# Lessons Learned for Better Management of Master Geometry

Tümay Mart, Can Cangelir

# LESSONS LEARNED FOR BETTER MANAGEMENT OF MASTER GEOMETRY

Tümay MART[1], Can CANGELİR[1]

[1]Turkish Aerospace Industries Inc., Ankara, Turkey 06980

tmart@tai.com.tr, ccangelir@tai.com.tr

**Abstract.** When an aircraft is thought as a final product, it has a complex structure with numerous parts to be managed. Complexity requires multifunctional design activities, and multifunctional design needs collaborative way of working for continuous success. This cooperated approach could only be accomplished by the help of concurrent engineering techniques. Currently, several distinctive design activities are performed at digital environment of CAD tools. Position information and interrelations between parts of a product are provided by the help of associative physical CAD links. Requirement of CAD links during design activities paves the way for the usage of Master Geometry models as an official source of aircraft shape and a geometrical reference for all actors involved. Master Geometry models have to be managed in Product Lifecycle Management tools in order to provide effective implementation and usage of models from conception, through design and manufacture, to service and disposal of product. Some improper cases could be observed when a correlation is tried to be generated between Master Geometry models and 3D models of product at CAD environment. In this paper, these cases will be examined and potential solutions, which are the results of lessons learned activities, will be proposed with concrete examples.

**Keywords:** Master Geometry, Master Geometry Creation, Master Geometry Validation Workflow, Buffer Geometry.

## 1 Introduction

Concurrent engineering techniques provide collaborative strategies, which are totally focused on cost and time reduction of product development processes in parallel with improving quality level of final products. These improvements have to be seen as the key for success by all companies who want to be a leading force within their own field of industrial expertise [1]. It is mainly a question of process and way of working. For conventional method, product development processes are performed sequentially and this type of method does not answer the requirements of being a global player of challenging and competitive worldwide economy [2]. Many aerospace companies attain success only with adapting cooperated way of working strategies, due to high level competition resulting from reduced product life cycles, growing product complexity, multifunctional design activities and the need for a large number of product variants [2].

For aerospace industry, product development processes start with works at aircraft level and iteratively continues through the level of detailed elementary parts. In another words, it could be stated that the aircraft design process is an iterative and top-down activity. When the complexity of an aircraft is taken into consideration, a final product could only be achieved by involvement of several distinctive disciplines. Additionally, there have to be continuous exchanges of information between all interested parties within a protective environment during product lifecycle. The digital environment created and leaded by concurrent engineering provides this type of collaborative work media where all the related departments can communicate with stakeholders. Integrative design environment has been a subject of intense research over the past several years. According to recent studies, NIST Core Product Model (CPM) is described as a product information-modeling framework. In CPM, a product is modeled as a triad of its function (what it is intended to do), its form (what is its shape and material) and its behavior (how it implements its function) [3]. Open Assembly Model (OAM) is defined as an extension of CPM, and OAM is used to provide a standard representation and exchange protocol for assembly and system level tolerance information [4]. Another method is The Cooperative Design Modeler (CoDeMo). CoDeMo assists the integration and the cooperation of each participant who would be an external or internal actor. It achieves, thereby, a formal network of cooperation based on the shared database, which is manipulated by the design external actors and managed by the internal actor [5,6].

In this context, Master Geometry models get on the stage as a set of 3D models, which represents a single geometrical reference database of the main aircraft geometry for all interested parties. It has to be noted that management of Master Geometry models and preserving interrelation between product and Master Geometry during product lifecycle period is important.

At following sections of this paper, three different improper incidences, which possibly could be faced with during generation, usage and management processes of Master Geometry models, will be identified and exact solutions to mentioned incidences will be proposed. Additionally, in order to provide background information about main topic, brief descriptions of product structure, product lifecycle and detailed description of creation and management of Master Geometry will be mentioned.

## 2 Definitions

### 2.1 Product Lifecycle

Product life cycle is a generic term covering all phases of acquisition, operation, and logistics support of an item, beginning with concept definition and continuing through disposal of the item [7]. As the product development activity of an aircraft proceeds, it passes through a series of reviews of increasing detail. Design reviews evaluate the technical progress toward meeting specification requirements [8]. Each review is tailored to ensure that the emerging design is ready to enter the next stage of development.

### 2.2 Product Structure

Product structures show component relationships and enable visualization of a product in relation to its higher and lower level components, from any level. Product structures are typically portrayed in a top-down manner starting with the end product and going down to the lowest level [9]. Product structure is a hierarchical breakdown of the product that contains 3D models and attributes of product. Attributes of product are data, which gives alpha-numeric values about part description, part number, material information, manufacturing process, version, engineering parameters etc... Product structure has to keep latest design information to prevent inconvenient design activities. It is essential to manage all involved data of product properly with up to date versions. With this purpose, Product Lifecycle Management tools are being used as a single database, which could be reached by different functional disciplines accordance with their needs.

## 3 Master Geometry

As mentioned previously; during product life cycle process of an aircraft, several different groups are involved in design, manufacturing and after sales service support activities. Although those groups have totally different disciplines, there has to be a strong relation between different disciplines for aircraft design. Consider a design group whose main responsibility is structural part design of the aircraft such as designing frames, ribs, spars, stringers etc. On the other, there has to be another group whose main responsibility is system design. System designers individually know the content of what needs to be generated as a system deeply and location of this system on the aircraft roughly. However, geometrical interaction between systems, absolute geometrical installation points and dimensional limitations also need to be known. This information somehow needs to be shared between different disciplines. The same situation would be observed between two different structural design groups working for different sections of the same aircraft with geometrical dependencies.

In order to make sure that design activities are performed on right location of aircraft, location information of designed parts or systems on aircraft has to be identified. Designers need design parameters or geometrical indications, which they can use as a reference point from aircraft geometry. Exact locations of all parts on final product could be provided by the help of physical CAD links. Generating links from part to part could be the first technique comes to mind. However, generating links from other parts or geometrical elements are not recommended, because of location information of common parts and geometrical elements on the aircraft could be changed due to dynamic nature of the design activity and they could not be considered as a reference point.

In this context, implementation of Master Geometry models has significant importance for aircraft development process. Master Geometry file is the collection of all primary references necessary for design of aircraft primary structure and system installation. Master Geometry models form the basis for all geometry levels of the aircraft. Thus, it has to be stated that structural parts can only be physically linked to Master Geometry features in CAD environment, since Master Geometry models are definitely controlled references. Generating links from part to part or from other geometrical elements is not recommended.

### 3.1 Content of Master Geometry Models

Master Geometry is a 3D CAD model, which represents the outer geometry and the elements forming the structure of the aircraft all together. This geometrical composition consists of surfaces, planes, lines and points and includes all necessary geometrical dependencies and constraints required for design of the aircraft. Following definitions show the detailed content of Master Geometry; indications e.g. planes, coordinate systems of main structural components e.g. frames, ribs, spars, cut-outs like doors or windows and the positions of main sections [10]. It has to be noted that Master Geometry is not an actual part or section that is manufactured, but it is only a conceptual part, containing a sketch or general shape of the overall design and important design parameters [10]. Following Figure 1 shows the examples of Master Geometry content.

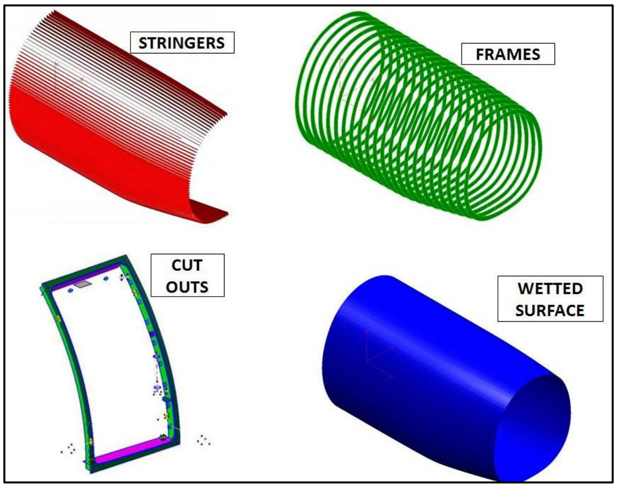


**Fig. 1.** Examples of Master Geometry Content

### 3.2 Creation of Master Geometry Models

Master Geometry creation process has to be started at conceptual design phase and mainly frozen just after the detailed design phase. However, management of the master geometry database continues for the life of the aircraft. Master Geometry models are the structural reference of the whole aircraft that contains all the external shapes of the aircraft and the main geometrical references, which could be used as a solid basis by structural designers, subcontractors, manufacturing engineers, stress engineers and aerodynamic engineers. Master Geometry models include inputs from all related disciplines especially structural design, aerodynamic, structural analysis, tool design, EMI-EMC group and system engineering. External aircraft geometry, which is an output of aerodynamic studies, could be stated as the main source for generation of Master Geometry models.

## 4 Management of Master Geometry

Generating Master Geometry models would be not enough for a complex product development process. Master Geometry could be evolved due to the modifications, improvements and change requests through design phases, and this evolution has to be managed within a protective and controlled environment. Thus, a special product structure, a special role and a special workflow have to be defined for Master Geometry models with the help of Product Lifecycle Management tools.

Special product structure brings hierarchical breakdown of Master Geometry models in an organizational way. Authorized role provides controlled access of creating and modifying 3D models of Master Geometry. Only the users, who have Master Geometry Specialist role, would be able to perform 3D model creation or modification tasks. Special workflow provides approval and traceability of 3D model modifications of Master Geometry. However, several problems could be observed during the 3D model generation and management periods of Master Geometry models, due to the nature of geometrical attributes of Master Geometry. Each case and potential solution will be separately analyzed at following subtitles.

### 4.1 Reduction of Feature Intensity

System installation and structural design groups have to use Master Geometry models during their 3D modeling activities. When the design activity becomes more detailed, Master Geometry models shall have ability to answer to requirements of all design groups. Sometimes a single Master Geometry model at aircraft level could not be used properly for detailed design activities within a dynamic environment. For a basic trainer aircraft, Master Geometry models at aircraft level includes approximately 14000 features like lines, points, planes, surfaces etc. Following Figure 2 shows the intensity of features just for a significant section of an aircraft.

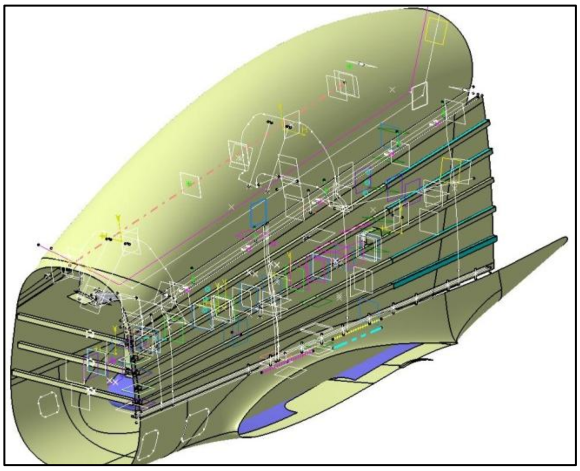

**Fig. 2.** Intensity of Features (lines, planes, points et.)

Using one big model for Master Geometry could be a chaos for detailed part design activities. Consider a structural designer which works on wing and totally responsible for structural parts of a definite section of the wing. When this designer tries to use Master Geometry model as a reference, he/she has to refer aircraft level model which includes all detailed geometrical information of fuselage, empennage or other major components which could be classified as out of scope according to his responsibilities. This excessive information kept in single model will causes confusion among design groups and poses as a risk for performed designs. Same situation also would be a problem for a system installation responsible.

**Solution 1.** If whole aircraft is being designed, the general Master Geometry shall be broken down into convenient sections, to avoid excessive information in each model and to align the Master Geometry more in line with the design and manufacture task breakdown, instead of using single model. There have to be separate Master Geometry models for structural design group and system installation group.

In order to provide better management of details and integration with design teams, Master Geometry models of structural design group shall be broken to major components, sections and ATA (Air Transport Association of America) sections sequentially. Breakdown principle totally depends on requirements of design group. For instance, there could be separate Master Geometry models for wing, fuselage, and empennage in terms of structure. Still, it can be divided into further indices if necessary. Aircraft level Master Geometry model generated for structural design includes approximately 5000 features and it is observed that the number of features included in one Master Geometry model could be reduced to 800 by splitting into further indices.

Master Geometry models of system installation group shall be derived from the Master Geometry models generated for structural design. Additionally, Master Geometry models of system installation have to be physically linked to the ones of structural design. In order to prevent excessive information in each model, system installation

Master Geometry models can be split into sub-sections. There has to be a separate Master Geometry model for each system. Aircraft level Master Geometry model of system installation includes approximately 9000 features and it is observed that the number of features included in one Master Geometry model could be reduced to 250, if a separate model is created for each system. Following Figure 3 shows the reduction rates of feature intensity with approximate values of a real splitting case.

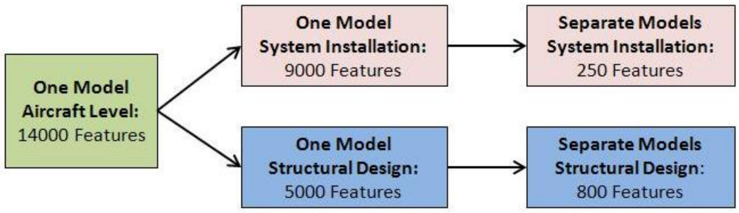


**Fig. 3.** Reduction of Feature Intensity

### 4.2 Using Buffer Geometry

As mentioned previously, all detail parts except some brackets have to be linked to Master Geometry models and Master Geometry models have to be physically linked to external aircraft geometry models at CAD environment, in order to provide association between models. This means if an external geometry model is changed, associated Master Geometry model will give link update warning, so do detail parts due to updating Master Geometry models.

For a basic trainer aircraft, there are more than 4000 detail parts. It could be estimated that updating one detail part at CAD environment takes 1 minute. Each external geometry modification causes detail part updating workload, which approximately equals to 4000 minutes for whole aircraft. Every modification of external geometry would not have an impact on detail parts. Thus, there has to be a monitoring interface between external geometry and Master Geometry models in order to prevent unnecessary updates of Master Geometry and to avoid extra workloads at detail part level.

Additionally, sometimes it is possible that external aircraft geometries could be provided by aerodynamic group as a coarse model. Coarse models include draft surfaces, lack of cut out sections of the surface etc. In this case; first of all, some arrangements and fine tunings have to be performed on models which have been directly taken from external aircraft geometry, and then these models shall be transferred to Master Geometry. These arrangements include totally CAD operations. And these all CAD operations have to be performed in order to make Master Geometry models applicable for design specifications. During detailed design phase, there will be excessive information in Master Geometry models such as initial information taken from aerodynamic group, results of CAD operations and final geometrical features intended to use as Master Geometry. When all information is kept within a same model, it would be impossible to use Master Geometry models properly.

**Solution 2.** If CAD operation for fine tuning of data which has been taken from external aircraft geometry is a frequent activity, there has to be a transition medium between external aircraft geometry models and Master Geometry models.

In this context, Buffer Geometry model gets on the stage as a solution. Buffer Geometry functions as a transition and monitoring model between external aircraft geometry and Master Geometry. All elements taken from the external aircraft geometry are transferred to the Master Geometry after being arranged using the Buffer Geometry. If the surfaces taken from aerodynamic engineering group have been provided as a coarse model, the Buffer Geometry shall be used to make these surfaces fine to prevent excessive information in each Master Geometry model. There shall be a Buffer Geometry model for each Master Geometry model. All geometrical elements in the Master Geometry model shall only be linked to the corresponding Buffer Geometry. In this case, Master Geometry will be linked to Buffer Geometry and Buffer Geometry will also be linked to external aircraft geometry sequentially. Changes on external aircraft geometry will directly have impact on Buffer Geometry. With the help of Buffer Geometry, only effective changes could be transferred to Master Geometry models and this way of working prevents unnecessary link updates of detail parts and provides 80% time reduction for link update task at detail part level. Following Figure 4 shows the CAD operations performed on a Buffer Geometry model.

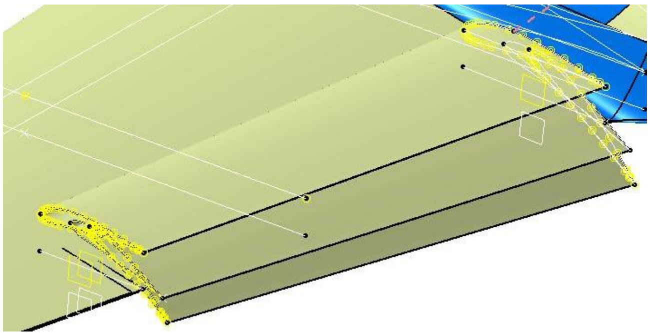

**Fig. 4.** Buffer Geometry (CAD arrangements and fine tunings)

### 4.3 Master Geometry Validation Workflow

The design data of a product has to be approved and released through workflows with revision control in order to make it applicable for stakeholders within a protective and controlled way. Same identification has to be also implemented for Master Geometry models. Consider a final product with high complexity; all parts of the product could be linked to same Master Geometry model. When this Master Geometry model could somehow up issued from Revision-A to Revision-B due to new requirements or change requests, all items which have CAD links to this Master Geometry model also have to be up issued. Otherwise, associative CAD links between parts and Master Geometry model will become broken because associative links keeps track of the file name of Master Geometry models. Updating links and up issuing of all parts will be a heavy work load for design group.

**Solution 3.** Giving "Released" status and issue tracking for Master Geometry models is not recommended. Because when you release an item through workflows, you have to keep track of the revision control of that item. In case of Master Geometry models; instead of using "Released" status, "Valid" status has to be used with a proper workflow.

Consider a change request has been received for an existing Master Geometry model. According to predefined rules of the Master Geometry Workflow; following steps will be performed sequentially: at first step; Master Geometry Specialist role informs and requests to rearrange the Master Geometry model in accordance with the design requirements. This first stage is "Request" step of the workflow and during this phase the data is frozen. At second step; Engineering Leader role confirms that the Master Geometry change is required and acceptable. This second stage is called "Assessment" step and at this step, Engineering Leader role can also reject the request. The data is set free from now on. At third step; Master Geometry Specialist role applies the changes to Master Geometry model. Additionally, Master Geometry Specialist starts validation request. This third stage is called "Request for Validation" step. At fourth step; Engineering Leader role confirms that the corrections and/or improvements are applied correctly. This fourth stage is called "Approval of Validation" step and at this step, Engineering Leader role can reject the corrections and modifications. After the "Approval of Validation" step, the Master Geometry model will be again frozen and has "Valid" status. Please refer Figure 5 for details of Master Geometry Validation Workflow.

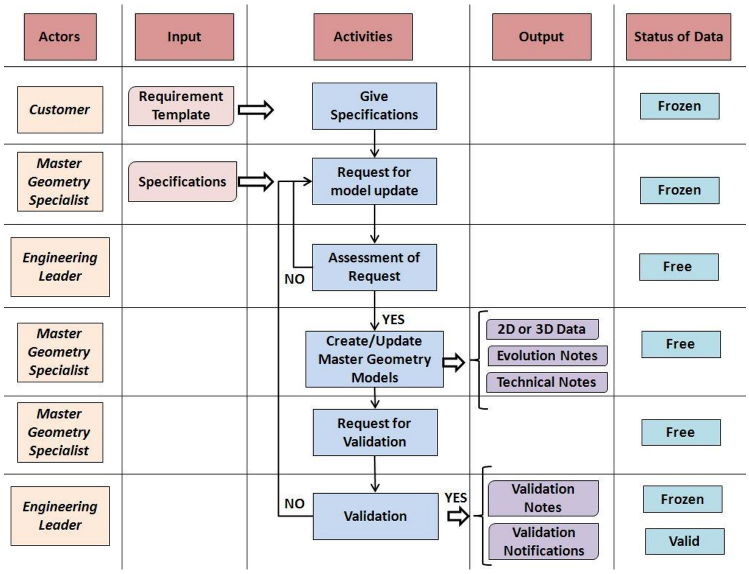


**Fig. 5.** Master Geometry Validation Workflow

## 5 Conclusion

This paper is aimed to present the importance of Master Geometry models on multi-functional design activities. Basically, interactions of structural design activity, system design activity and manufacturing process with Master Geometry models have been identified. Generic geometrical content of Master Geometry models has been also defined. In order to provide coherency between Master Geometry and other indications, brief descriptions of product structure and product life cycle are given. Afterwards, three different problems could be faced with during implementation and management period of Master Geometry has been deeply analyzed and presented with supportive convenient examples. These problems could be defined in a nutshell as follows; problem number one was about excessive content of usage single Master Geometry models during whole product development process. Problem number two was about filling out Master Geometry models with unnecessary geometrical information which makes Master Geometry models useless. And finally, problem number three was about unsuitable consequences of released status of Master Geometry models and workloads of link updates. After that, accordance with the results of lessons learned and know how activities potential solution techniques have been proposed.

Future work will concentrate on issues related to the implementation and management of Space Allocation Mock-up which is a digital mock-up made of simplified 3D solid models in CAD formats. The place of Space Allocation Mock-up design within overall aircraft development will be highlighted and the link between Space Allocation Mock-up models and Master Geometry models will be presented in details.

## 6 References


1. Hartley J. R., Concurrent Engineering, Productivity Press, 15--27 (1998)
2. Parsei H. R., Sullivan W. G., Concurrent Engineering, Chapman & Hall, 4--19 (1993)
3. R. Sudarsan, S.J. Fenves, R.D. Sriram, F. Wang, A product information modeling framework for product lifecycle management, (2005)
4. Sudarsan, R., Young-Hyun, H., Foufou, S., Feng, S. C., Roy, U., Fujun W., Sriram, R. D., Lyons, K. W., A Model for Capturing Product Assembly Information, Journal of Computing and Information Science in Engineering, (2005)
5. Noel F., A product-process-organization integrative model for collaborative design, Laboratory 3S, University of Grenoble, France (2006)
6. Lionel R., Serge T., CoDE: A Cooperative Design Environment- A New Generation of CAD Systems, Domaine Universitaire (2000)
7. MIL-STD-973, Military Standard Configuration Management (1992)
8. MIL-STD-1521 B, Military Standard Technical Reviews and Audits for Systems, Equipments and Computer Software (1976)
9. EIA-649-B, National Consensus Standard for Configuration Management Department of Defence (2011)
10. Dolezal, W., Success Factors for DMU in Complex Aerospace Product Development, Technische Universität München (2007)
11. Les A. P., Ten challenges in computer-aided design, Department of Computer Science and Engineering, University of South Florida (2005)