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Some aspects of CAD technology implementation during design and production of Lasta airplane

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Some aspects of CAD technology have been implemented within the Military Technical Institute (MTI) Aeronautical Division Departments in design and production monitoring of Lasta aircraft and they are presented in this paper. The methods of CAD technology implementation during design and analysis of the designed assemblies, integration of systems and equipment, analysis of manufacturer's requirements for updating of prototype documentation, design of wind-tunnel test model, production of detailed parts and assemblies in aircraft factory, etc., are explained. The further and wider aspects of using this technology in the future during design and production of Lasta 95 airplane are outlined in the end.

Key words: **airplane, aircraft design, CAD technology, 3D design.**

Introduction

THE process of aircraft design without the usage of computers has been inconceivable for a number of years. Design of aircraft structures all over the world is closely related to the application of CAD programs. Visualization and screen display of designer's ideas are shown almost immediately upon their development and design. Development of CAD programs is closely related to its application. Initially, CAD programs were used for two dimensional - 2D drafting during design of airplanes, for e.g. Boeing 757 and Airbus A310 (Computervision CADDS 3). After a while they were used for 3D design, modelling and drafting of airplanes, for e.g. Boeing 767 and Airbus A330/A340 (Computervision CADDS-4X and CATIA 3). First application of 3D solid bodies for a complex aeronautical assembly happened during design of engine wing pylon for aircraft Boeing767 (CATIA).

Implementation of CAD technology on the Lasta airplane project is not of recent date. It dates back to early nineties, when during the process of design and production of project documentation, a modern system Computervision CADDS-4X was chosen. This system was widely used by many world companies engaged in design and production of aircraft and aircraft equipment. During that time, Aeronautical Institute (MTI nowadays) was keeping track of the newest trends and its reaction was rapid, so the official licence for this CAD program was obtained in 1982, and has been used for projects of the time. Having finished training courses both in the country and abroad, the new young staff accepted the challenge of the new technology, easily implementing the new trends into the current projects. This CAD software was used in projects, such as structure analysis for supersonic aircraft (NA) in the phase of conceptual design, analysis of main structure assemblies of wind-tunnel test model of Ilyushin Il-114 passenger aircraft, shape design and analysis of main structure assemblies for unmanned aerial vehicle IBL-92, production of complete manufacture documentation of integral fuel-tank fuselage section assembly of supersonic aircraft (NA), production of complete manufacture documentation of Super Galeb (G-4) aircraft aileron, analysis, shape definition and production of complete manufacture documentation of underfuselage fuel-tank pod for modernised Super Galeb (G-4M) aircraft, etc. The accumulated knowledge from these projects proved to be huge yet insufficient to have modern CAD program and experienced design staff. It was therefore necessary to form a new set of design rules (in the form of standards) suitable for the new design approach using the chosen CAD software **[1]**. Subsequent design projects made in the MTI have confirmed this attitude.

Great impetus in using CAD technology in the MTI has occurred after participation of several MTI engineers in design and production of Airbus A330/A340 aircraft parts and assemblies during 1988 and 1989 in Toulouse, France. This collaboration with Airbus Industry was adopted in our aircraft industry as a particular transfer of technology into the design process as well as in production. Soon afterwards domestic design and aeronautical industry formed a working group of trained professional engineers with the tasks to implement all the acquired knowledge into our aeronautical practice, as soon as possible. The series of Internal Aeronautical Standards (IAS-VIS) and Technical Directions (TD-TU) were issued as a result of this group's effort, [9], [10]. The standards and directions have defined the layout of documents, the way of making documentation and processes during design and production of aeronautical parts and assemblies using CAD technology. These standards and design practice were used soon afterwards, during design of fuselage and cockpit of Lasta 2 aircraft. A

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Lasta 2 static strength-test fuselage assembly ("static trial") was produced based on the defined design procedures.

Towards mid-nineties, tactical technical requirements for light piston a/c trainer were redefined, resulting in a new program of realization study for modernized Lasta aircraft. This brought about the project Lasta 95 aircraft with complete technical documentation prepared in the traditional way, due to the outdated CAD software that was used in the MTI at the time and the absence of new CAD technologies.

Implementation of new generation CAD software on the Lasta program

There have been great developments on the CAD market in the last several years. Modern CAD software has strong mathematical support, quite universal application in the domain of design (parts and assemblies) and creation of constructive documentation. Further more, they are user friendly, and therefore easy to apprehend, so the extensive work is not tiresome or complex. What distinguishes the latest versions of such CAD software is the possibility of modelling complex shapes using 3D solid model objects efficiently. One such model was chosen to be used as official CAD software in the program Lasta aircraft. The milestone in using such a modern and constantly upgraded programme, is mastering its application.

Mastering the modern CAD software, above all Unigraphics and I-Deas, was based on internal and organized courses that were prepared and run in the MTI aeronautical departments. Having finished the required courses, main design groups of appropriate departments were able to apply the chosen CAD software for design and modelling upon finishing the course (Unigraphics). These design groups were equipped to use any CAD software of the latest generation. That was an indispensable condition to fulfill prior to *modelling of complete Lasta 95 airframe using computer's* modern CAD software and its solid modellers. There were good reasons for this decision, some of which were: need for accuracy checking of previously completed documentation made in the traditional way, accomplishing the necessary changes of parts and assemblies before entering the production / assembling phase (which was made possible by simultaneous analysis of the designed assemblies), decreasing the production prices, reducing the production time of parts and assemblies, verifying the CAD trained personal for practical CAD application on actual problems, etc.

After the training was completed, the modelling of parts and assemblies could be undertaken. However, the existence of computer-defined shape of the Lasta aircraft, the so called *aircraft loft*, for defining structure element parts was introduced. Such computer-defined shape of the Lasta aircraft was already in existence as a result of the experience gained during making lofts of aircraft Orao, G-4 (Super Galeb), Lasta 1 and Lasta 2 several years before. Outer shapes of aircraft had been made by precise drawings, using the so called *lofting* method [8]. In time, computers were introduced into the process and a series of close aircraft station (cross) sections were computer-defined (for fuselage and lifting surfaces) based on previously mathematically defined aircraft shape. The series of close aircraft station (cross) sections were used only as a first phase and an instrument for generating 3D surfaces formed by CAD software Computervision CADDS-4X. The whole set of these 3D surfaces defined the outer Lasta 2 aircraft shape, and were distributed to the manufacturer in this state. The manufacturer was able to define and produce all parts and assembly tools for Lasta 2 aircraft using loft definition in the previously mentioned way. The mathematical definition of aircraft outer shapes was the start for Lasta 95 aircraft loft and this definition was, in fact, a series of close aircraft station (cross) sections using in-house developed computer software. Such sections were used for making 3D surfaces that became the bases for forming complex solid model elements. The complete Lasta 95 aircraft outer shape was defined using these complex solid model elements, and distributed to the manufacturer.

Modelling and design of structure parts and assemblies of aircraft Lasta 95 were done using the previously described CAD model of aircraft loft and Unigraphics software. Provided that the whole structure and all aircraft systems had been previously designed in the traditional way, on a board, the design principle *bottom-up* was used during computer modelling of structure parts and entire aircraft systems. This principle implies modelling of single parts and their attaching to assemblies and subassemblies, with respect to the structural relationship. This principle is opposite to the frequently used *top-down* principle that can be used for constructing brand new designs. Since in this case all assemblies had been designed previously, it was logical to apply the *bottom-up* principle.

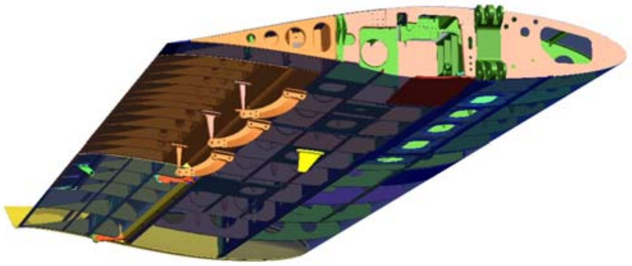

Figure 1. Lasta 95 aircraft wing structure assembly layout modelled by means of Unigraphics CAD software

The computer model of any part of aircraft structure was obtained starting with 3D aircraft solid model at location where the respective part of the airframe structure is located. Then, it was modelled using the well-known methods of solid modelling and Booleans operation and "shaped" according to the design configuration previously defined by original documentation. The layout and complexity of models of airframe parts and assemblies were adjusted to designers' requirements during design. In addition, the models were adjusted to manufacturer's resources. This means that the sheet metal airframe parts were not defined using computer module *Sheet metal* due to the lack of capacity on part of the domestic manufacturer at the time i.e. the lack of modern technology which would enable adopting the advantages of this module.

Having modelled all the airframe parts using the mentioned CAD software, the computer model of assemblies of aircraft Lasta 95 fuselage, wings and tail units was formed. These assemblies then served for detailed calculation in the second iteration, for *stress analysis, air-elasticity flight phenomenon calculation, mass and balance analysis and for attachment and integration of all other aircraft systems*. The effective conversion of all the data of different CAD software Unigraphics and I-Deas was established. The Lasta 95 aircraft wing CAD layout (with aileron and flaps assemblies) is shown in Fig.2 along with the main wing-fuselage fittings.

Virtual aircraft model enabled designers to define the idea of forming the fuselage airframe assembly for experimental static stress testing, (“static trial”) more clearly. Namely, in order to minimize the production costs, it was decided to use forward part of aircraft Lasta 2 fuselage and new-formed rear part of Lasta 95 aircraft fuselage for making fuselage airframe assembly for experimental static stress test of Lasta 95 aircraft. The computer model of the rear part of the fuselage was delivered to the manufacturer as well as construction schemes, drawings and parts lists.

The layout of the rear part of Lasta 95 aircraft fuselage for experimental static stress testing is shown in Fig.2.

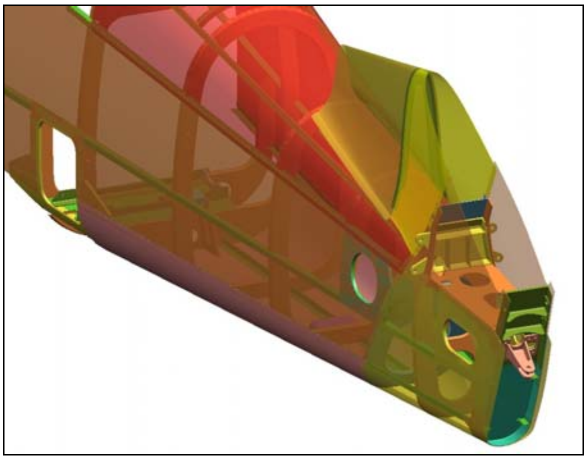

Figure 2. Rear part of aircraft Lasta 95 fuselage for experimental static stress testing made at Unigraphics CAD software

In order to obtain an aircraft with the required characteristics at the end of the design process an inevitable phase during design process is testing of the aircraft model (usually on a reduced scale) in the wind tunnel. Therefore, a reduced model of Lasta 95 aircraft was designed and produced on scale 1:5. This model was made of steel framework and duralumin skin plates. The complete process of design and production was executed using CAD/CAM technology beginning with a computer-defined loft, computer-designed model of parts and assemblies, production of documentation using CAD software, production of parts using CNC machines, and computer aided quality control. The Fig.3 shows the installation drawings of all parts of Lasta 95 aircraft fuselage assembly with all joint elements.

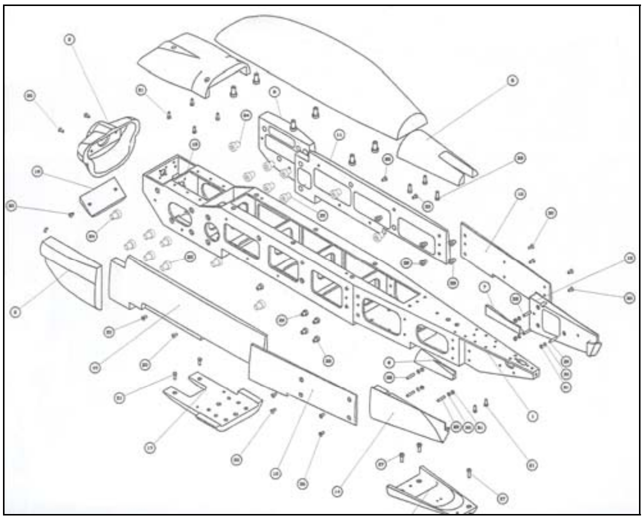

Figure 3. Installation drawing of aircraft Lasta 95 fuselage model for wind tunnel testing

Integration of aircraft systems, installations and equipment into the aircraft structure

It is common aeronautical practice to make mock-ups of parts of assemblies or the whole aircraft during design and production of prototype of any new aircraft. These mock-ups help designers to clarify some critical but vital locations in the design process before technical documentation for these critical locations is completed. Also, these mock-ups usually serve as an instrument to check any design in the sense of accessibility and maintainability, e.g. to meet different ergonomic cockpit requirements. These mock-ups are true models of real aircraft structure and systems (usually made of wood in combination with metals) and they can be on original or reduced scale. The modelled CAD assemblies of Lasta 95 airframe and its 3D solid elements have formed a particular virtual mock-up as a substitute for the real mock-up. This virtual mock-up enables executing all kinds of checks that can be done with real mock-ups, with significant timesaving and perhaps more importantly, cost savings. This virtual mock-up of the whole Lasta 95 airframe was being used, after its distribution to other departments, during design and integration of other aircraft systems and assemblies. The department responsible for fuel integration and fuel storing into the airframe, for example, was able to accommodate optimal fuel amount into the reserved space in the wings and fuselage, and to analyse the path of fuel installation from fuel tanks to power plant, as well, providing mass optimization. Aircraft undercarriage attachment is very important for any aircraft and particular attention is always paid to it during design. Whereas the undercarriage attachment had been made in the traditional way, the easy control of undercarriage kinematics and clearance control enabled using computer-modelled undercarriage and its “attaching” onto a virtual model of airframe. Instrument and equipment attachment into cockpit requires coordination of many parameters and requirements such as design, ergonomic, production, exploitation, equipment interference, etc. The layout of instrument attachment in the aircraft cockpit with a part of adjacent airframe is shown in Fig.4.

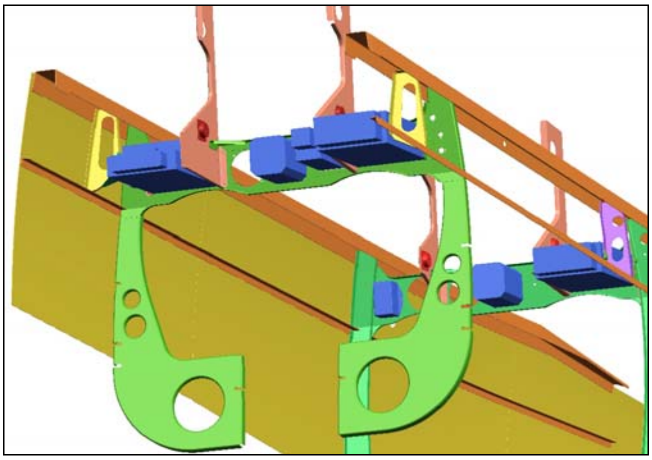

Figure 4. Layout of instrument installation in Lasta 95 aircraft cockpit with adjacent structure parts significant for attachment (made in Unigraphics CAD system)

The improvement in communication among the MTI departments was obtained as another benefit, especially for interpretation of design from other departments. The information that circulated among many departments was based on a unique 3D solid model and not on the interpretation of design solutions made on paper drawings and done by other departments. In other words, all departments had one 3D solid model to consider according to their own demands, instead of trying to visualize 3D shape of previously designed assemblies by analysing many 2D drawings rich of different views and section views, like in prior practice.

Technological preparations, assembly analysis and production in aircraft factory

The already created 3D solid model airframe assembly of the whole aircraft became mutual database of all parts built for Lasta 95 aircraft. This has enabled simple and rapid analysis of interference among all relevant parts, clearance and contact checking. These analyses were performed and are still being performed to control the classically designed assemblies or as an action on demand of manufacturer during aircraft prototype production. In this way, almost 65 small design problems related to interference relationship among built-in parts were detected, which would not have been detected in the traditional way. These problems were quickly eliminated in constructive documentation and the computer model of the airframe and the designed changes were delivered to the manufacturer. Such practice enabled an actual updated version of any aircraft part to be present at the design bureau as well as with the manufacturer, in both constructive documentation and computer model. A relatively small number of the noticed design mistakes and problems have shown that aircraft constructive documentation made in the traditional way was correct and contained a few mistakes due to the huge knowledge and experience of designers that participated in the aircraft design.

Chronologically, delivering the CAD models of aircraft parts and assemblies to the manufacturer was preceded by delivering the aircraft classical construction documentation. By this time a significant number of parts were already in the phase of production. The manufacturer's choice of CAD software did not necessarily coincide with the MTI choice. These factors made the use of CAD software on Lasta 95 project less efficient. However, the efficiency requirements were still satisfied, which could be proven by the following: parts that had not been produced before and needed CNC machining, their CAD models could be used directly for tool path creation on CNC machines at the manufacturer's; CAD models could also enable the tool designer to produce simpler tools more efficiently; CAD models also enabled the assemblage technology engineer to have a clearer insight into every part location within the airframe along with the installation sequence, etc.

Perspectives of cad technology application on the Lasta project

Extensive application of CAD technology on Lasta 95 aircraft to the prototype level, was chronologically speaking, preceded by constructive documentation prepared in the traditional way. The logical extension and expansion of CAD technology application on the Lasta project in our environment could be: making complete project of Lasta series aircrafts including their constructive documentation using CAD technology. It implies constructing the computer models of complete aircraft structures, all aircraft systems, all installations and equipment, including all standard elements with joint elements with their lists of assemblies' parts. Naturally, this is possible and rational provided that certain conditions are previously satisfied. Principally, it means provision of modern equipment (computers and plotters), strong 3D CAD software proven in aeronautical application (one of the high-ranking concurrent is CATIA software **[3]**), integrated and developed system for project documentation management and integrated system of the whole project on relation designer – manufacturer and vice versa, including previously adopted and compulsory set of project standard documents. Project standard documents would define the official project CAD software that would be obligatory for all project participants, the layout and form of documentation, which would be provided using the chosen CAD software so that it is easily readable by all manufacturers and to overcome the differences among manufacturers according to different CAD technology adoptions, and with costs / benefits ratio, which would provide profitable completion of tasks.

Naturally, 3D solid model of airframe and integrated airplane systems will serve as good basis for making all other aircraft technical documentation that is due to follow the huge process of aircraft design and production. Aircraft technical documentation comprises parts catalogue, product description and maintenance, user manual, check technical lists, etc [6]. All of these documents need perspective views of all main systems, section views, installation and exploded views, installation sequence layouts of main aircraft parts and assemblies. All of these views and layouts could be easily provided using the previously made 3D model of the entire aircraft. Namely, according to the traditional aeronautical practice it has been shown that these drawings and views are necessary during exploitation.

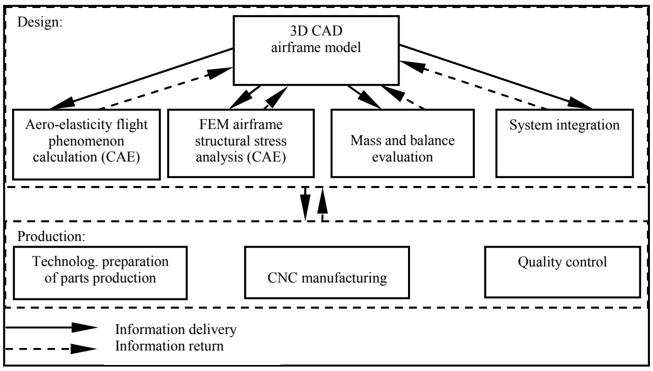

Figure 5. Representation of CAD data flow during design of Lasta 95 aircraft

Conclusion

All previously shown procedures related to the design and manufacture of Lasta 95 aircraft demonstrated that the overall objective was achieved. The 3D CAD solid model was made using modern computer software. The airframe assembly analysis was made, previous design mistakes detected and remedied, and the need for physical mock-up was eliminated since the 3D CAD model of airframe was used as digital mock-up, reducing the overall costs. The time for structural stress analysis and aero-elasticity calculation were reduced as well. The time needed for integration of the airplane systems into the airframe was reduced and bilateral communication designer-manufacturer was established, etc. (Fig.5). All of the mentioned elements along with many others enabled the CAD technology to be adequately adopted in the design/production practice of our aeronautical industry. Furthermore, it enabled establishing the connection and keeping pace with the latest world trends in the aeronautical industry.

There is no doubt that the only possible way to take in effective design of airplanes would be the rational use of modern CAD technology. It is also applicable to the phase of aircraft production, which must be maximally adapted to the new demands of CAD technology. Our design practice has shown that it is necessary to have a compatible system from design to manufacture (from software to standards), and not that of isolated, incompatible and inefficient system of design.

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Neki aspekti primene CAD tehnologije u procesu projektovanja i proizvodnje aviona Lasta

U radu su prikazani neki aspekti primene CAD tehnologije koji su se koristili i koji se i dalje koriste u stručnim službama Sektora za vazduhoplove tokom projektovanja i praćenja proizvodnje aviona Lasta. Objašnjeni su načini primene CAD tehnologije u projektovanju i analizi projektovanih sklopova, integraciji sistema i opreme,analizi zahteva proizvođača za ažuriranjem prototipske dokumentacije, pri projektovanju modela aviona za aero-tunelska ispitivanja, proizvodnji delova i sklopova u fabrici, itd. Na kraju su naznačeni dalji i širi aspekti upotrebe ove tehnologije u perspektivi, u projektovanju i proizvodnji serije aviona Lasta 95.

Ključne reči: **avion, projektovanje letelice, CAD tehnologija, 3D projektovanje.**

Некоторые аспекты применения ЦАД-технологии в процессе проектирования и производства самолёта "Ласточка"

В настоящей работе показаны некоторые аспекты применения ЦАД-технологии, которые пользовались и до сих пор пользуются в специалистических службах Сектора для летательных аппаратов в течении проектирования и сопровождения производства самолёта "Ласточка". Здесь растолковываны способы применения ЦАД-технологии в проектировании и в анализе проектированных узлов, в интегрировании систем и оборудования, в анализе требования производителя ради актуализации и корректировки документации для прототипов, и при проектировании моделей самолёта для исследований в аэродинамических трубах, при производстве частей (деталей) и узлов на заводе и.т.д. В конце назначены более далёкие и более широкие аспекты употребления (пользования) этой технологии в будущем, в проектировании и в производстве серии самолёта "Ласточка 95".

Ключевые слова: самолёт, проектирование летательного аппарата, ЦАД-технология, 3Д проектирование.

Quelques aspects de l’application de la technologie CAD dans l’élaboration du projet et de la production de l’avion Lasta

Ce papier présente quelques aspects de l’application de la technologie CAD qui étaient utilisés et que l’on utilise encore par les services de spécialistes du Secteur d’ aéronefs lors de l’élaboration du projet et pendant la poursuite de production de l’avion Lasta. On a expliqué les moyens d’emploi de la technologie CAD dans le cadre du projet et de l’analyse des ensembles projetés ainsi que dans l’intégration du système et de l’équipement. On a fait aussi l’analyse

des exigences des producteurs pour mettre à jour la documentation du prototype pendant l'élaboration des modèles d'avion pour les recherches dans la soufflerie aérodynamique, la production des pièces et des ensembles à l'usine,etc. Finalement, on a souligné les aspects plus larges de la future utilisation de cette tehnologie dans la producton de série de l'avion Lasta 95.

Mots clés: **avion, projet d'aéronef, technologie CAD, projet 3D.**