produce pictures with resolution of less than ten centimetres. At the other extreme, geostationary satellites with orbits of 36,000 kilometres—used for meteorology, early warning, navigation and communications—provide coverage of almost the entire earth, but picture resolution is on the order of one kilometre.

A simple satellite with ordinary instruments can cost fifty to a hundred million dollars and the launch cost can be in the same range. Satellites with complex instruments (such as large radar antennas) can cost many times more. The price of a KH-11, for example, is reportedly five hundred million US dollars per satellite.[4] Electrical power requirements strongly affect a satellite's size and cost. Large instruments can require thousands of watts of power, usually derived from large solar arrays or nuclear reactors. A surveillance spacecraft must be stabilized very precisely, because stability affects its instruments' resolution. Therefore complex and expensive attitude control systems are often needed for large spacecraft.

Surveillance missions provide a large amount of raw data. For example, SPOT has a telemetry stream of 50 megabits per second. Once on the ground, this data is processed into a useful format using specialized software. Depending on the application, the computing equipment needed can range from a personal computer to a high speed mainframe with array processing capability. For many surveillance tasks it is not necessary to process the data in "near real time", as it is for an early warning satellite system.

Analysis and interpretation are critical, and the techniques developed for remote sensing are applicable for surveillance and verification missions as well. As mentioned previously the use of multiple instruments, multiple modes of operation of these instruments and multiple means of technical and nontechnical verification, leads to the most objective and accurate interpretation. After processing the data, it has to be efficiently transmitted, or made available on demand, to individuals and organizations who need it. Scientific projects, such as NRC's CANOPUS, have shown that dedicated computer networking works well. A dedicated communications satellite (such as Anik) channel can be utilized to transmit this computer-to-computer data.

FUNDAMENTALS OF EARTH OBSERVATION INSTRUMENTS

Satellite and airborne instruments are similar to those used on earth. The differences are chiefly in the design details and materials chosen, not the operational principles. Almost all remote sensing instruments operate by sensing some form of electromagnetic radiation, such as visible light, infrared heat, or telecommunications signals. These energy-bearing electromagnetic waves all travel at the same velocity in the vacuum of space—the speed of light (3×10^8 metres per second). A wave therefore can be pictured as travelling through space while oscillating sinusoidally.

There is a simple relationship between a wave's frequency* and wavelength:**

$$\text{wavelength} = \frac{\text{speed of light}}{\text{frequency}}$$

Consequently, since the speed of light remains the same, a particular electromagnetic wave—for example a radio signal—can be described equally unambiguously by stating either its wavelength or its frequency.

Table 2 shows the regions of the electromagnetic spectrum, categorized according to wavelength, and the types of instruments which are used for surveillance and remote sensing:

TABLE 2 The Electromagnetic Spectrum and Typical Instruments

Wave Type	*Wavelength*	*Instrument Types*
radio	10 km-20 cm	receivers, sounders
microwave	20 cm-0.1 cm	receivers, radars, sounders, radiometers, scatterometers
infrared	1 cm-0.75 μm	imagers, detectors, radiometers
visible	0.75 μm-0.4 μm	optics, lasers, lidars
ultraviolet	0.4 μm-3 nm	imagers, spectrometers
X-Rays	3 nm-.03 nm	detectors, spectrometers
gamma rays	1 nm and shorter	detectors, spectrometers

*Frequency is the number of cycles of wave oscillation in a given time, and one cycle per second is defined as one "Hertz." The prefixes kilo-, mega-, and giga- refer to one thousand (10^3), one million (10^6) and one billion (10^9) Hertz respectively.

**Wavelength is the physical length of a complete propagating wave cycle and it is usually expressed in metric units, such as metres, centimetres (cm.) and kilometres (km.). A millimetre (mm.) is one thousandth (10^{-3}) of a metre, a micrometre (μm.) is one millionth (10^{-6}) of a metre and a nanometre (nm.) is one billionth (10^{-9}) of a metre.