The Tentative CDIO Practices in AIR, Tsinghua University

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ABSTRACT

The centre of Aero Innovation and Realization for students (AIR) provides the students in Tsinghua University with a place, where their innovative ideas on aeronautics can be proposed, realized and tested. After learning the basic courses such as aerodynamics, aero-structure, aircraft design etc., the students are encouraged to enroll in the programs hosted by AIR. They can propose new ideas on airframe, propulsion system or avionics. With the facilities, materials and funding provided by AIR, they can put the idea into detailed design and produce the prototype. Finally they are required to have the prototype tested to prove their idea or design. During the whole process, teachers who are specialized in aeronautics can provide guidance or advises on demand. The centre also has a professional aero-model coach. The students are required to grasp the skills of aero-model control in order to test fly their own aircraft. We believe the principal ideas of the AIR coincide with the four basic elements of CDIO, which are Conceiving, Designing, Implementing and Operating. We are trying our best to put the AIR into a key node in the CDIO system of the School of Aerospace in the Tsinghua University.

KEYWORDS

AIR, Student, Engineering Education

HISTORY OF AIR

Early in 1930's, the Tsinghua University was among the first universities who owned the departments of aeronautics. However in the year 1952, due to the China's education system reform, the aeronautics department was removed. The faculties and facilities were scattered to other specialized aeronautics universities all around China. The current Beijing University of Aeronautics and Aerospace (BUAA) was largely formed basing on the legacy.

In the year 2004, on the demands of the fast growing Aeronautics and Aerospace (A&A) industry of China, the School of Aerospace of Tsinghua University was reestablished. The new school was primarily based on the original Department of Engineering Mechanics (DEM). Although having very strong basis of solid mechanics, fluid dynamics and thermal science, with a 50-year blank in A&A education, the school badly lacked the specialized courses at its beginning. Although had "engineering" in its title, the old DEM used to be dominated by a more "science oriented" culture. Moreover, in China, there was a trend spreading in the universities to teach students more and more theory, simulations and virtualizations, and give them less and less training on operation and realization. For the teachers, who are always pressed by their universities to improve their "academic" levels, this trend may be natural and comfortable. However, for the students who will after their graduation improve their country's A&A products and industry, this trend is irresponsible and dangerous. Therefore the newly established School of Aerospace had an urgent demand to set up its faculty, facility, environment and even the atmosphere for the engineering practical education, which is known as the core of A&A education.

With this background, the idea of establishing the AIR was originated. The new born school was invited to participate a student aero-robot competition among Universities. Two authors of this paper voluntarily organized a team, and took part in the competition. With little experience and support, in only a month, the students managed to build a very rough UAV (Unmanned Aerial Vehicle). They gained only an ugly place in that match. The young teachers realized that although the Tsinghua University possessed the best students in China, the lack of practical training would make its A&A graduates uncompetitive to those students graduated from other specialized aeronautics universities.

The teachers tried their best to keep the team from being dismissed after the match. They kept appealing for funding and space to make the students able to continue their practices on model aircrafts and UAVs. Step by step, their efforts were gradually recognized by the school and the university. More and more funding was granted. More and more space was offered. More and more teachers joined the advisor consortium. Above all, more and more students got enrolled in the practical training activities. Finally in Nov.11, 2007, the centre was formally inaugurated. Almost the whole steering board of the school attended the opening ceremony. Together with a student representative, the vice president of the university cut the ribbon and unveiled the centre’s plaque. As shown in fig.1, the plaque was designed by students themselves. The logo symbolized a student who is releasing an airplane from his hand. This is just the tenet of the centre.

Fig.1 The AIR’s plaque designed by students

The history of the AIR’s development was a reflection of the reformation in the school’s teaching objectives and philosophy. What kind of A&A graduates do we want to “produce”? This should be the first question the school must answer when it was established. Scientists or engineers, the two options, however, are still being argued among the influential professors. Nevertheless, A&A is out of question a field with extremely strong engineering characteristics. During the years the AIR was being gestated and developed, the importance of engineering education to the A&A students is gradually accepted by the school’s faculty. More and more emphasis was put onto the practical education, not only officially by the school, but also spontaneously by the teachers themselves.

In 2008, the school joined the CDIO organization. The AIR is expected to be built into an important component of the CDIO system in the school. With a bright future, the AIR pledges to contribute “to educate tomorrow's leaders through innovative educational programs and pedagogies".

CURRENT AIR

Nowadays, the AIR has been developed into an important practical education base of the school. Annually, more than 50 students from the whole university can be accepted to the center. They have won dozen of medals in different kinds of aero competitions. Scores of students who have graduated and entered the A&A industry are gaining their reputation. The teacher consortium has grown to consist of 6 young professors, whose research fields range from aerodynamics, aircraft structure, flight mechanics to avionics. In the year 2008, a national RC (Remote Control) aero-model champion winner joined AIR to work as the coach and technical specialist.

AIR has set up certain hard- and soft-environment for students’ practical activities. The around 60-square-meters space is divided into discussion room, electronic and design room, machining room and a hall way used for assembly. The major facilities include mechanical tools such as laser cutter and various machine tools, outfield gears such as mobile power generator, and some electronic test devices and computers. These facilities can meet the basic demands of model airplane and UAV development. The students also have designed and built some equipment by themselves, including the engine test bed, wing structure static strength measurement rig and so on.

AIR has also set up its rules and operation guidelines to make sure students can get best engineering training and practices, while preserving their curiosity, interests and creativity on aeronautics. With the supports from the school and the university, funding can be now provided to support students to conduct projects proposed by themselves. Currently, there are four primary types of activities in AIR. The first one is organizing, training, and supporting the student teams to take part in the scientific aero-competitions. The second one is supporting the aeronautics courses. The third one is funding, hosting, supporting and supervising the student’s aero-innovation projects. The fourth is hosting and supporting the student’s graduation research projects.

TYPICAL CDIO PRACTICES IN AIR

Since 2006, the center keeps organizing student teams to take part in the annual National Championship of Scientific Aero-Model. Two competitions are chosen, which are “weight-lifting” aircraft and aerial photography. The object of the former is to design a model aircraft with total airframe weight no more than 1 kg, to carry as much water load as possible and finish a close flight course. During the flight, the water load needs to be dropped to a target area (as is shown in fig.2). The heavier the load, the more accurate the drop, the higher will be the score. The aerial photography game is to design, build and operate a UAV to take birds’ eye photos of a circular target on the ground (as is shown in fig.3). The score is determined by the size of the circle in the frame, and its roundness.

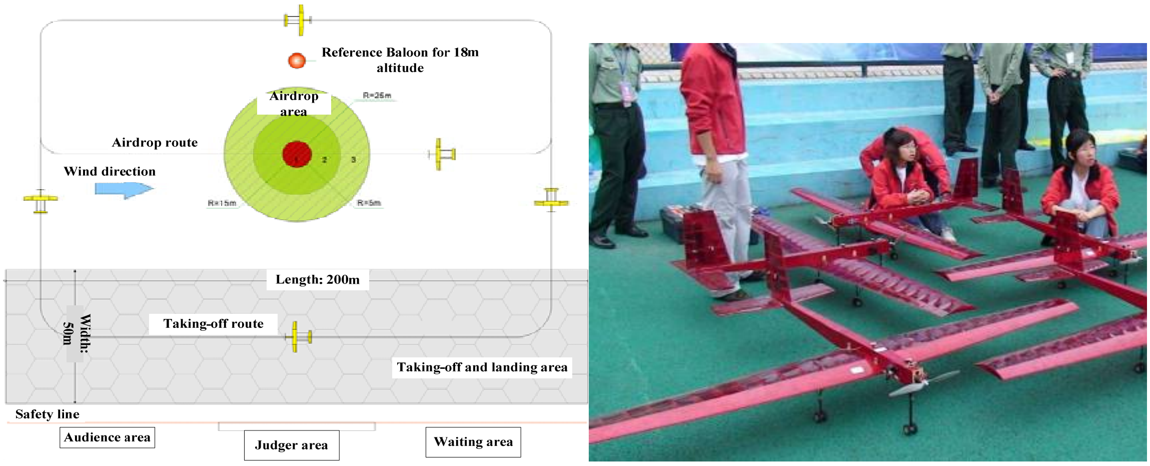

Fig. 2 Required flight path and the AIR fleet of Weight-Lifting aircrafts.

Fig.2 shows the aircraft fleet the students designed and built for the 2009 game. The record for this aircraft can take as much as 7.4 kg water. Through the competition, the students can learn how to design, manufacture, cooperate and communicate. The competition is full of challenge, failure and even depression. But these strengthened their motivation for aeronautics.

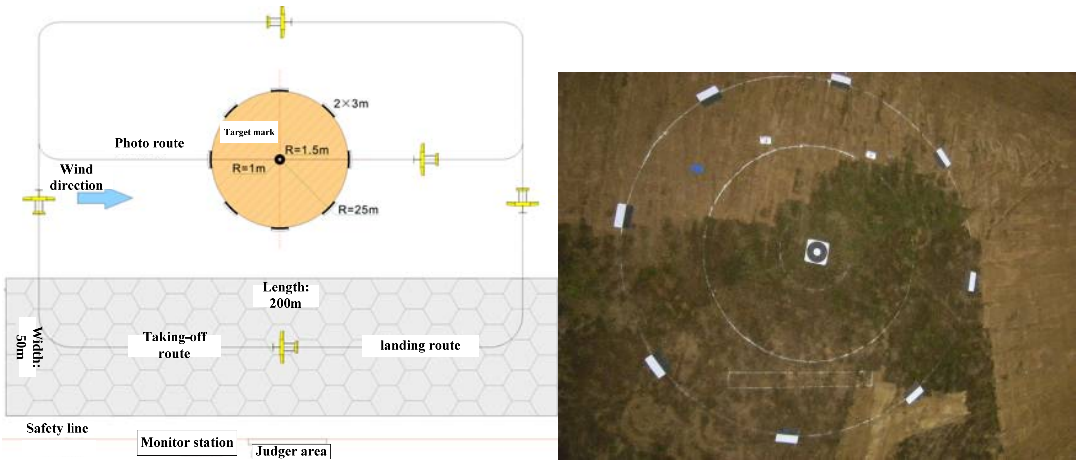

Fig. 3 Required flight path and the AIR's shot of aerial photography game

These two games post great challenge on aircraft design and manufacture, and are believed good for the A&A college students. After learning some basic aeronautics courses, the students have got some fundamental knowledge of aircraft and aviation. As an example, by taking part in the "weight- lifting" aircraft competition, they need to use their aerodynamics knowledge to select or design high L/D (Lift/Drag) airfoils, they need to use their knowledge on aircraft structure and strength to design a light while tough airframe. They can use their knowledge of flight mechanics to design the layout of the components to keep the aircraft stable and controllable. Their theoretical knowledge from the books can be applied and tested. And they can have a better understanding of it. But the students will soon realize that those are far from enough. During the production, they will find they have to reduce the wing aspect ratio. Although a high aspect ratio wing will reduce the drag, just as they are told by the books, the pencil like wing will be as soft as an osier. Yet it can be strengthened, the weight will over the limit…… During such kinds of try

and error, the students begin to think as an engineer. They can know the concepts of robustness, off-design considerations, expense and time control, and compromises.
In the name of the competitions, the students are required to experience a complete aircraft design and development process. Through several rounds of brain storm CONCEIVING, presentation and discussion, they need to determine an appropriate layout of the configuration. Then the DESIGN process begins. They optimize the aerodynamics, sketch and evaluate the strength, trim the center of gravity……. The students are encouraged to use all kinds of professional software, like AAA, CFX, ANSYS, just as the real aircraft engineers do in their work. As the results, they need to complete the detailed digital design with CAD (Computer Aided Design) tools. When the design is finally determined, they need to IMPLEMENT the aircraft by their own hands. They test and choose materials from the shelf. They operate the laser cutter to shape the wing ribs and other components. They then put everything together to finish their aircrafts. During this process, they may need to design and build some fixture. They need to consider how to control the error. If lucky, they may encounter the problems such as the material deformation caused by intrinsic stress. When these happen, the teachers will prompt the students to relate these problems to the knowledge in books, and encourage them to find solutions and document these problems and the solutions into design guides.

The game rules require the model aircraft to be controlled by the students. Hence, after the implementation, the students must learn and practice the OPERATION of the plane. Through the test flights, they can find the problems in the design and implementation process and correct them. They can also have better understanding of how the flaps, rudders are working, what will happen when the angle of attack is too high. They can also become “tough” when they repeatedly crash their production and understand this is a necessary penalty to make an aircraft reliable.

The process of preparing and taking part in a competition is out of question a best way to raise the teamwork spirit of students. During the different phases, different grouping are made by the students. Sometimes there are competitions among groups. However there is more cooperation. Usually a senior undergraduate or a graduate student will be selected to coordinate the work distribution and control the progress. Inside each group, members are playing different roles. A leader will assign different jobs to different people. However, they are encouraged to alternate their role and jobs to make every member be able to have abundant experiences during the process. In the competition, they must cooperate very well. Since the time to finish the flight is limited. Besides the controlling of the aircraft, there are many things to do by a 3-member group. Starting the engine, changing the battery, loading the water, monitoring the plane’s status in the air, recovering the failures, all these work can be done only when the group members are perfectly organized and trained.

INTEGRATION OF AIR INTO THE CURRICULUM SYSTEM

The initial purpose of AIR in 2004 was to have a place for students to make model planes to take part in a competition. And then the organization was developed to a workspace for students’ extracurricular scientific activities. However, the teachers gradually found that the activities in the centre can greatly help the students better understand their courses. Therefore, more and more hands-on experiments in AIR are added into their courses. Nowadays, the teachers are considering how to adjust their courses to make better use of the AIR. For some courses, part of the in-class lecture time is changed into design experiment projects in the centre. The student’s performance in their projects can play an important role in the final evaluation of these courses. Some new courses are also set up with activities in AIR as their core components. According to the standards of the CDIO system, the AIR is being integrated into the aeronautics course system of the school.

Aircraft Structural Mechanics is a course opened in the school by an AIR teacher. In its first year, the course used almost all its time on classroom lecture. Students' feedbacks complain that there are too many equations, which they don't know where to use. The teacher decided to change this situation. A wing design competition was added to the course. Students can organize teams with no more than 3 members. They must design and manufacture a model-aircraft wing with limited budget, material and time. Their produces need to pass eight tests to get evaluated. Every team needs to submit a final report and make a final presentation, which should include their design ideas, the analysis methods they used, the comparison between their design computation results and the test results, and a thorough analysis. The performance of their final presentation will also be taken into account. Fig. 4 shows some pictures when the competition was taking place.

Fig. 4 Wing structure design competition in the course

Other courses, such as Introduction to Aeronautics, Aircraft Design, Flight Mechanics and UAV System Design are also utilizing AIR as their platform of experiments. The teachers are shifting more lecture time into research projects and experiments. The students are quite enjoying the shift. The knowledge is no longer filled by tedious math deduction and equations. It is now the tool they can use to improve their own design, their own product, and their own operation.

The undergraduates of Tsinghua University should finish a graduation training paper for the degree. It needs student to do some real engineering work in aeronautics department. AIR can accept about 5 students for graduation work every year.

The student can finish their graduation design or research project in AIR. Sometimes, the teacher will let them to design one aircraft, make it and fly it. The first graduation research finished in AIR was a B-2 like model plane as in fig.5. Four students formed a team and finished the work. They decomposed the work into four different parts and finished four graduation theses respectively. The theses were on aircraft system design, aerodynamic analysis and optimization, electronics system design and structure design. They finished very beautiful analysis and built a beautiful model plane. Although at the end, the model was too heavy to fly, they all got high score in the thesis defense. It was from that practice, the teachers realized that our students were so short of experience and training on implementation and operation.

Fig.5 B2 model designed and made by students

From then on, more implementation and operation education program are provided in AIR. If they like, through these programs, the students can get enough experience before they begin their graduation projects. One year later, another student designed a joint-wing aircraft for his graduation work and sent it into the sky. He experienced the whole CDIO process. Although the aircraft also crashed in a test flight, he gained a lot of valuable findings in the process. After that, during his graduated study, he became the student leader in AIR and won the champion of the weight-lifting aircraft competition in 2007. Being the school's top 1 master graduate in 2008, he joined a leading aircraft design institute in China and has now become a real aircraft designer.

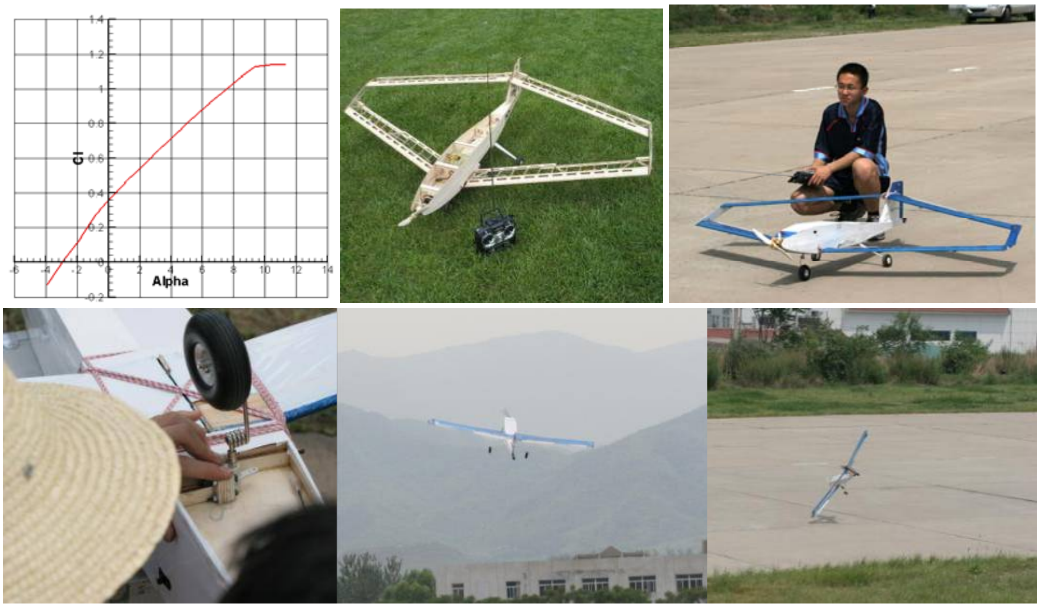

Fig.6 Joint-wing aircraft designed by the student

THE PROMOTION OF STUDENTS CREATIVITY

As its name indicates, the AIR is not a place only for training. It is much more a place for students to raise their ideal of flying and help them to realize it. In the center, the students are encouraged to conceive their own ground breaking ideas, design them and implement them. To support this, the AIR host, or even fund student self-proposed research projects.

With their innovative ideas, the students can apply funding from programs out AIR, such as Innovative Project for the State College Students, Beijing Student Research Project, Tsinghua Student Research Training Project. AIR can help students on the application. When approved, the projects can be finished in the centre with the AIR's material, space, facilities and teacher's guidance. If necessary, AIR can provide supplementary funding.

Air can also provide funding for all students in it. Every year, AIR issues Request for Proposal to students. Before a deadline, they need to organize a team to write the proposal. The teachers will review the proposals. About three to five projects will be approved every year. Every approved team should submit a budget and a project plan. In the middle term, the teachers will check the progress and give some advices. When the project is finished, the team should submit the report and the deliverable listed in the plan. The expense for the project need also be checked according to the budget. A board made up by students and teachers will review the project. Through the projects in the AIR, students are encouraged and supported to improve their creativity. And at the same time, they can experience all the elements in a project's procedures. They can learn how to write proposal, how to work on schedule, how to demonstrate their research results. They also can learn the responsibilities in the scientific research.

Fig. 7 on screen display system

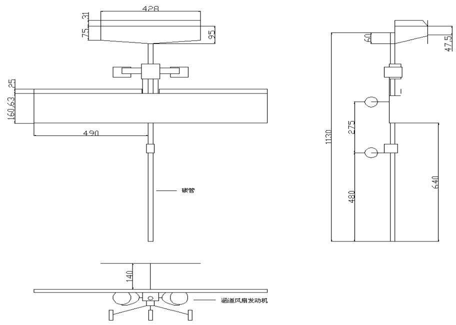

Fig. 8 three view of thrust vector aircraft

Fig.7 demonstrates the main interface of the OSD system developed by students under the AIR project. The simple while effective system uses a video camera as the pilot's eyes in flight. With the real-time image transmitted to the monitor on ground by RF signal, the operator can conduct the BVR (Beyond Visual Range) control of the model airplane. They also used screen video overlay technology, to let the necessary flight information, such as the GPS (Global Position System) location, remained battery capacity, flight speed, heading, altitude, climb rate and so on, to be known by the operator. These data are added into the analog video signals, and transmitted to the ground station. As is shown in fig.7, the controller can fly the aircraft like that he is sitting in the cockpit and looking out through a HUD (Head – Up Display) .

In Fig. 8 is the three-view for a thrust vector aircraft. The student used two ducted fans mounted on both sides of the fuselage. The pitch angles of the fans can be controlled independently to realize the vectoring thrust. Although ugly, the plane shows perfect maneuver properties in flight.

SUMMARY AND HOPES

AIR commit itself to make the students to better learn the aero-knowledge through the C-D-I-O way; to let the students better understand what engineering is; to help the students know and practice the whole process how an engineering project can be proposed, can get approved, can have a good budget, can be well organized and conducted, can be finished in time and can be useful to humankind; to educate the students to improve their good engineering properties and habits, such as teamwork, well planning, good communication…… and even compromise.

Currently the CDIO system in the school is still under construction. The students' activities in AIR need to be better coordinated into the whole curriculum system. The most important is that the student's efforts, contributions and achievements should be better recognized. The teachers are complete volunteers. Even without the work in AIR, they have been overloaded by their "own" teaching and research. Although to themselves, their hard work in AIR is just about their commitment to the students, they hope the CDIO system construction could make their work more valuable and better understood.

Biographical Information

Dr. Haixin Chen is an associate professor in School of Aerospace, Tsinghua University. His research interests include CFD (Computational Fluid Dynamics), aircraft design, turbo-machinery fluid dynamics. He is one of the founders of AIR and the first head of the teacher consortium.

Dr. Chunhua Hu is an assistant professor in School of Aerospace, Tsinghua University. His research interests include aircraft automatic control and avionics. He is one of the founders of AIR.

Dr. Dongyun Ge is an associate professor in School of Aerospace, Tsinghua University. Her research interests include aero-elasticity and vibration control. She is the currently the head of AIR's teacher consortium

Mr. Guici Yang is the technical specialist and the coach of AIR. He won the national champion of China F3A RC model competition.

Prof. Song Fu is the deputy dean of the School of Aerospace, Tsinghua University. He is a world recognized researcher in fluid dynamics. He is currently in charge of the teaching affair in the school and taking the responsibilities of building the school's CDIO system.

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