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AN OVERVIEW ON THE CONCEPT OF UAV SURVIVABILITY

Adrian MURARU

Faculty of Economics And Public Administration, "Ştefan Cel Mare" University, Suceava, Romania

Abstract: *UAV's are becoming more and more active in the modern battlefield; there is no question about it, these types of aircraft are in the proliferation state because of the low costs and relatively good life/cost benefits. To address the modern problem of UAV's a word comes to mind that is survivability. Survivability is the ability of the UAV platform to perform ingress, fly over the target area (including weapon release and guidance) and egress while being subjected to threats. It is nearly impossible to address the survivability of only one subsystem, the aspect has to be treated as a hole, although most modern studies are concentrating on the susceptibility of the unnamed aircraft. Susceptibility and vulnerability reduction are key factors in the further development o of UAV's. The paper discusses the necessary steps for implementing the survivability concept for modern UAV.*

Keywords: UAV - Unmanned Aerial Vehicle, UAS - Unmanned Aircraft System

SURVIVABILITY AN OVERVIEW

UAV's are becoming more and more active in the modern battlefield; there is no question about it these types of aircraft are in the proliferation because of the low costs and relatively good life/cost benefits. To address the modern problem of UAV's a word comes to mind that is survivability. Survivability is the ability of the UAV platform to perform ingress, fly over the target area (including weapon release and guidance) and egress while being subjected to threats. It is nearly impossible to address the survivability of only one subsystem the aspect has to be treated as a hole, although most modern studies are concentrating on the susceptibility of the unamend aircraft. Susceptibility and vulnerability reduction are key factors in the further development o of UAV's.

TERMS SPECIFIC TO UA SURVIVABILITY

Survivability. The capability of an aircraft to avoid or withstand a man-made hostile environment

Susceptibility. The inability of an aircraft to avoid the threats in a man-made hostile environment

Vulnerability. The inability of an aircraft to withstand a man-made hostile environment.

Expendable. The UAV is minimally survivable. Loss of the UA has minimal cost and operational impact; the UA can be quickly replaced or is not critical to operational success.

Survivable. The UAV is highly survivable. Loss of the UA will have a significant cost and/or operational impact.

1. UAV SURVIVABILITY IN COMBAT

UAV's are not a new concept they have been used since 1944 the TDR-1 assault drone that were guided by a pilot in the loop using television to drop bombs on Japanese positions in the Pacific, they lost 3 units out of 50 during the first 2 months of service due to hostile fire.

During the Vietnam War, the AQM-34 was used to collect reconnaissance data. Limited data from 1964-1989 show UAS combat loss rates of 3.9/year during the Vietnam conflict (1964-69), 4.5/year in the Bekka Valley conflict (1981-82) and 1/year over the period of the Angolan Border War (1983-87).

More accurate data set include non-combat losses so that we can differentiate between when the UAV is subjected to direct fire and when it is a case of subsystems failures. Therefore for the period of 1991-2003, which covers the major conflicts Desert Storm (1991), Allied Force (1999) and OEF and OIF (2001-2003), over that 13-year period 185 UA losses were recorded, an average of 14.2 per year. Considering the specific periods of major conflict; 20 RQ-2 Pioneer UA were lost in Desert Storm over a period of less than a year, 18 were combat losses and two were non-combat losses. In Operation Allied Force in Kosovo, 45 UA of various types were lost. Of the 45 losses, 26 were combat and 19 were non-combat. Data available from OEF and OIF over the period of 2001-2003 show a substantial decrease in UA loss rates, with an average of 2.0 combat losses and 2.7 non-combat losses per year over the three-year period.

UAV threats have evolved since there creation, but most of them still remain military jets, and SAM's, while most recent conflicts attribute UAV loses to small arms, air defense artillery and unspecified ground fire, any number of modern tactical, strategic, technological and political factors will continue to affect the threats of UAV's in the future.

Latest threats for unnamed areal systems are not lethal systems but based on electronic warfare or information warfare techniques, that affect they electronic systems and subsystems such as communication, data links, GPS systems. All of these techniques can impale or render the UAV useless.

2. SURVIVABILITY AS A SYSTEMS DESIGN DISCIPLINE

Modern military require that UAV mission take place in "a man-made hostile threat environment. In order for the mission to succeed survivability must be considered but not as an improvement for existent system but as a design feature embedded early on in the design on the UAV to limit the cost of survivability.

The problem of low cost and large numbers versus high cost less numbers and less vulnerable is an onwards debate, if we were to look at manned system's the human life of the pilot would considered the deciding factor and a high survivability would be a priority. But that is not the case for unnamed systems however the mission success there deciding factor, to meet that requirement in a potential hostile environment survivability has to be met, and it has to be taken into account since the design process. However designing such a system requires many more subsystems such as range, payload, cost these will take precedent over the survivability feature.

This aspect may also be true if a large number of expendable assets are available to perform the mission. If one or more of the assets are destroyed, the mission can still accomplished at lower life-cycle cost. A more critical mission in a higher threat environment increases the importance of survivability design features. If few assets are available, completing the mission the first time and with a single vehicle may be imperative. It is important to weigh all the factors in determining how "survivable" a UAS must be to fulfill its specified functional capability.

Considering the survivability from the start of the design process one can make design trade-offs and minimize the potential cost and performance impacts. Changing some aspects later on in the design cycle will come with some performance and cost penalties. An example to prove this point is to band together critically components and shielding them from small arms fire, and from onboard fire. Considering all the faces of the design early on will decrease the overall life-cost cost.

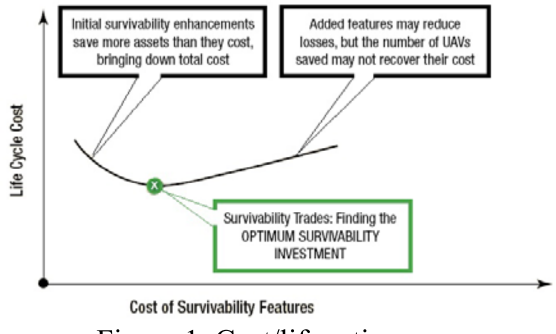

Figure 1. Cost/life ratio

3. UNMANNED AIRCRAFT SYSTEM SURVIVABILITY CONSIDERATION

No matter the class of the UAV they all share the same components: one or more aircraft, a system for command and control of the aircraft and associated payloads, payload(s) and a means of disseminating the information obtained by the payload.

3.1. Aircraft

Because of their wide range of sizes and performances a standard survivability approach is close to impossible. Therefor passive susceptibility reduction measures, such as visual and acoustic signature reduction, may be the only way to increase the survivability of small aircraft due to their limited size. Larger aircraft can support the introduction of active susceptibility reduction measures such as flares, chaff, other decoys, and/or traditional aircraft vulnerability reduction design concepts. The cost and intended purpose of the unmanned aircraft system will inform the decision to invest in the survivability of the aircraft.

3.2. Command and Control System

UAS's have a command and control system for preprogramming the flight and/or direct remote piloting. The command and control system consists of uplink and downlink communications that can be encrypted, navigation equipment and Global Positioning System, applications software to control the aircraft and the payload. The UAV ground station may vary between an laptop to a fixed plant installation within the country of origin, and of course the physical treat to the ground station varies according to this factors.

The uplink transmits command and control information from the ground station to the UAV while the downlink provides health and status information from the UA to the operator.
Information for the control of the payload can also be transmitted in the downlink. Generally, these communications channels emit continuously, thereby allowing radio direction finding techniques to be employed against the ground station and its UAV. Depending upon the UAS, the command and control links may be interleaved with the payload (i.e., information dissemination) data link or there may be two separate links.

Vulnerability in the data links is jamming and intrusion by hostile forces. Jamming may degrade the ability of the system to transmit signals between the ground station and the UAV, especially if the antenna on the UA is omni-directional, vice steerable. UAV operating within radio line of sight from their control stations are more likely to use an omni-directional antenna approach, while UA operating through communication satellites are more likely to employ a steerable dish antenna with a relatively narrow beam. Unintentional jamming from friendly or neutral communications emitters may also degrade the UA's capabilities. Hostile forces may intrude into either the C2 or the data link in order to take over the UA or degrade the UA control or payload data reception so that it cannot carry out its intended mission.

Navigation equipment, most likely GPS, and mission management software provide the UAV the capability to fly a given route and execute its intended mission. We have to take in account that GPS is the propriety of UAS and access to it can be easily limited, also GPS jamming is also a vulnerability that has to be Taken into account, leaving the UAV grounded or worst.

The mission management software can also be affected through several means either before or after the aircraft is launched. Viruses, Trojan horses, and other hostile software agents can infect the UAS' software and keep the system from fulfilling its mission.

3.3. Payloads

The mission payloads vary according to the UAV type, with the overwhelming majority of UAV payloads being imaging payloads; therefore this discussion will be limited to imaging payload survivability. Payloads can be either external, as in a ball or pod that hangs from the aircraft, or internal. In smaller, less expensive UAS, locating the payload internally does not dramatically decrease vulnerability. Payloads are generally not specifically targeted in the smaller aircraft because it is just as easy to destroy or degrade the UAV itself.

Although payloads are not subjected to physical treats do their small sizes, they are most likely to be affected by collateral damage, however the payload is the point of UAV's mission any damage to this subsystem will render the UAV useless.

3.4.Dissemination Means

The normal way of an UAV to disseminate information is via data links. Depending upon the system, information may be processed onboard the aircraft or transmitted to the ground for processing. In either case, the communications channel is susceptible to detection, radio direction finding, intercept, and electronic attack efforts. If the UA is transmitting a live video feed, the communication channel is likely to be wideband and continually emitting.

Encryption of the data links would reduce the possibility of successful intercept and exploitation. Depending upon the UAV system, the dissemination data links and the command and control links may share the same frequencies and be interwoven through multiplexing schemes.

The data links and the transit and receive equipment associated with the dissemination of information are susceptible and vulnerable to the same efforts that threaten the command and control links. The dissemination data links on larger aircraft should be encrypted, as they are more likely to be relaying data that are of interest to higher echelons. Conversely, handheld/small and tactical UA may not require encryption devices because it is harder to intercept their dissemination signals (closer to the ground station and flying at lower altitudes) and because the information they collect and disseminate is highly perishable.

4. SURVIVABILITY CLASSIFICATIONS

If we are to consider the survivability of the airframe it is more logical to divide the UAV's in 3 categories (small, medium and large) based on the size, operational altitude and speed. These categories will help consider the type of threat that they are susceptible and also their operating environment so that survivability can be applied. Although categories are useful this should not be taken into account has a deciding factor, studies for individual UAV is key, for they are unique in their design and missions.

Small. UAV with a MTOW weight less than 225 kg, a wingspan of 6 meters or less and that operate at altitudes below 3,000 meters and 185 km/h. They are generally used for tactical reconnaissance. Examples include the Raven, Dragon Eye, Pioneer and Shadow.

Medium. UAV with a MTOW weight between 225 and 2250 kg, a 6-18 meters wingspan and generally operate at altitudes of 3,000-10,000 meters and below 460 km/h. They are generally used for tactical or operational reconnaissance, they can be equipped to for supplies drop offs. Examples include the Predator and Fire Scout UAV

Large. UA with a MTOW weight above 2250 kg, wingspan longer than 18 meters and that operate above 9,000 meters and over 460 km/h. Used for operational or strategic reconnaissance, these types of UAV have long endurance and also can be outfitted with weapons. Examples include the Global Hawk, Euro Hawk and also Taranis.

5. THREATS BY SURVIVABILITY CLASSIFICATION

For the real assessment of UAV threat the system has to be treated as a one that includes ground stations and data link as well as the aircraft itself. The wide varieties of weapons have to be taken into account such as energy weapons (DEW) and nuclear, biological and chemical. Table 1 shows a basic of the threats that UAV have to face on the modern battlefield.

Table 1. Survivability classification lethal threat matrix

Survivability Category	Ground Fire	Air Defense Artillery	Shoulder Launched Missiles	RF Missiles	Air-to-Air Missiles	Laser	NBC
Small	✓					✓	✓
Medium	✓	✓	✓	✓		✓	
Large – Low Altitude	✓	✓	✓	✓	✓	✓	
Large – High Altitude				✓	✓		

Table 2. Survivability classification non-lethal threat matrix

Survivability Category	Jamming	Deception	Meaconing	Intrusion and Exploitation
Small	✓	✓		
Medium	✓	✓	✓	✓
Large – Low Altitude	✓	✓	✓	✓
Large – High Altitude	✓	✓	✓	✓

6. SURVIVABILITY EFFECTIVENESS

The decision sub-criteria identified for evaluating survivability effectiveness are as follows: (1) Situational awareness; (2) Stand-off range; (3) Signature reduction; and (4) Countermeasures.

6.1. Situational Awareness:

The overall information is shared over a network enabled system that is self-synchronized to enhance survivability. The extent of awareness is calculated by an assessment program that includes the following: (1) Systems integrated in the network; (2) Degree-of-communication across systems; and (3) Criticality of the data in enhancing survivability. The system gives a score depending on the above factors which is measured an a degree of situational awareness, although the score may vary in a short period of time the total an average score is kept.

6.2. Stand- Off Range:

Stand-off range is the distance that a system can effectively operate while still being beyond the effective range of hostile threats. Greater standoff ranges provide increased survivability

6.3. Signature:

Signature reduction enhances survivability by limiting the capability of the adversary to detect the system and follow offensive action. The type of signatures and the way adopted to address survivability is as follows:

Visual: This signature is governed by physical size of the system (VTUAV), where survivability is enhanced by smaller designs. UAVs are classified as micro, small, medium, and large based on its maximum takeoff weight, wingspan, operating altitude, and speed. The size difference is significant between the variant classifications, but does vary within the classifications.

Acoustic: The main contributors to noise are the propeller, and motors. The acoustic signature is estimated based on an assessment matrix which includes the following: (1) Type of motors - electric, turbine, diesel, solar-powered and futuristic technologies; (2) Location - external or internal; (3) Tip shape and speed - lower tip speeds and non-squared tip shapes provides low acoustic signatures; and (4) Tail propeller configuration -NOTAR anti-torque system reduces acoustic signature. The system in consideration is allocated scores based on these parameters. The total score is a measure of the acoustic signature.

Thermal: The major source of heat is the propulsion subsystem of the UAV. The thermal signature is estimated based on an assessment matrix which includes the following: (1) Mufflers that reduce heat from engine exhaust; (2) Heat-absorbing materials; and (3)

Cold air mixing that reduces heat from the engine exhaust. Air friction creates heat on the leading edges of an aircraft. The system in consideration is allocated scores based on these parameters. The total score is a measure of the thermal signature.

6.4. Countermeasures:

Active countermeasures such as warning sensors (radar, laser, and missile), jammers (radar and infrared), and chaff and flare dispensers enhance survivability by countering the threat of missile fire. Contribution to survivability from a system's countermeasures is measured by the number of defensive systems in the payload design and their effectiveness in countering the threat identified in the operational environment.

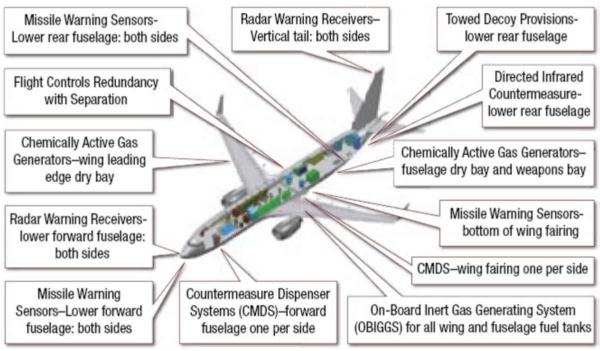

Figure 2. Types of countermeasures

CONCLUSIONS

UAVs present major challenges if they are to survive as an independent system. It is necessary to implement better procedures that require new and innovative technologies, with better and safer capabilities in the automation and optimization of mission planning in unstructured environments within the entire flight envelope. It is also necessary to accommodate subsystem/component failure modes without major performance degradation (the maximal takeoff weight and the aerodynamics of small vehicles are very sensitive to all the additional equipment's) or loss of vehicle and to perform extreme maneuvers without violating stability limits.

The future work regarding the swarm problem opens new avenues of research where the intelligent control community can contribute significantly in terms of smart coordination / cooperation technologies.

We believe it would be very important to continue work on this study with reference to specific situations, especially military actions, under different conditions from the above study. The primary characteristic is represented by the existence of hostile environment. In this case in the same airspace there will operate aircrafts (including UAVs) from both conflicting sides, which will not be cooperate with each other to achieve the separation minima, but they will even try to postpone or even collide with the enemy aircraft. This situation is more complex as in the same airspace is shared with operating civil aircrafts from some operators that are neutral to the conflict.

The survivability concept has been presented as a new view on the way to designing future UAV's, although implementing the survivability on existing systems is not always recommended because of the cost/life beneficiary, this remains to be established for the individual UAV's already existing on the market.

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