designing line replaceable units from the maintainability perspective

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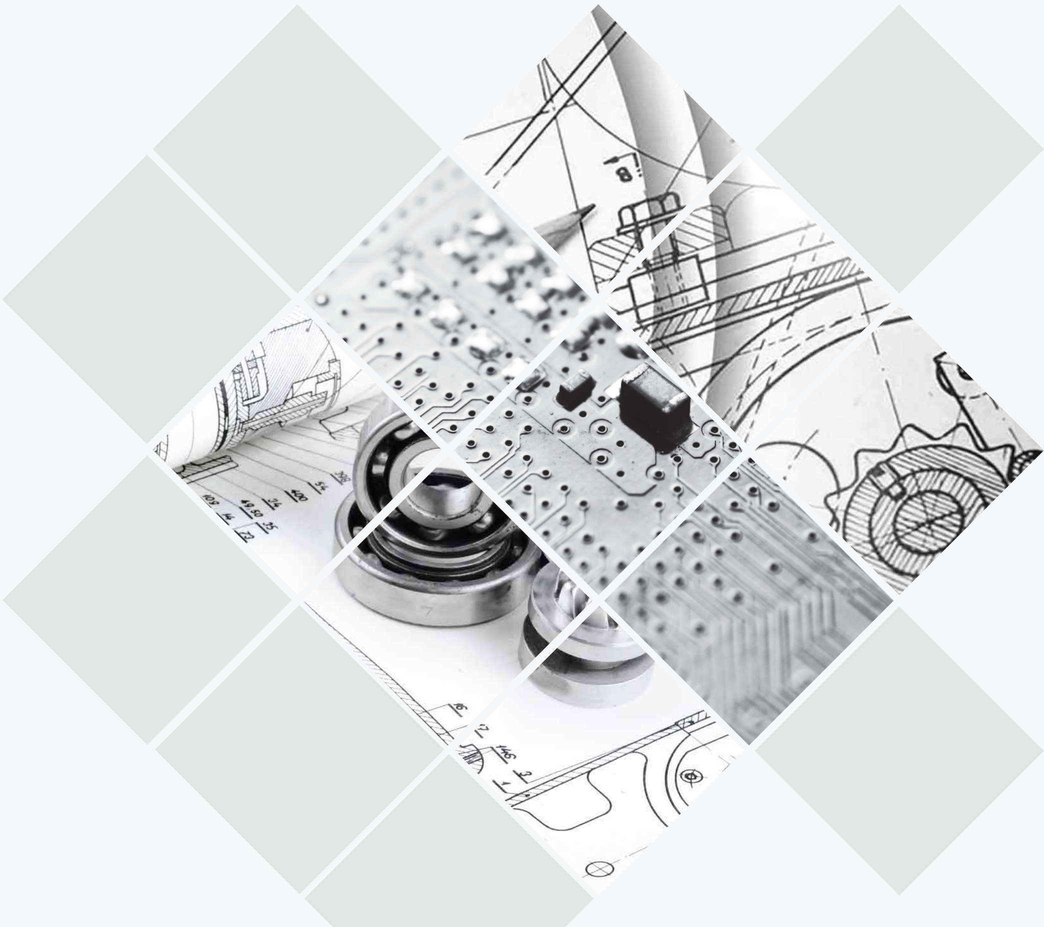

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Abstract

Maintainability assessment of an engine or unit helps in identifying and validating whether or not the actual design of an engine or unit meets the maintainability characteristics (for example, ease of accessibility, the maximum time for replacement, health monitoring, interfaces, and so on).

Maintainability assessment is an important requirement while designing an aircraft engine because it determines whether Line Replaceable Units (LRUs) can be accessed for replacement or periodic inspection or on-wing adjustments. In the past, its study has been largely manual and labor intensive. Whether it is by physical prototyping or by using real human subjects, the process relies on the accuracy of human intervention to reach the engine parts.

This white paper helps to understand the maintainability of the overall aircraft engine and systems engineering efforts. The paper describes the relationship between the maintainability and design process, presents the approach to understanding the maintainability of LRUs during the design phase, explains the associated tasks and activities, and proposes an alternate method to assess the maintenance tasks and activities.

Need for Optimal Maintenance of Line Replaceable Units

Optimal maintenance of Line Replaceable Units (LRUs) is required to achieve the following objectives:

- Minimize spare parts inventory
- Increase the engine's availability reducing downtime
- Reduce operating and maintenance costs

Detecting maintainability issues early in the design cycle provides an opportunity to address the issues during the design phase, simplifies troubleshooting, and enables an easier set up. By applying human factors engineering to the equipment maintenance, the time and effort required to perform the scheduled (periodic or preventive) maintenance, as well as the unscheduled maintenance, can be significantly minimized.

Designing for Optimal Maintenance - Benefits

Precise information for the equipment design from the maintenance program's perspective gives the following benefits to the equipment manufacturers:

- Reduction of human errors during maintenance
- Minimization of the number of accidents and injuries due to human errors
- Usage of the correct support facilities and equipment at operational facilities
- Proper guidance for maintenance support and procedures
- Robust and cost-effective maintenance programs
- Deleting nonessential maintenance
- Reduction in the maintenance frequency and failure intervention

About Line Replaceable Units

In developing an aircraft engine, certain parts need to be replaced based on the scheduled or unscheduled maintenance requirements. For example, the fuel pump, the oil pump, and the fuel regulatory control unit in an aircraft engine need to be replaced after the completion of TBO (time between overhaul); the fuel, oil, air filters, or drains need to be removed for periodic maintenance (for cleaning), and the electrical harness, the thermocouples, and the junction box need to be accessed for periodic checks (for testing). To reduce the amount of time taken for the maintenance service, adequate access paths to these parts are preferred. In designing such a unit, it is essential to ensure that enough room is kept for an LRU for safe and convenient access.

After an engine is designed, the maintenance engineers need to go through a maintainability study process to ensure that there is a clear access path for the LRU. Traditionally, prototypes or human subjects are employed for the engine or unit being designed, and this is an expensive and time-consuming process. In addition, it is difficult to accurately capture an LRU's movement, which affects its access holistically.

The trend is veering towards using virtual animation. With animation, a removal path can be systematically documented and can also be used to constrain possible future design modifications.

Aircraft Engine Maintenance - Scope

The LRUs could be fuel, oil, air system accessories, electrical units, sub-assemblies, modules, and so on. The maintenance assessment uses the design details that are available in the engine Digital Mock Up (DMU) accessing through the Team Center and Product Lifecycle Management.

The scope involves maintainability assessments of different LRUs of the engine during the design stage using application tools such as Vis-Mock Up and Unigraphics, with the introduction of the human and tooling interface in a virtual environment.

Typically, maintenance assessments:

- Assess the accessibility of a unit on an engine
- Evaluate the accessibility of tools to reach the relevant fastener locations
- Study the effect on the interface components
- Define a robust procedure for the removal, inspection, and replacement of parts
- Determine the time involved to carry out a maintenance procedure
- Highlight the issues (for example, clashing of tools, accessibility issues, and so on) in the maintainability of a unit. (The design team takes cognizance of these and makes recommendations to overcome those challenges.)

The assessment of the maintainability of an engineering product during the initial design phase, and the incorporation of these recommendations into the product, is a parallel engineering process. By addressing the issues identified and validated in a virtual environment, benefits in the significant reduction of lead times, identification of delays, and the detection of problem areas are realized.

Line Replaceable Units Maintenance - Challenges

LRUs are usually driven by constraints imposed during the engine design phase. Results from such constraints indicate that the engines and their parts have a major impact on industrial applications.

Constraints of Traditional Methods and Processes

Traditionally, physical prototyping and human subjects have been used to understand and validate product performance, maintainability, fit, and safety. However, these are not cost effective and often result in product redesign. In some cases, when the LRU is part of a high level assembly, it can severely impact the development lead time of the engine and the aircraft.

Primary challenges – To understand the maintainability (removal, inspection, and replacement) procedure of a unit, as well as check the ease of maintainability of a unit.

Peripheral challenges – To adopt a concurrent design approach involving the key stakeholders from design and modeling by validating constraints of removal and assembly requirements. The complete task is to be assessed by understanding the maintenance personnel workflow and the constraints.

Project Management

Team Center - The DMU was continually updated through the Team Center. Design changes from the various work-sharing partners were incorporated into the existing engine design, and the work was expected to be carried out in this dynamic environment. The risk of not resolving the maintainability issues during the design phase meant that maintainability issues could potentially arise during the build.

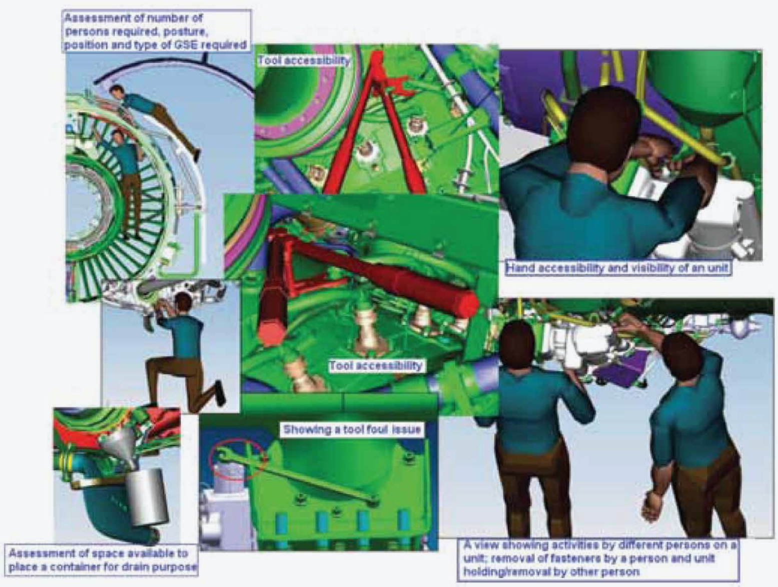
A human and tool interface in a virtual environment overcomes the challenges faced in traditional methods, and this can help not only reduce the turnaround time for checking the maintainability of a product, but can also provide more accurate feedback to the designers on the potential maintenance problems.

Maintenance of Line Replacement Units - The Virtual Assessment Process

The task involved performing maintainability assessments (removal, inspection, and assembly) of different LRUs on an engine, as part of the aircraft maintenance process. The assessment was carried out to show that the maintenance activity on LRUs is achievable within the aircraft maintenance activity, and to highlight issues, if any, in carrying out maintenance activities by using the Vis-Mock Up and Unigraphics applications so that the issues could be addressed during the design phase.

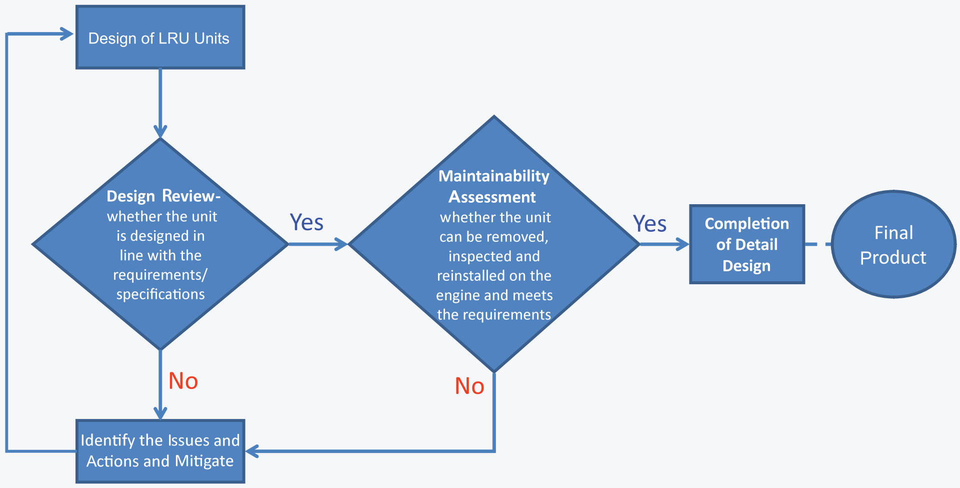
Maintenance assessments include:

- Evaluating the accessibility of a unit, including identifying the part labels and marking the visibility
- Calculating the number of personnel required to carry out a maintenance activity and the type of GSE (ground support equipment) required to reach the units while they are working on the engine
- Reviewing the accessibility of filters and drains in the unit
- Assessing the space available to place the containers to collect the drain fluid, as required
- Assessing the accessibility by hand for the removal or installation of the unit
- Appraising accessibility by hand for the removal or installation of fasteners
- Gauging the access to lock out or disconnect features
- Assessing the tooling access for the removal/ installation of fasteners (bolts, nuts, unions, and so on)
- Measuring the time involved in the removal or installation of a unit
- Assessing human factors (arm's reach, weight lifting limits, body position, and access)
- Documenting the procedure for the removal or installation of a unit
- Defining the zones required for the units' removal or installation, so that other interfacing or neighboring hardware will be limited to extend into this zone during the design activity
- Completing an assessment of the task to be carried out from a mechanic's viewpoint to demonstrate that each step of the task is achievable



Virtual Maintenance Study - Assessment Results

By this assessment, it was possible to identify critical issues within the units, from a maintenance perspective, during the initial phase of the design itself. The following block diagram is representative of the typical workflow.



The redesign of such units was done by addressing the specific issues. During the assessment, on the LRUs, the issues such as no provision of drain point, no clear hand and tool access for removal or installation of the unit, missing the complementary design change on the mating part of an LRU associated with its design change, and so on were identified and they could be subsequently addressed during the redesign process. If the issues were detected and identified during the later phases of the design stage (for instance, during the validation with the physical hardware after the unit had manufactured it) it would have necessitated major rework and the redefinition of the units; and it would have affected the complete product development program in terms of the additional costs and time.

Keeping the importance of this assessment in mind, customers are making the maintainability check a part of their design review checklist, and have made it mandatory to get acceptance, validation, and sign-off from the maintainability assessment process before a new definition is approved for manufacturing.

Conclusion

In the past, physical prototyping and human subjects have been used to understand and validate the product's maintainability. However, none existed to validate its maintainability aspect using the digital representation of the original product. This modern approach of a virtual maintainability study to assess the LRU from the maintainability perspective is the most reliable method to validate an engine design to reduce maintenance efforts and costs.

Author Profile

Pradeep Kumar

Pradeep Kumar specializes in aerospace engine design, manufacture, assembly, repairs and fault analysis, and troubleshooting.

Pradeep has received a Bachelor of Technology degree from the Regional Engineering College (REC), Warangal (Andhra Pradesh), in 1996 with distinction.

He has worked for 10 years at Hindustan Aeronautics Limited (HAL) in the Aerospace Engine division, Bangalore. His profile comprises managerial responsibilities in the manufacturing, assembly and investigations of the various aerospace engines such as Adour, Pegasus, and Artouste engines.

Pradeep has been working at QuEST for the last 6 years.

Pradeep has many achievements to his name, such as:

- Author of as many as 400 technical reports
- Customer Satisfaction Champion at QuEST Global (2008-2009), for receiving consistent appreciation from the customer
- Best Officer, Engine Division, HAL (2004) for standing high with good results in all the tasks assigned
- Certificate in Management Development Programme from IBAC (International Business Awareness Course) in 2000, conducted by Rolls-Royce
- Certificate in Management, HAL Management Academy (1997)
- Certificate in Integrated Materials Management from Indian Institute of Materials Management, Bangalore
- Approved technical reviewer for the design work packages at QuEST

At QuEST, his role includes:

- Supporting Rolls-Royce in the component design and system engineering of aerospace engines from the problem analysis to finalization of the solution
- Supporting the various work packages that include cost reduction and weight optimization
- Supporting the competency development of design teams in organizing training programs

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Calvin C. Varkey specializes in aerospace engine installation design and detailing, maintainability, and instrumentation routing.

He has worked for seven years at the QuEST Rolls-Royce business unit, Bangalore. His career at QuEST began as a detailer and then he subsequently moved on to become a designer. He is currently working as the interface support and project leader for the installation team with Rolls-Royce business unit.

Calvin received a Bachelor of Engineering from M. V. Jayaraman College of Engineering, Bangalore (Karnataka), 2003 with distinction.

At QuEST, his role includes:

- Supporting QuEST UK for the fully managed service (FMS)
- Interfacing with QuEST UK, EKES, and QuEST India
- Projecting leader at QuEST and Quality reviewer
- Meeting the compliance requirements of the technical review process

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About QuEST Global

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QuEST partners with customers to continuously create value through customer-centric culture, continuous improvement mind-set, as well as domain specific engineering capability. Through its local-global model, QuEST provides maximum value engineering interactions locally, along with high quality deliveries at optimal cost from global locations. The company comprises of more than 7,000 passionate engineers of nine different nationalities intent on making a positive impact to the business of world class customers, transforming the way they do engineering.

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