Unmanned aerial systems and the sensors they carry

Types of UAS

Fixed-wing	Rotor
Advantages: A fixed-wing aircraft generates lift as it moves through the air, meaning that the propeller doesn't have to do all the work of keeping it aloft. Thus, fixed-wing UAS typically have larger payload capacity, higher top speed, longer flight times and longer range compared to rotor systems with similar battery capacity. For these reasons, fixed-wing systems are particularly useful for collecting data over a large area.	**Advantages:** Rotorcraft are highly maneuverable, with the ability to hover, rotate and capture images at almost any angle. Manual takeoff, flying and landing are easy to learn, and some models have built-in "sense-and-avoid" technology. There are many low-cost models on the market, along with more costly units with larger payload capacity and/or flight time.
Disadvantages: Compared to rotor UAS, fixed-wing systems are less maneuverable, require more open space for landing and more skill to pilot, and tend to be several times more expensive than similar-grade rotor systems.	**Disadvantages:** Shorter range and flight time compared to similar-grade fixed-wing UAS are the main drawbacks to rotorcraft.

Autopilots

Both fixed-wing and rotor UAS can be flown manually, but nonrecreational users rely primarily on what are known as "integrated flight systems" that enable safe precision flying, improved stability control and the ability to precisely replicate data-collection flights. These systems typically include GPS-enabled autopilots, inertial measurement units (IMU) to monitor the aircraft's orientation, battery-monitor systems to ensure that the UAS reserves enough charge to fly "home" and systems that attempt to land in the event of an emergency.

Flights are generally planned and executed through a tablet or phone application. GPS waypoints along flight paths can function as trigger points that activate or deactivate an on-board sensor. The autopilot systems are flexible and can be altered in midflight, for instance, by activating preset flight commands such as loiter (stay in one place), circle, land or return to home.

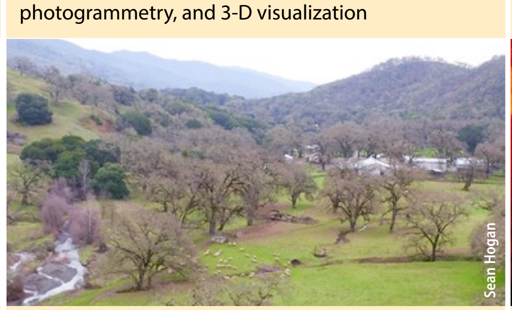
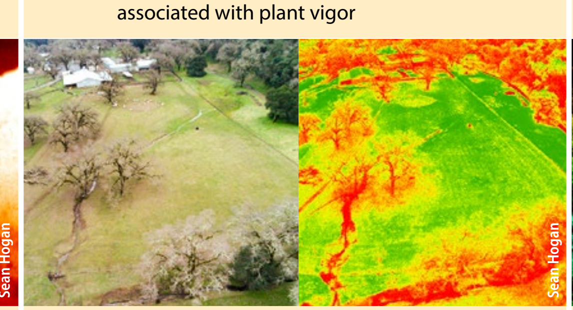
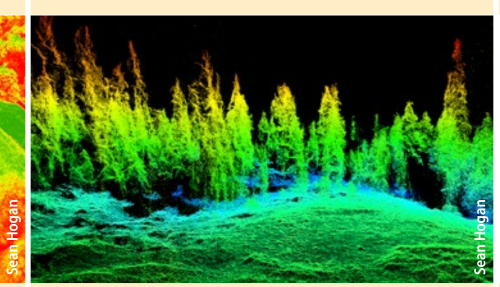
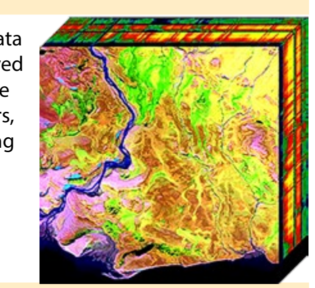
Integrated flight systems also can be programmed to assist during manually controlled flights by limiting flight speeds and flight distances. Recent advances in these systems include object avoidance systems and built-in maps of restricted airspace. Continuing improvements in the technical integration of flight controllers, UAS firmware (the control-system code in the UAS itself) and sensor software should result in safer and more reliable UAS that can further reduce safety issues and data-collection problems arising from user error.

Controller for a 3D Robotics Solo drone. The attached Android tablet displays a programmed flight plan.

Will Suckow

Controller for a DJI Inspire 1 drone. The attached tablet shows an inflight view and other information.

UAS sensors

	RGB digital camera	Thermal camera	Multispectral camera	LIDAR (light detection and ranging)	Hyperspectral sensor
Description	Captures visible-spectrum (red, green and blue, or RGB) photographs or video between 390 and 700 nanometers in wavelength	Captures thermal images or video in the long-infrared range, roughly 7,000 to 12,000 nanometers	Captures images from wavelengths in the visible spectrum (RGB) and from one or more segments of the infrared spectrum (>700 nanometers)	Uses laser pulses to map surface elevations at a very high level of accuracy.	Collects imagery for a large number (typically more than 50) of narrow spectral bands over a continuous range, generally somewhere between 300 and 2,200 nanometers
Typical applications	Creation of true color orthomosaics (composite images of a large area), topographic modeling using photogrammetry, and 3-D visualization	Monitoring relative surface temperatures to provide information on, for instance, water features, wildlife, evapotranspiration and soil moisture content.	Agricultural and natural vegetation monitoring, by sensing reflected light wavelengths associated with plant vigor	3-D modeling of surfaces, most commonly for forestry and structural surveying	Precision agricultural monitoring requiring the detection of spectral signatures associated with specific plant traits
Image example	 Sean Hogan	 Sean Hogan	 Sean Hogan	 Sean Hogan	Hyperspectral data are often displayed as a cuboid made up of many layers, each representing a single spectral band.  NASA
Other considerations	Photogrammetry can be used to model elevation at a spatial resolution similar to that of the processed image pixel resolution. Visible-spectrum photogrammetry is not effective for mapping below-canopy vegetation and ground elevation.	Generally not suitable for photogrammetry due to lack of sharp contrast	Same photogrammetry possibilities and limitations as RBG sensors	Collects elevation data but not spectral data. Generally most suitable for mapping surfaces below a vegetation canopy, because lasers have better penetration than spectral instruments. LIDAR sensors tend to be heavier than others.	Higher cost than the other sensor types profiled here. Generates large amounts of data and requires more sophisticated methods of data analysis. Not appropriate for photogrammetric estimates of surface elevation.

The type of sensor that a UAS can carry is determined by the UAS's designed payload capacity. Any type of instrument may be used as long as it's light enough for a given UAS platform. Most conventional UAS have a maximum payload between 300 and 1,500 grams (0.66 to 3.3 pounds). There is a tradeoff between instrument payload and fight time, especially for rotorcraft.

Most sensors can transmit a live video stream to a base station receiver for the pilot or pilot's observer to monitor. This functionality drives much of the public's interest in UAS and has been useful for search and rescue and police applications. For most scientific purposes, however, the data are recorded for later visualization and analysis.