DESIGNING PROCESS OF UNMANNED AERIAL VECHICLES.

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Over last decades the strong development of unmanned flying objects known as a Unmanned Aerial Vehicles (UAV) has been observed. Despite being almost as old as the manned aviation (first such craft was flown in year 1908) the fast development of UAVs dates since 60's. Today the UAVs form a group of aircraft quickly developing and entering the world aviation market, which starts to compete successfully with traditional manned aircraft.
The development of UAVs lead to creation of separate market niche with more or less specialized manufacturers. Some of them are present also at the other parts of aviation and military market while others are limiting their activity only to this very specific branch.

The UAVs are finding customers mainly within military operators. The civilian use is still a future. They are so unussual that non of civil aviation authorities is ready to start negotiations about their usage in the civilian air space. However realizing benefits from pilotless aircraft some civil companies have already initiated programs reviewing possibilities of introducing them into service.
After pioneering years companies have gathered knowledge and more experienced teams are starting to create new UAVs. This would result in designs better fitting to still growing customers' needs. Also design procedures which are used are changing and they are becoming much more professional than before. Software and hardware used to support teams is also more and more sophisticated.

The modern UAV design process looks very interesting if not paradoxically. The flying object can be designed according to procedures developed for General Aviation aircraft. Most of the craft from this group has take-off weight lighter or similar to the average homebuilt airplane. Some of new projects lead to the heavier machines but procedures can be still used successfully. However often design sollutions are symillar to those used in aircraft modeling and experience in that helpful.
On the other hand the UAV's project is very complex. The "payload" or "mission equipment" is often technologicaly very advanced to allow completion of difficult missions. This and operational requirements are calling for large infrastructure to keep craft operational and efficient. From this point of view program is much more similar to modern fighter-bomber than light GA plane.

The initial concept of the new craft could come from the potential operator as a result of experience or theoretical concept or be born in mind of the engineer working in the design office. Later the whole process begin to be iterative effort and well known the "Design wheel" remains unchanged (see Fig. 1.). It clearly shows internal influences in the process. Two areas of engineering efforts "Design concept" and "Design analisys" are often mistakenly made equil. The "Design concept" means mainly mental work leading to creation new construction while "Design analysis" aims toward new concepts and technology.

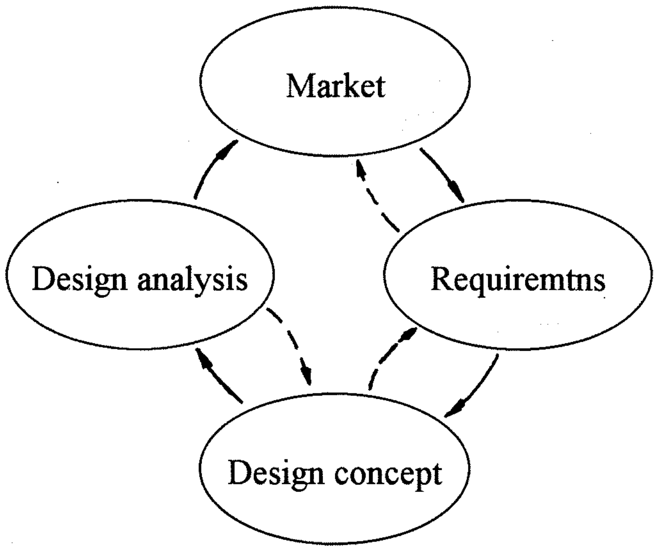

Fig. 1
The Design wheel presents relation of the design process.

A new UAV's system can be considerated within several separate groups:

- aircraft;
- mission equipment;
- autopilot,
- control and data link systems;
- propulsion;
- ground control and mission planing station;
- launching and recovery unit:
- logistics unit.

Creation and development of each of them can be carried on very much independently however sometimes the integration process will have to appear and for many causes it is the crucial part of the project. Designer of UAV must still keep this in mind and try to solve potential problems, it leads to increasing collaboration between separate teams responsible for parts of the final product. There is no such problem in general aviation but it is well known to heavy liners manufacturers. The test technics used by them and "Iron bird" concept applies tests of most modern jet liners is very useful for UAV's design teams.

The design process always should start with the market research and requirements received from prospective operator. Those requirements are in the form of operational requirements or are better known as the technical requirements. After those have been formulated design process can be initiated. (se Fig. 2.)

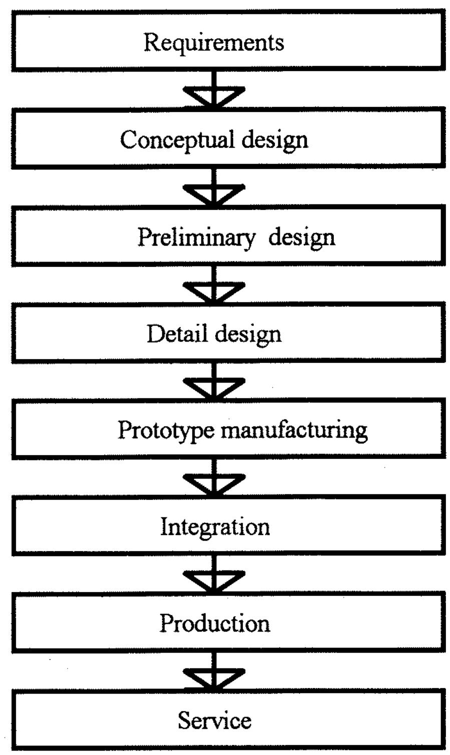

Fig 2.
The sequence of creation of a new UAV.

The Conceptual Design should give answers for several questions as follows:

- Can it meet requirements?
- How it should look like?
- What it is capable to do?
- How much should it weight?
- How much should it cost?

The phase allows to create initial focus of the new design. The several optional layouts can be drawn including various configurations differing externally in lifting surface allocation and size and internally with various configurations of placement equipment, avionics, fuel etc. The wide variety of propulsion can be also taken into considerations. Approximate answers about planes performances, weight and its costs must be received. The equipment to be placed instead on a board should be matter of initial investigations.

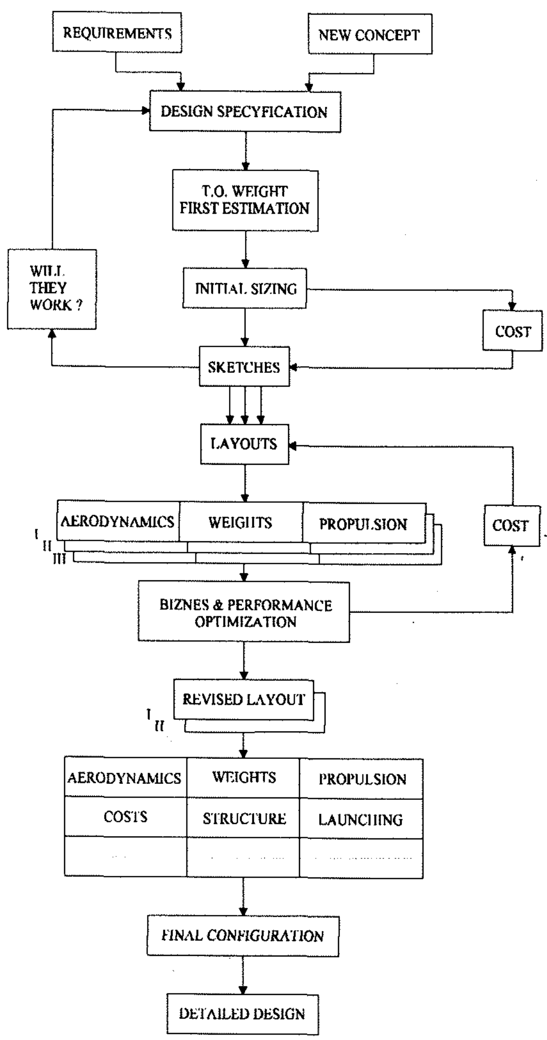

Fig. 3.
Iteration process used for conceptual and preliminry design phases.

Its serviceability and maintainability as well as ability to survive on modern battle field should become matter of interest as they are vital factors influencing successful service.
Several optional missions often not mentioned in the requirementsshould be investigated. The process may lead to new solution with better multimission capabilities. At that stage the requirements might be modified and potential customer may show some flexibility to receive better product.
Analysis of launching and recovery methods and mission planing strategy will take additional time to create efficient aircraft as both are plaing major role in its general layout as well as in the UAV's structure. A part from that initial review of the used materials and parts commonalty should be completed.
During the whole design process the ground support infrastructure must be kept in mind even if designer have no serious reasons to influ this part of the project. First of all the facility plays significant role in the costs and it is one of the key to the success and customers' satisfaction. Also a good coexistence of the plane, its avionics and mission equipment with all supporting installation on the ground will make large contribution to the good or bad opinion about the project. This requires maintainability of the plane.

The Preliminary Design phase is a time for final solutions. Answers awaited here are more specific:

- Which is the best configuration?
- What is the best sizing and weight?
- What is the configuration of operational equipment ?
- What is the best propulsion?
- What are launching and recovery concept?
- What technologies, design solutions and materials are to be used for the structure?
- How much will it cost to purchase and to operate?
- How much damages will it be able to withstand?

- How long ill it be able to be modern and operationally sensible?
- What are the loads to be met by craft during operations?

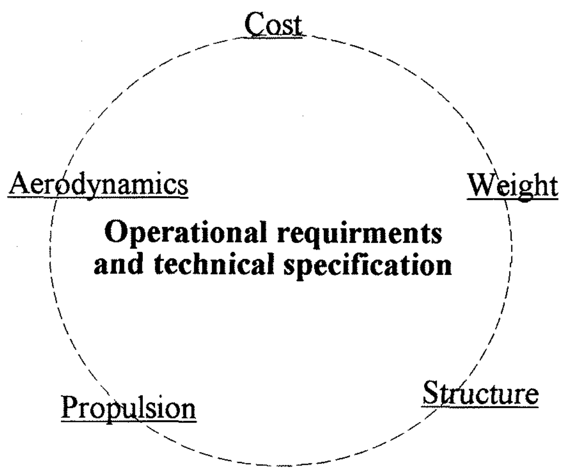

Fig. 4.
The "Design wheel II" used for optimalization of the new craft.

This is time for selection of final configuration and propulsion. After the major changes are over, the design must be optimized to to give as much as possible from its take-off weight. The whole geometry of the craft ie: wings, fuselage, stabilizers must be worked out and optimized. All details concering mission equipment must be agreed however some options might be left for the flexibility of the process and variety of missions. The internal layout should be freezed and basic concept of the structure must be reviewed.

Also all aspects of plane's serviceability and maintainability must be rewiewed. They will have to cover wide range of problems to be faced by serving staff during everyday preflight checkout before and after flight as well as while carring out heavy maintenance and repairs. All of them must be simulated to find any potential problems and solve them before manufacturing begins. This is the beast way to save additional spending necessary if modifications are required while testing or entering service.

At this phase the final decisions are expected about planes flexibility, parts standardization, generally used materials and manufacturing strategy.

The Detail Design phase covers all efforts necessary to prepare technical documentation of the new design.

With requirements already setled the activity carried by engineer can be expressed by playing with five factors: weight, structure, aerodynamics, propulsion and costs. Today the last factor must be understood deeper than only as traditionally optimized Direct Operating Costs (DOC). With DOC still being major factor in economics comparisons the purchase cost and life cost are becoming more and more important for operators. The first makes simply product available for customer or to expensive. The other influences on long terms strategic financial planing what may reflect in the budgets years later after introduction into service. Those two factors are not so significant for large and financially healthy countries. the smaller and not to reach ones may take both of them as the major factors putting less attention on DOCs. This process can be realized in the aviation as well.

The full set of calculations must be done to estimate expected operational loads from maneuvering, turbulence, launching and landings as well as ground service. Methods used to build up the load envelope are based mainz on local solutions as no methods were unveiled by any of the manufacturers. Knowledge about the UAVąs loads during their service is vital to new designs as it allows optimalization of the structure. This benefits as reduced weight and longer life, reduced damages etc. Those information are classified by manufactures and probably creation of civilian airworthiness rules may give more light to the problem.

The Structural Design or Detail Design solves number of local questions:

- What are the the loads?

- What are the detailed design solutions?
- What materials are to be used for particular parts?
- What is the level of parts interchangeability?
- What are the methods of assembling and disassembling of the craft and its equipment?
- How the craft will be manufactured?

The design of the structure must start with detailed calculation of loads which will be taken by particular parts. It is followed by preparation of drawings of all parts of the structure. Also the preparations for manufacturing process including tooling design must be initiated.

Here the main designing process finishes. However the following periods require active participation of the designers, as manufacturing process usually brings some unexpected problems. All tests of the new design must be worked out and than integration process must be passed with separate testings covering all possible aspects of UAV's future service. The final stage will be operational tests carried out in the presence of the operator proving ability of whole system to meet requirements.

As mentioned above design process can be carried out in a similar wat to the General Aviation plane. This is more or less true for whole group, however some-time the requirements to which new unmanned craft is to be built call for extreme performances like super high altitude or very long endurance. As the UAV group develops and planes are becoming more sophisticated and complex more efforts must be undertaken to finish the design.

Lack of human being on board of plane reduces number of problems. Several of installations are reduntant while the other once might be strongly reduced. The available loads and safety also might be seen in a new light. As a consequence for average UAV the complexity of its structure seems to be much lower than for modern GA category airplane due to usually smaller size and less parts. This makes their designer life much easier. The manufacturing process might be also simplified in many causes what brings benefits in lower investments and shorter development time. Unfortunately the high requirements will be strongly limiting advantages mentioned above as structure become complexed.

At the moment an increasing number of aviation engineers starts to be engaged in the designing of UAVs. As a consequence many of new projects appearing on market start to be more and more complex and sophisticated but also sensible. Growing number of experienced aviation engineers benefits with designs optimized for their duty and not built like copies of earlier designs, what often happens in case of lack of knowledge. In the past habits used to play significant role while creating new craft. From time to time is can be realized even today.

Large percentage of operated UAVs are in pusher, twin boom configuration. This solution copied from the projects of 60's is still appearing in the designs of 90's. The good examples of this configurations are Scout, Ranger and Pioneer from Israel, Italian Mirach 26, troubled Phoenix from UK and Swiss Ranger (see Fig. 5).

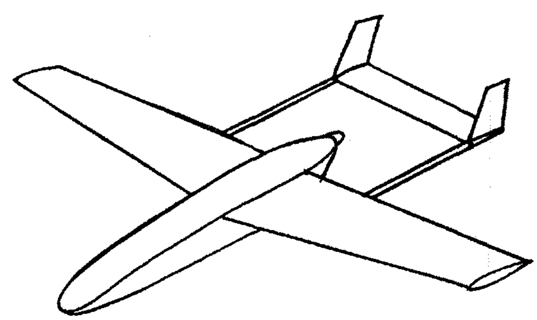

Fig. 5.
Twin boom UAV concept.

Having its logical explanation to allow conventional configuration of wing and tailplane married with pushing propeller it leads to some penalties in weight and more complex design and difficult maintenance. In such case UAV's structure requires reinforcement to take operational loads due to used flat framework concept. The attachment points are much heavier and complex to allow assembling and disassembling during service. Optionally it may lead to disassembled structure but in that case penalty is larger size of the UAV and creates problems about its transportation and storage. The answer is different configuration as proved in service with designs like: Raven from UK or French Fox AT (see Fig.6).

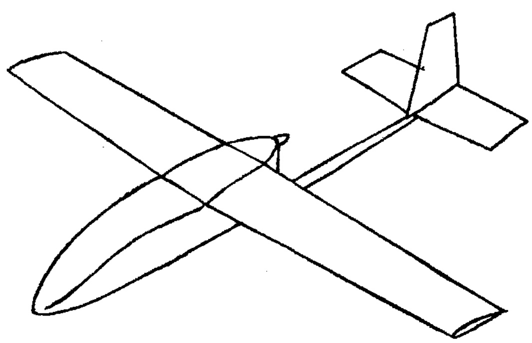

Fig. 6.
Single boom UAV concept.

Those UAvs have got both configuration and structure much more compact. Single boom at the bottom of fuselage seems to be lighter and less complex, easier to maintain and service and already proved its operational capabilities.
Often the main undercariage, if used, also shows similar process. instead of simple streat sollution curved leags are used adding weight to the whole structure.

A part from already mentioned UAVs are offering to their designers other very interesting opportunities hard to achieve in the other areas of manned aviation. The whole system can be compared to the idea known to most parents as a LEGO System. Parts of the plane, its equipment or mission systems can be easily transferred from one to the another design. This enables much quicker reaction to changing requirements and customer's needs.

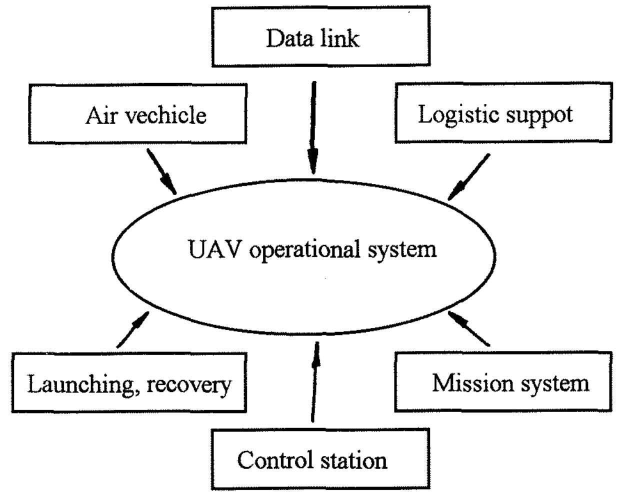

Fig. 7
UAV's system commonality strategy

Also manufacturers gets flexible product easier to be modified.
For aircraft structures this problem is well known and manufacturers like Cessna, Piper, Robin or Socata and other have been practicing it for a long time. For UAV it may lead to specially designed tooling or simple modifications enlarging production output from existing tooling. This may have significant influence on the profitability.
On the other hand production is often limited to short series and molds and jigs are simpler and chiper to build to reduce costs. The avionics and mission equipment are easily transfferalable as well as powerplant is. What again may lead to higher flexibility. UAVs are usually smaller and simpler it-self. The lower costs of their development and manufacturing enables shorter production series with the same level of profitability. This means more differences and modifications including creation of two or more optional solutions which are entering at the last prototyping phase. The only serious problem is special technology of fast prototyping and tooling which are the key for the success under those specific conditions.

That flexibility leads to something very rear at this years: capabilities to see and test large number of planes. The experience received from this activity might become one of the key problems allowing future success in the massive service of the design.

The approach and formulas used while estimating the loads can be also transferred for light aviation. The take off weight of many unmanned planes can be compared to very light airplane and their sizes are at the areas available for some of flying and produced planes registered in the experimental group. The reaction to the turbulence is also similar because of close ranges of used lifting surface loads. While creating structure of pilot less aircraft much can learned from modeling as the lightest UAVs are pretty close to the powered or unpowered gliders build by a little more experienced modelers. The knowledge about the manufacturing technics used for composite gliders and homebuild planes may also bring some profits. However the importance of the product suggests procedures used during creation of a new machine to be more similar to the real plane with benefits from lack of human being on board, size and weight.

For some time the details of design methods used by UAVs manufacturers will remain clasified knowladge. The possibilities of their introduction into civilian operations and creation of civilian airworthines requirements will allow more information to be made awailable for public but this will not take place so soon.
However the process is enough simple that more and more team is undertaking efforts to design and build their own UAV. Many of them have had never before any practical experience in the UAVs or air structures at all. All this recalls earlz dazs of aviation whan planes were build by more or less luckz amators not qualified engineers. The developing market will change this over next years and progress will be chapening faster and faster.

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