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Digital certification of aviation equipment on the basis of “Siemens PLM Software” technologies

Цифровая сертификация авиационной техники на основе технологий “Siemens PLM Software”

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Abstract

The article is dedicated to the analysis of digital certification of aviation equipment on the basis of multifunctional “Siemens PLM Software” (PLM - Product Lifecycle Management) technologies and “Verification Management” solution. In the theoretical part of the article, the authors point out that during certification a project usually goes through two stages: validation and verification. The first stage involves checking the project requirements for correctness and completeness, while the second stage aims to confirm that the designed aircraft is fully consistent with the validated requirements for it. The article states that the implementation of modern systems engineering practices is based on various instrumental components, methodology, and professional competence and is implemented as part of the general PLM strategy of an enterprise using “Siemens Digital Industries Software” products. In the course of the research, the authors of the article came to the conclusion that “Verification Management” solution in the “Teamcenter Siemens PLM Software” system helps enterprises in the aerospace and defence industries to successfully implement projects on creation of innovative products within a given timeframe and budget. “Verification Management” solution forms a closed traceability cycle for all stages of the control process of project decisions aimed to confirm compliance of the design with specified requirements. “Verification Management

Аннотация

Статья посвящена анализу цифровой сертификации авиационной техники на основе многофункциональных технологий “Siemens PLM Software” и решения “Verification Management” (PLM – Product Lifecycle Management - Жизненный Цикл Изделия). В теоретической части статьи авторы указывают на то, что в ходе сертификации проект, как правило, проходит два этапа: валидацию и верификацию. Первый этап подразумевает проверку правильности и полноты, предъявляемых к нему требований, тогда как второй этап призван подтвердить, что разработанное воздушное судно полностью удовлетворяет предъявляемым к нему требованиям, прошедшим валидацию. В статье отмечается, что реализация практик современной системной инженерии базируется на различных инструментальных компонентах, методологии, компетенциях специалистов и осуществляется в рамках общей стратегии PLM предприятия, с использованием продуктов “Siemens Digital Industries Software”. В ходе проведенного исследования авторы статьи пришли к выводам, что решение Verification Management в системе Teamcenter Siemens PLM Software помогает предприятиям авиационно-космической и оборонной отраслей успешно, в заданные сроки и в рамках бюджета реализовывать проекты по созданию инновационных изделий, оно образует

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Catalyst” module accelerates the enterprise’s transition to digital technology; therefore, this transition improves reliability and productivity while lowering the total cost of ownership. “Teamcenter” system supports verification of the implementation of product development programs, reduces the time and cost of project decisions, which ultimately improves the entire work of the enterprise. “Verification Management” solution is a fully functional lifecycle management solution that is able to transmit product requirements and their changes to all participants of the design process.

Keywords: design automation, digital certification, systems engineering, technological upgrading, virtual testing.

Introduction

Today digitization is a defining trend of global transformation of processes and models of relationships between participants in the value chain, which is based on the integrated implementation of digital technologies and the integration of information and computer resources into physical processes. The digitization process of industrial production and the transition to the fourth-generation industry paradigm is based on a large number of various “smart” devices that are built into products, their components, and production equipment. New cyberphysical systems and intellectual devices create huge amounts of data and require complex integration, coordination and optimization in a single multidimensional dynamic system. To succeed, aviation equipment developers have to rethink approaches to aircraft design and testing, to resort to using new solutions and materials, and to increase the products complexity. This increases the time of ground and flight testing of the aviation equipment and its certification in accordance with new standards. As a result, the cost of certification testing increases. Implementation of modern digital technologies allows saving and accelerating the development of aviation equipment by automating a significant share of calculations and certification testing.

замкнутый цикл прослеживаемости всех этапов процесса контроля проектных решений, направленного на подтверждение соответствия конструкции заданным требованиям. Также отмечено, что модуль Verification Management Catalyst ускоряет переход предприятия на цифровые технологии а, следовательно, такой переход повышает надежность и производительность при снижении общей стоимости владения. Система Teamcenter поддерживает проверку выполнения программ разработки изделий, сокращает сроки и стоимость контроля проектных решений, что, в конечном счете, улучшает всю работу предприятия. Решение Verification Management является полнофункциональным решением для управления жизненным циклом, способное передавать требования к изделию и вносимые в них изменения всем участникам процесса проектирования.

Ключевые слова: автоматизация проектирования, виртуальные испытания, системная инженерия, технологическая модернизация, цифровая сертификация.

Theoretical base

The main purpose of certification is to confirm that the aircraft and its systems are fully compliant with airworthiness standards. During certification, a project goes through two stages: validation and verification. The first stage involves validation of the project requirements for correctness and completeness, while the second stage aims to confirm that the designed aircraft is fully consistent with the validated requirements for it. “Siemens PLM Software” solutions help to bring the verification process to earlier development stages, providing great potential for reducing budget and terms of the program. “Siemens PLM Software” technologies allow creating verified models of aircraft, their units, components and systems, as well as conducting their virtual testing. For typical aviation systems and components, solutions are offered by existing libraries of customized models, which allow performing reliable calculations and abandoning a part of field testing. Its results are replaced by virtual testing results (Tolstykh, Gamidullaeva, Shkarupeta, 2018).

Reducing certification terms is possible due to more accurate planning of the field testing. Thus, the verified models obtained with the help of “Simcenter” solutions allow determining in advance the places of the best placing of sensors and test modes of individual components, units and aircrafts

assembled. Moreover, with the help of “Simcenter Testing” technologies, it is possible to significantly automate the testing process, i.e. to conduct automatic calculations and analysis of experimental data directly in the pace of testing. In this case, the risk of human error is reduced and the need for “manual” processing of a huge amount of data is mostly eliminated. “Siemens PLM Software” solutions allow organizing the verification process, taking into account the development of several aircraft configurations. Different aircraft configurations may include units of several producers, a part of the flight testing of which can be conducted in the laboratory or even replaced by calculation, significantly reducing the volume of flight testing and expenses on its preparation and conduct. Reports on the results of such testing or calculations serve as the basis for the confirmation of requirements verified by certification authorities (Kondratiev, Lyubimtsev, Merkulov, 2015).

The process of building modern products includes many stages, within which the requirements for the future product, its functions, design, production technology, etc. are determined. Research shows that even despite the widespread use of automated systems of design, reverse engineering, and engineering data management (Computer-aided design (CAD)/Computer-aided manufacturing (CAM)/ Computer-aided engineering (CAE)/Product Data Management (PDM), the following problems remain:

- only 28% of projects are compliant with the planned terms and budget;
- over 45% of the development budget can be “spent” on corrections and alterations;
- up to 50% of the total amount of work is spent on correcting errors in the design.

Leading practitioners of systems engineering highlight six fundamental practices of systems engineering:

- **Model-oriented design.** The practice of it consists in using models of various degrees of abstraction and detail to support design processes. Models offer an effective way to study and update aspects of the system and provide information on them, while significantly reducing or eliminating the dependence on the need to use traditional documentation. There is a strong correlation between the efficiency of engineering processes and the level of enterprise orientation on the use of models.
- **Business analysis.** The practice of it helps to correctly identify the image and

characteristics of the product to be designed and manufactured. The lack of business analysis or its substandard performance results in a lack of understanding of the particular objectives and interests of the parties involved, which leads to chaos and high level of uncertainty in the design process of the product (Babkin, 2018).

- **Requirement engineering.** The most important component of the creation of complex engineering facilities is requirements management. All large companies involved in the development of complex equipment recognize that well-organized requirements engineering is critical to the success of projects and is one of the key elements to improve competitiveness of enterprises and their products in the global market. The practice of requirements engineering is aimed at identifying and managing requirements for the designed product. It allows connecting the requirements with other engineering information, thus ensuring the accounting fulfillment of requirements at all stages of design. Every requirement will be taken into account (Sergeeva, 2018).
- **Architectural design.** The practice of it is aimed at identifying possible areas for solving the problem of technical system design. It is based on the comprehensive multi-aspect view of the system to be created. The essence of architectural design is structuring. Structuring can extract order from chaos, that is, give shape to the functions of the system, and turn vague customer thoughts into a workable model. Product design based on the joint use of system architecture and simulation modelling tools (ID analysis) allows shifting efforts to the product design to early stages (technical proposal, draft design), adjusting various implementation options, and choosing the optimal one, which reduces changes and costs (Ananin, 2018).
- **Verification and validation.** People are capable of error, so the later the error is detected, the more expensive is the correction. Errors made at the conceptual stage are the most expensive in terms of their impact on the project and the cost of their correction. Therefore, the sooner errors are detected, the less time, budget and other resources will be spent on their correction. Verification (checking) and validation (acceptance) are the most significant stages of technical system

design. These practices should be built into the very processes of design; otherwise, checks should be performed after every design stage, starting from the earliest. It is also necessary to remember that any verification and validation process should begin with planning (Korrespondent.net, 2017).

- Configuration management. The design process is inseparable from the process of emergence and change of information. The larger the product is, the more information emerges. Each new option or change increases the probability of irrelevant data. It was the need to ensure data integrity that led to the development of configuration management practices within systems engineering. By configuration management we mean ensuring data integrity. Engineering documentation must comply with the requirements. The product that leaves the workshop must comply with the engineering documentation and as a result it must comply with the initial requirements (Babkin, 2018).

Implementation of systems engineering practices is based on instrumental components, methodology, and competencies of specialists and is carried out as part of the general PLM strategy of the enterprise, using “Siemens Digital Industries Software” products:

- architectural modelling tools – “Capella”;
- engineering data management tools – “Teamcenter”;
- 3D modelling tools – “NX”;
- simulation modelling tools – “Simcenter Amesim”.

The complexity of the development of aerospace and defense products and the amount of customers’ requirements are constantly increasing. Such products are a “system of systems” consisting of mechanical components, software, and electronics. Their development requires long-term interdisciplinary programs that include necessary processes of monitoring for compliance of design solutions with customer requirements and existing standards. Aerospace and defense enterprises compete in the global market. They implement international programs with the participation of a huge number of partners and suppliers (Korrespondent.net, 2017). In order to succeed in such circumstances it is necessary to demonstrate the ability to implement projects within the framework of the “expanded enterprise” and to deliver products complying with all the requirements within a set time

and budget. “Verification Management” solution developed by “Siemens PLM Software” company allows enterprises to achieve these goals by combining product requirements with design, calculation, and testing problems, as well as design data.

Methodology

Analytical assessment of the development forecasts of the construction and development technologies of digital enterprises of the company presented by the “Siemens PLM Software” experts is used as a research method. The research is based on a comprehensive analysis and subsequent assessment of the main results of the implementation of technological transformation processes of industry, followed by determination of its key areas and directions. The analysis is based on the materials compiled by Russian and foreign scientists, and data provided by leading high-technology enterprises. Product requirements are set by customers, set out in contracts, contained in enterprise safety standards, as well as industry standards set by authorities such as Federal Aviation Administration (FAA, United States of America) and European Aviation Safety Agency (EASA, European Union). The Siemens PLM Software Teamcenter system manages the entire product creation cycle, from selecting initial goals to setting requirements for individual details and components. Teamcenter guarantees that each requirement has an approved method of verifying its implementation, this method is applied, and the results of the verification are recorded. This provides full compliance with product requirements (Novikov, Veas Iniesta, 2019).

The “Siemens PLM Software” portfolio includes “Verification Management” solution from the Catalyst line based on “Simcenter”. It connects product requirements with the methods of testing or numerical modelling. When changes are made to the production technology, it is possible to immediately determine which tests should be conducted. Such working principle is very helpful in repeated testing. A similar approach applies to the CAE area. It is possible to determine which model and type of calculation each detail relates to. Testing and calculations in the aerospace industry can last several years, and changes are made to the design throughout the project. Modern CAE system should allow the following:

- strength calculations under static and dynamic load;
- calculation of natural frequencies and vibration forms;

- calculation of critical loads and buckling forms;
- two-dimensional and three-dimensional calculations for volumetric, thin-walled, and lattice constructions.

Modern CAD system developed by specialists as part of “Verification Management” solution should contain the following functional modules (Siemens PLM Software, 2017):

- “Fidesys Dynamics”:
 - application of the spectral element method for both linear and nonlinear problems;
 - solution of non-stationary problems;
 - analysis of wave processes;
 - seismicity modelling;
 - non-destructive testing modelling.
- “Fidesys Composite”:
 - analysis of the effective properties of composites;
 - building a realistic composite microstructure;
 - calculation of products made from composite materials (including porous, layer-fibrous);
 - determination of the monolayer properties;
 - rubber cord modelling.
- “Fidesys HPC”:
 - parallelization of the main calculation stages;
 - acceleration of calculations up to 30 times;
 - Open Multi-Processing (OpenMP) technology: use of all working kernels of the workstation;
 - Message Passing Interface (MPI) technology: use of several workstations in a network.

“Verification Management” system provides end-to-end traceability down to testing equipment. Automated Test Correlation, an automatic correlation module for testing results for “Verification Management” system, is currently being developed. Thus, numerical simulations and “Simcenter SCADAS” (SCADAS - Supervisory Control and Data Acquisition System) hardware modules can be used in combination with the “Simcenter Testlab” system to solve the problem of placement of measuring instruments. The technology allows seeing the results of numerical simulations in “Siemens NX”. The engineer selects the location of the instrument, and the testing requirements are created automatically; acceleration rates are set, data are collected in the “Simcenter Testlab” system, equipment is calibrated, and the testing results are automatically output. It is no longer necessary for test engineers to go through

numerous data collection channels to determine, what data is coming and what sensors it is coming from. They just take measurements, and the results are displayed automatically.

Discussion

Field testing of aerospace and defense equipment is necessary to verify compliance with design requirements. To confirm the correctness of the results, it is necessary to trace the entire chain, from requirements to the testing plan. This allows checking whether the testing purpose, equipment and its settings are correctly selected. This is the exact type of chain that is supported by “Verification Management” system, from requirements to the testing plan and the product tested. It allows confirming that the testing is necessary, correctly developed and conducted. If changes are made to product requirements, Teamcenter immediately identifies their consequences in terms of testing plans and products tested. For instance, it is clear which of the conducted tests should be repeated. Moreover, “Verification Management” system keeps records of all tested products and testing equipment. This ensures complete traceability of the executed works and used calculation models. “Verification Management” implements full traceability of measuring equipment, from measurement requirements set out in the test application to the measurement plan, a list of instruments, information on their calibration, and the raw and processed data received, on the basis of which the conclusion on compliance with the requirements is made. Full traceability allows showing that the tested facility complies with the design project in its current state at all stages (Dmitriev, Novikov, 2019).

The open and customizable solution architecture of “Siemens PLM Software” company allows the user to change the interface appearance and operation logic of programs both in a complex PLM environment and as an autonomous subsystem for design solutions control. Accelerated introduction modules contain all recommended software products, tools for designers networking, setup procedure, optimal processes, and training materials on implementation issues. “Verification Management Catalyst” module accelerates enterprise conversion to digital. Such conversion improves reliability and efficiency while reducing the total cost of the product (TAdviser, 2019).

Results

The integrated multiphysical modelling platform for complex technical Verification Management

systems allows modelling and analysing the work of the studied technical systems in dynamics and offers the opportunity to connect external control systems to the developed models to adjust and validate algorithms and system management strategy. “Verification Management” provides an opportunity to assess the efficiency of the developed product at the early stages of design, before the development of design documentation, which allows saving time and money. This product provides new opportunities for the development of complex high-technology equipment (Dmitriev, Novikov, 2019).

“Siemens PLM Software” solutions are successfully used by the developers of aviation equipment around the world. In some cases, during the certification process the developers used the results of virtual testing, selectively confirmed by real checks. European aircraft building company Airbus resorted to virtual testing in developing the refueling boom of the Airbus A330MRTT tanker aircraft. In this project, reliable results were obtained at the stage of flutter modelling and were later confirmed by field testing. Another example of successful use of digital approach to design, testing and certification is the development of the Airbus A380. The French company “Safran Landing Systems”, which developed the chassis for this aircraft, used the “Simcenter Amesim” solution. The A380 was put into operation with a nose landing gear designed and adjusted fully on the 1D model developed by “Simcenter Amesim”. The results of virtual testing of the chassis were fully confirmed by field testing. In addition, the developer successfully accelerated the project implementation due to accurate test planning and predictability of the experiment.

Airbus used “Simcenter Amesim” to develop digital twins of the A380, its fuel system and engines, which were then tested on a virtual stand. The technology of digital twins allows to successfully develop a high-precision virtual model of the future product, which can be constantly adjusted on the basis of the results of various field experiments. Using such virtual stand, specialists were able to predict and assess the effects of pressure pulsation in the fuel system. According to the developers assessment, the digital approach allowed reducing the time required to refine and finalize the fuel system by almost 2 years. The traditional approach, which implies a full cycle of field testing, would require more time and resources to develop and set up a stand, and to check the operation of aircraft systems.

Conclusions

The stories of successful use of “Siemens PLM Software” solutions can be shared by many

developers, including Boeing, Airbus, Airbus Helicopters, Kaman Aerospace, Honda Aircraft, Embraer, etc. The experience gained in solving specific problems confirms that “Siemens PLM Software” solutions allow optimizing, accelerating, and reducing the cost of the aircraft certification process, which usually consumes a significant part of the project budget. “Teamcenter” allows quick creation of operational documentation, and most importantly, making changes to it without increasing the terms of preparing operational documentation and delaying the certification terms. Managing models, data and processes in “Teamcenter” allows the following:

- carrying out high-quality and efficient management of various calculation data and automation of calculation processes;
- using efficient solutions for storing files of calculation results;
- formalizing calculation business processes within the enterprise;
- realizing the possibilities of connecting the calculation data with the initial data (geometry, requirements, boundary conditions, normative and technical documentation, etc.);
- integrating all the CAE tools used by the enterprise into a single environment;
- automating the process of creating calculation model;
- using the connection of the calculation data with the requirements efficiently;
- using the mechanisms of connection of the calculation data with the testing data.

“Simcenter” is the main design tool and a significant part of the development process; specialists should perform calculations and model the characteristics of future products in the design. Often, specialists first design the product, and only after that certify it. Designing with “Simcenter” guarantees successful product certification. Using “Simcenter” reduces development terms and saves millions of dollars in large projects. The tool integrated with other processes of the enterprise (design, technological preparation of production, manufacturing) becomes absolutely necessary. Reducing certification terms is possible due to more accurate planning of field testing and significant automation of calculations and analysis of testing result.

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