Effective Use of Remote Sensing Products in Litigation*

Richard A. Jaynes

Center for Remote Sensing and Cartography
University of Utah Research Institute
420 Chipeta Way, Suite 190
Salt Lake City, Utah 84108

BIOGRAPHICAL SKETCH

The author's academic background: B.S., Range Science, Brigham Young University, 1976; M.S., Watershed Science, Utah State University, 1977; University of Utah College of Law, J.D., 1980. Admitted to the Federal and Utah State Bars in 1980. Photogrammetric and remote sensing training were received while employed as hydrologist/range ecologist at the Center for Remote Sensing and Cartography from 1977-1980, and as Center manager from 1980 to present.

ABSTRACT

A wealth of information regarding the use of remotely sensed images in litigation has been prepared in the past few years. The purpose of this paper is to review the most significant articles and encourage readers to obtain and carefully consider those articles. A boiled-down version of major legal principles affecting the admissibility of data and products from remote sensing devices is presented. It is suggested that enhancements or classifications of digital data (from scanning devices or from digitized aerial photography) be proffered as evidence in a fashion similar to the manner in which maps from photogrammetric techniques are introduced as evidence. Every effort should be made to illudicate the processes by which digital data are analytically treated or "manipulated." Remote sensing expert witnesses should be practiced in providing concise and clear explanations of both data and methods. Special emphasis should be placed on being prepared to provide a detailed accounting of steps taken to calibrate and verify spectral characteristics with ground truth.

INTRODUCTION

The objective in preparing this paper was to shed some light on the problems encountered where the legal system is introduced to new scientific data and processes. The introduction of maps prepared from digital data, obtained from satellite or airborne multispectral scanners and digitized photographs, permits opposing counsel the opportunity to use such insidious words as "manipulate" or "massage" with respect to the original data. The legal system mirrors human nature with its skepticism toward anything new and mystical, especially where one is told that

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truth about the world around us comes from invisible data after it has been crunched and spit out of a black box.

A number of sources of information addressing aspects of remote sensing in the legal process are available. The definitive work on evidentiary aspects of remote sensing was written by Latin, et al. (1976). The Northrup University Law Journal of Aerospace, Energy and Environment devoted an entire issue in 1979 to legal aspects of remote sensing, with emphasis on photogrammetric applications. Other useful sources of information will be cited herein in an attempt to highlight the major issues and legal principles that should be kept in mind when using remote sensing information in court.

A distinction should be drawn at the outset between photogrammetry and remote sensing, at least as used in this paper. Photogrammetry is the science of interpreting and making measurements of objects from photographic or other images of reflected electromagnetic radiant energy of those objects (A.S.P. 1983). The emphasis of the photogrammetrist is generally on interpreting features on continuous tone photographs and producing a spatially accurate map by tying photographic features to surveyed ground information (Quinn 1979a). A specialized branch of photogrammetry is remote sensing, in which imagery is acquired by a sensor (i.e., with prisms or crystals) rather than through a lens/filter/photographic film system. The emphasis of the remote sensing scientist is to produce a map which accurately correlates recorded spectral characteristics with ground features (although spatial accuracy is also important). Remote sensing data are often in digital form, thus making machine processing necessary to extract information. (See Latin, et al. 1976, pp. 1306, 1307.)

For purposes of simplifying the discussion below, photogrammetric products will be divided into two types: products derived from photographs where light reflectance was originally recorded on a photographic film; and products derived from machine processing of remote sensing digital data. The objective here is not to define the subtle differences between approaches to extract information from camera systems and spectral sensing devices, but to illustrate in an abbreviated manner some of the significant aspects of the legal treatment of both approaches. Courts readily admit photograph evidence, including aerial photographs, which record visible light since most people are familiar with the photographic process. In addition, recordings of visible light produces information which can be conveniently perceived and verified by human beings; most jurisdictions accept such photographs as independent evidence and not merely as a pictoral representation of witness' testimony (Latin, et al. 1976, p. 1306). The more unfamiliar a photogrammetric approach is, the greater will be the burden of demonstrating its reliability. For example, photographs which record both invisible infrared and visible green and red light on color infrared photographic film will need a bit more background explanation regarding the underlying scientific theories and reliability before being admitted.

Greater uncertainty surrounds the admission of remote sensing products from digital data. Skepticism on the part of the court will stem from its unfamiliarity with a high-tech science and the opportunities for the data analyst to adulterate original data to produce a product which, because of its graphic nature and impressive technical underpinnings, has great potential to overly impress and mislead the determiner of trial facts (i.e., jury, or judge if there is no jury). Remote sensing digital products should be further subdivided, for purposes of discussion, into reconstructed images and enhanced products. Computer processing of spectral data for reconstructed images is minimal; the goal is merely to make geometric corrections to the original data to improve its spatial accuracy. This step enables the data to be printed as overlays to standard base maps or in some other hard copy format (i.e., false color composite) and results in minimal modifications of the original data.

Enhanced digital products may go far beyond the steps outlined above. Whether the remote sensing data is originally in digital form or digitized from a photograph, various computer algorithms may be used to enhance contrasts, filter data, classify, use band ratios, etc. to increase the ability of the analyst to discriminate ground features. These efforts are directed toward identifying information via the analytical technique which is otherwise imperceptible or impractical to extract from a photographic-type product, and portray that information in map form. This process is identical, in principle, to the approaches utilized by engineering photogrammetrists who utilize sophisticated and "manipulative" analytical procedures in creating a topographic map from aerial photographs. Both approaches are building scale models of the areas mapped by concentrating on thematic ground features which are calibrated with the remote sensing medium.

LEGAL PRINCIPLES GOVERNING ADMISSIBILITY

The admissibility of remote sensing data and maps prepared therefrom in a particular litigation context will depend on adherence to the applicable rules governing scientific evidence. Each jurisdiction will have its own published rules of evidence, as well as additional judge-made requirements intended to assure the reliability of evidence from scientific procedures. The Federal Rules of Evidence ("F.R.E.") govern the admissibility of evidence in all federal jurisdictions and nearly half of the states have patterned their rules after the federal rules (McCormick 1982). The F.R.E. are generally fairly liberal in favoring the admissibility of evidence when it is relevant and where it will be helpful to the trier of fact, and will be cited herein as representative rules. Although the remainder of the state courts may be expected to have somewhat similar rules of evidence, the reader is cautioned to ascertain the rules of evidence governing his or her particular forum.

Only one case has been found in which the technical reliability, and therefore admissibility, of a particular

remote sensing technique was a central issue. This does not mean that there has been any lack of cases in which products from digital remote sensing data were introduced as evidence. Photographic representations of digital data have been admitted in evidence, apparently without objection, in a number of cases; in most situations, however, the evidence was used in conjunction with substantial quantities of ground observations and samples (Latin, et al. 1976, pp. 1349-1354). The most notable of these cases is U.S. v. Reserve Mining Co. 380 F. Supp. 11 (D. Minn. 1974). A Landsat image, thermal infrared image, densitometer analysis of color infrared photography, and the green band image from a 24 channel airborne multispectral scanner were presented to define the extent to which asbestos-like taconite tailings were being circulated within Lake Superior (Latin, et al. 1976, pp. 1352-1353; Owens 1979). However, it is not clear from the record whether the lack of objection to such data is simply a result of the opposing counsel's impression that the images were "photographs."

Since there is little judicial precedent directly addressing the admissibility of digital remote sensing evidence, the material below will draw upon relevant analogies. A significant basis for precedent is provided by the cases in which unenhanced digital data images were treated as photographs to prove important factual contentions or to clarify and supplement traditional types of demonstrative evidence. Another evidentiary analogy with aerial remote sensing is the use of x-ray photography, which must be acquired, authenticated, and interpreted by technical experts; this analogy is useful because it depends on the recording of information from a nonvisible spectral band, but has become universally accepted as admissible evidence (Lins 1979; Latin, et al. 1976).

The presentation of material below follows the format of the detailed treatment by Latin, et al. (1976). Since remote sensing data and analytical procedures are not part of a subject commonly known to lay persons, expert testimony is required to lay a foundation for remote sensing data or map products. The expert must first be qualified through his or her skill, training, and experience to render expert testimony (F.R.E. 401-403, 702). The second threshold to admissibility of evidence is achieved when the expert adequately documents the essential elements of the evidentiary foundation: (1) the reliability of the scientific theory utilized by the sensing technique; (2) the remote sensing device was operated by qualified individuals and worked in accordance with the underlying scientific theory; and (3) the authenticity of the data offered to court, and the propriety and accuracy of analytical methods to interpret the data (Latin, et al. 1976; Wick 1979; Owens 1979).

Expert Testimony

It is within the discretion of the trial court to determine whether a person proposed as an expert may give testimony. The court may appoint its own expert, and the facts and data used by an expert are subject to close

examination (F.R.E. 705, 706). In jury trials, the judge decides whether to qualify an expert with the jury absent and, if qualified, the credentials of the expert are reviewed in the presence of the jury to establish credibility.

Qualifying an expert for a case involving photogrammetric products is relatively simple. Counsel can focus on whether the expert is licensed by the state, or certified by the American Society of Photogrammetry, in addition to focusing on other aspects of his or her professional credentials. (See Quinn 1979a, 1979b, and 1983; Sanders 1979; Tachna, et al. 1983; Smith 1979; Klawitter 1979.) Remote sensing scientists have a wide diversity of background which may require greater care in qualifying an expert. The most important point to emphasize is the expert's demonstrated experience in the collection and interpretation of remote sensing data. Other factors include formal education, familiarity with the professional literature, publications authored by the expert directly on the matter at issue or related topics, membership in professional societies, professional recognition, and past and present occupational responsibilities (Latin, et al. 1976, pp. 1365-1374; Lins 1979). This approach corresponds to the methods used to qualify experts in other technical areas where there is no prescribed course of instruction or professional accreditation mechanism to reference.

Care should be taken to assure that both attorney and expert communicate clearly regarding the proper function of the expert in a particular case. Tachna, et al. (1983) presented an excellent review of important aspects of the attorney/expert relationship at different stages of litigation. The expert should be well informed and thoroughly qualified to document all aspects affecting the expert's opinion. In some remote sensing cases, it may be necessary to have one expert provide foundation testimony for the scientific theories behind the remote sensing device and data, while the scientist who analyzes and interprets the data should be called upon to describe analytical and mapping procedures (Latin, et al. 1976, pp. 1370).

Reliability of Remote Sensing Techniques

Judges have imposed an additional burden of proof on proponents of scientific evidence to prevent the trier of fact from giving undue weight to or being misled by experts with sophisticated evidence; scientific evidence must be shown to have passed from the "experimental" stage to the "demonstrable" stage of application. Some courts have applied a well-known test, commonly referred to as the Frye standard, where the requirement of reliability is met if the new technique or data has been shown to have received "general acceptance" by the professional community in the particular field. Frye v. U.S. 293 F.1013 (D.C. Cir. 1923). This judicial standard has been severely criticized since evidence from otherwise accurate and reliable techniques could be held inadmissible if not found to have received widespread acceptance (Giannelli 1980; McCormick 1982; Latin, et al. 1976, pp. 1374-1392). The modern judicial trend, which is

consistent with the F.R.E., is to admit evidence from techniques which have passed the experimental stage if their reliability is reasonably demonstrable.

The only case found which addressed the admissibility of remote sensing data from a scanning device is U.S. v. Kilgus. 571 F.2d 508 (9th Cir. 1978). In that case, evidence from an airborne forward looking infrared system was submitted as the means of identifying a plane allegedly involved in the illegal importation of drugs. The court applied the Frye standard and held the evidence was inadmissible because it could not uniquely identify the plane in question. The system's basic theory, design, and operating procedures were found acceptable, and would be admissible in a proper case. (See McCarty and Edmonds 1979.) This case offers encouragement regarding the admissibility of remote sensing products where sufficient foundation is supplied and reliable applications are made. When presenting remote sensing products as evidence, one should pay particular attention to documenting the accuracy of the products. Reference to acceptable accuracy measures published in the literature should prove sufficient (e.g., Arnoff 1982a and 1982b; Rosenfield, et al. 1982).

Proper Conduct of the Remote Sensing Process

Expert witnesses must establish, through their testimony, that the remote sensing data were collected in accordance with the underlying scientific theory. References must also be made to the calibration procedures used for the remote sensing device, and operating procedures applied to collect the data. It will also be necessary to establish the qualifications of the personnel who operated the remote sensing device (Latin, et al. 1976, pp. 1403-1418). In the case of Landsat data, it should be sufficient to establish that remote sensing scientists commonly and reasonably rely on the assumption that Landsat data are collected in accordance with the information published by N.A.S.A. or the U.S.G.S. with regard to the operation of the Landsat satellite and the nature of data collected by its sensors.

Authentication and Proof of Contents

Authentication is a basic requirement to the admissibility of all demonstrative evidence (F.R.E. 901). This condition may be satisfied by the testimony of a witness with personal knowledge of remote sensing data authenticity, or through self-authentication rules. Extrinsic evidence regarding authenticity is not required for certified copies of public records (F.R.E. 902, 1005). Remote sensing data from public agencies should also be protected from hearsay objections since such data may be characterized as either public records or records of a regularly conducted business activity (F.R.E. 801-803).

Latin, et al. (1976, pp. 1433-1443) demonstrated the difficulties to be expected if an attorney attempts to introduce a digitally enhanced image as "original" data or as a "duplicate" of the original data (F.R.E. 1101-1004). As with

a map from photogrammetric methods, digital enhancements often represent a substantial deviation from the original data; professional judgment has been applied to alter (i.e., organize, simplify, etc.) the original data in an effort to extract reliable information. Enhancements of digital data, which include processes such as density slicing a digitized photograph, are maps; the focus of attention should be on the basic soundness of the analytical approach, with emphasis on map calibration and verification of map accuracy.

A person who hopes to introduce a remote sensing map should carefully avoid the appearance of trying to hide any "manipulative" secrets. The trier of fact should be informed that although remote sensing data often contains valuable information without further analysis, enhancement to extract information is often as necessary to the remote sensing scientist as the sophisticated analytical plotting techniques are to the photogrammetrist. Sound calibration procedures and adequate accuracy verification will establish whether the remote sensing map is sufficiently reliable to be deemed admissible as an exhibit.

Submitting a remote sensing map product from any form of digital data would involve similar procedures. The discussion below describes recommended procedures, with accompanying rationale, for submitting a map prepared from Landsat multispectral scanner ("MSS") data.

The first step to submitting a remote sensing product from Landsat MSS data should be to introduce a duplicate of the original data. The original data, a certified copy of computer compatible tapes (CCT) from the EROS Data Center, should be available in the event opposing counsel objects to the duplicate or insists that the data should be submitted to satisfy the best evidence requirements (F.R.E. 1002). Since CCT's are of little analytical utility until reformatted to prepare the data for computer processing and geometrically corrected, it should be argued that data so reconstructed is an admissible "duplicate" of the original (with increased spatial accuracy). An alternate approach would be to initially introduce the EROS CCT, then introduce the corrected data after authenticating them with expert testimony regarding the routine nature and reliability of the processing technqiues used. In any event, the remote sensing expert should be prepared to illudicate the trier of fact regarding each step taken. Again, every effort should be made to invite confidence in remote sensing techniques by offering free access to the data used and operations performed.

As an additional aid, a graphical representation of the original digital, with geometric corrections, should be submitted. For example, a false color composite, prepared and certified by the EROS Data Center, could be introduced into evidence as the visual counterpart of the geometrically corrected data. Whether the hard copy is prepared by a government agency or by the expert, a concise description of the process for generating the hard copy will be necessary to allow the trier of fact to establish a link between the essentially invisible digital data and its visually meaningful

counterpart. The digital data hard copy should also be characterized as a reliable duplicate of the original data, although the data are depicted in a different medium. If opposing counsel objects to this characterization, then the hard copy may be considered a map; admissibility should not be a problem since the process of constructing a visual image from digital data makes only minor modifications to the data, and the modifications made increase image accuracy.

Introducing an unenhanced digital image should also provide a means to support the expert's arguments for conducting digital enhancement procedures. If the analytical algorithms applied to raw Landsat data are as effective, and as necessary as the expert claims, the improvements should be apparent by contrasting the analyzed product with the unenhanced image. In addition, in contrasting the two images, the trier of fact should be able to perceive that the "number crunching" did not serve to alter spatial registration or the ability to recognize dominant features. Other advantages to the digital processing approach may also be illustrated by way of contrast with the unenhanced image: for example, multitemporal change detection, acreage computation, geographic information system applications, use of ancillary data in classifying spectral data. If sophisticated enhancement analyses do not produce clearly demonstrable effects, the judge may conclude that the expert is attempting to establish credibility by intimidation and deny admissibility.

Finally, the digitally analyzed remote sensing product should be introduced as a map prepared by well documented and reliable analytical steps. An analogy should be drawn between maps prepared by photogrammetric and digital remote sensing techniques; both approaches begin with a type of remotely sensed data, then modify it to extract thematic information.* The primary distinction between the two mapping approaches is photogrammetric maps emphasize spatial accuracy (calibration efforts concentrate on linking ground survey information with photogrammetric measurements), but remote sensing products emphasize spectral accuracy (calibration efforts concentrate on the comparison of ground cover patterns with light reflectance characteristics). The legal adequacy of a map from remote sensing data to illustrate information depends upon the ability of the expert to establish the soundness of underlying scientific foundation for the original data and analytical procedures, and verification of map accuracy: a process photogrammetric mapping experts have been accomplishing for quite some time.

The approaches outlined above could arguably be avoided if the expert merely uses remote sensing products to illustrate his or her expert testimony. Under F.R.E. 703, the

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*Several general legal references regarding the admissibility of aerial photographs and maps may be useful: 57 A.L.R. 2d 1351; 23 A.L.R. 3d 825; 3 Am. Jur. Trials 289; 9 A.L.R. 2d 1044; 2 Am. Jur. Trials 669; 7 Am. Jur. Proof of Facts 601.

expert need not rely on admissible evidence if the data used is of a type reasonably relied upon by experts in the same field. However, opposing counsel may still inquire into the analytical procedures used and require as much justification as if the remote sensing product had been submitted as an exhibit (F.R.E. 705). The opposing counsel may also effectively create the impression that the expert was trying to suppress weaknesses in the expert's opinion by not introducing the remote sensing product as an exhibit.

CONCLUSIONS

The use of remote sensing products in litigation presents challenges to the attorney and expert which are similar to those confronted in any case involving innovative scientific techniques. Special evidentiary precautions have been adopted by judges because of increased opportunities to confuse and overly impress the trier of fact with concepts and procedures beyond the lay person's understanding. The complex physical theories underlying remote sensing devices and digital analytical techniques must somehow be reduced to concise and illustrated explanations which may be grasped by jury and/or judge. Successful use of remote sensing products will depend largely on the expert's ability to inspire confidence in his or her testimony through documented explanations of theory, procedures, and accuracy measurements. Liberal use of pre-trial discovery procedures should assist in reducing and simplifying the presentation of technical material at trial.

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