

# role of design for six sigma (dfss) in designing and building test rigs for commercial aircraft

An organization's success depends on its effort to continuously innovate and develop products. Having the capabilities to launch products at the opportune time and the ability to tightly integrate them into an organization's revenue and growth plans is the other essential factor.



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## Abstract

An organization's success depends on its effort to continuously innovate and develop products. Having the capabilities to launch products at the opportune time and the ability to tightly integrate them into an organization's revenue and growth plans is the other essential factor.

Critically, for a product's success in the market, the product's requirements must factor in the right balance of faster time-to-market and total value derived. Another important customer perspective is the quality and innovation that differentiates them from the competition. By being proactive in developing these aspects into the product development lifecycle, the success factors emerge. Design for Six Sigma (DFSS) methodology provides that essential ingredient to drive a product to success using specific and quantifiable metrics - at every stage - against a specific budget.

In designing and building Test Rigs for commercial aircraft, DFSS provides a rigorous, proactive, and

systematic methodology to integrate customer requirements with the Right First Time design approach and provides the ability to incorporate performance characteristics into the product development processes. It also provides the essential parameters to achieve product excellence by measuring, verifying, and optimizing the Test Rig design and build processes, at every stage.

QuEST's unique local-global model backed by domain expertise provides end-to-end solutions in designing and developing the Test Rig. This approach results in considerable cost reduction and reduces the risk on program management. Combining QuEST's unique model with DFSS, the development, testing, and servicing time of Test Rigs is reduced and delivers a significant reduction of the cost compared to actual flight testing.

## Processes Impact Business

This section discusses the market needs for DFSS and the challenges to design and build Test Rigs in a non-DFSS environment. It also includes an assessment on the impact of cost and other aspects that stifle an organization's progress in developing next generation products.

### Key Challenges

- Introducing a new product (Test Rig) to the market with limited product and domain knowledge
- Building the capability to develop an end-to-end solution with complete system level Test Rig design and build
- Achieving the ideal balance of product features against cost and quality
- Building in the required flexibility to manage the variability in customer requirements at various stages in the product development
- Complying with various tollgates requiring error-free processes
- Dependence on aircraft design maturity for the required delivery schedule
- Efficiently managing the supply chain and third-party vendors
- Measuring metrics and performance characteristics in adherence to the Critical To Quality (CTQ) benchmark

## Designing Test Rigs Using DFSS Methodology

The complexity of architecting, implementing, and servicing the Test Rig can be substantial. When the customer requires the highest performance, traditional methodologies such as the Waterfall or Six Sigma models require a relook.

To address this, the selection of the methodology to design the Test Rig was driven by the requirements for higher performance standard and service delivery by the

customer. When comparing the various methodologies, Six Sigma is driven by the process improvement principle whereas DFSS is suitable for larger and longer new product and development projects. While Six Sigma is focused on achieving one or two CTQ metrics, in the case of designing the Test Rig, the customer requirement was to adhere to CTQ 4.5 Sigma or better, which can be a limitation if the methodology used is Six Sigma.



In new product development, DFSS offers a unique approach and methodology that is clearly focused on helping organizations develop and introduce innovative products to the market.

DFSS looks at the product, service, and process delivery holistically. The other important parameter that helps in the case of DFSS is the need to avoid manufacturing and service challenges. By using advanced Voice of the

Customer and appropriate systems engineering techniques, bottlenecks in the process can be avoided early on in the project. For instance, factors that affect the Test Rig during on-ground service, such as fire prevention, can be factored in during the early requirement stages ensuring completeness in the development processes.

## The QuEST Approach

QuEST employed the Right First Time approach. DFSS methodology with the typical five step process - DMADV - given below:

- **Define:** Define what, why, when, who and how of project
- **Measure:** Understand customer needs and specify CTQs
- **Analyze:** Determine the best means of meeting requirements of product/process
- **Design:** Develop detailed and optimized design
- **Verify:** Verify product and process performance against target

## Define Stage - Deciding the Scope of the Project

The Test Rig is designed and built to allow first flight testing to be performed on-ground prior to the aircraft flight test program and will support the aircraft through Entry Into Service (EIS) and remain as a working test facility for the entire life (up to 25 years) of the aircraft program.

After receiving the requirements and inputs from the customer - Voice of the Customer, a Quality Function Deployment (QFD) exercise was carried out by capturing the explicit and implied customer requirements. Risks were identified and mitigation plans were prepared.

Test Rig Design and Build Requirements Test Rig designing and building involves testing flight controls, landing gear, and hydraulic systems of an aircraft. All these subsystems are connected together on the rig as in the real aircraft to ensure that the entire system operates on the rig exactly as on the aircraft. A high-performance force control system is developed to provide accurate dynamic loading of the primary and secondary flight control actuators, and the structure on to which the flight control actuators are mounted provides a mechanical load path with the same stiffness when compared to an actual aircraft.

## Measure Stage - Test Rig Performance Parameters

All aircraft landing gears are subjected to a wide range of excitation conditions, which result in conflicting damping requirements. For this purpose, many hydraulic cylinders and actuators have to be coordinated with a high degree of control effort and a dry run that pays off for all aircraft in the air. The testing machine cylinders used will not only ensure a real feeling of flight but also

permit the sustained and highly precise reproducibility of all movements.

- Achieving the required build tolerances of (+/- 0.15 mm) which involved laser alignment
- Modular design to fit into the shop bay
- Ease of transportation



## Analyze Stage - Determining the Best Possible Solutions for a Test Rig

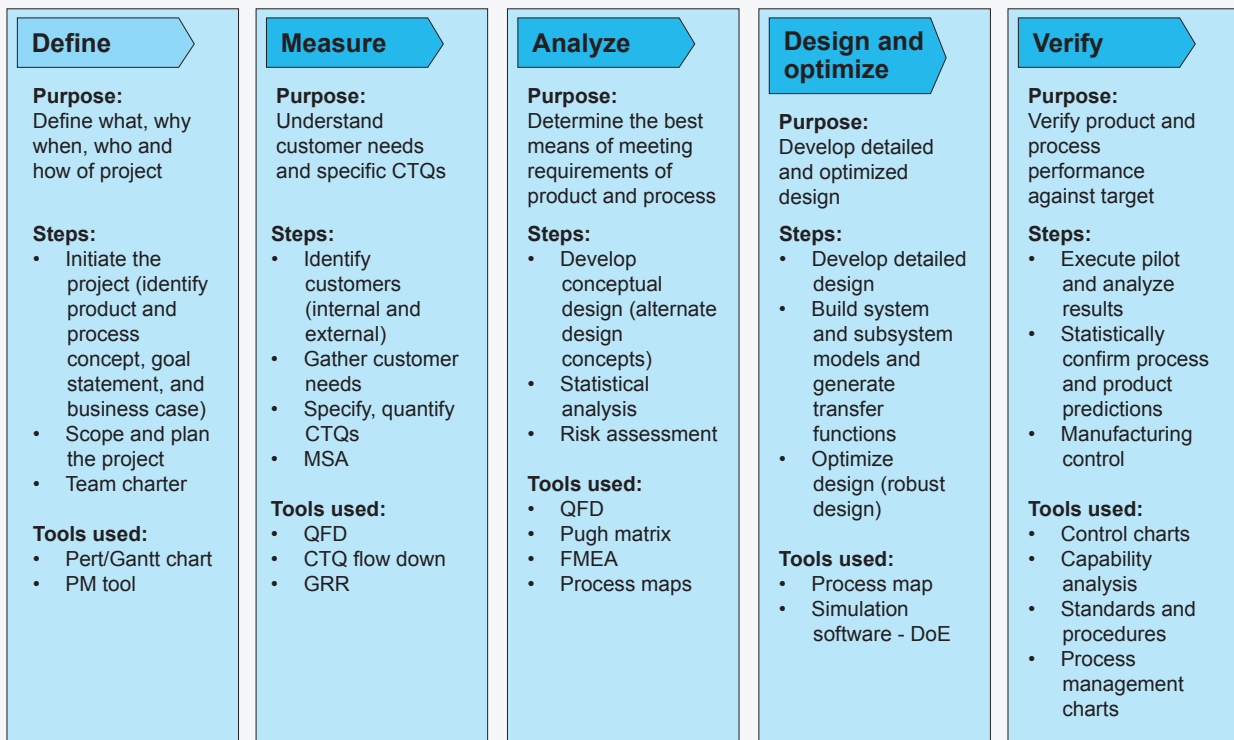
In the preliminary design stage, multiple solutions were proposed and evaluated using a Pugh Matrix. One or more solutions shortlisted using methods such as Design of Experiments (DoE) and a detailed DFMEA was carried out to arrive at a robust design solution. These were compared against the parameters set in the requirements and an optimum solution was chosen for a detailed design.

A prerequisite for a flight test program is ground testing and to meet certification requirements from various regulatory authorities. Ground testing involves realistic load testing and operating under controlled conditions to be certified ready for actual flight-testing. With ground testing, performance, reliability, and durability can be compared against the customer's requirements.

## Detail Design Stage

During the detailed design, stress analysis was carried out in parallel with manual calculations and Finite Element Analysis. The entire process passed through various tollgates.

The various stages of the process are described below:



## Measuring the Impact of DFSS Process in Test Rig Development

DFSS finds its roots in ensuring that products are able to meet customer requirements. Predicting product and process performance requires experience and a broad suite of advanced toolset in a variety of disciplines. QuEST received a Certificate of Conformity, which confirms the final technical documents delivered as below:

- Complete 3D Catia models and 2D drawings of all the assemblies, sub-assemblies and components
- Complete design report and stress report at Critical Design Review stage
- Laser tracking report for the primary work packs from build partner
- CoC (Certificate of Conformity) from the build partner



## Performance, Quality Metrics, and Verification

By using advanced simulation and verification tools in the product development environment, a powerful range of product and process performance predictions provides the bedrock for ensuring that products meet specific customer requirements, without the need for costly prototypes and tryouts. QuEST used the following parameters to translate customer requirements for the Test Rig against the performance, quality, and verification metrics.

- Proactive and rigorous tool to ensure Right First Time
- Conduct rigorous reviews internally and with the customer to keep the project on track
- Translate customer needs into critical factors which will affect the project and prioritization
- Work package breakdown for better understanding; provides easier control for well-defined projects and all the relevant requirements

## Post-Delivery Evaluation and In-Service Investigation

This section discusses the analysis and reporting provided to customers that help in developing the next generation products as well as the continued support during the aircraft's lifecycle.

- Simplify payment structure during each milestone. For example, KOM, PDR, CDR, DEL, and Final Closure
- Place a communication framework with different tier suppliers

- Prior to onsite installation of the rig, the customer to conduct a workshop and clarify onsite processes and procedures
- Regular knowledge sharing sessions to the team members conducted by chief engineers and domain experts to improve domain knowledge

## Conclusion

DFSS provides the flexibility that outlines one of the underlying success factors behind designing and building Test Rigs for commercial aircraft. DFSS is all about highlighting those aspects of a product and its accompanying product development processes that directly affect the customer requirements. By rigorously employing the methodology in building Test Rigs, organizations can reap unrivaled benefits as compared to other approaches such as the Waterfall model for

product development. With a dedicated Test Rig setup, an organization can continue to test any changes made in the aircraft design at a later stage of its development or the aircraft service lifecycle.

QuEST gained unique expertise and exposure to Test Rig design principles and complete product design process knowledge along with the necessary standards and methods specifically for Test Rigs

## Key Attributes for the Success of the Test Rig Offshore Project

- Face-to-face reviews during Kick Off Meeting (KOM)/Preliminary Design Review (PDR)/ Critical Design Review (CDR)
- Weekly Webex with a common focal point throughout the project
- Regular data transfer and DMU comparison and feedback from QuEST
- Onsite support during installation from QuEST
- Continued use of management tools such as, ECMs, data trackers, Microsoft Project plans, risk analysis, and so on
- Use of a professional manufacturing and tooling company



## Case Study: Nose Landing Gear Test Rig Using the Design for Six Sigma (DFSS) Methodology

### Situation

The scope of the project was to design, build and install a Test Rig to house a modern commercial airliner's Nose Landing Gear (NLG) along with doors and their integrated aircraft structural interfaces. The Test Rig with associated work packages required meeting the reserve factor one and safety factor four, and the laser alignment had to be done on all work packages with necessary tooling aids and balls.

Apart from the conditions mentioned above, the NLG had to meet the following conditions:

- Achieving the required build tolerances of +/- 0.15 mm and modular design to fit into the shop bay, and ease of transporting the NLG
- An end-to-end solution to introduce a completely new product to the market
- Manufacturing of NLG Test Rig
- Installation and commissioning of the Test Rig at the customer location
- Dependency on aircraft design maturity for the required delivery schedule and supply chain management (both local and global)
- Regular risk analysis and monitoring of Key Performance Indices (KPI) such as, budget, schedule and quality
- Measuring risk count against review dates as per service level agreements

### Solution

QuEST Global employed the Right First Time approach methodology. The local-global approach was the manufacturing strategy used; this ensured the NLG was deployed close to the client's location. Parts were sourced based on volumes both from global and local vendors, while the trial installation was completed at the build place.

### Benefits

- Achieved low-cost setup of the Test Rig for NLG
- Enhanced cost-effectiveness compared to actual flight-testing
- Developed a reusable build for the entire lifecycle of the aircraft during maintenance and upgrade
- On-time completion of project by using the scientific methodology - DFSS
- Delivered 25% cost benefit with QuEST's offshore development model



## Author Profile



### Subhash S

Subhash S. Tirumalai has over 29 years of engineering experience in product development and manufacturing. He is an accomplished designer of general and special purpose machines. He has spearheaded the design and development of Test Rig for the Nose Landing Gear (NLG) at QuEST. Subhash is an astute promoter of value engineering and brings ample innovation to the table. He has extensive experience in vendor development and product indigenization initiatives.

Subhash has won and received many accolades which include:

- Best Design award at IMTEX 1986 (Indian Machine Tool Exhibition)
- Best Technology award at INTEC 1988 (Industrial Trade fare, Coimbatore)
- Excellence in Aerospace Indigenization award at SIATI 2001 (Society of Indian Aerospace Technologies and Industries)
- Strong contender for Employee of the Year 2008 at QuEST India

The products he has supported and designed include:

- Machine tools (GPM and SPM)
- Industrial and lobe pumps
- Fixture designing, manufacturing and proveout of CNC machines
- Design of automation, conveyors, gantry and material handling equipments for FMCG
- Design of hydraulic and pneumatic circuits
- Design of Test Rigs and test benches for Aerospace and Industrial applications

Email: [subhash.tirumalai@quest-global.com](mailto:subhash.tirumalai@quest-global.com)





## About QuEST Global

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QuEST Global is a focused global engineering solutions provider with a proven track record of over 17 years serving the product development & production engineering needs of high technology companies. A pioneer in global engineering services, QuEST is a trusted, strategic and long term partner for many Fortune 500 companies in the Aero Engines, Aerospace & Defence, Transportation, Oil & Gas, Power, Healthcare and other high tech industries. The company offers mechanical, electrical, electronics, embedded, engineering software, engineering analytics, manufacturing engineering and supply chain transformative solutions across the complete engineering lifecycle.

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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