MOVING PICTURES: HOW SATELLITES, THE INTERNET, AND INTERNATIONAL ENVIRONMENTAL LAW CAN HELP PROMOTE SUSTAINABLE DEVELOPMENT*

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Despite — or perhaps because of — the so-called information age, what's required now is a Jeffersonian approach to the environment.

Al Gore[1]

One of the great values of satellite[s] is synoptic perspective; . . . if you're using a satellite to look . . . closely, you may as well get . . . close, unless you want to do it [in] somebody[ ] else's country, . . . that's another story.

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1. AL GORE, EARTH IN THE BALANCE: ECOLOGY AND THE HUMAN SPIRIT 204 (1992).

Frederick B. Henderson, III[2]

[P]rimates are visual animals above all.

Stephen Jay Gould[3]

I. INTRODUCTION

Remote sensing and other digital earth science data has an increasingly important role to play in keeping industrial development within the limits of the biosphere, and in achieving sustainable development. There are two reasons for this. The first is the improving ability of remote sensing technologies to provide useful data and information in connection with a wide spectrum of ecological conditions. The second is the increasing need for this earth science data as unsustainable development brings us closer and closer to the limits of the biosphere and reduces the margin of safety that separates us from global environmental disaster.

To use the stoplight analogy, we are now in the amber zone of global environmental danger, and we need to proceed with the utmost caution. We need the most sophisticated techniques of science and technology to show us how close we are in relation to the limits of the biosphere, and help us from running the red light.

The successful development of international environmental law, like all environmental law, requires, not only scientific tools to identify actual or likely environmental trouble, but also effective means for such concerns to be communicated to the public and to public policy makers in ways that spur regulatory action.[4] It is only with

2. Fredrick B. Henderson, III, *Remote Sensing Technologies, Users and Applications, in* EARTH OBSERVATION SYSTEMS LEGAL CONSIDERATIONS FOR THE `90S, at 123 (1990).

3. STEPHEN JAY GOULD, WONDERFUL LIFE: THE BURGESS SHALE AND THE NATURE OF HISTORY 17 (1989).

4. This paradigm has been clear at least since the environmental movement's early success banning the toxic pesticide DDT. *See* Frank B. Cross, *Paradoxical Perils of the Precautionary Principle*, 53 WASH. & LEE L. REV. 851, 870 (1996). Scientists studying industrial chemicals and their effects discovered that DDT had serious toxic effects on birds and other animals. *See* Elizabeth B. Baldwin, *Reclaiming Our Future: International Efforts to Eliminate the Threat of Persistent Organic Pollutants*, 20 HASTINGS INT'L & COMP. L. REV. 855, 856–57 (1997). Furthermore, Rachel Carson eloquently and powerfully educated the public about DDT with SILENT SPRING (1962), leading to the popular and political consensus necessary to ban the pesticide in the United States. *See* Allan Mazur, *Why Do We Worry About Trace Poisons?*, 7 RISK: HEALTH, SAFETY & ENV'T 35, 36 (1996).

real-time feedback of earth science data that our political, legal, and industrial systems will be able to respond in time to keep us within the limits of the biosphere.

Satellite data occupies important territory at the crossroads of scientific, educational, and legal information, promising a new kind of powerful eloquence for informing the public and those who make public policy about the environment.[5] The convergence of two trends makes this an exciting time in the development and use of satellite data. First, the sophistication and resolution of publicly available satellite images and data are set to significantly improve as new sensor equipment goes aloft and new tools are developed to utilize their output. Second, national and international environmental law and policy increasingly address concerns that cross political and geological boundaries and emphasize more than ever global ecosystem management with worldwide efforts to address issues such as desertification,[6] the preservation of biological diversity,[7] sustainable forest management,[8] protection of stratospheric ozone,[9] and climate

5. Paul F. Uhlir, *Applications of Remote Sensing Information in Law: An Overview, in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE `90S, *supra* note 2, at 8, 16–17. According to Uhlir,

> Remote sensing data will promote a more profound understanding of our planet's ecosystems and improve our predictive capabilities for better environmental management on national, regional, and international levels. Such information will challenge world leaders to establish appropriate environmental legislation and treaties, following the model of the Convention for the Protection of the Ozone Layer. And . . . new geographic information systems, which use remote sensing and other sources of data to form highly sophisticated data bases [sic], will become instrumental in developing more rational zoning and land use regulations.

Id.

6. *See generally* United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, June 17, 1994, U.N. Doc. A/AC.241/15/Rev.7, *reprinted in* 33 I.L.M. 1328 (1994) [hereinafter Convention to Combat Desertification] (outlining an integrated approach to combating desertification and mitigating the effects of drought).

7. *See generally* United Nations Conference on Environment and Development: Convention on Biological Diversity, June 5, 1992, 31 I.L.M. 818 (entered into force Dec. 29, 1993) [hereinafter Convention on Biological Diversity] (emphasizing a collective approach to the conservation of biological diversity, the sustainable use of its components, and the equitable sharing of the benefits of utilizing genetic resources).

8. *See Progress on Implementation of the Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests*, Feb. 5, 1997 [hereinafter *Montreal Process*] ("Forests are essential to the long-term well being of local populations, national economies, and the earths' biosphere as a whole."); United

change.[10] The potential for ecological data to inform environmental awareness, to serve as a starting point for the creation of soft law, to measure behavior, to facilitate the creation of appropriate treaties or customary law, and to monitor compliance makes increased access to satellite data an enormously promising development for international environmental law and sustainable development.

This Article discusses the value of satellite remote sensing information in connection with the development and implementation of fundamental normative principles of international environmental law — norms that often find expression in dynamic, but loose, expressions of values and goals — rather than contractual obligations between states. Such normative expressions, or "soft law," carry neither the formal weight of treaty obligations nor, in many cases, the imprimatur of customary law as classically defined. Soft law allows greater flexibility and more rapid adjustment to changing technological and ecological circumstances. However, because soft law lacks treaties' legal weight or the imprimatur of customary international law, it allows states and other international actors to espouse good intentions without meaningful efforts to alter their

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Nations Conference on Environment and Development: Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests, June 13, 1992, U.N. Doc. A/CONF.151.6/Rev.1, *reprinted in* 31 I.L.M. 881, 883 (1992) (stating that "forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual human needs of present and future generations").

9. *See generally* Montreal Protocol Parties: Adjustments and Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer, June 29, 1990, 30 I.L.M. 537 (entered into force Aug. 10, 1992); United Nations Protocol on Substances that Deplete the Ozone Layer, Sept. 16, 1987, 26 I.L.M. 1541 (entered into force Jan. 1, 1989) [hereinafter Montreal Protocol] (establishing specific obligations to limit the use of chemicals that deplete the ozone layer); Vienna Convention for the Protection of the Ozone Layer, Mar. 22, 1985, T.I.A.S. 11097, *reprinted in* 26 I.L.M. 1516 (1987) (providing for both cooperation in the research and development of control measures and implementation of policies regarding the human activities that impact the ozone layer).

10. *See generally* Conference of the Parties to the Framework Convention on Climate Change: Kyoto Protocol, Dec. 10, 1997, U.N. Doc. FCC/CP/1997/L.7/Add.1, *reprinted in* 37 I.L.M. 22 (1998) [hereinafter Kyoto Protocol] (encouraging the prevention of "dangerous interference with the climate system by limiting the emission of greenhouse gases into the atmosphere); United Nations Conference on Environment and Development: Framework Convention on Climate Change, May 9, 1992, 31 I.L.M. 849 (1992) (entered into force Mar. 21, 1994) [hereinafter Framework Convention on Climate Change] (establishing principles for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system").

behavior.

Comprehensive global coverage by satellites and other geographic monitoring and study tools present the international community with exciting, but not entirely unproblematic, opportunities to enhance monitoring of both global ecological status and states' compliance with international treaties, customary laws, and soft law principles. This global monitoring capability can lead to more precise and effective international environmental management and broader civil society participation in defining and monitoring sustainable development.

This Article also discusses the important roles for nongovernmental organizations (NGOs) and the public in connection with the use and dissemination of satellite data and in monitoring global ecological health and compliance with international environmental law. Along with this discussion, we introduce a collaboration between the Center for International Environmental Law (CIEL), the Center for Excellence in Space Data and Information Sciences (CESDIS) at NASA's Goddard Space Flight Center, and the Library of Congress funded by the National Aeronautics and Space Administration (NASA).[11] The collaboration aims to help integrate research, analysis, and use of satellite data in environmental law and policy.

II. SOFT, MEDIUM, OR FIRM?

In a wide variety of applications, international environmental law is increasingly developing along lines that initially emphasize normative goal-setting and flexible negotiated partnerships between and among states pursuant to what scholars call "soft law" processes.[12] Such "soft" processes are more normative, declarative, and subject to "constant renegotiation" than either form of classical international law — treaty or customary law.[13]

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11. *See* discussion *infra* Part VI. *See generally* NATIONAL RESEARCH COUNCIL, TOWARD AN EARTH SCIENCE ENTERPRISE FEDERATION: RESULTS FROM A WORKSHOP (1998) (establishing a framework to enable optimum ways to develop, produce, and distribute environment information and to provide associated services to science and society).

12. *See, e.g.*, Pierre-Marie Dupuy, *Soft Law and the International Law of the Environment*, 12 MICH. J. INT'L L. 420, 428 (1991).

13. As classically conceived, customary international law is that which is not found in explicit treaties, but nevertheless can be induced from consistent state practice and

Several factors account for this. First, the activities of international organizations like the United Nations and its various organs, together with proliferating NGOs, facilitate ongoing negotiations and the promulgation of evolving understandings of duties and responsibilities. Second, the increasing diversity of the international community (with the rise since the 1950s of post-colonial developing nations as state actors) necessitates broader and more complex negotiations in international relations. And third, integration of the world economy and the rapid growth of technologies that influence both our relationship to ecology and our ability to communicate with each other creates pressure for more dynamic, faster-moving forms of international environmental negotiation.[14]

Expressions of soft law appear in ethical guidelines and policy prescriptions, rather than in formal legal obligations — "shoulds" rather than "shalls." These soft expressions of international environmental law include the 1972 Stockholm Declaration,[15] the Rio Declaration,[16] and Agenda 21 that resulted from the 1992 United Nations Conference on the Environment and Development.[17] Ideally, soft law develops into firmer customary laws or norms as states act to implement such norms including, without limitation, the duty to avoid transboundary environmental harms, the duty to conduct and share the results of environmental impact assessments for potential transboundary harms, the duty to transfer technology to other coun-

some clear expression of legal obligation to explain it. *See* Daniel Bodansky, *Customary (and Not So Customary) International Environmental Law*, 3 IND. J. GLOBAL LEGAL STUD. 105, 108 (1995). The soft law expressions of international environmental goals and guidelines may be understood as the declarative aspects of customary law without necessary anchoring in consistent state practice. *See id*. at 110–19.

14. *See* Dupuy, *supra* note 12, at 421.

15. United Nations Conference on the Human Environment, June 16, 1972, U.N. Doc. A/CONF.48/14, *reprinted in* 11 I.L.M. 1416 (1972) [hereinafter Stockholm Declaration] (recommending numerous measures for the "preservation and enhancement of the human environment").

16. United Nations Conference on Environment and Development: Rio Declaration on Environment and Development, June 13, 1992, U.N. Doc. A/CONF.151.5/Rev.1, *reprinted in* 31 I.L.M. 874 (1992) [hereinafter Rio Declaration] (delineating a series of principles established to "protect the integrity of the global environmental and developmental system").

17. United Nations Conference on Environment and Development, Agenda 21, Annex II, ¶ 1.6, U.N. Doc. A/CONF.151/26 (1992), *available at* <gopher://gopher.un.org/00/conf/unced/English/re_vol1.txt> (visited Mar. 12, 1999) [hereinafter Agenda 21] (commenting on Agenda 21's intent to be flexible and dynamic).

tries to aid in environmental preservation, and the duty to take precautions despite the scientific uncertainty (otherwise known as the precautionary principle).

The vitality and flexibility of soft law should not relieve the international community of concerns about its meaningful implementation. By delinking legalistic expression of norms on the one hand and inquiring into whether such norms are in fact followed on the other, soft law has moved beyond the limitations of classical customary law, but permitted the perpetuation of nonconforming practices in the face of clear expressions of goals and values. How valuable the development of soft law can be depends ultimately on the extent to which it leads to more effective action on the part of states and other international actors. It has been noted, too, that lawyers may be doing a particularly poor job of distinguishing between window-dressing expressions of adherence to normative principles, on the one hand, and actual consistent practice that would lead to the formation of customary international law on the other. As articulated by Daniel Bodansky: "If we really wanted systematic surveys of state practice, anthropologists and historians would likely do a better job."[18] To Bodansky's anthropologists and historians, we should soon be able to add remote sensing experts and the lawyers who learn to work with them.

The increased availability of satellite remote sensing data, not just to governments with the technical capability to gather it, but to developing countries, academics, NGOs, and international organizations, would be a welcome new development. Such data can help inform both the creation of new soft law and its gradual incorporation into the serious obligations of the international community in the face of global ecological threats. Soft law can then be the means through which ecological concerns are documented, appropriate norms are developed, and states' compliance with their own normative expressions are observed. Ongoing, dispassionate observations from satellites can provide practical measuring sticks against which to hold international actors ethically accountable and, perhaps, legally accountable as well. Such compliance or non-compliance can then form the basis of further negotiations and lawmaking.

Because the development of international environmental law

18. Bodansky, *supra* note 13, at 113.

from soft law through the establishment of customary norms and treaties involves a broader range of participants than simply state actors, NGOs play an important role in informing the international community of ecological concerns and possible legal responses. If NGOs have access to and can use satellite data and image products, they will be able to help strengthen the entire feedback loop that incorporates ecological awareness, soft law negotiating, behavior monitoring, treaty drafting, and compliance monitoring.

Significant currents of opinion hold that compliance with international norms corresponds more closely to the availability of information and political incentives than to the formalization of sanction structures or other enforcement mechanisms.[19] The lack of explicit enforcement mechanisms is not unique to international environmental soft law. Explicit provisions for state liability in international treaties are rare, and even those in place are rarely enforced.[20] For example, scholars continually dredge up *Trail Smelter*[21] in which Canada was forced in 1941 to pay the United States reparations for sulfur dioxide emissions.[22]

In place of traditional domestic law enforcement procedures that emphasize the relationship between a bad actor and the individual harmed, international environmental law increasingly fosters noncompliance procedures (NCPs) that stress collective positive assistance to help states meet treaty obligations.[23] Such NCPs in international environmental law permit flexible incorporation of new scientific understandings and improved technical capabilities.[24] In contrast, formalized rule revision and dispute resolution proceedings triggered by each instance of noncompliance or alteration in

19. *See* Stephen Porter & David Hunter, *Dispute Resolution in the Context of Transboundary Environmental Impact Assessment: A Review of Selected Bilateral and Multilateral Agreements* (CIEL discussion paper, Mar. 1997), *in* DAVID HUNTER, JIM SALTZMAN & DURWOOD ZAELKE, INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 495, 496 (1998). *See generally* ABRAM CHAYES & ANTONIA CHAYES, THE NEW SOVEREIGNTY 3–28 (1995) (discussing the negotiation, adoption, and implementation of international agreements).

20. *See* HUNTER ET AL., *supra* note 19, at 482.

21. Trail Smelter Arbitration (U.S. v. Can.), 3 R.I.A.A. 1905 (1941), *reprinted in* 35 AM. J. INT'L L. 684 (1941).

22. *See* HUNTER ET AL., *supra* note 19, at 483.

23. *See* Günther Handl, *Compliance Control Mechanisms and International Environmental Obligations*, 5 TUL. J. INT'L & COMP. L. 29, 34 (1997).

24. *See* Handl, *supra* note 23.

scientific understanding could easily bog down in technical arguments and generate significant political resistance.[25] Consequently, it is in the less formalized ways international norms are shaped and reinforced that satellite data can be especially valuable. Satellites can provide common reference points for negotiating and the means for monitoring compliance with those international norms. Furthermore, they can monitor the effectiveness of the norms in slowing environmental damage and promoting sustainable development. Two examples illustrate this potential value to international law and policy — initiatives to control the depletion of stratospheric ozone and the warming of the earth's atmosphere.

A. Science and the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer[26] is a success story both for the influence of science on policy and for the role of remote sensing evidence in spurring the transition from expressions of soft law concern to real negotiated solutions. Over a relatively short time, ground-based and satellite data collection reinforced public and governmental understanding that ozone depletion posed a serious environmental threat, especially the dramatic hole that appeared annually and ever larger over Antarctica. NGOs played central roles both in the negotiation of the Protocol and follow up revisions.[27]

The Montreal Protocol exhibits one application of an NCP.[28] This mechanism turns on individually tailored recommendations by an Implementation Committee in response to self-reported failures to comply with the Protocol, together with technical and financial

25. *See* HUNTER ET AL., *supra* note 19, at 492–93.

26. Montreal Protocol, *supra* note 9.

27. *See* HUNTER ET AL., *supra* note 19, at 603–04.

28. *See* Handl, *supra* note 23, at 33–34. NCPs appear in several important recent international environmental legal instruments, including the 1994 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reductions of Sulphur Emissions, 33 I.L.M. 1540 (1994), and form the basis of negotiations in connection with the 1991 Protocol on Volatile Organic Compounds, 31 I.L.M. 568 (1992), the Framework Convention on Climate Change, *supra* note 10, the Convention to Combat Desertification, *supra* note 6, the Basel Convention on Transboundary Movement of Hazardous Wastes and Their Disposal, U.N.E.P. Doc. IG.80/L.12 (Mar. 22, 1989), *reprinted in* 28 I.L.M. 649 (1989), etc. *See* Handl, *supra* note 23, at 33–34.

assistance where appropriate.[29] If the Implementation Committee finds that a noncomplying state fails to take reporting and remediation seriously, it may be threatened with suspended access to financial and technical transfers in connection with the Protocol.[30] Any Party to the Protocol can bring a claim of noncompliance against any other Party, without such claimant having to show that it was particularly harmed by the noncompliance.[31]

However, to assess the adequacy of states' reporting and remediation measures under international regimes like the Montreal Protocol, treaty secretariats and other members of the international community need independent information about the scope of environmental problems and effectiveness of states' responses to them.

B. Climate Change

Promising territory for the application of satellite remote sensing is found in the evolving climate change negotiations. The 1992 United Nations Framework Convention on Climate Change identifies forests as key components to comprehensive climate management strategies.[32] Forests act as sources, sinks, and reservoirs of carbon, and subtle and radical changes in forests can lead to significant releases of carbon dioxide — the primary greenhouse gas — into the atmosphere.[33] Under the Framework Convention, Clean Development Mechanisms (CDMs) would encourage developed countries to devote resources, technologies, and expertise to minimize emissions of carbon dioxide and other greenhouse gases from developing countries while at the same time help those countries meet their needs for economic growth and rising standards of liv-

29. *See* HUNTER ET AL., *supra* note 19, at 480.

30. *See id*. at 480–81 (noting anecdotally that such threats have brought Mauritania, Kuwait, and Lebanon back into reporting compliance).

31. Philippe Sands, *Compliance with International Environmental Obligations: Existing International Legal Arrangements, in* IMPROVING COMPLIANCE WITH INTERNATIONAL ENVIRONMENTAL LAW 50, 60 (James Cameron et al. eds., 1996) (drawn from PHILIPPE SANDS, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (1995)).

32. *See* Framework Convention on Climate Change, *supra* note 10, 31 I.L.M. at 855.

33. *See* Donald M. Goldberg, Carbon Conservation: Climate Change, Forests and the Clean Development Mechanism 1 (1998) (unpublished report, on file with authors).

ing.[34] Although significant ambiguities remain as to how CDMs will be structured and monitored, land use and land cover, which is associated with extensive vegetation as found in forests, are particularly suitable subject matter for civilian remote sensing satellites.[35]

III. SATELLITES AND NORMATIVE PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW

As discussed briefly above, several principles of international environmental law find expression in a variety of emerging norms, established customs, and treaty regimes. This section discusses several such principles the application of which are likely to be strengthened by the wide dissemination and lawyer's use of satellite remote sensing data.

A. Sustainable Development

The challenges presented to sustainable development from global population increases and economic activity require that we develop new tools that allow us to measure and analyze the health of the biosphere and to communicate the knowledge so acquired to the public and the policy-makers responsible for developing and enforcing our systems of national and international environmental law. Sustainable development is both a customary normative principle of international law and an expression of the international community's hope that economic progress and environmental survival can coexist.[36] Sustainable development requires that we improve our ability to measure and manage the interaction between the industrial economy and the biosphere, and to ensure that we do not transgress the limits of the biosphere thus causing critical life support systems to fail.[37]

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34. *See* Framework Convention on Climate Change, *supra* note 10, 31 I.L.M. at 852–53.

35. *See* discussion *infra* Part IV.A.

36. As Judge Weeramantry, Vice President of the International Court of Justice, observed, "The principle of sustainable development . . . is an integral part of modern international law [and] has received considerable endorsement from all sections of the international community, and at all levels." Gabcikovo-Nagymaros Project (Hung. v. Slovk.), 1997 I.C.J. 3 (Sept. 25) (separate opinion of Vice-President C.G. Weeramantry), *reprinted in* 37 I.L.M. 162, 205–06 (1998).

37. *See* United Nations Conference on the Human Environment: Final Document,

Under both Agenda 21[38] and the Rio Declaration,[39] all nations have the duty to reduce and eliminate unsustainable patterns of production and consumption.[40] The United States, as one of the world's largest consumers,[41] bears a heightened responsibility to eliminate unsustainable consumption patterns and to help provide the means for the rest of the world to understand and respond to the damage such consumption causes.

The cumulative environmental impacts of population, industrial activity, and consumption are difficult to conceptualize. However, Paul and Anne Ehrlich have formulated a simple equation to help us parse out the factors that contribute to our cumulative harmful impacts on the environment: $I=PCT$, where I represents cumulative impact, P stands for total world population, C reflects consumption of products and resources per capita, and T represents the technologies effectiveness in reducing the destructiveness of consumption.[42] Each factor — P, C, and T — indicates an important area of concern for regulation if we are to gain any ground in the race to avert global ecological catastrophe.[43] However, the political will to tackle any of the individual factors can only come from a recognition of the cumulative impact, I, and how quickly that impact is growing.[44]

There may be no better means for illustrating such macroscopic environmental impacts (I) than satellite remote sensing. Satellites can help scientists understand the ecosphere and integrated ecological dynamics. Its public availability can help advocates communicate

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June 16, 1972, princ. 21, U.N. Doc. A/CONF.48/14/Rev.1, *reprinted in* 11 I.L.M. 1416, 1420 (1972); Rio Declaration, *supra* note 16, princ. 2, 31 I.L.M. at 876.

38. Agenda 21, *supra* note 17, ¶¶ 45–48 ("[S]pecial attention should be paid to the demand for natural resources generated by unsustainable consumption. . . . Developed countries should take the lead in achieving sustainable consumption patterns . . . .").

39. Rio Declaration, *supra* note 16, princ. 8, 31 I.L.M. at 877 ("To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of . . . consumption.").

40. *See* Convention on Biological Diversity, *supra* note 7, art. 6, 31 I.L.M. at 825 (calling on parties to ensure that the use of biological diversity is sustainable).

41. *See* Catherine L. Krieps, Comment, *Sustainable Use of Endangered Species Under CITES: Is It a Sustainable Alternative?*, 17 U. PA. J. INT'L ECON. L. 461, 500–01 (1996).

42. *See* Paul Ekins, *The Sustainable Consumer Society: A Contradiction in Terms?*, 3 INT'L ENVTL. AFF. 242, 249 (1991) (referring to PAUL & ANNE EHRLICH, THE POPULATION EXPLOSION 58 (1990)).

43. *See id*.

44. *See id*. at 251–52.

the importance of paying attention and responding appropriately.[45] Both the research and communicative values of satellite data can be dramatically enhanced by the use of other technologies that help us map and understand our dynamic environment. These technologies include geo-referencing global positioning systems (GPS),[46] geographic information systems (GIS),[47] and, of course, that manifestation of interconnected communication itself, the Internet's World Wide Web.

B. The Precautionary Principle and Foreseeability

International environmental law must advance on imperfect scientific knowledge about the environment. However, higher quality information will always enhance both the specificity and effectiveness of environmental law and the degree to which political consensus can be galvanized to enact and enforce new environmental standards.

Recurring debate over the degree of scientific certainty necessary to support new international environmental standards has resulted in the formulation of the precautionary principle.[48] One articulation of the principle appears in Principle 15 of the Rio Declaration that emerged from the 1992 United Nations Conference on the Environment and Development: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[49]

The precautionary principle may guide international environmental lawmaking, but its application in any particular negotiation must be informed by the best available facts — facts about the likelihood and magnitude of environmental harms and about the costs

45. *See* Uhlir, *supra* note 5 (discussing future applications of remote sensing).

46. GPS are computer software tools used to visualize and manipulate geographic and environmental information. *See infra* Part IV.C. *See generally* Robert Puterski, *The Global Positioning System — Just Another Tool?*, 6 N.Y.U. ENVTL. L.J. 93, 94 (discussing the technology and environmental monitoring applications).

47. *See infra* Part IV.B; *see also* LISA WARNECKE, NATIONAL AERONAUTICS & SPACE ADMIN., NASA AS A CATALYST: USE OF SATELLITE DATA IN THE STATES 1 (1997) (defining GIS).

48. *See* Daniel Bodansky, *Scientific Uncertainty and the Precautionary Principle*, ENVIRONMENT, Sept. 1991, at 4.

49. Rio Declaration, *supra* note 16, princ. 15, 31 I.L.M. at 879.

associated with dealing with them.[50] Nevertheless, without a conscientious application of the precautionary principle, progress in protecting the international environment will be hindered by claims that scientific uncertainty always warrants delay.

Satellite data and its use in conjunction with other technologies can enhance the application of this important tenet of international environmental law.[51] The increased use of remote sensing data will help scientists and advocates make their cases and strengthen the hands of those for whom the precautionary approach to environmental harms makes sense. More sophisticated data and data analysis will have a strong influence on lawmaking, as well as enforcement, as we learn how to integrate new tools and to design legal management systems to effectively track feedback from such tools.

By dramatically expanding our monitoring capabilities in connection with the global environment, we can and should raise the bar on standards of international environmental responsibility. Satellite capabilities can expand our sensitivity to environmental consequences of action or inaction on the part of individuals, corporations, governments and international organizations. The range of concerns that meet the general formulation of the precautionary principle ought to expand accordingly.

C. Duty to Prevent Transboundary Environmental Harm

Among the more fundamental and customary norms in international environmental law is the general duty to not cause environmental harm beyond national borders.[52] This duty is triggered when

50. For further discussion of limitations in the application of the precautionary principle, see Bodansky, *supra* note 48, at 4.

51. *See* Rio Declaration, *supra* note 16, princ. 15, 31 I.L.M. at 879. Principle 15's articulation of the precautionary principle follows generally its formulation in several other international environmental policy statements and instruments. *See generally* HUNTER ET AL., *supra* note 19, at 360–61.

52. The International Court of Justice has made the following statement:

> [T]he environment is not an abstraction but represents the living space, the quality of life and the very health of human beings, including generations unborn. The existence of the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control is *now a part of the corpus of international law* . . . .

Advisory Opinion on the Legality of the Threat or Use of Nuclear Weapons, 1996 I.C.J. 226, 241–42 (July 8) (emphasis added). This statement has been widely interpreted as there is "convincing evidence" that such harm will occur.[53] In determining the scope of this duty, a U.N. Department for Policy Coordination and Sustainable Development (DPCSD) report suggests consideration of "the likelihood of significant harmful effects on the environment and on potential or current activities in another State" and "the ratio between prevention costs and any damage."[54]

A related duty — the duty to conduct environmental impact assessments whenever transboundary environmental harms are likely — has likely risen to the status of customary international law. Principle 4 of the United Nations Environment Program's Principles on Shared Natural Resources[55] exemplifies this duty: "States should make environmental assessments before engaging in any activity with respect to a shared natural resource which may create a risk of significantly affecting the environment of another State or States sharing that resource."[56] Use of comprehensive satellite monitoring by environmental lawyers and policymakers should result in more thorough baseline assessments and impact analyses culminating in more defensible environmental assessments.

D. Common but Differentiated Responsibility

Under international environmental law, measures taken by developed countries to protect the global commons must be guided by the principle of common but differentiated responsibility, an equitable keystone to international environmental law.[57] Common but differentiated responsibility is expressed in Principle 7 of the

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acknowledging Principle 21 of the Stockholm Declaration, *supra* note 15, princ. 21, 11 I.L.M. at 1420, and Principle 2 of the Rio Declaration, *supra* note 16, princ. 2, 31 I.L.M. at 876, as a customary norm of international law. *See also Trail Smelter*, 3 R.I.A.A. 1905, 35 AM. J. INT'L L. at 685–86.

53. IUCN COMM'N ON ENVT'L LAW, DRAFT INTERNATIONAL COVENANT ON ENVIRONMENT AND DEVELOPMENT 40 (1995) (referring to *Trail Smelter*).

54. U.N. DEP'T FOR POL'Y COORDINATION & SUSTAINABLE DEV., REPORT OF THE EXPERT GROUP MEETING ON IDENTIFICATION OF PRINCIPLES OF INTERNATIONAL LAW FOR SUSTAINABLE DEVELOPMENT, U.N. Comm. on Sustainable Development, 4th Sess., Background Paper No. 3, ¶ 54 (1996) [hereinafter CSD EXPERT GROUP REPORT].

55. *Governing Council Approval of the Report of the Intergovernmental Working Group of Experts on Natural Resources Shared by Two or More States*, U.N. Environment Programme, 6th Sess., princ. 4, U.N. Doc. GC.6/CRP.2, *reprinted in* 17 I.L.M. 1091, 1098 (1978).

56. *Id*.

57. *See* Rio Declaration, *supra* note 16, princ. 7, 31 I.L.M. at 877.

Rio Declaration[58] and regularly included in multilateral agreements to protect the global environment.[59] This principle allocates responsibility for sustainable development according to a nation's impact on the global environment.[60] Generally, the principle holds developed nations to higher standards, faster timetables, and more stringent commitments than developing countries.[61] Further, the principle of common but differentiated responsibility is reflected in a number of international agreements that require wealthier nations to facilitate access to technologies that can contribute to sustainable development together with the needed financial and technical support.[62]

It is useful to frame discussions about how and where to disseminate satellite remote sensing data and information in the context of a wealthy nation's duty to provide financial and technical support to nations lacking the resources and wherewithal to obtain such assistance. The United States and other countries able to support civilian satellite remote sensing operations should make enhanced data and information products available to other nations and nongovernmental international community members. Such services would further their common but differentiated responsibility for promoting sustainable development and maintaining the global environment's integrity.

58. *See id*.

59. *See id*. (stating that "[i]n view of the differ[ing] contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment . . . ."); *see, e.g.*, Framework Convention on Climate Change, *supra* note 10, 31 I.L.M. at 851, 854–55; Montreal Protocol, *supra* note 9, art. 5, 26 I.L.M. at 1555; *see also Agreement for the Implementation of the United Nations Convention on the Law of the Sea of 10 Dec. 1982, Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks*, U.N. Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, 6th Sess., Part VII, ¶ 1, U.N. Doc. A/CONF.164/37 (1995), *reprinted in* 34 I.L.M. 1542, 1567 (requiring developed countries to provide assistance to developing countries); Convention on Biological Diversity, *supra* note 7, art. 8, 31 I.L.M. at 825–26 (requiring parties to "regulate or manage the relevant processes and categories of activities" and "[c]ooperate in providing financial and other support for *in-situ* conservation . . . particularly to developing countries").

60. *See* CSD EXPERT GROUP REPORT, *supra* note 54, ¶ 89.

61. *See id*. ¶¶ 89–90.

62. *See id*. ¶ 78.

E. Technology Transfer Obligations and Opportunities

Satellites and geographic information tools have been an important resource for the environmental movement ever since we took the first pictures of the earth from space.[63] However, the environmental movement must effectively combine mapping and research technology with communications technology to better understand obscure and gradual, yet significant, earth processes.[64]

As international environmental law develops, it increasingly incorporates the concept that the global environment is the "common concern of humankind."[65] With this concept has developed the understanding that because the developed world possesses more of the world's wealth, they should cooperate with the developing world to enable them to fulfil environmental obligations.[66] Technology transfer obligations form a part of international environmental norms where satellite data is as important a subject of international negotiation as it is a tool to aid such negotiations.

Traditionally, international law concerns relations between nation states, with national governments acting as representatives of their citizens' claims and liabilities.[67] In some respects, however, the rhetoric of technology transfer appears poorly suited to this state system.[68] Scholars and diplomats, arguing for technology transfer, talk of rights, equity, and fairness — talk that possibly transforms the state into more than a representative of its citizens, but rather into a personification of them.[69]

Viewing technology transfer provisions as a whole — probably a

63. *See* John Nobile Wilford, *Revolutions in Mapping*, NAT'L GEOGRAPHIC, Feb. 1998, at 6, 24 illus.

64. *See id*. at 12–39.

65. *E.g.*, Convention on Biological Diversity, *supra* note 7, pmbl., 31 I.L.M. at 822; Framework Convention on Climate Change, *supra* note 10, 31 I.L.M. at 851, 854–55.

66. *See Charter of Economic Rights and Duties of States*, G.A. Res. 3281, 29th Sess., Agenda Item 48, art. 5-28, U.N. Doc. A/RES/3281, *reprinted in* 14 I.L.M. 251, 254–60 (1975).

67. *See, e.g.*, Jonathan I. Charney, *Transnational Corporations and Developing Public International Law*, 1983 DUKE L.J. 748, 753 (mentioning the traditional theory of public international law).

68. For a discussion on technology transfer, see Gaëtan Verhoosel, *Beyond the Unsustainable Rhetoric of Sustainable Development: Transferring Environmentally Sound Technologies*, 11 GEO. INT'L ENVTL. L. REV. 49 (1998).

69. *See* Stanley Anderson, *Human Rights and the Structure of International Law*, 12 N.Y.L. SCH. J. INT'L & COMP. L. 1, 19–22 (1991).

reasonable way to view them given the hortatory nature of many — international law appears to view both governments and citizens as the appropriate beneficiaries of technology transfer. As one might expect from a body of law negotiated by state representatives, many of the provisions in international agreements focus on transfer to "the State."[70] Markedly, Articles 200 and 202 of the United Nations Convention on the Law of the Sea (UNCLOS)[71] require technical cooperation with assistance to "developing States,"[72] and Article 16 of the Convention on Biological Diversity requires "access to and transfer of technology among Contracting Parties."[73]

On the other hand, some international instruments suggest an obligation for technology to be transferred for the benefit of individuals. Principle 18 of the Stockholm Declaration, for example, states that "[s]cience and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind."[74]

Technology transfer remains a major issue in the international discussion of satellite remote sensing.[75] This should not be surprising since the number of states that own remote sensing satellites is still fairly small (although the number does include some developing countries).[76] Developing countries with satellite capability should view remote sensing policy as a good way to bolster their leadership on North-South equity issues, because in this area, along with developed countries, they may be subject to technology transfer obliga-

70. *E.g.*, Omnibus Trade and Competitiveness Act of 1988, Pub. L. No. 100-418, § 5121, 102 Stat. 1107, 1433 (1988); Mexico-Venezuela: Agreement on Energy Cooperation Program for the Countries of Central America and the Caribbean, Aug. 3, 1980, pt. XIV, 19 I.L.M. 1126 (1980).

71. U.N. Doc. A/CONF.62/122, arts. 200 & 202, *reprinted in* 21 I.L.M. 1261 (1982).

72. *Id*., 21 I.L.M. at 1309.

73. Convention on Biological Diversity, *supra* note 7, art. 16, 31 I.L.M. at 829.

74. Stockholm Declaration, *supra* note 15, princ. 18, 11 I.L.M. at 1420.

75. *See, e.g.*, Kai-Uwe Schrogl, *Legal Aspects Related to the Application of the Principle that the Exploration and Utilization of Outerspace Should Be Carried Out for the Benefits and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries, in* INTERNATIONAL SPACE LAW IN THE MAKING: CURRENT ISSUES IN THE UN COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE 195 (Marietta Benkö & Kai-Uwe Schrogl eds., 1991).

76. *See id*. at 198.

tions.[77] One of the most widely discussed recent proposals for technology transfer, a revised draft of Principles that the Exploration and Utilization of Outer Space should be Carried Out for the Benefits and in the Interest of all States,[78] was presented in 1993 to the Legal Committee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) by Brazil, a country outstripping any European nation in satellite capability.[79]

The international legal regime for remote sensing focuses strongly on technology transfer obligations.[80] For example, technology transfer is discussed right at the start of the only global treaty arguably governing satellite remote sensing — the Outer Space Treaty.[81] Article I mentions both the right of developing countries and the right of all mankind to the benefits derived from space technology: "The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind."[82] Most commentators and Declarations apply Article I of the Outer Space Treaty to the earth observation remote sensing regime.[83]

77. *See id*.

78. U.N. Doc. A/AC.105/C.2/L.182/Rev.1 (1993), *reprinted in* Schrogl, *supra* note 75, at 225.

79. *See* Schrogl, *supra* note 75, at 211. *See generally* Jefferson Hane Weaver, *Lessons in Multilateral Negotiations: Creating a Remote Sensing Regime*, 7 TEMP. INT'L & COMP. L.J. 29, 40 (1993) (noting that although Brazil was traditionally a fervent supporter of limiting data distribution, Brazil had also created one of the world's best national remote sensing systems, evincing a revision in their views on the dissemination of remote sensed data).

80. *See* Schrogl, *supra* note 75, at 201.

81. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, art. I, 18 U.S.T. 2410, 610 U.N.T.S. 205, *reprinted in* 6 I.L.M. 386 (1967) [hereinafter Outer Space Treaty].

82. *Id*. 18 U.S.T. at 2412, 610 U.N.T.S. at 207, *reprinted in* 6 I.L.M. at 386.

83. *See, e.g.*, Nandasiri Jasentuliyana, *Ensuring Equal Access to the Benefits of Space Technology for All Countries, in* THE USE OF AIRSPACE AND OUTER SPACE FOR ALL MANKIND IN THE 21ST CENTURY (Chia-Jui Cheng ed., 1993). *See generally* Eleonora Ambrosetti, *The Relevance of Remote Sensing to Third-World Economic Development: Some Legal and Political Aspects*, 12 N.Y.U. J. INT'L L. & POL. 569, 573–76 (1980) (noting that the actual sensing process occurs in space, so the Outer Space Treaty applies); Gary L. Hopkins, *Legal Implications of Remove Sensing of Earth Resources by Satellite*, 78 MIL. L. REV. 57, 69 (1978) (stating the general consensus is that the Outer Space Treaty

The most important international legal document specifically addressing remote sensing is the "Principles Relating to Remote Sensing of the Earth from Space,"[84] which almost wholly deals with technology transfer. Principle XII requires that "sensing" states provide "sensed" states with both primary and processed data concerning their territory — first, on non-discriminatory bases, and second, on reasonable cost terms.[85]

Technology transfer provisions also appear in a number of later documents concerning satellite remote sensing. The Economic and Social Council of Asia and the Pacific (ESCAP) produces a resolution every odd-numbered year concerning the use of satellite remote sensing in exploring and assessing natural resources.[86] A representative provision, Article 2 of the 1991 resolution, "[c]alls upon the developed countries to share more of their technical capacity in remote sensing with the developing countries."[87]

A fair amount of state practice exists in the context of remote sensing technology transfer: "affirmative" practice that is perhaps a little more persuasive as evidence of international law than the "negative" practice of states consenting to an open skies policy simply by failing to object.[88] As the General Assembly Principles contemplate, some technology transfer has been coordinated by intergovernmental institutions.[89] The United Nations Office of Outer

applies to remote sensing, even though it does not take place solely in space).

84. G.A. Res. 41/65, U.N. GAOR, 41st Sess., Annex, U.N. Doc. A/RES/41/65 (1986).

85. *Id*. princ. 12.

86. *See, e.g.*, New Techniques, Including Remote Sensing, for Identifying, Exploring for, and Assessing Natural Resources, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), 32d plen. mtg., Res. 1991/89 (July 26, 1991), *available at* <gopher://gopher.un.org/00/esc/recs/1991/89>; New Techniques, Including Remote Sensing, for Identifying Exploring for, and Assessing Natural Resources, ESCAP, 12th plen. mtg., Res. 1989/8 (May 22, 1989), *available at* <gopher://gopher.un.org/00/esc/recs/1989/8>; New Techniques, Including Remote Sensing, for Identifying, Exploring For, and Assessing Natural Resources, ESCAP, 14th plen. mtg., Res. 1987/9 (May 26, 1987), *available at* <gopher://gopher.un.org/00/esc/recs/1987/9>.

87. New Techniques, Including Remote Sensing, for Identifying, Exploring For, and Assessing Natural Resources, ESCAP, Res. 1991/89, *supra* note 86, ¶ 9.

88. *See* Sergio Marchisio, *Remote Sensing for Sustainable Development in International Law, in* OUTLOOK ON SPACE LAW OVER THE NEXT 30 YEARS 335, 340 (Gabriel Lafferranderie & Daphné Crowther eds., 1997) (arguing that state practice supports viewing technology transfer in the context of remote sensing as a binding international law obligation).

89. *See* G.A. Res. 41/65, *supra* note 84, princ. 8.

Space Affairs organized a number of centers in developing countries to train technicians to develop a degree of indigenous satellite remote sensing data interpretation and utilization capability.[90] The United Nations and the European Space Agency have in recent years collaborated to organize a series of workshops on basic space science, including interpretation of data from remote sensing satellites, primarily for the benefit of scientists in developing countries.[91]

Much technology transfer, however, has been organized independently by national governments, and one of the leaders in the field has been the United States.[92] The United States has consistently given far more credence to arguments that remote sensing data should be made widely available than to arguments that collecting data may violate national sovereignty.[93] One example is weather data that the National Oceanic and Atmospheric Administration (NOAA) makes available worldwide, often free of charge.[94] NASA's mandate[95] permits the agency to focus on international distribution of remote sensing data.[96] Accordingly, NASA has negotiated over 800 agreements with developing countries for distribution of remote sensing data and has drawn substantial praise even from developing country scholars generally critical of the global technology transfer regime.[97]

NASA's public spirited mandate should allow a degree of public interest technology transfer, limited by commercial and security concerns.[98] The findings of the current Land Remote Sensing Policy Act,[99] for instance, recognize the concern with satellite data costs, noting that "[t]he cost of Landsat data has impeded the use of such data for scientific purposes, such as for global environmental change

90. *See* Jasentuliyana, *supra* note 83, at 221.

91. *See Report on the United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis Techniques*, U.N. GAOR Comm. on the Peaceful Uses of Outer Space, ¶¶ 21–24, U.N. Doc. A/AC.105/687 (1997).

92. *See generally* CHARLES C. OKOLIE, INTERNATIONAL LAW OF SATELLITE REMOTE SENSING AND OUTER SPACE 109 (1998).

93. Telephone Interview with Dr. Peter Baklund, White House Office of Science and Technology Policy (Oct. 15, 1998).

94. *Id*.

95. *See* 15 U.S.C. § 5613(a) (1994).

96. *See id*.

97. *See* OKOLIE, *supra* note 92, at 109–10.

98. *See, e.g.*, 15 U.S.C. § 5651(a).

99. Pub. L. No. 102-555, 106 Stat. 4166 (codified at 15 U.S.C. §§ 5651–5672 (1994)).

research, as well as for other public sector applications."[100]

Although the Act requires NASA to consult with the Secretary of State regarding international obligations,[101] agencies are authorized "to provide remote sensing data, technology, and training to developing nations as a component of international aid."[102] NASA's authorization to distribute remote sensing data as development assistance is limited, however, by the obligation to not discriminate between classes of users.[103] This means that NASA is not authorized to distribute information to non-profit groups for free while selling the same information to industries or law firms. Thus, it seems likely that NASA will choose to distribute to the public a class of information with relatively low commercial value.[104]

F. The Principle of Subsidiarity

The principle of subsidiarity expresses a preference for decision-making at the lowest practicable level of government or social organization.[105] In the development context, those likely to have the best understanding of a proposed projects' potential impacts and those most likely to have their lives materially affected by such projects should have significant meaningful input into decisions about whether and how to proceed.[106] This principle stems from several threads of social and religious discourse, and is associated with democratic ideals, federal systems, and a preference for decentral-

100. 15 U.S.C. § 5601(4).

101. *See id*. § 5657(b)(1).

102. *Id*. § 5657(b)(2).

103. *See id*.

104. Likely candidates for free distribution would include low resolution or older data. Furthermore, one of NASA's policies is to

> [r]ecognize the worldwide and long-range character of environmental concerns and, when consistent with the foreign policy of the United States and its own responsibilities, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of the world environment.

14 C.F.R. § 1216.102(c) (1998). As Section VI, *infra*, describes, projects like the Environmental Law Information System (ELIS) may move beyond NASA's history of cooperation with developing countries as nation-states alone, towards an ethic of cooperation with the general public to protect the environment.

105. *See* HUNTER ET AL., *supra* note 19, at 370.

106. *See id*.

ized government.[107]

International law, including international environmental law, has in many ways represented the concentration of power and authority in nation states and increasingly in supranational organizations like the World Trade Organization.[108] Nongovernmental organizations' persistent assertion of the importance of voices from civil society and from social and political sectors that are otherwise under-represented in the international lawmaking process has served as an important democratizing influence on international law.[109]

Institutions that favor the principle of subsidiarity place an importance on democratizing international lawmaking and argue for broad, empowering access to resources such as remote sensing data to accomplish this goal.[110] This argument goes beyond the mere value of the data and is concentrated on means and avenues by which the information can be disseminated. Nongovernmental organizations play an important role in disseminating data so that global democracy and global ecology are fostered in concert.

IV. REMOTE SENSING AND RELATED TECHNOLOGIES

In this section, we identify and demystify basic technologies, including satellite remote sensing, that can help promote sustainable development. Remote sensing is simply the gathering of information concerning an object or place from a distance by detecting the light or other electromagnetic radiation it is emitting.[111] We have

107. *See id*. at 371.
108. *See id*. at 422.
109. *See id*.
110. *See id*.
111. *See* Joseph E. Lees, *Technological Breakthroughs May Usher in Era of Change*, 13 ENVTL. COMPLIANCE & LITIG. STRATEGY, Aug. 1997, at 1–2. Electromagnetic radiation is all around us and consists of light, radio waves, x-rays, and infrared (thermal) radiation. *See* FREDERICK J. BUECHE, INTRODUCTION TO PHYSICS FOR SCIENTISTS AND ENGINEERS 598 (4th ed. 1986). The electromagnetic spectrum can be divided into several frequency or wavelength intervals. *See id*. at 602. For example, visible light is electromagnetic radiation that falls within the frequencies of spectral response of the human eye. *See id*. at 603. The spectral regions, in order of decreasing wavelength (i.e., increasing frequency and increasing energy) are, with approximate wavelengths in parentheses: radio waves (centimeters and longer); microwaves (millimeters); infra-red (micrometers to tenths of millimeters); visible (hundreds of nanometers); ultra-violet (tens of nanometers); x-rays; and gamma rays. *See id*. Instruments also differ in their field of view (the area

been pointing cameras at earth from airplanes in earnest since World War I.[112] Applications for on-board aircraft cameras and other remote sensing devices are too numerous to describe fully here, but include mapping land use and land cover such as vegetation type,[113] detecting and tracking oil spills and other pollutants,[114] and targeting weapons.[115] Satellite remote sensing can best be thought of as digital photography from space across a much wider spectrum of electromagnetic energy than that represented by visible light.[116]

Satellite remote sensing serves essentially the same purposes as aerial remote sensing, but offers two advantages. First, satellites' stable placement in orbit allows them to remain active for long periods (providing comparative time series information) while expending relatively little energy.[117] Second, satellites' altitude makes them much more effective than aircraft for surveying large areas.[118]

Satellite-mounted sensors detect and distinguish between specific frequencies of light and other forms of electromagnetic energy[119]

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of land they can measure) and their spatial resolution. *See* Nicholas M. Short, *The Remote Sensing Tutorial: An Online Handbook* (updated Nov. 23, 1998) <http://rst.gsfc.nasa.gov/Sect13/nicktutor_13.4.html>. Spatial resolution determines the level of detail that can be resolved by the instrument. *See* JOHN R. JENSEN, INTRODUCTORY DIGITAL IMAGE PROCESSING 4 (2d ed. 1996). For example, an instrument with a spatial resolution of one kilometer per pixel will have difficulty distinguishing any features smaller than about two to four kilometers across. *See id*. Some sensors are now able to detect simultaneously a number of wavelengths and provide information about the relative strengths of each signal — a new capability with many useful applications such as measuring forest health. *See* Short, *supra*. Of particular importance in frequently cloudy areas are "Narrow Aperture Radar" (NAR) sensors, as found on the Canadian RADARSAT satellite. *See* Uhlir, *supra* note 5, at 20. These sensors are able to gather information on the ground or ocean surface through cloud cover, a capability lacking in most other sensors. *See id*.

112. *See* Wilford, *supra* note 63, at 31.

113. *See* JENSEN, *supra* note 111, at 45–48.

114. *See id*. at 203.

115. *See Joint Staff Endorses Targeting System for AH-1Z*, ARMED FORCES NEWSWIRE SERV., Nov. 20, 1998, *available in* 1998 WL 17229100.

116. *See* sources cited *supra* note 111.

117. *See generally* JENSEN, *supra* note 111, at 7 (using European Remote Sensing Satellite (ERS-1) to demonstrate the high quality and inexpensiveness of satellite remote sensing).

118. *See id*. at 37. Satellite remote sensing devices, such as Landsat MSS, have the ability to observe geographic areas 5000 times larger than that which can be observed via aerial photographs. *See id*.

119. *See id*. at 3. Both active and passive remote sensing systems record electromagnetic radiation that is emitted from an object. *See id*. The difference between the two systems depends upon the occurrence of the information returned. *See id*. For

such as color bands of visible light or different intervals in the infrared, ultraviolet, or microwave regions.[120] The spectral region of interest is determined by the research subject and the nature of the source.[121] Generally, brighter sources produce more accurate measurements.[122]

Unlike photographs, data from satellite-mounted sensors must be processed by computers and interpreted by specialists in order to produce meaningful images and other information products.[123] "Unenhanced" satellite data is either a stream of ones and zeroes, the digital, unprocessed form transmitted from orbit, or data which has only undergone data preparation or "preprocessing."[124]

Preprocessing is manipulating data in relatively straightforward ways such as to correct viewing-angle curvatures or the earth's curvature,[125] to orient data with respect to geographic reference

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example, passive sensors record energy that occurs naturally, whereas active sensors record information in man-made electromagnetic energy. *See id*. Basically, both systems measure frequency and wavelength to gain spectral information. *See id*. Although frequency and wavelength are mathematically related, *see generally* BUECHE, *supra* note 111, at 552 (using Maxwell's four-formula realization, discovering that there is a simple relationship between the wavelength and the frequency of the wave), some applications are historically discussed in terms of frequency and others in terms of wavelength.

120. *See* JENSEN, *supra* note 111, at 3–7.

121. *See id*. at 198. For example, the Landsat Thematic Mapper gathers information in the visible spectrum (TM3 from 0.63-0.69 nm and TM4 from 0.76-0.90 nm), and mid-infra-red (TM7 from 2.08-2.35 μm) bands have been found to provide valuable information about the health of forests. *See, e.g.*, W.B. Cohen, *An Introduction to Digital Methods in Remote Sensing of Forested Ecosystems: Focus on Pacific Northwest, USA*, 20 ENVTL. MGMT. 421 (1996); Mark E. Jakubauskas & Kevin P. Price, *Empirical Relationships Between Structural and Spectral Factors of Yellowstone Lodgepole Pine Forests*, 63 PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING 1375 (1997); ROBERT K. VINCENT, FUNDAMENTALS OF GEOLOGIC AND ENVIRONMENTAL REMOTE SENSING 270–74 (1997).

122. This is based on a common assumption of Poisson distribution of photon statistics, leading to the implication that the signal-to-noise ratio is proportional to the square root of the number of photons arriving at the detector. For a discussion of elementary methods, see PHILIP R. BEVINGTON, DATA REDUCTION ANALYSIS FOR THE PHYSICAL SCIENCES (1969).

123. *See* Uhlir, *supra* note 5, at 14.

124. 15 U.S.C. § 5602(13).

125. *See* Cohen, *supra* note 121, at 422.

points,[126] to calibrate the instruments' spectral responses,[127] or to fill in missing lines of data caused by faulty sensors or transmissions.[128] Each processing step introduces an additional uncertainty in the final result.[129]

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126. Prior to visual analysis of remote-sensing information, preprocessing operations transform image values to promote appropriate data interpretation. *See* THOMAS LILLESAND & RALPH W. KIEFFER, REMOTE SENSING AND IMAGE INTERPRETATION 557 (1979). Preprocessing includes restoration and enhancement but does not directly involve data interpretation. *See id*.

127. The instrument's measurement of electromagnetic intensity results from both the amount of radiation that impinges on the detector and the sensitivity of the detector. *See* SHIRLEY M. DAVIS ET AL., REMOTE SENSING: THE QUANTITATIVE APPROACH 55–58 (Philip H. Swain & Shirley M. Davis eds., 1978). The sensitivity of the detector can be calibrated independently by measuring sources of known intensity. *See generally* 1 AMERICAN SOCIETY OF PHOTOGRAMMETRY, MANUAL OF REMOTE SENSING 389 (Robert N. Colwell et al. eds., 2d ed. 1983) [hereinafter REMOTE SENSING MANUAL] (stating that the degree of sensitivity depends upon amplitude, speed, direction, and distance; all of which are known measurements). This process, known as intensity calibration, introduces uncertainties into the end result that are typically well understood. *See generally* FLOYD F. SABINS, JR., REMOTE SENSING PRINCIPLES AND INTERPRETATION 330–34 (Allan Cox ed., 1978) (using thermal plumes to demonstrate that data calibration promotes varying results). The electronics in the detector also cause some uncertainty, with such "detector noise" often varying with temperature. *See* REMOTE SENSING MANUAL, *supra*, at 332. These effects are typically well characterized prior to launch. *See id*. The detection of the rate of incident radiation also contains inherent uncertainties, which can be estimated by statistical means. *See id*. For instance, brighter sources may be measured with a greater degree of accuracy than dimmer sources. *See id*. at 480.

128. *See* JENSEN, *supra* note 111, at 108.

129. Numerous remote-sensing elements introduce uncertainties into data interpretation. *See generally* REMOTE SENSING MANUAL, *supra* note 127, at 19 (discussing the difficulty of providing published data that will inevitably still be questioned). These uncertainties may result from the design limitation or flaws in the measuring instrument, radiation intensity derived from the observed source, properties of the earth's atmosphere, or erroneous processing and manipulation techniques. *See generally* DAVIS, *supra* note 127, ch. 2 (discussing the four major parts of data acquisition and the problems associated with each part). To use processed measurements reliably, the manipulated raw data must be reproducible and the uncertainties in each step must be characterized and understood. *See, e.g.*, REMOTE SENSING MANUAL, *supra* note 127, at 873–919 (discussing techniques for image correction, the significance of reprocessing manipulated data, and the various sources of image errors).

Although time interval measurements are generally well documented by instrument developers, time factors yield uncertain results in the remote-sensing process. *See* LILLESAND & KIEFFER, *supra* note 126, at 365. For example, a certain amount of time elapses between the beginning and the end of an exposure. *See id*. at 40–42; *see also* REMOTE SENSING MANUAL, *supra* note 127, at 1599. The importance of the lapsed duration varies according to the time scale of the phenomenon under scrutiny. *See id*. at 1596. For instance, if one wished to measure the rate of urban development, the use of a sixty second exposure would not render the measurement useless. *See id*. at 1598–1601 (proclaiming that an hourly measurement of such things as pollution, cloud cover, tem-

Compared to unenhanced data, enhanced or processed satellite data is more complex, potentially more valuable, but also more problematic when used in administrative or enforcement actions.[130] Enhanced data are images interpreted by computers and/or technical specialists, and images to which other information has been added to illustrate particular ecological conditions or to make conclusions about information gathered by the satellite.[131] Data interpretation requires knowledge of both remote sensing and the sensed material's characteristics and involves extensive human labor and application of computer systems.[132] The added explanatory value of such enhanced information products makes them more attractive to almost every scientific, educational, and legal purpose; yet the very complexity of their creation makes their authority and credibility easier to attack.[133]

A. Civilian Remote Sensing Satellites

In 1960 the United States launched the first remote sensing satellite TIROS-1 (Television and Infrared Observation Satellite) to provide images of cloud patterns and other meteorological phenomena over North America.[134] The latest in this series of satellites (the

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perature, and precipitation is sufficient to maintain accurate readings of urban development). On the other hand, a sixty second exposure used to compare two satellite images obtained during differing orbits, would likely be too infrequent to be credible. *See id*. The atmospheric viewing conditions may have changed and the satellite may not be in the same place in the sky on subsequent passes, thus introducing a different viewing angle. *See id*.

Data processing techniques can address the above mentioned problems, but may introduce additional uncertainties into the final result. *See generally* DAVIS, *supra* note 127 (detailing inherent problems in data processing techniques). Significant problems are most likely to arise when the area of interest has a spatial scale that is comparable to that of the detector's spatial resolution. *See* REMOTE SENSING MANUAL, *supra* note 127, at 21–31, 365. For example, frequency measurements are generally calibrated absent major uncertainties, but the detector's frequency response is sensitive to the detector's temperature. *See id*.

130. *See* LILLESAND & KIEFFER, *supra* note 126, at 28–29.

131. *See id*. at 29.

132. *See id*.

133. *See* Uhlir, *supra* note 5, at 14. Examples of value-added data and information transformations include interpreting spectral data based on knowledge and assumptions about spectral characteristics of different vegetation types, to produce a vegetation map. For more in depth discussion, the reader is referred to an excellent tutorial on remote sensing provided by NASA on the World Wide Web. *See* Short, *supra* note 111.

134. *See* REMOTE SENSING MANUAL, *supra* note 127, at 1315.

15th) was launched in spring 1998.[135] The Landsat series of satellites, beginning with the Earth Resources Technology Satellite (ERTS-1) in 1972,[136] and leading up to Landsat-7, provide data about land cover for use in forestry, agriculture, water resources, and urban studies.[137] The National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellite (GOES) system provides continuous meteorological and climatological observation over the United States.[138]

NASA, together with NOAA and public and commercial operations from several countries,[139] is preparing to operate an integrated suite of satellite systems to gather information about global climate and ecology.[140] This international Earth Observation System (EOS) program will constitute the primary civilian satellite earth observation activity on the part of the United States and its partners in the coming decades (the program is currently designed to continue until 2017).[141] As of this writing, EOS AM-1, the first U.S. satellite in this program, is due to be launched in July 1999,[142] and its many advanced sensors with expansive spectral recording capabilities should make it useful for the study and monitoring of land cover, oceans, atmospheric conditions, ice cover, and a range of biological activity.[143]

Other countries with remote sensing satellites include France, Canada, the former USSR, China, Japan, India, and Brazil.[144] India has a particularly strong earth observation program, and aims to

135. *See* NATIONAL GEOGRAPHIC SATELLITE ATLAS OF THE WORLD 10 (1998).

136. *See* JENSEN, *supra* note 111, at 30.

137. *See id*. at 40.

138. *See* JANE'S SPACE DIRECTORY 375, 399–403 (Andrew Wilson ed., 12th ed. 1996–97); *see also* JENSEN, *supra* note 111, at 44.

139. *See* NASA, *ESE Partners* (last modified Aug. 31, 1998) <http://www.earth.nasa.gov/whatis/partners.html>.

140. *See* NASA, *EOS Program Description* (visited Feb. 28, 1999) <http://eospso.gsfc.nasa.gov/eos_homepage/description.html>. The integrated suite of satellites is part of Phase II of the Earth Science Enterprise program, which is a comprehensive program to study the earth as an environmental system. *See id*.

141. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 395.

142. *See* NASA, *Terra — EOS AM-1* (last modified Feb. 8, 1999) <http://terra.nasa.gov/>. EOS AM-1 is scheduled to launch in July 1999 from Vandenberg Air Force Base, California. *See id*.

143. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 395–96; *see also* JENSEN, *supra* note 111, at 7–8.

144. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 381–94.

have twelve remote sensing satellites in orbit by the year 2000.[145] Examples of European civilian remote sensing are the European Remote Sensing (ERS) satellites operated by the European Space Agency[146] and France's Satellite Pour L'Observation de la Terre (SPOT) satellite system,[147] capable of fine-resolution sensing down to ten meters resolution for some wavelengths,[148] with applications for land use, water resources research, and coastal monitoring.[149] Some new radar systems, such as that used by the Canadian RADARSAT satellite, are able to image the ground even in heavy cloud,[150] but this radar data is generally of coarser resolution and difficult to work with.[151]

A larger number of countries have satellite ground stations, which can take data from satellites.[152] For instance, Ecuador's Center for Integrated Surveys of Natural Resources through Remote Sensors (CLIRSEN) provides a ground station for Landsat data reception and has data interpretation capability for applications including surveys of mangroves and estuaries in Ecuador.[153]

B. Related Tools: Geographic Information Systems and Integrated Environmental Education, Planning, Lawmaking and Enforcement

While satellite imaging capabilities ramp up, developments in geography and other disciplines that use spatially-oriented data promise to correspondingly change the ways we visualize and think about the environment. The art and science of mapmaking itself has already begun a dramatic shift toward the use of computers to integrate and enhance information about the world from multiple sources.[154] Current trends in mapping and analysis are producing exciting possibilities for integrating disparate sources of information.[155]

145. *See id.* at 390.
146. *See id.* at 375–77.
147. *See id.* at 388–90.
148. *See* Wilford, *supra* note 63, at 33.
149. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 375–77, 388–90.
150. *See id.* at 381–82; *see also* JENSEN, *supra* note 111, at 7.
151. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 381–82.
152. *See id.* at 404–15.
153. *See id.* at 408; ENVIRONMENTAL LAW HANDBOOK FOR ECUADOR § 2.1 (CIEL ed., forthcoming July 1999).
154. *See* Wilford, *supra* note 63, at 6.
155. *See id.*

Among the most valuable technological shifts is the increased use of Geographic Information Systems (GIS) that represent data visually and can layer data sets to foster comparisons and interrelationships between them.[156]

The U.S. Geological Survey (USGS) is a leader in establishing the use of GIS storage and presentation of geographic and other types of spatial data.[157] Topographical maps — familiar to all hikers who rely on such maps' precise descriptions of terrain and altitude changes — are now available in electronically viewable and manipulable GIS formats.[158] GIS software and tools are already having a substantial impact on scientific research, natural resource-based commercial activities, environmental education, and policy-making, and ultimately will impact the monitoring and enforcement of environmental laws and regulations. GIS tools are already facilitating strategic environmental policy planning. A recently published monograph utilized GIS tools to make long-term projections of potential regional conflict hazards stemming from population and environmental pressures.[159]

As part of its democratization, modernization, and capacity-building programs, the Inter-American Development Bank has provided geographic information systems to several Latin American countries to help clarify and electronically catalog land titles with the aid of satellite pictures.[160] The World Bank, along with other agencies, has put some effort into the Program on Environment Information Systems (EIS), which "supports African countries as they assess their priority needs in terms of environment and land information systems and analyze the technical, . . . legal, and economic issues hampering their possibilities of meeting these needs," including increasing the awareness and understanding of environmental and geographic information systems.[161] A NASA-funded sur-

156. *See id*. at 22.

157. *See generally* USGS, *USGS Homepage* (visited Mar. 10, 1999) <http://www.usgs.gov>.

158. *See generally* USGS, *USGS National Mapping Information* (last modified Feb. 17, 1999) <http://mapping.usgs.gov/index.html>.

159. *See* DONALD KENNEDY, CARNEGIE CORP. OF N.Y., ENVIRONMENTAL QUALITY AND REGIONAL CONFLICT 12–15, 40–45 (1998).

160. *See* A. Martin Erim, *Financing Sources for Trade & Investment in Latin America*, 13 AM. U. INT'L L. REV. 815, 840 (1998).

161. Jennifer Myers, *Human Rights and Development: Using Advanced Technology*

vey of the Amazonian rain forest used satellite remote sensing capabilities and GIS to study rates and dynamics of tropical rainforest decline from 1978 to 1988, finding significant loss of forest and habitat over that period.[162]

The Commission on Environmental Cooperation, together with the University of Kansas and Mexico's Museo de Zoologia, have developed the North American Biodiversity Information Network (NABIN), which remotely searches data gathered from zoological research and held in the world's natural history museums.[163] The data can then be presented visually via GIS.[164] Further, computer programs that make predictive analyses of species distributions can be employed to model scenarios for biological diversity resulting from changes in climate or land-use patterns across a range of species, territories, and environmental scenarios.[165]

C. Related Tools: Global Positioning Systems

Global Positioning Systems (GPS) are distinct from satellite remote sensing, but merit mention as they can contribute significantly to environmental planning and monitoring.[166] Furthermore, it is likely their use will increasingly complement techniques like remote sensing. GPSs use a "transponder," which communicates its location via satellite to a ground-earth station.[167] Most GPSs are quite flexi-

to Promote Human Rights in Sub-Saharan Africa, 30 CASE W. RES. J. INT'L L. 343, 361 n.101 (1998) (citing *Environment Information Systems in SubSaharan Africa: An Internet Resource*, BULL. AM. SOC'Y FOR INFO. SCI., Apr./May 1995, at 24).

162. *See* Matthew B. Royer, Note, *Halting Neotropical Deforestation: Do the Forest Principles Have What It Takes?*, 6 DUKE ENVTL. L. & POL'Y F. 105, 156 n.3 (1996) (citing David Skole & Compton Tucker, *Tropical Deforestation and Habitat Fragmentation in the Amazon: Satellite Data from 1978 to 1988*, 260 SCIENCE 1905, 1909 (1993)).

163. *See* A. TOWNSEND PETERSON ET AL., NORTH AMERICAN BIODIVERSITY INFORMATION NETWORK, ASSEMBLY OF A DISTRIBUTED BIODIVERSITY INFORMATION NETWORK FOR NORTH AMERICA: LESSONS LEARNED 2 (1998) (on file with authors).

164. *See id*. at 2.

165. *See id*. at 2; *see also* USGS, *Introduction to Gap Analysis in Biodiversity* (last modified July 7, 1998) <http://www.gap.uidaho.edu/gap/AboutGap/introductiontoGAShort/index.htm> [hereinafter *Introduction to Gap Analysis in Biodiversity*].

166. *See generally* SCOTT PACE ET AL., THE GLOBAL POSITIONING SYSTEM: ASSESSING NATIONAL POLICIES (1995) (describing the findings of a one-year GPS policy study).

167. *See* Jonathan Donald Westreich, *Regulatory Controls on United States Exports of Weapons and Weapons Technology: The Failure to Enforce the Arms Export Control Act*, 7 ADMIN. L.J. AM. U. 463, 497 n.175 (1993) (citing EDWARD LUTTWAK & STUART KOEHL, DICTIONARY OF MODERN WAR 256 (1991)).

ble. For instance, someone operating the transponder can "take" a position reading, or someone operating a GPS network can require any individual transponder to report its reading at any particular time or on a set schedule such as every ten or twenty minutes.[168]

Within the United States, satellite imagery should become an increasingly important part of mapping biological diversity as the technology available to civilian sectors improves. Since the composition of vegetation is often a good indicator of the range of animal species such vegetation can support, satellite maps of forest cover and forest type are being used to estimate the ranges of animal and plant species.[169] On a broad level, information from satellites on the type and diversity of forests can be used to estimate the overall biological value of an area.[170] Researchers are now using this information as part of "Gap Analysis" techniques, combining predictions of vertebrate distributions with patterns of land ownership on a GIS to identify important "gaps" in protection that need to be filled.[171] On the individual species level, satellite mapping has been used to map "critical habitat" for two species under the Endangered Species Act: the Marbled Murrelet[172] and the Golden-cheeked Warbler.[173] Interestingly, both of these species are closely linked with coniferous trees in areas that are predominantly covered by oak: the Marbled Murrelets breeding in coastal redwood forest,[174] and the Warbler breeding in stands of Ashe Juniper.[175] Even the relatively poor resolution and spectral imaging of satellites currently aloft (compared with both aerial photography and the satellite technology that is to come), satellite mapping is able to distinguish coniferous and non-coniferous forest areas.[176] As the technology improves, satellites will

168. Telephone Interview with Andrew Bedford, Operations Manager, New Zealand Ministry of Fisheries (Oct. 26, 1998).

169. *See Introduction to Gap Analysis in Biodiversity, supra* note 165.

170. *See id*.

171. *See id*.

172. *See* Final Designation of Critical Habitat for the Marbled Murrelet, 61 Fed. Reg. 26,256, 26,269 (1996) [hereinafter Marbled Murrelet] (codified with some differences in language at 50 C.F.R. pt. 17).

173. *See* Final Rule to List the Golden-cheeked Warbler as Endangered, 55 Fed. Reg. 53,153, 53,155 (1990) [hereinafter Golden-cheeked Warbler] (codified with some differences in language at 50 C.F.R. pt. 17).

174. *See* Marbled Murrelet, *supra* note 172, at 26,256–57, 26,260.

175. *See* Golden-cheeked Warbler, *supra* note 173, at 53,153-54.

176. *See Introduction to Gap Analysis in Biodiversity, supra* note 165.

likely become more useful for gap analysis of animals associated with more subtle habitat characteristics.[177]

V. OVERVIEW OF USES OF SATELLITE DATA IN ENVIRONMENTAL LAW AND POLICY

Notwithstanding the great need to further educate environmental lawyers and policy makers about remote sensing capabilities, some significant legal and policy-oriented applications have developed in the U.S. and abroad.[178] These applications act as signposts for the future potential of remote sensing and associated geographic information to help identify and manage ecological threats.[179]

A. Land Use Policy

Satellites like Landsat and SPOT are particularly good at discriminating between subtle shades of color — that is, the variations in absorption and reflectance of different spectral bands of light and other types of electromagnetic energy.[180] Applications for this ability have been demonstrated in documenting and studying variations in forest cover, forest type, succession stage, and forest health.[181]

Forests also form a key focus of sustainable natural resource management, and satellite remote sensing data has long been used to help map forest cover.[182] Recent technological enhancements en-

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177. Lewis' capability to distinguish tree species, for instance, is likely to be useful for satellite analysis for animals, especially many insects, which often have a very tight relationship with host plants. *See* JANE'S SPACE DIRECTORY, *supra* note 138, at 398. Lewis will also make possible direct satellite mapping of some tree species. *See id*.

178. *See* Uhlir, *supra* note 5, at 13.

> The most far-reaching barrier at this time, yet the one potentially the easiest to remedy, is educational. The paucity of legal precedents in the utilization of remote sensing data as evidence, the lack of educational exposure and technical skills by lawyers and judges, and the virtual absence of any discussion of these issues in legal textbooks and reference materials have all created substantial roadblocks and uncertainties. As with all forms of scientific evidence, acceptance of technology and familiarity with its products will increase with time; but greater awareness of the benefits of remote sensing to the legal community could be fostered through publications and symposia by existing experts.

Id.

179. *See id*. at 10–11, 16–17.

180. *See id*. at 12.

181. *See* Cohen, *supra* note 121, at 428, 431.

182. *See id*. at 428–29.

able the sensors to make much finer measurements and discriminations, including distinguishing between undisturbed primary forest and forest that has been selectively logged.[183] Resource managers constitute one well recognized and well established group of satellite remote sensing data users.[184] Natural resource managers typically use satellite information, which covers a broad area, to supplement the more detailed aerial and on-the-ground surveys, which cover smaller areas at higher resolution.[185]

In the wake of the 1992 United Nations Conference on Environment and Development in Rio, several international efforts were initiated to better quantify and coordinate the study, protection, and sustainable use of forests.[186] Two such efforts in connection with temperate and boreal forests have gained considerable momentum — the Helsinki[187] and Montreal[188] processes.

The U.S. Forest Service research division has begun a pilot effort to coordinate with Canada and Mexico to develop practical

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183. Interview with Dr. Christopher D. Elvidge, NOAA National Geophysical Data Center (Oct. 20, 1998).

184. *See* OFFICE OF EARTH SCIENCE, NASA, EOSDIS POTENTIAL USER MODEL DEVELOPMENT EFFORT ¶ 9.0 (Dixon Butler et al. eds., 1995) [hereinafter EOSDIS POTENTIAL USER REPORT].

185. *See id.* ¶ 9.2.

186. *See infra* notes 187–88.

187. *See generally* Ministerial Conference on the Protection of Forests in Europe, *European Criteria and Most Suitable Indicators for Sustainable Forest Management* (visited Mar. 3, 1999) <http://www.mmm.fi/english/minkonf/criteria.htm> (adopted by the First Expert Level Follow-up Meeting of the Helsinki Conference Geneva, June 24, 1994). The purpose behind the Helsinki Process was to develop basic guidelines for the sustainable management of European forests. *See* Earth Negotiations Bulletin, *The Helsinki Process — Criteria and Indicators for Sustainable Management of European Forests* (Feb. 27, 1995) <http://www.iisd.ca/linkages/vol13/1301003e.html>. This is accomplished by identifying measurable criteria and indicators to evaluate the progression of European countries in their effort to follow the principles developed by the Process. *See id*. The six criteria adopted by the First Level Expert Follow-up meeting include:

> (1) maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles; (2) maintenance of forest ecosystem health and vitality; (3) maintenance and encouragement of the productive functions of forests (wood and non-wood); (4) maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems; (5) maintenance and appropriate enhancement of protective functions in forest management (notably soil and water); and (6) maintenance of other socio-economic functions and conditions.

Id.

188. *See Montreal Process, supra* note 8.

protocols for surveying and protecting temperate and boreal forests, incorporating the most prominent and shared features of the Helsinki and Montreal processes, and identifying those criteria and indicators of forest type, health, and productivity that are amenable to remote sensing.[189] The U.S. Forest Service inventories the health status and productive capacity of the nation's temperate and boreal forest resources and produces annual Forest Health Monitoring reports pursuant to several congressional mandates.[190] In surveying and analyzing the U.S. forests' status, the Forest Service relies on Landsat imagery to provide broad strokes of land cover classification and forest identification. This is supplemented by thousands of individual site visits to characterize forest species and their status.[191]

The group of resource managers using satellite data is broad. It includes private landowners, such as farmers who must decide what crops to plant and where to plant them, and public landowners, such as the Forest Service who must decide what portions of a protected area to open to logging and recreational use.[192] The group also includes regulators — governmental planners who draft regulations governing how resources can be used over a large area.[193] Furthermore, the group also includes private groups working with landowners or government regulators to influence policy.[194] Within the government, different types of regulations may have varying "legal" characteristics, and outside the government, efforts of individuals or private groups may have varying degrees of success in shaping law.[195]

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189. *See* W. BRAD SMITH, U.S. FOREST SERVICE, FOREST INVENTORY AND ANALYSIS (FIA) RESEARCH PROGRAM: BRIEFING MATERIAL 5 (1997).

190. *See id*. The Forest Inventory and Analysis (FIA) program began with the quaintly named Organic Act of 1897, which established our national forests and an obligation to monitor them. *See id*. Further mandates appeared in the 1928 Forest Research Act, the 1974 Resources Planning Act, the 1976 National Forest Management Act, and the 1978 Forest and Rangeland Renewable Resources Research Act — which direct the Secretary of Agriculture "to obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting, managing, and utilizing forest and rangeland renewable resources in rural, suburban, and urban areas." *Id*.

191. Interview with W. Brad Smith, Inventory and Monitoring Specialist, Science Policy, Planning, Inventory, and Information, USDA Forest Service, in Washington, D.C. (Oct. 15, 1998).

192. *See* EOSDIS POTENTIAL USER REPORT, *supra* note 184, ¶ 9.1.3.

193. *See id*. ¶¶ 9.0, 9.1.2, 9.1.3.

194. *See id*. ¶ 9.1.5.

195. *See* Uhlir, *supra* note 5, at 10.

Satellite remote sensing is being used by groups monitoring the effects of policy on land use changes, often in remote areas with poor infrastructure.[196] For instance, the Indonesian government is using satellite remote sensing data in a review of national regulations on plantations and forestry.[197] Also, the University of Arizona, Clark University, and the United States Agency for International Development (USAID) are collaborating to assist the Malawi government in environmental planning in a project called the Malawi Environmental Monitoring Project (MEMP).[198] One focus of MEMP is to evaluate the effects of policy changes on land use patterns in the country.[199] Because any empirical feedback on the effects of specific policies has the strong potential to influence future policy decisions, monitoring projects such as MEMP could possibly become "legal" in the long run.

Another example of the use of satellite data in land use and land cover analysis is the facilitation of "precision" farming — a system that uses data on weed infestations and topography to apply fertilizers, herbicides, and seed in a spatially variable manner.[200] Because the farmer is putting materials down only where they will be useful, precision farming saves money and reduces nonpoint source water pollution downstream from herbicides.[201] A number of companies are now offering precision farming systems on the Internet, and it seems likely that these systems will rely increasingly on satellite data.[202]

196. Electronic Memorandum from Ismo Hippi, Director, Forestry Planning, Enso Forest Development Oy Ltd., to Charles Davies, CIEL (Oct. 6, 1998) (on file with authors).

197. *See id*.

198. Arizona Remote Sensing Center, Office of Arid Land Studies, *Malawi Environmental Monitoring Project* (MEMP) (last modified Dec. 31, 1997) <http://ag.arizona.edu/OALS/oals/arsc/memp.html>.

199. The recent introduction of a new tobacco variety into widespread cultivation is an example of such policy changes. *See id*.

200. *See generally* John Charles Kluge, *Farming by the Foot: How Site-Specific Agriculture Can Reduce Nonpoint Source Water Pollution*, 23 COLUM. J. ENVTL. L. 89, 117–30 (1998) (noting that remote sensing can effectively help reduce herbicide use, but generally not reduce pesticide use).

201. *See id*. at 128–30.

202. *See, e.g.*, Deere & Company, *JOHN DEERE Precision Farming: The Future of GreenStar Precision Farming Systems* (visited Mar. 14, 1999) <http://www.deere.com/greenstar/future.html>; Giannotti Technical Services, *Precision Farming Solutions* (visited Mar. 14, 1999) <http://www.giannottitech.com/>.

B. International Monitoring, Policy, and Law

The line between policy and law is often difficult to define on the international level. Using satellite remote sensing to "quantify" compliance under binding legal obligations is still at an early stage.[203]

One project seeking to increase use of satellite remote sensing on the international level is Global Observations of Forest Cover (GOFC).[204] GOFC was established in 1997 as a pilot project of the Committee on Earth Observation Satellites (CEOS), an international organization comprised of representatives from each country with satellite capability. GOFC's mission is to use satellite technology to improve the quality of life on earth.[205] The GOFC project aims to improve the quality of satellite images of forest cover for the benefit of a number of different user groups, including the legal community.[206] In discussions with the Secretariat for the Convention on Biological Diversity, GOFC is focusing on how to most effectively use satellite data on forest cover to monitor the progress of the Convention.[207] Also, GOFC will likely contribute to the monitoring of a proposed International Convention on Forests, which the Intergovernmental Forum on Forests is currently discussing.[208]

A more binding international context in which satellite imagery may be applied in the future is to monitor compliance with the Framework Convention on Climate Change[209] and the Kyoto Protocol.[210] One major topic of discussion at present is whether and how to give countries "carbon emissions credits" for reforestation.[211] Re-

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203. Telephone Interview with Frank Ahern, Research Scientist, Canada Centre for Remote Sensing (Sept. 4, 1998).

204. *See* COMMITTEE ON EARTH OBSERVATION SATELLITES, CEOS PILOT PROJECT: GLOBAL OBSERVATIONS OF FOREST COVER 6 (Anthony C. Janetos & Frank Ahern eds., Draft Version 3.2, July 7–10, 1997) [hereinafter CEOS PILOT PROJECT].

205. *See id*. at 6–7.

206. *See id*.

207. Telephone Interview with Frank Ahern, *supra* note 203.

208. *See* CEOS PILOT PROJECT, *supra* note 204, at 11.

209. Framework Convention on Climate Change, *supra* note 10, 31 I.L.M. at 849.

210. Kyoto Protocol, *supra* note 10, 37 I.L.M. at 22.

211. *See id*. at 26, 35 (discussing the implementation of a program through which parties to the protocol may transfer carbon emissions credits and noting the opposition of several parties to such program).

growing forest and other vegetation may be a net "sink" of carbon — removing it from the atmosphere and converting it to form part of the biomass of the trees.[212] A recent, controversial study by a group of U.S. scientists concluded that forest and abandoned farmland regrowth in the United States may be a major "sink" of carbon dioxide.[213] Most forest assessment under the Framework Convention on Climate Change relies on on-the-ground surveys, but there is an active dialogue about increasing the use of satellite remote sensing in the future.[214] A 1996 Workshop hosted by the U.S. Forest Service, for instance, focused on remote sensing support for Global Forest Assessment and considered the need for the acquisition and screening of high resolution satellite data.[215] Remote sensing's contribution to climate change law, in particular its use by civil society, is discussed in more detail in the following sections.

C. Enforcement

In pure litigation contexts, satellite remote sensing is one of many tools that enforcement officials use to detect environmental offenses.[216] Satellite data has proven most effective in detecting possible violations meriting investigation,[217] while providing an overview or synoptic perspective to other, higher resolution and more easily qualified evidence obtained from aerial photography and

212. *See* S. Fan et al., *A Large Terrestrial Carbon Sink in North America Implied by Atmospheric and Oceanic Carbon Dioxide Data and Models*, 282 SCIENCE 442, 445 (1998).

213. *See id*. at 445; *see also* Jocelyn Kaiser, *New Network Aims to Take the World's CO2 Pulse*, 281 SCI. 506, 506–07 (1998) (discussing a network of towers which will help to monitor compliance with the Kyoto Protocol by measuring the terrestrial uptake of carbon dioxide).

214. *See Scientific Research, Forest Assessment and Development of Criteria and Indictors for Sustained Forest Management: Report of the Secretary-General*, U.N. Comm. on Sustainable Dev., 3d Sess., U.N. Doc. E/CN.17/IPF/1996/20 (1996) [hereinafter UNCSD]; Telephone Interview with Dr. Peter Baklund, *supra* note 93.

215. *See* UNCSD, *supra* note 214, ¶¶ 22, 23.

216. *See* Timothy W. Foresman & David R. Williams, *Remote Sensing: An Environmental Enforcement Tool, in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE `90S, at 30 (1990).

217. *See* Howard A. Latin et al., *Remote Sensing Evidence and Environmental Law*, 64 CAL. L. REV. 1300, 1338 (1976). Remote sensing often proves extremely valuable in targeting inspections, obtaining search warrants, or providing high-impact visual presentation, which may lead to a favorable out-of-court settlement. *See* Foresman & Williams, *supra* note 216, at 33.

on-the-ground inspections.[218] Most discreet, actionable environmental offenses do not occur over a large area of land.[219] Events like a toxic or oil spill are usually confined to a few square kilometers. This is an area easy to cover by aerial remote sensing, which can provide much greater resolution than satellite technology.[220] In cases where satellite remote sensing is appropriately used as evidence of a violation, however, most lawyers understandably prefer to build a stronger case by gathering more evidence on the ground.[221] This section will just give a few examples of how satellite remote sensing is used in environmental law enforcement.

One possible use for satellite remote sensing is detecting oil spills at sea.[222] Many enforcement and response authorities, however, prefer to rely on airborne remote sensing rather than on satellite technology.[223] The main reason is that many oil spills are sudden, fast-moving events.[224] Although satellite imagery may now be able to detect oil spills on nearly a real-time basis, airborne remote sensing offers the distinct advantage of being able to drop altitude and "zoom in" on the spill, both to collect more detailed information and possibly to identify the ship responsible.[225] Airborne remote sensing

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218. *See* Uhlir, *supra* note 5, at 14 ("Highly processed remote sensing data generally make more effective evidence in litigation; yet the more the data are processed the easier they may be discredit in court."). *See, e.g.*, Foresman & Williams, *supra* note 216, at 32–33, 36 (discussing the value of satellite data in identifying potential Superfund sites for investigation, supplementing other evidence, and promoting retention of environmental facts by jurors).

219. *See, e.g.*, Latin et al., *supra* note 217, at 1339 (discussing the applicability of remote sensing to offenses confined to small areas, such as, concealed effluent discharge outlets, air pollution sources, undesirable mining practices, irrigation violations, and ocean dumping).

220. *See* Foresman & Williams, *supra* note 216, at 32.

221. *See* Latin et al., *supra* note 217, at 1340 (noting that "[s]ome form of onsite inspection will be necessary in the prosecution of the vast majority of enforcement actions").

222. *See, e.g.*, United States Coast Guard Bilge Oil Monitoring Project: A Government Applications Task Force Demonstration Project [hereinafter Coast Guard Report].

223. Electronic Memorandum from Lorne Thomas, Lt. Commander, Response Operation Division, U.S. Coast Guard to Charles Davies, CIEL (Oct. 14, 1998) (on file with authors).

224. *See, e.g.*, Thomas A. Birkland, *In the Wake of the Exxon Valdez*, ENV'T, Sept. 1, 1998, *available in* 1998 WL 14641010 (noting the impact caused by the "suddenness" of the Exxon Valdez oil spill).

225. Electronic Memorandum from Lorne Thomas, *supra* note 223 (noting that the Coast Guard uses Side Looking Airborne Radar (SLAR) to detect and track oil spills); Telephone Interview with Lorne Thomas, Office of Response, United States Coast Guard

has proved a valuable tool for identifying violators, but prosecutors, of course, still prefer to board a suspect ship to gather more evidence.[226] One example is a successful prosecution of a Royal Caribbean cruiser in 1998.[227] A discharge of oil from the ship was detected using airborne Forward-Looking Infra-red Radar (FLIR) (a type of remote sensing), but the actual criminal prosecution was for a false entry in the ship's logbook discovered when officials boarded the vessel.[228] In addition, satellite remote sensing has been used in natural resource damage assessment following oil spills such as the Julie N oil spill in Portland, Maine.[229] More often, however, the satellite images are used to target on-the-ground assessment work or supplement aerial photography, rather than forming a primary basis of evidence in court.[230]

A recent Coast Guard pilot project reviewed the possible use of satellite imagery to monitor bilge oil discharges in the Gulf of Mexico.[231] Current satellite remote sensing techniques are able to identify areas with high levels of bilge oil discharge (by identifying characteristic surface oil slicks).[232] The Coast Guard, however, concluded that remote sensing should not be used because of the high cost and low flexibility of the technology at present.[233]

Sweden, however, appears set to increase the use of satellite remote sensing to monitor marine pollution.[234] The Swedish attorney general is currently reviewing Swedish marine pollution laws with a view to better incorporate new technologies, and in particular satel-

(Oct. 15, 1998) (referring to the full Coast Guard report on the project in the Gulf of Mexico that concluded satellite remote sensing was not useful).

226. *See, e.g.*, United States v. Royal Caribbean Cruises Ltd., 11 F. Supp. 2d 1358, 1361 (S.D. Fla. 1998) (noting that upon suspicion of an oil discharge detected by aerial radar, the Coast Guard boarded the ship to conduct a document and safety inspection).

227. *See id*.

228. *See id*.

229. *See* Dieter Bradbury et al., *Leak Halted After 100,000 Gallons of Oil Foul Harbor: Structural Damage Closes the Million Dollar Bridge Indefinitely as Officials Try to Determine the Cause of the Accident*, PORTLAND PRESS HERALD (Maine), Sept. 28, 1996, *available in* 1996 WL 13311297.

230. Telephone Interview with Joanne Halls, Director, GIS Division, Research Planning, Inc. (Nov. 6, 1998).

231. *See* Coast Guard Report, *supra* note 222, at ii.

232. *See id*. at iii.

233. Telephone Interview with Lorne Thomas, *supra* note 225.

234. Electronic Memorandum from Chrysler Colliander, Sales Manager, SPOT Asia to Charles Davies, CIEL (Sept. 25, 1998) (on file with authors).

lite remote sensing.[235]

Currently, satellite remote sensing technology lends itself particularly well to slow-moving, large-scale environmental problems.[236] It is particularly useful for agencies with responsibility for enforcement over a large, remote area. In the United States, the technology is in use by some, but not all,[237] state water resources departments.[238] An example is the Crop Watch program of the Arizona Water Resources Department, which detects illegal irrigation in the Central and Southern Arizona desert.[239] Crops show up quite clearly in the Arizona desert; thus, irrigation by landowners without water rights is quite easy to detect using satellite remote sensing.[240] Most importantly, crops do not appear and disappear overnight, so the Department need only buy one image per season — in late summer for cotton, the region's major crop, with perhaps an additional image in early summer for wheat and barley.[241] Although the images are expensive, they are cheaper than surveying the entire southern Arizona region on the ground or by plane.[242] Satellite information can be quite persuasive, so prosecutions rarely go to trial.[243] Usually, if the crop is young, the farmer is simply required to stop irrigating and plough it under, and if the crop is old, the farmer may sell it but a fine is assessed.[244]

Another government enforcement context in which satellite

235. *See id*.

236. Telephone Interview with Tom Elder, Arizona Department of Water Resources (Oct. 20, 1998) (discussing the usefulness of satellite data in monitoring a 750,000 acre area).

237. *See id*.

238. Interview with Judy Coover, Assistant Deputy Director, Office of Water Resources Management, Texas Natural Resource Conservation Commission, Office of Water Resource Management (Oct. 28, 1998) (noting that the Texas Natural Resource Conservation Commission does not currently use any type of remote sensing); *see also* Stephen R. Rubin, *An Analysis of Nontidal Wetland Regulation in Maryland*, 16 VA. ENVTL. L.J. 459, 500 (1997) (pointing out that Maryland does not yet believe it is feasible to use satellite technology for monitoring wetland loss). *But see* Telephone Interview with Tom Elder, *supra* note 236 (discussing Arizona's "Crop Watch" program which uses satellite remote sensing to monitor illegal irrigation of land without water rights).

239. Telephone Interview with Tom Elder, *supra* note 236.

240. *See id*.

241. *See id*.

242. *See id*.

243. *See id*.

244. *See id*.

images are used is in the Brazilian Amazon.[245] The Sistema de Vigilancia de la Amazonia (SIVAM) is a $1.4 billion project financed by the U.S. Import-Export Bank and undertaken by Raytheon Corporation.[246] This system will use satellite remote sensing in combination with a number of other monitoring techniques, including aerial photography, to provide comprehensive coverage for the Amazon region.[247] Brazilian authorities anticipate using the system to detect illegal mining and logging, and to measure air pollution from towns in the region.[248]

D. Global Positioning System Applications

One noteworthy use of GPS is as part of a Vessel Monitoring System (VMS).[249] VMS systems, currently used in the European Union, Hawaii, New Zealand, Australia, Argentina, Morocco, and the Forum Fisheries Agency in the South Pacific, monitor the position of vessels operating in territorial waters.[250] The VMS is primarily designed to monitor fishing vessels to ensure that the vessels fish within their assigned areas.[251] VMS may be only one component of a comprehensive monitoring system that incorporates self-report, vessel sightings, and quality control from aerial surveillance.[252] The VMS system is to be operated by the Forum Fisheries Agency, an intergovernmental association of Pacific Island nations, and is supported by all FFA member countries.[253] The system will be able to easily identify fishing vessels located outside their designated areas and, by comparing aerial and GPS monitoring, will be able to iden-

245. *See* Graham Clayton, *Brazil: Electronics Guard the Amazon*, SUNDAY TIMES, July 31, 1994, *summarized in* Chronological Summary, *Events of 1994 — Latin America*, 6 COLO. J. INT'L ENVTL. L. & POL'Y 129, 150 (1995).

246. *See id.*

247. *See id.*

248. *See* Chronological Summary, *Selected Environmental Events in the Western Hemisphere 1995*, 7 COLO. J. INT'L ENVTL. L. & POL'Y 225, 226 (1996).

249. *See FFA member Countries' Fishing Vessel Monitoring System — Cutting Edge Technology to Monitor the Operations of Foreign Fishing Vessels*, FFA Rep. No. 98/30 (1998) [hereinafter *FFA Vessel Monitoring System*] (photocopy on file with authors).

250. *See id.*

251. *See id.*

252. Telephone Interview with Andrew Bedford, *supra* note 168; *see also FFA Vessel Monitoring System, supra* note 249 (describing several compliance measures in addition to VMS).

253. *See FFA Vessel Monitoring System, supra* note 249.

tify unregistered vessels (those not fitted with a GPS transponder) fishing illegally inside the country's Exclusive Economic Zones.[254]

GPS use is less well developed on land, but is increasing. For instance, a new WasteTrack program in Western Australia requires trucks carrying hazardous waste to be fitted with GPS transponders.[255] The GPS tracks waste during collection to ensure it is disposed of at an appropriate site, and if loss occurs at an unapproved site, the GPS marks the location of the incident to within five meters.[256] GPS transponders have also been used to monitor animal positions, thus replacing the traditional radio collars and providing a greater variety of information.[257] One possible GPS use in the context of litigation is evidenced in Yellowstone national park.[258] Park officials are using GPS collars to track the position of bison within the park, in part to determine whether the bison are using snowmobile trails.[259] This information may be used in the Yellowstone Winter Sports Environmental Impact Statement currently being developed.[260]

In general, GPS systems appear to be used more effectively as a deterrent rather than for use in court. The system has been used successfully on the part of prosecutions in Queensland, Australia,[261] and in New Zealand.[262] In addition, the Western Australia WasteTrack system recently held a "mock trial" to test the admissibility of the GPS information.[263] Three solicitors from the Crown

254. *See id*.

255. *See* Adam J. Parker et al., *Liquid Waste Management in Western Australia: A Case Study in Enforcement and Compliance*, 1 PROC. FIFTH INT'L CONF. ON ENVTL. COMPLIANCE & ENFORCEMENT 221, 232–33 (1998).

256. *See id*. at 233.

257. *See Wyoming Grizzly Data Collared*, DENV. POST., Sept. 20, 1998, at B4, *available in* 1998 WL 18525193.

258. *See* Yellowstone Net Company, *The Yellowstone Net News Page: 1997 News Stories* at Sept. 19 (visited Mar. 15, 1999) <http://www.yellowstone.net/newsarchives1.htm>.

259. *See Scientists to Study Brucellosis Along with Behavior of Animals* (Dec. 2, 1997) <http://www.wildrockies.org/Talus/Bison/97media/gazette1.html>.

260. Telephone Interview with B.J. Schubert, Managing Director, Schubert & Associates (Oct. 14, 1998).

261. Electronic Memorandum from Debra Archdeacon, Acting Manager, Liquid Waste, Waste Management Division, Western Australia Department of Environmental Protection to Charles Davies, CIEL (Oct. 19, 1998) (on file with authors).

262. Telephone Interview with Andrew Bedford, *supra* note 168.

263. Electronic Memorandum from Debra Archdeacon, *supra* note 261.

Solicitors Office participated and concluded that the satellite information would be admissible under some circumstances.[264] In New Zealand, two prosecutions in 1994 resulted in jail terms for ship captains fishing illegally in New Zealand waters and, more significantly, forfeiture of the very large factory trawlers used.[265] These prosecutions appear to have acted as such an effective deterrent that very little illegal fishing has been detected since.[266] Now, the VMS system is actively used as a decision support tool.[267] For instance, when a number of endangered sea mammals (sea lions) are accidentally caught within an area in a short period of time (indicating that high numbers are present), the area may be closed off, and GPS may be used to ensure that all vessels have exited the area.[268]

In the future, GPS systems may incorporate an increased amount of remote sensing information; the two technologies are each natural components of a complete GIS.[269] For instance, the New Zealand Ministry of Fisheries currently combines GPS data from ships with satellite sea-surface temperature data to predict which fish a particular vessel is targeting or catching.[270] In the future, the system may be expanded to incorporate satellite data concerning the presence of actual fish shoals in an area.[271]

E. Citizen Enforcement

Citizens' groups generally use satellite remote sensing information in one of two ways. First, they may use the information much like a government prosecutor may — to identify and prosecute those violating environmental laws. Second, they may use the information for dramatic educational or lobbying purposes, highlighting the magnitude of environmental harm that can be viewed from space.

In 1997, Indonesia's extensive forest fires caused serious air pollution over much of Southeast Asia, including neighboring countries

264. *See id.*
265. Telephone Interview with Andrew Bedford, *supra* note 168.
266. *See id.*
267. *See id.*
268. *See id.*
269. *See id.*
270. *See id.*
271. Telephone Interview with Andrew Bedford, *supra* note 168.

like Singapore and Malaysia.[272] Satellite remote sensing was used extensively throughout the fire control effort.[273] In fact, remote-sensing may have been the only technology that could locate blazes over the vast, remote jungle areas of Borneo and Sumatra, especially since reports from the field were often inaccurate.[274]

The National University of Singapore (NUS) provided data, which it claimed identified landowners on whose property fires occurred, to the Indonesian Environment Ministry.[275] The Indonesian government later confirmed that it had identified a number of companies responsible for starting fires illegally, based on data from NOAA, NUS, and the Indonesian Space Ministry.[276] However, the technology that was useful for locating burns for the fire control effort would not be an acceptable basis for a prosecution.[277] Although the one kilometer resolution of much of the data can identify the rough location of fires, and may identify the property on which fires occurred, particularly when large landholdings are involved, it cannot identify who started the fire.

As an added complication, some of the Indonesian fires may have been politically motivated.[278] For instance, a number of landowners are believed to have started fires to clear huge tracts of plantation land.[279] Furthermore, burning near irregular pieces of land indicates small scale farmers may be burning areas for new farming land.[280] Therefore, prosecutors may need additional evidence, such as the burn pattern (a regular pattern in an area suitable for crop trees likely indicates a deliberate burning by the landholder).[281] Prosecutions by the Indonesian government for illegal burning have already resulted in some companies losing their operating per-

272. *See Japan, U.S. to Act Jointly on Global Problems*, DAILY YOMIURI, July 14, 1998, *available in* 1998 WL 12845227.

273. *See* Allison Lim, *What's Causing Haze?*, SING. STRAITS TIMES, Oct. 1, 1997, at 1, *available in* 1997 WL 12147752.

274. Interview with Iwan Gunawan, Ph.D., Director of Technology for Natural Resources Inventory, Agency for the Assessment and Application of Technology, Indonesian Technology Ministry (Oct. 13, 1998).

275. *See* Lim, *supra* note 279.

276. Interview with Iwan Gunawan, *supra* note 280.

277. Interview with Dr. Christopher D. Elvidge, *supra* note 188.

278. *See* Lim, *supra* note 279.

279. *See id*.

280. *See id.*

281. *See id*.

mits.[282] In addition, the Indonesian Environmental Forum (WAHLI) recently used NOAA satellite data in a tort case against a company, PT Musi Hutan Persada.[283] The South Sumatra court found the company responsible for starting deliberate fires, but did not award damages, requiring only that the company prevent future burning on its property.[284]

In Brazil, the Fundacao SOS Mata Atlantica used satellite remote-sensing mapping in an effort to protect the "Greater Atlantic Forest" ecosystem, one of the most threatened forest areas in South America.[285] The mapping identified forest fragments on private land, and sought to persuade landowners to conserve the forest.[286] A similar mapping project by Conservation International in the Maya Biosphere Reserve in Guatemala charted the effect of crude oil production on forest loss in the area using aerial and satellite mapping.[287] The project found that new areas of deforestation were concentrated near the access road.[288] The group presented its results to a press conference attended by high-ranking government ministers including the Guatemalan President, and may have affected some change in policy.[289]

In addition to use in prosecutions or monitoring efforts, citizens groups are using remote-sensing as an advocacy tool. One significant recent example is use by the Point-a-Pierre Wildfowl Trust in Trini-

282. *See Environmental Agency Denies El Nino Responsible for Haze*, AGENCE FRANCE-PRESSE, Nov. 12, 1997, *available in* WESTLAW, 1997 WL 13433200.

283. Electronic Memorandum from Iwan Gunawan, Indonesian Technology ministry, to Charles Davies, CIEL (Oct. 20, 1998) (discussing an Indonesian plantation company found guilty of negligence that led to forest fires) (on file with authors).

284. *See Two Firms Blamed for Forest Fires*, JAKARTA POST, Oct. 20, 1998, *available in* 1998 WL 13123990.

285. Electronic Memorandum from Eduardo S. Brondizio, Assistant Professor, Department of Anthropology, University of Indiana, to Charles Davies, CIEL (Sept. 23, 1998) (on file with authors).

286. *See id*.

287. *See Protecting a Fragile Planet*, 1998 CONSERVATION INT'L 7; *see also* Steven A. Sadler et al., Time-Series Tropical Forest Change Detection for the Maya Biosphere Reserve: Updated Estimates for 1995 to 1997, at 3, 5 (1997) (unpublished report on file with authors); Telephone Interview with John Musinsky, Director, Capacity Building Program in Science and Technology, Conservation International (Oct. 17, 1998).

288. *See Protecting a Fragile Planet, supra* note 287, at 7; *see also* Sadler et al., *supra* note 287, at 12–13.

289. *See Protecting a Fragile Planet, supra* note 287, at 7; Telephone Interview with John Musinsky, *supra* note 287.

dad and Tobago.[290] The Nariva Wetlands comprise the largest wetland area in Trinidad and Tobago and is the only such "wetland of international importance" protected by the country under its participation in the Ramsar Wetlands Convention.[291] For the past few years, the area has been significantly burned and drained by illegal rice farmers.[292] Recently, rice farmers dug numerous large canals in the wetland to divert water for crop irrigation.[293] A Canadian group diverted a RADARSAT satellite and provided the Point-a-Pierre Wildfowl Trust with images of the canals from space.[294] The images were presented to the Trinidad and Tobago government as part of an advocacy effort before the government and the Ramsar Convention Secretariat, and the government has promised to fill the canals swiftly.[295]

Another local use of satellite remote sensing was in the context of a proposed disposal site in Wicasset, Maine, for nuclear waste generated by the Maine Yankee Atomic Power Station.[296] A major issue in the proposal was whether nearby areas were "wetlands" into which waste could seep and contaminate groundwater.[297] Locals who had traditionally visited areas surrounding the site "to catch frogs and pick cranberries" were unable to persuade officials that these areas were wetlands.[298] A schoolteacher, however, had obtained a spot satellite image of the area one mile around the proposed waste site.[299] The image was interpreted for wetlands, partly

290. For more information about the Trust, see The Point-a-Pierre Wildfowl Trust, *The Point-a-Pierre Wildfowl Trust — Trinidad W.I.* (visited Mar. 15, 1999) <http://news.carib-link.net/~wildfowl/papwft./htm>.

291. Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Feb. 2, 1971, 996 U.N.T.S. 245, *reprinted in* 11 I.L.M. 963 (1972); *see* List of Wetlands of International Importance Designated by the Contracting Parties, Oct. 27, 1998, at 19 (created pursuant to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Feb. 2, 1971, art. 3, 996 U.N.T.S. at 247, 11 I.L.M. at 971) (on file with authors).

292. *See* The Point-a-Pierre Wildfowl Trust, *Big Rice Farmers Move in on Nariva Again!!* (visited Feb. 25, 1999) <http://news.carib-link.net/~wildfowl/wft/ricefarm.htm>.

293. *See id*.

294. *See* The Point-a-Pierre Wildfowl Trust, *Nariva* (visited Mar. 4, 1999) <http://news.carib-link.net/~wildfowl/wft/nariva98.htm>.

295. *See Big Rice Farmers Move in on Nariva Again!!*, *supra* note 292.

296. *See* EOSDIS POTENTIAL USER REPORT, *supra* note 184, ¶ 12.2.5.

297. *See id*.

298. *Id*.

299. *See id*.

by extensive "ground truthing" by the twelfth-graders, who visited each area to identify specific wetland characteristics before coloring each area red on the image map.[300] The map not only silenced state geologists in the public hearing, but also impressed high level state policymakers.[301]

A relatively new use for satellite images is in the field of customary land use mapping.[302] In many cases, a national or regional government may designate land for a particular purpose[303] without fully researching or acknowledging how the area is currently used.[304] The new activity may conflict with claims to land by local communities,[305] or it may cause displacement,[306] social disruption,[307] and possible environmental damage to nearby areas.[308]

Customary land use mapping aims to remedy this problem by providing accurate maps of community land claims that will persuade, or at least control the behavior of, those making land use decisions on a large scale.[309] An example of community mapping is work done with a Kenyah community in Kalimentan, Indonesia.[310] The researchers used GPS and GIS techniques to produce a map of community land rights to counter official land use maps of the area, some of which designated protected forest in land claimed by communities.[311] In addition to protecting property rights, the researchers hoped that the map would help protect forest by ensuring pro-

300. *Id*.

301. *See id*.

302. *See generally* Martua Sirait et al., *Mapping Customary Land in East Kalimantan, Indonesia: A Tool for Forest Management* (visited Feb. 25, 1999) <http://envgov.ewc.hawaii.edu/env/working.papers/jfox/ali.html>.

303. For instance, by gazetting a protected area or by granting a logging concession in a particular area. *See id*. at Introduction.

304. *See id*. at Introduction (citing THE REAL AND IMAGINED ROLE OF CULTURE IN DEVELOPMENT: CASE STUDIES FROM INDONESIA (Michael R. Dove ed., 1998)).

305. *See id*. (citing S. Moniaga, The role of Agrarian Laws in Transforming the Swidden Agriculture Practices in Long Segar, East Kalimantan (1986) (unpublished Sarjana thesis, Parahyangan University, Bandung, Indonesia)).

306. *See id*. at Discussion.

307. *See id*. at Results (citing J.A. Weinstock, Land Tenure Practices of Swidden Cultivators of Borneo (1979) (Master's thesis, Cornell University)).

308. *See* Sirait et al., *supra* note 302, at Introduction (citing THE LAST RAIN FORESTS: A WORLD CONSERVATION ATLAS (Mark Collins ed., 1990)).

309. *See id*.

310. *See id*.

311. *See id*. at Methods.

tected areas corresponded accurately to actual areas of forest not in use by local villages.[312]

This section has given some examples of how the legal community can use satellite remote sensing. It should be apparent that prosecution is only one of the many uses to which satellite remote sensing can be put, possibly one of the less important uses since prosecutors tend to prefer to supplement any prosecution with on-the-ground evidence.[313] Remote sensing has great potential, however, for environmental policy making, especially on the large international scale or in remote areas where on-the-ground surveys are impractical.[314] Most importantly, it has great potential for use by citizens groups who may not have access to as many sources of information as a government agency, and who can use the satellite information both for objective measurement and for emotional appeal.[315]

VI. NASA-FUNDED COLLABORATION TO DISTRIBUTE SATELLITE DATA FOR APPLICATIONS IN INTERNATIONAL ENVIRONMENTAL LAW

The opportunities presented by expanding use of satellite remote-sensing data are myriad and cross disciplines — from science, to education, to law enforcement — in ways that have never been possible before. How can we best take advantage of the historic opportunities?

In preparation for the significant amounts of new data expected from the international Earth Observation System (EOS) of satellites, NASA has developed relationships with academic institutions, nongovernmental organizations, and other entities interested in earth observation data, and is charging these partners with the design and implementation of data-dissemination mechanisms. These are the Earth Science Information Partners (ESIPs), created pursuant to the data management component of the EOS program, the Earth Observation System Data and Information Systems and

312. *See id*. at Introduction.
313. *See supra* note 221 and accompanying text.
314. *See* discussion *supra* Part V.B.
315. *See* discussion *supra* Part V.E.

Services (EOSDIS).[316] NASA has identified a number of groups that it expects to be interested in satellite data available on EOSDIS.[317] One of these groups is the legal community, and in particular, environmental lawyers.[318]

A central objective of the collaboration between CIEL, the University of Maryland, the Library of Congress, and the Center for Excellence in Space Data and Information Sciences (CESDIS) is to create an Environmental Law Information System (ELIS). An ELIS is a database management and search tool to help integrate textual national and international environmental law resources with the contents of NASA's satellite data storage warehouses, as well as information products created by other ESIPs.

CIEL and its partners aim to provide expertise, education, representation, and sophistication, and, where possible, help arrange funding to foster a broad array of civil applications of these new tools.

ELIS will access NASA's archived satellite data and information products and will contain a search engine allowing users to search both laws and remote sensing images simultaneously.[319] In response to a single search, ELIS could produce both NASA's data and satellite images concerning forest cover in a country of interest, international agreements concerning forests to which the country is a party, and national and regional laws regulating forests. The ELIS system will be one of the first of what CIEL hopes will be a new trend of databases providing both environmental laws and the environmental facts on which the application of those laws depends.

Finally, the ELIS will be integrated with CIEL's proprietary database of environmental laws, ELINE. Current plans for ELINE include an Internet-accessible database of environmental law from North, Central, and South American nations. ELINE is organized into country-by-country handbooks, identifying and indexing envi-

316. For information on the EOSDIS program, see NASA, *An Overview of EOSDIS* (visited Mar. 15, 1999) <http://spsosun.gsfc.nasa.gov/NewEOSDIS_Over.html>. The site provides links to other information, including general descriptions of the EOS satellites, and a list of the data sources included in the EOSDIS system. *See id*.

317. *See generally* EOSDIS POTENTIAL USER REPORT, *supra* note 184.

318. *See id*. ¶ 11.1.

319. For a preview of the prototype system on the Web, see *Environmental Legal Information System* (visited June 8, 1999) <http://www.cs.umbc.edu/~kalpakis/ELIS/welcome.html>.

ronmental laws by topic area. Handbooks for the United States, Mexico, and Canada are available through the Commission on Environmental Cooperation (CEC) website in English, Spanish, and French.[320]

The ELINE will include the full texts of laws presented in at least English and the original language (usually Spanish), other primary legal materials including court cases, and up-to-date news and analysis of important environmental law happenings in the ELINE countries. CIEL plans to expand the system to include useful access to sources of environmental data and analyses, including environmental impact assessments, geographic data processable by GIS software, and satellite remote sensing data from the ELIS system.

CIEL expects to attract a broad range of users for legal and remote sensing information, including government and international institutions, corporations, nonprofit organizations, and individual citizens in the United States and abroad.

VII. POLICY CONCERNS IN EXPANDED ACCESS AND USE OF REMOTE SENSING DATA

A. Cost and Access: Data and Expertise

Satellite remote sensing data represents the product of a highly sophisticated and costly infrastructure. A major dilemma for policymakers centers on questions of how to make this useful source of environmental information available to the public while at the same time treating public and private satellite operations as commercial enterprises.

The widely-used Landsat system underwent privatization and commercialization in 1984.[321] Throughout the 1970s, NASA operated the Landsat satellite system launching four satellites (Landsat-2 to Landsat-5).[322] In the early 1980s, however, Congress revisited the

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320. *See* Commission for Environmental Cooperation, *Summary of Environmental Law in North America* (visited Feb. 25, 1999) http://www.cec.org/infobases/law/index.cfm?format=1&lan=english>.

321. *See* Land Remote-Sensing Commercialization Act of 1984, Pub. L. No. 98-365, 99 Stat. 451 (1984).

322. *See* S. REP. NO. 98-458, at 1 (1984), *reprinted in* 1984 U.S.C.C.A.N. 658, 658; H.R. REP. NO. 98-647, at 5 (1984).

role of the Federal government in civilian satellite operation[323] and moved to privatize Landsat in 1984 with the Land Remote Sensing Policy Act.[324] A private corporation, the Earth Observation Satellite Company (EOSAT), became the Landsat operator and the sole owner of the satellite's data products.[325] Although the measure enabled Landsat to continue its data production, the move drastically affected the information's price.[326] A review of Landsat's privatization indicated that it effectively priced most researchers and local government users out of the market.[327]

Landsat's privatization program was partially reversed as a result of the 1992 Land Remote Sensing Policy Act,[328] which transferred operational responsibility for Landsat to the Defense Department and NASA.[329] The new Landsat data policy is to distribute unenhanced and preprocessed data at cost to United States governmental agencies, academics, and nonprofit institutions.[330] Private contractors retain the ability to sell commercially enhanced data products at the relevant market price.[331] Although this mixed policy helps to transfer raw data into a broad swath of civilian and government hands, it keeps the access to interpreted data and image products prohibitively high for many applications considered essential by the authors.[332]

Recall that data interpretation requires knowledge of both remote-sensing and the characteristics of the sensed material, and involves extensive human labor as well as knowledge of computer systems.[333] The price of image interpretation may vary considerably

323. *See* S. REP. NO. 98-458, at 2–3, *reprinted in* 1984 U.S.C.C.A.N. at 659–60; H.R. REP. NO. 98-647, at 2–3.

324. Pub. L. No. 98-635, 99 Stat. 451 (1984).

325. *See* JENSEN, *supra* note 111, at 30.

326. *See* KATHLEEN M. EISENBEIS, PRIVATIZING GOVERNMENT ACTION: THE EFFECTS OF POLICY ON ACCESS TO LANDSAT SATELLITE DATA 66–67, 122–24 (1995).

327. *See id.* at 122–24.

328. 15 U.S.C. §§ 5601–5672 (1994) (repealing 68 U.S.C. § 4201).

329. *See id.* § 5601(9).

330. *See id.* § 5601(13).

331. *See id.* § 5601(15).

332. *See id.* § 5601(4); *see also* EISENBEIS, *supra* note 326, at 122–24 (discussing high cost as a commercial effect). One purpose of this policy is to empower citizens, nonprofit government institutions, and poorer foreign governments by providing them with satellite data for environmental monitoring. *See* 15 U.S.C. §§ 5601(10), 5611(2).

333. *See, e.g.*, JENSEN, *supra* note 111, at 2–10 (describing the necessity for trained scientists in evaluating data); Short, *supra* note 111.

depending on the interpretation's complexity, but four-to-five figure prices are typical for individual interpreted satellite image "scenes," several of which typically need to be purchased to provide contiguous coverage of even local features.[334]

Furthermore, the image must be checked for accuracy. This process, called "ground truthing," typically involves sending people into various field locations to verify that the image corresponds to what exists on the ground.[335] Satellite data is best accepted as a convenient substitute, rather than a mere improvement upon the extensive field research of a large area. The combined cost of multiple data scenes, expert interpretation, and ground truthing may exceed thousands of dollars for a single image.[336] Predictably, many consumers, especially in the non-profit sector, are unable or unwilling to spend such amounts.

Like any advanced technology, satellite remote sensing is costly, thus creating access barriers for poorly-funded government agencies or the general public.[337] Because the commercial operation of satellites appears vital to ensure continued vigor of the technology, it is imperative to search for ways to make important information available for environmental management without unreasonable interference with commercial operations.[338] Thus, there is hope for the future that an increase in satellite remote sensing, coupled with less sophisticated information, can be offered for free. Another approach is for the government to make its information available at reasonably low cost to those who would not otherwise be able to afford remote-sensing data.

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334. *See* NASA, *Current Status and Summary Agreement Between Landsat Program Management and EOSAT Corporation on Cost and Reproduction Rights for Landsat 4/5 Thematic Mapper Data* (last modified May 1, 1997) <http://geo.arc.nasa.gov/sge/landsat/apr11.html#usgau>.

335. *See* OKOLIE, *supra* note 92, at 24; *see, e.g.*, Tom Sever, *The Peten Guatemala Ground-Truth Information* (last modified May 5, 1998) <http://www.ghcc.msfc.nasa.gov/archeology/peten_groundtruth.html> (demonstrating how ground-truthing is applied in Guatemala).

336. *See generally* D.L. Gustafson, *Remote Sensing* (last modified Feb. 5, 1996) <http://rivers.oscs.montana.edu/dlg/gis/remote.html> (mentioning the elaborateness of ground truthing); Sever, *supra* note 335 (providing an example of the combination of various techniques employed in data compilation).

337. *See* JENSEN, *supra* note 111, at 2–6; *see also* EISENBEIS, *supra* note 326, at 66.

338. *See* 15 U.S.C. §§ 5601(6), 5011(b)(4), 5611(c)(2); *see also* JENSEN, *supra* note 111, at 2.

B. Privacy

As satellite remote sensing technology advances, the Earth can be seen in finer detail and in a greater variety of ways. However, the prospect of more satellites operating with improved resolution and expanded spectral capabilities raises concerns about possible governmental intrusion upon the Fourth Amendment rights of privacy and freedom.[339]

A planning conference, titled "Mission to Planet Earth," is scheduled to address these privacy concerns surrounding increased satellite use.[340] The Supreme Court briefly considered this issue in the 1986 Dow Chemical case.[341] In the case, the court held that an EPA aerial surveillance of a private chemical plant was not an unconstitutional search under the Fourth Amendment.[342] Although the plant's ground-level was heavily secured from entry, the company had no reasonable expectation of privacy from aerial surveillance because their plant was open to the air and they had made no serious attempt to secure their property from aerial surveillance.[343]

However, the Court noted that "surveillance of private property by using highly sophisticated surveillance equipment not generally available to the public, such as satellite technology, might be constitutionally proscribed absent a warrant. But the photographs here are not so revealing of intimate details as to raise constitutional concerns."[344] The decision reinforces the concern that high resolution satellite images may raise privacy issues. Although as time passes, the assumption that satellite images will be any less accessible to the public than aerial photography images is uncertain.[345]

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339. U.S. CONST. amend. IV ("The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated . . . .").

340. *See* EOSDIS POTENTIAL USER REPORT, *supra* note 184, ¶ 11.4.

341. Dow Chemical Co. v. United States, 476 U.S. 227 (1986).

342. *See id*. at 239.

343. *See id*. at 236–38.

344. *Id*. at 238.

345. *See generally* Krysten C. Kelly, *Warrantless Satellite Surveillance: Will Our 4th Amendment Privacy Rights Be Lost in Space?*, 13 J. MARSHALL J. COMPUTER & INFO. L. 729 (1992) (arguing that erosion of privacy rights in connection with aerial surveillance portends further intrusions into privacy via more advanced satellite remote sensing capabilities); David A. Koplow, *Back to the Future and up to the Sky: Legal Implications of*

With respect to "intimate details," a recent and controversial group of cases addressing hand-held remote sensing devices have been upheld under the Fourth Amendment.[346] Most of these cases involve police using thermal imaging devices to gather information on heat emitted from a private home.[347] The resulting image often yields evidence of unusual "hotspots" that may relate to heat lamps used for the cultivation of illicit plants such as marijuana.[348] Relying on this evidence as "probable cause" of illegal activity, the police can search the private dwelling and may gather more convincing evidence of drug cultivation.[349] Courts have considered this issue and have held that thermal imaging did not constitute a "search" of a private dwelling and therefore did not require a search warrant under the Fourth Amendment.[350] These courts have created a general principle that an individual has no expectation of privacy rights concerning heat emanating from their home.[351] Because the heat is physically outside the home, the police, who rely on heat patterns to create an "image" of the home, are not actually intruding upon private space.[352]

The issue in these imaging cases is similar to the issue in satellite remote sensing cases.[353] The question is whether one has a privacy right to matter or energy that is outside the dwelling, but related to the activities within the home. Many activities or objects within the home release heat. Therefore, an observer with remote

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"Open Skies" Inspection for Arms Control, 79 CALIF. L. REV. 421 (1991) (commenting on how remote sensing raises important constitutional concerns related to warrantless governmental searches of overflown citizens).

346. The following cases held that the use of a thermal imager did not constitute a warrantless search and, thus, did not violate the Fourth Amendment: *United States v. Ishmael*, 48 F.3d 850, 856 (5th Cir. 1995); *United States v. Ford*, 34 F.3d 992, 997 (11th Cir. 1994); *United States v. Pinson*, 24 F.3d 1056, 1059 (8th Cir. 1994).

347. *See Ishmael*, 48 F.3d at 851 (demonstrating how police can use a hand-held thermal imager to detect unusual heat patterns); *Ford*, 34 F.3d at 993 (showing how a thermal imager can be a non-intrusive method used by law enforcement to detect abnormal heat).

348. *See Ishmael*, 48 F.3d at 851; *Ford*, 34 F.3d at 993; *Pinson*, 24 F.3d at 1059.

349. *See Ishmael*, 48 F.3d at 851; *Ford*, 34 F.3d at 993; *Pinson*, 24 F.3d at 1059.

350. *See Ishmael*, 48 F.3d at 851; *Ford*, 34 F.3d at 993; *Pinson*, 24 F.3d at 1059.

351. *See Ishmael*, 48 F.3d at 855–56; *Ford*, 34 F.3d at 996–97; *Pinson*, 24 F.3d at 1058–59.

352. *See Ford*, 34 F.3d at 998.

353. *See generally* Kelly, *supra* note 345, at 739 (predicting how advances in technology will put increasing pressure on our Fourth Amendment rights).

sensing technology can gather evidence of these activities with a thermal imaging device.[354] For instance, people give off heat, so one could theoretically locate people within a house using a thermal imaging device such as a satellite or a hand-held Forward Looking Infra-red Radar (FLIR) outside the home. Thus, the potential exists to capture and process energy sources, such as individuals and their private property, in an unsuspecting, albeit objectionable, way. For this reason, commentators have been generally critical of the United States' court decisions.[355] In fact, state courts in Montana and Washington have opted to extend the scope of their respective Constitutions to protect infra-red emissions from the home.[356] Whatever type of remote sensing is used, a balance must be struck between improving access to information and protecting individual's privacy rights.

Of course, privacy concerns have yet to severely restrict the proper use of remote sensing information in environmental law. The current uses which include mapping forest cover and settlements, concern large-scale commercial operations or land use monitoring.[357] More simply, most uses concern outdoor operations to which few cultures assign privacy rights.

Unfortunately, this does not settle the issue. The one meter resolution of new remote sensing products is probably too great to raise serious privacy concerns, and most of the information collected is not deemed private in most cultures. Nevertheless, remote sensing data basically operates on a system similar to the FLIR devices used by the United States police force. The improvement in resolution will enable the nation to collect information that is arguably private. Consequently, it is necessary to begin thinking about the issues involved with remote sensing so the industry is prepared to

354. *See id.* at 736.

355. *See, e.g.*, Jonathan Todd Laba, *If You Can't Stand the Heat, Get out of the Drug Business: Thermal Imagers, Emerging Technologies, and the Fourth Amendment*, 84 CAL. L. REV. 1437 (1996) (discussing how the use of advanced technology has constitutional implications); Susan Moore, Note, *Does Heat Emanate Beyond the Threshold?: Home Infrared Emissions, Remote Sensing, and the Fourth Amendment Threshold*, 70 CHI. KENT L. REV. 803 (1994) (discussing how remote sensing is offensive to Fourth Amendment protections).

356. *See* State v. Siegal, 934 P.2d 176 (Mont. 1997); State v. Young, 867 P.2d 593 (Wash. 1994).

357. *See* NASA, *NASA Celebrates the 25th Anniversary of Landsat* (visited Mar. 13, 1999) <http://geo.arc.nasa.gov/sge/landsat/lsat25b.html>.

use the technology in a socially responsible way when developed.

Possibly the most important issue involves the point at which an intrusion upon one's property occurs. Because there exists no interest in peoples' private lives when collecting environmental information, it seems acceptable to collect data on the interior of private property provided the information is not displayed or interpretated.

Various possible solutions exist when encountering the privacy problem. One way to limit privacy invasions is to place a resolution limit on remote sensing data. This limit should be great enough to provide a safeguard against privacy infringement yet low enough to permit the collection of environmental data. As the technology develops, however, the resolution limitation becomes less acceptable. For instance, sophisticated measurements of forest maturity and diversity requires the highest resolutions currently available.[358] Another approach may be to restrict data interpretation to areas away from human habitation, an approach that is less than satisfactory for community mapping projects.

The Endangered Species Act illustrates why the remote sensing community needs to consider privacy issues now.[359] A clause in the 1996 Appropriations Bill prohibited the U.S. Forest Service from collecting or analyzing data concerning endangered species on private land without the landowner's consent.[360] Requiring a landowner's consent prior to data collection is certainly one approach to resolving privacy concerns. As a model for international environmental monitoring, however, this approach would make any use of remote sensing for environmental purposes completely impractical; any map of the world would require the consent of billions of landowners in hundreds of political jurisdictions. Some advanced thinking about the privacy issue by the environmental and remote sensing communities is needed to quickly and intelligently suggest alternatives to "privacy" laws.

C. Sovereignty

358. *See* JENSEN, *supra* note 111, at 6.

359. *See* Omnibus Consolidated Rescissions and Appropriations Act of 1996, Pub. L. No. 104-134, 110 Stat. 1321, 1321-165 (1996).

360. *See id*.

At least to the extent that satellites are nationally owned and operated, the system could create some inequalities in power, with sensing countries able to collect information on (usually poorer) sensed countries, which might be exploited to economic effect in resource extraction agreements.[361] "Sovereignty" concerns regarding remote sensing go beyond simple information inequality. Because countries often permit on-the-ground natural resource surveys within their national borders, remote sensing may be perceived as a violation of, or control over, another's land.[362] Surprisingly, sensing states do not correspond frequently with countries in the developed world. Although developing world leaders like India and Brazil have long possessed some degree of satellite remote sensing capability,[363] states who are sensitive to the West seem nervous of the potential of satellite remote sensing. It is this potential that may threaten the principal economic asset of the developing world and may lead to the control of natural resources.

At the time the Outer Space Treaty entered into force in 1967,[364] satellite technology was in its infancy, and the issue of remote sensing was not addressed directly by its terms. When the United States launched Landsat-1 in 1972, however, the international community recognized the need for a legal framework for remote sensing, and the United Nations Committee on the Peaceful Uses of Outer Space delegated the issue to a "Working Group" within its Legal Sub-committee.[365]

The chief obstacle to a swift and binding agreement was the tension between advocates of an "open skies" policy and advocates of a policy of "prior consent."[366] The open skies policy, championed mainly by countries possessing the technical and financial ability to con-

361. *See* OKOLIE, *supra* note 92, at 28, 39; *see also* Weaver, *supra* note 79, at 29–33, 38–39 (discussing national security concerns and fears of Third World countries).

362. *See* EISENBEIS, *supra* note 326, at 28.

363. *See* Schrogl, *supra* note 75, at 198.

364. *See* Outer Space Treaty, *supra* note 81.

365. *See* CARL Q. CHRISTOL, THE MODERN INTERNATIONAL LAW OF OUTER SPACE 721 (1982).

366. *See* David A. Greenburg, *Third Party Access to Data Obtained via Remote Sensing: International Legal Theory Versus Economic and Political Reality*, 15 CASE W. RES. J. INT'L L. 361, 363 (1983); Stephen P. Krafft, *In Search of a Legal Framework for the Remote Sensing of the Earth from Outer Space*, 4 B.C. INT'L & COMP. L. REV. 455, 460–61 (1981); D.M. Polter, *Remote Sensing and State Sovereignty*, 4 J. SPACE L. 99, 100 (1976); Weaver, *supra* note 79, at 36–37.

duct remote sensing activities, would allow unrestricted acquisition and dissemination of sensed data by any county.[367] The United States was a leading advocate of an open skies policy.[368] "Prior consent" would require some degree of prior notification, and perhaps the approval of the sensed country, before data could be acquired and disseminated.[369] The proposals modeled around a prior consent regime fell into two categories: proposals, such as those by Argentina and Brazil, mandating prior consent at both the acquisition and dissemination stages;[370] and proposals, such as those by Russia and France, requiring prior consent only before dissemination.[371] The latter approach was implemented in 1978 when a number of communist countries entered into a treaty (no longer in force) that required a contracting party in possession of remote sensing data below fifty-meters resolution to obtain the explicit consent of the sensed state before disclosing the information.[372]

States supporting the prior consent principles believed that unrestricted sensing activities infringed upon the privacy and sovereignty of the sensed states.[373] Not only did states fear military implications of allowing more developed countries to gather information on their territory, but that this information would enable corporations to secure unconscionable terms in resource extraction

367. *See* Greenburg, *supra* note 366, at 364, 365 n.27; Krafft, *supra* note 366, at 459; Weaver, *supra* note 79, at 37.

368. *See* Weaver, *supra* note 79, at 41 (citing the United States Working Paper on the Development of Additional Guidelines, COPUOS Legal Sub-Committee, U.N. Doc. A/AC.105/C.2/L.103 (1975)).

369. *See* Greenburg, *supra* note 366, at 371; Krafft, *supra* note 366, at 457–58.

370. *See* Greenburg, *supra* note 366, at 367–68, 371; Krafft, *supra* note 366, at 458 n.42; Polter, *supra* note 366, at 104; Weaver, *supra* note 79, at 48.

371. *See* Greenburg, *supra* note 366, at 368–69, 371; Krafft, *supra* note 366, at 458 n.42; Polter, *supra* note 366, at 105; Weaver, *supra* note 79, at 37, 50.

372. *See* Convention on the Transfer and Use of Data of Remote Sensing of the Earth from Outer Space, adopted May 19, 1978 (by Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland, Romania, and the U.S.S.R.), *in* 2 SPACE LAW—BASIC LEGAL DOCUMENTS ¶ B.II.1 (Karl-Heinz Böckstiegel & Marietta Benkö eds., 1990).

373. Mongolia has argued that "[s]tates participating in remote sensing should respect the principle of full and permanent sovereignty of all States and peoples over their wealth and natural resources as well as their inalienable right to dispose of their natural resources and of information concerning those resources." CHRISTOL, *supra* note 365, at 736 (citing *Report of the Legal Sub-Committee on the Work of Its Fifteenth Session, COPUOS*, Annex 4, at 1, U.N.Doc. A/AC.105/171 (1976)).

agreements.[374]

Despite these sovereignty concerns, advocates of the open skies policy prevailed. Not one of the fifteen Remote Sensing Principles in General Assembly Resolution 41/65 suggests that sensing States must obtain prior approval in order to acquire or disseminate data.[375] The focus, instead, is access to data, particularly for information relating to the environment.[376] The question of legality was resolved in favor of open skies for several reasons. First, the fears of some States regarding the implications of remote sensing were, by 1986, not realized.[377] On the contrary, the benefits derived from satellite technology resulted "in the elimination of some of the more strident restrictive proposals."[378] Second, many of the concerns raised by sensed States had been acknowledged in the General Assembly resolution, with provisions according developing countries special treatment.[379] Third, some countries operate spy satellites more powerful than the technology used for natural resources sensing.[380] Developing countries probably realize that they have very little to gain by creating a body of international law prohibiting remote sensing of another state's territory, since most of the real industrial powers will continue to do it anyway for military purposes.[381] The focus of discussion away from prior consent and toward technology transfer may reflect an "if you can't beat them, join them" strategy.

Many scholars recognize the General Assembly Resolution as a

374. *See* Krafft, *supra* note 366, at 456–57 (citing Andhyarujina, *Remote Sensing of Earth Resources — Whether a Tool for Financial Intervention and Exploitation*, *in* INTERNATIONAL INSTITUTE OF SPACE LAW OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION 520, 521 (M. Schwartz ed. 1978)).

375. *See* G.A. Res. 41/65, *supra* note 84, princs. 1–15; *see also* Weaver, *supra* note 79, at 57 (stating that although the principles did not reference veto rights or restrictions on dissemination, provisions for limited consultations were included).

376. *See* G.A. Res. 41/65, *supra* note 84, princs. 1–15.

377. *See* CARL Q. CHRISTOL, *Remote Sensing and International Space Law*, *in* SPACE LAW: PAST, PRESENT, AND FUTURE 73, 74 (1991).

378. *Id*.

379. *See* G.A. Res. 41/65, *supra* note 84, princs. 2, 9, 12, 13.

380. An example is Russia's IMSAT satellite, capable of one meter resolution. *See Crowding in on the High Ground*, AIR FORCE MAG., Apr. 1997, at 38. The system also sells images at two meter resolution for commercial use. *See* Ambrosetti, *supra* note 83, at 575–76; *High Resolution*, FLIGHT INT'L, Dec. 18, 1996, at 23.

381. *See* Ambrosetti, *supra* note 83, at 576.

fairly strong statement of international law.[382] The Assembly approved the Resolution unanimously but without a formal vote, although there appears to be no strong impetus to transform the Resolution's Principles into formal treaty form.[383] In addition, commentators generally argue that state practice confirms the legality of remote sensing by non-government entities for the advancement of sustainable development.[384] Many countries formerly supporting a prior consent regime, however, are actively supporting satellite remote sensing activities, including activities over their territory, especially when linked to some form of technical support for the country.[385] A number of resolutions from the U.N. Economic and Social Commission for Asia and the Pacific (ESCAP) call for increased access to collected information regarding their territories.[386] A 1989 resolution, for instance, calls for "developing countries [to] gain easier and increased access to remote-sensing systems in order to optimize the exploration and exploitation of their natural resources," implying acceptance of remote sensing by developed countries of developing countries.[387] Indonesia, for example, now has a policy of freely permitting research on or above Indonesian territory to improve understanding of sustainable development. The policy was set in place by the former President Suharto and continues to the present.[388]

At least for the moment, then, some consensus has formed around issues surrounding remote sensing and sovereignty, at least at the United Nations, and we have established a regime where sovereignty restrictions on remote sensing have been replaced by technology transfer obligations.[389] The wide dissemination of remote sensing data, however, may raise new issues. For instance, some

382. *See, e.g.*, CHRISTOL, *supra* note 377, at 73-95. The authors prefer to avoid the terms "customary law," "binding," or "non-binding" because they imply a formal distinction that is probably not usefully applied in this situation.

383. *See id*. at 90–91.

384. *See* Marchisio, *supra* note 88, at 339–40.

385. *See id*. at 340.

386. *See, e.g.*, *supra* note 86 and accompanying text.

387. ESCAP Res. 1989/8, *supra* note 86.

388. *See, e.g., Indonesia Unprepared for Major Natural Disaster*, JAKARTA POST, Nov. 11, 1997, *available in* 1997 WL 13540759; Interview with Iwan Gunawan, *supra* note 274.

389. *See* Verhoosel, *supra* note 68, at 54.

governments may begin to rethink the global regime when data from U.S. satellites are used by groups within their borders to challenge government or corporate policy.

Somewhat surprisingly, sovereignty concerns may be one of the greatest strengths of satellite remote sensing. The relatively low resolution of the current technology makes it useful for many natural resources mapping applications, but less than useful for detailed ground monitoring.[390] For this reason, satellite imagery is much more palatable to governments than more detailed techniques like aerial surveys (though changes are in the offing with significantly enhanced resolution imagery now available or soon to be available from EOS system satellites, private vendors, and the former Soviet Union).

For many purposes, then, satellite remote sensing is just one of a suite of monitoring techniques that should ideally be used as part of a comprehensive GIS system. For some international purposes, however, satellite imagery may be important beyond its technical capacity since its resolution is apparently sufficiently low for countries not to be concerned about sovereignty issues.

VIII. CLOSING: ACCESS TO SATELLITE DATA AND SOME THOUGHTS ON THE WORLD WIDE WEB

> *Technology is fundamental to NGO's new clout . . . creating a circle of influence that is accelerating change in many parts of the world.*
>
> Jessica Tuchman Matthews[391]

We have illustrated how satellite data and related environmental monitoring technologies have the potential to significantly promote sustainable development throughout the full range of lawmaking activities from soft law to customs to treaties. All sectors of the international community have roles to play in helping realize this potential. Consequently, the CIEL is developing the ELIS database and its functionality with the Internet and the World Wide Web. It merits notice that satellite data today looks a lot like the World

390. *See* discussion *supra* Part V.

391. Jessica Tuchman Matthews, *Power Shift*, FOREIGN AFF. 50 (1997), *reprinted in* HUNTER ET AL., *supra* note 19, at 425.

Wide Web of not too many yesterdays. The Internet began in 1970 as a project of the U.S. Department of Defense Advanced Research Project Agency (DARPA).[392] The project, named ARPAnet, aimed to build a decentralized communications infrastructure, unlike the phone system that relies on a central switch, that could withstand a nuclear attack.[393] Although the system was designed for use by the military, the National Science Foundation (NSF) and some universities were invited to join the project.[394] Subsequently, in 1989, the European Laboratory for Particle Physics (also known as CERN) developed a new hypertext-based protocol that made the Internet easier to use and evolved into the World Wide Web as we know it.[395]

Millions of people now have access to the World Wide Web,[396] making the system unprecedented as a vehicle for information exchange. Unsurprisingly, people have used the Web as a vehicle for public information in areas where the official media are tightly regulated. For instance, the Chiapas Media Project aims to help communities in Chiapas communicate human rights abuses to the outside world,[397] and a home page based in Australia describes environmental problems facing the Banaban, a group indigenous to the South Pacific.[398] Another example is CIEL's ELINE database, using the Internet to help broaden and democratize access to legal information.[399] Satellite remote sensing information and the World Wide Web, then, marry historically as well as functionally. Both are

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392. *See* Barry M. Leiner et al., Internet Society, *A Brief History of the Internet* (last modified Feb. 20, 1998) <http://www.isoc.org/internet/history/brief.html>; *see also* ACLU v. Reno, 929 F. Supp. 824, 830–31 (E.D. Pa. 1996).

393. *See* Kelly Tickle, Comment, *The Vicarious Liability of Electronic Bulletin Board Operators for the Copyright Infringement Occurring on Their Bulletin Boards*, 80 IOWA L. REV. 391, 393 (1995); *see also ACLU*, 929 F. Supp. at 831 (stating that the goal of ARPAnet was "to allow vital research and communication to continue even if portions of the network were damaged, say, in a war").

394. *See* Leiner et al., *supra* note 392, at Transition to Widespread Infrastructure.

395. *See* Walt Howe, *A Brief History of the Internet*, *in* THE INTERNET 3, 5–6 (Gray Young ed., 1998).

396. *See* John M. Moran, *A New Culture Emerges*, BUFF. NEWS, Jan. 14, 1997, *available in* 1997 WL 6411591.

397. *See* Chiapas Media Project, *Chiapas Media Project* (visited Nov. 19, 1998) <http://www.chiapasmedia project.org/>.

398. *See* Roabeia Ken Sigrah, *Come Meet the Banaban* (last modified Mar. 18, 1999) <http://www.ion.com.au/~banaban>.

399. *See* Jocelyn C. Adkins, *The Internet: A Critical Technology for the State of Environmental Law*, 8 VILL. ENVTL. L.J. 341, 341 (1997).

functional tools for information exchange, and both have developed this public information role after being developed in relatively closed government settings.

The World Wide Web is a useful but not a perfect system for information exchange. One problem, of course, is that material is censored neither for political content nor for quality or accuracy.[400] Since it is easier to construct a Web page than print a book or a pamphlet, the amount of inaccurate or irrelevant material on the World Wide Web is probably quite high. As with books published by a respected company or papers published by a respected journal, people rely reasonably on information from sites with a good reputation for accuracy. The danger is that unsophisticated users, without any easy reference to the quality of information on the Internet, may obtain erroneous or deliberately misleading information. The discussion on this issue is similar to the international debate when communications satellites first appeared, between those favoring more information and those concerned with accuracy of information.[401]

At least regarding the environment, however, the first problem is largely subsumed by the second — one needs a computer to use the Internet. The ELIS/ELINE database should prove very effective at reaching a variety of relatively sophisticated corporations, government institutions, and non-government organizations. Citizen participation in environmental law is necessarily representative to some degree. Not everyone can work full-time to protect their environmental rights. Therefore, advocacy of citizens' concerns is often manifest by those who dedicate their careers to environmental issues, taking on trust that they will represent our interests with sufficient fairness and fullness. In addition, although citizens in developing countries might not have access to the Internet and to the ELIS database, neither would most have the tools to understand and use satellite images effectively. One may quite reasonably argue that the ELIS system will reach nearly all of those who could use satellite remote sensing data effectively to inform and protect the

400. *See* Kelly Kunsch, *Diogenes Wanders the Super-highway: A Proposal for Authentication of Publicly Disseminated Documents on the Internet*, 20 SEATTLE U. L. REV. 749, 759 (1997).

401. *See* Michael Allen Potter, *Human Rights in the Space Age: An International and Legal Political Analysis*, 4 J.L. & TECH. 59, 65–66 (1989).

public.

Another approach, however, proposes that a distribution of environmental information wider than could be possible on the World Wide Web might enable local groups to organize and act more effectively.[402] Although citizen action is to some degree representative, wider distribution of this type of information might encourage representation to be more local and even more representative. If local groups are limited by the information they receive, which many probably are, the Web might not be a satisfactory means of reaching the public with environmental information, especially if the greatest importance of the information is as a source where little other is available. Some professionals in the small field of community mapping have expressed discomfort at institutions such as NASA that are failing to make satellite information available to local communities, and report some success in training very local groups in GIS and satellite interpretation.[403]

One test for projects like ELIS, then, is whether they can help those who would otherwise lack access to sophisticated ecological monitoring data participate fully in the development and implementation of environmental law. Providing satellite images and laws, together with some basic GIS capabilities on the Internet will go some way toward this goal, thus helping the more sophisticated environmental groups to monitor or challenge environmentally destructive practices in the region by the government, corporations, or locals.

In the future, however, even wider distribution of and education about satellite remote sensing information could be even more valuable to the public. On a very basic level, this information could be used as a tool to educate communities about their environment. With a greater indigenous capacity to use this information, communities and local groups could almost certainly find a wealth of ways to use satellite information. In combination with citizen enforcement and public notification laws, communities might have the facts necessary to identify and challenge logging or mining concessions on land claimed by private individuals. In addition, communities could

402. *See, e.g.*, Peter Poole, *The Local Earth Observation (LEO) Project*, CULTURAL SURVIVAL Q., Winter 1995, at 29, 29–30.
403. *See id.*

use satellite information for activities not considered "environmentally friendly" by many national or international environmental organizations.

Whatever the result, satellite information will enable citizens to further their interests in environmental protection and the evolving norms of international environmental law in a more informed and participatory manner. Those making remote sensing policy for the future should give strong consideration to the benefits of public access to satellite information, both to strengthen the implementation of environmental laws, and to strengthen the legitimacy of environmental lawmaking as a democratic and participatory process. More than just furthering a worthy policy, however, projects such as ELIS that will help disseminate remote sensing information to the public are consistent with the international law framework for remote sensing. In exchange for the right to gather information about the Earth, or the common heritage of mankind, we have the duty to share the information not only with data-poor countries, but with data-poor people.