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# AIRCRAFT DESIGN EDUCATION FOR UNDERGRADUATE AND GRADUATE STUDENTS AT THE UNIVERSITY OF TOKYO

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**Keywords**: *aircraft design education, design course, undergraduate and graduate students*


## Abstract

*This paper introduces aircraft design education at the Department of Aeronautics and Astronautics, the University of Tokyo. The details of this activity is explained. The aim of the design education is to enhance students' ability to integrate engineering systems, which is one of the educational discipline and goals of our Department. To accomplish this educational goal, the aircraft design education plays an important role. This paper describes details of the aircraft design courses both for the undergraduate and graduate students.*


## 1 Introduction

First, educational objectives at the Department of Aeronautics and Astronautics, the University of Tokyo are explained. There are two objectives: 1) to give students a clear understanding of the problems of aircraft and space vehicles and 2) to give students training in engineering sciences such that students are with broad and flexible adaptability. To accomplish one of the educational objectives, aircraft design education has been playing a key role at the Department. The design education is thought to give students to experience the educational process aimed to accomplish the second objective. Students can experience the process to combine individual aerospace subjects such as aerodynamics, structural dynamics and flight dynamics into a single engineering system. During this "system integration" experience, students have to solve engineering problems they have not experienced before by utilizing their knowledge.

The overview of lectures and courses at the Department both for the undergraduate and graduate students is shown in Figure 1 [1]. Studies on aeronautics and astronautics begin at the second half term of second year of the undergraduate course. After studying the basics of engineering, third and fourth year students study different subjects in four main discipline of aeronautics, i.e. i) aerodynamics, ii) flight dynamics and control, iii) structures and material, and iv) propulsion. Furthermore, students also study design and system engineering subjects alongside the four main discipline. Fourth (final) year students begin their research experience to write up their "graduation theses". After finishing the graduation thesis, they spend about three months for the "graduation design" course until their graduation from the University. Graduate school study as a master course student begins after their graduation.

This paper explains details of the aircraft design course for undergraduate and graduate students together with some examples of student design results.

## 2 Aircraft Design Education

Details of the aircraft design education at the Department are indicated in Figure 2 [1]. In this chapter, design courses for undergraduate students and for graduate students are explained.

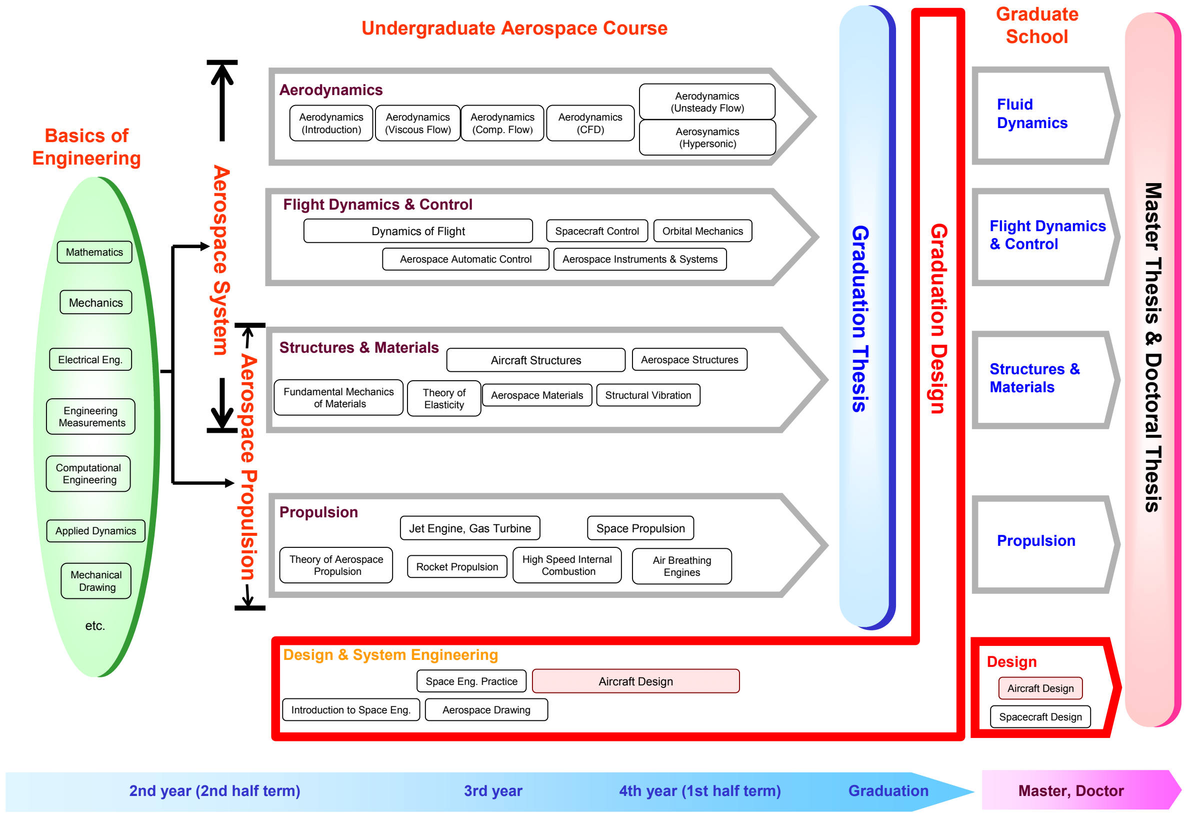



Fig. 1 Overview of Courses & Lectures at Department of Aeronautics & Astronautics [1]

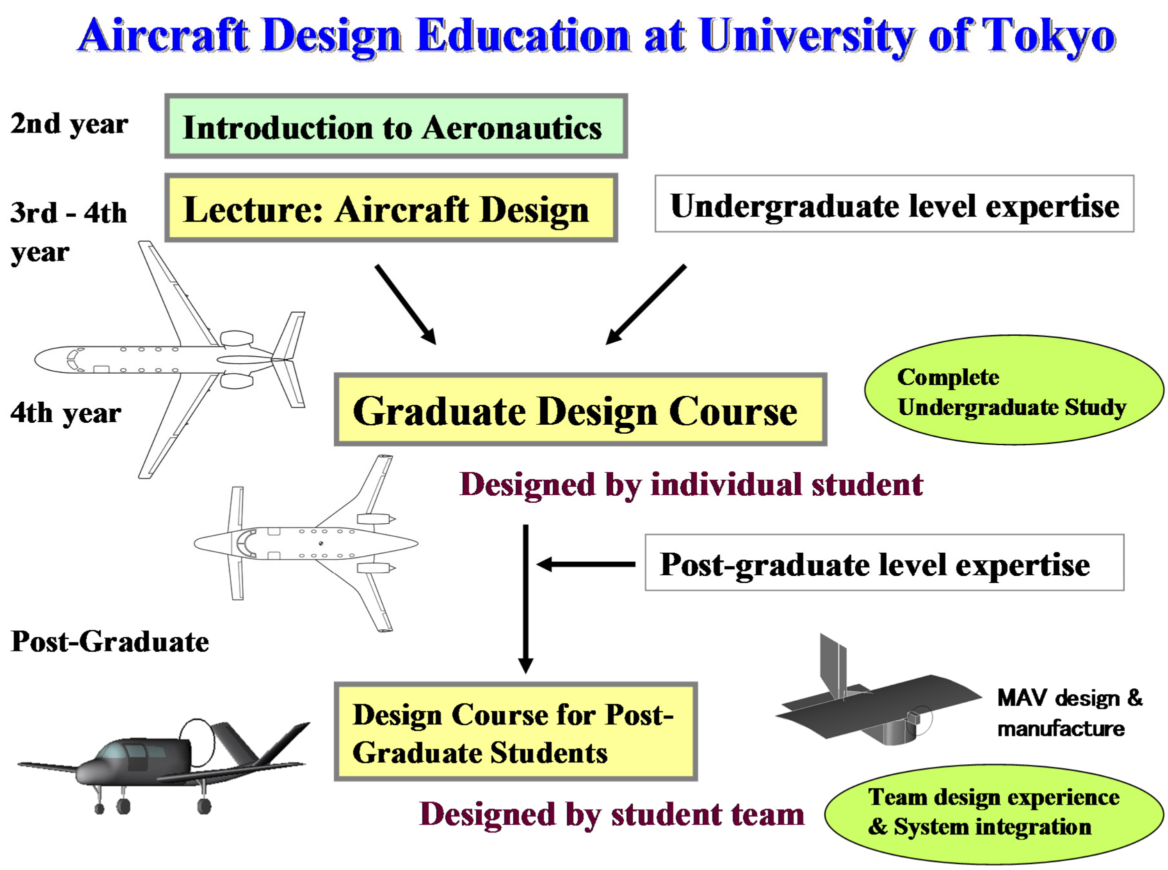



Fig. 2 Details of Aircraft Design Education [1]

## 2.1 Design Course for Undergraduate Students

### *2.1.1 Overview of the design course*

As explained in the previous chapter, the “graduation design” course begins about three months before their graduation. The “graduation design” course consists of aircraft design, spacecraft design and propulsion system design. In this paper, aircraft “graduation design” course is described. Total number of 15-20 students attend the aircraft “graduation design” course every year. Students can decide the design requirements by themselves. The aircraft they design range from a single engine propeller aircraft to an ultra high capacity jet transport, a supersonic transport and a space plane.

During the first month, conceptual design process is conducted by each student. Students utilize their knowledge studied at the aircraft conceptual design class which is based on the textbook [2] and is offered by the author for a year starting from the second half term of third year. Conceptual design process mainly consists of initial sizing and initial drawing of a three view. Refinement of their design is also made by estimating aerodynamic characteristics, flight dynamic characteristics and performance of their designing aircraft.

For the second and third months, structural design is mainly considered. Students can learn that the arrangement of main structural member is an important factor which interferes other factors, i.e. aerodynamic design or flight dynamic characteristics. Final stage of the design course is the final examination. Examiners (professors) orally enquire students any relevant questions about the designed results. Examiners’ intention is to check student abilities and their knowledge in aeronautical fields which are expected to be mastered during their undergraduate studies.

Aircraft types and designed aircraft numbers conducted by the undergraduate students during the "graduation design" course are shown in Table 1. This table is based on the data for the past 18 years. It can be seen popular types of aircraft are conventional jet transport, regional jet and executive jet. However, unconventional aircraft such as blended wing body aircraft (BWB), joined wing aircraft, 1000 passenger jet transport, forward swept executive jet, canard & pusher type turbo-prop aircraft, and a flying automobile are selected by the students. Many students design supersonic transport (SST) ranging from 250 passengers to 5 passengers as a supersonic business jet (SSBJ). One group consisting two students designed the liquid hydrogen (LH2) supersonic transport. Space plane that takes-off and lands horizontally and transports cargo or people to a space station in orbit is also interested in. Since the space plane design needs orbital calculation and aerodynamic characteristic estimation which is different from the aircraft, it is usually designed by a group of two students.

### *2.1.2 Design Examples*

Figure 3 shows some of the aircraft designed by the undergraduate students. They are a) a canard & pusher type turbo-prop aircraft [1], b) a 600 passenger blended wing body (BWB) aircraft [1], c) a box wing jet transport that may improve the cruise aerodynamic efficiency [1], d) twin fuselage transport [2], e) two-stage type sub-orbital space plane [3] and f) liquid hydrogen supersonic transport [4]. Aircraft of Figs. 3e) and 3f) were designed by a group of two students. Others were all designed individually.

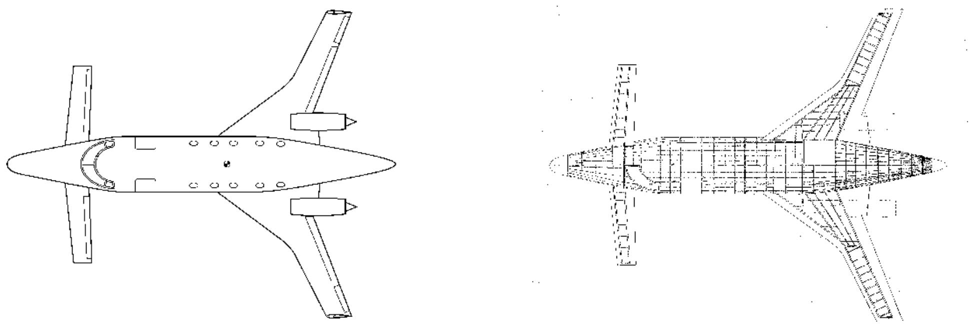
## 2.2 Design Course for Graduate Students

### *2.2.1 Overview of the design course*

As stated in the previous section, each undergraduate student who participates in the "graduation design" course designs an aircraft individually, except some cases as indicated in Table 1. In the actual aircraft design process conducted at aircraft manufacturing companies, many numbers of engineer participate in the design project using the highly advanced aircraft design techniques. It is not our intention for the undergraduate students to learn latest technology in aircraft design. This is partly because the lack of their ability and time, but what is important for the undergraduate students is to experience the conceptual design process by himself within a limited time.

Table 1 Designed Aircraft List by Undergraduate Students

| Type of Aircraft | No. of Student | | | |
|---|---|---|---|---|
| | Total | 2010～2015 | 2004～2009 | 1998～2003 |
| Jet Transport | 25 | 14 | 6 | 5 |
| Regional Jet | 39 | 18 | 9 | 12 |
| Freighter Jet | 18 | 5 | 6 | 7 |
| Ultra High Capacity Jet Transport | 7 | 0 | 1 | 6 |
| Twin Fuselage | 3 | 1 | 1 | 1 |
| Blended Wing Body Aircraft (BWB) | 5 | 0 | 4 | 1 |
| Joined Wing Jet Transport | 3 | 0 | 2 | 1 |
| Hydrogen Fuel Transport | 1 | 1 | 0 | 0 |
| Box wing Jet Transport | 1 | 0 | 0 | 1 |
| Executive Jet | 75 | 33 | 20 | 22 |
| Executive Jet (Forward swept wing) | 2 | 0 | 0 | 2 |
| Very Light Jet (VLJ) | 10 | 4 | 6 | 0 |
| Turbo-prop Aircraft | 15 | 5 | 4 | 6 |
| Turbo-prop Aircraft (with Canard) | 5 | 0 | 2 | 3 |
| Flying Boat | 9 | 2 | 4 | 3 |
| Amphibilian | 5 | 3 | 2 | 0 |
| STOL | 10 | 2 | 3 | 5 |
| Twin Prop | 3 | 1 | 1 | 1 |
| Acrobatic Plane | 6 | 1 | 1 | 4 |
| Jet Trainer | 5 | 1 | 3 | 1 |
| Supersonic Transport | 12 | 3 | 4 | 5 |
| LH2 Supersonic Transport | 1group | 0 | 1group | 0 |
| Supersonic Regional Jet (SSRJ) | 4 | 0 | 3 | 1 |
| Supersonic Business Jet (SSBJ) | 7 | 3 | 4 | 0 |
| Hypersonic Plane | 1group + 2 | 1group | 0 | 2 |
| Space Plane (TSTO) | 5groups | 2groups | 2groups | 1group |
| Space Plane (SSTO) | 2groups | 0 | 0 | 2groups |
| Airplane Launch Space Plane | 2groups | 0 | 0 | 2groups |
| Rocket Launch Spane Plane | 1 | 0 | 0 | 1 |
| Mars Airplane | 2 | 2 | 0 | 0 |
| Flying Automobile | 3 | 0 | 3 | 0 |
| Tilt Rotor | 7 | 0 | 6 | 1 |
| Electric Aircraft | 2 | 0 | 2 | 0 |
| UAS | 4 | 0 | 4 | 0 |
| Others | 8 | 1 | 6 | 1 |
| Total | 320 | 106 | 113 | 101 |



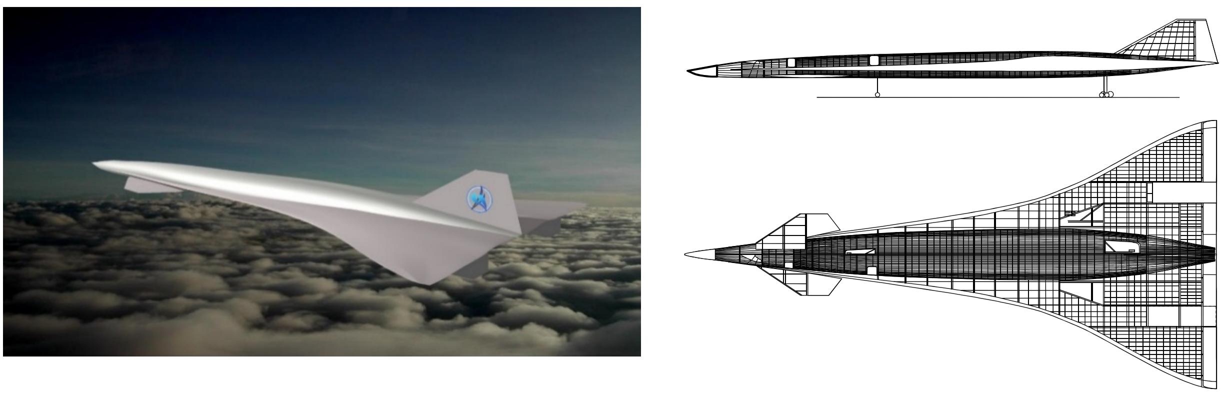
a) Canard Pusher TP [1]

b) Blended Wing Body [1]

c) Box Wing Aircraft [1]

d) Twin Fuselage Transport [2]

e) Two-Stage Type Sub-orbital Space Plane [3]



f) Liquid Hydrogen Supersonic Transport [4]

Fig. 3 Design Examples by Undergraduate Students

In the meantime, master course students have their specialty. They have deeper knowledge and more experiences than undergraduate students. Thus, it has been decided to begin a new design course for the graduate students in 2002. The target of this design course is aimed for the higher level of aircraft design. In this course, a group of graduate students who have different specialties in aeronautics design single aircraft. The first "group design" course for the graduate students was conducted in 2002 and participated by 7 master course students. Designed aircraft was a four seater single engine pusher propeller aircraft. Different role was assigned to each student, such as the design leader, a student in charge of aerodynamics, one in charge of flight dynamics, structures, performance estimations and propulsions. Two aircraft design engineers from the aircraft manufacturer evaluated their design after the course. According to their comments, experiences to design an aircraft by working together would be very important to obtain the higher "system integration" ability. Since then this "group design" course for graduate students is open every two years and each time the evaluation was conducted by the experts in the aeronautical field.

### *2.2.2 Design Examples*

In this section, design results of the "group design" course by graduate students are described. Table 2 summarizes the designed aircraft, including number of students attended the course. In 2004, 2006 and 2008, Design, Build and Fly Project to manufacture a miniature plane and to conduct a flight test was also selected as a theme for this design course.

Table 2 Designed Aircraft List by Graduate Students

| Year | Aircraft Type | Specifications | No. Students | Figure | Ref. |
|---|---|---|---|---|---|
| 2002 | Single-engine Pusher-propeller Aircraft | PAX 4, Range 1100nm | 7 | | [1] |
| 2004 | Mars Plane | Range 3000km, Span 8.9m, Weight 160kg | 5 | Fig. 4a), 4b) | [5] |
| | Medical Supply Transport UAV | Range 350km, Span 3.5m, Weight 30kg | 5 | | [1] |
| | Disaster Monitoring UAV | Span 3.5m, Weight 27kg | 5 | | [1] |
| | MAV (Design, Build & Fly) | Span 200mm, Weight 32.7g | 3 | | [1] |
| 2006 | Supersonic Regional Jet Transport | PAX 50, Range 3,500nm, M1.6 | 7 | Fig. 5a), 5b) | [6] |
| | Autonomous Indoor Flyer (Design, Build & Fly) | Video Navigation System (detecting moving object from video images), Weight 150g | 10 | | [7] |
| 2008 | Hydrogen Fueled Jet Transport | PAX 125, Range 2,500nm, M0.78 | 6 | Fig.6 | [8] |
| | (Design, Build & Fly) | Variable Wing Area Type UAV and Silent Supersonic Type Low-speed Flyer | 5 | | [9] |
| 2010 | Ultra Large Transport with Extra Wide Fuselage | PAX 800, Range 3,000nm, M0.8 | 8 | Fig.7a), 7b), 7c) | [10] |
| 2012 | Sonic Speed Cruise Business Jet | PAX 10, Range 4,500nm, M0.95 | 8 | Fig.8a), 8b) | [11] |
| 2014 | Hybrid Propulsion Aircraft | PAX 126, Range 3,000nm, M0.8 | 12 | Fig.9a), 9b) | [12] |

Figure 4a) shows Mars Plane (2004) for geographical and geological exploration. Figure 4b) explains observation instruments and equipment on board [5].

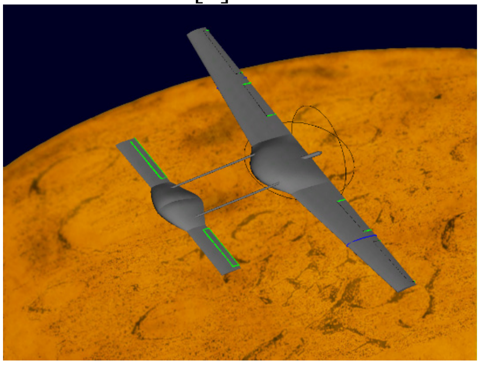


Fig. 4a) Mars Plane [5]

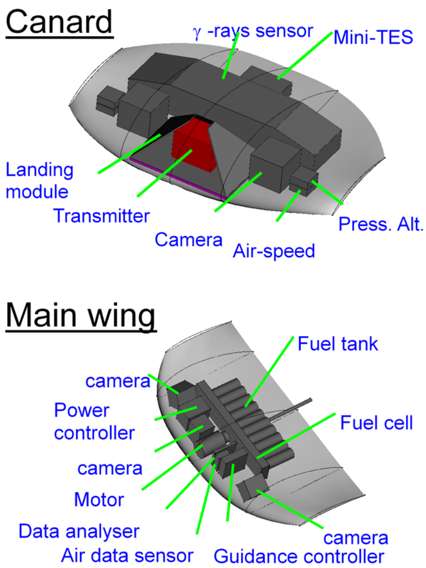



Fig. 4b) Instruments and Equipment [5]

Figure 5a) shows Supersonic Regional Jet Transport (2006) aiming low drag / low fuel consumption. Figure 5b) shows designed wing cross section configurations [6].

Fig. 5a) Supersonic Regional Jet Transport [6]

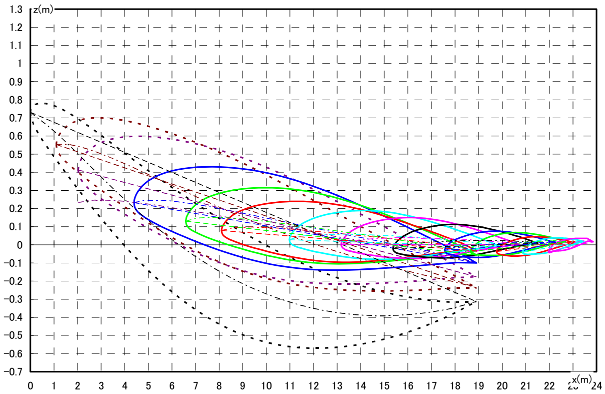



Fig. 5b) Designed Wing Configurations [6]

Figure 6 shows Hydrogen Fueled Jet Transport (2008) aimed to reduce the emission of carbon dioxide drastically. After comparing with different configuration, a wide body fuselage with twin liquid hydrogen external tanks was selected as a final configuration [8].

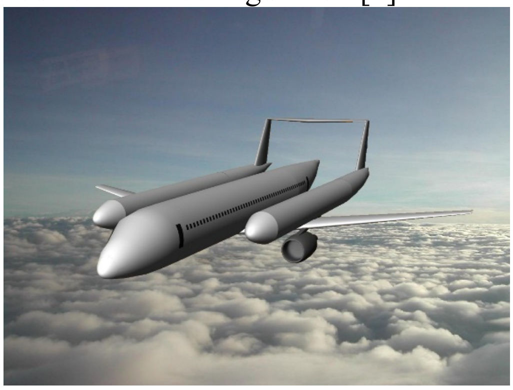


Fig. 6 Hydrogen Fueled Jet Transport [8]

Figure 7a) shows Ultra Large Transport with non-circular extra wide fuselage (2010, [10]). Students have begun to use a CFD tool developed by JAXA (Fig 7b)). Area rule was applied for the fuselage. Figure 7c) indicates results of FEM analysis of the extra wide fuselage.

Fig. 7a) Ultra Large Transport [10]

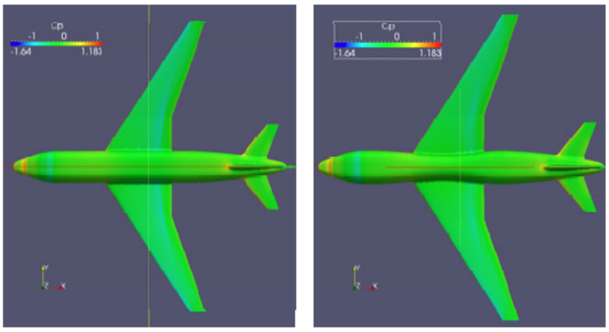


Fig 7b) Results of CFD Analysis [10]

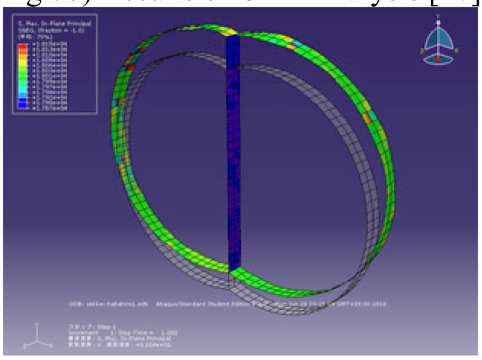


Fig. 7c) FEM Analysis of Fuselage [10]

Figure 8a) shows Sonic Speed Cruise Business Jet (2012). Two different configurations of conventional business jet type and supersonic transport type (Fig.8a) [11]) were considered. Students experienced the difficulty in estimating the cruise drag using the CFD tool (Fig.8b)).

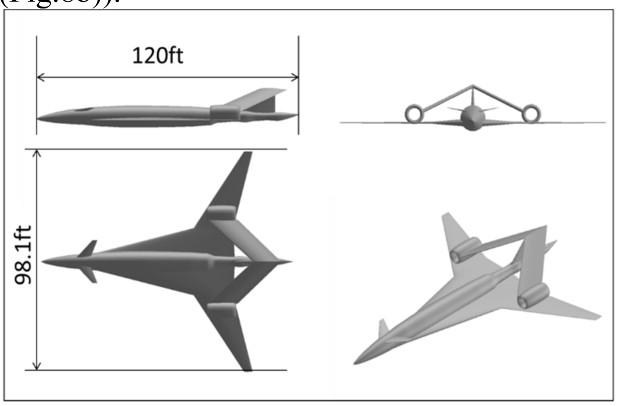



Fig. 8a) Sonic Speed Cruise Business Jet [11]

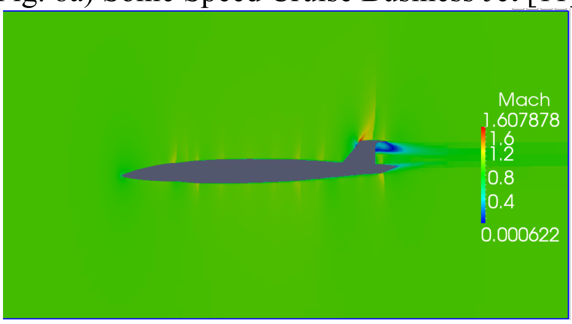



Fig. 8b) Results of CFD Analysis [11]

Finally, Figure 9a) shows Hybrid Propulsion Aircraft (2014). It is powered by two turbo fan engines and two electric fans. Conventional configuration and unconventional configuration with canard (Fig.9a) were designed [12]. Different propulsive scheme was considered for take-off/climb and cruise phases (Fig. 9b). It was indicated 5-10% fuel reduction can be expected, when 500 Wh/kg energy density batteries are equipped with.

Fig. 9a) Hybrid Propulsion Aircraft [12]

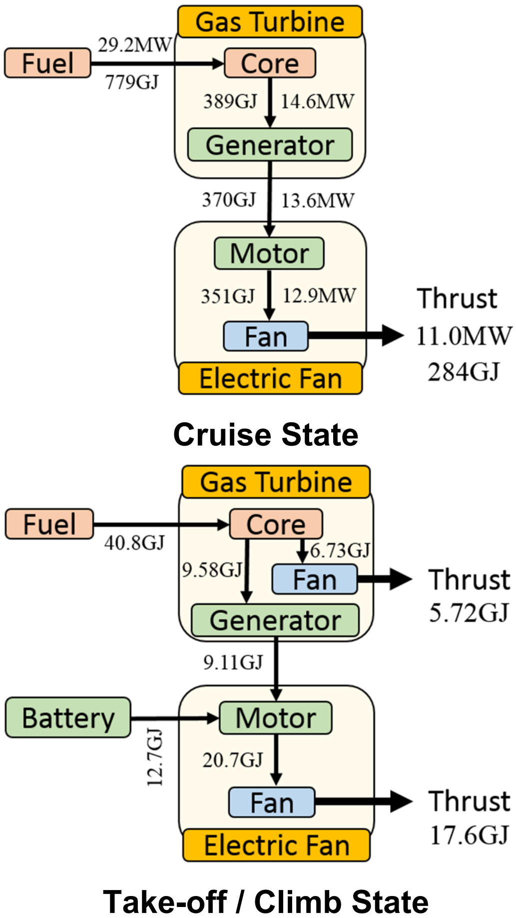



Fig. 9b) Energy Flow [12]

## 3. Conclusions

Overview of the aircraft design education conducted at the Department of Aeronautics and Astronautics, the University of Tokyo was given in this paper. Design conducted both by the undergraduate students and by the graduate students were summarized. Throughout the design course, students have to combine individual aerospace knowledge into a single engineering system. During this “integration” experience, students have a chance to solve engineering problems they have not experienced before by utilizing their knowledge.

The author would like to express his gratitude for those attended the design review conducted for the “group design” course by graduate students. Their comments were very helpful. The author also appreciates Japan Aerospace Exploration Agency (JAXA) for giving the graduate students opportunities to use the CFD tools developed by JAXA.

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