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UCAV: A Technology Assessment Project as a Complex Problem Case Study

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Abstract

It is generally accepted that the next generation of combat air systems will include Uninhabited Combat Air Vehicles (UCAV). This paper outlines the issues addressed during an international project funded by national European MODs under the scope of EDA concerning the technology needs for the next generation of UCAVs. The definition of the project structure and the timeframe for sharing work and for financing are discussed. The fact that this was an international project in a sensitive research area like defence was a constraint that had to be taken into account. The different partners' perspectives and capabilities are described. The approach was to choose the war scenarios where the combat air systems will be deployed before assessing the technology issues. The technologies needed to be developed for the definition of the planned air combat systems are summarily described with emphasis in the control systems, communications and maintenance procedures, discussing their availability and sustainability issues. Finally the costs associated to the combat air systems were briefly presented mainly comparing the alternatives for manned or unmanned systems and the cost associated with variable dimensions of the combat air systems (single and multiple platforms) according to the specific needs of each MOD defence policy.

Key words

Engineering Systems, human communication, complex systems, UCAV, UCAS, UAV, UAS.

1. Introduction

It is widely recognised that the next generation of combat air systems will be partly composed by aircraft without pilot on board. This type of aircraft called UCAV for Uninhabited Combat Air Vehicle, to be effective and to survive in hostile territory, shall be a complex machine and quite different from Remotely Piloted Vehicles (RPVs) or present generation of UAVs (Uninhabited Air Vehicles).

"Assessment of Technology needs for UCAV" was a research program devoted to the forecast, definition and evaluation of the technologies necessary to build complete UCAV autonomous systems. This program was carried out from mid 2005 to early 2008 in cooperation among seventeen companies and institutions in Italy, Norway, Portugal, Spain and The Netherlands. The program was developed under a contract issued by the WEAG CEPA 15 organization and successively novated by EDA.

From the beginning the complexity of the task was understood to be paralleled by the complexity of the system itself: in fact, the study could only be carried out if it would take, not only the UCAV itself as the object of study but, expanding its scope, the entire UCAS (for Uninhabited Combat Air System, see Figure 1), as needed by the customer (the MoDs). To cope with it, dynamic grouping of partners for each subtask was arranged and innovative thinking was discussed in brainstorming meetings at several levels. The process provided a useful case study from the Engineering Systems perspective.

2. Project structure

Within the European MOU under which this topic for research was defined, the rational for the appearance of a new project is based on a Request for Proposals (RFP), prepared by experts representing the MOD's of the participating nations that elaborate on the main goals to be achieved, on the operational requirements that the project should address and on the financial envelope, within a certain timeframe, available for the development.

Based on that RFP the biding consortia have to present a detailed proposal, covering all the aspects from technical to financial and management.

Being a cooperative project among seventeen companies and institutions from five nations, an issue to be addressed in first place was on the understanding of the capabilities and competences in place, on the best way to split the project into work packages and on the relative effort that should be put into each one. To solve this major problem a table with those entries was prepared and each company/institution filled it up according to their own perspective and interest (both at institutional and national level).

Despite the group being adequate to the required diversity of technologies to be accessed, some overlapping of competences and interests was evident and had to be harmonized. Also, the preliminary effort that was allocated to the different WP's and WE's was not in line with a balanced distribution, mainly due to the excessive weight of individual interests/know-how on the topic.

A first balance was obtained allowing for the elaboration of the biding proposal but real life showed, during the project execution, that in some cases such balance had to be re-evaluated for the sake of additional in-depth analysis that some topics needed.

A more sensitive question was on the WP leadership. But it was easily accepted that each nation should be in charge of at least one WP and also that the responsibility of the Project Management WP should be with the Consortium leader.

3. Defining the system: from the scenario definition to the prospective solutions, constrains and degrees-of-freedom.

Against other cooperative R&D projects lead by the Research Cell of WEAG, where the issue of a Request for Proposals is based on a comprehensive set of requirements, established by the agreement of MoD representatives of the participating nations and is delivered in advance to the biding partners, this project was faced with a much different approach. The explanation for this different attitude may be due to the fact of the sensitive nature of the topic under appreciation.

As a matter of fact, to establish the requirements for a UCAV System implies that the assumption of a doctrine to sustain the scenarios should be addressed prior to the definition of the different missions that would be performed by this type of aircraft; all this within a timeframe of 2018.

As for the doctrine, at the time this project was being prepared for RFP, the European Defence Agency was still under final definition and the European Security and Defence Strategy being finalized, so it was assumed that NATO's could be the ruling guide. But for scenarios the situation could be much more sensitive.

Under these circumstances the developing team of scientists and engineers tried a pragmatic approach to provide the establishment of a solid concept and a realistic roadmap to sustain it.

The team retained a scenario consisting of a conflict evolving from a Limited Scale War to a Peace Enforcement operation to a Peacekeeping operation. Evolving conflicts are considered to be typical situations in the near future (three blocks war). In addition, the scenario is located in a distant area, requiring that the deployment issues of a European Expeditionary Force should be addressed. As EU national survival and vital interests are not at stake under this generic scenario, it was also considered that there will be very low allowance for own casualties and collateral damage.

This wide result was obtained as the answer from a matrix, where alternate scenarios against selection criteria were filled up, trying to reproduce at one stage the most demanding situations and also emphasizing those that objectively were considered as more adequate for unmanned aircraft.

However, the final result showed that, based on the retained scenarios and corresponding missions, some of the missions were not adequate for UCAVs and were naturally skipped.
Accordingly, the logically chain was initialized with the “Operational scenario definition for UCAV systems” followed by the “Identification of threats envisaged in the operational scenario and by the “Mission definition to different scenarios” in order to investigate aspects of specific UCAV missions in relevant scenario.

4. Technical development

The first item then discussed in this study was the need for an un-inhabited combat air vehicle especially when compared with a manned combat air vehicle as used today. Although it was argued whether one is operationally better than the other, it is important to state that human lives (pilots) could be at stake and this overshadows most other issues. Once the need of such a vehicle was established, the study focused on identifying the typical missions that the unmanned aircraft would undertake during its operational life. Again, a special attention was given to missions where the civilian life-threat was considered very high.

The study then focused on how to accomplish these missions. A basic definition of the aircraft was established. Re-equating the tools needed for accomplishing the mission a new platform emerged where the capability of performing a mission was not based on one aircraft but on a swarm, so that, if one aircraft is damaged, its role is undertaken by another.

Three main types of UCAV System architecture and operational concepts were identified based on the analysis of possible future scenarios and missions for UCAV, each one of them having big impact on both the aerodynamic and system configuration of the UCAV air vehicles and as well on the autonomy needs for the mission execution.

The identified possible UCAS Architectures were:

- Single UCAV: all the functionalities in one platform
- Multiple UCAV: functionalities distributed among several platforms (swarm concept)
- Combined UCAV and manned platform: functionalities distributed between UCAV and manned platforms

This early result coming from scenario analysis, led the Industrial Consortium to the decision to continue the study by assessing two different types of air vehicles, one of bigger size, the other of smaller size, in order to better cover the requirements for the above three architectures and to explore as well the possible technological implications. Both types of vehicles were to be compared with the forecasted technology trends to assess their feasibility and were successively tested against the defined scenarios, using simulation, in order to evaluate the strength and/or the weakness of the preliminary assumptions and to evaluate possible further technological needs.

Of course this dual design concept may be seen as a compromise, a lack of focus and the project as a non conclusive. However, since this was a technological assessment, the diversity of concepts, technologies, and system approaches that were fully analyzed, weighted, and in certain cases even simulated, the double solution considered was believed to represent a significant contribution for future work to be performed and for modular architectures to be developed in follow-on activities.

The ground and space components of the UCAV System (Control Station, Data Links and SATCOM, logistics and training) were included in the study but were not part of the simulations.

The project was also to address the identified UCAV key capabilities and characteristics and their technological implications on UCAV sub-systems. Some relevance should be given to the vehicle autonomy in both the technological and operational aspects, and to the impact on the air vehicle Mission Management System (MMS).

Since the aircraft was un-manned the problem of controlling it was critical. The technology involved on data relay and processing, both for the ground stations and for the platform itself, was analyzed. Also of major importance was the possibility of deploying, or not, the control station. The logistical problem in both situations is quite different, not only based on the technological aspects (shipping/flying the platforms to the war theater), but also involved the human aspect (troop moral) since the troops could accomplish the mission away from the combat front.

The use of such a system (UCAS) on a combat zone will require a strong maintenance support to keep it available and in working conditions. A new approach to the maintenance was established where the front-line maintenance shall only identify the aircraft damaged parts of the aircraft and replace them with new ones. The damaged parts shall be sent back to the manufacturer for repair. For this two-step maintenance to work correctly the aircraft must have a diagnosis capability to identify which parts need replacing, meaning the development of SHMS[1] and SPHMS[2]

Also of great important was the human interface problem, not only the direct machine-human interface but also the ability that a person must have to operate the system. Therefore the training process was also an integral part of the study, focusing not only on the ability to certify of the various operators but also on the continuous training to keep the operators qualified.

The diversity of this project can be exemplified by the new concepts regarding the systems availability. For the operator (Armed Forces) this availability should be immediate and permanent. This means that the system itself must be able to identify if it is operational or not when in storage, but also that the personal operating the system must be kept fully operational even when the complete system is in storage. This lead to the “hands on”/“hands off” training approach, with the “hands off” approach being based on Computer Based Training.

Finally the whole cost of the system was identified for all the possibilities already explained. This cost was then compared with the cost of a currently existing manned aircraft.

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[1] Structural Health Monitoring System

[2] Systems and Powerplant Helth Monitoring System

This study therefore focused on the whole system and not only on the airframe itself (or on the purely control aspects), as illustrated in Figure 1. All relevant areas for the project, as a whole, were identified, from logistical problems to human factor problems.

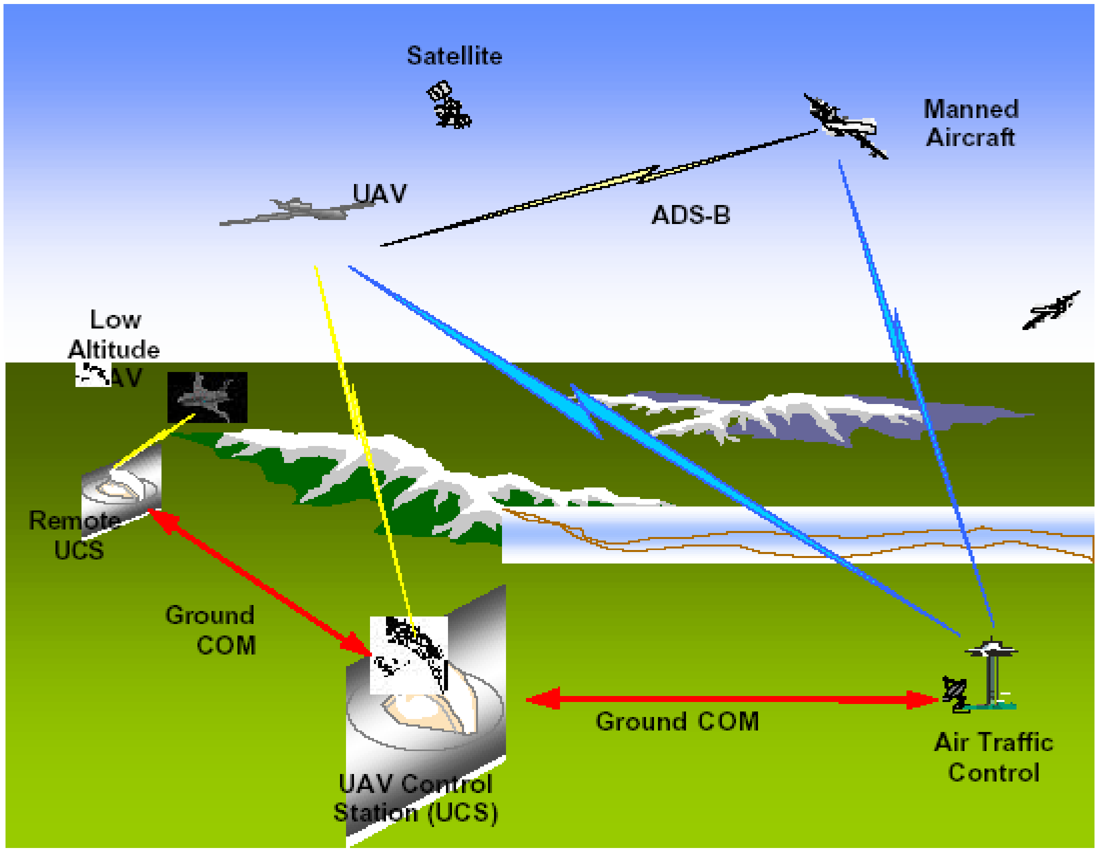

Figure 1: The UCAV System (UCAS)

Even if the technologies addressed were UCAV-related, it was understood that they would not be necessarily UCAV-only: in fact many of them will be applicable on other UAS or on manned aircraft, such as technologies for automation for decreasing pilot workload or data-link and human-machine interface for improving pilot situational awareness.

With all the system areas studied and detailed, the necessary technologies where identified and from these which needed further research so that the system would be operational on the required time frame; in fact, this was the main reason for the entire project: provide recommendations from the Industrial Group about the technological areas where research investment should be privileged in order to achieve an UCAV system technology level adequate before the foreseen industrialisation. The conclusions were presented specifying the foreseen necessary funds for each area.

As expected and besides the common goal of achieving a successful conclusion of the project, the different partners had quite different objectives to pursue during this project, depending on their respective capabilities and nature. A strong constraint not clearly foreseen at the moment was the decision to keep the project in an unclassified frame that limited the scope and depth of the analysis, avoiding the most sensitive options or trends, when this military project title would mean looking for innovation.

5. The partners' perspectives, capabilities and aims

In fact, the assumed scope of the project, that is, the technology assessment implied the definition of missions and capabilities for the aircraft and logistic requirements; the cost and performance estimates were used to compare the prospective solutions; and only after that, decisions about the necessary technologies and technology levels could be made. Since the project could help directing the future research effort from the governmental agencies, all partners had something to gain from knowing what would be the trends. In this process, the integrating companies could bring in and take out general concepts and subsystems, the more specialized partners would bring in their specific knowledge and take out the integrating constrains and the academics could bring in their more conceptual approach and take out the needs of industry for further research. Since there were so many partners, different perspectives arose about several points, from the more global issues such as the number and size of aircraft for an operational unit, to the more detailed points such as the type of sensor for a specific end or from the manufacturing and operating costs, to the maintenance philosophy. The different and sometimes opposite approaches were discussed within a framework where each option was scrutinized from the pros and cons of itself to the impact it could have on other aspects. The presence of people of different areas and with different experience provided a fruitful multidisciplinary discussion of a complex problem, without strictly predefined borders.

6. Internal communications and boundary objects

Since the consortium was made of seventeen companies and institutions form five different countries a barrier had to be overcome: efficient and timely information flow. This was an important factor not only within a working group (from a work element WE) but also from one working group to another (from one WE to another). Another important barrier to be confronted was proprietary information from a company. Since this project was labelled as unclassified this could lead to external companies having access to proprietary information, or even within the consortium between concurrent companies. It was therefore necessary to establish from the beginning some rules and boundaries so the project could develop with no major problems.

English was mandatory as the working language. Even though this seems an obvious solution, the fact there were no native English speakers in the consortium led inevitably to some side discussions among those sharing the same mother language that no-one else (or so it was assumed) would understand. This showed that, even among technically minded professionals, highly trained to discuss matters in international environments, the native language still prevails when more tricky arguments arise.

Also, since people had different areas of expertise, lead to same time at ambiguities in some terms used. These ambiguities were noticed from the first meetings and therefore the need for clarification arose quite early. It was decided to keep a “nomenclature definition” that aided with the interpretation of certain terms and acronyms.

To insure a high level of communication between all the partners, it was decided that each WE should start with a formal kick off meeting were all the partners for the WE should be physically present. The information was then transmitted verbally and visually. With the work share agreed between all, each partner would continue the work back home. The information was then passed trough by e-mail. The WE work would finish with another formal meeting between the partners before the final presentation to the client. Experience showed how these meetings increased the cooperation among partners: the personal contact smoothed the integration of the work done, since it allowed for a clearer understanding of each other concepts and ideas. Although teleconference systems nowadays provide almost the same kind of interaction as a physical meeting of highly cosmopolitan engineers, other issues affect the communication, not the least of them the traditional coffee-break: the relaxed conversation allows for a better comprehension of each other facial, gestural and voice intonation peculiarities that will be highly valuable for clear understanding during the technical discussions.

Also the introduction of new concepts, such as a new concept for maintenance, caused some discussion between the partners that proposed the new concept with other partners with established maintenance procedures that viewed the new concept as dangerous step that would not meet the project forecast deadlines. Again, relaxed moments during off-duty hours paved the way for understanding so that an agreement was reached that included all the expertise available.

The client (in this case the five countries MoD representatives) remained an active partner throughout the project. In the schedule meetings where the project development and work performed were explained by the consortium, the client had an active voice in how the objectives should be achieved and how different routes should be followed, forcing sometimes the consortium to alter some of the work already started.

Proprietary information was another issue that remained throughout the project, although the objectives of the project permitted this situation. Since the objective was the identification of technologies to be ready by the established time frame, it was not necessary to share or even explain how this achievement could be made. Therefore the information shared between partners was maintained at a level that permitted the successful conclusion of the project without sharing particular solutions to some of the problems identified. Quite interestingly, a lot of information interchange occurred, valuable enough for the partners although proprietary information remained closed. The assessment of the innovation that such interchange triggered is yet to be made, but some hints were already given and duly appreciated.

7. Building the project on a trade-off

Once these possible configurations were set, the performance oriented technology assessment was performed. For each of the technologies needed, an evaluation of the state-of-the-art against the required level was performed; when discrepancies existed, an experience-based judgement about the expected development of the technologies in time for implementation within the required timeframe was performed. Only the technologies that passed this filter were considered onwards.

Using the systems so defined, an initial cost estimate was made, identifying the main cost drivers.

ILS problems were addressed, in order to provide an optimal solution in the 2018 timeframe. This analysis considered the UCAV system as a driver itself for change, allowing for the implementation of challenging maintenance paradigms using emergent technologies to its full capabilities. This requires that the present investment in these technologies be increased so they become fully mature in time.

The technology upgrade needs and the resulting cost drivers were then analysed in order to provide a set of recommendations for development and their cost estimates. A cross-analysis revealed synergies where investment optimisation is possible. The same analysis was performed for Manufacturing, Operation and Maintenance and for both UCAV types.

8. Conclusion

According to its title “Assessment of Technology needs for UCAV”, the research program presented here appeared as an ambitious research project between a consortium gathering European research institutions and industrial partners in a politically sensitive area.
Since the objective of the research project was to assess the technologies for a future, still undefined UCAV, the requirements and specifications for it were part of the project itself.
On the other hand, the consortium elected to address this ambitious objective was mostly the result of a political balance between the countries involved (as seen in section 2). The modus operandi was consequently constrained by the political equilibrium, between countries or between research and industrials (sec.3, 4 and 6), often associated with pre-existing options or doctrines.
The final solution proposed for this research project in its final report was the possible answer to the initial ambitious objective, but conditioned by various and intrinsic constraints. Nevertheless a set of technologies were selected as needing further development in order to achieve a useful UCAV in 2018 that would comply with the needs of the partner countries

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