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REMOTE SENSING DECODED: MEETING THE CHALLENGES OF MULTIDISCIPLINARY AND INTERNATIONAL TECHNOLOGY TRANSFER

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ABSTRACT

Technology transfer is always a complex communications task. When the technology is as diversified as remote sensing and the arena is multidisciplinary and international, performing this task effectively becomes all the more difficult. Despite the difficulties, however, it is the thesis of this paper that the fundamental concepts and a practical working knowledge of remote sensing technology can be readily transmitted if the communicator recognizes the realities of the situation and adopts appropriate strategies. A number of effective strategies are outlined and illustrated using examples from the remote sensing technology.

1. INTRODUCTION

To make effective use of remote sensing technology and adapt it to meet the special needs of their society and environment, potential users of the technology need to understand the fundamental concepts upon which it is based. With such an understanding, the new user can develop realistic plans for implementing and utilizing remote sensing technology and work steadily toward its successful application as a significant tool for studying and better managing the natural resources of his region. Without such an understanding, progress toward fruitful application of the technology must take an uncertain course based on trial and error, dotted with partial successes and expensive failures. The effort may be prematurely terminated due to exhaustion of available resources or frustration from unrealized expectations.

This is a matter of particular import to developing nations, which stand to benefit most from new sources of information about their natural resources but to which effective communication of the technology involves crossing of national and cultural lines.

The task of communicating remote sensing technology is extremely complex,

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due in part to the multidisciplinary nature of the technology itself and also to the greatly diversified audiences needing to know how to make the technology work for them. This diversity extends as well to the range of applications to which remote sensing is appropriate and, corollary to that, to the spectrum of educational backgrounds of potential users and researchers. When casting this in a setting of international communication, often directed from high-technology countries towards the developing nations, involving differences in language and in cultural patterns, the difficulty of the task is further increased.

Despite the complexity of the information involved and despite the additional complexities imposed by the international and multidisciplinary setting, it is the thesis of this paper that the fundamental concepts and even, when appropriate, a practical working knowledge of the remote sensing technology can be communicated effectively. (Only the latter qualifies as technology transfer!) Accomplishing this depends strongly on recognition by the communicator of the realities of the situation and on his/her willingness and ability to adopt strategies for communicating the material. This thesis is not founded simply on theory or wishful thinking but rather on actual experiences the authors and their associates have had in dealing with the problem.

The paper identifies and analyzes some of the "traditional" means which have been employed for a decade by purveyors of remote sensing services and equipment, assessing numerous factors which have contributed to their failure to truly transfer the technology. A model of the communications process is developed which provides a framework for scrutinizing the communications process. Basically, the model consists of a transmitter (including the information source), a receiver (characterizing the technology user), and the medium (or media) through which communication can be accomplished. The paper focuses on ways in which these components interact and shows how the person who understands the model can select media and structure communications to maximize genuine transfer of information.

A number of effective strategies for communicating highly technical material are outlined and illustrated using examples from the remote sensing technology. Dangers inherent in such writing practices as "The Wool Factor," "The Delayed Denouement," and "Oversimplification" are also treated. The choice of medium and other special considerations relevant to those who have learned English as a second language are addressed.

2. A RELEVANT DIGRESSION

First we shall characterize some past efforts to transfer remote sensing technology and assess why they have fallen short.

Applying remote sensing to earth-resources monitoring may be likened to piloting a modern jetliner. The variety of operating conditions and environments encountered is so varied that the pilot must understand the broad spectrum of fundamental principles on which the behavior of his aircraft depends. There is no universal program for the pilot to follow; he must be prepared to adapt his actions to the operating environment -- or else suffer possibly fatal consequences.

Similarly, the user of remote sensing needs an insightful understanding of the fundamental principles of the technology. There is no standard "recipe" for dealing with the broad range of potential applications and environments for which remote sensing may be useful. Without the depth of understanding necessary to adapt the technology to new conditions, the user is bound for a "crash landing"-- disappointing results and missed opportunities to capitalize on the considerable capabilities of the technology.

Well, then, does the following scenario represent a case of effective technology transfer?

A remote sensing company delivers to the development planning body of a rapidly developing country a complete set of general land cover maps. The maps have been produced from satellite imagery and show the ground classified as "populated," "bare rock," "water," and "vegetated." The map documentation is self-contained; that is, the only aids provided for interpreting the maps are contained in the map legend. Personnel of the remote sensing concern gathered and analyzed the remote sensing data to produce the maps.

There are some obvious criteria by which this "product delivery" fails to qualify as technology transfer. Clearly, if the planning body found it needed an updated set of maps some years subsequent to the initial delivery, it would have to depend once again on an external organization (perhaps the original contractor if it were still in business) to produce the new maps. But more subtle problems may exist. If the members of the user organization do not understand the details of the processes used to produce the maps, they are likely to misinterpret the information conveyed by the maps. Significant details include: the resolution of the remote sensor, the size of the mapping unit (the smallest area interpreted), the precise operational definition of the ground cover classes identified, the reliability of the ground cover identification, the fidelity of the geometric properties of the maps, etc. Unless such details are conveyed to the user organization, that body may become frustrated in its attempts to use the maps, and it may even decide (fairly or unfairly) that it had wasted its money <u>and</u> that remote sensing cannot provide the sort of information it needs.

Consider another scenario.

A manufacturer of computers and image analysis sytems arranges to purchase remote sensing data and prepare the same sort of land cover maps described above. The maps are sufficiently impressive to convince the government of the subject country to purchase the computer system -- hardware and software -- used to produce the maps. The company delivers and installs the system, complete with detailed technical manuals describing both the hardware and software.

Anyone who has been involved with this sort of experience could point out that technology transfer still has not been achieved. A comparable situation would have an airplane salesman take a non-pilot for a ride in an airplane and then sell him the plane, complete with operating manual -- but without pilot schooling. The buyer may have acquired a handsome and sophisticated flying machine, but without the expertise to operate it. The buyer is still a long (and expensive) way from truly "acquiring the technology." In fact, he may not even have an adequate background to read the operating manual!

It would be possible to fill the space allowed for this paper with a catalog of "pseudo-technology transfer" scenarios, but we have much more constructive goals in mind. Therefore, we shall close this digression by summarizing some important LESSONS GLEANED FROM PAST EXPERIENCE, to wit:

1. As already illustrated, "product delivery" rarely qualifies as technology transfer. "Product understanding" is essential as well.

2. Technical manuals are important supportive reference material but rarely suffice for tutorial aids. While they may accurately document the technology for use by experts, they cannot serve effectively to convey insight to novices.

3. Contractor employees produce interpretive products efficiently, but their interpretive expertise goes with them when they move on to the next job. Although training "resident experts" may be expensive, it is the only way to guarantee bona fide technology transfer.

4. It is far easier for an agronomist to learn enough physics, photointerpretation, and computer science to become an agronomic remote sensing specialist than it is for a computer scientist to learn enough agronomy to be similarly qualified. Parallel remarks apply to other applications areas.

5. Novices learn fast in the company of interested experts equipped with well-prepared tutorial materials and facilities for hands-on experience with real data and real applications problems to solve.

Now we shall look in greater detail at some tactical considerations which facilitate the effective communication of highly technical material, which is essential for technology transfer. We take the point of view that high technology, such as remote sensing, is necessarily defined and described in terms of very complex and technical concepts and methodologies, and "coded," as it were, in terms of the terminology, notation and mathematics of the relevant technical disciplines. The job of the person whose aim is effective technology transfer is to "decode" the technology so that it is readily comprehensible by the intended recipients.

3. A MODEL OF A COMMUNICATIONS SYSTEM

In order to analyze the decoding process, it will be useful to take an "engineering" approach and consider the communications process as a system. In this way, the elements can be studied individually while their position and interactions in the whole system remain clear.

A simple communications system is shown in Figure 1 (see following page). It consists of three parts: the transmitter, the communications channel, and the receiver. For our purposes, the transmitter is the expert, and the receiver is the intended recipient of the communications. The communication system exists to transfer the knowledge contained in the mind of the expert to the mind of the receiver. If the system were perfect, the receiver's knowledge could be a replica of the expert's.

But we know, whether as experts or receivers, that transfer is inevitably imperfect; only rarely do we as receivers feel a part of a near-perfect communications system. But we <u>do</u> experience it now and then; and when we do, we find it much easier to open ourselves to become more perfect receivers and are energized by the exchange. As senders, we must strive to develop ways to so completely reach those who receive <u>our</u> messages that the transfer of understanding is complete.

There are many factors that contribute to making this transfer of knowledge less than perfect. Following this "systems" approach, we borrow a word from the field of communication sciences and call these factors "noise." In this system, we can define noise as anything that alters the perfect, pure transfer of the signal from the mind of the sender to the mind of the receiver. Our aim here is to show how understanding sources of noise can help us achieve more effective technology transfer in remote sensing.

3.1 THE RECEIVER

Let's look first at the receiver, a person who may or may not know the same language as the expert, may or may not be intellectually or even psychologically ready to receive what the system is delivering, and who has objectives of his/her own which may or may not coincide with the objectives of the expert sending the communication. Imagine, for example, the soil scientist in Argentina who heard that remote sensing can be used for mapping soils at a scale of 1:250,000. He wants to find out how to do that, but probably will have little tolerance for

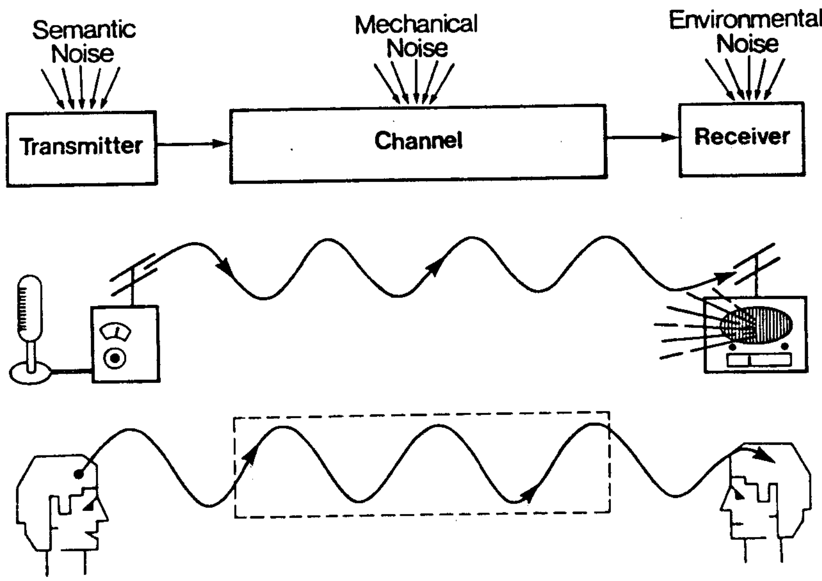


Figure 1. A model of a communications system.

discussions of the physical basis of remote sensing or the role of pattern recognition in digital analysis and classification. If he should first pick up English-language materials on these related subjects, no matter how well prepared and transmitted they are, there is little chance that they will be well received; that is, he is not likely to have the patience to assimilate such materials because they are only tangential to his immediate interest. Personal considerations may also interfere -- such as problems at home or on the job, a distracting physical environment -- but these factors, while they seriously affect the operation of the system, are largely beyond its control.

So, how can the message reach the receiver, and what must the expert do to insure minimum noise in the communication? In general, the obligation rests with the expert to be as aware as possible of who the audience is and how to affect the receipt of the message. We can begin by borrowing the ideas of educators who recognize that PEOPLE LEARN BEST WHEN:

- they see the reason behind the learning;
- they choose what and how they learn and can build on what they already know;
- the message is at a level that they can understand;
- they are actively involved in the learning; and
- the source of the message is perceived as being highly creditable.

The implications of this list are important to all senders of communications. Recognizing these conditions, the sender will take the following STEPS TO FACILITATE THE SUCCESS OF THE RECEIVER:

- Make receiving pleasant, active, stimulating.

- Provide the receiver with the information he needs to control his own learning. Make certain that objectives are clearly stated, so that if they do not coincide with the receiver's objectives, he can turn to something else rather than eventually resent having wasted time on the material.

- Build the learner's self-respect by allowing him to build on what he already knows and avoid put-down statements like "It is obvious that...." It may not be!

- Recognize that not all people approach problems in the same way. Differences may be related to a number of things, including academic discipline, culture, and experience. Noise is created in the system if the receiver feels that what he is reading is somehow not for him. The scientist's abstract views of remote sensing must be tempered with clarity and flexibility if they are to fulfill the user's desire to understand the scope and application of the technology.

3.2 THE MEDIUM OF TRANSMISSION

Now look at the medium of the transmission, that is, the physical object that carries the message. There are two kinds of medium-related noise that may affect the transmission. One is mechanical noise in the carrier itself, and the other is environmental noise. The sender must maintain control over both of these to the extent possible.

Mechanical noise includes such obvious noise sources as factual errors, typographical errors, poor quality of printing or photography, inadequate or incorrect labeling of figures or tables, and ambiguous punctuation. There is little need to belabor this point here. The really committed receiver can often overcome this kind of mechanical noise, although if the struggle becomes too great, confusion may overwhelm him and the credibility of the sender may be lost.

Generally speaking, environmental noise is beyond the direct control of the transmitter, but with some sensitivity and ingenuity, he can affect this, too. Environmental noise is made up of those irritating distractions -- a noisy office mate, a string of phone calls, and any number of things that divert the attention of the receiver. If the message is "captivating" enough, it may itself override these environmental noises. But to be so captivating, the piece must be flawless, or nearly so.

Through the right choice and effective use of the medium, the sender can also reduce the impact of environmental noise by capturing the attention of the receiver. The printed page -- unless created by a genius -- is one of the least attention-demanding media. It is too easy for us to pick up a book or report, scan it, and then lay it down with the intention to return to it some other time. In contrast, media that address more of the receiver's senses have a better chance of catching and holding his attention. It is true that the receiver needs to make the initial commitment, set up the videotape monitor or get out the set of slides; but once he does, he is the direct recipient of the electronic flow -- perhaps even away from the distractions at his desk and insulated from his surroundings by earphones. Some media may in this way help reduce the impact of environmental noise.

Another technique for lowering environmental distractions is to demand the receiver's active involvement in the transmission, such as working a problem or answering questions. These must not be rhetorical questions, which may only encourage distraction, but questions that help the receiver think through a problem to achieve a better understanding or to measure how well he is assimilating the information.

Although we have approached the transmitter from the point of view of reduction of environmental noise, there is much more that could be said about the selection of appropriate media for specific messages and specific receivers. Table 1 summarizes some of the most salient features of each medium.

Selection of medium should not be made casually. The decision must be based on careful analysis of many facets of the communication process, the most critical of which is the nature of the communication, that is: how technical is it; what should the receiver be able to do once he has received the communication; what are the characteristics of the students themselves, especially their backgrounds and accustomed learning styles?

Some media lend themselves naturally to conveying concepts but are inappropriate for highly technical presentations. Take videotape, for example. Perhaps the greatest strength of this medium is the sense of personal contact with the expert that a receiver gets. Videotape transmits faces as well as voices and gives the receiver a way to react at a human level to the perspectives and opinions of the expert. Through videotape he can travel vicariously to parts of the world he has never seen, or he can study -- in the middle of winter -- the full summer bloom of an agricultural field. But on the other hand, videotape is a very restrictive medium for transmitting quantitative relationships. Details in charts and equations may be lost through the relatively low resolution of the image on the screen and all too frequent misalignment of monitors. For this type of message, other media would be more appropriate transmitters to choose.

Suppose, for example, you wished to convey information to receivers about the analysis of "ratio images." The first question for the sender to address is whether the objective of the communication is for the receiver (1) to be able to

Table 1. Comparative suitability of media frequently used for technical communication. ("+" = generally most suitable; "0" = suitable; "-" = generally unsuitable)

	Medium				
Objective	Printed material	Illustrated lecture	Slide-tape program	Videotape program	"Hands-on" experience
Develop interest or change attitudes	-	+	-	+	-
Teach equipment-handling skills	-	-	0	0	+
Communicate basic concepts	0	+	+	+	0
Communicate complex information	+	-	0	-	0
Reinforce understanding thru problem-solving	0	-	0	-	+
Promote dialog and discussion	-	0	+	0	+
Provide further references	+	-	0	0	-

understand the concepts behind ratioing and its utility, (2) to be able to analyze ratio images themselves visually, (3) to be able to analyze ratio images digitally, or (4) to be able to create the ratio images. In the first instance, a short verbal description, perhaps supported by some illustrations, may be sufficient. In the second, carefully selected examples of ratio imagery would be required that could be used in a laboratory environment together with verbal commentary, which might be a lecture, audio tape, or printed material. As the analysis becomes more complex, should the receiver work with a real analysis or with a simulation of the process? Some kind of hands-on experience is required for all of the last three objectives, where learning how to do the analysis is critical.

Finally, historical and cultural factors must not be overlooked when international technology transfer is the goal. In most of the developing nations, the traditional means of communicating technical information are based on printed materials, textbooks, and the instructor with chalkboard and chalk. Emphasis is placed on the development of intellectual skills requiring imagination and memory to absorb and retain the material. The sender who elects a nontraditional medium of transmission should be aware that the potential advantages of the medium may be diluted, at least initially, by the receiver's need to become acclimated to it. And of course there is the consideration of availability of any special equipment required by the medium (e.g., video equipment, tape players).

3.3 THE TRANSMITTER

After this brief look at the receiver and the delivery channel, we are ready to focus attention on the most critical part of the system: the transmitter. As in any information system, the output can be no better than the input. Since (for most of us) ideas cannot pass directly from one person to another, the communications system we use is based on conventional symbols -- words, pictures, and numbers. The communication process, then, is one of encoding and decoding: the transmitter converts thoughts to symbols and the receiver converts the symbols back to thoughts. A critical consideration, therefore, is that we encode our thoughts in such a way and using such conventions that they can be accurately decoded by the receiver. This is challenge enough when the transfer of quantitative data is all that is at stake; but when we are talking about nonquantitative human communications, we need to find ways to transfer impressions, attitudes, and philosophies as well, and in a way that can be decoded by receivers with many backgrounds.

The encoding process is a potential source of substantial noise and must not be carried out casually. Earlier we identified two kinds of noise, environmental and mechanical, and we can now add a third: semantic noise. This is noise that results from problems with encoding ideas or concepts. At the most basic level, semantic noise is linked to word choice, but it extends beyond that to include the design of graphics and the pace of delivery. To start with the basic encoding unit, words, we recognize that in a technology developing at the rate with which remote sensing is developing, there is no well-established, universal technical vocabulary. As new techniques and concepts evolve, new terms are created or adopted from related fields. To look at an example relevant to remote sensing, the word "clustering" was adopted from numerical taxonomy and is now an essential term in discussing digital image analysis. Although there are some variations in understanding what "clustering" means, definitions can be found in almost any remote sensing text and now, with only minimal explanation, the word can be used as a valid symbol and be widely understood.

Unfortunately, many communicators who need a symbol to name a new concept or technique coin a new word, an approach that often is easier than searching for a suitable existing word. Words tend to be coined to meet the immediate need for a term with which to communicate with colleagues and those with whom the concept has been developed. Often words created like this are cumbersome concatenations of existing words which then, because of their length, are likely to be shortened to acronyms. Problems created by coined words are especially burdensome for those with English as a second language.

Another word-related problem is the case of synonymous terms that are used interchangeably by an author without concern for the reader who might look for differences of meaning among the terms. How long was it before you who are new to remote sensing realized that a "Gaussian distribution" (a term from mathematical physics) is the same as a "normal distribution," which refers to the familiar bell-shaped curve? Remote sensing technology transfer must start with a clear understanding of the terminology associated with all basic aspects of the technology.

4. THE WOOL FACTOR

The Wool Factor may be defined as those characteristics of communication that make it especially difficult for the receiver to receive a clear message. Although it generally is not intentional, the effects of these influences are the same as (as we say) "pulling the wool over someone's eyes." A high Wool Factor is sometimes caused by "wooly" (i.e., fuzzy or unclear) thinking on the part of the sender! More often it is the result of a lack of courtesy on the part of the sender who won't go to the trouble to reduce the Wool Factor adequately.

One frequently occurring form of the Wool Factor might be called "Messy Math." An example will satisfy the need for further description. Suppose you were reading through a section of a text describing the distribution of spectral response values of natural objects on the earth. You turned the page and found this:

$$f(x) = (2\pi\sigma^2)^{-\frac{1}{2}} \exp[-\tfrac{1}{2}(x-\mu)^2/\sigma^2]$$

Indeed, there are many people for whom this expression of the Gaussian density function is the clearest and most concise way in which this concept can be presented. It is a totally quantitative statement, leaving no room for uncertainty about the exact relationship among the quantities in the equation. It is so exact that it could be implemented on a computer for computation of values -- if that were called for. On the other hand, this messy mathematical expression conveys no information whatever to someone whose mathematical training has not reached a relatively sophisticated level.

Let's look at some other options for describing a Gaussian distribution. Another way to present the same material in a quantitative manner is shown in Figure 2(b). Without requiring complicated computations, the table provides roughly the same information as the mathematical equation. The limitations of this method over the previous are, first, the loss of conciseness; and second, the fact that the precision of the relationship is limited by the size of the table (only a limited number of values of x can be accommodated by the table). Furthermore, the reader seeking a qualitative or intuitive sense of how frequently various spectral response values occur certainly won't get much help from this form of the relationship.

If conveying such a qualitative notion is indeed the purpose of the communication, then the job might best be accomplished by a graphical or pictorial representation, as suggested by Figure 2(c). The general functional behavior is expressed without burdening the receiver with more detail than he needs or is prepared to use.

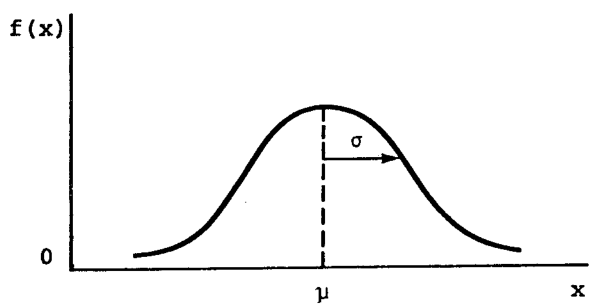
Still another option is possible in case even the graphical form of the relationship is foreign to the anticipated receiver. The concept can be described verbally, using only words (see Figure 2(d)). This form is certainly least concise, often least precise, but it is suitable for communicating with someone not familiar with the other modes of expression and for whom only the general description of the phenomenon is required. The verbal form of expression provides an opportunity for interpretation which can convey insightful understanding.

$$f(x) = (2\pi\sigma^2)^{-\frac{1}{2}} \exp[-\tfrac{1}{2}(x-\mu)^2/\sigma^2]$$

(a)

x	f(x)	x	f(x)	x
.00	.3989	.50	.1915	1.00
.01	.3989	.51	.1950	1.01
.02	.3989	.52	.1985	1.02
.03	.3988	.53	.2019	1.03

(b)



(c)

"The most frequently occurring spectral response value is μ, and the frequency of occurrence for values greater or lesser than μ decreases rapidly at a rate characterized by a constant σ."

(d)

Figure 2. Four ways to express a quantitative concept: (a) Messy Math (most precise, most concise). (b) Tabular. (c) Graphical. (d) Verbal (most intuitive, least precise, least concise).

The important point here is that the sender needs to realize that using Messy Math is not the only way to express a complex relationship. Any sender who truly understands the math is capable of translating it into the mode of communication most appropriate for the situation and should make the effort to do so in order to communicate most effectively.

The previous example suggested some merits of using graphics, but the following illustration of the Wool Factor points up the need for some caution here as well. The often-heard truism that "a picture is worth a thousand words" needs testing in the context of the communications model we've described. Have you ever had the experience of working laboriously through a report, reaching the conclusion, and then seeing the statement that "the results are shown in Figure 3"? What does Figure 3 demonstrate? What is important about it? Are we to conclude

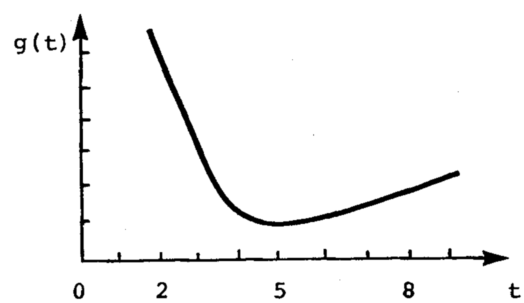
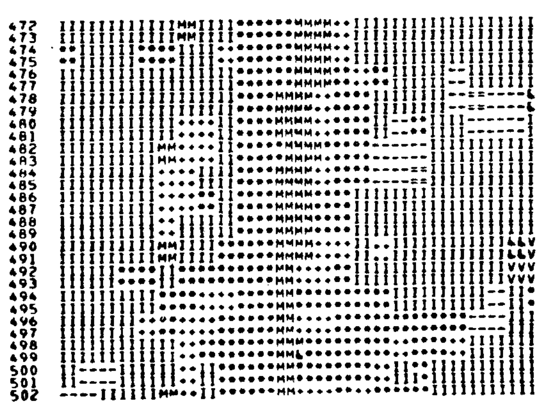


Figure 3. "Experimental results."

that what is important is that the function is less than at 8 than at 2; that the function has a minimum at 5; or that the function exhibits no local maximum over the range of observations? Given the figure, all of these conclusions are valid. But a thousand such pictures are of less value than a few words providing the essential interpretation.

Remote sensing literature is, unfortunately, replete with examples of pictures with inadequate interpretation. The classification map (Figure 4) may be the most flagrant remote sensing example of a high Wool Factor. You note in



Key

V	Agriculture
M	Water
&,*,+	Metropolitan
-,=	Residential
I	Grass

Figure 4. A segment of a typical classification map.

Figure 4 that there are 5 discrete classes named, each represented in the usual way by different symbols. Therefore, even a casual observer can perceive where the metropolitan area lies, where the water is, and so forth. But without further explanation, do we know what the class labels really mean? Is the class "grass," for example, really pasture, golf course, meadow, or lawns of private homes? This essential information is lacking. Furthermore, we know that classification maps are rarely 100 percent accurate, but how confident may the viewer be of the accuracy of the classification? No classification map of itself tells the whole story, yet too often it is assumed that it does. The receiver seeking information instead finds himself knee deep in Wool!

Sometimes in our zeal to avoid beclouding a technical subject with unnecessary detail, especially if the reader is likely to be a newcomer to the subject matter, we are guilty of a variant of Wooliness which could be described as "Reckless Oversimplification." The result may be misleading or even inaccurate communication. An excellent example of Reckless Oversimplification comes to mind relative to Landsat multispectral scanner imagery. It is often stated that measurements in Landsat channels 4, 5, and 6 have values that range from 0 to 127 and that Channel 7 has measurements that range from 0 to 63. The observer then assumes that the data in the first three bands represent more precise measurements of reflected energy than the data in Channel 7. This, however, is not the case. The range of 0 to 127 for the first three channels has been defined to take advantage of nonlinear characteristics of the data quantization and transmission system, and in fact only 64 specific levels out of the 128 are actually "active." The other values can never occur and the user who is not aware of this fact may make false assumptions that can affect the analysis of the data. In this case, the oversimplification of the exact nature of the data has caused inaccurate understanding.

The fourth and final type of communication with a high Wool Factor we term the "Delayed Denouement," which may, and frequently does, take a number of forms. Traditionally, in reporting scientific developments, authors adopt a relatively standard sequence in presenting their material. It runs like this:

1. Statement of problem.
2. Literature review.
3. Procedure followed in current work and anticipated results
4. Results
5. Evaluation of the results

Thus the real significance of the work is delayed with a "logical" position near the end of the report or article. The scientific audience accustomed to reading accounts in this format has learned how to skim through the material to locate and extract the information sought, whether it be an evaluation of the success of the project, details about the procedure used, or perhaps merely a survey of other work dealing with the same problem. While the organizing scheme set forth above is entirely appropriate for communicating technical information to one's peers, it is an ineffective way of organizing tutorial communications. Under these circumstances, readers need first to understand the problem, the general approach to its solution, and the nature of the results achievable. Only then are they ready to receive procedural and background information. Therefore a more appropriate sequence for presenting tutorial material would be:

1. Definition of the problem and an overview of the method of solution
2. Expected benefits of using the proposed method
3. Detailed description of the methodology
4. More details about the effectiveness of the procedure and the results obtained
5. References

This sequence presents the material in an order that prepares the receiver to deal with it by telling early what to expect and why it may be worthwhile to proceed through the material. (A well written abstract is only a first step in this direction.)

Let's apply this organization to communicating a remote sensing concept. Suppose you were writing about the digital image enhancement and compression process known as the "principal components transformation." In reporting on the development of the process, the traditional organization might flow as follows:

1. Describe the redundancy of information in, for example, Landsat data.

2. Discuss previous work in dimensionality reduction.

3. Describe the mathematical steps to be followed in the transformation, their theoretical basis, and their implementation in a computer program.

4. Present examples of results, e.g., images derived from principal components data.

5. Demonstrate how this transformation can benefit the analysis process.

This form of organization would be the kind most familiar to scientific and technical audiences.

Now, consider the situation in which the intended receiver is a person learning about how to use remote sensing in resource management tasks. In this case, a much more readable document might follow this organization:

1. In general terms, describe what principal components transformations do to the data, illustrated by examples of images produced by the transformation.

2. Discuss what the user of remote sensing data gains from incorporating the transformation into the analysis process.

3. Present the mathematics of the transformation and examples of its implementation -- only if appropriate for the objectives and the target audience.

4. Provide evidence of what can be gained (or lost) by using the transformation, with examples involving a variety of data types and applications.

5. Provide references to further reading on the subject.

In many instances, only Items 1 and 2 above might actually appear in a given communication. The mathematics in Item 3 might be moved to an appendix to the article. The benefit to the receiver of this ordering of the material is that instead of being overwhelmed by theoretical details before he understands what the transformation is good for, the rationale for using the transformation is shown first and provides motivation for the following discussion. This approach to organization of tutorial material is appropriate whether the level of presentation is very basic or somewhat more technical. Scientists successful at presenting tutorial discussions have learned how to follow this strategy, which is especially important for decoding technical material to a nontechnical audience.

5. CONCLUSION

Effective technology transfer changes lives, either by enabling people to do new things or by replacing present methods with more beneficial ways to accomplish the same ends. But the natural tendency of people is to resist change, at least until they believe they understand how the change will improve their lives to a degree warranting the temporary inconveniences which inevitably accompany the accommodation of change. Overcoming this natural resistance to change is an important part of the challenge of technology transfer. It explains why "product delivery" rarely accomplishes technology transfer. It explains why technical documentation by itself cannot accomplish technology transfer. And it explains in part why all efforts at technology transfer must be skillfully done, with great care given to effective communication in order to win and hold the interest and attention of the person or organization for whom the technology is intended until interest and understanding become self-sustaining.

While the other papers in this session of the symposium have dealt with perhaps grander issues in remote sensing technology transfer, this paper serves as a reminder that the indispensable ingredient in any successful recipe for technology transfer is good communication. The circumstances under which this communication must take place are tremendously variable: sometimes the frame of reference is politics or economics or environmental science or electrical engineering; sometimes the motivation is to argue for legislation, to explain computer needs to an engineer, or to justify a budget for the next fiscal cycle: sometimes the audience is a remote sensing specialist or group of specialists; a trained photointerpreter, a bureaucrat or a college student. Whatever the circumstances, the "sender" (in our communication system model) stands the best chance of transmitting a "decodable" message if he or she is sensitive to these circumstances and tailors the encoding appropriately. We have discussed the receiver's active involvement in the communication process, selection of medium and "noise" control, choice of vocabulary, use of modes of expression most appropriate to the receiver as well as the material to be transmitted, and "minimizing the Wool Factor." While we certainly have not cataloged all of the strategies which can benefit the technology transfer process, we hope our emphasis on communicating fundamental understanding and on accounting for the condition of the potential beneficiary will help the reader strengthen his approach to the task.