IT meets Airplane

The migration of Hardware parts to Software functions

and the 5 Root Causes for increasing trouble and excessive cost with Airborne Software Maintenance

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Cranfield, 26.11.2018

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Situation

- Since the late seventies we see a trend of transferring Hardware Parts to more Software Functions.
- It started internally in Avionics boxes where more analog functions became replaced by software. (embedded Software)
- Another Step was the separation of the Hardware P/N and the Software P/N including field loadable LRUs (**L**ine **R**eplaceable **U**nits)
- The next step became the modular avionics resources where a server platform hosts dedicated software applications in a multi tasking environment. Here we se Hardware, Operating System and Applications from different suppliers.
- The trend of Software functions replacing Hardware Parts is on full steam ahead today with every new Airplane to come (e.g. A380, A350, 787, 777X)
- This presentation addresses the gap we see for the Product Support and technical requirements to address reliability issues and commitments as previously given by MTBF our MTBUR for Hardware. (**M**ean **T**im **B**etween **F**ailure / **M**ean **T**ime **B**etween **U**nscheduled **R**emoval)

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What works good today for hardware…

- A hardware part, let's assume a valve, does come with reliability targets that are defined typically in a PSAA (**P**roduct **S**upport **A**ssurance **A**greement) or in an individual equipment purchase agreement.
- We have definition on the intended MTBF and we see definitions what has to be done by the Equipment Vendor in order to archive such MTBF.
- We see clear measures that have to be applied if the equipment is not compliant with the given targets. Usually this becomes a costly problem for the supplier if not fixed.
- So it becomes a positive business case for the vendor to improve the Hardware Part in order not to experience the penalty for a prolongated time.
- By the airframer's quality ranking for parts suppliers this method has led to an acceptable loop of quality regulation.

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…does not work today for Software

- A software part, let's assume a FM function (FM= Flight Management), usually has no targets for reliability and full spec functionality visible to the user or guaranteed by a PSAA or similar metrics.
- Not even basic functions are guaranteed for the buyer of an Airplane.
- Some basic functions are deferred for years in new airplane programs.
- No level of availability or reliability exists.
- Consequently the user (Airline) has no lever to measure the performance, missing functions or reliability of functions. There is simply no target to meet.
- Consequently no measures are in place to motivate the vendor to achieve a certain level of quality on those Software parts.
- Consequently no business case can be built at the vendor for improving bugs in Software since no financial or equivalent consequences exist for the underperforming supplier.
- Some equipment receives no bug fixes or completeness for years. Even after many years the quality of Software is still bad. It comes with malfunctions, resets and bugs. Usually with Block Point updates new Software failures are exposed to the user. Fixes to deliver what is contracted take years because the vendors pretend high certification cost and face no penalties. So bundling fixes to Block Point updates are normal. Letting the user wait for years to get what has been paid for.

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Image damage for unreliable and non-cooperative suppliers is not felt too hard by some

Some companies have always survived with a bad ranking regardless of Hardware or Software parts, consequently some do not care.

We must acknowledge we do see image damage for underperforming software suppliers.
This should enforce good product support and software quality.
But it does not seem to work for regulation of an acceptable quality of Software.

Reasons are:

In the newer business models for some new airplanes the airframer tends to delegates more and more responsibilities to the vendor.
But no guaranties for SW Quality are ensured for the user in a PSSA.

The Airline Ranking is not considered by the airframer during the supplier selection.
Good data exist, but the airframers look for a good deal and let the trouble with the airlines.

Most vendors are monopolists for a given airframe and don't care. (single source)

Others are doing really well. (not all are bad)

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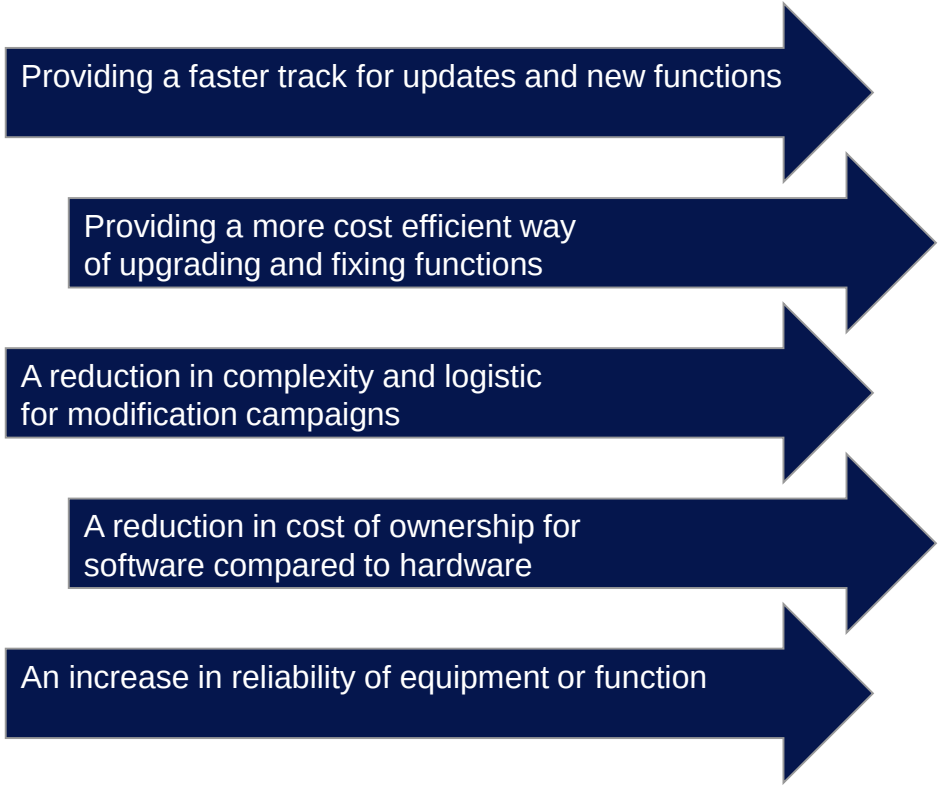
What was the vision when we entered into the migration of hardware to software



- All of those 5 reasons why to go for Software where believed and appreciated. But the result looks quite different today.
- The Airlines are very disappointed with the behavior of some suppliers.
- Our industry almost forgot to put regulations into place as they exist for hardware!

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How does the reality look today?

- Software problems are managed (by publications) and not fixed. Since no motivation other than reputation exists for the vendor. (no penalties)
- Corrections of Software are held back as long as possible in order to build blocks to save cost for certification for the vendor. But the airline is living for a long time with expensive or tiring workarounds.
- Software corrections are bundled with functional enhancements requiring extra price for a corrected Software. A clear separation of fix and update is impossible.
- New Software versions with new features are pushed out for commercial reasons with ever new bugs.
- Testing of Software happens in the field not at the vendor or airframe integrator. SB quality is low.
- We do not debate here the certification Level (per DO 178) or the criticality of function. But it would make the casual observer believe we are having higher and better standards of quality and maturity in aviation than in other industries. But this is clearly not the case. There are reasons for this but not everything can be explained or accepted for this. (Just look at your car's navigation device and compare with an FMS quality)
- We are familiar today to accept bad performance of Aviation Software and we believe it is normal not to get what we have purchased. But in essence we don't really know what we have purchased. There is simply a lack of commercial definition with the quality of Software Airplane Parts compared to Hardware Airplane Parts.
- There are no words today in an Product Support Documents like a PSAA or A-GTA (**A**ircraft **G**eneral **T**erms **A**greement) for Software Parts.
- This must change!

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What to do in order to improve the situation

- The biggest reason for our situation is: As Software came around to replace Hardware we forgot to develop or to transform the existing regulations and contractual requirements to fit for the purpose of Software Parts. In the Product Support Domain such items are treated in Product Support Agreements. No PSA exists today that relates to Software Quality definitions and service level agreements. You will find no single word on Software today.

- As the airframer protect us today from inadequate Product Support by individual Vendors with PSAAs, we need such protection also for Software parts. This becomes especially important if the airframer elects to disposition design responsibilities outside the company and/or elects to grant a single contract to one vendor for the lifetime of an A/C model.

- There is no definition of technical parameters that could be used to judge the reliability or quality of Software. Consequently those parameters must be defined. (This would be preferred as an industry standardization task)

- The aviation industry must establish working groups to define and agree on measurable parameters to define a level of reliability and quality for Software Airplane parts. (AEEC, AMC, IATA, A4A etc….)

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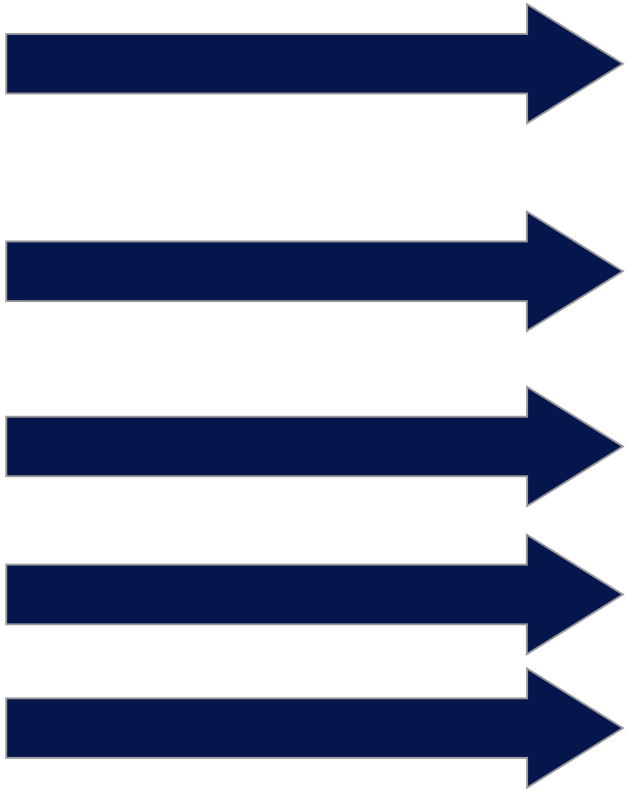
What parameters could this be?



- We can possibly learn from the IT Industry. There we find very well defined Service Level Agreements. We in Aviation have nothing close to this. There are tendencies in the IFE area to build such material and guidance. This must be continued and extended to other Aircraft Software parts. ITIL is an accepted Tool in other Industries.
- Monitors need to be included in the Software to provide vital parameters of a Software (e.g. rest counters etc.) Those exist on most equipment but are not made accessible to the user. So no consistent monitoring exists today. Interfaces to a maintenance device for regular reports need still to be defined.
- We need a categorization of disturbed functionality (e.g. economic impact, Pilot increased Workload, maintenance burden, etc.) and a measuring scale to judge the impact and the required commitment for fixing (e.g. need to be addressed in a revision in 3 Month, 6 Month, 12 Month etc.)
- We may need to measure the availability of a function (e.g. 95% or 99,5% availability when using the function)
- In order to provide motivation for fixes, penalties need to be defined for non-conforming SW in PSAs – or better a bonus for performing Software.

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History Summary

- Many people believe it is acceptable that we do not measure Software reliability, availability accuracy continuity etc. in the field.

- Many of us transform their private expectation for consumer electronic to aviation.

- Many of us believe Software Bugs are normal.

  But it is not normal. Software bugs must be reduced by process (ITIL) and contractual regulations (PSAs).

  Please fight against the resignations that poor quality is ok and cannot be measured or contracted against.

With the future development of Software dependency, we have to understand we must change the attitude.
Otherwise we will see an increasing impacts to:

- Safety
- Cost
- Comfort
- System/ Network Stability

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Five Root Causes for continuous issues with Software Quality

- **Lack of contractual Product Support coverage**
  a) Supplier PSAAs
  b) Integrator (Airframer) A-GTA
  c) Missing a right to repair for a missing or non-functioning Software
  d) Missing definition of max. lead time for corrections
  e) Missing definition of what is Software and how it is supported (pure SW Parts vs. Embedded Systems)
  f) Visible to the user is the function only. Regardless if Software, Hardware or a combination.
  g) Lack of definition of Software parameters (including Software Health Monitoring)
  h) No incentives for good performing Software (Bonus - Malus Scheme)

- **Inadequate rollout processes for Software (new or upgrades)**
  a) Too many bugs to start with (at a new A/C)
  b) Insufficient testing missing the real world's conditions
  c) No beta test in the field for updates
  d) Updates come with new bugs (new problems sometimes are more intrusive than previous Software version)
  e) Cascading effect of multiple Block point versions eats A/C use time (BP 17.0 / 17.1 / 17.1A etc. = 3 times full day)
  f) Multiple known problems well understood but combined effect not assessed

- **Lack of learning from IT industries**
  a) Unjustified proudness of airworthiness certification
  b) Certification has a meaning for Safety but no meaning for quality
  c) Aviation Industry ignores IT best practices of ITIL (Liberian for Lifecycle Software Support Tools)
  d) Believing we are different (or even better) in Aviation is wrong

- **Combining pure Bug Fixes with functional Upgrades**
  a) Keeps the operator without fixes for a long time, waiting for the huge update (Block Point)
  b) Makes the customer pay for bug fixes (Airframer waits until a chargeable new function is released)
  c) Reduces motivation for a timely fix and assigning resources. (solution sits in the drawer for years)
  d) Increasing A/C down time for huge updates if only a small tweak is needed.

- **Lack of Transparency**
  a) Problem reports kept secret by Airframer and Suppliers
  b) No defined starting point for a problem (consequently no measurement of time from first report to fix possible)
  c) No management of total count of problems (does it go down or up)
  d) No support for Software Health Monitoring in Aviation

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Airline Impact Categories for reduced Software Quality

Category
1. Line Maintenance workload
2. Engineering back office workload
3. Airplane turn time
4. Airplane use time
5. Flight Planning
6. Reduced mission capability
7. Pilot workload
8. Training
9. Cargo carriage impact
10. Cabin crew impact
11. Passenger impact

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ARINC Software Quality Metrics Committee Progress

Lufthansa Airlines
Reinhard Andreae (WG Chair)

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AEEC Software metrics working group – charter

APIM 16-001 calls for the development of software reliability metrics that will improve the performance of avionics software, i.e. software equivalent of MTBF or MTBUR. Two Step Approach (Phase 1 and 2)

- Goal: Define measurable parameters that can be used to improve the reliability and overall performance of avionics systems.

The term Software includes software used in all domains:

- Aircraft Control (AC),
- Airline Information Systems (AIS) and
- Passenger Information and Entertainment Systems (PIES) domains.

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AEEC Software metrics working group – contributors

Airlines	Airframers	Suppliers	Others
• Amercian • British • Etihad • Lufthansa • Swiss • TAP Portugal	• Airbus • Boeing	• GE Aviation • Honeywell • L3 / ACSS • Rockwell Collins • Thales	• Jeppesen • P3 Aero • LH Systems • LH Technik

- Three in-person meetings held (2017 to 2018)
- 4 Phone meetings held (2017)
- Not too much help from Airlines

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AEEC Software metrics working group – discussions

Discussion Topics

- **Scoping Statements and "Defining the Problem Space"**
  - What post-delivery in-service issues reported?
  - What is the impact? (e.g. aircraft dispatch, passenger service, etc.)
  - How can data be captured, normalized, and shared?
- **Handling of Reported Issues**
  - Classification of software-related errors
  - Defining metrics, parameters, and units of measurement (e.g. X per flight hour)
  - How to analyze data
  - Discussion of real Use Cases
- **Avionics Product Support Models**
  - Relates to potential extending ARINC Report 674 by ITIL Equivalent suggestions
- **Certification (e.g. DO 178 C)**
  - Out of scope

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AEEC Software metrics working group – the report

Summary Report Findings

- 31 Page Summary Report Published as AEEC Letter 18-037/SAI-053
- Document Overview:
  - I. Introduction
  - II. Defining the Problem Space
  - III. Research of Related Documents
  - IV. Criteria for Classifying Software Related Problems
  - V. Reporting Software Related Problems
  - VI. Proposed Measurement Techniques
  - VII. Opportunities for ARINC Standards
  - VIII. Discussed Use Cases and Related Presentations
  - IX. Open Issues and Clarifications

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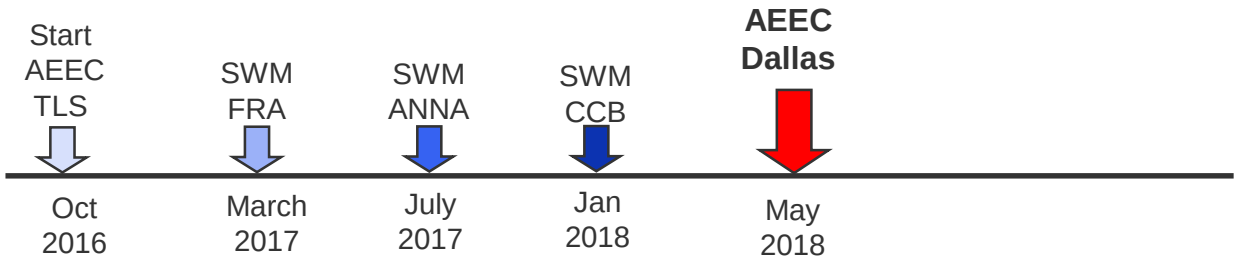
AEEC Software metrics working group – schedule



Ressources

				Total
Actual used	3	3	3	**9**
Planned	3	3	3	**9**

Summary Report Published March 1, 2018

Close APIM 16-001 for the time being

Future Work - No Plan at this Time

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AEEC Software metrics working group – achievements

Report published (biggest success)

- Mostly consensual between airframers and airlines
- Disconnects clearly spelled out

For the first time the problem space of Software Impact on Aviation is defined clearly and consensually

5 root causes for continuing dissatisfaction of airlines have been defined

Opportunities for measurement depicted

- Human based
- Machine based
- Ground based

Opportunities for standardization have been suggested

Position of the 3 main stakeholders of our industry defined

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Report published – biggest success

- For the first Time the problem Space was described in consensus between all Industry participants.
- The report lists opportunities for going forward
- APIM Phase 1 completed, Phase 2 postponed till ?
- Report can be downloaded here:

https://www.aviation-ia.com/products/summary-report-aeec-software-metrics-activity-2016-2018

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Opportunities for measurements

- **Human-Based** Measurements
- **Onboard Machine-Based** Measurements
  - **Self-Monitoring** by the Software Function Application)

Software Vital Signs (SVS) per function:

i. Number of expected and unexpected resets (per interval)
ii. Startup time (each case)
iii. Read write inabilities – memory access issues (each case)
iv. Out of memory events (each case)
v. No output data (each case)
vi. No input dada (each case)
vii. Output/Input data out of range (each case)
viii. Pointer stack overflow events
ix. Free to use error codes (1-2) (each case)

- **Ground-Based** Measurements
  i. Flight Operations Data Analysis (FODA)/ Flight Operations Quality Assurance (FOQA)
  ii. Aircraft condition monitoring function
  iii. Engine trend data
  iv. Data link traffic
  v. Post Flight Reports and others

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Opportunities for standardization

- **Free defined observations**
  a) Software faults per flight hour, Operational severity, Number of open Software issues per Aircraft type, Software problems introduced with new releases, Average software fix turn-around time (notice, time of notice, and time of fix)
  b) Report Formats (e.g. Figure 6-1 Example Reporting Hierarchy)
- **Format definition of Software Vital Signs (SVS)**
- **Open Formats** (adapted for aviation)
  a) As used in IT
  b) Onboard generated or at the ground converted
  c) Carbon: http://graphite.readthedocs.io/en/latest/feeding-carbon.html
  d) InfluxDB: https://docs.influxdata.com/influxdb/v1.3/write_protocols/line_protocol_tutorial/
- **Analysis tool**
  a) Graphite: http://graphite.readthedocs.io/en/latest/tools.html
  b) Grafana: https://grafana.com/ Grafana Demo: http://play.grafana.org/
- **Transparent Problem Database** (ATA Spec 2000)
- **Support Model** (e.g. ARINC Report 674: *Standard for Cost Effective Acquisition for Aircraft Lifecycle Support.)*
- **Log Files** (Activity at ARINC in planning)

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AEEC Software metrics working group – meaning for the industry

- The AEEC Initiative was a global endeavor to provide guidance on how to measure Software Quality. Those data may help one day to define Metrics to be used in the domain of Product Support Standards for Software.
- Boeing and Airbus were not very contributive in the working group. Consequently this initiative that was meant to help airframers was not too successful right now.
- Time needs to pass till the industry will pickup (e.g. Phase 2) to define Quality Metrics that will be used to measure and define Quality and Product Support requirements. Suppliers and airlines do clearly see the need and benefit of objective measurements of their success.
- Lufthansa helped to define what is needed but we alone cannot write those standards against the airframers and without the strong support of more airlines.
- The need for improvement stays open today.
- Knowledge of best practices exist in the IT Industry. (e.g. ITIL) we just need to pick those up and adapt them in the right dialect for aviation. Continuously not learning from other Industries would omit chances and be ignorant.
- Aviation needs a common standard for measuring Software Quality and needs to commit those in Product Support Agreements. **Without defining the rules of the game you cannot play the game fair!**
- Why is Boeing and Airbus fearing and fighting against transparency and measurability of their Software Products? Why don't they commit to something real in GTAs? A Minimum would be:
  1. **This product contains Software**
  2. **The Software will be supported over lifetime**
  3. **This is how the support works**
- Our working together spirit should be based on data and not on subjective opinions.

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About Software Quality in Aviation – regulator aspects

Safety, Quality, Efficency and Customer Satisfaction

DO 178C

Software Safety Certification

→ Meets requirements and specifications

Verification

OSED, ConOPS, OSA, etc

Operational Requirements

→ Fulfills its intended purpose

Validation

Verification + Validation ensures safety and operational usability

ITIL (may be adapted for Aviation)

Product Support Process

→ Fulfills User Expectations and supports a lifecycle cost optimization - **Cost-efficient use of Equipment**

Only all 3 components together ensure Quality and Customer Satisfaction

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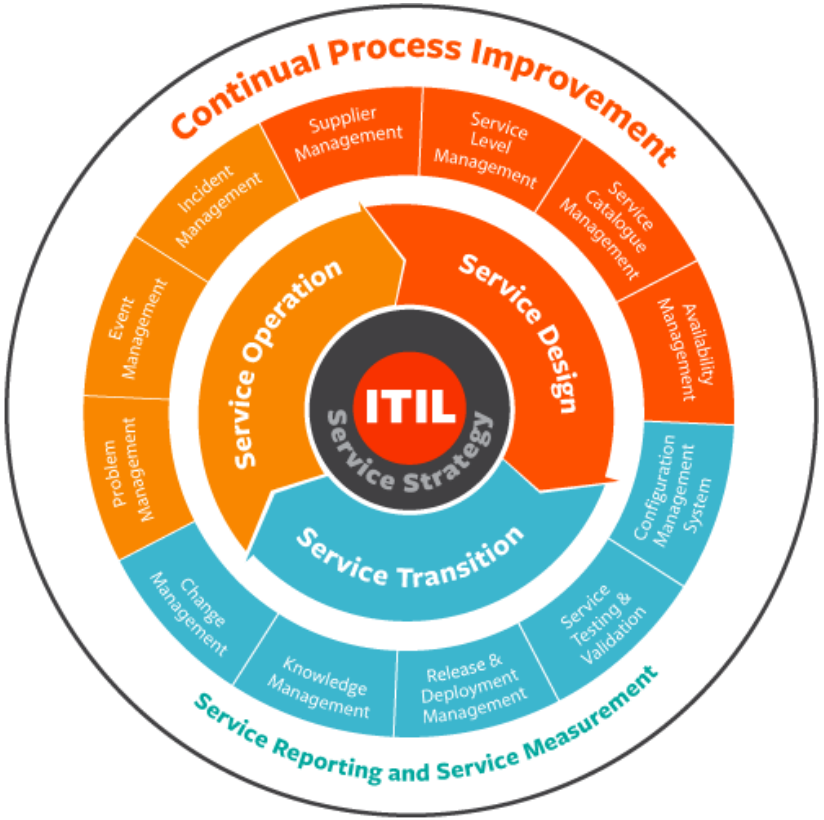
ITIL Process



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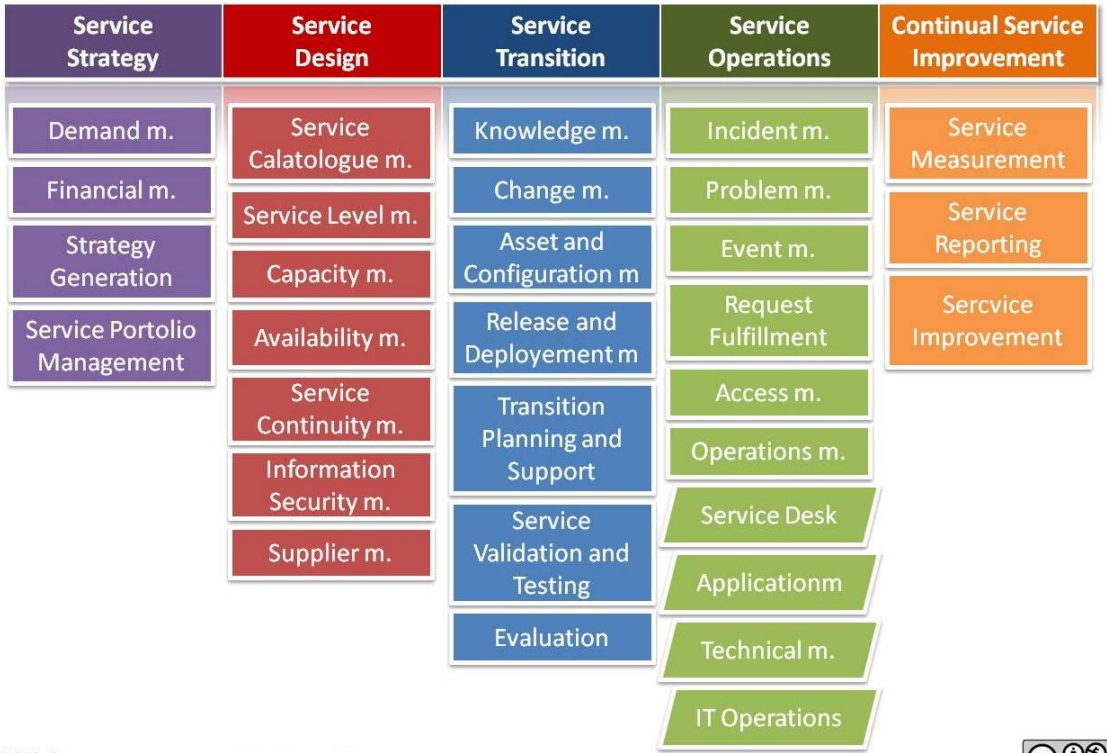
Opportunities in ITIL
Learning from the IT industry – the 5 books



ITIL V3 Structure | Péter Fehér | http://krpm.wordpress.com

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Tom deMarco: „You can‘t control what you can‘t measure“

Tom DeMarco (born 20 August 1940) is a well-known author, teacher, and speaker on software engineering topics. He was the 986 recipient of the Warnier Prize for "lifetime contribution to the field of computing," and the 1999 recipient of the Stevens Award for "contribution to the methods of software development".

Quotes:

- You can‘t control what you can‘t measure.
- The business of software building isn't really high-tech at all. It's most of all a business of talking to each other and writing things down. Those who were making major contributions to the field were more likely to be its best communicators than its best technicians.
- It's not what you don't know that kills you but what you know that isn't so.
- A day lost at the beginning of project hurts just as much as a day lost at the end.

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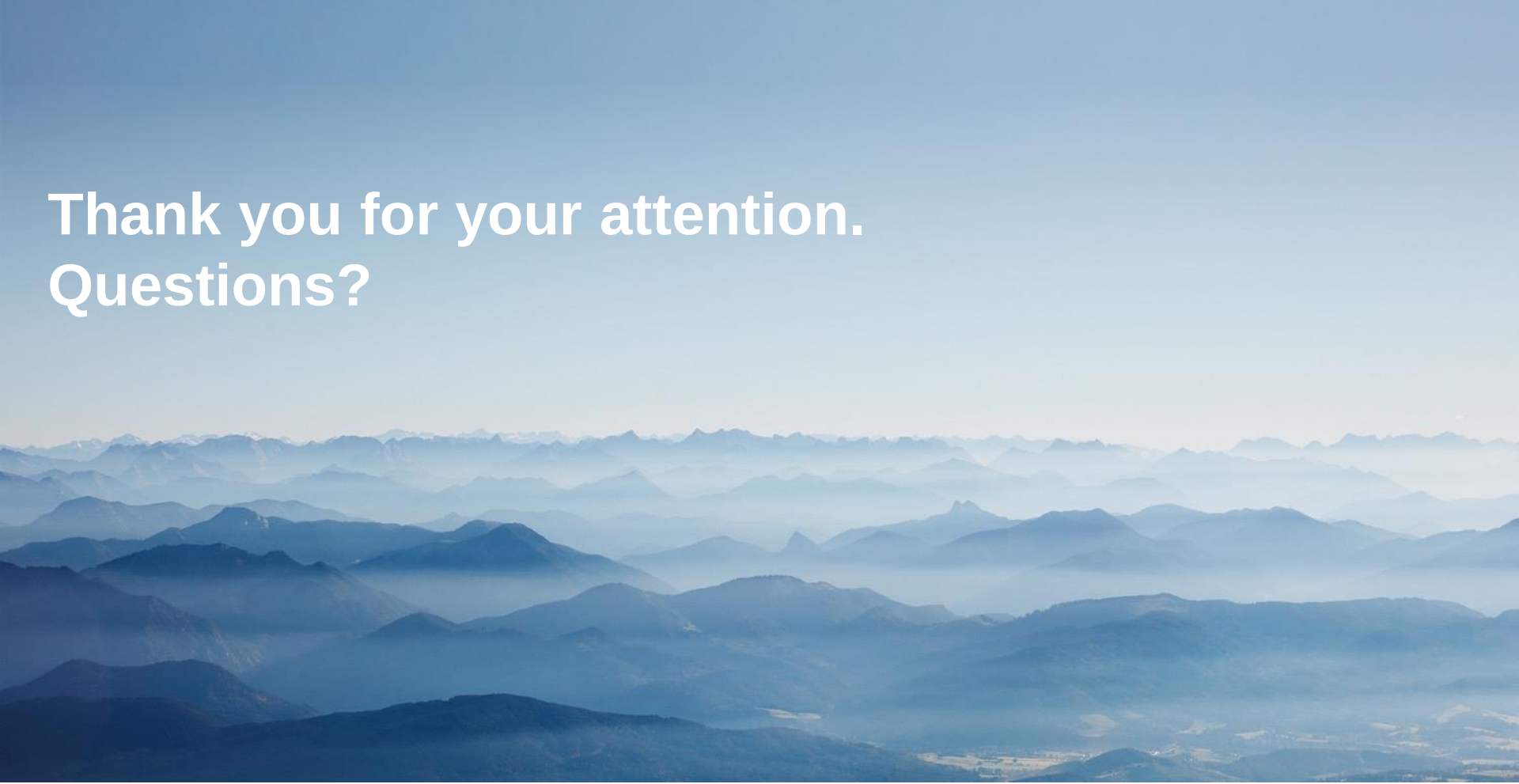

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