CHAPTER 2

UNMANNED AERIAL VEHICLE DESIGN AND CONSTRUCTION

INTRODUCTION TO DESIGNS

Current unmanned aircraft designs owe much of their performance and reliability to techniques developed in traditional manned and model aviation. Design elements that have been proven to function in model aircraft for decades are seen in today's small unmanned aerial systems (sUAS). Likewise, the design elements of larger and heavier unmanned aircraft can trace their origins to the successful application of technology derived from manned aircraft. From small aircraft to airliners; the materials, aerodynamics, and propulsion systems used in UASs are shared between the manned and unmanned segments of aviation.

MISSION DRIVEN DESIGN

The UAS, with few exceptions, is designed from concept, test flight, and deployment, to accomplish a fairly specific mission. A mission is defined as the expected use, or application, of the aircraft. It is the intended purpose for which the aircraft was created. It is the mission requirements that typically define almost every element of a given design. A design not created with a specific mission in mind is a design that may end up with a broad range of performance capabilities but will seldom perform any of them particularly well. For example, a user needs to determine if the mission requires vertical liftoff and/or hovering flight. If it does not, then a fixed-wing design might be a better alternative than a rotorcraft. But if vertical, or hovering, capabilities are a priority, than a rotorcraft of some sort will likely be needed. Other mission parameters that need to be defined include the flight stability attributes, mission duration, needed maneuverability, as well as the load carrying capacity of the aircraft. Each of these requirements will further refine the aircraft design selection.

Figure 2-1. Multirotor aircraft preparing for operation from unimproved field.

Figure 2-2. Fixed-wing hand launch for an agricultural imaging flight.

Figure 2-3. Some operating areas are more noise sensitive than others.

Figure 2-4. A catapult may be used in the absence of a suitable runway for takeoff.

For example, the need to operate from rural areas, without runways, is a common mission parameter in agricultural applications of unmanned aircraft. That requirement may dictate the use of a rotorcraft, or a fixed-wing design with capabilities such as catapult, or hand launch. The landing methods employed could include parachutes, slow flight into standing vegetation, or capture nets. The advantages of fixed-wing designs include low vibration, large payload capability, and lengthy duration. Those advantages must be weighed against the challenges inherent in using an aircraft that needs significant space for landing and takeoff.

PLATFORM SELECTION

The mission requirements primarily dictate the selection of either a fixed, or rotary wing design. There are advantages and disadvantages to each configuration, as well as personal preferences from operating experience. An experienced fixed-wing operator may be highly skilled, and well prepared, for flying safely and confidently with a conventional winged aircraft. When confronted with the differences in operating a rotorcraft, they may be less confident or skilled, and the risk of an operator error induced mishap rises. Likewise, a rotorcraft operator would face the same issues when operating a conventional fixed-wing design. Cross training can alleviate much of the risk, however most operators will still prefer piloting one type aircraft to another based upon personal experience.

SPECIFIC PLATFORM ADVANTAGES AND DISADVANTAGES

The traditional fixed-wing aircraft has many applications. They are relatively inexpensive to construct and repair compared to rotorcraft of comparable weight and capability. A fixed-wing aircraft uses natural stability in flight and is not dependent upon continuous propulsion to remain aloft. If anything goes wrong with the propulsion, or flight stability systems, a fixed-wing aircraft can often glide to a reasonably safe landing. Fixed-wing aircraft can usually carry more weight for a longer time than a comparable rotorcraft. Low vibration, as well as the ability to completely stop and restart the motors in flight, can assist in the use of cameras and other systems that are vibration sensitive. Fixed-wing, electric powered aircraft are also very quiet and may be desired for surveillance work or when flying in noise sensitive areas. These areas include neighborhoods, parks, and wildlife refuges to name a few.

Every aircraft design is a series of compromises. Fixed-wing aircraft cannot stop in flight or hover. They also require relatively smooth, lengthy surfaces for takeoff and landing. They can be difficult to transport to the operational site as they may be relatively large and time consuming to disassemble and reassemble on site. The use of fixed-wing aircraft in congested urban areas may be limited to higher altitudes due to their inability to easily avoid ground based obstacles and their limited maneuverability.

ROTORCRAFT ADVANTAGES AND DISADVANTAGES

The helicopter and other multirotor designs, have become common in small unmanned applications. Their primary advantages include the ability to stop in flight, or hover, as well as their vertical takeoff and landing capability. These flight characteristics make them ideally suited to congested urban operations as well as indoor use. Rotorcraft may be operated from small launch platforms as well as boats, providing access to areas that would otherwise be impossible to reach. Rotorcraft designs are extremely adaptable to increases in overall vehicle size and configuration. Rotorcraft with 1, 3, 4, 6, 8, or more motor driven propellers, providing both lift and flight control, are common.

Figure 2-5. Common quadcopter type multirotor.

Rotorcraft, as compared to fixed-wing designs, are relatively loud, high in vibration, and lack substantial duration and weight lifting capability. Multirotors are highly dependent upon flight control electronics for stability with tuning and adjusting required to achieve stable flight. An improperly tuned multirotor can be difficult, if not impossible, to fly. A flight controller failure will usually result in a loss of stability and a resultant out of control crash with a possible loss of the aircraft. If battery capacity and condition are not monitored closely, the multirotor may fail to complete a flight with an off field landing being the inevitable outcome. A multirotor aircraft will not glide like a fixed-wing aircraft, nor can they auto-rotate to a safe landing like a helicopter. The rotors also present an obvious danger to personnel and safety procedures are required to be in place at all times. A safety shroud not only protects the rotors from damage, but more importantly, it protects nearby persons or property.

Figure 2-6. Osprey tilt rotor aircraft transitioning to forward flight.

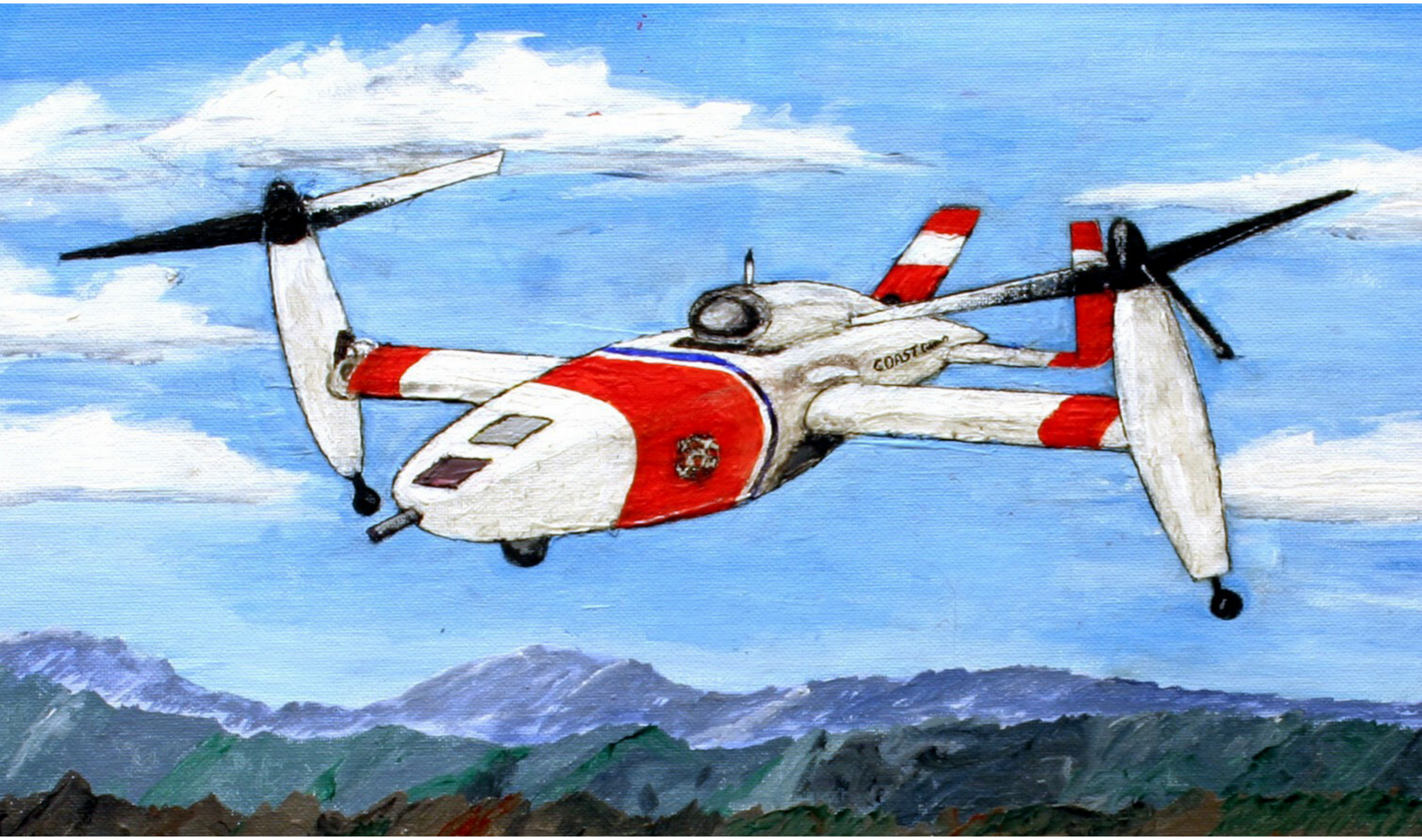

Figure 2-7. Unmanned tilt rotor aircraft.

HYBRID DESIGNS AND AIRSHIPS

Some unmanned aircraft do not fit into either the conventional rotorcraft or fixed-wing categories. These aircraft designs attempt to minimize the disadvantages and optimize the advantages of both types. The manned V-22 Osprey operated by the U.S. military is an example of this concept using large rotors for vertical lift, small wings for forward flight, and equipped with large horsepower engines to accomplish both tasks.

Figure 2-8. Takeoff and landing position of tail sitter unmanned aircraft.

There are similar unmanned aircraft designed to utilize rotors for vertical takeoff and landing, with high-speed forward flight capability. Aircraft of this type are challenging from a flight control standpoint as they must be stable and controllable in hover, then transition to forward flight, and back smoothly. The ability to hover, and fly in conventional forward flight, is easily achieved through electronic controlled stability. It is the transition between the two flight modes that has proven difficult.

The “tail-sitter” type aircraft is another hybrid design concept. With this aircraft, the propeller, or propellers, are positioned in the front as with any conventional aircraft. The difference is that the thrust provided

Figure 2-9. Unmanned airship performing research of power requirements for maneuverability.

is sufficient to lift the aircraft vertically from this nose up position. Flight is accomplished by lifting the vehicle vertically, pitching it over for horizontal flight, and then transitioning back to the nose up attitude for the tail first descent and landing. Backing the aircraft down, tail first, to a soft landing is extremely difficult.

Rigid airships have been used as unmanned aircraft as well. They provide high lift and duration characteristics not obtainable with other designs. Their low vibration, quiet operation, and long flight duration must be weighed against their susceptibility to wind, however. An airship tethered to the ground, called an aerostat, is a common method to utilize the advantages of this type of aircraft while managing the winds effects.

Figure 2-10. An aerostat type airship with tethering tower.

POWERPLANT SELECTION

The selection of the means of propulsion for a UAV will be based upon the proposed mission of the aircraft. Small unmanned vehicles often utilize battery powered electric motors for their clean, quit, reliable operating