Systems Engineering Approach in Aircraft Design Education; Techniques and Challenges

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Abstract

Aircraft design is primarily an analytical process; and essentially contains its own body of knowledge that is independent of the science-based analysis tools. The world of aircraft design involves many challenges and uncertainties. The traditional engineering education is structured to emphasize on mathematics, physical, sciences, and engineering sciences. This paper presents the systems engineering approach in aircraft design education. The approach opens a new horizon to aerospace engineering students and excites them to embrace the new challenges. Throughout this approach, various techniques for generating creative design alternatives are introduced. The nature of aircraft design project; complexity, multidisciplinary, and various constraints; suggests that the systems engineering approach to be the best candidate. The implementation of systems engineering requires a flawless interface between team members working toward a common system thinking to correctly execute the design process. The focus of this paper would be very much on techniques and challenges on curricular structures, course design, implementation; assessment and evaluation.

I. Introduction

Aircraft design is primarily an analytical process which is usually accompanied by drawing/drafting. Design essentially contains its own body of knowledge that is independent of the science-based analysis tools that is usually coupled with it. The world of aircraft design involves many challenges, uncertainties, ambiguities, and inconsistencies.

A design process requires both integration and iteration, invoking a process that coordinates synthesis, analysis, and evaluation. These three operation must be integrated and applied iteratively and continuously throughout the life cycle of the aircraft design. There are various decision making processes in aircraft components design (e.g., wing design, tail design, fuselage design, and propulsion system design). The decision making process plays a significant role in the configuration design of these primary components.

The traditional engineering education is structured to emphasize on mathematics, physical, sciences, and engineering sciences. The problem is the lack of sufficient concentration on design and creativity. The creative thinking and its attitudes is essential to design success. Creating a new design requires ability of creativity and overcoming its strong barriers. Many engineering professors find it more difficult to teach design than to teach traditional engineering science-based analytical topics. Every undergraduate engineering curriculum has a design component, although the extent and structure of that component may vary widely. Engineering design fundamentals are common to all engineering discipline – aeronautical, mechanical, electrical, civil, computer. Engineering design is a methodical approach to dealing with a particular class of large and complex projects. Engineering design provides the design engineer with a realistic design process.

Page 26.1453.2

Recent statistical data indicates a few significant challenges in the US higher education and competitiveness. About 36 percent of college graduates in a 2012 study [11] did not show any significant cognitive gains over four years. While the price of home dropped about 35% over the last seven years [11]; the college cost increased about 15%. The US global rank [11] in the higher education attainment is 10, in the since and technology researchers is 6; corporate investment in R&D is 5, and in government investment in R&D is 8. Half of the employers surveyed [11] said they had trouble finding qualified college graduates to hire.

Adopting the systems engineering approach will open a new horizon to aerospace engineering students and excites them to embrace the new challenges. Throughout this approach, various techniques for generating creative design alternatives are introduced. An effective approach in creative design as a source of new ideas is brainstorming which is mainly applicable in the conceptual design phase. In general, aircraft design requires the participation of six fundamental disciplines: 1. Flight dynamics, 2. Aerodynamics, 3. Propulsion, 4. Aero-structure, 5. Management skills, and 6. Engineering design techniques. The engagement of these disciplines indicates the true multidisciplinary face of the aircraft design education; which involves various challenges and methodologies.

Aircraft design is the culmination of all aerospace engineering activities, embodying engineering operations and analysis as tools to achieve design objectives. Aircraft design is the central activity of the aeronautical engineering profession, and it is concerned with approaches and management as well as design techniques and tools. The customer needs have to be translated into design requirements through goal and objectives. The design goal is usually revised through the benchmarking process which is to explicitly comparing the design to that of the competitor which does the best job for satisfying the customer requirements. The nature of aircraft design project; complexity, multidisciplinary, and various constraints; suggests that the systems engineering approach to be the best candidate. However, the systems engineering implementation is more challenging than understanding the system engineering process.

Aircraft design projects essentially include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impacts. The value-free descriptors associated with each objective; criteria; are quantified using the same bases for measurement and the same unit as their corresponding objectives. The cost of the aircraft design is about 1% of the total life cycle cost; however, this 1% determines the other 99%. Furthermore, the design cost is about 20% of the production (acquisition) cost. Thus, any necessary investment on the design team members is worth it.

Four ABET outcomes are directly related to aircraft design education. They are: 1. Outcome c: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; 2. Outcome d: an ability to function on a multi-disciplinary teams; 3. Outcome f: an understanding of professional and ethical responsibility; and 4. Outcome g: an ability to communicate effectively. All these outcomes are addressed in the aircraft design education process.

In the following sections, the systems engineering approach, challenges**,** curricular structures, course design, implementation, assessment and evaluation are presented. This paper will also examine and identify the aspects of collegial efforts exhibited by students participating in a multidisciplinary team competition (i.e., Design-Built-Flight) and the overall benefit to alumni in their professional life at Daniel Webster College.

II. Systems Engineering Approach

An aircraft is a system composed of a set of interrelated components working together toward some common aerial objective or purpose. Primary objectives include safe flight achieved at a low cost. Aircraft are extremely complex products comprised of many subsystems, components and parts. Aircraft systems, due to the high cost and the risks associated with their development are a major user of systems engineering methodologies. The design process is divided into three major phases: 1. Conceptual design phase, 2. Preliminary design phase, and 3. Detail design phase. These are artificial categories that, along with test and evaluation, make up the four basic phase of system design. After each round of design, a test and evaluation is conducted to compare the characteristics of the designed system with the design requirements.

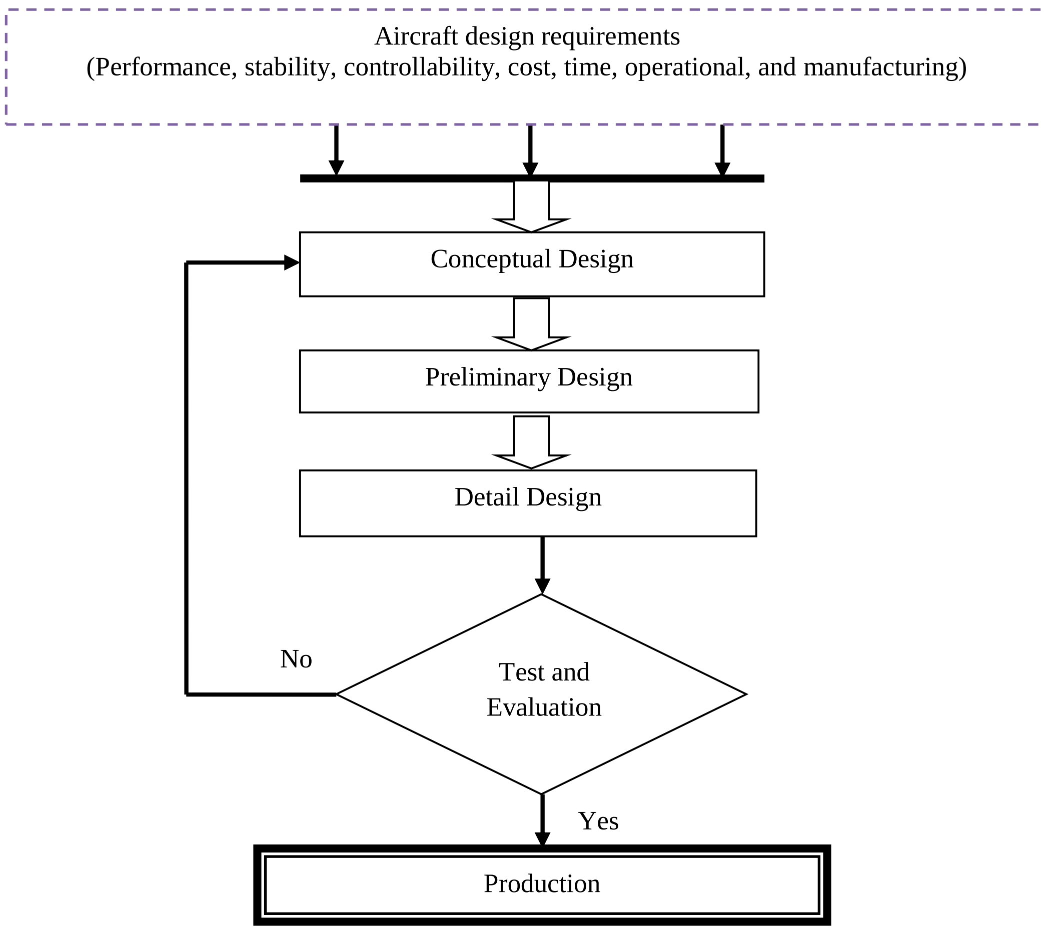

Figure 1. Design process

From the perspective of systems engineering, the design of aircraft should not only transform a need into an air vehicle, but should ensure the aircraft's compatibility with related physical and functional requirements. Therefore, it should consider operational outcomes expressed as safety,

producibility, affordability, reliability, maintainability, usability, supportability, serviceability, detectability, disposability, as well as the requirements on performance, stability, control, and effectiveness.
A design review provides a formalized check of the proposed system design with respect to specification requirements. Major problems; if any; are discussed and corrective action is taken. The design review also creates a baseline for all project design members. In addition, it provides a means for solving interface problems between design groups and promotes the assurance that all system elements will be compatible. Furthermore, a group review may identify new ideas, possibly resulting in simplified processes and ultimately reduced cost. The outcome of the design project is reviewed at various stages of design process. In principle, the specific types, titles, and scheduling of these formal reviews vary from one design project to the next. The following main four formal design reviews are recommended for a design project: 1. Conceptual design review; 2. Preliminary design review; 3. Evaluation and test review; 4. Critical design review.

Success in system engineering derives from the realization that design activity requires a "team" approach. A general challenge in today's environment pertains to implementing the overall system design process rapidly, in a limited amount of time, and at a minimal cost. Multidisciplinary teams; experiential learning approaches, capstone design experiences, warnings on tort of negligence, feasibility studies, project planning, design requirements and constraints, trade-off analysis techniques, functional block diagram, design flowchart, design feedbacks, design management, work breakdown structure, design steps and procedure, Design groups' unique visions and interests are important topics which are addressed and covered during the aircraft design teaching process. These experiences will significantly impact on student development, particularly on learning, self-efficacy, diversity, and the ability to innovate.

The implementation of systems engineering requires a flawless interface between team members working toward a common system thinking to correctly execute systems engineering process. Although there is a general agreement regarding the principles and objectives of systems engineering, its actual implementation will vary from on discipline to the next. The process approach and steps used will depend on the backgrounds and experiences of the individuals involved. The application of systems engineering to aircraft design discipline requires a multi-aspect study which related aircraft design requirements and functions to systems engineering principles. A functional analysis will pave the road to determine the links between functions of aircraft components to the overall design requirements.

The design of an aircraft within the system life-cycle context is different from the design just to meet a set of performance or stability requirements. Life-cycle focused design is simultaneously responsive to customer needs and to life-cycle outcomes. The design should not only transform a need into a system configuration, but should ensure the aircraft's compatibility with related physical and functional requirements. Further, it should consider operational outcomes expressed as safety, producibility, affordability, reliability, maintainability, usability, supportability, serviceability, disposability, and others, as well as the requirements on performance, stability, control, and effectiveness. Table 1 illustrates a summary of aircraft major components and their functions. This table also shows the secondary roles and the major areas of influence of each `component. The table also specifies the design requirements that are affected by each component.

Throughout the conceptual system design phase (commencing with the need analysis), one of the major objectives is to develop and define the specific design-to requirements for the system as an entry. The results from these activities are combined, integrated, and included in a system specification. This specification constitutes the top "technical-requirements" document that provides overall guidance for system design from the beginning. Conceptual design is the first and most important phase of the aircraft system design and development process. It is an early and high level life cycle activity with potential to establish, commit, and otherwise predetermine the function, form, cost, and development schedule of the desired aircraft system. The identification of a problem and associated definition of need provides a valid and appropriate starting point for design at the conceptual level.

No	Component	Primary function	Major areas of influence
1	Fuselage	Payload accommodations	aircraft performance, longitudinal stability, lateral stability, cost
2	Wing	Generation of lift	aircraft performance, lateral stability
3	Horizontal tail	Longitudinal stability	Longitudinal trim and control
4	Vertical tail	Directional stability	Directional trim and control, stealth,
5	Propulsion system	Generation of thrust	aircraft performance, stealth, cost, control
6	Landing gear	Facilitate take-off and landing	aircraft performance, stealth, cost
7	Control surfaces	Control	Maneuverability, cost
8	Control System	Control, guidance, and navigation	Maneuverability, stability, cost, flight safety

Table 1. Functional analysis of major components

The preliminary design phase is performed in three steps: 1: estimate aircraft maximum take-off weight, 2: determine wing area and engine thrust (or power) simultaneously. As the name implies, in the detail design phase, the details of parameters of all major components of an aircraft is determined. This phase is established based on the results of conceptual design phase and preliminary design phase. The aircraft configuration has been determined in the conceptual design phase and wing area, and engine thrust/power have been set in preliminary design phase. The parameters of wing, horizontal tail, vertical tail, fuselage, landing gear, engine, and subsystems must be determined in this last design phase. To compare three design phases, the detail design phase contains a huge amount of calculations and a large mathematical operation compared with other two design phases. If the total length of an aircraft design is considered to be one year, about 10 months is spent on the detail design phase.

This phase is an iterative operation in its nature. In general, there are four design feedbacks in the detail design phase. Figure 2 illustrates the relationships between detail design and design feedbacks. Four feedbacks in the detail design phase are: 1. Performance evaluation, 2. Stability analysis, 3. Controllability analysis, 4. Flight simulation. The aircraft performance evaluation includes the determination of aircraft zero-lift drag coefficient. The stability analysis requires the component weight estimation plus the determination of aircraft center of gravity (cg). In the controllability analysis operation, the control surfaces (e.g. elevator, aileron, and rudder) must be designed.

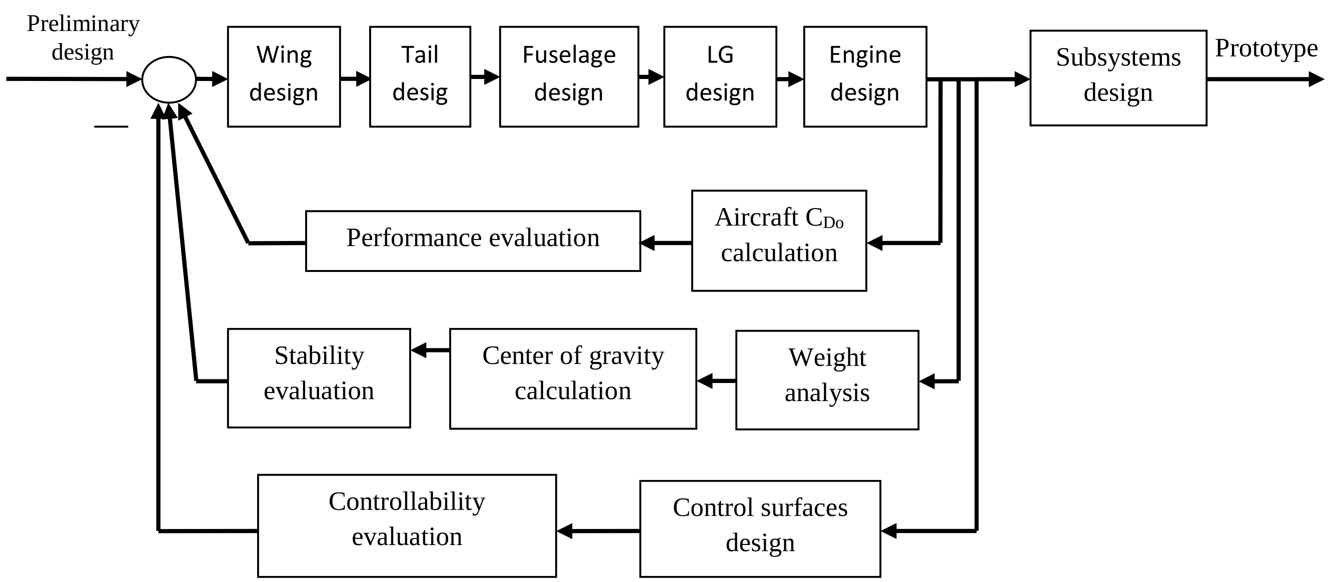

Figure 2. Relationship between detail design and design feedbacks

The integration of system engineering principles with the analysis-driven aircraft design process demonstrates that a higher level of integrated vehicle can be attained; identifying the requirements/functional/physical interfaces and the complimentary technical interactions which are promoted by this design process. The details of conceptual design phase, preliminary design phase, and detail design phase were introduced in brief. The following is a suggestion for the aircraft major design steps that summarize above-mentioned three design phases into 50 steps:

1. Derive aircraft design technical requirements, objectives and specifications from the customer order and problem statement
2. Design program and management planning (e.g., Gantt chart and checklists)
3. Feasibility studies
4. Risk analysis
5. Functional analysis and allocation
6. Design team allocation
7. aircraft Configuration design
8. First estimation of aircraft maximum take-off weight
9. Estimation of aircraft zero-lift drag coefficient
10. Calculation of wing reference area
11. Calculation of engine thrust or engine power
12. Wing design
13. Fuselage design
14. Horizontal tail design
15. Vertical tail design
16. Landing gear design

17. Propeller design or selection (if prop driven engine)/inlet design (if jet engine)
18. First estimate of weight of aircraft components
19. Second estimate of aircraft maximum take-off weight
20. First calculation of aircraft center of gravity limits
21. Relocation of components to satisfy stability and controllability requirements
22. Redesign of horizontal tail and vertical tail design
23. Design of control surfaces
24. Control system design
25. Calculation of aircraft C_{Do}
26. Re-selection of engine
27. Calculation of interferences between aircraft components
28. Incorporation of design changes
29. First modifications of aircraft components
30. First calculation of aircraft performance
31. Second modification of aircraft to satisfy performance requirements
32. First stability and control analysis
33. Third aircraft modification to satisfy stability and control requirements
34. Manufacturing of aircraft model
35. Wind tunnel test
36. Fourth aircraft modification to include aerodynamic considerations
37. Aircraft structural design
38. Calculation of weight of aircraft components
39. Second calculation of aircraft center of gravity limits
40. Fifth aircraft modification to include weight and cg considerations
41. Second performance, stability and control analysis and design review
42. Sixth aircraft modification
43. aircraft systems design (e.g., electric, mechanical, hydraulic, pressure, and power transmission)
44. Manufacturing of the aircraft prototype
45. Flight test
46. Seventh aircraft Modification to include flight test results
47. Trade-off studies
48. Optimization
49. Certification, validation or customer approval tests
50. Eighth Modification to satisfy certification requirements

III. Implementation, Course Design, and Curricular Structure

The implementation of systems engineering in aircraft design education progressed through a couple of years. The course materials and course design was evolved over a number of years. The implementation of systems engineering requires a flawless interface between team members working toward a common system thinking to correctly execute systems engineering process. Although there is a general agreement regarding the principles and objectives of systems engineering, its actual implementation will vary from on discipline to the next. The process approach and steps used will depend on the backgrounds and experiences of the individuals involved. The application of systems engineering to aircraft design discipline requires a multi-aspect study which related aircraft design requirements and functions to systems engineering principles. A functional analysis will pave the road to determine the links between functions of aircraft components to the overall design requirements.

The course basically has a fairly standard format; it mainly consists of three one-hour weekly lectures. The topics and the lectures are organized such that they follow the systems engineering approach. In practice; after one week of introduction; one week is spent on conceptual design; two weeks on preliminary design; and about 12 weeks on details design. In the details design section; the design of major aircraft components such as wing, tail (horizontal and vertical); fuselage, propulsion system; and landing gear are covered.

During the course of a semester, various design requirements are introduced. There are specific design requirements which are required by the customer, and must be addressed by the design team. However, there are other design requirements which customer is not necessarily aware of and may not verbally desire them. In this section a list of design-related requirements are briefly reviewed as follows: Performance requirements; Stability requirements; Handling requirements; Operational requirements; Affordability requirements; Reliability requirements; Maintainability requirements; Producibility requirements; Evaluatability requirements; Usability requirements; Safety (airworthiness for aircraft) requirements; Crashworthiness requirements; Supportability and serviceability requirements; Sustainability requirements; Disposability requirements; Marketability requirements; Environmental requirements; Detectability requirements; Standards requirements; and Legal requirements.

No	Design requirements	Aircraft component/parameters that affected most
1	Payload (weight) requirements	Maximum take-off weight
	Payload (volume and geometry) requirements	Fuselage
2	Performance Requirements (Range and Endurance)	Maximum take-off weight, fuel weight
3	Performance requirements (maximum speed, Rate of climb, take-off run, stall speed, ceiling, and turn performance)	Engine; Landing gear; and Wing
4	Stability requirements	Horizontal tail and vertical tail, weight distribution
5	Controllability requirements	Control surfaces (elevator, aileron, rudder), weight distribution
6	Flying quality requirements	Center of gravity, weight distribution
7	Airworthiness requirements	Minimum safety requirements
8	Cost requirements	Materials; Engine; weight, …
9	Design duration requirements	Configuration optimality
10	Detectability requirements	Materials, configuration

Table 2. Relationship between aircraft major components and design requirements

Table 2 represents the relationship between aircraft major components and design requirements. Payload has mainly two aspects: 1. Weight, 2. Volume. The weight of the payload will mainly influence the aircraft maximum take-off weight, however, the payload volume and geometry affects primarily the design of the fuselage. The aircraft performance requirements may be divided into two groups: 1. Range and endurance, 2. Maximum speed, rate of climb, take-off run, stall speed, ceiling, and turn performance. Range and endurance are largely fuel dependent, while other performance requirements are not primarily a function of fuel weight. Thus, endurance and range requirements will mainly influence the aircraft maximum take-off weight and required fuel weight. On the other hand, other performance requirements affect engine design, landing gear design and wing design.

The system (i.e., aircraft) design process includes: 1. Conceptual Design, 2. Preliminary Design, 3. Detail design, and 4. Test and Evaluation (Figure 1). The details of four phases of the integrated design of an aircraft are summarized in Table 3. Figure 1 illustrates the relationship among four major design activities in a systems engineering approach. The design process primarily starts with the conceptual design phase; based on design requirements. The details of conceptual design phase are presented first. The preliminary design begins right after the conceptual design phase and employs the output of this phase. The detail design phase begins right after the preliminary design phase and utilizes the output of this phase.

No	**Design phase**	**Design activity**	
1	Conceptual Design	Aircraft configuration design	
2	Preliminary Design	Determine 1. Aircraft maximum take-off weight, 2. Engine power or thrust, 3. Wing reference area	
3	Detail design	Part I	Design dominant components such as wing, fuselage, tail, and propulsion system, landing gear (non-mechanical)
		Part II:	Design servant components such as landing gear (mechanical), engine, structural design, cabin, cockpit, avionic system, electric system, and air conditioning system.
4	Test and Evaluation	Aircraft aerodynamic testing: Wind tunnel test using aircraft model	
		Aircraft flight dynamic testing: Flight test using a prototype	
		Aircraft structural testing using an aircraft structure	
		Propulsion system testing using an aero-engine	

Table 3. A summary of four aircraft major design phases

In the first week of the semester; basic fundamentals of the systems engineering approach are presented; and some fundamental topics such as management skills; Gantt chart; team-work principles; planning; and communication expectation are introduced.

The design project is defined to design an aircraft to satisfy the design requirements such as performance; mission, and payload. In addition, some basic requirements such as airworthiness, cost, maintainability, and manufacturability are also emphasized. For the topic of the design project; in one year, a two-seat GA aircraft is assigned; in another year, a 200-passenger transport aircraft is assigned; and in another year; a military aircraft is assigned. The topic is changed every year to let students experience the design for various aircraft types. To distribute the load and to help students to continuously practice what they learnt; three design reports are required. In this way, each five weeks, a design report is prepared by students.

The homework assignments are designed such that they are directly related to the project. The homework assignments are often designed such that they can be done by one student; thus, they could be performed individually.

To emphasize the issue of team-working; the design project is assigned to a group of two students. There are mainly two approaches to handle the design activities and establishing design groups: 1. Design groups based on aircraft components (Figure 3), 2. Design groups based on expertise (Figure 4). If the approach of Groups based on aircraft components is selected, the chief designer must establish the following teams: 1. Wing design team, 2. tail design team, 3. Fuselage design team, 4. Propulsion system design team, 5. Landing gear design team, 6. Equipment design team. The seventh team is established for documentation, and drafting. There are various advantages and disadvantages for each of the two planning approaches in terms of ease of management, speed of communication, efficiency, and similarity of tasks. However, if the project is large such as the design of a large transport aircraft, both groupings could be applied simultaneously. On the other hand, for the design of a small model aircraft, the work breakdown structure based on aircraft components work more efficiently.

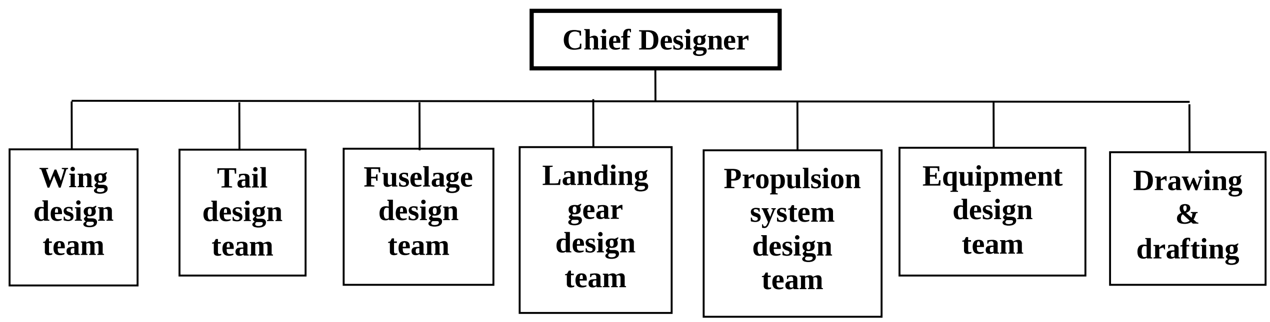

Figure 3. Work breakdown structure based on aircraft components during design phase

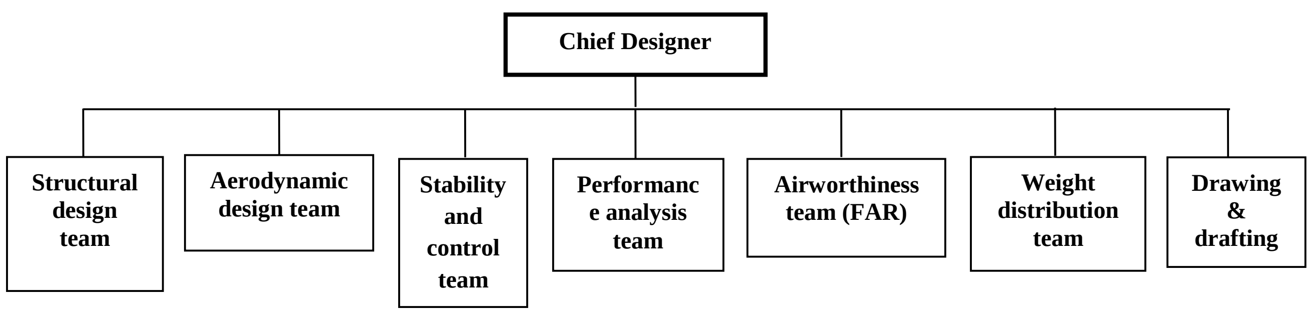

Figure 4. Work breakdown structure based on discipline during design phase

These two options are available for capstone design project; when the number of students is greater than 15. Both options are given to the students for the project team management. In some years, the group arrangements are based on the components; and in some other years, the students have preferred to work based on the expertise. The two work breakdown structures have pros and cons, and are working efficiently.

The objective of the aircraft design course is for the student to develop the ability to design an air vehicle through the three major phases of conceptual design, preliminary design, and detail design. Upon the completion of this course, the students will be expected to:

1. demonstrate the ability to synthesize basic engineering science to accomplish a mission-driven design of an aircraft, including conceptual design;
2. show proficiency in and an appreciation for performing trade-off studies of aircraft preliminary design;
3. gain experience working on design of an aircraft including mission definition, and application of the conceptual design approach to develop a frozen configuration that will be the basis for the preliminary design;
4. develop the ability to perform the detail design of major components such as wing, tail, fuselage and landing gear; .
5. gain experience and confidence in self-instruction and use of software for aircraft design, through a tutorial on the Advanced Aircraft Analysis (AAA) software and use of the software to perform sizing study as part of a design project; and
6. demonstrate familiarity with contemporary issues related to aircraft design.

The assessment of these objectives is discussed in the next section.

IV. Assessment and Evaluation

The course evaluation is generally applied through weekly homework assignments; a midterm test, a final comprehensive exam, and of course; a design project. In each major design phase (conceptual, preliminary, and detail), an evaluation should be conducted to review the design and to ensure that the design is acceptable at that point before proceeding with the next stage. There is a series of formal design reviews conducted at specific times in the overall system development process.

The purpose of conducting any type of review is to assess if (and how well) the design configuration, as envisioned at the time, is in compliance with the initially specified quantitative and qualitative requirements.

A design review provides a formalized check of the proposed system design with respect to specification requirements. Major problems; if any; are discussed and corrective action is taken. The design review also creates a baseline for all project design members. In addition, it provides a means for solving interface problems between design groups and promotes the assurance that all system elements will be compatible. Furthermore, a group review may identify new ideas, possibly resulting in simplified processes and ultimately reduced cost. The outcome of the design project is reviewed at various stages of design process. In principle, the specific types, titles, and scheduling of these formal reviews vary from one design project to the next. The following main four formal design reviews are recommended for a design project:

1. Conceptual Design Review (CDR)
2. Preliminary Design Review (PDR)
3. Evaluation and Test Review (ETR)
4. Critical (Final) Design Review (FDR)

Figure 5 shows the position of each design review in the overall design process. Design reviews are usually scheduled before each major design phase. These are mainly applicable in capstone design course; not one-semester aircraft design course.

The CDR is usually scheduled toward the end of the conceptual design phase and prior to entering the preliminary design phase of the program. The purpose of conceptual design review (CDR) is to formally and logically cover the proposed design from the system standpoint. The preliminary design review is usually scheduled toward the end of the preliminary design phase and prior to entering the detail design phase. The critical design review (FDR) is usually scheduled after the completion of the detail design phase and prior to entering the production phase. Design is essentially "fixed" at this point, and the proposed configuration is evaluated in terms of adequacy and producibility.

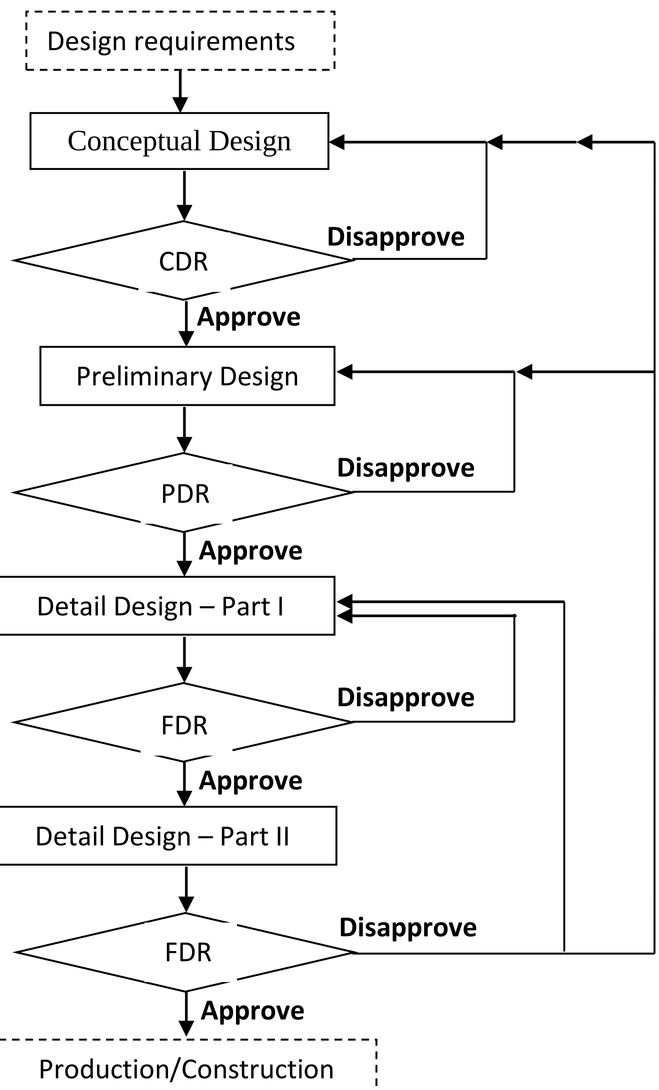

Figure 5. Formal design reviews

Students are evaluated in a number of different ways including homework, project, and examinations. The percentage breakdown of these pieces is as follows: Homework (20%); Project (45%); Class participation (5%); Mid-term test (10%); Final Exam (20%). The chronology of topics/assignments/project reports are illustrated in table 6.

At the end of each semester the college conducts the course evaluation (including aircraft design course). Students are provided a form to fill out; and also write their comments. A few sample students' comments from the course evaluation forms are as follows:

- The course taught real life design technique.
- The course provides an adequate albeit basic understanding of aircraft design that aids significantly in projects such as design/build/fix.
- The aircraft design project was a good experience. I liked how the homework could be directly related to individual projects.
- Very good course. I learned a lot about different aircraft and about design. I really liked the HW and doing it in groups.

V. Challenges

The systems engineering approach opens a new horizon to aircraft design students; and grants them motivation to embrace the new challenges. However, a number of challenges have been faced throughout the years. The focus of this section is on challenges on curricular structures, course design, implementation; assessment and evaluation. Throughout this approach, various techniques for generating creative design alternatives are introduced. The implementation of systems engineering requires a flawless interface between team members working toward a common system thinking to correctly execute the design process.

Week		Topic	Reading (Ref. 1)	HW/Test/Project
1	Sept. 3	Design fundamentals	Ch 1, 2, Hand-out	HW 1
2	Sept. 9	Design procedure, Conceptual Design	Ch 6, 7, 8, Hand-out	HW 2
3	Sept. 16	Take-off weight estimation	Ch 3, 5, 6	HW 3
4	Sept. 23	Preliminary sizing (Wing and engine)	Hand-out	HW 4
5	Sept. 30	Wing design – part 1	Sections 4.1 - 4.4	Project Report part 1
6	Oct. 7	Wing design – part 2	Hand-out	HW 5
7	Oct. 14	Fuselage design	Ch 7, 9	HW 6
8	Oct. 21	Tail plane design	Section 4.5	Mid-term test
9	Oct. 28	Tail plane design	Hand-out	HW 7
10	Nov. 4	Landing gear design – part 1	Ch 11	Project Report part 2
11	Nov. 11	Landing gear design – part 2	Ch 11	HW 8
12	Nov. 18	Propulsion system design	Ch 10, 13	HW 9
13	Nov. 25	Weigh estimation	Ch 15	HW 10
-	Nov. 27-29	**Fall Recess**	-	-
14	Dec. 2	Locating components and the cg, AAA	Hand-out	HW 11, Project Report part 3
15	Dec. 9	Drawing; Concept Unlimited + AeroPack	Hand-out	Final Project Report
16	Dec. 14-18	Final Exam	-	Final test

Table 4. Chronology of topics/assignments/project reports

The challenges include:
- Implementation
- Students' assessment
- Team-working issues
- Adjusting the topics based on 15-weeks semester
- Evaluation of students in a design project
- Relating homework assignments to design project
- Fairness of grades
- Coverage of topics
- Decision making challenges

In the case of capstone design, the team is exposed to another real-world challenge; working in a multi-discipline design team. These challenges are addressed and resolved over the years. However, they will influence the quality of education; the course objectives, and the teaching outcomes.

Conclusion

This paper presents the systems engineering approach in aircraft design education. This approach opens a new horizon to aerospace engineering students and gets them excited to embrace the new challenges. Throughout this approach, various techniques for generating creative design alternatives are introduced. The implementation of systems engineering requires a flawless interface between team members working toward a common system thinking to correctly execute the design process. The focus of this paper is on techniques and challenges on curricular structures, course design, implementation; assessment and evaluation. The approach can considerably progress the efficiency of learning by allowing young students to apply theoretical knowledge to real world projects. Furthermore, it inspires creativity and innovation, and develops communication, problem solving, and team-working skills.

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