

On Defining Remote Sensing

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ABSTRACT: An examination of definitions as tools explains why remote sensing has no generally accepted definition and why such a situation is likely to continue. In this study, we sketch the history of the term *remote sensing*, comment on its usage, note the continuing search for substitute terms, examine maximal and minimal definitions, compare synonyms and antonyms, and classify definitions into three groups. Finally, we offer extended meaning to the term *remote*, provide different definitions for various audiences, and suggest a set of essential elements to be included in a comprehensive definition.

INTRODUCTION

DEFINING REMOTE SENSING, a risky undertaking at best, is made even more difficult by the two-word term chosen as a name for the discipline. More than one author has at least alluded to the fact that there is no single, concise, and universally accepted definition of remote sensing (e.g., Reeves, 1975; Lintz and Simonett, 1976; NASA, 1976; Richason, 1978; and Dept. of the Army, 1979).

Considerable imprecision enters the picture in the first word of the term remote sensing. It is only natural to ask how far removed from an object a sensor must be in order to be called remote. One writer suggested that remote in the context of remote sensing could range from geostationary satellites located over 32,000 kilometres in space to hand-held instruments that record at close range, yet remotely (Avery, 1980). Alternatively, remote can imply an indirect measurement requiring symbolic transformation in order to assign meaning to the brightness values recorded by a sensor (e.g., Robino, 1982). The relative term *remote* allows personal judgment and ambiguity into the meaning of remote sensing, fogging the limits of the discipline and making difficult the specifying of its boundaries, range, and scope.

THE NEED FOR DEFINITION

Some scientists may question the need to define remote sensing. Don't workers in the field know what they are doing? To them, remote sensing is what remote sensing scientists do. To technicians wrapped up in their research projects, that approach has the ring of sweet reasonableness.

Ignoring definition, however, also ignores each new generation of students and their need to integrate the various scientific disciplines. Not only students in the field of remote sensing but also students in related fields need to be able to bound remote sensing by delineating its limits, noting its essential character by pointing to its core, specifying some of

its methods, noting how its diversities come together in an essential unity, distinguishing the field from other disciplines, and relating the field to other scholarly undertakings. All these needs require definition, which not only serves to initiate the work of students but also crowns the work of scholars.

We believe students and government decision makers need to know the scope, defining characteristics, and limits of the field of remote sensing — and far from all do. Administrators also need guiding definitions in order to interpret the methods of remote sensing and to enlighten uninitiated but interested audiences in a general understanding of remote sensing. Members of interdisciplinary task forces that bring remote sensing scientists into contact with colleagues in related fields need demarcating lines between disciplines that only the process of definition can provide. Finally, the public — the ultimate decision maker in our society — needs to know what remote sensing is and does if it is to support the funding of any research and development programs in this field. The old saying that "what you don't know can't hurt you" certainly doesn't apply to the government budgeting process.

Individuals that harbor even a momentary doubt about the need for definitions in remote sensing should note how many books and articles in this field start off with an author's definition of the subject (e.g., Luney and Dill, 1970; Holz, 1973; Rudd, 1974; Barrett and Curtis, 1976; Sabins, 1978; Ford, 1979; Siegal and Gillespie, 1980; and Colwell, 1983). But even more convincing yet is that throwaway line that frequently pops up in discussions these days: "Oh, everyone knows what remote sensing is." Nothing does more to establish the need for looking with all eyes open at the definitional process in remote sensing.

HISTORY OF THE TERM

The coining of the term remote sensing goes back to a white paper prepared in the early 1960s by the

staff of the Geography Branch, Office of Naval Research (ONR), for presentation to the Committee on Geography [Advisory to ONR] (Pruitt, Personal Communication, 1983). Chief architect of that paper was Evelyn L. Pruitt was closely assisted by Walter H. Bailey, a fellow staff member.

An understanding of the historical context of Pruitt's work is important. Aerial photo interpretation had been given a big boost by World War II, the space age was just getting under way, and agencies such as the Geography Branch of ONR were starting to pioneer in an expanded program of government-sponsored research. The space age offered opportunities to extend photo interpretation and at the same time to clear up some of its troublesome mysteries. Being well aware of new imaging opportunities offered by multispectral cameras, infrared films, and nonphotographic scanners, Evelyn Pruitt wrote:

The whole field was in flux and it was difficult for the Geography Programs to know which way to move. It was finally decided in 1960 to take the problem to the Advisory Committee. Walter H. Bailey and I pondered a long time on how to present the situation and on what to call the broader field that we felt should be encompassed in a program to replace the aerial photo-interpretation project. The term "photograph" was too limited because it did not cover the regions in the electromagnetic spectrum beyond the "visible" range, and it was in these nonvisible frequencies that the future of interpretation seemed to lie. "Aerial" was also too limited in view of the potential for seeing the Earth from space (Pruitt, 1979).

The newly envisioned field lacked even a name at that point, said Pruitt, explaining what prompted her search for an adequate term (Pruitt, Personal Communication, 1983).

The new term, remote sensing, promoted throughout a series of symposia sponsored by ONR at the Willow Run Laboratories of the University of Michigan, gained wide acceptance. But the problem of adequate definition remained; one author after another offered a new definition for remote sensing when writing about the field. The resulting variations seemed to be influenced, at least to some extent, by the particular research bent of each writer.

One aspect of the early conception of the field of remote sensing is an earthward or Earth-surface orientation (Pruitt, Personal Communication, 1983). Indeed, in its early history, remote sensing was focused on collecting information about the Earth's environment. In recent years, however, its technology has been used to collect information about other planets also and even about the nature of space itself. While the earthward focus seems not to be as prominent as in the past, it does suggest aspects of remote sensing that differentiate it from other disciplines such as geophysics, astronomy, and astrophysics.

MAXIMAL/MINIMAL APPROACH

One way to make a start at defining remote sens-

ing is by the use of the maximal/minimal approach. For the maximal case, this involves defining the term in its broadest sense, using as few qualifiers as possible. One typical maximal definition runs: *Remote sensing is the acquiring of data about an object without touching it* (e.g., Holz, 1973; Barrett and Curtis, 1976; Ford, 1979; and Siegal and Gillespie, 1980). Such a definition is short, simple, general, and memorable but, unfortunately, not wholly adequate. Its weakness is that it excludes little from the province of remote sensing.

The minimal approach to defining remote sensing draws sharp focus on the field, adding qualifier after qualifier in an attempt to make certain that only legitimate instances are included in the term's definition. The following is one such minimal definition:

Remote sensing is the noncontact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum by means of instruments such as scanners and cameras located on mobile platforms, such as aircraft or spacecraft, and the analysis of acquired information by means of photo interpretive techniques, image interpretation, and state-of-the-art image processing systems (e.g., Luney and Dill, 1970; Reeves, 1975; Sabins, 1978; and Gustafson, 1982).

A minimal definition can exclude vast areas and activities included by a maximal definition. The specific references to conventional photography and to regions of the electromagnetic spectrum that exceed the range of the human senses further delimit the meaning by emphasizing its technical aspects.

AN EXTENDED MEANING OF REMOTE

The term remote means not only distant but also indirect. In general-vocabulary English dictionaries, a reader can find separate senses entered for remote that include or approximate these: acting upon something indirectly, not arising from a primary or proximate action, not immediately present to the senses, and controlled indirectly or from a distance. The common meaning in these versions is *indirect* rather than *distant*.

Although Evelyn Pruitt (1979; Personal Communication, 1983) did not intend so, it seems to us that the *remote* in remote sensing suggests much more than the mere fact that data are often collected at great distances from their targets. We suggest that *remote* implies also that the standard methods of data manipulation typically involve symbolic transformation before interpreters can assign meaning to the overall form of the data. A good example might be the statistical clustering of Landsat pixels based on their multispectral reflectance properties and the subsequent naming of the resultant groups. Thus, one meaning of remote in the term remote sensing is that of the indirect presentation of data which then requires symbolic transformation before meaning can be assigned to its holistic form.

A STUDY OF GENUS TERMS

Analyzing definitions of remote sensing according to their genus terms reveals some far-reaching divisions among those workers who know most about the discipline's methods and mission. This reflects a basic problem about how remote sensing is to be understood, bounded, and described in relation to other disciplines. Many definitions fall within one of three groupings of genus terms. On this basis, remote sensing is most frequently understood as (1) a science or art, (2) a tool or technique, or (3) an activity or function. These three groupings of genus terms are far from exhaustive and in all probability contain some overlaps. Even so, these groupings help clarify the problem of defining remote sensing by concentrating on the most frequently used genus terms. These in turn offer some of the best evidence, based on agreement among workers in the field, for sharpening the question of what remote sensing is and does.

AS A SCIENCE OR ART

One frequent pair of genus terms is that of science or art. Many definers (e.g., Harper, 1976; Strahler and Strahler, 1978; Lillesand and Kiefer, 1979; Moore, 1982; and Richason, 1983) suggest that remote sensing is either one or the other of these, or both. Their definitions may begin: remote sensing is the science or art of . . .

Without a doubt, the recording of data from a distance by means of instrumented sensors and their manipulation by data processing equipment employing complex mathematically and statistically based software algorithms is an activity that easily can be subsumed under the rubric of science. But photo interpretation requires considerable experience along with thorough training and depth in educational theory before the data captured by the sensors can be placed in a meaningful context (ASP, 1960). There is, therefore, an aspect of remote sensing that definitely can be called an art. Because both aspects are present, the most accurate conclusion would seem to be that remote sensing is the science and art of . . . (e.g., Lillesand and Kiefer, 1979).

AS A TOOL OR TECHNIQUE

The related genus terms in this group are largely descriptive and indicative of a process orientation. Typically they rely on nouns to describe an instrumental technique such as activity, technique, practice, methodology, act, ability, observation, and use (e.g., Lillesand, 1974; Barrett and Curtis, 1976; Richason, 1978; Siegal and Gillespie, 1980; and Moore, 1982). Our literature search indicates that the term *technique* recurs frequently in this grouping. Such evidence implies that remote sensing could be thought of as a tool for problem solving, perhaps not unlike statistics or cartography. Definers who use a descriptive approach to set forth the meaning of remote sensing seem to conceive of the field as

basically a tool or methodology characterized by a particular technique for achieving an information-gathering goal.

AS A FUNCTIONAL ACTIVITY

Definers who describe remote sensing in terms of a particular functional activity are drawn to the use of verbs and verbals rather than nouns for their genus terms. Those who choose *-ing* verbals seem to fall rather naturally into this grouping. They typically use terms such as acquiring, collecting, measuring, observing, getting, obtaining, recording, and using (e.g., Holz, 1973; Kroeck, 1976; Harper, 1976; Dept. of the Army, 1979; and Ford, 1979); probably because the term in question, remote sensing, also contains an *-ing* verbal.

In general, functional definers include phrases and limiting terms that lend a tautness to their definitions, which share an affinity with the minimalist approach. From a search of the literature, we conclude that this functional/minimalist approach is the kind of definition most preferred by workers in the field of remote sensing. They define remote sensing in terms of what remote sensing does and, thus, there is a strong strain of pragmatism here.

SYNONYMS AND ANTONYMS

When seeking to bound a term, a definer may find it helpful to consider its synonyms and antonyms. For example, the remote sensing of vegetation has been called biosensing (Anonymous, 1978). In seeking greater precision in terminology, Jensen (1983) has used the extended term biophysical remote sensing. Others have sought to escape the awkward two-word term by coalescing remote sensing into a new coinage such as thermosensing (ASP, 1978) or thermography (Williams, 1972) to denote one particular branch of the field. Specialized branches such as tomography (Olins *et al.*, 1983) have extended the applications of remote sensing. These synonyms tend to be more specialized terms for certain types of remote sensing; however, a relatively large number of applications in the field are related to functional or technical orientations. Having a single term that gets away from the ambiguity of *remote* in the term remote sensing might be considered a gain by some scientists, but at the moment no likely candidate has appeared.

Antonyms for remote sensing are not easy to discover. Two terms of contrasting or opposite meaning are *proximal sensing* (Reeves, 1975) and *in-situ data collection* (Barrett and Curtis, 1976). Other commonly used terms that characterize the result of a contrasting process or function include *ground truth*, *surface truth*, *ground data*, *ground information*, and *reference data*. All these stress the close and intimate nature of the sensor/observer and the object observed. Perhaps that is why some writers make an effort to stress *in-situ* recording as a distinct varia-

tion from what has historically been thought of as remote sensing (Raines and Lee, 1975).

MARKS OF AN ADEQUATE DEFINITION

In the final analysis, what are the marks of a useful definition? A truly usable definition should have some of the following characteristics — in fact, as many as possible: To whatever extent possible, it should be (1) accurate, (2) adequate, (3) concise, (4) understandable, and (5) memorable.

To assemble all these characteristics in one general definition of remote sensing may be impossible. For what is unquestionably accurate may be far from concise. And what may be adequate may be far from memorable. So the definition that is short, readily comprehensible, and easy to recall — although highly to be desired — may not be the definition that is also accurate and adequate. That is one reason why publishers of dictionaries bring out different dictionaries for different user audiences.

DEFINITIONS FOR DIFFERENT AUDIENCES

A definition of remote sensing usable in all places by all persons for all occasions seems not to exist. That is because definitions themselves are basically tools. Thus, it would seem that there is no all-purpose definition of remote sensing that suits all people for every occasion.

One of our goals, therefore, is to identify a range of working definitions geared to different audiences, expressed in different levels of vocabulary, at various levels of complexity, and tailored to different needs. Depending on the level of meaning sought and depending on the needs and interests of a particular audience, a definer may wish to use any of the following examples:

- remote sensing is gathering information about an object without touching it.
- remote sensing is a method of collecting information from a distance by instruments carried typically on aircraft or spacecraft.
- remote sensing is the noncontact recording of information from the electromagnetic spectrum by means of mechanical, photographic, numeric, or visual sensors located on mobile platforms.

However, we suggest that writers, whenever possible, stress the point that the sensors are mechanical or that they are indeed instruments (e.g., Rudd, 1974; Reeves, 1975; and NASA, 1976).

ESSENTIAL ELEMENTS

Although an important goal should be to seek useful definitions expressed at different vocabulary levels and adapted to the needs and interests of various audiences, we are of course interested in seeking a most general definition of remote sensing for use with the widest possible group of readers. In this search for a comprehensive definition, some or perhaps all of the following elements need to be considered:

- the noncontact acquiring, collecting, or recording
- from regions of the electromagnetic spectrum (typically although not exclusively) that include but exceed the visible region
- through the use of instruments
- located on mobile platforms
- and the symbolic transformation of collected data
- by means of interpretive techniques and/or computer-aided pattern recognition.

By selecting elements from these various aspects, a reader can put together a definition that at least moves in the direction of comprehensiveness.

CONCLUSION

We conclude that because all definitions are heuristic, in terms of guiding inquiry, scientists need to concern themselves more, not less, with collecting, reviewing, criticizing, revising, updating, and generally sharpening working definitions within remote sensing. Such activity is necessary to give direction to the field of remote sensing, to help its workers hone their understanding of the nature of the discipline, to relate it meaningfully to other disciplines, and to interpret it to others outside the field.

The lack of a concise, consistent definition of the field of remote sensing may be, in the long run, harmful to our academic well-being. Some evidence of erosion has appeared, in the form of program telescoping and/or elimination. What will be the role of remote sensing *vis-à-vis* the current trend toward Geographic Information System (GIS) technology? Is our future role to be reduced to providing input to GIS activities?

Unlike cartography (whose home tends to be found in geography), statistics (which is a derivative of mathematics), and photogrammetry (which is most commonly associated with engineering), remote sensing seems to have no widely accepted academic roost. Is this a function of our lack of a definite focus? Or, is it a function of the traditional manner in which academic departments have been delineated? Courses in remote sensing are taught in American universities by foresters, geographers, geologists, engineers, agronomists, computer scientists, and perhaps others. Isn't it time that the process-oriented disciplines like remote sensing, cartography, and photogrammetry promulgate the importance of their relatively unique "how" orientation within the academic community? We suggest that working toward sharper definition of remote sensing can lessen the confusion regarding this field's place in the sciences as well as provide justification for remote sensing standing alone as an academic discipline.

Colwell (1984) pointed out "one measure of the newness of a science, or of the rapidity with which it is developing, is to be found in the preoccupation of its participating scientists with matters of terminology." The numerous recent definitions of the field found in the literature, and indeed in this paper,

support the contention that remote sensing still is a new and rapidly developing science.

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