Chapter 1
Introduction

1.1 UAV Imaging: A Disruptive Innovation

Wikipedia defines a "disruptive innovation" as one that

> helps create a new market and value network, and eventually disrupts an existing market and value network (over a few years or decades), displacing an earlier technology. The term is used in business and technology literature to describe innovations that improve a product or service in ways that the market does not expect, typically first by designing for a different set of consumers in a new market and later by lowering prices in an existing market.[1]

Aerial remote sensing has been around for some time, as have the visible, infrared, multispectral, and hyperspectral imaging sensors deployed on airborne platforms. Placing these sensors on a remotely piloted vehicle, automating some decision-making functions, and processing the data obtained via cloud computing[2] are some of the factors contributing to the new market and value network that unmanned aerial vehicle (UAV) imaging provides. Expensive, crewed airborne overflights and satellite images obtained between long revisit times are being steadily overtaken by cheaper, faster, and more-autonomous UAV imaging solutions.

This development, in turn, gives rise to two significant trends: the application of UAV imaging to new areas and the expedited development of new technologies to serve the quicker–cheaper–"smarter" UAV imaging system market.[3] This book is chiefly concerned with the technical principles underlying UAV imagers rather than the applications they serve. Table 1.1, which mentions some of those applications, helps define the broad range of disciplines that benefit from the proliferation of UAV imaging sensor systems.

Even as civilian applications proliferate,[4] military uses of UAVs are expanding toward the goal of continuous, remote monitoring far from military bases. The need to improve U. S. and allied operations in Southwest Asia, a strategic shift to the Asia–Pacific theater, and the downsizing of

Table 1.1 Some applications that benefit from UAV imaging.

Application	Benefit
Precision agriculture	Increased monitoring frequency; fused data from several sensors increasing accuracy of plant health metrics, such as Normalized Difference Vegetation Index (NDVI)
Emergency response	Continuous availability in danger zones after a natural disaster or toxic chemical release
Search and rescue	Ability to see in difficult terrain without endangering a human pilot
Intelligence, surveillance, and reconnaissance (ISR)	High-, mid-, and low-altitude ISR; persistent surveillance rather than surveillance only at regular intervals; fusion of data from several sensors in a region for more robust decision-making
Mining and minerals	Safety improvement when measuring sites remotely but at close range
Construction monitoring	Project monitoring at all phases available to both large and small efforts
Law enforcement	Remote situation monitoring reduces possibility for officer injury when responding to a call
Environmental monitoring	Continuous monitoring of oil spill/chemical/waste cleanup

Table 1.2 Some enabling technologies for UAV imaging systems.

Technology	Enabler
Hyperspectral imaging	Enhanced spectral and spatial resolution that improve detection, identification, remediation, and other tasks
Small gimbals	Increased pointing accuracy for small UAV payloads on both military and commercial platforms improves image quality
Miniaturization	Smaller detectors and optical components that improve the size, weight, and power (SWaP) of imagers
Uncooled thermal detectors	Decreasing price of imagers (particularly in the 7–14 μm region) for years along with increased resolution
CMOS sensors	Visible/NIR imaging detector arrays with individually addressable pixels particularly useful in small UAVs
High-definition television (HDTV)	Higher resolution than conventional video that improves target identification

military budgets all contribute to this trend.[5] Developments in technologies that enable UAV imaging help drive the application and are driven by it. Some technologies of particular importance to UAV imaging are listed in Table 1.2.

1.2 Components of a UAV System

As UAV imaging continues to expand, many vendors of smaller, commercial platforms become system integrators as well, utilizing commercial, off-the-shelf hardware (COTS) to meet customer needs.[6,7] Sensor developers whose past business was primarily military and government have expanded their product lines to focus on commercial applications and often form partnerships with platform vendors. Military development has also seen process improvements: recently, the U. S. Department of Defense (DoD) established guidelines to streamline integration protocols between unmanned vehicle

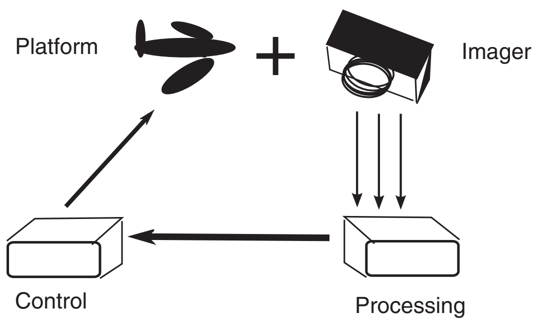

Figure 1.1 Generic UAV system components.

control systems and the software that guides them.[8] The net effect, in both commercial and government UAV development, is to generate platform-sensor system combinations whose development is expedited through collateral, rather than sequential, work on system components.

That said, it makes sense to clarify what these components are. At the most basic level, the UAV imaging system comprises a sensor, a platform (airborne vehicle), and a processor, with some capability for autonomous operation, as illustrated in Fig. 1.1.

There are numerous variations on this theme. Both control logic and data processing software may reside on board the platform. Alternatively, the control system may be on board the platform, with processing handled in the cloud. Platforms may feature more than one sensor: visible and infrared imagers, for example, are featured in many civilian and military applications. An unmanned aerial system (UAS) combines the UAV with some kind of ground processing and a data link (typical in military tactical and theater operations).[9]

1.3 Size, Weight, Power, and Platform

The range of UAV platforms is extensive. Global Hawk, a large military surveillance platform, weighs more than 32,000 pounds and carries payloads whose weight approaches a ton and a half. Many large military platforms include visible cameras, infrared cameras, and synthetic aperture radar (SAR); the MQ-1 Predator shown in Fig. 1.2 includes all three. SAR can be used to image through forest canopies, detecting targets that lie beneath.[10]

The fact that a UAV platform is not crewed allows its features to be optimized for a specific application. One commercial design, optimized for oceanic search and rescue, allows the aircraft to speedily transit to the search area and then hover over it at very low speeds, even in windy conditions.[11] The advantages of the approach become clear when contrasted with the 2014 Malaysian Airlines search and recovery mission, in which eight-hour plane rides to and from the site allowed a useful search window of only two hours.