Life Tracking System Keeps RM12 and the JAS 39 Gripen Fighter Safely in the Air With a Reduced Cost of Operation

AVT-369 Research Symposium on Digital Twin Technology Development and Application for Tri Service Platforms and Systems

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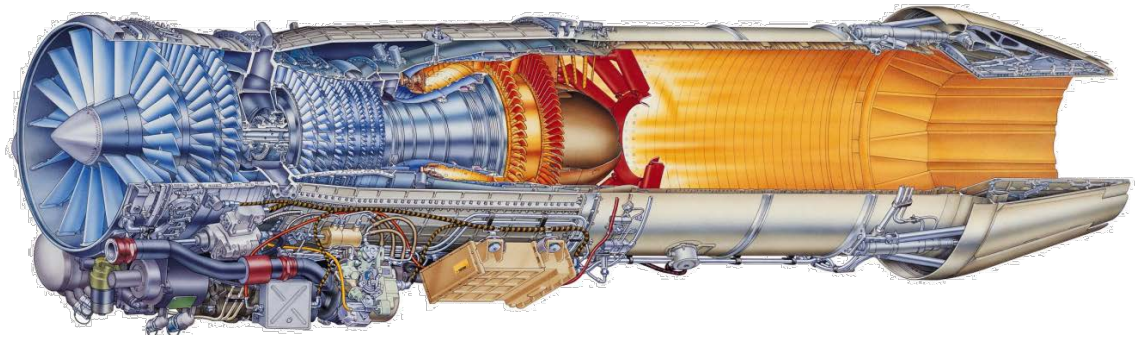
Topics

- Area of application
- Traditional Approach from Flight to Consumed Life
- Introducing the GKN Life Tracking System (LTS)
- The effect of using GKN Life Tracking System (LTS)
- The LTS system maturity as a “Digital Twin”
- Summary and conclusions

Area of appliction

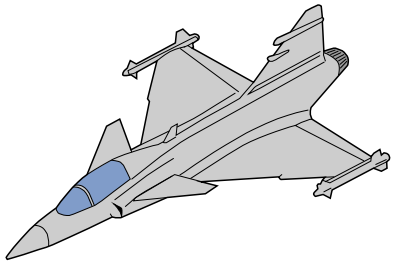
GKN RM12

- Low-bypass afterburning turbofan jet engine which is a derivative of the F404-GE-400 turbofan engine
- The F404 was originally developed for U.S. Navy's Boeing F/A-18 Hornet
- RM12 is a joint GE and GKN (formerly Volvo Aero Corporation) developed engine with special adaptations for a single engine installation
- RM12 powers the SAAB JAS39 Gripen Multi-Role Fighter, currently in service with the Air Forces of Sweden, the Czech Republic, Hungary, Thailand and South Africa.



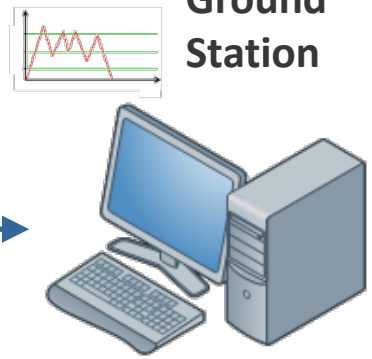
Traditional Approach from Flight to Consumed Life

GRIPEN Fighter



Time-resolved engine parameters logged in A/C

Ground Station



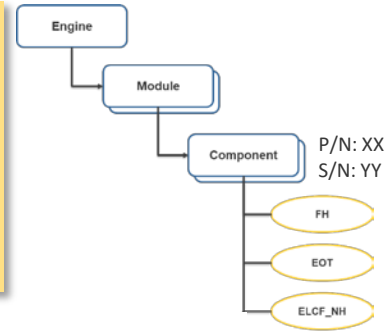
Calculated parameters

Flight hours
Cycles …

Maintenance System

Accumulated consumption on component level
- ***Flight hours***
- ***No of cycles***
- ***Etc.***

Life limits



Traditional Approach from Flight to Consumed Life

Pre-conditions

- GKN RM12 Life Management Program have modeled failure modes, performed stress analysis and life analysis based upon an intended use of the system (predefined distributions between information/strike/air defence missions)
- Safety factors needs to be applied to the life limits in order to take care of uncertainties in the analysis chain, one of the biggest uncertainties is the variation of loads (mechanical & thermal)

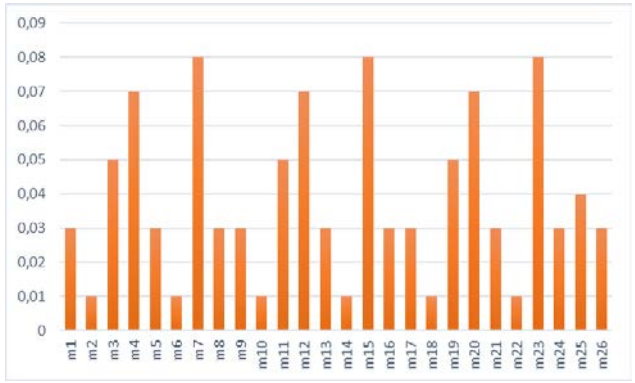
Challenges

- Only utilizing few of the recorded engine related parameters in the life consumption calculation
- Formula for calculating cycle consumption (damage factors) are based upon intended use, if the engines are not used according to the mission mix the life tracking of the parts will not be accurate

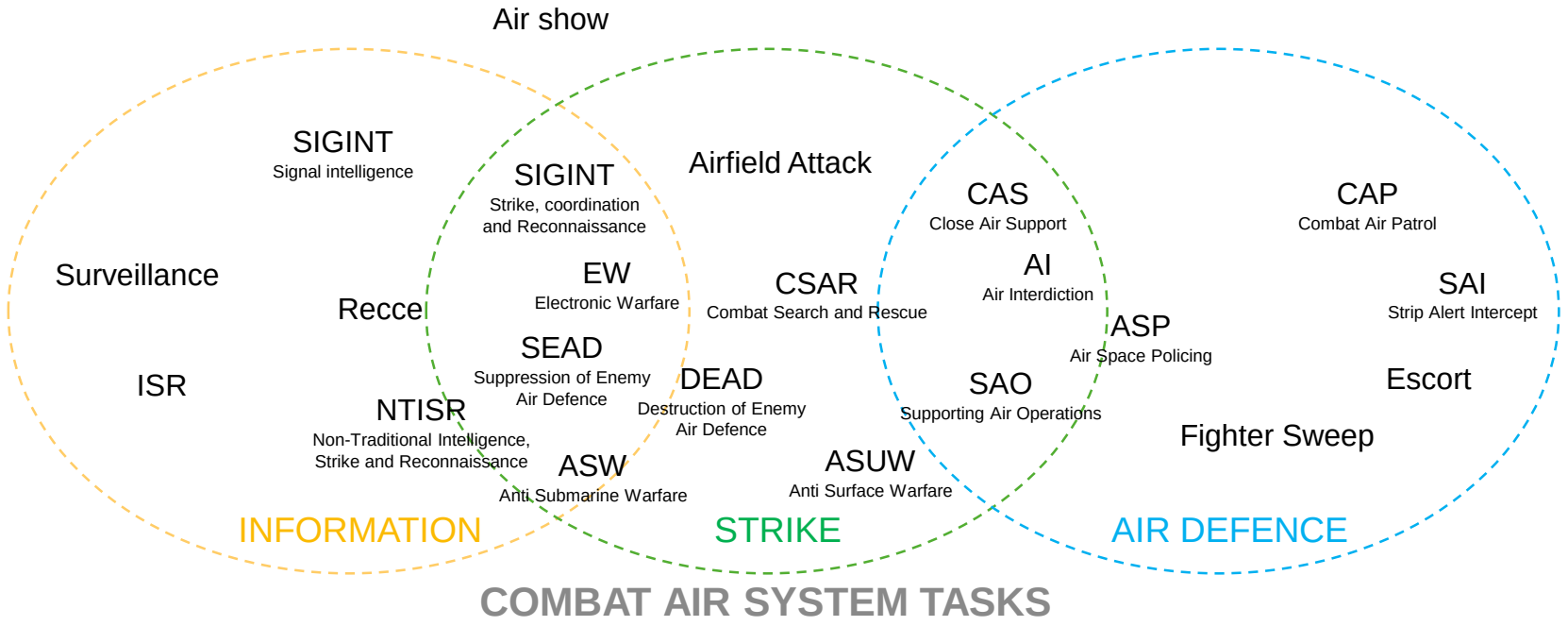
Traditional Approach
Complex environment with multiple mission types

Many different types of missions which can be performed

> Actual utilization of engines on an individual basis, especially for a military application, deviates from this pre-defined mission mix as a rule rather than the exception.



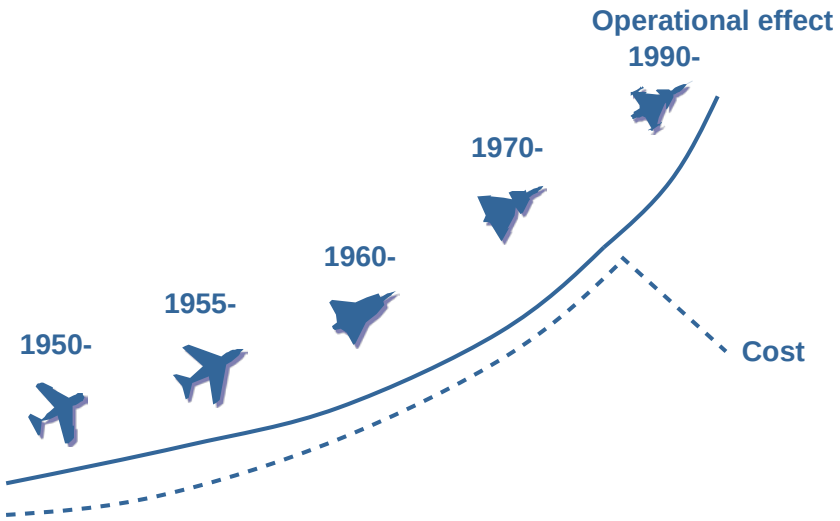
Illustrative picture, distribution between different mission types in the pre-defined mission mix

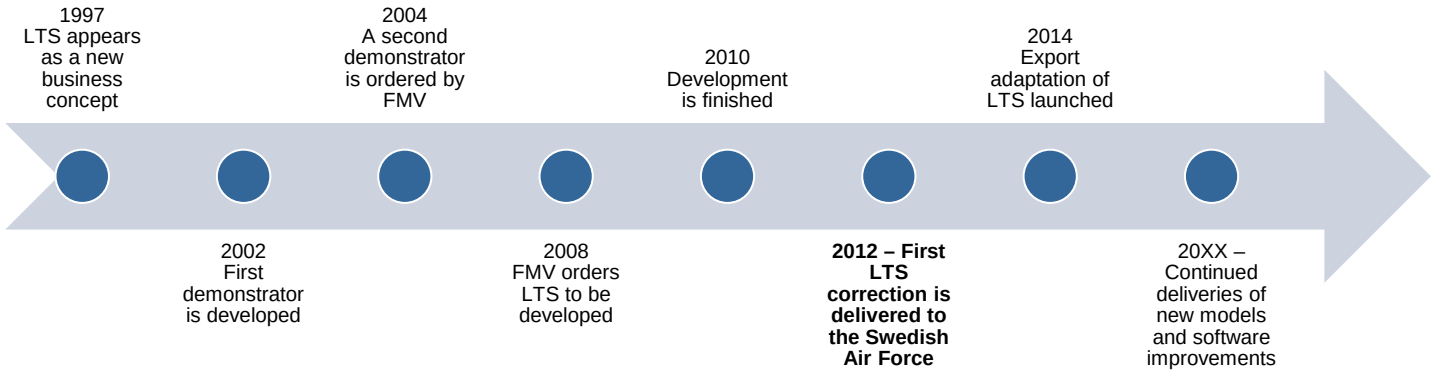


Introducing the GKN Life Tracking System (LTS)

Historical background

- Concept founded in the late 90:s
- Idea → thesis works → demonstrators → development → implementation → operation
  - a 15 year journey!
- Focusing on long time value of a customer relationship rather than individual transactions

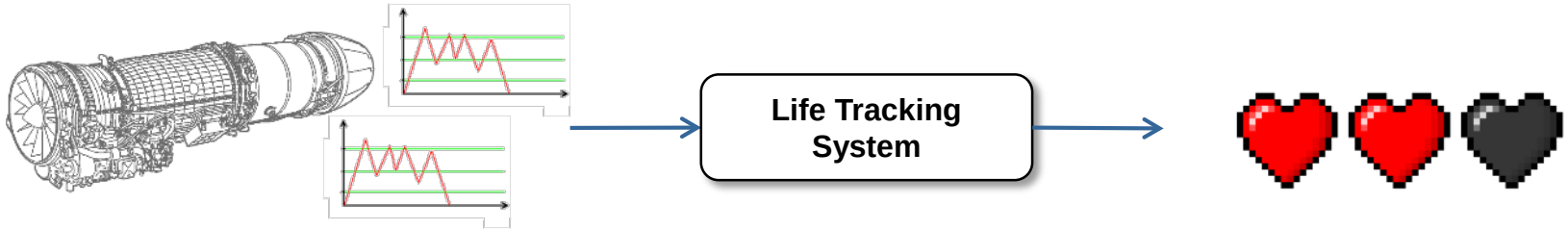




Introducing the GKN Life Tracking System (LTS)

This is LTS:

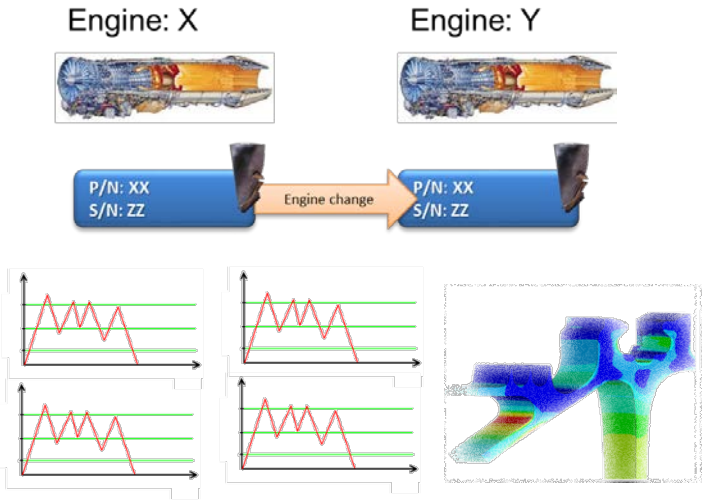
- LTS is a GKN in-house developed software for accurately tracking life consumptions for life limited parts
- LTS uses on-board logged time resolved engine data and extends the information with model based information
- LTS uses analysis models, which are developed by the GKN RM12 Life Management Program
- By using LTS the life consumption predictions will be accurate regardless of how the product/engines are used (i.e. independent of mission profile/mix)
- LTS is since 2012 in production for the RM12 engine which powers the GRIPEN fighter
- LTS enables safe and economical pooling of spare parts between operators with different operation profiles



Introducing the GKN Life Tracking System (LTS)

Necessary input/pre-conditions for LTS

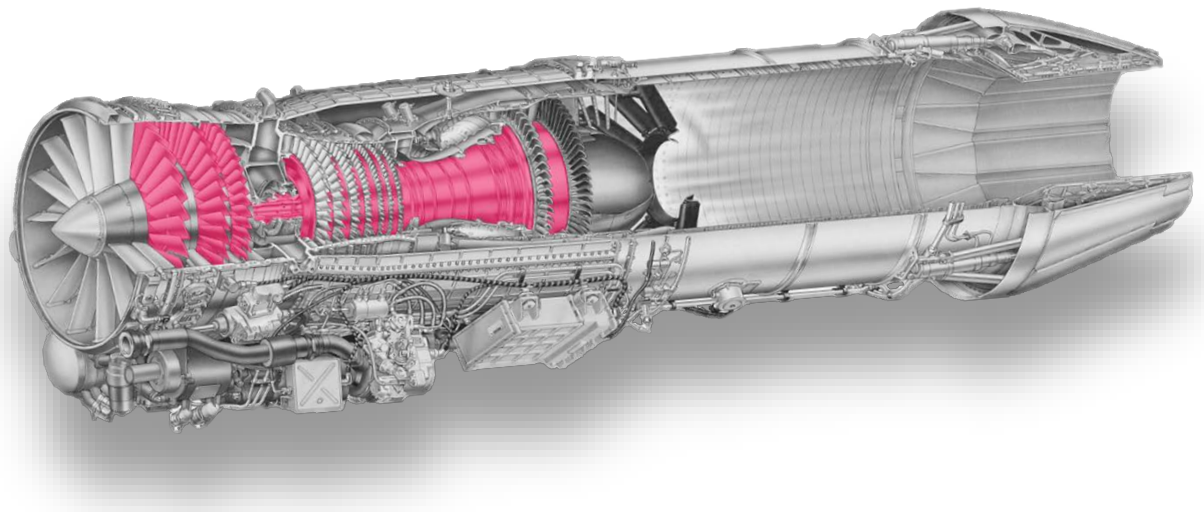
- Access to registered load data files (missions/engine files)
- Access to data from engine/product models
  - In order to supplement the measured information from the engines with additional model based information
- Access to valid (accurate and approved) life analysis models
- Access to historical and present engine configuration
  - For matching components/individuals with performed missions



Introducing the GKN Life Tracking System (LTS)

Parts that LTS is monitoring

- LTS is used for the most critical parts of the engine constituting >60% of spare part costs and 70% of labor costs.
- There are currently 140 rotating life limited parts enabled for LTS (additional are evaluated):
  - Fan
  - Compressor
  - Low pressure turbine
  - High pressure turbine
- Potential to include additional parts
  - Rotating
  - Static



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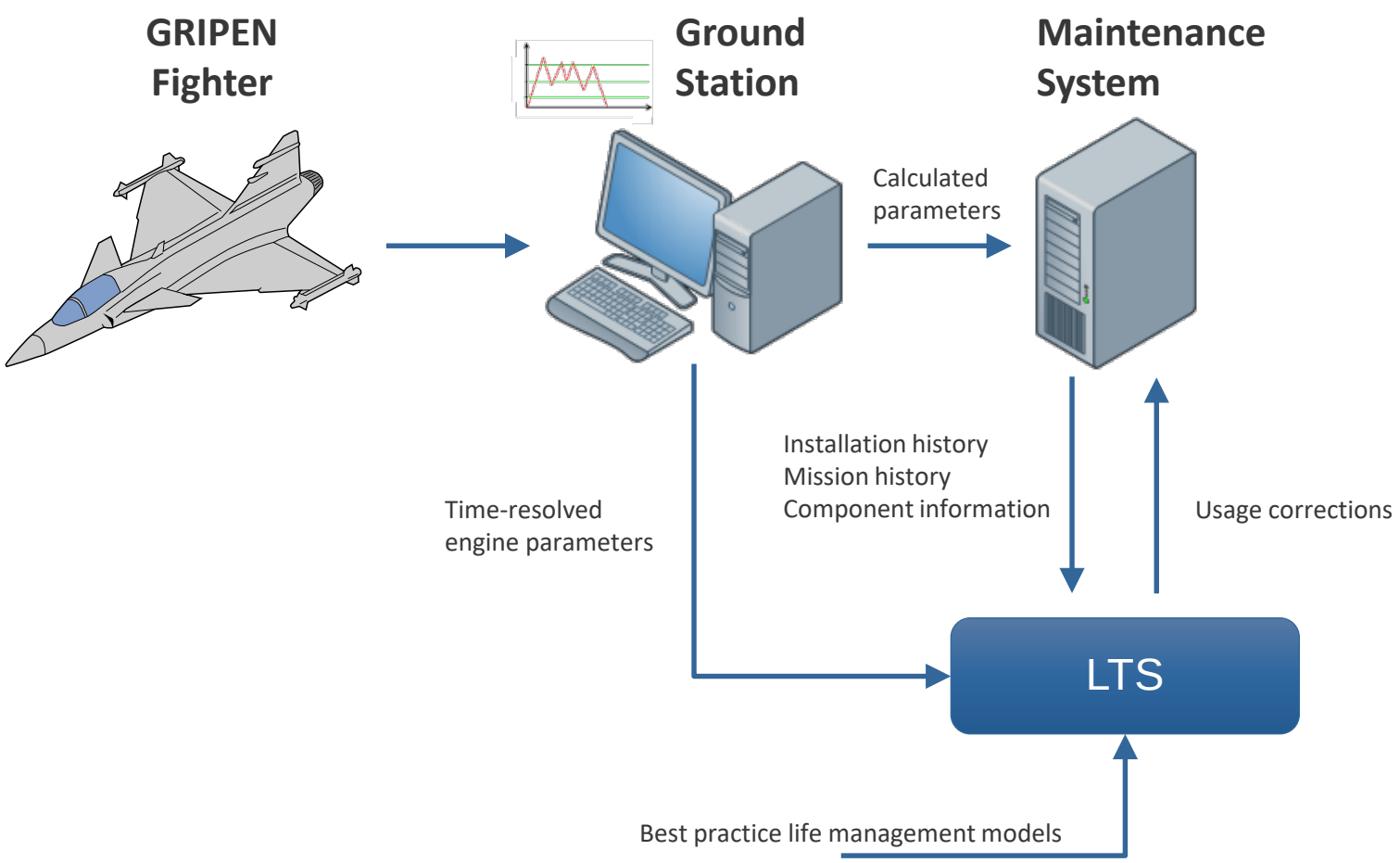

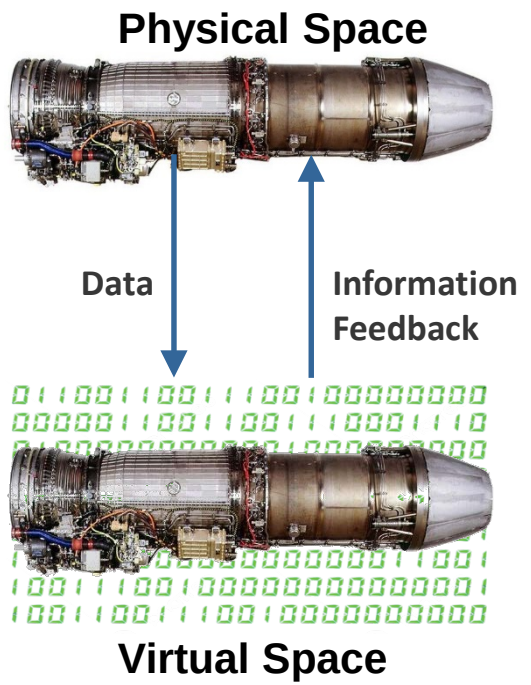

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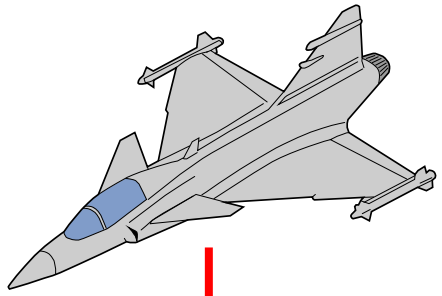

Ground Station

Pre-processing

Customer Maintenance Systems

Organize and administer results

Life Calculations

Life Tracking System

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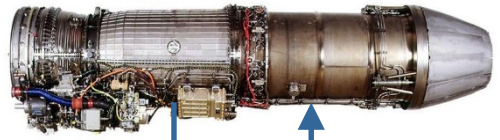
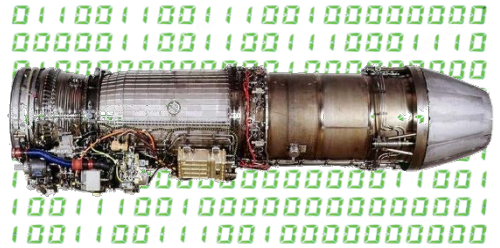
Physical Space



Data

Information Feedback

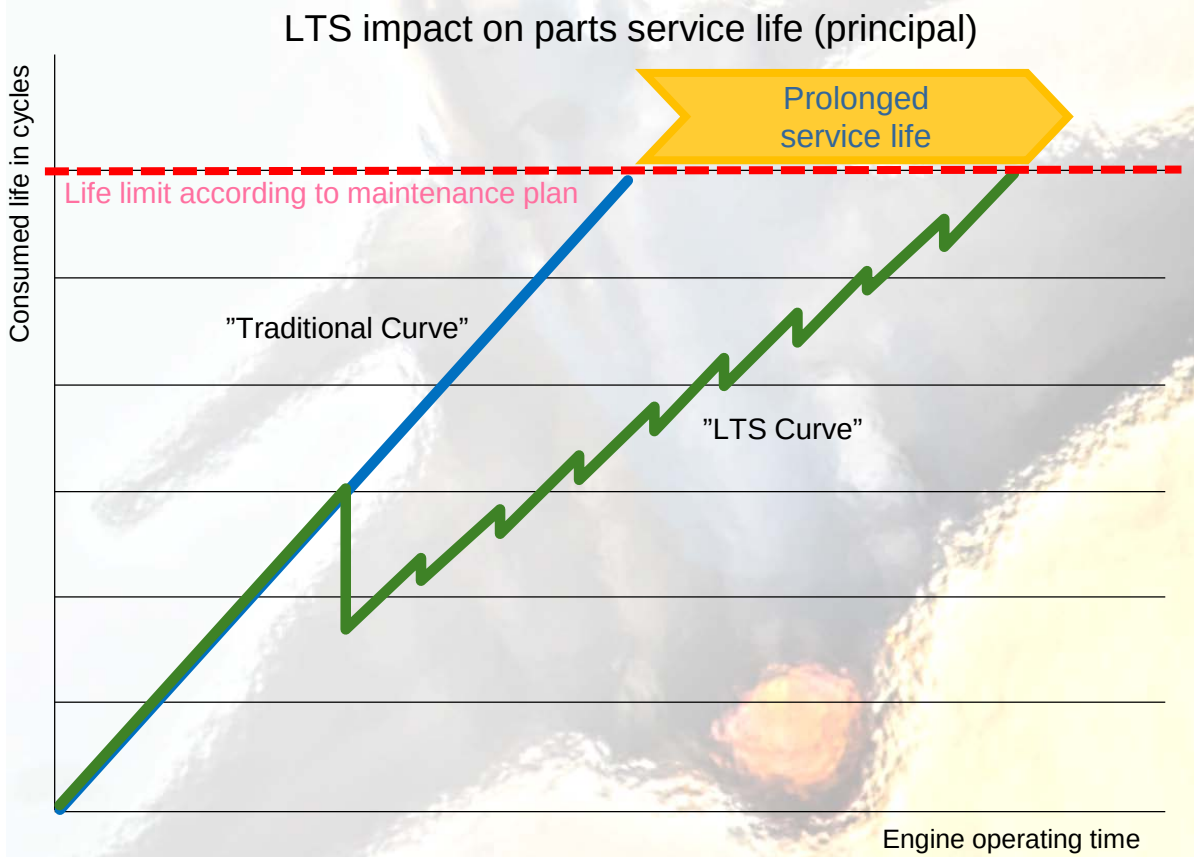


Virtual Space

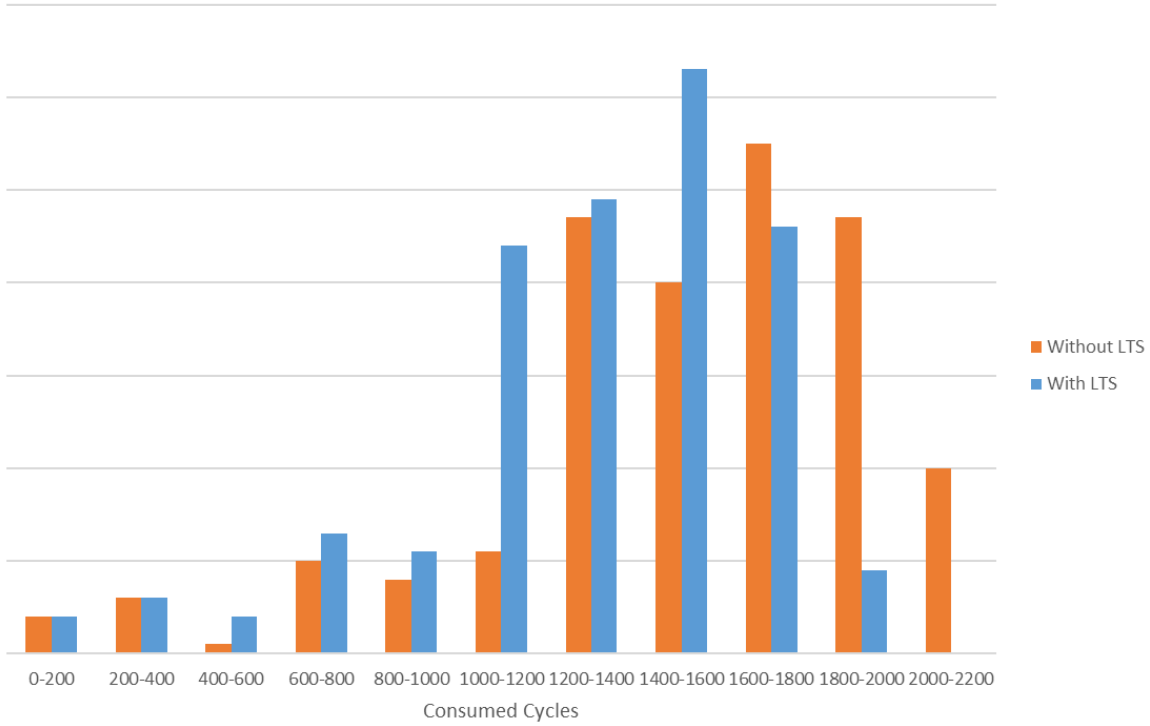
The effect of using GKN Life Tracking System (LTS)

Benefits

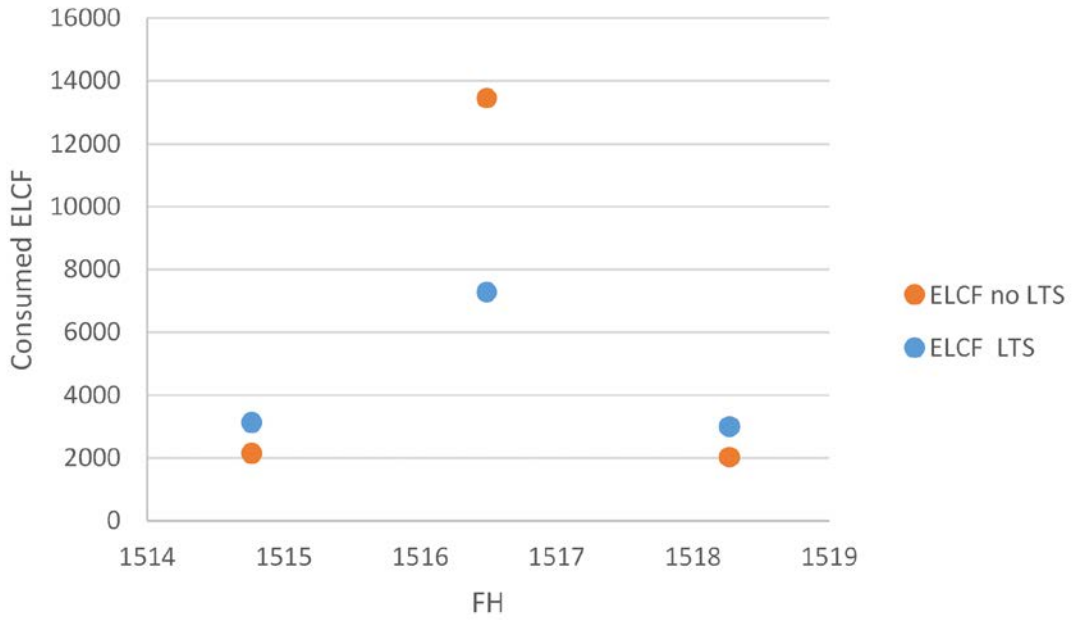
- Increase the flight safety by knowing the real utilization of life limited parts and their residual life
- Increase availability by enabling an increased utilization of life limited parts
- Achieve a Lower Life Cycle Cost (LCC) by less spare parts exchange over the life cycle
- Accurate life tracking despite deviations in actual operation compared to ideal mission profiles/mix



The effect of using GKN Life Tracking System (LTS)



Actual example for one RM12 component where the number of consumed ELCF cycles are illustrated with and without LTS Corrections applied.
Y-axis masked, but contains number of components in specified ELCF-interval

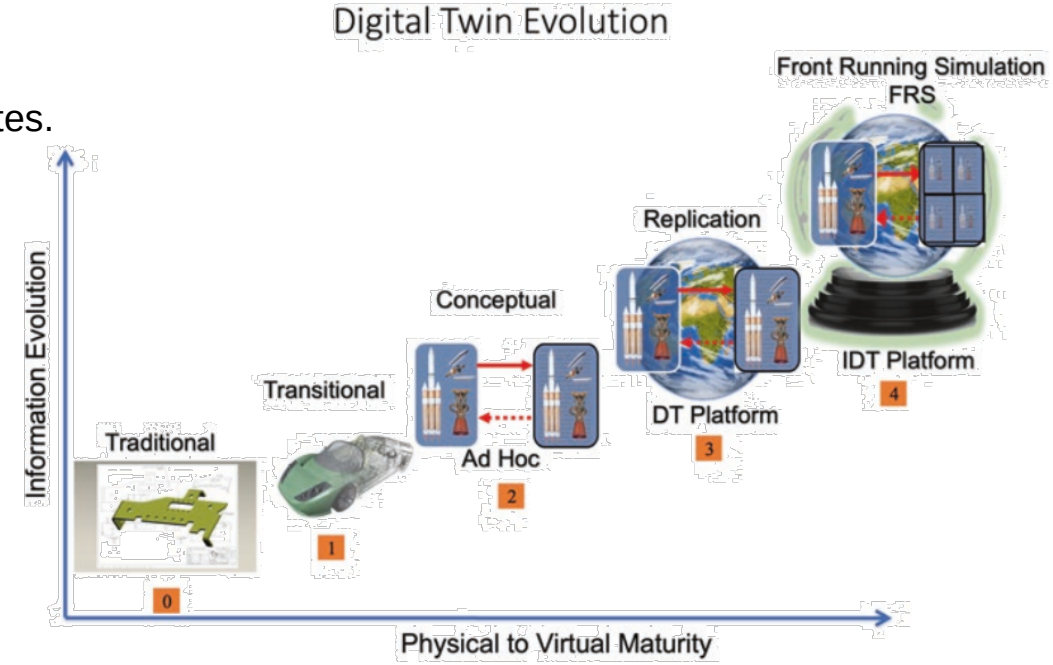


Actual example for one RM12 component where the number of consumed ELCF cycles are illustrated. In this case LTS both reduces the consumption for one component and increases the consumption for two other, this due to how the engines have been used

The LTS system maturity as a “Digital Twin”

When assessing the LTS maturity as a Digital Twin we have used Dr. Michael W. Grieves phases for Digital Twin Evolution

- Phase 0 – **Traditional**: paper/blue-print based, 2D CAD, “no” digital representation of the object/system
- Phase 1 – **Transitional**: moving into the virtual world, 3D models, DMUs, simulate and analyze object behaviors without super computers
- Phase 2 – **Conceptual**: entity created from disparate/fragmented data sources, conceptual models where we try to determine if the models can replicate past/current reality and predict future states. Goal to define useful aspects and refine the models.
- Phase 3 – **Replication**: technological platform established, repositories for information where requisite information is pulled together by the platform. Access to as-build products and data from its in use. Possible to aggregate data from multiple products and turn it into information.
- Phase 4 – **Front running**: predicting the future with the use of “intelligent digital twins” and front running simulations simulating the future, predicting potential system states using data from all products and provides probabilities on its predictions

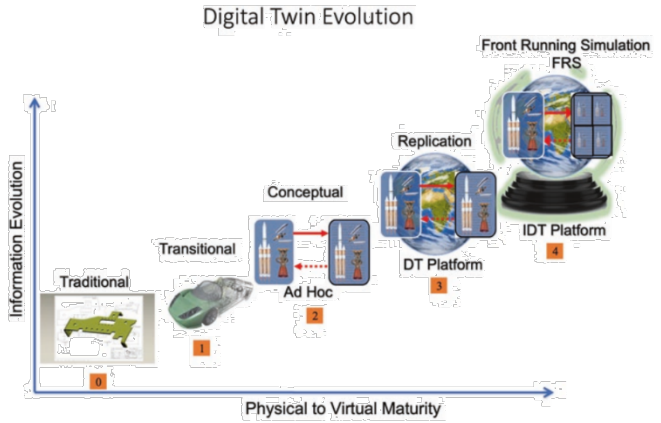


Source: (Grieves M., 2023)

The LTS system maturity as a “Digital Twin”

When assessing LTS maturity as a Digital Twin we have used Dr. Michael W. Grieves phases for Digital Twin Evolution (Grieves M., 2023)

- So where does this place the LTS-Tool in terms of maturity?
  - The tool is constantly (in our use case by a pre-defined cadence agreed with our customer) tracking and making adjustments on individual parts in individual engines
  - LTS provides an automatic platform that collects all necessary data for the analysis via data transfers
  - By collecting the data of the products as it is in use LTS can replace wasted physical resources
    - **Hence absolutely capturing the essence of phase 3 definition**
  - The cadence of LTS interaction with the customers is not constant/online all the time, the current cadence of interaction has been balanced in order to create customer value
  - LTS is constantly looking at the vast amount of data it has access to and provides information that it perceives that the user needs to know about at defined times
  - LTS could be feed with assumed missions, this is however not currently done
    - **Hence fulfils portions of phase 4 definition**

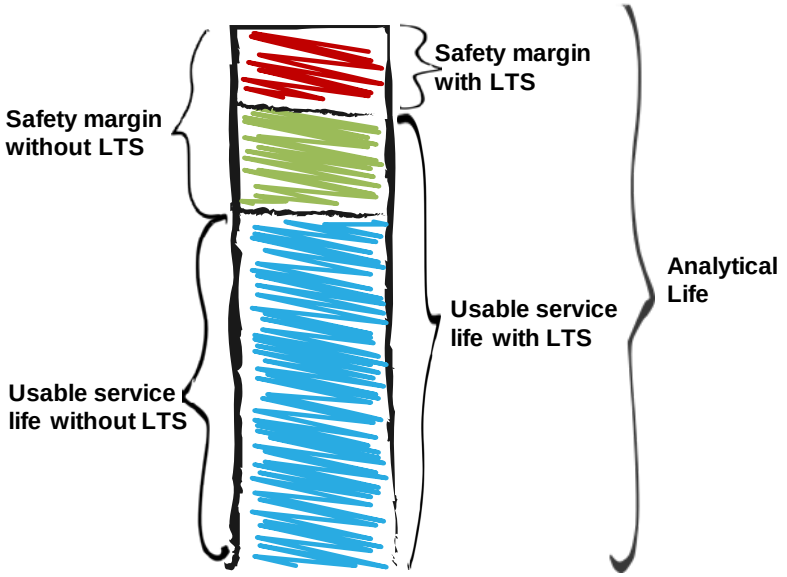


Source: (Grieves M., 2023)

*DTI = Digital Twin Instance **DTA = Digital Twin Aggregate ***DTP = Digital Twin Prototype

Summary and conclusions

- LTS is a system developed for tracking actual life consumptions for individual components based upon data from every single flown mission
- LTS provides
  - better operational flexibility
  - increases flight safety
  - decreases operating cost for the RM12 operators
- Enhanced life tracking with the possibility to use best available life calculation models, which also can be applied retroactively on historical missions
- LTS has been in operation for over 10 years
- Based upon Grieves framework for digital twins maturity (Grieves M., 2023), LTS is at a phase three to four depending on interpretation
- Enablers for a digital twin, such as LTS, are:
  - access to data
  - high quality of data over time
  - close collaboration and trust between partners
  - constant evolvement in order to make better digital replications possible
  - method development for optimizing computation times



Acknowledgements

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Questions?

Works cited

Grieves, M. (2023). Digital Twins: Past, Present, and Future. In N. D. Crespi, *The Digital Twin* (pp. 97-121). Springer Nature Switzerland AG.