has recently been proposed by the group seems an exciting possibility. Success in this work could lead to a stronger remote sensing component into the rather crude global land suitability models being developed by FAO (See Dudal (1978) in the Proceedings of the 11th Congress of the International Soil Science Society).

3.8 Other Application Areas and Conclusions

3.8.1 Other application areas are dealt with elsewhere under information systems. Clearly, numerous other possibilities exist, e.g., hydrological investigations, topographic map up-dating, but which may be considered well covered by other institutions. Nevertheless, it seems to me important that interests outside of the current studies on soils in the U.S. be actively explored, if only because the Program clearly becomes vulnerable to failure if virtually all its efforts are devoted to one application area (i.e., do not put all your eggs in one basket). It is not proven as yet that Landsat can definitely contribute in a cost- or accuracy-effective manner in an operational soil survey although present indications are very encouraging.

3.8.2 In this context the work on thermal properties of buildings represents an interesting development, involving a different sensor, different "platform", and different application area.

3.8.3 Furthermore, the same remote sensing data often contains valuable information concerning a range of applications. Multiple objectives will often result in a more cost-effective use of remote sensing data and its analysis; equally, an integrated view of the environment will maximize the extraction of useful information.

4. APPLICATION AREAS -- OVERSEAS WORK

4.1 The Justification for Overseas Work

4.1.1 Although the Earth Sciences Program has been involved in overseas work, as a proportion of its total research effort, such investigation has been relatively minor compared with its U.S. work. The Program's educational role overseas, primarily through the energies of Marion Baumgardner, has, of course, been major. There would seem to be several reasons why more effort should be put into such overseas efforts.

4.1.2 Remote sensing offers the greatest potential benefits to areas with the poorest data bases, which are usually in developing countries.

4.1.3 Information needs for developing countries in particular are crucial and America's international responsibilities in ensuring the maximum use of remote sensing technology should not be shirked. If the peaceful use of outer space means anything, it surely must include the diffusion of the techniques for using data acquired from space.

4.1.4 It cannot be assumed that methods or algorithms developed in the U.S. are applicable elsewhere without heavy modification. Research areas with different climates, physiography, land cover arrangements and crop management procedures, therefore, need to be carried out.

4.1.5 It is likely that activities as discussed in 4.1.4 can be frequently carried out through developments in the Visiting Scientist Program and through the Short Course, by scientists from these individual countries. If all such attempts were as successful as the recent Bolivian experience, then the need for overseas work would be reduced (though not eliminated -- see below). However, given that the recent Sudan experience may become typical, development and evaluation of the potential of remote sensing in such areas will depend on a continuing effort by LARS scientists.

4.1.6 Justification for work overseas also stems from attempts to develop international and even global information systems and, additionally, from the need for a continuing transmission of new LARS analysis procedures as they are developed.

4.2 Implementation of Overseas Work

4.2.1 It is easier to justify such overseas work than to suggest how it should be implemented. Various possibilities exist.

4.2.2 Individual LARS Members Visiting Overseas Countries

Although possibly the easiest approach, it has the drawback that such visits are often short which is particularly unproductive unless they are repeated. Notwithstanding this, by choosing appropriate countries, a diversity of research problems could be studied and types of areas investiaged and an extension of the activities of the Earth Sciences Program achieved. Funding would either be from American agencies, international agencies, or the host country. Such visits may be restricted by University of Purdue responsibilities. Probably of greater importance is the willingness and enthusiasm of people to work overseas. If overseas work is recogniqed as being important, this could be used as a significant criterion in the employment of new staff or graduate students. Hopefully, the latter will be able to play a role in any of the suggested implementations of overseas work.

4.2.3 Research/Educational Teams

A commitment by several individuals to overseas work should result in substantially greater benefits, but would logistically be much more difficult to organize. Such a team probably should contain personnel from other programs as well. One useful suggestion made was that an individual working full-time overseas could be assisted by periodic visits from LARS visiting staff.

On three occasions I have been a member of a group of scientists (one from a single university and twice from several universities) which largely by using "vacation" time were able successfully to complete major overseas projects.

It is almost inevitable that any such large teams will be involved in quasi-operational projects. It is worth emphasizing that it is perfectly feasible to achieve valuable research objectives within such a framework. Moreover, it may be argued that applied research is incomplete until and unless the applications have been evaluated in such a situation.

4.2.4 Permanent/Semi-Permanent Overseas Base

The previous category could be extended yet further by the establishment of a mini-LARS overseas, possibly in the model of ITC's institute in Columbia, and possibly in the way that South Dakota is moving in Nepal. Such relationships are in fact unlikely to provide a totally permanent overseas base, since local personnel would progressively take over all activities. Neverthe less, it should produce opportunities for overseas research and training and a continuing relationship between workers overseas and LARS personnel. This would in part be an extension of the existing Technology Transfer Program.

4.3 Prerequisites for Expansion of Overseas Work

4.3.1 The prerequisite has already been discussed, namely, enthusiasm of individuals to travel overseas. The second is a willingness of LARS as an institution to support such activities. Section 6.1 outlines my opinion concerning why I believe LARS has a responsibility to pursue overseas work. A third prerequisite must be a flexible approach to remote sensing data analysis and not a devotion to just one methodology (See Section 3), however valuable it is.

4.3.2 Lastly, it is important that grant-giving/contract-awarding authorities are given a realistic appraisal of the possibilities of the value of remote sensing. Happily for LARS at least, this latter point is unlikely to be a problem. Activities of other institutions and commerical organizations have done much to hinder application of remote sensing because of over-selling of the subject. Resistance to remote sensing in contract-awarding bodies as a result of this undoubtedly now needs to be overcome.

5. PROMULGATION OF DATA/IMPROVING INFORMATION SYSTEMS

5.1 Information Display

5.1.1 Although self evident, it is always worth reminding ourselves that a complete information system extends all the way from the recognition of the need for a particular set of information through to its actual usage. Those of us concerned primarily with data collection and analysis are liable to forget the latter stage in particular.

5.1.2 Transmission of data in usable form often means that they must have the appearance of a conventional map or comprise data tabulated with reference to appropriate areal subdivisions. The latter presents relatively few problems, but the former is more difficult. The symbols, coloring and/or shading need to be near conventional. It is important that the final cartographic output obtained from remotely sensed data be directly referable to topographic features (such as roads, railways, relief, and built-up areas), relevant administrative boundaries and grid-lines. Without such geographic reference data the user may have to spend an excessive amount of time in locating information, or more likely will discard the information and not use it. The latter, moreover, will more probably occur if the user or decision-maker is in a senior position.

5.1.3 Quite clearly the majority of output from LARS falls far short of the above standards. Alphanumeric output will provide problems for most users without a fair degree of familiarity with data processing. The output from the electrostatic photo is certainly an improvement, though it is a pity that a 32-level plotter was not obtained (e.g., like the Versatec), but generally it lacks reference data except for rivers as does the aesthetically delightful output from the Mead process. Output from the digital display unit could be useful at times though it has the disadvantage of having relatively poor resolution.

5.1.4 Reference data could presumably be added by means of the table digitizer, but this would be extravagant unless the reference data added were very small. Nevertheless, this procedure could be worthwhile if either the available topographic information were low or if particularly useful but simple data were added, in particular, the grid from existing topographic maps which greatly aids location. The proposed scheme to use transparent overlays for the soil survey seems potentially very fruitful for a variety of applications since the cost of combining topographic detail with remote sensing output could be reduced.

5.1.5 Methods for combining the two cartographic data sets need to be investigated considering such factors as degree of transparency of overlay, type of output suitable for overlaying (or underlaying), feasible density ranges, and the possibilities of physically combining the two "maps" to locate a single product. Although these are relatively mundane tasks, they should be given the priority they deserve.

5.1.6 Possibilities of photographically registering data sets, especially if geometric corrections have not been made might also be worth considering as a relatively low cost alternative.

5.1.7 One final comment on methods of information display is that for many purposes the high level of detail obtained from Landsat imagery is not appropriate and the display of mean properties for administrative units on a conventional choropleth map is all that is needed. Problems of data display are, therefore, minimized; harm to the potential applications of remote sensing can occur by displaying too much detail.

5.1.8 It was very usefully suggested to me that one individual be chosen to investigate the whole problem of cartographic display.

5.2 Incorporating Remotely Sensed Data into Operational Information Systems

5.2.1 A brief comment on obtaining accurate specifications of information needs and assessing current information systems is appropriate. This seemed to me to be an especially interesting development through the corn study. In particular, it seems important not only to ask what information people need and use now, but to probe more deeply into what they ideally would like. Remote sensing offers new opportunities for information gathering which in terms of spatial comprehensiveness and temporal frequency have been unavailable previously. It thus should be creating completely new information demands and these need to be explored.

5.2.2 It is surprising the small degree to which many operational information systems do not incorporate remotely sensed data. Potentially, remote sensing should be able to contribute substantially. The use of remote sensing in the open-cast mine derelict land survey is an excellent example of this. Many other information systems exist and their need for information could be explored (See Table 1).

5.2.3 Carrying through the incorporation of remotely sensed data into an information system and production of actual planning information can in itself involve important research tasks. An apparently good example of this work is that carried out by FMC Corporation in Iran (IBM 1976 Symposium on Earth Resources Management) for a pasture survey of Iran.

Table I *

State Land Use Programs

State	Type of State Program: Comprehensive Permit System [1]	Type of State Program: Coordinated Incremental [2]	Type of State Program: Mandatory Local Planning [3]	Coastal Zone Management [4]	Wetlands Management [5]	Power Plant Siting [6]	Surface Mining [7]	Designation of Critical Areas [8]	Differential Assessment Laws [9]	Floodplain Management [10]	Statewide Shorelands Act [11]
Alabama				X		X	A			X	
Alaska		X		X		X			B		
Arizona		X				X			A	X	
Arkansas						X	A, B		A	X	
California		X		X		X	X		C	X	
Colorado						X	X	X	A	X	
Connecticut		X		X	X	X			B	X	
Delaware		X		X	X				A		X
Florida	X	X	X	X	X	X	A	X	A, C		
Georgia		X		X	X		A, B				
Hawaii	X	X		X		X	X	X	B	X	
Idaho			X				X		A		
Illinois				X		X	A, B		B	X	
Indiana		X		X			A, B		A	X	
Iowa							A, B		A	X	
Kansas							A, B				
Kentucky						X	A, B		B		
Louisiana				X	X						
Maine	X	X	X (LTD)	X	X	X	A	X	B	X	
Maryland		X		X	X	X	A, B	X	B	X	
Massachusetts				X	X	X			B		
Michigan				X			X		C	X	X
Minnesota		X		X	X	X	X	X	B	X	X
Mississippi				X	X					X	
Missouri					X	X	X		A	X	
Montana		X	X			X	A, B	X	B	X	X
Nebraska			X			X			B	X	
Nevada		X	X			X		X	B		
New Hampshire				X	X	X			B, C		
New Jersey				X	X	X			B	X	
New Mexico		X				X	A		A		

See footnote at end of table. (Table continued on next page)

*Source: J. E. Hicks and T. Hauger. Managing Natural Resource Data: Minnesota Land Management Information System. The Council of State Governments, Lexington, KY. May 1977.

Table 1 – (continued)

State	Type of State Program			Coastal Zone Management[4]	Wetlands Management[5]	Power Plant Siting[6]	Surface Mining[7]	Designation of Critical Areas[8]	Differential Assessment Laws[9]	Floodplain Management[10]	Statewide Shorelands Act[11]
	Comprehensive Permit System[1]	Coordinated Incremental[2]	Mandatory Local Planning[3]								
New York	X	X		X	X	X	X	X	B	X	
North Carolina		X		X	X		X		B	X	
North Dakota						X	A		A		
Ohio				X		X	A		B		
Oklahoma							X		A	X	
Oregon		X	X	X		X	A	X	B		
Pennsylvania				X	X	X	A	X	B		
Rhode Island		X		X	X	X			B		
South Carolina				X		X	A		B		
South Dakota							A	X	A		
Tennessee						X	A, B				
Texas				X	X		X		B		
Utah		X					A		B		
Vermont	X	X			X	X	X		C	X	
Virginia			X	X	X		A, B		B		
Washington		X		X	X	X	A		B	X	X
West Virginia							A, B			X	
Wisconsin		X		X	X	X	X	X		X	
Wyoming		X	X			X	A		A		

[1] State has authority to require permits for certain types of development.

[2] State-established mechanism to coordinate state land use-related problems.

[3] State requires local governments to establish a mechanism for land use planning (e.g., zoning, comprehensive plan, planning commission).

[4] State is participating in the federally funded coastal zone management program authorized by the Coastal Zone Management Act of 1972.

[5] State has authority to plan or review local plans or the ability to control land use in the wetlands.

[6] State has authority to determine the siting of power plants and related facilities.

[7] State has statutory authority to regulate surface mines. (A) State has adopted rules and regulations; (B) State has issued technical guidelines.

[8] State has established rules, or is in the process of establishing rules, regulations and guidelines for the identification and designation of areas of critical state concern (e.g., environmentally fragile areas, areas of historical significance.

[9] State has adopted tax measure which is designed to give property tax relief to owners of agricultural or open space lands. (A) Preferential Assessment Program—Assessment of eligible land is based upon a selected formula, which is usually use-value. (B) Deferred Taxation—Assessments of eligible land is based upon a selected formula, which is usually use-value and provides for a sanction, usually the payment of back taxes, if the land is converted to a non-eligible use. (C) Restrictive Agreements—Eligible land is assessed at its use-value, a requirement that the owner sign a contract, and a sanction, usually the payment of back taxes if the owner violates the terms of the agreement.

[10] State has legislation authorizing the regulation of floodplains.

[11] State has legislation authorizing the regulation of shorelands of significant bodies of water.

SOURCE: Prepared by the Council of State Governments based on information collected by the Council of State Governments *Land Use Planning Reports 1974* and 1975, and the U.S. Department of the Interior, Office of Land Use and Water Planning; and the Resource Land Investigations Program. Data compiled October 1975.

6. EXTERNAL RELATIONS OF THE EARTH SCIENCES PROGRAM TO OTHER INSTITUTIONS

6.1 No single institution let alone a program can cover the whole range of remote sensing applications, nor its many facets. It is desirable, especially with reference to overseas work that links either within or outside the U.S. be established which would allow joint action on projects of common interests, and/or exchange of personnel at the faculty or graduate level. Such institutions should have complementary rather than over-lapping interests. Interests relevant to LARS could include institutions relying more especially on human image interpretation methods, or an institution more heavily committed to application areas, or an institution concerned with very different dimensions of environmental data, such as socio-economic onesor an institution specializing in cartographic research. Specific foci of common interest would need to be established to ensure maximum returns from these activities.

7. CONCLUSIONS AND SUMMARY

7.1 The high standards and valuable research of the Program should lead to its continued support by outside agencies and internal encouragement within LARS.

7.2 Additional work in the methodology of establishing soil characteristics and spectral responses should be pursued.

7.3 A readiness to exploit methods other than those offered by LARSYS algorithms should be maintained.

7.4 Several application areas could be pursued with more vigor than they apparently are at present.

7.5 For a variety of reasons, overseas work should be expanded.

7.6 Active involvement in applying remote sensing to information systems should continue to be pursued.

7.7 Display systems of output require substantial improvement.

7.8 Establishment of links with other institutions would be of value to the Program.

APPENDIX I

Interviews were conducted with the following people. Additionally, informal discussions took place with a variety of people outside the Earth Sciences Program.

Saleem Momin	Earth Sciences Program
Eric Stoner	Earth Sciences Program
Eric Hinzel	Earth Sciences Program
Chris Seubert	Earth Sciences Program
Sue Kaminsky	Earth Sciences Program
Dick Mroczynski	Ecosystems Program
Donna Scholz	Earth Sciences Program*
Paul Anuta	Data Processing and Analysis Research Programs
Lou Nash	Earth Sciences Program
Frank Kirschner	Earth Sciences Program
Phil Swain	Data Processing and Analysis Research Programs
Shirley Davis	Technology Transfer Programs
Dick Weismiller	Earth Sciences Program
Steve Kristof	Earth Sciences Program

*Currently working in other programs.

APPENDIX II

MATERIALS CONSULTED

(Given the numerous papers existing, I could not claim to have read everything available or to have read the following materials with the thoroughness they deserve. I hope, nevertheless, that my sampling has been representative.)

LARS Information Notes

052977 S. M. Davis. The Focus Series--A Collection of Single Concept Remote Sensing Educational Materials.

042778 Staff. Purdue/LARS Organization.

062076 D. A. Landgrebe. Remote Sensing Technology--A Look to the Future.

010577 M. F. Baumgardner. Computers, Satellites and Food--A Global Perspective.

010777 R. A. Weismiller, I. D. Persinger and O. L. Montgomery. Soil Inventory Prepared from Digital Analysis of Satellite Multispectral Scanner Data and Digitized Topographic Data.

042777 J. D. Russell and J. C. Lindenlaub. Disseminating Technological Information on Remote Sensing to Potential Users.

052576 J. C. Lindenlaub and B. M. Lube. Matrix of Education and Training Materials in Remote Sensing.

062277 R. A. Weismiller, S. J. Kristof, D. K. Scholz, P. E. Anuta, and S. M. Momin. Evaluation of Change Detection Techniques for Monitoring Coastal Zone Environments.

022278 E. R. Stoner and E. H. Horvath. The Effect of Cultural Practices on Multispectral Response from Surface Soil.

111477 A. N. Singh, S. J. Kristof and M. F. Baumgardner. Delineating Salt-Affected Soils in the Ganges Plain, India by Digital Analysis of Landsat Data.

030576 P. M. Mausel, W. J. Todd, M. F. Baumgardner, R. A. Mitchell and J. P. Cook. Evaluation of Surface Water Resources from Machine-Processing of ERTS Multispectral Data.

031276 P. W. Mausel, W. J. Todd and M. F. Baumgardner. An Analysis of Metropolitan Land-Use by Machine Processing of Earth Resources Technology Satellite Data.

060176 R. M. Hoffer. Computer-Aided Analyses of Skylab Scanner Data for Land Use Mapping, Forestry, and Water Resource Applications.

070576 J. K. Cochran and R. E. Bailey. Computer-Aided Extension of Digitized Remotely-Sensed Water Surface Temperatures into the Third Dimension.

081176 R. H. Beck, B. F. Robinson, W. W. McFee and J. B. Peterson. Spectral Characteristics of Soil Moisture, Organic Carbon and Clay Content.

082776 O. L. Montgomery, M. F. Baumgardner and R. A. Weismiller. An Investigation of the Relationship between Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soils.

101476 T. R. West, S. A. Mundy and M. C. Moore. Evaluation of Gravel Deposits Using Remote Sensing Data, Wabash River Valley North of Terre Haute, Indiana.

110976 D. A. Landgrebe, L. Biehl and W. Simmons. An Empirical Study of Scanner System Parameters.

111276 P. H. Swain. Land Use Classification and Mapping by Machine-Assisted Analysis of Landsat Multispectral Scanner Data.

022178 P. E. Anuta, S. Kristof, D. W. Levandowski, T. L. Phillips and R. B. MacDonald. Crop, Soil and Geological Mapping from Digitized Multispectral Satellite Photography.

070676 S. J. Kristof, J. D. Russell, T. K. Cary, B. M. Lube and R. A. Weismiller. Determining Land Use Patterns through Man-Machine Analysis of Landsat Data...A Tutorial Simulation.

070777 J. C. Lindenlaub and D. B. Morrison. The LARS Visiting Scientist Program.

072277 P. H. Swain and H. Hauska. The Decision Tree Classifier: Design and Potential.

081777 P. M. Adrien and V. Vanderbilt. Techniques for Estimating Scales and Areas for Landsat Data.

082477 S. J. Kristof, M. F. Baumgardner, A. L. Zachary and E. R. Stoner. Comparing Soil Boundaries Delineated by Digital Analysis of Multispectral Scanner Data from High and Low Spatial Resolution Systems.

090177 D. K. Scholz, J. Russell, J. Lindenlaub and P. Swain. A Case Study Using ECHO for Analysis of Multispectral Scanner Data.

090677 S. J. Kristof and R. A. Weismiller. Computer-Aided Analysis of Landsat Data for Surveying Texas Coastal Zone Environments.

092377 F. R. Kirschner, S. A. Kaminsky, R. A. Weismiller, H. R. Sinclair and E. J. Hinzel. Soil Map Unit Composition Assessment by Digital Analysis of Landsat Data.

110877 P. H. Swain. In Perspective: Meeting the Image Processing Challenge for Remote Sensing.

061575 R. M. Hoffer and Staff. Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data.

100175 J. B. Peterson, F. E. Goodrick and W. N. Melhorn. Delineation of a Buried Pre-Glacial Valley with Landsat-1 Data.

122475 S. J. Jordan and T. R. West. Highway Route Location Utilizing Remote Sensing Techniques, Ft. Wayne, Indiana.

052375 D. A. Landgrebe and Staff. A Study of the Utilization of ERTS-1 Data from the Wabash River Basin.

022575 P. E. Anuta and B. Mobasseri. ERTS Multispectral Image Transformations for Geological Lineament Enhancement.

031775 J. Thie, C. Tarnocai, G. E. Mills and S. J. Kristof. A Rapid Resource Inventory for Canada's North by Means of Satellite and Airborne Remote Sensing.

031875 C. Tarnocai and S. J. Kristof. Computer-Aided Classification of Land and Water Bodies Using ERTS Data--Mackenzie Delta Area, N.W.T.

101073 D. W. Levandowski, T. V. Jennings and W. T. Lehman. Applications of ERTS-1 Imagery to Mapping of Lineaments Favorable to the Localization of Ore Deposits in North Central Nevada.

111774 B. A. Follestad. Computer Analysis of ERTS-1 Imagery and Mapping of Surficial Deposits in a Test Area within the Monticello North Quadrangle, Indiana.

101773 J. E. Cipra. Mapping Soil Associations Using ERTS MSS Data.

112674 O. L. Montgomery and M. F. Baumgardner. The Effects of the Physical and Chemical Properties of Soil on the Spectral Reflectance of Soils.

032574 C. J. Stohr and T. R. West. Delineation of Sinkholes Using Thermal Infrared Imagery.

032774 S. Sinnock, W. Melhorn and O. Montgomery. Machine-Aided Analysis of Land Use-Land Form Relations from ERTS-1 Imagery, Sand Hills Region, Nebraska.

062874 F. Quiel. Some Limitations in the Interpretation of Thermal IR Imagery in Geology.

100372 J. E. Cipra, P. H. Swain, J. H. Gill, M. F. Baumgardner and S. J. Kristof. Definition of Spectrally Separable Classes for Soil Survey Research.

111072 E. R. Stoner and M. F. Baumgardner. Multispectral Determination of Vegetative Cover in Corn Crop Canopies.

010772 T. R. West. Engineering Soils Mapping from Multispectral Imagery Using Automatic Classification Techniques.

102871 A. H. Al-Abbas, P. H. Swain and M. F. Baumgardner. Relating Organic Matter and Clay Content to the Multispectral Radiance of Soils.

030570 M. Baumgardner, S. Kristof, C. Johannsen and A. Zachary. Effects of Organic Matter on Multispectral Properties of Soils.

043070 S. Kristof. Preliminary Multispectral Studies of Soils.

011069 R. M. Hoffer and C. J. Johannsen. Ecological Potentials in Spectral Signature Analysis.

112277 M. D. Fleming and R. M. Hoffer. Computer-Aided Analysis Techniques for an Operational System to Map Forest Lands Utilizing Landsat MSS Data.

010478 R. Hooley, R. Hoffer and S. Morain. Estimating Agricultural Production by the Use of Satellite Information: An Experiment with Laotian Data.

111573 W. N. Melhorn, S. Sinnock and R. Mroczynski. Applications of Machine Processed ERTS-1 Data to Regional Land Use Inventories in Western Colorado.

103073 P. Anuta. Geometric Correction of ERTS-1 Digital Multispectral Scanner Data.

011277 P. E. Anuta. Digital Registration of Topographic Data and Satellite MSS Data for Augmented Spectral Analysis.

<u>Publications and Documents by LARS Personnel</u>
<u>(Not in the LARS Information Note Series)</u>

1. LARS Capabilities (Mimeo)
2. LARS Contract Report 112977. M. F. Baumgardner et al. Requirements of a Global Information System for Corn Production and Distribution.
3. F. R. Kirschner et al. Map Unit Composition Assessment Using Drainage Classes Defined by Landsat Data (Pre-print).
4. R. A. Weismiller and S. A. Kaminsky. 1978. A Review of Remote Sensing As Related to Soil Survey Research. (Pre-print).
5. R. A. Weismiller et al. 1977. Soil Inventory from Digital Analysis of Satellite Scanner and Topographic Data. Soil Sci. Soc. Am. J. 41(6).
6. M. F. Baumgardner and Staff. 1975. Evaluation of ERTS Measurements of Major Crops and Soil Associations. NAS5-21785 NASA Contract.
7. P. M. Adrien and M. F. Baumgardner. 1976. Development Projects and Remote Sensing from Satellites.
8. LARS Contract Report 022378. R. A. Weismiller and R. P. Mroczynski. Photo-interpretation Handbook, Derelict Lands.
9. LARS Technical Report 012477. M. E. Bauer and Staff. Agricultural Scene Understanding.

10. Final Report NASA Contract NAS9-14016. D. A. Landgrebe.

11. S. J. Kristof et al. 1975. Inventory of a Nature Preserve Area in Lake County. Proc. Ind. Acad. Sciences.

12. S. J. Kristof and M. F. Baumgardner. 1975. Changes of Multispectral Soils Patterns witn Increasing Crop Canopy. Agronomy Journal.

13. Research Proposal for Determining Climatic and Genetic Effects on Relationships between MSS Reflectance and Properties of Soils.

14. S. A. Kaminsky. 1978. An Investigation of Analysis Techniques of Landsat MSS Data Designed to Aid the Soil Survey. M.S. Thesis.

15. Research Proposal for Study of Relationships between Soil Radiation Characteristics and Crop Yields.

16. LARS Contract Report 041278. Semi-annual Status Report. Applications of Remote Sensing Technology to Problems in Management of Resources in Indiana.

17. B. O. Blair and M. F. Baumgardner. Detection of Green and Brown Wave in Hardwood Canopy Covers. Agronomy Journal 69.

18. H. L. Mathews et al. Applications of Multispectral Remote Sensing to Soil Survey Research in Southeast Peru. Soil Sci. Soc. of Am. Proc. 37.

19. LARSYS User's Manual.

20. R.I.A.T.--Regional Inventory and Analysis Technique, East Central Section, Tippecanoe County, Indiana.

21. S. J. Kristof and A. L. Zachary. 1971. Mapping Soil Features from MSS Data. Photogrammetric Engineering.

22. M. F. Baumgardner et al. 1976. Using Satellites and Computers to Inventory the Natural Resources of the Tempisque Valley, Costa Rica.

Minicourses

#4 Spectral Reflectance Characteristics of Earth Surface Features

#16 Typical Steps in Numerical Analysis

#19 Interpretation of Radar Imagery

Video Tapes

V-3 System Parameters Fundamental to Information Extraction
V-9 Introduction to Radiation in Remote Sensing
V-10 Reflectance in Remote Sensing
V-11 Emission in Remote Sensing
V-12 Fundamentals of Remote Sensing Instrumentation

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