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"Every year if not every day we have to wager our salvation upon some prophecy based upon imperfect knowledge."[1]

I. Introduction

A universe of information is being gathered from afar through the world of technology known as remote sensing.[2] Of particular interest to the environmental litigator is data gathered remotely by earth observation satellites. Imagery gathered from satellites can convey complex facts in clear and concise pictures. In 1986, the world first came to know of the Chernobyl nuclear reactor disaster through the use of satellite images.[3] The technology "dramatically increases the scale and range of our world view."[4]

Satellites are a source of powerful scientific evidence useful in environmental regulation and litigation.[5] Imagery from satellites not only can assist a judge and jury to understand the issues, it can help maintain interest in otherwise

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1. Abrams v. United States, 250 U.S. 616, 630 (1919) (Holmes, J., dissenting).

2. *See* ROBERT K. HOLZ, THE SURVEILLANT SCIENCE: REMOTE SENSING OF THE ENVIRONMENT 2 (1985) [hereinafter Holz]. "Remote sensing is defined as gaining information about an object or phenomenon while at some distance from it and without any direct contact with it . . . ." *Id.* This information is transferred through electromagnetic energy or "light." *See id.*

3. *See* Timothy J. Brennan & Molly K. Macauley, *Remote Sensing Satellites and Privacy: A Framework for Policy Assessment*, 4:3 J.L. COMPUTERS & ARTIFICIAL INTELLIGENCE 233 (1995).

4. DAVID S. WILKIE & JOHN T. FINN, REMOTE SENSING IMAGERY FOR NATURAL RESOURCES MONITORING 31 (1996) [hereinafter WILKIE & FINN].

5. *See* Warren Ferster, *Courts Learning Strengths of Remote-Sensing Imagery*, SPACE NEWS, Jan. 16-22, 1995, at 19. Reporter paraphrased statement by Roger Mitchell, Vice President of Earth Satellite Corp. of Rockville, Maryland. Mr. Mitchell also stated in a telephone interview that satellite remote-sensing data is a legitimate tool for forensic purposes. Telephone Interview with Roger Mitchell, Vice President, *Earth Satellite Corp.* (Nov. 16, 1995).

The range of spatial and spectral characteristics are reasons "why remote sensing imagery is such a powerful descriptive and analytical tool." WILKIE & FINN, *supra* note 4, at 31.

dull and tedious explanations of the complex information.[6] In addition, pictures from space are often the only evidence that captures an event. Yet twenty-five years after the first release of satellite data to the non-military sector,[7] the technology remains greatly under-utilized by the legal community.

Earth observation remote sensing data can be gathered from aircraft, or more routinely from satellites. Data from satellites are generally transmitted back to earth in digital form and converted to interpretable images with sophisticated image processing software.[8] The focus of this paper is on the use of satellite digital data and the imagery produced from that data in the courtroom. Pictures from space have been used by numerous federal agencies[9] and international organizations for making decisions on matters of world peace,[10] for evaluating the extent and use of limited vital nat-

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6. *See* Marc Steinberg, *A Picture Can Be Worth a Lot More Than a Thousand Words*, 214 N.Y.L.J. 10 (1995), § 6 (Special Pullout Section), at col. 1 [hereinafter Steinberg]. "The greatest challenge facing trial attorneys today is the task of explaining complex legal issues to the lay jury or non-expert judge." *Id.*

7. Landsat earth observation satellite was first launched in 1972. *See* WILKIE & FINN, *supra* note 4, at 266.

8. *See* THOMAS M. LILLESAND & RALPH W. KIEFER, REMOTE SENSING AND IMAGE INTERPRETATION 3 (1979) [hereinafter LILLESAND & KIEFER]. *See also* R.N. Colwell, Manual of Remote Sensing (1983).

9. *See* Bruce S. Marks, *Dispute Resolution in the Space Age: Forensic Applications of Earth Observation Satellite Data Through Adaptation of Technical Standards Similar to DNA Fingerprinting Protocols*, 5:1 OHIO ST. J. ON DISP. RESOL. 19, 27 (1989) [hereinafter Marks]. Currently the data is used by Departments of Agriculture, Interior, and Defense, the Central Intelligence Agency, the Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers, and the National Aeronautics and Space Administration. *See id.*

The EPA and the U.S. Justice Department have used remote sensing in court "to provide unique synoptic views of the terrain . . . [and a] temporal dimension of time-sequenced historic aerial photography . . . ." Timothy W. Foresman, Ph.D. & David R. Williams, *Remote Sensing: An Environmental Enforcement Tool*, *in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE '90S 30 (1990) [hereinafter Foreman & Williams].

10. *See* Eric Schmidt, *Photos May Be of Bosnian Mass Graves*, AUSTIN AM.-STATESMAN, Aug. 10, 1995, at A10 (images from satellites and spy planes were presented to the United Nations Security Council, the first image showing hundreds or thousands of people in a stadium, the second image, taken a few days later, of an empty stadium and a freshly dug field nearby) [hereinafter Schmidt].

ural resources,[11] and for the identification of endangered species habitat.[12] Satellite imagery has occasionally been used by litigators in assessing oil and chemical spills, flood damage, and past and present land use.[13]

An important paper on this topic, *Remote Sensing Evidence and Environmental Law*,[14] was published twenty (20) years ago. It included a comprehensive survey of remote sensing data technology and applications in light of the then recently enacted national environmental laws.[15] The authors predicted that "in the coming decade, it is certain that a large volume of remote sensing information will ultimately be introduced as evidence in judicial and administrative proceedings . . . ."[16] Others have predicted "[a] rapid expansion of forensic use of [remote sensing] tools . . . ."[17]

Despite widespread application by research, business,[18] military and non-military sectors,[19] satellite data continue to be under-utilized in environmental conflict resolution.[20] The need for tools to effectively and efficiently resolve conflicts is great. "In both the state and federal courts, there is substantial support and precedent for the innovative use of neutral experts. The introduction of incontrovertible 'scientific' facts, where appropriate, tends to minimize the need to rely so ex-

11. Telephone Interview with Michael Golden, Environmental Analyst, *Pacific Meridian Resources* (Oct. 20, 1995).

12. *See* John Teply & Kass Green, *Old Growth Forest: How Much Remains?*, GEO INFO SYSTEMS, Apr. 1991 (from reprint copy supplied by Pacific Meridian Resources) [hereinafter Teply & Green].

13. *See* Ferster, *supra* note 5, at 19.

14. Howard A. Latin et al., *Remote Sensing Evidence and Environmental Law*, 64 CAL. L. REV. No. 6, 1300 (Dec. 1976) [hereinafter Latin].

15. *See id.*

16. *Id.* at 1364.

17. Foresman & Williams, *supra* note 9, at 40.

18. The Land Remote-Sensing Commercialization Act of 1984 ("Landsat Act"), 15 U.S.C. §§ 4201-92 (1984), provides that commercial remote-sensing data shall be available to all potential users.

19. *See* discussion of applications of satellite data to date, *infra* part II.A.

20. A survey of reported cases of the past 20 years that relied on the use of satellite data as evidence yielded only four cases. In addition, a telephone survey of numerous remote sensing value-added businesses and research scientists indicated limited forensic application of the technology. *See* discussion of satellite data technology characteristics and capabilities, *infra* part III.B.

clusively upon the art and science of advocacy."[21] An even more compelling reason to utilize innovative tools is the cumulative effect of inefficient litigation. "[T]he adjudicative process and its support systems in the United States is [sic] contributing materially to a reduced level of national productivity . . . ."[22] The use of satellite data can help reduce the costs and inefficiencies of the adjudicative process.

Under-utilization of the technology as evidence in the courtroom has several possible explanations.[23] Perhaps the data are so convincing that they serve as an impetus to settle cases out of court.[24] Ironically, the images have been disdained for being too revealing.[25] Dependence on satellite data by other end-user sectors indicates the data's reliability.

Another possible explanation for the under-utilization is the unfounded concern over the potential invasion of privacy, a concern not shared by the United States Supreme Court. In *Dow Chemical Company v. United States*,[26] the Supreme Court held that the trial court erred in rejecting remote sensing evidence.[27] Sensors with the power to penetrate surfaces, rather than merely detect the surface, potentially violate an individual's right to privacy,[28] the nation's security, and industrial trade secrets.[29] However, the topic of this discussion

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21. *See* Marks, *supra* note 9, at 33.

22. *Id.* at 30.

23. *See* discussion of possible explanations for the under-utilization of the satellite technology, *infra* part III.B.2.

24. Telephone Interview with Dr. Oscar Huh, Professor, Coastal Studies Institute, Louisiana State University (Nov. 10, 1995) [hereinafter Telephone Interview with Dr. Oscar Huh]. Dr. Huh provided imagery that was used in a case of a highjacked oil ship that was taken to Greece. The action brought by the insurance company was successfully settled out of court because the imagery was so compelling as to location of the vessel and evidence of oil loss after an accident. *See id.*

25. *See* Harold Hough, *Satellite Imagery: Right Medicine for Mining Problems*, EARTH OBSERVATION MAGAZINE 36 (Jan. 1993) [hereinafter Hough].

26. Dow Chem. Co. v. United States, 476 U.S. 227 (1986).

27. *See id.*

28. *See* Lisa J. Steele, *The View From on High: Satellite Remote Sensing Technology and the Fourth Amendment*, 6 HIGH TECH. L.J. 317, n.5 (1992) [hereinafter Steele]. *See also* discussion *infra* part II.C.2.

29. *See* Jane M. Gootee, *Current Developments in Remote Sensing Law and Practice*, *in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE '90S

is on sensors that merely detect surface energy and reflectance, not on sensors that penetrate.

Remote sensing provides "the historical perspective, the synoptic view of investigated sites, the permanent record of environmental conditions . . ., the strength of the legal evidence submitted to courtroom proceedings, and the high visual impact of the exhibitions for briefings [and discovery] and expert witness testimony . . . ."[30] Satellite data are non-interfering and can be gathered frequently and virtually instantaneously with an array of sensors having different spatial and spectral resolutions.[31]

The environmental litigator should be aware of several forensic applications concerns. Imagery derived from remotely sensed digital data used in litigation as either demonstrative[32] or as scientific evidence is subject to several evidentiary hurdles.[33] The fact that the "camera" (i.e., the sensor gathering the digital data) "can be made to lie," as demonstrated in such movies as "Jurassic Park" and "Forest Gump," illustrates several evidentiary problems regarding the admissibility of products of digital data.[34] "The resulting digital record can be very convincing indeed—yet very inaccurate."[35] An expert witness must be able to authenticate the data and explain the interpretation of the image that was created with technology beyond the ken of an average juror.[36] Admission of imagery as evidence is possible if admissibility

242, 245 (American Society for Photogrammetry and Remote Sensing and American Bar Association, 1990).

30. Foresman & Williams, *supra* note 9, at 40.

31. *See* WILKIE & FINN, *supra* note 4, at 30.

32. Demonstrative evidence is defined as "[t]hat evidence addressed directly to the senses without intervention of testimony. Such evidence is concerned with real objects which illustrate some verbal testimony and has no probative value in itself . . . ." BLACK'S LAW DICTIONARY 432 (6th ed. 1990). Examples of demonstrative evidence include maps, photographs, charts, and X-rays. *See id.*

33. *See* Jon L. Roberts, *Admissibility of Digital Image Data & Animations: Courtroom Concerns*, ADVANCED IMAGING 102 (Aug. 1995) [hereinafter Roberts]. Photographs and computer-generated images are hearsay. *See id.* *See* discussion of evidentiary standards, *infra* part II.C.1.

34. *See* Roberts, *supra* note 33, at 102.

35. *Id.*

36. *See* FED. R. EVID. 702 (Testimony by Experts).

standards are observed, especially the standards that address the risk of image manipulation. The value added to the litigation presentation by having an image admitted into evidence is great[37] and should be worth the effort and expense.

Although earth observation satellite technology has been used by the military, non-military, industry and science sectors for over two decades, its limited application in the legal community will possibly render it a novel science in most jurisdictions. Admitting this valid novel scientific evidence will not be difficult for the educated litigator. In the 1993 Supreme Court decision *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[38] the Court provided a framework for admission of novel scientific evidence. There, the Court interpreted the Federal Rules of Evidence (FRE) to require that "the trial judge must ensure that any and all scientific testimony or evidence admitted is . . . reliable."[39] Evidence can be admitted if a judge finds that it is relevant, reliable, derived by scientific method, and supported by appropriate validation.[40]

Several other concerns should be addressed when using digital data gathered from earth observation satellites. The value of an image created from satellite digital data can be either greater or lesser cost efficient than alternative data sources, depending on the area of coverage required and the type of information needed.[41] In some instances, cost will not be the principle concern because remote sensing data is uniquely capable of disposing the issue.[42] In addition, the archive of satellite data can prove to be invaluable if imagery

37. *See* Steinberg, *supra* note 6.

38. 113 S. Ct. 2786, 2795 (1993).

39. *Id.*

40. *See id.* at 2798.

41. *See* discussion of cost of satellite technology products, *infra*, part II.B.5.

42. Commercial satellite systems provide data from various channels of the electromagnetic spectrum (that enhance different features of the earth's surface), and have worldwide coverage at regular intervals, ranging from every 16 days for Landsat Thematic Mapper data to every 90 days for Russian data to every several years for the National High Altitude Photography Program. *See* EARTH OBSERVATION SATELLITE CO., COMPARISON OF SATELLITES AND SENSORS (1995) [hereinafter EOSAT]. *See also* WILKIE & FINN, *supra* note 4, at 46. *See* discussion of satellite data applications to date, *infra* part II.A.

is available on a critical date and time, but is unavailable from any other source.[43] However, satellite data is not unlimited in its capacity to depict dispositive information[44] and should not be oversold. Commercial technology of the past has provided images with resolutions of 10-80 meters, but satellites to be launched in 1997 will provide data of high resolution of 1-3 meters with very frequent repeat coverage (up to several times daily).[45] Careful project planning can assure proper application of the technology and litigation resources.

In Latin's seminal work twenty years ago, the authors called for "[f]requent legal assessments of the admissibility and utility of remote sensing data . . . ."[46] This comment explores applications of satellite data of the environment for litigation and the inherent evidentiary concerns with the data. Part II describes earth observation satellite technology, its current applications, and areas of concern for forensic application. Part III provides the suggested guidelines for the use of satellite data for litigation in light of the state of the technology and the legal environment. Current and potential applications of satellite data in environmental law are suggested. Assessment of the issues involved will be played against the characteristics of the data to predict the suitability of the application of remote sensing. Lastly, Part IV con-

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43. *See* William J. Broad, *Big Picture of Cold War: U.S. Spy Photos Go Public*, N.Y. TIMES, Feb. 25, 1995, at A8.

44. *See* LILLESAND & KIEFER, *supra* note 8, at 30. The authors state that many problems are not amenable to solution by remote sensing, but data acquisition and analysis project planning can ensure appropriate application of the technology. *See id.* *See* discussion of planning and preparation, *infra* part III.A.1.

Failure to conduct sufficient project planning for remote sensing data acquisition has rarely been more apparent than in the botched handling of the headcount analysis of the Million Man March by the National Park Service. *See* Farouk El-Baz, *Remote Sensing, Controversy and the Million Man March*, EARTH OBSERVATION MAGAZINE 16-18 (Feb. 1996) (the author concludes that in order to obtain accurate (< 20% error) headcount data should have been gathered on an hourly basis from a fixed-wing aircraft with a camera capable of obtaining high definition photographs).

45. *See* Lawrence W. Fritz, *The Era of Commercial Earth Observation Satellites*, PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING 39 (Jan. 1996) [hereinafter Fritz].

46. Latin, *supra* note 14, at 1305.

cludes that remote sensing satellite data provide powerful evidentiary tools that can resolve issues in cases where definitive data was heretofore unavailable. Although the nature of the digital data makes it subject to manipulation, precautions can be taken to assure its acceptance by the judiciary. The legal practioner who has a solid understanding of earth observation satellite technology can effectively work with the experts and the satellite data to clearly and concisely illustrate the answers to questions that frequently arise in environmental litigation.

II. The Technology

Reliance on earth observation satellite data has become routine outside the courtroom in some sectors. Reasonableness of such reliance is based on proven technology, extensive research and validation of the data, and conservative application. The uninitiated legal practitioner should heed the lessons learned by the other sectors. Those lessons begin with a review of applications to date and a primer on the elements of the technology.

A. Applications to Date

1. Caselaw Reporting Satellite Imagery Application

Although the use of satellite data in the courtroom has been limited,[47] the data has great potential.[48] The few reported cases that include reference to satellite data as evidence are worthy of a brief examination. An "early" case (1974) that involved the use of satellite data was *United*

47. A survey of reported cases in which satellite data was introduced as evidence of an issue at point in the case yielded only three cases: United States v. Reserve Mining Co., 380 F. Supp. 11 (D. Minn. 1974); Chevron v. U.S.E.P.A., 658 F.2d 271 (5th Cir. 1981); Gasser v. U.S., 14 Cl. Ct. 476 (1988). Search of WESTLAW, Allfeds and Allstates Libraries (Apr. 18, 1997).

48. Latin et al. in 1976 and Foresman and Williams in 1990 predicted a great increase in the use of remote sensing and satellite data in litigation, especially in areas of environmental law. *See* Latin, *supra* note 14, at 1444; *see* Foresman & Williams, *supra* note 9, at 40.

States v. Reserve Mining Co.[49] There, satellite images were entered into evidence to show the dispersion of taconite tailings by a mining company into Lake Superior.[50] Another case that mentioned use of satellite data was *Chevron v. United States Environmental Protection Agency*.[51] There, the court merely noted that "exotic" attempts were made to estimate acreage from satellite photographs.[52]

In a 1988 decision by the United States Claims Court, *Gasser v. United States*,[53] the court determined that flooding had increased in the area in question, as depicted on "satellite photographs."[54] The court in *Gasser* rejected the defendant's expert's testimony in favor of the evidence provided by satellite photographs.[55]

Satellite data played a vital role in a 1989 Southern District of Texas case, *ANR Production Co. v. M/V Mekhanik Dren*.[56] In that case, satellite photographs taken 34 minutes before and 4 minutes after the collision of the ship and the oil platform showed the weather conditions in the vicinity at the time of the accident.[57]

The 1986 Supreme Court decision in *Dow Chemical* provides some guidance on the acceptability of remote sensing

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49. 380 F. Supp. 11 (D. Minn. 1974), *stayed in part and remanded*, 498 F.2d 1073 (8th Cir. 1974), *motions to vacate denied*, 418 U.S. 802 (1974) (*citations omitted*).

50. *See* United States v. Reserve Mining Co., 380 F. Supp. at 39, n. 21. Taconite tailings are the undesirable particles that result when iron oxide rich iron ore particles are separated from those particles that are very lean or barren in iron oxide. *See id.* at 30.

51. 658 F.2d 271 (5th Cir. 1981) (involving dispute over the size of wilderness area, which affected classification and related visibility protection under the Clean Air Act).

52. In *Chevron*, the use of satellite data was deemed pertinent, but was not dispositive of the issue of acerage determination. *See id.* at 277. In that case, the acerage of the islands of Breton Wilderness Area fluctuated too greatly to be successfully measured using satellite data. *See id.* at 276.

53. Gasser v. United States, 14 Cl. Ct. 476 (1988).

54. *See id.* at 496. The case involved a dispute over the cause of flooding on plaintiffs' property and whether flooding constituted a takings.

55. *See id.*

56. ANR Production Co. v. M/V Mekhanik, 1989 A.M.C. 2299 (1989 S.D. Tex.) (case arose from damages to an oil platform sustained from the collision with defendant's ship).

57. *See id.*

data. Although the trial court there found remote sensing so superior to the human eye and the powers of interpretation from an image so great,[58] the Supreme Court held that "[t]he mere fact that human vision is enhanced somewhat . . . does not give rise to constitutional problems."[59] In that case, the chemical company objected to the use of aerial photography that provided excellent detail. The Court focused on the expectations of privacy of industry, which were not exceeded. The Court noted, however, that privacy expectations for the private residence are higher.[60]

2. Military, Non-military, Industrial and Scientific Applications

National and international security have long been placed in the hands of military intelligence personnel interpreting satellite imagery. Satellite photographs observed trucks supplying logistical support to the Iraqi troops just prior to the Kuwaiti invasion.[61] Satellite data provided evidence that Serbian troops executed hundreds of Muslim men and boys and buried them in a mass grave outside of Srebrenica.[62] The satellite photographs helped "provide the most compelling circumstantial evidence" of the Serbian activity, thus spurring the United Nations' Security Council debate.[63]

Fortunately, with the end of the Cold War, technology such as satellite reconnaissance systems previously used for

58. *See Dow Chem. Co.*, 476 U.S. at 227. The attorney for the defendant, Jane M. Gootee, presented her perspective and provided suggestions when using remote sensing in environmental enforcement, defense, and litigation. *See* Jane M. Gootee, *Aerial Searches: A Defendant's Perspective - Dow Chemical v. United States*, *in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE '90S 42 (American Society for Photogrammetry and Remote Sensing and American Bar Association, 1990). *See* discussion of constitutional issues, *infra* part II.C.2.

59. *Dow Chem. Co.*, 476 U.S. at 238.

60. *See id.* The private residence is unique in that it is the place of "intimate activities associated with family privacy," and the expectation of such privacy is not reasonably or legitimately extended to an industrial complex. *See id.* at 228.

61. *See* Robert S. Greenberger, *Policy Snafu: How the Baker Plan for Early Sanctions Against Iraq Failed*, WALL ST. J., Oct. 1, 1990, at A1.

62. *See* Schmidt, *supra* note 10.

63. *See id.*

arms control verification can now be used for more peaceful missions such as environmental monitoring.[64] Satellite data have been used for analysis of the environment of the entire globe[65] and for detection of various delicate land cover conditions.[66] Scientists have relied on the data to provide measurements of the entire sphere to assess the greenhouse effect.[67] Destruction of critical tropical rain forests has been proven[68] and future deforestation can be predicted through the use of satellite data.[69] The first reliable confirmation of scientists' theory that the ozone layer was being depleted was provided by satellite data.[70] Satellite data are being used to assess other vital features of the earth's surface including the rising global sea level,[71] reduction in rainfall related to tropical deforestation,[72] and the loss of habitat for many endangered plant and animal species.[73]

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64. *See* Stephen J. Orava, *Waging the Next War: The Carryover of Arms Control Verification Procedures to International Environmental Law*, 5 GEO. INT'L ENVTL. L. REV. 151, 153 (Fall 1992).

65. *See* Lewis D. Solomon & Bradley S. Freedberg, *The Greenhouse Effect: A Legal and Policy Analysis*, 20 ENVTL. L. 83, 110, n.24 (1990).

66. *See* WILKIE & FINN, *supra* note 4, at 4.

67. *See* Malcolm W. Browne, *Most Precise Gauge Yet Points to Global Warming*, N.Y. TIMES, Dec. 20, 1994, at C4 [hereinafter Malcolm W. Browne].

68. *See* Barbara J. Bramble & Gareth Porter, *Non-Governmental Organizations and the Making of U.S. International Environmental Policy*, C990 ALI-ABA 407, 429 (May 4, 1995).

69. *See* Steven A. Sader, *Spatial Characteristics of Forest Clearing and Vegetation Regrowth as Detected by Landsat Thematic Mapper Imagery*, PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING, Vol. 61, No. 9, 1145, 1148 (Sep. 1995) (the author observed that most deforestation occurs along existing roads).

70. *See* Michael David Ehrenstein, *A Moralistic Approach to the Ozone Depletion Crisis*, 21 U. MIAMI INTER-AM. L. REV. 611, n.13 (Summer 1990).

71. *See* Malcolm W. Browne, *supra* note 67.

72. *See* Allen M. Young, *The Rain Forest Loss Is Our Own*, WALL ST. J., July 11, 1985, *available in* 1985 WL-WSJ 227444.

73. *See* Michael D. Coughlin, Jr., *Using the Merck-Inbio Agreement to Clarify the Convention on Biological Diversity*, 31 COLUM. J. TRANSNAT'L L. 337, 375, n.100 (1993) (Satellite data, training, and equipment will be provided by NASA to the members of the Central American Commission on the Environment and Development to track land use, development, and pollution.) *See also* Teply & Green, *supra* note 12 (U.S. Forest Service used satellite data to map the vegetation over 12.5 million acres to analyze the status of old growth timber remaining in national parks in Oregon and Washington). A court order protects 6.9 million acres of the forest that is habitat critical for the survival of the spotted owl. *See* Jeb Boyt, *Struggling to Protect Ecosystems and Biodiversity Under*

The Environmental Protection Agency (EPA) has used satellite data to help illustrate the destruction of extensive wetlands that resulted in an out-of-court settlement of the restoration of 8,500 acres (subject to a $500,000 bond).[74] Other federal agencies use satellite data to monitor compliance. NASA, an agency frequently involved with environmental monitoring research, uses satellite data in its efforts to monitor its own impacts on the environment near the Kennedy Space Center, Florida, the launch site for many space missions.[75]

The same technology used by government agencies is used in the business sector. In a 1994 technology development project, a consulting company developed techniques useful in environmental assessments of both military bases and chemical manufacturing sites.[76] A major power producer used multispectral scanner data to map the thermal plume created from its production process, a determination required as part of the state's permitting process.[77] Government regulation, be it for environmental protection or safety sake, seems to be the impetus for other industrial use of satellite data. Satellites have been used to identify fishing vessels involved in illegal fishing in the Bering Sea.[78]

The marketplace also is driving the use of satellite data. Agribusiness is one such market segment. A potato farmer in Oregon uses satellite data in order to best assess irrigation[79]

NEPA and NFMA: The Ancient Forests of the Pacific Northwest and the Northern Spotted Owl, 10 PACE ENVTL. L. REV. 1009, 1010 (Spring 1993).

74. *See* Foresman & Williams, *supra* note 9, at 39.

75. *See* Mark J. Provancha et al., NASA, *Evaluation of High Spatial Resolution Multispectral Imaging for Resource Management at John F. Kennedy Space Center, Florida* 17 (1994).

76. *See* Jean Graffagnini, NASA, *Use of Geographic Information Systems for Environmental Assessments of Military Installations and Chemical Manufacturing Companies* 3-6 (1994) [hereinafter Graffagnini].

77. *See* NASA, *A Thermal Plume Characterization and Environmental Assessment: Warren Bayou and West Bay, St. Andrew Bay* 12 (1993).

78. *See* NASA EARTH OBSERVATIONS COMMERCIAL APPLICATIONS PROGRAM ANNUAL REPORT, 1992 [hereinafter NASA EOCAP]. The data also are used to locate lost vessels. *See id.*

79. The potato farmer operates hundreds of center pivot irrigation systems at great cost. *See id.* A center pivot irrigation system is a system with a well in the field's center which pumps water to the end of a pipe that rotates around

requirements in his fields and expected market conditions (by assessing the yields in his neighbors' fields).[80] The use of remote sensing is widespread in the exploration of minerals,[81] and the same characteristics that make it useful for uncovering minerals render it valuable for environmental monitoring.[82]

B. Technology Basics

It is important to understand the satellite remote sensing technology down to its basic elements in order to appreciate its strengths and weaknesses. This section will explain the spectral characteristics (electromagnetic energy in the visible range and beyond) and spatial characteristics (resolution or detail of the imagery), and coverage frequency of the data gathered by satellites. In addition, the data processing and costs expected to yield an image useful in dispute resolution are discussed.

1. The Visible and Beyond

The human eye, a simple camera, and airborne and space borne (i.e., on a satellite platform) electromagnetic energy scanners are all remote sensing devices.[83] The information gathered by sensors with capacity to detect energy beyond the visible spectrum are of particular interest to this discussion. Data from aircraft and satellite sensors provide a nondestructive yet revealing prospective, a unique detecting capability with an archive[84] not available with traditional forms of investigation and discovery.

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the well, distributing water to the large circular field. NATIONAL RESEARCH COUNCIL, ALTERNATIVE AGRICULTURE 420 (1989).

80. *See* NASA EOCAP, *supra* note 78.

81. *See* Amoco Prod. Co. v. Laird, 622 N.E.2d 912 (Ind. 1993).

82. *See* Hough, *supra* note 25, at 38. *See also* SPOT PRODUCTS SUMMARY, [hereinafter SPOT], *Managing Land From Space* (1995) (Bureau of Land Management uses satellite data to help manage 334 million acres of public land, including evaluating the environmental impact of a gold mine operation).

83. *See* Holz, *supra* note 2, at 2 and WILKIE & FINN, *supra* note 4, at 270.

84. *See* SPOT, *supra* note 82. Coverage of area of interest is available on a regular frequent basis and was used to show overspray damage from an adjoining farm operation during the past growing season. *See id.*

Digital earth observation data are gathered from aircraft or satellites and are then processed into an image. Traditional photographs[85] have long been relied upon as evidence and are easily admissible,[86] but the argument has been made that traditional photography is no longer free from the threat of manipulation.[87] The advances in image processing technology and its widespread accessibility make traditional photographs as suspect to manipulation as images synthesized from digital data,[88] and photography will perhaps come under increased scrutiny.

Satellite scanners can gather digital data of the earth's surface by passively receiving reflected or emitted energy of surface attributes, be it land, water, vegetation, cultural features or a combination.[89] Electronic (non-photographic) sensors collect the reflected and emitted energy in fixed bands, or

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85. Reference to aerial photography will be made only when necessary to illustrate an example.

86. Telephone Interview with Terrence Slonecker of the EPA, Environmental Scientist of the Environmental Photographic Interpretation Center, EPA in Warrenton, VA (Oct. 3, 1995) [hereinafter Telephone Interview with Terence Slonecker]. Mr. Slonecker stated that the EPA generally prefers to use photographs as compared to images produced from digital data due to the requirements for proving chain of custody and assuring that the images have not been manipulated. *See id. See generally* Latin, *supra* note 14, at 1327-64.

In addition, a survey of reported case law indicates thousands of cases in which aerial photography was accepted and relied upon. Search of WESTLAW, Allfeds and Allstates Libraries (Apr. 18, 1997).

87. *See* Christine A. Guilshan, *A Picture is Worth a Thousand Lies: Electronic Imaging and the Future of the Admissibility of Photographs into Evidence*, 18 RUTGERS COMPUTER & TECH. L.J. 365 (1992) [hereinafter Guilshan]. The author calls for new, more stringent standards for the admissibility of all forms of photographic evidence. However, one expert explained that chain of custody and manipulation concerns can be addressed by inspection of a photographic negative with a 50x (or even more powerful) microscope. Telephone Interview with Mr. Roger Mitchell, Vice President for Program Development, *Earth Satellite Corporation*, in Rockville, Md. (Nov. 10, 1995). Mr. Mitchell stated that a negative created by the optics of an electronic system has taletell linear features from the scanning process, visible under a microscope. Thus, an expert who has inspected the negative used in producing a photograph can authenticate it. *See id.*

88. *See* Guilshan, *supra* note 87, at 365.

89. *See* LILLESAND & KIEFER, *supra* note 8, at 27-28. Some sensors are referred to as active, e.g. radar, which transmits an energy pulse and records the echoes that return. The return values are assimilated and processed into images. *See id.* at 488-89.

channels, of the electromagnetic spectrum.[90] Such a sensor is referred to as multispectral scanner.[91] The various bands of the satellite or airborne multispectral scanners are designed to discriminate features of interest on the earth's surface.[92]

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90. *See* Latin, *supra* note 14, at 1306-08. The spectral characteristic of a pixel, or picture element, is an energy value depicted as a level of gray ranging from 0 to 255 for each distinct channel. *See* LILLESAND & KIEFER, *supra* note 8, at 562-63. The discussion in this article is focused on satellite image data that is recorded, transmitted, and reconstructed through digital data media. *See* Latin, *supra* note 14, at 1308. The authors provide a representation of the electromagnetic spectrum that includes the wavelength ranges and spectral bands (e.g. X-ray, visible, infrared, radar). *See id.*

For a fascinating discussion on the 1800 discovery by William Herschel of the electromagnetic spectrum beyond the visible portion, *see* HOLZ, *supra* note 2, at 171.

91. *See* LILLESAND & KIEFER, *supra* note 8, at 30. Another common passive sensor is the panchromatic scanner. It usually produces a resolution two to five times higher than the multispectral scanner with which it shares a platform. *See* SPOT, *supra* note 82 (SPOT panchromatic image resolution is 10 meter and multispectral data is 20 meter). *See also* Fritz, *supra* note 45, at 39 (new satellite systems will provide panchromatic images with resolutions of 1-3 meter and multispectral data with resolutions of 4-15 meter).

92. *See* LILLESAND & KIEFER, *supra* note 8, at 581-82. The authors describe the channels of the thematic mapper (TM), a multispectral scanner flown on a satellite platform. *See id. See also* Marks, *supra* note 9, at 23. The Landsat TM has provided 30-meter resolution data of the specifications outlined by the authors, and has been in use since 1982. *See* EOSAT, *supra* note 42. Lillesand and Kiefer identified seven channels of the TM and described the purpose of each:

Band one (0.45 to 0.52μm) - designed to provide increased penetration into water bodies as well as supporting analyses of land use, soil, and vegetation characteristics.

Band two (0.52 to 6.0μm) - primarily designed to look at the visible green reflectance peak of vegetation lying between the two chlorophyll absorption bands . . . [and] intended to emphasize vegetation discrimination and vigor assessment.

Band three (0.63 to 0.69μm) - resides in one of the chlorophyll absorption regions and emphasizes contrast between vegetation and non-vegetation features as well as contrasts within vegetation classes.

Band four (0.76 to 0.90μm) - responsive to amounts of vegetation biomass present in a scene . . . [which] will aid in crop identification, and will emphasize soil-crop and land-water contrasts.

Band five (1.55 to 1.75μm) - important to the determination of crop type, crop water content, and soil moisture conditions.

Band six (2.08 to 2.35μm) - important in the discrimination of rock formations.

Band seven (10.40 to 12.50μm) - thermal infrared channel known to be contributory to vegetation classification, vegetation stress analyses, soil moisture discrimination, and a host of other thermally related phenomena.

LILLESAND & KIEFER, *supra* note 8, at 581-82.

The sensor records the earth's surface as a grid of energy values.[93]

2. Resolution

Resolution of an image refers to the level of detail possible for a given remote sensing system.[94] The dimension of each picture element, or pixel, determines this resolution.[95] Each pixel has a spectral value. Manipulation of images and possible distortion of the data set occurs when the individual pixel's spectral value is altered.[96]

The energy value for each section of the grid is captured on an array of receptors as the multispectral scanner progresses along routine paths above the earth's surface. The information is converted to digital format. Output from a scanning device is composed of pixels.[97] The area on the earth's surface (i.e., the section of the grid) represented by the pixel is determined by the aperture of the source and receiving optics used,[98] and the orbit or flying altitude of the platform.[99] The spatial characteristic, or pixel size, determines resolution, or width of the smallest object clearly distinguishable.[100] The smaller the pixel, the higher the resolution. Resolution of the most commonly used commercial satellite

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The TM channel bandwidths were selected primarily for agricultural management purposes. *See* HOLZ, *supra* note 2, at 350.

Photographic systems have a spectral range of 0.4 to 1.3μm, whereas the electronic detectors of multispectral scanners can range from 0.3 to 12.5μm and beyond. *See* WILKIE & FINN, *supra* note 4, at 65, 265, 273, and 21, Table 2.4.

93. *See* LILLESAND & KIEFER, *supra* note 8, at 458.

94. *See* WILKIE & FINN, *supra* note 4, at 270.

95. *See id.* at 268. The smaller the pixel, the higher the resolution.

96. *See id.* at 194-95.

97. *See* LILLESAND & KIEFER, *supra* note 8, at 349.

98. *See id.*

99. *See* Steele, *supra* note 28, at n.5 (angle of the satellite also affects the area represented by a pixel).

100. *See* Marks, *supra* note 9, at 23. The grid of receptors can be analogized to a piece of grid paper. The paper has a certain number of squares determined by the number of divisions, each square an element of the whole. An increase in the number of divisions on the paper results in smaller squares. If a picture is made by coloring each square a different color, the resulting image would be more detailed if made on grid paper with more divisions (i.e. result in a higher resolution). *See id.*

data currently available ranges from 10 meters to 80 meters.[101] The proposed systems scheduled for launch in 1997 will provide much higher resolutions, ranging from 1-3 meters for panchromatic data and 4-15 meters for multispectral data.[102]

Data currently available[103] is of somewhat gross resolution, which helps explain why the EPA uses the data primarily just as a screening tool.[104] Image resolutions have increased continually over the past twenty years: SPOT data are of better, higher resolution than Landsat data, Russian data are better than SPOT, and increases in resolution are promised for the future.[105] The commercial ventures previously mentioned are launching high resolution (1-3 meter) satellite systems scheduled beginning in 1997.[106] In addi-

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101. SPOT Panchromatic single band data has a 10 meter resolution, and SPOT Multispectral three band data has a 20 meter resolution. *See* SPOT, *supra* note 82. Landsat Thematic Mapper seven band data has a 30 meter spatial resolution, and Landsat Multispectral four band data has an 80 meter resolution. *See* EOSAT, *supra* note 42.

Advanced Very High Resolution Radiometer (AVHRR) data, available from the National Oceanographic and Atmospheric Administration, is the common weather data and has a resolution of 1.1 - 4 kilometers. *See* EOSAT, *supra* note 42. As further contrast, some military satellites are reputed to produce data with a resolution of between 7.17 centimeters and 23.23 centimeters. *See* Steele, *supra* note 28. Note: This comment does not provide a comprehensive survey of commercially available satellite data.

102. *See* Fritz, *supra* note 45, at 39.

103. In *Dow*, the court held that "highly sophisticated surveillance equipment not generally available to the public, such as satellite technology, might be constitutionally proscribed absent a warrant." *Dow Chemical Co.*, 476 U.S. at 237. Although data and technology which currently is commercially available is quite sophisticated, industry is in place to process data and provide technical support. *See generally*, PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, Professional Directory. In addition, per the Landsat Act, data is available to all interested purchasers. LANDSAT ACT, 15 U.S.C. §§ 4201-92. Unavailability of the technology is not the issue, unfamiliarity is.

104. *See* Videotape: EPA's Eye in the Sky (EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV 1988) [hereinafter Videotape: EPA's Eye in the Sky].

105. *See* Warren Ferster, *Looser Spy Imagery Rules Worry Industry*, SPACE NEWS, Dec. 18-24, 1995, at 3. Due to the end of the Cold War and release of significant amounts of Department of Defense imagery, the future of data availability is somewhat unclear). *See* Broad, *supra* note 43.

106. Telephone Interview with Dr. Eric Christensen, Applications Developer for EarthWatch (Oct. 4, 1995). Dr. Christensen stated that the EarthWatch

tion, airborne multispectral data (very high resolution) data are available through custom data acquisition.[107] Exponentially greater numbers of pixels are required for each increase in resolution.[108] The cost and logistics of data handling can affect data resolution choice.[109]

3. Repeated Geographic Coverage

Satellites pass over a given location every 16 to 26 days, with the SPOT satellite capable of revisiting a particular location seven times within its 26 day cycle.[110] Satellites pass at regular intervals, so investigation into the particular date and time of coverage is required to determine if the flyover coincides with the relevant date and time.[111] With the promise of a system that is capable of two to three data captures per day,[112] the likelihood of relevant data coverage is increasing. Images derived from several sources can be combined to depict the whole story. For satellites orbiting the earth, the time of coverage occurs at approximately the same time on each pass.[113] Satellites that remain focused on one position can provide useful time lapse images depicting change within a short time frame.[114]

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commercial satellite system will be capable of delivering 1 meter resolution Panchromatic data and 4 meter multi-spectral scanner data. *See id. See also* Fritz, *supra* note 45, at 39.

107. *See generally*, PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, Professional Directory.

108. *See* WILKIE & FINN, *supra* note 4, at 51-53.

109. *See* SPOT, *supra* note 82, and EOSAT, *supra* note 42, for a comparison of data coverage to price. *See also* Fritz, *supra* note 45, at 43 (summary of new satellite data and products available in the near future).

110. *See* Steele, *supra* note 28, at 319. *See also* Fritz, *supra* note 45, at 42 (Resource 21 satellite system proposes to provide two to three daily revisits).

111. Most inquiries into data availability can be conducted over the phone if the latitude and longitude of the four corners of the area of interest are known. *See* SPOT, *supra* note 82, and EOSAT, *supra* note 42.

112. *See* Fritz, *supra* note 45, at 42.

113. *See* LILLESAND & KIEFER, *supra* note 8, at 584.

114. *See id.* at 592. One example is the Geostationary Operational Environmental Satellites (GOES) weather satellites. *See id.* Geostationary (geosynchronous) orbit is defined as one that "matches the speed and direction of the earth's rotation so that a satellite remains over a fixed point on the earth's surface." *See* WILKIE & FINN, *supra* note 4, at 263.

4. Data Processing

Understanding the steps in data generation and processing is critical to the legal practioner who uses satellite data. Imagery derived from any digital data is either demonstrative evidence, illustrating the testimony to be offered by the expert who interprets the data, or it is real scientific evidence, offered as facts themselves.[115] A recurring theme in two experts' analyses[116] of forensic applications is that, in addition to the relatively easy tasks of having a qualified expert testify, authenticating and proving contents of the data, one must prove that the proper, accepted digital imagery processing techniques were employed.[117] Satellite data can be processed or "enhanced" in varying degrees to bring out features of interest to the investigator.[118] There are many methods of remote sensing image processing, some which create serious evidentiary characterization problems.[119] Therefore, one must be aware of the various methods of image processing. The processing of satellite data is described next to help the litigator understand how the data can be manipulated and how to process the data in a manner free from the risk of manipulation.

Satellite image production begins when the digital data are transmitted from the satellite to a receiving station on the ground and recorded on magnetic tape.[120] Data are archived at central distribution facilities and made available for purchase as raw data, corrected data, or photographic representations of the data.[121] Raw data are processed, or en-

115. *See* Roberts, *supra* note 33, at 102.

116. *See id. See also* Marks, *supra* note 9, at 20, 21.

117. *See* Marks, *supra* note 9, at 49-50. *See also* Jon Roberts & Charles Suits, *Admissibility of Digital Image Data: Concerns in the Courtroom*, 1995 ACSM/ASPRS Annual Convention & Exposition Technical Papers, at 165 [hereinafter Roberts & Suits].

118. *See* Marks, *supra* note 9, at 51.

119. *See* discussion of data processing, *infra*, Part II.B.4.

120. *See* LILLESAND & KIEFER, *supra* note 8, at 540. By contrast, Russian satellites acquire photographic film which is jettisoned down to earth at regular intervals. *See* Steele, *supra* note 28, at 317-18.

121. *See* SPOT, *supra* note 82. Raw data is information as the sensor detected it. Corrected data is adjusted for atmospheric and geographic "shifting."

hanced, for several reasons: (1) to clarify the visible contents; (2) to emphasize features without significantly altering the *content* of the data; and (3) to classify into a discrete number of surface feature categories from the original 256 values possible from the scanner.[122] Mere "enhancement" of the data is free from the interpretive manipulations, and processing of data can end at that stage.[123] On the other hand, "classifying" the data requires interpretation, and is subjective in nature.[124] Data processing cannot be held to one standard because techniques vary with application and data type.[125] One authority indicates that the EPA has not developed standard processing procedures, and any procedures used have been identified in the professional literature as non-standard.[126]

Processing to enhance the clarity of the visible contents usually involves the application of mathematical algorithms that clusters the pixel values that represent the edges of two surface features. The data usually are corrected geometrically and adjusted for atmospheric interference.[127] Such processes do not impact the validity of the data set or image produced because the processes are mathematically based and do not involve subjective interpretative manipulation of individual pixel values.[128] Additional enhancement is gained by emphasizing particular features through ratioing pixel values from two or more of the multispectral scanner chan-

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The photographic products for sale by SPOT are derived from corrected data. *See id. See also* Latin, *supra* note 14, at 1317.

122. *See* LILLESAND & KIEFER, *supra* note 8, at 562-63.

123. *See id.* at 558-59.

124. *See id. See also* Marks, *supra* note 9, at 53.

125. Telephone Interview with Phil Arberg, Scientist, Environmental Protection Agency (Oct. 17, 1995).

126. *See* Christopher D. Elvidge et al., *Relative Radiometric Normalization of Landsat Multispectral Scanner (MSS) Data Using an Automatic Scattergram-Controlled Regression*, PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, Oct. 1995, at 1255, 1260. Although specific data processing procedures are not defined within the EPA, the use of remote sensing is suggested for each step in an environmental protection investigation, in accordance with the *EPA National Enforcement Investigation Center Policies and Procedures* (1986). *See* Foresman & Williams, *supra* note 9, at 33-35.

127. *See* LILLESAND & KIEFER, *supra* note 8, at 558-59.

128. *See* Marks, *supra* note 9, at 51.

nels.[129] This process yields, by objective means, a different but extraordinarily useful image without manipulating individual pixel values within the data set.[130]

"Classifying" the data is different from processes that merely enhance the data.[131] The "suprevised" classification process is a series of interpretive decisions involving the grouping of the pixels of differing values together to make an image more understandable.[132] The classification of digital data is accomplished with the aid of aerial photograph interpretation, ground verification, or experience of the interpreter.[133] Important to the expert's interpretation of the data is verification through reference data of the area of interest.[134] A photographic representation then can be generated from enhanced or classified data for illustrative purposes.[135] Output also can be generated in the form of statistics, if so required.[136]

5. Costs

The legal practitioner should first consider the impact an image which clearly and concisely depicts a complex data set will have on the trier of fact. If nothing else can capture the meaning of the data as well as a satellite image, then "[t]he cost . . . [will be] insignificant in comparison to the benefit it can provide when it comes to winning a case."[137] Although "insignificant" to some, the purchase price of the raw satellite data, image processing costs, and expert fees for interpretation and testimony are major considerations for most liti-

129. *See* Latin, *supra* note 14, at 1440-41.

130. *See id.* at 1441.

131. *See* LILLESAND & KIEFER, *supra* note 8, at 562-63.

132. *See* Marks, *supra* note 9, at 51. The data originated as values ranging from 0 to 256. Classification is the process of altering or accentuating certain pixel values to highlight features of particular interest. *See id.*

133. *See* WILKIE & FINN, *supra* note 4, at 171.

134. *See* LILLESAND & KIEFER, *supra* note 8, at 24-25. Reference data include soils maps, crop statistics, or ground truthing in the field. *See id.* at 2.

135. *See* EOSAT, *supra* note 42.

136. *See* Marks, *supra* note 9, at 51.

137. *See* Steinberg, *supra* note 6.

gators.[138] Fortunately, the "[u]ses and forms of computer-generated graphics have developed over the years so that for all cases, depending upon subject matter, complexity and budget, one form or another of computer-generated evidence is available to the litigator."[139] Remote sensing made practical the required inspection of vegetation stress in a 1974 case involving the environmental and budgetary issues of the Cross-Florida Barge Canal.[140] Cases that involve assessment of conditions over a large geographic expanse are likely candidates for the application of satellite data and aerial photography.

The cost effectiveness of the data might depend upon how large an area is involved in the investigation and the level of detail required.[141] "[I]t is exceedingly important that the choice of image resolution be problem driven."[142] A satellite photograph with coverage over an area 5,000 square kilometers and resolution of 30 meters produced from Landsat Thematic Mapper is $2,700, a photograph with coverage over an area 2,000 square kilometers and a resolution of 2 meters digitized from Russian high resolution camera photographs is $3,500,[143] and a traditional aerial photograph with a cover-

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138. Interview with Robert F. Kennedy, Jr., Co-Director, Pace Environmental Litigation Clinic, Sept. 23, 1996. Cost examples are a photograph derived from SPOT data which costs $1,300 and covers an area 1400 sq. mi. and an aerial photo which may be as inexpensive as $200 but covers an area approximately 24 sq. mi. Therefore, aerial photography coverage of the area covered by one SPOT scene would cost about $12,000. *See* SPOT, *supra* note 81.

Advancements in digital data technology have reduced costs of systems and data dramatically. A satellite system that would have cost $1 billion 10 years ago can now be built for under $100 million. *See* Fritz, *supra* note 45, at 39.

139. Marshall S. Turner & Andrew T. Houghton, *Interactive Animations are Wave of the Future*, N.Y.L.J., Feb. 16, 1993, at § 1, at col. 5.

140. *See* Latin, *supra* note 14, at 1354 (citing Canal Authority v. Callaway, 512 F.2d 670 (5th Cir. 1975)) (remote sensing (aerial photography) cost-effectiveness was demonstrated in the litigation in which the health of hundreds of thousands of trees was at issue).

141. *See* WILKIE & FINN, *supra* note 4, at 51-53. In addition, advancements in digital data technology have reduced costs of the systems (and therefore the data) dramatically. *See* Fritz, *supra* note 45, at 39.

142. *See* WILKIE & FINN, *supra* note 4, 53.

143. *See* EOSAT, *supra* note 42.

age of approximately 24 square miles is about $200.[144] Increases in the area of interest and resolution result in increases in data processing costs.[145]

Perhaps more critical to the analysis of cost effectiveness is the information gained from the products. For example, multi-spectral scanner digital data from satellites provide information very different than photography gathered from aircraft. As mentioned earlier,[146] the multispectral scanner is specifically designed to provide distinct channels of information that give superior detection of various earth surfaces. Photography is photography, and as such, is limited to a spectral range much more narrow than multispectral satellite data.[147]

C. Forensic Application Concerns

1. Evidentiary Standards

Because the data can be manipulated and made to *appear* to provide all the answers, understanding of the technology's limitations and data availability is essential for proper legal application. Recently, a commercial satellite imagery company was investigated on suspicion of fraud for selling a bogus image purported to be taken at a critical moment of an alleged murder conspiracy.[148] The company claimed that the

144. *See* SPOT, *supra* note 82. However, aerial photography coverage of an area 1,400 square miles (coverage of one SPOT scene) would cost about $12,000. *See id.*

145. *See* WILKIE & FINN, *supra* note 4, at 51. Because the human eye is limited at some point in distinguishing detail and energy level depictions (the 256 shades of gray available from common sensors), "more data is not always synonymous with more information." *Id.* At some point very little extra visual information is provided. *See id.*

146. *See* discussion of the visible and beyond, *supra* part II.B.1.

147. At best, photographic systems have a spectral range of 0.4 to 1.3μm, whereas multispectral scanners found on satellite systems range from 0.3 to 12.5 μm and beyond. *See* WILKIE & FINN, *supra* note 4, at 65, 265, 273, and at 21, Table 2.4. However, if traditional photographic products (black and white, natural color, or color infrared) provide the spectral characteristics sufficient for the investigation, and the area of interest is not extensive, photography probably will provide the most cost effective illustrative tool and present the least evidentiary hurdles. *See id.* at 53-60.

148. *See* Warren Ferster, *Firm Suspected of Misrepresenting Imagery*, SPACE NEWS, Jan. 16-22, 1995, at 16 [hereinafter Ferster]. Psytep Corp. allegedly sup-

image was made from satellite data, when in fact it turned out to be an aerial photograph taken at a time not relevant to the case.[149] Although remote sensing and other digital image data such as computer simulation have proven to be valuable as evidentiary tools in enforcement actions and alternative dispute resolution, evidentiary concerns will remain. "[T]he admissibility of remote sensing information must be examined within the context of the general requirements for admission of scientific evidence and expert opinion . . . ."[150]

Remote sensing technology includes a variety of sensing techniques and applications, and the technology varies in its applicability to the legal setting. Evidentiary hurdles include foundation, chain of custody, and credibility issues.[151] In general, "[t]he reliability of evidence derived from a scientific theory or principle depends upon three factors: (1) the validity of the underlying theory, (2) the validity of the technique applying that theory, and (3) the proper application of the technique on a particular occasion."[152] Proper application of the scientific technique includes insuring proper working order of instrumentation, following proper procedures, and employing properly qualified persons using the technique and interpreting the results.[153] The evidence will be held to stan-

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plied the Kansas Bureau of Investigations a photograph which helped convince a grand jury that two murder suspects lied about their whereabouts at the time a murder was committed. The image came under suspicion when the Kansas Bureau of Investigation consulted with a few experts in remote sensing as to the resolution of the image. Psytep claimed they could take data capable of 18 meter resolution and enhance it to a resolution of 2 to 5 meters. When the bureau tried to verify the data in preparation for trial, they began to suspect fraud. Several experts told them that there currently is no commercial satellite capable of producing images of resolution high enough to detect automobiles. When authorities concluded that the image was a fake, they dropped the indictments against the murder suspects. *See id.* Psytep's CEO pleaded no contest to one count of false advertising and faces up to six months in jail. *See* Terry Hatcher Quindlen, *Sale of Bogus Imagery Draws $50,000 Fine*, SPACE NEWS, Jan. 8-14, 1996, at 2.

149. *See* Ferster, *supra* note 148.

150. Latin, *supra* note 14, at 1304.

151. *See* EDWARD J. IMWINKELRIED, THE METHODS OF ATTACKING SCIENTIFIC EVIDENCE *passim* (1982).

152. PAUL C. GIANNELLI & EDWARD J. IMWINKELRIED, 1 SCIENTIFIC EVIDENCE 1-2 (1993) [hereinafter GIANNELLI & IMWINKELRIED].

153. *See id.* at 33.

dards of logical and legal relevance, which the judge may determine with information beyond the bounds of the Federal Rules of Evidence.[154]

a. Reliability

Reliability is defined in terms of the data's accuracy and repeatability.[155] The distinction between accuracy and repeatability is rarely explicitly cited by the court, but scientific evidence has been ruled inadmissible if the margin of error was unacceptable.[156] Data processing techniques can impact the accuracy and confidence level.[157] Accuracies of 90% with 95% confidence can be obtained,[158] a level acceptable for civil and criminal trial application.[159]

The reliability of the data is most often brought into doubt when substantial human interpretation of the scientific evidence is required or the conditions under which the test (or data collection) occurred cannot be duplicated.[160] *In situ*[161] measurements or observations, known as "ground truthing," best support the validity of the remotely sensed data.[162] The acceptable margin of error can be identified and applied to a standard in quantitative terms.[163] Furthermore, the reliability of the remote sensing data must be compared

154. *See* FED. R. EVID. 104(a) (Questions of Admissibility Generally); FED. R. EVID. 401 (Definition of "Relevant Evidence"); FED. R. EVID. 402 (Relevant Evidence Generally Admissible; Irrelevant Evidence Inadmissible).

155. *See* Latin, *supra* note 14, at 1384.

156. *See id.*

157. *See* WILKIE & FINN, *supra* note 4, at 203-10. Confidence level is defined as the long run frequency with which a given value is outside a given parameter. *See* GIANNELLI & IMWINKELRIED, supra note 152, at 432.

158. *See* WILKIE & FINN, *supra* note 4, at 204.

159. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 155-56.

160. *See* Latin, *supra* note 14, at 1385. Some interpretation is required in remote sensing applications, but as with X-ray images, the court can be convinced that the image is one upon which it can rely. *See id.* at 1386.

161. *In situ* is defined as "in the original place." THE CONCISE OXFORD DICTIONARY 613 (1990).

162. *See* Latin, *supra* note 14, at 1386.

163. *See id.* at 1400.

to alternative methods of proof available.[164] In addition, judicial notice, on a case by case basis,[165] or legislative recognition, for all applications of the technique,[166] relieves the offering party of the burden of proving validity of the evidence type.[167]

b. Data Characterization

Satellite images can be characterized as charts, summaries, or calculations and allowed as evidence under FRE 1006.[168] However, the data may be presented also as an illustration of the expert witness' testimony.[169] If an enhanced image is considered independent evidence, the best evidence rule[170] applies, and the data must be authenticated according to FRE 901(b)(9).[171] The process or system cannot be held to one standard because processing techniques vary by application and data type (and time of day and year that data was received).[172] A single standard processing method has not been adopted by experts in this field.[173] FRE navigation skills are helpful in this venture. Enlargements of images produced are duplicates and usually are admitted easily under FRE 1001(4) and FRE 1003.[174] Local court rules should be considered when preparing images for exhibit in court, with an eye toward getting the image admitted into ev-

164. *See id.* at 1401. The comparison to alternative methods of proof will help support the use of satellite data which would "replace haphazard human inspections with systematic measurement and recording techniques." *Id.*

165. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 2.

166. *See id.* at 6.

167. *See id.* at 2.

168. *See* Latin, *supra* note 14, at 1443.

169. *See id.* at 1441.

170. The best evidence rule requires that an original writing, recording or photograph be used before a secondary source can be admitted. *See* FED. R. EVID. 1002.

171. *See id.* (FRE 901(b)(9) requires that the party present proof that the process or system used produces an accurate result).

172. *See id. See* discussion on data processing, *supra* Part II.B.4.

173. *See* Telephone Interview with Phil Arberg, *supra* note 125.

174. *See* FED. R. EVID. 1001(4) (Contents of Writings, Recordings and Photographs, Duplicate Defined) (included enlargements); FED. R. EVID. 1003 (Admissibility of Duplicates) (a duplicate is admissible to the same extent as an original under most conditions).

idence and into the record for appeal, if necessary.[175] Hearsay objections should be expected when the images produced from digital data are offered in court for the truth of the matter asserted.[176] The expert witness should be able to allay the hearsay credibility concerns.

c. Use of Expert Witness

Of particular concern to the practitioner proffering novel scientific evidence such as satellite imagery are the rules applicable to the expert witness. Although most potential jurors understand that great reliance is placed on X-ray images and weather satellite pictures, the use of multispectral scanner data is not mainstream. Thus, the expert with specialized training can assist the trier of fact.[177] The expert can provide her interpretation of the data if the basis of her opinion testimony is reasonably relied upon by experts in the remote sensing community,[178] even if the opinion goes to an ultimate issue in the case.[179] However, the expert must be prepared to disclose underlying facts or data supporting the opinion.[180] Finally, a state's general rule of competency will apply to the expert, as to any witness in a federal court.[181]

d. Chain of Custody

Per FRE 901(a), the chain of custody must be shown when the *condition* of the evidence is at issue,[182] a likely situation in the use of satellite data. The federal courts are split regarding chain of custody requirements under the FRE.[183]

175. *See* Gootee, *supra* note 29, at 247.

176. *See* Harlan J. Onsrud, *Evidence Generated from GIS*, 2-3 (1995). This unpublished article is an expansion, rewrite, and update of *Evidentiary Admissibility and Reliability of Products Generated from GIS*, which appeared in TECHNICAL PAPERS OF ACSM/ASPRS ANNUAL CONVENTION, Vol. 1, 1991, 197-201. GIS is an acronym for Geographic Information Systems.

177. *See* FED. R. EVID. 702 (Testimony by Experts).

178. *See* FED. R. EVID. 703 (Bases of Opinion Testimony by Experts).

179. *See* FED. R. EVID. 704 (Opinion on Ultimate Issue).

180. *See* FED. R. EVID. 705 (Disclosure of Facts or Data Underlying Expert Opinion).

181. *See* FED. R. EVID. 601 (General Rule of Competency).

182. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 199.

183. *See id.* at 208.

Links in the chain can be supported with certification of the data by the data supplier.[184] Some courts interpret FRE 901(a) to require sufficient proof that the evidence, in this case, satellite imagery, is what it purports to be.[185] Such proof can be provided by reference data in the form of data gathered on the ground, traditional aerial photographs, and maps.[186] In addition, FRE 406[187] can be used to support the chain of custody.[188] Also, a chain of custody document can be developed which allows a supervisor to confirm the chain.[189] The expert who processed the data is often in a position to provide testimony to most issues of chain of custody of the satellite data.

e. Admissibility of Novel Scientific Evidence Under *Daubert*

In the 1993 decision *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[190] the Supreme Court provided clear guidance for admitting novel scientific evidence.[191] The Court interpreted the FRE to require that "the trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable . . . ."[192] The Court held that FRE 702[193] superseded the "*Frye*" test[194] which had required for the previous seventy years a harsh "general acceptance" standard for testimony of scientific or technical evi-

184. Telephone interview with Dr. Oscar Huh, *supra* note 24.

185. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 207.

186. *See* LILLESAND & KIEFER, *supra* note 8, at 23-26.

187. FED. R. EVID. 406 (Routine Practice of Person or Organization).

188. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 212.

189. *See id.* at 1996 Supp. § 7-5, Methods of Proof.

190. 113 S. Ct. 2786 (1993).

191. *See id.* at 2795. Standards may vary under state's rules of evidence, but this discussion is limited to the FRE. Actions for violations of federal environmental statutes are allowed in federal court due to federal question jurisdiction, and as provided by statute. *See, e.g.*, 33 U.S.C. § 1365.

192. *Daubert*, 113 S. Ct. at 2795.

193. FED. R. EVID. 702 (Testimony by Experts).

194. In addition to the factors that the Court requires for acceptance of expert testimony under *Daubert* (reliable foundation and relevance), the standard under *Frye* includes a general acceptance of the technique by the professional scientific community. *See Daubert*, 113 S. Ct. at 2790.

dence by an expert.[195] The Court in *Daubert* relaxed the general acceptance requirement and held that novel scientific evidence can be admitted if the judge finds that the evidence is relevant, reliable, derived by scientific method, and supported by appropriate validation.[196] This comment is limited to evaluating the applicability of evidentiary standards under the FRE, and to providing suggestions for navigating those standards under current legal interpretations. However, the "Frye" test, followed by several states, requires review of, in addition to the elements under *Daubert*, the general acceptance level of the methods of the scientific investigation in the profession. This standard is also met by satellite data, as indicated by a survey of the professional literature in this field.[197]

2. Constitutional Issues

Constitutional concerns that arise when using remotely sensed data are in the arena of invasion of privacy and prohibition of warrantless searches. Until 1986, the leading case applicable to the standard of privacy in our high technology world was *Katz v. United States*.[198] In *Katz*, the Court declared the standard of privacy to be the reasonable person's expectation of privacy.[199] In 1986, in *Dow v. United States*,[200] the Supreme Court again addressed privacy rights in this ever-advancing world of high technology. The Court held that an aerial search of a large industrial complex for investigatory purposes did not violate the plaintiff's protection against warrantless searches or expectation of privacy.[201]

195. *See id.* at 2794.

196. *Id.* at 2790.

197. *See generally*, PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING, EARTH OBSERVATION MAGAZINE, and SPACE NEWS.

198. Katz v. United States, 389 U.S. 347 (1967). *Katz* established a standard that was intended to protect privacy in an environment of enhanced technology capable of surveillance without entry into the area inspected. *See* Gootee, *supra* note 58, at 54.

199. *See* 389 U.S. at 347.

200. 476 U.S. 227.

201. *See id.* at 237.

Society is aware of advancements in high technology and expectations of privacy are ever decreasing.[202]

Other possible areas of concern are violations of national security and industrial trade secrets. National security issues should not be of serious concern, however, because commercial satellite data vendors in this country must receive a license to operate a satellite system from the Federal Communications Commission in order to get off the ground.[203] In addition, the courts have upheld federal regulations that restricted access to satellite data over militarily sensitive areas during Operation Desert Shield.[204] Trade secret violations should be treated as an issue of privacy similar to the concerns for the individual.[205]

III. Navigating the Hurdles

Although a trial judge has the task of determining which evidence is reliable and relevant, a jury also will be exposed to the evidence that has been admitted. Any such evidence must be comprehensible to be credible.[206] Therefore, in jury trials, the foundation laid for the judge regarding the type of evidence to be admitted should be made with the jury in mind. Each trier of fact needs a brief introduction to the principles of remote sensing and image processing and interpretation. Illustrations of common applications of the princi-

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202. *See* Steele, *supra* note 28, at 333. Steele cautions against "bringing Orwell's vision closer to reality . . . ." *Id.*

203. *See* Jo Treadwell, *EarthWatch Obtains FCC License*, PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING, Oct. 1995, 1195.

204. *See* Nation Magazine v. United States Dep't of Defense, 762 F. Supp. 1558, 1580 (S.D.N.Y. 1991).

205. Although the Supreme Court of Indiana addressed concerns for trade secret protection involving the use of remote sensing in a 1993 case involving a company conducting oil exploration, the real trade secret protection issues there were the management decisions that led up to the use of the remote sensing data and the focused geographic areas of the remote sensing investigation. *See Amoco*, 622 N.E. 2d, at 912.

206. *See Morning Edition: DNA Evidence Often Too Complex for Jurors* (NPR radio broadcast, Oct. 17, 1995). A major weakness in the prosecution's use of DNA evidence in the O.J. Simpson trial was the presentation. *See id.* If jurors do not understand experts, especially disagreeing ones, they tend to ignore the evidence and rely on their own common sense observations. *See id.*

ples will help connect the unfamiliar technology to the collective "everyday" experience. Although the technology is sophisticated, if data control is assured and the evidence is presented properly, a juror could feel comfortable relying on the data.[207] Furthermore, presenting the basic principles as a solid foundation is crucial for the acceptance of novel scientific evidence.[208]

A. Getting the Satellite Data Into Evidence: A How-To Guide

1. Planning and Preparation

From the initial moment of considering the use of remotely sensed data, steps should be taken to assure acceptance of the evidence by the judge and the jury. As any scientist or engineer using satellite data would begin an environmental investigation, so must the legal practitioner. Use of any remotely sensed data, including satellite data, should be planned, considering, at a minimum:

> (1) clear definition of the problem at hand, (2) evaluation of the potential for addressing the problem with remote sensing techniques, (3) identification of the remote sensing data acquisition procedures appropriate to the task, (4) determination of the data interpretation procedures to be employed and the reference data needed, and (5) identification of the criteria by which the quality of information collected can be judged.[209]

The legal practitioner who uses satellite data will meet greater opposition than the scientist or engineer meets. Where the scientist might be opposed for the sake of science, be it for theoretical or applied scientific concerns, and the engineer might be opposed for the sake of project solution, the legal practitioner will be opposed for the sake of one or more parties' liberty or property. Opposing counsel might attack

207. Telephone Interview with Dr. Joanne Gabrynowicz, Professor, Remote Sensing Law and Policy, *University of North Dakota* (Nov. 4, 1995).

208. *See id.*

209. LILLESAND & KIEFER, *supra* note 8, at 30.

the "credentials of the expert offering the testimony, the procedures used to arrive at the data being presented and whether the techniques being used in evaluating data are those generally used by the profession for the task at hand."[210] Therefore, the satellite data expert must be a worthy proponent of the evidence and be knowledgeable of the evidentiary hurdles to be encountered. Preparing the expert to address the concerns of the court and opposing counsel should be a repeat of the steps the legal practitioner takes in determining that satellite data serves as evidence helpful in making her case.

2. Connecting With the Trier of Fact

Connecting with the fact finder is key to successful use of satellite data as evidence. The expert must teach the jurors the general principles and convince them of the validity of the technology.[211] The legal practitioner working with the satellite data expert must establish convincing answers to several questions. First, is this expert qualified to testify about the technology of satellite data and its applications? The "knowledge, skill, experience, training, or education"[212] and participation (including publication of peer reviewed articles) in professional organizations impress a trier of fact that the expert is reasonably reliable.[213] Next, is the testimony that the expert is providing regarding the satellite data reliable? At the risk of becoming too technical, the expert should, when appropriate and helpful, demonstrate to a trier of fact that the data are "of a type reasonably relied upon by experts in the particular field in forming opinions or inferences . . . ."[214] The expert can explain that this data has been relied upon by military and civilian government agencies and businesses for years, and the fact finder also can be comfortable relying upon the data. The expert must be prepared to disclose un-

210. Roberts & Suits, *supra* note 117, at 161.
211. *See* EDWARD J. IMWINKELRIED, EVIDENTIARY FOUNDATION 136 (1980).
212. *See* FED. R. EVID. 702 (Testimony by Experts).
213. THOMAS A. MAUET, FUNDAMENTALS OF TRIAL TECHNIQUES 121-22 (1992).
214. FED. R. EVID. 703 (Bases of Opinion Testimony by Experts).

derlying or background facts or data to the opposing counsel.[215]

Hearsay rules apply when the images are being offered for the truth of the matter asserted by the expert.[216] The business records exception under FRE 803(6) provides that the data gathered in a routine manner of the organization's everyday activity are reliable and are allowed despite their hearsay nature.[217] Satellite data used to make the images are gathered on a frequent and regular basis[218] and thus meet the requirements of the business records exception.

Another question in the minds of the triers of fact might be whether the satellite data (and the image produced from the data) have been manipulated to appear to illustrate what the proponent wants, or is it an accurate representation of the data the satellite captured? The expert should ensure that the data set was properly handled by the satellite data collection company, the transporter of the data (by inspection of the data upon arrival, or perhaps by certification),[219] and that the processing and interpretation by the expert has a basis in scientific method with appropriate validation.[220] The chain of custody should be demonstrated, including a showing that data security within the workplace was maintained at all times. The expert should provide supporting evidence of the validity of the satellite data. Supporting evidence includes accurate maps (e.g., maps prepared by the United States Geological Survey), aerial photography, and sample measurements or observations (including photographs) taken

215. *See* FED. R. EVID. 705 (Disclosure of Facts or Data Underlying Expert Opinion).

216. *See* FED. R. EVID. 801(c) (Definitions). *See also* Onsrud, *supra* note 176.

217. *See* FED. R. EVID. 803(6) (Records of Regularly Conducted Activity).

218. *See* WILKIE & FINN, *supra* note 4, at 31.

219. *See* GIANNELLI & IMWINKELRIED, *supra* note 152, at 203-06.

220. *See Daubert*, 113 S. Ct. at 2795. *See supra* note 194 for an explanation of the *Frye* standard. A review of the remote sensing professional literature makes it clear that earth observation satellite technology has many valid applications. *See generally,* PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING, EARTH OBSERVATION MAGAZINE; SPACE NEWS.

on the ground by experienced trained scientists that verify the interpretation results that the expert has reached.[221]

Presenting aerial photography to support the validity of the satellite data also helps tie the novel science to the familiar experiences of a juror or judge. Making incremental steps that include the everyday experience enables a fact finder to make only a small leap to the unfamiliar satellite technology. The use of aerial photography and photography taken at ground level as evidence is common,[222] familiar, and comfortable. A fact finder does not feel foolish relying on what others have done before or what he can sense himself (as if he were viewing the earth from a plane).

But the leap to accepting satellite data, which "sees" beyond the visible portion of the electromagnetic spectrum, is risky if the fact finder is not given some demonstration that reasonable people rely on such data. A very common example of images made with data beyond the visible portion of the spectrum most people can grasp is X-ray pictures.[223] A brief explanation of the electromagnetic spectrum would be helpful.[224] The expert can explain how energy is emitted in various wavelengths—some wavelengths that our eye cannot see, but that the sensor can detect. Just as the family dog can detect sounds that the human ear cannot hear, the multispectral scanner flown on a satellite can detect energy that the human eye cannot see. The expert can also provide examples of business and government relying on satellite data,[225] which is particularly helpful if the data is the exact same type or it relies upon the same principles. Finally, data processing steps need to be explained in terms that at least the average personal computer user can understand. Prefer-

221. *See* Foresman & Williams, *supra* note 9, at 39.

222. Hundreds of cases over the past forty years reported using aerial photography as evidence. Search of WESTLAW, Allfeds and Allstates Libraries (Apr. 18, 1997).

223. Telephone Interview with Dr. Joanne Gabrynowicz, *supra* note 207.

224. *See* Latin, *supra* note 14, at 1308. The authors provide an excellent diagram of the electromagnetic spectrum clearly indicating the spectral bands, including the x-ray, visible (to the human eye) light and other spectral band wavelengths selected for use in multispectral scanners. *See id.*

225. *See* discussion of applications to date, *supra*, part II.A.2.

ence should be given to using the data processing techniques that do not impact the validity of the data set or image.[226]

B. Forensic Potential of Satellite Data

Congress provided within the Land Remote Sensing Commercialization Act of 1984 that agencies are encouraged to incorporate satellite data into their activities,[227] thus indicating confidence in the validity of the data. "While the question of specifically *what* the problem is can generally be evaluated only by detailed ground observation, the equally important questions of *where*, *how much*, and *how severe* can often be best handled by remote sensing analysis."[228] Often the question of *when* can also be answered by remotely sensed satellite data.[229] Remote sensing information is useful in litigation:

> (1) to document conditions over a large or inaccessible geographical area, (2) to document transient or intermittent conditions, and (3) to provide a visual representation of conditions primarily documented by more conventional types of evidence.[230]

1. Future In-Court Applications

Based on successful in-court and out-of-court applications,[231] the technology is just a small step away from widespread use in the court room. For example, data used to convince the United Nations to act in Bosnia or for an oil company to make substantial investments for exploration have the mark of reliability which surpasses a preponderance of

226. *See* discussion of data processing, *supra* at part II.B.4.

227. LANDSAT ACT, 15 U.S.C. §§ 4201-92.

228. LILLESAND & KIEFER, *supra* note 8, at 31 (emphasis in the original).

229. Telephone interview with Terrence Slonecker, *supra* note 86. Mr. Slonecker stated that archived aerial photography was used to determine when barrels had been deposited at a Superfund site. *See id.*

230. Latin, *supra* note 14, at 1349.

231. *See* discussion of applications of satellite data, *supra* part II.A.

the evidence and in some cases, are reliable beyond a reasonable doubt.[232]

Regardless of the scarcity of cases reporting the use of satellite data as evidence, numerous authorities have made a call for increased satellite data applications in the area of environmental law. The applications of data will spur some activity,[233] as will recognition of the power of satellite data to provide unique historical perspectives.[234] Litigation areas identified include cases involving pollution monitoring, environmental impacts assessment of of development activities, determination of land and water boundaries, wetlands mapping,[235] and detection of agricultural subsidy fraud.[236]

Multiple date data sets can be entered into a Geographic Information System (GIS) which relates all information to its geographic coordinates.[237] A GIS is a computer data base management system that allows multiple sources and types of geocoded data, including satellite multispectral scanner data sets, to be entered and analyzed.[238] By comparing the earth's reflected energy value that the satellite has detected for the pixels on one data set to the pixel values that correspond geographically from a subsequent data set within a

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232. *See* discussion of reliability of evidence, *supra* part II.C.1.a.

233. *See* Lamont C. Hempel, *EPA in the Year 2000: Perspectives and Priorities*, 21 ENVTL. L. 1493, 1501 (1990) (NASAs Mission to Planet Earth program will generate huge amounts of satellite data).

234. *See* Foresman & Williams, *supra* note 9, at 40.

235. *See* Latin, *supra* note 14, at 1349-64.

236. *See* Joanne I. Gabrynowicz, REMOTE SENSING LAW: OBSTACLE OR OPPORTUNITY FOR GEOGRAPHIC INFORMATION SYSTEMS?, (visited Apr. 28, 1997) <http://www.spatial.maine.edu/tempe/gabrynowicz.html> (stating that the European Community has adopted a policy to use satellite data to apprehend and to prosecute the perpetrators).

237. *See* Graffagnini, *supra* note 76, at 4-5.

238. *See* Videotape: EPA's Eye in the Sky, *supra* note 104. GIS technology, like other remote sensing related technologies, has advanced greatly over the past 10 years. Much of the data management can be accomplished on a reasonably affordable computer hardware. *See id.* Many third world countries are using GIS and satellite technology to best use their limited resources. *See* Ake Rosenqvist, *Magical Views of Amazon Rain Forest*, EOSAT NOTES, Fall/Winter 1995, at 6.

GIS, the computer system can detect exactly which areas appear to have changed.[239]

The growth of satellite data use (assessment, remediation, and restoration) is predicted for the area of military installations and chemical manufacturing companies for three key reasons.[240] Those key factors are:

> 1) many Department of Defense and Department of Energy projects are now entering the cleanup phases of their life cycles, 2) Congress has ordered the closure of a number of military installations, and 3) the Clean Air Act [and other environmental statutes are] requiring private industry to meet stronger emission regulations and guidelines.[241]

Another area of great potential for application of satellite data is in the identification of potentially responsible parties for purposes of hazardous waste cleanup enforcement under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980.[242] Pursuant to 42 U.S.C. § 9607(a)(4) (1988), CERCLA strict liability flows to past and current owners and operators of the site. Archived satellite data of the property on particular dates can provide evidence of activities that indicate the actual responsible party. Relatedly, the innocent purchaser defense to CERCLA liability should probably be denied parties who customarily use satellite data in their business management practice but fail to employ it in a pre-purchase audit. In addition to use in the courtroom, satellite data is a invaluable tool in pre-trial

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239. *See* Teply & Green, *supra* note 12. This process is commonly referred to as change detection. *See* WILKIE & FINN, *supra* note 4, at 209-10.

240. *See* GRAFFAGNINI, *supra* note 76, at app. (the author, an environmental consultant with Addax Corporation, participated in the NASA Visiting Investigator Program to develop techniques to more effectively conduct environmental assessments).

241. *Id.*

242. Comprehensive Environmental Response, Compensation and Liability Act of 1980 ("CERCLA"), 42 U.S.C. §§ 9601-75. Applications of satellite data also would be beneficial to the disposition of cases between potentially responsible parties who sue one another to collect cleanup costs after a CERCLA enforcement.

discovery and settlement activities.[243] Because satellite data has such great legal application potential, one authority has made a call to bring the legal community into the satellite data collection system planning process for identification of user requirements.[244]

2. Reasons Technology Is Not There Yet

The under-utilization of satellite technology for forensic purposes can possibly be explained by several phenomenon. One expert proposes that cases in which satellite imagery is introduced during discovery subsequently settle out of court because the data is so convincing.[245] The data have been used frequently to assess liability in cases that have settled.[246] Ironically, the images have been disdained for being too revealing.[247] In one instance, a mining company in Nevada detected a plume of arsenic dust using remote sensing while conducting a mineral exploration. The company refused to further use the data set "for fear that the government would take legal action against it for pollution it didn't cause."[248] On the other hand, many mining companies are using satellite data to develop baseline studies before buying

243. Telephone Interview with Dr. Oscar Huh, *supra* note 24; Telephone Interview with George Wilkinson, Esq., Vinson & Elkins, Houston, TX (Nov. 4, 1995) [hereinafter Telephone Interview with George Wilkinson]; SPOT, *supra* note 81.

244. *See* Marks, *supra* note 9, at 67.

245. Telephone Interview with Dr. Oscar Huh, *supra* note 24. Dr. Huh provided imagery that was used in a case of a highjacked oil ship that was taken to Greece. *See id.* The action brought by the insurance company was successfully settled out of court because the imagery was so compelling as to location of the vessel and evidence of oil loss after an accident. *See id.* (referring to Bereson v. New Castle, 38 N.Y.2d 102, 341 N.E.2d 236, 378 N.Y.S.2d 672).

246. Telephone Interview with George Wilkinson, *supra* note 243. Mr. Wilkinson stated he did not know of in-courtroom applications of digital remote sensing data by anyone in his firm, but the data has been used in assessing liability for planning settlements. *See id.* This is not to say that the data is so compelling (that is, incriminating) that the firm recommends settlement based on the imagery alone. *See id.* Mr. Wilkinson merely stated that settlement occurred on those cases for one reason or another. *See id.*

247. *See* Hough, *supra* note 25. Conversely, the EPA uses the data primarily just as a screening tool. *See* Videotape: EPA's Eye in the Sky, *supra* note 104.

248. Hough, *supra* note 25, at 37.

new property.[249] This seems to be an appropriate putting of the horse before the cart. An industry participant sophisticated enough to use the data for mineral exploration perhaps should be held to a similar investigation as a measure of due diligence or appropriate inquiry by a purchaser of property.[250]

Another explanation for the under-utilization mentioned earlier is the unfounded concern over the potential invasion of privacy. Finally, unawareness of satellite data availability and lack of appreciation of the evidentiary value could explain the under-use. As the new higher resolution data come on-line in 1997, the applications and visibility of the technology will grow rapidly.

3. Overcoming the Hurdles

Five main issues are either the obstacle or the key to the furtherance of satellite data applications for litigation. First, by taking heed of the lessons learned by others proffering novel scientific evidence such as DNA data, the practitioner using satellite data can follow tried methods. Those methods have been presented here. Second, by connecting the technology that is beyond the ken of the average juror with their common day experiences, the litigator gives the trier of fact evidence they can understand and rely on.

Next, it is best to be conservative with the data application. Work toward attaining the highest accuracy and confidence level possible. The litigator must plan the use of satellite data as evidence much the same way the engineer or scientist would. Relatedly, do not oversell yourself or the jury on the power of the data. It cannot solve all problems.

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249. *See id.*

250. The innocent landowner defense can only be claimed if the owner undertook "appropriate inquiry" when she bought the property. *See* CERCLA, 42 U.S.C. § 9601(35)(B). It is unclear what is required as appropriate inquiry. *See* DONALD C. NANNEY, ENVIRONMENTAL RISKS IN REAL ESTATE TRANSACTIONS 325-26 (1993). A Phase I Environmental Audit usually consists of a physical inspection of the property, a title search, a review of government records of the property, and a review of archived aerial photographs. If problems are suspected, *in situ* measurements are taken and analyzed, achieving a Phase II Environmental Audit. *See id.* at 341-43.

IV. Conclusion

"Satellite Remote Sensing is just crossing the threshold into maturity . . . ."[251] Earth observation satellite technology is not a junk science, and this comment has told the litigator how to use the data properly to ensure successful acceptance as evidence. Prudence is essential in the application of satellite data, and the legal practitioner must keep an eye toward several areas of concern including reliability of the particular data set, characteristics of the data, and costs.

Remote sensing data are desired as both scientific and demonstrative evidence. The litigator must have the expert prepared to address concerns of the opponent and the court. The call has been made to bring the legal community into the planning process for identification of user requirements, as has occurred in other satellite data user communities. This comment has explained some of the reasons satellite data have not had a major entry as evidence in the courtroom, mainly success of the satellite imagery in pre-trial settlement actions and unfamiliarity with the satellite data technology. Following the practical guidelines presented in this paper will facilitate the practitioner in the appropriate and successful use of satellite data, a technology that is ripe for litigation application.

251. Fritz, *supra* note 45, at 39.