Space in Context
"SPACE IN CONTEXT"

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ABSTRACT
Over the years, space activities have made important contributions to science, human knowledge, and our daily lives on Earth. Space industry is mature, even though embroiled in a process of dynamic change and consolidation. Many space technologies and products have penetrated terrestrial markets, serving a spectrum of social and industrial needs.

"Space in Context" addresses space exploration and exploitation along with their research, commercial and security implications in the context of social and industrial developments now taking place here on Earth. After reviewing some trends in postgraduate education and space systems engineering, the lecture concludes by outlining potential long-term space developments and their implications for life on Earth in the next century.

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Note: This document contains the emeritus lecture of Prof. Stoewer, held on 15 November, 2000, at the Delft University of Technology, The Netherlands


**SPACE IN CONTEXT**

Mijheer de Rector Magnificus, Leden van het College van Bestuur, Collegae Hoogleraren en andere leden van de universitaire gemeenschap, Colleagues from industry and space agencies, Dames en Heren studenten en alumni, Family and Friends, Dames en Heren.

![Earth in Context](image1)

**PREFACE**

Let’s pretend that today is the 15th of November in the year 2020! I can then start this lecture with a stunning story, which will be the dominating news item tonight around the world.

In the last four days, scientists have drawn first conclusions from the data of a space probe that, just one month ago, descended onto Europa, one of Jupiter’s moons. The probe had succeeded in drilling through Europa’s 500 meter thick ice layer, to confirm the hypothesis of a huge ocean of water. What the scientists have discovered from the images relayed from this hidden ocean has gone far beyond their wildest imagination.

![Europa](image2)

**Discovery of Life on Europa**

They had identified a series of artificially looking structures and animal like creatures traversing the waters. These creatures seemed to propel themselves through this, by Earthly standards hostile environment, at hypersonic speeds and would frequently change bodyforms.

This news from Europa was immediately impounded by top management. A confidential emergency gathering of politicians, philosophers, religious leaders, and defense experts was called to assess and interpret the dis-
turbine news and make some first recommendations regarding possible courses of actions.

The DELFT Alliance Assembly in 2020
The assembly’s first reaction was one of total disbelief and disarray. The controversial debate that the release of some images from the Next Generation Hubble Space Telescope had created only 3 months earlier was fresh in their mind. The Hubble team had found a purple-colored planet of about the size of Mars in a nearby stellar constellation. They also thought to have identified some artificial structures which did not seem to originate from “normal” geological evolution, along with inexplicable pulsing light beams, interconnecting this mysterious purple planet with another unidentified heavenly body some 5 million kilometres away. The majority of the population mistakenly tried to relegate the Hubble discovery to the category of science fiction.

However the news from Europa with unquestionable images from real living “subjects” has another dimension. This time no one can escape the fact that for the first time higher level, maybe even intelligent, subjects have been identified outside our own planet. Moreover these “creatures” are only some two to four Earth-years of conventional space travel away.

Question after question and a whole spectrum of reactions, ranging from total disbelief to “we have to develop a Europa creature defense shield” drove the confidential meeting, which incidentally took place in the secret headquarters basement of the “International Defense Liaison, Free Markets, and Technology Alliance, in short DELFT-Alliance”, the successor organization to NATO, somewhere in Europe, not far from here.

To cut a long story short, the scientific evidence was overwhelming and the Public Information Act of DELFT left the assembled dignitaries no choice but to face the facts. This new space discovery would change history and mankind’s perception that our planet Earth may after all not be unique, or the only “heavenly body” with highly developed life forms in the Universe.

Welcome back to Delft in the year 2000
Ladies and Gentlemen, dear friends, back to 15 November 2000. You have of course in the meantime realized, that, even though the Europa mission and the Next Generation Hubble Telescope are both in the planning stage, a scenario in which they might discover life elsewhere is of course purely hypothetical. Something like this will never happen! Or will it? Will space discoveries continue to question century old beliefs, values and perspectives? Will they open new windows on our perception of life, and may be help to bring mankind on Earth closer together? Could they indeed change the context perception of “mankind”, like Copernicus did, when in 1514 he questioned the generally accepted theory of the Earth as the Center of this Universe?

To someone like me, who has had the privilege of working in the space field since the early 1960’s, such stories are not purely science fiction. They have an air of possibility and probability associated with them, and I personally tend to think more about when, rather than whether, they actually could happen. Maybe in 20, 100, 1000, or 10,000 years?

INTRODUCTION

Space discoveries have steadily changed human perception of our earthly context ever since Sputnik sent its first “beeps”, and then the first humans escaped Earth’s gravity. Jules Vernes’ wonderful stories, and the dreams of Ziolkowski, Oberth and others, have already become a reality, at least in part. Scenarios like the one above are constantly screened on television and in movie theaters, and they are a part of our children’s computer games.

When selecting the theme for my Emeritus Lecture “Space in Context”, I wanted to put some of our past and future space developments into the context of other developments on Earth. And I wanted to give you some food for thought beyond pure engineering and science.

In all humility, I know that my attempt to do this within less than 45 minutes is close to impossible. But I hope that a few examples and correlations between space and terrestrial developments will stimulate you to reflect further on some of the points that I am trying to make, and to fill in some of the holes and questions that I will undoubtedly leave. Known as an optimist by most of you, I am nonetheless fully aware of the risks of major accidents, and the way they can derail modern technological enterprises, as the Challenger or Chernobyl accidents did in 1985 and 1986. Nonetheless “doomsday scenarios” for the future are neither in keeping with my nature nor with human history.
THE RESEARCH AND EXPLORATION CONTEXT

Research is the “Ur-Suppe” (primordial soup) of scientific progress from which most applications and practical products derive! Scientific and technological research, in tackling bold goals, draws upon the brightest, most imaginative talents in academia, research institutions, and industry. Space Research and technology development has created an enormous body of knowledge and the know-how for space applications and commerce. It has created a new branch of industry.

Today I want to draw your attention to two research and one exploration topic.

Discovering the mysteries of our solar system and understanding our “System Earth” are two research foci with wide-ranging impacts on human destiny. The International Space Station, the largest collaborative enterprise ever undertaken by humans, opens new dimensions of space exploration.

OUR SOLAR SYSTEM

The Star of our lives

Our Sun has enabled life on Earth to develop. It provides the fuel for our continued existence. In some 10 billion years it will have become a giant star with a diameter 100-fold its diameter today. It will then radiate about 2000 times more strongly than today, and will usurp our planet.

Yet when we take stock of what we know about its specific inner physical and chemical processes, its plasma, electrical paths, life cycle variations, geodynamics, etc. it is still rather rudimentary. Experts amongst you will argue that we do know a lot about its age, rotation, energy cycles, Sun spots, flares, etc. New discoveries by the world-class European spacecraft, Ulysses, SOHO, Cluster and other non-European probes, however unveil new facts on a weekly basis.

For example, “we have just now been able to confirm that also the Sun’s magnetic field has a memory returning it to approximately the same configuration in each 11 year solar cycle” 1 (Reference: Dr. Marcia Neugebauer, visiting scientist at NASA JPL). We have, for example, also just learned from Ulysses’ passages over the Sun’s poles, that there is strong penetration of incoming cosmic rays, nuclei of atoms travelling at nearly the speed of light, and that the solar winds emissions are different at the poles and the equatorial zones. Sun quakes have been observed in much detail recently and research from SOHO has identified that the Sun’s surface is covered with depressions and bumps similar to oceanographic features (Reference: Jeff Kuhn, Univ. of Hawaii). The hills are caused by a grid of weak cyclones. These few examples of recent discovery teach us that there is much more to learn about the fundamental processes taking place in the Sun, the biggest fusion machine around. The Sun’s life has a direct influence upon our lives on Earth.
The other Heavenly Bodies in our Solar System

When we ask ourselves what we know about the planets, moons, comets and asteroids in our Solar System, the answer is similar, namely still “very little”. One of the astrobologists most burning questions is, for example, how life on Earth evolved, what processes built the bridges from the “primordial soup” to the formation of the building blocks of organic life (DNA). Yet every atom in our bodies came from the inside of stars (reference Dr. Donald Brownlee, University of Washington). It seems well proven that thousands of kilos of rocks have been catapulted over history from Mars to Earth. Consequently astrobologists ponder, or at least do not exclude the possibility, that human life may have come from Mars (ref. IAF Astrobiology plenary panel, 4. October, 2000).

NASA’s Stardust and future Genesis missions are trying to catch particles that are travelling through our Solar System, containing heavy chemical elements, originating in the stars. Other spacecraft are on the way to a number of Solar System bodies, e.g. to volcanic Io, another one of Jupiter’s moons, to Saturn, to Neptun, or Eros. While these probes fly to their distant targets, with accuracies equivalent to threading a needle as far away as Siberia, the real discoveries are only just beginning. Each new probe raises as many questions as it attempts to answer. During the last few years, for example, water has been discovered on the Moon and Europa, and theories about Jupiter’s giant red spot, or the rings of Saturn have been underpinned by new scientific measurements.

The first orbital and in-situ observations of Mars have provided some answers on weather and climate, soil composition, geology, radiation and more. More than 30,000 images to date! First data, first approximations, in-situ measurements at easy to reach geographic locations! By comparison, it is as if two extraterrestrial probes would have landed on Earth, one in the Sahara and one in the Gobi desert. What knowledge about Earth would they have communicated back to their originators? Earth based telescopes go a long way to explore the universe. Multi-mirror and interferometry technologies have produced enormous advances. But many observations can only be accomplished in space. NASA’s planet-finder and ESA’s Darwin spacecraft could, by 2020, be the ones delivering breakthrough knowledge on life somewhere else in our Universe or not (yet)?

Expanding the Knowledge Base about our History and Destiny

Ladies and Gentlemen, we live in a fascinating world of new discoveries regarding our Solar System and Universe. Space probes are questioning age-old theories, like Magellan did, when in 1519, he challenged the theory of a flat Earth in situ. The knowledge base about our history and destiny, seen in the context of current space and Earth based research, is rapidly expanding, more so than ever before during our history. Without modern spacecraft the pace would be much slower, many discoveries would not take place, and the context of human faith would be much more difficult to fathom.

THE PUZZLE OF SYSTEM EARTH

Even though the human species has inhabited and explored our planet Earth now for some 10,000 years, our knowledge beyond a few 100 meters in depth or some 10’s of kilometers in height is very limited. Thousands of geologists, oceanographers, atmospheric scientists, biologists and others are continuously advancing the knowledge base within their chosen fields.

Fig. 7: Only satellites can provide a global perspective of Earth: here a scan of ozone concentration.
The recent intensive observations of the El Nino and La Nina effects by the Topex-Poseidon, ERS, and other satellites have provided new insights into sea-level temperature and height changes, changes in crucial upwelling, heat and nutrition transport processes, and ocean currents. Small changes in one part of the globe, in this case the Pacific equatorial zone, have had dramatic effects upon Southeast Asia, North- and South-America, the Caribbean and beyond. The Atlantic Gulf Stream, another miraculous ocean phenomenon, is highly sensitive to small subtropical temperature and water salinity changes. The difference between prosperity and an ice-age for Europe may in the end lie in a few degrees of Gulf Stream temperature and a few promille of salinity!

Fig. 9: The oceans are highly sensitive to external disturbances, as evidenced by the recent El Nino observations: when heat and nutrition transport mechanisms change, large portions of the Earth’s population can be affected.

Fig. 10: Phytoplankton and sediment monitoring yields insights into health and vitality of ocean waters; it provides vital clues for the fishery industry.

The fact that the El Nino phenomenon probably already existed, as evidenced by analyses of glacial sediment probes, some 13,500 to 17,500 years ago (see recent research by the University of Nebraska), is just another piece of the puzzle of global climate dynamics. The oceans are the most effective CO2 recycling machines. CO2 is absorbed in enormous quantities...
The Human Contribution: any Action?
Natural phenomena such as volcanic eruptions or major forest fires can have dramatic effects on our weather and climate. But they are of a temporary nature! There is growing evidence that anthropogenic contributions are not "non-negligible", they may even be dramatic. As more and more of these complex facts come together and highly sophisticated computerized simulation tools advance to better correlate space with in situ data and historic records, the mystery of the status of our planets health will further unravel. As awareness of the effects of anthropogenic contributions grows, the acceptance of lifestyles more in line with "System Earth" should emerge during this 21st century. The issue before us in the next decades is to understand the various levels of human imposition that our planet can tolerate and to manage and preserve the abundant natural resources accordingly. Then we might at some time in the future arrive at a natural balance with our environment all over the world, and not just in a few National Parks!

LIVING AND WORKING IN SPACE
The Russian space pioneer, K.E. Ziolkowskij wrote:
"The Earth has been the cradle of mankind, but there comes a time when you grow up and leave the cradle".

The German space pioneer Herman Oberth formulated it in this way:
"Die Menschheit und die menschliche Kultur wird nicht auf unseren Planeten beschraenkt bleiben, sondern wir werden- inzwischen reif geworden - Technik und Kultur in das All hinaustragen, soweit dort nicht andere Menschheits, falls es sie gibt, schon ebenfalls eine Kultur geschaffen haben. Mit diesen koennen wir dann Kenntnisse austauschen und gemeinsam das ursprungliche Chaos (griechisch: Wirrwarr) zum Kosmos (altgriechisch: schoene Ordnung) machen".

Space is a Dangerous Environment
Human space-flight is dangerous and expensive! There is more important research to be done on Earth! Such and other statements by sceptics and opponents of human space-flight initiatives are often reinforced by pointing to the limited public budgetary resources available. But they forget to ask the question: who is there to stop mankind from exploring the unknown and challenging the limits? The extent to which this human drive may be rational or not is entirely irrelevant. It is as much a part of human nature as breathing, eating and sleeping.

at the surface by algae and other biological structures and deposited in the ocean bottoms, where part of it is converted into calcium deposits. Fresh water upwellings at the coasts of Africa or South America bring new life to the surface. Nutrient rich waters support a vast biodiversity and create an economic basis for fishery flotillas. Oceans are major heat sinks. The global warming causes the waters to expand and threatens extensive coastal zones and island groups worldwide. Oceans transport incredible quantities of energy from equatorial zones to nurture life in the North and South. They are the breeding grounds for winds and devastating cyclones. The consequences of seemingly minute deviations from customary in water temperatures and atmospheric compositions are being felt in each and every part of this planet. Yet we have only recently learned through satellites, that some of these cyclic processes exist, we can only now measure altimetric differences at accuracies, which are meaningful for climate modelling and weather prediction. Yet what do we know about what happens beyond a few thousand meters of depth? Or sensitivity of environmental changes on biological life? The oceans will remain one of the most important research topics for the uncifering of the climate enigma.
Stepping Stones to Future Options

We know that one day in the very distant future our Earth will become extinct. Our Sun will eventually swallow it! When exactly, in one or two billion years, Earth will become uninhabitable may be still an open question. We also know that there could be other influences, that could make our planet, or large parts of it, uninhabitable much earlier. One such inherent danger lingers in space and may be responsible for the extinction of our dinosaurs, namely Asteroids. But we know that there may be other places beyond our present confines, which could possibly provide a decent living environment for our species.

So the only question open for discussion, it seems to me, is “when” we will explore potential settlement conditions in our Solar System and beyond and not “whether” we will have to do so. The pace and dimension of the enterprise is the variant! Just 40 years have past since the first human spaceflights of the sixties. Salyut, Skylab, MIR, Shuttle, Spacelab were follow-up stepping stones towards the International Space Station (ISS), which has just started operation. This living and working laboratory represents the largest peaceful human cooperative project ever. It presently brings together 16 nations, many more will probably be part of it before the end of its operational lifetime, a few decades from now.

Fig. 13
16 Nations cooperate in building and operating the ISS, the largest peaceful enterprise ever undertaken by mankind.

Fig. 14
The station is a laboratory of human Experimentation and development; it should moreover yield important scientific results and offer laboratory space to commercial terrestrial enterprises.

A Laboratory for Human Experimentation

The ISS will be a further irreversible step in the exploration and exploitation of space and in the human perception of our potential and limits. Seeing it pass over our heads as an artificial star night after night, and weekly news from the scientists and engineers working up there will make it evident to a large part of our population, that living and working in space together is real.

It is likely that this laboratory will moreover yield some fascinating research results in tangible fields such as medicine, pharmaceuticals, materials, astronomy, or physics, which could help to further justify its expense. But this is not the point! Is it not better to spend this money on international cooperation, technology, science, and on advancing human options for the future, than on military confrontations? After all the budget for the ISS is only a minute percentage of the world’s defence budgets, and probably still less than what we spend on lipsticks, liquor or jewelry.

Settlements beyond Earth?

But where does this lead us? Where are the limits? None of us knows! There are no limits to human inquisitiveness and imagination, nor frontiers where exploration will be halted. The pace, resources, and risks are the issue! I would not be surprised to see human settlements developing in Earth orbit, at libration points, or on the Moon or Mars, within the next 2 or 3 human generations. And just as there have been daring people throughout history who have explored seemingly uninhabitable parts of our planet, there will be people in the future who will do the same, going to at first sight even less comfortable places, elsewhere in our Universe. In a historic context this is not only unavoidable, it is part of human nature!
THE COMMERCIAL AND EXPLOITATION CONTEXT

Space science and exploration, largely financed by public money, have led to many practical applications and commercial industrial products here on Earth. For example photovoltaic solar generators, liquid hydrogen and oxygen technologies, fuel cells, and jet pipes are essential "space ingredients" for future regenerative and clean terrestrial energy and transport systems. The information systems revolution, another talking point for politicians, has many links to space technology. Space based telecommunications, geo-information and navigation systems are important contributions to this end. Space systems have also fundamentally changed defence scenarios. Emphasis has shifted towards "intelligence superiority" and "meta-systems", (or "systems of systems"), towards conflict avoidance, well targetted interventions and peacekeeping missions.

Fig. 15: Space technology is a motor for advancing regenerative energy applications on Earth; solar generators, fuel cells and hydrogen technology are more and more utilized for terrestrial applications.

THE FUTURE INFORMATION INFRASTRUCTURE

Telecommunications satellites serving the needs of our modern multimedia information society have become the most successful space business. Space-based communication is a tiny, but important contribution to an ever-growing worldwide information network. Applications-oriented remote-sensing data from satellites, the second slowly emerging commercial space business, provide added value to a terrestrial geo-information systems market of enormous proportions. The same applies to space-based navigation and agricultural support systems. They represent intelligent space contributions to gigantic telematics and agricultural markets, governed by powerful terrestrial industries.

Space Industry's Golden Opportunities

The space industry, in order to penetrate these markets, must make substantial additional efforts to understand the needs, opportunities and dynamics of these terrestrial markets. Too often new "revolutionary" space solutions are not measured up against sometimes equally fast moving terrestrial technological solutions. The recent demise of high-flying, principally space-based, multibillion-dollar mobile communication system, such as the IRIDIUM or others, which did not properly anticipate the rapid development of terrestrial services, keyword GSM, speaks cruelly to this effect.

On the other hand, who would have predicted some twenty years ago that the relatively little known Very Small Aperture Terminal (VSAT) services industry would break the 3 billion dollar turnover barrier this year? Or that millions of ships, airplanes, trucks, automobiles, geologists, mountain climbers, and others would come to rely on a space-based military navigation system?

Fig. 16: Communication is a basic human need; Satellites are effective complements for the 21st century information infrastructure.

Agriculture – Yield Prediction

Fig. 17: Agricultural planning an monitoring will reach a new quality once remote sensing information will be available and affordable.
Information Markets Change with High Dynamics

Business opportunities for space-based solutions to help satisfy our 21st century information society’s quest for more and more information will continue to grow. Space systems have sufficiently unique characteristics, and sometimes business advantages, to make substantial contributions. But terrestrial information networks, associated technical solutions and competition are also changing at a revolutionary pace. Prices are falling and business-cases are in flux. The chairman of Shin Satellite plc, Mr. D. Kasemset, brought it to the following point in a recent Space News interview:

“The conventional satellite technology we use today is technology of last resort; people use satellites when they can’t get terrestrial lines, not because space-based systems offer advantages to Internet users.”

Consumer behaviour in our “Internet society” is changing in unpredictable ways. The president of the successful Dutch telecommunications enterprise, KPN, while addressing the International Astronautical Congress last year in Amsterdam, noted that strategic planning cycles in his industry have rapidly become ever shorter and that at this point no executive in his company would dare to predict consumer behaviour beyond a period of some two years ahead. This is typical for most industrial branches in the multi-media and Internet-dominated markets. Earth- and space-based solutions have to be seen in context. Only well thought out integrated “end-to-end” system solutions, with built-in life-cycle adjustments, have a chance of succeeding.

21st CENTURY DEFENSE SYSTEMS

Technology is a crucial denominator for military superiority. This was so when the Phoenicians, Romans, or Mongols created their empires. The conquest of the Americas, Africa, or Southeast-Asia by the Europeans is due to gun powder and naval superiority. Radar played a substantial role in World-War II.

Changing defense scenarios Europe’s dilemma

Space technology served as a public demonstrator of technological superiority during the cold-war decades. In the recent set of conflicts in the Middle-East or former Yugoslavia, it became clearer than ever that information, or “intelligence”, about an opponent’s capabilities and movements has become the crucial factor for good or bad decision making. Modern defence geo-information, communications, weather prediction, navigation, guidance, precision localization, and command capabilities, to name just a few, are based upon, or enhanced by space-based systems. Two-way realtime information exchange with forces in the field has become feasible on a larger scale through satellites. Strategic and tactical integration of the different services of modern, often multi-national, globally operating defence, intervention or peace-keeping forces, i.e. the coordinated control of air, sea and land units, requires an extensive space systems capability. Europe has long neglected investment in this direction and today finds itself at a serious disadvantage and heavily dependent on the USA.

Fig. 18: Modern Telematics Infrastructures and millions of day to day activities have come to rely on space-based navigation; services have the largest added value business potential.

Fig. 19: The Shuttle Radar Mission (SRTM) as seen by Earth-based radar from the ground (FGAN, 25 cm resolution).

Europe Needs New Eyes and Ears

“Only from the distance you see clear”, Lao Tse 5th century BC. Beyond HELIOS, a high-resolution optical satellite system, Europe has no eyes in the precision regime of something like a one metre resolution or smaller. In bad weather these eyes are largely blind. High-resolution radar systems, e.g. SAR-Lupe, are on the drawing board (Reference: Air and Space Europe, Vol 2, No. 4, August 2000), and will at best be operational by 2004. Beyond this, few
space-based intelligence-gathering or communications devices exist in Europe. Yet contingency planning scenarios and “management” capabilities for future world conflicts depend upon such strategic capabilities. Strong investments in these domains have contributed to making the US the dominating world power and they have advanced US economy. As a consequence the US produces some 70% of the world’s commercial telecommunication satellites and it is estimated that they have a similar share of the space-based remote sensing information market. The US also dominates global navigation services by almost 100%. For Europe, only Ariane, the work-horse for launch services has to date scored a similar success in the commercial space field. A long term strategic commitment, predominantly by France, has made this possible.

THE INDUSTRIAL SCENE

Europe’s aerospace industry is finally consolidating. But it is doing so in response to giant marriages in the US. The currently weak EURO is providing unexpected if temporary help in boosting European aerospace products in the global marketplace (which is governed by US dollar prices). Beyond consolidation, the messages are clear. They culminate in efficiency, i.e. product cost and return on investment, market knowhow, and service offerings for improved global competitiveness.

Integration, Alliances and Divorce

Horizontal integration, or strategic alliances with “terrestrial market” industries, sales multipliers and service industries are prerequisites for the exploitation of many future commercial markets. Space companies often do not understand the mechanisms of commercial, let alone consumer markets. But a number of space products are headed in this direction. Alliances with Internet providers, network companies and consumer electronics companies could be attractive for many applications. Israel’s Gilit Satellite Networks Ltd partnerships with Microsoft and Radio Shack, or SES’s comparable intentions for Internet services are pointing in this direction. Also Astrium's approach for the set-up of their TerraSar venture, involving a chain of value adding market multipliers or OHB’s Hanesar and Kayser Threde’s Rapid Eye are noteworthy in this context. If space industry on the whole does however not move more pro-actively in this direction, it is likely to lose more of the commercial opportunities to terrestrial industries entering into, or buying up, the space assets they need to complement their portfolios.

Space agencies in turn need to let go of controlling industry and imposing government rules and standards. The respective roles of agencies and industry have to be adapted further, if competitiveness in global markets is to be strengthened. The recent decision to strengthen industry’s role in the sale of radar images from ESA satellites is a small step in this direction. But the publicly funded manpower in government organizations in Europe relative to the publicly funded manpower in industry and the research community is still too high. Further integration of agency competences, well beyond networking, is unavoidable in the years to come. True partnerships with complementary roles are needed.

The Public and Commercial Cultures Gap

Within industry there seem to be camps of people working for the government, and those working for the commercial markets. Sometimes the walls are high and cultural barriers substantial. Let me quote the current president of the International Council of Systems Engineering, INCOSE, Dr. Donna Rhodes, who recently changed employers. She left the Lockheed Martin Corporation to join the Lucent Technologies Group. Commenting on the differences between a company competing mostly for government contracts to one which has to earn money in the commercial marketplace, she recounted amongst others (Reference: Keynote to the 2nd European Regional Systems Engineering Conference, Munich, 13.9.2000), that the environment in these 2 industrial sectors is in many respects very different, e.g. flat organization, minimal standardization, cultural differences, terminology, product renewal cycles, time-to-market, market orientation. Her final quote put it into context:

“Standing in the middle of the defense (space) business, it is just not possible to fully understand the commercial product development world!”

THE SYSTEMS ENGINEERING CONTEXT

The space business as a whole is changing at an ever-increasing pace as public budgets become more scarce, the industry matures, and space penetrates into more domains of society and industry. This is not without its effect on engineering practices in the field. Space engineering changes moreover as a result of the substantial advances in terrestrial engineering practices, in particular due to the enormous advances in computing, software and microelectronics.

The Payload Imperative

Early space systems consisted primarily of light-weight mechanical structures with thermal protection, guidance and attitude control, rocket propulsion, some electrical, electro-mechanical and electronic components, rudimentary computing capabilities and simple instruments. Modern space systems, not unlike their terrestrial counterparts, employ distributed archi-
tectures with plenty of embedded information-processing capabilities. They are “driven” by even more sophisticated instruments and payloads, which account for the majority of advances in science and practical uses. Satellite platforms can be bought “off the shelf” for many mission applications. A good proportion of ground segments are procured from commercial terrestrial markets. Only some 2 decades ago most of the space computing and data processing equipment was custom-made, with enormous R&D investments in soft- and hardware.

The Complexity Paradigm
On the other hand, modern spacecraft and launch systems, particularly such incredible machines as the Space Shuttle, have grown enormously in terms of number of functions and components. A similar trend is evident in “terrestrial” products. Today’s telephones, washing machines, video cameras, or children’s toys often include more computing power and control loops, than, for example, an old refinery plant of the 1960s. A typical STOEWER autocar of the twenties or the thirties, was built up of approximately 4,000 – 5,000 parts. A modern high-end automobile consists of some 40,000 equivalent parts, not counting the myriad of electronic components. Along with this goes a 100 to 1000 fold multiplication in electrical/electronic functions which dominate a modern car’s capabilities.

A New Systems Design Environment
The fundamental progress of computer-based engineering techniques, once driven by demanding aerospace requirements for low mass, extreme reliability, safety, structural, thermal and aerodynamic environments, enables advances in design and engineering speed, transparency, interconnectivity, depth of analysis, and cost. Engineering tools for many sophisticated technical analyses have become available as PC-versions.

This has for the first time opened the possibility of extending computer-based simulations to comprehensive systems analyses and design activities, improving efficiencies by a factors of 5 to 10, and reducing e.g. concept study times from 6 - 9 months to about 5 - 6 weeks. Such an integrated concurrent system design capability was first developed by the Aerospace Corporation, in cooperation with TRW and NASA JPL, and has in the meantime been adopted and extended by, e.g. ASTRUM and ESA/ESTEC. Several universities, who want to remain in the avantgarde for space education, have started to develop appropriate concepts to set up “mini design centres”.

Fig. 20:
Modern satellites have sophisticated instruments and complex payload complements; these are the “drives” for satellite design.

Fig. 21:
Technical complexity of space systems has increased; the same holds for most modern “terrestrial” products, such as automobiles, telephones, children’s toys (Stoewer V8, 1925).

Fig. 22: Integrated and concurrent Systems Engineering processes have become feasible because of information technology advances; they enable quantum efficiency improvements during conceptual design phases.
Unfortunately, the Delft Aerospace Engineering Faculty, which had the opportunity to be one of the first, decided some time ago, against such an initiative.

**POSTGRADUATE EDUCATION: a 21st Century Revolution**

The composer Benjamin Briten once stated something like: "Learning is like rowing against a river's current. Stopping means falling back!"

There is a revolution in the making in the educational field. It is fueled by ever shorter knowledge update cycles, by new learning means, and by industry's recognition, that investments in upgrading their workforce's capabilities has become a competitive necessity. Life-long learning, distance learning, international cooperation and competition between universities and between universities and industry, are becoming major factors. New multi- and interdisciplinary studies, with changes to traditional knowledge and discipline barriers, are on the increase. New forms of industry cooperation with academia are being tested. Virtual industry universities and academies are completing knowledge and skills gaps not provided by traditional universities. Some educational institutions will expand beyond national boundaries and continue to grow in quality and influence. Those with dynamic leadership will prevail, others will fail in the long term.

*SpaceTech, a Delft Postgraduate Initiative*

When in this University, some 5 years ago in TopTech, with the help of three enthusiastic young aerospace engineers (B. Theelen, G.J. van Rie and H. Rehorst), and a highly competent international Core Curriculum Committee (Dr. Dieter Davidts, Prof. Dr. Phil Hartl, Prof. Wiley Larson and Prof. Dr. Gunnar Stette), we embarked on developing one of the best programmes for space systems engineering worldwide SpaceTech we redefined systems engineering. Our own experience in the real world, not textbooks, shaped this initiative. We wanted to make an innovative contribution towards upgrading the space community's tools and visions. Competitive turn-key, or "end-to-end" solutions, which integrate all stakeholder requirements into one holistic solution to meet market needs, were the yardstick. This involves at different times planning support, delivery of hard- and software, installation and training, operations support, life-cycle maintainance, and other services. Such solutions require imaginative and experienced systems engineers, who can assess the entire problem, are able to work effectively with teams of specialists, and can arrive at competitive answers to a customer's needs or market demands.

For engineers, to fathom "markets" is extremely difficult! Market analyses, as opposed to (government) requests for proposals, produce mostly soft data, which are moreover changing over time. Soft data do not have a place in an engineer's dictionary. So how can any good engineer, who respects his or her trade, amalgamate soft market with hard engineering data? Finding solutions for changing markets? Admittedly that's tough! But it is also real life!

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**SpaceTech: a postgraduate programme for young professionals**

Fig. 23: Postgraduate Education is tied to ever shorter "knowledge-update cycles" in the scientific and engineering world; SpaceTech is a TUD Space Systems Engineering Initiative.

**Business Driven Solutions**

The time of perfect technological solutions looking for a customer has more or less gone. Today's successful concepts need to be competitive businesswise and yield a solid return on investment. Good returns on investment can in most cases not be made from selling satellites (or launch vehicles) alone.
Most demands for space-based solutions offer ample opportunities for service. Telecommunication-satellite lifetimes, for example, have grown to about 15 to 20 years. Countless new companies have sprung up during the past 2 to 3 decades which are making big profits from operating such satellites, and from offering the associated services. SES in Luxembourg, commonly known as Astra, is just one of many such companies.

"End-to-End" Systems Engineering
The conclusion, which we have drawn upon for SpaceTech so successfully, is that modern space systems engineering must derive technical solutions in response to market needs, in line with sound business plans.

Again this is not really different from other high-tech industrial sectors, such as the transportation, computer or logistic sectors, except that the space community has a long history of being led by government agency customers and all the idiosyncrasies that go along with public markets and contracting.

SYSTEMS ENGINEERING FOR AEROSPACE STUDENTS
In the mid-80's the Faculty Management made a wise decision when it added systems engineering to the curriculum and opened the student's vistas to issues beyond their speciality. I admit, I had great fun teaching this topic and trying to build some bridges into real life for all those years. The Faculty Management's decision to also add design projects, so-called "ontwerp synthese oefeningen" to further deepen the students systems understanding, was equally wise, since these projects could serve as excellent learning foci and moreover brought in some industry and agency specialists to help.

An equally good decision in principle was the one in the mid-90's which resulted in the creation of two special systems engineering chairs, one for aircraft and one for space. Then the Faculty Management Board was reorganized. A layer of administration was installed on top of the product managers, the professors. The council of professors was abolished. The rest is history.

The DELFI Initiative
Counting on the strength of the idea and some start-up budget, Barry Zandbergen and I embarked in 1997/98 on defining a series of small satellites to serve as the Faculty's focus for space systems engineering, in what we called the "DELFI"-programme. The idea was enthusiastically embraced by everyone, including a number of colleagues in other faculties, who were prepared to bring in some much-needed competences in exchange for participation in the application of cutting-edge technologies. We developed three strategic lines, each of which had specific potential for future developments. They would put the University into an excellent position for developing "hands-on" systems engineering, along with an education-oriented small-satellite competence.

Fig. 25: The Delfi Small Satellite Initiative. Delfi-1sat, Delfi-Dart, and Delfi-Smart, is an opportunity for the University to stay at the forefront of hands-on space systems engineering.

Structure Subsystem
Basic Configuration

- Facetted surface
- Aluminum shell
- $F_{inf} > 60$ Hz
- Structure mass is 0.7 kg
- Center of gravity at 4.4 cm from center of pressure
The first step was to start with the modification of an existing satellite (DELF-SAT), which was to be realized relatively quickly, thanks to a generous agreement with Kayser-Threde, Munich. In parallel we developed the idea of a small reentry vehicle (DELF-DART), to stimulate the combined aero- and space competences in the Faculty. To prepare the University for one of the most exciting future developments, namely that of very tiny satellites, employing so called micro- and nanotechnologies, the Nano-Satellite idea (DELF-SMART) was introduced. Top international experts were brought in to help. Experts from ESTEC, FSS, NLR, NIVR, Kayser-Threde and other organizations started to share our excitement. This was a great opportunity for the University! But unfortunately the Faculty Management, after only a few months into this, changed the approach. As a result, some of the external support did not materialize, and the pace has slowed. The ensuing discussions were fortunately not without effect and space activities in the Faculty seem to advance again.

THE LONG-TERM CONTEXT

Long-term space developments will largely depend upon the contributions space can make to tomorrow’s society and industry. Their needs, and the opportunities that space will offer in terms of human development, will decide which of the dreams will indeed become reality.

The Launcher Bottleneck

The most important denominator for the pace of future space developments are the cost, reliability and safety of future transport systems. Full reusability and airplane-like operations for the “Low Earth Orbit” transport jobs are the goal. NASA’s design marks for each next generation of such launch systems, which presently includes a Shuttle upgrade, are a factor 10 reduction in cost and a 100-fold increase in safety. The fourth generation, some decades from now, should eventually transport people with a safety standard similar to commercial aircraft today. Space tourism will then rival adventure holidays here on Earth. Geostationary and interplanetary transport systems may feature space fueling facilities and orbit-to-orbit shuttles and will become fully reusable more slowly.

Dreams will have to stand up to society’s priorities

A large part of human society, the so-called “average citizen” in industrialized countries and even more so in the jungles of Africa, the mountains of Peru, or deserts of Asia, has quite different needs and dreams, when compared to privileged scientists or engineers.

There are many learned sources which attempt to categorize and prioritize these needs for us. For example the problem of water-shortage. The Head of the UN Environment Agency, Dr. K. Toepfer, during the October 2000 Water Conference in Berlin warned: “Ten years from now all countries in the world, with the exception of Canada and the Scandinavian countries will realize water shortages”.

Other basic human priorities which fall in this priority category are: food, energy, employment, security and peace, environment, population growth, mobility, shelter, health, welfare and education! Space strategists are well advised to face these needs and measure the many fascinating space dreams against some of these priorities - the more since space systems can indeed contribute to many of them.
During my TUD Inaugural lecture in 1988 here in this Aula (Reference: Technology for Europe, The Significance of Advanced Technologies for Europe's Future, published as ESA BR 50), I postulated a number of potential developments. Let me recall:

"The prospects for future space developments in Europe appear promising and the next twenty to thirty years will probably see many new organisations and firms, most of which are likely to be operating on a global basis. One could imagine future firms or organisations with such titles as:

- **AGRISPACE**: An organisation evaluating agricultural production on a world-wide basis and making an important contribution to the management of the World's food supply.
- **ECOLOSPACE**: An organisation charged with monitoring the Earth's resources and pollution.
- **SPACE-RESCUE**: An organisation concerned with the monitoring of disasters and emergencies, and the real-time instigation of help actions.
- **SPACEMAC**: A company providing services for manufacturing new products in space and operating a (free-flying) space factory, e.g. in the vicinity of the International Space Station or the European Columbus research facilities.
- **DATAREL**: A company offering data-relay services for low-Earth-orbiting satellites, by operating one or several relay satellites in geo-synchronous orbits.
- **ENERSPACE**: An industrial consortium harnessing and converting solar energy in space and beaming it as electrical energy directly to the industrial nations."

12 years farther on, we are generally headed in this direction. The United Nations UNISPACE III Conference last year in Vienna provided added impetus to some of the above. Technology has advanced, but political barriers are still strong and economic viability has yet to be proven.

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**Fig. 28:** Weather and Hurricane predictions from satellites have saved many lives; space systems can in the future make many more contributions for disaster prediction and mitigation.

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**Fig. 29:** The 21st century may see first human experimental outposts and settlements on Moon, Mars or other heavenly bodies.

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**The ESA Vision**

ESA has recently published a remarkable report on the long-term future of space, as envisaged by its Long-Term Space Policy Committee: Investing in Space, the Challenge for Europe (Reference ESA SP-2000, May 1999 and P. Creola, A Long-term Space Policy for Europe, Vol 15, Journal of Space Policy, Nov. 1999). The Committee has developed an Action Plan containing 20 points:

1. Search for Earth-like planets.
2. Encourage cheaper access to space.
3. Make full use of the International Space Station
4. Develop a European navigation service.
5. Develop space systems for security and peacekeeping.
6. Create a European telecommunications regulatory body.
7. Encourage small business as a source of technological innovation.
8. Improve Europe's micro-miniaturization capability.
9. Monitor compliance with environmental regulations.
10. Examine the possibility of disaster warning from space.
11. Improve understanding of space weather.
12. Take action on space debris.
13. Tackle the threat of a cosmic collision.
14. Instigate a telepresence demonstration project.
15. Launch a European lunar initiative.
16. Study the exploitation of space energy and resources.
17. Examine the possibilities of weather modification from space.
18. Create a European space education programme.
19. Create a public awareness initiative.
20. Create a European space policy institute.
A space facility powerful enough to dissolve hurricanes, or clouds, generate rain or otherwise influence weather and mitigate catastrophes?
A transport system to catapult dangerous Earthly waste into orbit or to burn it in the sun?
A multination DELFT-Alliance joint military command-post in orbit to coordinate our Earthly and extraterrestrial defence systems?

Any of these could happen in this new century. Some would need substantial new technology advances! But then most of the technologies that we employ today were not around some 50, 30 or even 10 years ago. Advances, sometimes breakthroughs in science and technology happen all the time: optical communication, nanotube structures, molecular pumps, bio-computers, neural networks, biosensor robots, interferometry techniques, etc. etc. etc. Most of the time it is not technology which limits human progress. Our ability to accept and use new technologies ethically and safely is the issue!

Got the message? There are neither limits to space, nor to ideas and imagination on what could happen out there. Scientific exploration and commercial exploitation, defense and security, or plain human adventure, if seen and dealt with in the proper context, will continue to prosper. Both dimensions of space, the one oriented outward, towards our moon, planets, sun and universe, and the one oriented downward towards our Earth, both offer ample opportunity for future developments. Let’s deal with them wisely and in the context of society’s and industry’s needs and priorities.

CONCLUSIONS

Space investments in the past decades have developed the fundamental technologies for access to space and its utilization. Space research has advanced fundamental scientific knowledge about our planet, our Universe, human history and destiny. Space applications have improved living conditions on Earth. The space business has matured, is alive and well and continues to grow worldwide.

Outlook and Perspectives
The space industry is small compared to other industrial sectors, but its contributions are innovative and strategic. The 21st century will see many more users of space assets and witness mankind’s next steps towards exploring living conditions away from Earth. We may even find out that there are other (highly developed?) life-forms elsewhere in our Universe. The space community needs to interact in the future even more strongly
with the “terrestrial communities on Earth” to understand the service that it can offer to the fulfillment of society’s needs and priorities.

Roles and Relationships
The space business is in the midst of a substantial process of change, which affects established roles and structures. The relationship between public-funded and commercial markets is shifting. In 1998 there were more satellites built worldwide on commercial orders than on public orders. Many new players have entered the scene, some have dropped out. The role of European space agencies and their relationships to industry, user and political organisations, will change further. The space agencies’ manpower in Europe is high in relation to the funded space competences in universities, research institutions and industry. Rationalization of agency competences across Europe is unavoidable. Better networking will not be sufficient. Better integration, to avoid duplication, is needed for Europe’s space community to best utilize the public resources and to maximize global competitiveness.

Commercial Markets Exploitation
Commercial opportunities for the space industry continue to grow. To exploit them the space community needs to better understand that space assets are often only a small complement to much larger terrestrial systems and markets. These in turn are driven by return on investment, consumer needs, and long-term service opportunities. Predominantly technologically driven solutions have little chance of success.

Space-based telecommunication systems, providing nodes for the 21st century information society will, despite recent setbacks and big question marks in the near Earth segments, continue to benefit from new and attractive opportunities as broadband internet and multimedia driven demands grow.

The challenges for the emerging remote-sensing business rest in the development of the terrestrial markets, in the penetration of space data into established and mostly conservative government user dominated, or industrial sectors. The commercial potential is there, but the market still largely consists of many disparate small customers, almost all of which need tailor-made information and all weather, long-term delivery and update guarantees, before they will rely on space in lieu of their existing data sources.

The “navigation battle” will continue with a special global dimension. Commercial or quasi-commercial solutions, à la Galileo, competing with public-funded “free” solutions, à la GPS and upgrades, will have great difficulties in mobilizing the enormous financing needed to bring them to operational maturity. An unwavering commitment to European independence and self-reliance, à la Airbus and Ariane, will have to be the overriding political criteria for the Galileo venture to survive.

Interweaving geoinformation with navigation and/or communication/data services may open new business opportunities.

Modern Defense Scenarios
Modern societies defence systems are unthinkable without space-based intelligence, communication and navigation services. Europe above all needs better eyes and ears and means for exchanging information to support its intervention and peacekeeping forces effectively and to live up to its international commitments. Dual use of civil and defence systems and selective industry partnerships could accelerate the solutions and offer efficiency leaps. Often science requirements or those for commercial products are not far from what is needed for modern defence forces. Disaster management and bulk communication are just two such examples.

Future Research Destiny Questions
Fundamental questions relating to the destiny of the human species and our planet, fuel space research and exploration. The management of our global resources within tolerable limits, and the knowledge base, regarding mankind’s course of history within our Solar System and beyond, are two fundamental questions of human faith. Space systems can make the difference.

Our Sun has enabled highly developed life forms to inhabit the Earth. As a red giant it will eventually usurp our planet. In 1 to 2 billion years it is unlikely that the Earth will still be inhabitable. Other places in the Universe could offer asylum and may be quite hospitable. “Whether” we need to explore these options is not a question, but only “when and how”, at which pace. The International Space Station is, next to many other qualities, one of the stepping stones in this direction, a laboratory for human experimentation. But it will remain an expensive and risky enterprise!

Systems Engineering Renaissance
Global cooperation and competition are driving factors not only for the space industry. More and more industrial sectors follow suit as other markets open. Integrated concepts and concurrent processes are dominating factors for competitiveness improvements. Technical integration, the classic domain of systems engineering, is not sufficient anymore. Finding “end-to-end” systems
solutions which take dynamic markets, business plans and service opportunities into account, is the yardstick. The informatics revolution has enabled concurrent systems engineering processes based upon more extensive modeling and simulations. Integrated interactive concurrent systems design processes are in the advance and are becoming a strong competitiveness discriminator in most business sectors.

Technological Advances and Risks
One of the system engineer’s challenge remains an even-handed adoption of technologies from the different technological R&D streams into competitive system design solutions. Risks need to be traded against added value, time to market, and return of investment. Space missions tend to challenge technologists and scientists to advance more than many other projects. They create fundamental knowledge and often cutting-edge technologies on which commercial developments thrive - and with them many of the terrestrial products of tomorrow. The technological edge of a country is an important factor in its global industrial competitiveness. Space activities are modest contributors to this end, there are many other sectors with similar or higher weight in this respect.

Society Needs, Priorities, and Space In Context
Some of the best brains work in the space field around the world. Their contributions to the 21st century knowledge society are enormous. There is no lack of fascinating new ideas for future missions. The scope and pace regarding publicly financed new space ventures will in the future, even more than in the past, be governed by the extend to which such missions can continue to make genuine contributions to society’s real needs. These include water, food, energy, employment, security and peace, environment, mobility, health, welfare and education. Fortunately space systems can make essential contributions towards many of them.

The market opportunities for privately financed space ventures will continue to grow. Many new fields could open up in the coming decades. In most cases there are alternative, sometimes better terrestrial solutions, to fulfill inherent needs. Space based solutions often are not unique, but can be excellent complements to other terrestrial developments.

Space, when dealt with in the context of society’s needs and terrestrial developments on Earth, will continue to contribute towards a better future of our planet and its population.

Fig. 32: Biological systems and their extended utilization for innovative applications on Earth are helped by space technologies; harnessing light/energy conversions for technical applications is one of the goals.

Making light of living cells

Fig. 33: Robotics combine many sophisticated technologies; models of the human hand with its bionics feedback loops and sensors remains one of the biggest challenges.

Fig. 34: Human destiny and that of our planet are better understood in the "context of space".
PERSONAL REMARKS

I feel very privileged of being part of the space community since 1962, when I started as the 5th member of the first space projects office of the Bölkow Company, which later became MBB, DASA, Daimler Chrysler Aerospace and now part of ASTRUM / EADS. In 1967, I joined the Douglas Astronautics Company, which then became McDonnell Douglas Astronautics and is now part of Boeing.

In 1973 I joined ESRO, which then became the European Space Agency, ESA. Finally in 1990 I returned to Germany, after 24 years of international service, to help build the new German Space Agency DARA, which then became DLR after I retired. In 1995 I founded the Space Associates GmbH, SAC, a virtual network company, consulting in the fields of space, environment and telemedicine.

In 1985 I lectured for the first time in Delft. In 1987 the University established a special ESA/ESTEC chair, which I had the privilege to assume. I would like to thank Mr. Marius LeFèvre, then Director ESTEC, for his support to the establishment of this chair. When I left ESTEC in 1990, this chair was continued by Prof. Ockels. I then held a special German Space Agency, DARA, chair; I would like to thank in this context Prof. Dr. Wolfgang Wild, then Director General of DARA, for supporting my activities then. In 1995 I assumed the Space Systems Engineering Chair, also in a part-time function. Between 1995 and 1999 I helped build and lead the international postgraduate programme for space systems engineering, SpaceTech, as its Founding Programme Director.

THANKS!
Dames en Heren, studenten, alumni en collegae, I am very grateful for having had the opportunity to serve the University for almost 15 years in a part-time function. I saw my mission as building bridges for our students, bringing my experience from industry and agencies into the Faculty and for providing the impetus for modern, real-life, space systems engineering. I enormously enjoyed the opportunity to create one of the world’s most respected postgraduate space systems engineering programmes, SpaceTech. The opportunity to draw in some of the top professionals from Europe and beyond to support us in Delft allowed us to create a genuinely congenial international team with mutual respect and friendship within the Curriculum Committee, supporting staff and participants.

Let me take this opportunity to apologize to some of my colleagues within this University community, if my drive for world-class standards, or my impatience and limited tolerance with administration and bureaucracy, has at times caused strain or disappointment. I know however, that most all of you continue to share my objectives, visions and approaches.

My primary motivation was the dialogue with the many gifted and enthusiastic students and young professionals here, and the challenge of keeping up with them. I hope I have been able to provide at least some of you with a few stepping stones towards your future professional life. You should know that, also as an emeritus, I will remain available to help.

Hooggeleerde Wittenberg, beste Hans, it was a genuine pleasure working with you during your reign as Dean of this Faculty. You knew how to create an environment of academic creativity and personal trust, with an absolute minimum of bureaucracy. The privilege of succeeding you in one of your many functions outside the University, as Chairman of the Joint Space Advisory Committee of the NLR and NIVR, is truly an honour.

Hooggeleerde Bloemendaal, beste Willy, you were the first part-time space professor from industry in the Faculty. I have treasured the cordial collegueship and the friendship between us. In a way I have tried to pick up some of the threads that you had begun to weave.

Mijnheer de Rector, beste Karel, for all these years you were my closest colleague and the only full-time “space professor”. I cannot recall any issue that we could not resolve in the course of the shortest of conversations. Your positive, no-nonsense, pragmatic approach, your openness towards new initiatives, and your untiring attempts in moving this Faculty, and indeed since a number of years this University forward, are most highly valued. This was and is so much in line with what I thought I could, in my modest way, do for the University, that working with you in complete confidence and friendship was and is both a privilege and a pleasure. I know you will have the continued courage and strength to drive this University towards continued renewal, more international cooperation and postgraduate education, no matter what the perils in your way might be.

Liebe Ingrid,
Let me close my remarks with an anecdote from a seminar of a very successful human resources consultant, Dr. Steven R. Covey. In this anecdote (Dr. S. Covey: The seven Habits of Highly Effective People, 1996) he wanted to differentiate between direction and activity, leadership and management. So he describes an operation of clearing a jungle somewhere in the wilderness with the means of machetes, a major expedition. There are a number of managers in action. One supervises the machete manufacturing operation, one the maintenance and repair shop, one runs an efficiency and improvement operation, and so on and of course there are many workers busy cutting through the jungle brush. While this is going on, the leader of the operation climbs up the highest tree and surveys the area, trying to get an overview and to determine in which direction to best drive the operation. Soon he comes to a terrible conclusion, and calls down: WRONG JUNGLE!!! Instantly the reply comes back: SHUT UP, WE ARE MAKING PROGRESS!

![Image of a steam engine]

Fig. 35: Technological Progress sometimes engenders panic, but without it, many of today's problems on Earth will remain unresolved.

Dear friends in this and other Universities, in Space Agencies, Research Centres and Industry, it is a privilege being part of the space family. As most of you know, I will continue my many other international space engagements in the future, including those in the Netherlands, albeit I hope at a slightly reduced pace. Let's continue to move forward together to exploit the exciting opportunities that this challenging and stimulating field offers!

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**IK HEB GEZEYG**

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