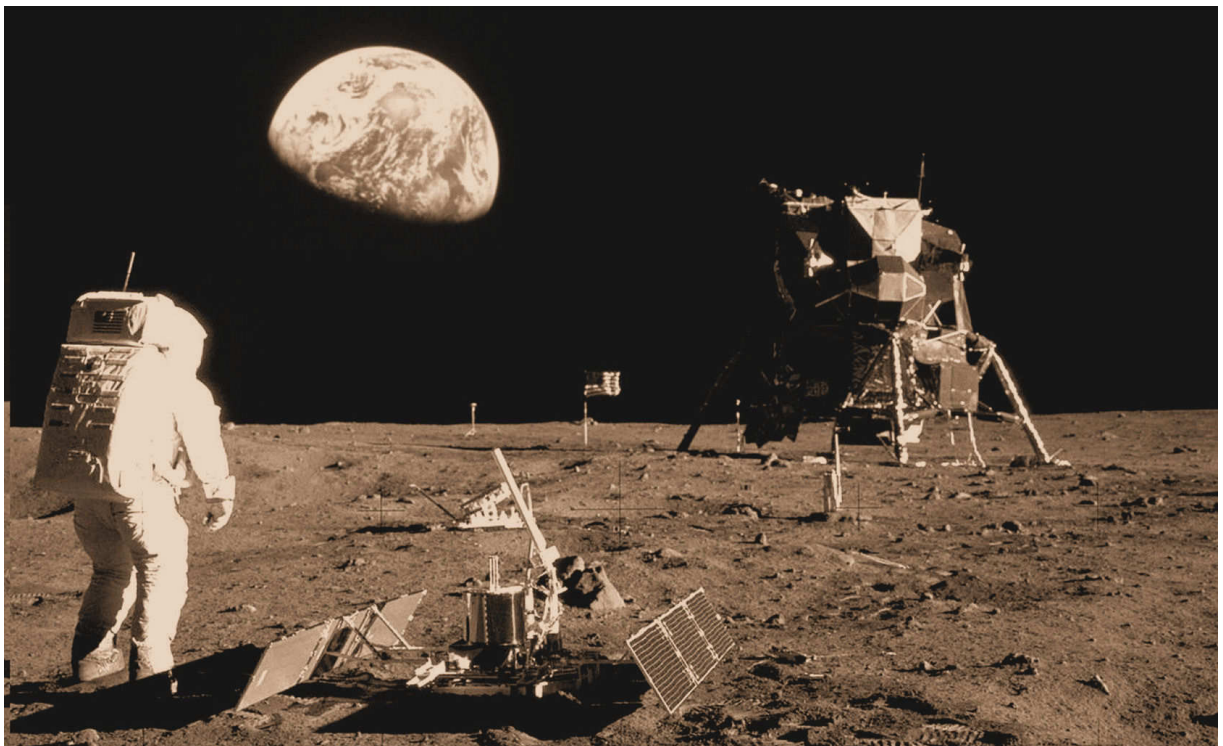


Pioneering in Aerospace

Back to the future?

Intreerede

Prof.Dr.Ir. J.M. Hoekstra



30 Januari 2008

Pioneering in Aerospace

Back to the future?

Inaugural speech

Prof.Dr.Ir. Jacco Hoekstra

January 30th, 2008

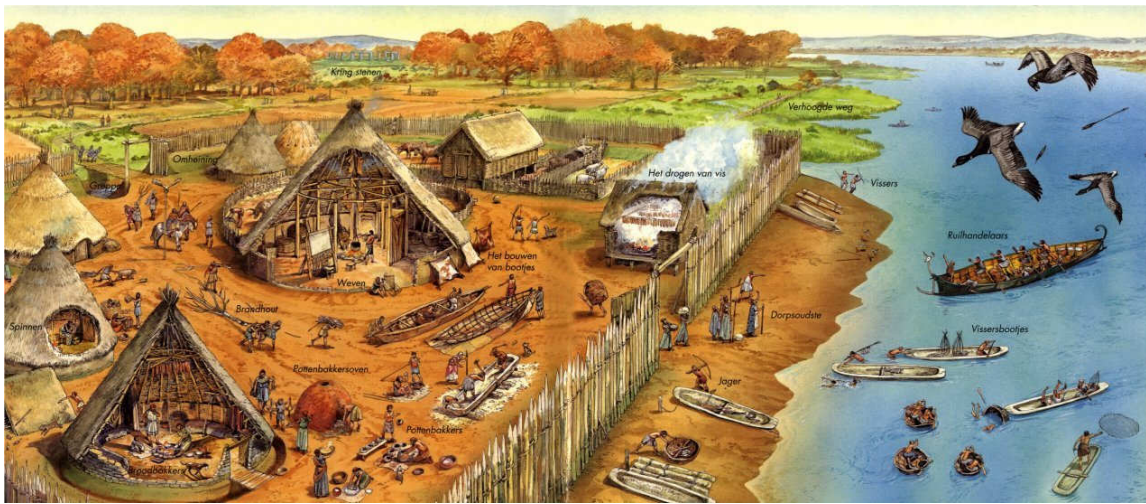
Mijnheer de Rector Magnificus
Leden van het College van bestuur,
Collegae hoogleraren en andere leden van de universitaire gemeenschap,
Zeer gewaardeerde toehoorders
Dames en heren,

*Front page:
Largest technological achievement of mankind so far:
a man walking on the moon*

Progress: a continuous process in history?

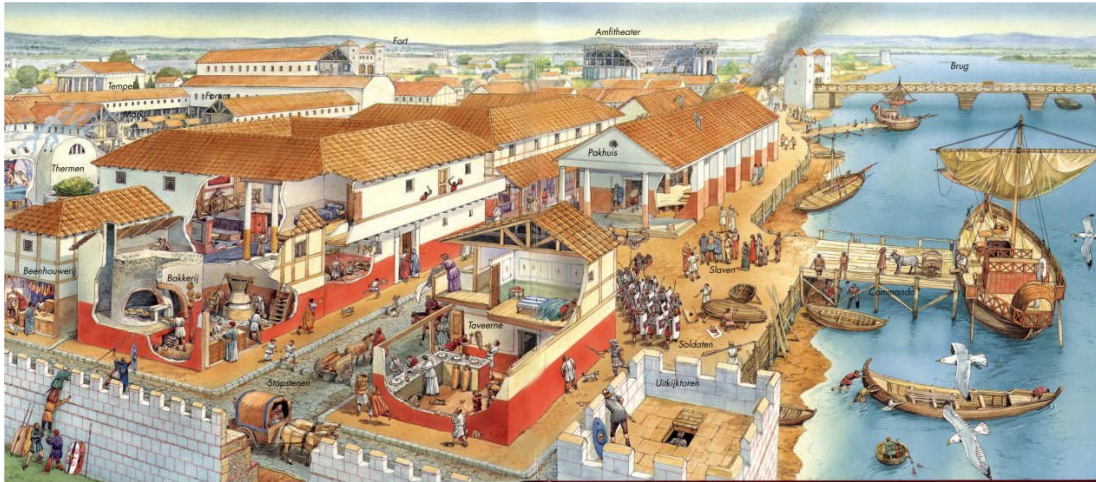
The title of this lecture is “Pioneering in Aerospace- Back to the Future”, and it is about progress in Aerospace in the past, present and future. But before we will discuss Aerospace, let us have a look at the progress of our civilization in general.

The progress of mankind is often presented as a continuous process, one civilization building on the progress of the previous, and this on and on, leading to our current status. When people start talking about a topic, they often start with a Greek philosopher or an Arabic mathematician as the origin of their science. But is this the real picture, or is this just an idealistic representation of how history really went?



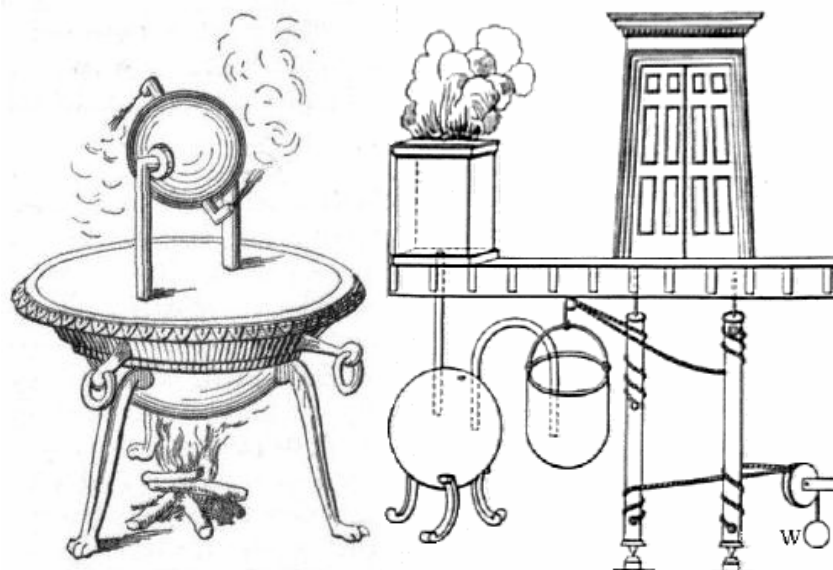
Dutch village at the end of the prehistoric age ±1000 BC

On the figure above we see a small village, a thousand years before Christ in the Netherlands. At the end of the prehistoric times, people were able to have cattle and do agriculture. They changed from a nomadic existence to living in little villages. This created more food and more time, which also allowed technological progress to accelerate.



Same Dutch village after Romanization in the year 100 AD

In some places this went faster than in others. In the Middle East, especially Egypt, and Babylon, advanced technological civilizations arose, and via the Greek and Roman civilization this reached our area. In the picture above we see the same village in the Roman times: houses with brick walls, tiled roofs, glass windows. In many ways a modern human would feel at home in a town like this. Still often we don't realize how modern the civilization of the classical antiquity really was.

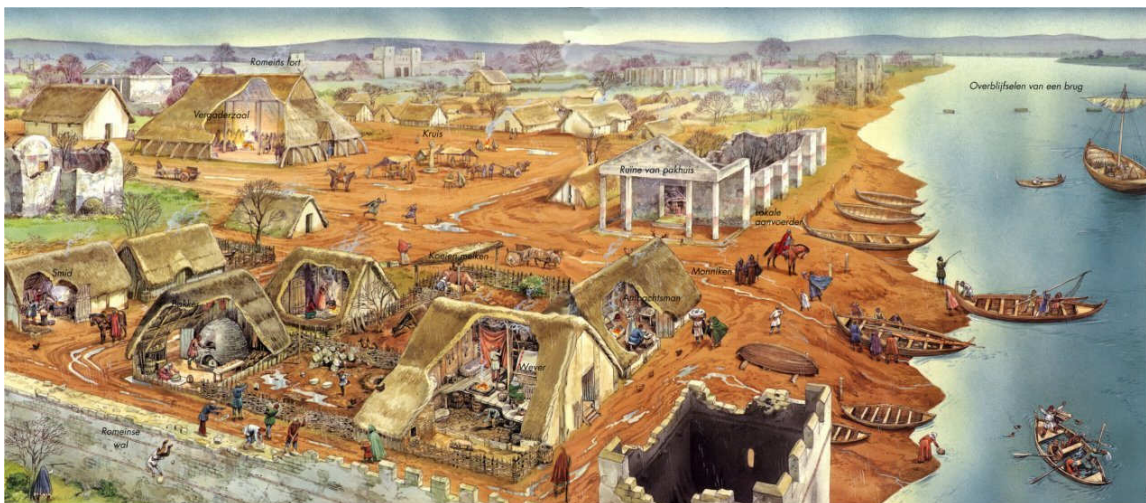


Inventions of Hero of Alexandria (400 BC): Steam engine with jet propulsion of sphere (left) and automated moving pieces of scenery for an Alexandrian theatre (right)

The steam engine for instance; we often believe this was invented in the 18th century by James Watt. In reality, he only patented an improvement to make it more fuel efficient. There was already in the ancient Greek times a man called Hero of Alexandria in Egypt, who invented the steam engine – and jet propulsion

by the way – as is shown on the diagram: a kettle with water heated, resulting in steam coming out of exhaust pipes, resulting in a rotating sphere. The same man was responsible for the invention of fountains, windmills and even a stage which was completely automated: moving doors. This machine was actually built and used in a theatre in Alexandria. Most of his inventions were later forgotten.

Because what was the next step of our civilization after the civilisation of antiquity? The dark ages. Whether it was due to barbarians, shortage of food supplies from the colonies or corrupt politicians: the roman civilization collapsed completely in the west, and we were thrown back in nearly prehistoric times.



Same village after the collapse of the Roman Empire in the year 620 AD

So the same town where we had the Roman village, looked 500 years later, very much like the prehistoric town 1500 year before the same town. How is this possible?

It was not a short collapse: it took at least 1000 years to get back to the same level of civilization as we had in the Roman times. Is the fact that the medieval times lasted a 1000 years is that a warning for us? It is something that we hardly think is possible. Maybe technological progress is not a rule but a rare exception in history.

For instance, if we look at the prehistoric human. Homo sapiens, exactly the same species was we are. They were just as intelligent and creative as we are today. Still, they lived for 100.000 years in the very much the same way. They did not get any further than using stone tools and fire. They did not think of agriculture, the wheel, a writing system or any other technological advances in those days. One hundred thousand years is one thousand centuries of hardly any no progress, try to imagine how that's possible.

We have a hard time comprehending that, because we are lucky to live in our own exceptional times. The 20th century clearly was a century in which there

were many engineering achievements. It was the century of electricity, of the car, of new energy sources. Below is a list of the greatest engineering achievements of the twentieth century.

- Highways
- Spacecraft
- Internet
- Household Appliances
- Health Technologies
- Petroleum and Petrochemical Technologies
- Laser and Fiber Optics
- Nuclear Technologies
- High Performance Materials
- Electrification
- Automobile
- Airplane
- Water Supply and Distribution
- Electronics
- Radio and Television
- Agricultural Mechanization
- Computers
- Telephone
- Air Conditioning and Refrigeration

List of greatest engineering achievements of 20th century (ref. Globalfuture.com)

It is due to the technology invented in the 20th century that our image of the world has shrunk as much as it has. The increased possibilities and speed of transport and communication has resulted in a much smaller world and the resulting globalization.

First century of flight

We all know the legend of Icarus who wanted to fly, flew too high and fell. It is actually about the vanity of mankind, but it also shows one of the oldest dreams of mankind. For as long as we know humans have dreamt of flying as a bird. It was this dream that formed the inspiration to another major achievement of the 20th century: flight.

Leonardo da Vinci clearly dreamed of flying. He analyzed birds and the way they flew and tried to replicate it in designs for aircraft too advanced for the time that he was living in.



Drawings of flying vehicles by Leonardo da Vinci (1452-1519)

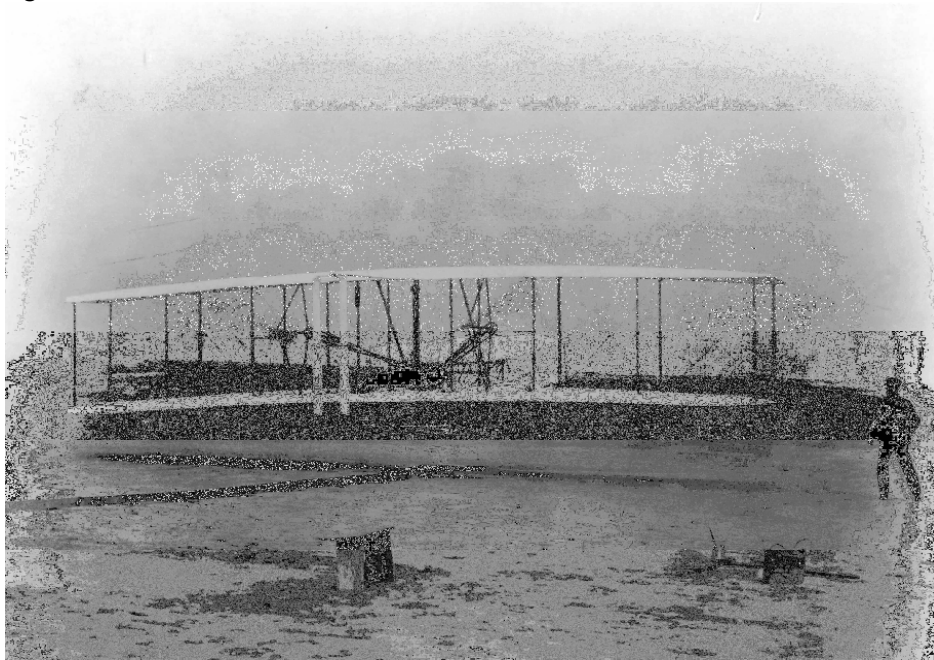
In the figure above there are some of his designs: an ornithopter with flapping wings and a very early predecessor of the design of the helicopter.

In the 19th Century man finally flew, but in a different way, using balloons filled with gas or hot air. This was flight only with vehicles lighter than air, and many renowned scientists, like Lord Kelvin, said that it was impossible to fly with anything that was heavier than air. This was physically impossible, and at the same time, the birds were flying around their heads.

Still many inventors, inspired by the glider experiments of Otto Lilienthal, kept trying to develop a motorized aircraft at the end of the 19th, beginning of the 20th Century. Most of these vehicles did not fly in the end. Often they were too heavy. For instance, the mere weight of a steam engine (!) disabled many models to get off the ground.

Wright Brothers: Wright flyer I

The first motorized vehicle that did fly is the Wright flyer. This was in many aspects the real predecessor of today's aircraft. It had an engine which was much lighter, designed and built by bicycle manufacturers: the Wright Brothers, and tested at Kitty Hawk, a place in Virginia along the Atlantic Ocean, known for its strong winds.



Famous picture of the third and last flight of the Wright Flyer I

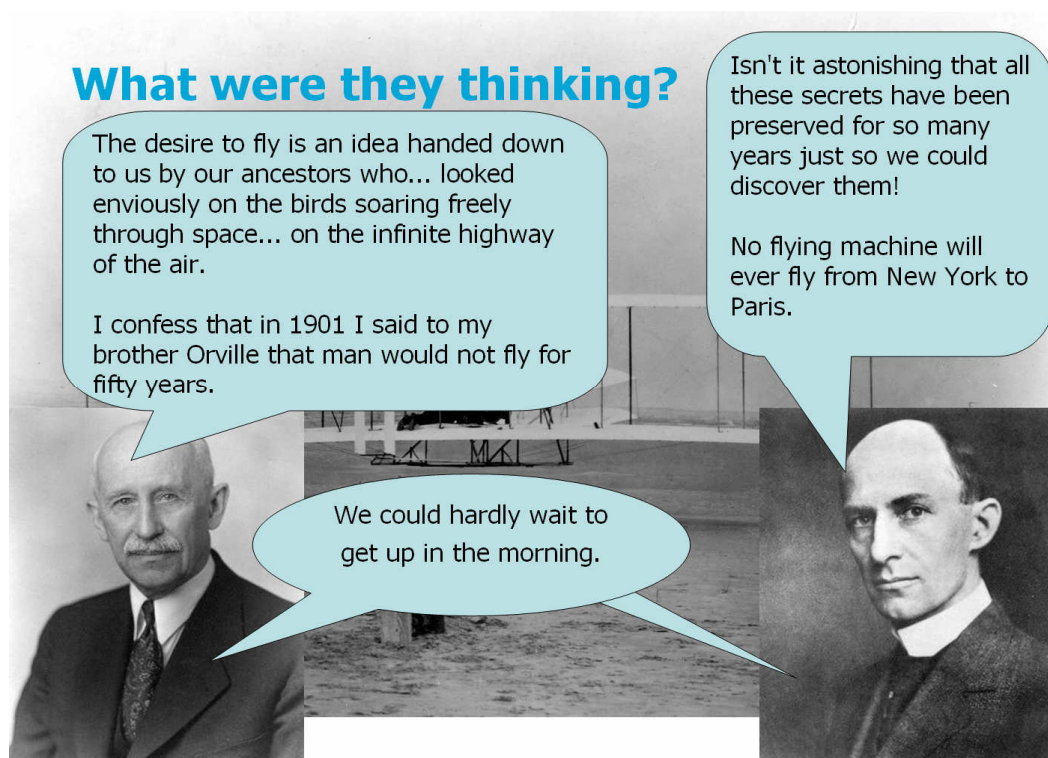
And so we finally flew in an aircraft, on this famous day, December 17th, 1903. Who of the Wright brothers was the first one to fly? That depends on your criterion. Orville flew 120 feet, and an hour later Orville flew 200 feet. Around noon it was Wilbur's turn. He flew a distance of 852 feet, and even more than 2000 feet relative to the air, because of windy Kitty Hawk. After this long flight, during the landing, the elevator was damaged, and when they tried to get the

vehicle back to the hangar to repair it, a sudden gust of wind tipped it over and the complete vehicle was destroyed on the same day it flew for the first time.

Another thing the Wright brothers had done right was their PR: they brought with them the photographer of a local newspaper to take pictures of their milestone. And this is probably one of the reasons they stand out amidst the other pioneers of motorized flight. It also resulted in work on several other Wright Flyers for the US military.

So it is thanks to the pioneering of, among others, these two men that we are now able to fly. To go to our meetings abroad, to travel as tourists around the world, to have fresh flowers and vegetables from all over the world, to be able to drop bombs on armies from the air. But were these applications the dream they were pursuing? Were the practical applications of air transport their motivation? What were they thinking?

Well, we know what they were thinking; they were not thinking about these applications at all. Let us look at some of their quotes that were recorded:



What were they thinking?

The desire to fly is an idea handed down to us by our ancestors who... looked enviously on the birds soaring freely through space... on the infinite highway of the air.

I confess that in 1901 I said to my brother Orville that man would not fly for fifty years.

Isn't it astonishing that all these secrets have been preserved for so many years just so we could discover them!

No flying machine will ever fly from New York to Paris.

We could hardly wait to get up in the morning.

They were thinking about birds soaring freely through space. And, what we also notice is that they themselves were not sure it was possible. In 1901 Wilbur said to his brother Orville that he thought it would take at least another 50 years. And even after they flew Orville said "No flying machine will ever fly from New York to

Paris”, even though they laid the groundwork to make this possible. (Charles Lindbergh crossed the Atlantic Ocean 24 years later, in 1927)

Trying to achieve the impossible and discovering all the secrets was very motivating. And I find it astonishing to see the huge disconnect between their motivation and the actual use for such an important invention as flight.

Kelly Johnson: SR-71 Blackbird



SR-71 Blackbird: proposal in 1959, prototype flew in 1962

Another example later in the 20th century from aerospace, in 1959. Remember, in those days the first family cars appeared in the streets. We had the first jet propelled passenger aircraft but there were still many propeller driven aircraft like the constellation. Flying was mainly for the rich. And in those days there was already somebody thinking of what would become, in my opinion, the most advanced aircraft of the 20th century.

And this man was Kelly Johnson, and the aircraft that he thought of in those days, for which he already made a proposal in 1959, was the Blackbird SR-71.

The SR-71 was a stealth aircraft before the word 'stealth aircraft' even existed. It was able to fly Mach 3.2+, it still holds the altitude record for sustained flight of 85,000 feet and had a range of nearly 6,000 kilometers. The SR-71 version was designed for an extremely challenging mission, a reconnaissance mission high over enemy territory out of reach of the ground-based air defense system and outside the range of scrambling fighter jets. It had a completely new flight envelope: it was to fly higher-faster-and-further than any aircraft had ever flown until then. It was constructed using of new material, titanium, which meant that to prevent damage leading to corrosion, new tools had to be used; new aerodynamics were needed, a completely new type of jet engine, new systems, new temperature range of operation: everything about this aircraft was new. Still, with only 300 persons working in Skunk Works on this aircraft, it was developed, and the first prototype was produced within 3 years.

Werner von Braun: Apollo Saturn V rocket

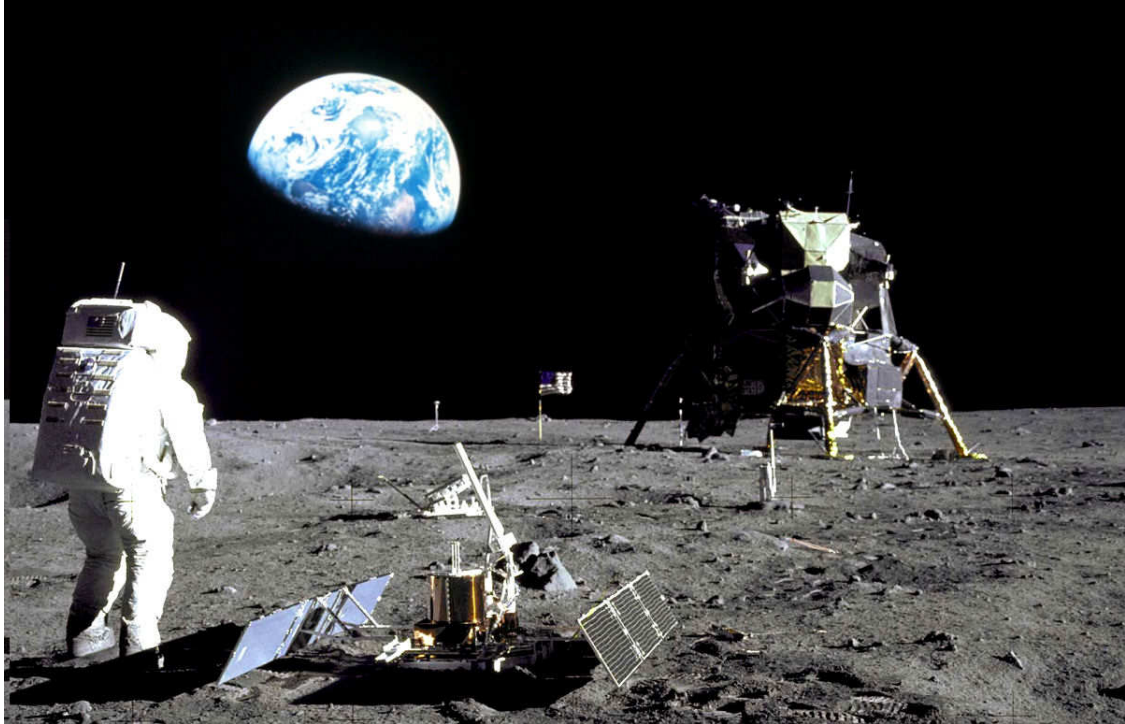
Another example: Werner von Braun was the father of the Apollo project. He designed and produced the Saturn V rocket, still the largest rocket ever built by mankind.



Apollo project: Saturn V Rocket which enabled mankind to reach the moon

And this rocket allowed us to achieve an enormous milestone: a man on the moon. The first man walking on another body than the planet earth.

Before the age of the modern computers, they used the first specifically developed primitive computers for space. In fact the predecessor of most modern computers can already be found in the old Mercury capsules. With these primitive, ampere consuming computers, they were able to fly three men to the moon.



Apollo astronauts worked many hours outside their lunar module (NASA)

In the actual operational phase of Apollo no crew ever died, they all returned safely to earth. Only one crew died due to a fire during the test phase of Apollo 1 on earth. We all know of course that it was a narrow escape with the Apollo 13, but think of the robustness that allowed the lunar module to be used as the main capsule and propulsive system of the whole configuration.

At the end of the Apollo program, on the Apollo 17 mission, Cernan and Schmidt lived and worked on the moon for 3 days, using the lunar module as their little house and driving to work in their car, the lunar rover, to do geological, or more accurately, "lunalogical" research.

Personally I regard this milestone of a man on the moon as the peak of our civilization, so far.

Mission Earth

So this is how far we ever traveled in space: to the moon....And then? Then we returned to earth. We built satellites; we built the space shuttle, which is able to escape from the atmosphere and fly at an altitude of 380 km which is the orbit of

the international space station. And true, it is flying in space, because it is flying outside the atmosphere, but compared to the moon at a distance of 384.000 km, it is merely flying a bit higher than aircraft. At some point the motto for the space activities at NASA was "Mission Earth". This was the long term goal: Mission Earth. Understanding the earth is very relevant. But as a long term goal of space travel? Aren't we already at the earth? How would this lack of ambition inspire new technology?

One could say: but manned space travel is too unpractical and not necessary. And that the decrease of effort in that area is compensated by an increase of using unmanned vehicles travelling to the planets, so humans don't have to go that far. We only need robots to explore for us.

But even that is not going as fast as it was in the sixties. Look at the two lists below to get an impression of the unmanned space vehicles launches now and in the sixties.

▪ Luna 8 - 3 December 1966 - Lunar impact (attempted soft landing) ▪ 1966 ▪ Luna 9 - 31 January 1966 - 1st Lunar Lander ▪ Cosmos 111 - 1 March 1966 - Attempted Lunar Orbiter? ▪ Luna 10 - 31 March 1966 - 1st Lunar Orbiter ▪ Luna 1966A - 30 April 1966 - Attempted Lunar Orbiter? (Launch Failure) ▪ Surveyor 1 - 30 May 1966 - Lunar Lander ▪ Explorer 33 - 1 July 1966 - Attempted Lunar Orbiter ▪ Lunar Orbiter 1 - 10 August 1966 - Lunar Orbiter ▪ Luna 11 - 24 August 1966 - Lunar Orbiter ▪ Surveyor 2 - 20 September 1966 - Attempted Lunar Lander ▪ Luna 12 - 22 October 1966 - Lunar Orbiter ▪ Lunar Orbiter 2 - 6 November 1966 - Lunar Orbiter ▪ Luna 13 - 21 December 1966 - Lunar Lander ▪ 1967 ▪ Lunar Orbiter 3 - 4 February 1967 - Lunar Orbiter ▪ Surveyor 3 - 17 April 1967 - Lunar Lander ▪ Lunar Orbiter 4 - 8 May 1967 - Lunar Orbiter ▪ Venera 4 - 12 June 1967 - 1st Venus Atmospheric Probe ▪ Mariner 5 - 14 June 1967 - Venus Flyby ▪ Cosmos 167 - 17 June 1967 - Attempted Venus Probe ▪ Surveyor 4 - 14 July 1967 - Attempted Lunar Lander ▪ Explorer 35 (IMP-E) - 19 July 1967 - Lunar Orbiter ▪ Lunar Orbiter 5 - 1 August 1967 - Lunar Orbiter	▪ 2001 ▪ 2001 Mars Odyssey - 7 April 2001 - Mars Orbiter ▪ Genesis - 8 August 2001 - 1st Solar Wind Sample Return ▪ 2002 ▪ CONTOUR - 3 July 2002 - Attempted Fly-by of three Comet Nuclei ▪ 2003 ▪ Hayabusa (Muses-C) - 9 May 2003 - Asteroid Lander and Sample Return (expected return June 2010) ▪ Mars Exploration Rovers - 10 June/7 July 2003 - Two Mars Rovers ▪ Mars Express - 1 June 2003 - Mars Orbiter/Attempted Lander ▪ SMART 1 - 27 September 2003 - Lunar Orbiter ▪ 2004 ▪ Rosetta - 2 March 2004 - Comet Orbiter and Lander (expected arrival 2014) ▪ MESSENGER - 3 August 2004 - Mercury Orbiter (expected arrival 18 March 2011) ▪ 2005 ▪ Deep Impact - 12 January 2005 - 1st Comet Impact ▪ Mars Reconnaissance Orbiter - 12 August 2005 - Mars Orbiter ▪ Venus Express - 9 November 2005 - Venus Polar Orbiter ▪ 2006 ▪ New Horizons - 19 January 2006 - Pluto/Charon and Kuiper Belt Flyby (expected arrival 14 July 2015) ▪ STEREO - 26 October 2006 - Two spacecraft, Solar Orbiters ▪ 2007 ▪ Phoenix - 4 August 2007 - Mars Polar Lander ▪ SELENE - 14 September 2007 - Lunar Orbiter ▪ Dawn - 27 September 2007 - Asteroid Ceres and Vesta Orbiter
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*Overview unmanned mission in 60s and beginning 21st century of Wikipedia:
notice the striking difference in number of missions per year*

It is good to see that since a few years, we have several plans to return to the moon. The Ares configuration for instance, for the Orion spacecraft, is going back to the same configuration as the Saturn V with Apollo. So within 10 or 20 years we might be back where we once were in the Sixties. And there are plans not to stop there this time, but to continue and go to Mars next.

Passenger aircraft design unchanged for many decennia

And how is that for aircraft: here is the 707, developed in three years in the fifties, one of the first jet-propelled passenger aircraft to be used widely. And what has changed in this basic design since then? Look at the Airbus A340: it is basically the same aircraft from a distance. Okay, it has winglets. But this step took eleven years to develop, this relatively small step compared to my previous examples.



*From left to right: a Boeing 707, Airbus 340, Airbus A380
Aircraft from different era but with generally
the same design from 1952 to 2007.*

And of course the newest, largest passenger aircraft ever, the airbus A380. It is pushing the technology to the limits, with new materials and engines, making it the largest passenger aircraft ever.

But we also notice it is basically the same layout as the Boeing 707 of 1959. And this last step took 16 years to develop! What is happening, smaller steps, larger periods? It is almost as if the innovation is slowing down? Is this because we have reached the end of the innovation lifecycle? But with new fuels, a pressure on reducing CO₂ emission, longer ranges and longer flying times, isn't it time of new technology to start.

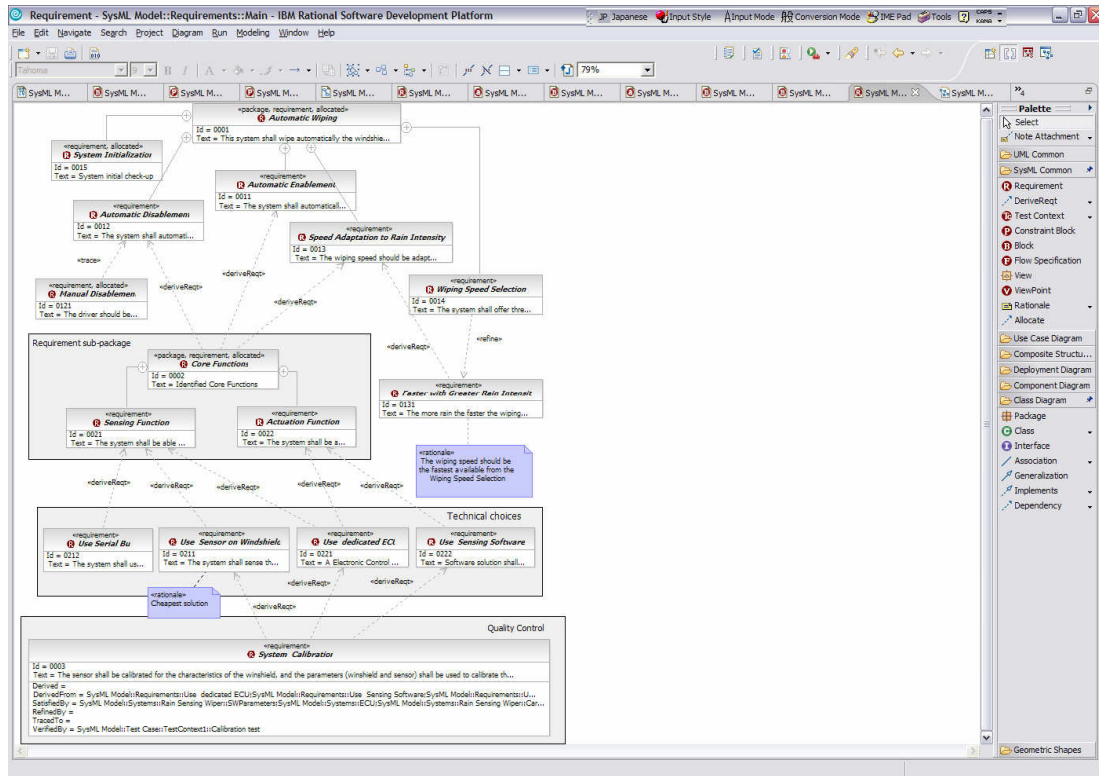
Losing goal orientation? Requirements lists instead of tests?

One thing that seems to go wrong, is that for every new system or subsystem, people spend many, many times splitting hairs in meetings. Who would expect progress from a project, which holds a requirements review meeting on Work Package 2.1.3.1.4a! I have been in projects like this. Is this a way to speed up innovation?

Some people seem to assume that a 'technology push' is a bad thing, even though all major achievements in aerospace started this way. But they stress the pull; and hence that we should focus on requirements, resulting in a culture which does not attract the most creative minds and loses its goal orientation. The approach also assumes infinite knowledge, resulting in a one shot approach: from analyzing the requirements to the best solution. Instead of the trial and error method, with the resulting iterative design which brought us to the moon. Werner von Braun once said:

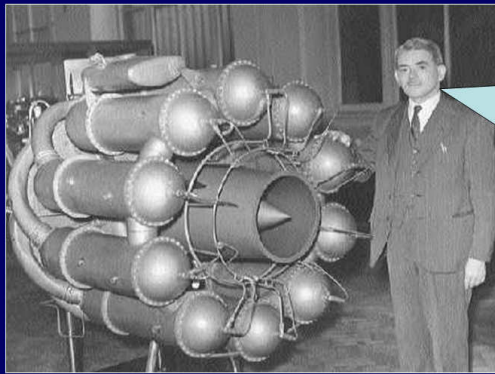
"One test result is worth more than a thousand expert opinions".

What does this mean for all of these project review meetings where we only get the expert opinions? It was trial and error that brought us to the moon.



A software tool to develop requirements into a subrequirements tree using XML.

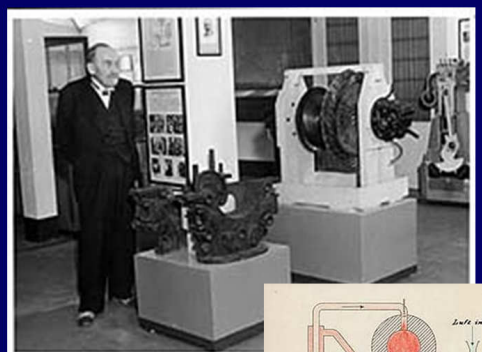
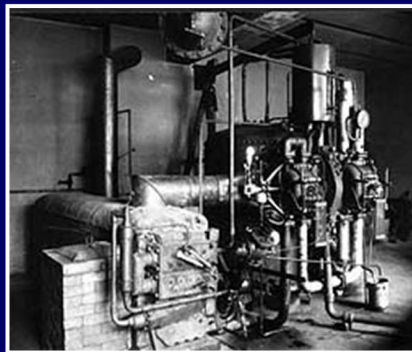
We have computers which are many magnitudes more powerful than the computers in the days of Apollo and the Blackbird. Those people would dream of the possibilities that we have with these computers. And what do most of the professional engineers do with it? Next to e-mailing up to several hours per day, they use these powerful computers to analyze the requirements. They split every requirement in a sub-requirement, and every function into a sub-function. Is this the way to innovate? Would the Apollo team or the Skunk Works team use these powerful computers primarily for this?



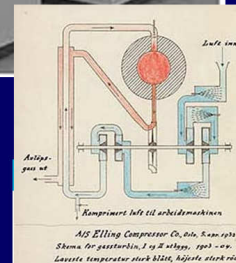
I analyzed the requirements, fast and high, and to my surprise this came out of the analysis.

- Frank Whittle, inventor of the jet engine? (1907-1996)

And for requirements: did Frank Whittle, the supposed inventor of the jet-engine, did he only analyze the requirements (fast and high) and the jet engine came out? Of course not. In fact he did not even invent the jet engine, he applied it in aircraft because he believed in its potential.



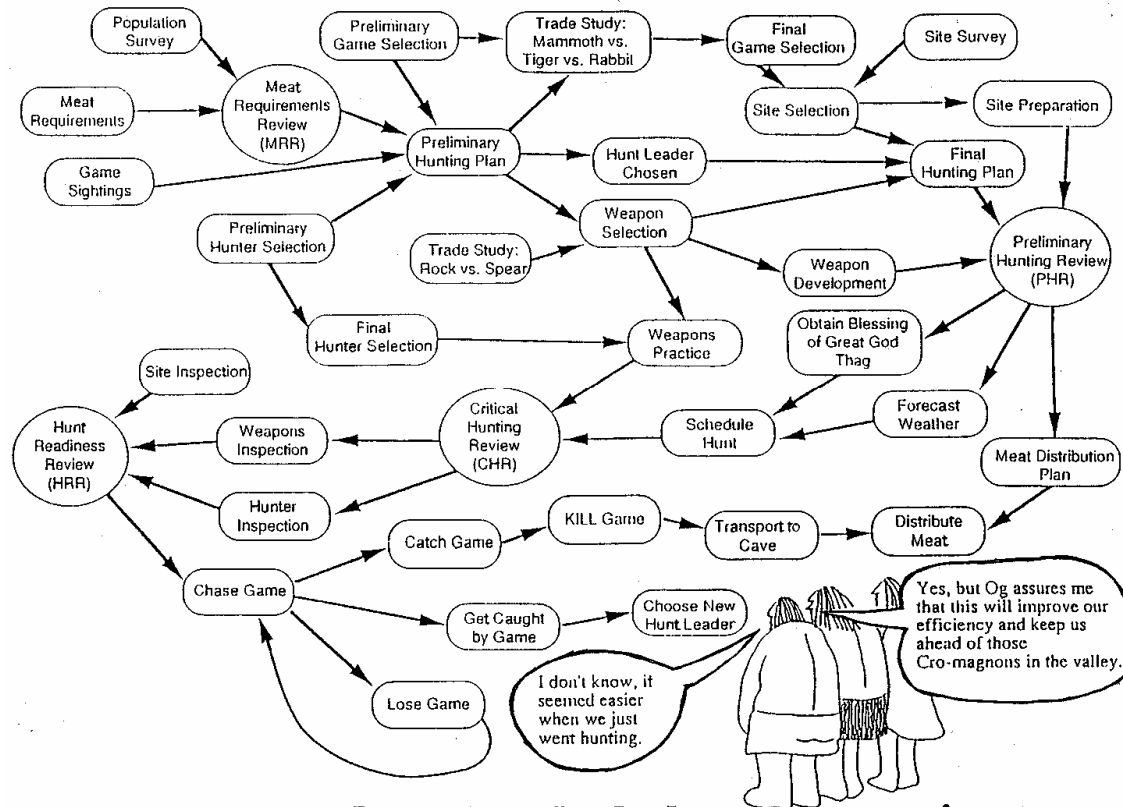
- Jens William Ægidius Elling (1861 – 1949)



The jet engine was invented by many people before him in steps; one clear step is the first combination of the rotary compressor and turbine, which was invented by Jens Elling, a Swedish inventor. Not by using requirements tree diagrams by the way, but sketches, like the lower right thermodynamics scheme.

How can the focus on requirements lead to a process orientation instead of a goal orientation? That is best illustrated by a cartoon. We see a diagram of how a hunt should be organized: before you start hunting you have to know how much meat you need, to avoid spending efforts or taking risks hunting something that you don't need, so therefore we need to know the population and their requirements and this will result in the first review meeting, the meat requirements review. Then you have to know what is available, so there has to

be preliminary game selection, trade studies: mammoth versus tiger, versus rabbit, and this is all part of the preliminary hunting plan, etc. etc.



Why the Neanderthals became extinct.

On paper the best approach to hunting...

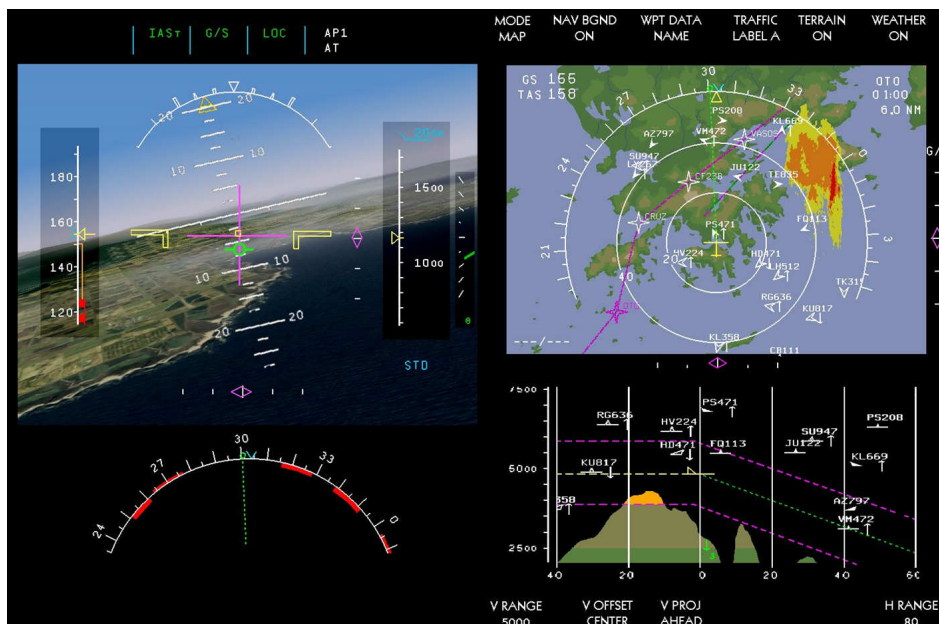
The funny thing of this cartoon that it is clearly making the whole approach ridiculous, but on paper there is nothing of which you can say that you could do without, you could argue that you could never start hunting without going through these steps. On paper it looks superior but still it is often better to just try it.

But there is more that slows down innovation. One of the key things that is slowing innovation is fear, instead of hope, resulting in an extreme risk-avoiding behaviour.



Boeing 747-400 Electronic Flight Instrumentation System as is found in many modern airliners

An example of how this works: here we have the electronic flight instrument system of the Boeing 747. Nowadays we have large LCD screens instead of the old dials. But what is drawn on those screens? We see the same dials; we see a rotating compass, moving tapes and an artificial horizon as if it is a gyroscope. We see only beacons indicated by short abbreviations. Why do we draw these old fashioned instruments on a modern LCD-screen.? For safety.



Alternative display configuration showing, terrain, traffic & weather information using same display technology

Technologically we could easily design a system like the one in the figure above, with synthetic vision, moving map displays, terrain information. The system knows where we are, and the system knows what the earth looks like. Still, this is not done in airline cockpits. Why not? Because it is different from what we did before and hence considered, by default, as unsafe. And therefore, for any

minute change, a large and expensive certification process is required. So manufacturers are stimulated to use modern technology in the old fashion.

But is using old instrument symbology not less safe? In 1995 an American Airlines Boeing 757 flew into the mountains near Cali, Colombia, because they were heading for the wrong beacon named 'R'. This happened due to a discrepancy between the Jeppessen approach plates and the database in their computer and a subsequent loss of situational awareness. There was another beacon with the same name in the area. Not surprisingly with such a name.

On their displays they only saw the beacon and their route towards the beacon, and everything seemed to be fine. Even though the aircraft's systems perfectly well knew where it was and there were no system failures, 160 people died, only 4 survived.



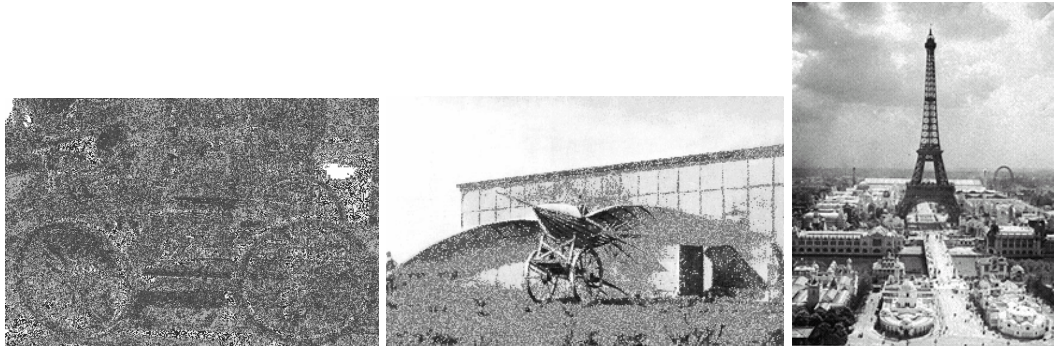
Would American Airlines 965 have crashed in December 1995, if the crew would have had displays that technology allowed at that moment? (CNN)

With the other type of displays, it would have shown the mountain coming up in synthetic, on the map display and in the profile display. This would make it very unlikely to crash into this mountain in this way because of the intuitive way the information for situational awareness is shown. So we see that the certification process, which is there for safety, freezes the whole system and thereby in the end threatens safety. It is the result of fear instead of vision.

After this and many other accidents, research on improving crew situational awareness has been accelerated. Twelve years later, still not in airliners but in small business jets, the first results are finally visible and look very much like the alternative display set up shown here.

Back to the beginning of the 20th century....

What should we do to prevent this slowing down of progress. It is a dangerous signal, the failure to react sufficiently to changing circumstances could even signal the first step of the collapse of our civilization, back to a lower level and its historically stable, common situation of standstill.



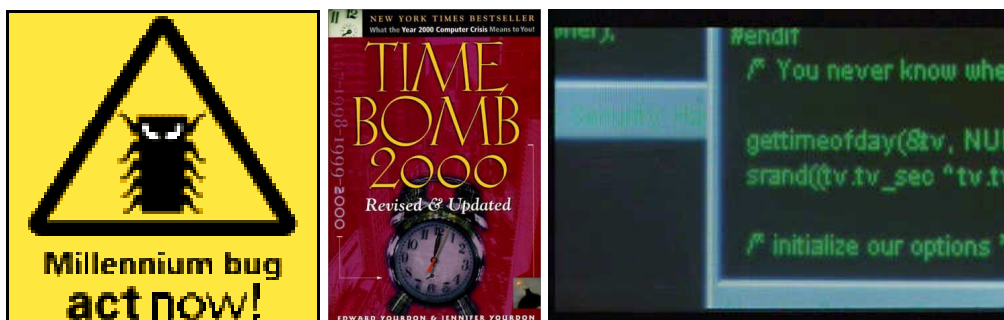
1900: a new century begins, visions of cars, flight and electricity

Let us have a look at the beginning of this extraordinary 20th century again: the year 1900. There was the exhibition in Paris, the World exhibition. People then had Utopian visions of the year 2000. Electricity would make the poor people rich, and it would never be dark again. This may seem naïve at first sight, but it is in fact an accurate description of what happened: nowadays we have problems with the fact that at night, it is not dark enough to be able to see the Milky Way anymore. And it is the invention of electricity that allows even poor people in the western civilization to have the luxury which is equivalent of 25 to 40 slaves, if compared to the Roman times, due to the electric equipment in their homes.

One might wonder, is there a causal relation between the dreams they had, the visions, their ambitions in 1900 and the reality in 2000? This looks at least probable. For every major innovation we can find a key person pushing the innovation. And in most cases this person is motivated by what an average person would call 'merely dreams'. Maybe having these dreams is required for real innovation, for the step changes in technology. Maybe we should all discuss our dreams for the future more often.

Pioneer again for our future?

So what are the current visions and ambitions? One hundred years later, only seven years ago in 2000, it was not only the start of a new century; but even of a new millennium. But I did not notice much about visions for the year 2100, nor for the year 3000. The next century and the next millennium were not on the agenda at all!



2000: A new century and a new millennium: visions of...the millennium bug

In the newspapers and on television was a lot of news about the “millennium bug”. There were concerns whether we still would have water and electricity in our homes, whether perhaps the nuclear weapons would be launched by accident due to a computer glitch, or nuclear power plants would become unstable, communication systems that would shut down. Some people even envisioned a total apocalypse, and claimed you would have to hide in your house with food and water to make sure you would live through the first weeks of the new century. I wonder how many people actually prepared for this period. In reality nothing happened, most cases were easy to predict and fix beforehand.

It struck me as strange that at the start of the new century, of this new millennium, there were no dreams, no visions, we saw only fear.

It also shows an alarming lack of the pioneering spirit as we had at the beginning of the century. I think we have to get the pioneering spirit back to save our future. Therefore focus should be more on images of where progress is aiming at: the future.

5 Century Goals for the second century of flight

A goal is simply a dream with a deadline and I would like to list five major goals, which I propose to set ourselves for the second century of flight.

Century Goal #1: Much cleaner way of flying

First and most importantly is to make sure that we survive on this earth and avoid catastrophic climate changes. Therefore we have to, among other things, limit the exhaust of CO₂ and hence the use of resources like fossil fuels, which will soon become scarce anyway. To save the planet, to save ourselves, we dramatically need a cleaner way of flying.

In our faculty we are trying, by using a skunk works approach, by thinking out of the box, to invent a completely new type of aircraft, which will be much cleaner.

And instead of working in worldwide committees doing reviews of each other's requirements, we think the way we got to the moon might be a better way. So we are thinking of a competition to promote the pioneering spirit.

So the first Century Goal (and urgent so for the first decades of the century) is a cleaner and greener way of flying.



Logo of the Delcraft works Cleanera project aiming at a new type of aircraft for a greener way of flying

Century Goal #2: Health and comfort for the passenger

Who wants to spend 10 or more hours in a tube of aluminium, packed as efficiently as possible? Today, we luckily have our little screens with the in-flight entertainment system. But still the lack of movement together the low air pressure and dehydration, pose a serious health threat on the longer trips.

The Boeing Clipper aircraft already had a better way of flying in the forties. The passengers would dine in the dining room and at the same time staff would change the salon into a bedroom, where you could go to rest after your dinner.

Airbus also aims to restore that with the Airbus 380. But it is up to the airlines to use it. And up to the passenger to demand it for their own health.

If we want to continue travelling around the world, we need to have more comfort for the passengers, or they will stay at home and the world will become larger again. Or for continental travel they will use other means. if we do not do something to improve the care for the health and comfort level of the passengers.

So this is the second Century Goal, which might also be achieved by travelling much faster and reaching the US in two hours from Europe.



More comfort and health for the passengers of the A380? (Airbus)

Century Goal #3: Air travel on demand: flying cars & taxis

Something else is wrong with the way we fly at the shorter distances. If we want to fly somewhere we first have to spend hours in traffic jams. Then we have to spend hours at busy airports. Then we spend the ten hours packed tightly together in an aluminium tube. And then when you arrive at the airport, the whole cycle starts again, standing in line in the airport and in the traffic jam. This is not how the customer wants to travel.

Often people do not realize this, but right now we basically only have public transport in the air. While what we really want is on-demand transport. Just like with video and shopping and music, we want it when and where we need it. So what we really want, and have wanted for long time, is a flying car.

Of course this is often seen as fantasy, which can only be real in science fiction movies. But there are many people trying to build such a prototype and some are actually flying already. For instance the Möller Skycar would, if produced in series like a car, it will cost the same as a car. And imagine that we would no longer use the car but use a vehicle with the specifications on the slide: 500 km/h, a fuel efficiency comparable to cars, but now used for great circle travelling. Vertical take-off & landing, and no traffic jams.

But will he be able to realize these? He has been promising this for many years now, but has only hovered for a short while, so far.



*Individual, on demand air transport, instead of public transport like modes
(fig right:PAL-V)*

It is true: Some of the models make too much noise, many use too much fuel, are perhaps very polluting. But will they all fail? I do not think so. Someone will put the right pieces of technology together sooner or later and complete the jigsaw puzzle soon.

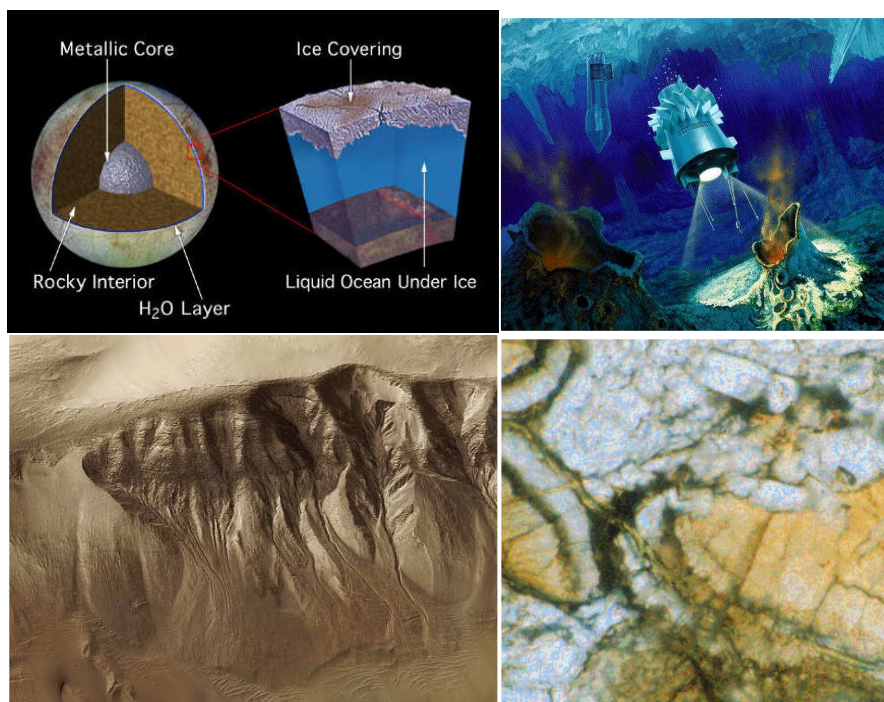
And if we want to use a cleaner way of taking off and landing, we could first drive to the highway and use a short strip there to fly and continue as a gyrocopter, as this Dutch company PAL-V proposes with their flying motorcycle (vehicle on the right in figure above)

Will all these individual vehicles fit in the sky? Remember, we will then have 3 dimensions, instead of 1 per lane as for the current car, and by using Free Flight Principles, as I have studied during my promotion studies, I see no reason why we should not be able to accommodate this number of aircraft in the sky.

So the third Century Goal is on-demand flying, individual air transport instead of public air transport: a flying car is the extreme implementation, and a large, affordable application of the air taxi is the first step, and soon to be a reality.

Century Goal #4: Search intensively for extraterrestrial life

And what about astronautic, is space technology ready? No, there are also some goals there to be reached this century in space.



Intensify the search for extraterrestrial life in the most likely places in our solar systems: Mars for fossils, Europe for living organisms under the ice (NASA)

Finding extraterrestrial life, or at least looking for it at some likely places, like Mars is such a goal. We still don't know whether the traces found in the Martian meteorite indicate life, or whether it is just a coincidental combination of non-biological processes. The Martian surface clearly shows traces of huge amounts

of water, of oceans in the past. And we know there is still an ice lake in the Mars South Pole, and perhaps even sometimes some water. So what about life there?

And there are other places in our own solar systems which are even more likely candidates of finding life today. For instance beneath the ice sheets of Europe, a moon of Jupiter. If it is indeed filled with a huge liquid ocean under the ice, which seems to be indicated by the crack patterns, then this could be an ideal place to find life. The moon is continuously bent by Jupiter's gravity field, and the resulting thermal activity could be the reason the oceans are there.

We already have found a colour on the cracks which seem to indicate molecules generated on earth only by bacterial life.

So we have to find out whether there is life below the ice sheets, i.e. by using a little submarine in a spacecraft which melts its way through the ice sheets, and starts looking for the geothermal vents, which are one of the most likely places where life is still present today close to earth.

Is this realistic? Does extraterrestrial life even exist? Looking at the likely numbers of stars, planets and galaxies and the fact that we are not in a unusual place in the universe, the proposition that our planet is the only one with life, seems extremely unlikely.

Why is this important? If we find this life, we can determine how related we are. Are these bacteria using DNA? Do they use the same enzyme coding language? Or is it a more distant relation on molecular building block level? Or did it originate independently? The answers to these questions provide insight to the biggest question of all: what is our origin? It is the missing link between the theory of how the universe evolved to starts with planets and how life evolved on Earth.

So intensify the search for extraterrestrial life is the fourth Century Goal, which I think we should set ourselves for this century.

Century Goal #5: Find extraterrestrial places to live

With old civilisations you always see two modes: to expand or die out. If our earth is not sufficient anymore, and we already need six earths in the near future, isn't the inevitable conclusion that we need to conquer space to survive in the long term. Why don't we spend more effort on a permanent presence in space? We could try first on the moon, later on Mars and even further later. Perhaps even try to live in free space in the neighbourhood of a star for supplying energy. The real challenges here are not just aerospace challenges, but also to maintain an ecological system within a colony, our spaceship. And this happens to be same knowledge that we need to preserve our earth.

So I believe that these are the five goals we should set ourselves for the next century. With the last one we should start this century, but reaching a mature level of space colonisation might be a millennium goal: Let us make sure we have colonized other planets and space in 3000.



Three steps in colonizing space: Mars, Callisto and Stanford torus (NASA)

Conclusion

One might say the five century goals are too ambitious. But even if you do not reach a goal, the pay-off will always be rewarding. For instance, if we try to develop a flying car, but we not yet be able to do it due to the propulsion system, we might already have developed a very safe cockpit that everybody might be able to use. There are many other examples of pay-off by striving for these ambitious goals.

Of course, I think we are able to reach them. Remember that many of the goals that were reached in the 20th Century would seem impossible at the beginning of the 20th Century. And if it seems a bit daring or unrealistic to you, realize that it is one of the characteristics of innovators in the past that they were willing to try the seemingly impossible. To lift the barriers that are currently slowing down innovation we have to think different.

Another way to look at it: if we are mainly concerned with preserving what we already have, then on a cosmic scale, it is not a waste if we die out. It would be equal to admitting that this is all what we as a species is capable of. I am optimistic that we can achieve much more if we really want to. But progress is aimed at the future and so to get progress we have to go back to focus on imagining our future.

So I would want to conclude with an anonymous quote, (that I've changed slightly):

Innovation can only be obtained if you:

*...care more than others think is wise;
...risk more than others think is safe;
...dream more than others think is practical;
...expect more than others think is possible."*

Ik heb gezegd.

Jacco Hoekstra