Fast and Flexible Communication of Engineering Information in the Aerospace Industry

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Objectives and Goals

The objective of this project is to improve the design and production of complex mechanical assemblies that are produced in agile partnerships, with a focus on improving first time capability. Complex assemblies illustrate most of the problems of partnership manufacturing since they include many components with tight relationships to each other. Company partnerships between customers and suppliers are very common and will continue to be the dominant mode of manufacturing for the foreseeable future. New tools and methods will therefore be needed to carry out both the design and manufacture of these items and the management of design and manufacturing processes ongoing simultaneously at many companies.

The project is being carried out in close collaboration with a sister project that is focusing on the automobile industry. These industries share the characteristics listed above. Many opportunities exist for each industry to learn from the other in spite of differences in production rate and manufacturing processes.

Background

The project's approach consists of the following six steps:

1. Map selected elements of the product development process using Transactions Analysis
2. Benchmark these elements individually and as a system within and across the target industries, identifying useful metrics
3. Formulate "best practice" hypotheses based on transactions mapping and benchmarking, capturing best practices in new tools or methods
4. Create pilot projects to test, demonstrate, and customize these best practices by using the tools and testing their usefulness
5. Assess pilot outcomes using the metrics developed, and develop migratable practices within and beyond the target industries
6. Synthesize, document, and publish the findings

In conjunction with a sister project focusing on the automobile industry, we are working with several partner companies in the auto and aircraft industries:

Vought (Division of Northrop-Grumman), Boeing
Ford, Budd Company, General Motors Saginaw Division

Project activities have been selected to provide insight into a broad range of product development phases in order to grasp the whole process and determine how to affect it as a whole.

Tools Being Developed

The tools being developed or adapted for use are Transactions Analysis (a process mapping tool), Web Diagrams (for capturing the business and technical relationships between customers and suppliers), Key Characteristics (a way of identifying and structuring the critical requirements of a product, assembly, subassembly, or part in terms of deliverables to a customer), Contact Chains (for capturing the physical relationships between parts in an assembly), the Design Structure Matrix (for capturing inter-related information flows in a process and to highlight iterations and concentrated transactions), and Activity-Cost Chains (to determine the total costs of sets of related activities in a process).

Work During the July - September 1995 Quarter

Vought Pilot Project

The main activity this summer was a pilot project to define assembly process design methodologies for aircraft structures that are designed by one company, built by a second company, and finally assembled by the first company. Five students spent various amounts of time at MIT, Boeing, and Vought gathering data and applying, developing, or testing the above tools in support of this pilot. This project was carried out in parallel with ongoing efforts at Vought to understand how to accomplish high quality aircraft structural assembly without the use of inflexible fixtures. Advantages would include lower investment over a series of programs, less floor space, faster throughput, lower direct labor, and ability to increase production capacity for an assembly by using flexible equipment originally designated for another (sufficiently similar) assembly.

The pilot was designed to test the tools on all the phases of product and process design to the extent possible given the fact that the students' target product, the 767 horizontal stabilizer, was designed 15 years ago. The students' missions, site locations, and tasks were as follows:

Student	Site(s)	Mission	Tools Used or Developing
Don Lee	Boeing, Vought, GM	• Create method for generating and flowing down customer level KCs to suppliers and permitting supplier KCs to be defined	• Definition of three kinds of KCs: customer, assembly, and fabrication • Key Characteristics flowdown to define initial geometry for supplier parts and assemblies
Tim Cunningham	Vought	• Create method for generating and flowing up assembly process level KCs • Define assembly, subassembly, and fabrication KCs • Map as-is process • Generate candidate new processes • Do tolerance analysis	• Design Structure Matrix to organize the pilot and document as-is processes • Contact Chains and assembly sequence analysis to define assembly KCs • Tolerance analysis to evaluate candidate processes and define fabrication KCs
Mary Ann Anderson	Vought, Ford	• Do financial and timing analyses in support of the business case	• Transactions Analysis to define processes
Tariq Shaukat	Vought	• Understand human resource issues, learning, and skill requirements for new assembly processes	• Transactions Analysis to define relationships between assembly teams, understand incentives, and evaluate ability to meet KCs
Krish Mantripragada	MIT	• Create CAD tools capable of supporting KC definition and assembly process design • Help define candidate assembly processes and sequences	• Feature-based Design to define product geometry needed to deliver fabrication and assembly KCs and to permit assembly process planning and tolerance analysis

Table 1. Student Missions and Tools Used or Being Developed in Summer Pilot Study

The following activities were accomplished:

1. Analysis of 767 horizontal stabilizer at Boeing and definition of final and subassembly requirements in terms of quantitative KCs

2. Analysis of 767 horizontal final assembly at Boeing

3. Definition of horizontal assembly-level KCs required at Vought required to support final assembly at Boeing plus subassembly-level KCs required at skin subassembly level to support assembly-level KCs at Vought

Steps 1 - 3 utilized an enhanced definition of KCs that identifies three classes: PKCs (product level KCs that deliver customer requirements), AKCs (assembly level KCs that are needed in order to deliver the PKCs) and MKCs (manufacturing KCs needed to provided individual parts with the surfaces and features needed so that AKCs can be delivered, plus specifications on fabrication and measurement processes needed to deliver these features).

4. Analysis of as-is fixture-based assembly method used at Vought for 767 skin subassembly and horizontal final assembly

(Steps 1 - 4 are illustrated in Figure 1)

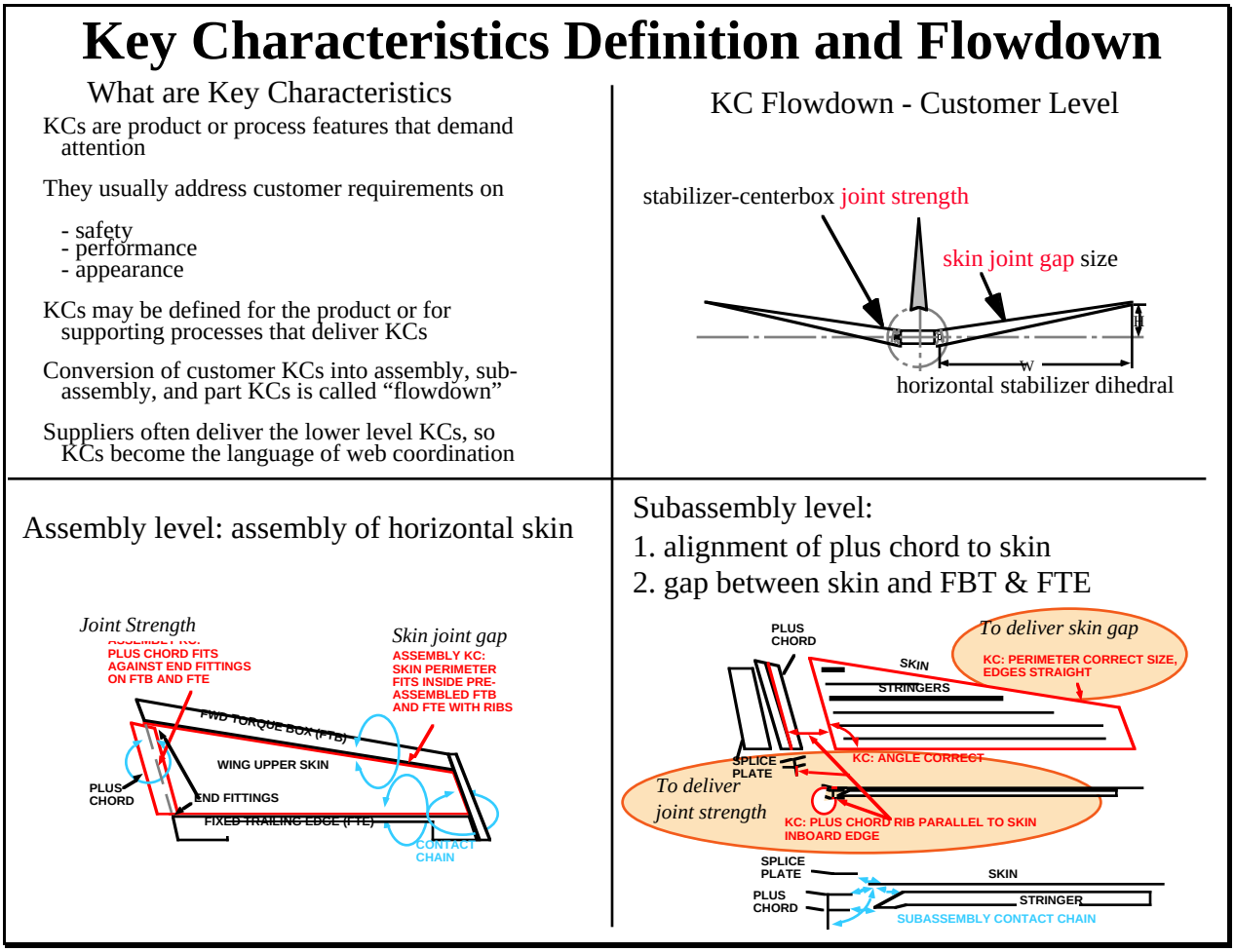

Figure 1. Outline of Key Characterisitics Flowdown from Final Assembly at Customer to Parts Fabrication and Assembly at Supplier

5. Generation of alternate assembly processes for the skin subassembly that deliver the horizontal stabilizer assembly KCs but do not depend on rigid fixtures; includes generation of feasible assembly sequences including fabrication processes embedded in assembly, such as applying contour to skins, match drilling holes, and disassembling to deburr holes (this effort was conducted using the World Wide Web to link Mr Cunningham in Dallas with Mr Mantripragada in Cambridge for on-line use of the assembly sequence generating and editing software running at MIT; this capability was created in response to the requirements of the ARPA-sponsored ACORN project). This activity benefited from cross-fertilization with the companion MIT Fast/Flexible project on the automotive industry in the form of better understanding of how Ford controls variation in car body assemblies.

6. Definition of part fabrication features to support alternate assembly processes, together with understanding of potential sources of variation

7. Generation of time and cost estimates for the different candidate assembly processes (ongoing)

8. Generation of tolerance analyses of different candidate assembly processes to determine if they can deliver the assembly KCs (ongoing)

9. Generation of skill and training requirements to support equipment and processes needed (ongoing)

Results of the study were presented to Mr Cliff Harris, VP of Operations at Vought on August 23. It appears from reactions of several people at Vought and Boeing that this is a more systematic process than has been used in the past and represents a more pro-active approach to KCs than has been applied before.

A paper describing the process used in this pilot is currently being written for submission to the 1996 Conference on Flexible Automation to be held in Boston in July 1996.

A briefing package was developed comprising high level tutorials about the major tools being developed on the project. Each tutorial consists of 6 to 8 slides which introduce the tool, give examples of its use, and indicate its importance and applicability. This package was delivered to the sponsor.

Other Activities

The Principal Investigator, Dr. Whitney, is also co-supervisor, along with Prof. Fine and Prof Thornton, of two Leaders for Manufacturing (LFM) students associated with the companion Agile automobile project. Each student is working at a different division of General Motors. One is studying Japanese and US stamping die development and procurement processes, including customer-supplier relations. A major focus of his study is transactions and contact chain analyses of each process. The main lesson so far, based on a transactions analysis, is that the Japanese supplier has less-capable analytical and design CAD tools but is able to make dies in

substantially less time because its organization is more responsive to customers and contains fewer non-productive steps in its process.

The other student is studying GM's procurement strategies for complex systems including anti-lock brakes and active suspensions. Complex issues arise due to the interaction between these systems and the car's structure, as well as questions regarding retention of core design and system engineering competence inside GM. This study is utilizing transactions analysis and Design Structure Matrices to describe the technical and strategic issues. The main lesson learned so far is that the choice of make and buy as defined by GM's top level purchasing strategy seems to break several tight dependency chains that deliver product performance KCs, as revealed by a Design Structure Matrix analysis. These dependency chains suggest grouping components that share tolerance chains or share similar rates of technological advance. Thus design of a supply web needs to be done in a larger context than GM presently takes into account.

Dr Whitney, Prof Fine, and Prof Thornton also co-supervise an LFM student working at Boeing on the problem of outsourcing doors. The task is to understand doors from the point of view of KCs and assembly and fabrication processes so that a relatively inexperienced company in a foreign country can learn how to become a competent door supplier. At the moment, the knowledge about door assembly is primarily in the heads of Boeing employees who naturally are reluctant to reveal it to others who might take their jobs in the future.

Steps have been taken to link the Fast/Flexible project with the Lean Aircraft Initiative at MIT with the following results:

1. A meeting was held on August 2 between Prof Fine, Dr Whitney, and Dr Kirk Bozdogan, director of the Supplier Relations Focus Group of LAI to plan a supplier relations survey project that would include a focus on assemblies in order to leverage the Fast/Flexible project's knowledge in this area. LAI hired a new research student in September to start this work.

2. A 2 hour presentation of the Fast/Flexible project was made by Prof Fine and Dr Whitney to a meeting of the LAI industry focus group on Supplier Relations on August 17.

3. A one hour briefing of the Fast/Flexible project was given by Dr Whitney to LAI personnel on September 12.

3. Prof Janice Klein, director of the Human Resources Focus Group of LAI, has agreed to assist Fast/Flexible student Tariq Shaukat's research.

A proposal was submitted to the Air Force for a follow-on extension of the project.

Mr Carlo Cadet resigned as Program Manager to begin his studies for an MBA at the MIT Sloan School. He will become a research assistant on this project. Mrs Gina Milton has taken over his responsibilities with the exception of occasional sponsor interface. We wish Mr Cadet the best in his studies, which will include a thesis in connection with this project.

Activities Planned for the Next Quarter

The results from the summer will be consolidated by means of the paper written for the Flexible Automation Conference. Tolerance analyses will be conducted to determine which of the candidate assembly processes does the best at delivering the assembly level KCs. A report to Vought will be written suggesting a process, including a business case under several scenarios and recommendations for improving long term learning, skill development, and process development.

Discussions will be held with the Air Force to select a site and project objectives for the one year extension period. The goal is to have a set of candidate sites by the end of the quarter, and a site on board by the end of the follwing quarter.

Activities will begin that support new work to be conducted by Prof Tom Malone of MIT to develop a database of Agile practices and cases. The MIT Fast/Flexible Aero and Auto projects will act as "lead users" for this effort.