# Digital Transformation of the Process of Creation of Aviation Techniques based on the Mind Sphere Platform

**Sergey V. Novikov, Andrey A. Sazonov**

***Abstract*: The article is dedicated to the analysis of the digital transformation processes of the procedure of making aviation technics based on the usage of high technological platform MindSphere. The architecture and tools of the Siemens IIoT MindSphere open cloud operating system are reviewed. There are the capabilities of the MindSphere platform for the digital transformation of industrial enterprises. In theoretical part of this article, the authors consider perspective technologies of digitalization at domestic aviation enterprises, where the main factors are work in the sphere of introducing artificial intelligence and creating unique digital twins of aircrafts. The research is based on the comprehensive analysis and synthesis with the following forming of the final grade of the main results of realization of technological domestic enterprises' transformation. In the course of the study, the task is to identify key areas and areas of technological transformation and the possibility of using promising information technologies (IT) systems. The article's authors point out that for solution of tasks of predictive analytics, multivariate analysis, trend prediction, and pattern analysis based on artificial intelligence / machine learning methods aviation enterprises have to use technological abilities of the platform MindSphere. It is defined that the development a full-fledged virtual object model based on technologies included in the platform Mindsphere will allow solving a lot of problems during its development and also there comes up an opportunity to qualitatively analyze the various options for the developed product and optimize the time / expenses connected to its last development. During the conducted analysis, it was found out that technologies Siemens PLM (Product lifecycle) Software on the platform MindSphere allow making verified models aircraft, their units, components and systems, as well as conduct their virtual tests. For typical aviation systems and components of the solution suggest available libraries of customized models, due to which reliable calculations and rejection of part of field tests are possible. In the result of the conducted research authors come to the conclusion that with the help of the platform MindSphere enterprises, holdings, and even whole industries it will be able to close digital chains between the design, manufacture, and product operation.***

***Keywords*: Advanced IT systems, MindSphere technology platform, digitalization of production, digital twin, aircraft verification.***

## I. INTRODUCTION

Aircraft industry is one of the first branches of Russian industry, where digital technologies were already used on the beginning stage of designing and producing new techniques. The first big industrial products, which were fully designed in Russia in digital projects, not on a culmination, were all new Russian aircrafts: passenger liners SSJ-100 and medium-haul Irkut MC-21, combat training aircraft Yak-130, latest fighters Sukhoi SU-35, and fifth generation fighter T-50. Conceptual sketches of aircrafts and helicopters of new generation are now born in three-dimensional form and move in electronic way among the developers, pilot and mass production, pickers, test and various certification centers, and in near future, undoubtedly, the network of service high-tech enterprises that service mass-produced domestic aircraft. Digital technologies allow making modern fifth generation combat aircrafts and passenger aircrafts for the commercial market in which all achievements in the field of high technologies are applied. Moreover, the nowadays level of technological development in the world actually does not allow making really demanded product without large-scale design and production cooperation through integrated IT-systems.

## II. THEORETICAL BASIS

In 2018 air companies all over the world completed 38 million flights, transported 4.4 billion people and 59 million tons of cargo. According to experts' forecasts up to 2023, the volume of air transportation of passengers and cargo will increase, at least twice. Wherein about 72% of air transportation growth will be in already existing route network. Air companies take into consideration this growth and plan building up aircraft fleet. In this time, the demands to the noise and environmental friendliness of new aircraft become stricter. Existing Paris agreements in the field of reducing volumes of harmful emissions demand to decrease in two times the volumes of greenhouse gases emission by aviation up to 2050. On the one hand, the growing demand on new aircrafts stimulates aircraft manufacturers to make new airplanes and helicopters, but on the other hand, toughening of environmental standards and requirements for fuel consumption significantly complicates and increases the cost of developing aviation technology [1].

In existing harsh conditions, the cost of the mistake is higher than ever.

Delay of the program of passenger liner Airbus A350 for two years due to the need of redesigning individual nodes of an airplane led to the increasing of the cost of the project almost on 3 billion euros. Serious financial loss due to the postponement and construction mistakes had European concern Airbus and in project military transport development of an airplane A400M. The cost of the development program of the Japanese regional aircraft MRJ by the company Mitsubishi Aircraft due to the delays for 6 years was a

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bit more than 3 billion dollars. In order to have success aviation technology developers have to rethink approaches to designing and testing of aircrafts, resort to using new decisions and materials and also increase the complexity of their products. This expands ground and flight dates of testing of aircrafts and its certification according to new standards. As a result, the cost certification tests increase [2].

rather conservative area, where such changings are being introduced gradually and very carefully. The responsibility and the cost of mistake are too high. Technical decisions, which are made in new aircrafts, always balance at the junction of a bold flight of creative engineering, the latest achievements of science, technology and experience, lessons learned, including from accidents and disasters. Reckless implementation of all new methods and approaches in aircraft industry is strictly unacceptable. For example, PJSC United Aircraft Corporation ("UAC") pays a lot of attention to consistent and comprehensive studying of all new technological approaches, practices of their application in other industries, where possible side effects technology applications are not so critical, testing them in pilot tasks. And only after confidence in the effectiveness and safety of the technology, it is launched for industrial implementation. Perspective technologies of digitalization on domestic enterprises are [3]:

- artificial intelligence technologies (both airborne, which is used in aircraft's avionics complex, and in special supporting tasks of creating equipment);
- analytics on the base of "Big Data", semantic search for large amounts of information;
- tasks of projecting, optimization, manufacturing structures using additive technologies, compositional materials, and creation of isogrid structures;
- making digital twin of an airplane for solving different tasks;
- usage of augmented and virtual reality in the design, manufacture, and support of aircraft operation;
- industrial internet of things (IoT);
- technologies of forecast (predictive) analytics of failed states.

software, starts with conceptual projecting and ends with certification. In case of passengers, aircrafts the cost of all certification activities may be more than 100 million dollars, moreover, it is the certification process that often leads to delays in the development of aviation technology and an increase in the cost of the program as a whole. Often the stage certification trials defines whether the project will be profitable or unprofitable. The main goal of certification is confirmation that aircraft and its systems fully comply with airworthiness standards. During certification, the project goes through two stages: validation and verification. The first involves checking the correctness and completeness of the requirements for it. While the second has to define that the made aircraft fully satisfies validated requirements [4].

The usage of integral decisions Siemens PLM Software really fastens the process of verification and later certification. For example, usage of the decision Teamcenter Verification Management makes it possible to integrate manage requirements, configurations and changes, calculation and test data, and provide a guarantee of direct and reverse traceability of all requirements and characteristics. In the result, you can avoid mistakes, connected with the human factor and the need of synchronization of the results among different departments and collaborators. Thanks to Teamcenter, all relevant data at any time is available to all participants in the verification process.

## III. METHODOLOGY

As methods of research there is used an analytical assessment of forecasts of development of technologies for building and developing digital enterprises presented by company experts Siemens PLM Software. The research is built on the comprehensive analysis and the following assessment of the main results of the industries' technological transformation realization, with the next definition its key areas and directions. The analysis is based on materials of domestic and foreign scientists, and data provided by leading high-tech enterprises.

The digital twins technology allows making successful highly precision virtual model of the future product, in which you can always make certain adjustments taken from various fields of experiments. The usage of the digital twins technology may be realized in unique digital environment of "virtual high-tech enterprise", which combines a unique practice-oriented training of specialists with the opportunity of organization teamwork on projects to make information technology better. Implementation of the digital twin of production technologies really makes projecting of the products easier, taking into account the requirements of manufacturability and quality. The digital twin of the production contains many connected factors that rely to real production. Both traditional technologies and additive manufacturing processes and mixed processes are supported. Product operation data are given to digital twins of production processes. As far as the highest profit of the enterprise begins to bring sales not of the actual products, but of additional services, the modeling of the behavior of the products in the process of exploitation becomes the most important stage.

Digital twins create the fabric of the new economy by interlacing not one but two threads, ensuring its strength and reliability. Virtual and real aspects of the digital twin complement each other on all stages of the life circle.

The made digital model of the object will allow closely predict its behavior during the whole life circle. The digital twin gradually changes during its advancement on the life circle's stages. The digital twin can unit with the operational system of the things internet MindSphere, which actually allows effectively implementing the idea of digitalization. The platform MIndSphere provides the connection of the equipment and physical infrastructure with digital world and provides powerful industrial applications and digital services, which can make the productivity and efficiency of the entire business better.

With the platform MindSphere we can shorten the downtimes, increase production, and use equipment more efficiently. For example, projecting and production of aircrafts earlier was based on plazo-template method (PTM). If specialists tried to use these decisions for optimization of PTM, there would be no benefit. It is more effectively to use the decision of the electronic layout, which allows solve the tasks of development and further production of aircrafts more effectively, without using PTM. This technology is useless because the electronic layout allowed doing the linking of the design in electronic form [5].

For solution of the tasks of predictive analytics, multivariate analysis, trend prediction, and pattern analysis based on artificial intelligence / machine-learning methods on the platform MindSphere there are additive tools and specialized services. They include [6]:

- Data Exploration: interface and tools for preparation and uploading industrial data to analytics and visualization of popular tool Tableau, which allows making deep and versatile analysis of big amounts of information, which does not require training for business users and costly implementation.
- Visual Flow Creator: decision for fast creation of data processing processes, rules, and steps of reaction on events based on the Node-RED: tool open source developed by IBM's new technology group, which allows making apps in the future, just by uniting made components in in a graphical editor that does not require programming skills.
- Visual Analyser: quickly focused app for analyzing streams / data series, which allows making different displays and view slices of streaming and historical data with additional data parameters for a deeper analysis of the park equipment work.
- Report Builder: tool for fast building retrospective and operational reports, software-based data display panels TIBCO Jaspersoft. It can combine different sources of data and helps searching for dependencies and relationships in data.
- Predictive Learning: set of ready-made libraries and algorithms for creating predictive of equipment models, based on machine-learning methods. This tool allows optimizing the work of the equipment in a short period, make the transition from its scheduled maintenance to state maintenance and effectively prevent system malfunctions.

Due to the complex decision of MindSphere production companies can harness all the benefits of IoT technologies and lower the downtime of the equipment. The basic amount of services MindSphere already includes an existing app Fleet Manager, which provides necessary tools for data analysis. Additionally, various algorithms and application libraries with open programming interfaces (API) are available on the platform, for example, signal analysis, trend prediction, KPI calculation, anomaly detection, etc. On platform MindSphere a big attention is paid to questions of safety, confidentiality, and data storage reliability. All customer data on the platform is stored in encrypted form. The access to them is made through a single gateway of authentication MindSphere Gateway. In the moment of passing on the platform the data is protected with SSL / TLS SSL / TLS encryption with 256 Bit key length. All decisions for providing cyber safety that are used in MindSphere, are set up on international standards ISO 27001, IEC 62443 and others, which provides the higher level of protection.

The abilities of platform MindSphere are not limited by collecting and analyzing only industrial data or data from physical devices. Interfaces and ready apps of the platform allow connecting and using data from IT-systems of the enterprise for analyzing (for example, enterprise resource planning (ERP), customer relationship management (CRM)), from PLM management systems, production and quality management (manufacturing execution system (MES) / manufacturing operations management (MOM), quality management system (QMS), antenna pointing control system (APCS)). Combination of these data with data about real production equipment functioning, data on the operation of finished products, taking into account the location, weather, and climatic conditions, allows creating a single analytical center for operational and business data.

## IV. DISCUSSION

Decisions of Siemens PLM Software help to transfer the process of verification on earlier stages of development, providing a big potential for lowering budgets and terms of program. Technologies of Siemens PLM Software allow making verification models of aircrafts, their units, components and systems, as well as conduct their virtual tests. For typical aviation systems and components of decision there already exist libraries of made models, due to which it becomes possible to perform reliable calculations and rejection of part of field tests. Their results are misplaced by the results of virtual tests. Due to high quality of verified 1D-models Simcenter Amesim sometimes results of modeling differ from the results of real tests for no more than 1%. Usage of other decision of Simcenter, which combines technologies for 1D and 3D modeling, and for nature tests, allows making reliable calculations for modes that are difficult or even impossible to verify as part of physical tests. This, in particular, is about calculating flutter boundaries or modeling various emergencies [7].

The platform MindSphere has all necessary tools for building systems of predictive diagnostics. MindSphere Predictive Learning package has an amount of algorithms and libraries for creating predictive models using methods of deep machine learning, neural networks and based on mathematical models. In MindSphere the ready analytical modules can be quickly configured and connected to industrial data sources showing the operation of industrial systems. With the help of the module Data Science Workbench, which is included in the package Predictive Learning, users can create and adapt models, saving them later to the storage Zeppelin Notebook. Each instance of the model can be trained on a series of real data collected in MindSphere, and the analysis result is visualized. Models can be made using already-known algorithms and numbers of libraries, such as TensorFlow, Spark, NumPy, Scikitlearn, Keras, SciPy, Matplotlib, Pandas, as well as distributed computing libraries, for example MLib. The data

analysis specialist also has the ability to configure the necessary computing resources for the models to work. Ready functions of the tool Predictive Learning allows quickly analyzing and transforming big amounts of data without programming and making scripts. This makes it possible to create new series of data that can be applied on different versions of models or in another model repository, which simplifies the interaction of experts and specialists from different fields [8].

Using ERP-systems, high transparency of most processes taking place at the enterprise is ensured, it becomes possible to effectively manage various types of risks, as well as transform the existing business and bring it closer to international standards, solve problems associated with increasing the level of competitiveness of products in the domestic and foreign markets. A complex information platform will let us use all areas from production planning to financial and management accounting of the enterprise, connect various production processes, optimize the procurement, and marketing of products. The ERP system will make it possible to fully utilize the mechanisms of detailed planning, reduce the number of stocks, and create effective intra-production cooperation. It should also be noted that it would enable it to include various data received from suppliers, which will make it possible to track the entire supply chain. The world's leading aircraft manufacturers, such as Airbus, Safran, or Pratt & Whitney, have long been implemented and operate using advanced ERP systems (SAP, ORACLE, etc.). Their experience in implementing ERP systems demonstrates an increase in the accuracy of production planning to the level of 95%, an increase in the productivity of working personnel up to 35% and an increase in customer satisfaction by 15-25%. The expected result from the implementation of ERP systems is a synergistic effect due to the integrity, completeness, and consistency of the data generated in the course of the enterprise [9].

## V. RESULTS

Many European production companies change to digital methods of monitoring and predictive equipment service, actively controlling its condition, and reducing downtime. The technologies and approaches offered by the MindSphere platform allow such a transition to be carried out rather quickly and without significant upfront costs. Using the platform MindSphere enterprises, units and even whole industries will be able to shut down digital chains among projecting, production and operation of products. And this is not a notional abstraction, but an imperative of the market, which requires the transformation of traditional enterprises into dynamic, adaptive, self-managing production, sensitively responding to customer requirements and constantly optimizing production processes, and manufactured products. IoT technologies are one of the most important components of technological stack of conception “Industry 4.0”, in fact, a “connecting link”, which provides the opportunity to build cyber physical systems based on the integration of information and computing resources into physical processes [10].

The platform MindSphere, which is the base for systems of production IoT, allows making analysis of equipment data, systems, devices, etc. in MindApps applications and create the corresponding virtual intelligent models (“digital counterparts”), and then use this data to reduce the time for launching new products on the market, increase the degree of production flexibility, product quality and production process efficiency. The results of the implementation of the platform MindSphere are presented in the Table 1.

**Table - I: Results obtained from the introduction of the technology platform MindSphere in the activities of high-tech enterprises**

| Enterprise name | Enterprise profile | Activities implemented | Result of the implementation |
|---|---|---|---|
| ***Konecranes*** | Group of companies, which is a world leader in the development and production of lifting equipment under the “lifting businesses” brand, provides services to a wide range of customers representing manufacturing industries, shipyards, ports, and cargo terminals. | Crane failure prediction to prevent unplanned downtime<br>Ability to offer additional services to end customers | Revenue from services 12% ↑<br>Downtime 10% ↓ |
| ***Gehring*** | Produces machines for small series and large-scale production, and also specializes in the production of a wide range of honing tools for all types of whole machining. | Organization of digital services offering goods and services to end users<br>Ability to obtain information about the use of machines | Revenue from services 10% ↑<br>Downtime 5% ↓<br>Increased usage 8% ↑ |
| ***Gammerler*** | Innovative solutions in the field of production optimization. Printing equipment: sale, production | Failure prediction to avoid unplanned downtime<br>Warranty Compliance | Revenue from services 10% ↑<br>Downtime 10% ↓ |
| ***Kautex Maschinenbau*** | Manufacturer of innovative blown plastic extrusion equipment | End-user uptime increased<br>Receiving additional income from services based on data processing optimization | Revenue from services 10% ↑<br>Downtime 15% ↓<br>Increased usage 8% ↑ |

## VI. CONCLUSION

The platform MindSphere allows making vertical clear of the processes and data on all level of managing of an enterprise, but on the opposite, make possible the tight integration and cooperation of enterprises and service companies on the scale of production holdings and industries at all stages of the value chain of products. Development of a full virtual model of an object, based on technologies that are in the platform MindSphere will allow solving many problems during its development.

Digital twin, made on the base of using MindSphere technologies will allow:

- quickly analyze the various options of the developed product and optimize the time / cost associated with the final development of the product;
- replace part of bench / field tests with digital ones;
- increase the indicator of reliability, resource, performing actual maintenance according to the condition of the facility, and not on operating time;
- get all the characteristics (given and promising) of the product due to the accurate description of the processes occurring in it;
- digitally analyze all technical solutions and thereby develop the necessary scientific and technical groundwork;
- qualitatively increase economic efficiency by studying the features of operating modes.

Digital twin is formed in the process of product design and incorporates all its descriptions, such as:

- 3D models created by CAD tools;
- System models used by solutions for system design of complex products;
- Material Specifications (BOM);
- 1D-, 2D- and 3D-models for calculations and analysis using CAE-systems;
- Embedded software developed and tested using ALM tools;
- Electronic part of the project.

The result of using these elements is a comprehensive computerized model that provides almost 100 percent virtual validation and testing of the designed product. All these elements are needed to develop, improve product quality and provide the ability to quickly rework in response to the wishes of customers. MindSphere allows vertical transparency of processes and data at all management levels of an individual enterprise, and, on the other hand, enables tight integration and cooperation of enterprises and service companies across production holdings and industries at all stages of the value chain of products.

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