IMPROVING UAV RELIABILITY

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Unmanned Aerial Vehicle (UAV) or Unmanned Aircraft System (UAS) - Background

The UAV/UAS has become a staple of the mission options available to the Department of Defense, with its roles and capabilities increasing along with utilization. However, this increase in utilization has been accompanied by significantly higher failure rates when compared to conventional airframes. The general aviation mishap rate is about 1 per 100,000 flight hours, while military UAV systems have experienced failure rates 2 orders of magnitude higher, nearly 1 per 1000 flight hours [1]. By another metric, some UAV systems have a failure rate of 25% [7)]

Figure 1: Various Configurations for Unmanned Aerial Vehicles [2]

This insight is critical at a time when domestic use of UAVs is poised to experience unprecedented growth. The projected spending on these types of aircraft in the next few years is projected to be almost $6 billion, with an eventual total spending of $94 billion by 2023. Some forms of UAVs are already being used for border patrol, firefighting, disaster relief, search and rescue missions, training, and research and development. In addition, there is an entirely separate market for UAVs that will be used for recreation not to mention the recent commercial sector excitement over the potential to use them for logistics and package delivery. Failures of these systems, which are not expected to be as rigorously tested or as well-manufactured as military systems, present a potential for danger and safety risk should they fail. [2]

According to a Washington Post investigation, more than 400 large U.S. military drones have crashed in major accidents around the world since 2001, a record of calamity that exposes the potential dangers of throwing open American skies to drone traffic [3]. Although no one has died due to a commercial UAV crashes since they were approved to fly over the US in 2013, UAVs have hit homes, farms, highways, waterways and in one case experienced a mid-air collision. The rate of commercial UAV failure events is expected to increase beyond that experienced in the military because commercial UAVs are developed without redundant systems, such as sensors and wireless communication links.

As UAVs become more integrated into our commercial airspace, the need for improved reliability is even more obvious.

The benefits of UAVs include the ability to perform dangerous missions, such as firefighting, without putting their human operators at risk, and the ability to perform continuous operations. In addition, commercial UAVs are expected to have price points that make them attractive replacements for tasks such as package delivery that currently require large investments in labor and more expensive delivery trucks. Ironically, by encouraging a perception of UAV as consumable hardware this low price point may increase risk and dis-incentivize those activities that would normally lead to gains in reliability and safety.

When military UAVs fail during missions, the need to prevent the technology from falling into the wrong hands typically requires the complete destruction of the vehicle at the crash site, preventing any forensic investigation into the cause of the failure. For commercial UAVs, the cost of the forensic investigation, when weighed against the low cost of simply replacing the vehicle may risk a similar lack of understanding of the cause of failure. This lack of understanding will prevent or at the least impair any corrective improvements, whether in design, materials, or manufacturing.

Failure Modes and Mechanisms

Electronics failures are reported for about 25% of all failures, the rest being attributed to weather and pilot error. Military UAV systems provide increasing protection against human induced failures and enhanced performance through improvements in flight control software. These systems also have multiple sensors to detect and predict deterioration or failures. However, the low-cost commercial systems attractive to some of the leaner and cost-sensitive small to mid-sized businesses may not have the same level of redundancy to provide failsafe operation. This will place a greater reliance on the reliability of each electronic component. As control software improves and the balance of high-end redundant systems versus less redundant low-to mid-range systems shifts, DfR Solutions expects to see a dramatic increase in the share of electronics failures as the cause of UAV mishaps. This is in no small part due to the relative complexity of electronics in UAV systems.

Figure 2 is an example of the typical electronics and components that comprise a commercial grade UAV.

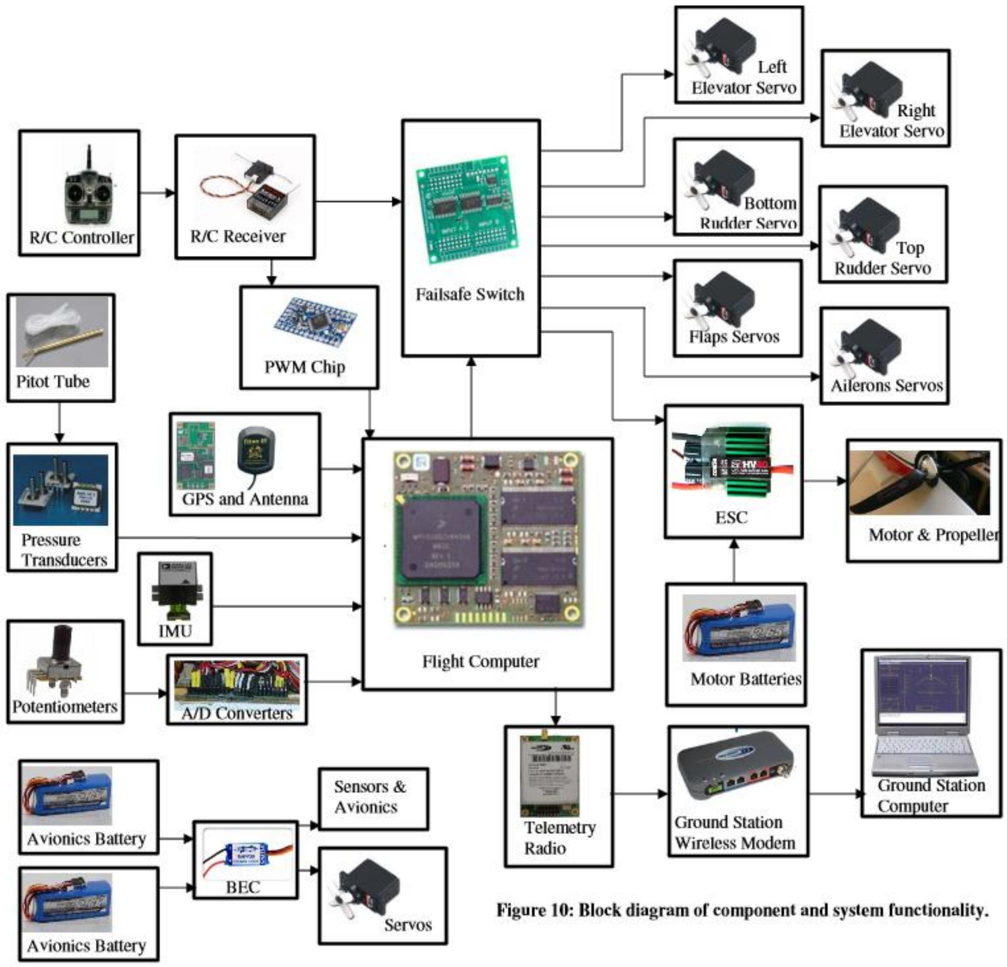

Figure 2: Typical Electronics Components for a Commercial UAV [5]

As can be seen, the system is comprised of a flight computer, telemetry radio, wireless modem, failsafe switch, A/D converters, sensors, batteries, GPS unit and antenna, and a pulse width modulation (PWM) chip. Fairly sophisticated electronics for less than $1000. Consequently, there are several opportunities for the electronics to fail. This mix of assemblies means that failures can occur from Electro-Static Discharge (ESD), Electrical Overstress (EOS) from a power surge, vibration causing connector and solder joint issues, along with thermal fatigue of interconnects due to material properties such as coefficient of thermal expansion (CTE).

Reliability Assessment

Designers of these products have used various methods to ascertain component failure susceptibility. Some have used the Non-Electronic Parts Reliability (NPRD)-2011 from the Defense Systems Information Analysis Center, while others have used Telcordia SR332. Using these actuarial tools indicated that the failure rates for commercial products was typically 2-3 times higher than if military grade parts were used. This is alarming when considering that these same actuarial methods are statistical tools whose approximations do not typically take into account the effects of the environment on design configurations or material interactions. To do this a physics of failure (PoF) approach is required.

Some key questions to be asked are: What are the environmental ranges that UAVs can withstand (e.g. temperatures, pressures, vibration in flight, shock on landing, turbulence [3]) without incurring an electrical failure. As with most new technologies, failure analysis plays a critical role in understanding why a failure occurs, at the component and material level, and provides the information required to mitigate future failures.

However, as discussed, most users of commercial UAVs will replace their unit rather than pay the costs to analyze the failure that occurred. If the cost of unit replacement were the only financial consideration as is the case with most consumable devices, this may be understandable. However when weighed against the liability of serious harm to bystanders, the calculus changes. A UAV falling out of the sky and hitting a child in their back yard is a serious liability for the operating company, and will likely result in stricter regulation of the industry as a whole, increasing the overall costs of UAV operation and in some cases making participation prohibitive for those innovative small to mid-sized companies. When weighed against these risks, the costs of failure analysis become much more palatable and the benefits much more attractive.

The environments that the commercial grade UAV may encounter could include temperature ranges of -40°C to 70°C, vibration, shock, moisture, pressure and storage. Understanding the effects of these various stresses as early in the design stage as possible would be beneficial, even to the commercial applications, to avoid the issues with crashes and personnel safety. With this understanding in mind, there are two activities that can be performed by UAV designers and manufactures that can provide a greater level of reliability assurance: critical component testing and a physics of failure based design analysis.

Because of the typical operating environments for commercial UAVs, DfR believes that the most common failed components would include electrolytic capacitors, connectors, optocouplers, oscillators, printed wiring boards, resistors and solder joints, all of which are integral to most UAVs. Supplier requirements and reliability test plans that reflect these operating requirements for these critical components during vendor selection, along with an appropriate screening program throughout the life of production, would mitigate much of the associated reliability risk.

While accounting for a small portion of overall system cost, the design of the hardware accounts for 80% of the final product reliability [6]. To maintain pricing attractive to the commercial sector while mitigating the risk of failure, reliability analysis at the design stage is critical. Recent advances in Automated Design Analysis™ software make these activities cost effective and have greatly reduced the impact of reliability assurance on product development schedules.

Finally, a deep understanding of the potential issues that can impact a UAV is critical and this is where DfR's expertise can be beneficial to you, the consumer. For example, most commercial UAVs are expected to be propeller-driven due to lower cost, lower fuel consumption, and the ability to execute customer requirements at speeds less than 300 mph (most likely even hovering).

However, the lower mass of the flight vehicle will result in far more severe vibration than normally experienced in commercial or military aircraft. These higher vibration levels, if not adequately captured and mitigated, can result in relatively rapid times to failure of the avionics systems.

All UAVs, until they become truly autonomous, rely on wireless transmission for control and the sending and receiving of data. Military UAVs have relied on a robust series of overlapping communication systems to ensure continuous transmission during operation (Figure 3). Designers of commercial UAVs may have a poor understanding of range, transmission probability, and radio interference in real world applications. This is especially true for the majority of applications that will likely rely on GPS, mobile protocols (e.g., 4G LTE) and next generation WiFi (WiMAX).

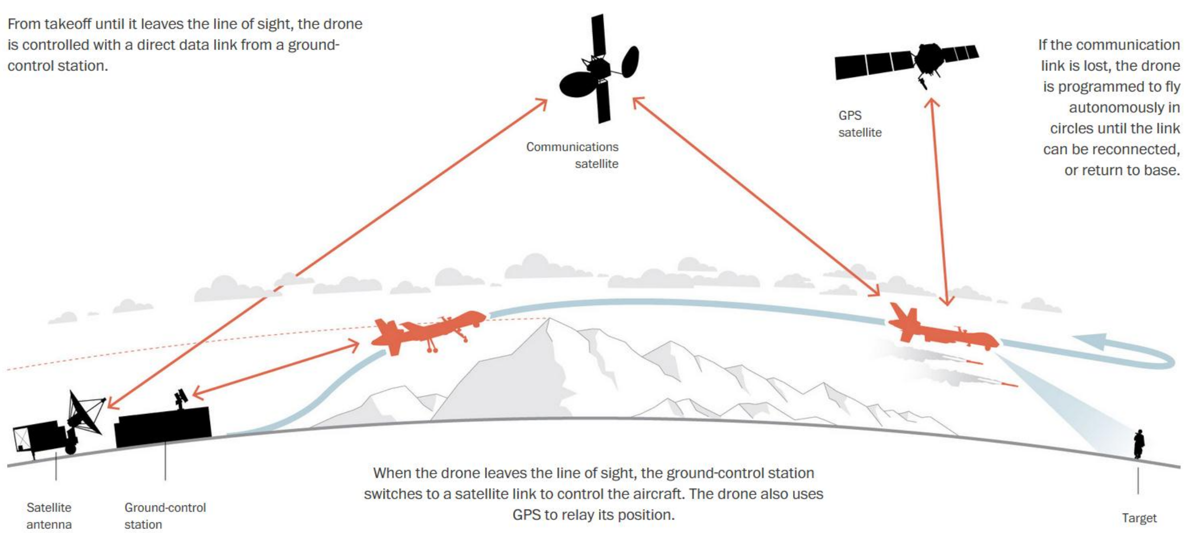

Figure 3: Typical Wireless Communication System for Military UAVs [4]

Testing for EMI/EMC susceptibility is a well-known process for most engineers. In fact, it's almost too well known. UAV exposure to EMI/EMC is currently unknown and could range from non-existent to over 10,000 volts per meter if they fly too close to power lines. While traditional aircraft have several levels of EMI/EMC protection (from the individual LRU's to the overall fuselage), the commercial UAVs are expected to have minimal ability to filter radiated noise. The real challenge is most engineers have been trained on the test method and not on the critical low-cost design techniques to avoid susceptibility in the first place.

With DfR's combined Automated Design Analysis software (Sherlock™) and extensive service offerings such as failure analysis, component test plan development, test execution and design reviews, DfR can facilitate improved reliability, allowing developers to incorporate the required design improvements prior to launching the product, thus reducing overall UAV operational risk. Call us at 301-640-5825 (Greg Caswell) or 301-640-5811(Ed Dodd) and let us help you out.

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