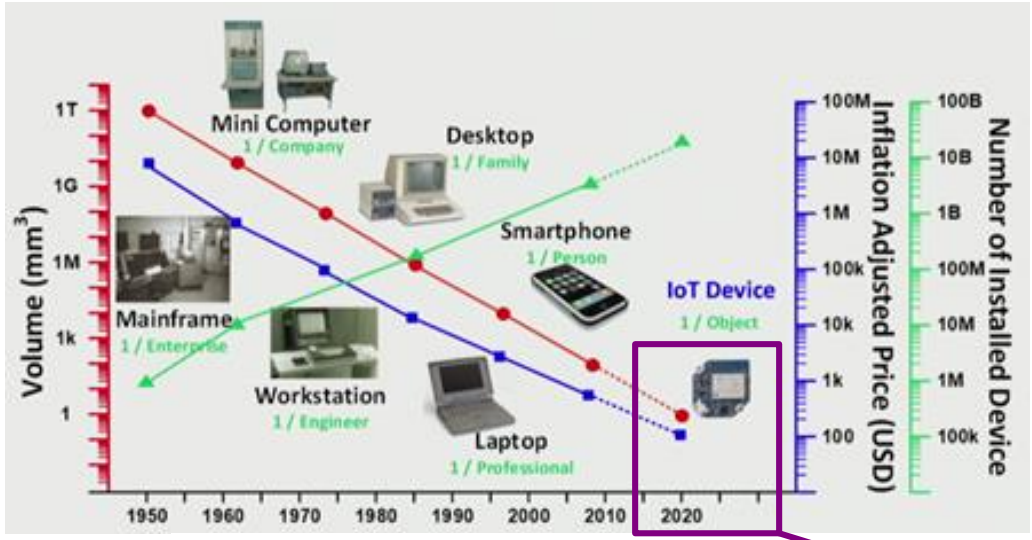

CERN

Machine Learning and EPC – in about 10 minutes

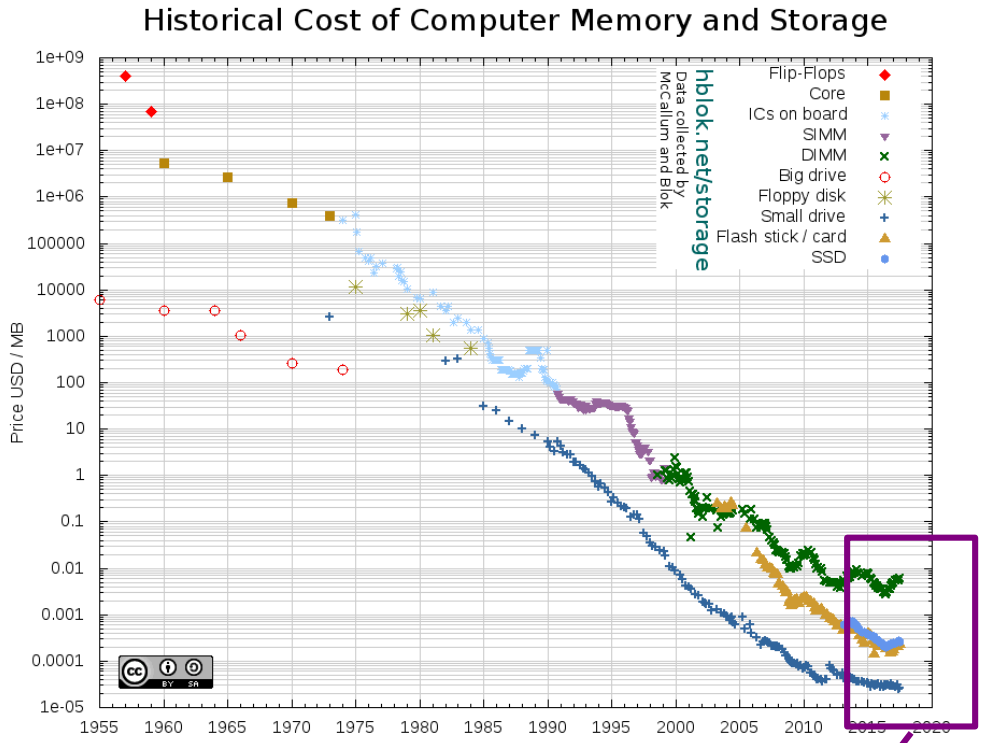
B. Todd , L. Felsberger et al.

Context – Industrial Trends

considering **Machine Learning** by seeing CERN's engineering in the **wider context** of **industrial trends**…



Bell 1971, ACM 2008, Morgan Stanley 2012



McCAllum, Blok, 2020

why are engineers heading towards Machine Learning for **data analytics**?

- many **more things** are recording much **more data**
- Sometimes we **don't know** what information there is
- **Extracting** information from this data needs automation
- This information can have great **commercial value**…

Context – EPC/CCE Ambition of Total Availability

1000s of power converters, **fault**, **diagnostics** and **repair** over **40 years**.
Converter Controls Electronics aim for controllers with **1Mh MTBF**, **zero impact** on system level availability.

"total availability" = analogous to "total quality"
Apollonio, Felsberger, Schmidt, Todd, et al.

Traditional approach: highly **reliable**, with **redundancy** at higher level. e.g. FGClite & 60A converters achieved 1Mh MTBF, via three Master's theses

- *Reliability **analysis** of … new [FGClite]…* – V. Schramm 2016
- *Quantitative reliability **demonstration** from production to operation [of FGClite]…* – T. Tevetoglu 2017
- *Evaluation and **improvement** of the design for reliability process [of FGClite] …* – J. Schwenk 2018

Context – EPC/CCE Ambition of Total Availability

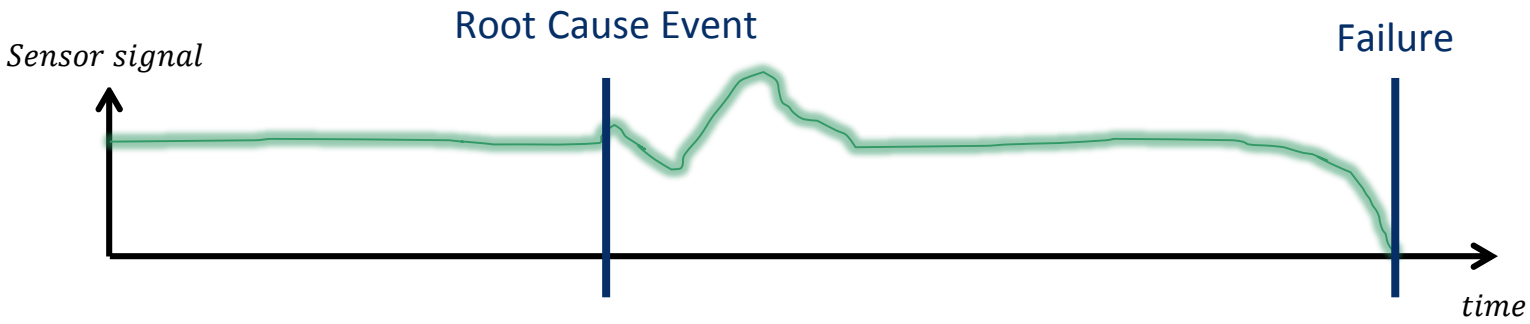
Historically =

- **remove** root cause /
- reduce **likelihood** of occurrence /
- reduce **impact** of occurrence

= better availability

DIAGNOSTICS

failure → diagnostics → root cause event



How can we achieve this?

PROGNOSTICS

root cause event → prognostics → mitigation

Felsberger, 2019

The Future =

- **Lessen** impact
- Take action to **mitigate** entirely

= even better availability

Context – EPC/CCE Ambition of Total Availability

Types of maintenance;

1. Corrective Maintenance

Run to failure → Repair

Least cost-effective for operation

2. Planned Maintenance

Replace at a specific interval, whether needed or not

3. Condition-Based Maintenance

Measure, and react at a warning threshold

Most **cost-effective** for operation

Most **effective availability**

What can we learn from our experience about converters and controls?

What about larger projects, such as FCC?

Doctoral Research – Program

Not an important task for EPC, but an interesting avenue to look at, building on our work on FGClite, anticipating the future

Started a Ph. D. program in 2017.

FTE from EPC: ~0.1 (B. Todd)
Funding: quasi-zero (Gentner student)
Funding project: FCC.
Thesis: "Quantitative Assessment of Reliability and Cost Aspects for Complex Systems"
Student: L. Felsberger (AT)
University: Prof. Dr. Dieter Kranzlmüller, Ludwig-Maximilians-Universität München (DE)

A. Apollonio,
T. Cartier-Michaud,
A. Mueller et al.

No Innate Expertise in EPC
- Strong collaborative effort with TE/MPE from the start
- Many synergies.

Doctoral Research – Outcomes

1 journal paper, **3** peer reviewed conference papers (**2** more in submission), **1** report, **11** presentations, and soon… **one doctoral thesis**

Data Collection:
- **absolutely useful**, proven to improve reliability historically
- **Easy** to communicate results.

Simple Analyses (Weibull etc.):
- **Useful** when coherent data available from testing / operations
- **Manageable** to communicate results.

Advanced analyses (Weibull + Acceleration Models):
- **Proven to be useful** based on accelerated testing data
- of academic interest when based on operational data.
- Leads to general insights potentially useful in practice
- Results **harder to communicate**, mathematically heavy.

Simple machine learning:
- Successful proof of **concept**
- **Few proven** deployments in industry
- Academically interesting.
- Results **easy to communicate** but interpretation **not intuitive**.

Advanced machine learning (Deep learning/LASER project):
- Successful proof of **concept**
- **Few proven** deployments in industry
- Of academic interest.
- Surprisingly powerful.
- Results **easy to communicate**, but interpretation **not intuitive**

proving something improves field-reliability is hard:
needs capital investment and observation over years.

Doctoral Research – Outcomes

Signals + **Faults** can be **recorded** and **used** at a later date – EPC has the potential to create a **valuable data set**.

- This information may lead to ways to improve reliability
- We should make sure to have the data, as we may want to exploit it later.

Short term – could be interesting to carry on this work as **research projects**.
Long term – application & investment from EPC side is **not proven** and is **not requested**.

EPC record useful **Signals** as a normal part of a converter operations

- to fix LASER (after LS2)
- to check what is logged (after LS2), making sure it's consistent
- If we identify a measurement of interest, just a case of adding it to CALS
- E.g. **no additional effort** (technical/manpower) on recording signals

EPC **Faults** are already recorded and logged as a normal part of operations

- We use them for internal tracking
- We use the Accelerator Fault Tracker
- We use them for root cause analysis
- E.g. **no additional effort** (technical/manpower) on recording faults

EPC Position on Machine Learning

short term

- make sure EPC keeps **coherent data**
- consider other **researchers** to work on data recording / learning from past data – but **not a priority**.

long term

- wait and see.

Personal Position on Machine Learning

Most important: EPC data sets for operation of converters are potentially **valuable**, can provide information to our domain

- That's true regardless of machine learning though.
- The data quality needs to be high
- Should consider "systems designed for automatic reliability data collection" - a new concept we are developing

This is a **difficult, mathematical** subject

- very easy to draw the wrong conclusions

Interesting insights have been generated from our data, by using Machine Learning approaches

- Are these "insights" interesting **academically** – **absolutely**.
- Could these "insights" provide a **return on investment** – **perhaps**.

Don't see electronics engineers becoming experts in machine learning, at least not in a reasonable time frame.

- It's too easy to do it wrong, whilst thinking you're doing it right
- Although correlating variables and least squares regression = understand popular machine learning methods

Machine learning experts coming from university have a good foundation for engineering (on the other hand)

- There is a new emerging class of engineer education, which we are not quite prepared for…
- machine learning experts still need electronics engineers to make sense of results