Electromagnetic Surveillance

11

X-Rays

1. Introduction

X-rays are invisible, penetrating rays that have a seemingly magical ability to travel through many substances and to generate images that show the relative density of materials, allowing us to peer through solid objects. This adaptation of X-rays is often colloquially called 'X-ray vision.' X-ray vision has become symbolic for many surveillance activities, from medical imaging and extraplanetary observation, to clairvoyance and voyeurism. In the context of this chapter, X-ray technology is described in terms of common professional applications.

Within the Earth's protective ozone and atmospheric envelope, we don't have very high levels of natural X-radiation. Because it is not prevalent on our planet and because of its particular high-frequency characteristics, humans have not evolved any natural 'immunity' or protection against the damage that might be caused by exposure to X-rays. Most X-rays are synthetically generated and used in carefully controlled situations.

X-radiation is a very useful phenomenon. It behaves in predictable ways when aimed at particular substances, making it a practical tool for determining information about substances

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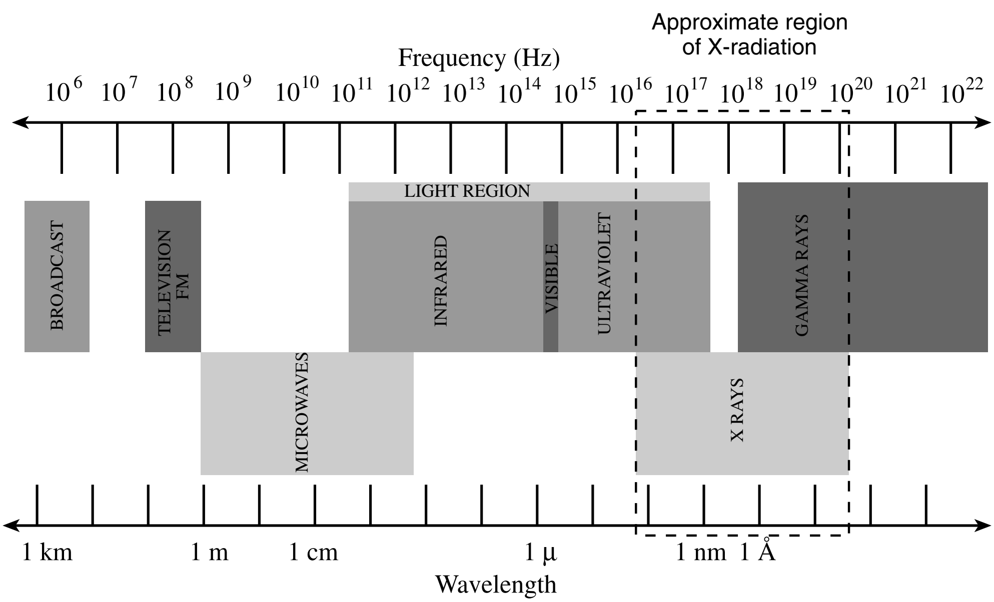
A nickel prototype mirror being optically tested at the *Advanced X-Ray Astrophysics Facility*-S (AXAF-S). X-ray telescopes are providing new ways to study black holes, cosmic clouds and other phenomena in the universe that we have never before been able to see or record. [NASA/Marshall news photo, released.]

down to the atomic level, and for imaging materials that are sensitive to its effects. X-ray technologies are often used in conjunction with other surveillance technologies, including chemical and visual surveillance devices. X-rays can be used to look inside containers and living beings without direct handling or surgical intervention. This makes it possible to detect smuggling, manufacturing defects, possible contamination, and various diseases or physical abnormalities. X-ray technologies are also used in astronomy for surveilling cosmic emanations and studying the origins of life.

X-rays allow us to 'see' inside things. X-rays penetrate different materials to different extents, depending on their density. Since bone is denser than skin, X-rays passing through a body onto a photosensitive surface like an X-ray film or digital X-ray detection array, will stimulate the imaging surface more or less depending on whether the rays passed through bones or skin. The rays don't pass as readily through bone, so they don't stimulate the imaging system as much as the rays that passed through the skin. This creates an image with relatively lighter or darker areas, depending on the characteristics of the imaging surface. With newer, digital imaging systems, the values can be inversed or processed with colors to make the picture more readable. The characteristics of medical X-rays can be readily applied to industrial and other applications, as well.



2. Types/Variations

X-ray machines are used in many aspects of surveillance and thus they vary in terms of size, portability, power, and cost. This text does not go into depth about X-rays that are used for medical purposes; radiological and diagnostic medical texts should be consulted for this information.

X-ray machines come in a variety of configurations. The size of the machine used to be a good general indicator of the power and price of the system, but with computer technologies this is no longer true. It is now possible to pack powerful capabilities into smaller-sized systems. Microelectronics has made it possible to equip vans with high-power X-rays for special events, mobile, or semi-permanent, on-site applications.

X-ray technology is basically passive or active:

passive X-ray detector system - one that reacts to X-rays without generating X-rays. Passive systems are used in detection devices such as X-ray space telescopes or in situations where X-rays are suspected of being used as a weapon. Passive systems are also used to detect and measure leakage from active X-ray machines.

active X-ray system - one that generates X-rays and which may or may not have a detector or imaging system to 'capture' the emitted rays. An *active sending system* simply generates X-rays, as in a scientific experiment to observe their effects on bacteria. An *active sending-and-sensing system* is the one we commonly see in airports or hospital radiology labs–the system sends out X-radiation and detects and displays the information that is generated by the X-ray probe.

X-ray images from passive sensing systems or active sending-and-sensing systems are displayed in a number of ways:

traditional grayscale photographic images on film - these resemble large negatives and are the types of images used by radiologists and some manufacturers or quality assurance testers who are recording materials fabrication processes or documenting possible defects in production components.

realtime 'light-box' style illuminators - images that are projected onto realtime or near-realtime viewers in airport and crowd security systems, especially the small conveyor-belt systems used in airports or small-scale industrial production lines.

realtime or delayed computerized display - digitized images that may be realtime, near-realtime, or on-demand database entries that can be displayed and sometimes manipulated on a computer screen. They are used for more specialized applications, usually for experiments or observations in scientific labs.

Detected X-rays are most often viewed as grayscale images, since X-rays are not part of the visible spectrum that we perceive as color. However, sometimes assigned colors can aid in interpreting an image and 'false color' or 'pseudocolor' systems are becoming more common. These color assignments are also found in infrared and ultraviolet imaging systems. Some pseudocolor systems can toggle between the grayscale and color interpretations so that the 'raw' data can be cross-referenced with the image that has been colored by the computer.

Basic System Design

Baggage inspection machines are one of the more common X-ray surveillance technologies. This text doesn't go into detail on the mechanics and electronics of the different types of X-ray machines, but a simple baggage X-ray machine will be described to give an idea of how X-ray baggage-inspection systems work.

- X-rays are generated by using an electron gun that emits electrons, a system that is similar to the electron guns in a cathode-ray tube (CRT) to display TV or computer images. High voltages are then used to accelerate the electrons until they collide with a barrier (usually metal). The speeding electrons are abruptly halted and scattered by the barrier, resulting in the generation of radiation in the X-ray spectrum. Sometimes more than one energy level of X-rays is produced, depending on the purpose of the system.

- The generator that produces the X-radiation is usually positioned above or below the baggage conveyor belt. When the machine is activated, the beams are directed up or down through the belt and through any baggage that is passing by on the belt.
- Between the X-ray generator and the conveyor belt are devices called *collimators* which control the direction of the beam, usually processing the rays so that they are parallel and spaced as desired. X-rays normally spread out in a cone shape, like a flashlight beam, and it is usually necessary to narrow and focus the beam for practical use.
- On the other side of the baggage are *detector bars* that are stimulated when they are hit by the X-radiation. The information from the detectors is translated into data that may be stored or processed and which is sent to a display system. On baggage systems, this display looks like a light box with ghostly grayscale or pseudocolor images of the various objects displayed against a light background.

Dual-energy beams that use two different voltages have been devised to aid in discriminating between different substances, such as between organic and inorganic materials.

Improvements in Technology

Since digital technologies are becoming more prevalent and microelectronics finer and more precise, it is now possible to design X-ray sensor arrays that are very high resolution. As the number of elements in the array increases, generally the resolution increases (as does the price).

Note, this book doesn't have a separate chapter on gamma-ray surveillance, because the science is recent and is mainly used in theoretical and space sciences, but there are some interesting developments in which low-dose gamma rays are being designed into cargo-inspection systems, without some of the protective enclosure limitations of certain X-ray technologies.

Since gamma-rays lie at the extreme high-frequency end of the electromagnetic spectrum, roughly following X-rays, many of the more general concepts relating to X-rays also apply to gamma rays, especially in space telescope applications. You are advised to consult physics texts and industrial suppliers if you wish to learn more about gamma ray applications.

Product Specifications

X-ray systems are usually specified in terms of their overall size, the size of the opening for the X-rayed objects, their weight, power consumption, beam orientation, resolution, storage capacity (digital systems), color (grayscale or pseudocolor), dosage per inspection, radiation leakage, and penetration. If the X-ray system includes a conveyor system for moving objects through the X-ray beams, the speed of the belt will also be specified.

Beam orientation is important in systems designed to X-ray larger containers, such as cargo pallets. It is necessary to match the system and the direction in which it points to the needs of the task. For small baggage inspection, a downward-pointing beam is fine, but this wouldn't work for scanning a cargo truck or shipping container from the side.

3. Context

While X-ray surveillance is not inherently tied to any particular setting or application, because of its risks and cost, X-ray technology tends to be used almost exclusively in professional contexts. Trained personnel and special housings and facilities are required to contain the X-radiation. Traditionally, X-ray equipment has been large and somewhat immobile, though new computer technologies are succeeding in putting certain X-ray capabilities on electronic chips, which may spawn a new generation of portable equipment. In general, though, X-ray technology is not a casual consumer market and X-ray equipment is not commonly used outside of professional settings and is generally used by personnel who have been through safety training or certification programs.

The contexts in which X-ray surveillance are most often used include

medicine and preventive health care - X-rays are used for anatomical studies, medical monitoring and diagnostic procedures, forensic investigations (e.g., internal injuries leading to death) and, in some cases, assessment of prenatal conditions.

cargo and luggage inspection - Many organizations use X-ray machines for luggage inspection, including public and military transportation providers, customs and border patrol officials, private and public mail and courier services, and public events crews.

archaeological, artifact, and art inspection - X-rays allow artifacts, art, bones, caves, ancient buildings, and other objects to be inspected for characteristics that cannot otherwise be seen, to aid in their identification, preservation, and authentication.

fraud detection - X-rays are sometimes used to examine documents or items that have been subjected to vandalism or tampering, though other less hazardous technologies are usually chosen first.

industrial testing, inspection, and quality control - X-rays can be used to check for quality, consistency, defects, contamination, internal characteristics, and other production fabrication qualities.

military - X-rays have been studied for specialized military applications such as weapons and detection devices and for assessing the health of personnel.

astronomy - X-ray telescopes are one of the more exciting technologies that are being used to probe the cosmos and several have been put into space in the last several years, often in conjunction with infrared and ultraviolet sensing devices.

It takes skill and experience to interpret X-rays, particularly medical X-rays. It takes a different type of skill to interpret the X-ray view screens on conveyor-belt industrial product control or airport security systems. On conveyor-belt systems, a constant parade of objects is moving by at medium or high speed. It requires constant attention to assess each and every image that goes by hour after hour, especially if irate travellers are complaining about the delays and creating distractions. To maximize efficiency and decrease the chance of errors, those viewing the screens should be put on rotating shifts that allow them to do some other type of activity at least every two hours, to give their eyes and brains a break.

Most X-ray systems require visual interpretation, but some of the computerized systems may also have alarms that can sound if certain triggers are detected. Wholly automated systems may also exist in some circumstances where the objects being inspected are all alike or follow similar patterns, as in industrial production line or quality inspection systems.

Displays

The types of displays that are used depend on the context. In medicine, where accuracy and high resolution are essential to the interpretation of sensitive medical information, a system which takes longer to display (or chemically develop) the image is usually better than a fast system with lower resolution. However, digital high-resolution systems with the potential to revolutionize X-ray technology in medicine were becoming available in the late 1990s.

In transportation security systems, realtime or near-realtime display is important, since it isn't practical to keep passengers waiting while X-rays are being developed and processed. Hence these systems tend to use low or medium resolution images displayed on a small screen that resembles a 'light box' which is brightly illuminated and shows the contents of baggage. Some of the more automated systems will sound an alarm or highlight an area if they detect objects of a suspicious nature.

For industrial purposes or cargo surveillance, sometimes multiple-monitor systems are used. Two screens may be used to display the cargo from different vantage points, while a third might be used to display information from a barcode or database that gives information about the cargo, such as the cargo manifest and shipping history.

Spin-Offs from X-Ray Technology

Holography is an interesting technology which evolved from research into X-rays. It now has many applications in security and surveillance.

Holography has contributed to the design of counterfeit-deterrence features, UPC scanners, non-destructive quality and defect testing, and pattern-recognitions systems in computer software and robots. Holographic storage concepts, which are related to holographic recording concepts, are important to microcomputer research as they hold promise for improved mass storage devices. Inexpensive mass storage is desirable for the storage of surveillance information, particularly 'high-bandwidth' applications like sound and video.

4. Origins and Evolution

The existence of X-radiation wasn't known until less than 200 years ago, making it a very recent discovery and an even more recent surveillance technology. Unfortunately, the pioneers of X-ray science didn't realize how very dangerous high-level X-ray energy could be or how it could damage human tissue. The history of X-ray technology is not just a history of the generation of X-rays and improvement of the technology, but is also a history of how to protect ourselves from its dangerous effects and side effects.

The Discovery of X-Rays

William Crookes (1832-1919) was an English physicist with a strong interest in spectroscopy, radiation, and the phenomenon of luminescence. In the course of his research, Crookes noted that cathode rays traveled in straight lines and had sufficient energy to turn a small wheel. There was discussion at the time over whether cathode rays were a wave phenomenon or a particle phenomenon. While doing experiments with a Crookes tube, Crookes observed some of the effects of X-rays but didn't recognize the significance of the observations until after X-rays had been more systematically studied by Wilhelm Röntgen.

Wilhelm Konrad Röntgen (1845-1923) was a German physicist working at the University of Würzburg, Bavaria. He had been experimenting with Crookes tubes and generating cathode rays, the technology that eventually led to cathode-ray tubes (CRTs) several decades later, when he observed that some chemicals had a particular tendency to luminesce (to light up when stimulated). To better see the effect, he darkened the room and applied cardboard light-blockers and discovered that materials at a distance luminesced when the cathode rays were activated. The rays had passed right through the cardboard. He found that it would work even through walls. He had discovered 'invisible' rays that could pass through solid matter. Since he wasn't able to immediately identify the nature of the rays that were apparently passing through solid substances, he called them X-rays, after the convention of mathematicians to use the symbol *x* to indicate an unknown value or quantity. These rays were called Röntgen rays (in English it is often spelled Roentgen), in honor of Röntgen's discovery, right up until the 1950s, but the shorter term *X-rays* is now more prevalent. X-ray doses are still expressed in units called *roentgens*.

A little more than a month after his important discovery, after numerous experiments, Röntgen published a paper on X-rays, in December 1895. At a lecture demonstration about a month later, Röntgen X-rayed the hand of an octogenarian volunteer and spurred a fever of research and activity over the new discovery.

Soon after Röntgen published his important paper on X-rays in Europe, studies of X-rays were beginning on the other side of the world, in Japan. Kenjiro Yamakawa and Han-ichi Muraoka, who had studied in Röntgen's lab at Strasburg University, took an X-ray photograph, aided by the founders of the Shimazu Company. These early X-rays clearly showed a pair of glasses, a key in a lock, and the bones of a hand wearing a wedding band.

Discovering the Properties of X-Rays

Subsequent experiments revealed that X-rays were increasingly impeded as materials became denser. This made it practical for taking 'pictures' of human tissue that showed the bones and cartilage in contrast to the soft tissues, effectively making it possible to 'look inside' human beings. No one yet understood the cumulative effect X-rays would have at the basic cellular level.

It took a while to determine the type of energy X-rays represented. Some scientists thought it might be a longitudinal wave phenomenon, somewhat like sound. Others asserted that it was a particle phenomenon, like cathode rays. Still others felt it was electromagnetic, like light (which had itself not yet been fully explained).

Charles Glover Barkla (1877-1944), an English physicist, began investigating X-rays while at Cambridge and noticed that X-rays could reveal information about gases by the ways in which the rays were scattered when directed at the gases. The pattern of scattering was related to the density of the particular gas and thus could reveal its molecular weight. It also revealed, in 1904, that X-rays apparently were a particular type of wave that was unlike longitudinal sound waves. Barkla further observed that the degree to which the X-rays could penetrate matter was related to which element had been used to scatter the rays.

A German physicist name Max T. F. von Laue (1879-1960), who had been an apprentice to the great quantum physicist Max Planck, began to experiment with crystals as a natural type of 'atomic grating' that could be used to control the passage of rays such as X-rays. Just as Barkla had discovered that gases could scatter X-rays to reveal information about those gases, von Laue discovered that crystals could influence X-rays to reveal information about the crystals and the X-rays themselves. Crystals are useful in science because they have a very regular and somewhat predictable atomic structure that makes them useful for precision applications that cannot be easily achieved by other means. Many crystals also have particular vibratory qualities that are valuable for timing applications in electronics. Von Laue found that crystals could also be used to reveal more about the nature of various radiant energies. By aiming X-rays at particular crystals and observing the resulting effect or direction of the scattering of the rays (depending on what was being studied), clues as to the nature of the rays could be discerned. Von Laue took advantage of the nature of crystals to study X-rays and not only added evidence to the argument that X-rays were a form of electromagnetic radiation, but also created a new way to study the crystals themselves. Thus, the science of X-ray crystallography was emerging.

Research on X-rays continued in both Japan and Europe. A father and son team, William Henry Bragg and William Lawrence Bragg picked up on the work of von Laue and continued to study the effects of passing X-rays through different crystals. By doing so, they learned more about the energy frequencies emitted by X-rays and where they stood in the electromagnetic spectrum in relation to other phenomena such as visible light. This work earned them the 1915 Nobel Prize in physics. A Japanese researcher, Torahiko Terada, also did pioneer work on X-ray diffraction. Peter J. W. Debye subsequently demonstrated somewhat surprisingly that powdered crystals or mixtures of powdered crystals could be used as well as solid chunks of crystal for X-ray analysis. This opened up many possibilities for variations on the technology and possible industrial applications.

While the relationship may not be immediately apparent, X-ray technology allowed scientists to fill in many gaps in the Periodic Table, a cataloguing of atomic elements that was as yet somewhat rudimentary and incomplete at the time. Henry Moseley (1887-1915), an English physicist, made use of the potential of William H. and William L. Bragg's crystallographic research for comparing X-ray wavelengths with atomic weights. The Periodic Table was reshuffled a bit into a more workable pattern through the work of Moseley and he formulated the concept of the atomic number in 1914. Thus, X-rays became an important aspect of analytical chemistry and Moseley developed the early science of X-ray spectrometry.

It was about this time that the first basic X-ray apparatus were developed in both Europe and Japan.

Karl Manne Georg Siegbahn (1886-1978), a Swedish physicist, built on the work of earlier scientists and refined the study and production of X-rays. Just as visible light is divided into different spectra that we perceive as different colors, X-rays had spectral qualities that were somewhat similar to light. In 1924, Siegbahn was awarded a Nobel Prize in physics for the development of X-ray spectroscopy.

The 20th Century - Practical Applications

The obvious application for X-rays was in medicine and physiology. Radiology books and journals became common at the beginning of the 1900s, with many picture examples of broken or abnormal bones and cartilage.

The prospect of looking inside things, especially inside humans, was so irresistible, that X-ray machines were showing up everywhere. Some of the major shoe manufacturers were even putting X-ray machines in shoe stores, where the sales reps would X-ray a person's foot in order to equip him or her with the 'perfect fit.' Remarkably, after the many scientific experiments that had been done with X-rays, people still didn't fully realize its dangers. There were X-ray movies made of people eating and swallowing, which were delightful to watch, but may have had serious consequences for the subjects of the movie. Some people directed X-rays at their heads, trying to get a 'buzz.' Not only were X-rays dangerous, but many of the early machines delivered high doses of radiation. Not only were they a danger to the people near the machines, but they would travel right through the walls and across the street to expose the people working unawares many meters away.

The idea of using X-radiation for industrial inspection may have been born around the same time that experimenters were developing devices that used acoustics or magnetism to inspect tracks, girders, and large industrial vessels such as military ships and tanks. X-rays provided a new way to look inside certain types of materials, particularly wood, thin metals, fabrics, and liquids. The impermeability of lead to X-rays made it a suitable material for masking off areas or providing protection from the hazardous radiation.

In 1947, Dennis Gabor (1900-1979), a Hungarian scientist living in Britain, was seeking a means to greatly magnify X-ray images and essentially invented holography in the process, for which he received a Nobel Prize in physics in 1971.

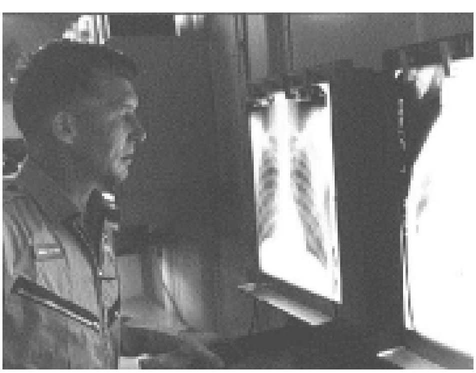
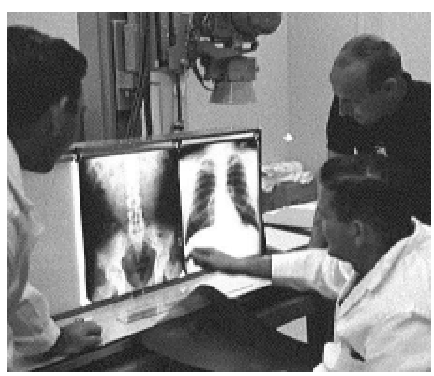
By the 1950s, X-ray diffraction techniques were being used to try to discern more about a structure called DNA that was found in living tissues and which was the fundamental 'blueprint' for the development of living cells, leading to some important discoveries. (See the Genetics Surveillance chapter.)

In the 1950s, many older dentists using traditional methods of diagnosis weren't yet using X-rays, but younger dentists, who had more recently graduated from dental school, were installing X-ray equipment to aid in detecting tooth decay and abnormalities. X-rays in those days were sometimes used overzealously. There are dentists from that time who are reported to have cellular damage to their fingers from exposure to X-rays and the machines still delivered fairly high doses. But there were also starting to be concerns when X-rays could lead to cancer, particularly leukemia.

Space Science

Like ultraviolet astronomy, X-ray astronomy is a relatively new discipline. Inside the Earth's protective ozone envelope, it's difficult to detect or measure any of the weak sources of X-rays that come from other parts of the universe. It's also difficult to separate weak X-ray sources from the stronger X-rays emanating from our Sun. Space travel really needed to get off the ground before extraplanetary X-ray surveillance could come into its own as a science.

After the launching of the Russian Federation Sputnik satellite in 1957, the United States embarked on its own space program and launched a number of rockets during the late 1950s and early 1960s. Telescopes and other instruments were sometimes sent along with the rockets as the *payload* to provide scientific data about space exploration and the environment of space. John Lindsay and other members of the NASA Goddard Space Flight Center took the first X-ray image of the Sun, from a rocket, in 1963.

X-ray technology is very versatile. In the space program, X-rays were used not only to ascertain the health of astronauts before subjecting them to the rigors of space, but also as reference documents, for assessing any changes that might occur in the astronauts when returning from their flights. At the same time, X-ray telescopes were being launched into space to study the universe beyond our planet and our solar system. Left: Astronaut Walter Schirra views his X-rays after his 1962 space flight. Right: Astronaut Charles Conrad (in the dark shirt) was the pilot for the Gemini 5 space flight. He is shown discussing X-rays with the medical team at Cape Kennedy in August 1965. [NASA/JSC news photo, released.]

As space travel improved, the first of a number of scientific flights and laboratories were established in space. The Skylab mission was a way to study the characteristics and rigors of space more closely and provided a way to deploy telescopes outside the Earth's atmosphere and ozone layer. This made it possible to study emanations that would never reach the telescopes on Earth. One of these was an X-ray telescope which recorded many thousands of images over a period of nine months.

Scientists began to look for ways to take X-ray pictures of cosmic phenomena outside our own solar system. In 1975, Paul Gorenstein, with the Smithsonian Astrophysical Observatory, and his colleagues, used a mirror and X-rays to photograph the constellation Virgo.

X-Ray Technologies in Other Disciplines

By the 1960s, research into holography was improving the science and by the early 1970s, artists and scientists had produced some stunning images, some as large as about 1 *x* 2 feet, that were exhibited around North America in a traveling show that inspired commercial, industrial, and artistic development of the technology, some of which is now used in computer and surveillance applications.

X-rays were now being used in many ways, to check luggage and cargo containers, to aid in quality assurance in industrial and commercial settings, and in many aspects of medicine.

X-rays were being used to monitor the progress of a fetus in the womb, but as understanding of the dangers of X-rays to the developing embryo improved, this practice was largely discontinued by the 1970s, except for instances of serious problems that could not be assessed any other way. Gradually, the use of fetal X-rays gave way to the use of ultrasound which, when used correctly, was found to be much less hazardous to human tissue than X-rays.

X-Ray Imaging of Luggage and Hand Baggage

As X-ray machines on public transportation systems continued to develop and concerns over terrorist threats mounted, the possibility of damage to photographic film increased as well. In March 1978, the Federal Aviation Administration (FAA) required that signs be posted informing passengers that they had the right to request hand inspection of their photographic film in order to avoid X-ray exposure of the film.

In 1988, Pan Am Flight 103 exploded over Locherbie, Scotland, from plastic explosives hidden in a suitcase. This tragedy focused greater attention on airline security measures and resulted in the mobilization of government intelligence agents and the local installation of equipment and personnel to help prevent such disasters in the future.

The 1990s - Transition to Digital

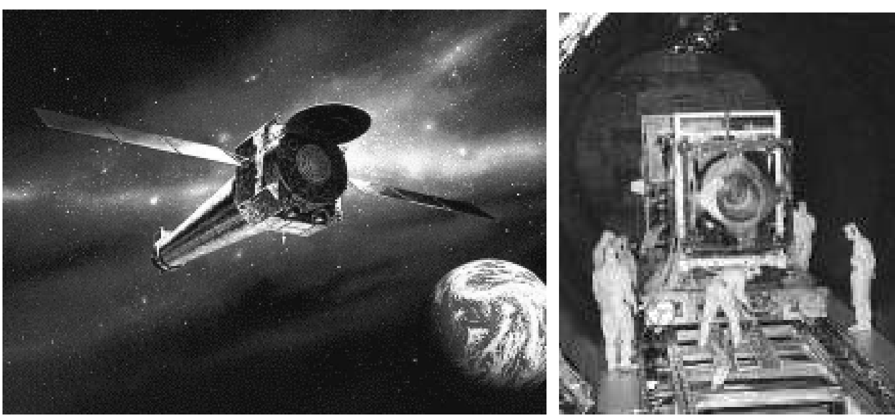
The entire electronics industry had been substantially affected by the microcomputer revolution and, like many other technologies, X-ray devices gradually began to incorporate digital electronics. In earlier systems, however, mass storage and resolution were limitations that made it difficult to match the clarity of traditional film images. This changed in the mid-1990s, however, when multigigabyte computer drives dropped dramatically in price and resolution increased. In November 1999, PerkinElmer Optoelectronics announced the introduction of a digital X-ray camera with a monolithic active detector that was equal in size to a traditional sheet of X-ray film.

Digital technology had many advantages for X-ray images. A computer could allow the viewer to pan and zoom, to store specific parts of an image, to email the image or discuss it with other professionals through Internet or intranet 'whiteboarding' (simultaneous viewing), to compare two X-rays side-by-side, or as thumbnails of images taken over a period of time. The speed of viewing of the image was greatly increased as well, as no photographic chemical development is necessary with a digital system, and X-rays can be retaken immediately if there is a problem with the first image without having to reschedule appointments. These advantages could benefit medical radiologists, industrial inspectors, and production line quality assurance professionals using X-rays.

1980s and 1990s Space Science

Space science had come a long way from the early experiments in the 1960s. A great deal of new information about the universe was gathered in the 1980s and 1990s through recently developed computer and imaging technologies, including infrared, ultraviolet, and X-ray photography from space and on other planets (e.g., Mars).

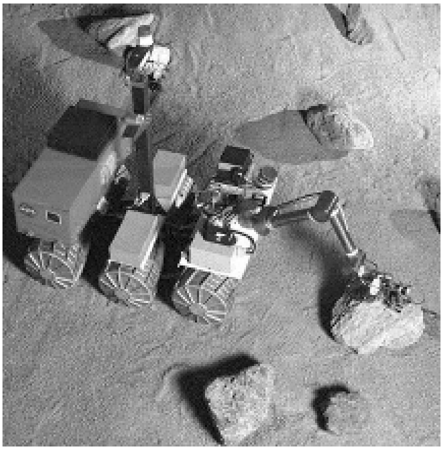
Space exploration involves putting equipment and people in unfamiliar environments and subjecting them to stresses that aren't a part of normal Earth travel. This requires a commitment to studying the effect of space travel on various materials and instruments and the development of many new technologies. In 1994, the Light Alloy Laboratory was opened at the NASA Langley Research Center, to provide state-of-the-art analytical instruments as well as materials testing and processing equipment. Along with various microscopes and thermal analysis devices, X-ray diffraction equipment was installed that could be used for various identification and analysis tasks. Not all the technology is used in space; special alloys, coatings, and paints also have applications for aeronautics research for Earth-based, high-speed and high-altitude surveillance aircraft.



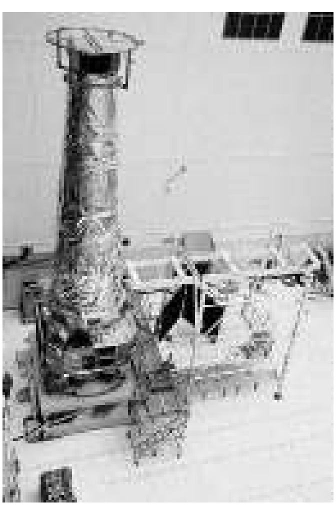
Left: An artist's concept of the Advanced X-Ray Astrophysic Facility deployed in space. Right: Engineers at the X-Ray Calibration Facility (XRCF) at work integrating the High Resolution Mirror Assembly into the Advanced X-Ray Astrophysics Facility-1 to create the most powerful X-ray telescope ever built. [NASA/Marshall news photos, 1995 and 1996, released.]

In 1997 the Mars Pathfinder project included a number of interesting technologies, including an X-ray spectrometer that was used on the Mars rover, a terrain robot that was used to explore Mars.

Surveillance technologies have resulted in some remarkable discoveries. Black holes were once just theoretical ideas, but in 1998, scientists were able to indirectly observe matter spiraling into a black hole and gaseous jets appearing to escape from the hole. X-rays were used to detect the matter disappearing into the black hole and infrared and radio waves were used to detect the jets of gas appearing to come out of the black hole.



Left: An *X-ray defracometer* is extended out from the arm of a *Marsokhod Rover*, a planetary exploring robot. The defracometer was being tested by sensing a rock in this simulated Mars-like terrain, in 1995. Right: This is the rover robot that was carried on the Mars Sojourner interplanetary mission to study the planet Mars. The rover was photographed on Mars in 1997 while using the Alpha Proton X-Ray Spectrometer (APXS) to study a rock the scientists named "Moe." The Mars Pathfinder mission was developed and managed by the Jet Propulsion Laboratory for NASA's Office of Space Science. [NASA/Ames and NASA/JPL news photos, released.]



The Advanced X-Ray Astrophysics Facility, now called the *Chandra X-Ray Observatory* consists of a spacecraft, a scientific instrument module (SIM), and the most sensitive X-ray telescope in the world. The Observatory is designed to help astronomers detect black holes and high-temperature gas clouds yielding information about our origins and the universe around us. Chandra was designed to be launched on board the Space Shuttle Columbia. Left: The 50,162-pound Chandra X-Ray Observatory being prepared for its mission in March 1999. Right: Astronauts took this photo of the Chandra tucked against the Space Shuttle while in Earth orbit. Here it is being tilted just prior to release from the Shuttle Columbia. [NASA/KSC news photos, released.]

Border Surveillance

During the 1990s, U.S. Customs invested in additional staff and technologies, including X-ray devices, to aid in the detection of smuggling of illegal goods and substances into the U.S. Additions and upgrades in equipment during the 1990s included baggage, pallet, and mobile X-ray units for surveilling trucks and containerized cargo. These were often used in conjunction with other detection measures, including substance-sniffing dogs and fiber-optic scopes to examine gas tanks and other enclosed areas. For secondary inspections, a mobile X-ray van would sometimes be used for large or heavy items. A truck X-ray system was in use at the Otay Mesa crossing, along the southern border, for carrying out random and referred X-ray inspections of large cargo vehicles. For visual inspection of large trucks and containers without the use of X-rays, a 'cherry picker' (a hoist like those used by above-ground utility-line technicians) would sometimes be used.

As part of the 1998 National Drug Control Strategy, the U.S. Government planned the implementation of a *Port and Border Security Initiative,* to include new Border Patrol agents and new technologies such as advanced X-ray devices and remote video surveillance along the southwest U.S. border. Nonintrusive inspection/surveillance technologies were also included.

Innovations

The more important innovations in X-ray technologies emerging in the 1990s included the development of X-ray telescopes, pseudocolor display systems, digital X-ray imaging systems, and 3D imaging arrays. Stereoscopic X-ray systems which make it easier to visualize the spatial orientation of objects being scanned are particularly valuable for luggage and cargo inspection as they help the inspectors interpret the display more easily.

Illegal Entry and Smuggling Concerns

In the early part of 2000, the U.S. Congress debated the proposed rehabilitation of the San Diego and Arizona Eastern (SD&AE) Railroad, a service that would cross the southern border in two areas. Opposition to the reopening of the railroad was based, in part, on a fear that crime would increase along the U.S.-Mexico border. Opponents felt that the economic benefits would be overridden by substantial needs for increases in surveillance, enforcement, and equipment to safeguard the operation of the line. Input from the U.S. Immigration and Naturalization Service (INS), the U.S. Customs Service, the U.S. Border Patrol, and the Office of National Drug Control Policy (ONDCP) were sought in order to assess the increased security needs that would be involved in this project. Currently, the border has problems with theft, illegal entry, and smuggling. Railways are one means by which these criminal activities are carried out and thus must be anticipated and handled. Over 30,000 illegal entrants are reported to have been found in Union Pacific rail cars in 1999. The risk of injury and sometimes death is present when aliens jump trains or hide for hours in hot rail cars. In congressional testimony on transportation, Duncan Hunter reported the following:

> "... I requested the General Accounting Office (GAO) to conduct a comprehensive study on what resources would be required by border enforcement agencies to properly maintain control of the border should the SD&AE Railroad be reopened. Stating it would be difficult to estimate resource needs for modern freight service, U.S. Customs and Border Patrol officials made their recommendations for basic service, of non-cargo freight only. Among the equipment listed as needed were radios, railcar X-rays, generators, video surveillance and security devices, inspection and office space, computers and as many as 31-35 additional agents....

The amount of time needed to adequately inspect railroad cars at border crossings must also be addressed. As a result of both U.S. and Mexican Customs officials examining each railway car, the time to properly inspect these cars and cargo can often take up to twenty-four hours. Consequently, a great strain is realized, making this project practically unfeasible with current resources...."

[Duncan Hunter, "Testimony of Congressman Duncan Hunter (CA-52): House Appropriations Subcommittee on Transportation," 10 February 2000.]

5. Description and Functions

X-ray detection is a versatile technology and is now a regular tool of many industries. The list of applications is long. Mail and courier services use it to detect hazardous cargo; customs agents use it to enforce public safety and import and export laws; industrial production lines use it to assess quality and to detect flaws; astronomers use it to detect emanations from black holes and high-energy cosmic events; archaeologists and art historians use it to inspect artifacts; geologists use it to study crystals; physicists use it to investigate atomic properties; and forensic investigators use it to detect fraud or injuries to victims of crime. The next section on applications provides some more specific descriptions and illustrations of X-ray technology in practical use.

6. Applications

Cargo Surveillance

Luggage and hand baggage that are taken by passengers on aircraft are now routinely inspected with X-rays to check for explosives, weapons, and sometimes smuggled items. The primary reason for these machines is staff and passenger safety. The intensities used for luggage are usually stronger than those used for hand baggage. Large-format air cargo that is taken on cargo transports is also screened with more powerful X-ray equipment, since it must penetrate large pallets and containers, and is similar to that used to inspect the loads of transport trucks. Gamma rays, which share many of the characteristics of X-rays, are also being used to inspect cargo at border crossings.

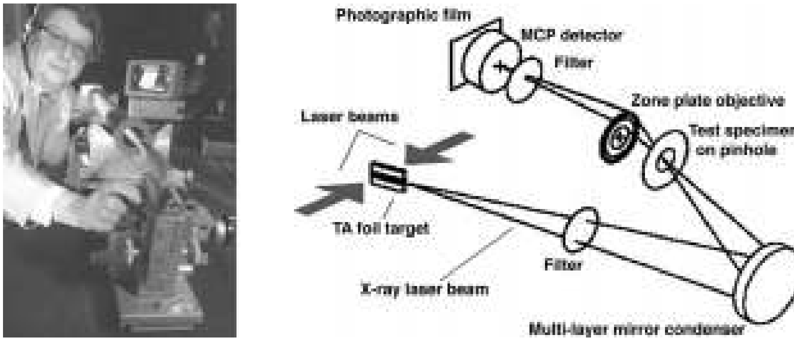
Microscopy

X-ray microscopes make it possible to view materials in a different way. Very high resolution images are possible with X-ray technology.

Conventional microscopes use light to illuminate a subject. An X-ray microscope, on the other hand, uses X-rays to selectively penetrate the subject and, instead of the operator looking at a slide on a lit platform, the image is sent to a camera or digital system for display.

Different types of substances can be studied with an X-ray microscope. When viewing most types of specimens in a conventional microscope, it is necessary to slice the specimens into very fine pieces. This isn't practical for all types of specimens and impossible for many. The X-ray microscope allows the viewing of thicker specimens because the X-rays can penetrate more deeply into the tissue or object than an optical microscope.

X-rays are absorbed by water in such a way that organic substances contrast quite strongly with water in an X-ray image. This makes it a good technology for studying organic materials and thus a useful technology for surveillance, with particular relevance for agricultural testing, quality control, and the detection and identification of possible contaminants in a variety of agricultural and industrial environments.



Left: This is a multilayer water-window imaging X-ray microscope being demonstrated by its inventor. Right: A basic schematic of the main parts of an X-ray microscope. This illustration is from the Lawrence Livermore National Labs Web site on high-energy lasers recommended in the Resources section. [NASA/Marshall news photo, 1992; LLNL tutorial photo, released.]

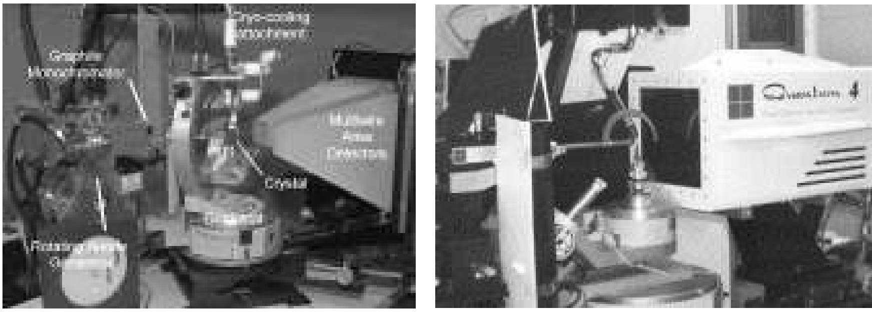
Crystallography

X-ray crystallography is used in many fields, but it is especially important to materials science and engineering. It is widely used in mineralogy, because it allows us to determine crystalline structures. This, in turn, provides information that is useful in classifying minerals and studying the properties of gemstones. X-ray crystallography can help us learn more about minerals on Earth and the mineral structures of samples gathered from other planets.

Essentially, X-ray crystallography is based on aiming intense X-ray beams at crystalline substances and collecting and studying the diffracted X-rays. By looking at the different patterns and comparing them to the sources, very fine discriminations can be made and information about their basic atomic structure can be inferred.

Astronaut Dr. Bonnie Dunbar gets a briefing about the X-Ray Crystallography Facility from engineer Lance Weiss (left) and engineer Stacy Giles (right). The Facility is under development at the Center for Macromolecular Crystallography of the University of Alabama at Birmingham. This equipment expedites the collection of information from crystals grown on the International Space Station. [NASA/Marshall news photos, 1999, released.]

At Lawrence Livermore National Labs (LLNL), there is an X-ray crystallography group with the Biology and Biotechnology Program. The lab includes computer-controlled crystallization robots, microscopes, and temperature-controlled rooms for studying many aspects of molecular biology.



The Lawrence Livermore National Labs X-ray diffractometers. This is a type of instrument traditionally used in high energy physics. Left: There are two detectors in this ADSC dual multiwire system, located 50 to 150 cm from the crystal. The instrument is kept running continuously. Right: The LLNL four-module X-ray detector used in cryo-crystallography. This detector uses CCD technology, focusing mirrors, and a cryo-cooler. When X-rays hit the system, the imaging phosphor faceplate emits photons. [LLNL news photos, released.]

Medicine

X-ray imaging of human and animal tissues is a regular part of human and veterinary medicine. X-rays are used to determine growth, damage, abnormalities, dental decay, and many other aspects important to diagnosing disease and maintaining health.

Teleradiology

Teleradiology is a term for digital X-rays that are sent over computer networks or other communications pathways to be displayed on a monitor at a remote location. This technology is still fairly new, and not yet common, but in the future it is likely to be particularly valuable for agents or military personnel stationed overseas or on ocean-going vessels. Missionaries, relief workers, foreign diplomats, travelers, and military service members on aircraft carriers and submarines can be away for months at a time, and many of them are subject to illnesses of one sort or another. Many foreign countries do not have easy access to good medical resources or diagnostic information. The capability of sending information to medical specialists thousands of miles away in a few seconds greatly extends the effectiveness and reach of people working far from home.

Remote X-rays can also be used for engineering professionals and others to collaborate on the production of large-scale industrial projects, including oil rigs, highrises, ships, and bridges in distant locations.

In terms of covert surveillance, teleradiology could be used to forward information to agents stationed in foreign locations who need medical, industrial, or other information that might be derived from X-ray images generated at a station in another location.

Industrial Fabrication and Testing

X-rays can be used to test for defects, conformity, contaminants, and other problems that may show up in industrial production. The *Total X-Ray Reflection Fluorescence* (TXRF) system, for example, is a nondestructive X-ray technology that is used to assess contaminant concentration, using conventional and synchrotron X-radiation. It can be used to detect contamination from a variety of organic and inorganic sources, including chemicals, gases, dirt, and ion effects. It can yield not only structural information, but also information about chemical composition.

Environmental Research and Monitoring

When we think of the environment, we don't usually think of X-ray technologies, but they can provide a means to facilitate chemical analysis of a variety of substances, making the technology of *X-ray fluorescence* applicable to many areas.

An X-ray fluorescence analysis system developed by the Pacific Northwest National Laboratory. This system can chemically analyze a variety of synthetic and natural materials, including biological and geological substances. It serves in environmental research and monitoring applications. [Courtesy of the Pacific Northwest National Laboratory, 1996 news photo.]

7. Problems and Limitations

Health Hazards

The most significant limitation of using X-rays for surveillance is that the radiation is hazardous to living tissue and thus must be used with effective shielding and only by trained technicians in carefully monitored settings.

People who take the risk of stowing away in trucks and cargo ships to try to illegally enter another nation run the risk of being exposed to the higher radiation levels from X-ray machines that are used to check the presence, composition, and integrity of cargo at border crossings. These machines are designed for imaging through metal and packages, not human tissue.

Damage to Film from X-Ray Machines

The X-ray machines used for security purposes are not all alike. Sometimes more powerful systems are used for luggage, as opposed to hand baggage. However, since the effects of X-ray exposure are cumulative, several trips through X-ray machines, as when changing planes, can fog film.

There were reports that early X-ray machines in public transportation systems might fog high-speed films, but most people were told that there usually wasn't a problem. This is not entirely true, as high-intensity scanning machines have been developed that can affect film. X-ray machines in airports can fog film, according to tests conducted by the Photographic and Imaging Manufacturers Association. The widely distributed CTX-5000 X-ray machine, which is used for checked luggage, can fog all unprocessed film.

Lower-energy hand-luggage surveillance systems may not cause as many problems unless the film is very fast or of an especially sensitive nature (e.g., medical films).

It is recommended that unexposed film be carried by hand and passed across the trays supplied by most security checkpoints rather than being sent through the X-ray machine. Lead-lined pouches don't usually help because pouches will look suspicious on the X-ray viewing screen and the contents will probably be sent through again without the pouch.

Vigilance

X-ray devices to detect weapons, explosives, and contraband are only as good as the people who are using them. Training, experience, vigilance, and the ability to concentrate are necessary for the reliable identification of materials that may be hazardous. A concerned attitude and rotating shifts, to reduce boredom and eyestrain, are as essential as training and good equipment. These guidelines are particularly important in situations where X-ray detection is being used to prevent terrorist weapons.

Vigilance has a psychological aspect as well. Some people are too young, or too yielding, to withstand the barrage of complaints from people who are in a rush to catch their train or plane or who are trying to get across a border. X-ray operators must be able to concentrate on their task and slough off the persistent complaints rather than allowing them to distract them from their work.

Expense and Inconvenience

Unfortunately, the use of X-ray surveillance for surveilling luggage in public transportation stations, border crossings, museums, sports events, and various workplaces creates greater expense (in equipment, personnel, and maintenance) and greater inconvenience for everyone. 100% of the people are impacted by the 2% to 10% or so who might be carrying weapons, controlled substances, or illegally smuggled items.

8. Restrictions and Regulations

Because of the potential for harm to living tissues, there are a number of federal and international standards for the size and composition of X-ray cabinets, for the strength and direction of the beam, the amount of permitted leakage, and the specific applications for which X-rays may be used (e.g., Federal Standard 21-CFR 1020.40).

Film Exposure to X-Rays

In the United States, travellers may request visual inspection of sensitive photographic films as per the Federal Aviation Administration's FAA Reg. 108.17.

X-Rays as Forensic Evidence

X-rays are often used as demonstrative evidence in court cases involving personal injury, smuggling, and illegal entry (stowaways). Authentication of these X-rays before presentation in court is important. The interpretation of X-rays is a specialized skill and lay jurors are not permitted to interpret X-rays without advisement by an expert.

Mine Workers Surveillance

The *Federal Coal Mine Health and Safety Act of 1969* was established to set respirable dust standards for coal mines in order to reduce diseases such as pneumoconiosis (black lung) and silicosis. This led to great improvements, but the Department of Labor Mine Safety and Health Administration also set forth actions for an X-ray surveillance program for surface miners to further detect and prevent lung problems associated with the work.

Medical X-Rays

X-rays can be dangerous and should be avoided unless absolutely necessary. The American College of Radiology has stated that "Chest radiographs should not be required solely because of hospital admission. All 'routine' diagnostic studies for the sake of 'routine' should be avoided." There are training, certification, and use guidelines in place in nearly all aspects of medicine that govern procedures and the careful use of X-ray equipment.

Agricultural X-Rays

There are a number of health and agricultural guidelines governing the use of X-rays in products that are for human and/or animal consumption. The World Health Organization, for example, publishes guidelines for the X-raying of foodstuffs. The U.S. Food and Drug Administration (FDA) also publishes guidelines.

Transportation Security

Transportation systems are vulnerable to terrorist activities, as are large events where people congregate. There are a number of guidelines that are designed to aid in the protection of conveyances and spaces that are often occupied by many people. One example is the 1990 Aviation Security Act.

In 1997, the Federal Aviation Administration (FAA) announced that it was purchasing over $7 million worth of explosives-detecting equipment for screening airline baggage. The automated systems would take some of the strain off the operators by automatically alerting to suspicious objects and were planned to be in place by 1998.

Systems used for security by the FAA include dual-energy automated X-ray machines and vertical-beam, dual-energy devices.

In 1998, the FAA also addressed the need for properly trained X-ray operators to ensure that operators were sufficiently skilled to operate X-ray machines effectively.

9. Implications of Use

The four main areas in which X-ray detection devices are used are cargo surveillance, industrial inspection, medical surveillance, and astronomical surveillance.

Cargo-checking for dangerous or smuggled items is done on a daily basis at thousands of ports, mail depots, and border crossings around the world and is generally considered to be a deterrent to terrorist activities. The one area of concern is possible harm to illegal aliens stowing away in cargo containers. Since fairly high levels of X-rays are used to probe large trucks and shipping containers, anyone hiding inside is exposed to levels much higher than from other sources, such as medical X-rays.

Extraplanetary surveillance through X-ray telescopes and space probes is yielding a great deal of new information about the cosmos. Even though the surveilling of stars and black holes may not seem important to daily life, the knowledge and technology that come from these activities and experiments lead to new fabrics, electronics, coatings, medical procedures, computer algorithms, and new ideas. Satellites that were originally launched to explore space are now used as communications relays. Coatings that were developed to launch a telescope into space on a rocket are used in industrial environments.

As long as X-radiation is used within strict safety guidelines, it is generally considered to be beneficial and there has not been a lot of controversy over its use for surveillance.

10. Resources

Inclusion of the following companies does not constitute nor imply an endorsement of their products and services and, conversely, does not imply their endorsement of the contents of this text.

10.a. Organizations

Australian X-ray Analytical Association (AXAA) - Formed in 1968 to promote the exchange of scientific and technological information in the fields of X-ray diffraction, fluorescence, surface analysis, and crystalline structures. http://www.latrobe.edu.au/www/axaa/

Federal Aviation Administration (FAA) - The primary U.S. aviation regulatory body, the FAA publishes standards, overseas certification of pilots, and serves as a handler for aviation-related travel and mechanical reports. One of the jobs of the FAA is overseeing security in aircraft and airports. http://www.faa.gov/

Hard Facts Investigative Engineering - Art graphic presentation including photographic documentation, X-rays, computer graphics, aerial photography, video surveillance, and courtroom displays. http://www.hardfacts.net/grafpres.htm

International Union of Crystallography (IUC) - A member of the International Council for Science which provides professional services for crystallographers. http://www.iucr.org/

MicroWorlds - This is an online science education publication from Lawrence Berkeley National Labs which includes quite a bit of information on X-ray microscopy and images of the equipment and X-rayed samples. Lawrence Berkeley Labs has a Center for X-Ray Optics.
http://www.lbl.gov/MicroWorlds/

National Synchrotron Radiation Laboratory (NSRL) - This facility is in China, at the University of Science and Technology. It is China's first dedicated synchrotron radiation facility, built between 1984 and 1989. Among many other applications, synchrotron technology has been used to research microscopy, X-ray lithography, holography, and spectroscopy.

PerkinElmer Instruments, Inc. - A prominent supplier of X-ray and metal detecting devices for surveillance applications. The Web site includes specifications for a wide variety of systems.
http://instruments.perkinelmer.com/

World Health Organization (WHO) - WHO promotes health and well-being and maintains guidelines for the use of X-rays and the X-raying of foodstuffs. http://www.who.int/

10.b. Print Resources

Some of the following publications may be out of print. If so, it is sometimes possible to find them in second-hand book stores or to borrow them through interlibrary loans.

Aprile, Elena, Editor, "Gamma-ray detectors," Bellingham, Wa.: SPIE, 1992, 311 pages. Illustrated proceedings of the 1992 San Diego conference. Of interest for gamma-ray spectroscopy.

Bertin, Eugene, "Principles and Practice of X-Ray Spectrometric Analysis," New York: Plenum Press, 1970.

Carpenter, John M., "Neutrons, x rays, and gamma rays - imaging," Bellingham: SPIE, 1992, 369 pages. Conference proceedings.

Fabry, David, "Explosives detection devices developmental: Final Report," Atlantic City, N. J.: Atlantic City International Airport, FAA Technical Center, 1993.

Hoover, Richard B., "X-ray detector physics and applications," Bellingham, Wa.: SPIE, 1992, 250 pages. Related to X-ray spectroscopy, proceedings of a 1992 conference.

Jenkins, Ron, "X-Ray Fluorescence Spectrometry," New York: John Wiley and Sons, 1988.

Saraceni, Pete, Jr., "Quick reaction automated explosive detection," FAA Technical Center, 1983. For FAA use only.

Workman, S. T., "Modular automated X-ray experimental airline," Washington, D.C.: Department of Transportation, FAA, 1980, 55 pages.

Articles

Bazalon, Judge David, "Civil Liberties - Protecting Old Values in the New Century," *New York University Law Review*, 1976, V.505, p. 511. An impassioned opinion on the emerging surveillance technologies and the difficulties of enforcement given their 'invisible' nature.

Beardon, J. A., "X-Ray Wavelengths," *Review of Modern Physics*, 1967, V.39, p. 78. X-ray emission-line energies.

Evans, J. P. O.; Robinson, M., "The development of 3D X-ray systems for airport security applications," Boston, Mass.: SPIE V.1824, *Applications of Signal and Image Processing in Explosives Detection Systems*, pp. 171-182. Evans and Robinson have written an extensive series of articles on 3D X-ray imaging technologies and techniques.

Fuller, Matthew, "Talk for New Visions," 1994. While this does not directly relate to surveillance, it does discuss the use of technologies such as X-rays for purposes outside the mainstream of thinking and thus provides a fresh perspective, which is sometimes a welcome respite and a good way to stimulate lateral thinking. http://www.altx.com/interzones/london/new.visions.html

Robinson, I. K.; Tweet, D. J., "Surface X-ray diffraction," *Reports on Progress in Physics*, 1992, V.55(5), pp. 599-651. Introduction to X-ray diffraction and how it can be applied to surface and interface study.

Sincerbox, Glenn T., "Holographic storage: are we there yet?" University of Arizona. The author is the Director of the Optical Data Storage Center at U of A. The basics of holographic recording and storage are discussed along with information on mass storage devices.

Sincerbox, Glenn T., Editor, "Selected Papers on Holographic Storage," Bellingham, Wa.: SPIE Optical Engineering Press, 1994.

Templeman, Bob, "Generating X-Rays with Receiving Tubes," *The Bell Jar*, October 1994, electronic issue No. 2. The use of old TV tubes as cold cathode X-ray emitters.

"The X-ray Century," this was published in the 1890s and contains illustrated articles of the early discoveries in X-ray science. It has been republished by the Medical Physics Publishing Corp. Information is available online from the Department of Radiology at Emory University.
http://www.cc.emory.edu/X-RAYS/century.htm

Journals

"American X-Ray Journal" and "American Electro-Therapeutic and X-Ray Era," historic journals from late 1800s to early 1900s which are usually shelved in rare materials sections in medical libraries. Interesting historical perspective on the development of X-ray science and technology.

"Synchrotron Radiation Online," a service for subscribers to the *Journal of Synchroton Radiation*. Includes information on source technology, instruments, and techniques over all spectral ranges in synchrotron radiation research, published by the International Union of Crystallography.

10.c. Conferences and Workshops

Many of these conferences are annual events that are held at approximately the same time each year, so even if the conference listings are outdated, they can still help you determine the frequency and sometimes the time of year of upcoming events. It is very common for international conferences to be held in a different city each year, so contact the organizers for current locations.

Many of these organizations describe the upcoming conferences on the Web and may also archive conference proceedings for purchase or free download.

The following conferences are organized according to the calendar month in which they are usually held.

"AXAA National Conference," sponsored by the Australian X-Ray Analytical Association, Melbourne, Australia, 8 - 12 Feb. 1999.

"X-99, The 18th International Conference on X-ray and Inner-Shell Processes," Chicago, Illinois, 23-27 August 1999.

"XAFS Conference on X-Ray Absorption Fine Structure," Ako City, Japan, 27 - 31 July, 2000. Sponsored by the International XAFS Society for physicists working with atomic excitation using X-rays and electrons.

"The X-Ray Conference," 49th annual conference sponsored by the International Centre for Diffraction, Denver, Colorado, 31 July - 4 Aug. 2000.

10.d. Online Sites

The following are interesting Web sites relevant to this chapter. The author has tried to limit the listings to links that are stable and likely to remain so for a while. However, since Web sites do sometimes change, keywords in the descriptions below can help you relocate them with a search engine. Sites are moved more often than they are deleted.

Another suggestion, if the site has disappeared, is to go to the upper level of the domain name. Sometimes the site manager has simply changed the name of the file of interest. For example, if you cannot locate http://www.goodsite.com/science/uv.html *try going to* http://www.goodsite.com/science/ *or* http://www.goodsite.com/ *to see if there is a new link to the page. It could be that the filename* uv.html *was changed to* ultraviolet.html, *for example.*

Airport Security: A Seven-Part Series. This illustrated series of articles on the Newsday site discusses airline bombing disasters, FAA regulations, passenger and baggage checking, and cargo containers. http://www.newsday.com/jet/airdex.htm

LLNL X-Ray Laser Sources. There is a very good technical information site on X-ray lasers and X-ray microscopes, with lots of illustrations on the Lawrence Livermore National Laboratories site. http://www.llnl.gov/science_on_lasers/11RSources/RS-C_XRL.html#FigVI-21

Ricoh X-Ray Science in Japan. The Ricoh site sponsors a brief illustrated history of the course of X-ray science and technology as it progressed in Japan from the 1800s to the present. In the early days, Japan was almost neck and neck with the Europeans and there were cross-communications between scientists in those parts of the world. The content is provided by Masatoshi Kobayashi of Tokai University. http://www.ricoh.co.jp/net-messena/NDTWW/JSNDI/XRAY.html

X-Ray for kids. This is a great site for any age. There are basic introductory image sample X-rays of plants, animals, insects, objects, and shells. This gives an introduction to the ways in which certain tissues and structures will admit or impede X-radiation. http://www.yhrad.com/kids.html

X-Ray Systems and Research. There is a good Web site at the Nottingham Trent University, in collaboration with the Police Scientific Development Branch (PSDB) in the U.K., which has illustrated pages showing the basic components of an X-ray system and sample images of a variety of types of X-rayed objects. http://eee.ntu.ac.uk/research/vision/asobania/index.html

X-Ray WWW Server. Since 1994, this server from the Dept. of Physics at Uppsala University, Sweden is a COREX biibliography and database repository of the Henke atomic scattering factors and other information pertinent to X-ray spectroscopy, including research, conferences, and other Web sites. http://xray.uu.se/

Note: If you don't enjoy typing in long Web addresses (URLs), you can access the links on the support site set up by the author for your convenience. http://www.abiogenesis.com/surveil

10.e. Media Resources

"Barbara McGill Balfour - SoftSpots," an art exhibit of abstract printmaking related to medical imagery, organized by the Southern Alberta Art Gallery and the Canada Council, 17 Oct. - 22 Nov. 1998. A quote about this exhibit is probably the best way to illustrate why it has been included in this book about surveillance technologies, "The medium is an appropriate metaphor, as printmaking involves the emergence of an image or marks on a surface, and some of the terminology involved - stretching, or bleeding for example - can carry a double meaning in this context. Her work also deals with the pervasiveness of medicine in our contemporary lives, and the constant surveillance - through X-rays, blood tests, and biopsies - that we have set up as a line of defence against disease."
http://earth.online.uleth.ca/~saag/exhibits/balfour/index.htm

"Medical Imaging," is a *History Channel* Modern Marvels series show on ultrasound and X-ray history and current uses in medical imaging. It also chronicles the case of an executed murderer who left his body to science. VHS, 50 minutes. May not be shipped outside the U.S. and Canada.

11. Glossary

APXS	Alpha Proton X-Ray Spectrometer - an instrument used on the Mars Sojourner
AXAF	Advanced X-Ray Astrophysics Facility
burst	brief, intense emission
EMA	electron microprobe analysis
scintillator	a crystal which converts gamma-ray energy into detectable light such that it can be detected
synchrotron emission	radiation emitted by charged particles that have been accelerated against a barrier by a magnetic field
TRXRF	total reflectance X-ray fluorescence
XRF	X-ray fluoresence spectroscopy
XTE	X-Ray Timing Explorer