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Human versus artificial intelligence in the cockpit
Are robots learning to fly?

Autonomous traffic systems – here is an attempt at an energy balance-sheet

Artificial intelligence (AI) is currently a much-discussed topic in media, research and politics. Since the mid-50s, there has been a lot of hype about AI. The actual developments have so far lagged far behind the announcements and fears.

The term artificial intelligence (AI), is attributed to the logician and computer scientist John McCarthy. He was a participant at the Dartmouth Conference in the summer of 1956, where mathematicians, information theorists, cyberneticists, electrical engineers, psychologists and economists tried to describe learning and characteristics of intelligence so precisely that a machine could be built to simulate these processes.

The Dartmouth Conference did not yield any concrete result; it failed, among other things, because of the difficulties in sufficiently and precisely defining intelligence and learning.

In my opinion, translating AI as "künstliche Intelligenz" (KI) in German is difficult, as AI and KI are not identical, AI and KI should not be used synonymously. In the German-speaking world, intelligence is associated with creativity, discovering something new, thinking analytically, applying something familiar alternatively, developing problem-solving strategies, to name but a few aspects. In the Anglo-Saxon-speaking world, however, AI is also understood in the sense of investigating, probing, finding out (see CIA). Irrespective of language-specific differences, one definition of AI with broad acceptance cannot be found. Distinctions are made between mathematical, linguistic, technical, musical, social and emotional intelligence. A distinction is also made between weak and strong AI. In aircraft with weak AI (which are rather assistance-systems), the pilots are supported - this is semi-autonomous flying, the pilots retain the power of decision. Autonomous aircraft, on the other hand, require strong AI with numerous governance systems, which take over the flight guidance completely, pilots are not required.

As an aid to defining AI, the Turing Test is often used, which was devised by the mathematician Alan Turing in 1950. According to this test, a machine or an electronic system is considered intelligent if a human being, after intensive questioning of such a black box, to pass the test in its favor.

However, AI has laid many foundations for future developments. Even the name AI - although rated as not optimal by all participants of the conference - has been kept until today. Today, experts prefer the term "machine learning" - but AI is catchier for the media.

At present, it is high-performance processors, neural networks and networking via the Internet that are once again attracting the proponents and opponents of AI. Whether it will ever be possible to reproduce and model the best 'computer' on earth, our brain, remains questionable. If one compares the still rather jerky movements of current robots with the filigrane fine motor skills of a ballet dancer or a pianist, one gets an idea of how far the motor skills of AI-controlled robots are still away from those of humans.

In November 2018, the German government published a strategy paper on artificial intelligence www.ki-strategie-deutschland.de. The government hopes that Germany will be at the forefront of AI as an industrial nation characterized by innovative technology. In 2019, 500 million € have been approved for this and an additional 3 billion € will be made available until 2025.

Currently there are very optimistic announcements in aviation from various manufacturers and operators of aircraft for autonomous flying, flight guidance by AI instead of human intelligence, i.e. pilots.

Will AI (or machine learning) significantly change commercial aviation? If so, how will this affect the operation of future commercial aircraft?

Autonomous flying: Unresolved key questions to be answered before possible introduction:

1. ***Artificial intelligence:*** state of research and development? How intelligent is artificial intelligence? Is the current level of AI development good enough for autonomous flights? Can learning machines be creative or are they determined?
2. ***Reliability:*** Are IT safety and security of hardware and software adequate, what about redundancy?
3. ***Responsibility:*** who is responsible, the operators on the ground, the programmers, the computer, the developers and manufacturers, the air traffic control or the airline?
4. ***Acceptance?*** Will passengers accept autonomous commercial aircraft?
5. ***Costs / Savings?*** Is autonomous flying cheaper?
6. ***Advantages / Disadvantages?***
7. ***IT electrical energy expenditure (EE)?*** What about the EE costs of autonomous aircrafts, what about the ecological balance-sheet?

No ideologies help to answer these questions, but rather research and development, which generate scientifically verifiable statements. The above-mentioned aspects/questions must be clarified before a possible deployment of autonomous commercial aircraft in scheduled service.

The following article deals exclusively with the question of IT requirements for electrical energy (EE), an aspect that has hardly been considered so far!

The physically incorrect but widespread term "power consumption" is not used. Correct is Electrical Energy Requirement (EE), physically correct Electrical Power (P(ower), measured in Watt or Kilowatt) and Electrical Work (W(ork) or Energy, measured in Wh or kWh).

So far, in my opinion, it is unclear to many people who have commented on the subject of autonomous transport systems what IT-energetic challenges this planned autonomy will trigger. First, it should be discussed how much electrical energy is actually required for IT technology in general; there is sufficient data available on this.

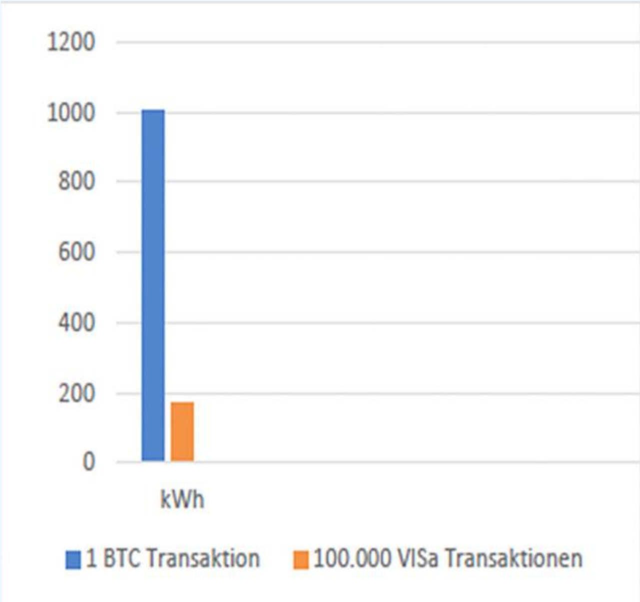
The electrical energy demand (EE) of IT systems consists of two areas:

1. The energy consumption of the terminal equipment used, i.e. the avionics systems in the aircraft or the automotive electronics, which are supplied directly from the on-board power supply or from accumulators. This electrical power can be easily determined with a power meter, a watt- or kilowatt meter, for example. The domestic meter determines the electrical work, i.e. the power multiplied by time. $W = P \cdot t$.
2. The required EE "behind the scenes", i.e. the indirect EE demand. It is much more difficult to determine this, as this data is not accessible to the end user. - What is meant by this? Every so-called online action, e.g. a search query on Google or Wikipedia, sending an email, downloading a podcast, a video clip, (e.g. streaming) triggers considerable computer activity in data centers, which we do not notice in normal operation, as they take place in servers, which typically are hidden from us. Music live from the Internet e.g. via Spotify, or even more so video streaming, e.g. watching videos via Netflix, YouTube, video conferencing via Skype, require considerable e-energy. Depending on the location, many data centers around the globe may be involved.

Here are some facts and figures on this:

- The ratio between direct and indirect RE requirements is about 1 : 2, which is an estimate of the average value from which significant upward deviations are possible depending on the type of IT activity.
- Each autonomous car, on average, generates data of 4 TB/day ≙ Data of 3000 people (IT users)
- One million autonomous motor vehicles generate or process as much data as about 3 billion people.
- An average data center has the electrical energy requirements of a city of about 30,000 inhabitants.
- Data centers in Frankfurt/Main have more renewable energy needs than the entire FRAPORT airport with 18.85% of the renewable energy needs of the city. The data centers in Frankfurt (e.g. Equinix, E-Shelter, Interxion, Telehouse etc.) require 19.42% of the total renewable energy demand of the city of Frankfurt with an increasing tendency.
- Equinix (F-Gutleutstraße, 370 employees): The largest cost-item (40%) of the gross value added is the E-Energy costs!

- Telehouse (F-Kleyerstraße) has the same e-energy requirements as the town of Dreieich with approx. 40,000 inhabitants.
- The energy requirement of the IT sector amounts to 7 - 8% of the worldwide EE requirement with an increasing tendency.
- The renewable energy demand in Germany for data centers, IT-clouds etc. amounts to approx. 57 TWh ≙ 10 power plants. - Converted into CO2 equivalents, this corresponds to the entire German air traffic.
- According to estimates by the e-energy producer E-On, streaming platforms and video conferences alone generate approximately 200 billion kWh per year worldwide, about as much as private households in Germany, Poland and Italy need together.
- The computing power of today's PCs, compared to those of the 70/80s, is 3,000,000 times greater.
- If one were to build a computer with the computing power of today's PC or laptop using the Zuse or Nixdorf technology of about 70 years ago (discrete design with relays, tubes and individual transistors), a smaller power plant (about 500 MW) would be required to operate it.
- Data centers require the largest share of IT energy including cooling.
- 200 Internet search queries ≙ the EE requirement for electric ironing of a shirt.
- Google and its services, such as Maps, YouTube or Drive, consume around 5.7 terawatt hours per year. That is about as much as San Francisco consumes per year.
- A transaction of the crypto currency BitCoin ≙ EE requirement of a refrigerator for 8 months.
- The waste heat of a data center could be used to heat about 1500 apartments. And another incredible fact: "Evan Mills, a scientist at Lawrence Berkeley National Laboratory, has calculated that the production of legal marijuana in the US consumes 1% of the country's total electricity, or 41.71 billion kWh of electricity, at a cost of $6 billion. That is enough electricity to supply 3.8 million homes or the entire state of Georgia.
- The 'hunger for data' is constantly growing, with an annual growth rate of 10% currently expected".



A look at the renewable energy needs of the crypto currency BitCoin worldwide:

The administration of this crypto currency (block chain) is extremely energy intensive. As for every transaction all participants of this currency worldwide need to be electronically involved, an average transaction requires 1005 kWh. A three-person household in Germany uses about 2500 - 4000 kWh per year. Three BitCoin-Transactions require as much EE as a 2 - 3 person household in one year. 100,000 visa transactions on the other hand 'only' need about 170 kWh.

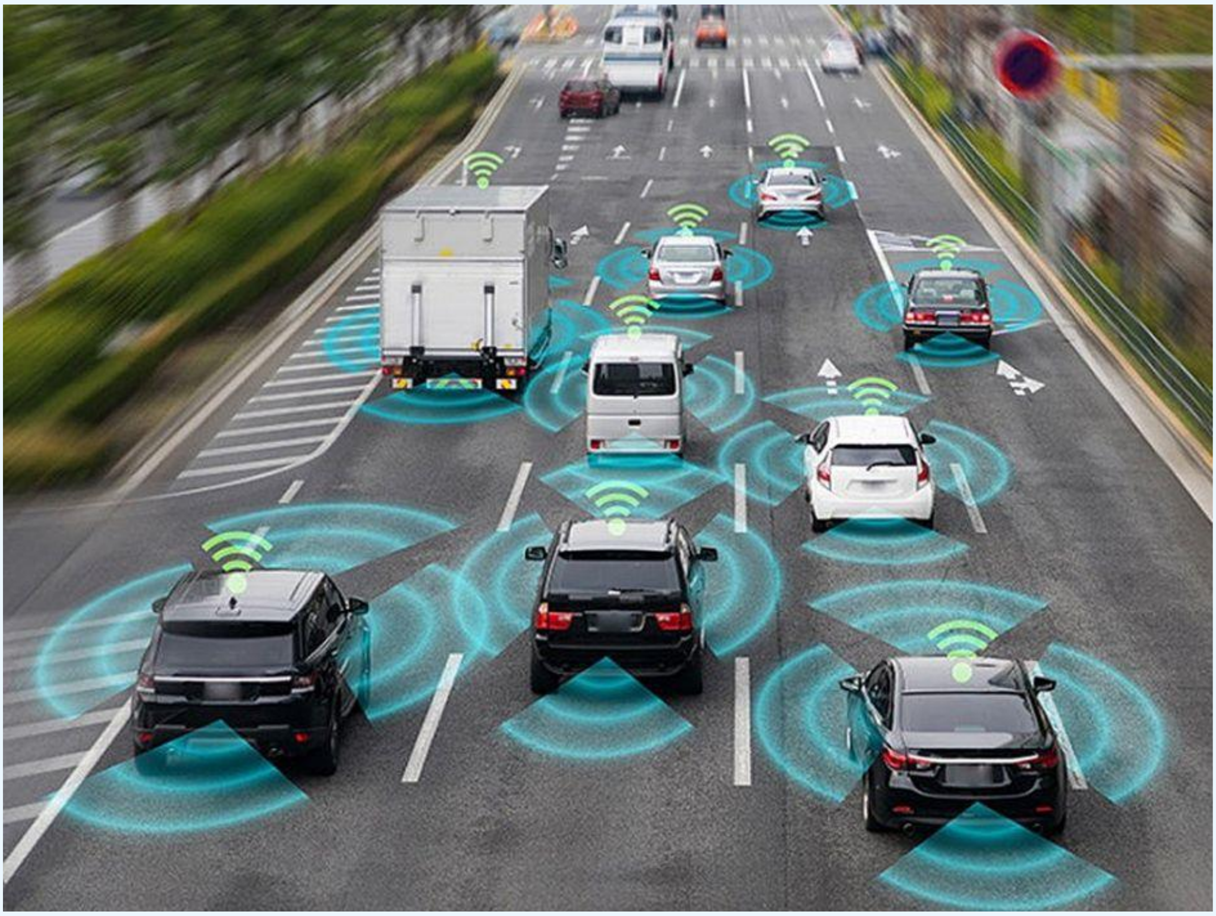
The annual worldwide renewable energy expenditure of this crypto currency is slightly larger than the total demand of Switzerland or the Czech Republic.

It is hard to believe that all of Austria could be supplied with the renewable energy needs of this currency.

Extrapolations show, for example, that the world's renewable energy needs might be exceeded if BitCoin should ever reach the upper limit of subscribers (21 million).

Let us take a look at autonomous transport systems:

As the figure below shows, all autonomously moving vehicles must communicate with each other via mainframe systems.

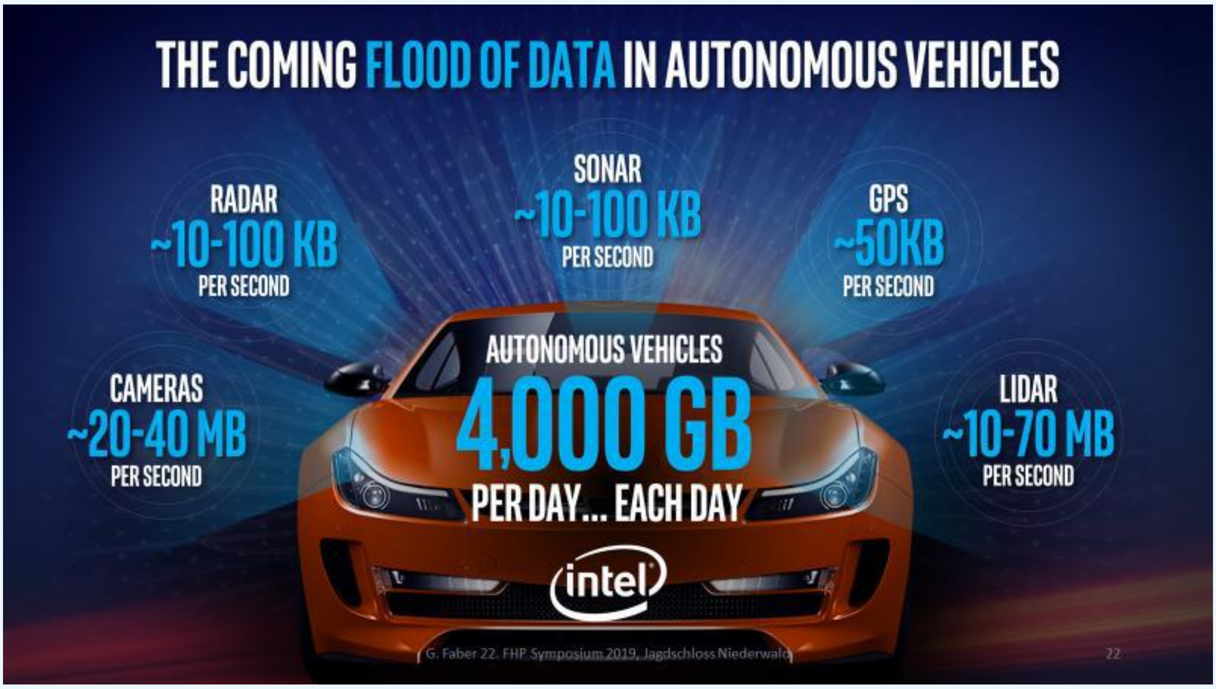


According to current Intel estimates, the data flood of an autonomous motor vehicle will amount to 4 TB per day, i.e. 4,000,000,000,000 bytes. It is not clear which redundancies will be required to achieve the current level of road safety. Without any redundant systems autonomous driving will hardly be possible. With approximately 50 million motor vehicles registered in Germany, huge amounts of data would be generated if one wanted to switch to fully autonomous driving.

Below is an overview by the company INTEL on the data generation per second of the different systems required for autonomous driving: GPS, camera, lidar, radar and sonar. Lidar and the camera are data intensive.

As a reminder: A bit is the smallest unit of information, e.g. an indicator light with two states, on or off, generates one bit.

Nobody can even come close to estimating the total EE requirement of completely autonomous traffic, but it will be gigantic. Large investments in data centers, power plants and networks will be necessary. It is doubtful whether the EE infrastructure can grow in parallel to a possible conversion of our transport systems to full autonomy. If we assume a high percentage of electric vehicles, the demand for renewable energy will additionally increase exponentially. It is considered certain that with the current infrastructure, the EE networks would be completely overloaded. Autonomous transport systems would require a considerable expansion of our networks and power plants. Since only part of this energy can probably be generated by solar, wind and hydroelectric power plants, CO2 pollution is likely to increase considerably again. It is more than questionable to what extent this necessary renewable energy demand can be provided by so-called 'green electricity'.



Autonomous air transport

It is estimated that the amount of data to be processed in air traffic will be even higher than in vehicle traffic due to the third dimension and the necessary triple redundancy, if the current safety standard of 10E-6 or better is to be achieved.

It is unclear whether the additional EE costs for autonomous commercial air transport are lower than the pilot salaries, i.e. whether there will be an economic gain.

In addition, the following questions must be answered:

- Can the current safety level of 10E-6 be achieved?
- Will autonomous commercial aircraft find acceptance among passengers?
- What is the legal situation, who is responsible if there is no PIC on board, ground services, developers, manufacturers, air traffic control, CIC?
- Can learning electronic systems for flight guidance do the same as the "Hudson River Crew" CPT Sullenberger and F/O Skiles or the crew of Ural Airlines' A 321, which recently made an emergency landing in a cornfield in Russia?

To put it in a nutshell, AI is not an intelligence according to our understanding. Even learning machines remain determined.

The more I deal with the topic of autonomous traffic systems, the more skeptical I become, despite all the euphoric reports of success. From a safety and redundancy perspective, full autonomy will hardly be achievable, solely because of the compatibility with conventional systems (Uber-Accident in Phoenix, AZ). It is also doubtful that autonomous traffic systems will become safe enough that liability and comprehensive insurance could be dropped and accident figures will be close to zero, as claimed by automotive experts (see HR info podcast on autonomous driving, F. Dudenhöffer, 13-01-2017).

It seems highly questionable whether the gigantic investments required in autonomous transport systems will pay for themselves. Certainly, there will be partial results of the AI research which will be very helpful for the technology of the future, but a complete autonomy of the transport systems will probably not be possible.

We should continue our FHP efforts to increase safety in air transport by training, further training and education of premium pilots. Savings in ATPL training, which lead to a reduction in the quality of pilots, are counterproductive in the long term. Highly qualified pilots with good system awareness, i.e. knowledge of subsystems, have often been the last line of defense.

Unfortunately, there are no statistics on how many incidents and accidents were prevented by highly qualified pilots. Push Button Operators, who have only limited subsystem knowledge of their aircraft, have less chances to develop problem solving strategies in time-critical situations. During normal operations the human-machine interface of today's commercial aircraft cockpits is comfortable and controllable with regard to the amount of data that is generated. In the event of a malfunction, however, the amount of data can increase to an extent that the maximum limit of our conscious brain processing capability (16 bit/s) is reached or exceeded. Highly qualified, experienced pilots then have better chances.

Glossary

AI	Artificial Intelligence
Assistence System	serve to support the operators, e.g. brake boosters
ATPL	Airline Transport Pilot License
Bit	Binary Digit, Unit of Information
BitCoin	Cryptocurrency
Block Chain	Interlinked continuously expandable crypto-data sets
Byte	consists of 8 Bit
CIA	Central Intelligence Agency
CIC	Computer in Command, humorous allocation of responsibility
Cloud	Data storage outside own computer
CPT	Flight Captain
EE	electrical Energy
F/O	First Officer (Co-Pilot)
Governance system	actively intervenes in flight control, e.g. MCAS
GPS	Global Positioning System, US- Satellite radio navigation system
HR	Hessischer Rundfunk (German Radio Station)
Intel	Intel Corporation - a US multinational semiconductor technology company
IT	Information (data processing) + telecommunication technology
Kilo	> Mega > Giga > Tera > Peta > Exa > Zetta (10E3, 10E6, 10E9, 10E12, 10E15) kW Kilowatt (Power) (736 W ≙ 1 PS) kWh Kilowatthours (Work)
LASER	Light Amplification by Stimulated Emission of Radiation, accurately focusable light
LIDAR	Light Detection and Ranging - Radar system on LASER basis, higher accuracy through light
Live-Streaming Media	simultaneous transmission of video and audio files via Computer networks (computer centers)
MCAS	Maneuvering Control Augmentation System is a flight control law (software) written into the Boeing 737 MAX flight control system which attempts to mimic pitching behavior similar to the Boeing 737 NG, especially in high angle of attack (AoA) flight (Wikipedia)
NETFLIX	US- Media service e.g. for video streaming
PIC	Pilot in Command, Flight-Captain
RADAR	Radio Detecting And Ranging, system based on the reflection of electromagnetic waves to locate objects
SONAR	Acronym for sound locating system
TB	Tera Byte = 10E12 Byte
TW	Tera Watt (1000 000 000 000 Watt, 1 Trillion Watt)
TWh	Tera Wattstunden (1 Trillion Wattstunden)
Visa	US-Financial Services Company
W(ork)	P(ower) · t (tempus/time)
YouTube	US Videoplattform for Onlinevideos

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Concluding remark: Some of the data and figures mentioned in this paper are based on estimates and extrapolations. Completely accurate data can only be obtained with great effort, if at all. Nevertheless, the existing data material is suitable for trend identification.

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