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Current Usage of Unmanned Aircraft Systems (UAS) and Future Challenges: A Mission Oriented Simulator for UAS as a Tool for Design and Performance Evaluation

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Abstract.

This paper summarizes background fundamentals of unmanned aircraft systems (UAS) as related to terminology and diverse applications. This information is followed by a discussion on the challenges that need to be overcome in order to take full advantage of what UAS may offer, focusing on control system design, autonomy and cooperation. A UAS simulator currently under development at the Technical University of Crete, capable of simulating complex aerial systems under operational environments, is presented. The simulator is mission oriented and is focused on the design and performance evaluation of these systems.

Keywords: UAV, fault tolerant control, simulation

1 Introduction

Unmanned air vehicles (UAVs) were once the stuff of rumor and legend, identified in the press as new and mysterious. "New shapes in the sky," declared the headlines at one time in the recent past. Now they seem to be commonplace, on the battlefield at least, where they are seen carrying out surveillance missions and deploying weapons with great accuracy. They are now truly the solution to some of the dull, dirty and dangerous tasks for which they were first proposed. However based on the annual reports of the U.S DOD ([1]-[3]), main contributor to the future evolution of UAV systems for military use, being the main R&D funder, there is a long road ahead.

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Whatsoever, apart from the military applications there are many jobs to be performed in commercial and government applications in surveillance, monitoring and trouble-shooting in the fields of utilities, maritime rescue, customs and excise and agriculture to name only a few. Some police forces are collaborating with industry to develop systems to replace helicopter surveillance. Numerous studies indicate a possibility for an increasingly growing market for UAV systems that can reach a total of 17 billion dollars in the next decade ([4]). The main barrier to their application has so far been the difficulty in obtaining certification to operate in controlled airspace.

Despite their success however, UAS are not well understood in terms of their true perspective since most users and researchers focus on the aerial vehicle itself ignoring that UAS is a complete system and should be treated as such. Scope of this paper is to present an overview of UAS focusing on terminology, history and applications. Future challenges both for military and civil applications are discussed focusing on autonomy, cooperation and control system design. Finally, a simulator, being developed at the Technical University of Crete to address the above issues and support research activities, is presented. The simulator treats UAS as a System of Systems (SoS) and is mission oriented trying to assist system design by assessing system elements interaction that impacts top-level system performance for specific missions.

2 The Unmanned Aircraft System (UAS)

The following discussion partly reproduced by [5] clarifies some of the terminology used for Unmanned Aircraft Systems. An Unmanned Aerial Vehicle, UAV, also known as a drone, refers to a pilotless aircraft, a flying machine without an on-board human pilot or passengers. As such, ‘unmanned’ implies total absence of a human who directs and actively pilots the aircraft. Control functions for unmanned aircraft may be either on-board or off-board (remote control). This is why the terms Remotely Operated Aircraft (ROA) and Remotely Piloted Vehicle (RPV) are in common use as well. The term UAV has been used for several years to describe unmanned aerial systems.

Recently, the most ranked international organizations like the International Civil Aviation Organization (ICAO), the EUROCONTROL, the European Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA), as well as the US

Department of Defence (DoD), adopted the term UAS or Unmanned Aircraft System as the right and official term. The changes in the acronym are caused by the following aspects:

- The term "unmanned" of the UAS refers to the absence of a pilot from the flying part of the system
- The term "aircraft" signify that UAS is an aircraft and as such properties like airworthiness will have to be demonstrated
- Finally the term "System" was introduced because of the fact that UAS is not just a vehicle but a (distributed) system consisting of ground control stations, communication links and launch and retrieval systems in addition to the aircraft itself. A typical UAS comprises system elements in three major segments (Figure 1):
    - **Air Segment**: this segment includes one or more Unmanned Aircrafts (UA) with their payloads. Each one of the UA includes the airframe and the avionics and propulsion system. The payload consists of systems that support the intended mission capabilities. It is formed by the required systems for the mission such as cameras, sensors, antennas, etc.
    - **Ground Segment**: distributed in different parts, the Ground Control Station (GCS), the Payload Control Station /Ground Data Terminal (GDT) and if necessary the Launch and Recovery System (LRS). In the ground segment, the GCS is the most important part. It includes all the required equipment for the UA pilot, flight planning and mission monitoring. Also, it translates pilot inputs into the appropriate commands to be transmitted over the communication link to the aircraft segment.
    - **Communications Segment**: It is divided in the Command & Control data link, the Payload data link and the External Communications. The main categories of link are defined according to the distance at which the UAS is operating: Visual Line of Sight (VLOS), Line of Sight (LOS) and Beyond Line Of Sight (BLOS).

Without loss of generality, the term UAV or UA can be used to refer to an unmanned aircraft, while the term UAS is used in instances where other parts of the system like the control station are relevant. The same terms could be used when referring to one or multiple systems.

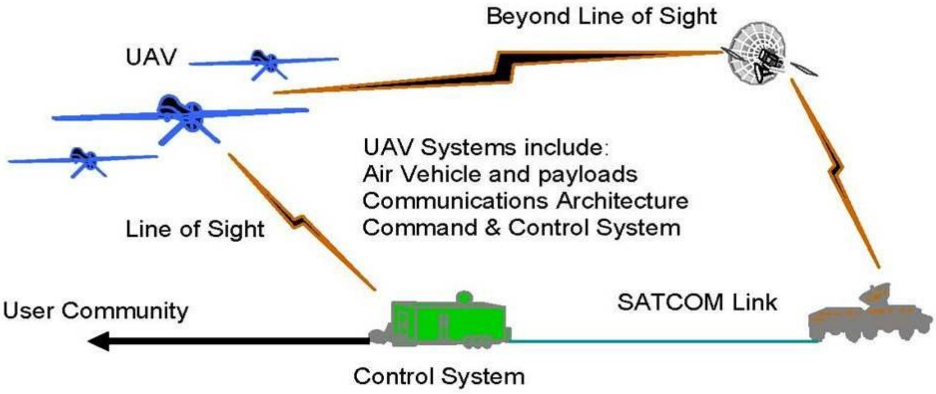

Figure 1. A typical Unmanned Aerial System (UAS)

3 Military UAS Usage

Although their first use dates back to the First World War and the Vietnam War, widespread use of UAS and their incorporation into military tactical forces started practically after the Gulf War in 1991, as their ability to conduct operations with minimal cost in human lives for the allied forces was proved in combat. The utilization of these systems in recent conflicts over Iraq, Serbia and Afghanistan, have proven UAS to be an invaluable asset in the hands of military commanders.

Currently UAS seek a place and role at any level in the chain of command from the corpse to the battalion and recently to the platoon level. Most military unmanned aircraft systems are used for intelligence, surveillance, reconnaissance (ISR), and strikes. The main user is the U.S. DOD, followed by the Israeli Military Forces. However a number of countries including Greece have conducted development efforts for a UAS system and more have already incorporated at least one UAS system in their military forces.

The main characteristics of modern military UAS are summarized below:

- Diverse size and ranges depending directly on the level of integration (battalion, platton, strategic, etc)

- Increased vulnerability and attrition rates mainly due to their low cost/reduced reliability construction and the reduced situation awareness caused by the absence of an on-board pilot.
- One at least human user per aircraft (usually a mission equipment user is present per aircraft)
- Limited autonomy (based on flight control functions available in most manned aircraft)
- Direct handling/piloting by the human user and increased reliance on command/control communication links
- Missions demand low maneuverability typical for Air-to-Ground surveillance
- Mission endurance measured in hours
- Control systems are based on linear control techniques
- Path planning based on waypoints
- Low cost inertial units and sensors increase dependence on GPS systems for navigation and control
- Minimal emphasis on operational security, thus fairly easily detectable acoustic, thermal, visual and communication signatures.
- Payloads designed for integration with a single platform

The next generation of UAS will execute more complex missions such as air combat; target detection, recognition, and destruction, strike/suppression of an enemy's air defense, electronic attack, network node/communications relay, aerial delivery/resupply, anti-surface ship warfare, anti-submarine warfare, mine warfare, ship to objective maneuvers, offensive and defensive counter air, and airlift. Facing significant budget cuts and continuous pressure from voters and the public for decrease in losses, the military is expected to replace as many manned missions as possible covering a significant part of warfare activity. This future trend is also tied to the general trend towards information warfare and net-centric systems.

The DOD goal is that by 2017-20, one third of the aircraft in the operational deep strike force should be unmanned ([3]).

Part of the above mentioned CONOPS is depicted in Figure 2.

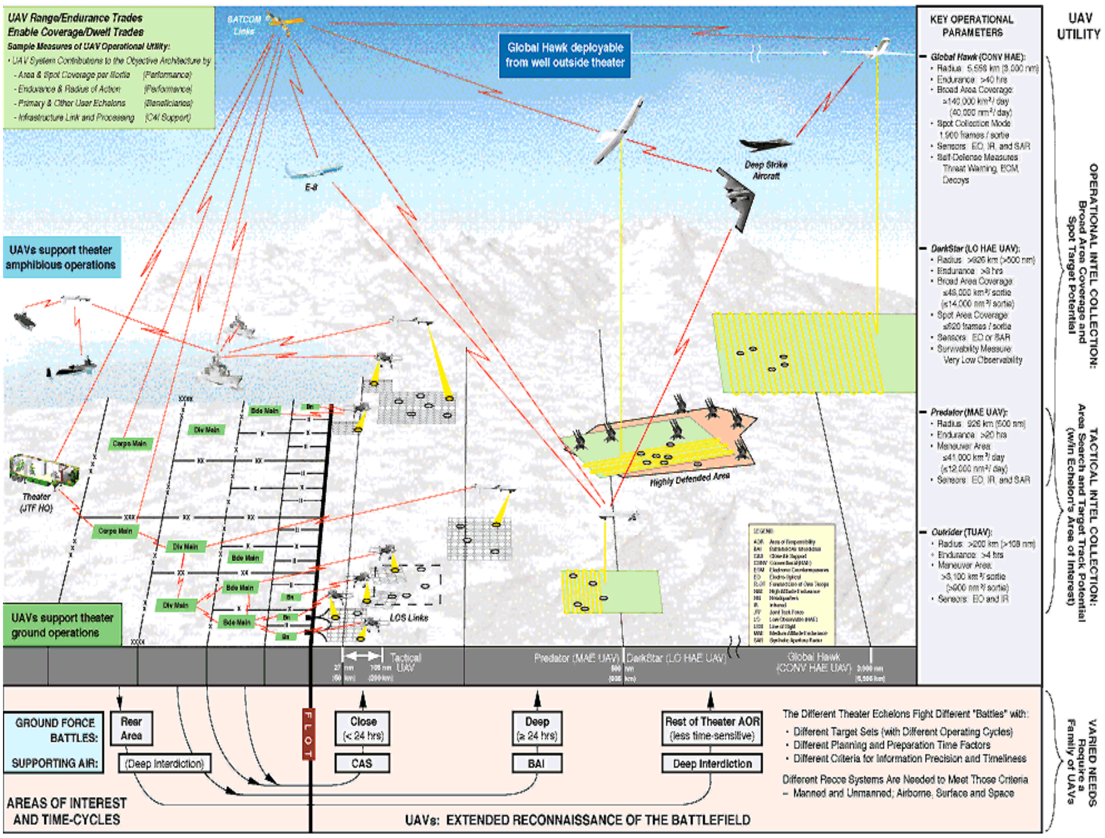

Figure 2 CONcept of OPerationS for future UAVs in the Theater of Operations

According to the US DOD reports [1]-[3], the performance envelope for unmanned systems must keep pace with the demands of the missions that will be expected of these types of systems, thus performance attributes associated with unmanned systems are expected to evolve significantly. Key performance attributes UAS must exhibit in order to enable the projected missions and tasks are:

- The level of autonomy should continue to progress from today's fairly high level of human control/intervention to a high level of autonomous tactical behavior that enables more timely and informed human oversight. Thus today's remotely controlled systems will turn to highly autonomous UASs (or groups of UASs) that will act as flocks.
- Performance would thus be able to evolve from today's human operator to platform ratio of many to one or at best one to one, to a single operator being able to monitor multiple unmanned systems performing across domains as collaborating teams.

- The focus of human interface with the machine should evolve from today's current physical interfaces such as joysticks, touch screens, etc., to interaction such as hand signals, and ultimately to natural language understanding in order to be tasked for missions.
- In order to carry out missions in a covert manner, low observable and signature management attributes will be desirable. As the need of communication between humans and UAS will always be a requirement, the spectrum in which UAS communicate must evolve past radio frequencies and exhibit an agility to hop around in the spectrum to ensure robust and secure communications.
- Mission duration should increase from hours to days, weeks, months, and feasibly years. This is a key, desirable attribute as manned tasks are always constrained by the human body's need for food and sleep.
- Survivability, maintainability and reliability issues should be resolved if longer mission durations are to be accomplished. Minimally, UAS must be reliable enough to keep up with mission endurance times.
- Mission equipment packages will be required to be interchangeable between platforms and potentially even across domains.
- Situational awareness is also a significant issue. In the air, UAS will need the ability to sense objects and avoid them, the biggest challenge being small objects moving at high speeds. The situation awareness capability is closely related to the availability of increased range sensors and highly intelligent processing algorithms.
- Speed and maneuverability could also increase well beyond that of manned systems where limitations are imposed by human physical limits. The human body can only sustain 9 Gs of Acceleration, whereas technology is the only limiting factor for unmanned systems being able to execute maneuvers that create forces reaching or exceeding 40 Gs

The X-45 Unmanned Combat Aerial Vehicle (UCAV) built by Boeing Corporation, European nEUROn and EADS Baracuda all already share some of these design objectives.

4 Civil UAS Usage

Nowadays and after many years of development, UAS are reaching the critical point in which they could be applied in a civil/commercial scenario. The potential civilian applications can be categorized into five groups (Figure 3) ([5]):

- **Environmental (or earth science) applications:** These include remote environmental research (i.e. magnetic field measurement, ice thickness monitoring etc.), atmospheric monitoring and pollution assessment (i.e. stratospheric pollution monitoring, CO_2 flux measurements etc.), weather forecast, geological surveys (i.e. mapping of subsidence and mineral distribution, oil search, etc.).
- **Emergency applications:** These include firefighting, search and rescue, tsunami/flood watch, nuclear radiation monitoring and catastrophe situation awareness, humanitarian aid delivery, etc.
- **Communications applications:** Telecommunication relay services, cell phone transmissions or broadband communications are several of communication applications.
- **Monitoring applications:** These include homeland security (marine and international border patrol, coastal monitoring, law enforcement etc.), crop and harvest monitoring, fire detection, infrastructure monitoring (oil/gas lines, high voltage power lines, pipelines, etc.) and terrain mapping (forest mapping, remote sensing of urban areas, etc.).
- **Commercial applications:** These include aerial photography, precision agriculture-chemical spraying, transportation of goods and post, etc.

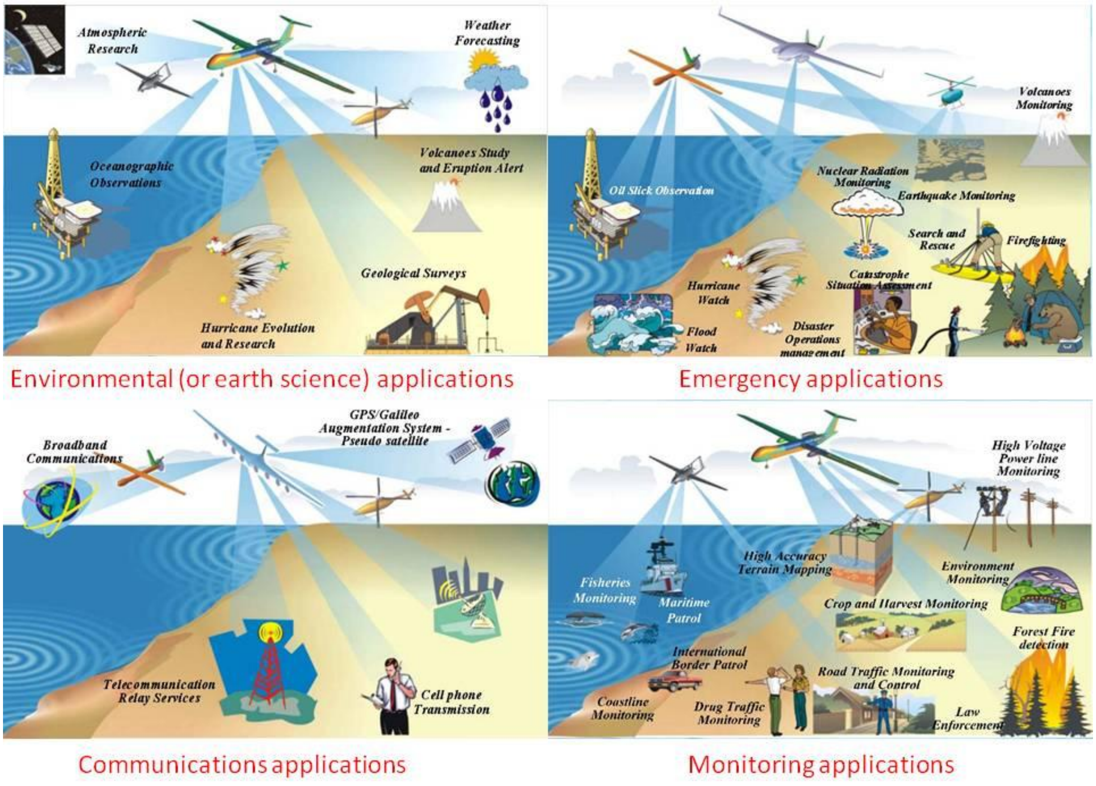

Figure 3. Potential Civil Applications for UAS

There are several companies developing and producing hundreds of UAS designs. Indeed, major defense contractors are involved in developing and producing UAS (like Boeing, Lockheed-Martin and EADS). At the same time, newer or smaller companies have also emerged with innovative technologies that make the market even more vibrant. U.S. companies currently hold about 63–64% of the market share, while European companies account for less than 7% ([6]).

Several market studies have predicted that the worldwide UAS market will expand significantly in the next decade. Even conservative studies, predict the total expenditure to reach 7.3 billion by 2017, the most significant catalyst to this market being the enormous growth of interest in UAS by the US military however the civil UAS market is expected to slowly emerge over the next decade, starting first with government organizations requiring surveillance systems similar to military UAS such as coast guards, border patrol organizations and similar national security organizations. A commercial, non-governmental UAS market is expected to emerge much more slowly ([7]).

As indicated in [8], the main drivers for UAS civil market expansion are expected to be:

- **Increased capabilities** (especially endurance, real time deployment and full spectrum coverage) when compared with other technologies (Figure 4): Endurance, closely related to mission duration over a target of interest and full spectrum coverage, a characteristic of the sensors deployed, seem to be the main advantages of UAS over manned aircraft, ground observers and satellites.

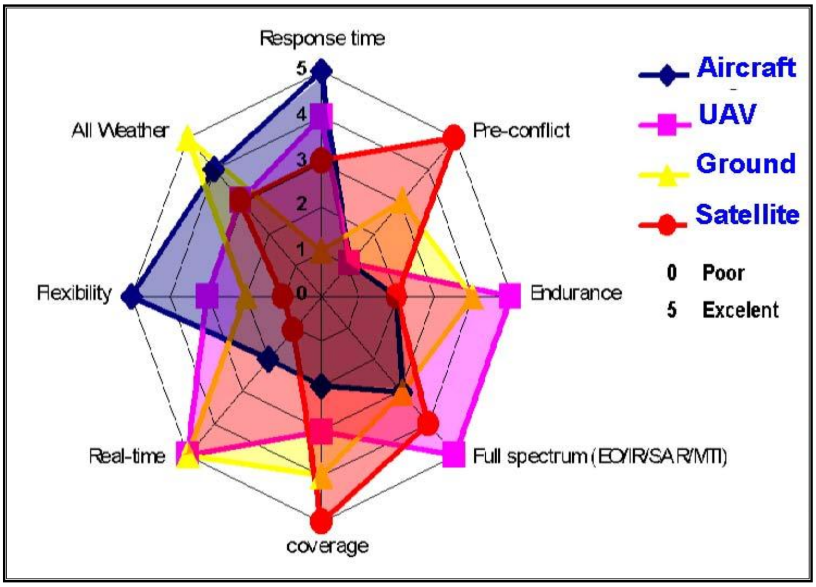

Figure 4 UAV capabilities compared to competing technologies

- **Cost advantage**: UAS are often expected to be more cost effective than other competitive technologies. The cost, which can be broken down into procurement and operational cost, is only one component of the achieved efficiency however, since it must be related to the benefit obtained by the system operation/deployment which is highly mission dependent. For a typical surveillance mission (Figure 5), the benefit can be expressed by the product of area (square km) times the mission duration (flight hours). It is obvious that for the mission examined in Figure 5 there is a window of opportunity based on cost for UAV system usage, caused by the relatively low initial cost of procurement and deployment and the high benefit (area coverage per mission) due to their long endurance.

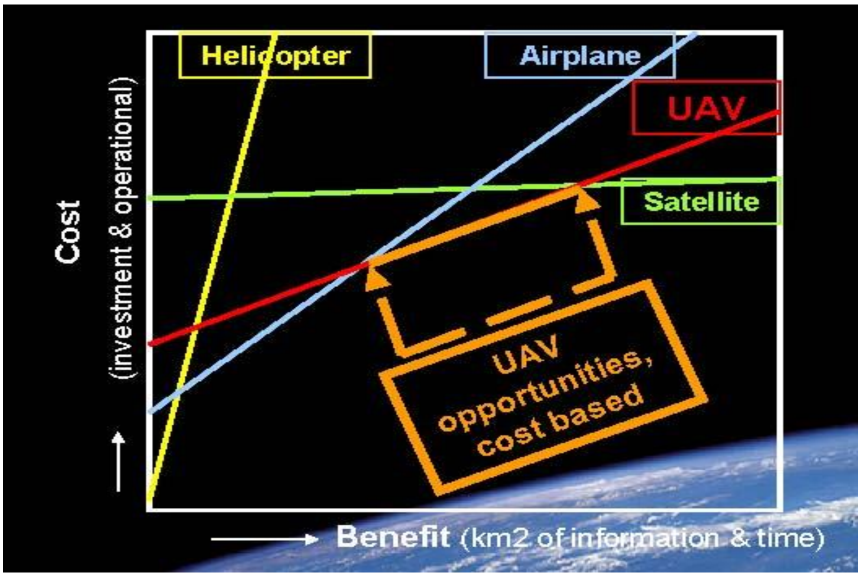

Figure 5. UAV cost advantage for surveilance missions

- **Technology maturation**: Mainly due to military applications UAS technology is expected to mature leading to cost reductions, safer operation and public approval.
- **New applications:** The widespread use of small and medium size UAS is expected to create more applications tailored to their use.

Similar to the military use, the research effort in order to respond to the potential use of UAS for a variety of science and civil operational missions-applications is led by two American organizations (the Radio Technical Commission for Aeronautics (RTCA) and NASA) and one European (UAVNET). Although a unified roadmap has not yet been published, there are general guidelines i.e. [8]-[10] for potential UAS-based civil mission concepts and requirements:

- The major barrier to civil UAS expansion has been identified as their restricted operation in a segregated part of the airspace. Virtually all of the civil applications discussed will require access to either a country's specific national air space (NAS) and/or foreign air space at some point in the flight pattern. Even missions intended for remote areas require access to get the aircraft to the area. This has not (for the time being) been the case for military use of UAS that are deployed in conflict areas where most civil aviation is ceased). However civil use requires UAS to be operated in close proximity to human activity and to be fully integrated into the Air Traffic System (ATS). This requires both the development of standards and regulations and the improvement of UAS design cycle that needs to be based on airworthiness requirements similar to those of manned aviation ([11]).

- Secure and reliable communications have to be established both between the UA and the control station and/or the ATS control station and the UAS to support the procedures developed.
- Reliability has to improve significantly to meet airworthiness requirements but also to meet the requirement for longer mission duration.
- A high level of autonomy in the mission management function is required to take advantage of using a UAS platform to support the missions. Less direct human interaction in flying the UA allows less on-station personnel, less on–station support infrastructure, and one operator to monitor several vehicles at a given time. These goals must be balanced with the requirement for the operator and vehicle to respond to air traffic control in a timely manner. The mission management system should also allow re-direction of the mission (including activating the contingency management system) from the ground. This would especially be useful for dynamically changing operation environments which cannot be adequately foreseen at mission initiation. It is envisioned that the human interaction with the onboard mission manager system will occur at the mission objectives level.
- Just like military UAS, the use of swarms of UAVs is going to be necessary for the cost-effective application of UAS in many civil applications, especially those involved with monitoring.
- Longer durability and robustness to weather conditions and turbulence will also be a requirement depending on application.

5 Future Requirements for UAS control system design

Based on the above discussion, future UAS focused both on military and on civil markets will be based on the lower investment and operational costs, the higher robustness/endurance to climatic conditions and the longer mission duration. Each of these requirements creates the need for additional ones from the point of view of control and navigation system design as illustrated in Figure 6:

- The need for lower investment costs imposes the requirement for a simpler and faster design process accompanied by less modeling efforts than today's manned aircraft ([12]). Current design process for air vehicles control systems demand careful modeling based on wind tunnel and flight testing and a complicated and intuition based gain scheduling effort. Future control algorithms are expected to have increased requirements for robustness to modeling uncertainties while a «generic» control law for similar designs with the need of minor tuning will be desirable. Thus both robust and adaptive flight control designs are expected to be favored instead of the current static PID based control laws ([13]).

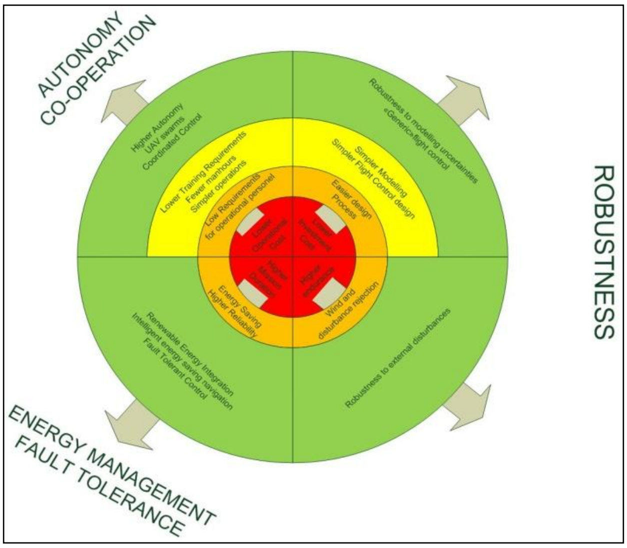

Figure 6. Future UAV Design Requirements for Flight Control and Navigation Systems

- In a similar manner, higher endurance to weather conditions and disturbance rejection is expected to push for clever and robust control algorithms that will allow the UAS to be deployed in harsh conditions. Although size and inertia are key elements of robustness to external disturbances, future systems are expected to rely on bio-inspired designs mimicking animals like bees and insects or birds that use the weather conditions rather to achieve their goals instead of counteracting them like current man-made aircraft.

- Lower operational costs are also expected, leading to lower operator to air vehicle ratio, higher autonomy and close co-operation. The above mentioned functions are one step ahead current flight control designs for manned aircraft that are limited to stability and control augmentation and simple altitude/attitude hold functions. This is going to be a major break-through since future systems will be expected to achieve autonomous take-off and landing, sense and avoid functions, chose between maneuvers much like a current pilot would and conduct a flight plan (both off-line and on-line). What's more, they should be able to switch between controllers in a near optimal way to achieve specific goals based on the mission phase and objectives exhibiting «behavior». The ability to learn and improve by training their «behavior» and choices like a pilot would, will also be a desirable characteristic. Finally, swarm formations, which are a key element of lower operational cost, especially for surveillance missions, demand the implementation of distributed control functions in order to form and sustain formation flight. Designing controllers for such a large and interconnected system is a daunting challenge necessitating a structured approach and system architecture.
- Finally, higher mission duration is identified as another key future characteristic for cost to benefit reduction. In order to achieve the desired mission durations UAS navigation algorithms need to become adaptive and intelligent, aiming to energy efficient navigation. Moreover, UAS reliability has to be significantly improved. Based on manned aircraft experience, this can be achieved by a combination of a stringent development process both for hardware and software, hardware (and software) redundancy (the use of triple or quadruple sensors and other equipment in safety critical systems is common to all aircraft ([14])) and dissimilarity and installation segregation of critical components. However, unlike manned aircraft, unmanned equivalent impose additional constraints in the above process due to limited payload and weight restrictions that prohibit the use of physical (hardware) redundancy in the system. Moreover the cost involved in the use of high reliability equipment could restrain the cost benefit of UAS in civil applications. It is thus necessary to develop

reliable algorithms for fault detection and isolation using the concept of analytical (or software) redundancy (FDI) combined with algorithms that make possible to control the vehicle in faulty situations (fault tolerant control (FTC) concept). Despite the high variety of methods ([15]), FDI/FTC techniques are not widely adopted in the aerospace industry and only some space systems have incorporated these techniques in the final design. The reason for this is the immaturity of the methods especially for nonlinear systems as well as the complexity of the designs and the possibility of high false alarms in case of large modeling uncertainties and/or disturbances. What's more, the high risk of human lives in manned aircraft, along with the mature and tested alternative of hardware redundancy, makes the incorporation of the above methods less attractive. This is not the case for UAs where the reduced payload prohibits (or restricts) the use of existing hardware redundancy schemes.

Additional requirements are imposed by the need of increased performance especially for military applications. These requirements will need to expand the flight envelop of current UAS significantly, from low maneuver, waypoint navigation to the accomplishment of demanding maneuvers. Control systems should then evolve from simple, linear based to non-linear, adaptive designs.

What's more, the use of UAS swarms especially for surveillance missions, will favor agent based software architecture ([16]). This architecture may be the answer to UAS equipment interoperability issues as well. Under this framework, a UAS swarm will form a large, decentralized sensor network that will allow the formation/action of agents in the form of software components residing somewhere in the network that can achieve a specific goal. In the case of a deployed UAS for example, two different search and rescue tasks, one involving a human team and another a boat emitting a rescue signal will be represented by two independent software agents initiated by two different ground control stations. Each of these agents will be able to form teams, access sensor information and possibly interact with individual vehicle control system to form search plans and navigation paths.

Finally as outlined in ([17]), the future control system will be required to accomplish multiple, complicated tasks autonomously, like take-off, cruising, maneuvering, landing, choosing targets etc. In most research projects a dedicated controller has been proposed for each task, therefore switching between controllers maybe necessary. Also most projects require planning and navigation algorithms that adapt to mission changes and supervise the «analog» low level controller. The interaction between discrete and continuous dynamics is neglected in most works and hybrid modeling and control theory is expected to provide a unified framework to consider the system as whole.

6 UAS Simulation

The above requirements are new to industrial flight control system design. They bring together the fields of artificial intelligence and computer science along with the field of control system design and embedded systems. Although such research is active for almost a decade, no fielded UAS exhibit for the time being such concepts in control system design.

Moreover, the interaction of several elements of UAS that impact top-level system performance is very difficult to assess during the design phase. For example, the interactions between sensor resolution, unmanned aircraft number in a given typical mission, energy consumption and information collection (area covered times endurance) is difficult to optimize during the early design phase. A simulator capable of accurately predicting the operational use of UAS would be an invaluable asset.

The main features of such a simulator would be the following:

(1) Low cost and wide acceptance by the research community
(2) Accurate simulation of flight dynamics and available sensors to enable low level control system design
(3) Capability for fault injection by changing the dynamics of sensors and actuators or the vehicle itself. Such capability is essential for adaptive and fault tolerant control system design
(4) Multi Vehicle simulation, possibly heterogeneous, capable of sharing the same environment and mission. The number of participating vehicles can be medium between three and twenty for an envisioned UAS.
(5) Communication between the vehicles is another essential feature. Imperfection or failures in the communication channels should be supported.

(6) Agent Based simulation is another useful feature, for the capability of simulating the behavior of autonomous entities (being the vehicles or software elements) that can cooperate for the success of a given mission.
(7) Capability for hybrid systems simulation to allow the exploration of interactions between the discrete high level controllers and the «analog» low level ones.
(8) Dynamic response from sensors like images could be useful, as well as autonomous operation of other agents that do not belong to the UAS.

Many simulators, including game engines have been proposed in the literature for Unmanned Aircraft Systems ([18], [19] provide a good survey). However, Commercial Of The Shelve (COTS) simulators that offer accurate aircraft models and realistic environment visualization, like X-Plane and Microsoft Flight Simulator apart from their cost, have proprietary APIs making difficult their modification and use for adaptive and fault tolerant control design. Game engines on the other hand do not attend the requirements when aerodynamics is a major focus ([20]). Open source platforms like FlightGear is a possible candidate, since it provides accurate flight dynamics simulation, networked mode of operation and capability of importing external flight dynamics sources like Matlab, however it does not at the time being support hybrid systems simulation. Matlab/Simulink is another platform that has already been used for aircraft control design and simulation. It is widely accepted in the research and engineering community and has a lot of available toolboxes like Aerosim or Flight Dynamics and Control (FDC), for aircraft simulation. Matlab environment through SIMULINK/STATEFLOW provides also excellent modeling and simulation capabilities for control and data flow applications mixing continues and discrete time domains [21]. Matlab/Simulink has already been used for Multi-UAV simulation [22], however the application assumes perfect communication channels, 2D navigation only and is limited to a target destruction military scenario. Other simulations based on discrete event or agent based simulations (mainly implemented in Java), like those proposed in [23] or [24] (CoUAV), implement kinematic models only for the aircrafts involved to avoid heavy computations. AgentFly proposed in [25] is another multi UAV simulator capable of simulating large numbers of aircraft simultaneously (in the order of tens of thousands) while incorporating accurate physical models. However AgentFly is built to simulate Air

Traffic Control (ATC) Systems and its architecture is not very efficient for control system design since the aircraft's control system is split in different computer nodes making hybrid systems simulation a challenge.

In order to promote research in the areas outlined in section 5, a simulator is being developed by the Technical University of Crete. The simulator is modular allowing for easy access and modification of different parts of the simulated vehicles and is developed in Matlab/Simulink with the use of FDC toolbox. STATEFLOW provides the means of simulating hybrid parts of the system, especially fault injection and controller switching in the individual aircraft level. Communication channels provided by MultiUAV2 simulator were modified to allow for faults and inaccessibility typical in wireless communication. The simulator's architecture is shown in Figure 7.

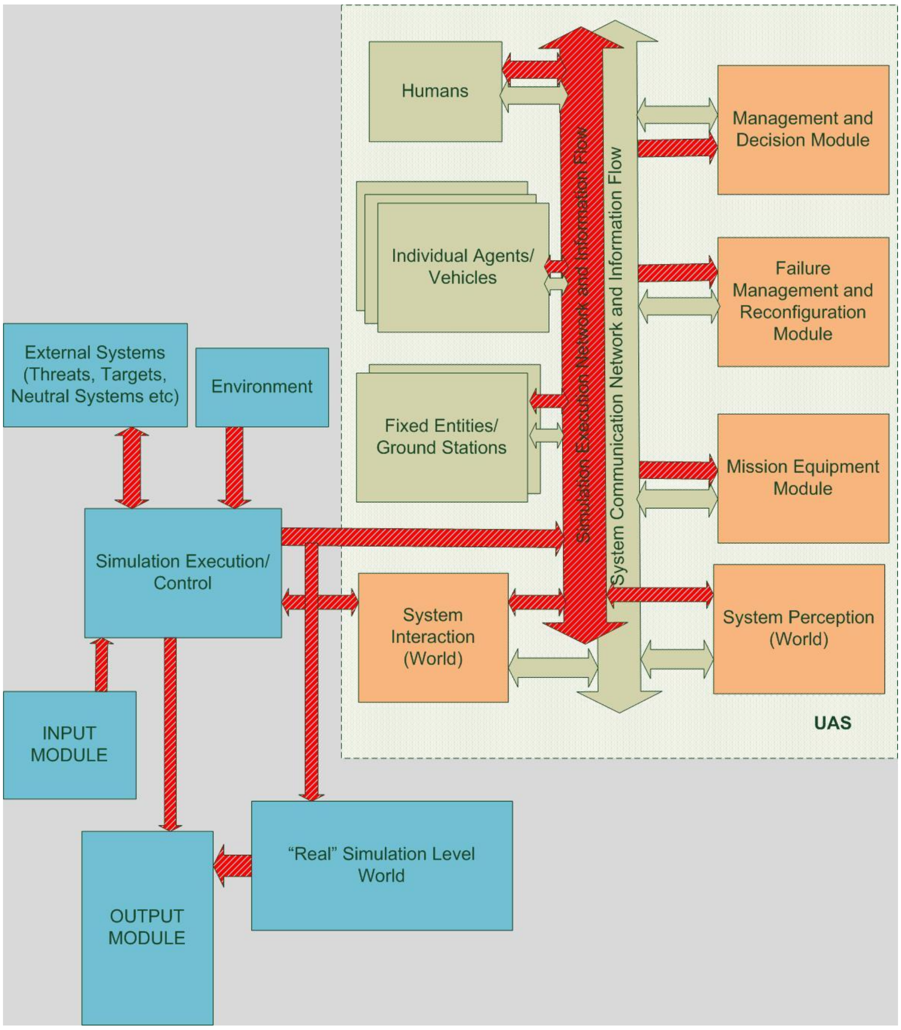

Figure 7. UAS Simulator Architecture

The architecture of the simulator is based on two separate Network and Information Flow Buses. The Simulation Execution and Information Flow Bus is used for the simulation execution only and carries «true» information about the world and the state of the UAS system and the other contains the UAS perceptions of the world that may differ between separate entities inside the UAS.

The simulation is controlled by the «Simulation Execution and Control» module, that provides interaction of the UAS with the «real world» including other hostile or neutral systems and the environment, supports input functions through the «Input» module and produces the outputs of the simulation based on specific metrics through the «Output» module.

The UAS is composed of two different kinds of entities the «fixed» ones depicted in grey in Figure 7, are separate physical entities like the aircrafts, the ground station and other components of the UAS. Another kind of components represents software entities (agents) that can be executed in several nodes at the same time, can be triggered or aborted and can «negotiate» UAS resources, like the UAS «perception» module or the «Failure Management and Reconfiguration» module. These modules are modeled as agents also through the SimEvents toolbox of Matlab.

The main features of the architecture are transferred to every level like the individual aircraft module shown in Figure 8 below.

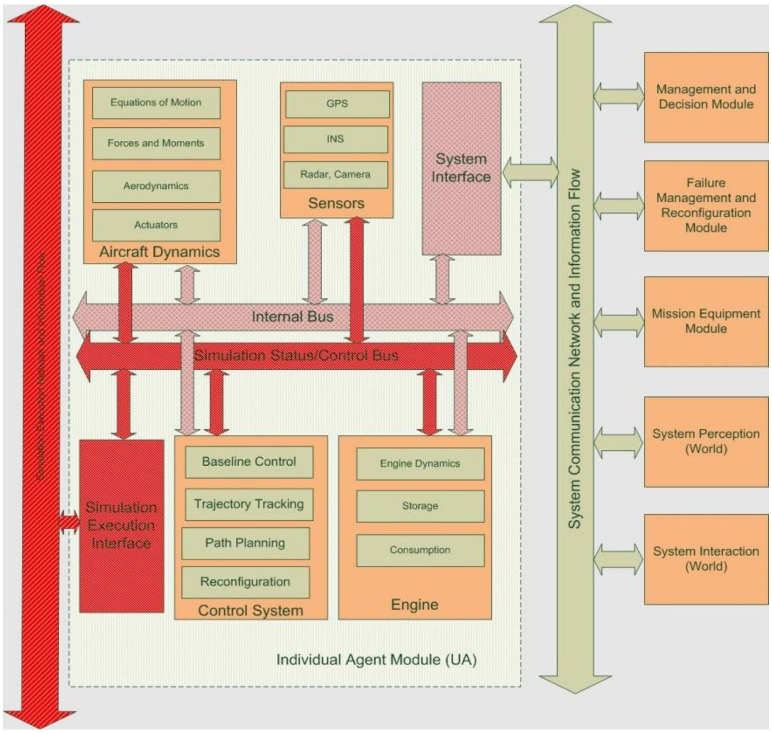

Figure 8 Individual Aircraft Agent Module **A**rchitecture

7. Conclusions

In this paper we have presented background fundamentals of unmanned aircraft systems (UAS). Focusing on the systems engineering framework we outlined UAS components and current usage in both military and civil sectors. Future characteristics of UAS based on reports from major research funders like the US DOD and NASA (for the military and civil sectors respectively) were discussed and the requirements they impose on the control system design of future UAS were presented. It seems that high performance nonlinear control algorithms robust and possibly adaptive will eventually take the place of simple linear waypoint following approaches currently in service. Increased cooperation and swarm behavior even for small teams of UAs forming a UAS will become necessary and algorithms for the implementation of such behaviors will need to be developed. Hybrid theory framework could be the tool of validation of these algorithms and the effects that their discrete dynamics will have on the continuous dynamics of UAS.

Future UAS design will have to be based on solid simulation tools to help the designer optimize the system in an early phase. Such a simulator based on modular architecture is being developed at the Technical University of Crete to support current research directions. The architecture of the simulator was presented and detailed description of the implementation will be included in a future work.

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