The Integration of Academic Education and Research and Development

September 2001

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The integration of academic education and research and development

Emeritus lecture
held on the 26th of September 2001
at the Delft University of Technology

by

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The scientist explores what is, the engineer creates what had not been.

Theodore von Karman
The integration of academic education and research and development

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The integration of academic education and research and development

Mijnheer de Rector Magnificus en overige leden van het College van Bestuur,

Geachte collegae hoogleraren, docenten en medewerkers van de Universiteit,

Geachte dames en heren studenten,

Beste familieleden, vrienden en collegae van buiten de Universiteit,

Dear friends and colleagues from abroad,

Valued listeners,

Today I have the honour of addressing you on the occasion of my retirement from a period of education and research in the field of aerospace engineering at the Delft University of Technology.
The Delft University of Technology

During my inaugural speech of the 9th of June 1993, I attempted to present a vision of the role of the technical university within our society. The society to which I referred was still somewhat limited. At the time, we focussed mainly on the Dutch society; feeling that we were largely responsible for the future of Dutch industry. Much has changed since then. Enormous advances in information technology have led to a globalisation of our societies and the co-operation of universities around the world.

Delft University of Technology wants to belong to the world’s top-ranking research universities in the field of science and technology. I support this ambition wholeheartedly: every self-respecting university must, of course, contribute to the efforts to push the bounds of science by fundamental research.

On the other hand, restricting ourselves to carrying out only fundamental, science-based research, would be to deny the true nature of research across the whole field of science and technology. This is, however, the current trend within what are known the world’s top technical universities. I am of the opinion that this is not a route the Delft University of Technology should take. Delft is known the world over for the technical products its engineers produce, such as the Delta-works, the construction of harbours, the design and
manufacturing of ships and aircraft, electro-technical products, exploration for oil and gas, process-technologies etc. These advanced products are the basis for the respectable reputation the Delft University of Technology has earned throughout the world.

Research always requires a goal. We want to know what we don’t know, do what we can’t do, create what doesn’t exist, and all with our society in mind. Between 1605 and 1608 Simon Stevin van Brugghe published a series of teachings he gave Prince Maurits from 1593 onwards, entitled “Wisconstighe Ghedachtenissen” (Mathematical Notions). One of his notions concerned the ‘mixing of reflection and deed’, the combination of theoretical contemplation and practical execution. According to Stevin it is impossible to practise a craft without an understanding of the theory behind it. As the motto of the Dutch Royal Institute of Engineers says:

"Scheppend denken, denkend doen".
(Think creatively, create thoughtfully)

Education and research are inseparably joined. There can be no education without research, nor research without education. This is my premise. The Delft University of Technology is a technical university: ‘university’ stands for scientific education and science-oriented research, ‘technical’ stands for object-oriented research (design).

This trinity forms the foundation of a technical university. We therefore need to obtain a good balance between science-oriented research, object-oriented research and scientific education.

The role of the Delft University of Technology is no longer in question. This role is prominently international. But let us not allow ourselves to be trend-followers instead we should be trend-setters. Scientific publication should not be the only thing that counts, pioneering design is equally important. To assure a leading position in the European educational market means competing with the best European universities. This requires a clear education and research strategy, transparent leadership and output-controlled process-organisation.
Faculty of Aerospace Engineering

The Faculty of Aerospace Engineering supports the university-wide mission wholeheartedly. It goes without saying that a self-respecting university must contribute to the advancement of science through important achievements in fundamental research. The faculty owes its respected international position to the merging and integration of various fields of study; this process is essential to integral aircraft and spacecraft design. The faculty's unique character stems from its object-oriented nature, in other words, its primary focus on air- and spacecraft throughout a comprehensive set of relevant, in-house fields of study. Insight and overview, interconnectivity and collaboration are all pivotal notions for both faculty staff and aspiring students within the faculty. An essential aspect of being a scientist in a scientific engineering environment is that progress is made as a result of intense interaction between theory and practise.

There is no doubt about the striking success of the faculty, mainly due to its continuous striving for a balance of responsibilities—scientific research, object-oriented research, and system integration, in addition to academic education.
Chair Aerospace Structures and Materials

A typical Delft Chair.

"Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world." (Albert Einstein)

In my chair, besides research, the education of young creative MSc and PhD students is our main incentive, the red line through our large Structures and Materials Laboratory. Education by performing research. Advanced research keeps our lectures up to date and highly stimulates our student design projects, which are performed in every year of our curriculum.

An engineer as we see him/her is a creator of technological objects using knowledge and methods derived from science. Our title "ingénieur" (according to our USA ABET assessment equivalent to the USA MSc) is derived from ingenious. An ingenious, creative person. Our goal is the training of "top level" "ingénieurs" with a broad fundamental knowledge-base and a market-oriented approach. A materials engineer who knows about the design and application of material systems in relation to structural design and fabrication.
The duty to synthesis

No computer-screen engineers, but engineers educated in a realistic environment: we call it the "University Workfloor".

So we prefer to let our students perform their MSc and PhD research in our own laboratory rather than sending them to work in the industry.

Our workflow is a technology and science shopfloor for the industry. This is an advantage for both parties; the industry gets access to a source of technological knowledge and creativity, the university can keep its laboratories up to date, while the students work on realistic projects. It is a co-operation of
equal partners. A leading university never needs to be afraid of losing its academic freedom. Our education always stays the red line through our science and object-oriented research.

The university workfloor, including the Structures and Materials Laboratory, stands at the centre of a network, with lively contact between the university and the community around it.

Surrounding this are a number of self-supporting institutes that function as windows to the outside world. These institutes are responsible for the transfer of knowledge and acquisition of new projects. At the moment these are:

- Foundation Fibre Metal Laminates Centre of Competence (FMLC), an equal co-operation between the National Aerospace Laboratory (NLR), Stork Fokker Aerostructures (Fae) and Delft.
- Centre of Lightweight Structures (CLC), a cooperation between the Netherlands Organisation for Applied Scientific Research (TNO) and Delft.
- Adhesive Institute Delft, an interfaculty institute.
- Koiter Institute of Computational Mechanics, an interfaculty institute.

The outer circle contains our permanent research partners, national and international companies, research institutes and governmental organisations. Crossing the circles from the inside out is a stream of young entrepreneurs. These entrepreneurs remain attached to the 'umbilical cord' of the 'womb' (the workfloor) for as long as necessary until becoming companies in their own right in the outer circle.
The chair follows a top-down approach as regards most of the research.
Society (industry) has a need for design capabilities or new developments that need to be undertaken. These requests are usually made via the institutes and end up reaching the university workfloor. Projects that can be solved using ready made solutions and knowledge, those which have already been developed, are usually undertaken by the institutes, where many contract researchers ("toegevoegd onderzoekers") from the university will work on them. Projects that require the development of new knowledge and new techniques are usually passed on to the scientific university staff and post-graduate students. Graduate projects are mostly performed in both groups. This leads to the education of the "ingenieur" with a broad fundamental background as well as a market-based attitude.

I have heard critics comment that this system looks very similar to a higher technical education ("HBO"). This is not the case, however. Both "HBO" and the technical university educate engineers, both design products, but the "HBO" engineer will use existing tools to do this, whereas the TU graduate should also be able to use his science-oriented background to invent new and innovative tools to help create new solutions and pioneering designs.

Object-oriented research embedded in science-oriented research

A vertical projection of the preceding picture makes this clear. The object-oriented research is fully embedded in an environment of science-oriented research.
MSc projects are completed in one year, while PhD projects take four. To keep the quality of these projects as high as possible, the students need to have a modern and fully equipped laboratory at their disposal. This is essential for efficient research.

The chair has a large national and international network that goes beyond aerospace engineering. Lightweight constructions, the expertise of the chair pur sang are becoming important in many other industries and have a significant potential throughout the whole transport and civil engineering sectors. This specialisation derives its specific characteristics from the stringent demands made by the aerospace industry. The product weight must be as low as possible, while carrying as large a load as possible and using as little fuel as possible. At the same time, the structure must be extremely reliable and require only efficient and cheap servicing and repair. The need for long life-spans means that modern aircraft must be durable, in other words free from cracks and corrosion problems. They must also be resistant to damage and be damage-tolerant; the structure needs to have a fail-safe character. Even under rare and extreme circumstances, the aircraft should not fail.

This opposition, high safety versus lightweight construction has led to the development of highly specialised materials within the aerospace industry, and thereby exceptional construction concepts and manufacturing techniques. In particular one can name:

Materials:
- hybrids such as fibre-metal laminates
- fibre-reinforced plastics
- new aluminium alloys

Structural concepts:
- thin-skin, self-supporting shell structures
- sandwich structures
- space-frame structures
Manufacturing techniques:
- Splicing concept for hybrids, filament winding of large components, vacuum injection moulding, advanced forming techniques and advanced joining techniques.

"In fact we have to give up taking things for granted, even the apparently simple things. We have to learn to understand nature and not merely to observe it and endure what it imposes on us. Stupidity, from being an amiable individual defect, has become a social vice."

(J.D. Bernal, New Scientist, taken from The New Science of Strong Materials, J.E. Gordon)

Technology has been a formidable force within society during the last two centuries, and this is still the case. Technological innovation has greatly altered our way of life: such innovation is directly linked to economic growth, with a growing level of supply and demand and longer life-spans in the western world. Well-being and prosperity are largely the result of...
the innovativeness of a country’s business community. A lack of regenerative business leads to poverty and unemployment. Only the presence of regenerative business allows us to determine our own paths, in other words to retain our personal freedom and responsibility (KIVI workgroup "Regenerative business"). The universities in particular have a special role to play in this. They are the breeding-place for the young, creative engineers who will form the backbone of the regenerative industries as well as being the breeding-place for new developments through long-term strategic research.

President Marvin Goldberger of CalTech University says: "Select the very best people, give them the very best facilities and stand aside". This is how the Structures and Materials Laboratory was created in Delft.

The laboratory spends most of its time developing ‘products’, often up until the prototype stage. Such products include aircraft and spacecraft components, robot-arms, predictive computational models (fatigue, residual strength), new material systems, new production techniques and new design tools (CAD, FEM, etc.). We concentrate on advanced products with a high added value and acceptable labour costs. This inevitably leads to the development and application of new materials and clever design and production techniques. One should not concentrate on only one group of materials when designing products. Lightweight structures are usually built up from various materials and use a variety of different joining techniques. Integrated and modern design and production methods make an important contribution, allowing us to compete in an environment in which the competition is becoming more global. Applying new techniques helps us to overcome the handicap of the traditionally high Dutch wages and our social, economic and environmental constraints.

Most of the research in our chair is performed in the Structures and Materials Laboratory. The research efforts of the laboratory have three corner stones:

- Science-oriented research. Successful application of new materials and design strategies can only be achieved if based on a thorough scientific understanding of the mechanical, physical and chemical aspects of materials and the optimal lay-out of structures.
- Integration of various disciplines. The laboratory has the knowledge, skills and equipment to cover the complete development of a structure: from materials science, structural design and manufacturing techniques to the fabrication and testing of full-scale components.
- Close co-operation with industry. The laboratory has a strong design-oriented approach. Input and questions from the industry are essential to guide the research, which is directed towards the gathering of engineering knowledge for the solution of practical problems.
The expertise of the laboratory covers an area from micro-mechanics of materials via design and manufacturing techniques up to full-scale testing of components. A thorough knowledge of and insight into the relationship between micro-structure and macro-properties of materials is of increasing importance when optimising the application of materials in constructions. This relationship is pursued experimentally, in combination with model development. The material behaviour which has been investigated includes the resistance against mechanical loading, both static and dynamic, durability, workshop properties, forming and environmental consequences like recycling.

The tendency towards more advanced materials, more powerful computational tools, modern design methods, more flexible and computerised manufacturing techniques and last but not least destructive and non-destructive inspection, requires an integration of the various disciplines involved.

There is now a strong interrelationship between material selection and properties, structural design and processing.

A representative selection of some of our research topics is given in the following:

Development of Fibre-Metal Laminates

The development of this family of materials is a typi-
A380 high capacity aircraft

Through GLARE, the university workflow reached international fame and realised a "technology mature" hybrid structural material with a combination of excellent material properties. Furthermore, the splicing concept offers the possibility to increase the size of FML structures without decreasing the excellent residual strength and fatigue properties. Integration of aircraft production steps in the production of FML in combination with the application of the splicing concept yields a cheaper aircraft (in terms of production, operating and maintenance cost) at an increased safety level: damage tolerance is built into the material and GLARE also has a high burn-through resistance.

Damage Tolerant Repair Techniques for Pressurised Aircraft Fuselages

The need for good repair techniques predates powered flight and continues to be an integral part of flying today. Structural repairs on commercial airliners and military transport are most typically required for fatigue cracking, corrosion and incidental damage such as impact. For military aircraft, battle damage joins the above list.

In 1991 an ongoing joint project with the USAF was initiated to develop a computer design tool (with the acronym "CalcuRep"), which enables a user to accurately design a safe bonded repair in which all affecting variables are accounted for. An inherent fatigue, corrosion and impact-resistant material, like GLARE, may help to ensure a damage tolerant solution for bonded repairs.
Compared to mechanical fastening, adhesive bonding provides a more uniform and efficient load transfer into the repair patch and can reduce the risk of high stress concentrations caused by riveted repairs. The effects of different temperatures and moisture levels on the bonded repair efficiency were investigated. This meant gaining knowledge of the effects of different environments on each component of the repair through extensive testing, even in-flight, backed up by finite element modelling. Techniques like Ultra Sonic Scanning and Scanning Electron Microscopy (SEM) were used to visualise and qualify those environmental influences.

Repair of the Panorama Mesdag

Panorama Mesdag

The water damage inflicted on the huge and world-famous Panorama Mesdag, a true piece of Dutch national heritage, by a heavy thunderstorm on the 2nd of June 1983, clearly meant that something had to be done.

The Panorama Mesdag is one of the few 19th century panoramas that still exists; the others in Europe were given up after such damage. In their search for knowledge, the restorers called on our laboratory with a view to applying advanced methods of repair to the Panorama as used for aircraft.
The backing chosen was a nylon fabric. We carried out computer calculations to estimate the stresses that would occur and the shape of the canvas before and after lining it with the nylon. The Panorama canvas has a unique concave "hourglass" shape which was not to be affected by the restoration. Calculations showed that the peculiar shape would be preserved. Advanced repair techniques were developed using heat blankets and a vacuum frame to apply the accurate uniform pressure during the bonding process.

To master the lining process, a model of a Panorama segment having a height of 9 metres and in the same double-curved shape was built at the laboratory.

An extensive durability test programme ensures that the repair will hold for at least 50 years. The scene of the peaceful beach of Scheveningen of 1880 has thus been preserved. An official opening by Queen Beatrix marked the completion of the successful high-tech restoration project.

Development of the Dart, Delft Aerospace re-entry test demonstrator

The Dart is a small experimental spacecapsule, designed to investigate the extremely hot gasflow around the capsule during re-entry into the atmosphere.

The capsule will be made from the super alloy PM 1000. This is an alloy based on nickel and chromium and it can resist temperatures up to 1200 °C. When it oxidises, a thin oxide layer will be formed that will protect the structure against further attack.

To avoid overheating the metal, an ingenious water protection system has been developed. During re-entry the water vapourises, the steam is discharged, and so overheating will be avoided. Calculations have shown that only 10 litres of water is enough to discharge the heat of the free fall into our atmosphere.

![DART re-entry capsule diagram](image)

A = Steam discharge pipe
B = Porous layer, saturated with water
C = Metal skin
D = Metal water reservoir
The development of an ultra-light sustainable concept car

The Dutch-EVO (EVO stands for evolution), prototype study of a car, has been undertaken to stimulate innovative, multidisciplinary object-oriented research. The parties who initiated the program are the Faculty of Industrial Design (design and control), Applied Earth Sciences (product life cycles) and the Faculty of Aerospace Engineering (structural design, aerodynamics and safety) in co-operation with TNO.

The framework for the Dutch-EVO consists of: minimal fuel consumption (2.5 ltr/100 km), 4 passengers and luggage, lightweight design (mass 400 kg), environmentally friendly, application of renewable material resources. This goal can not be achieved with the available technology. New techniques have to be developed, a special aerodynamic shape, advanced designing techniques, especially for impact, new materials and new suspension techniques. The project aims for the realisation of a full-scale operating prototype.

Dutch-EVO

New structural concepts

Teamwork

Part of the research group Structures and Materials Laboratory

Teamwork is the ability to work together towards a common vision. The ability to direct individual accomplishment towards organisational objectives. It is the fuel that allows common people to obtain uncommon results.

It is not my style to look back; I am much more interested in the future. I strongly believe in a prosperous future for my own group: students, staff and institute members. What a fantastic team! Without our team
spirit and a strong mutual belief in a risky research project, GLARE would never have become a success. My grandfather advised me, when he heard about my choice for a scientific carrier, never to take the common road. He was a wise man. So I chose, remembering his advice, the road of hybrid materials. And that was not an easy one.

Belief in the future is more important than predicting it. An engineer must never let himself attempt to predict the future. That is impossible, since almost everything is possible. Flying by manpower is impossible according to Giovanni Alfonso Borelli in his famous book "Matu Animation" (about the motion of animals). He was wrong and I always taught my students to be stimulated by such absolute statements to prove the opposite. Daedalus tried to do so. The myth of the Icarus story is intriguing and I used to ask my first-year students about the reason for the accident. Was it pilot error or the wrong structural design?

Maybe Daedalus and his son forgot to team up with others. Then they might have come to the conclusion that the available materials and joining techniques were not good enough and more research had to be done first. Anyhow, with GLARE we did not make that mistake but teamed up with specialists, the best in their field, AKZO Nobel, 3M, ALCOA, Fokker, Airbus Industry, NLR and, with flying colours, the Structural Laminates Company (SLC).
Closing remarks

I have now come to the end of my speech and would like to thank my foreign guests for their patience as I switch to my mother tongue to say my final words of thanks.

Dames en heren,

Het is heel lang geleden, namelijk in september 1957, dat ik mij meldde als 1e jaars student aan de toen nog Technische Hogeschool Delft. Een rekensommetje leert mij dat ik bijna drie kwart van mijn huidige leven verbonden ben geweest aan de TU Delft. Ik mag dus met recht zeggen dat ik een echte Delftenaar ben, en dat voelt heel erg goed.

Bij mij is tegenzin in het werk nooit echt aan de orde geweest. Natuurlijk had ik ook mijn mindere momenten, maar dan was daar altijd de koffietafel in het laboratorium, waar mijn studenten zaten, jonge veelbelovende mensen, altijd enthousiast met een vast vertrouwen en zin in de toekomst. Dan sloeg mijn slechte stemming snel over en besef je waar het echt om gaat.

Dames en heren studenten, het was voor mij een voorrecht om voor U te mogen werken. Ik zal U missen.
In mijn intreerende heb ik de mythe van Sisyphus aan-gehaald. Sisyphus als symbool voor de moderne inge-nieur. Voor de mensheid zal nooit een moment komen om op de top van de berg te rusten. Ons werk zal nooit zijn voleindigd. Dat stel mij als emeritus hoogleraar weer een beetje gerust. Ik blijf dan toch maar in de buurt, zij het op bescheiden afstand.

Voor mij was natuurlijk de meest vertrouwde omgeving die van de leerstoel en van het laboratorium. Creatief en vooral grensverleggend bezig zijn, ik heb ervan genoten. En dat in een Faculteit die tegen de verduikking in, denk maar aan het faillissement van Fokker, gestag blijft groeien. Dat komt vooral door dat wij voor onze eigen weg kiezen, en niet meelopen in de grote massa. De Faculteit verkiest trendsetter te zijn en niet trendvolger.

Aan veel mensen ben ik dank verschuldigd. Zowel binnen als buiten de TU-gemeenschap. Gaarne zou ik al die namen willen noemen waarmee ik heb samenge-werkt en die zo enorm hebben bijgedragen aan mijn werkgeluk. Helaas is dan nu niet mogelijk. Een uitzon-dering wil ik maken voor: Jaap Schijve, mijn leermeester en nog steeds betrokken bij de leerstoel, voor Jan Willem Gunnink, directeur van SLC, nu directeur van FMLC, mijn directe partner en motor bij de ontwikkeling van Vezel-Metaal Laminaten, voor Theo de Jong, die als decaan ons afschermde van de bestuurlijke perikelen, en zoveel heeft bijgedragen aan het goed functioneren van de Faculteit, voor Ad

Vlot, mijn opvolger met zijn enorme inzet, kunde en loyaliteit, voor René de Borst en Adriaan Beukers, mijn inspirerende collega's, and last but not least for Jens Hinrichsen, director Structural Engineering, Airbus Large Aircraft Division, promoter of GLARE within Airbus Industry, who highly stimulated my research team. During the opening of the Fibre-Metal Centre of Competence on May 6th 2001, Jens gave a presentation “GLARE, how to get an idea flying”, and I like to show you now two of his last slides.

"Technology is People"

Thanks to you, preparing for A380 the most advanced material and related manufacturing processes in a successful co-operation between TU Delft, Stork/Fokker, and NLR with Airbus

Thanks for the outstanding support from NIVR

Thanks to the experts from airlines, designing with Airbus maintainability into the A380 concepts.

Thanks to my colleagues in the Airbus community and in the Netherlands for their efforts to pioneer design, industrialization and commercialization of GLARE.

Thanks to all of you for teaming-up for the A380 success story

Teaming-up with Airbus, NLR and Stork/Fokker
The integration of academic education and research and development

Good Luck for the FMLC

...Your A380 Team

Teaming-up with Airbus, NLR and Stork/Fokker

Al bijna 40 jaar deel ik mijn leven, en zal ik ook mijn toekomst, delen met Vonnie. Dankbaar ben ik mijn vrouw voor haar aanmoedigingen, haar opofferingen en haar begrip. Zonder haar had ik dit werkstuk nooit geklaard. Het is dan ook mede haar werk.

Ladies and Gentlemen, I thank you for your attention.

Ik heb gezegd.