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80 Years of Aerospace Engineering Education in the Netherlands

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This year, 2020, the Faculty of Aerospace Engineering at Delft University of Technology in the Netherlands celebrates its 80th birthday. This paper describes the history of the department since its founding in early 1940, just before the start of World War II in the Netherlands, until present day. The paper will highlight how its research and education developed within the socio-economic context of the Netherlands and the developments in aerospace over the past 80 years.

Introduction

This year, 2020, marks the 80th anniversary of the Faculty of Aerospace Engineering at Delft University of Technology, located in Delft in the western part of the Netherlands. Since its commencement in May of 1940 until present day the Faculty has developed itself into one of the largest Aerospace Departments in the world, with an annual intake of over 400 Bachelor students and 400 Master students as well as the presence of 270 PhD students. The university ranks 10th in the Shanghai ranking for Aerospace Engineering. The aerospace curriculum is fully taught in English and the Faculty of Aerospace Engineering employs over 150 academic staff members. Delft University of Technology, as a whole, totals over 25,000 Bachelor and Master students and 2,500 academic staff.

In this paper the authors will tell the history of the Faculty of Aerospace Engineering at Delft University of Technology from its creation in 1940 till the present day within the socio-economic context in the Netherlands and in particular of the Dutch aerospace industry. Furthermore, its history will be positioned within the development of Engineering and in particular Aerospace Engineering as a branch of study over the past century. This perspective will be based on a multitude of historic sources and is based in part on previous research performed by the first author, Saunders-Smits [1], as well as records of subsequent events and publications since.

I. The Development of Aerospace Engineering as a University Degree

Although Leonardo da Vinci (1452-1519) was one of the first engineers to record possible designs of flying crafts, he, like the first aircraft designers after him, was predominantly an auto-didactic with little formal training in engineering at an academic level. To fully understand how aerospace engineering became an academic degree course, it is important to examine this development in the context of the development of engineering education at Higher Education level, and the development of aerospace as an established field of science. Therefore, in this section these developments and the birth of the first aerospace departments in the world will be discussed before exploring the conception of aerospace within the Netherlands and the history of the Faculty of Aerospace Engineering at Delft University of Technology.

A. Defining Aerospace Engineering

To avoid confusion in this paper, the authors would first like to define what they mean with Aerospace Engineering as a field of science, as the term is often loosely used, especially internationally. The authors would like to use the

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definition as listed in the Encyclopedia of Aerospace Engineering [2] which defines *aerospace engineering* as: "*the primary field of engineering concerned with the development of aircraft and spacecraft*". This definition was coined when the field of *aeronautical engineering*, defined as "*the primary field of engineering concerned with the development of aircraft,*" increasingly started to extend their work to include vehicles operating in (outer) space, also leading to the renaming of the National Advisory Committee for Aeronautics, NACA to the National Aeronautics and Space Administration, NASA in 1953. In literature, when referring to (outer) space engineering, the terms *astronautical engineering* or *space engineering* are also used, defined as "*the primary field of engineering concerned with the development of spacecraft*".

B. Development of Engineering Education at Higher Education Level

Engineering was one of the last fields of sciences to be developed as scientific field of study. Natural sciences were already studied by ancient civilizations and considerably developed as an independent field of science in the 16th and 17th century with the emerging of scholars such as Copernicus (1473-1543), Galilei (1564-1642), and Newton (1642-1727) and the founding of the Royal Society (of London for Improving Natural Knowledge) in 1660. The logical explanation for this is discussed by Saunders-Smits [1] and Lintsen et al. [3], who tell of the Dutch science philosopher Van Peursen who likens the development of engineering as a science to the water cycle [4]: with first the development of formal sciences, followed by the development of the empirical sciences and, for now, conclude by the applied sciences, which includes the field of Engineering, as being closest to social reality. In this analogy it makes perfect sense that engineering is not offered as a university degree nor is it researched at a university level until the late 18th century and the first half of the 19th century. This of course also coincides with the start of the Industrial Revolution in the United Kingdom, greatly aided by the further development of Newcomen's Steam Engine by James Watt in 1765, creating a societal need for more applied knowledge in order to prosper.

Fig. 1: The building of the Faculty of Aerospace Engineering at Delft University of Technology when it opened in 1965 (left) and currently (right) – *Images © TU Delft*

Historians are in disagreement on when and where the first institutionalized scientific training of engineers took place. Simon Stevin (1548-1620) was asked by the Dutch prince Maurits of Orange (1567-1625) to found a military engineering school at the University of Leiden (in the Netherlands) in 1600. However, this school taught in Dutch as opposed to Latin, which was the primary language used at universities at the time. As a result, the school struggled to gain real recognition for more than a century as an academic institution and was eventually abandoned [5]. It is therefore not seen as an academic institution by historians.

Gregory [6] suggests that the "*École Polytechnique*" – Polytechnic School, was the first school to be founded in France in 1795, but other historians, such as Emmerson [7] and Armytage [8] mention an earlier school in France: the "*École des Ponts et Chaussées*" – School of Bridges and Roads, founded in 1747. After these, other European countries followed in rapid succession with the Freiburg School of Mines in Germany in 1765 and a military engineering academy being founded in Delft by King William I in 1814, which would become the Royal Academy for Civilian Engineers by 1842 by order of his son King William II. This school was renamed to "*Polytechnische Hogeschool*" in 1864 and became a formalized Higher Education Institute named "*Technische Hogeschool*" in 1905, modelled after the French model of "*Écoles Polytechniques*". It is this school that laid the foundation for the present Delft University of Technology or "*Technische Universiteit Delft*" in Dutch, commonly referred to as "*TU Delft*." [5]. In England it took until 1840 for the first chair in engineering to be set up in London. In Glasgow, Scotland an engineering chair was set up in the same year, followed by Dublin in Ireland in 1842 and Belfast in Northern Ireland in 1849.

Which college was the first engineering college in the United States of America, is still a topic of an ongoing debate. The consensus, however, is that the following four schools [9] can be considered the first engineering colleges:

- The United States Military Academy at WestPoint, New York (first engineering graduate in 1817),
- Norwich University, Northfield, Vermont (first Civil Engineering degree awarded in 1834)
- Rensselaer Polytechnic Institute, Troy, New York (first graduate in Civil engineering 1835)
- Union College, Schenectady, New York (degree course in Engineering offered from 1845)

C. Development of Aerospace Engineering Education

The development of the field of aerospace initially focused on aeronautics. The push to teach subjects related to aeronautics and create academic degree programs was greatly aided by the first recorded sustained flight of an aircraft by the Wright Brothers in 1903 and the rapid rise of other aircraft designers who followed soon after. However, as to who taught the first courses in aeronautical engineering, is still an ongoing debate in literature. McCormick [10] states that Professor Lucien Marchis of the University of Paris, France was the first to teach formal courses in aerodynamics at university level in 1910. These claims are disputed by other sources. Ransom and Self [11] list the claim that Imperial College in London, England taught its first course in aeronautics in 1909. They also report that the first chair in Aeronautics at Imperial College was founded in 1920. In addition, Queen Mary's College London, England proudly lists on its website, that they are the oldest aeronautical engineering department in the United Kingdom, founded in 1909 and already teaching courses in aeronautics from 1907. The first institution reported to be established to award a degree in aeronautical engineering was the "*L'École Polytechnique de L'Aéronautique*" in 1909 in Toulouse in France. This school still exists today under the name "*ISAE SUPAERO"*. In the United States of America, the first degree and 4-year program in aeronautical engineering was founded in 1916 at the University of Michigan combined with founding of a department in aeronautical engineering. In 1926 the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts. founded its aeronautical engineering department. From the 1930s onwards more schools were founded all over the world and this accelerated after the outbreak of World War II. With the start of the space program most aeronautical universities also started to include space in their curricula, which from 1958 onwards led to many institutes changing the name of their departments from aeronautical to aerospace engineering.

II. Developments in Dutch Aviation until 1940

The Netherlands has its own strong tradition in aerospace engineering. The most famous of Dutch designers, Anthony Fokker, flew his first design the "*Spin*" (Spider) on its maiden flight in 1911[12]. He had a fierce competitor named Frits Koolhoven whose aircraft the "*Heidevogel*" (Moor bird) also took to the skies in 1911 [13]. Fokker left for Germany due to a lack of customers in the Netherlands, where he became a successful aircraft designer during the First World War with his Fokker DR-I gaining notoriety among the Allied Forces. For similar reasons Koolhoven left for England where he was a designer for British Deperdussin, Armstrong Whitworth and British Aerial Transport. Both returned to the Netherlands after the First World War to start their own factories. They were however, not the only Dutch aircraft designers at the time. Spyker, initially built Farman aircraft in license and later started to produce his own aircraft the "*Spyker V1, V2 and V3*". Then there were the Pander factories which produced the "*Pander D"* and the *"Pander E"* as well as the "*S.4 Postjager.*" The latter took part in the 1924 London-Melbourne race. Pander's designers continued in 1934 at the Schelde factories building the *S.12* and the *S.20* [12]. Finally, there was Hugo Lambach, a graduate in Mechanical Engineering of TU Delft who built two aircraft, the "*Lambach HL I*" and the "*Lambach HL II*" [14]. None of these companies ever reached the same size of Fokker and Koolhoven who employed over 1,200 people each.

On the operations side, KLM Royal Dutch Airlines was founded by Albert Plesman in 1919 and soon started regular flights to the Dutch East Indies (present day Indonesia) from the first Dutch Civil Airport, Schiphol. Schiphol initially was a military airport but became a civil airport in 1920 and is now a major hub airport.

The Dutch armed forces, similarly to the British armed forces, started a Flying Corps, (in Dutch: "*Luchtvaartafdeling*") upon the urging of General Snijders in 1913. During the First World War, the fleet of this unit was greatly extended by over a 100 foreign aircraft, which were confiscated from both sides of the conflict who sought refuge in Dutch neutral territory. Of these recovered aircraft 69 were restored to flying condition and added to the Dutch military fleet. During the interbellum the air unit continued to grow to become an independent branch of the Dutch Armed Forces, now known as the "*Royal Netherlands Air Force*" [15].

Also, to support the ongoing developments in the field of aviation, the Dutch National Study Department for Aeronautics (in Dutch: "*Rijksstudiedienst voor de Luchtvaart*") opened its doors in 1919. This organization still exists and is now known as the "*Royal Dutch Aerospace Center*" (NLR).

As a result of all these developments, there was a great need for highly trained and skilled aeronautical engineers.

III. History of Aerospace Engineering at Delft University of Technology

To address this need, from the 1930s onwards, the first courses in aeronautical engineering were being taught at TU Delft within the department of Mechanical Engineering and Shipbuilding, according to the history book of the Faculty published on the occasion of its 50th anniversary in 1990 [16]. Professor Burgers taught the basic principles of Aerodynamics and Professor Biezeno taught the principles of Aircraft Structural Analysis. Early industry collaboration was started, asking ir. J. Roosenschoon from the Fokker Aircraft Company to also teach aeronautics part-time. The abbreviation "*ir.*" is for the Dutch word "*ingenieur*" meaning engineer and is a protected title under Dutch law that can only be used by holders of a Master of Science in Engineering degree from one of the Dutch Universities of Science and Technology. This is not be confused with the abbreviation "*ing.*" which indicates a bachelor of engineering degree from one of the Dutch Universities of Applied Sciences.

A. The Founding of the Faculty and the Outbreak of World War II in the Netherlands

However, the formal starting date of Aerospace Engineering at TU Delft is seen as May 6, 1940, when the first Full Professor in Aeronautical Engineering, Professor Van der Maas is appointed by the Dutch Crown within the Department of Mechanical Engineering. This appointment was later than initially intended, as the first candidate for the job, ir. A.G. Baumgartner, a helicopter designer and flight mechanics expert was killed during a 1939 test flight of Boeing Stratoliner in the United States of America. This was not the only bad fortune to hit the start of the Faculty. Just four days later on May 10, 1940, Germany declared war on the Netherlands and invaded. The Dutch Armed Forces felt compelled to surrender after only 5 days to avoid further mass bombardments of large cities. This after Rotterdam, the largest harbor city of the Netherlands, some 5 miles South of Delft, was almost completely destroyed by German aerial bombardments.

Although the university at first continues to operate and Professor Van der Maas held his inaugural lecture entitled: "the Start" and in 1943 he even instigated the degree program in aeronautical engineering [16], teaching was suspended in 1943. In 1944 Professor Van der Maas was forced into hiding with his wife and 11 children as he was warned he was to be taken hostage by the occupying forces [16]. Therefore, the degree program did not formally start until September 1945. As Professor Van der Maas was a very religious, Calvinistic Protestant, he was a firm believer that idle hands are the devil's playground: he used his time in hiding to write the lecture notes for the aeronautical curriculum and taught students who had not signed the Loyalty Statement to the Third Reich [17] to allow them to make a quick start once the war was over. Among them was one of the future deans of Aerospace Engineering, Professor Wittenberg.

B. 1945 – 1975: The After Bellum

After the end of World War II, the degree program in aeronautical engineering started to take off. The first twenty years can really be characterized as foundation years and investment in the future. A second full professor, Professor Van der Neut, in the field of aircraft structures was appointed in 1945 and by 1965 a total 16 full professors in aeronautical engineering had been appointed of which three were also working in industry. At the start of its degree program, aeronautical engineering was not an independent department. It was part of a larger department including mechanical engineering and shipbuilding.

In 1953 this department was split into two: The Department of Mechanical Engineering and the Department of Aeronautical Engineering and Shipbuilding. At the same time heavy investments were made to develop research facilities (more on that later) and in 1965 the Department of Aeronautical Engineering moved into its own building (See Fig. 1), which is still in use as the Faculty of Aerospace Engineering today.

The students also started to organize themselves. In 1945 the "*Aerospace Study Association, Leonardo da Vinci*" was founded to support students in their studies and personal development as well as provide entertainment.

The Fokker aircraft company resurged from World War II with the launch of the turboprop aircraft Fokker F27 Friendship in 1955 and the jet-powered Fokker F28 Fellowship in 1962. It also built many U.S. military aircraft under license, such as the Gloster Meteor and the Lockheed F-104 Starfighter. As a consequence, there was a growing need for aeronautical engineers in the Netherlands.

Educationally, the 5-year integrated master degree program quickly took shape. From the restart of the degree in 1945, aircraft design was the focal point of the degree with students initially being required to create two preliminary designs of aircraft (one glider and one engine powered aircraft) with supporting courses in aerodynamics, flight mechanics, stability and control and structures [16]. Very early on, in 1947, it was recognized that in order to achieve the deemed necessary, in-depth knowledge of a topic, students should differentiate and specialize in the last two years of their degree. The initial specializations were aerodynamics and flight mechanics, industry & production engineering, structures, and finally, elastomechanics. This in-depth two-year specialization still exists in the current 2-year Master program and is what sets a TU Delft MSc in Aerospace Engineering, content-wise, apart from most other aerospace engineering degrees in the world. The education program was continually monitored and updated to include the latest developments. The first courses on spacecraft were taught from 1961 by Professor Kooy as an external professor from the Dutch Royal Military Academy in the 4th year of the degree. As many students could not wait until then Professor Wittenberg, a keen space enthusiast himself, taught extra-curricular classes in space engineering in the evenings [16][18].

Next to being the leading figure in the aeronautical engineering degree, professor Van der Maas also ensured that sufficient aeronautical facilities in the Netherlands were provided. He played a leading role in the founding of the Dutch Institute for Aircraft and Spacecraft development, known as "*NIVR*" and served as its first chairman until 1970. He also became chairman of the earlier mentioned Royal Dutch Aerospace Center (NLR) in 1950 and held this position until his retirement in 1971. He used his leading role in all three organizations to promote the Dutch aviation industry and aeronautical research. Some say this is why the Netherlands played such a strong role in aerospace, however, one historian [19] feels that this powerbase also led to maintaining an unsustainably large aviation industry in the Netherlands, which could only survive if there was continued (financial) support from the government. When this support was finally stopped, the demise of the Fokker Aircraft Factory in 1996 became inevitable.

Professor Van der Maas can also be credited for his promotion of space research contributing to the founding of *SRON*, the Netherlands Institute for Space Research and the effective lobbying at the European Space Agency, resulting in the permanent establishment of the European Science and Technology Centre (*ESTEC*) in Noordwijk, the Netherlands after a short period in Delft [16]. Internationally, he ensured international collaboration by becoming one of the founding fathers for both the Advisory Group for Aeronautical Research and Development (*AGAR*D) in 1952 and the International Council for Aeronautical Sciences (*ICAS*) in 1957.

Table 1: List of employers of aerospace graduates in 1980 based on an alumni survey (N=298) [20]

Employer	AE Alumni
Fokker Aircraft Company	18.1 %
NLR	13.8 %
TU Delft	10.1 %
KLM	2.7 %
Rijksluchtvaartdienst (Dutch Airworthiness Authorities)	2.7 %
Philips Electronics	2.0 %
Oil Companies	2.0 %
Other Aircraft Manufacturers	1.7 %
TNO	1.7 %
Ministry of Defense	1.7 %

C. 1975 -1997: An Independent Faculty and Growth

In 1975 the Department of Aeronautical Engineering and Shipbuilding was split into two independent departments. The term "aeronautical" was replaced with "aerospace," reflecting the developments within the field of space, and from then on, the department was known as "*Aerospace Engineering*."

The term department was dropped in 1986 in favor of the term faculty, when Delft was given formal university status and renamed to "*Technische Universiteit Delft"* often shortened to *"TU Delft*" (Delft University of Technology) [5]. The formal name now became "*Faculty of Aerospace Engineering*", a name still in use today. The Faculty continued to grow and by 1975 had 18 full professors. The year 1976 saw the first professor in Space Engineering being appointed, Professor Bloemendaal. Student numbers were also steadily rising (see Fig. 2) and employment was good. Research by the "Aerospace Student Association Leonardo da Vinci" showed that in 1980, 18% of its alumni worked for the Fokker Aircraft Company (See Table 1) [20].

Changes in the Dutch Education system saw the formal introduction of the PhD trajectory at Aerospace Engineering in 1982. Although TU Delft has had PhD awarding rights since 1906, only occasional PhD degrees had been awarded before this time. There was no formal system of appointment and training of PhDs until then. By 1990 formal PhD student numbers had grown to 30 [16]. The year 1982 was also the year in which the 2000th student of the integrated Master program in Aerospace Engineering from TU Delft graduated.

The Netherlands as a country continued its investment in Space, with the Fokker Aircraft Company setting up a Space department named Fokker Space (Now part of Airbus Defense and Space) in Leiden and sent up its first astronaut, Wubbo Ockels (1946-2014), on the STS-61A Challenger mission in 1985. In 1992 Ockels was appointed as a part-time professor in Manned Space Flight at Aerospace Engineering and later on as tenured Professor in Aerospace for Sustainable Engineering and Technology.

The degree program in Aerospace Engineering was now an established name, delivering an integrated Master's Program, initially spanning 5 years, but under government budget cuts reduced to a nominal 4 years. In view of the stipulated workload of 1640 hours per year by the Dutch government, the 4-year integrated Master degree, in terms of work load, outperformed most 4-year Bachelor programs in the United States of America, even when followed by a 2-year Master program. In 1995 however, after serious government lobbying, the 5-year degree program was reinstated. The degree became very popular, as can be seen in Fig. 2. The number of students had to be capped at 305 in the early nineties in order to have sufficient staff and class rooms. In 1995 the degree program was given the prestigious ABET substantial equivalency status, making it easier for graduates to have their degree recognized in North America.

By the early nineties there were 13 research groups and well over 20 full professors. There were excellent industry relations within the Netherlands, but also within Europe and with NASA in the United States of America. The Faculty's research was gaining worldwide recognition: In the fields of aerodynamics ir. Boermans rose to fame by designing many high-performance wing profiles for gliders and Professor van Ingen as an international expert in boundary flow [18]. In the area of design, Professor Torenbeek wrote his famous textbook "*Synthesis of Subsonic Airplane Design*" and together with professor Van Tooren designed the EXTRA 400. Professor Gerlach was a renowned expert in the area of Flight Dynamics, his methods used by NASA to develop programs to read out Flight Data Recorders. He also succeeded professor Van der Maas at the NLR and as AGARD representative [18]. Within the area of aircraft materials, Professor Vogelesang, Professor Vlot (1962-2002) and others invented the fiber metal laminates GLARE and ARALL [20] and Professor Schijve was a leading expert on fatigue [22] . At the same time, in the Structures section, leading research into buckling and imperfections was carried out for NASA under the leadership of Professor Arbocz, whilst in the area of Space, Professor Wakker became an international expert on orbital mechanics and was appointed as director of SRON in 2003. To celebrate his work, NASA decided to name an asteroid after him in 2010 [18].

Students would perform their thesis research in one of these groups, either in-house or in industry under university supervision. By the end of their second year, students would opt to specialize in either Space or Aeronautics and all students were expected to complete a mandatory industry internship as part of their degree, with the Dutch Aerospace Center and the Fokker Aircraft Company offering many positions. The reputation of the quality of our students was also spreading. From the late nineties, aerospace students, among them third author, ir. Michiel Schuurman, were welcome to do an internship at the U.S. National Transportation and Safety Board in Washington D.C., which were highly coveted placements.

The aerospace students were also becoming increasingly interested in practicing engineering already during their degree. To celebrate the 50th anniversary of aerospace engineering and the 45th anniversary of their study association, students decided to build a replica of the earlier mentioned *Lambach HL II*, the only copy of which was destroyed in the 1940 bombardment of Ypenburg airfield near The Hague by the Germans. In their optimism they felt they would only need one year to build it and would have it fly in 1990, however, it would take five more years before she flew during our 55th anniversary in 1995 [14]. The Lambach HL II replica is currently not flying and on display in the Early Birds ("*Vroege Vogels*") Museum in Lelystad in the Netherlands with an intent to restore her back to flying condition. The students' intention to keep building and designing continued and work was started on the design of a small composite 2-seater aircraft, known as "*Impuls*". However, this project was abandoned a few years ago due to lack of progress and interest.

In 1983, the Fokker Aircraft Company launched the successors of the Fokker F27 Friendship and the F28 Fellowship, the Fokker 50 and the Fokker 100, respectively (However, the latter was certified as an F28 Mark 0100 to save cost). Although initially very successful in the market, the unfavorable US dollar – Dutch Guilder exchange rate provided increasing problems for Fokker and in 1996 the Fokker Aircraft Company was declared bankrupt.

This bankruptcy also severely affected the Faculty of Aerospace Engineering. Several part-time professors who were paid by the Fokker Aircraft Company lost their job, ongoing collaborations were halted and questions were being asked whether in the Netherlands a university degree in Aerospace Engineering could continue to exist, now that the Netherlands no longer had an independent aircraft manufacturer within its borders. Partly as a result of the bankruptcy, the Faculty itself had a budget deficit, the building of a new simulator was also facing setbacks and to make things even worse, in what was intended to be a small maintenance activity to update the air-conditioning system of the aerospace building, serious amounts of asbestos were found. As a consequence, the aerospace building had to be temporarily abandoned and the structure had to be stripped down to its bare steel frame. It would take 2.5 years before the building could be used again. During these years staff and students were relocated over a series of locations on campus, putting a great strain on staff and students. On top of that, as a result of the Fokker bankruptcy, the popularity of the degree also plummeted: the number of enrollments of freshmen in 1996 dropping to its lowest point in over a decade with only 146 new enrolments (See Fig. 2).

D. 1997 – Now: Surviving the Fokker Aircraft Company Bankruptcy

Action had to be taken and a reorganization was deemed necessary. This reorganization started in 1997 and led to an involuntary reduction in staff of approximately 30%. A new faculty structure was invented which saw two research sections banded as "*horizontal*" design groups in Aircraft and Spacecraft Systems Design, respectively, across the "*vertically*" more in-depth oriented other research groups, to better mimic the synthesis and systems approach in aerospace design.

Just after the Faculty of Aerospace Engineering had recovered from the aforementioned set-backs, a university-wide reorganization was initiated. This reorganization was deemed necessary because at the time TU Delft consisted of many (more than 14) relatively small faculties with only a limited number of students. The board of the university concluded that the overhead this created had become too extensive. Therefore a "clustering" operation was started to reduce the number of faculties which eventually resulted in only 8 faculties remaining. Thankfully, the Faculty of Aerospace Engineering managed to escape this clustering operation and remained the independent faculty it had been since 1975.

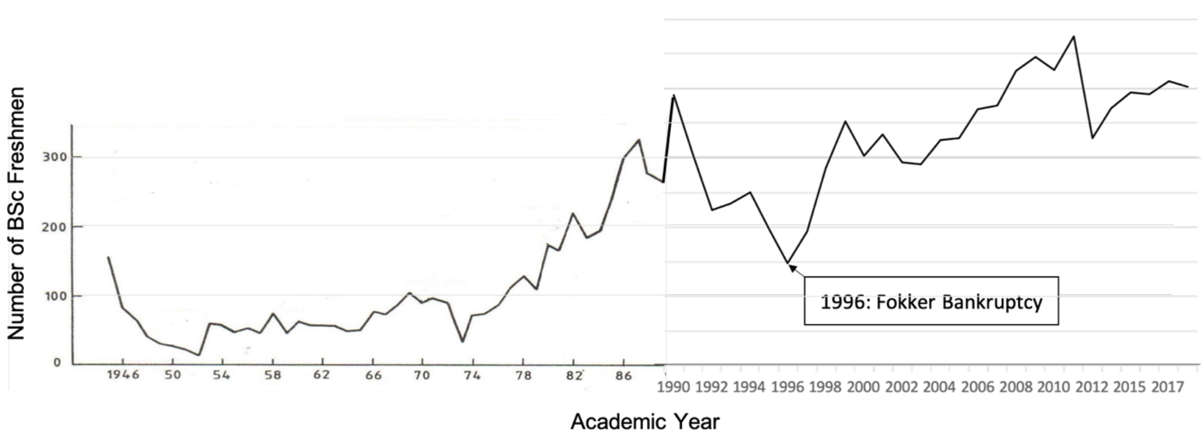

Fig. 2: Development of the number of freshmen in the integrated Master (until 2005) and Bachelor students (2005 onwards) over the years. ***(Sources: [16] and TU Delft)***

Dedicated action was taken after the drop to 146 students to attract more students. Education was made more attractive by introducing project and problem-based learning, including a 10-week capstone design project in teams, known as the Design Synthesis Exercise [23] with their own dedicated project spaces to meet the new ABET 2000 accreditation standards. This resulted in a rapid rise in student numbers entering the program. By 1999 the number of students was back at the levels it had in the early 1990s (see Fig. 2) and the Faculty retained its coveted ABET substantial equivalency status in 2001. In June 1999, the Faculty decided to introduce an English language curriculum. This started in the first year of the integrated Master's program where one third of the students were given the opportunity to follow the program in English. This involved a great transition in terms of translating teaching resources and communication outings and five dedicated staff members were hired, among them Gillian Saunders-Smits, the first author of this paper. In the five years that followed the whole curriculum slowly transformed to being taught in English. The fraction of students in the English language stream was also increased gradually, from one-third to one half to two-third of the students interested in being taught in English increasingly outstripping Dutch. Today, the possibility to follow the course program in Dutch has disappeared completely, both on Master and Bachelor level. In 2002 the 3000th student graduated with a MSc in Aerospace Engineering.

The Dutch aerospace industry also recovered from the Fokker bankruptcy. The maintenance part and the aircraft parts manufacturing plant of Fokker Aircraft were sold to Stork N.V, and are still in existence today, now part of GKN Aerospace. Their profitability was greatly aided by the selection of the GLARE material for parts of the *Airbus A380* in 2001, which also gave an enormous boost to the research and development output at the faculty with more than 30 people working towards the implementation and certification of GLARE [21]. In that same period the Royal Netherlands Air Force heavily invested in new helicopters from the United States of America. As part of the economic offset program, internships were offered at McDonell-Douglas, now Boeing and when the Netherlands joined the Joint Strike Fighter Program in 2002 as a Level 2 partner, a similar intern program was started with Lockheed Martin, which is still running today, to great satisfaction of both parties involved.

Shortly after the 1996 bankruptcy in an attempt to still retain end-line manufacturing of aircraft in the Netherlands, an investor founded the company Euro-ENAER in Den Helder with the aim to further develop and produce the Chilean ENAER 2-seater aircraft named the *Eaglet*. The Faculty of Aerospace Engineering and several of their staff members among which second author, ir. Joris Melkert who acted as a flight test engineer, were responsible for the certification of the aircraft and its components [24]. The aircraft was JAR-23 certified in July 2001, but shortly after the company got into financial difficulties as a result of the downturn in the aviation industry after 9-11 and went under. The sole Eaglet protoype is now owned by the Faculty of Aerospace Engineering and can be seen suspended from the ceiling in the main hall of the aerospace building.

Fokker's Space division became an independent company renamed in 2002 to Dutch Space. This company was acquired by EADS in 2006 and is now part of Airbus Defense and Space, being the largest supplier of solar arrays in Europe and one of the leading developers of structures for the European launchers *Ariane 5* and *Vega*. With the growth of student numbers and the recovery of the aerospace industry, the Faculty itself also grew to 135 academic staff in 2010. The number of research groups changed rapidly in this period. University wide restructuring saw groups in Remote Sensing, Engineering Mechanics, Wind Energy, Aerospace for Sustainable Engineering and Technology, and Fundamental Aerospace Materials being added, some of which were later either assimilated into other groups, or moved to another faculty within the university in the case of remote sensing. Only the Wind Energy group, the Aircraft Noise and Climate Effects group and the Fundamental Aerospace Materials group, now using the name Novel Aerospace Materials remained. In 2011 the concept of horizontal banded research chairs was abandoned and their design activities and staff redistributed. The Space department expanded greatly as did their research activities, which saw them launching their first small satellite, the Delphi C-3 in 2008, which is still in operation today [25]. As a result of this growth the capacity of the aerospace building was reached, which led to its expansion connecting the Delft Aerospace Structures and Materials Laboratory (DASML) to the main building in 2002 and a dedicated new building for teaching, named the Fellowship being built in 2008. More on the development of our research facilities later.

In 2007 the faculty took its first steps towards more sustainable aviation, with the multi-disciplinary CleanERA project in which a team of young PhD students under the leadership of experienced industry and academic staff would design a 125- seater environmentally friendly airplane [26]. The prototype was shown at the World Exhibition in Shanghai, China in 2010 and can currently be seen standing in front of the Science Centre of TU Delft.

At the same time under the leadership of Professor Ockels, new sustainable energy harvesting methods were developed. He is seen by many as one of the founding fathers of Airborne Wind Energy. The group also researched sustainable transport solutions, prototyping the idea of electric vehicles carrying many people at the same time using dedicated traffic lanes. As a proof of concept, the so-called "*Superbus*" carrying 23 people was built and road-tested [27].

Employment opportunities for aerospace engineering graduates remained high (see Table 2) and although there is a noticeable shift in where graduates worked in 2005 compared to 1980 (See Table 1), many (40%) still worked in aerospace [1].

Table 2: List of employers of aerospace graduates in 2005 based on an alumni survey (N=692) with employers marked with * indicating the surviving companies from the Fokker Aircraft Company [1]

Employer	AE Alumni
Stork Fokker*	6.9 %
KLM	4.8 %
TU Delft	4.5 %
NLR	4.0 %
TNO	2.8 %
Dutch Space/EADS-ST*	2.2 %
Airbus	2.0 %
Own Enterprise	1.9 %
Shell	1.9%
Ministry of Defense	1.7 %
Philips Electronics	1.7 %

In the early 2000s as part of the implementation of the European Higher Education System known as the "*Bologna Process*" the integrated five-year Master of Science curriculum was split into a three-year Bachelor and a two-year Master program. This also ended our ability to be accredited by ABET as they judge bachelor degrees by years and not by hours of workload. In term of hours of workload required, the TU Delft 3-year Bachelor programs are more than comparable to the 4-year US bachelor programs, in view of the earlier mentioned requirement by Dutch law to have a yearly study load of 1640 hours. Initially, this split into two separate degrees was conceived as rather artificial by both students and staff, but by now it is an established format.

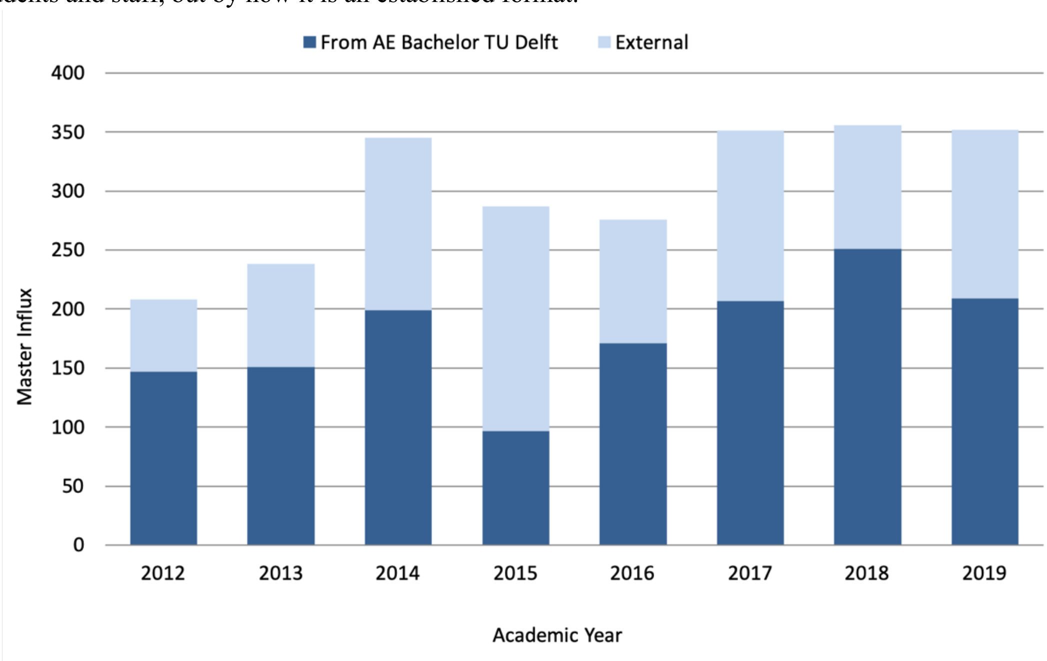

Fig. 3: Overview of influx into the Master program ***(source: TU Delft)***

All these changes meant that it was time to rethink our education program and create dedicated Bachelor and Master programs. As a result, a new Bachelor program was launched in 2009 [28], followed by a new Master program in 2010. In this new Master program students, upon entering, specialized in one of the 5 tracks available to them. Until then almost all students starting and finishing the Bachelor curriculum in Delft carried on in our Master program and the influx of international master students was very low, but after the curriculum renewal that started changing. More and more students decided to stop their studies after the Bachelor, and move to another program within TU Delft or even move to another university for their Master program. Our current retention rate of Bachelor students into our

Master program is 82%. At the same since 2014, there has been a steady compensating influx of Master students both from other Dutch universities and abroad (See Fig. 3). As a consequence, the number of non-Dutch nationals in the student body has increased. At the moment the influx of non-Dutch nationals is approaching the 50%-mark as can been in Fig. 3.

As students' interest in the Bachelor degree was growing, the Faculty had to reinstate a cap on the number of Bachelor students in 2012 (See Fig.4). Where the cap in the early nineties was set at 305, the new cap was set at 440. Since the introduction of the new cap, the number of students applying to be admitted to our Bachelor program has gone up to over 1,500. As a consequence, there is now a strict selection before admission which is also resulting in an increase in the quality of the Bachelor freshman students.

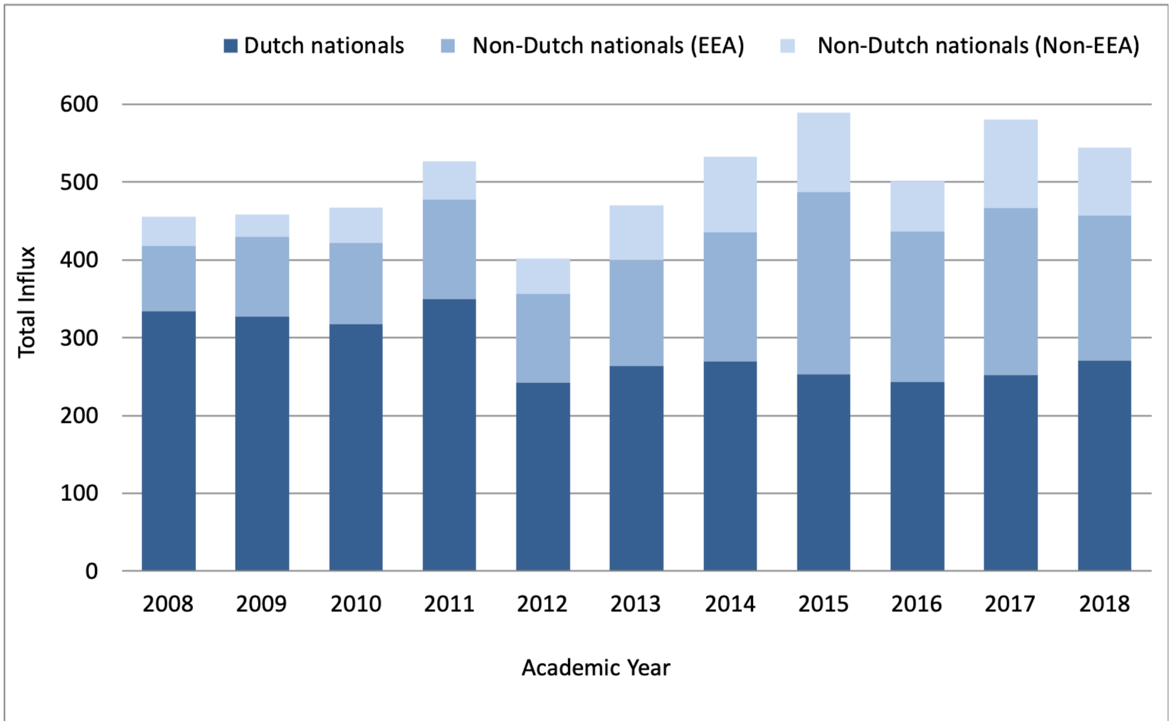

Fig. 4: Increasing number of non-Dutch Students - EEA stands for European Economic Area ***(source: TU Delft)***

In 2013, under the leadership of the first author, Dr. ir. Gillian Saunders-Smits, the Faculty started to offer online courses in Aerospace Engineering, as part of the university's initiative to develop online learning for all, starting with paid online Master courses in the field of Structures and Materials. Today, more than 15 paid online aerospace courses for professionals are available. In 2014 Professor Hoekstra and his colleagues created the first MOOC in "*Introduction to Aeronautical Engineering*" on the edX platform with a MOOC in "*Forensic Engineering*" being launched by the third author, ir. Michiel Schuurman, in 2017 and a third MOOC "*Introduction to Aerospace Structures and Materials*" in 2018, taught amongst others by Dr. ir. Gillian Saunders-Smits. In total these MOOCs have attracted well over 140,000 learners to date, with TU Delft ranking number 1 on the MOOCLabs World University Rankings.

Our students have also increasingly made an impact themselves. Aerospace Engineering students have been at the forefront in taking part in inspiring student challenges around the world. It all started with the World's Solar Challenge in Australia in which the TU Delft Nuna Solar car won for the first time in 2001 and has won multiple times since then. The breaking of altitude records by the rocket engineers of DARE, Delft Aerospace Rocket Engineering and our student Hyperloop team which won the overall prize in Elon Musk's Hyperloop challenge in 2017 with its student members have gone on to found their own Hyperloop company called Hardt are other examples of our students' achievements. Another recent feat was team Silverwing which participated in Boeing's GoFly Challenge. In early 2018 a small group of aerospace engineering students from the TU Delft submitted their concept for an electric flying motorcycle. The concept was among ten winners selected out of nearly 200 submissions. They quickly put their concept to the test, individually testing key components of the aircraft as well as flying smaller scale models. In March of 2019, the result of this work placed them among five winners globally.

To assist and stimulate students to do these types of activities, in 1999 a special foundation was created to house and provide teams with facilities on campus. This has become known as the birth of the Delft DREAM Teams, housed in their own dedicated D:DREAM hall, with D:DREAM standing for "*Delft: Dream Realization of Extremely Advanced Machines*" [29]. Although almost every team consists of students from all the different faculties of TU Delft, our aerospace students continue to participate in these teams in large numbers.

IV. Laboratory Facilities

Education and research in Aerospace Engineering would not be possible without laboratory facilities. In this section we discuss the wide variety of laboratory facilities at Aerospace Engineering, past and present, and how they continue to contribute to our research and education.

A. Wind Tunnels

The university already had a laboratory for aero- and hydrodynamics since 1918, which was part of the Mechanical Engineering Department. Initially, most of the experiments were carried out there. However, plans for a separate dedicated low speed wind tunnel laboratory were drawn up in the late 1940s and in 1953 the Low Speed Wind tunnel Laboratory was completed. This laboratory has been extended and renovated over the years and is still in existence today and contains a closed-circuit low turbulence tunnel, several open circuit tunnels and a vertical wind tunnel for aeroacoustics research, all of which are still actively used in education and research. A worthy example of the research is the development of the speed strips which were stuck on the legs and head of speed skaters which reduced drag by 5% [30]. As a result, the Dutch speed skaters were highly successful during the Winter Olympic Games in Nagano, Japan in 1998 and many world records were broken as a result.

In 1959 the first high speed wind tunnel was opened in the basement of one of the buildings, and by 1969 a separate dedicated High Speed Wind Tunnel Laboratory was opened across the road from the main aerospace building, which is still in use today, housing a transonic/supersonic wind tunnel operating Mach numbers between 0.5 and 4.2, 2 more supersonic wind tunnels and since 2001 one hypersonic wind tunnel that goes up to Mach 11. In 2009 this laboratory was extended by a subsonic open jet facility with an outlet diameter of almost 3 meter allowing for testing of larger models.

All wind tunnels are used extensively in both research and education.

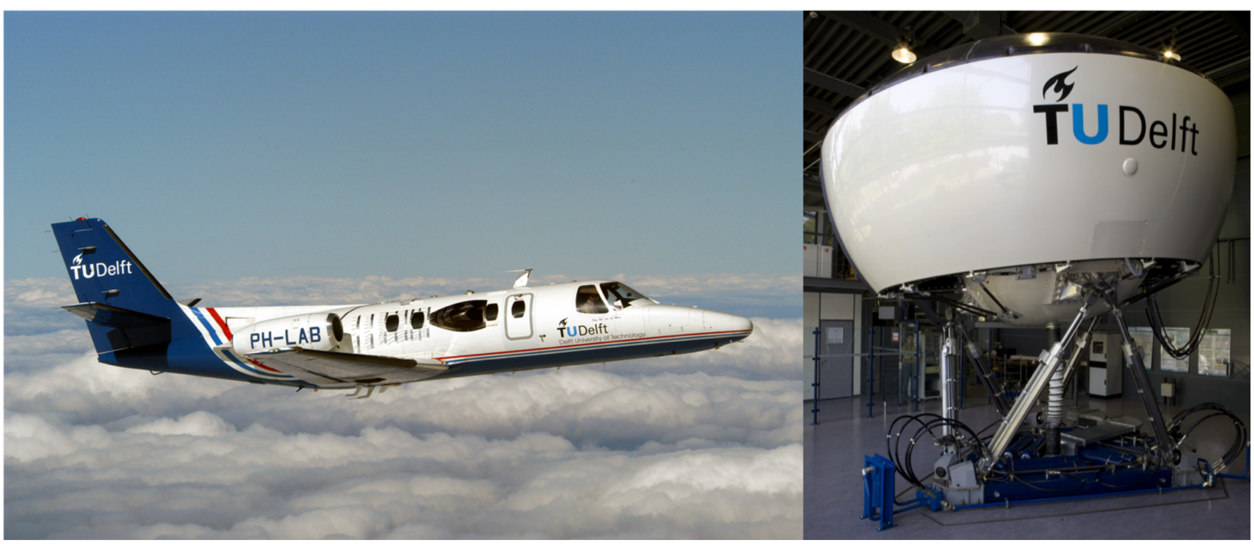

Fig. 5: Our current research aircraft, the PH-LAB Cessna Citation II on the left and our SIMONA Flight Simulator on the right – *Images © TU Delft*

B. Flying Labs

In 1948 the Faculty was given use of its first laboratory aircraft, a Koolhoven FK-43 with registration PH-NAU, renting it from a flying school at nearby Ypenburg Airport in the Hague, which at that time was still in existence. This aircraft was used both for research and for student lab work. When it was retired from service it was replaced by an Auster Autocar J5.B, with registration PH-NEH, which was used extensively for research and student flight tests. In 1958 the faculty was able to purchase its own laboratory aircraft, a De Havilland Canada 'Beaver' with registration PH-VTH. To aid research, it was fitted with a fully digital autopilot. This aircraft would be used for both research and education until the early nineties when it was replaced by a Cessna Citation II with registration PH-LAB (See Fig. 5). The Control and Simulation department continues to operate this aircraft, modified to serve as an airborne research and education platform, which is owned and operated jointly with the Royal Dutch Aerospace Center. Two faculty members are also trained research pilots. The faculty does own one other aircraft, which is not yet registered, a Vans Aircraft RV-12, which is currently being built by consecutive groups of Master students as part of the Aircraft Manufacturing Course run by the second author, Joris Melkert, who received a TU Delft Educational Fellowship for initiating this project[1].

C. Flight Simulators and Human Interaction Laboratory

Already in the 1960s the first rudimentary flight simulator was created by Professor Gerlach [31]. New flight simulators were developed in-house over time and the need to move away from just fixed-base simulators became more apparent. By 1969 a 3 degrees of freedom simulator was built in-house and fitted with the cockpit of a Fokker F27 Friendship. By the early 1990s there was an increasing need in for research and education for the Faculty to have its own motion-based 6 degrees of freedom flight simulator as developments in automation and the desire to stay ahead in the field warranted such a simulator. Instead of buying off-the-shelf, it was decided to design and build the SIMONA simulator in-house using the various areas of expertise present within the different faculties within TU Delft (See Fig. 5). The SIMONA simulator is housed in a separate building connected to our main building and her first flight was in 1998. She is being operated by the Department of Control and Operations. SIMONA is both used for education and research in the fields of flight simulation technology and human-machine interaction and can realistically simulate all types of aircraft, helicopters and even cars. With the help of our in-house calibration laboratory the inertia sensors used in the Cessna Citation and the SIMONA simulator can be calibrated. Closely associated with the simulator is the Human-Machine Interaction Laboratory which consists of a fixed base simulator for either cars or aircraft next to other fixed base simulators. This facility can be used to research control tasks or visual perception. These facilities are used by staff for research and throughout the education program, be it in courses or by MSc and PhD students for their graduate research.

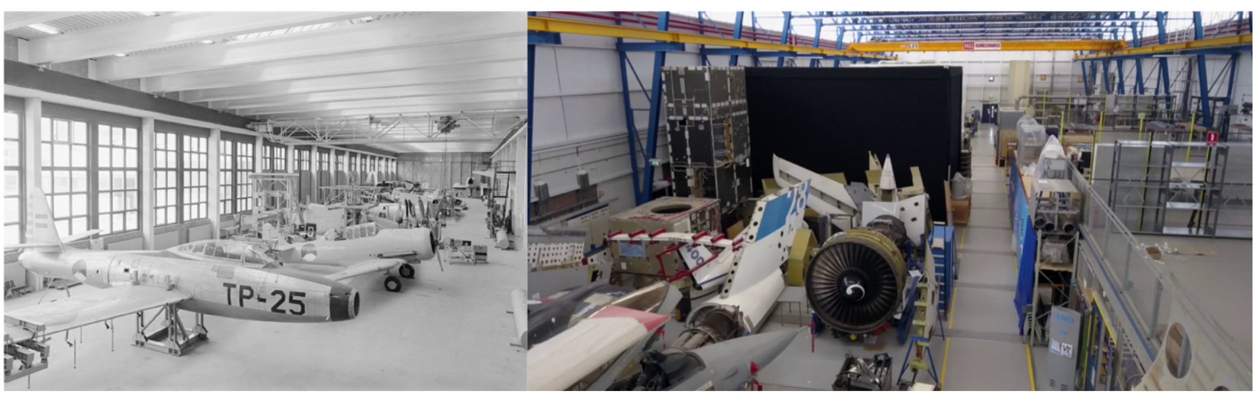

Fig. 6: The Aircraft Structures and Materials Laboratory at the Leeghwaterstraat in 1961 (left) and the current Aerospace Structures and Materials Laboratory at the Kluyverweg (right)
– Images © TU Delft

D. Aerospace Structures and Materials Laboratory & Study Collection

With the appointment of Professor Van der Neut in 1945, research in aircraft structures took off in earnest. There was a consensus that for this research sufficient dedicated laboratory space should be available. With that in mind the first dedicated aerospace structures laboratory was given its own building in 1957 (See Fig 6 – left). This building housed, next to the aerospace structures laboratory, two draughting rooms, two workshops for wood and metal work

[1] see: https://www.tudelft.nl/en/ae/organisation/departments/dasml/aircraft-manufacturing-laboratory/ to follow their progress.

and the large, almost unique collection of aircraft and aircraft parts that were used as study object, known as the "*Study Collection.*" This collection was started in 1945 and contained many aircraft and aircraft parts, initially from old Fokker and Koolhoven aircraft, but also from the many leftover now surplus World War II aircraft. As a result of this in the fifties the collection housed a Boeing B17G Flying Fortress, 2 North American Mustangs and two Republic Thunderbolt jets and as well as a Lightning and a de Havilland Mosquito [16]. Over the years many more aircraft and aircraft parts were added and by the time the laboratory moved to its dedicated hangar building now attached to the current Aerospace building in 1965, the hangar contained more aircraft and aircraft parts as study objects than it contained test equipment [16][17]. Klompé in his personal history of the Structures and Materials laboratory [32] lists all aircraft and aircraft parts that at one point in time were part of the study collection among which a F104 Starfighter and a F-16 Falcon Fighter. Over the years these objects were not just used for students to look at as inspiration for their design, they were also extensively used to demonstrate structural principles and measurement techniques by loading them in a 3-point bending test for instance.

Over the years the research in structures and materials expanded and more and more test equipment and manufacturing capability came in to the laboratory, which led to the study collection being reduced in size and partially moved to the cellar of the main building. Currently there is still a significant collection of items present in the laboratory itself, among which a mockup of the ENVISAT satellite, a General Electric CF6 engine, the test model of the EXTRA 400 which was used for both flight testing and load testing and much more (See Fig. 6 – right).

The Delft Aerospace Structures and Materials Laboratory (DASML) currently houses various fatigue, tensile and compression testing systems, in which materials can be tested under various conditions to its limits. The chemical and physical laboratories provide support in the development of ceramics, polymers, self-healing materials and coatings. The composite laboratory and production area is equipped with a KUKA robot as well as an autoclave allowing for the testing of new production methods. There is a dedicated laser facility in which a 1kW pulsed xenon monochloride (XeCl) laser can be used for cutting, drilling and surface treatment of different materials as well as a composite welding lab, an NDT lab and 2 workshop areas, one dedicated for student projects and one for all education and research needs. The hangar also houses the CyberZoo, which is dealt with separately. On top of the smaller labs two dedicated production areas have been established, one of which is used for the aforementioned Aircraft Manufacturing Laboratory and the other area houses the Scaled Flight Testing lab, where scale models of radical, innovative aircraft concepts, designed for low energy consumption, are being built. Recently the Aerospace Structures and Materials Laboratory was added to Google Streetview[2].

E. MAVLab & CyberZoo

In the early 2000s the use of drones for commercial use really began taking off. This led to an upsurge in research in drones. That is why in 2005 the Micro Air Vehicle Laboratory (MAVLab) was established after the successful design of the DelFly flapping wing UAV made by 3rd-year Bachelor students as part of the capstone Design Synthesis Exercise. Within the MAVLab fundamental technological challenges of Micro Air Vehicles are being solved in order to maximize their utility and safety. The DelFly is still one of its greatest successes. The DelFly has increasingly been miniaturized from a 50 centimeters wingspan and weighing 21 grams (2005) to only 3.07 grams and a wingspan of 10 cm [33] [34]. The newest addition to the project is DelFly Nimble, which is tailless, weighs 29 grams and has a wingspan of 33 centimeters and actually mimics the movement of an insect when flying. Together with the Delft Robotics Institute they make use of the CyberZoo, a dedicated space available for researchers and students to perform test flights of new designs and MAV control systems. The CyberZoo is equipped with 12 high tech cameras to analyze robots both flying and ground-based. The lab can be set to different environments and house different obstacles to allow for thorough testing in practical environments.

F. Cleanroom & Ground Station

With the growth of the space department and their ambition to build their own satellite, there was a need for the Space department to have a dedicated Space grade Cleanroom facility at their disposal. In 1999 a dedicated portacabin style cleanroom was installed in the Delft Aerospace Structures and Materials Laboratory. In 2004, this cleanroom was abandoned and a new and improved cleanroom was taken into use on the 8th floor of the aerospace engineering building. This cleanroom has been used to build and test the Delfi-C3 [25] and Delfi-N3xt CubeSats. These two CubeSats were subsequently launched by the Delft University of Technology and still provide scientific data which is used in research. The cleanroom is equipped with various test rigs used for testing nanosatellite systems and is currently being used to build the next Delfi-PQ Satellite.

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[2] To access the virtual tour go to: https://www.tudelft.nl/en/ae/organisation/departments/dasml/

To facilitate the Delfi program a multiband satellite ground station was established for satellite communication on top of the highest building on campus, the Faculty of Electrical Engineering, Mathematics and Computer Science. The ground station is equipped with two Tracking VHF/UHF antennas, one in the amateur space frequency band and one in the commercial space frequency band, an S-band antenna, and omnidirectional VHF and UHF antennas in the amateur frequency bands. The facility is a cooperation between TU Delft, the Delft Space Institute and ISIS – Innovative Solutions in Space, an Aerospace Engineering spin-off company.

V. Impact of Aerospace Engineering at TU Delft

Now that Aerospace Engineering as an established field of science within TU Delft is 80 years old, it also time to look at the impact it has had on Dutch society and further afield. What is the value of Aerospace Engineering from Delft? What is its impact on the Netherlands and on the world?

A. Famous Alumni

Over the years the Faculty of Aerospace Engineering has graduated many people who are now household names in the Aerospace Engineering world. Aircraft designers and textbook authors Egbert Torenbeek and Jan Roskam (University of Kansas) are among our alumni as well as the author, academic, and past director of the Dutch Royal Meteorological Institute, Henk Tennekes (1936) who also wrote the popular science book "*The Simple Science of Flight*" [35].

Famous helicopter designer, Jan Meijer Drees – designer of the NHI-Kolibrie helicopter, who later moved to Bell Helicopters in the U.S., was also a TU Delft Aerospace Engineering graduate. Another well-known alumnus was the late Prince Friso of Orange-Nassau (1968-2013). Our alumni are successful and unemployment under TU Delft Aerospace Engineers is low [1]. Many of our graduates have gone on to have successful careers within the Dutch aerospace industry, as well as further afield. As a result, you will find our alumni at strategic positions in research, industry and government.

Honory doctorates in Aerospace Engineering have been bestowed on Albert Plesman, founder of KLM Royal Dutch Airlines (1947), Kees van Meerten, chief designer of the Fokker F27 Friendship (1975), Burt Rutan, owner and designer at Scaled Composites and The Spaceship Company (1990), B.D. Tapley , senior Research Fellow at the University of Texas (1998) and Deborah Hersman, former Chairman of the U.S. National Transportation Safety Board (2014).

B. Spin-Off and Innovation

Another way to look at the impact of the Faculty of Aerospace Engineering is to look at our contribution to innovation and spinoffs based on our research. Over the past 15 years many spin offs have been started and over 40 of them have developed in well-established independent businesses that started life within the walls of our departments. There are successful examples from each research group, but by far the largest number of startups stem from the Aerospace Structures and Materials Department. Examples of successful startups are *Airborne Composites*, a high-end composite structures manufacturer, *Aircraft-End-of-Life Solutions* in the area of aircraft recycling, *ISIS Innovative Solutions in Space* in realizing small satellite missions, *KE Works* in the area of Knowledge Based Engineering and *Ampyx Power* to further Airborne Wind Power. These startups provide employment to over 500 people and many continue to grow rapidly.

To continue to promote spinoffs the faculty has instigated a Startup Voucher program in 2016, in which BSc, MSc and PhD students can apply for a Startup voucher of 2,500 Euros and coaching. With this program the Faculty aims to bridge the gap between graduation and existing pre-incubation programs at TU Delft and has so far already resulted in the launch several companies that are now part of the TU Delft incubator program "*YES!Delft*".

One of the main factors in the success of our spinoffs is the support of a dedicated Valorization Center within TU Delft. They support staff and students at the Faculty in applying for patents, paid for by TU Delft to aid valorization. Also, TU Delft has a pragmatic way of allowing startups to use these patents, by not asking for money up front, but instead opting for a share in future profits, which significantly reduces the startup costs lowering the threshold to start one's own company. On average, the Faculty is awarded 8 patents each year.

C. Student Numbers and Societal Impact

In its 80 years the Faculty of Aerospace Engineering has by now given out over 7000 "*Ingenieursdiploma's*" or Master of Science degrees in Aerospace Engineering. Its student numbers over the years have increased and are now stabilizing around the 2,600 students mark. Each year some 300 Bachelor, 300 Master and 30 PhD degrees in aerospace engineering are awarded. In comparison, in the whole of the United States of America each year some 4,000 Bachelor and 1,500 Master degrees in aerospace engineering are awarded according to ASEE [36]. In Fig. 7 the 2017 normalized diploma data per million inhabitants for the United States of America, and TU Delft is shown. It is clear that the Netherlands, by means of TU Delft, produces almost 4 times as many Aerospace Master of Science Graduates than the United States of America as a whole. This shows the contribution Aerospace Engineering at TU Delft makes to the Dutch "*Knowledge Society*," putting the Netherlands at a strategic advantage.

This contribution can in part be explained if we look at how much aviation and space contribute to the Dutch economy. A 2015 report on developments in aviation states that aviation in the Netherlands accounts for 114,000 jobs and 1.5% of our economy, contributing 9 billion euros [37], with the aviation related part of our manufacturing industry reportedly accounting for another 16,000 jobs and contributing 4 billion euros. Space was estimated to account for 7,000 jobs and a contribution of 0.1% to our economy (0.6 billion euros) [38]. In total aerospace manufacturing and operations account for over 137,000 direct and indirect jobs and more than 2% of the Dutch economy.

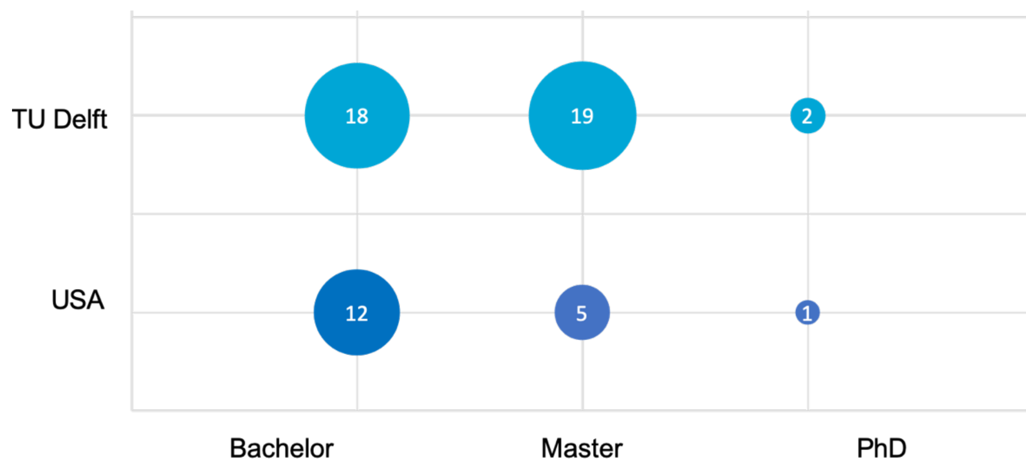

Fig. 7: The number of aerospace engineers per million inhabitants in the Netherlands and the USA that graduated in 2017 (Sources: ASEE [36], CBS.nl, and tudelft.nl)

Over the years we can see a shift in the focus of the Faculty. In the early years the focus was much more on education. Over the last 20 years however, the focus shifted much more to research in part to contribute towards the overall TU Delft ambition in being seen as leading university in Science and Technology. This shift can be seen in the number of PhD defenses per year which is steadily growing (Fig. 8) as well as in the number of staff who hold a PhD degree. While in the early years very few staff members held a PhD degree, today, the opposite is true and having a PhD is a minimum requirement for acquiring a position in the academic staff of the Faculty with few exceptions. Also, our scientific research output has increased: the number of refereed journal articles has risen sharply from 111 in 2007 to 198 in 2013 as reported in our research accreditation in 2014 [39].

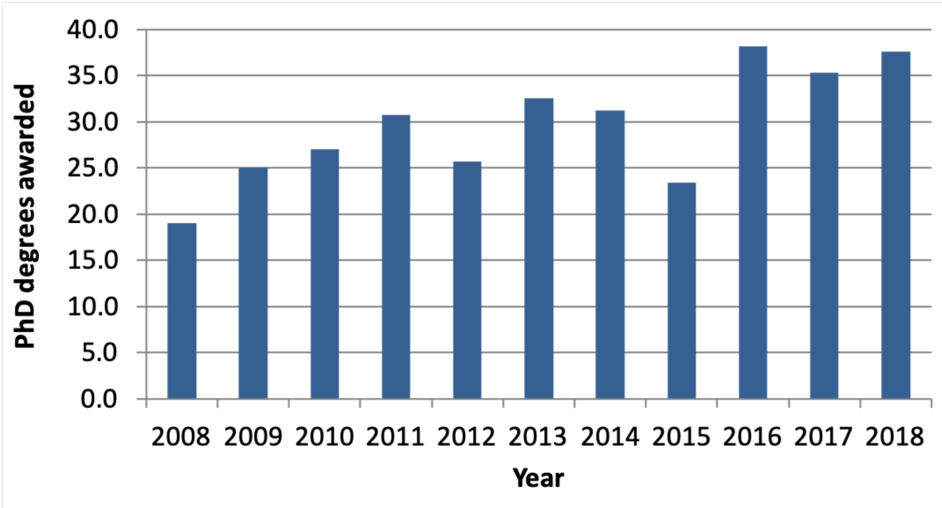

Fig. 8: Development of number of PhD degrees awarded each year
(source: tudelft.nl)

A final measure of impact is the position of the Faculty in international rankings. In the only international ranking that distinguishes between Mechanical and Aerospace Engineering degree programs, the so-called Shanghai ranking, the Faculty of Aerospace Engineering is the only European Aerospace Engineering department in the top ten, with TU Delft as a whole ranking fourth in the world in the QS ranking for Mechanical, Manufacturing and Aeronautical Engineering, which for a country with a population of only 17 million people is a great achievement.

Fig. 9: The model of the Flying V in our Scaled Flight Testing Lab
– Images © TU Delft

VI. Future Outlook

Currently, the Faculty of Aerospace Engineering is a strong faculty with a healthy student body and a good growth perspective. It consists of 4 departments: Aerodynamics, Wind Energy and Flight Performance & Propulsion; Aerospace Structures and Materials; Control and Operations; and Space Engineering. Within each department several, more specialized, research groups each with their own mission are present, but all following the collaborative principle in Delft of actively involving students in our research.

The Faculty of Aerospace Engineering receives over €33 million in funding each year of which €13 million is external research (2016) and although there is a steady but slow growth, the Faculty must remain vigilant in an uncertain and ever-changing funding landscape. Scientific staff actively participate in many national and international research initiatives, have close ties to industry, and generate close to 500 refereed publications and on average 8 patents per year. In the area of research, the Faculty is an active partner in many European Union projects under the Horizon 2020 umbrella for research and innovation. Similarly, the faculty cooperates in research with many Original Equipment Manufacturers and airlines in developing and testing new concepts. An example of this is SAM|XL – A Smart Advanced Manufacturing Innovation Hub in which the Faculty is collaborating with industries such as Airbus and Fokker GKN Aerospace to collaborate in maturing automated manufacturing technology. At the same time our Space Department is working on its next satellite: the Delphi – PQ to be launched in the near future.

The faculty aims to continue to make a difference in the future and play its part in creating a more sustainable future. One of the primary focal points for the next few years will be Climate Neutral Aviation, as explained in more detail in the inaugural speech of our current dean, Professor Werij [40]. Examples of the realization of these goals are the Flying-V, a design collaboration with KLM, to design and prototype a scaled flight test model of a V-shaped aircraft with the passenger cabin, cargo hold and fuel tanks integrated in its wing structure (See Fig. 9 and [41]), the building of an electrical flying test bed at International Airport Teuge, and a range of research projects aimed at sustainable aviation at Rotterdam-the Hague Airport, the new home of our research aircraft.

Our students are also actively looking at making a continued contribution. Our Aerospace Study Association, "Leonardo da Vinci", celebrates its 75th anniversary this year, and new aerospace D:DREAM teams are on the horizon, such as Phoenix, a project in which students are trying to design the world's first liquid hydrogen-powered aircraft, more specifically, a motor glider). This unique motor glider will have a range of 2,000 kilometers allowing the pilot to fly all around Europe on one tank of hydrogen, thus contributing towards more sustainable aviation.

The Faculty of Aerospace Engineering od Delft University of Technology in the Netherlands can therefore be considered to be an active and still developing octogenarian, who will most certainly continue to be around to make it to its centennial in 2040.

Acknowledgments

The authors wish to acknowledge their colleagues in the Faculty of Aerospace Engineering who assisted in finding out all particulars of the history of the Faculty, as well as the Chair of the AIAA History Committee, Kevin Burns, for inspiring us to write this paper.

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