Appendix 1: Answers to Questions

Chapter 1

Answers to Review Questions for Chapter 1

**Question 1** The French inventor Joseph Niépce is generally credited with producing the first permanent photograph in 1827, which depicted the view from his upstairs workroom window.

**Question 2** The oldest existing aerial photograph is a view of Boston, taken from a balloon by James Wallace Black in 1860.

**Question 3** In 1900, Eastman’s company, Kodak, released the Brownie, an inexpensive box camera for rolled film, making photography accessible to a mass audience for the first time.

**Question 4** The Wright brothers’ first successful flight, in 1903, took place on the shores of the Outer Banks, North Carolina.

**Question 5** The first satellite image of the Earth, showing a sunlit portion of the Pacific Ocean and its cloud cover, was captured in August 1959 by Explorer 6.

**Question 6** “The Blue Marble,” which is often cited as the most widely reproduced image of the Earth, was taken in December 1972 by the crew of Apollo 17.

**Question 7** Electromagnetic radiation (EMR) is defined as all energy that moves with the velocity of light in a harmonic wave pattern (i.e., all waves are equally and repetitively spaced in time).

**Question 8** The following interactions are possible: absorption, reflection, scattering, or emission of EMR by the matter, or transmission of EMR through the matter.

**Question 9** Landsat of the US and Satellite pour l’Observation de la Terre (SPOT) of France.
Question 10  Remote sensing provides data with high richness values (high spectral and spatial, spectral, and radiometric resolution) that reach a very broad user community (global). This is an example of disrupting the relationship between the reach and richness.

Question 11  Going from rooftop photography to birds, balloons, helicopters, airplanes, satellites, space shuttle, unmanned aerial vehicles (UAVs), and the International Space Station.

Question 12  Acquiring data over large areas very quickly and very cost-effectively.

Chapter 2

Answers to Review Questions for Chapter 2

Question 1  The primary benefit of higher radiometric resolution is that spectral information is more finely quantified. This may make it possible to distinguish subtle differences between the spectral signatures of target features that might otherwise appear the same at a lower radiometric resolution.

Question 2  One of the main challenges of using high-spatial-resolution satellite image data is that target features (e.g., trees) may be represented by multiple pixels. These pixels can vary considerably in terms of their spectral values, for example because of shadows on a portion of the target feature.

Question 3  The first multispectral environmental remote sensing satellite was Landsat-1, also called ERTS-A and ERTS-1 at early stages in its development. It was launched in July 1972.

Question 4  Both WorldView-2 and the Operational Land Imager (OLI) sensor on Landsat-8 have a specialized band for coastal applications. In both cases, the range of wavelengths captured by the band (0.43–0.45 μm for OLI, 0.4–0.45 μm for WorldView-2) sits at the lower end of the blue portion of the visible electromagnetic range. Other bands in the blue and near-infrared wavelengths may be useful, respectively, for penetrating water bodies and distinguishing between land and water features.

Question 5  Airborne remote sensing is still a viable option because users can tailor a mission to meet their project needs, for example in terms of extent and desired resolution. Now that most aerial photography is digital, many of the automated techniques used for satellite imagery can also be applied for airborne imagery. With respect to LiDAR, no satellite-based systems are currently suitable for applications such as surveying or precise topographic mapping. Ultimately, airborne remote sensing remains more cost-effective for many local- or regional-scale projects.

Question 6  The two primary instruments aboard Landsat-8 are the OLI and the Thermal Infrared Sensor (TIRS). The OLI has eight 30-m resolution multispectral
bands, ranging from 0.433 to 1.39 μm as well as a 15-m resolution panchromatic band. The TIS has two 100-m resolution bands, one at 10.6–11.2 μm and the other at 11.5–12.5 μm. They both have 12-bit radiometric resolution, as compared to the 8-bit radiometric resolution of the Enhanced Thematic Mapper Plus (ETM+) sensor. Together, the OLI and TIS have 10 multispectral bands covering a similar range of wavelengths as the eight multispectral bands of ETM+; most notably, the OLI has two specialized bands for coastal applications and cirrus cloud detection that the ETM+ sensor does not. However, ETM+ offers somewhat better spatial resolution in the thermal infrared range than the TIRS.

**Question 7** The Indian Space Research Organization (ISRO) is an especially active agency, launching 18 Earth-observing satellites since 1988.

**Question 8** A sun-synchronous orbit means that a satellite passes over a given location on Earth at approximately the same local time each day. A geostationary orbit means that a satellite remains fixed in a particular location above the Earth, typically the equator, and orbits in the direction (and at the speed) of the planet’s rotation.

**Question 9** The red edge refers to the narrow range of wavelengths where vegetation reflectance transitions from low to high. It sits between the red and near-infrared portions of the electromagnetic spectrum, hence the name red edge. The red edge may provide information about plant health, especially by analyzing differences in red edge values between images of the same location captured at different times.

**Question 10** Radar and LiDAR are both active remote sensing systems, meaning that they generate and send their own electromagnetic pulses toward target features and then process the returned signal. Interferometric radar and LiDAR can both be used to map terrain and develop digital elevation models. Radar systems use microwaves, while LiDAR systems use lasers. Radar systems can operate both day and night and in all weather conditions. However, LiDAR systems are sensitive to weather and other conditions that interfere with laser pulses.

**Chapter 3**

*Answers to Review Questions for Chapter 3*

**Question 1** The processing of multispectral image data is typically divided into three stages: preprocessing, processing, and post-processing.

**Question 2** In a false color composite (FCC) where the green band of the input image is displayed using the blue color ramp, the red image band is displayed using the green color ramp, and a near-infrared band from the input image (e.g., Band 4 from a Landsat TM image) is displayed using the red color ramp, this type of FCC display is popular in vegetation studies because it can be used to highlight the presence of healthy green vegetation. Healthy green vegetation may also be used to
determine the health of a forest or stand of trees in relation to water stress, drought, insect infestation, etc.

**Question 3** A remote sensing analyst may employ these various operations in order to prepare the best possible input data for the actual image processing stage with the objective in mind to minimize distortions and/or errors in an image that could hinder successful classification or to ensure the extraction or enhancement of an image’s most critical information, thus making classification more straightforward.

**Question 4** The process of image pan-sharpening may be of great value to an image analyst, because by combining a lower resolution image (typically multispectral) with a higher resolution image (typically panchromatic), the resulting image is usually nearly equal to the resolution of the higher panchromatic image. This color, higher resolution image may be useful in aiding the interpreter in distinguishing features on the ground with subtle differences, such as tree canopy heights, vegetation growing season differences, or even built surfaces compared to natural surfaces.

**Question 5** A successful image classification, when working with multispectral data, should aim to convert the original spectral data, which are variable and may exhibit complex relationships across several image bands, into a straightforward thematic map (typically a land cover map) that is easily understood by end users.

**Question 6** In a supervised classification procedure, the analyst selects multiple training sites during the initial stage of the classification project that serve to establish the relationships between the classes of interest and the image spectral data. These training sites are carefully selected by the analyst based on a priori knowledge (i.e., background knowledge or familiarity) of the study area being classified. Additionally, the analyst will typically rely on ancillary data sources, such as aerial photography, existing GIS coverages, or field visits to identify the training sites, thus providing some valid assumption that training sites are in fact real representations of what is being seen in the image to be classified. This step of training site selection is not conducted in an unsupervised classification, thus actually category classifications may only be validated at the conclusion of the classification process and after an appropriate accuracy assessment has been completed.

**Question 7** Image accuracy assessment should be an important part of remotely sensed land use and land cover (LULC) study, because without assessing the accuracy of the classified data the reliability and repeatability of the output products are in question.

**Question 8** In developing an LULC change detection study, an appropriate spatial and temporal resolution is necessary to provide the foundation for sound change detection and should be considered prior to starting an image-based change detection procedure or delineation of study area. Spatial considerations should include the assessment of the same or near the same geographic areas for the images being considered. Temporal considerations should include the assessment of the same or near the same anniversary dates for the images being considered. Similar atmospheric conditions should also be considered in the change analysis.
Chapter 4

Answers to Review Questions for Chapter 4

Question 1 Terrestrial applications of remote sensing are very diverse, and remote sensing continues to play such a vital role in large geographic area observations because it may be the only viable mechanism for synoptic and continuous tracking, mapping, and monitoring LULC changes at the subregional, regional, and global scales. As well with programs such as the Landsat program, a valuable historic record of these large areas remains easily assessable for comparative studies.

Question 2 LULC maps, created from imagery and used to categorize natural and human-made features into classes and provide important information to resource managers and researchers, are used to study everything from plant composition to fossil fuel and mineral deposit detection, from regional agriculture production to vegetation and forest health, from human settlement patterns to national security observations in water, air, land use, and political and military operations.

Question 3 The urban sprawl’s impacts on urban growth have made research an issue of increased interest as this expansion increases demand on physical area and ecological and social resources. Remote sensing may aid decision-makers at the regional scale to complement traditional census sources by providing an efficient means to monitor the extent of land area expansions in relation to socioeconomic and demographic data provided by the census. This combination of data sources from both remote sensing and census may help to better understand urban change dynamics, including the spatial distribution of the population and the related socioeconomic drivers.

Question 4 The limitation usually incurred in traditional field and aerial-based large animal movement studies may be overcome or supplemented by satellite remote sensing, in that satellite remote sensing may be useful for monitoring, over a large area, known migration and habitat utilization patterns that are typically tied to the landscape and vegetation patterns and/or changes in the landscape and vegetation patterns. While satellite remote sensing may be limited in directly identifying the animals, regional-scale remote sensing can acquire data over very large areas that would be cost-, labor-, and physically prohibitive.

Question 5 Remote sensing of water and water-related resources has shown advantages in using spectral remotely sensed data for various applications. However, to gain useful information in these types of studies, spectral remote sensing has to overcome the difficulties inherent in interpreting reflectance values of water, as clear water provides little spectral reflectance, the longer wavelengths are absorbed, and the reflected shorter wavelengths—which are typically the wavelengths sensors rely on for surface feature detection—are subject to higher atmospheric scattering.
Question 6 Remote sensing applications to identify status and patterns of deforestation in the Amazon have been manifold. Remote sensing techniques used to study large area deforestation in this region range from LULC classification approaches, statistical modeling procedures derived from remotely sensed data, to the development of vegetation indices that are related to spectrally reflective values of the forest tree canopy and the intensity of vegetation change.

Question 7 The Normalized Difference Vegetation Index (NDVI) is essentially an index of vegetation “greenness” that results from light interacting with the vegetation canopy. Within the leaf’s structure, chlorophyll a pigments found in the leaves of healthy vegetation, that make up the forest canopy, interact with incoming solar radiation by strongly absorbing visible light in the blue and the red range of the electromagnetic spectrum. This absorption, along with light being reflected within the green and the near-infrared ranges of the electromagnetic spectrum, makes up the typical healthy vegetation spectral signature curve. This healthy vegetation curve may be compared to vegetation that is undergoing drought, insect invasions, suffering from exposure wildfires, climate change, or other stressors.

Question 8 Remote sensing has been shown to play a critical role in the study of wildland fires, delineating burned area, deriving indices of burned and non-burned vegetation, recording the frequency at which different vegetation types are affected, prevention of fires, supporting existing fire propagation models, and even developing effective strategies for extinguishing an ongoing fire event through the identification of the dryer, water-stressed areas. Remotely sensed data applied to wildfire studies have a unique advantage in that these data can be used to collect timely measurements over larger fire-prone areas, including burn severity, extent, fuel and vegetation composition, etc. Additionally, remotely sensed data may be used to provide estimates of fire characteristics that are relevant for the ecosystem as well as smoke and fire fuel load parameters, including species composition, biomass estimates, landscape structure, fire history, fuel moisture content, and fuel availability.

Question 9 Airborne Synthetic Aperture Radar (SAR) or LiDAR data as active systems, and multispectral data such as Landsat, SPOT, or even hyperspectral data such as AVIRIS as passive systems.

Question 10 No remote sensing technology directly measures biomass or forest carbon. Rather, they all measure a variety of structural parameters of vegetation that can then be used with field-derived allometric equations to estimate vegetation volume, biomass, and carbon. Allometric relationships or allometry are mathematical equations describing the relationship between one or more parameters of an object and its shape. Chave et al. (2004) reviewed the literature on the use of allometric equations to estimate forest biomass and carbon. They found four types of uncertainty that could affect biomass estimates: (i) errors related to tree parameter estimates; (ii) errors related to the selection of allometric equations; (iii) sampling error due to sample plot size; and (iv) how representative the study plots were of the entire ecosystem. Overall, they concluded that the choice of allometric equations was the most important source of uncertainty. These findings point to the care
that must be taken when using remote-sensed data to estimate forest biomass and carbon.

**Question 11** The most common landscape parameters used in smoke emission modeling are vegetation cover, fuel load, fuel moisture, fuel consumption rate, and fire boundary.

**Question 12** Figure 4.15 shows that leaf area index (LAI) is strongly correlated with field biomass measures ($R^2 = 0.68$) while fCover ($R^2 = 0.50$) and NDVI ($R^2 = 0.30$) are every bit as strongly correlated. This suggests from the perspective of estimating biomass that using technologies that directly measure the amount of vegetation present is important for accurately estimating biomass.

**Question 13** The challenge of effectively tracking the movements of refugees and internally displaced peoples in many developing nations may be aided by the use of very high spatial resolution (VHSR) remotely sensed imagery. This high-resolution imagery may be useful in identifying past and current human activities across a large region, such as verifying burned and razed villages, documenting the existence of mass graves, identifying food, grazing, and water sources, as well as identifying the extent of violent conflicts within an area that may arise as a result or resulted from the movement of the refugees or internally displaced peoples.

**Question 14** The evolution of satellite image analysis has transformed the field of archaeology, allowing researchers to exploit an enormous wealth of data of the earth’s surface and subsurface contained in various types of satellite images along with aerial photography. Archaeologists can examine a broad spectrum of reflectivity signatures and bands within the remotely sensed data to focus in on prospective archaeological sites to determine if there are evident soil or vegetation disturbances in the surface structure of the landscape, the potential existence of subsurface structures, or even the proximity to possible sources of building materials or other historic human activities.

**Chapter 5**

*Answers to Review Questions for Chapter 5*

**Question 1** Extreme weather is defined as weather at the extreme of its historical distribution beyond the usual range that has been seen in the past. Extreme weather includes unusual, severe, or unseasonal weather. It is typically based on a particular location’s recorded weather history and defined as lying in the most unusual 10%.

**Question 2** Remote sensing aids in the precision of weather forecasting by sensing minute details such as the phase changes of water within the clouds of a storm system. Weather forecasting accuracy is improved by remote sensing by using each variable detected by sensors to develop better predictive models.
Question 3 Pollution is defined as an excess of naturally occurring substances or chemical compounds that cause harm to human and natural ecosystem health. Pollution can take the form of chemical substances or energy (e.g., heat, light, or noise). Pollution can be localized or widespread (e.g., air pollution over a region).

Question 4 Algorithms and models can be developed to harmonize the variety of data collected by satellite remote sensing.

Question 5 Remote sensing can predict episodic events such as volcanoes by measuring thermal changes. Interferometric synthetic aperture radar (InSAR) uses the phase component of radar images to determine the position of the Earth’s surface. Digital elevation models (DEM)—crucial in predicting pyroclastic flows and lahars—with centimeter-scale accuracy, are produced from simultaneously recorded images from different radars. Deformation is measured by using time-separated images. Satellite data provide a global perspective, mapping tectonic strain across continents.

Using visible through short-wave infrared (Vis-NIR-SWIR) optical spectra data recorded in the 900–2500 nm wavelength range by the ARTEMIS sensor (flown on the TacSat-3 spacecraft), the temperature and heat flux of an active lava lake within a crater can be estimated. Elevated radiance in the NIR-SWIR wavelength regions recorded a portion of the blackbody radiation function from small, hot areas of the lava lake, which were inverted to determine the temperature and power output of the crater.

Question 6 Satellites do not measure temperature. The intensity of upwelling microwave radiation from atmospheric oxygen is measured by microwave sounding units (MSUs), which must then be mathematically inverted to obtain indirect inferences of temperature. Sensors deteriorate over time and corrections are needed for orbital drift and decay. An understanding of this is critical because the amount of deterioration can affect the accuracy of the data used in creating models.

Question 7 No right or wrong answers. This is a thought question.

Chapter 6

Answers to Review Questions for Chapter 6

Question 1 Sensors such as scatterometers and SeaWIFS. Ocean Surface Currents Analyses Real-time (OSCAR) is one such product.

Question 2 Monitoring hypoxia and dead zones; evaluating the status of an ecosystem; identifying locations of phytoplankton (useful in commercial fishing).

Question 3 Color scanners map chlorophyll and suspended solids. Hyperspectral data is used for water quality and water pollution detection including nitrogen and phosphorous.
**Question 4** The most important variable in assessing coral reef health is determining the conditions that promote coral bleaching. This is evaluated by measuring the relative magnitude of ocean currents necessary to produce sufficient tidal mixing. Where surface currents do not meet the threshold for sufficient mixing of the water column, coral bleaching is more likely to occur. Coral bleaching is caused by high ocean temperatures, pollution (e.g., oil spills), and excessive algal levels. Coral die-off has consequences for species that depend on them and increases hypoxic zones.

**Question 5** Sustainable fisheries techniques largely function by developing management plans that map out critical fisheries habitats and nursery grounds, as well as limit the number of species caught in a particular area to prevent overfishing.

**Question 6** Chlorophyll, sea surface temperature, salinity, mesoscale ocean structures, pollution levels, presence of oil slicks, etc. One could argue that a national government should provide this free of charge. Alternatively, this could be provided by a private service that a commercial fisherman subscribes to on an annual basis.

**Question 7**
- Color scanners: used for ocean color mapping (chlorophyll and suspended sediments, diffused attenuation coefficients, etc.)
- Multispectral data: used for water quality studies (chlorophyll a, suspended solids, and turbidity)
- Infrared Radiometer data: used for sea surface temperature and currents mapping
- Synthetic Aperture Radar: used for surface waves, swells, internal waves, oil slicks, etc.
- Hyperspectral data: used for water quality and pollution detection studies
- Altimeter data: used for sea surface topography, currents, and surface roughness
- Scatterometer data: used for amplitude of short surface waves (surface wind velocity, roughness)
- Microwave radiometer data: used for microwave brightness temperature (salinity, surface temperature, water vapor)

**Question 8** Case 1 waters are characterized by a ratio in which the concentration of phytoplankton (chlorophyll a) is higher compared to other dissolved inorganic particles in the water column. In Case 2 waters, the dissolved inorganic particles are higher compared to the level of the chlorophyll a concentration in the ratio. Thus, optical properties in Case 1 waters are determined primarily by phytoplankton and related colored dissolved organic matter (CDOM), and Case 2 waters optical properties are largely influenced by constituents other than phytoplankton concentration.

**Question 9** Eutrophication is the biological process by which aquatic primary production is augmented through an increase in the rate of organic matter and nutrients (e.g., nitrogen and phosphorus from fertilizers, sewage effluent, and other pollutants) delivered to surface water (e.g., river, lake, estuary, and coastal waters). Eutrophication promotes excessive algae and plankton growth and can cause a severe reduction in water quality.
**Question 10** Synthetic Aperture Radar (SAR) in various forms.

**Question 11** The rate of marine primary production is determined by temperature, light (strongly influenced by surface turbulent mixing depths), and limiting nutrients—particularly nitrogen, phosphorus, iron, and silicon for some plankton (Doney 2010). Thermal bands and multispectral and hyperspectral bands in remotely sensed data can be used for quantifying marine primary production.

**Question 12** We still have trouble interpreting the reflectance values of water. For example, clear water provides little atmospheric reflectance, with the majority of the shortwave radiation scattered in the atmosphere and longer wavelengths absorbed within the few millimeters of the water’s surface. In addition, most sensors were designed to for detecting land features and not for use in aquatic environments.

**Question 13** The US Integrated Ocean Observing System (IOOS®) is a national–regional partnership created to ensure the sustained observation of US coastal areas, oceans, and the Great Lakes, and to develop near real-time and retrospective information products from those observations to assist people in their lives and livelihoods. The primary focus is to provide timely information through national and regional collaboration.

The Pacific Islands Ocean Observing System (PacIOOS) is one of 11 regional associations in the IOOS. PacIOOS addresses familiar question such as: where are the fish today? Which beaches are safe to visit today? Can I bring my vessel in to the harbor safely? Is my home going to be inundated?

**Question 14** LiDAR data once integrated with global positioning systems can be used in obtaining accurate topographic and bathymetric maps, including shoreline positions. LiDAR surveys can produce a 10 cm vertical accuracy at spatial densities greater than one elevation measurement per square meter.

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**Chapter 7**

**Answers to Review Questions for Chapter 7**

**Question 1** The Hubble Space Telescope enabled scientists to make the most accurate estimate to date of the age of the universe (13.82 billion years). It also allowed researchers to discover that the universe is expanding at an increasing speed, a phenomenon referred to as “dark energy.” In addition, the Hubble Space Telescope provided evidence of supermassive black holes at the center of most galaxies, and yielded the first visible-light images of an exoplanet.

**Question 2** Saturn’s moon Titan is believed to most resemble a primitive Earth. Titan has a dense, hazy atmosphere as well as extensive hydrocarbon lakes and seas.
Question 3 One approach scientists use to detect exoplanets is to measure the “wobble” of a star, which is caused by the gravitational pull of an orbiting planet, using the Doppler Effect; in short, they are looking for a shift in the wavelength of the star’s visible light. A second approach, the transiting method, looks for a characteristic decrease in a star’s brightness when an orbiting planet passes in front of it.

Question 4 Space weather describes solar flares, solar winds, and coronal mass ejections emitted by the Sun. These emissions cause geomagnetic storms that can disrupt satellites, communications, and power systems. Better forecasting of solar weather will allow scientists to better anticipate and prepare for these potential disruptions.

Question 5 The Kuiper belt contains some of the most primitive and least thermally affected matter in the solar system. Scientists hope that data from Pluto and other Kuiper belt objects collected by the New Horizons mission will provide insights about the early history of our solar system, including its formation.

Question 6 Dust devils arise when surface heat is re-radiated to near-surface “air” (i.e., atmospheric gases). The heated air rises into cooler air above it, which can cause it to rotate. Because Mars has a comparatively thin atmosphere, the heated air is able to rise to much higher altitudes than would be possible on Earth.

Question 7 The size and orbit of an exoplanet are the primary indicators of potential habitability: scientists typically focus on planets that are roughly Earth-sized and orbiting reasonably close to their parent star. In addition, observations in certain spectral wavelengths may provide information about an exoplanet’s temperature and composition, including whether it is likely to be rocky or contains certain indicator compounds like oxygen (O₂), ozone, water, and carbon dioxide.

Question 8 In August 1993, Galileo passed through the asteroid belt between Mars and Jupiter, capturing images of the asteroid 243 Ida. Those images revealed that 243 Ida has a satellite, later named Dactyl. Scientists had previously suggested that some asteroids probably had satellites, but this was the first confirmatory evidence.

Question 9 Gamma-ray bursts are extreme explosive events with luminosity a million times greater than the luminosity of an exploding-star supernova. They are associated with the deaths of massive stars, and are likely caused by the gravitational collapse of matter that results in black holes.

Question 10 Water is considered essential to support life, so the availability of water (even in the form of ice) on the Moon or Mars has important implications for possible future human exploration and/or habitation. In the case of Mars, evidence of once-extensive water bodies suggests that the planet may have once supported microbial life, although no data have been found to substantiate this.
Chapter 8

Answers to Review Questions for Chapter 8

Question 1 Every year (in Vienna, Austria). 1958.

Question 2 Ease tensions between the US and the former Soviet Union as both were becoming superpowers and both countries were flying reconnaissance missions over military installations. President Eisenhower understood that preventing the acquisition of data by another entity would be nearly impossible.

Question 3 Five. These include:

1. 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)
2. The *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space* (Rescue Agreement)
3. The *Convention on International Liability for Damage Caused by Space Objects* (Liability Convention)
4. The *Convention on Registration of Objects Launched into Outer Space* (Registration Convention)
5. The *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* (Moon Treaty)

Question 4 The three basic issues that virtually every national and international law address include:

The *right to acquire* remotely sensed imagery/the right to launch remote sensing satellites
The *right to disseminate* remotely sensed imagery without prior consent of the sensed state
The *right to obtain* remotely sensed satellite imagery from a particular state

Question 5 This is a thought question that requires critical thinking; there is no right or wrong answer. One could say that it is an invasion of privacy (particularly on a national scale), but no more so than security cameras installed in urban areas and that it provides more benefits than harm.

Question 6 Space law was needed to ensure governance of this common space along with peaceful cooperation between countries in outer space. This includes harmonization of global navigation systems, the use of nuclear power in space, weather monitoring, maintaining safe operations in orbit, space debris issues, etc.

Question 7 A determination that the request is a hoax or that it is a means for a country to obtain information by false pretenses. Assistance is provided regardless of the political status of a country. Other reasons?
Question 8 A crisis situation that impairs a substantial land area or affects a significant population of a country due to human or natural causes (e.g., the Haitian earthquake, the Great Sendai Earthquake, the Indian Ocean earthquake and tsunami, the Black Saturday Bushfires in Australia, etc.).

Question 9 Pick any two discussed in the chapter.

Question 10 Thought question.

Question 11 With respect to remote sensing, transparency is open access without restrictions. Second part of the question is a thought question.

Question 12 Thought question; no right/wrong answer.

Chapter 9

Answers to Review Questions for Chapter 9

Question 1 Placement of LiDAR data acquisition devices on satellites, further development of Terrestrial Laser Scanners (TLS) and Airborne Laser Scanners (ALS), differential absorption LiDAR (DIAL) and laser Doppler.

Question 2 Detection of cars via very high resolution image acquisition at 50 cm or higher resolution enabling automated computer vision techniques leading to car model identification and the associated parameters.

Question 3 News agencies, Web sites, and a host of other visual media services will continue to benefit from the advances in remote sensing and continue to use remotely sensed data to provide current, relevant, and near-real-time geospatial information regarding events around the world. Google Earth is a good example.

Question 4 A change in the mission of the US Geological Survey (USGS) includes climate and land use change, which is currently developing a science strategy that will guide USGS prioritization for research in the 2020s, and aid in the USGS developing methods to explain how changes in land use, cover, condition, and management alter climate, impact natural systems, and affect human health and welfare.

Question 5 The use of remote sensing by researchers, along with NGOs and ordinary citizens to mobilize support for situations requiring policy development, that is, the crisis in Darfur.

Question 6 The integration of mobile technology with real-time remotely sensed geospatial data is already supporting the development of decision support tools for a variety of applications such as wildland fire risk and damage assessment, large-scale drought conditions and impacts, irrigation and water allocation systems, flooding risks and damage assessments, and public health as well as infrastructure development of maintenance. In addition, “apps” for mobile devices such as Android and
iPhone are now being developed for routine applications and monitoring for disaster warning and emergency management.

**Question 7** First, manufacturing, launching, and operating cost less than larger satellites. This facilitates “risk taking” during design and encourages technical innovation. Second, small satellites can be developed in only a few years or less. Shortening the time to launch adds resilience and flexibility to the satellite systems, allowing for nimble response to emerging issues such as the need for a deeper understanding of global climate change. Third, operating only a small number of instruments per satellite allows orbits to be optimized for a particular set of measurements.

**Question 8** The AAAS Center for Science Diplomacy has been instrumental in advancing scientific engagement as an essential element of foreign policy and of building vital bridges between societies. Examples include involvement of Cuban and Myanmar government ministries and scientific NGOs to discuss health science, forestry, education, and the role of science in public policy.

**Question 9** Challenges include the difficulties in storing massive and complex data, intensive irregular data access patterns, managing remotely sensed “Big Data” on multilevel memory hierarchy, optimal scheduling of a large amount of interdependent tasks as well as the efficient programming for these vast databases.

**Question 10**

- miniaturization and integration of electronics
- further development of UAV-based data acquisition systems
- increases in computational power such as heterogeneous parallel computing, cloud computing, and quantum and biological computing
- progress in large apertures and larger antennas
- increases in transmitter power for active systems
- miniaturization of optics
- increase in storage technology
- development of small satellites
- advances in screen technology and mobile computing
- increases in tunable systems and flexible frequencies
- advances in techniques for processing “Big Data”
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