Proposing a Special Strategy for Platform RDTE Design Cycle of MAV and Small UAV Aircrafts

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ABSTRACT

The present research proposes a special strategy for the platform RDTE (research, development, test and evaluation) design cycle of the fix wing large MAV (micro air vehicle) and SUAV (small unmanned air vehicle) aircrafts which are two modern classes of unmanned air vehicles. Considering design cycle of classic aircrafts, requirements of these new generations and with respect to main disciplines which govern to the design space of these new classes of aircrafts, essential task items which are affecting their design process were selected. On the base of these tasks a systematic strategy for RDTE design cycle for MAV and the SUAV aircrafts is proposed. In this way in addition to present an academic design strategy which accounting for main platform design features, rather than a per case one, applying the proposed strategy to design such air vehicles has some positive consequences, like robustness of design path and reduction of the required time and cost of MAV and SUAV aircrafts RDTE design cycles.

1 INTRODUCTION

The advance situation of the present automatic systems has made possible accomplishment of more complex operations by the unmanned air vehicles which there have observed their progress continually every day. It may be said that in a near future, with progress in research and development of science and technology in the field of autopilot and control systems, unmanned air vehicles take more serious and strong role in different branches of aerospace operations which is a motivation to have more attention to them in the civil and the military fields.

Some modern, efficient and economic class of unmanned air vehicles are the micro air vehicles (MAVs) and the small unmanned air vehicle (SUAVs). Because of their physic, they have their special design disciplines. These aircrafts use advanced control systems and autopilots in their operations to accomplish different missions. Their advanced mounted electronic systems have made them capable for data acquisition, surveillance, intelligence and recognition.

Governing disciplines such as pointed above, on the nature of their mission, nevertheless of their small dimensions, lead to use the high technology for design and manufacturing these aircrafts, which their effects are appeared in the MAVs and SUAVs design cycle process.

The consequence of consideration of different disciplines in all engineering problems containing aircraft design is the complexity of the problem. Also it must be mentioned that many parameters and processes have essential effects on different phases of the RDTE phases of the MAV and the SUAV design cycle. The affection of different design parameters on each other and on the overall aircraft design and meanwhile, the MAV and the SUAV multidisciplinary nature, like limitation in weight and dimensions, application of advance miniature systems and the expectation to be capable in various operations and flight environments are the causes to establish a complex space for decision making in their RDTE design cycle. In this way applying sophisticated RDTE design cycle in processing the design tasks, may reduces the various effects of design cycle complexities with the consequence of reach to desirable results, in a shorter time , with lower cost and less energy consumption.

To the knowledge of the authors, there is no academic and classic published strategy to RDTE design cycle of the MAV and the SUAV aircrafts. Although many aircrafts in these classes have been designed and manufactured, it seems that their design strategies are performed per case. But it must be mentioned that per case designing gets more energy.

The present research proposes a special systematic strategy to engage with **the fix wing electric engine platform RDTE design cycle for large MAV and small UAV aircrafts**.

2 THE DESIGN DEFINITION AND DIFFERNT PHASES OF THE RDTE PROCESS IN THE AIRCRAFT DESIGN CYCLE

In conforming to some references, design process has been defined as a process at a decision making space and meanwhile try to reach to some acceptable quantities and satisfying some constraints [1]. In other words, design process contains accomplishment of some decision making process on the base of the need, different constraints, standards, stakeholder and user ideas in such a way that lead to create a new system [2]. In the aircraft design process different parts of the RDTE is divided into three essential sections, i.e. conceptual, preliminary and detail design cycles. The definitions of these different phases are presented in any aircraft design reference like [3], [4].In all of the design cycles, the design process is accomplished in different parts of RDTE phases with limited repetition of the design loops, to get some acceptable convergent results. In the next section a brief review of some design cycles are presented.

3 REVIEW OF SOME CLASICAL AIRCRAFT DESIGN CYCLES

Because generally the systems in their initial design steps are not without shortcomings, so the designed systems are corrected by some sequence of design loops till they reach to acceptable results during pass through their design cycle.

The classical aircraft design cycle processes were considered and were analyzed from various features in different references. As examples, some of them which may be used as a background to the present research are introduced in the present section briefly.

Corning (1953) in his book has considered the concepts of transport sub sonic and supersonic aircrafts [5]. This book is

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one of the first documents in the aircraft design field which mostly considered the relation between different disciplines. **Wood** (1966) has presented the fundamentals of amphibious aircraft in his book [6]. This matter was an innovation in his time, because when an aircraft has various flight phases in its mission, various groups of requirements must be satisfied in its design process. These requirements must satisfy different disciplines, which many times they are not similar and the oppositions in the design must be dismissed in some manner. **Stinton** (1966) has considered the structure and different requirements of propeller driven aircrafts [7]. His approach and feature to the design problem has a notification to the aircraft accidents and their original reasons in terms of the designers' decisions making. From this point of view, it may be said that he presented a new feature in his time to induce the idea to the designer that their unfavorable decisions may have dangerous consequences which their effects are more than affecting the flight quality and aircraft performance parameters like range and maximum velocity of the aircraft.
Nicolai (1975) presented a method for weight approximation in conceptual aircraft design with a trend toward military fighters and supersonic aircrafts and also considered the materials which were used for aircraft design and the parameters which were affecting the estimation of aircraft cost [8]. So, he was the pioneer of considering economical feathers in aircraft design. **Roskam** (1985) presented a comprehensive method with the emphasis on the different disciplines of aircraft like aerodynamics, structure, flight dynamics, propulsion, aircraft systems and standards for conceptual and preliminary aircraft design in his 8 volumes series of books [3]. **Whitford** (1989), in his book explained the evolutionary process of the fighters design from World War I until now [9]. He presented a qualitative explanation about different requirements and disciplines and the effect of them to each other in the design of fighter aircrafts. **Tornbeek** (1990) has considered the subsonic transport aircrafts [10]. He introduced some experimental relations for performance parameters and presented a method for weight estimation of different components of the transport aircrafts, their engines, propellers and standards. **Raymer** (1992) has explained different subjects of the aircraft design and presented some issues about capability of high maneuverability, drag forces in supersonic flight, refers to the application of the state of the art sciences like computational fluid dynamics and finite element methods and also the importance of the lofting in his book [4]. **Anderson** (1999) has considered the design of aircraft with notification to the relation of the aircraft performance and aircraft design; also he presented different performance relations of the aircraft in his book [11]. In fact while he presented the performance of aircrafts as the primary axis of the book , implies that performance of the aircraft is completely coupled with its design and simultaneous integration of the different subjects about the aircraft like flight dynamics , aerodynamic and propulsion are necessary condition in aircraft design problems.
Mean while the existence of some classic design strategies, the reasons of need to some new strategies for designing MAV and SUAV aircrafts and the shortcomings of classical ones are presented and explained in the next section.

4 WHY SOME NEW AND SPECIAL DESIGN STRATEGEY FOR MAV AND SUAV AIRCRAFTS IS NEEDED?

All of aforementioned aircraft design methods have their own strategies for approach to the designing of the classic aircrafts, but The MAVs and SUAVs have essential differences with the classic aircrafts and designing them with classic strategies will be faced with some shortcomings or some unused and unfavorable design concepts, so it seems that a new strategy that is more compatible with the nature of the MAVs and the SUAVs and more concerned with their requirements and disciplines is needed to design them rather than using and applying the classic ones. An aircraft class foundation is related to the accepted logic in the design of the same aircraft class. So, perhaps the first questions in the designer's mind to design MAV and SUAV aircrafts are asked in this way:
Is the logic of design cycle for today's unmanned air vehicles the same and confident with the logic which is governed to the design cycle of classic aircraft? Is it possible or suitable to define a special design cycle or a corrected design cycle for designing these classes of aircrafts to cover and overcome the differences? What are the important disciplines that govern to the design of such unmanned aircrafts?
Considering the need to these classes of aircrafts, the continues expanding application of them and the aforementioned questions and their development, may become a motivation and opening a horizon to more research about new design strategies of unmanned air vehicles to get an academic shape to their design cycle.

5 SOME SPECIAL DESIGN DISCIPLINES OF THE MAVS AND SUAVS

Since these classes of aircrafts are some kinds of unmanned aircrafts, many facilities, equipments and systems which are used in a manned aircraft do not exist in them, so the design cycle becomes simpler for them from this point of view. For example the required equipments for environmental control of cabin or cockpit, satisfying special operational standards, structural complexity related to wings and body and empennage, expensive fixtures, hydraulic systems, complex fuel systems, landing gear systems, complex loading and various weight and balance scenarios, reliability studies, inspection and maintenance considerations which are the inseparable parts of classical aircraft design cycles, do not exist in the design of these classes of aircrafts and so, must be extracted from their design cycle process.
On the other hand new subjects have specific importance in their design which makes the design cycle more expanded. For example the problem related to make the aircraft intelligent, apply and use from miniature and small size electronically data acquisition systems, interrelated with optical and communication miniature equipments , advanced miniature autopilot systems for stable and controllable navigation during flight, stealth capability , mounting the systems and equipments on the miniature structure, morphing structures for better performance in operation, management of energy, integration with ground station, communication with the satellites for navigation and technology jumps

challenges and changes during the time are added to their RDTE design cycle [12],[13].

Again these explanations present some of the differences between the nature of the classic aircrafts and MAVs and SUAVs aircrafts and so emphasize to research and apply new design strategies to cover their special design requirements.

6 PROPOSING A SPECIFIC PLATFORM DESIGN CYCLE FOR THE MAV AND THE SUAV AIRCRAFTS

There are high coupling between different items in the aircraft design problems [3], [4]. So, to approach the design of MAV and SUAV aircrafts, at first, the authors recognized and selected 20 essential task items which must be covered in MAV and SUAV aircrafts design cycle (explained items 1 through 20 in the following), and then the design structure matrix (DSM) method has been used to determine the different influences and effects which might be existed between the selected items.

By observing the MAV and the SUAV aircrafts, their operations and comparing them with classic aircrafts, the authors were inferred that the more important subjects in MAV and SUAV aircrafts RDTE design cycle, to accomplish their mission, are three followed essential parts:

Autopilot Navigation	Platform Design	Pay load Selection

With notification to this matter and to insure from performance capabilities of the aircraft in its mission and operation, different concerning design items i.e. platform, autopilot, pay load, needed simulations and various required tests were presented in the proposed aircraft design cycle with more emphasis on the platform design.

Also in the present research different design items, have been presented *holistically and qualitatively* to present the deign strategy and their general details were not considered, but the author's experiences in every design item were highlighted.

The influences of the different items on each other which are in the *design path direction* were not drown in the presented design path in the appendix A, but have mentioned in the paragraphs with the title *"Pointing to the Main influence features"* at the end of every design item.

Anyway, authors propose the various task items which are more important in **platform RDTE design cycle of the fix wing electric engine Large MAV and the SUAV aircrafts** as followed and also the design cycle path is presented in the appendix A to complete each other :

1- The aircraft Mission

The mission of the MAV and the SUAV aircrafts possessing an essential role in their design cycle process and it governs to other important items of these aircrafts like autopilot and pay load. All of the requirements and specifications for the platform, autopilot and pay load are presented in the mission. The designer makes the decisions with respect to the mission requirements for the capabilities and characteristics of the aircraft as for the capabilities of the systems. For example decision making about selection of autopilot subsystems, pay load precisions and abilities, range, loiter, velocity and flight altitudes. It should be said that in the design process of any aircraft, containing the MAVs and the SUAVs, the aircraft has a complete conformity with its mission.

Pointing to the Main influence features:

The mission *has influences on* determination of the flight path, the kind of autopilot system (way point, full autopilot), the pay load kind and its precision, the aircraft required performance parameters and the propulsion system set (battery-engine-propeller) capabilities; and *is influenced by* the pay load, the autopilot, the propulsion system set functionalities and the flight test results.

2- The flight path and required maneuverability

In design process, the optimum six degree of freedom flight path may be chosen for the aircraft with respect to flight altitude, required curvatures during the flight maneuvers, applying autopilot flight path or pass through some special and indicated waypoints, the locations of the obstacles (like mountains, trees, buildings and air turbulences) which it is required the aircraft pass through them during its flight and the required velocities and accelerations of the vehicle in every phase of the flight path that indicate the aircraft performance flight conditions.

Pointing to the Main influence features:

The flight path *has influences on* autopilot (generating correction signals) and pay load (resolution), performance capabilities (engine power and wing area, rate of rotations and rate of climb) and software modeling analysis of flight path characteristics; and *is influenced by* autopilot navigation corrections, pay load capability, software modeling and the flight tests results.

3- The miniature pay loads and related mechanisms

Generally the main mission of these aircraft is carrying a payload that contains some systems. Different payloads with various applications and capabilities relative to the mission of the aircraft may be selected and mount on the MAV and the SUAV aircrafts. These pay loads may be contain various cameras and sensors with required resolution and precision, different advanced miniature equipments and seekers which may be used for surveillance/ recognition/ environmental analysis and indicating special locations during the operational phase of the aircraft [13]. Selection different kinds of pay load characteristics have a great effect on the total cost of the aircraft and of course its capabilities. Sometimes it is necessary to make and mount some additional micro mechanism to link and mach the pay load to the autopilot (like gimbals and signal generator ejectors) to make the aircraft more capable and more accurate in accomplishment its mission.

Pointing to the Main influence features:

The pay load *has influences on* weight estimation, the overall configuration (pay load shape and required mechanisms), ground station receiver, aircraft weight and balance process, aircraft structural design reinforcement, autopilot flight path corrections and flight tests results; and *is influenced by* required autopilot's controller signals for local motions, dictated required resolution from flight pass, ground station communication, hardware in the loop tests (favorable performance) and flight tests results evaluations.

4- The initial weight estimation

In these class of aircrafts, the total weight is contained from the weight of engine, batteries, systems, payload and the aircraft empty weight. The Initial weight estimation is used primitively at performance analysis in the design cycle. Similar aircraft statistical weight information as a data base may be used to estimate the initial weight of the aircraft which is to be designed in the initial phases of design to begin with and then correct it in the design loops, a suitable position is at the aircraft weight and balance task.

Pointing to the Main influence features:

The initial weight estimation *has influences on* performance analysis, weight and balance process and loading analysis of the aircraft; and *is influenced by* the weights of the designed structure, the propulsion system set, autopilot system, pay load and other required systems.

5- The performance analysis

Because of unmanned discipline which is governed to design of these classes of aircrafts, the design philosophy of them is on the base of operational performance. Some other design features like human appreciation limitations, safety and marketing have less importance to allow for. In this way, satisfying the performance equations of the various operational requirements like rate of climb, maneuverability, cruise speed and accelerations of the aircraft during accomplishment of its mission operation are in priority. According to the author's experience, Energy methods [14] or performance base methods (on-going work with authors) are more suitable to analyzing their performance to draw the matching chart and find the design point and design parameters of the aircraft.

Pointing to the Main influence features:

The performance analysis *has influences on* determining wing area, engine power (thrust), aircraft overall configuration, estimation of aerodynamic coefficients, motion equations in aircraft stability and control analysis, software in the loop inputs and structural design load factors; and *is influenced by* overall configuration (aerodynamic coefficients), stability analysis equations (instabilities from engine thrust effects), software in the loop simulations (unfavorable performance characteristics), weight estimation and the overall aircraft flight tests.

6- The overall configuration

Overall configuration has a great contribution on the aerodynamics, stability and control of the MAV and the SUAV aircrafts. Because of the low flight velocity and the small dimensions in MAV and SUAV aircrafts, configuration selection is an essential item in their design cycle process. Generally under the Reynolds number of 300000, there are some aerodynamic problems on the wing of the aircrafts (for example reduction of the lift/drag L/D), which causes the performance reduction and rick of the wing stall. Sophisticating configuration selection, make it possible to well-being the performance of the aircrafts [13]. For example, one way to optimize the performance and stability of these aircrafts in low Reynolds number is harmonic change of the wing shape relative to the existing conditions of the flight environment (morphing configuration) or flexible wing configurations [13]. Another important issue in configuration is aircraft drawings. Digital design tools may be used to preparing the different layouts of the aircraft which are used as inputs to other aerodynamic, structural analysis and flight dynamic simulator softwares. When the aircraft configuration task is satisfied, notification may concentrate to the inside arrangement of the aircraft's components.

Pointing to the Main influence features:

The overall configuration *has influences on* the situation and distribution of the forces , moments , moment of inertias of the aircraft, aircraft stability and control analysis, aircraft weight and balance process, loading analysis on the aircraft structural design, weight estimation, aircraft layouts, manufacturing process and the propulsion system set design; and *is influenced by* the stability and control analysis (angles, geometry and stability and control coefficients), the aircraft weight and balance process, the performance analysis, the propulsion system set, manufacturing process and aircraft overall flight tests results.

7- The propulsion system integration

With respect to the achieved design parameters from performance analysis, engine, propeller and energy supply (which are coupled subsystems) will be selected and integrated over the aircraft as the aircraft's propulsion system set. These components also have a great dependency with the mission and the overall configuration of MAV and SUAV aircrafts. Also the propulsion system has an important effect on aircraft capabilities in its operational phases.

Pointing to the Main influence features:

The propulsion system integration (battery-engine-propeller) *has influences on* overall configuration (angels, position , space of engine and propeller mounting, lunching, propeller down wash on surfaces and crash) , stability and control equation analysis (thrust, inertias), weight and balance process (CG potato) , aircraft structural design (cutouts, engine mount, montage, mounting angles and reinforcements) and aircraft mission; and *is influences by* performance analysis (engine power, mission and also implicitly contains software in the loop simulations), autopilot control signals (speed controller) , overall configuration, weight and balance process, hardware in the loop tests, aircraft stability and control analysis (thrust terms) and aircraft overall flight tests (functional capability of battery's capacity, engine power and propeller efficiency).

8- Inboard profile

In this phase the available space of the aircraft must be determined and it is necessary to arrange the various systems and subsystems like the propulsion system set, speed controller, electronic and communication components, servo motors, autopilot, pay load and antennas in the wing and/or the body of the aircraft in terms of their spaces and weight to make the aircraft ready for the weight and balance process. Corrections may be needed to the overall configuration to accomplish the task.

Pointing to the Main influence features:

The Inboard profile *has influences on* overall configuration, the aircraft weight and balance process, loading analysis and stability and control equations (the moment of inertia distribution); and *is influenced by* overall configuration, weight & balance, systems shape and dimensions.

9- Weight and balance process

Weight and balance process must be done to find the CG potato of the aircraft and specify the locations of CG for stability and control analysis process. Also weight distribution and different moments of inertias of the aircraft may be calculated and applied to complete and solving the loading analysis and dynamic equations.

Pointing to the Main influence features:

The Weight and balance process *has influences on* aircraft loading analysis (location of forces and moment quantities, implicate effect on structural design), stability and control analysis (CG potato and CG location), and inboard profile (system locations); and *is influences by* inboard profile, aircraft stability and control analysis, manufacturing process and structural analysis.

10- The computational fluid dynamics (CFD) analysis / wind tunnel tests

By determining aircraft configuration , it is possible to apply The CFD analysis softwares and/or arranging wind tunnel tests to consider and recalculate the aerodynamic coefficients and aircraft performance analysis outputs in a loop to review the design cycle. Design loops are required until the results converge to each other in an acceptable manner. Flow visualization and CFD modeling validation may be accomplished with particle image velocimetry system (PIV) as an advanced and complimentary measuring [13]. As an essential complimentary task or to become confirm from CFD results, wind tunnel tests may be applied.

Pointing to the Main influence features:

The CFD analysis and / or wind tunnel tests *has influence on* the main performance loop, structural analysis and stability analysis; and *is influenced by* the weight estimation, performance analysis, propulsion system, overall configuration and model manufacturing.

11- Aircraft loading analysis

To determine the forces and the moments distributions which are acting on the aircraft, analytical or experimental loading analysis may be done. The results of these processes may be used as inputs to different computer programs or any other analyzing methods, to study the stability analysis equations and the structural design of the aircraft.

Pointing to the Main influence features:

The loading analysis *has influences on* stability and control equations and structural analysis of aircraft; and *is influenced by* weight estimation, performance analysis, propulsions system, overall configuration (aircraft shape) and inboard profile (location of systems).

12- Stability and control analysis

The motion equations of the aircraft are used to determine the transfer functions, different mode shapes and the response of the aircraft to analyze its behavior during its flight [13]. The responses of the aircraft may be studied to determine the level of stability and controllability of the aircraft and comparing the results with the operational requirement of the aircraft during its mission. For example sometimes it is not necessary to have a stable aircraft and its instability is a necessary requirement for accomplishing its mission during the operation. As an example, during surveillance operation, sever aircraft lateral stability leads to put aircraft in Dutch-roll mode with the consequence of low quality of the camera movies. If the stability situation of the aircraft does not match with operational criteria of the aircraft's mission, feedback loops to overall configuration and performance analysis must be done to overcome the problem.

Pointing to the Main influence features:

The stability and control analysis *has influences on* overall configuration, aircraft weight and balance process (change the CG location), autopilot (programming), aircraft performance (contain implicate effect on the proportion system set), and mission (possibility); and *is influenced by* loading process (stability and control equations), weight and balance process (CG location), autopilot (functionality), software in the loop (simulation of motion), autopilot (need to correction of the equations in the design loops), aircraft performance and overall aircraft flight tests (acceptation of stability and control level).

13- The aircraft structure design

In addition to aircraft flight loadings and load factors, almost every landing of these aircrafts is a crash, because generally they have no landing gear. Many times they must be carried in a back pack and need to be separated in different structural parts. Sometimes they have morphing configuration and moveable parts and also the effect of force and moments during montage and manufacturing process must be accented for. The effects of mentioned loads mostly are very greater than flight loads and must be carefully considered [13]. Also various systems must be mounted in the wing or body of them which need many wing and fuselage cut-outs. so structural design is an important item in their design cycle. In more advanced cases like flexible strictures visual image correlation system (VIC) may be used to analyzing the geometrical and elastic deformation of the structure [13].

Pointing to the Main influence features:

The structural design *has influences on* weight estimation, loading analysis (capability of supporting the loads), weight and balance (selection the mounting location of the systems), the overall configuration (change in configuration) and manufacturing process; and *is influenced by* loading analysis, overall aircraft configuration, manufacturing process, different exerted force during carrying and tests (supporting the different possible loads).

14- Manufacturing of Remote control aircraft and remote control tests

Because of the physical situation of MAV and SUAV aircrafts, manufacturing of them do not take a great amount of cost and time relative to classic aircrafts, so it is possible to build some remote control samples and accomplish a lot of useful ground and remote flight control tests on the aircraft before designing and mounting the autopilot systems on the aircrafts. The remote control flight tests are very important and have crucial effects on refining the designed aircraft [15]. In this way it is possible to become familiar with the aircraft characteristics and consider its behavior during the flight to make required corrections. In the worst situation with some aircraft crash, it is possible to evaluate and confirm design bases during these initial tests. In these tests some weight with similar dimensions instead of the autopilot may be put in the aircraft to have a similar weight and inertia distribution during the tests with the auto piloted aircraft. Also it is possible to determine and fix the inboard profile and accomplish weight and balance process for aircraft stability. So, it is possible to stabilize the used design fundamentals and continuing the design cycle with more aircraft operational performance insurance. It seems that, because of less developed knowledge in the case of the smaller size

MAVs, determination of their behaviors in design process is still more dependent on the tests and experience than other methods. So for these cases the importance of tests is more important and significant.

Pointing to the Main influence features:

All the previous items make it ready to engage with manufacturing the remote control aircraft model and begin the fight tests. The flight tests may have *effect on any of the previous items* to make necessary and required changes. It must be mentioned that manufacturing and flight tests of remote control models may be begin in even primitive steps in the design cycle to confirm from applied design fundamentals and decisions which have been made during design cycle. The other benefits of these tests is presentation of the aircraft's flight to the stake holders and give the opportunity to them to state their idea for improving the aircraft performance or correction of short comes.

15- The aircraft autopilot navigation

Generally in the operational field of the MAVs and the SUAVs, containing battlefields, deserts and mountains, these aircrafts are used by some personnel who were trained for different missions and professionally other than piloting and so they consider the aircraft as a tool to complete the operation. So after lunching, the aircraft must be able to fly with the help of its automatic systems and accomplish the required maneuvers for continuation its flight to complete the mission and have the capability to face with different possible scenarios in its mission. This requirement leads to use from advance electronic systems and autopilot control to navigate the aircraft during flight which must be considered in their design cycle.

Another point to be mentioned is that, in theory, if a pilot can manually control such an aircraft, an autopilot should also be able to control it in most of the situations. To overcome some possible shortcomings in desired aircraft navigation of the mounted autopilots on the aircraft, we might need to employ faster processors, more sensitive sensors and most of all more advanced autopilot programming. If there was a checking step , confidence from designing process of every item and also successful remote control tests, shortcoming in full autopilot aircraft should be addressed in this step without going back to previous ones.

Also, it must be reminded that although these kinds of aircrafts have high technology, but they must have a simple operatory to be successful in their operations because of the situations of their operational fields.

Pointing to the Main influence features:

The aircraft autopilot *has influences on* weight estimation, operational flight path, pay load (altitude control signals), stability and control analysis, hardware in the loop tests (test arrangements), overall aircraft flight tests (accepting the functionality), aircraft propulsion set (control signals to speed controller); and *is influenced by* flight path, software and hardware in the loop simulations and tests (performance and functional insurance), stability and control analysis (programming), and ground station (control signals to the autopilot).

16- Software in the loop

After designing the autopilot it is possible to model the 6 degree of freedom flight equations of motion with determining the various aircraft parameters in simulator software to check the feedback gains of the autopilot, different aircraft mode shapes, aircraft flight response and behavior of the aircraft during its flight path at the autopilot mode, in a virtual simulated space. If the characteristics and aircraft parameters were calculated or selected in a wrong way, the behavior of the aircraft is unfavorable in the simulated space and selected parameters must be corrected in the design cycle. In this way it is an efficient method to adjust these quantities before real tests which improve aircraft performance during its real flight to save cost and time.

Pointing to the Main influence features:

The Software in the loop simulation *has influences on* autopilot (programming and correction of gains) and flight path; and *is influenced by* aircraft performance, stability and control analysis, and autopilot (program).

17- The hardware in the loop tests

The aircraft complexities which rise from unmanned discipline use some variety of autopilot and pay load subsystems and also facing with the aircraft systems problems, which appear in practice during the operational phases, leads the design cycle to apply various hardware in the loop tests for the different aircraft systems before its automatic flight tests.

Applying hardware in the loop tests instead of real flight tests in the aircraft design cycle has many positive consequences like insurance of perfect performance of the systems and subsystems, specification and prevention from systems and subsystems functionality errors, troubleshooting the defective systems, avoiding from the practical problems during the tests which lead to canceling the tests , economy in the required facilities and equipments and preventing from consumption of professional human-hour and the time and the cost of the flight tests during the different phases of RDTE aircraft design cycle.

Pointing to the Main influence features:

The hardware in the loop tests *has influences on* payload subsystems, aircraft propulsion system set, control surfaces servos (testing their functionality) and autopilot subsystems(their functionality); and *is influenced by* autopilot systems.

18- The ground station integration

The communication systems relate aircraft to the ground station and all the information which were gathered with the aircraft pay load systems during flight, may be presented at the ground station. The different systems of the aircraft must be matched with the systems in the ground station for best performance, so there is a necessity to have consideration about ground station systems in the overall design cycle of these aircrafts to have a perfect performance.

Pointing to the Main influence features:

The ground station *has influences on* flight path (correction and change) and autopilot (control signals); and *is influenced by* autopilot (communications) and overall flight tests.

19- The manufacturing and montage process

Generally the manufacturing and montage processes of these aircrafts are low cost and quick. They need not many complex and valuable facilities, jig and fixtures, equipments, infrastructure and personnel which are positive points of view to use from them for required needs and missions. Most of the autopilot or payload systems of them may be selected from standard parts which mostly are available; generally they need not a basic study or manufacturing process to prepare their systems or components, so need not to great payment or time. There are some exceptions in the military cases, which are for every other military aircraft, too. If the required components are ready, manufacturing and montage of them may be done in a small workshop at a limited period of time related to their complexity.

Pointing to the Main influence features:

The manufacturing and montage process *has influences on* the aircraft overall configuration and structural design, and *is influenced by* the same items and considering the available manufacturing technologies.

20- The aircraft flight tests and evaluations

The Flight tests of the aircrafts have determining role in the process of the RDTE design cycle; in fact they determine the real performance and quality of every system, subsystem and also the whole aircraft during flight. Because the theory behind the MAV and the SUAV aircrafts has not fully developed (especially for smaller size MAVs), so many things may not be modeled quietly realistic and there is a necessary to tests and combine analytical studies and physical activities together to solve their design problem [16]. So the aircraft must pass the flight tests and the tests results must be evaluated to judge about the aircraft performance, to make required changes or to accept its situation. If there is any shortcoming from any system of the aircraft or any item in the design cycle, the design loops must be repeated to overcome the problem. So flight tests may send feedback to any item, component or system of the aircraft. Finally the successful flight tests determine the aircraft certification for accomplishment of its mission.

Pointing to the Main influence features:

The overall flight test *has influences on* almost all the systems and the design items and it is possible to change any one of them to improve the aircraft performance; and also *is influenced by* every design item, component, system and sub system of the aircraft.

The overall RDTE design path is presented here, but there are many other *internal* design loops which have not shown on the design path in the appendix A to prevent its complexity.

During follow the design path, the output of every item must be *checked* and *compare* with the available data of the other similar aircrafts to control the parameters ranges, and after insurance from integrity of the results, passing through the current task item is permitted, to prevent from unflavored re-designing and more required correction design loops.

Since nowadays the technology rapidly changes with time, it must be mentioned that to get more efficiency, the effect of *technology change with time* must be considered on the design or on the selection of various systems like propulsion system set, autopilot, pay load and manufacturing process at the beginning of the design cycle to make the best decisions.

And finally, it should be emphasized that in the RDTE design cycle of the MAVs and the SUAVs, which are some multidisciplinary systems, all the important and essential design features in the form of a *holistic strategy* must be possibly considered. The designer should have an eye on all design disciplines and all features and performance issues of the aircraft should be considered for decision making in the design process at the same time .The proposed RDTE design cycle has mentioned this matter in its structure as an inherent characteristic because of its holistic feature to almost all the design tasks in the design cycle.

7 CONCLUSION

The contributions of the present research are as follow:

1-A special systematic strategy for RDTE design cycle of the MAVs and SUAVs is presented.

2-Applying proposed design strategy has some positive consequences like a reduction in the required time, cost and energy of the MAV and SUAV aircraft RDTE design cycle (use from remote control flight tests, software and hardware in the loop simulations).

3-The RDTE design cycle of the MAVs and SUAVs finds a systematic structure which not only prohibits a per case design of these aircrafts but also develops a structural organization to their design space. In addition, the design cycle is more traceable and the designer could easily modify or alter any task items in the design cycle to control it.

4- Since there exists a robust design strategy to follow, the probability of the design cycle convergence is more and mean while the probability of confusing the designer team during the design process is less. This matter helps and leads the designer team to easier cross over from different design cycle items and Finally, the faster convergence of the design cycle, the quicker presenting the aircraft to the stakeholders than other competitors.

REFERENCES

[1] D. N. Mavris and D. A. DeLaurentis and O. Bandte and M.A. Hale . A Stochastic Design Approach for Aircraft Affordability, AIAA 98-0912

[2] R. Whitford. Design for Air Combat , Bulter and Tanner Ltd,1989

[3] J. Roskam.Airplane Design, (part I to VIII) , DARCORP, 1992

[4] D.P. Raymer. Aircraft Design, A Conceptual Approach, Second Edition, American Institute of Aeronautics and Astronautics, Inc., Washington D.C., 1992

[5] G. Corming. Supersonic and Subsonic Airplane Design , Edwards Bors, Inc. Ann Arbor, Michigan, 1953

[6] K.d. Wood. Aircraft Design, Johnson Publishing Co., Boulder, Colorado, 1966

[7] D. Stinton. The Anatomy of the Airplane, American Elsevier Publishing Co. ,New York, N.Y., 1966

[8] L.M. Nikolai. Fundamentals of Aircraft Design, METS Ins., San Jose, California,1975

[9] R. Whittford. Design for Air Combat. Bolter and Tanner Ltd., 1989

[10] E. Torenbeek. Synthesis of Subsonic Airplane Design, Delft University press, ISBN 90-274-2724-3, 1990

[11] J. D. Anderson. Aircraft Performance and Design, McGraw Hill, 1999

[12] M. Abdulrahim and J. B. Cocquyt. Development of Mission - Capable Flexible-Wing Micro Air Vehicles, Department of Aerospace Engineering, Mechanics and Engineering Science, University of Florida, 2002

[13] T.J. Mueller and J.C. Kellogg and P.G. Ifju and S.V. Shkarayev. Introduction to the Design of Fixed-Wing Micro Air Vehicle, AIAA, 2007

[14] J.D. Mattingly and W. H. Heiser and D. H. Daley, “Constraint Analysis for Electric Powered Mini Aerial Vehicle”, Aircraft Engine Design, AIAA Education Series, 1987

[15] M. Koelemay and A. Streett and M. Reid and S. Healey and M. Blanc and J. Calandro and J. Joseph and J. Lemmon and A. Gillis. MICRO AIR VEHICLE SURVEILLANCE PLATFORM, Multi-Disciplinary Engineering Design Conference Kate Gleason College of Engineering Rochester Institute of Technology Rochester, New York 14623,2006

[16] F. Barnhart and M. Cuipa and D. Stefanik and Z. Swick. Micro-Aerial Vehicle Design with Low Reynolds Number Airfoils, 2004

APPENDIX A: THE PROPOSED RDTE DESIGN CYCLE PATH FOR LARGE MAV AND SMALL UAV AIRCRAFTS