receiving station and recorded onto a server or hard drive.[29] Data are archived at central distribution facilities and made available for purchase as raw data, corrected data or photographic representations of the data.[30]

The data can then be turned into effective exhibits with the use of a Geographic Information System (GIS).[31] A GIS is a framework for gathering, managing and analyzing data.[32] Developed out of the science of geography, GIS integrates various types of data.[33] By analyzing spatial location along with layers of information into visualizations using maps and 3D scenes, GIS provides insights into patterns, relationships and situations.[34] This information can be very valuable to scientists, business people, farmers and lawmakers, as well as the judicial system. GIS has long been used by professional mapmakers. Today, reasonably affordable computer

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[29] Rychlak et al.*, supra* note 3, at 213-14.

[30] Raw data are information as initially detected by the sensor. Corrected data are adjusted for atmospheric and geographic shifting. For instance, the SPOT Historical archives contain images received in 1999 from the SPOT IMAGE Corporation. The French space agency, Centre National d'Etudes Spatiales (CNES), owns and operates the SPOT satellite system, but worldwide commercial operations are anchored by private companies (i.e., SPOT IMAGE Corp. of the United States). The photographic products for sale by SPOT are derived from corrected data. *See* Howard A. Latin et al., *Remote Sensing Evidence and Environmental Law*, 64 CALIF. L. REV. 1300, 1317 (1976). *See generally* Earth Resources Observation and Science (EROS) Center, *USGS EROS Archive - Commercial Satellites - SPOT Historical ACTIVE* (July 12, 2018) https://www.usgs.gov/centers/eros/science/usgs-eros-archive-commercial-satellites-spot-historical (last visited Dec. 31, 2022).

[31] *See* EVIDENCE FROM EARTH OBSERVATION SATELLITES: EMERGING LEGAL ISSUES, *supra* note 22. *See also* Waltraud Baier, et al.*, Introducing 3D Printed Models as Demonstrative Evidence at Criminal Trials*, 63 J. FORENSIC SCIENCES 4 (July 2018) (noting the traditional thought that 3D printed models generally adequately represent anatomical features but are not sufficiently accurate to take measurements directly from, but noting that technologies have developed, and it may be possible to take highly accurate measurements from 3D models in the near future).

[32] The GIS system is computer-based and uses digital mapping information. Features such as land use and land cover, roads, zoning, threatened and endangered species habitat, streams and wetland coverages are all stored independently as a separate coverage or layer. The GIS system allows the user to select different coverages and layer them over each other to perform land use planning analyses.
In re Adoption of N.J.A.C. 7:15-5.24(b), 420 N.J. Super. 552, 561 (App. Div. 2011). *See also Wyoming v. U.S. Dept. of Agric.*, 661 F.3d 1209 (10th Cir. Oct. 21, 2011) (involving GIS maps depicting National Parks).

[33] *What is GIS? A Spatial System that Creates, Manages, Analyzes, and Maps All Types of Data,* ESRI*,* https://www.esri.com/en-us/what-is-gis/overview (last visited Dec. 31, 2022].

[34] *Id.*

software and hardware put its capabilities within the reach of any moderately ambitious computer operator.[35]

GIS offers the ability to link a variety of data (tabular, spreadsheet, database or other attribute information) and display the information based on various features.[36] Mapping the locations of elderly persons might, for instance, reveal those areas where special services are needed. Mapping customers' homes and work locations can help banks decide where to locate their automated teller machines. Mapping migration routes of birds may help protect endangered species. Mapping crime scenes can help reveal where there may be a need for increased police patrols or extra security for businesses.[37]

With the use of color, even more patterns may be brought out. For instance, an exhibit featuring accidents on a stretch of highway might start with a map of the highway. GIS might be used to mark locations of known accidents and they could be color-coded based upon the time of day when they occurred. One color might locate those accidents that took place in the morning, a second for those that occurred during the day, and a third might be used for the

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[35] Although GIS has many attractive features in the context of legal applications, there are still physical and technical restraints that can limit its usability as evidence. The central point is that, even if digital maps obtained via satellite leave small room for human error with respect to the production of the image, said room is much larger when we are dealing with interpreting the image. This means that, in practice, in those cases where satellite technology is used as evidence, judges are relying on the opinions of experts—who have been called to interpret the information—and not directly on the satellite information itself. Sylvia Maureen Williams, *La Información Satelital Como Prueba En Litigios Nacionales e Internacionales*, 75 REVISTA DEL COLEGIO DE ABOGADOS DE LA CIUDAD DE BUENOS AIRES 153 (2015). *See also* Leopoldo M. Godio, *Satellite Images and Data as Evidence in Local Administrative and Judicial Processes. Some Debates on its Admissibility and Autonomy,* EN LETRA, 181-195 (Aug. 2014) http://www.todaviasomos-pocos.com/aportes/las-imagenes-y-datos-satelitales-como-medios-de-prueba-en-procesos-administrativos-y-judiciales-locales-algunos-debates-sobre-su-admisibilidad-y-autonomia/.

[36] RYCHLAK, *supra* note 26, at 648 n. 25 ("In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology. Google Maps or Google Earth images are a composite of images and data captured at different times using satellites, aerial photographs, and remote sensing geographic information systems. They are not always current, and they may have limited resolution.")

[37] For a fascinating remote-sensing investigation of a twenty-year-old crime, *see* Carl Walter, *In the Pursuit of Justice and Closure, Twenty Years Later*, ESRI (Nov. 1, 2018), https://www.esri.com/about/newsroom/blog/gone-twenty-years-but-not-forgotten/.

night. This could reveal complex patterns that would otherwise be overlooked.

GIS software has become almost as user-friendly as word processing programs. The underlying digital maps and attribute data for different applications are widely available either for free or for a minimal charge.[38] These systems can overlap different map layers to create a trial exhibit that presents detailed information in an interesting, easy-to-understand way.

For courtroom purposes, if information is superimposed on a backdrop of an aerial photograph or satellite image, both of which are readily available from the federal government, an exhibit can give an extremely convincing presentation of a particular location. Furthermore, if the location of persons, substances, structures or property lines are further corroborated by Global Positioning System (GPS) "fixes," or the location of known geographical landmarks, the presentation gives a more-or-less irrefutable foundation or backdrop for the location of points of interest that are relevant to the offering party's case.[39]

In cases where there has been a release of gas, flood damage, or an oil or chemical spill, an aerial photograph or satellite image can be enhanced by merging it with GIS data so that the plume of gas or the oil slick can be seen in relation to the other matters.[40] This type of environmental exhibit can also be used effectively in mass tort actions, class actions and similar matters.[41] Because these exhibits are based on aerial photographs, real-time video, satellite images and mathematical models, they usually are easy to verify and have admitted into evidence.

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[38] *See* GISGeography, *13 Free GIS Software Options: Map the World in Open Source* (last updated May 29, 2022), available at (last visited Dec. 31, 2022).

[39] Scott D. Makar & Michael R. Makar, Jr., *Geographic Information Systems: Legal and Policy Implications*, 69 FLA. BAR J. 44, 44 (1995) (citations omitted).

[40] Andrew C. Wilson, et al., *Tracking Spills and Releases: High-tech in the Courtroom*, 10 TUL. ENV'T L.J. 369, 371 (1997). *See* Sharon Hatch Hodge, *Satellite Data and Environmental Law: Technology Ripe for Litigation Application*, 14 PACE ENV'T L. REV. 691 (1997), citing Warren Ferster, *Courts Learning Strengths of Remote-Sensing Imagery*, SPACENEWS, Jan. 16-22, 1995, at 19; Purdy & Macrory, *supra* note 6.

[41] Bloomberg Law, *Insight: Geographic Information Systems for Environmental Litigation* (Sept. 18, 2018) https://news.bloomberglaw.com/environment-and-energy/insight-geographic-information-systems-for-environmental-litigation.

III. PREPARATION OF THE EXHIBIT

A. Finding the Data

Since the National Oceanographic and Atmospheric Administration (NOAA) issued the first operating license in 1993,[42] several American companies have placed commercial remote sensing satellites into orbit.[43] Imaging companies now have high-resolution commercial satellites that provide a steady source of imagery data for a broad range of commercial and government customers.

If a satellite image exhibit might be of benefit to a case, it is crucial to examine this possibility as early as possible. The purchase price of raw satellite data, image processing costs and expert fees for interpretation and testimony can be substantial. As such, these costs should be considered before making commitments. Fortunately, a great deal of information is available to practitioners which enables the preparation of very persuasive exhibits at reasonable expense.

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[42] Under the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), private U.S. entities in outer space require the "authorization and continuing supervision" of the United States Government. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, art. VI Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty]. In the United States, the Land Remote Sensing Policy Act of 1992 (51 U.S.C. 60101 et seq.) authorizes the Secretary of Commerce to fulfill this responsibility by issuing and enforcing licenses. The Secretary's authority is currently delegated to the NOAA Assistant Administrator for Satellite and Information Services. Regulations.gov, *Licensing of Private Remote Sensing Space Systems*, posted by the National Oceanic and Atmospheric Administration on May 13, 2019, available at https://www.regulations.gov/document/NOAA-NESDIS-2018-0058-0011(last visited Dec. 31, 2022) ("Under its regulations implementing the Act, found at 15 CFR part 960, NOAA has issued licenses for over 1,000 imaging satellites.") See also Center for Strategic & International Studies, *Commercial Space Remote Sensing and Its Role in National Security* (Feb. 2, 2022) https://www.csis.org/analysis/commercial-space-remote-sensing-and-its-role-national-security.

[43] There are thousands of satellites in the sky above us at this moment, orbiting Earth. Satellites have many uses for the government, military, and even civilians. They provide us the ability to have things like Internet access, television, GPS, and much more. They also have scientific purposes such as Earth and space observation and provide the means for high-level technology development. More than half of the 4,550 satellites orbiting Earth are used for communications purposes . . .
DEWESoft, *Every Satellite Orbiting Earth and Who Owns Them* (Jan. 18, 2022) https://dewesoft.com/daq/every-satellite-orbiting-earth-and-who-owns-them (identifying the 50 owner/operators of the most satellites orbiting earth).

Digital maps and usable data for many projects are available from several sources, either for free or for a nominal charge. For example, the US Geological Survey (part of the Department of the Interior) lists a variety of geological information, such as maps showing locations of earthquakes, oil discoveries and much more at their web site—usgs.gov. The Department of the Interior also has a site called *Earth Explorer* that provides access to maps of the US and the various individual states. With some basic navigation, visitors to the site can display maps illustrating data such as relative income, crime rates, cancer, agriculture output and more in different parts of the nation and particular states.[44]

Although it is unlikely, an attorney might get lucky and find that satellite data was collected at the precise time relevant to a legal case. For instance, in *ANR Production Co. v. M/V Mekhanik Dren*,[45] satellite photographs taken 34 minutes before and four minutes after a collision between a ship and an oil platform off the coast of Dubai, United Arab Emirates, precisely showed the weather conditions in the vicinity at the time of the accident, which helped resolve the case.

Even if data of that quality is not available, relevant archived photos or even older, public domain images may be available. However, attorneys should not wait too long to find this data, or there is the risk of not having all exhibits prepared in time. Moreover, circumstances may have changed dramatically since the incident making it difficult to locate archived images and impossible (or at least very difficult and expensive) to create a new exhibit.

B. Obtaining the Right Data

When contracting with an imaging company to prepare an exhibit, an attorney should be sure to discuss the case in detail. Experts may have ideas, but the attorney is in control and must deliver the right level of precision as well as give clear instructions about the size of the geographic area to be presented. Effective exhibits show the important features but do not distract with

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[44] *See Maps*, USGS, https://www.usgs.gov/products/maps/overview (last visited Apr. 15, 2021).

[45] *ANR Prod. Co. v. M/V Mekhanik Dren*, No. G-87-304, 1989 WL. 180064 (S.D. Tex. July 14, 1989) (case arose from damages to an oil platform sustained from the collision with defendant's ship).

irrelevant details. If there are several important features the jury needs to see and understand, the use of more than one exhibit may be necessary. The exhibits should be constructed so that each one focuses on different important details.

An image created with satellite data can be very cost-efficient, depending on the area of coverage required, the type of information needed, the age of the image and the means of display. Sometimes, cost will not be the most important concern because remote sensing may be the *only* way to prove a point.[46] This is particularly likely if the satellite archive contains the only image of the scene on a critical date and time.

C. Evidentiary Concerns

From an evidential weight point of view, there are three important stages in the use of images: creation, transmission, and storage.

i. Image Creation

When an image is created, information needs to be captured as part of an image identification process. For example, it may be necessary to prove the time at which the image is captured, the location of the scene being captured and the location of the capture system. Processes must be in place to preserve this information (image metadata) and demonstrate accuracy. Such processes may depend upon accurate time clocks and GPS systems.

ii. Image Transmission

Once an image has been created, it needs to be transferred to a storage system. As part of the evidential weight issue, it may be necessary to demonstrate that the storage system received the image and the associated metadata without significant

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[46] Commercial satellite systems provide data from various channels of the electromagnetic spectrum and have worldwide coverage at regular intervals. *See* Jeffrey Bardin, *Satellite Cyber Attack Search and Destroy in* CYBER SECURITY AND IT INFRASTRUCTURE PROTECTION, (John R. Vacca. ed. 2014), https://www.sciencedirect.com/book/9780124166813/cyber-security-and-it-infrastructure-protection. *See also* DAVID S. WILKIE & JOHN T. FINN, REMOTE SENSING IMAGERY FOR NATURAL RESOURCES MONITORING 46 (1996); Purdy & Macrory, *supra* note 6.

loss/corruption. It may also be necessary to authenticate the source of the images using a secure identification process.

iii. Image Storage

Finally, once captured within a storage system, it may be necessary to demonstrate that the images have not been compromised during storage. This involves a review of the security processes applied to the storage system, including virus protection and accidental/deliberate actions related to the technology implementation and to the organizational processes applied to the systems. There may also be issues where images are moved from one storage system to another (migration) or from one storage format to another (conversion).[47]

IV. PROCESSING SATELLITE DATA

A. Not "True" Photographs

While it is tempting to think of satellite imagery in terms of photographic prints, it is important to recognize that the data from satellites provide information that is very different from that provided by traditional photography.[48] Satellite data is produced in digital form and, in most cases, it will never be used in the form of a traditional photograph.[49]

The operator of a geographic information system (GIS) receives the satellite data and analyzes it along with multiple layers of data of the same scene from other sources.[50] In this way, GIS

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[47] *See generally,* EVIDENCE FROM EARTH OBSERVATION SATELLITES: EMERGING LEGAL ISSUES, *supra* note 22.

[48] That is why an officer mis-read a satellite photograph and, as a result, the search warrant erroneously described the target building's color. State v. Spivey, No. W2010-01853-CCA-R3-CD, 2011 WL 4346653 (Tenn. Crim. App. Sept. 19, 2011).

[49] In fact, a true "photographic" type of exhibit taken from that altitude of a satellite would not be very helpful. Details would be lost and it might end up confusing the jury. Traditional photography is limited to a spectral range much more narrow than multispectral satellite data. At best, photographic systems have a spectral range of 0.4 to 1.3mm, whereas multispectral scanners found on satellite systems range from 0.3 to 12.5 and beyond. *See* WILKIE & FINN, *supra* note 46, at 21 tbl. 2.4, 65, 265, 273.

[50] A geographic information system, geographical information system, or geospatial information system is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographically referenced data. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology. Google Maps or

technology complements satellite imagery by integrating diverse data from satellite and aerial imagery, digitized maps, tabulated information and other digital data into one single exhibit.[51] By combining this data and using the global positioning system databases, attorneys and their experts can prepare highly visual and persuasive exhibits that look like traditional charts, maps or other drawings.[52] The results can be displayed on a screen, monitor or in hard copy format.[53]

B. Data Subject to Alteration

Although remote sensing and other digital image data have proven to be valuable as evidentiary tools in enforcement actions and alternative dispute resolution, evidentiary concerns remain. Satellite data is digital data, which means it is subject to alteration. Moreover, although this is not true photographic evidence jurors

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Google Earth images are a composite of images and data captured at different times using satellites, aerial photographs, and remote sensing geographic information systems. See Walters v. State, 206 So.3d 524, 526 (Miss. 2016) (court did not err in admitting Google Earth images of property, because the State made a *prima facie* showing that they accurately depicted the property on the dates at issue); Commonwealth v. Suarez-Irizzary, 15 Pa. D. & C. 5th 106 (C.P. Aug. 6, 2010), in which the court concluded that the police officer's prior calibration of Google Earth maps, finding them accurate to within one foot of his actual measurements on the ground, were sufficient to allow the officer to testify to his computer-generated satellite-based distance calculations in this case.

[51] Raw data are processed, or enhanced, for several reasons: (1) to clarify the visible contents; (2) to emphasize features without significantly altering the content of the data; and (3) to classify into a discrete number of surface feature categories from the values possible from the scanner. Wyoming v. U.S. Dep't of Agric., 661 F.3d 1209 (10th Cir. 2011) (involving GIS maps depicting National Parks).

[52] The exhibit might include information derived from satellite imaging, aerial photographs, land-based photography, eyewitnesses, scientific models developed by expert witnesses, or other sources. The idea is to be as accurate as possible while remaining persuasive and uncluttered. Imaging firms known as value-added resellers (VARs) buy and resell data for international satellite systems and convert the raw remotely sensed data into exhibits tailored for their customers' requirements. *See*, e.g., Surfrider Found. v. Dalton, 989 F. Supp. 1309 (S.D. Cal. 1998) ("The GIS surveys are digitized documents that draw from 60 years of aerial photographs, 70 years of water resource data, and 25 years of natural and cultural data.")

[53] "The GIS system is computer-based and uses digital mapping information. Features such as land use and land cover, roads, zoning, threatened and endangered species habitat, streams and wetland coverages are all stored independently as a separate coverage or layer. The GIS system allows the user to select different coverages and layer them over each other to perform land use planning analyses." *In re* Adoption of N.J.A.C. 7:15-5.24(b), 420 N.J. Super. 552 (App. Div. 2011).

might come to think of it as such, therefore there is a higher chance of prejudicial impact than is common with other exhibits. As a result, "[t]he admissibility of remote sensing information must be examined within the context of the general requirements for admission of scientific evidence and expert opinion."[54]

Processing satellite data to enhance the clarity of the final product is common, and it usually involves the application of mathematical algorithms that cluster the pixel values representing the edges of two surface features.[55] Essentially, the data is corrected geometrically and adjusted for atmospheric interference.[56] In other words, this kind of process does not impair the validity of the image. In fact, since the processes are mathematically-based and do not involve subjective manipulation, they actually make the exhibit *more* reliable.[57] Traditional photographs have long been used as evidence and are routinely admitted, even though there is a development process that the film has to go through.[58]

In addition to processing for clarification, satellite data may be enhanced, emphasizing particular features by adjusting pixel values.[59] This is essentially akin to highlighting a particular area of the exhibit. Attorneys must exercise care so that this is not done in a misleading way. However, done properly, this can create a very effective, admissible exhibit.

Unfortunately, satellite data is also susceptible to the kind of manipulation that could render an exhibit "very convincing indeed—yet very inaccurate."[60] An expert witness must be able to authenticate the data and explain how the image was created.[61] In

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[54] Latin et al., *supra* note 30, at 1304.

[55] RYCHLAK, *supra* note 26, at 649.

[56] *See* THOMAS M. LILLESAND & RALPH W. KIEFER, REMOTE SENSING AND IMAGE INTERPRETATION 558-59 (4th ed. 2000).

[57] *See* Bruce S. Marks, *Dispute Resolution in the Space Age: Forensic Applications of Earth Observation Satellite Data Through Adaptation of Technical Standards Similar to DNA Fingerprinting Protocols*, 5 OHIO STATE J. ON DISP. RESOL. 19, 51 (1989).

[58] *See also* Hodge, *supra* note 40 (noting that the EPA generally prefers to use photographs as compared to images produced from digital data due to the requirements for proving chain of custody and assuring that the images have not been manipulated.) *See also* Rychlak et al., supra note 3 (setting forth a new approach for government use of digital photos and the resulting change in chains of custody).

[59] *See* Latin, *supra* note 30, at 1440-41.

[60] Jon L. Roberts, *Admissibility of Digital Image Data & Animations: Courtroom Concerns*, ADVANCED IMAGING 105 (Aug. 1995).

[61] *See* FED. R. EVID. 702.

other words, he or she must be able to explain the processing that was done and justify it. In the end, satellite imagery should be admissible and persuasive if proper procedures are followed.

V. FOUNDATION FOR ADMISSION

Courts are already familiar with aerial photographs. Like other photographs, they are admitted if relevant, accurate and a proper foundation is laid.[62] Satellite images are similar. They can assist a jury in understanding the issues and help maintain interest in explanations of complex information. Observations by witnesses, photographs or other evidence, known as "ground-truthing," may be an additional method to not only authenticate the remote satellite imagery, but also provide the court with more familiar forms of evidence that may tend to corroborate the satellite information and make admission more likely.[63] In addition, these pictures are often the only evidence that fully captures an event.[64]

In order to use satellite data, an attorney must: qualify the expert witnesses; authenticate and prove the contents of the data; and establish that proper and accepted digital imagery processing techniques were used. The need for the latter two steps arises particularly because satellite data are almost always manipulated.

By itself, information from space data can be impossible to understand and would certainly not be useful as an exhibit. With GIS technology, however, data can be enhanced to bring out features of

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[62] Hubert v. City of Marietta, 164 S.E.2d 832, 834 (Ga. 1968) (foundation laid when knowledgeable witness testified that aerial photograph was accurate); Dillon v. Reid, 717 S.E.2d 542 (Ga. App. Ct. 2011) ("Notwithstanding that he did not have the exact same aerial view as the tendered photographs, Brad Reid explained the basis for his testimony as to the date of the photographs, and he testified that the photographs accurately depicted those locations as of those time periods. Accordingly, it was within the broad discretion of the trial court to allow the photographs to be introduced….")

[63] EVIDENCE FROM EARTH OBSERVATION SATELLITES: EMERGING LEGAL ISSUES, *supra* note 22, at 84.

[64] *See, e.g., NutraSweet*, 227 F.3d at 788 (plaintiffs used aerial photographs to establish the dumping sequence in which Volatile Organic Compounds were dumped on X-L's land and then migrated through the groundwater onto NutraSweet's land); St. Martin v. Mobil Expl. & Producing U.S. Inc., 224 F.3d 402 (5th Cir. 2000) (plaintiffs introduced aerial photographs to show open ponds produced by the oil companies that were eroding their marsh, presenting a series of photographs that showed the progression of the deterioration of the marsh).

interest.[65] Judges understand that this must be done and jurors will also accept it, but these processes leave the data open to potential misuse. Therefore, in addition to the relatively easy task of having a qualified expert authenticate the contents of the data, an attorney must prove that proper, accepted digital imagery processing techniques were employed.[66] An attorney must also trace its chain of custody to prove that it was not later manipulated or altered.

In general, the reliability of evidence derived from a scientific theory or principle depends on: 1) the validity of the underlying theory, 2) the validity of the technique applying that theory, and 3) the proper application of the technique on a particular occasion.[67] This includes: ensuring the proper working order of instrumentation; following proper procedures; and employing properly qualified persons using the technique and interpreting the results. Federal Rule of Evidence 901(B)(9) allows "[e]vidence describing a process or system used to produce a result and showing that the process or system produces an accurate result."[68] This may be established by testimony that the satellite data collection company and the transporter properly handled the data and that the expert who processed and interpreted the data used an approved scientific method.

It is necessary to have a witness(es) who can: 1) testify about the accuracy and reliability of the technology, the equipment and the processing techniques; 2) certify the data supplier's possession and transfer of custody of the images prior to trial; and 3) reference more conventional data (aerial photographs, maps) and other factors that dispel the fear of manipulation of the images. The best witnesses, of course, would be able not only to authenticate the data but also to explain it in a manner that the average juror can understand.

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[65] Unlike the satellite data, GIS data consist of an accumulation of governmental data bases. In other words, these data are essentially business or public "records" or a "data compilation" such that they should satisfy the hearsay exceptions set forth in Rules 803(6) and 803(8). *See* United States v. Asarco Inc., 214 F.3d 1104 (9th Cir. 2000) (GIS database was part of the EPA's administrative record). At the same time, since GIS is not scientific evidence but rather a form of map, "the test for its admissibility should be whether it accurately represents what it purports to represent." Commonwealth v. Al Hamilton Contracting Co., 665 A.2d 849, 852 (Pa. Commw. Ct. 1995). *See* Marks, *supra* note 57.

[66] *See* Marks, *supra* note 57, at 49-50. *See also* Roberts, *supra* note 60, at 165.

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

[68] FED. R. EVID. 901(b)(9).

An authenticating witness does not have to be a programmer involved in developing software, but he or she must be familiar with the field and office procedures that produced the exhibit and be able to explain why errors and mistakes are unlikely to have crept into the system.[69] The data suppliers should be able to certify that proper, accepted digital imagery processing techniques were employed and that the satellite images were produced by the data processor in a routine way.[70]

VI. ANTICIPATING OBJECTIONS

A. Generally

Satellite images can be presented as substantive evidence in charts, summaries or calculations and introduced as summary evidence under Federal Rule of Evidence 1006.[71] The data may also be presented as an illustration of a witness's testimony.[72] If an enhanced image is submitted as independent evidence (as opposed to an illustration of testimony), the best evidence rule applies, and the data must be authenticated.[73] Attorneys should consider local court rules and be sure to preserve the exhibit for the record. Attorneys should also expect a hearsay objection when the images produced from digital data are offered in court for the truth of the matter asserted.[74] With some advance planning,[75] however, an attorney should be able to overcome this objection.

Other objections to anticipate regarding exhibits (or to consider regarding an opponent's exhibits) include the credentials of

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[69] *See* Velsicol Chem. Corp. v. State, 442 A.2d 1051 at 1052, 1054 (N.J. Super. Ct. App. Div. 1982) (finding "maps and overlays showing the incidence of mean high tide flow, based upon infrared aerial photographs," which were themselves based upon a report of natural color photography and of field observation, insufficient to sustain State's burden of proof where no witnesses responsible for preparation of the report testified to the application of biological methodology, or the gathering, collating and analysis of scientific data.)

[70] FED. R. EVID. 406. *See also* Carole E. Powell, *Computer Generated Visual Evidence: Does Daubert Make a Difference?*, 12 GA. ST. UNIV. L. REV. 577, 585 (1996).

[71] *See* ARMY REGULATION 15-6: PROCEDURES FOR ADMINISTRATIVE INVESTIGATIONS AND BOARDS OF OFFICERS, ARMY PUBL'G DIRECTORATE (2016). *See also* Purdy & Macrory, *supra* note 6.

[72] *See* Latin, *supra* note 30, at 1441.

[73] FED. R. EVID. 901(b)(9).

[74] Hodge, *supra* note 40; Purdy & Macrory, *supra* note 6.

[75] See, e.g., RYCHLAK, *supra* note 26, at 164 ("Planning in Advance for Objections").

the expert offering the testimony, the procedures used to manipulate the data and whether the techniques used in evaluating data are generally used by the profession.[76] Objections can also relate to distortion, over- or under-inclusion of details or inclusion of details that are beyond the capabilities of the GIS operator. If the foundation has been established, all of these matters should have been disposed of during the operator's testimony. Attorneys should make certain that the images created for presentation at trial, like all other testimony aids, are not overly "argumentative." Suggestive colors or labels should be avoided. If there is anything unusual about the scale or the way the scale is represented, it must be addressed when laying the foundation. Properly handled, this should help avoid any serious problems.[77]

It is instructive to review examples of problems that arise when attempting to lay the foundation for a satellite data-created exhibit. According to retired Vermont judge, Merideth Wright, a 2008 case brought in New York, raised the question of whether certain wetlands had been modified due to excavation or dredging.[78] The plaintiff's expert compared two sets of aerial photographs, one from 1994 and the other from 2001.[79] Both had been taken by the US Geological Survey and both were stored in digital form as data sets.[80] The expert attempted to explain that he had processed both sets into photographic form, enhancing certain spectra characteristic of vegetation so that the ditches or tracks of heavy machinery would be more visible.[81] Although the witness explained that the

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[76] Roberts, *supra* note 60, at 161. Of course, relevancy is always a concern. *See generally id.* at chapter 6.

[77] Why should terrestrial photographic evidence, collected three years after commission of the offence, be accepted over high-resolution EO imagery captured just after clearing has occurred? Accurate measurements can readily be taken from geo-referenced EO images but this is not the case for terrestrial photographs taken using non-professional cameras. *See generally* EVIDENCE FROM EARTH OBSERVATION SATELLITES: EMERGING LEGAL ISSUES, *supra* note 22.

[78] Merideth Wright, *The Use of Remote Sensing Evidence at Trial in the United States—One State Court Judge's Observations*, in EVIDENCE FROM EARTH OBSERVATION SATELLITES: EMERGING LEGAL ISSUES, *supra* note 22, at 315, (*citing* her conversation with plaintiffs' attorney Karl S. Coplan, September 23, 2011 and Peconic Baykeeper v. Suffolk County, N.Y., CV-04-4828 (ADS) (U.S. Dist. Ct., E.D.N.Y.)(trial transcript 615–639, April 24, 2008)).

[79] *Id.*

[80] *Id.*

[81] *Id.*

technique is common and done in order to "enhance or amplify" the contrast between the land and the water surfaces, he used the term "false color photograph."[82] The judge did not "understand how these photographs were conceived," and he concluded that "[t]his enhancement of the information, enhancement of the color, false colors, all of this is disturbing and would indicate to me that these photographs are not admissible..."[83]

B. Chain of Custody

Under Federal Rule of Evidence 901(a), the chain of custody must be shown when the condition of the evidence is at issue.[84] This *can* be an issue when the evidence is satellite data. To establish the chain, it is necessary to show: 1) the accuracy and reliability of the data, including all formulas, calculations and assumptions used in defining and analyzing it, 2) the accuracy of the data as it was entered into the computer, 3) the reliability and capability of the computer hardware and software, 4) the process of software used for the computer graphics and 5) the reliability of the final presentation. Links in the chain can usually be supported with certification of the data by the data supplier.[85]

Experts who process the data are probably in the best position to describe the system used to produce the exhibits. They are probably also in the best situation to lay the chain of custody and thereby establish the foundation.[86] The data suppliers should be able to demonstrate that data security within the workplace was maintained at all times. If the court requires proof that the evidence is what it purports to be, proof can be provided by reference data gathered on the ground, traditional aerial photographs and maps.[87]

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[82] *Id.*

[83] *Id. See* Peconic Baykeeper, Inc. v. Suffolk County, 600 F.3d 180 (2d Cir. 2010).

[84] FED. R. EVID. 901(a)

[85] Hodge, *supra* note 40; Purdy & Macrory, *supra* note 6.

[86] In Velsicol, the court found that maps and overlays which showed the incidence of mean high tide flow, based upon infrared aerial photographs, and which were based upon a report of natural color photography and of field observation was insufficient to sustain State's burden of proof where no witnesses responsible for preparation of report testified to application therein of biological methodology, its gathering, collating and analysis of scientific data. Velsicol, 442 A.2d at 1052.

[87] *See* LILLESAND & KIEFER, *supra* note 56, at 23-26. *See also* Bayou Des Familles Dev. Corp. v. U.S. Corps of Eng'rs, 541 F. Supp. 1025 (E.D. La. 1982) (expert used remote sensing to show indications of wetland hydrology).

In addition, Federal Rule of Evidence 406 can be used to support the chain of custody.[88] Finally, a chain of custody document (manifest) can be developed which allows a supervisor to confirm the chain.

C. Illustrating Testimony

If all else fails, and an exhibit is inadmissible due to failure to meet a hearsay exception or failure to meet authentication requirements, it may still be possible to use it to illustrate the testimony of witnesses. In fact, this is usually the easiest way to use such an exhibit.[89]

VII. SPECIAL CONCERNS

A. Privacy, National Security and Admissibility

Data with limited pixel clarity have been used for a long time to monitor agriculture and forestry. Using GIS to combine social and economic data with Earth Observation (EO) data creates the potential to identify individuals and their characteristics from the interpretation of databases.[90] Today, with ultra-high-resolution data, individual privacy issues have become a significant concern.[91]

The admissibility of domestic satellite evidence that might otherwise be considered confidential was addressed in the landmark case of *Dow Chemical Company v. United States*.[92] In that

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[88] FED. R. EVID. 406 (Routine Practice of Person or Organization).

[89] In *State ex rel. J.B.*, No. FJ-19-337-08, 2010 WL 3836755 (N.J. Super. Ct. App. Div. Sept. 27, 2010), a juvenile was accused of burglary. The prosecutor sought to show the juvenile's location at time of the burglary by showing that cell phone calls made by him at the time of the burglary were routed through a tower closer to the burglarized residence rather than through a tower closer to the juvenile's own residence. Satellite photographs generated by Google Earth were allowed because they were not being offered as substantive proof of the distances between the residences and the cell towers, but merely as illustrative aids to the witness' testimony. *See also* Swayden v. Ricke, No. 103250, 2010 WL 4977158 (Kan. Ct. App. Nov. 19, 2010).

[90] See Meenal Dhande, *Integrated Earth Observation and Geospatial Information: Empowering SDGs*, GEOSPATIAL WORLD (Jan. 24, 2017), https://www.geospatialworld.net/blogs/earth-observation-geospatial-information-sdgs/. *See generally* JONATHAN WILLIAMS, GIS PROCESSING OF GEOCODED SATELLITE DATA (2001).

[91] The current maximum resolution commercially available is 0.3 m. *See High Resolution Satellite Imagery*, *supra* note 23.

[92] Dow Chem. Co. v. United States, 476 U.S. 227 (1986).

case, Dow objected to the use of aerial photography that provided excellent, detailed images of a large industrial complex.[93] The Court focused on Dow's expectations of privacy. The trial court found aerial remote sensing more invasive than the human eye and concluded that the information that could be derived from the data violated Dow's expectation of privacy.[94] The Supreme Court, however, held that "the mere fact that human vision is enhanced somewhat ... does not give rise to constitutional problems."[95] The aerial search of a large industrial complex for investigatory purposes did not violate Dow's protection against warrantless searches or expectation of privacy.[96]

Nevertheless, sensors with the power to penetrate surfaces, rather than merely detect surfaces, may violate an individual's right to privacy. In *Kylo v. United States*,[97] the Supreme Court ruled that use of a device to detect the temperature of an exterior wall to detect criminal activity inside a home did indeed violate the fourth amendment to the Constitution.[98] Typical satellite-style remote sensing, however, uses sensors that merely detect surface energy and reflectance; it does not penetrate the sensed objects, structures or materials.[99]

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[93] *Id.* at 229, 238.

[94] *Id.* at 230.

[95] *Id.* at 238 (noting privacy expectations for the private residence are higher because that is the place of "intimate activities associated with family privacy," and the expectation of such privacy is not reasonably or legitimately extended to an industrial complex).

[96] In *State v. Jackson*, 46 P.3d 257 (Wash. Ct. App. 2002), the defendant was convicted of first-degree murder, and he appealed. The Court of Appeals held, in part, that: "in a matter of first impression, police installation of Global Positioning System (GPS) tracking device on defendant's vehicles did not offend either Fourth Amendment or state constitutional provision protecting a person's home and private affairs from warrantless searches; (4) seeking grant of judicial permission in form of search warrant to install GPS tracking devices on defendant's vehicles was appropriate." "Defendant's privacy interests were insufficient to require warrants, given that monitoring of his public travels in his truck by use of GPS device was merely sense augmenting, revealing open view information of what might easily have been seen from lawful vantage point without such aids."

[97] Kyllo v. United States, 533 U.S. 27 (2001).

[98] *Id.* at 40.

[99] It is possible that such information could violate Constitutional rights. In general, however, the type of information discussed in this chapter should not create problems along these lines. *See also* Yankton Sioux Tribe v. U.S. Army Corps of Eng'rs, 83 F. Supp. 2d 1047 (D.S.D. 2000). Some sensors can detect anomalies under the ground and other such information. *See* Kline v. Green Mount Cemetery, 677 A.2d 623 (Md. Ct. Spec. App. 1996) (petition to have the body disinterred from grave of John Wilkes Booth; a forensic

State v. Gordon,[100] involves a defendant who pled guilty to statutory rape, rape, taking indecent liberties with a child, assault and kidnapping. The sentencing court issued an order mandating that the defendant enroll in lifetime satellite-based monitoring under a state statute following his eventual release from prison.[101] The State made no showing as to the intrusion or the information that would be revealed under the program, whether the monitoring device in the future would be similar to those used now, or whether defendant would be on supervised or unsupervised release.[102] The order was vacated because the State could not establish that his submission to such monitoring would constitute a reasonable Fourth Amendment search in 15 to 20 years when he would be released from prison. Moreover, the State was unable to adequately establish the government's need for such search.[103]

National security and industrial trade secrets can also affect admissibility. Domestic security issues should not be of serious concern because commercial satellite data vendors in this country are required to hold a license from the Department of Commerce to operate a satellite system.[104] The licensing regime imposes restrictions on remote sensing system operators.[105] For example, courts have upheld federal regulations that restricted access to satellite data over militarily sensitive areas during Operation Desert Shield.[106]

Trade secret violations should be treated as an issue of privacy similar to the concerns for the individual.[107]

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scientist testified that ground-penetrating radar simply indicates an anomaly under the surface of the soil; it then becomes a question of interpretation); *Yankton Sioux Tribe*, 83 F. Supp. 2d at 1052 (remote sensing to find graves).IS THIS CITED CORRECTLY AND ITALICIZED CORRECTLY? IT IS CITED IN THIS FN ALREADY.

[100] State v. Gordon, 820 S.E.2d 339, 341 (N.C. Ct. App. 2018). *See also* Park v. State, 825 S.E.2d 147, 150 (Ga. 2019) (holding lifetime satellite-based monitoring of a sex offender unconstitutional where offender was no longer serving any part of his sentences).

[101] State v. Gordon, 820 S.E.2d at 248.

[102] *Id.* at 257-59.

[103] *Id.*

[104] 15 C.F.R. § 960.1 (2020).

[105] *See supra,* note 42 (reviewing the licensing process and citing to government programs that set forth the demands put upon licensees).

[106] *See* Nation Mag. v. U.S. Dep't of Def., 762 F. Supp. 1558, 1580 (S.D.N.Y. 1991); Students Against Genocide v. Dep't of State, 257 F.3d 828 (D.C. Cir. 2001).

[107] The Supreme Court of Indiana addressed concerns for trade secret protection involving the use of remote sensing in a 1993 case involving oil exploration. The trade

B. Fraudulent Images

An unusual cause for concern was revealed when a commercial satellite imagery company was investigated on suspicion of fraud for selling a bogus image purported to be taken at a critical moment of an alleged murder conspiracy. The company claimed that the image was made from satellite data, when in fact it turned out to be an aerial photograph taken at a time not relevant to the case.[108]

The company in question, Psytep Corporation supplied the Kansas Bureau of Investigations (KBI) with a photograph which helped convince a grand jury that two murder suspects lied about their whereabouts at the time a murder was committed.[109] The image came under suspicion when the KBI consulted with experts in remote sensing as to the resolution of the image.[110] Psytep claimed it could take data capable of 18-meter resolution and enhance it to a resolution of 2 to 5 meters.[111] When the KBI tried to verify the data in preparation for trial, agents began to suspect fraud.[112] Several experts told them that there was no commercial satellite capable of producing images of resolution high enough to detect automobiles.[113] When authorities concluded that the image was a fake, they dropped the indictments against the murder suspects.[114] Psytep's Chief Executive Officer pleaded no contest to false advertising.[115]

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secret protection issues in that case were the management decisions that led up to the use of remote sensing data and the focused geographic areas of the remote sensing investigation. *See* Amoco Prod. Co. v. Laird, 622 N.E.2d 912 (Ind. 1993).

[108] *See* Atsuyo Ito, *Improvement to the Legal Regime for the Effective Use of Satellite Remote Sensing Data for Disaster Management and Protection of the Environment*, 34 J. SPACE L. 45, 57 (2008) (*citing* Warren Ferster, *Firm Suspected of Misrepresenting Imagery*, SPACE NEWS, Jan. 16, 1995).

[109] *Id.*

[110] *Id.*

[111] *Id.*

[112] *Id.*

[113] *Id.*

[114] David Clouston, *Firm Pleads to Offering Fake Photo*, THE SALINA (KANSAS) J. (Dec. 20, 1995) https://www.newspapers.com/image/1893301/?clipping_id=31572728&fcfToken=eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJmcmVlLXZpZXctaWQiOjE4OTMzMDEsImlhdCI6MTY3MjU5OTU4NiwiZXhwIjoxNjcyNjg1OTg2fQ.wuHUatTXPMWuFsYNDoubmtmfI7RcQUXB29oW4KnHj0. *See also* Flynn v. Psytep Corp., 175 F.R.D. 691 (D. Kan. 1997) (voluntary dismissal of civil case against Psytep Corp.)

[115] Clouston, *supra* note 114. *See also* Terry Hatcher Quindlen, *Sale of Bogus Imagery Draws $50,000 Fine*, SPACENEWS, 2 (Jan. 8-14, 1996); Karen Geer, *The Constitutionality*

VIII. STILL A MEANS OF GETTING AT THE TRUTH

A. Timing, Modeling and Plumes

Although it is unlikely that a satellite will be directly overhead at the precise time a disaster or crime strikes, it sometimes does happen. Importantly, however, post-accident imagery can be very valuable even in cases where there is no image from the exact moment in question. It could be indispensable in mass tort litigation.

In most situations, the evidentiary value of satellite imaging will depend on having some form of pre-event imagery to serve as a comparative baseline. Imagery from space and airborne platforms already archived can provide a valid pre-accident baseline for most areas of the US. By comparing pre- and post-disaster images, it is possible to track the results of an event[116]—this is most commonly used with respect to oil spills and gas or smoke plumes.

Tracking of some plumes, especially chemical plumes, requires a more advanced technology, commonly called hyperspectral imaging systems. These systems use spectrographic analysis, which permits experts to use a mathematical equation or "model" to determine where the gas, smoke or chemical drifted following release.[117] A trial expert can also develop a colorized "plume model" depicting the release. In many situations, traditional satellite imagery can serve as a valuable backdrop that helps establish the geographic boundaries for a dramatic and persuasive exhibit.

Holli Riebeek notes satellite images "are like maps: they are full of useful and interesting information, provided you have a

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of Remote Sensing Satellite Surveillance in Warrantless Environmental Inspections, 3 FORDHAM ENV'T L. REP. 43 (1991).

[116] Smoke is sometimes visible by satellite imagery especially against a distinct background such as fresh snow, but until recently it was very hard to track plumes unless the plume was huge. The problem had to do both with resolution and frequency of a satellite fly over of the same spot. With better resolution and more frequent overflights, satellite tracking of smoke plumes and oils spills is easier today. When they are available, exhibits like this accurately depict the scene and are very persuasive.

[117] *See generally EPA Handbook: Optical and Remote Sensing for Measurement and Monitoring of Emissions Flux of Gases and Particulate Matter,* U.S. ENVIRONMENTAL PROTECTION AGENCY OFFICE OF AIR QUALITY PLANNING AND STANDARDS AIR QUALITY ASSESSMENT DIVISION MEASUREMENT TECHNOLOGY GROUP (Sept. 1, 2018) https://www.epa.gov/sites/default/files/2016-06/documents/gd-052.pdf.

key."[118] These images can show how a city has changed, how crops are growing, where a fire is burning and when a storm is coming. To unlock this information, you need to:

1. Look for a scale;
2. Look for patterns, shapes and textures;
3. Define the colors (including shadows);
4. Find north;
5. Consider your prior knowledge.[119]

These tips come from NASA Earth Observatory, whose mission is to "share with the public the images, stories, and discoveries about the environment, Earth systems, and climate that emerge from NASA research, including its satellite missions, in-the-field research, and models."[120] They are an excellent starting point when trying to examine what visualization options might be available.

B. Illustrative Cases: Adams, Avenal and Rivera

In *Adams, et al. v. Marathon Oil Co.*,[121] the court used a plume footprint to decide the parameters of the class of claimants who would be entitled to proceed in an action for damages suffered due to a release of an excessive level of a chemical odorant used in natural gas.[122]

Dr. Bruce Turner, an expert witness for the defense, used meteorological data, the testimony of fact witnesses, and reports with the Department of Environmental Quality to develop various diagrams of the path of the plume of ethyl mercaptan, which provided estimated concentrations of the substance in question.[123] He noted

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[118] Holli Riebeek, *How to Interpret a Satellite Image: Five Tips and Strategies*, NASA EARTH OBSERVATORY (Nov. 18, 2013) https://earthobservatory.nasa.gov/features/ColorImage.

[119] *Id.*

[120] *About the Earth Observatory*, NASA EARTH OBSERVATORY, https://earthobservatory.nasa.gov/about#:~:text=The%20Earth%20Observatory's%20mission%20is,%2Dfield%20research%2C%20and%20models (last visited Jan. 1, 2023).

[121] Adams v. Marathon Oil Co., 688 So.2d 75, 82 (La. App. 5 Cir. 1/15/97).

[122] *Id.*

[123] *Id.*

the highest concentration of ethyl mercaptan would be the area at the plant, around the sump at the time of its release.[124] Additionally, there were no indications of concentrations above 50 parts per billion off Marathon's property.[125] As such, those individuals "located outside of the plume as shown in the GIS tracking graphic offered by the defendant were excluded from the class."[126]

Evidence like this was also admitted in a class action related to oyster lease damages. In *Avenal v. State of Louisiana*,[127] the plaintiffs alleged that their oyster leases were damaged by the freshwater outfall from the Caernarvon freshwater diversion structure located on the lower Mississippi River in Plaquemines Parish.[128] Although the court initially certified a class of all plaintiffs in the Breton Sound area, the court later concluded that many plaintiffs' leases within the class had not been damaged, based in part on GIS tracking data presented by the defendant, the state of Louisiana.[129]

In *Rivera v. United Gas Pipeline Co*.,[130] residents of a neighborhood were evacuated as a result of a natural gas leak. They filed a class action against the owner of the pipeline as well as against a contractor who was working on the pipeline at the time of the incident.[131] As part of the defense, the defendants presented a computerized plume showing the extent of the natural-gas leak and the limited exposure of residents of the community.[132] This plume was superimposed on a backdrop of a color photograph of the area that was, in turn, integrated with a GIS database.[133] This allowed counsel to demonstrate the location of both the parameters of the plume as well as the residents of the neighborhood with considerable

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[124] *Id.* (The concentration at this location was calculated to be less than 500 parts per billion).

[125] *Id.*

[126] Wilson et al., *supra* note 40, at 392-93 (1997).

[127] Avenal v. State, 668 So.2d 1150 (La. App. 4 Cir. 11/30/95).

[128] *Id.* at 1151.

[129] Avenal et al. v. State, 2001-CA-0843 (La. App. 4 Cir. 10/15/03, https://caselaw.findlaw.com/la-court-of-appeal/1133959.html.

[130] Rivera v. United Gas Pipeline Co., 697 So.2d 327 (La. App. 5 Cir. 6/30/97).

[131] *Id.* at 332.

[132] Wilson et al., *supra* note 40, at 393, *citing* Rivera v. United Gas Pipeline Co., C.A. No. 23908 "Div. C" (40th J.D.C., Parish of St. John the Baptist, State of Louisiana (June 7, 1995)).

[133] *Id.*

accuracy.[134] The exhibit showed that few if any of the residents were exposed to dangerous levels of the gas.[135] As a result, the jury returned only a nominal verdict for the plaintiffs and held that they were not entitled to punitive damages.[136]

IX. PERSUADING THE JURY

Like any computer evidence, satellite data can be presented to the jury in printout format or as an animation (on a video screen or via a projector), a slide or a static photograph. With satellite data, however, new concerns are raised. While the trial judge has the task of determining which evidence is reliable and relevant, in a jury trial, the jurors will base their decisions on all the evidence that has been admitted. Exhibits must be easy to understand. Therefore, when preparing the exhibit, and laying the foundation for them in court, attorneys must be conscious of how such exhibits will be received by the jury.

Although most jurors appreciate that great reliance is placed on x-ray images and weather satellite pictures, the use of multi-spectral scanner data is not well understood. Thus, experts with specialized training can be indispensable. Experts can interpret the data as long as their opinion is based upon information reasonably relied upon by experts in the remote sensing community, even if the opinion goes to an ultimate issue in the case.[137] Of course, the expert must be prepared to disclose underlying facts or data supporting the opinion.[138]

The role of the expert is to teach the jurors the general principles of satellite remote sensing technology and convince them of its validity. The exhibit's credibility will depend on the answers to a few questions: First, why is the expert qualified to testify about satellite data and its applications?[139] Second, is the data reliable? At the risk of becoming too technical, the expert should demonstrate

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[134] *Id.*

[135] *Id.*

[136] *Id.*

[137] *See* FED. R. EVID. 704 (Opinion on Ultimate Issue);

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

[139] The "knowledge, skill, experience, training, or education" and participation (including publication of peer reviewed articles) in professional organizations impress a trier of fact that the expert is reasonably reliable. THOMAS A. MAUET, FUNDAMENTALS OF TRIAL TECHNIQUES 121-22 (1992).

that comparable data is regularly used in all kinds of other applications.[140] Finally, the expert has to explain what processing steps were undertaken in order to make the exhibit that is being considered. This means addressing whether the satellite data (and the images produced from them) have been overly manipulated so that they no longer reflect the truth. Expert witnesses can provide supporting evidence, including accurate maps, aerial photography[141] and sample measurements or observations (including photographs) taken by experienced trained scientists that verify the expert's interpretation of the results.[142]

Simply put, each jury needs a brief introduction to the principles of remote sensing along with image processing and interpretation. Illustrations showing common applications of the principles will help connect the unfamiliar technology to the collective "everyday" experience. Although the technology is sophisticated, if the evidence is presented properly, the jurors' familiarity, comfort with and, ultimately, confidence in the evidence will most likely be gained. For this reason, presenting the basic principles as a solid foundation is crucial for the acceptance of novel scientific evidence.[143]

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[140] FED. R. EVID. 703 (Bases of Opinion Testimony by Experts). The expert should explain that this kind of data has been relied upon by military and civilian government agencies and businesses for years, and the fact finder should therefore be comfortable relying upon it.

[141] Using aerial photography to support the validity of the satellite data also helps tie the novel science to the familiar experiences of a juror or judge. Hundreds of cases over the past forty years reported using aerial photography as evidence. *See* Hodge, *supra* note 40; Purdy & Macrory, *supra* note 6.

[142] *See* Timothy W. Foresman & David R. Williams, *Remote Sensing: An Environmental Enforcement Tool*, *in* EARTH OBSERVATION SYSTEMS: LEGAL CONSIDERATIONS FOR THE '90S 30, 39 (1990). *See also* State v. Wright, 752 A.2d 1147, 1157 (Conn. App. Ct. 2000) ("Through his testimony, [the prosecution's expert witness] indicated that he went to the actual locations depicted on the map to determine the actual locations and then entered the data into the computer that generated the map. He further testified that the program utilized to generate the map included formulas created by others to generate the distance between the school and the location where the defendant was arrested. He also testified that the coordination method that is the basis for the entire system was checked by the state of Connecticut and private engineering companies. He pointed out that the coordination system was not, in fact, displayed on the map entered into evidence, but the result was checked against the coordination system. Finally, he testified that the map was a fair and accurate representation of the distance from St. Mary's school to 19 Walnut Street.") *Id.*

[143] *See* Hodge, *supra* note 40; Purdy & Macrory, *supra* note 6.

X. CONCLUSION

Modern science has had numerous impressive breakthroughs that create tremendous opportunities for engaged litigators. Among the most interesting is the availability of satellite imagery. Related exhibits are the result of complex technical and methodological processes, but they can be understood, and they can be explained to judges and jurors. When handled properly, such evidence can be very helpful in finding and proving the truth.

It is impossible to predict what science will bring in the future, but effective litigators need to keep up with the science. It is true that every new technology creates new legal problems, but it is also true that new technologies—like many of those described in this article—can lead to new exhibits to help attorneys better represent their clients. Remote sensing and satellite data, especially when developed with GIS, is already available and waiting to be used.

THE DEVELOPMENT OF LABOR LAW IN OUTER SPACE - A COMPARISON WITH THE AMERICAN FRONTIER AND THE HIGH SEAS

Connor Hogan[*]

ABSTRACT

As industry and commerce develop above the Earth's atmosphere, it is conceivable that we may see communities of people living and working in outer space before the end of this century. The space environment presents serious challenges for workers: it is instantaneously lethal; remote from the international community and regulatory bodies; and any oversight or enforcement of existing labor law is extremely difficult. This article examines these challenges and explore two cases of developing labor law in similarly remote environments: the American frontier over the course of the 19th to early 20th centuries; and the modern high seas. The article suggests that the development and enforcement of a legal regime to protect workers in extreme frontier environments are characterized by a relative lack of compliance with regulation. Additionally, workers' ability to effectively organize, engage in dispute resolution, and dissent is diminished in a remote and dangerous context. Finally, the development of labor law in extreme environments is also influenced by the often-specialized nature of the work performed there. The article concludes that the environment of outer space is analogous to these cases, and thus pre-emptive legal measures will be needed to ensure the rights and dignity of workers as the space industry continues to develop.

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I. INTRODUCTION

"I want to thank every Amazon employee and every Amazon customer, because you guys paid for all of this"

- Jeff Bezos, CEO of Amazon, on returning from his first private spaceflight.[1]

The 21st century is set to see an increase in the amount of people living and working in space. Several developments give us reason to suppose this: National Aeronautics and Space Administration's (NASA) continued development of its Artemis lunar program;[2] the completion of China's new Tiangong space station; preparations to send taikonauts to the Moon in the 2020s;[3] the rise of private actors like SpaceX, Blue Origin and Virgin Galactic (all of which intend to develop a space tourism industry);[4] the European Space Agency's (ESA) recruiting of astronauts for the first time in a decade;[5] India's development of a crewed space program;[6] and legislation in the United States[7] (US) and Luxembourg,[8] among others in anticipation of asteroid mining in the near to medium term. If these developments continue apace, it is conceivable that an

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[1] Tyler Sonnemaker et al., *Amazon Workers React to Jeff Bezos Thanking Them After Space Flight*, BUS. INSIDER (July 20, 2021), https://www.businessinsider.com/amazon-workers-react-jeff-bezos-thanks-blue-origin-space-flight-2021-7 (quoting Jeff Bezos).

[2] Parul Agrawal., *Returning to the Moon: NASA's Artemis Missions*, NASA (Jan 5, 2023), https://ntrs.nasa.gov/api/citations/20230000123/downloads/Artemis%20Orion%20Presentation.pdf.

[3] Ling Xin, *China Astronauts Say Hello from Completed Tiangong Space Station*, S. CHINA MORNING POST (Nov. 3, 2022), https://www.scmp.com/news/china/science/article/3198266/china-astronauts-say-hello-completed-tiangong-space-station; Andrew Jones, *China Unveils Lunar Lander to Put Astronauts on the Moon*, SPACE NEWS (Feb 27, 2023, https://spacenews.com/china-unveils-lunar-lander-to-put-astronauts-on-the-moon/.

[4] *See generally* CHRISTIAN DAVENPORT, THE SPACE BARONS: ELON MUSK, JEFF BEZOS, AND THE QUEST TO COLONIZE THE COSMOS (2019).

[5] Tereza Pultarova, *Astronauts Wanted: Engineers With Nerves of Steel Welcome*, 16 ENG. & TECH, 1 (May 2021).

[6] Chethan Kumar, *India Has Been Quietly Working on Key Technology to Enable Space Station*, THE TIMES OF INDIA, (June 13, 2019), https://timesofindia.indiatimes.com/india/india-has-been-quietly-working-on-key-technology-to-enable-space-station/articleshow/69775029.cms.

[7] 51 U.S.C. §§ 51301-51303 (2023).

[8] *Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace*, Journal Officiel du Grand Luxembourg, July 20, 2017 (entered into force J uly 20, 2017), https://data.legilux.public.lu/ file/eli-etat-leg-loi-2017-07-20-a674-jo-fr-pdf.pdf.

increasingly large and varied population of people may begin working and living in space over the course of this century. Such communities will exist in a working environment that is "instantaneously lethal."[9] Under these uniquely challenging circumstances, there will be potentially no remit for disobedience or collective bargaining, as the precarity of the labor force will consist of not only the need to eat, drink and be sheltered, but to simply exist.

Furthermore, the relative remoteness of space from the international community and regulatory bodies means that oversight and enforcement of any existing legislation is an immense challenge,[10] and future workers may find themselves marooned without a stringent, pre-emptive response. The problem of enforcement is a known issue within space law and policy, and the foundational Outer Space Treaty[11] which governs activities above the Earth's atmosphere has found itself under strain in recent years.[12] Contemporary discourse in this regard has mainly focused on the role of States and private companies, with little discussion of the relative position of human individuals and communities of workers.

This article will explore the primary factors influencing the development, effective enforcement and protection of labor rights in extreme and remote contexts, to make inferences about a possible future configuration in the early decades of a space-based economy. To do so, the article will examine two analogous cases in which remote, extreme and dangerous spheres became regulated, and a

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[9] CHARLES S. COCKELL, DISSENT, REVOLUTION AND LIBERTY BEYOND EARTH 1 (Charles S. Cockell ed., 1st ed. 2016).

[10] For more detail, *see* Matthew C. Weinzierl, *Space, The Final Economic Frontier*, 32 J. OF ECON. PERSPECTIVES. 173, 173-92 (2018); Tony Milligan, *Constrained Dissent and the Rights of Future Generations, in* DISSENT, REVOLUTION AND LIBERTY BEYOND EARTH 7-20 (Charles S. Cockell ed., 2016); Kurt Mills, *Who Will Own Outer Space? Governance Over Space Resources in the Age of Human Space Exploration*, *in* HUMANS IN OUTER SPACE – INTERDISCIPLINARY PERSPECTIVES 23 (Ulrike Landfester, et al. eds., 2012); Patrick Lin, *Look Before Taking Another Leap For Mankind—Ethical and Social Considerations in Rebuilding Society in Space*, 4.3 ASTROPOLITICS 281, 281-294 (2006).

[11] 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, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

[12] *See* ANNETTE FROEHLICH, A FRESH VIEW ON THE OUTER SPACE TREATY (Annette Froehlich ed. 1st ed. 2018); RAM S. JAKHU & JOSEPH N. PELTON, GLOBAL SPACE GOVERNANCE: AN INTERNATIONAL STUDY 19-52 (Douglas A. Vakoch et al eds., 1st ed. 2017); Karl Leib, *State Sovereignty in Space: Current Models and Possible Futures*, 13.1 ASTROPOLITICS 1, 1-24 (2015).

legal regime of labor rights and protections developed for workers within them: the American frontier over the course of European expansion; and the modern high seas. By tracing the mechanisms and challenges which informed the development, enforcement and protection of labor rights in these instances, the article develops a conceptual lens through which to examine similar challenges in outer space.

Part II of this article surveys the current literature on space regulation, governance and the international treaties, the role of individuals and workers, and highlights the need for an empirical study on labor rights. This part also introduces the established analogues between outer space and other frontiers in the literature, and contemporary maritime labor law. Part III outlines the central theory of the article, that the development and enforcement of a legal regime to protect workers in extreme environments are characterized by a relative lack of compliance with regulation in the absence of effective oversight, the diminished bargaining power of workers in a physically perilous context, and the often-specialized nature of the work performed there. Part IV outlines the methodology employed. Finally, Part V presents the results of this research, and provides a detailed account of both case studies from within the conceptual framework outlined in the theory section, applying them both to the context of outer space. Finally, the article concludes with preliminary recommendations.

II. CURRENT CONTEXT

Shortly after the launch of Sputnik-1 in 1957, an international norm was established for outer space which emphasized scientific use and limitation of arms.[13] This norm formed the bedrock of international space policy and law, and is the foundation of the Outer

[13] *See e.g.,* International Cooperation in the Peaceful Uses of Outer Space, G.A. Res. 1472 (XIV) (Dec. 12, 1959); International Cooperation in the Peaceful Uses of Outer Space, G.A. Res. 1721 (XVI) (Dec. 20, 1961); Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, GA Res. 1962 (XVIII) (Dec. 13, 1963). For an extended analysis of this history, *see* Franz von der Dunk, *International Space Law*, *in* HANDBOOK OF SPACE LAW 1-28, 35-7 (Franz von der Dunk & Fabio Tronchetti eds., 2015)

Space Treaty.[14] Article II of the Treaty famously states that: "Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[15]

Other widely ratified space treaties (including the Rescue Agreement,[16] the Space Liability Convention[17] and the Registration Convention[18]) similarly uphold the extraterritorial nature of space. In practice, this means that outer space and bodies like the Moon remain a *terra nullius* in international law. Much of the debate within the space governance literature concerns the so-called "common heritage [of humankind] principle"[19] and State sovereignty[20] particularly in the context of private actors,[21] developing nations[22] and national security.[23] Whereas the previously small number of State actors in the space industry meant that legal and regulatory problems could be solved on an *ad hoc* basis, the increasing number

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[14] Outer Space Treaty, *supra* note 11. *See* Franz von der Dunk, *International Space Law*, *in* HANDBOOK OF SPACE LAW 35-7 (Franz von der Dunk and Fabio Tronchetti eds., 2015).

[15] Outer Space Treaty, *supra* note 11, art. II.

[16] The Agreement on the Rescue of Astronauts, The Return of Astronauts and The Return of Objects Launched into Outer Space, Apr. 22, 1968, 672 U.N.T.S. 119.

[17] The Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 961 U.N.T.S. 187.

[18] The Convention on Registration of Objects Launched into Outer Space, June 6, 1975, 1023 U.N.T.S. 15 [hereinafter Registration Convention].

[19] *See* FRANCIS LYALL & PAUL B. LARSEN, SPACE LAW: A TREATISE 330-36 (2nd ed. 2020); Mills, *supra* note 10, at 16.

[20] LYALL & LARSEN, *supra* note 19, at 263-90. *See also* FROEHLICH, *supra* note 12; Leib, *supra* note 12; Christophe Venet, *The Political Dimension*, *in* OUTER SPACE IN SOCIETY, POLITICS & LAW 73-91 (Christian Brünner & Alexander Soucek eds., 2011); Carol R. Buxton, *Property in Outer Space: The Common Heritage of Mankind Principle vs. the First in Time, First in Right, Rule of Property*, 69 J. AIR L. AND COM. 689, 689-91 (2004).

[21] *See e.g.,* LEWIS D. SOLOMON, THE PRIVATIZATION OF SPACE EXPLORATION: BUSINESS, TECHNOLOGY, LAW & POLICY (2017); Gbenga Oduntan, *Aspects of the International Legal Regime Concerning Privatization and Commercialization of Space Activities*, 17 GEO. J. INT. AFF. 79, 79-90 (2016).

[22] *See e.g.,* Timiebi Aganaba-Jeanty, *Introducing the Cosmopolitan Approaches to International Law (CAIL) Lens to Analyze Governance Issues as They Affect Emerging and Aspirant Space Actors*, 37 SPACE POL'Y. 3, 3-11 (2016); Joel A. Dennerley, *Emerging Space Nations and the Development of International Regulatory Regimes*, 35 SPACE POL'Y. 27, 27-32 (2016).

[23] *See, e.g.,* BLEDDYN E. BOWEN, WAR IN SPACE: STRATEGY, SPACEPOWER, GEOPOLITICS (2020).

of active participants means that a more robust international framework is needed.[24]

In addition to the international treaties, "soft law" has played an increasing role in the contemporary governance of outer space as the number of actors in the industry continues to rise.[25] In essence, certain international norms and aspirations (such as the need to reduce space debris) have been encouraged and expressed on a national, voluntary basis, effectively preceding binding resolutions.[26] It is from within this emerging context (the continuing but contested role of the international space treaties and increasing number of active entities in the industry) that this article locates the issue of labor rights.

Whereas some work has been done on the jurisdiction of individuals within space,[27] an empirical investigation of the potential relationship between individuals and more powerful State and private actors is needed. In his discussion of space ethics, Patrick Lin highlights the urgent need for scholars of space law and policy to engage with questions of social organization, warning that without a "big picture" strategy for space settlement, future generations may be at the mercy of unaccountable actors.[28]

While outer space and celestial bodies remain beyond State sovereignty in international law,[29] Article VIII of the Outer Space Treaty states that: "[a] State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body."[30] Thus, space vessels remain tied to their State of origin's national laws in a manner

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[24] Katrin N. Metcalf, *A Legal View on Outer Space and Cyberspace: Similarities and Differences*, 10 TALLINN PAPERS 1, 4-9 (2018).

[25] CASSANDRA STEER & MATTHEW HERSCH, WAR AND PEACE IN OUTER SPACE: LAW, POLICY, AND ETHICS 98 (2020); JAKHU & PELTON, *supra* note 12, at 45-51.

[26] JAKHU & PELTON, *supra* note 12, at 45-51.

[27] *See e.g.,* P.J. Blount, *Jurisdiction in outer space: challenges of private individuals in space*, 33 J. SPACE L. 299 (2007).

[28] Lin, *supra* note 10, at 292. Lin advocates employing a Rawlsian Original Position to the question of space development and argues that "applying the veil of ignorance to rules in space helps ensure that the processes we set up are fair and consider the interests of all people, including protecting the worst-off people from an even worse and uncaring fate." *Id.*

[29] *See* LYALL & LARSEN, *supra* note 19, at 263-90.