*Journal of Machine Engineering, Vol. 10, No. 3, 2010*

*model based definition,*
*design, methods*

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# ADJUSTMENT AND IMPLEMENTATION OF CAD/CAM SYSTEMS BEING USED IN POLISH AVIATION INDUSTRY

This paper describes the detailed methods and process of creating MBD model (Model Based Definition) - presently used in aviation and automotive industry. Existing formats of the Authority dataset have been presented. Using CAD/CAM systems requires introduction of full control of all software used during entire manufacturing process. To maintain DPD (Digital Product Definition) data configuration, controlling production hardware and tools, all media created on the DPD data need to include dataset clear name, revisions level and any other additional unique client identification. There are two methods of reliable verification of data translation or transmission among CAD/CAM systems: Points Clouds and Space Analysis DMU CATIA. Today the practical preparation of technical production is made in virtual reality by the use of computer hardware and software. The purpose of this paper is to present new rules of working with CAD/CAM systems in modern enterprises using manufacturing technologies of XXI$^{st}$ century.

## 1. INTRODUCTION

**C**omputer **A**ided **D**esign (**CAD**) has its beginning in 1958 when Dwight Bauman, Steven Anson Coons and Douglas Ross, the employees of **MIT** were to make another step which was introducing of APT (**A**utomated **P**rogramming **T**ools) system by **ITRI** in aviation industry. This system has inaugurated using computers in mechanics, called now Computer Aided Design. Aviation industry and research institutes of Great Britain, France and USA have a considerable influence on Computer Aided Design software products (**CAD**) such as **GNC** (**G**raphical **N**umerical **C**ontrol), **POLYSURF**, **NMG** (**N**umerical **M**aster **G**eometry) with **BAC** (*author Malcolm Sabin*) and **DAMS** (**D**esign **A**ll **M**anufacturing **S**urfaces).

These products in connection with tools languages as **APT**, **2CL**, Profile Data, **EXAPT** enlarged constructors and technologists' possibilities. In the lapse of time the number of **CAD** systems started to increase. New products have been created: **CADDS5** by **Computervision, APT/Fmill, APT Sculptured Surfaces, CAM-X, CIS Medusa, CAM-I, Cadam**, **CATIA** (**Dassault**), **Pro Engineer**, **EUCLID** or **UNIGRAPHICS** (**Mc Donald Douglas**) and **DAMS** system in Poland [1].

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## 2. STANDARD FOR THE EXCHANGE OF PRODUCT MODEL DATA

Aviation industry has developed wide co-operation among different divisions more than other branches of industry. The variety of created **CAD/CAM** systems has forced at once the problem of their integration and data exchange between these systems.

Nowadays, one of the most important problems which constructors all over world encounter during applying electronic construction description is graphical information exchange among co-operating divisions and also integration among different computer systems.

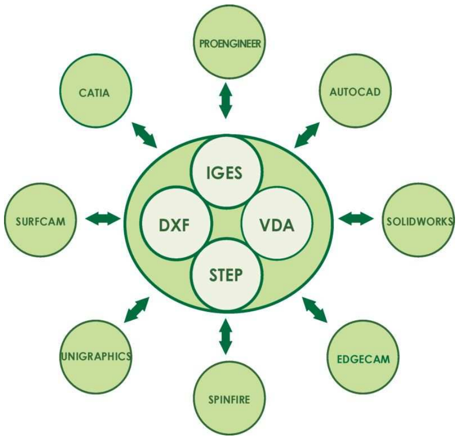


Fig. 1. Standard packets for data exchange in CAD/CAM systems [5]

Problem of data standarization connected with exchanging constructional documentation among partners using different **CAD/CAM** systems becomes more and more important issue. Systems may be integrated in different ways. That is why better solution is to use standard size of data transfer, which makes collaboration among different systems possible. The most known standard packets of data transfer are:

- **STEP** and **IGES** (**I**nitial **G**raphics **E**xchange **S**pecification) - *Great Britain* [8]
- **SET** (**S***pecifications du* **S***tandard* D'**E***xchange et de* **T***ransfert*) - *France*
- **VDA-FS** - *Germany*
- **DXF** - **AutoCad** Autodesk

- **IGES** packet transfers data between 2 different systems by creating a neutral collection. For 4 systems one needs 8 translators. Adding the 5th system requires only 2 translators, i.e. *"preprocesor"* to read and *"postprocesor" to* write (Fig. 1.). Nowadays **IGES** packet is proposed in most **CAD** systems. Its restrictions are well known, for example version number 4 does not take so called solid model (which one can now find almost in every **CAD** system) into consideration. Problems, which **IGES** standard made after international consultation, were the reason of creating and development of **PDES** Standard (**P**roduct **D**ata **E**xchange **S**pecification), which is equiponderant to **STEP** Standard (**S**tandard for **t**he **E**xchange of **P**roduct Model Data).

## 3. CAD/CAM SOFTWARE AND PART NUMERICAL DATABASES

Model-based definition involves moving away from paper drawings and other external means of product definition and making the CAD model the sole source for defining the product and mold geometries.

This is the engineering definition provided in a **3D** representation of the product, viewable on a Computer Aided Design (**CAD**) system. In addition to the Authority dataset (**CAD** model), the entire product definition may typically include additional media such as parts lists, part coordination documents, material specifications, etc.

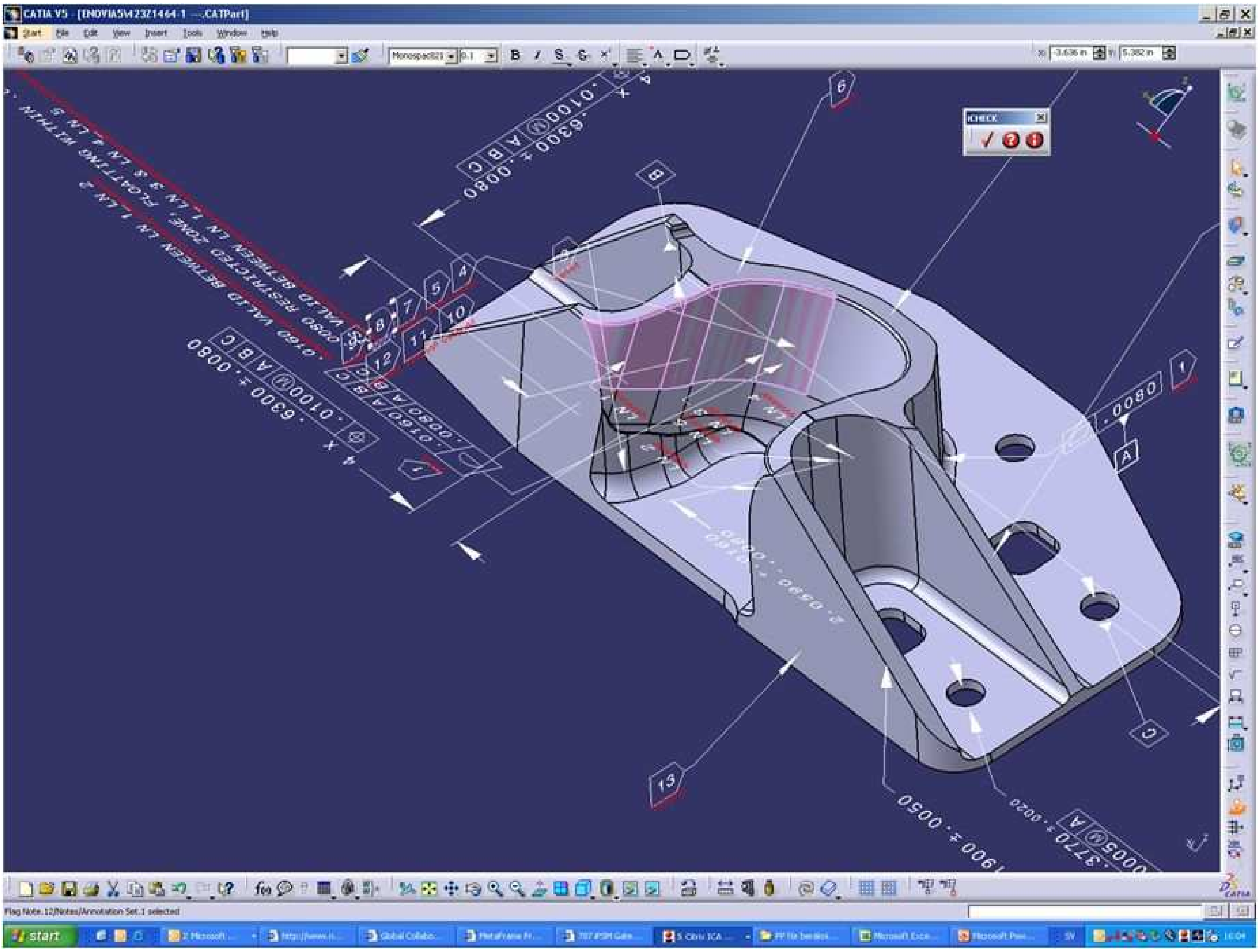

Fig. 2. Example of a Digital Product Definition DPD. The 3D Model and the engineering requirements displayed as text within the 3D viewing area of the model

**The Authority dataset** will exist in one of **four possible formats** [5]:

1. **The Authority dataset** may include both the **CAD** model and fully dimensioned **2D** drawing sheets.

2. It may include the **CAD** model and **2D** drawing sheets having engineering requirements but not all linear dimensions.
3. Or **the Authority dataset** may only include the **3D** model, with no **2D** sheet and the engineering requirements displayed as text within the **3D** viewing area of the model.
4. Or **the Authority dataset** may only include the **3D** Model and the engineering requirements displayed as text within the **3D** viewing area of the model, as well as the remaining engineering requirements (in **2D** form - notes list, part lists, etc.).

All four formats are considered **Digital Product Definition (DPD).** The second case is a reduced content format, and is sometimes labeled as **Reduced Dimension Drawing (RDD)** or **Simplified Drawing (SD).**

The third and fourth cases are termed **Model Based Definition (MBD).** Procedures introduced [7] by big companies (Boeing) are to help co-operants to improve electronic information flow during entire manufacturing process of a part (i.e. designing, realization

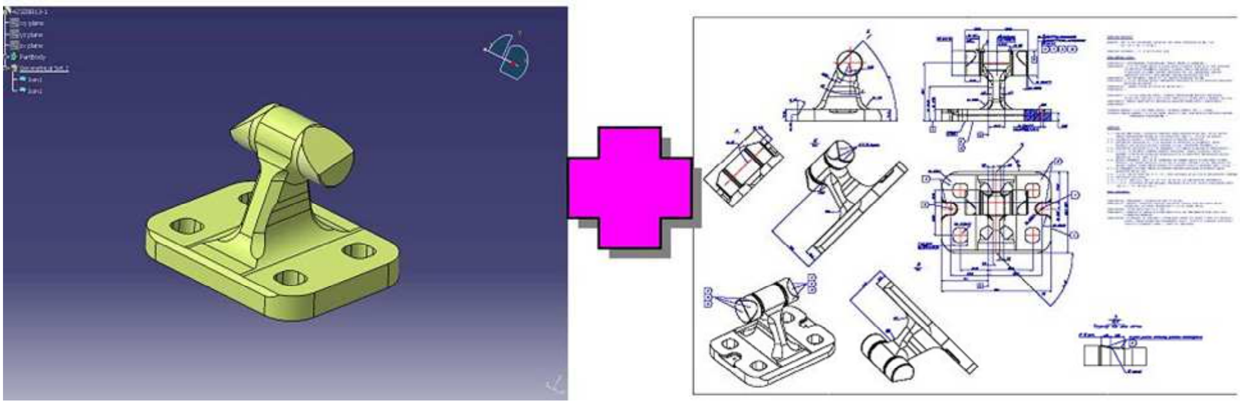

Fig. 3. Example of a Digital Product Definition DPD. The **CAD** model and fully dimensioned **2D** drawing sheets

of engineering changes, creating technological processes, simulations, tools manufacturing, machining parts on CNC machines, inspection with **CMM** (Coordinate Measurement Machine) measurements). In the past **2D** drawing sheets with geometric dimensions and tolerances were used to define a part. Next **3D** models with **2D** drawings, projections, geometrical dimensions, tolerances were used. This method is also in use today (Fig. 3). But the future will be model based definition **MBD** with one main file containing **3D** geometry data with dimension and tolerances **GD&T** (**G**eometry **D**imensions &**T**olerance) and **FT&A** (Fig. 2). So, model based definition includes one system file, model **3D** geometry, **GD&T** data with notes and comments such as base coordinate system, dimensions, tolerances, flag notes and technical comments concerning material, surface smoothness, weight and general notes.

Model Based Definition (MBD) is a process that allows the design team to input all their information into the 3D model, thus eliminating the need to create a drawing. In CATIA, this is done with the assistance of the Functional Tolerancing & Annotation

(FT&A) workbench. The FT&A workbench allows designers to add the information required to manufacture and inspect a part (e.g. dimensions, tolerances, surface finishes and flag notes) directly to the 3D model. The largest impact of implementing MBD is that the manufacturing and inspection teams now have to live without drawings. Therefore, a proper MBD implementation involves finding solutions for all departments that touch the 2D and 3D data. Model Based Definition data creation phase is essential for any company that will be creating design data without the use of 2D drawings. This creates the following benefits:

- Reduced time to design and manufacture parts.
- Reduced amount of data created, stored, and tracked for a given part.
- Increased accuracy through the use of a single object for all design, manufacturing, and inspection information.
- Increased data re-use throughout all departments.
- Designers no longer need to perform tedious drawing creation.
- Reduced printed documentation which has a limited effectivity.

The largest impact of implementing **MBD** is that the manufacturing and inspection teams now have to live without drawings. Therefore, a proper MBD implementation involves finding solutions for all departments that touch the 2D and 3D data. These solutions must support the fundamentals of the current methodologies, while strategically aligning them with the use of a 3D model as the source of all their critical information.

## 4. MODEL BASED DEFINITION DATA CREATION

In this phase, the design environment will be modified for use with MBD methodologies, the design team will be instructed on how to efficiently and accurately add manufacturing and inspection information to the 3D model and company specific best practices will be established and documented. This phase is essential for any company that will be creating design data without the use of 2D drawings. Tasks include:

**1.** Model Based Definition **MBD** Assessment
- *Identify CATIA V5 Administrators and Super-Users.*
- *Review MBD goals and objectives.*
- *Review MBD functions and pre-defined templates and processes.*

**2.** CATIA V5 Administration
- *Review current CATIA V5 environment.*
- *Configure CATIA V5 environment.*
- *Review current Drafting Standards and configure for* ***FT&A.***
- *Review CATSettings and configure for* ***FT&A.***
- *Deploy CATIA V5 environments and CATSettings.*

**3.** Model Based Definition CATIA V5 Implementation
- *Develop CATIA V5 strategy for* ***MBD****,* ***FT&A.***
- *Implement start templates.*
- *Implement methodologies.*

- *Test and validate MBD template and methodologies.*

**4.** CATIA V5 FT&A Best Practice Development Plan On-Site
- *Review and implement Best Practices on defined methodologies.*
- *Review and implement methodologies for supply chain, quality control and/or manufacturing.*
- *Manufacturing.*

**5.** MBD CATIA V5 Training Session
- *Attend the CATIA V5 Functional Tolerancing & Annotation (FT&A) Training.*
- *Up to 10 leaders.*
- *On-site in customer training facility.*
- *Provide post training "on the job" suppor.t*

## 5. QUALITY SYSTEM FOR DIGITAL PRODUCT DEFINITION

Boeing company has introduced D 6-51991 procedure (Quality Assurance Standard for Digital Product Definition at Boeing Suppliers) to define correctness of using computer systems for production and to control the integrity of computer systems. The procedure includes all requirements which should be fulfilled in order to become a qualified Boeing supplier. One of main requirements is also verification and control of the software used – so called **P**roduct **A**cceptance **S**oftware **PAS** [7]. PAS means the introduction of full control of all software used during entire manufacturing process. Numerical model backup copy should be made and stored on another computer. To maintain **DPD** data configuration, controlling production hardware and tools, all media created on the **DPD** data need to include dataset clear name, revisions level and any other additional unique client identification. This requirement is applicable to:

- *Computerized measurement system (**CMS.**)*
- ***CAD /CAM** software and datasets.*
- *Data analysis software.*
- *Customer delivered datasets and datasets.*
- *Standard packet of data exchange **IGES, STEP.***

**CAM** software and datasets need to have visible revision level and have to be directly related to **DPD** data file, which was used to create derived data (*all data created with or on the basis of source main data*). Software version level and

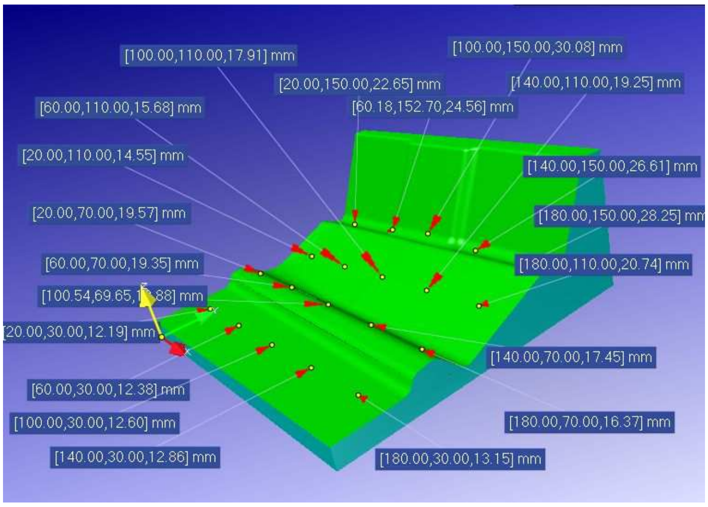


Fig. 4. The model with points clouds after translation

**CAM** data need to be included in each report of testing validation for software and datasets. FAI report also needs to contain such information as **CAM** software and datasets, level of revisions used during manufacturing of the part. Any change in **CAM** software or datasets must result in increasing revision level. Before accepting the part, **PAS** software will be validated, no matter who the software supplier is. After verifying **CAM** software and numerical datasets (according to validation ***PAS*** procedures) and approval from Quality Manager the **CAM** software may be used to part acceptance [7].

Obsolete software versions are removed from user access, the current version master copies are securely stored – password protected and the Supporting programmer is responsible for control over the PAS. This person also must make a backup copy of the accepted PAS and store it in separate location. Procedure during acceptance of new version of software is given below:

- install new version of software as a second,
- open both applications and in both of them open model that contains much information (geometrical, text with developed tree of model structure),
- check that all information shown in the old version is also shown in new version of software,
- check that the drawings of the given part generated with old version and new version of software contain the same information and dimensions, surface shape, etc. not changed,
- when the part is manufactured the dimensions shall be inspected and compared with measurement results of the old revision of software,
- after getting positive results of this analysis the measurement report is signed by CMM operator, engineer, software administrator and network administrator.

There are two methods of reliable verification of data translation or transmission among **CAD/CAM** systems [5]:

1. **Points clouds**

For defining correctness of translation the following is needed:

- Creating numerical model of surface.
- Overlaying the model with points clouds after translation – Fig. 4.
- Translation of the model to the other **CAD/CAM** system.
- Measuring the points and determine their accuracy comparing to the original points.

Fig. 4 presents the results of measurements after points clouds translation.

2. **Space Analysis DMU CATIA**

To achieve acceptable result when validating conversions of datasets from Catia V5 into in-house systems, a revised process for validating conversion of datasets is needed. Recommendation is to use Catia V5's Spatial Analysis functions to compare converted data (*DMU Space Analysis*), intended to use for final inspection, towards the master model received from Boeing.

- Measuring the points and determine their accuracy comparing to the original points

Fig. 4 presents the results of measurements after points clouds translation.

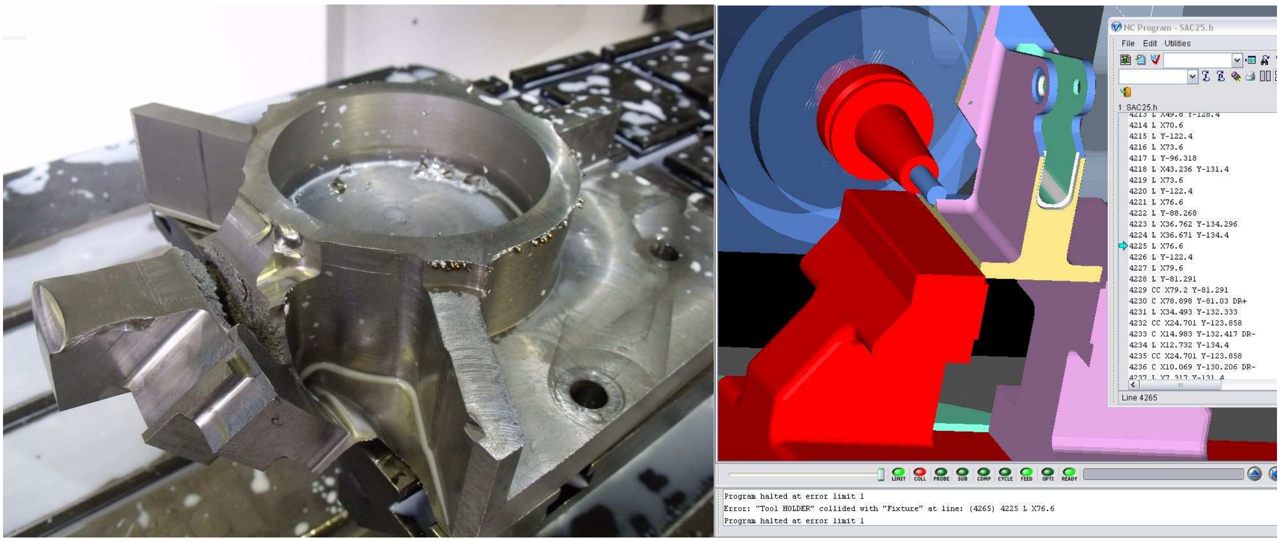


Fig. 5. Examples of real and virtual collisions on CNC machines

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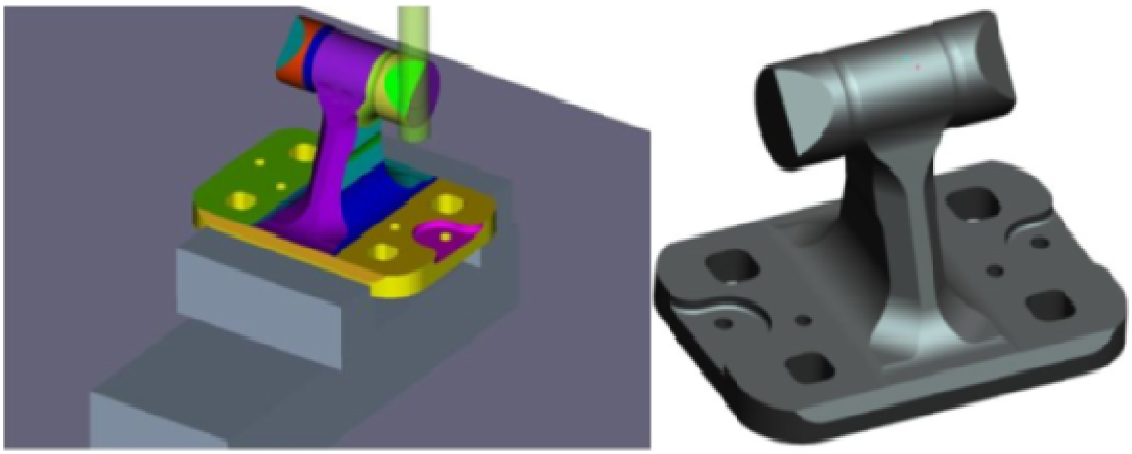

Fig. 6. The part as a result of virtual machining simulation and the real part made on a CNC machine

**CAD/CAM** systems being used and their electronic data related with numerical part database have their own procedures in quality assurance system. These procedures describe information flow during entire manufacturing process of the part.

Over the years the aviation industry companies have elaborated standards of working with **CAD/CAM** systems. Standards include the following issues:

- Layers arrangement.
- New projects naming and numbering rules.
- Drawings creation rules.
- **3D** models creation rules.
- Rules of creating models of parts machined on CNC machines.
- Notes, comments, tolerances.
- Basic Datum, Local Datum.

What are the basics of modern MBD?

- One file system.
- Contains 3D model geometry.
- Contains GD&T information & other annotations.

•Datums.
•Dimensions.
•Tolerances.
•Flag Notes.
•Annotations.

- *Material.*
- *Surface finishing.*
- *Weight.*
- *General Notes.*
- *Title Block information.*

Layers can be used to assign information to a specific “folder.

Filters can be used as graphic settings for which Layer(s) to display [6].

Before starting mass production in aviation industry there is a requirement of manufacturing the first part - **FAI** (**F**irst **A**rticle **I**nspections). FAI part needs special

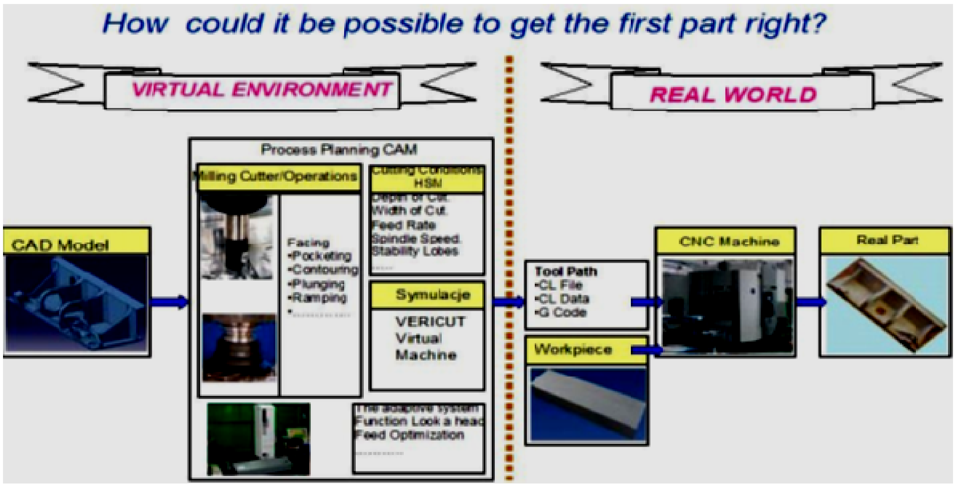


Fig. 7. How to get first part right [5]

control and has to be manufactured strictly according to electronic engineering documentation, with no aberrances. Acceptance of FAI allows to start mass production of the part. FAI inspection consists of four steps:

- Loading **3D** model – importing **CAD** model to metrology software (**STEP**, **IGES**).
- Setting – using metrology software, setting basis, metrology datum.
- Measuring – the measurement of given part features and comparing to the model.
- Reporting – presently computer systems generate reports basing on nominal data and **FT&A** or **GD&T** (**G**eometry **D**imensions & **T**olerance).

Today the practical preparation of technical production is made in virtual reality by the use of computer hardware and software (Fig. 7). The following rule may be derived [5]:

**The more work and effort one does to prepare production in virtual reality, the less work and problems exist in real world. Work costs in virtual reality are significantly smaller than costs in real world. The more work is transferred from real world to virtual reality, the more significantly increases the probability of manufacturing good part for the first time.**

## 6. CONCLUSIONS

This paper is angled towards providing the Design department of an aviation company with methodologies and tools in order to accelerate their product development lead time by identifying their detained knowledge and applying it from the early phases of the product development process. Nowadays, the most known format of the Authority dataset used in the aviation industry is the one including both the **CAD** model and fully dimensioned **2D** drawing sheets. The future is to use the format which includes the **3D** model and the engineering requirements displayed as text within the **3D** viewing area of the model, as well as the remaining engineering requirements. One of main requirements in aviation industry is also verification and control of the software used – so called **P**roduct **A**cceptance **S**oftware **PAS.** The best method of reliable verification of data translation or transmission among **CAD/CAM** systems is the method known as **Points clouds.** The implementation of the above mentioned principles, consistent with the Boeing requirements presented, carries high cost savings and increase in engineering performances, thanks to the effective support in design, verification and control of the software used in modern aviation manufacturing technologies of XXI$^{st}$ century.

ACKNOWLEDGEMENT

*Financial support of Structural Funds in the Operational Programme - Innovative Economy (IE OP) financed from the European Regional Development Fund - Project "Modern material technologies in aerospace industry", Nr POIG.01.01.02-00-015/08-00 is gratefully acknowledged*

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