



(a) Students deploy a "drifter" (with GPS unit attached to the top of the mast) in the Gulf of Mexico in 2010.

▼Figure 1.22 GPS application in the Gulf of Mexico. [(a) Monty Graham, Dauphin Island Sea Lab. (b) NOAA.]



(b) Movement of the drifters with surface currents helped scientists track and predict the movement of oil.

GPS system can record fault movement as small as 1 mm (0.04 in.).

- GPS units attached to buoys in the Gulf of Mexico helped track the spread of the 2010 *Deepwater Horizon* oil spill (Figure 1.22).
- In Virunga National Park, Rwanda, Africa, rangers use handheld GPS units to track and protect mountain gorillas from poaching.

For scientists, this important technology is both convenient and precise, reducing the need for traditional land surveys that require point-to-point line-of-sight measurements on the ground. In your daily life and travels, have you ever used a GPS unit? How did GPS assist you?

Remote Sensing

The acquisition of information about distant objects without having physical contact is **remote sensing**. In this era of observations from satellites outside the atmosphere, from aircraft within it, and from remote submersibles in the oceans, scientists obtain a wide array of remotely sensed data (Figure 1.23). Remote sensing is nothing new to humans; we do it with our eyes as we scan the environment, sensing the shape, size, and color of objects from a distance by registering energy from the visible-wavelength portion of the electromagnetic spectrum (discussed in Chapter 2). Similarly, when a camera intercepts the wavelengths for which its film or sensor is designed, it remotely senses energy that is reflected or emitted from a scene.

Aerial photographs from balloons and aircraft were the first type of remote sensing, used for many years to improve the accuracy of surface maps more efficiently than can be done by on-site surveys. Later, remote sensors on satellites, the International Space Station, and other craft were used to sense a broader range of wavelengths beyond the visible range of our eyes. These sensors can be designed to "see" wavelengths shorter than visible light (such as ultraviolet) and wavelengths longer than visible light (such as infrared and microwave radar). As examples, infrared sensing produces images based on the temperature of objects on the ground, microwave sensing reveals features below Earth's surface, and radar sensing shows land-surface elevations, even in areas that are obscured by clouds.

Satellite Imaging During the last 50 years, satellite remote sensing has transformed Earth observation. Physical elements of Earth's surface emit radiant energy in wavelengths that are sensed by satellites and other craft and sent to receiving stations on the ground. The receiving stations sort these wavelengths into specific bands, or ranges. A scene is scanned and broken down into pixels (picture elements), each identified by coordinates named *lines* (horizontal rows) and *samples* (vertical columns). For example, a grid of 6000 lines and 7000 samples forms 42,000,000 pixels, providing a detailed image when the pixels are matched to the wavelengths they emit.

A single remotely sensed image requires a large amount of data, which are recorded in digital form for later processing, enhancement, and image generation. Digital data are processed in many ways to enhance their utility: with simulated natural color, "false" color to highlight a particular feature, enhanced contrast, signal filtering, and different levels of sampling and resolution.

Satellites can be set in specific orbital paths (Figure 1.24) that affect the type of data and imagery produced. Geostationary (or geosynchronous) orbits, typically at an altitude of 35,790 km (22,239 mi), are *high Earth orbits* that effectively match Earth's rotation speed so that one orbit is completed in about 24 hours. Satellites can therefore remain "parked" above a specific location, usually the equator (Figure 1.24a). This "fixed" position means that satellite antennas on Earth can be pointed permanently at one position in the sky where the satellite is located;



GEOREPORT 1.4 GPS origins

The GPS devices commercially available worldwide were originally devised in the 1970s by the U.S. Department of Defense for military purposes. In 2000, the Pentagon shut down its Pentagon Selective Availability security control, making commercial resolution the same as military applications. Additional frequencies were added in 2003 and 2006, which increased accuracy significantly, to less than 10 m (33 ft). *Differential GPS (DGPS)* achieves accuracy of 1 to 3 m by comparing readings with another base station (reference receiver) for a differential correction. For a GPS overview, see <http://www.gps.gov/>.