STUDY OF DELFT AEROSPACE ALUMNI

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Proefschrift

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PREFACE

Teaching the next generation of engineers is a privilege I cherish. With this privilege, in my opinion, comes the obligation to ensure that the engineers of the future get the best possible education tailored, not only to their current, but, more importantly, also to their future needs. It is this perspective that first attracted me to the field of Engineering Education Research to learn more about how students learn, about how to determine what students need to learn, and about how lecturers have to adapt to the ever changing needs of students.

I was fortunate enough that in my job as project education coordinator at the Faculty of Aerospace Engineering at Delft University of Technology I met Erik de Graaff, who inspired me to take up the challenge of working towards a PhD in Engineering Education. With the support of Erik, together with the late Prof. dr. ir. Theo de Jong, I set off in the summer of 2002 on a journey which is culminating in the thesis that lies before you.

I would like to take the opportunity here to thank Erik for all his advice, patience, his sharing of knowledge and his ability to keep me motivated even when the rest of my work was starting to overgrow my PhD work. Erik, thanks to you I have developed a hunger for research, I did know I had in me. I hope our friendship will continue after this project and that many more projects will follow. A special thank you here also goes to the late professor Theo de Jong. Even though he has not been able to see this project come to completion, he was brave enough to embark on a new path of research in education in early 2002 and I will always be grateful for that. At this stage I would also like to thank Professor Zafer Gürdal for bravely taking on the challenge of taking over the supervising of this project half way through and helping me see this to an end. Your suggestions and comments have been gratefully received. Your trust in me makes me feel proud.

Many other people deserve my gratitude for their support over the last 7 years. I will attempt to name them all here, but should I forget anyone please know that I am still grateful. First of all Gert-Jan van Helden, Rolf Oosterloo and Tom van Baten for insisting I should get a PhD. Although at the time I did not see the need, I definitely do now! Also I would like to thank the former dean of the Faculty of Aerospace Engineering, Ben Droste for his never ending support during this research. A further, special thanks goes to Bernard Reith, the former director of education at the Faculty of Aerospace Engineering. Bernard, I treasure the many times we spend talking about education, the plans we made for the Faculty and your support and advice on the research carried out.

I would also like to thank all the members of the expert panel as well as those on the test panel for your cooperation and suggestions. Your contributions were essential to the research done in this thesis. Of course all alumni who participated in the questionnaire also deserve my heartfelt thanks. I hope the results will be of great interest to you all. The logistics of this research would not have been possible with the help from the TU Delft Alumni Office in particular from Anneke Oosterhof and Charlotte de Kort as well as Mark Orie formerly from the Marketing & Communication Department at Aerospace Engineering. I would also like to thank Meta de Hoon and Rebecca Rennestraum for their help with the data processing, my father-in-law Sandy Saunders for his corrections to my English, Bob van der Laaken for his checking of my translations of my propositions and Drs. Holierhoek for his advice on copyright. Thank you to Maartje van den Bogaard for agreeing to be my paranimf.

Many thanks to all my colleagues at the Faculty of Aerospace Engineering and the Faculty of Technology, Policy and Management as well as all my friends for the many conversations we had, and the encouragements and suggestions you gave me. In particular I would like to thank Maartje van den Bogaard, Lesley de Putter-Smits, Peter Nixon, Eveline van den Boogaard, Vivace Ebben-Schreurs, Jessica Holierhoek, Jeroen Krijnen, Juliana Early, Paul Roling, Otto Bergsma, Jan Hol, Jan de Vries, Eelco Jansen, Joris Remmers, Miguel Gutierrez, Joris Melkert, Aldert Kamp, Ricky Curran, Annemarie van Lienden, and Vincent Brügemann as well as all (other) members of the Aerospace Structures Group.

A final very big thank you goes to my husband Paul and my children, Hannah and Rebecca. Paul, you have been my biggest support throughout this journey, putting up with all my highs and all my lows, patiently listening, helping out where you could and most importantly letting me get on with it whilst at the same time being a wonderful husband and a great dad to our two children. Over the past seven years your love and support has been fantastic and I could not wish for a better husband! To my daughters, thank you for letting your mum finish this and being the most wonderful babies. May you find in your future lives something to care about as passionate as I do about education!

CONTENTS

'A fool's brain digests philosophy into folly, science into superstition, and art into pedantry. Hence university education.'

George Bernard Shaw (1856 - 1950)

CHAPTER 1: INTRODUCTION

The numerous technological inventions and scientific discoveries during the twentieth century have brought about change in the twenty-first century. The 'Industrial Society' which had been in place during most of the nineteenth and twentieth century is changing to a new type of society known as the 'Knowledge Society'. In a report of the STRATA-ETAN expert group commissioned by the European Commission, knowledge society is defined as:

> *A post-industrial society based on production and dissemination of information that increases individuals' and companies' knowledge.*

(Source: Bourgeouis, E., STRATA-ETAN expert group, 2002)

The report (Bourgeouis, 2002) suggests that in this new society the relationship between labour, leisure and education is changing with more time becoming available for the latter two. In order to survive in the knowledge society a person must have higher level job qualifications, not only in terms of knowledge, but also in terms of generic and complex cognitive, social and emotional competencies. As in the knowledge society, knowledge and the associated technologies are growing exponentially, the need for an individual to constantly and rapidly acquire new knowledge and skills to continue to be a productive member of society is apparent. Individuals must 'learn to learn' if they are to be successful. This of course results in a new set of challenges for higher education and research. Higher education and research institutes must also evolve to meet these new requirements.

For engineering education, it means that whereas it used to be limited to train students in engineering skills and prepare them for the vocation of engineer, there is currently an ongoing shift in emphasis on what engineering education entails. De Graaff and Ravensteijn (2001) report that an engineer should not only be a perfect engineer in terms of technical knowledge, they should also have additional skills in the fields of Organisation and Management and Communicative and Social Skills. This changing perspective on engineers and what they should be able to do also means that the education of engineers must change.

1.1 Research Outline

This thesis reports on the attempts to evaluate the outcomes of learning of aerospace engineers at the Faculty of Aerospace Engineering at Delft University of Technology over the past 30 years, and how the teaching of aerospace engineers has been adapted so far to deal with these changing demands and what adaptations still need to be made.

Over the past 12 years the education of the aerospace engineer at Delft University of Technology (TU Delft) has changed considerably since the gradual introduction of project based learning in 1995. These changes were implemented with a view to better prepare aerospace graduates for their working life by including additional competencies in the final objectives such as teamwork. Next to that, mandatory courses in oral and written communication were added to ensure that those competencies that had been part of the final objectives of the degree in aerospace engineering at TU Delft since the seventies would be reached. This validation is carried out by investigating and describing the alumni population of the Faculty of Aerospace Engineering at Delft University of Technology in Delft, The Netherlands who graduated between 1975 and 2000. The research also tried to determine whether the skills with which alumni leave their institution are sufficient for alumni to achieve professional success. This was done by setting up a model to determine when an aerospace engineer can be called successful. Also a set of competencies, an engineer should have to be successful, was developed and validated. The success model and the list of competencies were then used to evaluate alumni from the Faculty of Aerospace Engineering at Delft University of Technology. It is expected that the results from this alumni study will show that certain competencies such as the ability to work in teams and people management skills are important for engineers in their professional lives.

As early as 1967 the Faculty of Aerospace Engineering stressed the importance of the aforementioned competencies (Directoriaat voor de

Arbeidsvoorziening 1967, 1969, 1973, 1979). They were formally added to the new final objectives for the 'ingenieur' degree (MSc in engineering) in 1995 in a comprehensive programme review (Faculty of Aerospace Engineering, 1995). At that time project based design education was introduced throughout the first three years of the 5-year curriculum in which these competencies were embedded.

1.2 Why Alumni Research?

As mentioned before, over the last 12 years the aerospace curriculum at Delft University of Technology has undergone many changes. These changes were partly caused by increasing student numbers, a new educational structure at high school level in the Netherlands, the Bologna agreement on a European level, and partly by the vision of many within the faculty of aerospace engineering that as a faculty performing world-class research and high level teaching (VSNU, 1995 and 2002) its education system must meet the same standards in order to remain a leader in the field. In Chapter 2 a full overview of all the major changes at the faculty of aerospace engineering over the years can be found.

Although one can look at students' evaluations of courses to monitor quality, these do not however, provide a form of feedback based on the long-term experiences of the workplace. It was this need that directed the research towards alumni.

There is an increasing need for more information on and from alumni. In 2004 the Department of Education, Culture and Science in the Netherlands issued the 'HOOP 2004' policy paper in which it aspires to have The Netherlands belong to the best of the world's knowledge economies by 2010 (Hoger Onderwijs en Onderzoek Plan, 2004). This of course means that graduates of higher education must be of sufficient quality and it falls upon the shoulders of institutes of higher education to ensure and prove that they deliver graduates with the right skills to achieve this ambition. Furthermore, the results of the accreditation carried out in 1995 listed as a shortcoming that the Faculty keeps very poor track of its graduates (Sikkes, 1996). Although steps have been taken to remedy this situation since by the founding of alumni organisations, a comprehensive alumni policy including a strategy for long term following of alumni is still under development. Finally, in 2000, the American Accreditation Board for Engineering and Technology (ABET) changed its criteria by which it accredits Engineering Colleges throughout the United States and abroad. In its new criteria (Engineering Accreditation Commission, 2000) it lists the need for a BSc programme to have a process in place that periodically evaluates its objectives based on the needs of the programme's various constituencies. The constituents named in this criterion consist of various parties including government, industry and alumni. A good description of the alumni population and their employers as well as their opinion on the educational programme will help to fulfil the requirements for continued accreditation.

The problem, however, with longitudinal studies of alumni is that some of the feedback from our graduates is based on curricula which have long since been changed. It is important however, to understand the make up of these curricula and their context if any validations of the curriculum is carried out and recommendations for future curricula are to be made.

1.3 Thesis Overview

Chapter 2 presents an overview of the development of the curriculum at the Faculty of Aerospace Engineering of TU Delft since its beginnings in 1940, placing it in the contexts of the development of aerospace engineering as an independent field of science, the history of the Faculty of Aerospace Engineering, the history of Delft University of Technology, the development of engineering education in the Netherlands, and of the education system in the Netherlands as a whole. Chapter 2 will also give a brief overview of how the curriculum developed from 1940 to present day, in particular the acquisition of competencies other than engineering knowledge, and the reasons behind the changes with a focus on project education at the Faculty of Aerospace Engineering over the past 12 years.

Chapter 3 contains a brief literature study into the competencies required by engineers other than engineering skills. It describes past research efforts in the field of alumni research amongst engineering graduates world-wide as well as calls from industry with regards to the required skills of engineers. It also describes any previous and current alumni research carried out at Delft University of Technology among aerospace engineering alumni. The chapter continues with description of the devised model for professional success, and the competencies required for achieving such success. It also describes the verification of the model by a panel of experts. The chapter concludes with a final list of competencies believed to be critical for professional success.

In Chapter 4 the research design of the alumni survey is discussed. It describes the research methodologies used, the process which was followed when the survey was put out in the field as well as the data analysis, analyses pertaining to the reliability of the survey, and the validity of the data.

Chapter 5 deals with the results of the actual research carried out and reports on the results based on the results of the survey. The chapter can be split into seven parts. The first part gives a description of the population of aerospace alumni of Delft University of Technology; the second describes the current job responsibilities of the alumni. The third section deals with the alumni's experience of their education at the Faculty of Aerospace Engineering whilst the fourth part deals with continuing education. Finally, the last three sections deal with the results of the importance of the competencies developed in Chapter 3, job success and the explored potential relationship between those competencies and job success.

Chapter 6 reflects on the outcome of the research and recommends what changes should or should not be made to the current curriculum in the BSc and MSc phase at the Faculty of Aerospace Engineering at TU Delft. The chapter also contains recommendations for future research.

'Daedalus interea, Creten longumque perosus
exsilium tactusque loci natalis amore,
clausus erat pelago. 'Terras licet' inquit 'et undas
obstruat, at caelum certe patet; ibimus illac.
Omnia possideat, non possidet aera Minos.'

Ovidius, Metamorphoses, Liber VIII

CHAPTER 2: DEVELOPMENT OF AEROSPACE ENGINEERING

This chapter explains how the aerospace curriculum at Delft University of Technology started and developed to its present state. This is, however, impossible without putting the development of the curriculum in its historical context. Many different external historical factors have contributed to the existence of the Faculty of Aerospace Engineering and its curriculum over the years.

The chapter starts off with a brief overview of how engineering developed itself into a science and how engineering as a science developed itself in the Netherlands and in particularly in Delft. The second part of the chapter deals with the development of aerospace engineering as an independent field of science, how it developed in the Netherlands, and how it became a degree programme at Delft University of Technology. The final part of this chapter will take a closer look at the curriculum of aerospace engineers and how it has developed from the appointment of the first professor in aeronautical engineering in 1940 until 2007 in terms of the development of non-engineering competencies.

2.1 Engineering as a Field of Science

Although engineering is an old practical art going back to antiquity, the development of engineering as a recognised field of science is relatively young. The development of engineering as a science is best described by using the model of the water cycle analogy by van Peursen (1969). This model (see figure 2.1) as explained by Vlot (Lintsen et al., 1997) shows of what is, in van Peursen's opinion, the natural order of the sciences. He distinguishes three types of sciences: The formal sciences, the empiric sciences and the applied sciences.

The formal sciences such as mathematics and logic in this model gather data on the reality surrounding us and based on this give us the instruments needed for empiric sciences such as physics and psychology. They in turn use the methods of the formal sciences and supply theories and data to the applied sciences who in their turn apply the knowledge acquired. As engineering is an applied science, it is naturally the last science to develop over time.

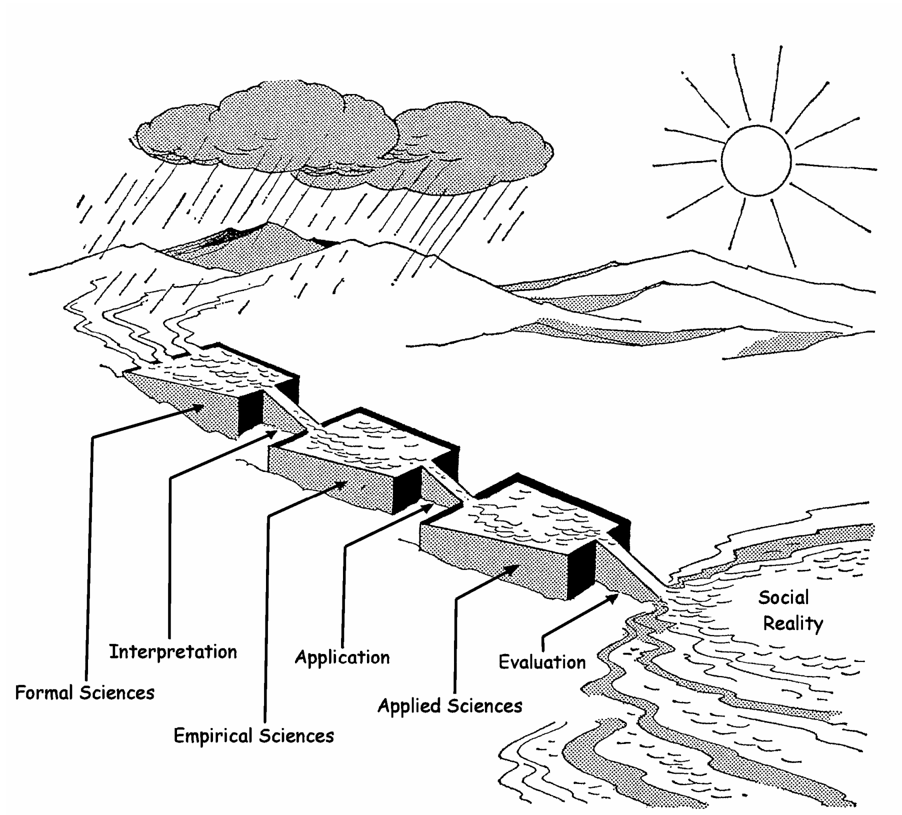

Figure 2.1 Development of applied sciences
(Copied and translated with permission from Van Peursen, 1969)

Hence, taking van Peursen's model into account one understands why engineering, an applied science, does not become an academic degree or a topic of research at universities until the late 18th and the first half of the 19th century. According to Gregory (1971) France was the first country to scientifically train engineers by founding the École Polytechnique in 1795 based on the needs from the military for well trained engineers. However, both Emmerson (1973) and Armytage (1976) mention an earlier military academic school, the École des

Ponts et Chaussées, founded in 1747. This example was followed rapidly throughout Europe, with Delft starting a military academy in 1814, which would become a civilian engineering institute by 1842 and in Germany in 1765 with Freiberg School of Mines. The first chairs of engineering in the United Kingdom were not set up until 1840 in London and Glasgow, followed by Dublin (1842) and Belfast (1849). The first Engineering colleges in the United States were also modelled partly on the French model. Although there is some argument as to which is the real first engineering college in the United States of America, WestPoint (first engineering graduate in 1817 – one year course), Rensselaer Polytechnic Institute (first Civil engineering degree awarded in 1835), Norwich (first Civil engineering degree awarded in 1834) and Union (started offering Civil Engineering in 1845) are generally agreed to be the first four engineering colleges in the US (Jewell et al., 2001).

2.2 Engineering Education in the Netherlands

Until 1818 vocational education was organised through the system of guilds, which stemmed from the Middle Ages in which young men wanting to acquire a skill started off as an apprentice to be trained in the workplace until a satisfactory level of skill had been achieved and he could call himself a journeyman, followed by the final rank of Master craftsman. Other engineering skills could be acquired through the military to help defend the Netherlands. In 1600 Prince Maurice of Orange founded a school in Leiden under the direction of the engineer Simon Stevin (1548-1620) for military engineering to train his officers. The school struggled continuously but survived for more than a century although it was never regarded to be of real academic standing as the language of instruction was Dutch and not Latin or French (Baudet, 1992).

2.2.1 Delft University of Technology

In 1814 King William I founded a military academy in Delft with the aim to train officers in engineering skills. Baudet, in his standard work on the history of Delft University of Technology (1992), stated that in 1842 this academy was transformed into a civilian engineering institute under de name: ‘Koninklijke Academie ter Opleiding voor Burgelijk Ingenieurs’, by his son King William II, which would be re-established in 1864 as the ‘Polytechnische School’. At that time the ‘Polytechnische School’ was still listed by law as a form of secondary education, even though a diploma from a secondary university prep school was required (Gymnasium B or HBS-B) to enter and its level of education superseded secondary education levels. The degree programme at the 'Polytechnische School' had a length of 5 years. It was not until 1905 that the school was elevated to the Higher Education system with academic status and renamed to 'Technische Hogeschool' (TH) after the French system of Engineering Schools, the Écoles Polytechniques. The TH then continued to grow, but was severely hit during the Second World War by closures and persecutions. It slowly restarted again in 1945.

In 1956 a second engineering school with academic status was opened in the Netherlands: the 'Technische Hogeschool Eindhoven'. This was followed in 1961 by the 'Technische Hogeschool Twente' in Enschede. Later on the University of Groningen and the Open University both also started to offer engineering courses.

In 1982 the Dutch government introduced the so-called: 'Wet op de Twee Fasen structuur in het Hoger Onderwijs', which saw the 5-year degree at Delft University of Technology shortened to a 4-year degree (first phase). As the second phase of study, formal PhD programmes were introduced; something which had not existed until 1982, as well as a two year post master courses in design. Finally, in 1986 all three THs were awarded the title of University of Technology (TU) and since then they have been known as 'TU Delft', 'TU Eindhoven' and 'Universiteit Twente', respectively. See figure 2.2 for an overview.

However, it was soon found by many that the 4-year degree in engineering was not long enough to properly train engineers. In 1995 the government gave into pressure from industry and the TUs and allowed all engineering degrees to become 5-year courses again.

The last major development in academic engineering education in the Netherlands was the implementation of the Bologna agreement in 2002 (The European Higher Education Area, 1999), which split the 5-year degree in a 3-year Bachelor of Science degree in engineering and a 2-year Masters of Science degree in Engineering. Currently, Delft University of Technology is the largest university of technology in the Netherlands with some 13 000 students and 2300 scientists.

Currently, a national initiative is under way in which the 3 TUs to operate as one under the name of 3TU, with a view to enhance their innovative ability and its significance to the Dutch knowledge economy by combining and concentrating the strengths of all three institutes in research, education and knowledge transfer.

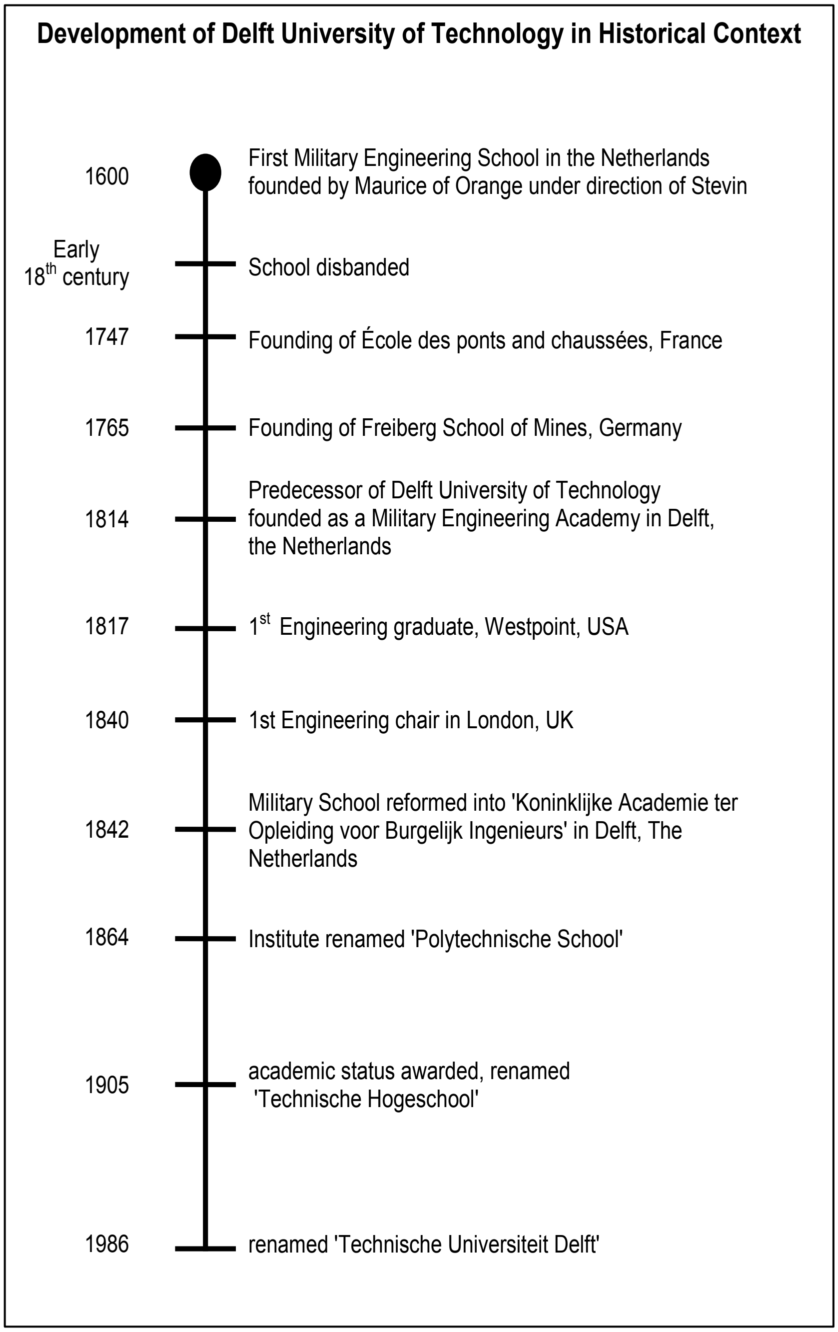

Figure 2.2 Development of Delft University of Technology in Historical Context

2.2.2 Secondary education and Vocational engineering education in the Netherlands

With the Industrial Revolution reaching the Netherlands in the 19th century, as well as changes in the political system also in the 19th century, the secondary education systems started to change. The guilds were formally abolished in 1818, being replaced by so-called 'ambachtscholen' where basic vocational engineering skills were taught such as woodwork, and soon the upcoming industrial factories found that they needed more skilled personnel. Control of the education system shifted from independent initiatives by the gentry and the churches to the (local) government (Schippers, 1989).

In the mean time industry established a need for an intermediate school between the 'ambachtscholen' and the 'Polytechnische School' which lead to the founding of the 'Middelbare Technische School' in different towns across the Netherlands. At the same time, the so-called 'Latijnse Scholen' were reformed into a 6-year secondary school called gymnasium and a 5- and 3- year upper secondary education school was founded called 'Hogere Burger School' (HBS) followed shortly afterwards by the founding of a lower secondary education school known as 'Meer Uitgebreid Lager Onderwijs' (MULO).

The vocational engineering school system remained more or less unchanged until the end of the Second World War in 1945. The government then started to reorganize vocational education and, in 1957, the 'Middelbare Technische School' (MTS) became 'Hogere Technische School' (HTS) and the upper level 'ambachtscholen' now started to carry the name 'MTS' and the lower 'ambachtschool' became 'Lager Technische School' (LTS). A more detailed history of the development of vocational engineering education can be found in Schipper's book on the history of higher engineering education (1989). The 'HTS' now part of 'Hoger Beroeps Onderwijs' (HBO) is today still considered to be the more practically orientated engineering school as opposed to the academic and theoretically oriented universities of technology.

From 1864 onwards access to TH Delft could only be obtained if a student had an upper intermediate diploma known in Dutch as 'Gymnasium' or '5-year HBS' (both upper secondary education schools) providing a student had taken the sciences track known as B or beta, or by taking an entry exam if one came from the MTS. This all changed in 1968 when a diploma of the HTS gave direct access. The HTS could be accessed with a diploma from the 'MULO', '3-year HBS' (both lower secondary education schools) or 'MTS' and before the founding of the MTS, the 'ambachtschool'.

In 1968 the government carried out a large operation in which it changed the structure of secondary education, known as the ‘Mammoet wet’. Although the way this system is being taught has changed since the system was introduced, the main structure still exists today. In figure 2.3 an overview is shown of the current system. From the figure it can be observed that for a person to enrol at a University of Technology they must either have completed their ‘VWO’ with the exam subjects Nature and Technology or Nature and Health or must be in possession of at least the propedeutic diploma of a ‘HBO’ beta or engineering allowing for students who are more practical inclined to still eventually find their way to an academic degree.

2.2.3 Engineering Degrees Awarded in the Netherlands

The highest and only academic engineering qualification in the Netherlands (ingenieur or ir., equivalent to an MSc) can only be awarded by the Technische Hogescholen known from 1985 as Universities of Technology in Delft, Twente or Eindhoven, certain engineering courses at the University of Groningen and the Open University and to students of Wageningen University which teaches agriculture. The graduates from the ‘HBO’ engineering schools are also allowed to call themselves ‘ingenieur’ but as the level is not considered to be at the same par as a diploma from the Technische Hogeschool they initially had to put the title behind their name and were only allowed to shorten it to ‘ing.’, indicative of a diploma at BEng level. They are allowed to put the title ‘ing.’ in front of their name.

With the implementation of the Bologna agreement in the Netherlands in 2002, (The European Higher Education Area, 1999) all universities in the Netherlands were required to split their degrees in a two tier system consisting of a bachelor and a master degree. For the TUs this meant they split their 5-year degree in a 3-year BSc in engineering and a 2-year MSc in engineering. All HTS were required to start awarding BEng and if they have been granted the right to also teach a Master programme they can only award a MEng.

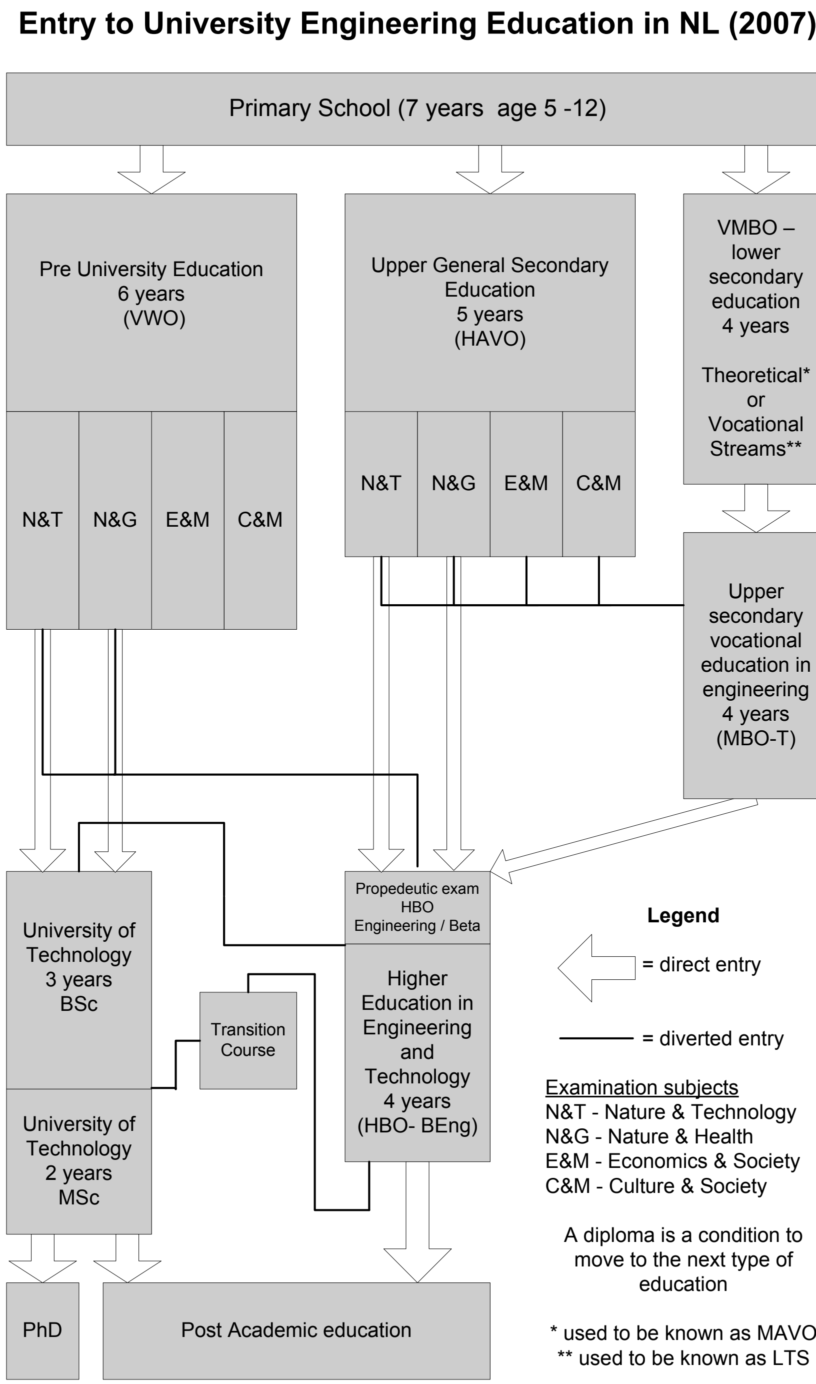

Figure 2.3 University education access chart for the Netherlands

At the time of writing, a degree from the universities mentioned above is still the only academic qualification in engineering in the Netherlands. Although HTSs are allowed to call themselves universities abroad and they award the title BEng to their graduates, those qualifications are currently not considered academic qualifications in the Netherlands, which is in sharp contrast with international practice, particularly in Anglo-Saxon countries. The BSc and MSc in engineering can only be awarded by a university registered as such in the Netherlands. The Dutch government has also decreed that the Dutch title system of 'ir.' and 'ing.' will continue to exist next to the bachelor and master system.

2.3 Development of the Field of Science of Aerospace Engineering

The first scientist to study and publish about the design of flight vehicles was Leonardo da Vinci (1412-1519). After a long period of no apparent development, the next experimental designers on the horizon were the inventors of the hot air balloons, Joseph and Jacques Montgolfier (1740-1810 and 1745-1799 respectively). The first person to steer away from the flapping wing concept was George Cayley (1799-1853) followed by the first successful glider designer Otto Lilienthal (1848-1896) who was the first person to understand the conflict between control and stability of aeroplanes. The first successful manned, motorised aircraft was, of course, the Wright Flyer built by Wilbur and Orville Wright which had its first successful flight in 1903. Between da Vinci and Cayley, science evolved tremendously. Some of history's greatest mathematicians and physicists such as Hooke, Newton, Bernouilli, Euler, and D'Alembert, developed and verified essential theories without which the science of flying would not have furthered itself. Some 10 years after Cayley's death, in 1866 the Royal Aeronautical society was founded in London to further developments in the field of aeronautical science. This society still exists today. This was shortly followed by similar associations and institutes in France, the USA and Germany.

Wittenberg (Lintsen et al., 1997) names Goddard (1882-1945) as the father of modern Rocket Technology. However, the first mention in literature on rockets dates back to the Antiquity, when, in 400 BC, the roman author Aulus Gellius mentioned the endeavours of a Greek scientist named Archytas who propelled a wooden bird using steam. However, other than this source, no further evidence has survived. The development of the field of rocket science is deemed by many to have its origin in the early Middle Ages in China with the invention of the fire rocket. Rockets continue to be used as a primitive weapon on the battle field until the 1900s, slowly being developed to be more effective and to be able to travel further. Astronomy also firmly lies at the base of the development of ‘rocket science’. In the 16^{th} and 17^{th} century, astronomers such as Keppler (1571-1630) studying the skies developed theories on the movement of celestials. It took until World War II however, for rocket science to really start to develop with the development of the V2 rocket by Werner von Braun (1912–1977) who, after World War II continued his work as part of the US space programme. It was the development of rockets that allowed people to start dreaming of space travel, although space travel did not become a reality until 1957 when the unmanned Sputnik 1 was launched by the Soviet-Union. The first scientific interest group in Space Science was started in 1927 in Germany. The ‘Verein für Raumfahrt’ aimed to build and tests rockets. This was followed shortly by the British Interplanetary Institute in 1933 as well as similar associations in France, U.S.A. and the Soviet-Union. However, the slow recognition of space as a separate science can be seen from the fact that it was not until 1953 that the National Aeronautics and Space Administration (NASA) was founded as a successor to the National Advisory Committee on Aeronautics (NACA).

There appears to be some discussion as to where the first courses in aeronautical engineering were taught. According to McCormick (2002) the first formal courses in aerodynamics at academic level were taught in France by Professor Lucien Marchis at the University of Paris in 1910. Imperial College in London, England claims that they first taught a course in aeronautics in 1909 with a first chair in aeronautics established in 1920 (Ransom and Self, 2002). The first established degree in Aeronautical Engineering was offered in France at the École Polytechnique de l’Aeronautique (and later et l’Espace) in 1909. The example was followed by many, and in 1916 the first 4-year programme in aeronautical engineering was established at the University of Michigan together with a department of aeronautical engineering, followed in 1926 by an aeronautical engineering department at Massachusetts Institute of Technology in Boston. During the 30s all over the world aerospace engineering degree programmes were started with even more commencing after the Second World War. It was not until 1958 that many American institutes changed their name in Aerospace Engineering or added the name Astronautics.

2.3.1 Aerospace Engineering in the Netherlands

Torenbeek and Wittenberg (2002) in their book on aeronautics state that one of the first Dutch designed aircraft to fly was the ‘Spin’ (Spider) designed by Anthony Fokker which flew in 1911. He has a fierce competitor in Frits Koolhoven who designed his ‘Heidevogel’ (Moor bird) also in 1911. Due to a lack of customers in the Netherlands, Fokker departed to Germany where he became a successful fighter plane designer during the First World War. At the end of World War I he returned to the Netherlands and continued building and designing planes, competing with Koolhoven who returned from England. It must be mentioned here however, that although Koolhoven and Fokker were the most important aircraft designers in the Netherlands in this Interbellum that there were other factories and designers such as Spyker who initially built Farman aircraft in license and later produced the Spyker V1, V2 and V3, the Pander factories who produced 7 aircraft, such as the Pander D and E and the S.4 ‘Postjager’ between 1924 and 1934 and whose designers continued in 1934 at the Schelde factories who produced the S.12, the ‘Scheldemusch’, the ‘Scheldemeeuw’ and the S.20, and the Delft engineer Hugo Lambach who built two aircraft the Lambach HL 1 and HL2. None of those initiatives would ever be on the same scale as Fokker and Koolhoven.

In 1919 the KLM was founded by Albert Plesman and soon he started regular flights to the Dutch East Indies and even had on of its aircraft take part and win an award in the 1934 Melbourne Race. Also, the armed forces saw the benefits of the use of aircraft and upon the instigation of General Snijder on 1 July 1913 the ‘Luchtvaartafdeling’ was founded. The fleet of aircraft was greatly extended during the First World War by confiscation of foreign aircraft who sought refuge in neutral territory. It continued to develop as an independent arm of Dutch armed forces during the 20s and 30s (de Jong, 1988).

The developments described above, resulted that in the 1930s the first courses on aeronautical engineering were taught at the department of Mechanical Engineering and Shipbuilding in Delft. In May 1940, just before the start of World War II, the first professor in aeronautical engineering was appointed at Faculty of Mechanical Engineering in Delft (Faculteit der Luchtvaart- en Ruimtevaarttechniek, 1990). In 1934 at the then MTS (later known as HTS) in Haarlem, a separate two year evening course in aeronautical engineering was started which became a 4-year full-time course in 1936.

2.3.2. Aerospace Engineering at Delft University of Technology

Following the appointment of the first professor in aeronautical engineering, Prof. dr. ir. van der Maas in 1940, the university instigated the degree of aeronautical engineer ('Vliegtuigbouwkundig Ingenieur') in 1943. During World War II professor van der Maas, however, was forced into hiding. The aerospace engineering degree programme therefore did not formally start until September 1945 (Faculteit der Luchtvaart- en Ruimtevaarttechniek, 1990).

The first 20 years can be characterized as years of investment in the future. The number of full professors expanded in 1945, with Professor van der Neut as the first professor in Aircraft Structures, to a total of 13 full professors and 'lectors' and 3 part-time professors in 1965. Initially, aeronautical engineering was not an independent department. It was part of a larger department combined with Mechanical Engineering and Shipbuilding. In 1953 this department was split into two: Mechanical Engineering, and Aeronautical Engineering combined with Shipbuilding. The laboratories were also built up during those years resulting in not only a laboratory aircraft, but also a low speed wind tunnel laboratory, a supersonic wind tunnel laboratory, and an aircraft structures and materials laboratory, resulting in aeronautical engineering having world class research facilities. The final icing on the cake in those years was the establishment of an own building in 1965, a building that is still in use as the Faculty of Aerospace Engineering today.

From 1961 space courses were formally included in the curriculum. In 1975 Aerospace Engineering became an independent department and over the next 30 years the number of students started to grow rapidly as can be seen from the available data of the last 25 years, displayed in figure 2.4. In 1985 all departments are renamed faculties.

In 1991 the number of students had to be limited to 400 in order to be able to manage the large number of students. The faculty then experienced a drop in its number of applicants in 1997 after the bankruptcy of NV Nederlandse Vliegtuigfabriek Fokker. At the same time the faculty was also hit by financial problems and a reorganization of the different research groups took place, resulting in some professors being made redundant. However, soon afterwards numbers started to pick up again rapidly due to a good recruitment strategy and the restructuring of the faculty. The faculty not only grew in terms of numbers of students but also in numbers of staff: over the past 10 years 7 research groups were added to the faculty. See figure 2.5 for an overview.

The Faculty of Aerospace Engineering at Delft University of Technology currently (2008) has some 1900 students and 17 different research chairs divided over 3 departments and, as such, is one of the largest faculties within Delft University of Technology and the only Faculty of Aerospace Engineering in the Benelux. The intake in the MSc programme is currently difficult to measure due to the transition into the BSc/MSc–system (Faculty of Aerospace Engineering, 2007a). In a programme review in 2001 the Faculty was found to have a teaching programme of high calibre and good research climate by the Association of Universities in the Netherlands (VSNU), and an American ABET substantial equivalency evaluation was granted (Faculty of Aerospace Engineering, 2002) for the second time. The last programme review carried out in November 2007 concluded that both the MSc and the BSc degree course in Aerospace Engineering met all requirements required for accreditation with no single facet being scored lower than satisfactory (QANU, 2008).

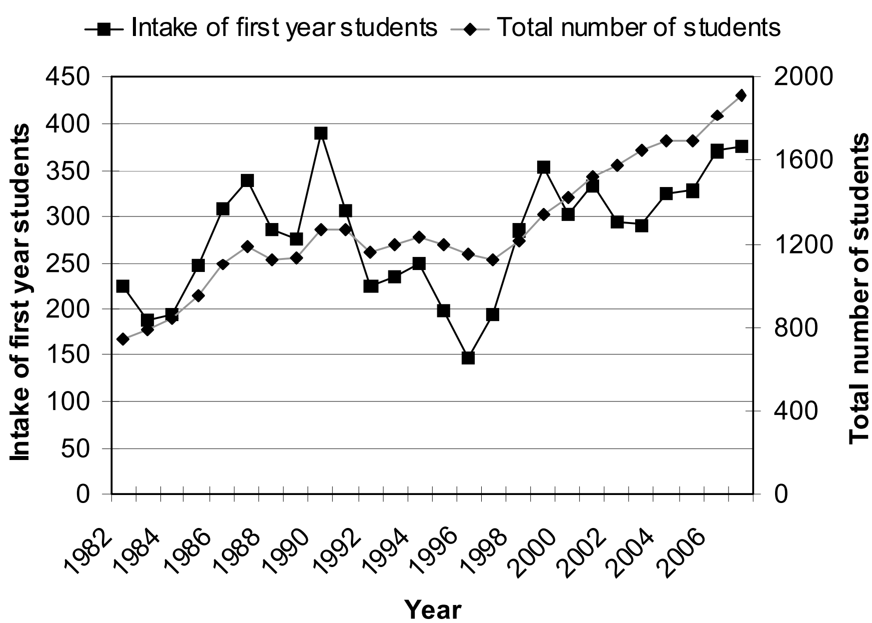

Figure 2.4 Intake of first year aerospace engineering students over the past 25 years (Staf college van Bestuur, 2002 and Faculty of Aerospace Engineering 2007a)

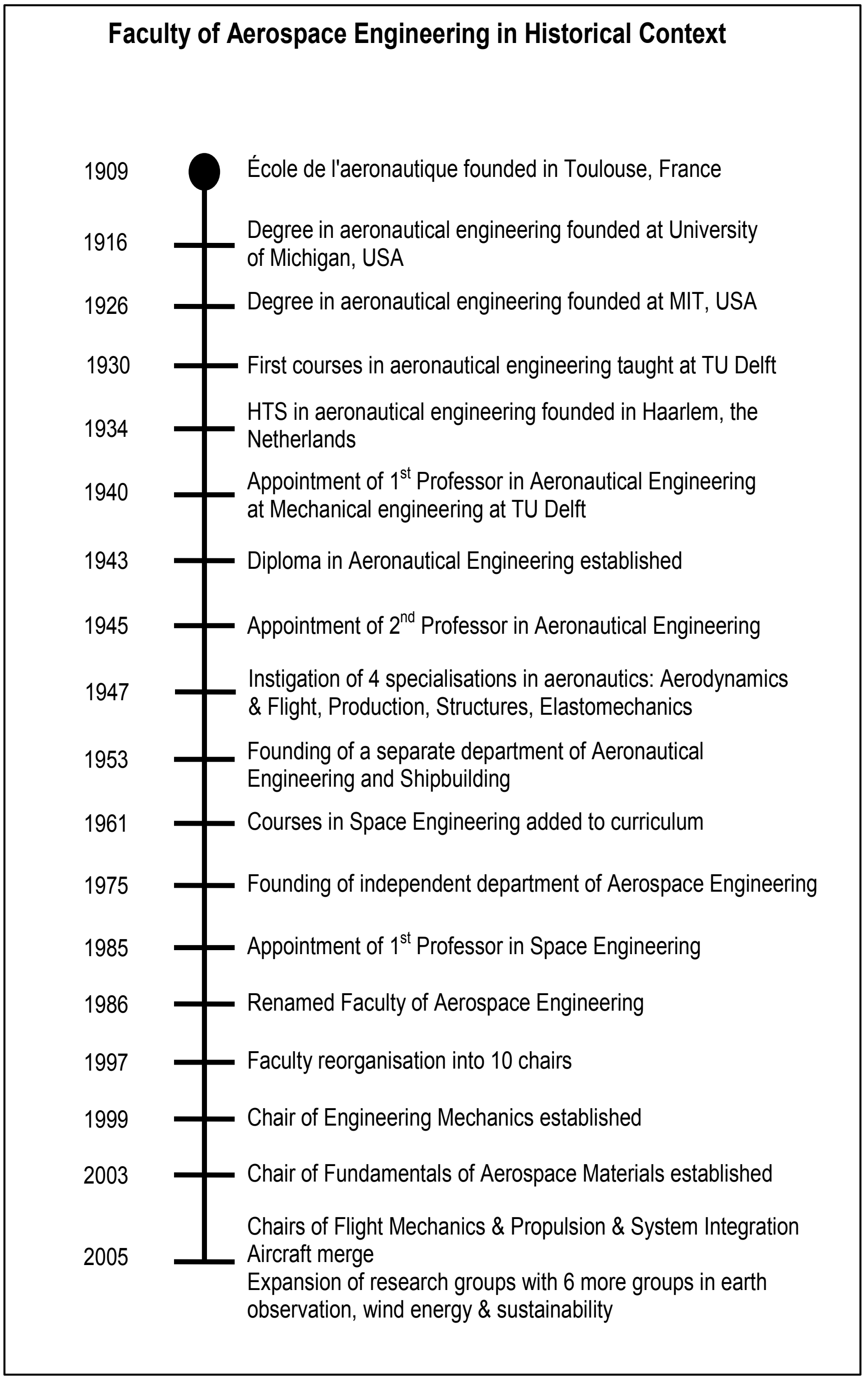

Figure 2.5 Faculty of Aerospace Engineering in Historical Context

2.4 The Development of the Aerospace Curriculum at TU Delft

In this section the development of the curriculum will be discussed with an emphasis on the gradual introduction of additional non-engineering learning objectives in the curriculum.

As stated in the previous section the degree programme did not practically start until 1945. The history book of the Faculty of Aerospace Engineering (Faculteit der Luchtvaart- en Ruimtevaarttechniek, 1990) describes the initial curriculum as mechanical engineering with some aerospace courses, all of which were aimed at low speed aircraft with propellers and piston engines. However, in those first years the initial foundation of the curriculum as it still stands today was laid. The focal point is the design of aircraft and the disciplines connected to it such as aerodynamics, propulsion and performance, stability and control, aircraft structures and mechanics of materials for aircraft. The history book also explains that already in 1947 it was recognized that to obtain sufficient scientific depth it was necessary for students to differentiate in research topics after two and a half to three years which would lead up to a Masters thesis on this topic. This practice still exists today. Over the years aerospace subjects would develop to form a much larger part of the curriculum, a situation which still exists today (Faculty of Aerospace Engineering, 2007a and 2007b).

2.4.1 Final Objectives of the Degree

Formal curriculum development at the Faculty of Aerospace Engineering did not start until the seventies. In 1975 for the first time formal final objectives of an aerospace engineer were compiled by Professor Wittenberg (Faculteit der Luchtvaart- en Ruimtevaarttechniek, 1990). These remain unchanged until 1995 even though the degree was shortened from 5 to 4 years in 1982. A translation of these final objectives can be found in Appendix A.

Looking at the objectives it can be seen that, in the seventies, competencies such as analytical and problem solving skills (final objective 2) were already part of the final objectives. It is interesting to see that the communication skills (final objective 4) of aerospace engineers were also part of the final objectives. Although communication courses were not a formal part of the curriculum, elective courses in oral and written communication were offered university wide. It must be mentioned here however, that some research groups within aerospace engineering chose to make communication courses mandatory in the specialization phase of the degree.

In 1995 when the degree programme was again extended to 5 years, new final objectives were compiled. (See appendix A) These final objectives were much more specific in terms of knowledge & courses required. When looking at the required competencies in the objectives it can be seen that oral and written communication skills (final objective 6) and problem solving skills were still on the list as well as analytical skills (final objective 5). Added to the list of required competencies in these objectives were the ability to work in teams, the ability of life-long learning (both in final objective 9) and the ability to synthesize (Final objective 5). Also here for the first time mention was made of the need for engineers of a basic understanding of their surroundings (final objective 7).

In 2001 the final objectives were reformulated to meet changing accreditation requirements and again in 2002 to allow for the introduction of the Bachelor/Master structure. Small adaptations had been made for the academic year 2005-2006 to allow for introduction of minors, and addition of disciplines at TU Delft. Their content, as can be seen from Appendix A, did not deviate drastically from the 1995 objectives.

In 2006 the final objectives were reformulated as Final Qualifications (Faculty of Aerospace Engineering, 2007a) based on a joint initiative of TU Delft, Eindhoven University of Technology and the University of Twente to come to a systematic framework for Academic Bachelor's and Master's curricula for Engineering degrees in the Netherlands (Meijers et al., 2005). The latest set of Final Qualifications can be found in Appendix A. Although formulated differently than before, the new qualifications still reflect the need for the same competencies as discussed earlier.

2.4.2 Project Education in the BSc phase of Aerospace Engineering

As a consequence of the extension of the degree programme to 5 years and the new final objectives, a shift took place in the way of teaching. This change was brought about by the then director of education, Dr. B.A. Reith who, in close cooperation with academic staff, recognized the changing demands society was putting on aerospace engineering. He initiated a new curriculum in which non-engineering competencies also started to play a large role and he redrafted the final objectives. This meant that whereas up until 1995 the degree consisted mostly of traditional lectures and exams combined with lab work, draughting and design exercises, either carried individually or in very small groups, from 1996 project based education was slowly introduced into the first three years of the curriculum at aerospace engineering replacing the traditional design exercises to gradually introduce non-engineering competencies into the curriculum.

In the first three years of the degree, the so-called ‘grounding phase’, five group design projects were introduced which were mandatory for all aerospace engineering students. It was aimed that during these projects students acquire team working and people management and networking skills through learning-by-doing. The organisation of the project experience is such that the students must organise themselves, divide tasks, make deadlines and have joint accountability for the end result. They also must acquire knowledge and obtain assistance which requires interaction with those around them, such as tutors, fellow students or industry experts. At the same time the engineering contents of the projects ensures that the students acquire and practice their problem-solving, analytical and synthesizing skills by solving the engineering design problem given to them. When reporting their results students acquire skills in written and oral communications. Skills which are to be honed by coaching, not only by the project tutors, but also by technical communication experts from the Faculty of Technology, Policy and Management.

It is important to stress here that students gain these skills regardless of the quality of the actual design. Students also learn from communication failures, mistakes in their analytical deductions providing reflection on these mistakes is offered. This is why the results of all projects are evaluated with the students and individual feedback to each student is given. Not only in terms of a grade but also orally in terms of their contribution to the design and to the group process.

As the projects are an educational experience, the design result comes second to the learning outcome. This does not mean however, that the quality of the design is not important. This must be guaranteed by ensuring that students have the required knowledge and skill level before entering a project by setting applicable entry requirements. Furthermore, the assignment given to the students must have a reasonable scope and the tutors involved must have sufficient understanding of the topic of the assignment to steer the students.

Before describing the projects at Aerospace Engineering in more detail it is good to define the types of educational projects educational experts agree upon Kolmos (1995) and later De Graaff and Longmuss (1999) distinguish three types of projects with an increasing ownership by the students:

- Assignment projects (AP) - Projects characterised by considerable planning and control by tutors, where problem, methods and subject are chosen beforehand.
- Subject projects (SP) - Projects in which the tutors define the subject beforehand. Students have a free choice among a number of described methods.
- Problem projects (PP) - Projects in which a problem is the starting point. The problem will determine the choice of disciplines and methods. The problem is chosen within a wider frame set by the tutors

The way the projects are organised at Aerospace Engineering reflects these types. The projects can be characterized by increasing ownership and independence.

The projects in the first year reflect the introduction into aerospace engineering. The first project is related to Aerodynamics, Astrodynamics and Mechanics in the shape of developing, building and testing of a water rocket and the second project is related to Aerospace structures, Aerospace Materials and Mechanics in the shape of the design to specification, the building and the testing of a wing or satellite box. Each project has a study load of 8 hours a week and lasts for 7 weeks. The objectives of the first year projects are:

- To apply knowledge gained in the lectures aeronautical and space engineering and mechanics by solving problems and acquiring insight in these subjects
- To learn how to work in teams by doing
- To get an introduction into using laboratory equipment

At the same time the project has the additional (hidden) objective to keep the students motivated for the study of aerospace engineering during a first year, which is difficult as the program consists mostly of core engineering subjects and math courses.

The projects in the first year can be very much characterized as assignment projects as topic, activities and methods are predetermined, although it must be stated the outcome is not universal as both projects include some form of design optimization and taking measurements using electronic equipment which means that students groups must compete with each other for the best design. On average almost 400 students per year take this course in groups of 8-10 students.

As this number is somewhat impossible to manage by faculty members alone, extensive use is made of senior students as tutors. Each tutor has two groups of 8-10 students in their care and also serves as a mentor during the first year. The tutors are trained beforehand on tutoring and counselling and are in close contact with faculty staff. The tutors make a recommendation on the grade the individual student gets, but the lecturer determines the final grade (Andernach and Saunders-Smits, 2006).

During the second year there are two projects on the subjects of the design of a multi-component (active) control mechanism of an aircraft or satellite and the simulation of the flight path of an air- or spacecraft. Each project has a study load of 12 hours a week and lasts 7 weeks. The main learning objectives of these projects are:

- Practicing team effort in designing a multi-component mechanism fulfilling a given set of design requirements (project 1).
- Acquiring basic problem-based programming experience applied to a multi component simulation program describing an aircraft or spacecraft mission whilst working together as a group (project 2).

Again the projects are closely linked with the lectures given in the second year. The first project can be classified as a hybrid form between an assignment and a subject project. Although the subject, the design of a mechanism is set, as well as the design requirements, the design freedom within the project is rather limited by the lecturers for fear of students running out of time or coming up with unfeasible designs. Additional laboratory exercises are also part of this project to give students the necessary feel for the introduction of forces in structures. The group size is 8-9 students.

The second project can be classified as a subject project. The choice of methods is restricted by the knowledge gained in lectures and the programming environment. Also students have a set time, in which to complete the project. Integrated with the second project is a course in Technical Writing and Business Communication. All reports produced during the project are also assignments for this course thus ensuring student motivation and dedication to take part in a course which is regarded as ‘soft’ by many students. The group size is 6-8 and the students are not in the same group as the first project, as students must learn to work together with anyone. Again, for both projects, extensive use is made of teaching assistants as tutors. Although each group has a member of staff acting as a client, a tutor is present for every two groups. The selection of those tutors is stricter as the tutors do not only guide the group process, but must also have enough subject knowledge to deal with first line questions. Extra training in tutoring and on subject matter is given.

In the fourth, final period of the third year the capstone project of the Bachelor program takes place. The Design Synthesis Exercise lasts 10 weeks and is only accessible for students who have completed the first two years of the curriculum. Students work in groups of ten on a design topic chosen from a selection of topics. Each disciplinary group in the faculty is required to provide one or two principle tutors who must write a multi-disciplinary design assignment suitable for this level of students. The project can therefore be classed as a problem project.

The objectives of the design synthesis exercise are to enhance the student's skills in:

- Designing
- Application of knowledge
- Communication (discussion, presentation, reporting)
- Working in a team
- Sustainable development

Integrated with the exercise are courses on topics such as Systems Engineering & Project Management and Oral Presentations. The assignments for those courses are incorporated in the exercise, e.g. all reviews are also graded on their oral presentation skills and their system engineering and project management approach to their design must be demonstrated in their reports. Also a library user course is given to allow students to use the library more effectively.

The design synthesis exercise is divided into different parts:

- Organization & Planning
- Requirements analysis
- Conceptual Design Phase
- Refined Conceptual Design Phase
- Analysis and Evaluation
- Detailed Design Phase
- Reporting

Each team is assigned one principal tutor and two auxiliary tutors. Each tutor is a faculty staff member and comes from a different disciplinary group within the faculty to ensure a multidisciplinary tutoring team. During the exercises there are three major reviews, the first after two weeks, the second half way and the last at the end of the exercise. The exercise is concluded with a one-day symposium at which all groups present their work to their peers and parents. A jury consisting of academic and industry experts awards a prize to the best group of the day. The faculty publishes all abstracts of the reports in a yearly book

(Melkert, 2006). More information on the particulars of this exercise can be found in Brügemann et al. (2005).

Experience over the last 12 years has shown that students like being responsible for their own assignment. This responsibility gives them a high degree of ownership and as a result no plagiarism or fraud in design projects has occurred over the past 8 years, even when groups of students were given the same assignment. However, a problem in projects can be that people for whatever reason, are not emotionally committed to a project and therefore their participation in the project decreases and sometimes even reduces to none. This can be because they are not motivated for the degree or the topic of their project assignment, or because their required skill level falls short. A second problem in projects is that students all contribute individually to the project and all develop their non-engineering competencies in different ways. This means that giving a group grade is unfair as it does not reflect an individual's student learning curve. Therefore individual grades are given to each student at aerospace engineering projects. Although the onus for grading will always lie with the tutor involved, staff members need more input then just their own observations. In order to tackle both problems, a web-based system of peer- and self evaluations has been set up within the project education framework (van den Bogaard and Saunders-Smits, 2007).

2.4.3 Project Education Facilities

In order to support project education, the Faculty of Aerospace Engineering invested heavily in additional educational facilities. The faculty has 25 project rooms of 5 by 10 meters dedicated to project education. Each room is fitted out with 8 PCs, a whiteboard, a cupboard, a meeting table and chairs. During the scheduled hours students have access to these rooms. Additionally, for the first year aerodynamics project, 3 small wind tunnels are available and for the structures project a dedicated workshop is set up to manufacture their designs as well as state-of-the-art CAD software in the form of 320 CATIA licences. For design reference purposes the faculty has a 600 m^2 aircraft and spacecraft parts collection enabling students to see design solutions of past and present to help them with their designs as well as an extensive library in the faculty building which is part of the university library which is considered to be the largest technical library in Europe.

'A man is a success if he gets up in the morning and goes to bed at night and in between does what he wants to do.'

Bob Dylan (1941 – present)

CHAPTER 3: THE SECRET OF SUCCESS

In this chapter a definition of a successful aerospace engineer will be proposed, as well as the indicators used to judge whether an aerospace engineering graduate is successful or not. The definition of what success is will first be explored by looking into literature. During the literature review, a list of competencies an engineer must possess in order to be successful is also compiled. This list is based on previous studies into the success of alumni as well as on published calls for needed chance in the skills engineers possess by employers of engineers. In addition to the literature review a summary of all relevant alumni research which has been carried out over the past 25 year at Delft University of Technology is included. The next part of this chapter reports on the validation of the list of competencies required for engineering graduates to be successful by an expert panel of aerospace employers in the Netherlands. At the end of the chapter a success definition is presented along with a list of competencies an engineer should possess in order to be successful. The content of this chapter will form the basis of the research presented in Chapters 4 and 5.

3.1 What is Success?

That is not an easy question to answer. For the purpose of this research, objective criteria for professional success must be formulated. As a result of the application of those criteria part of the aerospace engineering graduates taking part in this research will be classified as successful and another part as unsuccessful. However, some individuals who form part of this population may not perceive themselves to be successful or unsuccessful at all. Their definition of what being successful means may be entirely different, and based on other factors which are much more subjective. Their definition of success may include factors such as personal satisfaction (Vermeulen-Kerstens, 2006) and circumstances, happiness, choices because of family life. For the purpose of this research an attempt has been made to define objective criteria for professional success. More subjective criteria such as the factors mentioned above have not been taken into account in this research.

So what is success and what does being successful mean? The Merriam-Webster on-line Dictionary list success the following meaning of success:

> ***suc•cess***
> *1 obsolete :OUTCOME, RESULT*
> *2 a : degree or measure of succeeding b: favorable or desired outcome; also : the attainment of wealth, favor, or eminence*
> *3 : one that succeeds*
>
> *(Source: www.m-w.com)*

Of these definitions one commonly agreed upon definition of success is a favourable or desired outcome (explanation 2b). What favoured or desired means to someone depends of course on what they set out to achieve in the first place. Invariably, the individuals themselves and their environment set the criteria by which they judge whether the outcome is desirable for them. However, the dictionary definition does show that it is commonly agreed upon that success is a positive thing. For the purpose of this research the definition of success as a favourable or desired outcome will be used as a starting point for the definition of professional success for alumni. After all for the Faculty of Aerospace Engineering at Delft University of Technology the professional success of its graduates is vital for continued existence as an institute of education.

In the dictionary definition it is also stated that measures of success can be the attainment of wealth, favour, or eminence. However, this definition does not quantify how much wealth etc., as that will be up to an individual's standard. To obtain an objective success definition, quantifiable criteria must be found as well as a baseline for each criterion. These measures, referred to as indicators from now, must be specific and measurable if they are to be of any use. Moreover, these indicators must be specific enough to distinguish between the different aerospace engineering graduates.

3.2 Measuring the Success of Alumni – A Literature Review

For this search the library of Delft University of Technology, the Education Resources Information Center (ERIC) database, and Google scholar as well as the on-line resources of the American Institute of Aeronautics and Astronautics (AIAA) and the American Society for Engineering Education (ASEE) have been accessed. The reasons found in literature for the success of engineering graduates can be roughly divided into two parts: in literature which reports on actual research carried out under engineering graduates, and in literature consisting mainly of calls for change in engineering education by employers to include 'new and necessary' skills they feel engineers need.

3.2.1 Previous research on engineering graduates

During the present literature study only very few research studies on the subject of engineering alumni's professional success were discovered. This was also noted by **Yechout** (1992), when he surveys 51 ABET accredited aerospace universities. He notes that most schools at that time did not have any programmes in place to evaluate their alumni. He finds it interesting that, although all schools indicate that their programmes are under constant review, no one actually carries out any alumni research. When the lack of alumni research is discussed, most schools indicate that they think it is inefficient and expensive and that it is hard to quantify its added value.

It is therefore not surprising that most papers on alumni research found date from the late 60s and early 70s followed by a small surge again in the 90s apparently coming from communication teachers and due to new requirements from the accreditation boards (Education Accreditation Commission of the Accreditation Board for Engineering and Technology, 2000).

In his research on the need for continuing education in the aerospace industry **Landis** (1971) lists a number of factors indicated by aerospace engineers as important factors towards promotion. These factors are, listed in order of importance:

- Ability to gets things done on time
- Ability to communicate both verbally and in writing
- Ability to get others to work effectively for you.
- Willingness to assume additional workload
- Ability to form rapid and effective judgments
- Provide technical leadership
- Technical competence in specialty
- Broad technical competence in terms of company products or processes
- Knowing all aspects of the 'business'

- Seniority

This list was compiled by surveying aerospace engineers working in the New York area for both industry and research institutions.

Landis also looks at the career path of engineers. When engineers are in their 30s with some years of work experience as a professional they have to decide which way their career will go: will they become specialists or managers? He indicates that this decision is a difficult one to make, in particular for engineers of that age, due to heavy family and financial pressures.

Although the article itself deals with the need for continuing education, it does make some useful points. The author makes a distinction between the two types of engineering careers, the engineering manager and the engineering specialist. It can be expected that both will have different success factors or at least a different way of demonstrating their ability within a success factor. A similar distinction will also be made in the research of this thesis. Landis lists important factors for promotion given by engineers working in the aerospace industry. In a wider perspective this list has been used as input for the list of success factors used later in this research. Especially the factors: the ability to communicate both orally and verbally, technical competence in speciality, and broad technical competence are useful competencies.

In a journal article on occupational success of Kansas State University graduates **Hoyt** and **Muchinksky** (1973) list the following 10 factors of job success in engineering. This list was compiled in consultation with college of engineering officials:

- Scientific-Technical knowledge
- Understanding of Engineering Problem-Solving Methodology
- Creativity- Originality
- Persuasiveness
- Interpersonal Competence
- Managerial Skill
- Written communication
- Oral Communication
- Precision-Care
- Practical Judgement,

They asked the Kansas State graduates and their current supervisors in their place of employment to rate the importance of each factor on a 4-point scale.

The supervisors were also asked to rate their employee's performance in a 5-point scale.

An 'overall success' measure was developed:

$$overall\ success = \frac{\sum importance\ of\ \ factor \times employee's\ \ performance\ rating}{\sum importance\ of\ \ factor}$$

Using this formula the list above was put in order of importance with practical judgement as the most important factor to successful performance in an engineering career. Interpersonal and managerial skills were also found to have a significant impact. Supervisors also rated oral communication and precision-care as important factors. The least important factors appeared to be scientific-technical knowledge and creativity-originality.

The authors also asked graduates to rate the helpfulness of four college experiences in developing these skills. These four college experiences were engineering courses, other courses, organised extra-curricular activities, and informal activities. Of these four experiences engineering courses were found to contribute most to practical judgement and precision and care whereas other courses contributed to managerial skill and oral communication. The graduates rated interpersonal competence as being best developed during informal activities. When asked about recommendations to enhance their college experience graduates listed wishes such as courses becoming more applications-orientated, more teamwork in design, internships, and the introduction of business and communication courses.

Hoyt and Muchinksky's paper is interesting as it asks both the graduates and their supervisor for their opinion. However, no further explanation is provided as to how exactly the list of factors of job success was compiled. It is unclear from the article if the list of competencies was compiled based on previous research or by talking to colleagues over a drink. Also when putting the list of competencies to their research population, it appears they have not asked whether there were any other competencies missing in the opinion of their respondents. A further interesting point from this paper is that graduates feel that their interpersonal skills were best developed during informal activities. However, this fact is not supported with any statistical analysis in the paper. Also it is worthwhile noting that the alumni will have graduated in the 50s and 60s, a time in which classes were structured very differently than they are now.

When looking at the conclusions of the research reported in this article, it is interesting to see that scientific-technical knowledge is rated as one of the least important factors. Although the research itself has not provided any reasons why scientific technical knowledge is rated as least important, it may be speculated that scientific-technical knowledge is taken for granted. Every engineer is expected to have acquired this knowledge during their degree. It is the additional skills engineers possess which allows them to distinguish themselves from their peers. The measure of success that was developed could be useful for the research in this thesis as it takes into account the actual performance of the engineer. The drawbacks however, are that it would also mean getting the supervisors of alumni involved. This could seriously hamper the response rates and is therefore not very attractive as alumni may feel uncertain about asking their supervisor to fill it in and supervisors may be hesitant to fill in such a questionnaire for fear of their answers being used against her. Another point made in this research is the research into the source of learning of the job success factors. Insight into when and where the acquiring of these skills takes place can be very useful, but that may differ from country to country as university traditions very greatly throughout the world.

When comparing the Landis list of factors towards promotion to the list of job success factors by Hoyt and Muchinsky a lot of similar factors such as written and oral communication are found that are used in this research but Hoyt and Muchinsky also offer additional success factors such as managerial skills, interpersonal skills and problem solving ability.

By far the most comprehensive report on the success of engineers found is a report by **Klus** and **Jones** (1975) on engineers involved in continuing education. They approached a large number of engineers in the work field with a view to discover their opinion and ability for continuing education. It defines job success as engineers who function above the median in certain factors such as:

- Years with the present company
- Present job satisfaction
- Salary increases and promotions
- Salary with respect to age
- Salary with respect to job responsibilities
- Salary with respect to age and job responsibilities

For the salary it uses statistical data from the government to decide the median. It also makes use of governmental statistical definitions of job responsibilities.

Using these objective variables they then measure the relationship between certain abilities and skills and these variables.

The research by Klus and Jones is very interesting in its set-up. In this research the main variables are clear and straightforward as it defines success as being above a median in salary and job responsibilities. The method Knus and Jones use to investigate the relation between salary with respect to age and job responsibilities and their aptitude for continuing education is easily transferable to the research in this thesis in which the link between success and a person's abilities is investigated. The type of data acquisition required for the determination of the success factors can also be applied in this research. Information such as salary and level of job responsibility can easily be acquired from respondents. Age may not be a good factor in the Netherlands as students take a variety of lengths of time to complete their degrees, using years of work experience would be a better success factor.

In a more recent article by **Pinelli et al.** (1995) it is noted that aerospace graduates lack both oral and written communication skills. The authors especially feel that these communication skills are lacking due to the inability to 'reacculturate' their communication. That is when a graduate switches membership of one community (student-life) to another (professional life). The graduate will need to learn the changes in way of communicating, the new 'language' of that other community which they enter. They base their conclusions on a survey carried out among both aerospace students and professionals.

The survey taken by the students also asks what the career goals are of aerospace students. A distinction is made between 3 career goal orientations: engineering, science, and management. Pinelli et al. found that 49.9% of the students aspire to advance to a 'high-level staff technical position' in the engineering orientation, 51.0% aspire to 'establish a reputation outside your organisation as an authority in your field' in the science orientation, and in the management orientation 41.0% want to 'become a manager or director in their line of work'.

The distinction Pinelli makes could lead to the impression that there may be 3 career paths for engineers: high-level engineer, scientist, and manager. Pinelli et al. (1995) however, do not make that distinction. They believe that an aerospace engineer's career is a mix of all three paths with emphasis on one or more of those paths whilst still carrying out the other functions as well. If in this research it is decided to distinguish in 3 different career paths, Pinelli et al. do provide interesting suggestions as what could be used as a measure of success in these fields. Pinelli expresses this in terms of what aerospace engineering graduates may aspire to achieve, such as obtaining patents and coordinating positions. Although it can be argued that there is some truth in Pinelli's opinion that an aerospace career is a mix of three, this thesis will initially assume that 2 of them will always dominate. A graduate either becomes a manager or a specialist. In this case the scientist would be categorised as a type of specialist. It will leave room however, for a person to be undecided between the two.

In terms of gathering information on engineers and their career track, the National Science Foundation in the United States (**Kannankutty** and **Keith Wilkinson**, 1999) gathers statistical data on scientist and engineers. The data gathered is all stored in a database called SESTAT. It contains data on almost all engineering graduates in the United States and holds information on their primary job, salary, type of employer, job function, membership of professional societies etc. The tool can be used by any interested party to compile briefs on the engineering graduate population in the United States.

The NSF database tool could possibly be used to make a comparison of US engineering graduates and Delft engineering graduates and their success. Although it is not of direct use to the research in this thesis the tool could serve as an example of what Delft University of Technology as well as the other engineering colleges and universities should try and set up of their own. A search of data held by statistical agencies in the Netherlands revealed that they do not hold specific data on engineering graduates.

A survey among the alumni and their employers of North Caroline State University (NCSU) was carried out by **Hoey** and **Gardner** (1999) to measure the impact of their education on the alumni several years after graduation. Hoey and Gardner report that the NCSU graduates are doing well and that their degree prepares them fairly well for the important aspects of their job. In the survey both employers and alumni list leadership and management skills as important but gave the alumni low ratings on those skills. Next to that the employers listed general communication skills particularly listening skills to be very important to their graduates' current positions as well as workplace skills, dealing with higher order conceptual and analytical abilities of which problem-solving was rated the highest. The alumni also listed listening skills and problem-solving abilities as important. The research also shows that campus staff finds this type of surveys useful and that it helps them determine key programmes, activities and service features.

Hoey and Gardner show the value of this type of research. It is more than just another survey; alumni surveys can be used to adjust curricula. The results from the alumni research itself do not really contain any real surprises. They just reiterate what others such as Landis (1971) and Hoyt and Muchinksky (1973) have also found to be important skills for alumni and confirm that those skills should be included in the research in this thesis.

Research conducted by **Snover** (1999) reports on an alumni survey for the Massachusetts Institute of Technology (MIT). MIT wanted to know how their alumni were doing and track their career path. At the same time MIT also wanted to find out if their degree from MIT had contributed to or hindered their progress. Alumni listed the following skills and abilities as essential to do their job:

- To write clearly and concisely (92%)
- Have analytical and problem-solving skills (85%)
- The ability to think critically (94%)
- Capacity for life-long learning (91%)
- Foreign language knowledge (27%)

The percentage behind each item indicates the percentage of the respondents who rated this item important or very important. When asked how much MIT contributed to these skills, 92% said that MIT contributed a bit or very much to their analytical and problem-solving skills, but only 25% said that of writing. Alumni also indicated that because of their lack of writing skills their career path slowed down. As a result of this survey the communications programme at MIT was seriously enhanced.

Similarly to Hoey and Gardner, Snover looks at what specific skills and competencies alumni have and how useful they are and which skills are missing and uses that information to adapt the curriculum. Snover's research is particularly interesting in that it identifies what the effects are of lacking of certain skills for career tracks of alumni. From his research it is also clear that analytical skills are also very important and must be included in the list of competencies used in the research in this thesis.

In a survey by **Volkwein** and **Bian** (1999) alumni of the State University of New York in Albany were asked about their abilities important to success in their lives and in their careers, which they learned mostly from their academic experience. The alumni listed on the personal and intellectual side (in descending order of essentiality):

- Functioning independently without supervision
- Exercising personal responsibility
- Listening effectively
- Exercising self-discipline
- Exercising problem-solving skills
- Maintaining openness to new ideas
- Thinking analytically and logically
- Acquiring new skill and knowledge on one's own
- Possessing clear goals
- Writing effectively
- Learning how to learn

And on the interpersonal side, skills learned mostly outside the classroom (in descending order of essentiality):

- Speaking effectively
- Evaluating and choosing between the alternative course of action
- Coping with conflict
- Understanding oneself
- Leading and supervising tasks and groups of people
- Functioning effectively of a member of a team

Albany used the outcomes of Volkwein's and Bian's research to change the way they receive students as well as their curriculum.

What is interesting in Volkwein's and Bian's paper is the distinction in where alumni acquired skills: student-life and classroom life. The skills and abilities listed are not that different from the ones in other publications. The list is however more detailed than most: e.g. instead of just stating communication skills they have split that up into even more skills and abilities such as speaking effectively, listening effectively etc. It can be suspected that this was done in order to further separate what learning is done in the classroom versus learning outside the classroom. For the purpose of the research in this thesis it is only of interest to know what competencies are learned in the classroom.

3.2.2 The opinion of engineering employers

This section reports on what employers of engineers think defines a successful engineer. Engineering employers often readily have an opinion to offer on what qualities they would like engineering graduates to possess. These employers' calls for change are going back as far as 1985, yet some of the points raised by those employers are still valid today. The next paragraphs summarize the calls found in chronological order.

The first of such calls for change was an article by **Thomas** (1985), from Airbus Industries, on training engineers for joint programmes for the European aerospace industry. He notes that there are serious absences in European aerospace engineering education. He lists these shortcomings to be:

- No training for tasks in international business
- Lack of knowledge of foreign languages and the ability to report verbally or in writing
- No training in time-management and decision making techniques.

He also notes that there is a too high a degree of specialisation in aerospace engineering courses and that there should be more emphasis on interrelation of subjects in order to effectively work within one's speciality. Finally, he notes that only if an engineer is truly mobile and flexible and has the ability to overlook national interests and pride they will have a successful career.

What is noticeable from this paper is the cry for the need for communication skills and how important they are if an engineer is to be successful in Thomas' opinion. Another point of interest for continental European aerospace engineering graduates and therefore also for the engineering graduates of Delft University of Technology is the need for knowledge of foreign languages and the ability to communicate efficiently. Since the Dutch language is not a dominant world language Dutch engineers will have to be proficient in a foreign language, most likely English. The ability to be proficient in the English language could be an additional competency for Dutch engineering graduates whereas it is a given constant for their Anglo-Saxon colleagues.

However, it must be remarked here that most aerospace literature is in English and English is a mandatory subject for at least 6 years in the secondary education phase in the Netherlands and is also taught at primary schools. Moreover, the Faculty of Aerospace Engineering now offers both its BSc and MSc programme in English. This competency is therefore not used in the research of this thesis.

A journal article by **Ackermans** and **Trum** (1988) reports on a two-year post-graduate design course started at Eindhoven University of Technology and industry in 1985 by a joint agreement between the departments of Economic Affairs and Education. The impetus for this initiative was that industry felt that design engineers were insufficiently trained. The Dutch industry listed that the following skills were missing in design engineers and should be part of the objectives of the new course:

- Ability to perform interdisciplinary work in teams
- Creativity
- Modern design techniques
- Cost-accounting and manufacturability
- Design methodology
- Quality
- Presentation of ideas, orally and in writing

Although this article does not have a direct link to competencies critical for professional success, it does list a number of skills employers believe graduates are lacking which is hindering their usefulness to their employers. In other words it could be interpreted as skills engineers need to be successful.

In his article on engineering education's contribution to the space programme **Guyford Stever** of the National Academy of Engineering (1988) points out that engineers working on the space programme should have:

- A broad knowledge of modern science instruments
- Fundamental knowledge of all engineering sciences
- Appreciation and capability for detail and system design
- Understanding of cost and competitiveness
- Familiarity with materials, machines and manufacturing

All in all it becomes clear that in order to be successful, an engineer must be a jack of many trades.

Again here the call for multi-disciplinarity and understanding of the interdependence as essential engineering skills even for the engineering specialist is made. This again underlines the importance of a broad engineering knowledge base before specialising as made by Thomas (1985) and by the author of the next article to be discussed.

Observations by **Eugene Covert** from the Massachusetts Institute of Technology (1992), based on conversations with successful aerospace engineers, show that aerospace engineering is a dynamic profession and that today's knowledge is inadequate for tomorrow's practice. He calls for a broad grounding in aerospace engineering and not too much specialisation. He feels that there is a risk that most lecturers however, are engineering specialists and hence their teaching can become too narrow and focussed.

It is his opinion that professional judgement is something that will be gained by work experience only and cannot be taught. He gives an overview of what in his opinion the BSc degree in aerospace engineering should look like. He also calls for additional skills such as problem solving abilities, communication skills, and highly ethical behaviour to be included in the curriculum.

What it is interesting in Covert (1992) is his notion that most teaching in aerospace engineering is done by engineering specialists and not by engineering managers or generalists. He also admits that as much as universities would like to, universities are not there to teach professional judgement. His opinion that this can only be gained through experience is probably very true.

In a paper by **Spurgeon** (1997) from the Toltec company a distinction between two types of engineers is made, the individual contributors and the managers. Their career paths can be seen in figure 3.1. He lists the following required skills and characteristics for managers:

- Technical competence
- People
- Conceptual skills
- Judgement
- Character

His paper is useful from the perspective of employers. He lists how employers view the development of staff. It is interesting that he also distinguishes two career paths similarly to Landis (1971) although he does not call them engineering specialists but individual contributors.

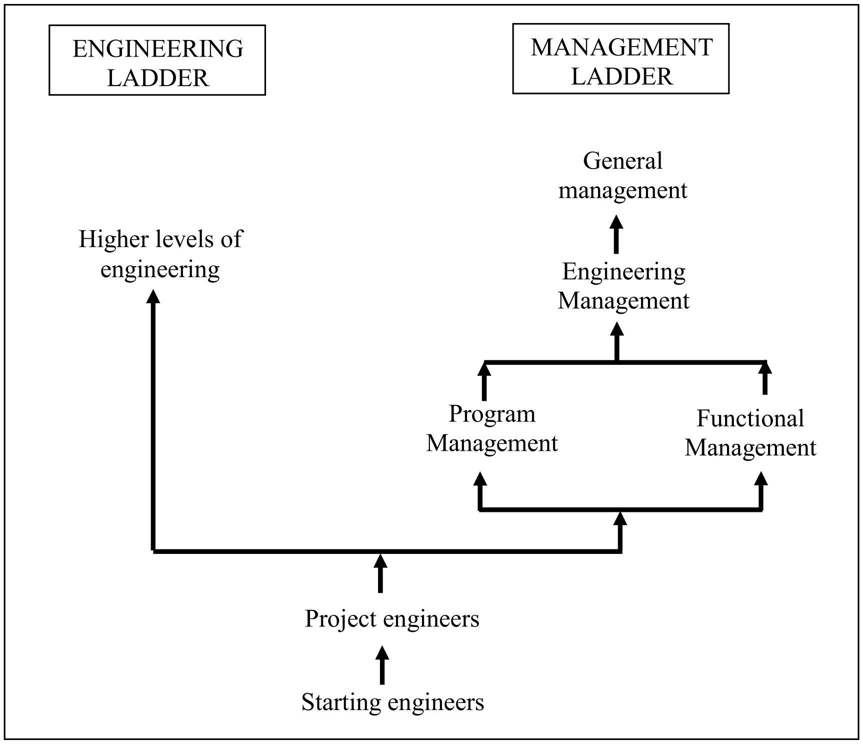

Figure 3.1 Career progressions for engineers (Spurgeon, 1997)

Similar calls to Thomas (1985) and Guyford Stever (1988) can be found in a set of three papers by **McMasters et al.** (1996, 2002, and 2003). McMasters from the Boeing company talks about the Boeing list of 'Desired Attributes of an Engineer'. These are:

- A good understanding of engineering science fundamentals
    - Mathematics
    - Physics and life sciences
    - Information technology
- A good understanding of design and manufacturing processes
- A multi-disciplinary, systems perspective
- A basic understanding of the context in which engineering is practiced
    - Economics
    - History
    - The environment
    - Customer and societal needs

- Good communication skills
    - Written
    - Oral
    - Graphic
    - Listening
- High ethical standards
- An ability to think both critically and creatively – independently and cooperatively
- Flexibility. The ability and self-confidence to adapt to rapid or major change
- Curiosity and a desire to learn for life
- A profound understanding of the importance of teamwork

He also calls for the need of engineers to keep on learning and their ability to do so. He emphasizes the need for starting engineering practice early in degrees by using design projects.

McMasters' calls are again confirmation of how important aerospace companies find other skills next to just engineering skills. It has to be noted here that most of the criteria listed by McMasters were incorporated in the new ABET 2000 requirements (Education Accreditation Committee, 2000).

McMasters opinion is confirmed in a paper by **Koen** and **Kohli** (1998) on the new ABET 2000 criteria (Education Accreditation Committee, 2000) in which they report on which of the 11 new ABET criteria supervisors of new engineering undergraduates think they should definitely possess. The five most important attributes listed by them in descending order were

- Problem solving
- Ability to design and conduct experiments
- Recognition of the ability to engage in a life-long learning
- Understanding of professional and ethical responsibility
- Ability to function in multi-disciplinary teams

Koen and Kohli's paper is interesting because of it validates the criteria ABET has put in place. Some of these criteria have been used as competencies required for professional success in this research.

A journal article by de **Graaff** and **Ravenstein** (2001) states that a future engineer in order to be successful and recognised as an expert by society must possess the following additional skills next to Technical-scientific (professional) knowledge and skills:

- Knowledge and skills in the field of 'science technology and society'
- Knowledge and skills in the field of organisation and management
- Communicative and social skills

This article highlights the inability of engineers to communicate with non-engineers - the rest of the world. Engineering skills itself are not enough to be successful, an engineer must also be able to have their work accepted by non-engineers in order to be successful. To achieve this they must acquire extra skills such as communication skills. The additional skills in the field of organisation and management and communicative skills listed here again can be seen as success factors for engineers and will be used as such in the research of this thesis.

3.2.3 Concluding Remarks

The literature suggests that engineering skills such as being able to design or do engineering calculations are taken for granted by both employers and the graduates. It is what extras in terms of competencies one has to offer that makes one successful or not. Although the research in this thesis focuses on aerospace engineers it can be concluded from literature that there are no unique competencies only required for aerospace engineers. They appear to apply across the engineering spectrum. Furthermore, there seems to be one common agreement between both the graduates and the graduates' employers: Communication skills, both written and oral, are named by all as something graduates should possess. This is almost immediately followed by the competencies problem-solving skills, interpersonal/team skills as well as the ability to see the bigger picture. From the literature survey a list of competencies will be distilled in the next section which can serve as success factors. What is however lacking from the majority of the literature is the solution to this lacking of competencies. Virtually no one actually suggests how the acquiring of these competencies might be introduced or improved in engineering curricula. If they do suggest that the curriculum has been changed to reflect the need of these new competencies (Volkwein and Bian, 1999) no indication has been given on how this has been done and whether the results have been validated.

A second trend which can be distilled from the literature survey is that there is no one type of engineer. Several people (Landis 1971, Pinelli et al., 1995, Covert, 1992, and Spurgeon, 1997) argue that engineers can follow two or three career paths: the engineering manager, the engineering specialist and in Pinelli's case also the scientist. If this is the case: the engineers on these different career paths may have different needs. This must also be investigated in the scope of this thesis.

Research into the success of engineers seems to have been carried out in the late sixties, early seventies and then not again until the late eighties, early nineties when industry starts complaining about the skill level of engineers. It then goes quiet again until the end of the nineties, and early in the 21st century when the new ABET accreditation criteria come in. It is worrisome that so little research is done and so little seems to have been learned from it as research from both eras indicate the same set of skills required and the more recent research indicate that those skills are still missing. This is especially worrying considering that both North American (Engineering Accreditation Commission, 2000) and European (Quality Assurance Netherlands Universities, 2004) accreditation authorities require universities to keep track of their alumni and to actively ensure that their courses still meet the requirements of their stakeholders. It is therefore important that it is investigated if the competencies listed in the next section are indeed lacking and if they are not whether it was their education at engineering college that contributed to the acquisition of those skills so that a set of recommendations can be made as to the implementation of the learning of these competencies in engineering curricula.

3.3 Alumni Research at Delft University of Technology

The previous section reported on the results of a literature survey on actual research of engineering alumni and calls from engineering employers on what skills engineers should have in order to meet industry demand. This section aims to look at what previous research has already been carried out at Delft University of Technology and evaluates its use for this thesis. Three types of alumni research pertaining to aerospace students were found: Research into alumni employment within 2 years after graduation, research for marketing and recruitment purposes, and student association surveys amongst former students.

Research into alumni employment is a standard graduate survey which Delft University of Technology has carried out each year among alumni who graduated in the previous year. The 2004 and 2005 reports (Desan Research Solutions, 2004 and 2005) show that of the aerospace graduates who graduated in 2002, 93% are employed with an average gross wages of €14.80 per hour in

2004 and €13.27 in 2005. 58% work in a job for which aerospace engineering was one of the preferred degrees. 80% had a job within 3 months after graduating. The year before, in 2001, this number was even higher at 96% but in 2002 the economy started to slow down and the effect of this can be noticed in the data. Additionally, the survey reports on the satisfaction of alumni with their degree and the skills they have acquired and to what extent the degree prepared them for the job market.

Although this is a useful survey as it is done yearly and the results of subsequent surveys can be used to compare the opinions of recent graduates of different years to each other, the number of graduates participating is low (circa 35 participants) and it does not track the graduates for the rest of their career. Its uses to measure the long-term impact are therefore limited.

Research for marketing purposes is done by the Alumni Office of Delft University of Technology which itself was only founded in 2000. The alumni office recently published the results of a short survey under all of its alumni on their career track and the effects of their Delft education on it (TU Delft, Marketing and Communication Office, 2004). According to this survey, the 277 aerospace graduates who took part rated their degree with 8 out of 10. The survey lists no further specific information on aerospace engineering graduates.

Finally, there are the white papers written by the Aerospace Student Association 'Leonardo da Vinci' (known in Dutch as 'Vliegtuigbouwkundige Studievereniging Leonardo da Vinci' or VSV Leonardo da Vinci) at Delft University of Technology. White papers ('witboek') in this context are reports in which the students and staff reflect on their degree by means of interviews and small educational research. All in all between 1975 and 1995 this student association has published 5 white papers. The second white paper, 'tweede witboek' (VSV Leonardo da Vinci, 1980) contained a report on an alumni survey carried out in March 1980 among all aerospace alumni of whom the address was known since 1950. The response rate of that questionnaire was 40.9%. In it the survey reports on where alumni are working. At that time the NV Nederlandse Vliegtuigenfabriek Fokker, which went bankrupt in 1996, is by far the largest employer, see also table 3.1.

Furthermore, the report shows that 44.7% of the graduates still work in aerospace and that contrary to the present situation, students found it harder at the end of the seventies to find a job immediately after graduation. Some 10% of the alumni took more than 3 months. This is excluding those who went on to first fulfil their military service which was mandatory for all Dutch young men until 1995 when it was suspended. The survey also asked about the day-to-day activities of aerospace engineers. The top 3 specific characteristics of their work were: management followed by research and education.

Employer	Percentage
1. NV Nederlandse Vliegtuigfabriek Fokker	18.1 %
2. NLR	13.8 %
3. Delft University of Technology	10.1 %
4. KLM	2.7 %
Rijksluchtvaartdienst (Airworthiness Authorities)	
6. Philips	2.0 %
Oil companies	
8. Other aircraft manufacturers	1.7 %
TNO	
Ministry of Defence	

Table 3.1 Current employers from the 1980 alumni survey, (N = 298)
(VSV Leonardo Vinci, 1980)

The alumni were also asked about the engineering contents of their current job, see table 3.2.

Engineering contents current job	Percentage
Predominantly engineering	43.4%
Partly engineering	35.4 %
Non-Engineering	21.2 %

Table 3.2 Engineering contents in current job from the 1980 alumni survey, (N = 288)
(VSV Leonardo Vinci, 1980)

The students also asked the alumni about the level of supervisory responsibilities alumni had:

Supervisory responsibilities	Percentage
Substantial	36.3%
Some	37.0 %
None	26.7 %

Table 3.3 Current supervisory responsibilities from the 1980 alumni survey, (N = 281) (VSV Leonardo Vinci, 1980)

Graduates were also asked if they would choose aerospace engineering as a degree again if they had the choice, see table 3.4.

Do degree again?	Percentage
Yes	33.7%
Maybe	36.0%
No	25.3 %
Don’t know	5.0%

Table 3.4 Would you do the same degree again? from the 1980 alumni survey, (N = 300) (VSV Leonardo Vinci, 1980)

Finally, graduates were asked if they took any additional courses after graduating. Some 60% answered yes, most which had taken additional courses in management, business and economics.

The student association carried out a much smaller survey for the ‘Derde Witboek’ in 1985. The response for this survey was 32%. This survey focussed more on the ease with which alumni obtained their job and what subjects could be eliminated from the degree now that the degree was becoming shorter (from 5 to 4 years). As the survey was not the same as the 1980 survey a question-by-question comparison could not be carried out. However, it is reported in this survey that 59.3% of the respondents still work in aerospace and that some 19% of the respondents still work at the NV Nederlandse Vliegtuigenfabriek Fokker. In this questionnaire alumni were also asked to indicate if they had taken any additional courses to which 86% answered yes. Again, just like in the 1980 survey, the alumni mostly took courses in management, business and economics.

Most of the alumni surveys carried out among Delft aerospace alumni give a first overview of where most graduates of the entire university end up. However most data is either too old or cannot be used directly to measure the success of alumni or the contribution of the individual degrees to the alumni's career path. For that purpose more detailed new research would need to be done.

3.4 How to be Successful

As described by Landis (1971), Pinelli et al. (1995), Covert (1992), and Spurgeon (1997) there are different career tracks for an engineer to follow. As it can be argued that there will be different emphasises on how success is measured between the career tracks it is important to define these career tracks more clearly. In this study two different career paths were identified for an engineering graduate to follow: the engineering specialist and the engineering manager.

In this distinction the engineering specialist and the scientist are grouped together in one career track as individual contributors, as that seems to be the commonly accepted definition in literature, see for instance Landis (1971) and Covert (1992). An additional problem was foreseen in differentiating between the engineering specialist and a scientist, as an engineer can very well be both at the same time. (For instance the part-time professorships offered to experts from engineering companies). It is also worthwhile to keep in mind the career path identified by Spurgeon (1997), which distinguishes between managers and individual contributors, as this criterion can be used to class an engineer as either an engineering specialist or an engineering manager.

It can be observed that at some point in their career graduates make the choice within the environment they are working in whether to become a specialist or a manager. The work presented in this thesis will not focus on why an engineering graduate chooses one career path over the other but will utilize the fact that engineers do make that choice and that they might switch affiliations between the two tracks over their career before settling into one of the two. This is one of the main reasons why the research in this thesis will focus on alumni who graduated at least 5 years ago.

As mentioned at the start of this section two career tracks were identified: the engineering manager and the engineering specialist. These two tracks will be used throughout this study to see if those different career tracks have different needs. At this point it is appropriate to define each of these tracks:

An *engineering specialist* is defined as an engineer who either works within a company or a research institute and is an expert in a part of engineering science and is not really involved in the running of the business or the institute only in the product it delivers. They are individual contributors who apply their specialized engineering skill and knowledge. Product in this context could mean anything from aircraft parts to calculations. Typically scientists at universities, researchers at research institutes or research & product development departments, etcetera fall in this category.

Similarly an *engineering manager* is defined as an engineer who supervises the process leading to the product. They generally have to look at the bigger picture and are not as specialised although they have a broad technical knowledge. They use their engineering skills to analyse and influence generic processes. They typically have taken up a position of responsibility, such as manager, director, chairman, dean etc.

These definitions do of course leave room for somebody who will have a hybrid function. However, Spurgeon (1997) says this hybrid function will only pertain to fewer than 5% of our research population. As Sturgeon's research at the time when the survey was carried out is almost 10 years old it must determined if this hybrid group currently still is smaller than 5% If the group is indeed found to be smaller than 5% they will be eliminated in the data analysis, if this is not the case however, the results of this hybrid group will also be taken into account in the analysis.

3.4.1 Research questions

After defining the career track of engineers it is necessary to define what qualities a successful engineer must have. As mentioned before success is the attainment of wealth and eminence. How such attainment can be measured will be defined in the next chapter. First the main research questions of this research must be posed. The main research question is:

> *'What competencies differentiate successful engineers from those with less successful careers?'*

This then leads onto the second research question:

> *'Do engineers working as engineering managers and engineering specialists need different competencies to be successful?'*

These questions have been researched using alumni from the Faculty of Aerospace Engineering of Delft University of Technology who graduated between 1975 and 2000. Limiting this research to this group was done for practical and financial reasons as well as the personal interest of the author. By limiting this research to one faculty it is possible to come to concrete recommendations on the way competencies are taught in the curriculum at the Faculty of Aerospace Engineering at TU Delft. This results in the final research question:

> *'What are the consequences of the outcomes with regards to the representation of competencies in the aerospace engineering curriculum at Delft University of Technology?'*

The answers to the question however, are also expected to be valid for aerospace curricula throughout the world and most likely also for similar engineering degrees such as mechanical, civil and maritime engineering. With the research questions in mind it must now be addressed what the competencies referred to in the research questions are that engineers must possess to be successful. Also it will need to be researched if the competencies needed to be successful differ depending on whether the alumnus is an engineering specialist or an engineering manager. In the next section an initial list of relevant competencies a successful engineer should possess is proposed. The final list of competencies can be found in section 3.5.

3.4.2 Competencies & skills

To answer the research questions from the previous section the competencies a successful alumnus should have must be defined. In this section a set of competencies will be proposed and then validated by putting them to an expert panel of employers of engineering graduates.

The list of competencies is shown in table 3.5. This list was developed based on what was found in the literature as described in the previous sections. It is expected that these competencies are to be more or less applicable for both career tracks, although in the scope of the research in this thesis, any differences between the two career tracks will of course be analysed.

Competencies	
C.1.	Ability to synthesise
C.2.	Analytical skills
C.3.	Problem solving skills
C.4.	Managerial skills
C.5.	Written communication skills
C.6.	Oral communication skills
C.7.	Net worker
C.8.	Have broad technical knowledge
C.9.	Have specialist technical knowledge

Table 3.5 Suggested required competencies and skills of a successful engineer (MSc level).

The first competency, the ability to synthesise, was chosen based on the calls for a multi-disciplinary view by McMaster (1996, 2002 and 2003). Rather than just following a rulebook of design, an aerospace engineer must be able to integrate all the aspects of the design into one self-sufficient entity. An aerospace engineer must be able to weigh up those different options. The competencies analytical skills and problem solving skills can be traced back to Snover (1999), and Volkwein and Bian (1999) who list these as important skills for alumni to do their job. The managerial skills stem from calls by Hoyt and Muchinkski (1973), Thomas (1985), Volkwein and Bian (1999), and de Graaff and Ravensteijn (2001) who indicate the importance of this particular skill for engineers. Virtually every reference discussed in the literature survey earlier in this chapter clearly stated engineers should possess good oral and written communication skills. Networking is not mentioned as a specific competence but was derived from remarks by Hoyt and Muchinkski who suggest that engineers should have interpersonal competence and persuasiveness, Volkwein and Bian who indicate the importance of coping with conflict, and de Graaff and Ravenstein's call for social skills. The competency broad technical knowledge stems from Guyford Stever (1988), Covert (1992), McMaster (1996, 2002, and 2003). Finally, the competency specialist technical knowledge was added to see if there was a sharp contrast between the knowledge required for engineering specialist and engineering managers. A similar distinction between those two types of knowledge was also made by Landis in 1971. Whether knowledge can be defined as a competence is a point of argument. Bloom's taxonomy on educational objectives (Bloom, 1956) defines three domains of educational objectives: cognitive (intellectual knowledge and skills), affective (feelings, attitude and values) and psychomotor (manual and physical skills). However, the type of skills listed in the list of competencies cannot really be classed as psychomotor skills so they do not appear to fit in Bloom's model. However, Romizowski in his book on designing instructional systems (1981) argues that Bloom's taxonomy is inadequate as it fails to deal with interpersonal skills such as team working skills. Therefore, in the research of this thesis competencies are defined as a collection of intellectual knowledge, abilities, and skills which form part of Bloom's cognitive domain but which also includes the interpersonal skills.

3.4.3 Panel Questionnaire

The list from table 3.5 was put in front of a panel consisting of people working within the aerospace industry in the Netherlands as well as people working at universities and research institutions who regularly employ aerospace graduates from Delft University of Technology. After having been explained the purpose of the questionnaire as well the distinction made between the two different types of engineers, they were asked to indicate for each group of engineers the relevance of every competency. The level of relevance could be indicated on a 5-point Likert scale ranging from 'very unimportant' to 'very important'. Next to that they were also asked if they felt any competencies were missing and how they would rate those competencies for each type of engineer. The list of companies and institutions, which the participants represented, and the actual list of questions can be found in Appendix B.

The panel consisted of 19 people of whom 11 worked in government-funded institutions and 8 in industry. A total of 7 different companies and institutions were represented. Of the panel 9 deemed themselves to be specialists and 10 deemed themselves managers.

The panel was asked to rate the importance of each competency on a 5-point Likert scale with 1 being not at all important and 5 being very important. The average rating for each of the two types of engineers is displayed in table 3.6 and figure 3.2. In order to check whether there are any significant differences between the results for each competency for the manager and the specialist in this survey a dependent *t*-test with a 95% confidence interval was carried out. This statistical test determines if two means collected from the same sample differ significantly using Student's *t* – distribution (Field, 2005). The results are deemed to differ significantly if p is smaller than 0.05. The results of the t-test can be found in table 3.6. The last column indicates whether there is a significant difference between the results.

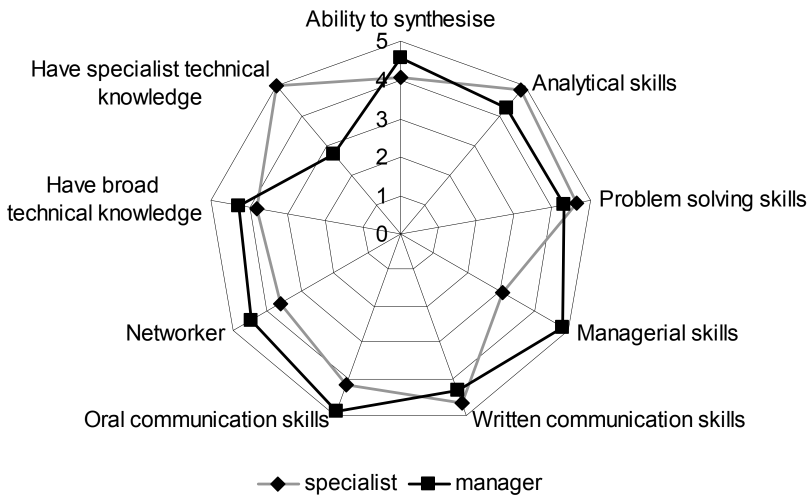

Figure 3.2 The average rating of the importance of competencies for engineering managers and engineering specialists by the expert panel (1 = totally unimportant – 5 very important)

	Competencies	Specialist	Manager	t(18)	Sign.
C.1.	Ability to synthesise	4.1	4.6	2.5	*
C.2.	Analytical skills	4.8	4.3	-4.2	**
C.3.	Problem solving skills	4.6	4.3	-1.5	-
C.4.	Managerial skills	3.1	4.8	9.1	**
C.5.	Written communication Skills	4.7	4.3	-2.1	*
C.6.	Oral communication skills	4.2	4.9	4.4	**
C.7.	Net worker	3.6	4.5	4.5	**
C.8.	Have broad technical Knowledge	3.8	4.3	2.0	-
C.9.	Have specialist technical Knowledge	5.0	2.7	-10.1	**

Table 3.6 The average rating of the importance of competencies for engineering managers and engineering specialists by the expert panel
*(1 = totally unimportant – 5 very important, * $p < 0.5$, ** $p < 0.01$.)*

From the *t*-test it can be concluded that the competencies 'Problem solving skills' and 'Broad Technical Knowledge' do not differ significantly between the two types of engineers, all other competencies do. The table clearly demonstrates that, except for one, all of the competencies were found to be important competencies for engineer to have regardless whether they are on the specialist career track or on the managerial career track. The one competency deemed not important for the managerial engineer is specialist technical knowledge. As was expected managerial skills are still a necessity for engineering specialists even though they are not deemed as important as for managers.

When asked the question if the expert panel felt there were any competencies missing a total of 38 competencies were named, some of which were named multiple times. The panel was also asked to score those competencies for their importance for managers and specialist respectively. The competencies which occurred more than once were grouped and their average scores are listed in table 3.7. Competencies which were mentioned only once are listed in table 3.8 with their individual score.

	Additional suggested competencies	Specialist	Manager
A.	Ability to work in teams (6 x)	3.7	4.3
B.	Social skills (5 x)	3.3	4.6
C.	Ability to change (2 x)	4.5	5.0
D.	Planning and Organising/Systematic Planning (2 x)	4.0	4.0
E.	Continuous education (2 x)	5.0	4.5

Table 3.7 Additional competencies suggested multiple times by the expert panel and their importance to engineering managers and engineering specialists (1 = totally unimportant – 5 very important)

From table 3.7 it can be observed that the ability to be a team player and having social skills were each mentioned multiple times and the ability to change, continuous education and planning and organising were also mentioned more than once. It can also be noted, especially from table 3.8 that sometimes character traits have been listed and not competencies such as modesty, and decisiveness. These traits, although undoubtedly important for anyone to have a successful career, are not competencies and have therefore not been considered. Other competencies mentioned are imbedded in the competencies listed in the original list. An example is that part of oral presenting skills should be the ability to present a paper, similarly negotiating skills are part of management skills and abstraction skills lie closely to analytical skills. All depends on the exact definition one uses.

	Additional suggested competencies	Specialist	Manager
A.	Vision	5	5
B.	Intuition	5	5
C.	Ability to initiate	5	5
D.	Creativity/inventiveness	4	5
E.	Problem stating ability	4	5
F.	Multi-disciplinary thinking	3	4
G.	Process based thinking	4	5
H.	Ability to specify	5	3
I.	Ability to negotiate	3	5
J.	Ability to present a paper	5	3
K.	Cost awareness	5	5
L.	Decisiveness	3	5
M.	Knowledge of different cultures	3	4
N.	Entrepreneurship	5	5
O.	Pioneering/trend setting	5	3
P.	Trend following	2	5
Q.	Ability of Abstraction	5	5
R.	Didactic Abilities	3	4
S.	Ability to gather and filter information	5	5

Table 3.8 Additional competencies suggested only once by the expert panel and their importance to engineering managers and engineering specialists (1 = totally unimportant – 5 very important)

The expert panel was also given the opportunity to add their own views and comments to the questionnaire. A total of nine persons did so. Based on the comments given in the questionnaires it was decided to add two more competencies to the original list:

The ability of life-long learning

The ability for life-long learning was not included in the initial list. The employers in literature mentioned the ability as desirable by the likes of Snover (1997), Koen and Kohli (1998), Volkwein and Bian, (1999) and McMasters (1996, 2002, 2003), but Landis in 1971 showed in his research that most working engineers are not interested in life-long learning and did not considered it important. Hence it was left out initially. It will be interesting to see if attitudes of graduates have changed since the 60s. It could be argued that this is not a competency that can be taught. However, most of the current way primary and secondary school students are taught in the Netherlands is based on the principle that students should not just have knowledge but more importantly should also be able to independently acquire new knowledge when they need it. In other words they are being taught the ability to learn. It can therefore definitely be considered a competency.

The ability to work in teams

This ability was not mentioned in the earlier articles from the 60s and 70s but was found to be important by the employers (Koen and Kohli, 1998, McMasters, 1996, 2002, and 2003, and Ackermans en Trum, 1988) particularly in the last decade. Only one alumni survey from the last decade mentioned the ability to work in teams (Volkwein and Bian, 1999). It is probably a sign of changing times where company structures have changed from a highly hierarchical with clear 'command and control'-structure to one in which multi-disciplinary teams are operating under a team leader. The importance of this ability was probably not recognised at that time.

Furthermore, it was suggested by three members of the expert panel that the term managerial skills was too vague and should really be elaborated upon. Summarising it was concluded that the solution was to divide managerial skills into 2 parts:

- People management skills (coaching, performing of performance reviews, negotiating)
- Operational management skills (decision making, financial responsibilities)

Although some respondents suggested to use the term organisational skills, this term would not quite reflect the business (financial responsibility, decision making) side of the intended competencies so its name has been changed to operational skills. Another suggestion was to keep negotiating as a separate skill but as negotiating is really about persuading someone it was considered part of people management skills.

Several respondents commented that there was a middle group between the manager and the specialist the multifunctional engineer, or the systems engineer. For the purpose of this study such an engineer would be classified as a specialist with as its specialism: multi-disciplinarity or systems design. Finally, it was rightly pointed out that the different competencies manifest themselves differently. This different manifestation will be taken into account in the next part of this research.

3.4.4 Concluding Remarks

The competencies found in literature were validated by the expert panel. Based on the suggestions of the panel changes were made which results in a new list of a total of twelve competencies, which are expected to be indicative of a successful engineer:

Competencies	
C.1.	Ability to synthesise
C.2.	Analytical skills
C.3.	Problem solving skills
C.4.	People management skills
C.5.	Operational management skills
C.6.	Written communication skills
C.7.	Oral communication skills
C.8.	Net worker
C.9.	Have broad technical knowledge
C.10.	Have specialist technical knowledge
C.11.	Ability for life-long learning
C.12.	Ability to work in teams

Table 3.9 Final list of competencies indicative of the successful engineer

This list has been used in the next phase of the research in which alumni from the faculty of aerospace engineering were approached. In this research the relation between these competencies will be determined empirically. No assumptions have been made as to the relationship between the different competencies themselves. The next chapter will explain the design of the alumni study carried out.

'Though this be madness, yet there is method in it.'

William Shakespeare (1546-1616)
from Hamlet, act 2, scene 2

CHAPTER 4: DESIGN AND METHODOLOGY OF THE ALUMNI SURVEY

In Chapter 3 the main research questions were formulated and a set of expected competencies for engineers to have in order to be successful was found and validated. In this chapter the choice of research method is explained as well as the design of the survey. The definition of success is made operational, so that this can be taken into account in the survey design. It also describes the procedure followed during the execution of the survey and the response rate. The last part of the chapter reports on the data analysis, the research methods used, the reliability of the measurement instruments used, and the validity of the data.

4.1 Purpose of the Survey

The alumni survey has the following purposes:

1. To obtain an accurate description of the current alumni population of the Faculty of Aerospace Engineering at TU Delft,
2. To determine how successful the Delft Aerospace Engineering alumnus is professionally,
3. To determine if the overall level of ability in the total set of competencies can be linked to professional success,
4. To determine if there are specific individual competencies contributing to professional success,
5. To determine if different competencies are important to the success of the engineering manager versus the success of the engineering specialist, and
6. To formulate specific recommendations with regards to the competencies needed to be successful, and the aerospace engineering curriculum at TU Delft.

Note: The success models developed in the previous chapter deliberately do not look at the reasons why an engineer is not classed as successful by these models, as these models do not distinguish between career failure and voluntary career changes. It is emphasized here that only occupational success is studied here. Happiness, personal satisfaction, etcetera are not part of the definition of success used in this thesis.

4.2 Method

To obtain all necessary information the instrument of a survey was chosen as that uniquely allows a researcher to obtain large amount of data from a relatively large group of people within a reasonable time period and without great expense (see Baarda et al., 2000 and Salant & Dillman, 1994). A conscious choice was made not to use a web-based questionnaire as the software and server space to design and run such a questionnaire were not readily available and would take too much time to develop. A second argument was the limited availability of email addresses of the sample as well as the lack of guarantee of server stability when the server gets confronted with large number of simultaneous database accesses which might negatively impact the response.

Based on records held at the Faculty of Aerospace Engineering a total of 3282 students have graduated with an MSc in Aerospace Engineering since its first graduate in 1943. For the purpose of this survey only alumni still likely to be part of the active workplace are of interest. Therefore only graduates from 1975 and later were included in the population of this research. Also it is assumed that graduates will take a while to settle in a certain career path so it was decided to limit the sample to those with a likely work experience of 5 years and more. This restricted the population to graduates who graduated in 2000 and before. This reduced the population of this research to 2148 graduates (TU Delft 2002).

As the university has not kept track of all of it graduates, this research is limited to all graduates who are registered with the alumni office. The Delft University Alumni Office (www.alumni.tudelft.nl) maintains an active database of all alumni who have indicated that they would like to stay in touch with the university. Almost 41 000 alumni out of the 60 000 plus graduates Delft University of Technology has had since 1905 are registered in this database and the office receives more than 150 mutations per day.

Of the research population of 2148 graduates who graduated between 1975 and 2005 the Delft University Alumni Office had records for 1769. Some 80 records of alumni whose graduation date was unknown were also included. Therefore a non-probability sample was taken consisting of 1849 graduates. Using non-probability samples for this type of survey is a frequently used strategy for research like this (Fink, 1995), as it is not practical to try and find the graduates who have not registered with the alumni office.

4.3 Survey Design

4.3.1 Variable definitions

As discussed in Chapter 3, Knus and Jones (1975) suggest six factors which are related to an engineer's success: years with present company, present job satisfaction, salary increases and promotions, income with respect to age, income with respect to job responsibility, income with respect to job responsibility and age. They use these 6 factors as their dependent variables in their research.

The problem with using the same factors in this study would be that in the current job market people tend to change employer and/or department much more regularly. There is no longer a clear hierarchical structure in companies in which you are promoted upwards in an organisation. Job rotation or cross-company promotions as well as job-hopping from one company to the other are very common making the factor 'years with the present company' an unsuitable factor. One might even argue that staying with the same company can even be a sign of no success in some cases. Because of the regular changes in employment and the lack of a clear job description system in the Netherlands, it is impossible to accurately describe a promotion. If this is combined with the complex system of wages (which are regulated by Collective Labour Agreements and are not necessarily based on performance in the Netherlands) the factor number of salary increases and promotions becomes unsuitable. A third problem occurs with using age. The Dutch university system allows students to take, in principle, indefinitely to complete their degrees. In practice many students do not complete their degree in the officially allotted time (TU Delft, 2002). If age was to be taken as a criterion it would not provide a representative measure of work experience.

Looking again at the six factors for professional success listed by Knus and Jones (1975) the first three factors: years with present company, present job satisfaction, and salary increases and promotions are not feasible for use in this survey and were excluded as explained in the previous paragraph. The factor job responsibility will be used and explained in more detail in the next section. Finally, the factors income with age and income with age and job responsibilities were amended by replacing age with years work experience which leads to the following three factors to be used as dependent variables for the purpose of this thesis:

- Job responsibility
- Salary with respect to work experience
- Salary with respect to work experience and job responsibilities

By using job responsibility as an indicator of success it means that the respondents must be working. Therefore any retired, unemployed or otherwise non-working respondents will have to be excluded from the analysis of the professional success of alumni.

Job responsibility

Knus and Jones (1975) use the 'Occupational Definitions' of the National Survey of Professional, Administrative, Technical and Clerical Pay. The occupational definitions consist of two scales of five levels of supervisory and technical responsibility. Added together they form a 10-point scale. For the purpose of this research the same definitions will be used in this survey to define a person's level of job responsibility. The supervisory and technical responsibilities scales are listed in Appendix C. Success will be determined by the score of a graduate on the scale as defined in table 4.1.

Level of success	Responsibility score
Below average	4 or less
Average	5 or 6
Above average	7 or more

Table 4.1 Success definition for job responsibility

Salary with work experience

As the survey considers alumni who graduated between 5 and 25 years ago a distinction must be made in their salary according to work experience. Using salary alone would give a too distorted image. Few salary surveys have been carried out amongst aerospace engineers, mostly with a poor response. In terms of finding salary information on Dutch aerospace engineers little data on the average salary in 2005 could be found as the data was either outdated (KIVI –

Zijdenbos, 2001) or unsuitable for use in this research. This included the internet based salary indicators on employment advertisement sites such as Monsterboard or Intermediair. They compare someone's personal situation with other people in that situation. The level of detail used in those indicators is too specific for this research. Other data found on this topic was data from a management consultant agency Breedt & Partners BV who do salary research amongst engineers. They shared their data, listing the average salary of a Delft University of Technology graduate in 2006 to be € 49 320, however this number is based on only 27 respondents. However, in April 2007 a comprehensive salary survey of engineers was published commissioned by amongst others the Royal Institute of Engineers (Smits and Sieben, 2007). Although the research itself reports on the positive financial career prospects of having engineering degree, it also lists the median annual income of engineers in 2006 in 4 categories of work experiences, see also table 4.2 below. This median annual income will be used to divide engineers in above average, below average or average successful. The survey also lists the median salary for aerospace engineers as a whole independent of years of work experience. This median salary is €45 000. Unfortunately, Smits and Sieben did not have sufficient data to calculate the median salary for aerospace engineers taking into account years of work experience. This median is therefore slightly biased towards aerospace graduates with 5 years or less work experience. Although all the data is based on 2006 this data will be used as a benchmark for lack of more accurate data.

Years of work experience	Median Salary
5 years or less	€ 34.300
6 – 10 years	€ 45.900
11 – 20 years	€ 60.000
More than 20 years	€ 75.200

Table 4.2 Median annual salary in 2006 of engineers (Smits and Sieben, 2007)

As explained previously, age is therefore not a good variable, however, years of work experience is. Using the data in table 4.2, table 4.3 was developed which shows the success definition in terms of salary and work experience used in this survey.

Work experience	Below average successful	Average successful	Above average successful
< 6 years	< € 30 000	€ 30 000 - € 45 000	> € 45 000
6 – 10 years	< € 45 000	€ 45 000 - € 60 000	> € 60 000
11 – 20 years	< € 60 000	€ 60 000 - € 75 000	> € 75 000
> 20 years	< € 75 000	€ 75 000 - € 90 000	> € 90 000

Table 4.3 Success definition in terms of salary with work experience

Salary with work experience and job responsibility

The final success definition developed combined the two success definitions above. This success definition is defined by combining the job responsibility success definition with the salary with work experience success definition as shown below. This combination will give result in 3 groups of twelve combined scores, each of which indicate whether a graduate is below average successful, average successful or above average successful. In table 4.4 it is explained how this success definition is derived for each salary stratum.

	Below average responsibility score	Average responsibility score	Above average responsibility score
Below average salary for work experience	-	-	±
Average salary for work experience	-	±	+
Above average salary for work experience	±	+	+

Table 4.4 Success definition in terms of salary with years of work experience and job responsibility (- below average successful, ± average successful, + above average successful)

The independent variables in this research will be the competency related scales based on the list of competencies derived in Chapter 3. The following scales will be used:

Scale	Likert scale
1. How important do alumni perceive this set of competencies for their current job?	1-5
2. How competent do alumni perceive themselves in this set of competencies?	1-4
3. How much did alumni perceive that aerospace engineering contributed to these competencies?	1-4
4. How important do alumni perceive this set of competencies is to an engineering specialist?	1-5
5. How important do alumni perceive this set of competencies is to an engineering manager?	1-5

Table 4.5 Defined competency scales

4.3.2 Survey structuring

Following the suggestions made by Baarda et al. (2000) the survey was structured in different categories which were each introduced by a short introduction. The categories themselves were then put in a logical order and in increasing level of difficulty as advised by Baarda et al. (2000) and Christiaans et. al. (2004).

To achieve the first objective of the survey, the first part of the questionnaire contained questions with the aim to obtain the data needed for analysis such as age, gender etcetera. Also some general information about their time spent studying aerospace engineering in Delft was asked. In order to obtain their study length the year they started in aerospace engineering and their year of graduation were asked. The graduates were also asked which research group they graduated from. The research group was left as an open question as these groups tended to change names very frequently over the years (See also Faculteit der Luchtvaart- en Ruimtevaartttechniek, 1990). Also to look at where the alumni had ended up they were asked to list the name of their employer, their current job title and the sector they are working in and whether or not an (aerospace) engineering degree is required for their current job.

The second category included the requests for information which are required for our independent variables: information about their financial situation such as gross salary, their contract hours, whether or not they had a company car etcetera were asked. Salary was measured in and ordinal scale using strata of 15 000 Euros each, starting at less than 30 000 and ending at more than 120 000 Euros. The reason for asking salary in strata it is the personal experience of the author that few people can accurately indicate how much money they earn on a yearly basis and even fewer people are willing to disclose it. Making use of strata leads to a higher response. Also the respondents were asked to list their supervisory and technical responsibilities. These are each 5-point scales. Their overall level of responsibility can then be calculated by adding both scores together. The other variable belonging to this section is what type of engineer they are: an engineering manager, an engineering specialist or undecided. This category questions should yield the following dependent variables:

- Salary (in strata)
- Years of work experience
- Level of job responsibility
- Type of engineer: engineering specialist, engineering manager or undecided

In the third category the questions pertaining to the independent variables where asked, see also table 4.2. Scale 1 and 4 and 5 were designed using a 5-point Likert scale and questions 2 and 3 on a 4-point Likert scale. The reasoning behind the latter was to avoid a central tendency bias. The total score for each of those questions is calculated by adding the score for each competency together.

The fourth category included questions towards the alternative competency scale. These questions asked graduates to indicate their activities in their day-to-day work. This was done in case scale 2 in table 4.5 proved unreliable. People often portray themselves as better than they really are and also they may have different definitions of the competency. In order to tackle this problem an alternative scale of their competence based on the activities they undertake in their day-to-day work as well as their achievements was developed.

In table C.1 in Appendix C activities and achievements for each competency and the reasoning behind it are proposed. It is expected that a successful engineer, be it a specialist or a manager, must encounter these types of activities and achievements if they are skilled in these competencies as is argued below. Questions pertaining to the stated activities and achievements above were included in the questionnaire.

Finally, in the fifth category questions were asked about the alumni's educational experience at aerospace engineering and general questions such as whether they would choose the same degree all over again and whether or not they would recommend the current degree in aerospace engineering to anyone else. In this section the respondents were also able to write any comments or questions they might have.

4.4 Procedure

The fielding of the survey was set up according to generally accepted standards as stated by Salant and Dillman (1994). The procedure was designed with the purpose in mind of pleasing the participant and therefore increasing the response. This section explains the steps taken.

4.4.1 Organisation

An accompanying letter was sent out with the survey. In the letter the purpose of the survey was explained as well as the structure of the survey. Instructions on how to return the survey and a contact for more information were also included in the letter. Finally, as an appetizer, the letter offered five rewards of 150 Euros each to be won by anyone returning a complete survey. The letter was signed by the Dean of the Faculty of Aerospace Engineering, the director of the alumni office and the author.

The survey was styled according to the corporate standards of the university and had a clear lay-out. A picture of the faculty building was added to the front of the personalised questionnaire as advised by amongst others Salant and Dillman (1994) and Hilkhuysen (1999) as means to enhance response. A prepaid envelope was included to further enhance the response rate.

Also upon advice from amongst others Baarda et al. (2000), Hilkhuysen (1999), and Salant and Dillman (1994), a reminder card system was put in place which was to be sent out one month after the initial survey went out to all who had not responded. Again the reminder card was styled according to the cooperate standards of the university and a picture of the faculty building was put on the front.

4.4.2 Test panel

The questionnaire was piloted by a test panel of 7 aerospace engineers both working in and outside of the university as recommended by Field and Hole (2003), Baarda et al. (2000), and Hilkhuysen (1999).

The feedback received was that particularly the questions about the details of the PhD students did not guarantee anonymity and that that would put them off in taking part. As this research primarily focus on the MSc degree in aerospace engineering it was decided to limit questioning on PhD's to whether the respondent obtained a PhD and where the PhD was obtained. For the same reason of lack of anonymity the question regarding the name of the professor supervising the MSc was omitted.

The survey given to the test panel was one large document in which a lot of personal information such as age and salary were asked. Feedback from the panel was that they did not feel anonymity was guaranteed. Based on this feedback and after exploring the existing possibilities in the alumni database, it was decided to split the questionnaire in two.

All other comments from the panel were positive. They felt the survey was clear, well formatted and understandable.

4.4.3 Alumni database limitations

A few other changes were made after taking into account the data held on file at the alumni office. It was decided to switch from age to date of birth and to use the alumni's office's division of sectors in which the alumni are working as that information was already available on file. Also upon the request of the alumni office the questionnaire was split into 2 parts allowing part 1 to be customised for each alumnus and part 2 to be completely anonymous. Part 1 could then also serve as an opportunity for the alumni office to verify if all data they held was still correct.

4.4.4 Final Survey put out in the field

The final survey consisted of two parts. A list of the questions in English can be found in Appendix D, the questionnaire itself was sent out in Dutch. Part I contained non-anonymous data as already held by the alumni office for correction, requests for more information on academic records, such as MSc research group and start year, and requests for further cooperation. It was filed for future uses such as contacting those interested in talking part in future research and the awarding of the rewards. Part II was anonymous and only used for statistical analysis. Part I and II were only linked through a unique registration number, no identifying data was stored in the computer files for statistical analysis.

A total of 1849 questionnaires were sent out on 4 May 2005. A non-anonymous reminder card was sent out on 1 June 2005 to all participants who had not yet returned their questionnaires. The questionnaire was also posted on the website of the Faculty of Aerospace Engineering to facilitate people who misplaced their copy.

4.4.5 Response

A total number of 482 responses were received before the reminder card was sent out on 1 June 2005 and 19 questionnaires were returned as undeliverable as the address on the database was no longer valid. This half time response rate was 26%.

By 1 September 2005 a total of 733 responses (of which 54 partial) were received and a total of 36 questionnaires were returned as undeliverable. This brings the total response rate of the questionnaire to 40%.

This rate compares favourably to response rates from similar questionnaires amongst engineering alumni in the United States (Collins and Strange, Hoey and Gardner, Kelley, McGuire and Casey, Nash and Murphy, Mulgetta, Snover, Volkwein and Bian, 1999). Those questionnaires have response rates averaging between 25% - 40% depending on the topic of the questionnaire. In the Netherlands this response seems reasonable, for example an alumni study, set up among a similar response group, carried out in 1994 among law graduates of the Free University of Amsterdam had a response rate of 40% (van Rijn en Poortinga, 1994).

Questionnaires were sent out all over the world. There is a risk that the response amongst alumni living abroad is considerably lower as they have to make more effort in terms of returning the questionnaire. For instance the postage free envelope was of no use to alumni living abroad. An analysis of the sample learned that of the sample of 1849 alumni, 212 lived abroad. The response rate of the questionnaires sent abroad was 41%, the response rate of the questionnaires sent within the Netherlands was 38%. This means that the response rate of alumni living abroad was even slightly higher but not so much higher that it affects the validity of the questionnaire.

4.4.6 Data preparations

A total of 733 questionnaires were returned. Every questionnaire was given a unique identification number, coded according to the codebook, assigned a variable name and entered into an SPSS data file. The data was then checked for any errors which were corrected by checking them against the original questionnaire. Among the respondents there were alumni who did not meet the requirements of the population as they graduated outside the 1975 – 2000 period.

Those records were deleted. Also records of International MSc students who only attended the last 2 years of the MSc degree were deleted (1 record). As this research is limited to current professional success also any records of people not working (be it retired, unemployed, unable to work or voluntarily not working – a total of 8 records) were deleted in the analysis of the competencies and their link to success.

A total of 54 questionnaires were only partially returned, meaning that either part I or part II of the questionnaire was missing. Although these questionnaires cannot be used for all types of analyses they were included in the data file. Overall a total of 716 usable records were left.

A further operation was carried out on the names of companies employing the alumni. Often departments or division names were added to the company's name blurring the overview. They were standardised by using just the company's name. Next, certain operations were carried out to create new necessary variables. Age and study length were calculated using the original data such as date of birth and starting year of the degree and year of graduation. The answers to the question of which research group they graduated from was coded into 8 different groups. These groups represent the research groups as they were present at the faculty through the eighties and early nineties (See also Faculteit der Luchtvaart- en Ruimtevaarttechniek, 1990). The question in which alumni were asked to name three subjects from which they still benefited was coded into a total of 16 different subject areas and courses as names of subjects have frequently changed over the years. The questions asking about the reasons why they would or would not choose aerospace engineering as a degree programme again as well as the question asking why they would or would not recommend aerospace engineering to someone else as a degree programme now were analysed and categorised. If a reason appeared often enough to be 1% or more of the total response to this question, a separate category was formed. Also any negative worded items such as from question 16 (see Appendix D for the questionnaire) were reversed such that the reliability of the survey as a measurement instrument can be calculated and such that total scores of certain scales can be added up (Pallant, 2005 and Field, 2005). Finally, the overall competency scales and the division into levels of success as per the definitions earlier in this chapter were calculated. This file was then used for all further analyses.

4.5 Reliability

In this section the reliability of the survey as a tool of measurement is investigated. Of particular interest is the reliability of the set of competencies as a measurement scale. The set of competencies was designed based on a literature survey and the opinions of the expert panel, but it is important to also check empirically that the scale consistently reflects the construct it is intended to measure. The most common measure of scale reliability is Cronbach's coefficient α (Field, 2005) which focuses on the internal consistency of the scale.

Cronbach's coefficient α as used in SPSS is also known as standardised Cronbach's α is defined as:

$$\alpha = \frac{N \cdot \overline{c}}{\left(\overline{v} + \left(N-1\right) \cdot \overline{c}\right)} \qquad (4.1)$$

In equation (4.1) N is the number of items in the scale, $\overline{c}$ is the average between all covariances between the components and $\overline{v}$ equals the average variance. Cronbach's α equals 1 if all covariances of the items are all equal indicating one underlying factor unifies all items in the scale. A value lower than one indicates a less than perfect internal consistency. If that is the case Cronbach's α indicates a lower bound on reliability. The accepted rule of the thumb is that if Cronbach's α is lower than α = 0.7 the scale does not reliably measure the underlying construct (Field, 2005, Pallant 2005). The value of Cronbach's α reflects the correlation among the items. To raise the value of Cronbach's α of a scale, items that correlate very low or negative with other items can be deleted, as such items negatively affect the internal consistency of the scale.

4.5.1 Preparation of data-file

Before Cronbach's α for the scales identified in table 4.6 could be calculated, the data file needed to be made suitable for this analysis. That meant reversing the scores for negatively worded items and deleting the data from the questionnaires of which only part I was returned as they would make the calculation impossible as this would result in a matrix with rows of zeros.

4.5.2 Scales

In total the following scales can be identified (see table 4.6) in the questionnaire. For each of those scales Cronbach's coefficient α was calculated. Looking at the results in table 4.6 it can be seen that for the first scale: 'how important do alumni perceive this set of competencies is for their current job' its Cronbach's α is below 0.7. This means that the scale does not reliably measure an underlying construct. Inspection of the SPSS calculation revealed that the low Cronbach's α is mainly caused by the scale item: 'Specialist Technical Knowledge'. Excluding this item the calculation was run again. The new scale consisting of only 11 items resulted in a Cronbach's α of 0.71 as can be seen from the second column. This new scale consisting of 11 of the 12 original competencies, excluding 'Specialist Technical Knowledge' can be accepted as sufficiently internally consistent by the generally agreed standards.

Scale	Cronbach's α for all competencies	Cronbach's α for all competencies minus specialist knowledge
1. How important do alumni perceive this set of competencies for their current job?	0.65	0.71
2. How competent do alumni perceive themselves in this set of competencies?	0.61	0.65
3. How much did alumni perceive that aerospace engineering contributed to these competencies?	0.72	0.71
4. How important do alumni perceive this set of competencies is to an engineering specialist?	0.71	0.72
5. How important do alumni perceive this set of competencies is to an engineering manager?	0.72	0.70

Table 4.6 Cronbach's coefficient α for the initial scales in the questionnaire

The same procedure was carried out for the second scale: 'How competent do alumni perceive themselves in this set of competencies?'. The results of this scale also show that Cronbach's α is lower than 0.7. Inspection of the SPSS calculations shows that Cronbach's α improves somewhat by deleting the item 'specialist technical knowledge'. However, the SPSS calculations showed that Cronbach's α does not increase by further deleting competencies from the scale. According to the above mentioned criteria his scale is therefore deemed insufficiently internally consistent to be regarded as a uni-dimensional scale. However, the discrepancy is not large. Values of α suggest there is at least substantial cohesion within this scale.
The remaining three scales were also tested for their internal consistency and the results for those three scales as listed in table 4.6 show a Cronbach's α above 0.7.

As can be seen from table 4.6 for only one of the scales: 'How important do alumni perceive that this set of competencies is to an engineering specialist?', Cronbach's α increases if 'specialist technical knowledge' is deleted as a scale item. For the other two scales Cronbach's α decreases if specialist technical knowledge is omitted from the analysis.

Overall it can be concluded that with the exception of the scale: 'How competent do alumni perceive themselves in this set of competencies?', the scales in table 4.6 are very reliable. The scale 'How competent do alumni perceive themselves in this set of competencies?' does not meet the generally accepted requirements and is therefore less reliable but will still be of use.

An alternative scale to the measuring of the perception of an alumni's ability in the competencies was composed consisting of descriptions of activities in the workplace. The descriptions and arguments behind each of the items in the scale are reported in Appendix C. The Cronbach's α for this scale was also calculated and equalled 0.852. This value of Cronbach's α indicates that the scale is highly consistent. However, this alternative scale cannot provide a measure for the networking competency as the questions relating to that particular competency (such as: 'are you a member of a professional or social network or professional body – yes or no') are not Likert scale type questions and hence they cannot be combined. The same problem was encountered with the question whether the alumnus holds any patents, which was part of the activity question set for the competency specialist technical knowledge. However, there are more than enough other criteria asking about specialist technical knowledge to overcome any potential problems for this competency.

4.6 Validity

In this section the sample as a whole will be described. This description of the sample serves to provide evidence that the sample is representative of the alumni population of Aerospace Engineering alumni who graduated between 1975 and 2000. Of the alumni responding the male/female distribution can be seen in table 4.7. The first female student at aerospace engineering started in the early sixties and the universities alumni monitor 2002 (TU Delft, 2002) reported that between 1975 and 2000 a total of 95 female graduates, with just two female graduates between 1975 and 1989. The overall number of graduates in the 1975 – 2000 period was 2148 which means that female graduates accounted for only 4% of the total number of graduates. Although the number of females responding to the questionnaire may seem low (3%) it is in line with expectations based on statistical data from TU Delft.

	Frequency	Percent
Male	686	97.2
Female	20	2.8
Total	706	100

Table 4.7 Sex of respondents (N=706)

In addition a check was carried out to see whether the response was representative over the years of graduation. To do this the number of graduates per year based on the numbers held at TU Delft (2002) were compared with the response. Table 4.8 lists the actual number of graduates per year and the proportion of the response per graduation year of the survey. It can be observed from the table that only the years 1980 and 1991 seem underrepresented in the response with 1979, 1995 and 1997 overrepresented. As this seems to be the only numbers out of the ordinary, and overall 33% of the total alumni population between 1975 and 2000 the response was deemed representative.

In selecting the sample it was decided to look at engineers who graduated between 1975 and 2000. It was assumed that alumni were in their mid twenties when they graduated. It is therefore reasonable to expect that most of them were between the ages of 30 – 55 in the summer of 2005 when the survey was carried out. A more accurate age prediction is impossible due to liberal way the Dutch higher education system is organised. Students can more or less take as long as they wanted in completing their degree. Also students can start at any age provided they meet the university entry conditions. At the time only two obstacles in study length were limitations in funding by the government after a certain number of years, meaning no more student grants and higher tuition fees and, for the male population until 1996, military service but many still returned to complete their degree after they completed their military service. However, in 1996 conscription was abandoned in the Netherlands. The time a student takes to complete a university degree in the Netherlands is at time of writing still uncapped. From table 4.9 it can be seen that the age of our alumni population is well between the expected brackets with a few outliers on either side. The average age was 40.28 years and the median 39 years.

Graduation year	No. of graduates	Response	Percentage
1975	37	11	29.7%
1976	35	12	34.3%
1977	43	14	32.6%
1978	44	16	36.4%
1979	25	14	56.0%
1980	47	8	17.0%
1981	37	14	37.8%
1982	51	18	35.3%
1983	46	21	45.7%
1984	37	16	43.2%
1985	65	16	24.6%
1986	89	23	25.8%
1987	141	37	26.2%
1988	92	43	46.7%
1989	71	24	33.8%
1990	95	33	34.7%
1991	130	27	20.8%
1992	114	45	39.5%
1993	116	33	28.4%
1994	141	29	20.6%
1995	108	53	49.1%
1996	145	38	26.2%
1997	115	59	51.3%
1998	106	33	31.1%
1999	111	40	36.0%
2000	107	28	26.2%
Total	2148	705*	33%

Table 4.8 Proportion of response per graduation year

** Not all respondents have indicated their graduation year*

Age	Frequency	Percent
<= 30	16	5.5
31-35	72	24.7
36-40	85	29.1
41-45	47	16.1
46-50	35	12.0
51-55	26	8.9
56-60	11	3.8
Total	292	100.0

Table 4.9 Age of respondents (N = 292)

Also the survey aimed to target alumni who had between 5 – 25 years of work experience. Table 4.10 shows that by targeting the graduates between 1975 and 2000, some 85% of our respondents fall into that bracket.

Years of work experience	Percent
5 years or less	7.0
6 - 10 years	34.7
11 – 20 years	38.5
20 – 25 years	11.7
More than 25 years	8.1
Total	100.0

Table 4.10 Years of work experience (N=681)

Finally, a check was carried out to see if all the research groups in which the alumni carried out their MSc thesis were represented. These results were grouped based on the research groups as they were present at the faculty through the eighties and early nineties (See also Faculteit der Luchtvaart- en Ruimtevaartttechniek, 1990). It must be noted here that the research group set-up named here reflects the set-up in the 1975 – 1997 period. In 1997 several of the groups below were split in two or have since ceased to exist, see also Chapter 2. The distribution of the alumni over the different research groups and therefore the distribution of the MSc. specialisations within the faculty are shown in table 4.11.

Research Groups	Percent
Aerodynamics	8.4
Aircraft Performance & Design	19.5
Control & Simulation	19
Materials & Production Technology	20.4
Aerospace Structures	12
Space	9.9
Industrial Organisation	6.7
Aircraft Operations & Management	4.1
Total	100

Table 4.11 Distribution of the alumni over research groups (N=706)

From table 4.11 it can be seen that all groups were well represented. The Industrial Organisation and the Aircraft Operations and Management groups may seem under represented but that is in-line with expectations as they were both small research groups within aerospace engineering in terms of number of graduate students. Also the aircraft operations and management group known as 'Luchtvaarttechnische Bedrijfskunde' was not started until 1987.

Based on the arguments above it is reasonable to say that the sample is representative for the population and a non response analysis is not needed.

'Facts are stubborn things, but statistics are more pliable.'

Mark Twain
(1835 – 1910)

CHAPTER 5: RESULTS OF THE ALUMNI SURVEY

This chapter contains the results of the survey of which the set up was described in Chapter 4. In this chapter first a description of the characteristics of the population of aerospace alumni of Delft University of Technology is given. The second part of the chapter describes the current job responsibilities of the alumni. The third part covers the alumni's experience of their education at the Faculty of Aerospace Engineering, whilst the fourth part deals with continuing education enjoyed by the alumni. The following parts of the chapter explore the results of the importance of the competencies developed in Chapter 3, the professional success of alumni and the explored relationship between those competencies and job success. Finally, the chapter concludes with reporting on the contribution of aerospace engineering to the competencies defined in Chapter 3 and professional success.

All statistical analyses were carried out using SPSS12 and SPSS13 from SPSS Inc, which is the most commonly used statistical calculation software package in social sciences. Advice on which statistical test to use has been drawn from Cohen, Manion and Morrison (2007), Field (2005), and Pallant (2005).

5.1 Details on the Employment of Alumni

Market research carried out under alumni who recently have graduated in aerospace engineering (Dessan Research Solutions, 2004) shows that fewer than 3% of recently graduated aerospace engineers from Delft University of Technology were still unemployed 3 months after graduation. In the analysis carried out for this thesis, only aerospace alumni who completed the 4- or 5-year course with between 5 and 25 years of work experience or more were taken into account. In this section, which describes the alumni population, all received responses falling in that category regardless whether they are working have been analysed. The employment figures for this group of graduates are even better as can been seen from table 5.1:

	Percent
Employed	98.8
Voluntarily unemployed or retired	0.6
Looking for work	0.3
Unable to work	0.3
Total	100

Table 5.1 Employment figures for Aerospace graduates (N = 678)

Of all the respondents 8 indicated that for different reasons they were currently not working which makes up only 1.2% of the respondents. The majority of the graduates work for relatively large companies as can be seen from table 5.2.

Size of employer	Percent
Less than 100 people	21.7
100 - 1000 people	25.4
More than 1000 people	52.9
Total	100

Table 5.2 Size of employer (N= 677)

Of the respondents some 40% still work within aerospace as can be seen from table 5.3. This is 19% less than in 1985 when 59% of alumni worked in aerospace (VSV Leonardo da Vinci, 1985). This can probably be contributed to the bankruptcy of NV Nederlandse Vliegtuigenfabrieken Fokker in 1996.

	Percent
Yes	40.4
No	59.6
Total	100

Table 5.3 Working in Aerospace (N= 676)

Most graduates remained in the engineering sector as can be seen from figure 5.1 which shows the distribution over the different sectors. Some 11% work in the transport and logistics sector which is also not surprising given the fact that KLM is part of the top 10 employers of aerospace alumni (see table 5.4) with the top employer being Stork N.V. However, some of the other sectors could also be considered part of the engineering sector such as consultancy.

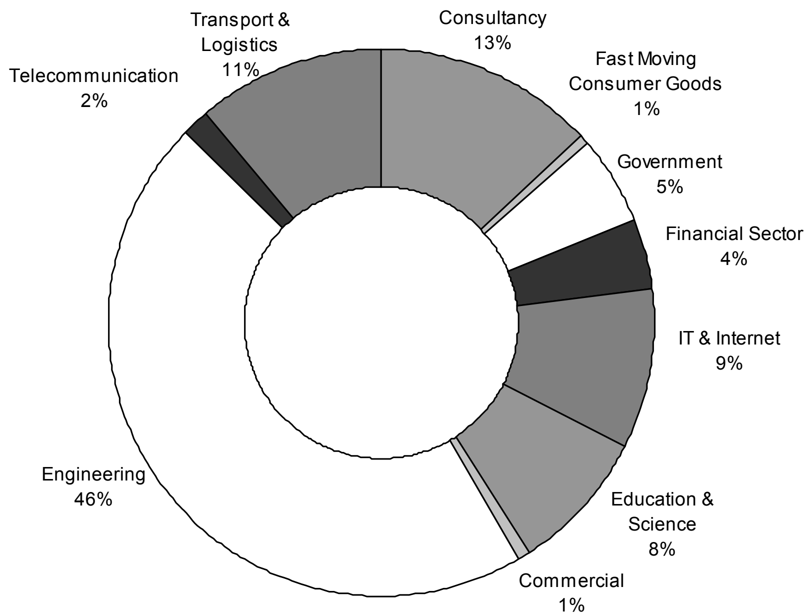

Figure 5.1 Area of employment (N=698)

The fact that Stork N.V. takes first place on the list is not very surprising. Stork N.V. bought up the profitable parts of the N.V. Nederlandse Vliegtuigenfabriek Fokker in 1996 and is the key aerospace engineering manufacturer in the Netherlands still. Other popular areas of employment are the (engineering) research institutes in the Netherlands: Delft University of Technology, TNO and the Dutch National Aerospace Laboratory (NLR). The only non-Dutch company in the list is Airbus. They have over the past 10 years aggressively recruited Dutch engineers, taking on ex-Fokker personnel as well as new staff. The involvement of Stork and Delft University of Technology in the development of new materials in the Airbus A380 project may also have caused an increased popularity of Delft engineers at Airbus. It can also be seen from table 5.4 that a considerable number of alumni have their own enterprise.

Employer	2007 (%)	1980 (%)
1. Stork*	6.9	18.1
2. KLM	4.8	2.7
3. Delft University of Technology	4.5	10.1
4. NLR	4.0	13.8
5. TNO	2.8	1.7
6. Dutch Space/EADS –ST*	2.2	-
7. Airbus	2.0	-
8. Own Enterprise	1.9	-
Shell	1.9	-
10. Ministry of Defence	1.7	1.7
Philips	1.7	2.0

Table 5.4 Top 10 employers (N = 693)
**Stork and Dutch Space are surviving companies from the N.V. Nederlandse Vliegtuigenfabriek Fokker.*

If this is compared to the only available previous large alumni survey among aerospace alumni carried out in 1980 (VSV Leonardo da Vinci, 1980) one can truly see the effect the bankruptcy of N.V. Nederlandse Vliegtuigenfabriek Fokker in 1996 had on where aerospace graduates work. Its influence on other employers such as the Dutch Aerospace Laboratory NLR and the ‘Rijksluchtvaartdienst’ (Dutch FAA) can also be observed, see also table 3.1. It appears that aerospace engineering graduates have moved into far more diverse fields. The bankruptcy is not the only reason for the shift, also in the past 15 years the number of aerospace graduates over the years has increased significantly as reported in the university’s yearly statistical report (TU Delft, Staf College van Bestuur, 2002), so market saturation at the employers in the table above have probably also led to graduates diversifying their careers to companies outside this top 10.

Looking at table 5.5 it can be observed that most graduates (87%) have stayed in the Netherlands, only 13% moved abroad. As mentioned in Chapter 4 the response was more or less equal among the alumni living abroad versus alumni living in the Netherlands, making this a valid conclusion.

Of the countries abroad Germany (Airbus) tops the list, followed by Belgium. The position of Belgium can be explained by the fact that there is no degree in Aerospace Engineering available at university level. Delft therefore has a Belgium contingent at aerospace and the number here simply reflects the

Belgium students going home to find employment there. The reason for most alumni to stay in the Netherlands has not been explored in this survey.

	Percent
Netherlands	87.7
Germany	2.1
Belgium	1.8
USA	1.8
United Kingdom	1.3
France	1.0
Elsewhere	4.3
Total	100.0

Table 5.5 Current country of residence (N=706)

Most aerospace engineers earn quite well in terms of salary. The distribution of the respondents over the salary scales from the questionnaire is listed in table 5.6 as well as the distribution of the respondents over salary combined with years of work experience. The mode lies in the category of € 45 000 - € 60 000 and the median in the category of € 60 000 - € 75 000, which compares favourably with the reported average hourly salary of aerospace engineers irrespective of work experience of € 27.67 as reported in Smits and Sieben (2007).

	Overall (%)	< 5 yrs (%)	5 – 10 yrs (%)	10 – 20 yrs (%)	> 20 yrs (%)
Less than € 30 000	3.4	8.5	5.2	1.5	2.3
€ 30 000 - € 45 000	14.2	44.7	23.5	6.1	3.0
€ 45 000 - € 60 000	26.4	34.0	33.0	24.1	16.5
€ 60 000 - € 75 000	21.9	10.6	19.6	24.9	24.1
€ 75 000 - € 90 000	13.1	0.0	7.8	17.6	18.0
€ 90 000 - € 105 000	6.1	0.0	4.8	7.7	7.5
€ 105 000 - € 120 000	3.4	0.0	2.6	3.4	6.0
More than € 120 000	11.5	2.1	3.5	14.6	22.6

Table 5.6: Distribution of gross annual salary in Euros (N = 671)

The distribution of those working shows that the vast majority indicates that an engineering degree is required for their current job as can be seen in table 5.7.

	Engineering degree required? (%)	Aerospace Engineering degree required? (%)
Yes	68.3	22.4
No	31.7	77.6
Total	100.0	100.0

Table 5.7 Type of degrees require for current position (N=678)

The requirement for holding an aerospace engineering degree in their current position is lower, which is not a surprising result given that only 40% still work in the aerospace industry (table 5.2). Further analysis showed that for 50% of those still working in the aerospace industry an aerospace engineering degree is required and an engineering degree was required for more than 62% for those not working in aerospace and more than 76% for those who were.

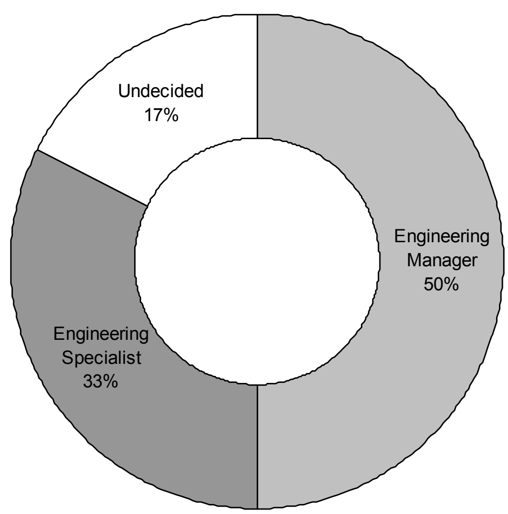

Figure 5.2 What type of engineer are you? (N=677)

5.2 Job Responsibilities of Employed Alumni

All participants in the questionnaire were given the definition of an engineering manager and an engineering specialist, as listed in Chapter 2. They were asked to indicate what type of engineer they thought best describes their professional life. The results are listed in figure 5.2.

From figure 5.2 it can be observed that only about 33% still consider themselves engineering specialists, 50% consider themselves managers, and 17% are undecided. This is an interesting result. Pinelli et al. (1995) claim that aerospace engineers have some form of a hybrid job description: part scientist, part engineer, part manager. However, looking at the results above it can be seen that this only applies for 17 % of our graduates. The hybrid form does exist amongst aerospace engineers according to their own ranking but is not as widespread as Pinelli et al. (1995) would have people believe and is more than 5%. Therefore this group cannot be considered negligible and must be analysed as a separate group.

The relatively low number of engineering specialists within the group of aerospace alumni confirms a worrying trend of a lack in numbers of engineering scientists. Governments and industry in Western Europe and North America alike have recently called in several press releases for more qualified engineering specialists. Also industry is actively looking to recruit engineers from upcoming countries such as India and China. The argument that there are not enough specialists by industry is however somewhat flawed. From table 5.7 it can be seen that only 68 % need an engineering degree for their work. The remaining 32% do not, and are working outside their field. Figure 5.3 may shed some light on the reasons why there are few engineering specialists. In this figure it is clearly visible that being an engineering specialist is not the best paying option and is probably the reason why many engineering graduates move into the more lucrative engineering manager jobs.

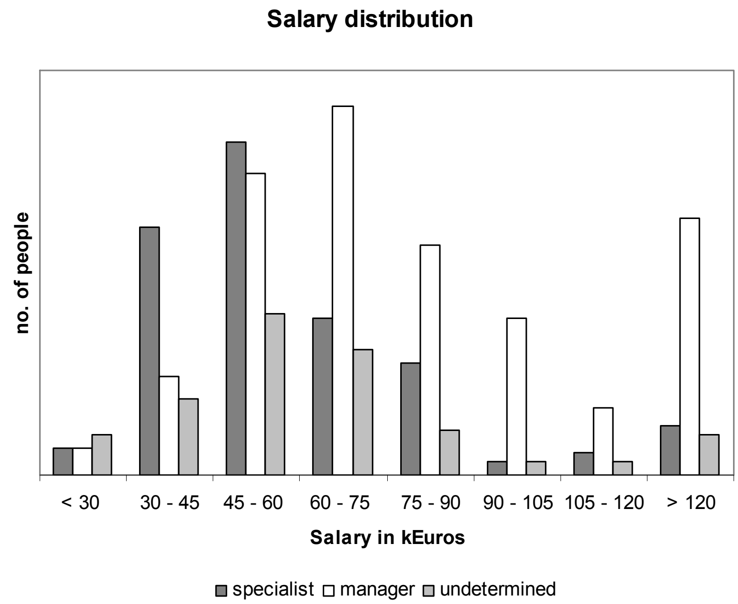

Figure 5.3 Salary divisions between different types of engineers

Using the definitions used by Klus and Jones (1975) the participants were also asked to indicate what their level of supervisory responsibility was and to indicate their level of job independence. The exact definitions are listed in Appendix C. Tables 5.8 and 5.9 show the results.

	Overall (%)	< 5 yrs (%)	5 – 10 yrs (%)	10 – 20 yrs (%)	> 20 yrs (%)
No supervisory responsibility	33.1	41.7	37.6	29.2	29.9
Supervision of technical and/or non-technical personnel EXCEPT engineering and scientific	22.5	27.1	25.2	21.9	16.4
Supervision of engineering and/or scientific personnel	28.8	22.9	27.4	30.0	31.3
Supervision of lower and/or middle management personnel	5.8	8.3	4.7	6.9	4.5
Executive (upper management)	9.9	0	5.1	11.9	17.9

Table 5.8 Level of supervisory responsibilities (N = 677)

	Overall (%)	< 5 yrs (%)	5 – 10 yrs (%)	10 – 20 yrs (%)	> 20 yrs (%)
Perform limited assignments with specific direction under an experienced engineer	0.4	0.0	0.9	0.4	0.0
Perform assignments with limited direction under an experienced engineer	0.7	2.1	1.7	0.0	0.0
Independently performs most work with directions only to general results expected	35.1	47.9	40.8	30.5	29.1
Independent work in extending known engineering techniques, data, etc.	18.2	8.3	19.7	17.6	20.1
ORIGINAL research or engineering development on unknown blocks of data	10.3	8.3	8.2	12.5	10.4
Not applicable	35.3	33.3	28.8	39.1	40.3

Table 5.9 Level of technical responsibility (N = 672)

It can be seen from table 5.8 that some 33% of the respondents have no supervisory responsibility. This is an interesting number since more that 83% indicate that they are an engineering manager or cannot decide if they are a manager or a specialist. As expected, however, the majority of the respondents have some form of supervisory responsibility. When looking at the level of technical responsibility, it can be seen that most engineers work independently, although it can also be seen that a large number of them have no technical responsibilities at all.

5.3 Educational Experience in Aerospace Engineering at TU Delft

The time graduates took to complete their degree is displayed in table 5.10. The mean is 6.92 years and the median is 7. This is in line with numbers reported in publications of the TU Delft (2002 and 2005).

	Percent
Less than 4	3.1
5	10.2
6	32.3
7	26.9
8	14.2
9	6.4
10	3.4
more than 10	3.5
Total	100.0

Table 5.10 Total study length in years (N = 677).

The next two tables (5.11 and 5.12) display the answers to the question whether alumni would choose the same degree programme again if they had to make the choice again and why or why not? The why or why not question was an open question. All the answers were categorised afterwards in the categories listed in table 5.12.

	Percent
Yes	75.9
No	24.1
Total	100.0

Table 5.11 Would you choose this degree again? (N = 668)

Some 76% would make the choice again and those who would not make the same choice again mostly indicate that they would rather have had a different career (table 5.12). The level of alumni unsatisfied with their degree alumni is low, only 8% of those answering the question of table 5.12 indicate some sort of dissatisfaction with their degree.

	Percent
Good degree	50.5
Not a good degree	1.3
Rather had different career	15.4
Too theoretical	2.5
Too practical	4
Other	26.3
Total	100.0

Table 5.12 Why (not)? (N = 479)

The question whether an alumnus would choose the same degree again was also asked in the last alumni survey among aerospace graduates of 25 years ago. In that survey (VSV Leonardo da Vinci, 1980) only 35.7% of the alumni would choose the same degree again, and 36.0% said maybe. From this it can be concluded that satisfaction with their degree has gone up among alumni.

The alumni were also asked whether they would advise anyone else to do this degree. Those results can be found in table 5.13. The alumni were then asked to explain why or why not. The answers to this question were collected in table 5.14. Again it has to be noted here that this was an open ended question and that the answers were grouped together afterwards.

	Percent
Yes	86.8
No	13.2
Total	100.0

Table 5.13 Would you advise anyone else to do this degree (N= 660)?

Again the mood here is overwhelmingly positive, of those indicating why not only a few percent indicate that in their opinion there are issues with the current quality of the degree.

	Percent
Good degree	57.2
Not a good degree	1.1
Good chance at a job	8.4
Too theoretical	1.1
Too practical	0.9
Too difficult	0.4
Current quality degree is poor	0.6
Other	30.3
Total	100.0

Table 5.14 Why or why not (N= 465)

The respondents were also asked to name a maximum of 3 subjects or courses during their degree from which they still benefit today. This was an open ended question. The results in table 5.15 were achieved by first collecting all answers and then grouping them according to subjects and courses.

From table 5.15 it can be observed that subjects, of which it is expected that they require a student to use their ability to synthesise and their analytical skills: the MSc thesis, the internship, and the design exercises, are high in the list. They obviously are very influential in shaping aerospace engineers from Delft. Secondly, the core engineering courses such as calculus, mechanics and structures are also deemed important. In seventh and eighth place are management and communication courses. Finally, it can be observed that courses dealing specifically with aerospace applications such as aerodynamics, aircraft performance and aircraft stability and control are not very high on the list. On first glance the directly aerospace related courses seem to be the gravy that gives the degree its flavour. However, it must be noted here that the thesis, the design exercises and the structures courses are all also very aerospace oriented. It can therefore not be concluded here that there is no point in aerospace related courses.

	Percent	
1.	MSc Thesis	18.9
2.	Internship	11.7
3.	Calculus etc.	10.4
4.	Design Exercises	9.7
5.	Structures	7.8
6.	Mechanics	6.9
7.	Management	6.8
8.	Communication skills	5.6
9.	Materials	5.4
10.	Computer & Programming skills	4.6
11.	Aerodynamics	4.1
12.	Aircraft Performance	3.1
13.	Aircraft stability and control	1.7
14.	Manufacturing	1.4
15.	Maintenance	1.0
16.	Space	0.9
	Total	100.0

Table 5.15 Subjects from which I still benefit today (N=1252)

From an educational science point-of-view it can be seen from table 5.15 that of the first five courses listed, three can be classified as problem-based learning courses. The MSc thesis and the internship are both problem-based learning (PBL) exercises as the starting point of these courses are a problem often based on real life situations. MSc thesis work often takes place in industry or in the laboratories and often closely resembles a real job. An internship takes place in industry and allows students to prepare themselves for their professional life. Before a student starts on the problem, those supervising the student during their MSc thesis or internship have typically ensured that the problem posed has been modified to achieve the educational learning objectives. Also the student is expected to use the knowledge gained prior to the assignment, and independently make up for any gaps in their knowledge. Although the result of the work done in these courses is important, it is still subsidiary to the learning process and result. It is this type of learning that can be defined as PBL (De Graaff and Kolmos, 2003). Firmly in fourth place are the design exercises which are team-based, active problem based learning experiences. It is interesting to point out that many of those exercises already existed in a team format long before active learning and project-based learning were formally introduced at the faculty in 1995. The results from table 5.15 clearly show that alumni value their active learning experience in their professional career and that they do not see it as a ‘fashion fling’ of educationalists.

Summarizing it can be said that overall alumni are still satisfied with their degree further along the line and more so than they were 25 years ago. Market research by TU Delft also shows that aerospace engineering graduates are also very satisfied shortly after graduating (Dessan Research Solutions et al., 2004, 2005).

5.4 Continuing Education Activities of Alumni

In the survey enquiries were made to find out if alumni continued their formal education after obtaining their MSc degree. In table 5.16 the number of graduates who, after their degree, took post-academic courses excluding PhDs and the distribution over the different types of engineers is shown and in table 5.17 and figure 5.4 the type of courses they took and the distribution over the different types of engineers:

	Overall (%)	Engineering specialist (%)	Engineering Manager (%)	Undecided (%)
Yes	18.4	14.1	22.7	11.9
In progress	2.8	0.9	3.1	4.6
No	78.8	85.0	74.2	83.5

Table 5.16 Post academic degree courses excluding PhDs (N=680)

The first thing that can be noted from table 5.16 is that few alumni undertake any serious form of continuing education; only about 20% with more of them being engineering managers than engineering specialists and undecided respondents.

	Overall (%)	Engineering Specialist (%)	Engineering Manager (%)	Undecided (%)
MBA, business studies	45.8	9.4	63.4	41.2
Project management	1.4	0.0	2.4	0.0
2 year post-academic	9.9	18.8	3.7	17.6
Other engineering	23.2	46.9	13.4	29.4
Other non-engineering academic	12	6.3	15.9	5.9
Other non- academic	7.7	18.8	1.2	5.9

Table 5.17 Type of post-academic courses (N=142)

Looking at table 5.17 and figure 5.4 it can be observed that the majority of those taking courses take up management and business courses. This is particularly true for engineering managers of which some 63.4% go on to obtain an MBA or a business degree. Engineering specialists however, predominantly take up additional engineering courses and the two year post academic design courses.

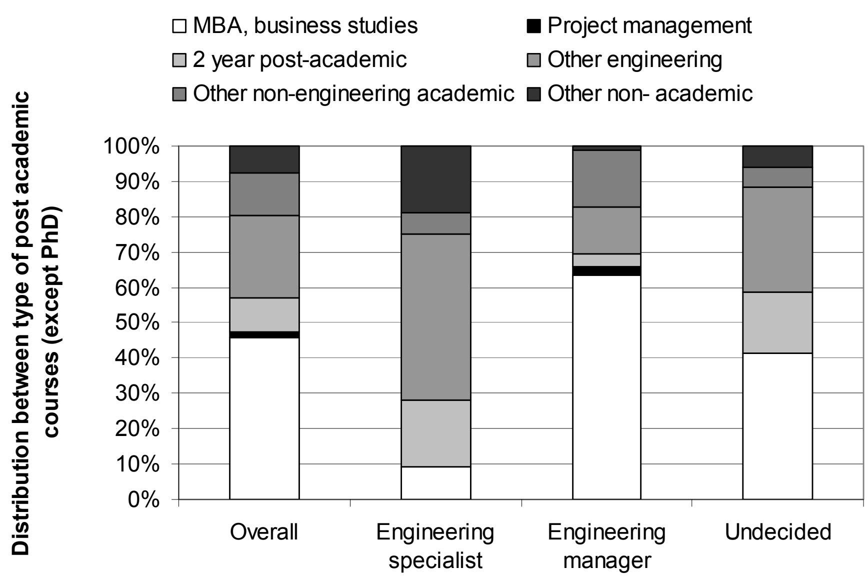

Figure 5.4 Distribution of post academic courses except PhD (N=142)

The number of people who went on to obtain a PhD degree is shown in table 5.19.

	Overall (%)	Engineering Specialist (%)	Engineering Manager (%)	Undecided (%)
Yes	7.6	11.2	4.4	9.0
In progress	2.5	5.6	0.3	2.7
No	89.9	83.3	95.3	88.3
Total	100.0	100.0	100.0	100.0

Table 5.18 Alumni having or working on a PhD (N= 683)

The number of people who have or are pursuing a PhD degree seems low even for specialists. Only 17% of the engineering specialist either holds or is working on a PhD. This can probably be explained, however, by the fact that TU Delft did not have a formal PhD programme until 1985. Also the Faculty of Aerospace Engineering at TU Delft is still the only faculty in the Netherlands where a PhD or an MSc in Aerospace Engineering can be obtained. Only the recent growth in research groups at the Faculty has opened up quite a few PhD opportunities. Before then they were often scarce. The institute, at which most of the respondents undertake or have undertaken their PhD, as can be observed from table 5.19, is TU Delft, probably because of the aforementioned reason. Only few, 23%, have obtained or are obtaining their PhD at institutions other than TU Delft. It is also interesting that the second largest location to obtain a PhD from is outside the Netherlands.

	Percent
Aerospace Engineering TUD	56.2
Abroad	16.4
Elsewhere in TUD	13.7
Mechanical Engineering TUD	6.8
Elsewhere in NL	6.8
Total	100.0

Table 5.19 Location of PhD training (N= 73)

Overall it can be concluded here that few alumni seek further education on an organised level and by far the most in some form of business studies related courses. In-company training was not measured.

5.5 Competencies of Alumni

In previous sections the characteristics of the alumni population were described. In this and the following sections the results of the core of the survey are to be discussed: starting with the competencies defined in Chapter 3 and their relation to the professional success of alumni. In this section the results of the answers on questions regarding the perceived importance of the individual competencies for alumni in their current job as well as their perceived ability to use each competency are presented and discussed. Also the results are presented of how important alumni think the individual competencies are for engineering managers and engineering specialists, and what engineering managers and engineering specialists themselves have to say on how important those competencies are.

First of all the respondents were asked to rate the competencies discussed in Chapter 3 for their importance in their current position. Table 5.20 displays the mean score for each competency as well as listing of the standard deviation σ for each competency. Figure 5.5 gives a graphical representation of the results.

	N	Mean	σ
Ability to synthesise	662	4.29	0.73
Analytical skills	674	4.63	0.58
Problem solving skills	675	4.70	0.53
People Management skills	676	4.11	0.89
Operational Management skills	674	3.77	0.99
Written communication skills	675	4.30	0.72
Oral communication skills	676	4.56	0.58
Net worker	675	3.85	0.95
Have broad technical knowledge	676	3.89	1.01
Have specialist technical knowledge	676	3.46	1.32
Ability to work in teams	675	4.14	0.78
Ability for life-long learning	676	4.53	0.65

Table 5.20: The perceived importance by alumni of each competency in the alumni's current position? (1 = totally unimportant – 5 = very important)

From the results it can be observed that all of the competencies listed alumni perceive them to be important to very important in the alumni's execution of their current job. There are some interesting points that can be highlighted here. First of all, it seems that many alumni perceive the ability for life-long learning to be very important, however, few of them (18.4% according to table 5.16) actually engage in any formal form of learning after graduation. Furthermore, specialist technical knowledge, although important, is rated the least important followed by operational management skills. Problem solving and analytical skills however, are considered the most important by the alumni for their current position.

The standard deviations show that there is large spread in the responses. However, a closer study of the data revealed that the data was very positively skewed with very few respondents (less then 10%) indicating that a competency was unimportant or totally unimportant, meaning that the spread in data is limited between the scores 3 and 5.

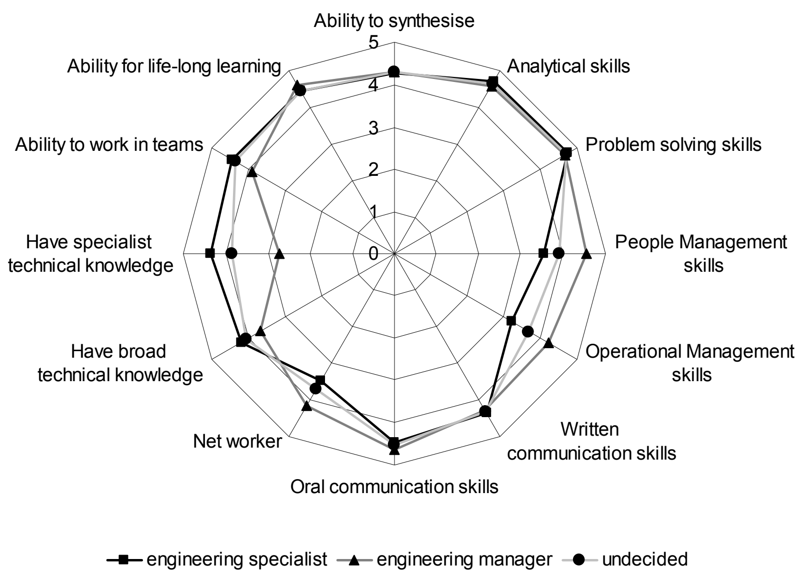

Figure 5.5 Mean scores for the perceived importance by alumni of each competency in an alumnus' current position split whether respondents are managers, specialists, or undecided. (1 = totally unimportant – 5 = very important).

The distribution of the perceived importance by alumni of a competency in the alumni's current jobs according to their job function of being an engineering manager, engineering specialist, or undecided is shown in figure 5.5. From figure 5.5, it can be observed that most competencies are deemed important to very important by the alumni for all types of engineers. However, specialist or broad technical knowledge and ability to work in teams for managers were not found to be as important and the same goes for people and operational management and networking skills for specialists and undecided. Now most of this was expected, with exception of the lesser importance of teamwork skills for managers. It appears here that if you are in charge it is not as important whether or not you can work in teams.

The perceived importance of each competency split along the requirements of the job is shown in figures 5.6a and 5.6b. The perceived importance of each competency has been plotted whether the alumni works in the aerospace industry, whether an aerospace engineering degree is required, and whether engineering degree is required or not. From these figures it can be observed that all competencies but two are perceived by alumni to be important to very important for all jobs. The only two competencies that are not perceived to be as important for those working in a job that does not require an engineering degree are specialist and broad technical knowledge, which is hardly surprising.

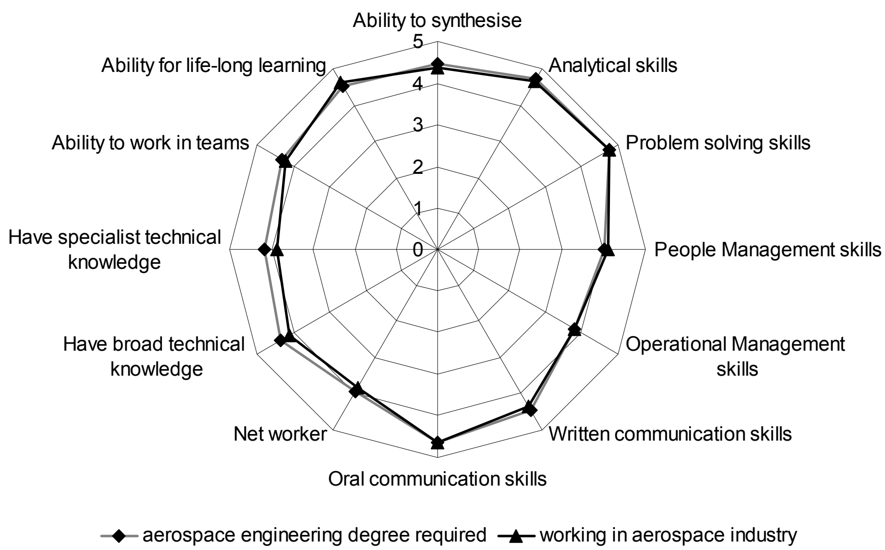

Figure 5.6a Mean scores for the perceived importance by alumni of each competency in an alumnus' current position split along aerospace job requirements (1 = totally unimportant – 5 = very important)

However, it can be concluded that (apart from those two competencies) having the competencies as stated in figures 5.6a and b makes an engineer extremely desirable as those competencies are required throughout the academically trained workforce. This is why engineering companies may want to seriously look at finding sufficient enticements to keep engineering graduates in engineering practice.

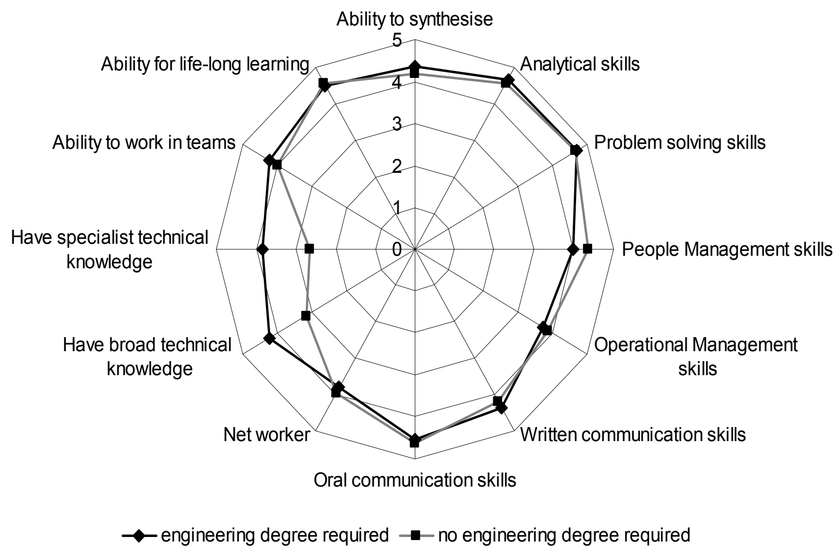

Figure 5.6b Mean scores for the perceived importance by alumni of each competency in an alumnus' current position split along engineering job requirements (1 = totally unimportant – 5 = very important)

Alumni were also asked to rate themselves in their ability in each of the competencies. Those results are listed in table 5.21 and figure 5.7.

What is interesting when looking at the mean for each of the competencies is, that there are three competencies in which alumni feel they are less competent. This concerns the competencies of people and operational management skills, and networking. Also, if the results are split along the lines of engineering manager, engineering specialist and undecided, it can be observed (see figure 5.7) that those are still weaker areas for each type of engineer, with engineering managers indicating to be somewhat more proficient. It can also be observed that engineering managers score themselves low on their specific technical knowledge. A closer analysis of the data showed that again the data is very positively skewed. Less than 10% of the respondents indicated that they deem themselves very incompetent in a competency.

	N	Mean	σ
Ability to synthesise	665	3.34	0.56
Analytical skills	677	3.71	0.47
Problem solving skills	677	3.62	0.49
People Management skills	677	2.96	0.64
Operational Management skills	674	2.86	0.68
Written communication skills	678	3.39	0.61
Oral communication skills	678	3.29	0.59
Net worker	678	2.70	0.75
Have broad technical knowledge	677	3.19	0.66
Have specialist technical knowledge	678	2.83	0.92
Ability to work in teams	678	3.12	0.61
Ability for life-long learning	678	3.48	0.56

Table 5.21: How competent are you in each of these competencies?
(1 = very incompetent, 2 = incompetent, 3 = competent, 4 = very competent)

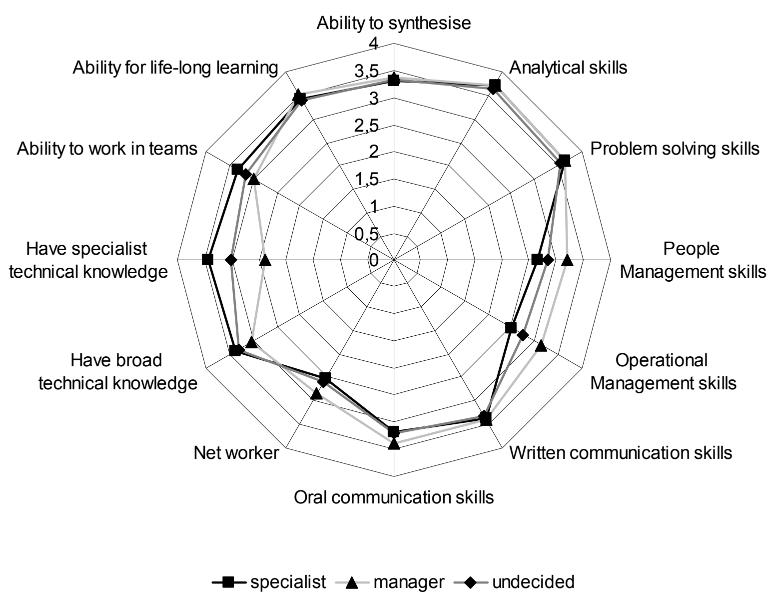

Figure 5.7 How competent are you in each of these competencies split for managers, specialist and undecided? (1 = very incompetent, 2 = incompetent, 3 = competent, 4 = very competent)

In order to assess a person's ability in a competency there are several options: a self assessment by the respondent, an assessment by a peer, or a superior or an assessment based on the activities belonging to such a competency. In the questionnaire the alumni were asked to rate themselves in each competency, however, the data was very positively skewed, as discussed previously. This may have something to do with it being difficult for people to objectively assess themselves. Therefore, in the questionnaire a second form of assessing ability was included as described in detail in Chapter 4 and in Appendix C. The alumni were asked about their day-to-day activities and professional achievements to see how they performed on a certain competency. It was also shown in Chapter 4 that this is a highly reliable scale. It must be noted here that the competency networking skills was not taken into account in this scale.

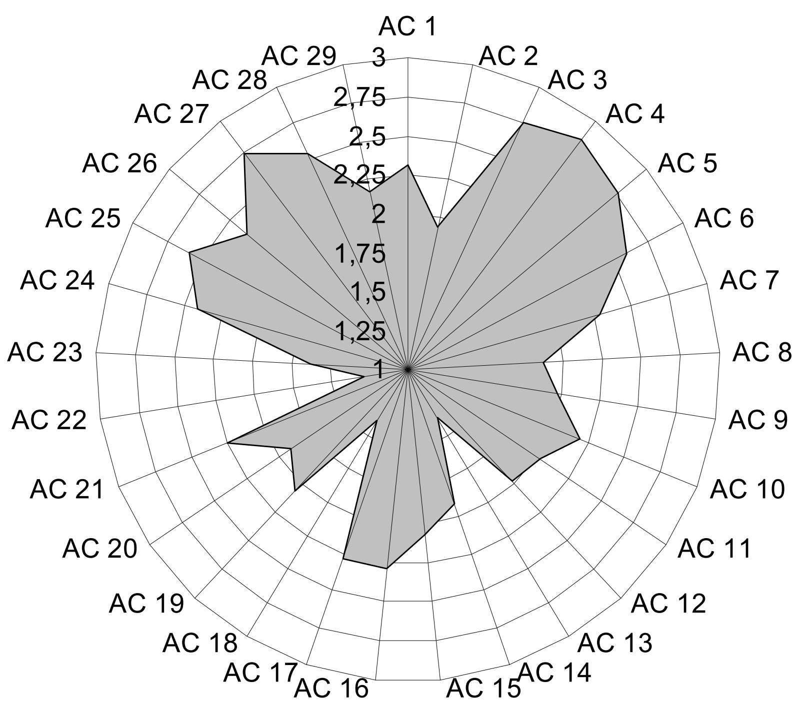

Figure 5.8a Alternative competency scale
(1 – never, 2 – sometimes, 3 – often/very much)

For every competency except networking a list of relevant activities belonging to that competency was developed (see Appendix C and table 5.22). The frequency distribution for each activity belonging to a certain competency is shown in table 5.22. The activities are ordered per competency. A graphical representation of the same results is shown in figure 5.8a. From figure 5.8a it can be observed that engineers often work on multi-disciplinary teams (AC 1), however, they are not often asked to lead such teams (AC 2). A similar conclusion can be drawn with regards to teamwork in general (AC 28 and AC 29). However, engineers do really like working in teams (AC 27). The ability of engineers to analyse and solve problems is again highlighted here, with many indicating that these are often occurring activities (AC 3 – AC 6). In terms of people management skills, engineers are in charge of staff and are evaluating staff (AC 7 and AC 8). In terms of written and oral communication skills it can be observed that although few write (AC 13) and present scientific articles (AC 18) many are often involved in other communication related activities (AC 14 – AC 17). In terms of receiving professional recognition in the form of awards (AC 22); this does not occur to many engineers. In terms of ongoing learning it can be observed that they have often taken additional courses, find it often useful and would like to continue to take courses (AC 24 – AC 26).

Competency		Activity	N	Mean	σ	Mode
C.1 Ability to synthesise	AC1.	Is asked to be part of multi-disciplinary taskforces, working groups or research teams	675	2.31	0.67	2
	AC2.	Is asked to head multi-disciplinary taskforces, working groups or research teams	674	1.94	0.73	2
C.2 Analytical skills	AC3.	Is often asked by others for their view on problems	679	2.75	0.45	3
	AC4.	Their analysis of a problem is often accepted	680	2.85	0.36	3
C.3 Problem solving skills	AC5.	Their solution to a problem is often accepted	680	2.76	0.43	3
	AC6.	Is often asked by others to solve tedious problems	679	2.58	0.55	3
C.4 People Management skills	AC7.	Is in charge of a number of staff in current position	678	2.28	0.79	3
	AC8.	Reviews staff on performance reviews	679	1.87	0.89	1

	AC9.	Is mandated to negotiate contracts on behalf of employer	679	1.97	0.83	3
C.5 Operational Management skills	AC10.	Current position comes with financial & budget responsibility	678	2.19	0.84	3
	AC11.	Sets up new organizational structures & processes	680	2.03	0.82	3
	AC12.	Makes regular operational decisions effecting organisation and working of processes in the company	676	1.97	0.83	1
C.6 Written communication skills	AC13.	Writes scientific papers/articles	679	1.36	0.61	1
	AC14.	Writes policy documents/ Financial or Business plans.	680	1.90	0.75	2
	AC15.	Is asked to write documents by colleagues and supervisors	676	2.06	0.65	2
C.7 Oral communication skills	AC16.	Gives presentations on behalf of their company	680	2.28	0.69	2
	AC17.	Presents to colleagues within the company	679	2.29	0.61	2
	AC18.	Is a regular presenter at scientific conferences	679	1.38	0.65	1
C.9 Have broad technical knowledge	AC19.	Reads general engineering literature	680	2.07	0.72	2
	AC20.	Reads engineering management literature	678	1.90	0.73	2
C.10 Have specialist technical knowledge	AC21.	Reads specialized engineering literature	678	2.24	0.69	2
	AC22.	Receives awards for their work	679	1.28	0.52	1
	AC23.	Is a regular guest speaker at conferences etc.	678	1.63	0.70	1
C.11 Ability for life-long learning	AC24.	Has attended a number of courses after graduation	677	2.40	0.55	2

	AC25.	Finds acquiring additional knowledge useful	677	2.60	0.51	3
	AC26.	Intends to attend more courses in the future	676	2.34	0.60	2
C.12 Ability to work in teams	AC27.	Likes working in teams	680	2.74	0.45	3
	AC28.	Is often asked onto team projects	678	2.53	0.62	3
	AC29.	Is asked to head project teams	679	2.17	0.72	2

Table 5.22 Alternative competency scale (1 – never, 2 - sometimes, 3 – often/very much)

The alternative competency scale was also split according to whether the respondents deemed themselves managers, specialist or undecided. The results of this can be seen in figure 5.8b, the table containing the data can be found in Appendix E. From this figure it can be observed that for engineering managers most activities occur frequently with the exception of the activities writing scientific papers/articles (AC 13) and presenting at scientific conferences (AC22). This is not really surprising as that is not something one would expect a manager to often do.

When looking at the engineering specialists it can be observed that they are far less likely to head multi-disciplinary teams than engineering managers (AC 2) and that they also hardly ever manage people (AC 7 – AC 9), neither are they very involved in the operational side of their employer. It is also interesting to see that engineering specialists do not often appear to share their expertise by writing scientific papers or articles even if they do this more often than the engineering managers (AC 13). As can be expected specialists do read more general and specialised engineering literature than the managers (AC 19 and 21) and very little management literature (AC 20). The last large difference is again in leadership: although specialist often work on project teams (AC 28) they rarely appear to lead them (AC29).

Finally, looking at the group who is undecided as to whether they are an engineering specialist or an engineering manager, they seem to be in the middle in terms of the frequency of occurrence of activities between the managers and the specialists. A notable exception is that the undecided group tends to be the most frequently invited to be a guest speaker (AC 23). Other exceptions are that they appear to do less life-long learning activities (AC 24 and 25) and working in teams (AC28 and AC 29). It would be interesting to carry out further research to find out why this is the case.

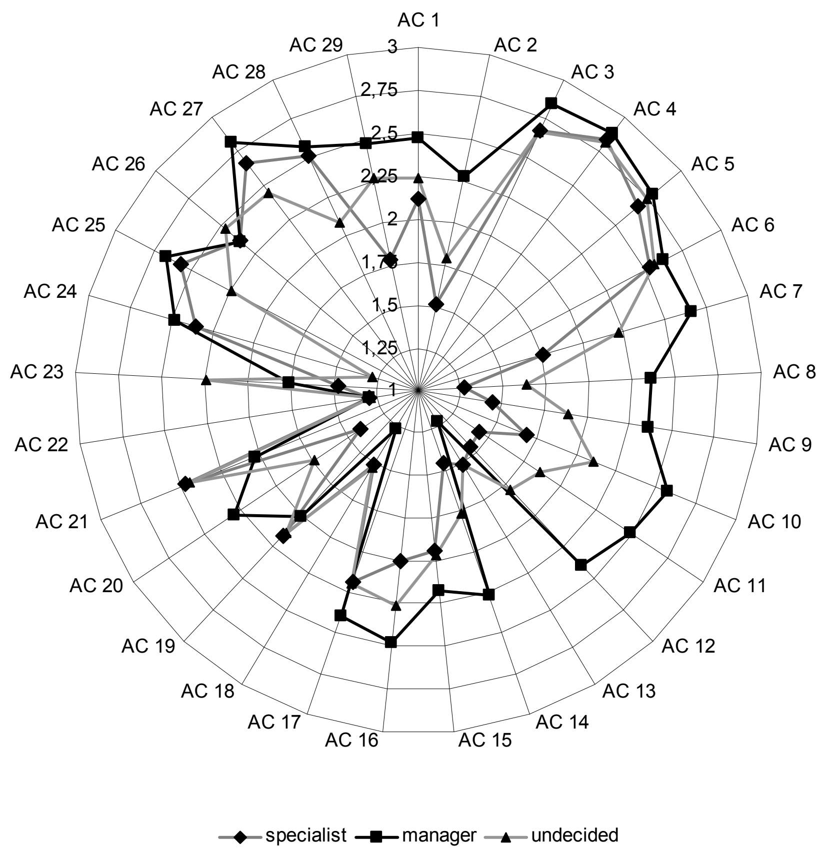

Figure 5.8b Alternative competency scale split according to whether the respondents deem themselves engineering specialists, engineering manager or undecided.
(1 – never, 2 – sometimes, 3 – often/very much)

At this point in the survey it was explained to the participants that engineering careers can be divided into two typical career paths: the engineering specialist and the engineering manager. The participants were asked to rate how important they thought each of the competencies in Chapter 2 were for each of the two career paths. The results are shown in table 5.23 and figure 5.9.

Figure 5.9 shows that in the opinion of the alumni, operational and people management skills are deemed not very important for engineering specialist, just as specialist technical knowledge is not deemed very important for an engineering manager. Next to that the ability to work in teams and having broad technical knowledge is only found somewhat important by the alumni.

	Engineering specialist			Engineering manager		
	N	Mean	σ	N	Mean	σ
Ability to synthesise	649	4.36	0.67	646	4.25	0.75
Analytical skills	659	4.83	0.41	655	4.21	0.76
Problem solving skills	659	4.71	0.50	657	4.43	0.67
People Management skills	661	2.97	0.84	658	4.89	0.33
Operational Management skills	659	2.83	0.87	658	4.65	0.55
Written communication skills	661	4.27	0.61	659	4.37	0.61
Oral communication skills	661	4.02	0.70	659	4.76	0.43
Net worker	659	3.23	0.91	658	4.53	0.61
Have broad technical knowledge	660	3.93	0.90	658	3.86	0.94
Have specialist technical knowledge	661	4.90	0.34	658	2.48	0.95
Ability to work in teams	660	4.77	0.45	657	3.71	0.87
Ability for life-long learning	659	4.26	0.70	658	4.62	0.59

Table 5.23 How important do alumni think each competency is for an engineering specialist and an engineering manager, respectively? (1 = totally unimportant – 5 = very important)

The data in table 5.23 show that the standard deviations for the competencies people management skills, operational management skills, networking skills and broad technical knowledge are quite large. This means that the respondents are not in unilateral agreement as to whether an engineering specialist must have these competencies; the data spread is very large. In case of the competencies important for an engineering manager the standard deviation indicates that opinions are much divided on the competencies specialist technical knowledge, broad technical knowledge and the ability to work in teams.

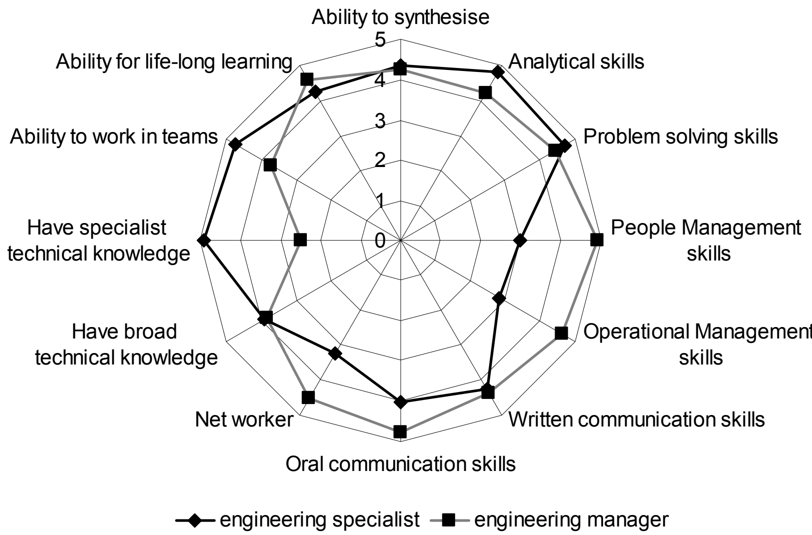

Figure 5.9 Mean scores for how important alumni think each competency is for an engineering specialist and an engineering manager, respectively? (1 = totally unimportant – 5 = very important)

A comparison between how important engineering specialists themselves think each competency is for their job and how important aerospace alumni think each competency is for an engineering specialist is shown in figure 5.10. The figure clearly shows that people and operational management skills are still important to engineering specialists and therefore they should also acquire those competencies during their training. Also important, although to a less so, are the networking competency and the competency of having broad technical knowledge.

Furthermore, engineering specialists indicate that having specialist technical knowledge is important but not as important as alumni overall indicate they think it is. It can therefore be concluded that in the training of engineering specialists a broad foundation of technical knowledge with an assortment of competencies best prepares them for the workforce.

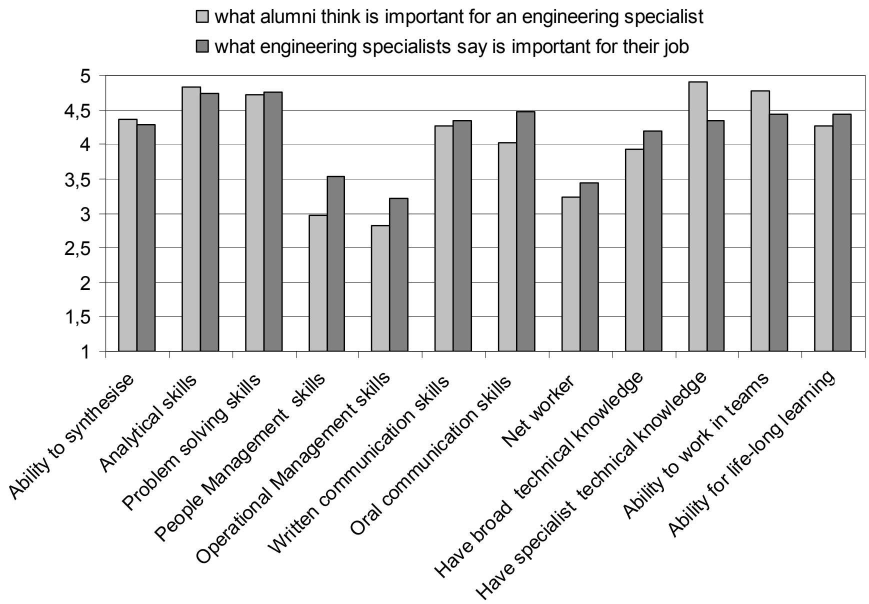

Figure 5.10 A comparison between the means of how important each competency is for the job of an engineering specialist according to an engineering specialist and how important aerospace alumni think that competency is for an engineering specialist. (1 = totally unimportant – 5 = very important)

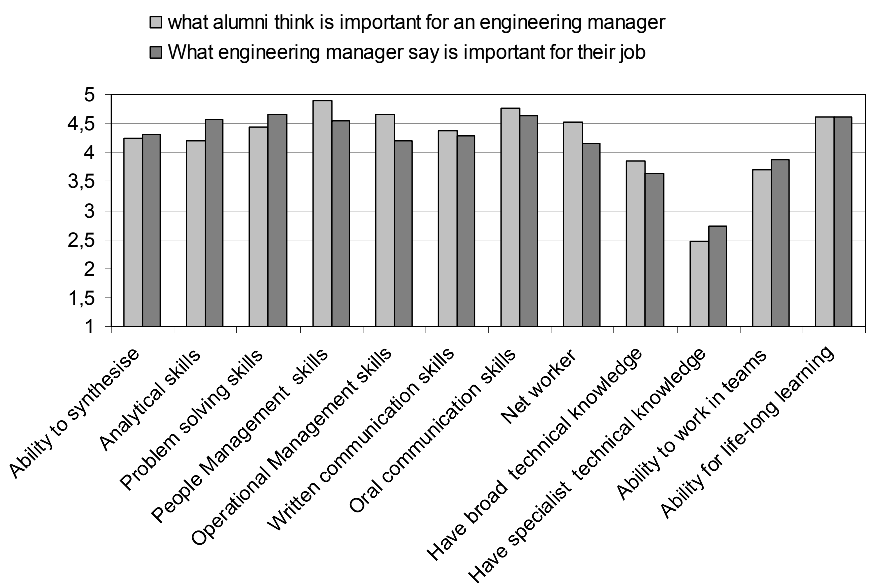

Figure 5.11 A comparison between the means of how important each competency is for the job of an engineering manager and how important aerospace alumni think that competency is for an engineering manager. (1 = totally unimportant – 5 = very important)

A similar comparison is made in figure 5.11, this time for the engineering manager. In this case the need for people and operational management skills and networking skills are somewhat overestimated by the alumni but they are still deemed important by the engineering manager. Interestingly, the competency of analytical skills is deemed more important by engineering managers than the alumni think, as is specialist technical knowledge although not greatly.

The contribution of the aerospace engineering degree

Finally, alumni were also asked to indicate in what way they felt their degree contributed to the acquiring of those competencies. The results are listed in tables 5.24 and figure 5.12.

From the table it can be concluded that in the opinion of the alumni there are several competencies their degree did not or hardly contribute to. This concerns the competencies people management skills, operational management skills, oral communication skills, networking skills and the ability for life-long learning. This in itself is not strange as those types of competencies were not part of the final objectives of the Aerospace Curriculum until 1995 (see Appendix A). The introduction of intensive team based projects which aimed to reach some of these objectives did not begin until 1997 as did the introduction of a mandatory course in oral communications. As table 5.20 indicates oral communication skills are important for graduates to do their job properly, and as table 5.21 shows the graduates also indicate that they feel that they still lack those skills.

It must be concluded here that in order to help alumni be more competent in these competencies which they indicate are important to their careers, these competencies must be included in the objectives of the aerospace curriculum at TU Delft.

	N	Mean	σ
Ability to synthesise	668	3.24	0.67
Analytical skills	679	3.71	0.51
Problem solving skills	677	3.45	0.61
People Management skills	678	1.65	0.65
Operational Management skills	681	1.76	0.67
Written communication skills	680	2.73	0.72
Oral communication skills	680	2.28	0.74
Net worker	680	1.90	0.70
Have broad technical knowledge	681	3.37	0.63
Have specialist technical knowledge	680	3.52	0.65
Ability to work in teams	675	2.96	0.76
Ability for life-long learning	679	2.45	0.74

Table 5.24: Degree to which alumni felt their aerospace engineering degree contributed to each of the competencies (1 = not contributed – 4 = considerably contributed)

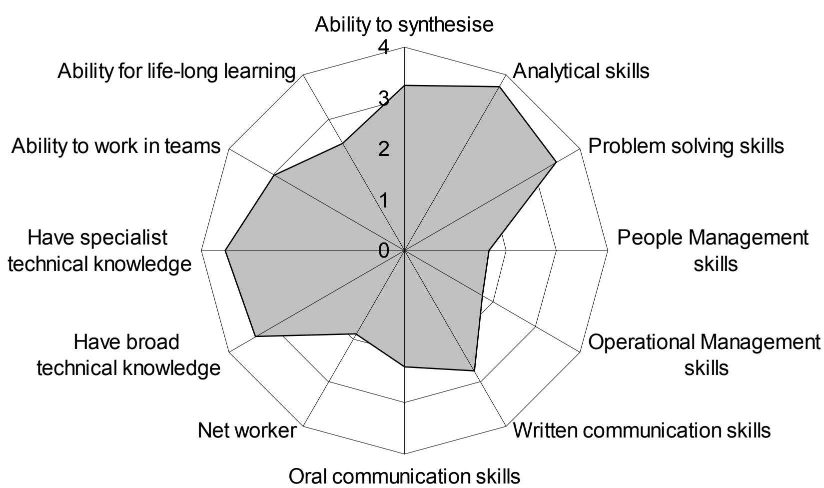

Figure 5.12: Degree to which alumni felt aerospace engineering degree contributed to each of the competencies (1 = not contributed – 4 = considerably contributed)

5.6 Professional Alumni Success

In this section the success of alumni is investigated. Using the success definitions introduced in Chapter 4 the alumni can be divided into three groups for each of the definitions: below average successful, average successful, above average successful. The first success definition, as defined in table 4.1, to be investigated is the division of the respondents according to job responsibility levels as displayed in table 5.25.

Success in terms of job responsibility	
below average successful	43.8
average successful	37.9
above average successful	18.3
Total	100.0

Table 5.25 Success of alumni in terms of job responsibility (N=671)

Looking at the results it can be seen that in terms of job responsibility aerospace engineering graduates are not overly successful according to these definitions. They are not widely managing their peers or in charge of lower and middle management or working independently on innovative matters or independent research.

Success in terms of salary and work experience	
below average successful	31.9
average successful	27.7
above average successful	40.4
Total	100.0

Table 5.26 Success in terms of salary and work experience (N=671)

In terms of salary with work experience however, as indicated in table 5.26 aerospace engineers are more successful than engineers as a whole. More than 40% earn more than average, as defined in tables 4.2 and 4.3 in Chapter 4.

The results for the combined success definition, (see table 4.4) which combines job responsibilities and salary, is indicated in table 5.27. Again here it can be seen that only 27% are classified as above successful. However, the number of engineers scoring above average is far more (9%) than if we only look at salary with work experience. From the data displayed in tables 5.25 – 5.27 it can now be concluded that although aerospace engineers may not always be working on the forefront of developing technology in their field or managing great amounts of people, they are however paid considerably more than their fellow engineers with the same amount of work experience, to do their work, making them more successful on that aspect.

Success in terms of salary with work experience and job responsibility	
below average successful	38.2
average successful	34.7
above average successful	27.1
Total	100.0

Table 5.27 Success in terms of salary with work experience and job responsibility (N = 660)

The division of success in terms of job responsibilities split over whether the respondents are specialist, managers or undecided is shown in figure 5.13. Looking at the division it can be observed that when it comes to job responsibilities a larger number of the engineering specialists are average or above average successful than the group as a whole. For engineering managers the opposite is true. They seem less successful. They generally manage non-scientific and non-engineering staff and have specific directions of their jobs. But by far the most successful group in terms of job responsibilities are the undecided. They seem to manage both being in charge people and do groundbreaking and innovative work as well.

The results represented in figure 5.14 however, show that in terms of salary with work experience that engineering specialists are classed as below average successful. More than half of them earn below average for their work experience. Interestingly, for engineering managers it is the other way around. However, the group of undecided respondents show the same level of success as they do for success in job responsibility.

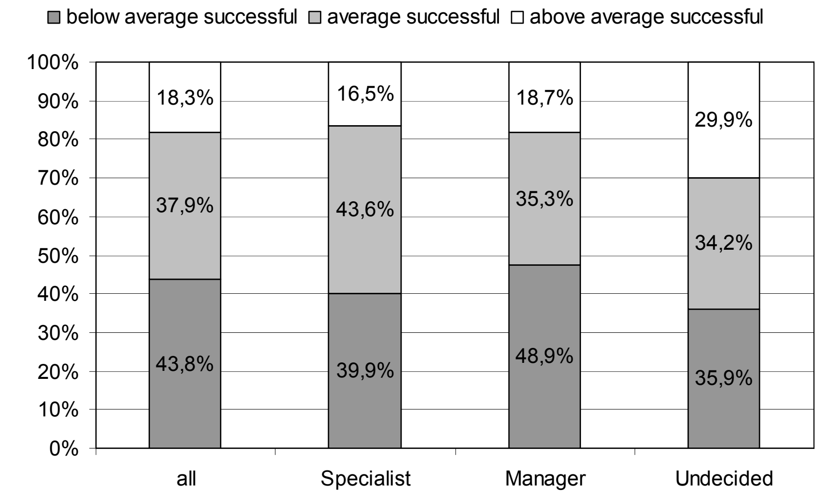

Figure 5.13 Success in terms of job responsibility for engineering specialist, engineering managers and undecided.

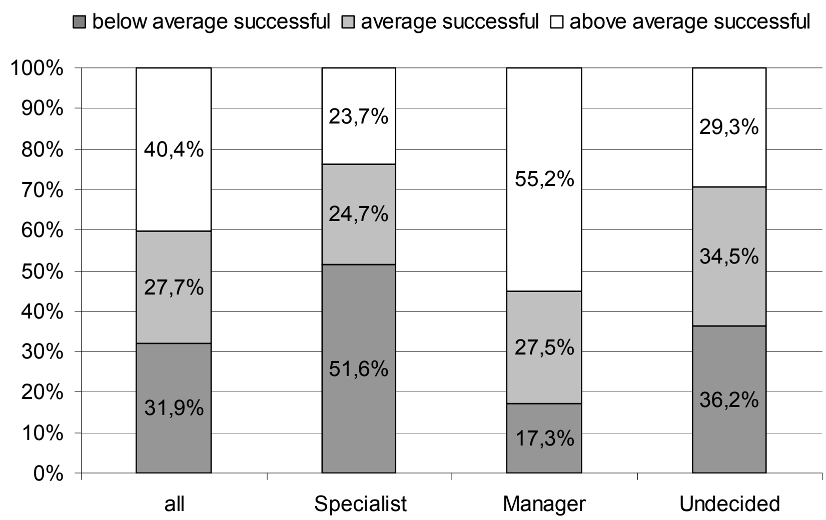

Figure 5.14 Success in terms of salary and work experience for engineering specialist, engineering managers and undecided.

Finally, in figure 5.15 the combined success levels for three types of engineers are shown. The combination shows that engineering specialists are not very successful in terms of salary. For them it would be more sensible to go along the undecided track. Engineering managers seem to be the most successful out of the three types. However, the levels of job responsibilities they have are low.

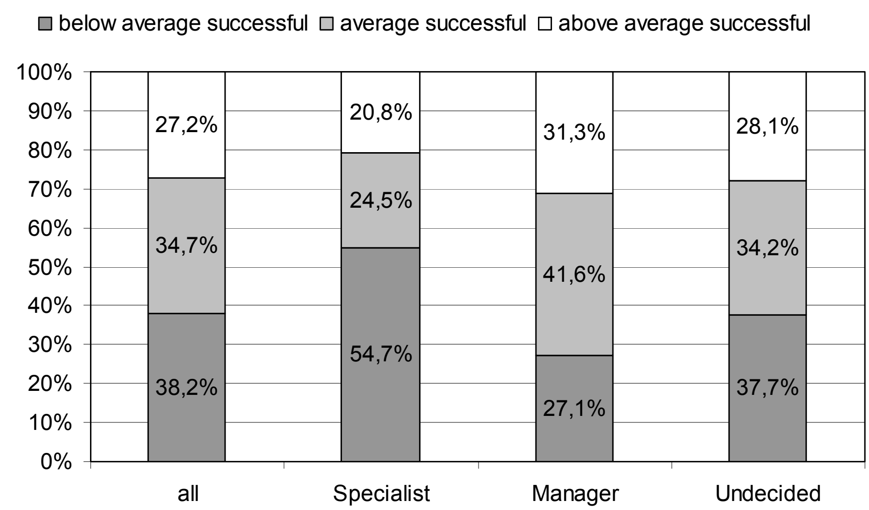

Figure 5.15 Success in terms of job responsibility and salary and work experience for engineering specialist, engineering managers and undecided.

5.7 Competencies and Professional Success

In this section the existence of any relationships between the competencies and professional success as defined in Chapter 4 will be explored. This will be performed both per individual competency and on the overall competency score as a whole.

5.7.1 The contribution of individual competencies to success

First, the existence of any significant relationships between each individual competency as developed in Chapter 3 and an alumni's professional success will be explored. The success definitions from the previous section have resulted in 3 nominal values: below average successful, average successful, and above average successful. Each of the questions related to the competencies were scored on either a 4- or a 5-point Likert scale which is an ordinal scale. To discover whether a significant relationship exists between these two variables, the literature on statistics (Pallant, 2005, Field, 2005 and Cohen et al., 2007) suggest carrying out a χ^2 – test for independence.

A χ^2 – test for independence works out whether two categorical variables are statistically associated and not just by chance. This is done by calculating the difference between a statistically generated expected result and an actual result to see if there is significant difference between them. The value for χ^2 is calculated according to the following equation:

$$\chi^2 = \sum \frac{(O-E)^2}{E} \tag{5.1}$$

In this equation O are the observed frequencies and E the expected frequencies. The observed frequencies are the frequencies from a contingency table which tables the two variables in one table in which in each cell the frequency of each combination of variables is plotted. See Appendix F for the relevant contingency tables for the analysis in this thesis. The expected frequencies are calculated using:

$$E = \frac{RowTotal \times ColumnTotal}{n} \tag{5.2}$$

In equation (5.2) the *row total* is the sum of the frequencies in the row of the cell concerned, *column total* the sum of the frequencies in the column of the cell, and n the total number of observations.

The null hypothesis in a χ^2-test is always that there is no significant relationship unless the probability p was smaller than 5%. This is determined using standard tables (see Field 2005) in which the probability is listed as a function of the χ^2-score and the degrees of freedom of the variables. The degrees of freedom, *df* of a χ^2-test is calculated using:

$$df = (c-1)(r-1) \tag{5.3}$$

In equation (5.3) c represents the number of columns and r the number of rows in the contingency table. In order to compute χ^2 at least 80% of each possible combination must have a data count of at least 5, as stipulated in literature (Field, 2005, Pallant, 2005, and Cohen, at al. 2007).

If a significant relationship is found, i.e. the null hypothesis is rejected; the type of relationship is still unknown. To see what type of relationship exists between the two variables, the contingency table must be inspected to see the trend of the relationship, e.g. positive or negative. In order not to unduly flood this thesis with tables only the contingency tables for the competencies whose χ^2 calculations showed a significant relationship with the success definitions have been included. They can be found in Appendix F.

As reported in the section 5.5 the data obtained from the competency questions are rather positively skewed. Therefore there was insufficient data in the category combinations: ‘(very) unimportant’ and ‘neutral’ versus ‘successfulness’. The same phenomenon occurred for the category combinations: ‘(very) incompetent’ versus ‘successfulness’. In order to still investigate whether any significant relationships exist the data used to compute relationships between the importance of competencies for an alumni’s current position and success was compacted by adding the data for very unimportant, unimportant and neutral together thereby reducing the degrees of freedom from 8 to 4. Similarly for the relationship between the ability of an alumnus and success, the data was compacted into two levels of ability: competent and incompetent reducing the degrees of freedom from 6 to 2. Despite these measures it was still impossible to calculate χ^2 for certain competencies due to lack of data in certain cells. No conclusions can therefore be drawn for these competencies.

The importance of competencies in an alumni’s current job

The first null hypothesis to test was that no significant relationship exists between how important alumni think an individual competency is for their current job and success in terms of job responsibility. The hypothesis is rejected if p is smaller than 0.05 in which case a significant relationship exists. The results of the calculations between the perceived importance of an individual competency and success in terms of job responsibility are presented in table 5.28.

Competency	$X^2(4)$	p	Significant
Ability to synthesise	15.532	.004	*
Analytical skills	20.308	.000	*
Problem solving skills	19.642	.001	*
People Management skills	11.502	.021	*
Operational Management skills	14.657	.005	*
Written communication skills	2.553	.635	
Oral communication skills	1.356	.852	
Net worker	5.345	.254	
Have broad technical knowledge	53.517	.000	*
Have specialist technical knowledge	53.962	.000	*
Ability for life-long learning	20.216	.000	*
Ability to work in teams	3.456	.485	

Table 5.28 Results of the χ^2-test for the perceived importance by alumni of a competency for the alumni's job and success in terms of job responsibility (= significant relationship exists)*

From table 5.28 it can be seen that there are eight competencies whose perceived importance for an alumni's current job have a significant relationship with job success in terms of job responsibility. The contingency tables in Appendix F show that for all competencies which showed significant relationship, a positive relationship exists. This means that the majority of those alumni who find a competency for their current job very important can be classed as above average successful themselves. This can be interpreted that for an alumni to obtain success in terms of job responsibility they end up in jobs for which having these competencies are important. Therefore, mastering the competencies concerned: the ability to synthesise, analytical skills, problem solving kills, people and operational management skills, have broad technical knowledge and specialist technical knowledge as well as the ability for life-long learning can be beneficial towards job success in terms of job responsibility.

The results displayed in table 5.29 show that there are also eight competencies whose perceived importance for an alumni's current job have a significant relationship with success in terms of salary and years of work experience: people and operational management skills, oral communication and networking skills, broad and specialist technical knowledge, the ability of life-long learning and the ability to work in teams. The contingency tables in

Appendix F show however, that the relationship between the competencies and success is not straightforward. For people and operational management skills as well as oral communication skills (tables F.2a to c) a positive relationship exists between those competencies and job success in terms of salary with work experience. For networking skills (table F.2d), the ability of life-long learning (table F.2g) and the ability to work in teams (table F.2h) the type of relationship is not clear as the tables appear to show that regardless of how successful one is those competencies are perceived as important. Finally, a negative relationship appears to exist for the competencies broad and specialist technical knowledge (tables F.2e and f) as they appear to show that specialist and broad technical knowledge are not perceived as important in their current job for those who are average or above average successful.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	3.989	.407	
Analytical skills	.445	.979	
Problem solving skills	6.126	.190	
People Management skills	82.391	.000	*
Operational Management skills	56.796	.000	*
Written communication skills	9.426	.051	
Oral communication skills	23.650	.000	*
Net worker	28.714	.000	*
Have broad technical knowledge	17.904	.001	*
Have specialist technical knowledge	27.462	.000	*
Ability for life-long learning	12.617	.013	*
Ability to work in teams	18.016	.001	*

Table 5.29 Results of the χ^2-test for the perceived importance by alumni of a competency for the alumni's job and success in terms of salary and work experience (= significant relationship exists)*

It can be concluded that in order to be financially successful, people and operational management skills, oral communication skills are skills that are important in the jobs of above average successful people. It also shows that the competencies broad and specialist technical knowledge are not important for their job for those in average or above average successful jobs. Finally, it can be said that networking skills, the ability for life-long learning and team working skills are important or very important for all alumni regardless whether they are financially successful.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	10.883	.028	*
Analytical skills	16.688	.002	*
Problem solving skills	13.975	.007	*
People Management skills	62.575	.000	*
Operational Management skills	52.856	.000	*
Written communication skills	1.028	.906	
Oral communication skills	17.028	.002	*
Net worker	11.473	.022	*
Have broad technical knowledge	8.736	.068	
Have specialist technical knowledge	9.999	.040	*
Ability for life-long learning	6.363	.174	
Ability to work in teams	10.873	.028	*

Table 5.30 Results of the χ^2-test for the perceived importance by alumni of a competency for the alumni's job and success in terms of salary and work experience and job responsibility (= significant relationship exists)*

When looking if a significant relationship exists between the perceived importance by alumni of a competency for an alumni's job and success in terms of salary with work experience and job responsibility, nine such significant relationships exist as indicated in table 5.30. These concern the competencies ability to synthesise, analytical skills, problem solving skills, people and operational management skills, oral communication and networking skills, specialist technical knowledge, and the ability to work in teams. When examining the contingency tables of each competency, these competencies can be split into three groups. The first group of competencies consists of the ability to synthesise (table F.3a) and operational management skills (table F.3e). Both show a positive relationship. The second group consists of the competencies analytical skills (table F.3b), problem solving skills (table F.3c), people management skills (table F.3d), oral communication skills (table F.3f), networking skills (table F.3g), and the ability to work in teams (table F.3i). For this group the relationship is not immediately clear but again the tables appear to show that regardless of how successful one is those competencies are important. The last group is formed by the competency specialist technical knowledge.

Again the relationship is not immediately clear but in this case the contingency table F.3h shows that the importance of specialist technical knowledge is either neutral or not important for an alumni's current job, especially for those who are average or above average successful.

Based on the results displayed in table 5.30 and Appendix F it can be concluded that specialist technical knowledge may not be as important in the current job of alumni who have achieved average or above average job success in terms of salary with work experience and job responsibility. It also shows that the other eight competencies are important to achieve job success in terms of salary with work experience and job responsibility in the current job of successful alumni.

The alumni's perceived ability in competencies

When looking for a significant relationship between an alumnus' perceived ability in a competency and their success in terms of job responsibility, it can be seen from table 5.31 that significant relationships were only found for broad technical knowledge and specialist technical knowledge.

Competency	$\chi^2(2)$	p	Significant
Ability to synthesise	0.362	.835	
Analytical skills	†		
Problem solving skills	†		
People Management skills	1.622	.444	
Operational Management skills	.309	.857	
Written communication skills	.979	.613	
Oral communication skills	4.093	.129	
Net worker	1.273	.539	
Have broad technical knowledge	6.013	.049	*
Have specialist technical knowledge	44.073	.000	*
Ability for life-long learning	0.105	.949	
Ability to work in teams	1.465	.481	

Table 5.31 Results of the χ^2-test for the alumnus' perceived ability in a competency and success in terms of job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

Further exploration of the contingency tables of these two competencies (see Appendix F) shows that being competent in broad technical knowledge has little or no positive influence on successfulness. However, looking at specialist technical knowledge it appears that, percentage wise, considerably more successful alumni in terms of job responsibility are competent in specialist technical knowledge. It can therefore be concluded that specialist technical knowledge may not be necessary in alumni's current job as previously discussed but that, percentage wise, more of the alumni who are competent in special technical knowledge are successful in terms of job responsibility which could indicate that specialist technical knowledge may have been helpful in getting them into their current job in the first place.

Competency	$\chi^2(2)$	p	Significant
Ability to synthesise	3.421	.181	
Analytical skills	†		
Problem solving skills	†		
People Management skills	16.804	.000	*
Operational Management skills	26.711	.000	*
Written communication skills	3.223	.200	
Oral communication skills	4.626	.099	
Net worker	5.982	.050	
Have broad technical knowledge	14.038	.001	*
Have specialist technical knowledge	34.489	.000	*
Ability for life-long learning	6.898	.032	*
Ability to work in teams	0.671	.715	

Table 5.32 Results of the χ^2-test for the alumnus' perceived ability in a competency and success in terms of salary and work experience (= significant relationship exists, † = impossible to calculate χ^2)*

However, when looking at the second success criterion, salary with respect to work experience, five significant relationships were found: the competencies people and operational management skills, broad and specialist technical knowledge and the ability for life long learning. The contingency tables for each of these competencies in Appendix F show that more, percentage wise, average successful and above average successful alumni are competent in people or operational management skills, again highlighting their importance. The opposite tendency is shown for the other three competencies. It appears that there are less, percentage wise, above average successful alumni in terms of salary with work experience competent in the competencies broad and specialist technical knowledge and ability for life-long learning.

Competency	$\chi^2(2)$	p	Significant
Ability to synthesise	4.338	.111	
Analytical skills	†		
Problem solving skills	†		
People Management skills	9.401	.009	*
Operational Management skills	20.473	.005	*
Written communication skills	2.851	.240	
Oral communication skills	4.364	.113	
Net worker	5.246	.073	
Have broad technical knowledge	2.659	.265	
Have specialist technical knowledge	10.088	.006	*
Ability for life-long learning	3.103	.212	
Ability to work in teams	0.075	.963	

Table 5.33 Results of the χ^2-test for the alumnus' perceived ability in a competency and success in terms of salary and work experience and job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

Finally, looking at the third success criterion, salary with respect to work experience and job responsibilities, significant relationships were found for the competencies people and operational management skills and specialist technical knowledge, see table 5.33. An examination of the contingency tables in Appendix F indicates that there are more, percentage wise, average successful and above average successful alumni competent in people or operational management skills than below average successful alumni. For specialist technical knowledge the relationship is not directly clear. From the contingency table in Appendix F (table 6c) it appears that percentage wise fewer average successful alumni are competent in specialist technical knowledge.

The perceived importance of competencies for an engineering specialist

Inspection of table 5.34 indicates that there are no significant relationships between the perceived importance by alumni of a competency for an engineering specialist and job success in terms of job responsibilities.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	1.741	.783	
Analytical skills	2.818	.589	
Problem solving skills	†		
People Management skills	†		
Operational Management skills	†		
Written communication skills	8.376	.079	
Oral communication skills	3.227	.521	
Net worker	0.562	.967	
Have broad technical knowledge	1.714	.788	
Have specialist technical knowledge	†		
Ability for life-long learning	†		
Ability to work in teams	3.603	.462	

Table 5.34 Results of the χ^2-test for the perceived importance by alumni of a competency for an engineering specialist and success in terms of job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

However, for success in terms of salary with work experience, see table 5.35, two significant relationships were found for the competencies networking skills and ability to work in teams.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	3.016	.555	
Analytical skills	†		
Problem solving skills	†		
People Management skills	†		
Operational Management skills	†		
Written communication skills	8.873	.064	
Oral communication skills	5.504	.239	
Net worker	10.538	.035	*
Have broad technical knowledge	2.953	.566	
Have specialist technical knowledge	†		
Ability for life-long learning	†		
Ability to work in teams	10.426	.034	*

Table 5.35 Results of the χ^2-test for the perceived importance by alumni of a competency for an engineering specialist and success in terms of salary and work experience (= significant relationship exists, † = impossible to calculate χ^2)*

Inspecting the contingency tables in Appendix F, demonstrates that networking skills are not deemed important for engineering specialists by any of the alumni regardless of their successfulness.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	2.094	.719	
Analytical skills	†		
Problem solving skills	†		
People Management skills	†		
Operational Management skills	†		
Written communication skills	1.308	.860	
Oral communication skills	0.664	.956	
Net worker	4.827	.306	
Have broad technical knowledge	1.922	.750	
Have specialist technical knowledge	†		
Ability for life-long learning	†		
Ability to work in teams	13.310	.010	*

Table 5.36 Results of the χ^2-test for the perceived importance by alumni of a competency for an engineering specialist and success in terms of salary and work experience and job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

Only one significant relationship between job success in terms of salary with work experience and job responsibilities was found (see table 5.36): the ability to work in teams. The contingency table in appendix F shows a positive tendency, meaning that the ability to work in teams is important to very important for engineering specialists according to average successful and above average successful alumni.

The perceived importance of competencies for an engineering manager

The results of the calculations for a relationship between the perceived importance by alumni of a competency for an engineering manager and success in terms of job responsibility are shown in table 5.37. Only for the competency broad technical knowledge a significant relationship was found.

The contingency table in appendix F (table F.9) shows that of the below average successful in terms of job responsibility 37.2% answered the question with neutral or important and only 20.2% with very important, in contrast with the above average successful were 21.0% answered the question with neutral or unimportant and 36.1% with very important.

Competency	$X^2(4)$	p	Significant
Ability to synthesise	1.866	.760	
Analytical skills	2.316	.678	
Problem solving skills	2.592	.628	
People Management skills	†		
Operational Management skills	4.929	.295	
Written communication skills	0.577	.966	
Oral communication skills	†		
Net worker	5.374	.251	
Have broad technical knowledge	16.714	.002	*
Have specialist technical knowledge	†		
Ability for life-long learning	9.081	.059	
Ability to work in teams	1.880	.758	

Table 5.37 Results of the χ^2-test for the perceived importance by alumni of a competency for the engineering manager and success in terms of job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	4.398	.355	
Analytical skills	10.198	.037	*
Problem solving skills	12.088	.017	*
People Management skills	†		
Operational Management skills	3.688	.453	
Written communication skills	9.093	.059	
Oral communication skills	†		
Net worker	14.602	.006	*
Have broad technical knowledge	5.165	.271	
Have specialist technical knowledge	†		
Ability for life-long learning	3.871	.424	
Ability to work in teams	3.561	.469	

Table 5.38 Results of the χ^2-test for the perceived importance by alumni of a competency for the engineering manager and success in terms of salary and work experience (= significant relationship exists, † = impossible to calculate χ^2)*

The results in table 5.38 show that for three competencies a significant relationship exists with success in terms of salary with work experience: analytical skills, problem solving skills and networking skills. A closer examination of these relationships using the contingency tables in Appendix F shows a positive relationship for analytical skills, for the other two competencies a conclusion with regard to what the relationship is cannot be drawn.

Competency	$\chi^2(4)$	p	Significant
Ability to synthesise	17.622	.001	*
Analytical skills	6.275	.180	
Problem solving skills	8.379	.079	
People Management skills	†		
Operational Management skills	3.239	.519	
Written communication skills	0.489	.975	
Oral communication skills	†		
Net worker	0.403	.982	
Have broad technical knowledge	5.006	.287	
Have specialist technical knowledge	†		
Ability for life-long learning	2.889	.576	
Ability to work in teams	4.442	.349	

Table 5.39 Results of the χ^2-test for the perceived importance by alumni of a competency for engineering manager and success in terms of salary and work experience and job responsibility (= significant relationship exists, † = impossible to calculate χ^2)*

Finally, from table 5.39 it can be observed that only the ability to synthesise has a significant relationship with success in terms of salary with work experience and job responsibility. However, from inspection of the contingency table in Appendix F no obvious relationship appears to exist.

Analysis per type engineer: engineering manager or engineering specialist

To further explore whether any specific competency is perceived to be important for engineering specialists or engineering manager the data was split in those viewing themselves as engineering specialist, those viewing themselves as engineering managers and undecided. χ^2-tests were run on the split data file to see what engineering specialists perceive to be important for their own group and what engineering managers think is important for themselves.

The results for the engineering specialists showed that there was no significant relationship between the importance of a competency for an engineering specialist and the success definitions. However, it must be noted that for the vast majority (26 out of 36) of competencies the calculations could not be calculated due to lack of data.

Results for the engineering manager showed there were significant relationships between the importance of a competency for an engineering manager for the competency broad technical knowledge with success in terms of job responsibility $\chi^2(4) = 17.250$, $p = .002$ and success in terms of salary with work experience $\chi^2(4) = 17.029$, $p = .889$. Also a significant relationship was found between the competency people management skills and success in terms of salary with work experience and job experience, $\chi^2(4)=8.751$, $p = .013$. Again it must be mentioned here that 12 out of 36 relationships could not be calculated due to insufficient data in certain data categories. The contingency tables of Appendix F show that having broad technical knowledge is important but not very important to be successful in terms of job responsibility or salary with work experience. With regards to people management skills there is a definite positive relationship.

5.7.2 Investigation of links between the importance of overall competency and success

In this section the research questions on the relationship between the three defined types of job success and the overall competencies will be assessed. The overall competencies are calculated by adding the scores of each respondent of all the competencies together. This results in an overall continuous competency variable, with values between 12 and 60 or 12 and 48 depending on whether a 4- or a 5- point Likert scale was used. In the case of this research these continuous variables are: the total perceived importance by alumni of the competencies, the total of perceived level of an alumnus' competence in the competencies, the perceived importance by alumni of the competencies for engineering specialists and the perceived importance by alumni of the competencies for engineering managers.

To assess if a relationship exists between a continuous variable (overall competency level) and a categorical variable (the groups of successful engineers from the success definitions in Chapter 4) there are two statistical tests that can be used. The first, a one way between groups ANOVA, cannot be used as the data is not normally distributed thus violating a primary condition for the use of this statistic. The second option is to use a Kruskall-Wallis test (Pallant 2005) which allows the user to compare a score on a continuous variable for three or more groups. It can be used on any random sample with independent observations as is the case here.

A Kruskall – Wallis test (Field, 2005) has as input ranked data. That is, all the scores from the continuous variable are ordered from lowest to highest regardless to which group of the categorical variable it belongs to and assigned a rank number. These rank numbers are subsequently ordered into the groups of the categorical value and added up. From this the test statistic H is calculated:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) \qquad (5.4)$$

In this equation N is the total sample size, n the sample size of a particular group and R_i the sum of the ranks for each group. The H-test statistic has a χ^2-distribution. Similarly to a χ^2-test, it can be calculated whether a significant relationship exists. The null hypothesis used is that there is no significant relationship unless the probability p is smaller than 5%. This is determined using χ^2- distribution standard tables (see Field 2005) in which the probability is listed as a function of the χ^2-score and the degrees of freedom of the variables. The degrees of freedom, df of the H-test statistic is calculated using:

$$df = k - 1 \qquad (5.5)$$

In which k is the number of the groups of the categorical variable. In the case of the success definitions $k = 3$ as there are three groups: below average successful, average successful, and above average successful. A one way significant relationship exists if the probability $p < 0.05$ thus rejecting the null hypothesis.

However, the Kruskall – Wallis test only indicates whether a significant relationship exists. It does not indicate what type of relationship. As this is of interest in the research of this thesis a post-hoc test has to be carried out. To be able to report the trend of a relationship for each significant relationship found, the Jonckheere-Terpstra test (Field, 2005) was applied.

A Jonckheere-Terpstra test allows for prediction of the trend of the medians of the three defined groups. It does this by incorporating information on whether the order of the groups is meaningful. In the case of this research it is expected that the level of competency goes up if the group is more successful.

The test-statistic J looks at how frequently different values occur and has a normal distribution. To calculate J it must counted for each of the categorical variables how often in the subsequent groups a score occurs that are higher than the score in that particular group. J is the sum of these counts:

$$J = \sum_{i<j}^{k} U_{ij} \tag{5.6}$$

In equation (5.6) U_{ij} is the score per subsequent group for the continuous variable. Next a z-score is calculated which is the value of the observation expressed in the standard deviation as it is calculated using:

$$z = \frac{J - \bar{J}}{\sigma_j} \tag{5.7}$$

It is calculated by taking the value of J, subtracting the mean of the sampling distribution $\bar{J}$ from it and dividing it by the standard deviation of the J statistic, σ_j. The mean sampling distribution $\bar{J}$ is defined as:

$$\bar{J} = \frac{N^2 - \sum n_k^2}{4} \tag{5.8}$$

With N the total sample size and n_k the sample size of each of the groups of the categorical value. The z-value can be compared against the standard tables for the normal distribution and is deemed significant if the absolute value for $z <$ 1.65 as the standard tables for normal distribution show that this indicates a probability $p < 0.05$. The final output is the effect size r_j. This variable shows whether a positive or negative effect exists. The value of r_j is calculated using:

$$r_j = \frac{z}{N} \tag{5.9}$$

A positive value of r_j indicates a positive relationship, and a negative value indicates a negative relationship between success and the perceived level of competence.

For the research in this thesis a Kruskall-Wallis test was performed to see for each of the continuous variables listed below if there was a relationship with the three success definitions from Chapter 4:

- the total perceived importance by alumni of the competencies,
- the total of perceived level of an alumnus' own competence in the competencies,

- the perceived importance by alumni of the competencies for engineering specialists,
- the perceived importance by alumni of the competencies for engineering managers.

If a significant results was found a Jonckheere-Terpstra test was performed to see what the trend of relationship was.

The first to be examined was the total perceived importance by alumni of competencies and professional success, which is shown in table 5.40.

	Total perceived importance by alumni of competencies for current job						
Success definition:	N	H(2)	p	Sign.	J	Z	r_j
Job responsibilities	645	22.800	.000	*	77823	4.752	.19
Salary with years of work experience	644	17.823	.000	*	79253	4.248	.17
Salary with years of work experience and job responsibilities	635	41.096	.000	*	82454	6.356	.25

Table 5.40 Results of the Kruskall-Wallis test for the total perceived importance by alumni of competencies for current job and success (= significant relationship exists)*

Inspection of the table indicates that significant relationships do exist between the overall perceived importance by alumni of the set of competencies for alumni's current job and the success definitions used. The results of the Jonckheere-Terpstra test show that a positive trend exists between being successful and the perceived importance of competencies. This reaffirms that the collective set of competencies is important for professional success.

Table 5.41 shows the results of the total perceived ability level of one's own competencies, although it must be kept in mind here that the scale of overall competence level in competencies was not found to be very reliable in Chapter 4.

		Total perceived ability level in competencies of alumni					
Success definition:	N	H(2)	p	Sign.	J	Z	r_j
Job responsibilities	647	3.194	.203	-	-	-	-
Salary with years of work experience	649	11.426	.003	*	78102	3.389	.13
Salary with years of work experience and job responsibilities	638	11.535	.003	*	75045	3.117	.12

Table 5.41 Results of the Kruskall-Wallis test for the total perceived ability level of one's own competence and success (= significant relationship exists)*

In this table two significant relationships were found: for salary with years of work experience and for salary with work experience and job responsibilities each with a positive trend in terms of success, and total ability level in the competencies of the alumni.

		Total perceived importance by alumni of competencies for engineering specialists					
Success definition:	N	H(2)	p	Sign.	J	Z	r_j
Job responsibilities	628	5.292	.071	-	-	-	-
Salary with years of work experience	630	6.296	.043	*	59649	-2.301	-.09
Salary with years of work experience and job responsibilities	620	1.629	.443	-	-	-	-

Table 5.42 Results of the Kruskall-Wallis test for the perceived total importance by alumni of competencies for engineering specialists and success (= significant relationship exists)*

The results of the tests carried out for the perceived total importance by alumni of competencies for engineering specialists and engineering managers are shown in tables 5.42 and 5.43 respectively. These results show only one significant relationship, between salary with years of work experience and the total importance of competencies for an engineering specialist. The Jonckheere-Terpstra results show a negative trend. The group of alumni classed as below average successful find the overall list competencies more important for engineering specialists than those who are above average successful.

	Total perceived importance by alumni of competencies for engineering manager			
Success definition:	N	H(2)	P	Sign.
Job responsibilities	628	2.160	.340	-
Salary with years of work experience	629	2.946	.229	-
Salary with years of work experience and job responsibilities	619	2.778	.249	-

Table 5.43 Results of the Kruskall-Wallis test for the total perceived importance by alumni of competencies for engineering managers and success (= significant relationship exists)*

From these results it can be concluded that a significant positive relationship exists between the importance of the set of competencies and professional success. Also a reasonably significant relationship seems to exist between the ability of alumni in the set of competencies as a whole and professional success.

No other relationships however, between the overall scores for competency questions and professional success could be computed. The scores for the competencies were found to be not normally distributed, hence violating the assumptions of any analysis of variance tests.

5.7.3 Investigation of the contribution of aerospace engineering to the competencies and success

The first step here was to investigate whether there were any significant relationships between the contribution of their aerospace engineering degree to a specific contribution as perceived by the alumni and job success. A χ^2-test was carried out for each competency and each success definition but no significant ($p < 0.05$) relationships were found for any of the competencies.

Secondly, to assess the total perceived contribution of aerospace engineering degree to the mastering of the competencies developed in Chapter 3 a Kruskall - Wallis test was again carried out. The results found in the table below show that no significant relationship was found.

	Total contribution of aerospace engineering degree to competencies			
Success definition:	N	H(2)	p	Sign.
Job responsibilities	647	1.905	.386	-
Salary with years of work experience	648	3.193	.203	-
Salary with years of work experience and job responsibilities	637	5.864	.053	-

Table 5.44 Results of the Kruskall-Wallis test for the total perceived contribution of their aerospace engineering degree to the acquiring the competencies and success (= significant relationship exists)*

This means no statistically significant evidence was discovered during the survey with regards to the contribution of aerospace engineering to the list of competencies and professional success.

This completes the discussion of the results of the alumni survey. In Chapter 6 the main conclusions and the consequences of these findings will be discussed as well as what recommendations with regards to future alumni research and future aerospace engineering curricula at Delft University of Technology can be made.

'The ideal engineer is a composite ... He is not a scientist, he is not a mathematician, he is not a sociologist or a writer; but he may use the knowledge and techniques of any or all of these disciplines in solving engineering problems.'

N. W. Dougherty, 1955
President American Society for Engineering Education

CHAPTER 6: REFLECTION, DISCUSSIONS AND RECOMMENDATIONS

The research reported in the previous chapters was inspired by the question whether the current curriculum at the Faculty of Aerospace Engineering at Delft University of Technology sufficiently prepares aerospace engineers for the emerging 'Knowledge Society'.

In order to answer this question it was decided to perform a study on the alumni of the Faculty of Aerospace Engineering at Delft University of Technology. This question was further developed into three main research questions:

1. *What competencies differentiate successful engineers from those with less successful careers?*
2. *Do engineers working as engineering managers and engineering specialists need different competencies to be successful*
3. *What are the consequences of the outcomes with regards to the representation of competencies in the aerospace engineering curriculum at Delft University of Technology?*

Alumni were chosen as research subject as they are, after all, in the best situation to assess the impact of their degree in aerospace engineering on their professional success and comment on what are important qualities for aerospace engineers to have in order to differentiate themselves from those with an average career. To discover what those qualities were, a literature survey was carried out which identified a number of competencies. These competencies were put in front of an expert panel consisting of employers of aerospace engineers. Based on a literature survey and feedback of an expert panel a list of 12 competencies, deemed important for the professional success of alumni, was developed (see table 6.1):.

Competencies	
C.1.	Ability to synthesise
C.2.	Analytical skills
C.3.	Problem solving skills
C.4.	People management skills
C.5.	Operational management skills
C.6.	Written communication skills
C.7.	Oral communication skills
C.8.	Net worker
C.9.	Have broad technical knowledge
C.10.	Have specialist technical knowledge
C.11.	Ability for life-long learning
C.12.	Ability to work in teams

Table 6.1 Final list of competencies indicative of the successful engineer

It was also derived from literature that there are two principal career tracks of aerospace engineers: that of the *engineering specialist* and that of the *engineering manager*. Hence it was decided to find out if there were different competencies needed to be successful as an engineering specialist than as an engineering manager.

The second step was to define success. Based on the literature survey carried out, a decision was taken to limit success to three factors: level of job responsibility, salary with respect to work experience and the combination of the two: salary with respect to work experience and level of job responsibility. Other definitions of success such as personal satisfaction (Vermeulen-Kerstens, 2006) or age were not included.

In order to answer the main research questions all aerospace alumni, listed in the Delft Alumni Office database, who graduated between 1975 and 2000, were approached using a questionnaire. The response to the questionnaire (40%) was good compared to similar large scale alumni questionnaires.

In the next sections the research questions will be answered and the results discussed and reflected on. The first two research questions are answered in section 6.1, section 6.2 reflects on the alumni of the Faculty of Aerospace

Engineering at TU Delft, whilst the last research question is answered in section 6.3. In section 6.4 the methodology used is commented on and in section 6.5 recommendations with regard to future research are made.

6.1 Reflections and Conclusions on the Importance of Competencies for Engineers

In order to answer the first two research questions the competencies compiled in Chapter 3 were analysed in Chapter 5. The main results of these analyses are summarised below

The competencies were analysed in three ways: First, the score for individual competency, secondly, by investigating links between an individual competency and professional success and finally, by looking at relationships between the set of competencies and professional success.

From the analysis of the importance of each competency it was found that they were all important to a certain degree for an alumnus' current job. When looking at whether any relationships existed between professional success and individual competencies, the results varied depending on the success definition used. Most competencies were found to have a significant positive relationship with one of the three success factors, apart from written communication skills for which no significant relationship was found. All relationships were positive with two sets of exceptions. Firstly, the competencies networking skills, ability to work in teams and ability for life-long learning have a significant relationship with the success factor salary in terms of work experience; however, there is no negative or positive trend in the relationship. The second exception is the negative relationship between success in terms of salary with work experience and job responsibility and specialist technical knowledge.

No significant relationship was found, between the contribution of aerospace engineering to the set of competencies and professional success. This means it is more difficult to draw general conclusions on how specific elements of the aerospace engineering programme contributed to the professional success of its alumni through these competencies as a whole. Also no significant relationship was found between the contribution of aerospace engineering to an individual competency and professional success. Comments can be made about how aerospace engineering contributed to the acquisition of individual competencies. From the results in Chapter 5 (figure 5.12) it can be seen that the alumni feel that the degree course in aerospace engineering did not contribute much to the competencies people management skills, operational management skills and networking skills, neither did their degree contribute to the competencies oral communication skills and the ability for life long learning.

The results also showed that when asked to rate their ability in an individual competency that the alumni feel they are less capable in people and operational management skills as well as networking skills. In terms of the links between individual ability in a competency and professional success a positive relationship was found for specialist and broad technical knowledge and success in terms of job responsibility but negative relationships were found between specialist technical knowledge and success in terms of salary with work experience as well as success in terms of salary with work experience and job responsibility. Other positive relationships found were between the ability in people and operational management skills and success in terms of salary with work experience and salary with work experience and job responsibility, again highlighting the importance of these competencies for a successful career.

As mentioned earlier the data was too positively skewed to carry out an analysis of variance calculation to see if engineering specialists and engineering managers needed different competencies for success. Instead the perception of all respondents on what competencies are important for engineering specialists and engineering managers was plotted next to what engineering specialists and engineering managers themselves thought were important competencies (see figures 5.10 and 5.11 in Chapter 5). It was found from those figures that engineering specialists feel that people management and operational management skills as well as networking skills are important for them to do their job. The general feeling amongst the respondents was that these three competencies were less important. It may be that as a result of this general feeling that these needs are not sufficiently taken into account in the education of engineering specialists. It was also found that although specialist technical knowledge is important to engineering specialists, it is not as important as all the respondents tended to think. Engineering specialist indicated that having a broad technical knowledge is almost as important as specialist technical knowledge. When looking at engineering managers it was found that engineering managers still find analytical skills important contrary to the general perceptions of respondents.

Before answering the main research questions it can be concluded that, as positive relationship was found between the perceived importance of the set of competencies as a whole and professional success, the list of table 6.1 is a very valid list of competencies aerospace engineers should possess to be successful in their jobs.

With regards to the first research question, it can be concluded from the results of the analyses that finding specialist technical knowledge important for one's current job you are more likely to be unsuccessful in terms of salary with work experience and job responsibility. It can also be concluded from the results that the competencies networking skills, ability to work in teams, and ability for life-long learning are found to be important regardless of success in terms of salary with work experience. With regards to the perceived ability in a competence of an alumnus it can be concluded that having good specialist technical knowledge does contribute to more job responsibility but not necessarily to more salary. On the other hand being very able in the competencies people and operational management skills will most likely result in being more successful in terms of salary with work experience and salary with work experience and job responsibility.

The answer to the second research question whether engineering managers need different competencies than engineering specialists the answer appears to be no, although no analysis of variance could be carried out. However, both groups indicate that they think all competencies are important to a certain extent, although the extent to which each competency is used in practice were found to differ.

These findings must be taken into account when designing a curriculum such that a balance is found between all the competencies.

6.2 Reflections on Delft Aerospace Alumni and their Experiences

Generally speaking, the alumni of the Faculty of Aerospace Engineering of Delft University of Technology do well. Almost all alumni were employed at the time of the survey and the vast majority, 82% earn well above the median salary for engineers. Just under half of the respondents still work in the aerospace industry and more than two thirds work in a position that requires an engineering degree. Aerospace engineers are still very much in demand and despite the fact that the aerospace industry in the Netherlands has decreased in size, the top 10 list of employers still contains 8 aerospace related companies and institutes. Most aerospace engineers stay in the Netherlands after obtaining their degree.

In terms of further education only one in four alumni undertake formal forms of further education such as a PhD degree or an additional Master degree. If they do continue in a form of further formal education other than a PhD degree, it is most likely an MBA or other business studies related degrees. It appears aerospace engineers are sufficiently equipped when they enter the work force. Additional degrees only appear to broaden their scope.

It was also found that quite a considerable number of aerospace engineers deem themselves to be engineering managers or undecided. However, according to industry and governments alike, society desperately needs more engineering specialists. It may be that a culture change needs to be brought about which should make choosing the career option of becoming an engineering specialist (financially) more attractive.

Since the last time degree satisfaction amongst the entire aerospace alumni population was researched (VSV Leonardo da Vinci, 1980), aerospace engineers have grown more satisfied with their degree. 75% of the aerospace alumni would choose to do a degree in aerospace engineering again if they had a choice as opposed to 35.7 % in 1980 with 36% saying maybe. From this it may be concluded that curriculum changes over the past 25 years must have had a positive effect of some kind on degree satisfaction.

Finally, the reputation of the degree in aerospace engineering in Delft is still very much intact among alumni. The overwhelming majority of the respondents (87%) would recommend the current degree course in aerospace engineering to someone else.

6.3 Consequences for the Current and Future Aerospace Curriculum at TU Delft

From the previous section it can be concluded that the degree in Aerospace Engineering at Delft University of Technology as a whole is still held in high esteem by its alumni. Based on the research reported in this thesis the consequences for the current and future aerospace curriculum of TU Delft have been shaped in the form of conclusions and recommendations with regards to the current and future curriculum. Recommendations are given both on the content of the curriculum as well as recommendations on the way curriculum is taught.

First of all the results of the results with regard to the courses in the curriculum are discussed. The alumni, when asked to name which three courses they thought they still benefited from today, named most courses currently still taught at aerospace engineering (see table 5.15). From the results it can be concluded that the most beneficial courses for alumni are the courses which emphasize synthesis and closely resemble the later professional work environment such as the MSc thesis, the internship and the design exercises. This in itself is of course not unusual: those courses most closely resemble professional practice. Next to that, it also shows that designing courses in this form has a longer lasting effect than that of single courses. Interestingly, there is also a clear need for fundamental courses such as mathematics, mechanics and structures. By contrast the results showed less need for the more specialist aerospace courses. This will partly be because 60% of the graduates work outside the aerospace industry which reduces their need for those courses but on the other hand it also shows that too much specialisation is not as important as might be perceived by those teaching those courses. Also when asking alumni about the importance of competencies they indicated that specialist technical knowledge is not as important as is commonly thought, even for engineering specialists. Engineering specialists indicate that broader technical knowledge serves them better.

These findings suggest that the curriculum needs to focus on three things to prepare aerospace engineering better for their professional careers: a good basic grounding in the fundamental subjects of mathematics, structures and mechanics, the fundamental aerospace courses without too much specialisation, and ensure that the design of courses closely resembles the professional working environment.

Current and future curricula, both in the BSc and MSc should avoid focussing too much on specialist courses. The added benefit of these courses is limited. For the BSc degree this means a clear focus on core aerospace topics and to not introduce too many different subjects. Students should have a solid foundation without too much diversification. Only in this way students will enter the MSc phase with sufficient engineering knowledge. Their good basic grounding will then allow them to tackle any MSc variant in aerospace engineering of their interest. In order to show students what research fields are available in terms of specialisation it would be a good idea to imbed those in the educational projects as students can in that way get a very realistic flavour of a certain research field.

Taking a look at the current curriculum in the MSc phase at TU Delft there is an even greater tendency to have a course for every single specialism, each course, of which is deemed absolutely essential by those teaching it before a student can obtain their MSc. To further clarify this point there are currently 25

MSc variants within aerospace engineering in which more than 120 different MSc courses in aerospace engineering subjects alone are offered. In the current system of financing of MSc courses funding is allocated per passed course, per student, per ECTS. This makes teaching courses attended by very few students an expensive way of teaching and alternative teaching strategies really should be explored here. These alternatives could consist of ideas such as teaching students research and intellectual skills such as the ability to solve problems, the ability to analyse and the ability for life long learning allowing them to independently, on their own or in small groups, gain the specialist knowledge needed for their MSc thesis rather than prescribing endless small courses. This will also considerably lighten the teaching load of members of staff.

As described earlier in this chapter most of the competencies developed have a positive relationship with professional success of aerospace alumni. It was also shown that the contribution of their degree in aerospace engineering to those competencies leave something to be desired. Skills such as networking skills, operational and people management skills and oral communication skills must become an integral part of the curriculum as this research has shown that they affect the professional success of aerospace alumni and that alumni feel that their degree aerospace engineering has not sufficiently contributed to those skills.

Looking at the current curriculum (Faculty of Aerospace Engineering, 2007a and b) a successful attempt has already been made to implement the teaching of the competency oral communication skills. A course in oral presenting is a mandatory part of the BSc curriculum and should remain so. For the remaining skills creating opportunities in the aerospace curriculum for students to develop and be assessed on networking skills as well as operational and people management skills is highly recommended. Suggestions could be that students are encouraged to work in a business type environment learning to write business plans and to expose students to an environment where they also have to learn to manage people. A perfect setting to stimulate this in is Project Based Learning, for instance by introducing a business project where students assume roles in a business and must involve outsiders.

Currently, some of the competencies listed in this research have already been imbedded in the projects which were introduced after the curriculum change in 1995. From the first year onwards students are made to work in teams and the development of synthesis skills is central those projects. Written reporting is also imbedded from the very first project onwards. The most successful example of integrating competencies within the current aerospace engineering curriculum at TU Delft is the third year Design Synthesis Exercise. In the exercise competencies such as the ability to synthesise, problem solving skills, analytical skills, oral and written communication skills, team working skills and the ability for life-long learning are already firmly imbedded. Next to that it also already makes a first, not yet formalised attempt for students to practice networking and people management skills as it already actively encourages students to go out and find support outside the regular framework of the exercise. This developing of networking and people management skills should be further encouraged and become a formal assessment criterion. This way the exercise will become even more effective.

A further way to encourage students to develop themselves in competencies such as networking and people management skills is to make it educationally more attractive to take part in student design competitions, such as the SAE Formula student competition, the World Solar Challenge, the Micro UAV competition and the International Submarine Races in which students work together in often multi-disciplinary teams to design, build, finance and race a vehicle. Currently, it is not always easy for students at aerospace engineering at TU Delft to get educational credit for taking part in these projects. This only happens on a case-by-case basis application to the Board of Examiners or because of good will of individual lecturers, unlike other universities (Ponsen, 2007) where a formalised system for the educational recognition for this type of activities has been set up. Aerospace Engineering students from TU Delft are actively taking part in these projects at the moment, and the teams are very successful in their achievements winning many of these competitions.

6.4 Reflections and Discussions on Methodology

In this section the methodology used in the research is reflected on. In the survey the alumni were asked to rate the importance of each competency for their current job and how important they thought the competencies were for engineering specialist and engineering managers. This was done on a 5-point Likert scale ranging from totally unimportant to very important. The scales were proven to be reliable (see Chapter 4) but the data was very positively skewed, which hampered the statistical analysis for any further investigation of the link between the importance of the overall set of competencies and success through an analysis of variances. A straightforward solution to the skewdness of this data does not exist. It was also not possible to rescale the data such that a normal distribution could be found. On the positive side, the reason the data was very positively skewed was that the competencies were found to be important to very important, which indicates that the list of competencies was very valid.

The alumni were then asked to rate themselves in each of the competencies and indicate to what degree their aerospace engineering degree contributed to the competencies. These two questions used a 4-point Likert scale. A 4-point scale was deliberately chosen in this case to avoid a central tendency bias. The answers to both questions were also positively skewed and therefore the distribution not normal. As this could not be corrected the statistical analysis was again hampered and any analysis of variance could not be carried out. The question to what degree their degree in aerospace engineering contributed to the list of competencies was found to be reliable. However, the question asking 'How competent do alumni perceive themselves in this set of competencies?' had a Cronbach's α of 0.68, which is just below the generally accepted level for a reliable scale. To measure the ability in competencies an alternative may be to link competencies to specific activities as was also done in this research. This scale was found to be highly reliable with a Cronbach's α of 0.851. To link the competencies accurately to day to day activities does require further research into what activity is specifically linked to what competency to further develop this scale as a measuring instrument.

Although the scales measuring the overall set of competencies was somewhat problematic, the effect between individual competencies and success could be calculated for the majority of the cases.

The success factors used in this survey relied heavily on income and responsibility. The availability of income data for engineers in the Netherlands however, is low. Therefore the income of the aerospace engineers was benchmarked against statistical data gathered in 2006. However, this was at the time that pay rises were limited in the Netherlands so its effects can assumed to be negligible.

Finally, although not critical for the answering of the main research questions of this thesis, in the survey the alumni were asked about their area of employment (question 6 of part I of the alumni survey, see appendix D). The division into the different categories was the one used by the Alumni Office of TU Delft. This categorisation was employed in the questionnaire so that the Alumni Office could also update their data, a condition for use of their database. However, from the responses it became clear that the list was not specific enough for our alumni. The alumni found it difficult to distinguish if they were employed as an engineering consultant to indicate for instance if they were working in engineering or in consultancy. Also alumni working for energy companies felt they did not fit anywhere in those categories. This did not hamper the main research but it may be beneficial for the alumni office to redevelop this categorisation of areas of employment.

6.5 Recommendations for Future Research

Institutes of Higher Education can learn much from studying their alumni. Long term study of alumni can give universities a much wider perspective on their degree courses; their relevance to alumni in the work force and their perception of the degree today and the changing needs of society. And yet throughout Europe very little, formal alumni research is carried out. With the arrival of the 'Knowledge Society' more demands will be made on institutes of Higher Education to adapt quicker to the changing educational needs of population as a whole. In order to do so better track of alumni and their needs must be kept. It is important to listen to their opinions and through those opinions learn about the requirements the workplace on the education of aerospace engineers.

The research currently carried out by universities in the Netherlands is too focussed on short term customer satisfaction (WO monitor) and marketing purposes (alumni offices). The need to formalise alumni research in the Netherlands has already been partly recognised by the accreditation authorities (QANU, 2004) however they currently appear to be satisfied with short term following of alumni (WO Monitor). If the continuing quality of degrees is to be taken seriously a more stringent requirement on the tracking alumni should be imposed.

Alumni research in the United States of America is a much more mature research field and helps universities to keep their curricula current with market needs. If Dutch universities are to sufficiently prepare themselves for the changing needs of society they would do well to follow their example. In addition to preparing for the changing needs of society, universities may also be selling themselves short financially. Although alumni are already slowly being approached for research funding, and donations for prizes, they currently do not contribute to the finance of education. At this moment universities rely on funding for education through the government with a relative small contribution from students (20%). Throughout Europe there is an increasing trend in the raising of student fees for Higher Education and a reduced availability of funding for education from governments. In the Netherlands suggestions in parliament have already been made to no longer fund Higher Education beyond Bachelor level. It is therefore not unlikely to expect that government funding will decrease in future; not only for students but also for educational facilities. This means universities will have start looking at alternative ways of funding the education facilities of their students. In the United States of America, alumni form a great part of that funding effort. Keeping track and listening to alumni now, may turn out to pay off significantly in the future.

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APPENDIX A: FINAL OBJECTIVES OF DEGREE 1975 – NOW

Version 1975 – 1994

Final objective 1:
The aerospace engineer must have a thorough knowledge of and insight in the specific requirements posed to aircraft and spacecraft with respect to safety, reliability, its aerodynamic and structural shape and its handling during the flight.

Final objective 2:
The aerospace engineer must be able to independently recognise, formulate and analyse engineering science problems and produce one or more acceptable solutions. He must have the ability to synthesise the different facets, to distinguish between the different possibilities and to be able to perform a trade off between the two.

Final objective 3:
The aerospace engineer must have acquired knowledge and insight of theoretical and experimental research during his degree. He must therefore have the required knowledge and skills in mathematics, physics, mechanics and measuring techniques and he must be able to use specialist literature.

Final objective 4:
The aerospace engineer must be able to clearly report on his engineering science activities both written and orally. Being able to express oneself in Dutch is a requirement, next to that he must be reasonably confident with the use of the English language within his area of specialisation.

Final objective 5:
The aerospace engineer must have gained insight during degree in his abilities and affinities in view of his future professional career.

Final objective 6:
The aerospace engineer must be able, after a short training period, to work in the different fields of aerospace engineering

Final objective 7:
The aerospace engineer must be able to have a clear insight and knowledge of the significance of aerospace for society.

(Source: Faculteit der Luchtvaart- en Ruimtevaartttechniek, 1989)

Version 1995 – 2000

FINAL OBJECTIVE 1: Basic sciences and technical tools

The aerospace engineer requires thorough knowledge of and insight into the scientific fundamentals of engineering including the generic methods and tools of engineering sciences.

Restriction of the breadth
The basic subjects have to be restricted to those fields of knowledge of general engineering which are of fundamental interest for the specific aerospace engineering subjects. The following basic subjects are required:
1. Statics and Dynamics;
2. Solid and Fluid mechanics;
3. Thermodynamics;
4. Electricity;
5. Chemistry.

Other physics subjects as Electromagnetic waves, Quantum mechanics, Optics, and Statistical mechanics are excluded for most (not all) students. The following generic methods and tools of the engineering sciences are required:
1. Parts of mathematics as Analysis (Calculus), Ordinary and Partial differential equations, Linear algebra, Numerical analysis;
2. Informatics;
3. Control theory/Theory of systems (experimental methods and use of instruments).

Restriction of the depth
The knowledge of fundamentals and tools is generic and not object-related. It concerns primarily ‘physics and mathematics for engineers’. The aerospace engineer requires a considerable skill to make these subjects operational in the typical engineering disciplines (Final objectives 2 and 3). The depth must be sufficient to understand the interconnections and coherence between the typical

engineering subjects. Physical modelling and use of mathematical and numerical methods have to be demonstrated (computer use).

FINAL OBJECTIVE 2: General engineering sciences

The aerospace engineer requires knowledge of and insight into the general engineering sciences at such a level that operational use is possible in 'non-standard' situations.

Restriction of the breadth

This objective concerns those engineering subjects with which the freshly graduated aerospace engineer regularly will be confronted in aircraft- and other similar high-tech industries. These subjects (including applications) are:

1. Strength of materials;
2. Engineering mechanics;
3. Materials and manufacturing methods;
4. Design methods in general;
5. Engineering fluid mechanics;
6. Control theory / Theory of systems.

Restriction of the depth

The aerospace engineer has to be able to make his knowledge on these subjects operational on 'state of the art' problems. Furthermore he has to be able to apply independently his knowledge and insight on new situations by problem analysis, selection of appropriate models and development of new models. Finally he has to be able to absorb new developments in these subjects, to assess the practical usefulness, and to apply them, if appropriate.

FINAL OBJECTIVE 3: Aerospace engineering disciplines

The aerospace engineer requires a broad and thorough knowledge and understanding of the demands on aerospace vehicles with respect to safety, reliability, aerodynamic and structural design, and flight performance. For this purpose he needs knowledge and understanding of the technical disciplines which are characteristic for aerospace vehicles:

1. aircraft- and spacecraft-aerodynamics;
2. performance, stability and control;
3. propulsion;
4. structures and materials;

5. strength and vibrations;
6. equipment and systems;
7. production, maintenance, industrial process management;
8. operational use, including air traffic control.

Restriction of the breadth

Irrespective of their choice for a discipline group in the final phase of their studies all students have to be familiar with the most important disciplines of aerospace engineering. Aerospace engineering disciplines originate from confrontation between general engineering sciences on the one hand and the typical requirements of aerospace products on the other hand. Therefore, a certain amount of familiarity with the actual product, technical practices and specific requirements, and regulations is also considered essential. Each aerospace engineer will be confronted with this aspect upon entrance in the practice of the high-tech industry.

Restriction of the depth

The depth of the basic education will be determined by the available course time. A broad scope of the basic program is given priority rather than a narrow focus with more depth. The discipline program in the final phase of the study aims to familiarize the student with solving a representative aerospace engineering problem and to teach him how to act as an independent engineer. For that reason the focus has to be narrowed on a more restricted area of aerospace engineering in order to reach more depth. The required depth in this phase is prescribed by the final thesis work.

FINAL OBJECTIVE 4: General and aerospace applications

The aerospace engineer requires knowledge, insight and skills about the applications of the studied subjects (as mentioned in final objectives 1-3). In addition he requires insight into the skills mastered by other professional colleagues in institutes or companies.

Restriction of the breadth

Training of skills has to occur through practical exercises linked up to (in principle) all subjects of the curriculum. The aerospace engineer does not necessarily require in detail the skills and knowledge of drawing and engineering departments, laboratories etc. However, insight and understanding of all technical skills practiced in institutes and companies are required.

Restriction of the depth

Exercises have to include preferably three aspects:

1. illustration of theoretical knowledge by application in practice;
2. demonstration of the hardware and training of skills needed for applications;
3. training in independent problem solving, both in a theoretical way and useful for applications.

Training and practicing of other technical skills that do not belong directly to the engineering profession have to be limited to some understanding of the difficulties connected to these skills.

FINAL OBJECTIVE 5: Technical-scientific attitude in professional problem solving

The aerospace engineer has to be able to recognize, to formulate and to analyze engineering problems in an independent way and to offer one or more acceptable solutions. He has to be able to make a synthesis between diverse facets of the problem, to distinguish and to evaluate more possibilities.

Restriction of the breadth

In general a representative technical question or problem will not be restricted to one single discipline. This interdiscipline aspect is part of the preliminary design exercise in the third course year aiming to develop the students' capability to synthesize and to integrate his knowledge. Final thesis work has to contain the same kind of synthesis/integration aspects. By preference physical modelling and use of mathematical and numerical methods will be part of the final thesis work.

Restriction of the depth

The process of solving of a representative problem generally consists of:

1. problem analysis;
2. collection of relevant information, including literature research and consultation of experts inside and outside the discipline concerned;
3. a plan to tackle the problem;
4. execution of the required activities;
5. report and transfer of conclusions and solutions.

FINAL OBJECTIVE 6: Transfer of knowledge

The aerospace engineer has to be able to report clearly about his technical scientific work, both orally and in writing. Proficiency in the Dutch language is required. In addition he has to be familiar with the use of technical English.

FINAL OBJECTIVE 7: The aerospace engineering branch

The aerospace engineer requires knowledge and understanding of the most important 'actors' and their mutual relation in aerospace industry (national and international) as well as in (research) institutes. A basic understanding is required of the context in which engineering is practiced:

1. economics;
2. history;
3. organization & management in industry;
4. ethics and the environment (focused on Sustainable Development);
5. customer and social needs.

Restriction of the breadth

The aerospace engineer requires insight into the 'map' of the aerospace branch, for instance:

1. type of industries, customers, research institutes, governmental institutes, education and their mutual relations;
2. sub-divisions of companies and organizations, their mutual relations;
3. relations of the aerospace branch with society.

Economics is restricted to the understanding that cost is the bottom line and usually determines whether a product sells or not. Understanding focuses on cost awareness and not on micro or macro economics.

Restriction of the depth

Aerospace engineers require understanding of these subjects without having thorough knowledge of it. These subjects are focused on the first entry-level professional positions.

FINAL OBJECTIVE 8: Capability and interest

The aerospace engineer has to obtain insight into his capabilities and interest in view of his coming professional position(s).

This insight will mainly be achieved during the final phase of the study. The breadth of the basic education offers a clue to the interests of the student in specific fields. The final phase of the study increases this insight by means of the choice of the discipline program and final thesis work.

FINAL OBJECTIVE 9: Preparation for professional career
The aerospace engineer must be prepared for a broad range of engineering duties in various aerospace engineering or related disciplines after a certain period of on-the-job learning and training.

The final objectives 1-8 have to guarantee that the freshly graduated aerospace engineer reached the following attainments:

1. a broad technical education, including a good understanding of the design process and manufacturing;
2. accessibility to a broad range of employment positions;
3. sufficient flexibility in the professional career;
4. ability to think critically and creatively;
5. understanding of the context in which engineering is practiced;
6. good communication skills;
7. ability to function in a team;
8. curiosity and a desire to learn during his whole life.

(Source: Faculty of Aerospace Engineering, 1995)

Version 2001 – 2002

Final Objective 1: Basic sciences
The aerospace engineer requires thorough knowledge of and insight into the basic sciences including their generic methods and tools insofar as these are relevant to engineers.

1. Knowledge of and insight into mathematics such as calculus, ordinary and partial differential equations, linear algebra, and numerical analysis and statistics
2. Knowledge of insight into physics: statics and dynamics, solid and fluid mechanics, thermodynamics, electricity and chemistry
3. Knowledge of relevant aspects of computer science and software
4. Familiarity with and experience in physical modelling and using mathematical and numerical methods to solve engineering problems

5. Extended knowledge of and insight into mathematics, physics, and computer science insofar as these relate to the final studies in one of the aerospace-engineering disciplines

Final objective 2: General engineering sciences

The aerospace engineer requires thorough knowledge of and insight into the general engineering sciences to be able to operate in 'non-standard' conditions.

1. Knowledge, insight, and skills concerning general engineering sciences: engineering mechanics, strength of materials, materials and manufacturing methods, engineering fluid dynamics, control theory & systems and design methods in general
2. Ability to relate general engineering sciences to aerospace-engineering disciplines
3. Ability to apply knowledge of general engineering subjects to new situations and to use this knowledge to solve operational problems
4. Extended knowledge of and insight into general engineering sciences insofar as these relate to the final studies in one of the aerospace engineering disciplines

Final objective 3: Aerospace engineering disciplines

The aerospace engineer requires a broad and thorough knowledge of the demands on aerospace vehicles as regards safety, reliability, aerodynamic and structural design, and flight performance.

1. Thorough knowledge of and insight into the engineering sciences related to aerospace vehicles:
    - aerodynamics;
    - performance, stability, and control;
    - propulsion;
    - structures and materials;
    - strength and vibrations;
    - equipment and systems;
    - production, maintenance, and industrial process management;
    - operational use, including air traffic control;
    - structural design of aircraft and spacecraft

2. Acquaintance with the diversity and interdependence of problems (synthesis) within the aforementioned fields.
3. Extended knowledge of and insight into aerospace engineering disciplines and their diversity, interdependence and coherence in problem solving activities (synthesis)

Final objective 4: General engineering and aerospace-engineering applications

The aerospace engineer requires the skills to apply his/her knowledge of engineering and aerospace sciences.

1. Knowledge, insight and skills concerning general engineering sciences applications through (lab) exercises:
   1.1. illustration and visualization through applications;
   1.2. skills in applications;
   1.3. training in problem-solving.
2. Knowledge, insight and skills concerning aerospace engineering applications through (lab) exercises:
   2.1. illustration and applications of engineering practice;
   2.2. skills in applications;
   2.3. training in problem-solving.
3. Training in use of scientific general engineering software
4. Training in the use and development of advanced scientific software for aerospace applications

Final objective 5: Technical-scientific attitude in professional problem-solving

The aerospace engineer must be able to recognize, formulate, and analyze engineering problems and to offer one or more solutions to these problems. He/she must be able to create a synthesis between diverse facets of the problem, to identify and to evaluate various possibilities.

1. Ability to synthesize and to integrate knowledge
2. Verifying developed theories and solutions through experiments
3. Selecting and analyzing relevant sources independently and critically
4. Reporting conclusions and solutions

Final objective 6: Transfer of knowledge

The aerospace engineer must be able to report clearly on his/her technical-scientific work both orally and in writing. Proficiency in technical English is required.

1. Skills in writing reports in English
2. Skills in oral reporting in English using state-of-the-art presentation techniques
3. ability to function in project teams and to contribute to the process of knowledge transfer’

Final objective 7: The aerospace-engineering industry

The aerospace engineer requires knowledge and an understanding of the (national and international) aerospace industry and (research) institutes. Furthermore, a basic understanding is required of the context in which engineering is practiced:

Knowledge of:

1. the most important ‘actors’ in the aerospace industry and their mutual contacts, both national and international;
2. the social context of the aerospace industry;
3. the implications of the aerospace industry on society;
4. industrial organization and management processes;
5. sustainable development;
6. the aerospace-engineering profession and industrial practice.

Final objective 8: Capability and interest

The aerospace engineer must obtain insight into his/her capabilities and interests in view of his/her future professional position(s).

Final objective 9: Preparation for professional career

The aerospace engineer must be prepared for a broad range of engineering duties in various aerospace engineering or related disciplines following a certain period of on-the-job learning and training.

Final objectives 1–8 must guarantee that the recently graduated aerospace engineer will achieve the following:

- a broad engineering education, including a good understanding of design process and manufacturing;
- accessibility to a broad range of employment positions;
- sufficient flexibility as regards professional career;
- ability to think critically and creatively;
- understanding of the context in which engineering is practiced;
- good communication skills;

- ability to function as a member of a team;
- curiosity and a desire to engage in life-long learning.

(Source: Faculty of Aerospace Engineering, 2001)

Version 2002 – 2005 Bachelor of Science

FINAL OBJECTIVE BSc-1 Basic sciences and technical tools

The BSc graduate has thorough knowledge of and insight into the basic sciences including their generic methods and tools insofar as these are relevant to engineering practice.

1. Knowledge of and insight into mathematics: calculus, statistics, ordinary and partial differential equations, linear algebra and numerical analysis;
2. Knowledge of and insight into physics: statics and dynamics, solid and fluid mechanics, thermodynamics, electricity and chemistry;
3. Knowledge of relevant aspects of computer science and software;
4. Basic familiarity with and experience in physical modelling and using mathematical and numerical methods to solve engineering problems.

FINAL OBJECTIVE BSc-2 General engineering sciences

The BSc graduate has thorough knowledge of and insight into the general engineering sciences to be able to operate in 'non-standard' conditions.

1. Knowledge, insight, and skills concerning general engineering sciences: engineering mechanics, strength of materials, materials and manufacturing methods, engineering fluid dynamics, control theory & systems and design methods in general;
2. Ability to relate general engineering sciences to Aerospace Engineering disciplines.

FINAL OBJECTIVE BSc-3 Aerospace Engineering sciences

The BSc graduate has a basic knowledge of the demands on aerospace vehicles as regards safety, reliability, aerodynamic and structural design, and flight performance.

1. Basic knowledge of and insight into the engineering sciences related to aerospace vehicles:
    - aerodynamics;

- performance, stability, and control;
- propulsion;
- structures and materials;
- strength and vibrations;
- equipment and systems;
- production, maintenance, and industrial process management;
- operational use, including air traffic control;
- structural design of aircraft and spacecraft.

2. Acquaintance with the diversity and interdependence of problems (synthesis) within the aforementioned fields;
3. Basic ability to synthesize and to integrate (aerospace) knowledge;
4. Selecting and analyzing relevant sources independently and critically.

FINAL OBJECTIVE BSc-4 General engineering and Aerospace Engineering applications

The BSc graduate has the skills to apply his knowledge of engineering and aerospace sciences.

1. Knowledge, insight and skills concerning general engineering sciences applications through (lab) exercises:
   1.1. illustration and visualization through applications;
   1.2. skills in applications;
   1.3. training in problem-solving.
2. Basic knowledge, insight and skills concerning Aerospace Engineering applications through (lab) exercises:
   2.1. illustrations and applications of engineering practice;
   2.2. skills in applications;
   2.3. training in problem-solving.
3. Training in use of scientific general engineering software;

FINAL OBJECTIVE BSc-5 Communication skills

The BSc graduate must be able to report his solutions and conclusions of his technical (-scientific) work clearly both orally and in writing.

1. Skills in writing reports;
2. Skills in oral reporting using state -of-the-art presentation techniques.

FINAL OBJECTIVE BSc-6 The Aerospace Engineering industry

The BSc graduate has basic knowledge and an understanding of the (national and international) aerospace industry and (research) institutes. Furthermore, a basic understanding is required of the context in which engineering is practiced. Knowledge of:

1. The most important 'actors' in the aerospace industry and their mutual contacts, both national and international;
2. The social context of the aerospace industry;
3. The implications of the aerospace industry on society;
4. Industrial organization and management processes.

FINAL OBJECTIVE BSc-7 Design and synthesis abilities

The BSc graduate must be able to recognize, formulate, and analyze engineering problems and to offer one or more solutions to these problems. He must be able to create a synthesis between diverse facets of the problem, to identify and to evaluate various possibilities. Under the supervision of senior staff he must be able to approach technical problems with an awareness of multidisciplinary solutions based on technical/scientific analysis.

1. Has obtained design experience;
2. Being able to apply and integrate aerospace knowledge in a multidisciplinary guided project;
3. Ability to function in project teams and to contribute to the process of knowledge transfer;
4. Have basic knowledge of sustainable development;
5. Have an awareness on how to approach technical problems from a scientific background.

(Source: Faculty of Aerospace Engineering, 2002)

Version 2002 – 2005 Master of Science

FINAL OBJECTIVE MSc-1 Basic sciences and technical tools

The MSc graduate has thorough knowledge of and insight into the basic sciences including their generic methods and tools insofar as these are relevant to engineering practice. The knowledge and insight must be aimed at application to complex problems.

1. Knowledge of and insight into mathematics including partial differential equations, linear algebra, numerical analysis and statistics;

2. Knowledge of insight into physics including dynamics, solid and fluid mechanics and thermodynamics;
3. Knowledge of relevant aspects of computer science and software;
4. Extended knowledge of and experience in physical modelling and using mathematical and numerical methods to solve engineering problems;
5. Extended knowledge of and insight into mathematics, physics, and computer science insofar as these relate to the final studies in one of the Aerospace Engineering disciplines.

FINAL OBJECTIVE MSc-2 General engineering sciences

The MSc graduate has thorough knowledge of and insight into the general engineering sciences to be able to operate in ‘non-standard’ conditions.

1. Knowledge, insight, and skills concerning general engineering sciences: engineering mechanics, strength of materials, materials and manufacturing methods, engineering fluid dynamics, control theory & systems and design methods in general;
2. Ability to relate general engineering sciences to Aerospace Engineering disciplines;
3. Ability to apply knowledge of general engineering subjects to new situations and to use this knowledge to solve operational problems;
4. Extended knowledge of and insight into general engineering sciences insofar as these relate to the final studies in one of the Aerospace Engineering disciplines.

FINAL OBJECTIVE MSc-3 Aerospace Engineering sciences

The MSc graduate has a broad knowledge of the demands on aerospace vehicles as regards safety, reliability, aerodynamic and structural design, and flight performance in general. Detailed knowledge of at least one of the aerospace engineering sciences as mentioned under 3.1.

1. Thorough knowledge of and insight into the aerospace engineering sciences:
    - aerodynamics;
    - performance, stability, and control;
    - propulsion;
    - structures and materials;
    - strength and vibrations;
    - equipment and systems;

  - production, maintenance, and industrial process management;
  - operational use, including air traffic control;
  - structural design of aircraft and spacecraft.
2. Acquaintance with the diversity and interdependence of problems (synthesis) within the aforementioned fields;
3. Extended knowledge of and insight into Aerospace Engineering disciplines and their diversity, interdependence and coherence in problem solving activities (synthesis);

FINAL OBJECTIVE MSc-4 General engineering and Aerospace Engineering applications

The MSc graduate has the skills to apply his knowledge of engineering and aerospace sciences.

1. Knowledge, insight and skills concerning Aerospace Engineering applications through (lab) exercises:
   1.1. illustrations and applications of engineering practice;
   1.2. skills in applications;
   1.3. training in problem-solving.
2. Training in use of scientific general engineering software;
3. Training in the use and development of advanced scientific software for aerospace applications.

FINAL OBJECTIVE MSc-5 Communication skills

The MSc graduate must be able to report clearly on his technical-scientific work both orally and in writing.

1. Skills in writing reports;
2. Skills in oral reporting using state -of-the-art presentation techniques;
3. Ability to function in project teams and to contribute to the process of knowledge transfer.

FINAL OBJECTIVE MSc-6 The Aerospace Engineering industry

The MSc graduate has knowledge and an understanding of the (national and international) aerospace industry and (research) institutes. Furthermore, a basic understanding is required of the context in which engineering is practiced. Knowledge of:

1. The most important 'actors' in the aerospace industry and their mutual contacts, both national and international;
2. The social context of the aerospace industry;
3. The implications of the aerospace industry on society;
4. Industrial organization and management processes;
5. Sustainable development;
6. The Aerospace Engineering profession and industrial practice.

FINAL OBJECTIVE MSc-7 Scientific attitude in professional problem-solving

The MSc graduate must be able to recognize, formulate, and analyze engineering problems and to offer one or more solutions to these problems. He must be able to create a synthesis between diverse facets of the problem, to identify and to evaluate various possibilities. With limited coaching of senior staff he must be able to approach technical problems with an awareness of multidisciplinary solutions based on technical/scientific analysis. This means the ability to:

1. synthesize and to integrate knowledge;
2. apply knowledge of conceptual design;
3. generate new ideas, being creative in finding solutions;
4. work independently;
5. develop (computer-assisted) tools to solve problems;
6. verify developed theories and solutions through experiments;
7. select and analyze relevant sources independently and critically;
8. work in multidisciplinary teams;
9. analyze and synthesize problems in the area of expertise;
10. take into account neighbouring fields of expertise when designing solutions to problems;
11. judge the consequences of choices made for neighbouring fields;
12. motivate the choices made;
13. report conclusions and solutions;
14. defend the work performed.

FINAL OBJECTIVE MSc-8 Capability and interest

The MSc graduate must obtain insight into his capabilities and interests in view of his future professional position(s).

FINAL OBJECTIVE MSc-9 Preparation for professional career

The MSc graduate must be prepared for a broad range of engineering duties in various Aerospace Engineering or related disciplines following a certain period of on-the-job learning and training. Final objectives 1–8 must guarantee that the recently graduated MSc graduate will achieve the following:

- a broad engineering education, including a good understanding of design process and manufacturing;
- accessibility to a broad range of employment positions;
- sufficient flexibility as regards professional career;
- ability to think critically and creatively;
- understanding of the context in which engineering is practiced;
- good communication skills;
- ability to function as a member of a team;
- curiosity and a desire to engage in life-long learning.

(Source: Faculty of Aerospace Engineering, 2002)

Version 2005 - 2006 Bachelor of Science

FINAL OBJECTIVE BSc-1 Basic sciences and technical tools

The BSc graduate has thorough knowledge and understanding of the basic sciences including their generic methods and tools insofar as these are relevant to engineering practice.

1. Knowledge and understanding of mathematics: calculus, statistics, ordinary and partial differential equations, linear algebra and numerical analysis;
2. Knowledge and understanding of physics: statics and dynamics, solid and fluid mechanics, thermodynamics, electricity and chemistry;
3. Knowledge of relevant aspects of computer science and software;
4. Basic familiarity with and experience in physical modelling and using mathematical and numerical methods to solve engineering problems.

FINAL OBJECTIVE BSc-2 General engineering sciences

The BSc graduate has thorough knowledge and understanding of the general engineering sciences to be able to operate in ‘non-standard’ conditions.

1. Knowledge, understanding, and skills concerning general engineering sciences: engineering mechanics, strength of materials, materials and manufacturing methods, engineering fluid dynamics, control theory & systems and design methods in general;

2. Ability to relate general engineering sciences to Aerospace Engineering disciplines.

FINAL OBJECTIVE BSc-3 Aerospace Engineering sciences

The BSc graduate has a basic knowledge of the demands on aerospace vehicles as regards safety, reliability, aerodynamic and structural design, and flight performance, supplemented by basic knowledge on operational use and exploitation of aerospace vehicles.

1. Basic knowledge and understanding of the engineering sciences related to aerospace vehicles:
    - aerodynamics;
    - performance, stability, and control;
    - propulsion;
    - structures and materials;
    - strength and vibrations;
    - equipment and systems;- production, maintenance, and industrial process management;
    - operational use and exploitation, i.e. earth observation and air traffic control;
    - structural design of aircraft and spacecraft;
    - sustainable development
2. Acquaintance with the diversity and interdependence of problems (synthesis) within the aforementioned fields;
3. Basic ability to synthesize and to integrate (aerospace) knowledge;
4. Selecting and analyzing relevant sources independently and critically.
5. Enrichment of knowledge, understanding and skills in one of the following domains:
    - Aerospace System Design and Technology
    - Aerospace Analysis and Development
    - Aerospace Operation and Exploitation
    - Earth and Planetary Observation Technology
    - Aerospace for Sustainable Earth
    - Mathematics

FINAL OBJECTIVE BSc-4 General engineering and Aerospace Engineering applications

The BSc graduate has the skills to apply his knowledge of engineering and aerospace sciences.

1. Knowledge, understanding and skills concerning general engineering sciences applications through (lab) exercises:
   1.1. illustration and visualization through applications;
   1.2. skills in applications;
   1.3. training in problem-solving.
2. Basic knowledge, understanding and skills concerning Aerospace Engineering applications through (lab) exercises:
   2.1. illustrations and applications of engineering practice;
   2.2. skills in applications;
   2.3. training in problem-solving.
3. Training in use of scientific general engineering software;

FINAL OBJECTIVE BSc-5 Communication skills

The BSc graduate must be able to report his solutions and conclusions of his technical (-scientific) work clearly both orally and in writing.

1. Skills in writing reports;
2. Skills in oral reporting using state-of-the-art presentation techniques.

FINAL OBJECTIVE BSc-6 The Aerospace Engineering industry

The BSc graduate has basic knowledge and understanding of the (national and international) aerospace industry and (research) institutes. Furthermore, a basic understanding is required of the context in which engineering is practiced. Knowledge of:

1. The most important ‘actors’ in the aerospace industry and their mutual contacts, both national and international;
2. The social context of the aerospace industry;
3. The implications of the aerospace industry on society;
4. Industrial organization and management processes.

FINAL OBJECTIVE BSc-7 Design and synthesis abilities

The BSc graduate must be able to recognize, formulate, and analyze engineering problems and to offer one or more solutions to these problems. He must be able to create a synthesis between diverse facets of the problem, to identify and to evaluate various possibilities. Under the supervision of senior staff he must be able to approach technical problems with an awareness of multidisciplinary solutions based on technical/scientific analysis.

1. Has obtained design experience;
2. Being able to apply and integrate aerospace knowledge in a multidisciplinary guided project;
3. Ability to function in project teams and to contribute to the process of knowledge transfer;
4. Have basic knowledge of sustainable development;
5. Have an awareness on how to approach technical problems from a scientific background.

(Source: Faculty of Aerospace Engineering, 2006)

Version 2005 - 2006 Master of Science

FINAL OBJECTIVE MSc-1 Basic sciences and technical tools

The MSc graduate has thorough knowledge and understanding of the basic sciences including their generic methods and tools insofar as these are relevant to engineering practice. The knowledge and understanding must be aimed at application to complex problems.

1. Knowledge and understanding of mathematics including partial differential equations, linear algebra, numerical analysis and statistics;
2. Knowledge and understanding of physics including dynamics, solid and fluid mechanics and thermodynamics;
3. Knowledge of relevant aspects of computer science and software;
4. Extended knowledge of and experience in physical modelling and using mathematical and numerical methods to solve engineering problems;
5. Extended knowledge and understanding of mathematics, physics, and computer science insofar as these relate to the final studies in one of the Aerospace Engineering disciplines.

FINAL OBJECTIVE MSc-2 General engineering sciences

The MSc graduate has thorough knowledge and understanding of the general engineering sciences to be able to operate in ‘non-standard’ conditions.

1. Knowledge, understanding, and skills concerning general engineering sciences: engineering mechanics, strength of materials, materials and manufacturing methods, engineering fluid dynamics, control theory & systems and design methods in general;

2. Ability to relate general engineering sciences to Aerospace Engineering disciplines;
3. Ability to apply knowledge of general engineering subjects to new situations and to use this knowledge to solve operational problems;
4. Extended knowledge and understanding of general engineering sciences insofar as these relate to the final studies in one of the Aerospace Engineering disciplines.

FINAL OBJECTIVE MSc-3 Aerospace Engineering sciences

The MSc graduate has a broad knowledge of the demands on aerospace vehicles as regards safety, reliability, aerodynamic and structural design, and flight performance in general. Detailed knowledge of at least one of the aerospace engineering sciences as mentioned under 3.1.

1. Thorough knowledge and understanding of the aerospace engineering sciences:
   1.1. aerodynamics;
   1.2. performance, stability, and control;
   1.3. propulsion;
   1.4. structures and materials;
   1.5. strength and vibrations;
   1.6. equipment and systems;
   1.7. production, maintenance, and industrial process management;
   1.8. operational use, including air traffic control;
   1.9. structural design of aircraft and spacecraft;
   1.10. earth and planetary observation
2. Acquaintance with the diversity and interdependence of problems (synthesis) within the aforementioned fields;
3. Extended knowledge and understanding of Aerospace Engineering disciplines and their diversity, interdependence and coherence in problem solving activities (synthesis);

FINAL OBJECTIVE MSc-4 General engineering and Aerospace Engineering applications

The MSc graduate has the skills to apply his knowledge of engineering and aerospace sciences.

1. Knowledge, understanding and skills concerning Aerospace Engineering applications through (lab) exercises:

   1.1. illustrations and applications of engineering practice;
   1.2. skills in applications;
   1.3. training in problem-solving.
2. Training in use of scientific general engineering software;
3. Training in the use and development of advanced scientific software for aerospace applications.

FINAL OBJECTIVE MSc-5 Communication skills

The MSc graduate must be able to report clearly on his technical-scientific work both orally and in writing.

1. Skills in writing reports;
2. Skills in oral reporting using state-of-the-art presentation techniques;
3. Ability to function in project teams and to contribute to the process of knowledge transfer.

FINAL OBJECTIVE MSc-6 The Aerospace Engineering industry

The MSc graduate has knowledge and understanding of the (national and international) aerospace industry and (research) institutes. Furthermore, a basic understanding is required of the context in which engineering is practised. Knowledge of:

1. The most important ‘actors’ in the aerospace industry and their mutual contacts, both national and international;
2. The social context of the aerospace industry;
3. The implications of the aerospace industry on society;
4. Industrial organization and management processes;
5. Sustainable development;
6. The Aerospace Engineering profession and industrial practice.

FINAL OBJECTIVE MSc-7 Scientific attitude in professional problem-solving

The MSc graduate must be able to recognize, formulate, and analyze engineering problems and to offer one or more solutions to these problems. He must be able to create a synthesis between diverse facets of the problem, to identify and to evaluate various possibilities. With limited coaching of senior staff he must be able to approach technical problems with an awareness of multidisciplinary solutions based on technical/scientific analysis. This means the ability to:

1. synthesize and to integrate knowledge;

2. apply knowledge of conceptual design;
3. generate new ideas, being creative in finding solutions;
4. work independently;
5. develop (computer-assisted) tools to solve problems;
6. verify developed theories and solutions through experiments;
7. select and analyse relevant sources independently and critically;
8. work in multidisciplinary teams;
9. analyse and synthesize problems in the area of expertise;
10. take into account neighbouring fields of expertise when designing solutions to problems;
11. judge the consequences of choices made for neighbouring fields;
12. motivate the choices made;
13. report conclusions and solutions;
14. defend the work performed.

FINAL OBJECTIVE MSc-8 Capability and interest

The MSc graduate must obtain understanding of his capabilities and interests in view of his future professional position(s).

FINAL OBJECTIVE MSc-9 Preparation for professional career

The MSc graduate must be prepared for a broad range of engineering duties in various Aerospace Engineering or related disciplines following a certain period of on-the-job learning and training. Final objectives 1–8 must guarantee that the recently graduated MSc graduate will achieve the following:

- a broad engineering education, including a good understanding of design process and manufacturing;
- accessibility to a broad range of employment positions;
- sufficient flexibility as regards professional career;
- ability to think critically and creatively;
- understanding of the context in which engineering is practised;
- good communication skills;
- ability to function as a member of a team;
- curiosity and a desire to engage in life-long learning.

(Source: Faculty of Aerospace Engineering, 2006)

BSc Final Qualifications 2006 onwards

The BSc graduate in Aerospace Engineering:

1. Is competent in the domain of Aerospace Engineering sciences
   He has a consolidated body of knowledge in the fields of basic and engineering sciences, and aerospace engineering sciences in particular, and has the skills to increase and develop this further through study.
2. Is competent in research
   He has an understanding at an introductory level of the most important research issues in aerospace-related sciences, and is aware of the connections with other disciplines.
3. Is competent in design
   He is able to recognise, formulate and analyse engineering problems independently and to offer one or more acceptable solutions for new or modified items or systems, with the intention of creating value in accordance with predefined requirements.
4. Is able to follow a scientific approach
   He has a systematic approach characterised by the application of theories, development of models and the making of coherent interpretations, has a critical attitude and insight into science and technology in the aerospace domain.
5. Is able to apply basic intellectual skills
   He is competent in reasoning, reflecting, and forming a judgement. These are skills which are learnt in the context of aerospace problems, questions or environment, and which are generically applicable from then on.
6. Is competent in cooperating and communicating
   He is able to work with and for others in a multi-national and multi-cultural environment. This requires not only adequate interaction, a sense of responsibility, and preferably leadership, but also good communication with colleagues and non-colleagues. He is also able to follow a scientific or public debate.
7. Considers the temporal and societal context
   He is aware of the fact that aerospace engineering sciences are not isolated and always have a temporal and societal context. He has knowledge and understanding of the context in which aerospace engineering and utilisation is practised by industry, institutes and organisations. He has the competence to integrate these insights into his work.

(Source: Faculty of Aerospace Engineering, 2007a)

MSc Final Qualifications 2006 onwards

1. The MSc graduate is familiar with existing scientific knowledge, and has the competence to increase and develop this through study
2. The MSc graduate has the competence to acquire new scientific knowledge through research. For this purpose research means: the development of new knowledge and new insights in a purposeful and methodical way.
3. The MSc graduate is familiar with the principles of design. Design is a synthetic activity aimed at the realization of new or modified artefacts or systems with the intention of creating value in accordance with predefined requirement and desires (e.g. mobility, health).
4. The MSc graduate has a systematic approach characterized by the development and use of theory, models and coherent interpretation, has critical attitude and has insight into the nature of science and technology.
5. The MSc graduate is competent in reasoning, reflecting and forming a judgement. These are skills which are learned or sharpened in the context of a discipline, and which are generally applicable from then on.
6. The MSc graduate has the competence to be able to work with and for others. This requires not only an adequate interaction, a sense of responsibility and leadership but also good communication with colleagues and non-colleagues. He or she is also able to participate in a scientific or public debate.
7. Science and technology are not isolated, and always have a temporal and social context. Beliefs and methods have their origins; decisions have social consequences in time. A university graduate is aware of this, and has the competence to integrate these insights into his or her scientific work.

(Source: Faculty of Aerospace Engineering, 2007b)

APPENDIX B: EXPERT PANEL QUESTIONNAIRE

B.1 Translation of the Questionnaire

1. Name
2. Name of Company/institution
3. Type of company: government/semi government/industry/self-employed
4. Size of company: small(less than 100 employees)/medium less than 1000 employees)/large (more than 1000 employees)
5. Job title
6. Number of people in charge of: less than 10/between 10 and 50/more than 50 people

In practice there appear to be two career tracks for engineers: the engineering specialist and the engineering manager.

An *engineering specialist* is an engineer who either works within a company or a research institute and is an expert in a part of engineering science and is not really involved in the running of the business or the institute only in its product. They are individual contributors. Product in this context could mean anything from aircraft parts to calculations. Typically scientists at universities, researchers at research institutes or research & product development departments, etcetera fall in this category.

An *engineering manager* is defined as an engineer who is in charge of the process leading to the product. They generally have to look at the bigger picture and are not as specialized although they have a broad technical knowledge. They typically have taken up a position of responsibility, such as manager, director, chairman, dean etc.

1. Please indicate for each of the competencies and for each type of engineer how important it is. (very unimportant, unimportant, not important/not unimportant, important, very important)

Competencies	
C.1.	Ability to synthesize
C.2.	Analytical skills
C.3.	Problem solving skills
C.4.	Managerial skills
C.5.	Written communication skills
C.6.	Oral communication skills
C.7.	Net worker
C.8.	Have broad technical knowledge
C.9.	Have specialist technical knowledge

2. Which competencies do you feel are missing in the previous list and how important do you rate these?
3. Do you consider yourself to be a specialist or a manager? If you feel you belong to both groups which of the two is most applicable? Specialist/manager
4. Questions/Comments

B.2 List of Originating Institutes and Companies of the Expert Panel

- Faculty of Aerospace Engineering, Delft University of Technology, Delft
- Aircraft Development and Systems Engineering, Hoofddorp
- Dutch Space, Leiden
- Stork Fokker Aerostructures, Papendrecht
- Nationaal Luchtvaart- en Ruimtevaart Laboratorium, Amsterdam, Emmeloord
- Koninklijke Luchtvaart Maatschappij, Schiphol
- European Patent Office, Rijswijk

APPENDIX C: DEFINITIONS AND CRITERIA OF THE SURVEY

C.1 Occupational Definitions

The list below is a list of 'Occupational Definitions' as used in Engineers involved in continuing Education: a Survey Analysis by Knus and Jones (1975) based on the definitions as stated in the National Survey of Professional, Administrative, Technical and Clerical Pay.

Supervisory Responsibilities (scoring 1 – no supervisory responsibility to 5 for executive):

- No supervisory responsibility
- Supervision of technical and/or non-technical personnel EXCEPT engineering and scientific
- Supervision of engineering and/or scientific personnel
- Supervision of lower and/or middle management personnel
- Executive (upper management)

Technical responsibilities (scoring 1 – limited assignments and 5 original research and 0 for not applicable):

- Perform limited assignments with specific direction under an experienced engineer
- Perform assignments with limited direction under an experienced engineer
- Independently performs most work with directions only to general results expected
- Independent work in extending known engineering techniques, data, etc.
- ORIGINAL research or engineering development on unknown blocks of data
- Not applicable

The answers on both questions are then added together to form the total score for job responsibility ranging from 1 – 10.

C.2 Alternative scale for competencies

As mentioned in Chapter 3, an alternative competency measurement scale was developed in order to establish how competent an alumnus is in certain competency. This alternative scale is based on questions about the alumnus' activities related to their work. Table C.1 shows each of the defined competencies in Chapter 3 and the related activities. Questions regarding each activity in table C.1 were also added to the alumni questionnaire. Most of those were based on a 3 point Likert scale with only some (in italic) based on straightforward yes and no questions. See also the questionnaire in Appendix D.

Competency	Validation criteria	
C.1	The ability to synthesize	Is asked to be part of multi-disciplinary working groups
		Is asked to head multi-disciplinary working groups
C.2	Analytical skills	Is often asked by others for their view on problems
		Their analysis of a problem is often accepted
C.3	Problem solving skills	Their solution to a problem is often accepted
		Is often asked by others to solve tedious problems
C.4	People management skills	Is in charge of a number of staff in current position
		Reviews staff on performance reviews
		Is mandated to negotiate contracts on behalf of employer
C.5	Operational skills	Current position comes with financial & budget responsibility
		Sets up new organizational structures & processes
		Makes regular operational decisions strongly effecting organization and working of processes in the company
C.6	Written communication skills	Writes scientific papers/articles
		Writes policy documents/Financial or Business plans
		Is asked to write documents by colleagues and supervisors
C.7	Oral communication skills	Gives presentations on behalf of their company
		Presents to colleagues within the company
		Is a regular presenter at conferences etc.
C.8	Net workers	Is member of relevant professional bodies
C.9	Have broad technical knowledge	Reads engineering management literature

		Reads general engineering literature
C.10	Have specialist technical knowledge	Is guest speaker at scientific conferences etcetera
		Receives patents for their work
		Receives awards for their work
		Reads specific engineering literature
C.11	Ability for life-long learning	Has attended a number of courses after graduation
		Finds acquiring additional knowledge useful
		Intends to attend more courses in the future
C.12	Ability to work in teams	Likes working in teams
		Is often asked onto team projects
		Is asked to head project teams

Table C.1 proposed activities and criteria for competencies

Every validation will now be discussed as to why these characteristics should apply.

Ad C.1 To be able to synthesize is important regardless of whether you are a specialist or manager. As a specialist you must know where you fit in a system in order to function and as a manager you must have an overview of how things depend on one another. If you are able to do so you will be asked in companies to take part in multi-disciplinary teams if you are not you will be asked once and never again. Of course as a successful manager you will at some point be asked to lead one of those teams.

Ad C.2 Having good analytical skills is again something, which applies to both. If you do not understand the problem you are dealing with, be it on a process or a product you simply cannot succeed. However, if you have good analytical skills, people will often ask you for your view on a problem and others will readily accept your analysis of situations in meetings.

Ad C.3 Again here this competency applies to both. Both types of engineers solve problems only different ones. Again if you are good at it people will accept your solution and ask you to solve difficult problems because they trust you to come up with a good solution.

Ad C.4 If you have good people management skills you are generally expected to be in charge of a number of staff in your current position and you review staff on performance reviews. Also if you are good at influencing people you will also have good negotiating skills and you are generally mandated to negotiate contracts on behalf of your employer.

Ad C.5 Indicators that one has operational management skills are the fact that you are asked to take on financial responsibility, to set up new organizational structures, new processes etc. Also you are trusted with making regular operational decisions effecting organization and working of processes in the company.

Ad C.6 To be able to put your ideas on paper is important for both. It is just the types of ideas that differ. For an engineer it is important to write business and financial plans and getting them approved, as well as an accepted product plan or scientific paper being proofs of competence. Other major indicators are whether other people ask your advice on writing or ask you to write for them.

Ad C.7 It goes without doubt an engineer must be able to put their point across. They must be good in presenting and communicating. If you are good at it, you will regularly be asked to be a guest speaker or asked by your supervisors to represent the company by giving a presentation.

Ad C.8 Unless people know you, you will not be recognized for your achievements. So a successful engineer has to be a good net worker regardless whether they are specialist or managers. Just the type of networks can differ. So membership of professional bodies is a necessity and in order to be successful you must do more than just be a member. As engineers also have an outlook further than just their professional bodies, a membership of social standing networks such as the Rotary or the increasingly more popular on-line networks or even membership of advisory boards can be seen as sign of their success.

Ad C.9 This is a useful thing for a specialist to have but not critical but absolutely essential for an engineering manager. Although you do not have to know every little detail, a broad knowledge of everything is needed to understand what the issues are and to be able to make decisions. This is why as a manager you must stay up-to-date on current issues by reading engineering management literature as well as general engineering literature. The latter is of course also applicable to specialists as they must be able to place their work in the bigger engineering picture but does not have to be critical to their success.

Ad C.10 As a specialist you must of course know the ins and outs of your subject area. This does not apply to a manager, as they need broad technical knowledge more than anything. They have to be careful not to get too lost in detailed knowledge so that they do not loose track of the bigger picture. If you are very good you will be asked by others to share your knowledge with them such as being a guest speaker. Also if you are good your knowledge will results in important results, which could lead to you winning awards for your research (e.g. a Noble Prize) or successfully apply for patents on products you have developed.

Ad C.11 If you are indeed a life-long learner it is to be expected that you have already attended a number of courses after graduation and that you finds acquiring additional knowledge useful. Of course you will expect to attend more courses in the future as your desire to learn more never seizes.

Ad C.12 Not everyone is a team player so to like working in teams is a must, secondly you might like working in teams but do others feel you are a team player? Are you often asked to work on team-based projects? Of course the absolute top is reached if you are asked to head project teams.

APPENDIX D: ALUMNI SURVEY

D.1 Questionnaire part 1 (Non anonymous)

Please correct the data we hold on our current alumni database:

1. Graduation year
2. Sex: Male/Female
3. Date of Birth
4. Current employer
5. Current job title
6. Current branche
    - Architecture
    - Consultancy
    - Fast moving consumer goods
    - Financial sector
    - Local government
    - Government
    - Internet
    - Information Technology
    - Education and Science
    - Engineering
    - Advertising and Marketing
    - Telecommunications
    - Transport and Logistics
    - Recruitment and Selection

The next questions are about data we would like to add to our database

7. In what year did you start your aerospace engineering degree?
8. What chair did you graduate with?
9. After completing your aerospace degree did you enrol in another (post-) academic degree
10. If so which one?
11. Have you done a PhD?
12. If so with what faculty and university?
13. It is intended to continue this research with face-to-face or group interviews in which an in-depth investigation of the quality of the degree of aerospace

engineering is carried out with the aim of come to recommendations to improve the quality of the degree. May we approach you for this? Yes/No

14. The faculty is also looking for alumni who would enjoy sharing their experiences during their degree and their career with future students. May we approach you for this? Yes/No
15. Finally, we would like to announce that the Faculty of Aerospace Engineering has her own alumni association: Delft Aerospace Alumni. Would you like more information on this? Yes/No/Already a member

D.2 Questionnaire part 2 (Anonymous)

1. How many years of work experience have you got? ___ years
2. Please indicate the highest completed education of each of your parents?
    - No formal education
    - Primary school
    - Vocational training (LBO)
    - Advanced Vocational Training (MBO)
    - Secondary education (MAVO, HAVO, ULO, MULO, MMS)
    - Preparatory Academic education (HBS, VWO, Atheneum Gymnasium)
    - Polytechnic level
    - Academic level
3. Are either of your parents engineers (ing. or ir.)? Yes/No
4. Please indicate in what category your gross annual income falls (including any holiday pay, 13^{th} and 14^{th} month, expense accounts, bonus and benefits)
    - Less than € 30 000
    - €30 000 - €45 000
    - €45 000 - €60 000
    - €60 000 - €75 000
    - €75 000 - €90 000
    - €90 000 - €105 000
    - €105 000 - €120 000
    - More than €120 000

We understand that this type of data is very confidential for most people. However, without this data it will be impossible for us to achieve the objectives of this research. We implore you to answer this question. All information in this questionnaire will of course be treated confidentiality.

If you are not currently employed you may continue at question 20.

About your current job:

5. Is an engineering degree required to carry out your current job? Yes/No
6. Is an aerospace engineering degree required to carry out your current job? Yes/No
7. How much % of a full time job (40 hours) do you work? ____%
8. Do you have a company car?
9. Please tick which of the descriptions below most applies to the managerial task of your current job?
    - No supervisory responsibility
    - Supervision of technical and/or non-technical personnel EXCEPT engineering and scientific
    - Supervision of engineering and/or scientific personnel
    - Supervision of lower and/or middle management personnel
    - Executive (upper management)
10. Please tick which of the descriptions below most applies to the engineering part of your current job?
    - Perform limited assignments with specific direction under an experienced engineer
    - Perform assignments with limited direction under an experienced engineer
    - Independently performs most work with directions only to general results expected
    - Independent work in extending known engineering techniques, data, etc.
    - ORIGINAL research or engineering development on unknown blocks of data
    - Not applicable
11. Are you a member of one or more professional bodies? No/Yes of ______________
12. If yes do you hold any positions in your professional body? Yes/No

13. Are you a member of one or more advisory boards? No/Yes of____________
14. Are you a member of one of more networks (such as Rotary, Lions) No/Yes of ___
15. Do you hold any patents? No/Yes _____(number)
16. Below there are a number of statements about tasks engineers perform. Please tick whether any of these task occur often, sometimes or never in your work. (where applicable read 'yes' for often, 'maybe' for sometimes and 'no' for never.)
    - Is asked to be part of multi-disciplinary taskforces, working groups or research teams
    - Is asked to head multi-disciplinary taskforces, working groups or research teams
    - Is often asked by others for their view on problems
    - Their analysis of a problem is often accepted
    - Their solution to a problem is often accepted
    - Is often asked by others to solve tedious problems
    - Is in charge of a number of staff in current position
    - Reviews staff on performance reviews
    - Is mandated to negotiate contracts on behalf of employer
    - Current position comes with financial & budget responsibility
    - Sets up new organizational structures & processes
    - Makes regular operational decisions effecting organisation and working of processes in the company
    - Writes scientific papers/articles
    - Writes policy documents/ Financial or Business plans.
    - Is asked to write documents by colleagues and supervisors
    - Likes working in teams
    - Is often asked onto team projects
    - Is asked to head project teams
    - Gives presentations on behalf of their company
    - Presents to colleagues within the company
    - Is a regular presenter at scientific conferences
    - Reads general engineering literature
    - Reads engineering management literature
    - Reads specialized engineering literature

- Receives awards for their work
- Is a regular guest speaker at conferences etc.
- Has attended a number of courses after graduation
- Finds acquiring additional knowledge useful
- Intends to attend more courses in the future

About the institute you are working for:

17. Please tick how many employees the company or institute you work for (the whole company not just your department)
    - small(less than 100 employees)
    - medium less than 1000 employees)
    - large (more than 1000 employees)
18. I work in the aerospace industry Yes/No

The competencies below may be of importance for engineers. The next question refers to the importance of these competencies in your current job.

19. Please indicate how important you think each of the following competencies in your current job (very unimportant, unimportant, not important/not unimportant, important, very important)
    - Ability to synthesise
    - Analytical skills
    - Problem solving skills
    - People Management skills
    - Operational Management skills
    - Written communication skills
    - Oral communication skills
    - Net worker
    - Have broad technical knowledge
    - Have specialist technical knowledge
    - Ability to work in teams
    - Ability for life-long learning

About competencies of engineers

The following questions pertain to the competencies of engineers and their career.

20. Please indicate how competent you deem yourself in each of the following competencies (-- very incompetent, - incompetent, + competent, ++ very incompetent)

In practice there appear to be two career tracks for engineers: the engineering specialist and the engineering manager.

An *engineering specialist* is an engineer who either works within a company or a research institute and is an expert in a part of engineering science and is not really involved in the running of the business or the institute only in its product. They are individual contributors. Product in this context could mean anything from aircraft parts to calculations. Typically scientists at universities, researchers at research institutes or research & product development departments, etcetera fall in this category.

An *engineering manager* is defined as an engineer who is in charge of the process leading to the product. They generally have to look at the bigger picture and are not as specialized although they have a broad technical knowledge. They typically have taken up a position of responsibility, such as manager, director, chairman, dean etc.

21. Please indicate for each of the competencies and for each type of engineer how important it is. (very unimportant, unimportant, not important/not unimportant, important, very important)
22. Do you consider yourself to be a specialist or a manager? If you feel you belong to both groups which of the two is most applicable? Specialist/manager/undecided
23. How much did your degree in Aerospace Engineering contribute to the competencies listed? (did not contribute, hardly contributed, contributed, contributed considerably)
24. Please list three parts of your degree (courses, practicals, internship, MSc thesis etc.) from which you still benefit in your current job environment?
25. If you had to choose a degree all over again would you again choose to study aerospace engineering? Yes/No
26. Why?
27. Would you recommend anyone to study aerospace engineering at the moment? Yes/No
28. Why?
29. Questions/Comments

APPENDIX E: RESULTS FROM ALTERNATIVE COMPETENCY SCALE

Competency		Activity	N	S	M	U
C.1 Ability to synthesise	AC1.	Is asked to be part of multi-disciplinary taskforces, working groups or research teams	675	2.12	2.47	2.24
	AC2.	Is asked to head multi-disciplinary taskforces, working groups or research teams	674	1.51	2.27	1.79
C.2 Analytical skills	AC3.	Is often asked by others for their view on problems	679	2.67	2.84	2.66
	AC4.	Their analysis of a problem is often accepted	680	2.83	2.88	2.81
C.3 Problem solving skills	AC5.	Their solution to a problem is often accepted	680	2.67	2.78	2.74
	AC6.	Is often asked by others to solve tedious problems	679	2.53	2.62	2.56
C.4 People Management skills	AC7.	Is in charge of a number of staff in current position	678	1.75	2.65	2.21
	AC8.	Reviews staff on performance reviews	679	1.27	2.36	1.63
	AC9.	Is mandated to negotiate contracts on behalf of employer	679	1.44	2.36	1.88
C.5 Operational Management skills	AC10.	Current position comes with financial & budget responsibility	678	1.68	2.57	2.10
	AC11.	Sets up new organizational structures & processes	680	1.43	2.49	1.86
	AC12.	Makes regular operational decisions effecting organisation and working of processes in the company	676	1.45	2.39	1.79
C.6 Written communication skills	AC13.	Writes scientific papers/articles	679	1.50	1.22	1.50
	AC14.	Writes policy documents/ Financial or Business plans.	680	1.45	2.26	1.76

	AC15.	Is asked to write documents by colleagues and supervisors	676	1.95	2.18	1.97
C.7 Oral communication skills	AC16.	Gives presentations on behalf of their company	680	2.00	2.48	2.26
	AC17.	Presents to colleagues within the company	679	2.18	2.39	2.19
	AC18.	Is a regular presenter at scientific conferences	679	1.50	1.26	1.53
C.9 Have broad technical knowledge	AC19.	Reads general engineering literature	680	2.16	2.00	2.13
	AC20.	Reads engineering management literature	678	1.41	2.30	1.73
C.10 Have specialist technical knowledge	AC21.	Reads specialized engineering literature	678	2.46	2.02	2.43
	AC22.	Receives awards for their work	679	1.29	1.29	1.28
	AC23.	Is a regular guest speaker at conferences etc.	678	1.47	1.75	2.24
C.11 Ability for life-long learning	AC24.	Has attended a number of courses after graduation	677	2.35	2.28	1.48
	AC25.	Finds acquiring additional knowledge useful	677	2.57	2.66	2.24
	AC26.	Intends to attend more courses in the future	676	2.36	2.35	2.47
C.12 Ability to work in teams	AC27.	Likes working in teams	680	2.66	2.81	2.45
	AC28.	Is often asked onto team projects	678	2.51	2.57	2.08
	AC29.	Is asked to head project teams	679	1.78	2.47	2.26

Table E.1 Means of alternative competency scale split according to whether the respondents deem themselves engineering specialists(S), engineering manager (M) or undecided (U). (1 – never, 2 - sometimes, 3 – often/very much)

APPENDIX F: CONTINGENCY TABLES OF COMPETENCIES VERSUS SUCCESS CRITERIA

This appendix contains all the contingency tables related to the χ^2 calculations in Chapter 5. Only the contingency tables for the significant relationships found between competencies and the success definitions have been reported here.

F.1 Importance of competency for an alumnus' current job

F.1.1 Job Responsibilities

Job responsibilities	Below average Successful	Average successful	Above average successful	Total
Neutral or unimportant	13.8%	8.4%	9.8%	11.0%
Important	50.4%	47.0%	35.2%	46.2%
Very important	35.8%	44.6%	54.9%	42.7%
Total	100%	100%	100%	100%

Table F.1a Ability to synthesize (N=653, $\chi^2(4) = 15.532$, p = .004)

Job responsibilities	Below average Successful	Average successful	Above average successful	Total
Neutral or unimportant	4.8%	1.2%	1.7%	2.9%
Important	35.4%	28.5%	19.0%	29.8%
Very important	59.8%	70.4%	79.3%	67.4%
Total	100%	100%	100%	100%

Table F.1b Analytical skills (N=665, $\chi^2(4) = 20.308$, p = .000)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	3.8%	1.6%	0%	2.3%
Important	31.8%	20.9%	19.0%	25.4%
Very important	64.4%	77.5%	81.0%	72.4%
Total	100%	100%	100%	100%

Table F.1c Problem solving skills (N=666, $\chi^2(4) = 19.642$, p = .001)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	21.6%	20.9%	15.6%	20.2%
Important	35.6%	45.8%	50.8%	42.3%
Very important	42.8%	33.2%	33.6%	37.5%
Total	100%	100%	100%	100%

Table F.1d People Management skills (N=667, $\chi^2(4) = 11.502$, p = .021)

Job responsibilities	Below average successful	Average Successful	Above average successful	Total
Neutral or unimportant	39.0%	26.7%	29.5%	32.6%
Important	36.0%	51.0%	47.5%	43.8%
Very important	25.0%	22.3%	23.0%	23.6%
Total	100%	100%	100%	100%

Table F.1e Operational Management Skills (N=665, $\chi^2(4) = 14.657$, p = .005)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	44.2%	23.3%	14.8%	30.9%
Important	34.9%	39.5%	39.3%	37.5%
Very important	20.9%	37.2%	45.9%	31.7%
Total	100%	100%	100%	100%

Table F.1f Broad Technical Knowledge (N=667, $\chi^2(4) = 53.517$, p = .000)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	60.6%	39.5%	24.6%	46.0%
Important	20.2%	29.6%	32.0%	25.9%
Very important	19.2%	30.8%	43.4%	28.0%
Total	100%	100%	100%	100%

Table F.1g Specialist Technical Knowledge (N=667, $\chi^2(4) = 53.962$, p = .000)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	19.9%	14.2%	10.7%	16.1%
Important	51.5%	52.2%	39.3%	49.5%
Very important	28.5%	33.6%	50.0%	34.4%
Total	100%	100%	100%	100%

Table F.1h Ability for life-long learning (N=666, $\chi^2(4) = 20.216$, p = .000)

F.1.2 Salary with work experience

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	36.8%	16.2%	9.3%	20.0%
Important	43.9%	46.5%	38.4%	42.4%
Very important	19.3%	37.3%	52.2%	37.6%
Total	100%	100%	100%	100%

Table F.2a People Management Skills (N=665, $\chi^2(4) = 82.391$, $p = .000$)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	47.9%	33.2%	19.8%	32.4%
Important	41.2%	44.0%	45.9%	43.9%
Very important	10.9%	22.8%	34.3%	23.7%
Total	100%	100%	100%	100%

Table F.2b Operational Management skills (N=663, $\chi^2(4) = 56.796$, $p = .000$)

Salary with work experience	Below average successful	Average successful	Above average Successful	Total
Neutral or unimportant	5.2%	1.6%	1.1%	2.6%
Important	42.5%	44.9%	29.9%	38.0%
Very important	52.4%	53.5%	69.0%	59.4%
Total	100%	100%	100%	100%

Table F.2c Oral communication skills (N=665, $\chi^2(4) = 23.650$, $p = .000$)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	37.3%	31.4%	25.5%	30.9%
Important	43.4%	49.7%	37.5%	42.8%
Very important	19.3%	18.9%	37.1%	26.4%
Total	100%	100%	100%	100%

Table F.2d Networking Skills (N=664, $\chi^2(4) = 28.714$, p = .000)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	23.6%	27.6%	39.6%	31.1%
Important	38.2%	40.5%	35.1%	37.6%
Very important	38.2%	31.9%	25.4%	31.3%
Total	100%	100%	100%	100%

Table F.2e Broad Technical Knowledge (N=665, $\chi^2(4) = 17.904$, p = .001)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	34.0%	45.4%	57.5%	46.6%
Important	29.7%	27.6%	21.3%	25.7%
Very important	36.3%	27.0%	21.3%	27.7%
Total	100%	100%	100%	100%

Table F.2f Specialist Technical Knowledge (N=665, $\chi^2(4) = 27.462$, p = .000)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	9.4%	17.9%	20.9%	16.4%
Important	51.4%	50.5%	47.0%	49.4%
Very important	39.2%	31.5%	32.1%	34.2%
Total	100%	100%	100%	100%

Table F.2g Ability for life-long learning (N=664, $\chi^2(4) = 12.617$, $p = .013$)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	5.2%	5.4%	4.1%	4.8%
Important	45.8%	36.2%	28.0%	35.9%
Very important	49.1%	58.4%	67.9%	59.2%
Total	100%	100%	100%	100%

Table F.2h Ability to work in teams (N=665, $\chi^2(4) = 18.016$, $p = .001$)

F.1.3. Salary with work experience and job responsibilities

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	14.2%	8.6%	9.1%	10.9%
Important	50.4%	46.4%	41.7%	46.7%
Very important	35.4%	45.0%	49.1%	42.5%
Total	100%	100%	100%	100%

Table F.3a Ability to synthesize (N=643, $\chi^2(4) = 10.833$, $p = .028$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	4.4%	1.8%	2.3%	2.9%
Important	32.8%	34.6%	19.3%	29.8%
Very important	62.8%	63.6%	78.4%	67.3%
Total	100%	100%	100%	100%

Table F.3b Analytical skills (N=654, $\chi^2(4) = 16.688$, $p = .002$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	4.0%	1.7%	0.6%	2.3%
Important	31.2%	24.0%	20.5%	25.8%
Very important	64.8%	74.2%	79.0%	71.9%
Total	100%	100%	100%	100%

Table F.3c Problem Solving skills (N=655, $\chi^2(4) = 13.975$, $p = .007$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	34.4%	11.4%	10.7%	20.0%
Important	41.2%	40.6%	46.9%	42.5%
Very important	24.4%	48.0%	42.4%	37.5%
Total	100%	100%	100%	100%

Table F.3d People Management skills (N=656, $\chi^2(4) = 62.575$, $p = .000$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	48.2%	25.9%	19.2%	32.6%
Important	38.6%	45.2%	49.7%	43.9%
Very important	13.3%	28.9%	31.1%	23.5%
Total	100%	100%	100%	100%

Table F.3e Operational Management skills ($N=654$, $\chi^2(4) = 52.856$, $p = .000$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	4.0%	1.3%	1.7%	2.4%
Important	46.4%	33.6%	33.3%	38.4%
Very important	49.6%	65.1%	65.0%	59.1%
Total	100%	100%	100%	100%

Table F.3f Oral Communication Skills ($N=655$, $\chi^2(4) = 17.028$, $p = .002$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	36.8%	30.3%	24.3%	31.1%
Important	42.8%	41.2%	43.5%	42.4%
Very important	20.4%	28.5%	32.2%	26.4%
Total	100%	100%	100%	100%

Table F.3g Networking skills ($N=655$, $\chi^2(4) = 11.473$, $p = .022$)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	44.8%	53.3%	40.1%	46.5%
Important	25.6%	25.3%	26.0%	25.6%
Very important	29.6%	21.4%	33.9%	27.9%
Total	100%	100%	100%	100%

Table F.3h Specialist technical knowledge (N=656, $\chi^2(4) = 9.999$, p = .040)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	4.8%	4.8%	4.5%	4.7%
Important	43.6%	30.1%	32.8%	36.0%
Very important	51.6%	65.1%	62.7%	59.3%
Total	100%	100%	100%	100%

Table F.3i Ability to work in teams (N=656, $\chi^2(4) = 10.873$, p = .028)

F.2 Ability of alumnus in a competency

F.2.1 Job responsibilities

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Incompetent	14.7%	10.8%	6.5%	11.7%
Competent	85.3%	89.2%	93.5%	88.3%
Total	100%	100%	100%	100%

Table F.4a Have broad technical knowledge (N=666 $\chi^2(2) = 6.013$, p = .049)

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Incompetent	45.5%	24.2%	17.1%	32.2%
Competent	54.5%	75.8%	82.9%	67.8%
Total	100%	100%	100%	100%

Table F.4b Have Specialist technical knowledge (N=667, $\chi^2(2) = 44.073$, p = .000)

F.2.2 Salary with work experience

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	29.1%	18.9%	14.1%	20.2%
Competent	70.9%	81.1%	85.9%	79.8%
Total	100%	100%	100%	100%

Table F.5a People management skills (N=667, $\chi^2(2) = 16.804$, p = .000)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	39.0%	28.6%	17.8%	27.6%
Competent	61.0%	71.4%	82.4%	72.4%
Total	100%	100%	100%	100%

Table F.5b Operational management skills (N=664, $\chi^2(2) = 26.711$, p = .000)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	7.5%	8.6%	17.5%	11.8%
Competent	92.5%	91.4%	82.5%	88.2%
Total	100%	100%	100%	100%

Table F.5c Have broad technical knowledge (N=667, $\chi^2(2) = 14.038$, p = .001)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	19.6%	30.3%	44.6%	32.6%
Competent	80.4%	69.7%	55.4%	67.4%
Total	100%	100%	100%	100%

Table F.5d Have specialist technical knowledge (N=668, $\chi^2(2) = 34.489$, p = .000)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	7.0%	13.0%	14.5%	11.7%
Competent	93.0%	87.0%	85.5%	88.3%
Total	100%	100%	100%	100%

Table F.5f Ability for life-long learning (N=668, $\chi^2(2) = 6.898$, p = .032)

F.2.3. Salary with work experience and job responsibilities

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	26.4%	16.2%	16.9%	20.3%
Competent	73.6%	83.8%	83.1%	79.7%
Total	100%	100%	100%	100%

Table F.6a People Management skills (N=656, $\chi^2(2) = 9.401$, p = .009)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	37.7%	22.4%	20.2%	27.6%
Competent	62.3%	77.6%	79.8%	72.4%
Total	100%	100%	100%	100%

Table F.6b Operational Management skills (N=653, $\chi^2(2) = 20.473$, p = .005)

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Incompetent	28.7%	40.4%	27.5%	32.4%
Competent	71.3%	59.6%	72.5%	67.6%
Total	100%	100%	100%	100%

Table F.6c Have specialist technical knowledge (N=657, $\chi^2(2) = 10.088$, p = .006)

F.3 Importance of competency for engineering specialist

F.3.1 Job responsibilities

Not applicable.

F.3.2 Salary with work experience

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	51.5%	58.0%	63.6%	58.2%
Important	45.6%	36.5%	31.8%	37.4%
Very important	2.9%	5.5%	4.5%	4.3%
Total	100%	100%	100%	100%

Table F.7a Networking skills (N=649, $\chi^2(4) = 10.538$, p = .035)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	8.4%	9.9%	15.8%	11.9%
Important	54.2%	53.0%	43.0%	49.3%
Very important	37.4%	37.0%	41.1%	38.8%
Total	100%	100%	100%	100%

Table F.7b Ability to work in teams (N=649, $\chi^2(4) = 10.426$, p = .034)

F.3.3. Salary with work experience and job responsibilities

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	8.7%	9.9%	18.3%	11.7%
Important	53.3%	52.7%	40.6%	49.6%
Very important	38.0%	37.4%	41.1%	38.7%
Total	100%	100%	100%	100%

Table F.8 Ability to work in teams (N=639, $\chi^2(4) = 13.310$, p = .010)

F.4 Importance of competency for engineering manager

F.4.1 Job responsibilities

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	37.2%	29.6%	21.0%	31.3%
Important	42.6%	40.9%	42.9%	42.0%
Very important	20.2%	29.6%	36.1%	26.7%
Total	100%	100%	100%	100%

Table F.9 Have broad technical knowledge (N=648, $\chi^2(4) = 16.714$, p = .002)

F.4.2 Salary with work experience

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	16.8%	18.4%	11.0%	14.9%
Important	49.5%	47.5%	44.3%	46.8%
Very important	33.7%	34.1%	44.7%	38.3%
Total	100%	100%	100%	100%

Table F.10a Analytical skills (N=645, $\chi^2(4) = 10.198$, p = .037)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	10.8%	8.3%	6.1%	8.2%
Important	42.4%	45.0%	34.1%	39.7%
Very important	46.8%	46.7%	59.8%	52.1%
Total	100%	100%	100%	100%

Table F.10b Problem solving skills (N=647, $\chi^2(4) = 12.088$, p = .017)

Salary with work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	3.0%	7.2%	5.7%	5.2%
Important	27.6%	39.4%	39.6%	35.8%
Very important	69.5%	53.3%	54.7%	59.0%
Total	100%	100%	100%	100%

Table F.10c Networking skills (N=648, $\chi^2(4) = 14.602$, p = .006)

F.4.3. Salary with work experience and job responsibilities

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	18.8%	7.9%	12.1%	13.2%
Important	40.2%	55.3%	43.9%	46.4%
Very important	41.0%	36.7%	43.9%	40.4%
Total	100%	100%	100%	100%

Table F.11 Ability to synthesize (N=627, $\chi^2(4) = 17.622$, p = .001)

F.5 Engineering managers on engineering managers

F.5.1 Job responsibilities

Job responsibilities	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	39.6%	29.6%	14.0%	32.1%
Important	41.5%	39.1%	44.0%	41.0%
Very important	18.9%	31.3%	42.0%	26.9%
Total	100%	100%	100%	100%

Table F.12 Broad Technical Knowledge (N=324, $\chi^2(4) = 17.250$, $p = .002$)

F.5.2 Salary with work experience

Salary and work experience	Below average successful	Average successful	Above average successful	Total
Neutral or unimportant	30.9%	21.1%	37.9%	32.1%
Important	32.7%	42.2%	44.0%	41.6%
Very important	36.4%	36.7%	18.1%	26.3%
Total	100%	100%	100%	100%

Table F.13 Broad Technical Knowledge (N=327, $\chi^2(4) = 17.029$, $p = .002$)

F.5.3 Salary with work experience and job responsibilities

Salary with job responsibilities and work experience	Below average successful	Average successful	Above average successful	Total
Important	19.8%	7.5%	8.9%	11.2%
Very important	80.2%	92.5%	91.1%	88.8%
Total	100%	100%	100%	100%

Table F.14 People Management skills (N=321, $\chi^2(4) = 8.751$, $p = .013$)

SUMMARY

STUDY OF DELFT AEROSPACE ALUMNI

This thesis was based on the desire to investigate if the current curriculum of the Faculty of Aerospace Engineering at Delft University of Technology sufficiently prepares its graduates for their future careers. This was done by studying the alumni of the faculty as they are in the best situation to assess the impact of their degree in aerospace engineering on their professional success and comment on what are important qualities for aerospace engineers to have in order to differentiate themselves from those with an average career.

To discover what those qualities were, a literature survey was carried out which identified a number of competencies. These competencies were then put in front of an expert panel consisting of employers of aerospace engineers. Based on a literature survey and feedback of an expert panel a list of 12 competencies, deemed important for the professional success of alumni, was developed. These competencies are: the ability to synthesize, analytical skills, problem solving skills, people and operational management skills, oral and written communication skills, networking skills, broad technical knowledge, specialist technical knowledge, ability for life-long learning and the ability to work in teams. It was also discovered in literature that there are two principal career tracks of aerospace engineers: that of the engineering specialist and that of the engineering manager. Therefore it was also important to find out if there were different competencies needed to be successful as an engineering specialist than as an engineering manager. Based on the literature survey carried out, a decision was taken to limit the success definition to three factors: level of job responsibility, salary with respect to work experience and the combination of the two: salary with respect to work experience and level of job responsibility.

All aerospace alumni, listed in the Delft Alumni Office database, who graduated between 1975 and 2000, were approached using a questionnaire. The response to the questionnaire was 40%.

The results of the questionnaire showed that the alumni are employed, earn above average salaries and are very satisfied with their degree. They would also recommend the current degree programme to others. Just under half of the respondents still work in the aerospace industry and more than two thirds work in a position that requires an engineering degree. Only one in four alumni

undertake formal forms of further education such as a PhD degree or an additional Master degree. Additional degrees only appear to broaden their scope. With regards to their degree in aerospace engineering alumni indicated that both the courses which emphasize synthesis and closely resemble the later professional work environment such as the MSc thesis, the internship and the design exercises as well as core engineering courses such as mechanics, mathematics and structures are still important to them today.

The results of the survey showed that all 12 competencies were important to a certain degree for an alumnus' current job. All relationships were positive with two sets of exceptions. Firstly, the competencies networking skills, ability to work in teams were found to be important regardless of success in terms of salary with work experience. The second exception is the negative relationship between success in terms of salary with work experience and job responsibility and specialist technical knowledge. The overall list of competencies was found to be a valid list of abilities aerospace engineers should possess to be successful in their jobs. No significant relationship however, was found, between the contribution of aerospace engineering to the competencies and professional success. Alumni feel that the degree course in aerospace engineering did not contribute much to the competencies people management skills, operational management skills and networking skills neither did their degree contribute to the competencies oral communication skills and the ability for life long learning. Alumni also indicated they, themselves, are less capable in people and operational management skills as well as networking skills. The results also showed that having good specialist technical knowledge does contribute to more job responsibility but not necessarily to more salary. It was again found that the alumni's ability in people and operational management skills have a positive influence on their professional success.

Finally, the results showed that contrary to the general opinion of alumni engineering specialists feel that people management and operational management skills as well as networking skills are important for them to their job. The contrary is true for specialist technical knowledge. When looking at engineering managers it was found that engineering managers still find analytical skills important contrary to the general perceptions of respondents.

The findings of this thesis suggest that the aerospace curriculum needs to focus on three things to prepare aerospace engineers better for their professional careers: a good basic grounding during the BSc in the fundamental subjects of mathematics, structures and mechanics, the fundamental aerospace courses without too much specialization, and ensure that the design of courses in both the BSc and MSc closely resembles the professional working environment. In order to show students what research fields are available in terms of specialization during the MSc phase it would be a good idea to imbed those in the educational projects in the BSc phase.

Competencies such as networking skills, operational and people management skills and oral communication skills must become an integral part of the curriculum as this research has shown that they affect the professional success of aerospace alumni and that alumni feel that their degree aerospace engineering has not sufficiently contributed to those skills. It is highly recommended to create opportunities in the aerospace curriculum for students to develop and be assessed on networking skills as well as operational and people management skills is highly recommended, for instance in a project based learning setting and by involving outsiders.

Currently, some of the competencies such as working in teams, written reporting and oral presentation skills listed in this research have already been imbedded in the projects which were introduced after the curriculum change in 1995. These initiatives must not be abandoned but to the contrary more competencies should be imbedded in those projects as well as other courses.

Gillian N. Saunders-Smits

SAMENVATTING

EEN STUDIE NAAR DE ALUMNI VAN LUCHTVAART- EN RUIMTEVAARTTECHNIEK IN DELFT

De totstandkoming van dit proefschrift werd geïnspireerd door de behoefte om te onderzoeken of het huidige curriculum van de Faculteit Luchtvaart- en Ruimtevaarttechniek aan de Technische Universiteit Delft haar afstudeerders voldoende voorbereid op hun toekomstige carrière. Daartoe is een studie uitgevoerd onder de alumni van de faculteit aangezien alumni zich in de beste positie bevinden om de impact van hun opleiding in de luchtvaart- en ruimtevaarttechniek op hun professionele succes te beoordelen en aan te geven wat belangrijke kwaliteiten zijn die een ingenieur lucht- en ruimtevaarttechniek moet bezitten om zichzelf van degene met een gemiddelde carrière te kunnen onderscheiden.

Om te ontdekken welke kwaliteiten het hier betreft is een literatuurstudie uitgevoerd waarin een aantal competenties zijn geïdentificeerd. Deze competenties zijn vervolgens aan een expert panel voorgelegd, bestaande uit werkgevers van luchtvaart- en ruimtevaart ingenieurs. Aan de hand van de literatuurstudie en de feedback van het expertpanel is een lijst van 12 competenties ontwikkeld, die belangrijk worden geacht voor het professionele succes van alumni. Het betreft hier de competenties: kunnen synthetiseren, analytisch vermogen, probleemoplossend vermogen, people en operationele managementvaardigheden, mondelinge en schriftelijke communicatie-vaardigheden, kunnen netwerken, brede technische kennis, specialistische technische kennis, nieuwe kennis opdoen/bijblijven en kunnen samenwerken in een team. Uit de literatuurstudie bleek verder dat er twee carrièrepaden voor ingenieurs luchtvaart- en ruimtevaart te onderscheiden zijn: die van de specialist en die van de manager. Het was daarom ook belangrijk om the onderzoeken of men andere competenties nodig had om succesvol te zijn als specialist dan als manager. Aan de hand van de literatuurstudie is ook de beslissing genomen om de succesdefinities te beperken tot drie: de hoeveelheid verantwoordelijkheid in een functie, salaris in combinatie met jaren werkervaring en een combinatie van beide: de hoeveelheid verantwoordelijkheid in een functie gecombineerd met salaris en jaren werkervaring.

Voor dit onderzoek zijn alle alumni luchtvaart- en ruimtevaarttechniek die in de database van de Delft Alumni Office geregistreerd staan en tussen 1975 en 2000 zijn afgestudeerd benaderd door middel van een enquête. De response van deze enquête was 40%.

De resultaten van de enquête lieten zien dat de alumni bijna allemaal werkzaam zijn, bovengemiddeld verdienen en erg tevreden waren met hun studie. De alumni zouden de huidige studie ook aan anderen aanraden. Iets minder dan de helft van het aantal respondenten werkt nog in de luchtvaart- en ruimtevaarttechniek en meer dan tweederde van de respondenten werkt in een functie waarvoor een ingenieurstitel noodzakelijk is. Slechts één op de vier alumni heeft nog verder geleerd in termen van een promotie of een andere master studie. Eventuele extra studies dienen vooral ter verbreding van de horizon.

Voor wat betreft hun studie luchtvaart- en ruimtevaarttechniek geven de alumni aan dat zowel de studieonderdelen die synthese benadrukken en erg op de toekomstige beroepspraktijk gericht zijn zoals hun afstudeerwerk, de stage en de ontwerpoefeningen, als de kernvakken in de techniek, zoals mechanica, wiskunde en constructies, vandaag de dag voor hen nog steeds belangrijk zijn.

De resultaten van de enquête toonden ook aan dat alle 12 competenties in bepaalde mate belangrijk zijn voor de huidige functie van een alumnus. Op twee gevallen na waren alle onderzochte verbanden positief. De uitzondering was dat de competenties kunnen netwerken en kunnen werken in teams belangrijk bleken te zijn ongeacht hoe succesvol de alumnus was qua salaris en jaren werkervaring. De tweede uitzondering was de negatieve relatie tussen succes in termen van de hoeveelheid verantwoordelijkheid in een functie gecombineerd met salaris en jaren werkervaring en specialistisch technische kennis. De totale lijst met competenties bleek een zeer valide lijst van competenties te zijn die ingenieurs luchtvaart- en ruimtevaarttechniek dienen te beheersen om succesvol te zijn. Er is echter geen specifieke relatie gevonden tussen de bijdrage van hun studie luchtvaart- en ruimtevaarttechniek en de competenties en het professionele succes van alumni. De alumni vinden verder dat hun studie luchtvaart- en ruimtevaarttechniek weinig bijdraagt aan de competenties people en operationele management vaardigheden, kunnen netwerken, mondelinge presentatie vaardigheden en nieuwe kennis opdoen. De alumni gaven ook aan dat zij zichzelf nog steeds in de competenties people en operationele management vaardigheden en kunnen netwerken te kort vinden schieten. Verder toonden de resultaten aan dat het hebben van specialistische technische kennis wel bijdraagt tot meer verantwoordelijkheid in een functie maar niet noodzakelijk tot meer salaris. Verder werd aangetoond dat de competentie van alumni in de people en operationele management vaardigheden een positieve invloed hebben op hun professionele succes.

Tenslotte, toonden de resultaten aan dat in tegenstelling tot de algemene mening van de alumni, specialisten aangeven dat people en operationele managementvaardigheden en kunnen netwerken ook voor hen belangrijk zijn bij het uitoefenen van hun functie. Het tegengestelde is het geval voor specialistische technische kennis. Voor managers werd gevonden dat analytische vaardigheden voor managers belangrijker zijn dan de alumni denken.

De resultaten van de proefschrift laten zien dat het curriculum van de studie luchtvaart- en ruimtevaarttechniek op drie zaken moet letten om hun ingenieurs beter op hun carrière voor te bereiden: Het verkrijgen van een goede basis tijdens de BSc in de kernvakken wiskunde, constructies en mechanica, in de basis lucht- en ruimtevaartvakken zonder te veel te specialiseren en er zorg voor te dragen dat de onderwijsvormen in de BSc en de MSc dicht bij de beroepspraktijk liggen. Om studenten te laten kennismaken met de vele specialisatiemogelijkheden tijdens de MSc is het een goed idee om de specialisatiemogelijkheden in te bedden in de onderwijsprojecten van de BSc.

Competenties zoals kunnen netwerken, operationele en people managementvaardigheden en mondelinge communicatievaardigheden moeten een integraal onderdeel van het curriculum worden. Dit onderzoek heeft aangetoond dat deze competenties een grote invloed op het professionele succes van afgestudeerden hebben en dat de alumni aangeven dat hun studie ze hier niet voldoende op heeft voorbereid. Het wordt aanbevolen om in het curriculum mogelijkheden te creëren waarbij studenten deze vaardigheden kunnen ontwikkelen en op kunnen worden beoordeeld, bijvoorbeeld in de setting van projectonderwijs en door buitenstaanders bij projecten te betrekken.

Momenteel zijn sommige van de genoemde competenties zoals het werken in teams, mondeling en schriftelijk rapporteren al ingebed in de projecten die tijdens de curriculumherziening van 1995 zijn geïntroduceerd. Deze initiatieven moeten vooral worden voortgezet en het aanleren van verdere competenties tijdens projecten en andere studieonderdelen dient verder te worden uitgebreid.

G.N. Saunders-Smits

CURRICULUM VITAE

Gillian Nicola Saunders – Smits was born on 9 July 1975 in Leiderdorp, The Netherlands. She attended the 'Christelijke Scholengemeenschap Dr. W.A. Visser 't Hooft' in Leiden, the Netherlands from which she obtained a 'Gymnasium' diploma in 1993. In the fall of 1993 she enrolled at the Faculty of Aerospace Engineering at Delft University of Technology from which she graduated with an MSc degree in 1998. Her Master thesis was on the effect of cross-coupling on the buckling load of imperfect, anisotropic, cylindrical shells under rigorous boundary conditions in the Aerospace Structures and Computational Mechanics Group under the supervision of Prof. Dr. J. Arbocz. During her time as a student she worked as a Mechanics teaching assistant tutoring third year students in advanced dynamics.

After a short stint as a facilities engineer at Shell International Exploration and Production B.V. in The Hague she rejoined the Faculty of Aerospace Engineering in 1999 to teach flight mechanics and propulsion in the chair of Aircraft Performance. In 2000 however, she returned to her old research group to become the Faculty's Project Education Coordinator. Currently, Gillian is still the Faculty's project education coordinator, coordinating all first and second year projects, next to being a member of the Design Synthesis Exercise coordination team and teaching first year mechanics courses in Statics and Mechanics of Materials. In 2003 she was part of the Design Synthesis Exercise team that won the 'Universiteitsfonds - Ritsema van Eck' prize for excellent teamwork. Within the Design Synthesis Exercise she is responsible for the short courses and the International Design Exercise with Queen's University Belfast, Northern Ireland.

In 2002 she started working on her PhD in Engineering Education under the direction of Prof dr. Erik de Graaff. Her research interest continues to be in engineering education and as such she is active in developing new teaching tools for use in projects and studying the outcomes of project education at the Faculty of Aerospace Engineering.