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The list of lectures on the theme

« ENGINEERING AND COMPUTER GRAPHICS-2. 3D MODELLING»

1. Theoretical basics of aircraft 3D modeling

2. Requirements specification. Draft proposal. Aircraft models.

3. Use of CAD/CAM/CAE/PLM-technologies in aircraft design external shape definition. Predesigning. Using CAD/CAM/CAE/PLM-technologies in modern conceptual aircraft design.

4. Using CAD/CAM/CAE/PLM-technologies in modern detail aircraft design.

5. Parametrical aircraft design.

6. Geometrical models data exchange in aircraft design.

7. Subject of weight design and control. Weight analysis.

8. Weight planning and weight control. Methods of weight calculations.

9. Models and documentation production in the different design stages. Preparation of drawings and documentation for manufacture.

10. Use of ontological knowledge bases and multiagent systems in aircraft design.

11. Introduction to aircraft assembly. Typical technological processes of aircraft subassembly.

« ENGINEERING AND COMPUTER GRAPHICS-2. 3D MODELLING»

LECTURE:5

PARAMETRIC AIRCRAFT CONCEPTUAL DESIGN

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Abstract

This paper presents the development of a design framework for the initial conceptual design phase. The focus in this project is on a flexible database in XML format, together with close integration of automated CAD, and other tools, which allows the developed geometry to be used directly in the subsequent preliminary design phase. The database and the geometry are also described and an overview is given of included tools like aerodynamic analysis and weight estimation.

1   Introduction

As part of Saab's 75th anniversary celebrations in Linköping in June 2012, a formation flight showed the development of Swedish jet fighters over the last 60 years (see Fig. 1). Re-evaluation of these aircraft–with respect to the technology level of the time–and comparison with the practical experience gained during service gave engineers valuable information which could be applied directly in the following model.

Nowadays, aircraft design engineers struggle with the absence of "lessons learned" from previous projects due to the dramatically extended product life cycle and development lead times, as well as a never before seen complexity due to enlarged system integration. Conceptual aircraft design is also at the breakpoint between statistical/empirical methods and physical-related system calculations in order to enhance prediction accuracy. Multidisciplinary, holistic design is the solution and is

becoming an additional field in the area of unmanned aircraft systems (UAS).

Fig. 1: Flying display of Saab fighters: (from left to right) J 35 Draken, J/S 29 Tunnan, JAS 39 Gripen,
A/J/S 32 Lansen, 105 "SK60" and JA 37 Viggen

The trend towards multinational consortium based product development, like the European
Eurofighter "Typhoon" project, has a further adverse effect: companies' functioning as aircraft component suppliers and system developers requires even sharper design engineers in order to secure the knowledge otherwise gained through their in-house design, development and construction. As a consequence, concept evaluation engineers have to take account of manned and unmanned aircraft, both military and civil, in fixed or rotary wing design. This requires a flexible, versatile and powerful framework during the conceptual aircraft design definition and evaluation phase, which should also support data sharing in collaborative research and industrial projects.

With the target of enhancing methodology and tool development, conceptual aircraft design has been a research field in the Swedish National Aviation Engineering Program (NFFP) since 1996 [1] and the most recent program

framework development in this sector will be explained in this paper.

1.1   Related Work

In the field of aircraft conceptual design, a great many programs from research institutes and universities and also commercial products can be found. Some, like the RDS software from D. Raymer [2] are a direct implementation from classical aircraft design handbook methods, as described for example in [3], [4] or [5]. Here follows a short list of related university/research projects and

- programs:
- CEASIOM [6]

padLAB : Preliminary Aircraft Design Lab [7]

- Vehicle sketch pad [8] Bauhaus Luftfahrt:
- Conceptual Design Tool (CDT) [9].

2   Conceptual Aircraft Design Methodology

The process in conceptual design development is focused on development and evaluation/comparison of different designs in order to benchmark the design and give feedback regarding the (partly negotiable) requirements. The main intention of the conceptual design phase is to reduce the number of possible layouts based on the design evaluation. The results of the conceptual phase should also:

- include all data and information used to develop the aircraft layout   allow a backtrack of the
- requirements support flexible output routines in
- order to reuse this data directly in the tools of the subsequent preliminary design phase.

The last point takes primary aim at reuse of the CAD data but also means a tool-specific export for, for example, subsystem simulation and development tools. As a consequence, data handling and a flexible and fast implementable data interface emerges as the critical point in multidisciplinary work involving different tools with the same data setup [10]. In order to maintain flexibility, the database should also include as much functionality as possible.

2.1   One-Tool Concept

In the aviation industry, the introduction of full computer aided design (CAD) data based product development and production has led to a trend towards a one-tool strategy that includes multidisciplinary work. In the European aviation industry in particular, with CATIA [11] as a standard the embedment of the simulation program Dymola [12], based on the Modelica language, into the CATIA V6 environment, has establish a new holistic approach together with the ABAQUS finite element method tool already included in CATIA V5. These programs are linked under the umbrella of CATIA V6 by means of a proprietary data format.

2.2   One Database Concept

By contrast, research institutes and universities, who are more interested in maximum flexibility and tool integration (in order to enlarge multidisciplinarity), prefer a non-proprietary (open source) database definition. One recently published proposed standard is the Common Parametric Aircraft Configuration Scheme (CPACS) devised by the German Deutsche Zentrum für Luft- und Raumfahrt (*DLR*) [13][14]. This data setup has been tested and used for several years at DLR in preliminary projects with different focus, for example aircraft noise emissions, structure analysis or even whole fleet simulations. [15] describes the implementation of CPACS within the CEASIOM project to improve the data definition. One drawback of using CPACS directly in aircraft conceptual design may be the extent of the data description, including fleet, helicopters and land-based vehicles up to a very highly detailed level of geometry and structure description. The approach in this project was also to define the data setup in a very robust, easy manner, accepting the adverse effect of design space limitations on the advantage of reduced complexity. Furthermore, the data definition should represent the mindset (of the developer) and represent the main design parameters directly. It must be remembered that during initial data setup development, the CPACS format definition was not available to the authors of this paper, but the similarities in data definition between CPACS and the small subset in

this project–which had already been defined when the CPACS format was published–were remarkable. As regards design details (close to or already in preliminary design), CPACS terminology has partly been directly adapted.

The main disadvantage of a central data setup definition is the size of the data file size, together with failure to update (and manage updated information), in particular when parameters are modified in different tools. These problems mainly occur when applying different analysis methods on the data setup.

With the complexity and multidisciplinary nature of conceptual design, it might also be useful to use high-level, graph-based design (modeling) languages to model the product data, including requirements and system configuration and architecture. One example is the Unified Modeling Language (UML) which is shown in [16] where it is applied to satellite design. SySML, as a development of UML, might be even more appropriate.

2.3   Challenging the Gap between Design Definition and Evaluation

Alongside the data setup definition topic, the matter of retrieval of the "perfect" designing tool appears. Somewhat oversimplified, this tool should support the developer in creating designs out of the requirements and evaluating/ benchmarking these designs according against them.
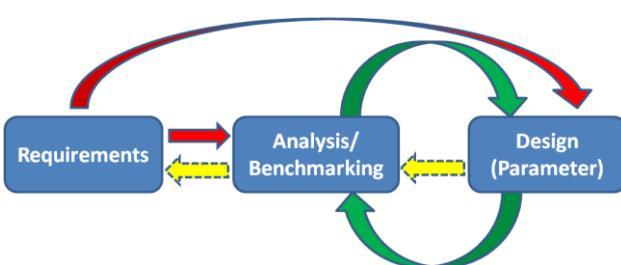

Fig. 2: Conceptual aircraft design phase: Requirement influence (red), main design loop (green) and
requirement update (yellow) correlation

In reality, finding the right design will be an optimization loop between the design definition that is being evaluated and the requirements, which also involves negotiation and

balancing of the requirements (see Fig. 2). This is particularly important in the conceptual phase.

Whereas for design definition a (subset of a) CAD program is particularly useful, it does not normally fit concept analysis and evaluation well. In the latter case, a scripting language combined with an adapted graphical user interface (GUI) is much more usable and gives the developer the possibility to add benchmarking or optimization algorithms of his or her own. Based on these considerations, CATIA V5 and Matlab were chosen as the main tools for the design process.
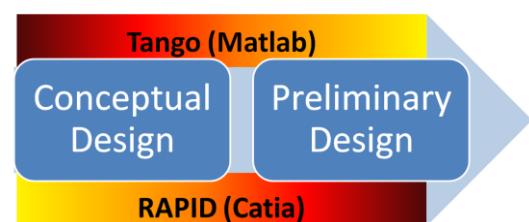

Fig. 3: Parallel implementation concept with a stepless fadeout of Matlab based design definition in more detailed design

In order to maintain flexibility and allow the developer to choose his or her preferred work method, both programs should be implemented in parallel (see Fig. 3). Switching between the two should be possible at any time. In normal mode, the common database is therefore hidden in the background by tool-specific XML interfaces so that the user feels that communication in both applications is done directly. Due to the nature of the work with these programs, and especially the limitation of graphical representation outside a full CAD environment, it is recommended that detail design and structure definition is more related to CATIA than to Matlab.

Combining an interpreter language with a graphical user interface (GUI) and CAD software, in this case both Matlab and CATIA V5, is not a new idea; it has already been used, but mainly for preliminary design, e.g. in the form of "PadLAB" (Preliminary Aircraft Design Lab), by the Institute for Aerospace (ILR), Technische University Berlin with the focus on cabin layout [7].

3 Implementation of the Conceptual Aircraft Design Framework

In the following, the data setup and the two programs Tango (Matlab based) and RAPID (CATIA V5 based) will be explained in detail.

3.1 Database Setup and Handling

Based on the requirements of a general database with a focus on flexible access, XML representation was chosen. This representation can be accessed by practically any programming languages via standard interfaces like the Document Object Model (DOM). Furthermore, by defining the structure as an XML Style Sheet (XSD), data setups can easily be checked for validity. Transitions within the parsers between the XML data setup and each connected tool can be implemented fairly quickly and easily with the help of the XML Stylesheet Language for Translation (XSLT). These translation files are implemented in the XPath language [18] to access nodes or node-sets in XML documents. This language however, has limitations regarding mathematical operations and complex parsing actions but functions well for hierarchical level translations.

During database style development, a particular focus was laid on a robust, parametric based data description in order to allow for automation and the application of optimization algorithm later on. The data setup should also be as similar as possible, regardless of aircraft type (civil/military or UAV). Therefore, and because the focus is on conceptual and not preliminary design, design limitations due to too strict data definition have to be accepted. As a consequence, this database might not function well for programs creating generic design apart from the (pre)defined design space.
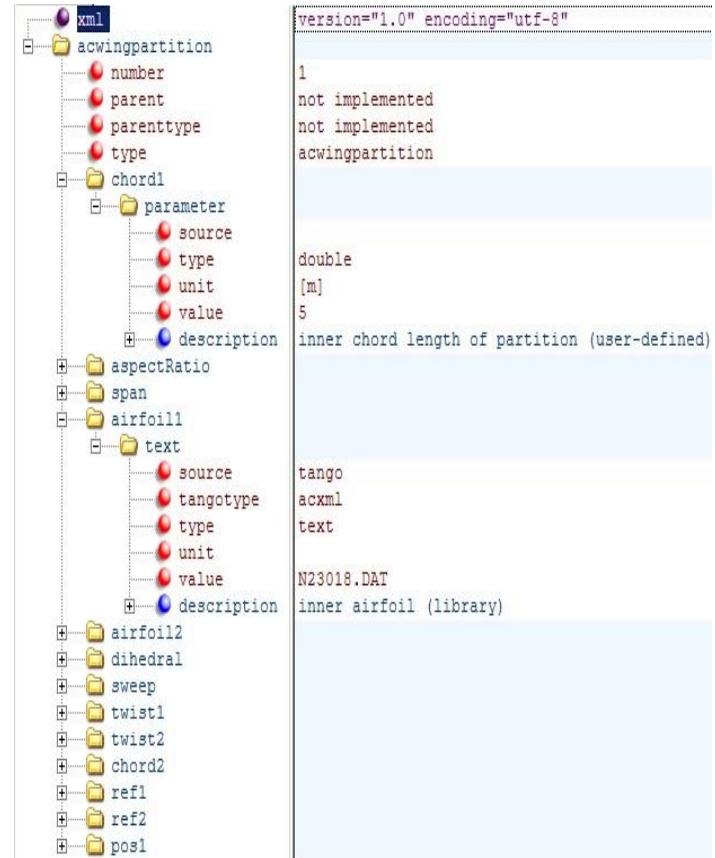

Fig. 4: Database example of a wing section definition

One example, shown in Fig. 4, is the definition of a wing section, based on the cross-section definition of airfoils. All airfoils are consistently defined by a Bézier curves method presented in [19].
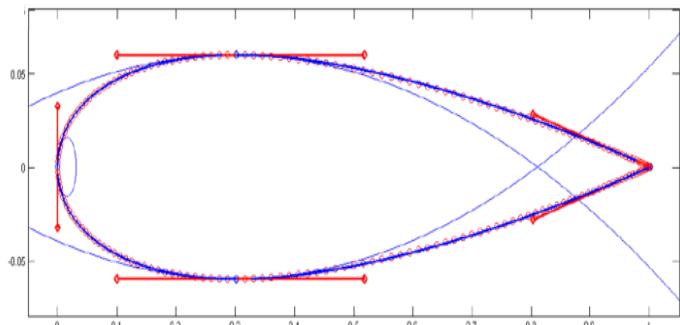

Fig. 5: Airfoil definition representation by Bézier curves control points

This method uniforms different airfoil descriptions in a very robust, computerinterpretable data definition, based on only a few dominant parameter (see Fig. 5). This definition has nevertheless a wide design space with the only drawback that it is not possible to model airfoils with an S-shaped trailing edge.

3.2 Tango (Matlab) Implementation

The Tango implementation makes use of the new class definition features of the Matlab language [20]. This enables an object oriented programming (OOP) implementation close to C++ together with interpreter language benefits regarding debugging (fast development) and the useful console input capability. The drawback is the vastly slower calculation speed and perhaps stability problems when program size and complexity increase compared to C++. However, using Matlab was a requirement from the industrial partner, because most of their engineers are used to this language. However, considering the open source approach, Python would be a proper alternative.
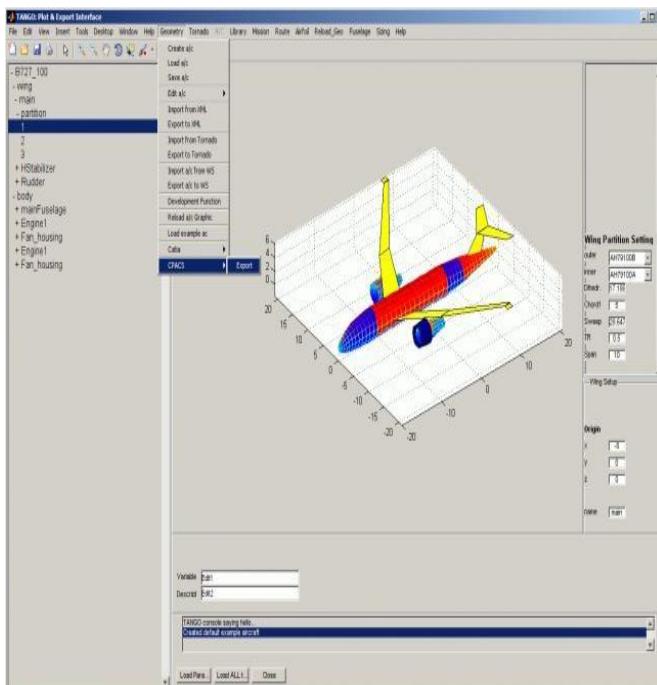

Fig. 6: Screenshot of the Tango start-up window

The strictly class based implementation allows for a modular program implementation based on physical systems, components and functions. All XML database support and all calculations specific to components, systems or parts (e.g. weight estimation) are performed within the class. This also allows for fast component exchange and replacement by means of standardized coupling ports and functions and ensures definition consistency through direct parameter access restrictions.

```
ac = acdata('exampleAC');
 ac.setting.setProperties('cg', [5.1807, 0,0.0972],...
                          'rp', [5.6223 0 0.0972]);
% 1.)Main wing            ac.addwing('main');
ac.wing{1}.setOrigin(-8, 0, 0); ac.wing{1}.addPartition();


%Inner wing: ac.wing{1}.partitions{1}.setProperties('chord1',5,...
            'span',    10, ...          'taper',   0.5, ...
            'sweep',   0.5, ...
            'dihedral', 0.3, ...   %pi/4
            'twist1',   0.1, 'twist2', -0.1);
%Outer wing:          ac.wing{1}.addPartition();          ac.wing{1}.partitions{2}.setProperties('sweep', 0.7);
%Winglet:
ac.wing{1}.addPartition(); ac.wing{1}.partitions{3}.setProperties('span',1.0,...
            'tr',   1.0, ...          'sweep', 0, ...          'dihedral', 0, ...
            'twist1',  0.0, 'twist2', 0.0);
```

A GUI with a rather strict hierarchy, supporting an easy to use working environment with a graphical representation of the current topic, is implemented on top of the class setup. Alongside this mode, design development and evaluation can be performed directly from the Matlab console or by using a certain scripting language to address the classes. Fig. 6 shows the default start-up GUI window and Fig. 7 a small script snippet of an aircraft geometry definition.

Fig. 7: Example of a basic aircraft geometry (wing) definition script

Besides the geometry (and system integration) definition, and sizing, weight estimation and aerodynamics are the central points during design development. Sizing is done classically by statistical methods as well as easy physics, supporting the user with the usual sizing diagrams, taking the selected certification (JAR, FAR 23/25) into account.

Fuselage weight is calculated sector-wise taking into account the airplane structure, location, size and shape of doors, windows, etc. as well as the installed (sub)system components. Here, the old classically weight calculation, based on the calculation of an equivalent skin thickness defined by the shear force and bending moment and adding penalty weight for windows, hatches, installations and (sub)system components [21], is combined with a more physically related weight estimation of the included systems and components. A detailed explanation of this method can be found in [22]. The wing is calculated either in the same way as the fuselage or from the wing structure CAD data, if already defined in detail.

Initial aerodynamic calculations—mainly needed for thrust and fuel consumption estimation—are calculated by the

lattice vortex panel method program TORNADO [23]. The export to TORNADO and the calculations take place automatically, and hidden to the user, within few seconds but can be changed if needed. With the help of the parameters obtained, the sizing results and the engine data, classical mission performance is calculated.

For more accurate evaluation capability, a full aircraft simulation export capability including (sub)system integration is currently under development using the Hopsan simulation package developed at Linköping University. Full system simulation using this software is presented in [26]. The export functionality is relatively generic and models can also be exported to Modelica. Besides higher accuracy, the simulation will give the designer direct feedback and thereby a better understanding of the design as well as the potential to investigate the effects of different (sub)system architectures and system integration. This topic becomes especially necessary with the transition to crosslinked electrically driven systems like the environmental control system (ECS) or the antiice system, which have a significant impact on both aircraft operating empty weight (OWE) and energy efficiency.

Other methods for design investigation and evaluation include:

- sensitivity and robustness analysis according to [24]
- maneuver analysis (especially for military aircrafts).

  Currently implemented export and import
- capabilities are:
- TORNADO
- CPACS format (limited)
- CEASIOM XML format [25]

Saab in-house aircraft conceptual design tool.

Most of these translations are solved by using XSLT translation style sheets.

Central parts in Tango, in contrast to RAPID, are the functional onboard power system implementation and the control topology. Currently implemented systems are:

- Propulsion system: Based on performance lookup tables normally supplied by the original manufacturer. Reference thrust, bypass ratio, pressure ratio and maximum turbine inlet temperature, for example, are generically derivable out of the central design parameter. Propeller-piston configuration is not implemented yet but may become more important with the upcoming new Kerosene/Diesel (piston) engines on the UAV market.
- Primary Flight Control System (PFCS): Includes control surface geometry, control topology and (hydraulic) actuator power system. This section–together with the hydraulic system description–is taken directly from the CPACS format [13] • Landing gear system, including track animation and actuator system
- Environmental Control System: Cooling and pressurization of the aircraft.

All these system classes include configuration help and data libraries in order to support the developer with automatically default adapted (architectures and sizing) systems.

3.3 RAPID (CATIA) Implementation

RAPID (Robust Aircraft Parametric Interactive Design) is a knowledge-based Aircraft Conceptual Design tool built in CATIA.

The main motivation to use CATIA for this purpose is to enable the propagation of the design and its contents from conceptual to preliminary design. The surfaces generated are A-class surfaces and can thus be used directly for initial aerodynamic analysis. It makes use of the two powerful automation technologies embedded in CATIA, viz. Visual Basic (VB) scripts and Knowledge Patten (KP). Power Copies (PCs) and User Defined Features (UDFs) are created and utilized by the VB scripts and KP respectively for instantiation.
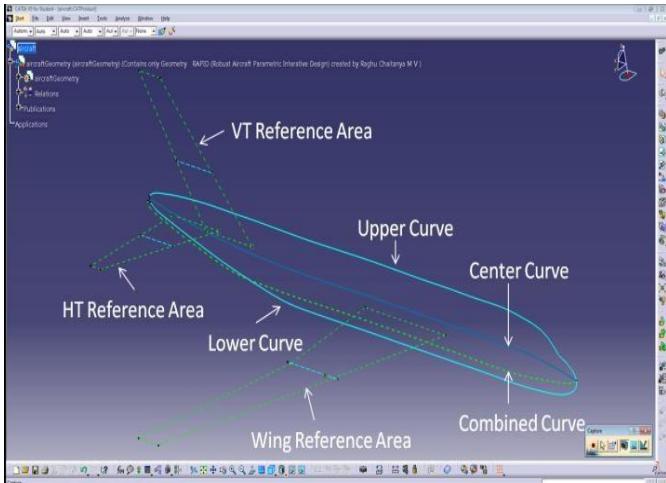
Fig. 8: Default RAPID start-up window

The design in RAPID is achieved either by a bottom-up approach or by modification of an existing aircraft configuration example. The flexibility of the model implementation allows changing from a civil aircraft to fighter or UAV. In a bottom-up approach, the user begins by modifying the fuselage according to requirements and later modifying the wing. From here on the other lifting surfaces are automatically sized; only configuration and positions have to be defined manually. Once the default RAPID aircraft model is loaded into CATIA, different aircraft from the XML database can be loaded and the model updated (see Fig 8 and Fig. 9).
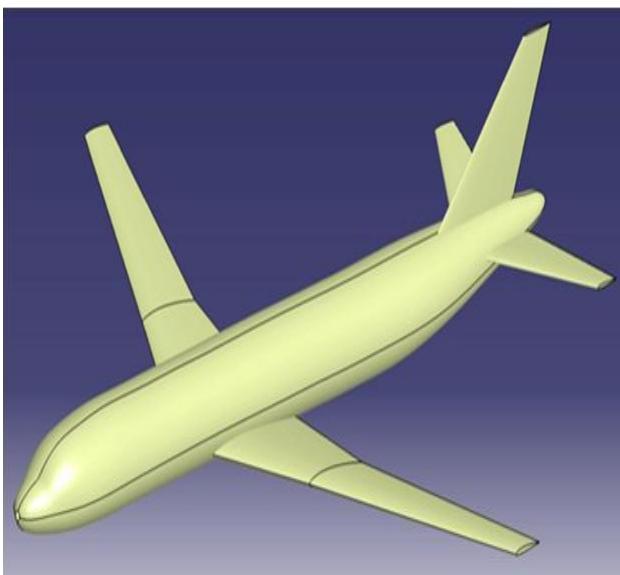
Fig. 9: Civil transport aircraft geometry loaded from database

The detailed Geometric Model (GM) can be sent directly to aerodynamic analysis and, as the model has fewer surfaces, it can be meshed with less effort and the process may be automated in the future. The GM is the basis for the Structural Model (SM) and the number of spars and ribs can

be chosen for the lifting surfaces as well as frames and stringers for the fuselage. The SM can be meshed automatically and is prepared for initial structure analysis. Heading towards preliminary design, control surfaces, windshield, fairings and winglets etc. can be defined for both the GM and the SM. Pilot model, cockpit model and cabin layout will be features added in the future.
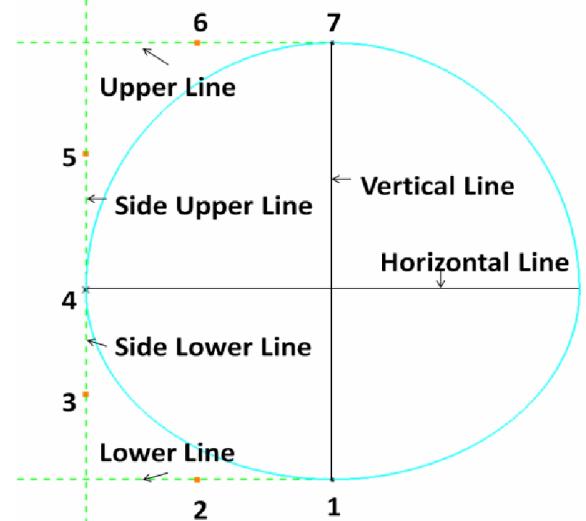

Fig. 10: Fuselage cross-section definition by 3rd-order Bézier curves

The data exchange to and from the XML database is implemented using VB scripts. All lifting surfaces make use of the same airfoil definition, shown in Fig. 5. A similar approach is used for the fuselage, shown in Fig. 10; here, a third-order Bézier curve is used to describe a quarter section of the fuselage cross-section where the upper and lower lines measure an angle with respect to the horizontal line, while side upper line and side lower line measure an angle with respect to the vertical line. Points 2, 4 and 7 are the intersection points with the fuselage curves shown in Fig. 10. Points 2, 3, 5 and 6 move along the respective curves and are positioned as ratios.
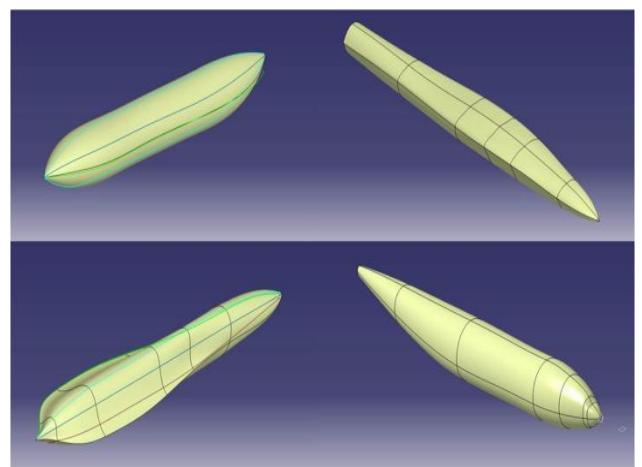
Fig. 11: Examples of different fuselage layouts Fig. 11 shows some examples of both civil and military fuselage layouts that can be modeled.

Engine sizing is an additional feature of RAPID. Turbofan and turbojet engines can be sized depending on design parameters (e.g. the bypass ratio). The nacelle is designed from the size of the engine; mixed flow and separate jet nacelles can be chosen accordingly. A wide range of parameters can be changed for the nacelle, from inlet diameter to exhaust diameter. Different gear boxes and pylon types can also be modeled. The pylon design depends on the type of nacelle; start and end positions can be chosen as necessary. Two configurations of the engine and engine installation are shown in Fig. 12.
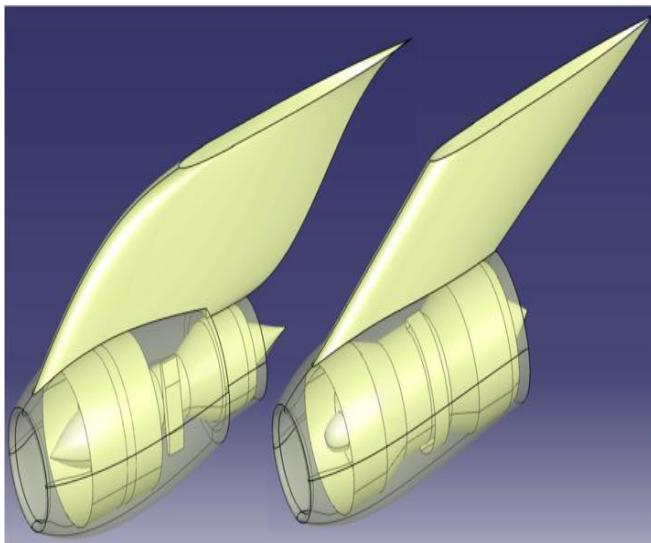

Fig. 12: Turbofan with trapezoidal gearbox, separate jet nacelle and smooth leading/trailing edge nacelle (left) and turbojet engine with circular gearbox, mixed flow nacelle and straight leading/trailing edge pylon (right)

Military air inlet channel definition work is ongoing, but no satisfying solution for this problem has been bound yet.

4 Discussion

According to the framework concept motivated in Chapter 2, the focus was on a robust, parametric data definition. This database supports extensive data export and import capabilities for flexible tool integration. The closeness of the CAD implementation to the data setup simplifies the integration of geometry-related sophisticated evaluation methods such as structure (FEM) and aerodynamic (CFD) analysis.

One central issue in all modeling tools is to create a constraint design space where the user should have as much freedom as possible, while designs that are clearly not valid are not present in the design space. This minimizes the amount of information that needs to be provided by the user. With the tools provided in this framework, the user can quickly generate detailed concepts with a minimum of parameters. Another improvement regarding old-fashioned implemented approaches (e.g. Fortran-based sizing tools) is the direct feedback to the developer, either directly in the CAD or in the Tango GUI. The direct graphical feedback ("what you see is what you get") is useful to avoid wrong inputs and unburden the user of imagining the design on his or her own.

During the project, the limitations of the used software/languages became quite clear; that is, on the one hand, the limited geometry definition and graphical representation capability outside a complete CAD environment, and on the other hand, the extremely slow code execution speed in a CAD environment (here VB scripts in CATIA). These experiences back the initial decision to use two main tools, Matlab and CATIA, in order to balance the needs for both, design definition and evaluation.

The replacement of empirical methods by physical implementation of (onboard power) systems and equipment is an indirect benefit of the above mentioned topics: through the extended usage of XML based airfoil-, wing-, aircraft-, sub- and system-component libraries and configuration help as well as the userfriendly machine-human interface, the modeling lead time can be shortened. This allows additional design properties, especially onboard power systems to be defined with the same time effort as before. This increase in (design) information can lead to higher estimation precision than empirical formulas can.

Drawbacks in this design framework are the absence of requirement handling and the rudimentary (product life cycle) cost analysis. The cost analysis can actually be seen as the main benchmark requirement in the early conceptual design phase, with the focus on feasible studies for requirement definition. This topic might be better solved with the competition approach mentioned, creating automated design with the help of graph-based

design languages. However, due to ongoing implementation work the framework has not been tested in case studies, re-evaluation of existing aircraft or by comparing the results with real data, handbook methods and other conceptual design tools.

4.1 Outlook

Negotiations regarding software and code publication are ongoing, but from Linköping University's point of view, the framework should be made available as open source software in order to support cross-company and cross-university collaborations and knowledge sharing.

The main focus in a continuation of this project will
- be on:
- simulation integration

additional and refined subsystem integrations enhanced weight estimation methods

- methods for requirement handling
- (implementation) • tool verification and adaptation through aircraft re-evaluation adding/enlarging databases/libraries

- adding tracking of the "designer workflow" (how
- has the designer built up the model) in order to replay projectspecific aircraft design development for both, education/training purpose as well as within requirement adoptions and optimization loops.

5 Conclusion

A flexible conceptual aircraft design framework, based on a solid data setup has been developed in collaboration between Linköping University and Saab Aeronautics. The robust parametric data definition together with the parallel/matching CAD model enables the application of optimization algorithms and a direct data reuse in the subsequent preliminary design phase. The split-up into a stand-alone, XML-based database and the design definition and analysis tools enable a flexible integration of external tools. Additionally, this database supports the geometry definition process through extensive component libraries and configuration functionality.

Product life cycle (LC) structure by Zeid

Design Process

Synthesis

Necessity of design → Technical requirements for design → Implementation analysis and information acquisition for design

CAD+CAE

Analysis

Project documentation ← Design review ← Project analysis and optimization ← Design ← Analytical model ← Project conceptualization

CAM

Processes planning → Production planning → Production → Quality control → Packing → Shipping

Processes planning → Design and new tools purchase

Processes planning → Materials order

Processes planning → NPC programming

Marketing

Manufacture Process
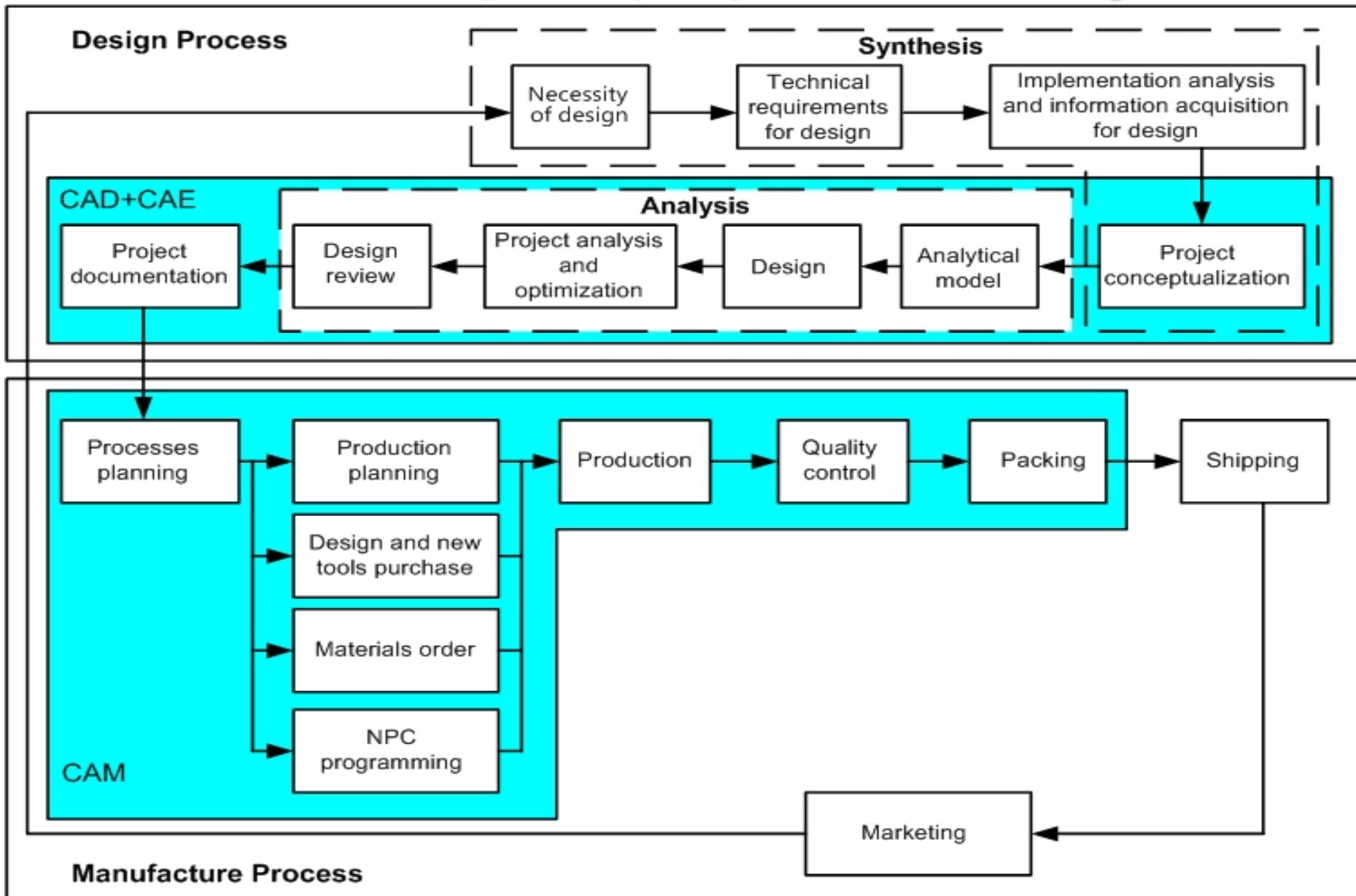
System Analysis (SA) is a scientific discipline aimed at developing methods and design of complex systems, as well as ways and means of solving the difficult applied problems, based on the methodological principles of a systems approach.

Methods for systematic structural analysis (SSA) has been successfully used to solve various problems, such as financial management, production planning, organizing logistics, construction of diagnostic systems of education and so on., as well as aided design and manufacturing. The technology of structural analysis and design SADT standardized in the USA as IDEF0 standard of federal standards ICAM DEFinition. SSA methods are basic for CASE-technologies (Computer-Aided Software Engineering).

According to experts in the field of SA for solving tasks of analysis and design of any object should be modeled:

- The function of the object, for example, using data flow diagrams - DFD (Data Flow Diagrams);

- The relationship between the data that it uses, for example, using diagrams "entity-relationship" - ERD (Entity-Relations Diagrams);

- The behavior of the object (event), for example, through state transitions diagrams - STD (State Transition Diagrams).

- The main instrument of knowledge-oriented system (technology) is knowledge. And the main objective of knowledge-oriented system (technology) is to deal with this knowledge.

The word "ontology" appeared in ancient times, from time immemorial, mankind has posed the question: what are the things around, if they have some other meaning, which remains inside even when things change, how can they be classified? It is these questions which part of life philosophy ontology tries to answer, namely to the correspondence between the existence of things and its essence.

The use of ontology in engineering

Research on ontology is becoming more progressive among researchers in computer science. While the term was philosophical and rather limited scope in the past, now it receives a specific role in artificial intelligence, computational linguistics and database theory. In particular, its importance is recognized in various research areas such as knowledge engineering, knowledge representation, qualitative modeling, language engineering, database design, information modeling, information integration, object-oriented analysis, search and data mining, management and organization knowledge of designing agent systems. Current areas of applications, including enterprise integration, natural language translation, medicine, engineering, standardization of knowledge product, e-commerce , geographic information systems, legal information systems and biological information systems, are disparate.

Ontology definition

Ontology, as defined by Gruber is specification of conceptualization, formalized presentation of the basic concepts and the relationships between it. Ontology necessarily accompanies certain concept of the area of interest. Often it is expressed by defining basic objects (individuals, attributes, processes) and the relationship between it. The definition of these objects and their relations are usually called conceptualization.

- 3D-modeling is a formation of superficial and solid-state models of subobjects of the aircraft;

- Mathematical modeling - mathematical methods and means which are used at aircraft design, for example the restrictions imposed on a design of the aircraft and considered at all design stages;

- Decisions on functionality (work of separate systems, blocks, units);

- Decisions on product structure (filling of a tree of the project at a certain aircraft design stage).

Description of ontology design

Development of an ontology, i.e., ontological engineering, is a non-trivial task nowadays. It requires professional knowledge development technology of knowledge engineering – from the methods of learning the procedures of conceptualizing, structuring, formalization to its implementation. Different languages and systems exist for describing the ontology, however, the most promising is the visual approach because visual patterns (e.g., graphs) poses cognitive force. Any graphical software package from PaintBmsh to Visio can be used as a primary tool for description ontology.

As formal ontology model understand the set consisting of three subsets:

$$O=<A, R, F>$$

- A – final set of designing process concepts;
- R - final set of relations between concepts of designing process;
- F - set of functions of the interpretation set on concepts.

The following requirements should be complied during constructing ontology:

- Ontology must contain conceptual rather than episodic knowledge and not depend on the natural language used to describe knowledge;

- Ontology should be well specified and internally consistent with the structure, names and content for all terms defined therein and compatible with a variety of sources (resources) of knowledge;

- Ontology should be well structured and easy to understand and search terms;

- Ontology is usually limited to a specific area of concern for definitions and must not contain all possible information about the visual aria, about surrounding world, but only those concepts that are needed for this application;

- Ontology should remember and to provide information about their previous state as far as development and support the following features: the ability to broadcast from one language (format) on the other, provide an opportunity to reuse, to be edited, the ability to be added or to supplement another ontology, be capable of joint user access.

Ontology of a subject domain "Aircraft Design" we will describe in the form of the following generalized algorithm of actions:

- Drawing up of the dictionary of a subject domain on the basis of components of aircraft design, considered more low (thesaurus);

- Reception under the subject domain dictionary of ontology a subject domain «Aircraft design», reflecting "natural" communications between concepts;

- Check by experts in the given area turned out of ontology a subject domain «Aircraft design», support and filling ontology.

Thesaurus

The thesaurus of area of aircraft design can be used as the tool of standardization and formalization of knowledge, and also for providing of access of users which solve problems of aircraft design.

The thesaurus «Aircraft design» is intended for the decision of following problems:

- Classification and unification of concepts of a subject domain;

- Classification of methods and problems of aircraft design; construction of descriptions of methods and problems of aircraft design in knowledge bases for support of aircraft design;

- Classification and search of the help information in the given subjects.

Aircraft design ontology

Aircraft design ontology uses the thesaurus and it is necessary to develop and fix the general understanding of area of considered knowledge; to present knowledge in a kind which is convenient for its processing by the automated systems of aircraft design; to provide possibility of reception and accumulation of new knowledge, and also to give possibility of repeated use of knowledge.

Ontology describes the basic communications and parities between parts of process of designing.

Aircraft design ontology
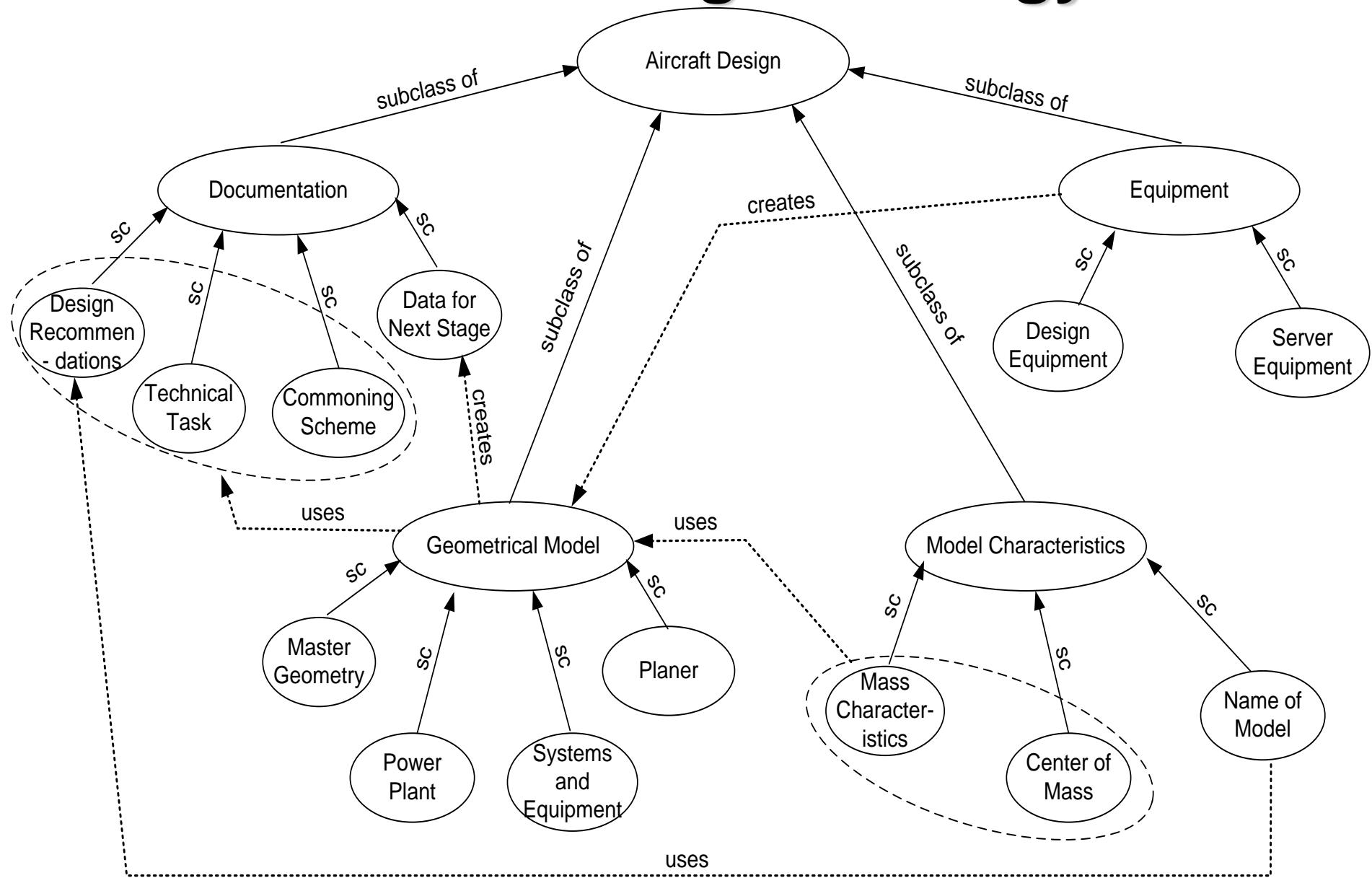
Data presentation in ontology

The basic part of given ontology is geometrical model and its division into objects and sub objects.

The geometrical model contains 3D-models and managing parametrical model (MPM), restrictions concerning requirements of external designing (on the basis of RS, DP and according to JAR, FAR and requirements ICAO) are imposed.
Code OWL by results of modeling in package Protégé 3.4.4 can be used in the further work in the knowledge base, processing the information since CAD/CAM/CAE-environment, using Java-application.

Let's divide aircraft GM design process at a stage of creation OAM:

- "Documentation",

- " Equipment ",

- «Geometrical model»

- «File characteristics»,

Which are in more details considered more low.

Each of these classes has own subclasses. We will consider the cores from it.

«Documentation»

- «Designing recommendations» is a set of the documents used at designing. For example, various standards, reference literature on designing;

- "Technical project" includes requirements to the basic specifications of the aircraft, such as: aircraft performance characteristics, a specification on weight of the aircraft; expected conditions of operation; the basic geometrical characteristics. The technical project acts as a separate design stage and shows the basic technical requirements to the further designing of the aircraft;

- «Layout schemes» - a selection of 2D-drawings of a construction, systems and the equipment, all basic compartments and the sections of the aircraft created on previous OAM design stages and it is direct at stage OAM which will be used further for realisation of 3D-configuration of the aircraft at development cycle OAM;

- «Data for a following stage» - the documentation which is transferred by results of designing of working out OAM to the following stage - CDPM in the form of the passport of the aircraft and various results of designing of 3D-models of the given stage.

«Equipment»

"Equipment" includes variants of software products and the hardware, used at designing of the chosen development cycle of the aircraft.

The class "Equipment" has following subclasses: «the Server equipment» and «the Designing Equipment».

«Server equipment» includes all necessary for maintenance of normal network work of designers the equipment in which special system administrators are engaged, or competent designers responsible for given works or programmers.

«Designing equipment» includes all necessary designer hardware and program tooling which is used in the course of designing. In particular, it is modern software packages of CAD/CAM/CAE-system: CATIA, NX … under control of such corresponding PDM-systems, as: Enovia, Teamcenter... Works are carried out or by personal cars under control of operational system Windows or Unix.

«Models characteristics»

«Model characteristics» describe the basic characteristics (attributes) of each file of 3D-model which are made out in the form of a txt-file attached to the basic file with solid-state model.

For models of details and assembly units the following minimum list of attributes is used: № groups, a name, mass, co-ordinates of the centre of mass, a material.

«Geometrical model»

 «The geometrical model» contains 3D-models according to the above described tree of the project.

All geometrical model includes all 3D-models of the aircraft at stage OAM, such, as:

■   "Master Geometry",

■   "Power-plant",

■   «Systems and the equipment»,

■   "Construction".

Between all aforementioned classes and subclasses ontology «Aircraft design» connection is described.

For example, the class "Equipment" "creates" «Geometrical model».

It means, that geometrical models of the aircraft "are created" by designers, using program and hardware of modern computer information technologies.

Aircraft ontology design with using IDEF 5
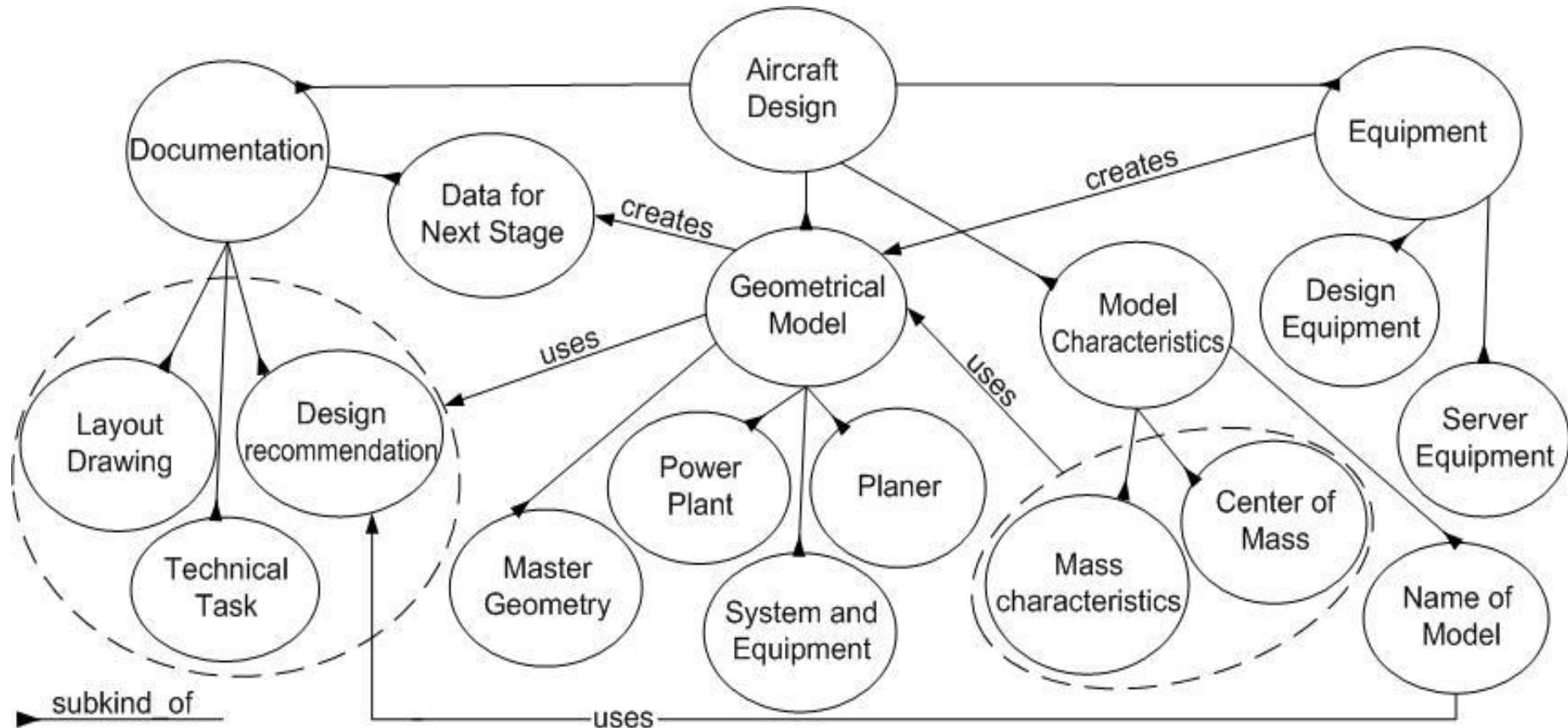
Ontology presentation

For representation of aircraft design ontology description ontology language OWL (Ontology Web Language) which consists of following components has been chosen: classes, properties of classes and individuals (representatives of classes or properties).

The example above described ontology at an preliminary design stage of the aircraft is presented in program Protégé.

Aircraft design ontology in Protégé environment
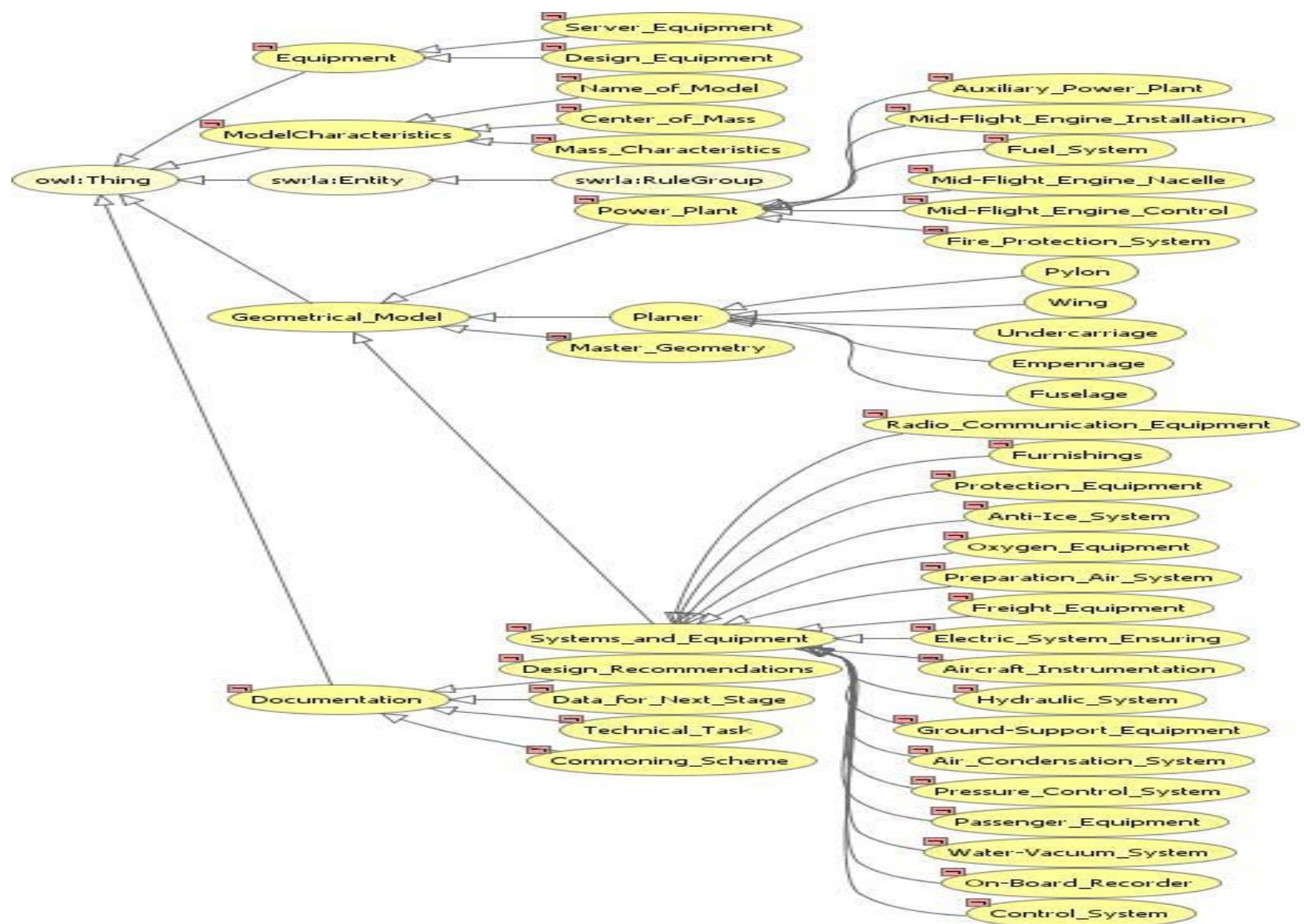
Multiagent Systems Design

Agent definition

Agent is an object that can perceive the surrounding environment through sensors and exercise influence on it by manipulators. Multiagent system is used for specific tasks of intelligent agents that receive input information and can exert influence on the process of solving the problem.

Thus the main task is divided into subtasks, and its decisions are implemented as composite behavior of agents, implementing the selection and execution of sequences available in their actions to achieve their own goals. This assumes the presence of agents of adaptation mechanisms and algorithms for their learning.

Agent-oriented approach

Agent-oriented approach (AOP) of program is a kind of submission software or programming paradigm in which the basic concept is the notion of agent and its behavior depends on the environment in which it is located.

Agent properties:

- Autonomy - the ability to perform actions on its own;

- Homogeneity/heterogeneity - the ability to combine homogeneous or heterogeneous functions;

- The presence of "intelligence" of learning, correction treatment to improve its own effectiveness;

- Active management, continuous exchange of information "inside" an agent and between the agent and the environment;

- Communication - data exchange with the environment;

- The perception of the environment - the existence of special "means" perception of the environment functioning agent;

- Mobility - moving agent inside other software and physical environments and / or components.

Concept of using modern design techniques

The structure of modern design suggests applying of multi-agent systems, ontology and technologies PDM, to realize a fast and reliable design process of modern aircraft.

Multiagent technology focuses on managing frequent changes and PDM is used to manage of the product of mass aircraft design and its equipment.

This structure includes the architecture of the PDM client / server and receives a federal framework for effective cooperation in terms of sharing a single, convenient packaging tool, decentralized management, coordination, etc.

Finally, a prototype of the multi agent -based system that is developed and tested to be used in aircraft production. Case studies show that the optimized and e- tuned instrument of aircraft design can be achieved through the developed system of cooperation.

Multiagent technology that emerged from artificial intelligence, received a lot of attention for its engineering characteristics which are different reactivity, autonomy, proactivity, etc. This task takes multiagent technology product design, explores a new approach to address the issues of cooperation in distributed design. And research as to assist designers in achieving consistent agreement on the design and the design process. Multiagent technology has advantages such as: openness, reliability, reactivity, flexible input, etc. in a distributed and joint problem

The integration between agents and PDM

Due to the complexity of application development for multi-agent system and PDM-system, both for it performance and its integration are very difficult. Just start to set up some of the technical systems that integrate the multiagent system and PDM- system. These systems use development environment Java- agent (JADE) for developing multi-agent systems and uses PDM- system. This environment provides application of integration exchange interfaces from each other, which means access to its data in the system. This is an effective solution for the production of integration application for multi-agent systems and PDM- system.

	Level
Multi-agent system — Application agent, Application agent, Application agent ...	Multi-agent system level
JADE Java API	Data exchange level
TCEng Java API — Login interface, TCEng session, UG manager session	
CATIA V5, UG NX4.0, Pro/E, AutoCAD...	Application tool level
TeamCenter engineering system	PDM level
Oracle server, File server, Web server	Server level
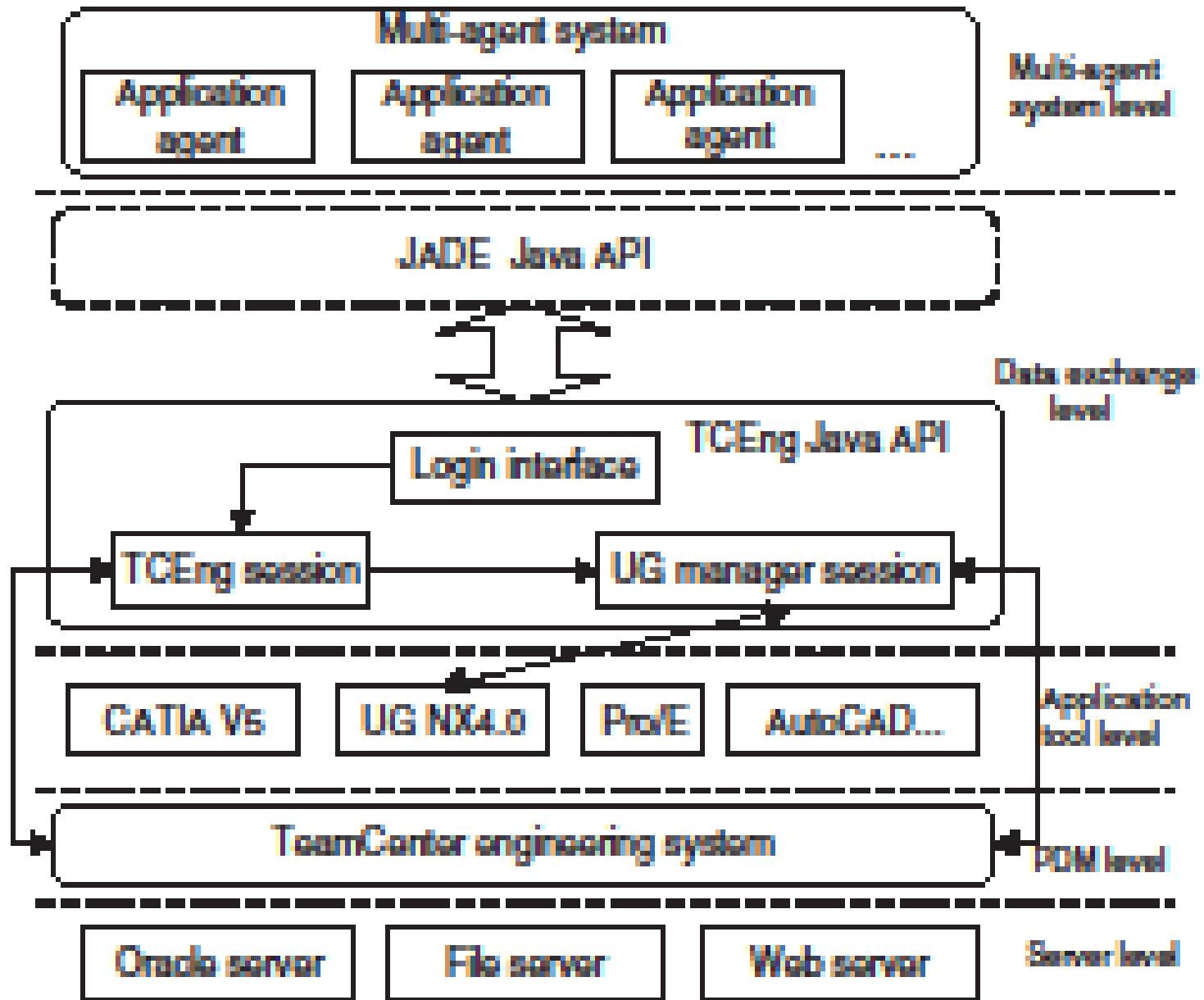
Example of MAS architecture in aircraft design

Design changes

Changes Analysis Agent

request of information

Aircraft Design Information Base

information about file

tasks

Design Changes Agent

changed file

new information for different users
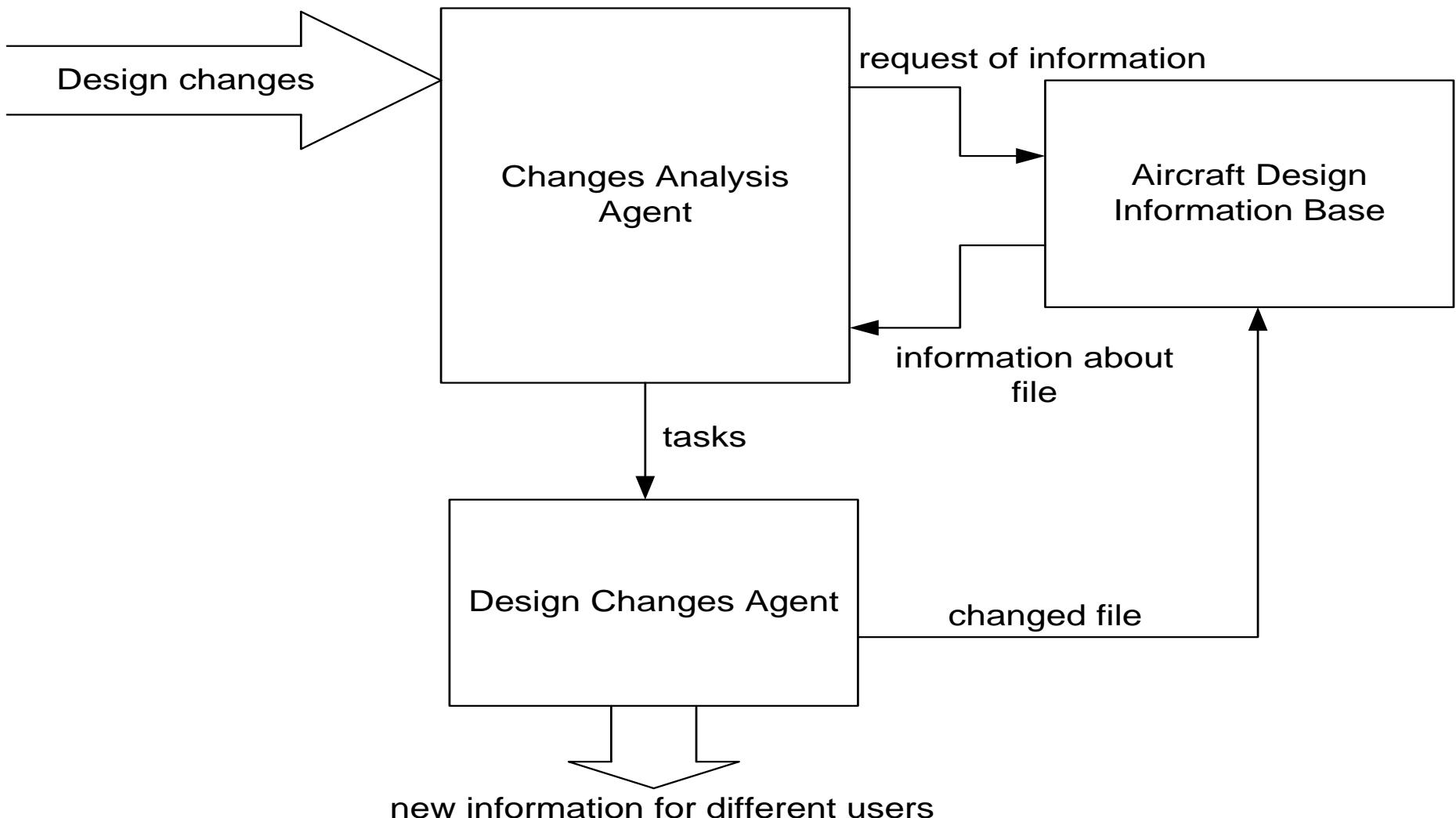
MAS architecture description

Changes Analysis Agent receives new 3D-files (GM and MPM) from designers, sends the request of the information to the knowledge base of designing of the aircraft about a situation with the given system, receives an old file, analyzes differences and sends the task to Design Changes Agent where there is a work with a file according to tasks.

The information with the changed file comes back in the knowledge base of designing of the aircraft. Design Changes Agent comprises the information about the given changes for different users.

Thank you for your attention!

The course theme:

Engineering and computer graphics-2.
3D Modeling

Konotop

Dmytro

Ihorovych, PhD

konotop.dmitriy@gmail.com

Lecture 10
Models and documentation production in the different design stages.
Preparation of drawings and documentation for manufacture.

Main aircraft design stages with using IT
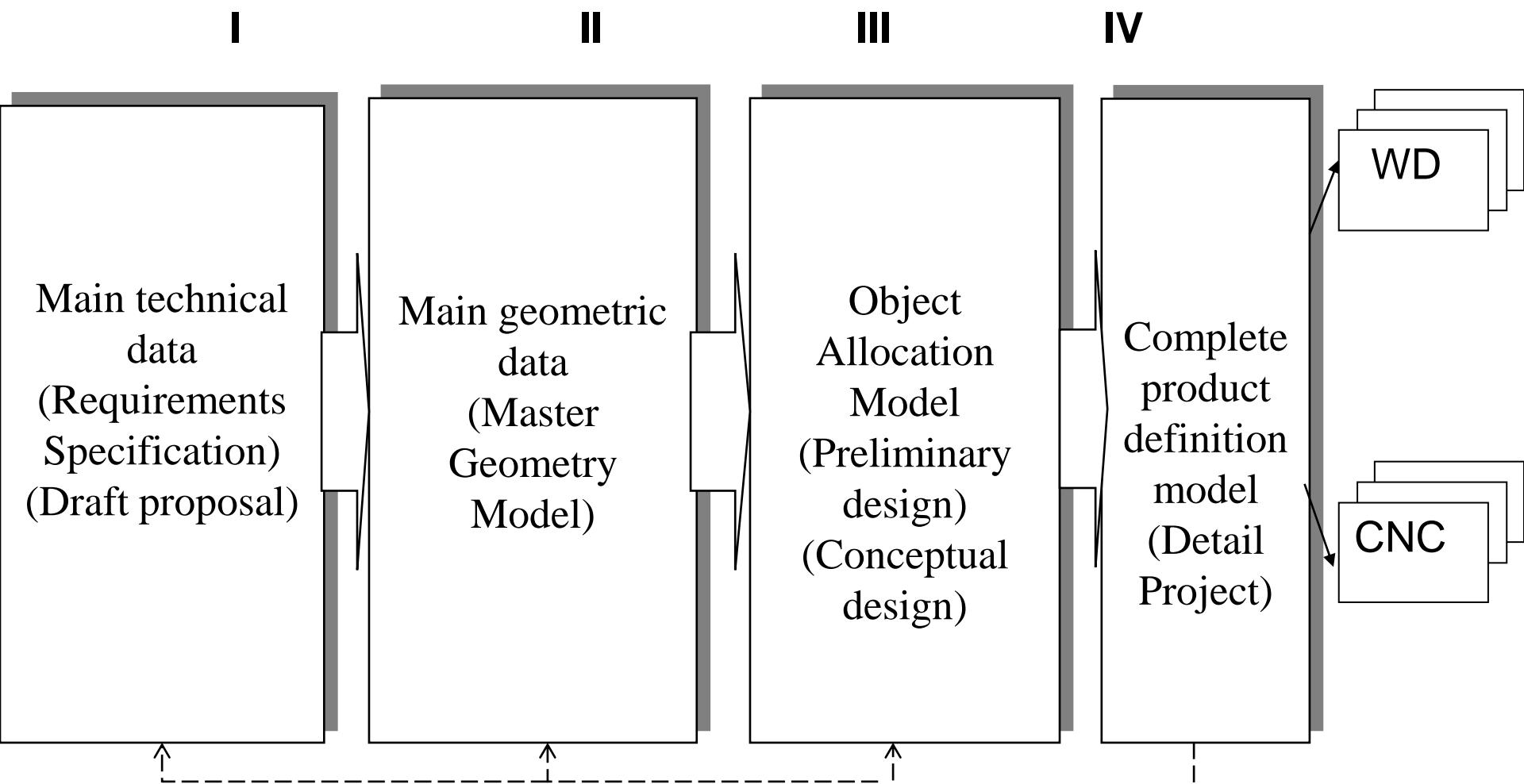
Introduction

Introduction of information technologies into the processes of life cycle of a product and document circulation at the enterprise demands definition of new concepts, such as electronic technical documentation, information object, the electronic digital signature, etc.

Definition of these concepts is necessary for standard maintenance of works on management of a product configuration in integrated information CAD/CAM/CAE/PDM environment.

Electronic technical documentation of product projects in computer information technologies should be developed and traced according to the standard and methodical documentation, taking into account their changes throughout all life cycle of a product and to be located in the uniform integrated information environment of the project.

- **Electronic technical documentation (ETD)** is the document containing the established set of the technical information on object which can be processed as a unit. It is created, stored and transferred by means of electronic means, affirms when due hereunder, can be presented in the form, suitable for visualization and the press.

- **The electronic digital signature (EDS)** is special cryptographic means of maintenance of authenticity, integrity and authorship of electronic technical documentation. EDS connects the maintenance of the document and the identifier of the signing person and does impossible change of the document without infringement of authenticity of the signature. Formation of EDS is provided with special software.

    Now, signing and statement of ETD is made by means of options of the project (has developed, has checked up, the technological control, normal inspection, has confirmed …)

Integrated information environment (IIE) of the enterprise is intended for providing of access to all authorized users to all developed electronic technical documentation of a product and available other information in directions of activity of the enterprise.

Generally IIE of the enterprise consists from:

- Databases (DB) of products;
- Databases of the standard environment of the product project;
- Databases of the methodical environment of the product project;
- Databases of help data files on various processes;
- Databases on a control system of the project and management of a configuration;
- Knowledge bases of divisions of the enterprise about a product;
- Information on the enterprise;
- Data on economy and the enterprise finance;
- Data about enterprise external relations;
- Data about the industrial-technological environment of the enterprise;
- Data about quality system;
- Other structured information of the enterprise.

Presented in IIE DB products should provide access to the authorized users to the information about ETD, both in a mode only for reading and changes.

ETD product databases are developed and change throughout all life cycle of a product according to the standard and methodical documentation.

In a control system of a product configuration at each stage of its life cycle all documents, by means of interaction with IIE are considered.

The product DB is formed of the electronic engineering specifications established by standard and methodical documents of the project, and changes to it in the form of notices, preliminary notices, technical deviations and deviations

Information object

The information object (IO) contains the information necessary for formation of electronic engineering specifications of the product project:

- Design;
- Technological;
- Industrial;
- Operational;
- Repair
- Other;

And it is tracing throughout all life cycle of a product.

On structure IO are conditionally divided on:

- IO individual type - simple (primitive things);
- IO compound (contextual) type - difficult.

Simple objects concern information objects of individual type, such as text fragments, graphic representations are indivisible fragments of data in the form of separate files. Objects of individual type are in structure of electronic technical documentation at the bottom level of hierarchy.

Information objects of compound type include IO individual type or IO compound type of lower level of hierarchy.

IO are represented in IIE only as a part of electronic technical documentation.

The description and structure of electronic technical documentation

For ETD account in a control system of a product configuration, it are exposed to classification and identification.

ETD classification should correspond to the standard and methodical documentation operating at the enterprise.

Each class of documents has the features and characteristics, the general standard base, templates for working out. Classes ETD concern:

- Text documents (including tabular);
- Graphic documents;
- 3-D models;
- 2-D structures;
- Other
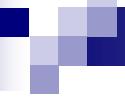
ETD has two forms of representation: internal and external.

- **Internal ETD form** - representation ETD on the machine carrier or in a computer memory in the form of a file or a set of files.

- **External ETD form** - representation ETD in the form of suitable for visualization and printing.

It is possible to state **internal representation ETD** in the form of two parts:

- Properties;
- Initial files - information objects.

Properties ETD part includes:

- Key attributes;
- The administrative;
- Attributes of history of formation of the document and modification;
- The attributes containing the information on software product in which they are developed also its version;
- Other

ETD requirements

For maintenance of management with a product configuration in PDM system all documentation on the project should be presented in the form of ETD.

For definition of requirements to the various ETD classes describing a configuration of a product at stages of its life cycle, it is necessary to make their lists, to describe features, to define communications and dependences on others ETD a hierarchy highest level.

In PDM system all ETD should be considered and traced throughout product life cycle as such which define the functional, physical and distributed configuration of a product.

For maintenance of management with a product configuration in PDM system ETD should have the obligatory attributes specified more low.

The structure and the list of attributes of each kind of ETD should be defined by corresponding templates - superstructures which will be developed for each class ETD at stages of life cycle of a product. For example, at a design engineering stage following kinds of ETD, as a rule, are developed:

- Structures of assembly units;
- Specifications of assembly units;
- Assembly drawings;
- Instructions (on assemblage, the control);
- Calculations (strength);
- Models of all entering details, including "non drafting";
- Drawings (drawing details);
- lists of drawings;
- The sheet of specifications;
- The sheet of purchased completing products;
- The notice;
- The preliminary notice;
- Other

Properties of ETD part

For management of a configuration of a product throughout its life cycle the Properties ETD part, basically, can be described the attributive information.

Key attributes - obligatory attributes of any ETD. They contain identification data about the most information object and data about an element of a configuration which they describe. Key attributes of ETD concern:

- A designation;

- The name;

- Primary application - a designation of the higher document (where enters);

- An action series;

- A functional code of system and a subsystem to which belongs ETD;

- The primary source;

- Presence of functional parameters;

- Other attributes which can be added as required (under requirements of departments)

- The attribute "designation" contains designation of ETD on the basic inscription of the document.

- The attribute "Name" contains name of ETD.

- Attribute "Primary application" - designation ETD where the given document for the first time enters, i.e. a following highest level of hierarchy.

- Attribute "an action Series" - a designation of a series of action of the document (on a product series).

- Attribute "the Functional code" - a designation of a functional code of system and a subsystem which describes data of ETD.

- Attribute "Primary source" - a document designation on which base it is developed ETD and on which it depends.

- The attribute "Presence of functional parameters" - specifies in presence of functional parameters in the document: "-" - at their absence, "+" - at presence. ETD which have additional functional parameters, are subject to the special account and the control which will be stated in other document.

Administrative attributes are the attributes with which are allocated ETD in the course of scheduling on their working out. They do not influence directly a product configuration, but can be registration and processed in a control system of a product configuration.

Administrative attributes contain data about developers of ETD throughout its life cycle, signs and structural characteristics of ETD.

It is possible to carry to administrative attributes:

- № a schedule on performance of design works;
- № of parts of schedule;
- A designation of the start document (the office memorandum or the notice);
- The work name;
- A department code;
- Labor intensiveness of work;
- Term planned;
- Term real;
- Labor intensiveness planned;
- Labor intensiveness real;
- Other

Attributes of authorization - obligatory which specify in developer of ETD and contain surnames of persons checking, matching and confirming it. They should be in project options in which are developed ETD, and to be transferred in IIE in the automated mode on demand.

Attributes of authorization concern:

- has developed;
- has checked up;
- Durability;
- The chief of design department;
- Normal inspection;
- The design control (at presence);
- has confirmed;
- The leading designer on a product;
- The technological control;
- It is matching (corresponding departments and surnames).

Attributes of history of formation of the document, modification and the status are obligatory attributes of ETD. Concern:

- The start or change document;

- change number;

- The document status.

The attribute "the start or change Document" contains a designation of the primary document of start (in the basic inscription) complete set ETD or a designation of the document on change.

The attribute "№ changes" - contains a serial number of change of ETD - under the notice on change - for primary start - "in" (again), further, for changes - the Arabian figures on increase.

The attribute "the document Status" - contains the data defining in what condition is ETD:

- Operating - by default a crossed out section "-";

- Limited and replaced on …- letters - "LR", a designation of the replacing document;

- Limited without replacement - the letter - "L";

- It is cancelled and replaced on - letters - "CR" and a designation of the replacing document;

- - It is cancelled without replacement - the letter "C".

Файл   Изменить   Вид   Вставить   Формат   Инструменты   Сборки   Tex. условия   Информация   Анализ   Настройки   Окно   Крепеж   Справка

Начало   Поиск команды

Нет фильтра выбор   Вся сборка

Вид моделирования 'ГЛАВНЫЙ ВИД' выбранный

Навигатор модели

Имя ▲	Слой	Комментар...
Режим истории		
Виды модели		
"ISO" (Рабочий)		
"ГЛАВНЫЙ ВИД"		
"Изометрия"		
"СЛЕВА"		
"Сверху"		
"Сзади"		
"Слева"		
"Снизу"		
"Спереди"		
"Справа"		
"ТТ"		
"Трехмерный"		
Фильтры сборки ТУ		
Камеры		
PMI		
История модели		

№ осей шп.   31   32   33   34   35   36

Ось стр. 6 прав.
5 прав.
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1 лев.
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6 лев.

ПСС

1. Модель мастер-геометрии 178.00.0280.200.000mg.
2. Требования к форме и качеству внешней поверхности по 178.00.1101.001.000И.
3. Неуказанные предельные отклонения размеров, формы и
   расположения поверхностей по ОСТ1 00022-80.
4. * - размер для справок.
5. Покрытие обшивки после склейки с подкладными листами:
   внутренняя поверхность - Гр.ЭП-0215 456 ОСТ1 90055-85, Эм Aerodur C21/100 RAL №6029 1 слой;
   наружная поверхность - Гр.ЭП-0215.469 ОСТ1 90055-85, кроме нанесения зон клея ВК-25.
6. Клепать по ТИ36-21-86, ТИ36-53-94 на герметике У30М3С-5М.
7. Покрытие головок заклепок : Гр.ЭП-0215.470 ОСТ190055-85, Эм. Aerodur C21/100 RAL №6029 1 слой,   кроме выходящих на ТК.
8. Металлизация по ОСТ1 01025-82 заклепками.
   Подготовка и защита мест металлизации по ТИ36-8-91.
9. Подкладные листы клеить к обшивке клеем ВК-51А по ТИ16-506-12,
   с защитой валиком герметика У30М3С-5М.
10. Маркировать (Чк) и клеймить (Кк) по ОПИ-63-06.
11. Стрингеры, шпангоуты и деталь 178.00.0280.200.005 устанавливать
    на внутришовном герметике У30М3С-5М в соответствии
    с инструкцией на сборку 148.20.0001.000.000И, глава 1,6.

Закончить эскиз

Thank you for your attention!

Product life cycle (LC) structure by Zeid

Aircraft basic units

It is possible at aircraft to allocate as the basic units:

- Airframe;
- Landing gear (chassis);
- Engines;
- The control systems serving an airframe, engines and the chassis;
- Mechanisms and the units providing performance of special functions;
- The special equipment and a communication facility.
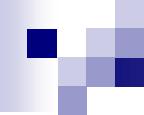
Aircraft
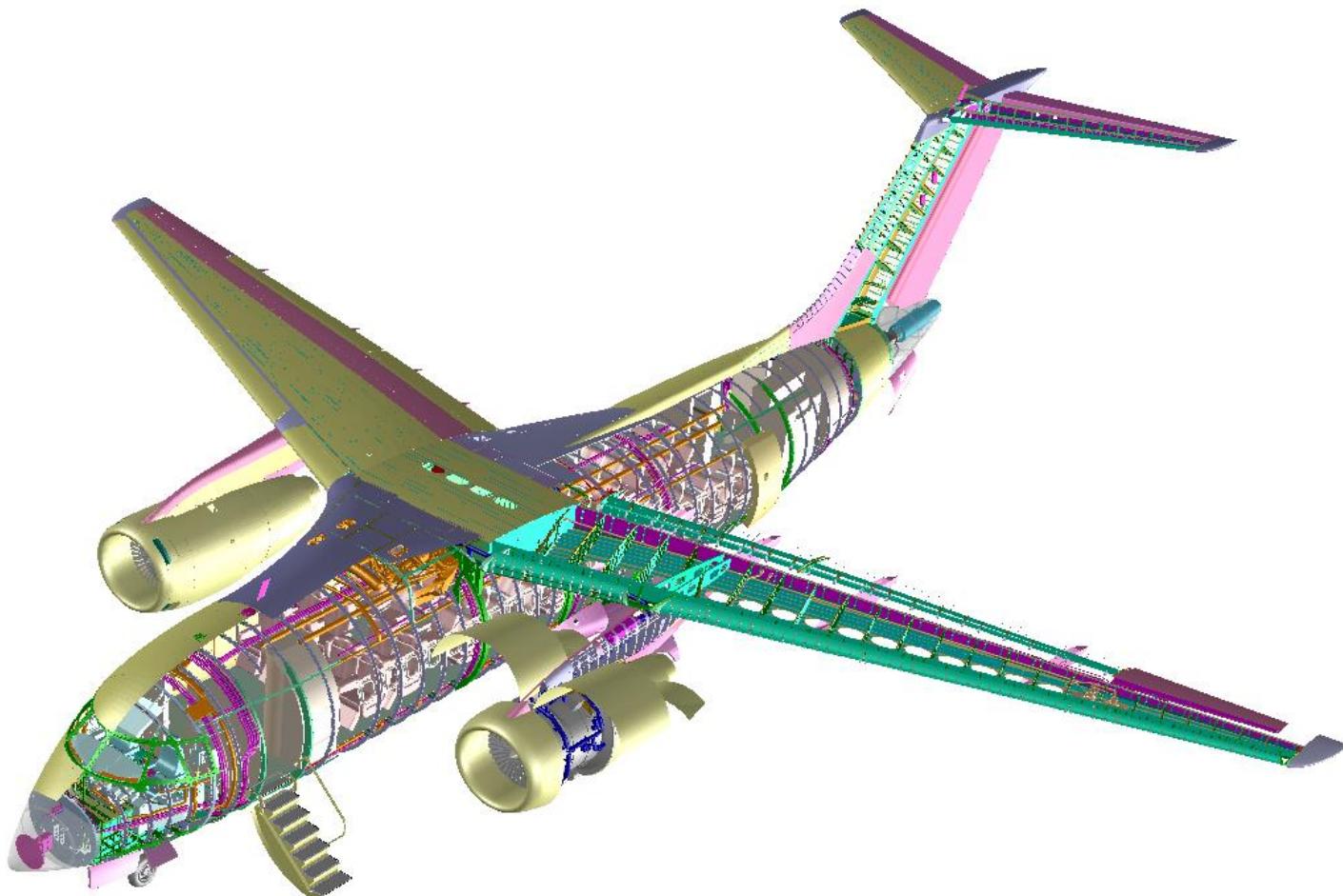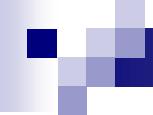
On a design and in the technological relation the specified units considerably differ from each other, therefore their manufacturing demands manufacture specialization. So, for example, in designing and manufacturing of airframes is engaged special design offices and the factories making specialized branch of aviation manufacture - aircraft construction.

Corresponding specialized branches of aviation manufacture are engaged in designing and manufacturing of engines, devices of various special equipment: propulsion engineering, instrument making, etc.
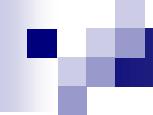
Aircraft construction represents the basic link connecting among themselves various branches of aviation manufacture as at aircraft constructing factories along with manufacturing and airframe assemblage installation and check in operation the engines is made, special equipment and other units of the aircraft.

The aircraft airframe consists of details, nodes, panels, compartments and units.

- *The detail* is called the elementary part of a product made of the whole piece of a material. The detail is a primary element of assemblage.

- *The node* is called some the details of a skeleton connected among them: modular longerons, frames, ribs etc.

- *The panel* represents connection of several details of a skeleton with a skin.

- *The unit* is a finished in constructive and technological relations a part of the airframe consisting of panels, nodes and details. Units are a wing, a fuselage, aileron, the stabilizer etc.

- *The compartment* is a unit part.

The constructive-technological partitioning of aircraft compartments and sections

- 1 - Forward fuselage (F1)
- 2 - Fuselage mid section with wing fairing and landing gear fairing (F2)
- 3 - Fuselage rear with fairing of vertical-tail (F3)
- 4 - Vertical-tail with rudders
- 5 - Tail plane with elevation rudder
- 6 - Center wing section
- 7 - Swing section of wing left
- 8 - Swing section of wing right
- 9 - Pylon left
- 10 - Pylon right
- 11 - Power-plant left
- 12 - Power-plant right

In assembly shops of aircraft design enterprise following kinds of works are carried out:

■ Assembly, including installation of details of an airframe in assembly position, their connection in nodes, panels and units. Airframe assemblage as a whole is the closing stage of these works;

■ Assembly, connected with installation on an airframe of engines, devices, control systems and a various sort of the special equipment.

The volume of assembly and installation works depends on quantity entering into a design of an airframe of details and quantity of mechanisms established on an airframe, devices and special equipment.

About volume assembly and installation works the following data concerning the four-motor aircraft can give representation. In a design of a airframe of such aircraft is to 60 000 various details, by the aircraft it is established more than hundred electric motors, 150 various devices, some radio stations and are mounted hundred of meters of various communications (electric, hydraulic and pneumatic systems).
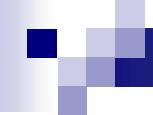
The technology of assembly works is developed taking into account properties of materials from which airframe details are produced, and ways of connection of details among themselves.

During working out of technology of assembly works the special attention should be given to questions of mechanization and automation of these works that allows mastering faster new products in a batch production, and provides their release in demanded quantities.

In aircraft construction mechanization and automation of assembly works develop on a way of the further introduction to manufacture of riveting-assembly and welding-assembly machine tools and automatic machines, mechanization of processes of installation and removal of products from assembly adaptations – building berths, mechanization of statement of bolts and screws.

The mechanized product lines for assemblage of nodes, panels and units are besides, created.
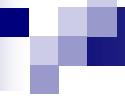
Necessity of partitioning of an airframe of the aircraft on details, panel nodes, compartments, and units is dictated by requirements of manufacture and necessity to have constructive, operational sockets and joints.

Airframe assemblage is being organized under the scheme of parallel-serial operations, since assemblage of substructures, nodes, panels, units and finishing the general assemblage of the aircraft as a whole.

On the basis of the developed sequence of assembly operations the scheme of assemblage which is one of the basic technological documents for assembly departments is made.
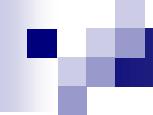
Instructions on an order of acquisition of a collected product are brought in the assemblage scheme by details and nodes, and also requirements specification on details and the nodes defining, in what kind they move on assemblage.

High requirements are shown to the details entering into joint connections as their slightest inaccuracies lead to the big adjusting works and break all system of interchangeability of details. The technological scheme of assemblage, defining an assembly order, is at the same time and the basic document for working out of requirements specification on assembly units - details, nodes, panels and units.
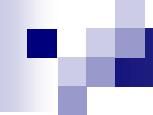
At assemblage of an airframe of the aircraft it is necessary to consider rigid requirements concerning accuracy of reproduction of its aerodynamic contours and achievement of the set durability of nodes and units.

By working out of technological processes of assemblage, adaptations and the tool at a choice of the equipment for performance of assembly works it is necessary to be guided by the requirements shown to accuracy of the collected node or the unit.

At airframe assemblage distinguish following principal views of works:

The central assemblage including assemblage of separate panels, ribs, longerons, frames etc.;

The modular assemblage representing assemblage of separate compartments and units;

The general assemblage, i.e. Assemblage of an airframe from units with the subsequent installation on it of the various equipment, devices and mechanisms.
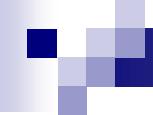
The volume of assembly works is defined by an airframe design, physical and mechanical properties of materials of which it is made, and kinds of preparations of which separate details and nodes are made.

With introduction in a design of the aircraft of monolithic details and panels the volume of assembly works decreases, and mainly as a result of reduction of amount of works by central and modular assemblages.

METHODS OF ASSEMBLAGE AND ASSEMBLY BASES

Assemblage represents set of technological operations on installation of details in assembly position and to their connection in nodes, the panels, units and the aircraft as a whole.

The sequence of performance of assembly operations in many respects depends on a design, overall dimensions and rigidity of collected details.

There are some methods of the assemblage, that differed by kind of the tool applied at assemblage, assembly adaptations and the equipment. The greatest distribution between them has received: assemblage on a base detail, on a marking, on assembly apertures and assemblage with application of special assembly adaptations.
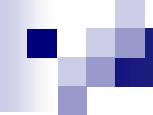
Assemblage on a base detail - process at which one of details accept for base, and to it in certain sequence other details entering into the collected node attach. This method is applied at assemblage of a product from the rigid details keeping under the influence of a body weight the form and the sizes. Details thus entering into a product divide into some assembly groups, each of which collect on the base detail entering into given group.

For the explanatory of process of assemblage on a base detail we will consider assemblage of the power cylinder of management by landing guards of the aircraft.

On a base detail, as a rule, products collect on impositions, sometimes apply also adaptations which keep a collected product and turn it in position convenient for the collector.

а)
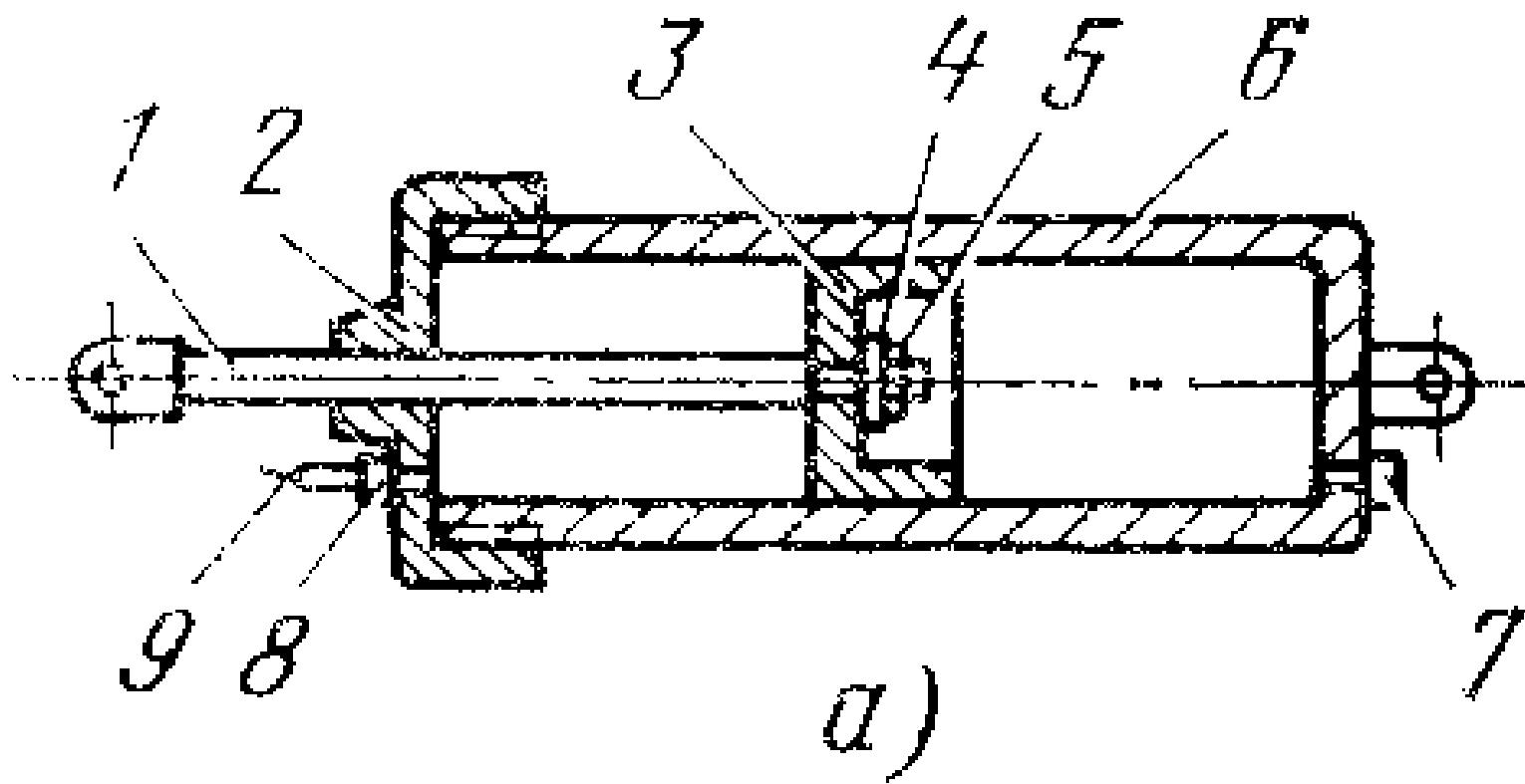
Assemblage according to assembly apertures (AA) - process at which the relative positioning of collected details is defined by position of assembly apertures available on them. At basing on AA collected details are combined with each other and for connection of details into assembly apertures insert clamps.

Basing on AA possible at formation of contours of the unit and installation in assembly position of elements of a longitudinal and cross-section set **(skeleton).**
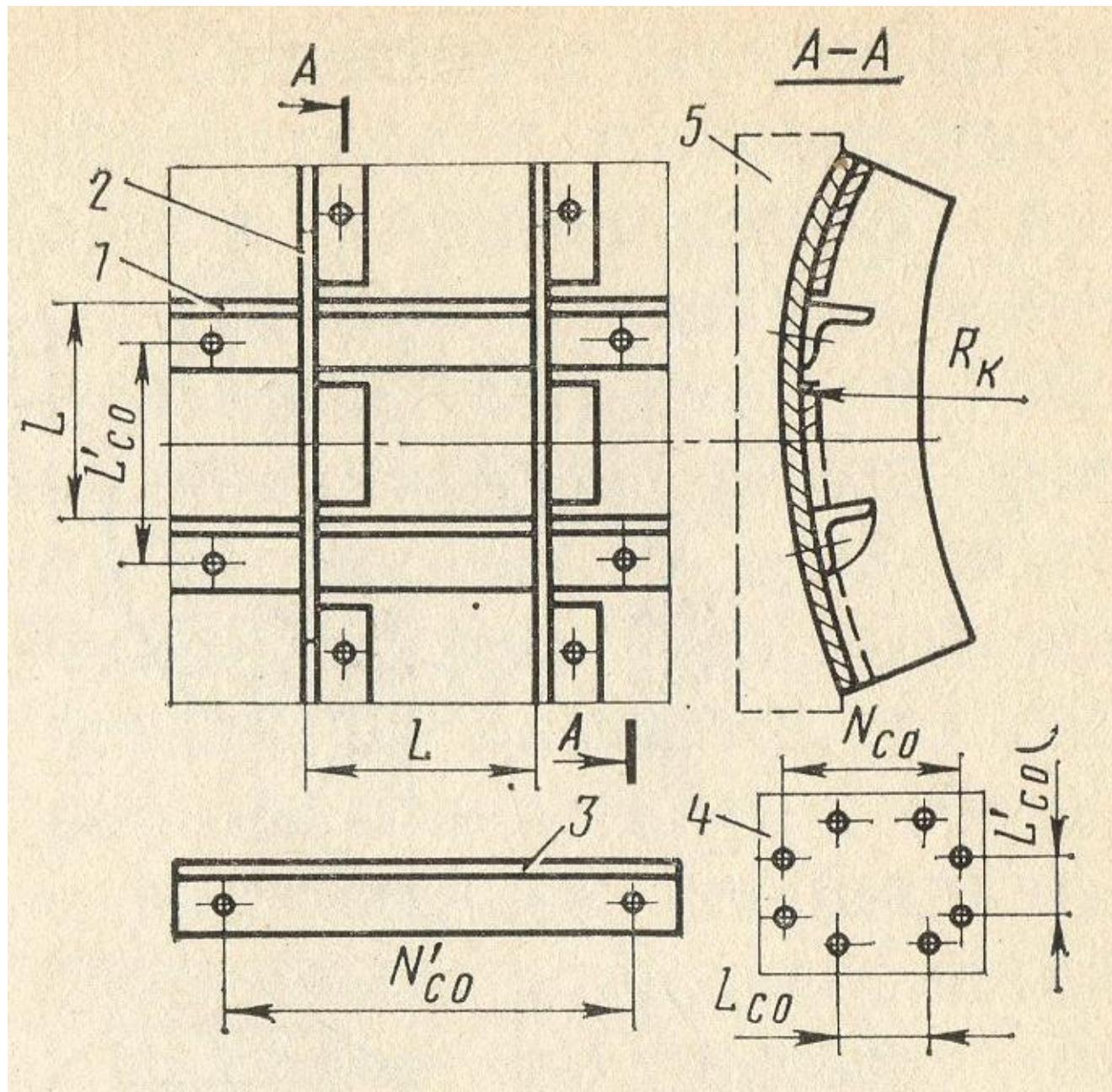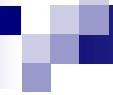
Assemblage according to marking - process at which mutual position of the details entering into knot; define directly measurement of distances between them and on the risks put on details at a marking.

Assemblage on a marking is made by means of universal metalwork tools and adaptations (clamps, scribing instrument, a core, meter, compasses, a manual and desktop vice etc.). The details which have arrived on assemblage, mark manually or a photo contact method (on special templates made).

Installation of details in assembly position on a marking is operation laborious and long. Interchangeability of knots and panels at assemblage with a marking is practically impossible.

Assemblage on a marking apply both in skilled, and in a batch production at small programs of release of products.

а)   б)   в)

г)   д)
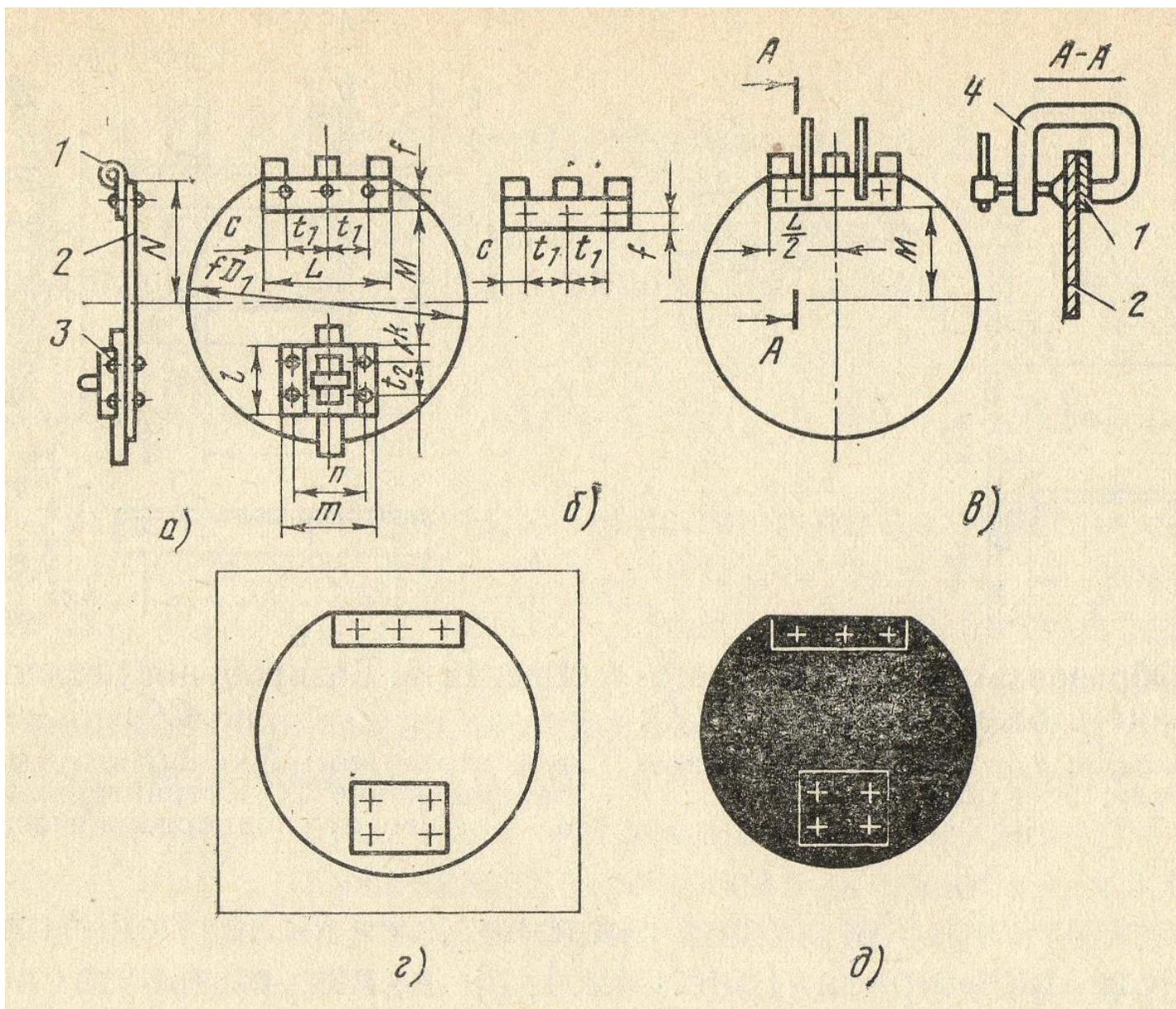
Assembly devices provide demanded mutual position of the assembled details, certain position of the processing tool concerning a detail, form giving to insufficiently rigid details and nodes in the course of assemblage. Following advantages in comparison with assemblage on a marking are thus created:

- The marking and adjustment of details is excluded;

- Assemblage process is accelerated and facilitated;

- Interchangeability of collected nodes, panels and units is reached;

- Mechanization of process of assemblage is possible.
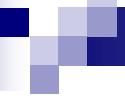
It wide application of assembly adaptations also speaks serial factories by manufacture of aircraft.

In aircraft construction at assemblage of nodes and units in adaptations apply specific ways of basing which in many respects depend on a site and appointment of collected details in a product.

So, at basing of the details defining external contours of units, as bases use surfaces of details of a skeleton and the skins which are coordinate fixing apertures (CFA), and at basing of joint nodes and nodes of fastening of the equipment to airframe elements use apertures for joint bolts (AJB).

REQUIREMENTS TO THE DETAILS ARRIVING ON ASSEMBLAGE

It was already noticed earlier, that details are more precisely made than it is easier to assembly them. From here manufacturing with high accuracy of interchangeable details is one of the primary goals of manufacture, its procuring and machining process shops.

Accuracy of manufacturing of rigid details of the simple form is easy for reaching, considering application possibility to them of system of admissions and universal measuring tools. At manufacturing of aircraft details of the difficult form and small rigidity the system of normal plantings and admissions does not provide demanded accuracy owing to what rigid carriers of the sizes are applied to the control of these details and the form. Besides, for the sizes of some details allowances which act in film in the course of assemblage are given. The sizes of allowances and special requirements are brought in specifications on detail delivery. Thus, the details arriving on assemblage should correspond to data of the drawing and satisfy to specifications on delivery.

Following basic demands to the details arriving on assemblage are made.

A) On interchangeability:

- Conformity within the established admissions of the actual sizes of a detail to its sizes under the drawing;

- Reproduction of a relief required under the drawing and forms (contours, cuttings, sliding bevels);

- Correctness of position of assembly, directing and base apertures concerning base axes of a contour;

B) On strength and operational properties:

- Use of materials of required marks, performance of conditions of heat treatment, maintenance of demanded quality of a surface and the set weight;

- Application of the set anticorrosive and decorative skins;

C) Under the special requirements stipulated in drawings, technical and technological conditions:

- Keeping of the set backlashes between glued or encapsulated surfaces;

- Preservation of perpendicularity of axes of apertures for butt bolts to end faces of butt frames;

- Presence of allowances on processing after assemblage in finishing stands of apertures and face joint combs.

- Requirements to the details arriving on assemblage are developed after the choosing of methods of basing, and the schemes of assemblage of units are coordinated with corresponding departments, compartments of nodes

GENERAL CHARACTERISTIC OF CONNECTIONS APPLIED IN AIRCRAFT MANUFACTURING

Connection of details, nodes, panels and units of aircrafts and at assemblage is made by various ways. Connections applied in aircraft construction are divided:

- *Motionless one-piece* (riveting, welding, the soldering, gluing);

- *Motionless demountable* (bolt and screw);

- *Mobile demountable* (jointed connections, bolts, shafts and bearings).

- Motionless one-piece connections and motionless demountable connections provide invariable position of collected details and nodes from each other. Mobile connections suppose such moving.

According to constructive-technological signs connections are divided:

a) The connections which are carried out by power points (rivets, bolts, welded points).

Characteristic signs of such connections are: easing of connected details because of apertures under rivets and bolts and heating of details in a zone of statement of welded points; concentration of pressure in a detail in a zone of statement of a power point at loading designs; low labor productivity at statement of power points owing to intermittence of performance of connections;

b) Connection by a continuous seam (welding roller and fusion, gluing, the soldering). Characteristic signs of such connections: easing of connected details at their heating in the course of welding, gluing, the soldering; considerable concentration of pressure in a detail in a seam zone; a continuity of process of the connection, facilitating mechanization and automation;

c) The combined connections (spot welding + gluing, riveting + gluing, riveting-bolt connection). Such connections possess all signs of connections by power points and a continuous seam.

The choice of this or that kind of connection depends on a design of the aircraft and materials of which its compartments, nodes and details are made.

In constructions of aircraft from light alloys a prevailing kind of connection is riveting.

At manufacturing of aircraft from steels and the titan (the skin means) connections carry out electrical contact and arc welding.

At application in a design of the aircraft of monolithic panels and nodes the quantity of riveted and welded connections decreases, but the quantity of bolt connections increases. Monolithic nodes and panels in these cases connect among themselves and to a skin using bolts.

For constructions from composite materials (CM) the greatest applications have riveting, glue-riveting and button-bolted connections. For connection of packages of the big thickness and the mixed packages (CM + metal) effectively use of bolts and bolts-rivets.

Thank you for your attention!