Proceedings of the 1992 Winter Simulation Conference
ed. J. J. Swain, D. Goldsman, R. C. Crain, and J. R. Wilson

SIMULATION OF ENGINEERING DESIGN CHANGE APPROVALPROCESS

Subramanian Prakash
Joel Schlotthauer
Department of Industrial Engineering
Wichita State University
Wichita, KS 67208, U.S.A

ABSTRACT

The ability to implement engineering design changes in a manufacturing facility plays a significant role in the company's competitiveness. Design changes have an effect on almost all departments of the company including manufacturing engineering, tooling, marketing, finance, and purchasing. This paper discusses a simulation model developed to study the engineering design change approval process in a major commercial aircraft company with the objective of identifying bottlenecks and redundancies. Some of the issues in developing such models are also discussed.

1 INTRODUCTION

It is well known that the longer the lead time from engineering design change inception to implementation, the greater the costs involved. To maintain a competitive edge in the market place a company must continually improve its ability to implement engineering design changes in a timely fashion. This however, is not an easy task due to the fact that a design change usually affects almost all departments of a company including manufacturing engineering, tooling, product engineering, product support, marketing, finance, master scheduling, handbooks, and purchasing. This task is further complicated by the inherent long production lead times with long useful lives of the product, namely aircraft. This obligates the manufacturer to have a strong product support group which must maintain a close and long term relationship with the customer and/or end user throughout the product's life cycle. Invariably customer demands, manufacturing producability, and technological changes necessitate changes to the product which may arise prior to production, after production, or after delivery. Moreover the nature of the product(s) requires that many major components be procured well in advance from outside suppliers. This has a significant effect on product design changes made after an order has been placed to a supplier. Therefore the company works closely with the suppliers to ensure that the engineering design changes are conveyed to the suppliers to enable timely delivery of the components. The dilemma then is how can a company best anticipate and prepare for engineering changes which may impact current and/or future production. This was motivation for analyzing the engineering design change approval process, and develop a model that may provide the company with some insight into the way the system behaves.

The remaining sections describe in detail the information flow process and the development of the simulation model that represents the system. Some of the outcomes of this analysis are also discussed.

2 GROUPS INVOLVED IN THE CHANGE PROCESS

The following groups/persons are involved in the engineering change approval process:

1. Chief Engineer who is the Vice President of Product Engineering
2. Product Change Executive Group (PCEG) comprised of senior management
3. Change Management Team comprised of middle management from program management, manufacturing technical services, materials quality, product engineering, configuration management, product support, marketing and finance.
4. Engineering Control Groups representing each major functional area in the company : avionics, electrical, interior systems, project, and propulsion.
5. Groups representing Materials and Process Engineering, Structural Engineering, Weights Engineering, Concurrent Engineering, and Manufacturing Engineering.
6. Engineering Change Control Representative
7. Data Control
8. Tooling
9. Purchasing

10. Configuration Management

3 ENGINEERING CHANGE PRIORITY LEVELS

An engineering change can be initiated at any level within the company. Depending on the importance and urgency of requested change, a priority level is assigned. *Priority 1* engineering changes are mandatory product changes required to resolve an issue which will otherwise halt the production line, hinder aircraft delivery, or ground one or more field aircraft if not implemented as soon as possible. Priority 1 changes are approved by the Vice President of Product Engineering and must have concurrence from PCEG. *Priority2* engineering changes primarily involveproduct changes resulting from customer requests, unscheduled replacements due to warranty, and foreign certification. Priority 2 changes are initiated and approved by the PCEG members with the final approval made by the Vice President, Product Engineering. *Priority3* changes are discretionary product changes which are not absolutely necessary but may lead to improvement in product and/or manufacture. These changes are approved by the program manager with assistance from the change management team. *Priority 4* changes are sustaining product changes required to resolve normal operating problems. Each of the priority levels have a time limitation within which the change should be implemented (Table 1).

4 CHANGE APPROVALPROCESS

The change approval process is shown in Figure 1. Priority 3 and 4 engineering changes begin as a change request which can be submitted by any employee in the company to the configuration management group who log and prepare the change request for the change management team review and approval. If rejected, the change request is routed with an explanation of rejection to the originator. If approved, the change request is assigned an engineering change record(ECR) number and the change management team assigns a priority level (3 or 4). If however, a change requires additional insight or research, a change management team member is assigned the task. After the ECR number has been assigned and the appropriate forms filled, the ECR package is routed to the engineering design organization which is comprised of five groups representing each functional area.

Priority 1 and 2 engineering change requests are received and approved by the PCEG. The PCEG, however, can change the priority level of a change request from 2 to 3 which diverts control of the change request to the configuration management group. The final approval comes from the chief engineer. The change request is then routed through the appropriate engineering change control representative to a

Table 1 : Priority Levels

Priority	*Changes*	*Time Limit*
1	Safety Concerns that may involve grounding of aircraft	Immediate
2	Product Changes due to customer requests, warranty replacements	1 or 2 years
3	Discretionary product changes	2 years
4	Product changes to resolve normal operating problems	Whenever Possible

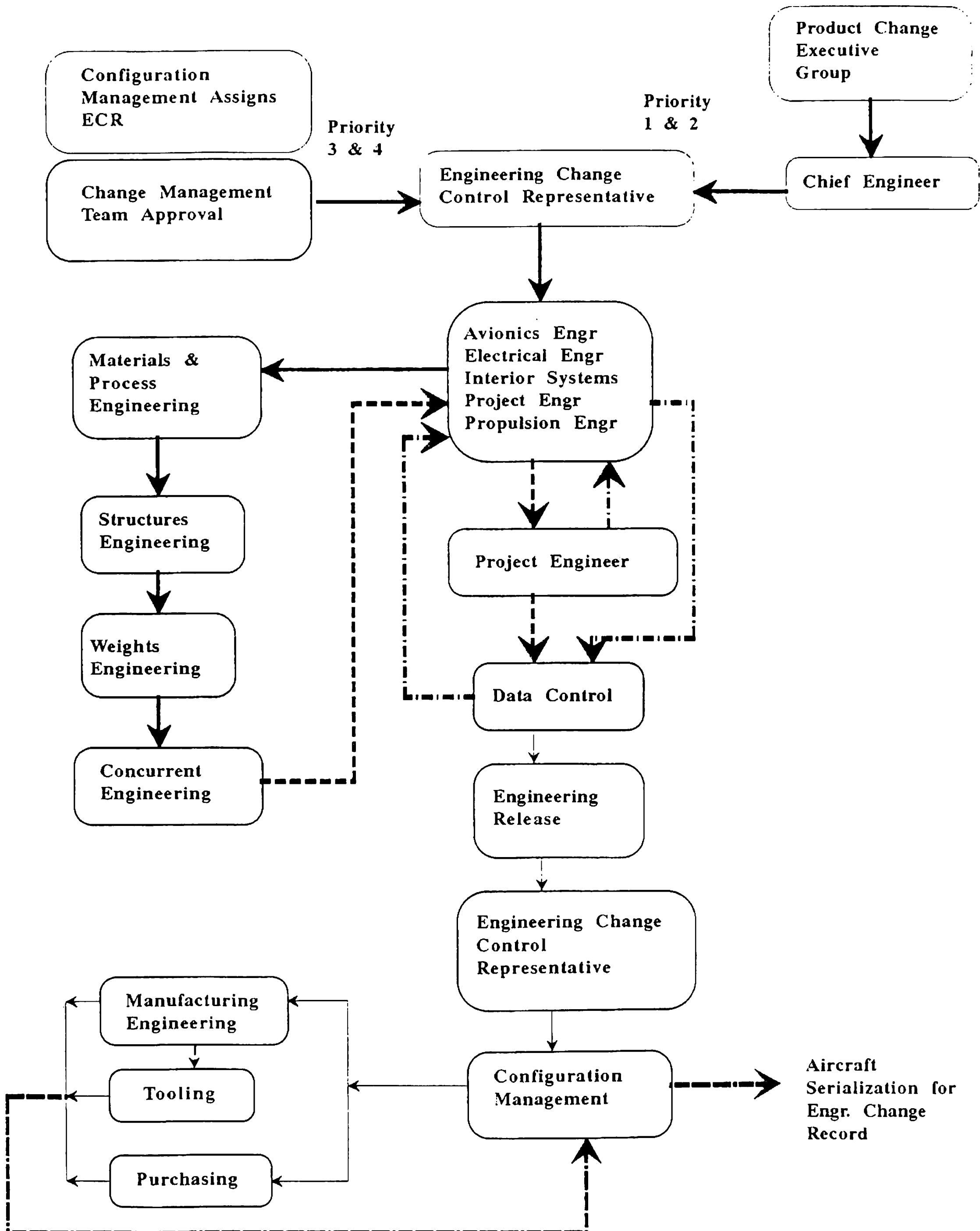

Figure 1 : Engineering Design Change Approval Process

particular engineering control group in the engineering design organization.

4.1 ECR Flow from Engineering Control Group to Configuration Management

The engineering control group, after updating the database, revises or creates new drawings and bill of materials which identify the changes that need to be made to implement the design change. Upon completion of the product change definition, the ECR package is routed to the materials and process engineering group. The function of this group is to review and ensure the changes have correct materials and heat treat usage, proper corrosion resistant finishes, etc. The ECR package is then routed to the structures engineering group where a detailed analysis of the changes are reviewed for structural integrity. From the structures group, the ECR package is sent to the weights engineering group who determine the product weight increase/decrease to assess if any flight characteristics will be altered due to a change in the aircraft center of gravity. If so, changes are noted on the drawings and the ECR package is routed to the concurrent engineering group. The concurrent engineering group is comprised of experts from manufacturing planning, NC programming, and tool engineering who review the ECR package to determine if producability requirements have been met. The ECR package is then sent back to the engineering control group where the changes suggested by all the groups are reviewed and implemented.

After the implementation of the desired changes to the ECR, it is routed to the Project Engineer who is responsible for the final product configuration. If the project engineer is completely satisfied with the ECR package, it is routed to the data control group. Otherwise the ECR is sent back to the appropriate engineering control group for revisions, and then sent to the data control group. The data control group is responsible for developing the new/revised bill of materials and for releasing the ECR package along with the accompanying paper work. If a bill of materials discrepancy is encountered, the ECR package is sent back to the appropriate engineering control group. Once the ECR is released by the data control group, the engineering release group takes appropriate actions to document and store the drawings in a data vault. The ECR is then sent back to the appropriate engineering control group representative, who ensures that all applicable ECR paper work is accounted for and all the required signatures are obtained. The ECR package is then sent to the configuration management group.

The configuration management group sends copies of the ECR drawings to manufacturing engineering and purchasing if required. Manufacturing engineering reviews the ECR package to determine what manufacturing changes will have to be made to implement the product change into the production line or field aircraft. If tooling revisions or additions are required, tool work orders are written by manufacturing engineering and distributed to tool engineering wh revise the required tooling. If purchasing is required, purchasing reviews the ECR package and determines when parts will be available for installation into the product. These derived committments to accomplish work are sent back to configuration management who interface with the master schedule to determine aircraft serialization for the ECR.

5 DATA COLLECTION

The first step in the development of the model was the understanding in sufficient detail the activities that take place in the approval process. This was followed by data collection. Known data was provided by the configuration management group in the form of a configuration management report for a particular year. This report included information such as the ECR number, if purchasing and tooling was required, revision level, aircraft model number, change management team or PCEG approval date, priority level, the date the ECR was received by configuration management from the engineering control group (this is the same date that the manufacturing engineering receives the ECR package from the configuration management). and the date configuration management set the aircraft serials for the ECR. Additional information provided by the configuration management group included the number of change requests that were approved and number that were disapproved. ECR flow times from the beginning of the data revision/new drawing by the engineering control group to ECR release by the data control group was also available. Some of the inter-departmental routing times that were not readily available were manually clocked. Since all of the data required for a detailed simulation analysis for the internal engineering flow was not readily available, expert opinion had to be relied upon for determining the time spent by the ECR in each of the groups through which it flows. The following was the distribution of the total flow time (from engineering control group to the data control group) :

45% --->	Engineering control group to develop new/revised drawings
5% --->	Materials and process engineering
25% --->	Structures engineering
5% --->	Weights engineering
5% --->	Concurrent engineering
3% --->	Engineering control group to make corrections suggested by above groups
5% --->	Project engineer review
1% --->	Engineering control group to make corrections suggested by project engineer
4% --->	Data control initial review
1% --->	Engineering control group to correct data control changes
1% --->	Data control to complete bill of materials.

This information was used to develop triangular distributions to represent the time spent in each activity. The ECR arrival for each priority level was obtained from the information included in the configuration management report. Whenever sufficient data was available the appropriate theoretical distribution was obtained using UNIFIT II [1].

6 SIMULATION MODEL

A simulation model of the approval process described above was developed using the SIMAN [2] simulation language. SIMAN was the language of choice for reasons of familiarity, and flexibility. Flexibilitywas important as it was anticipated that each of the groups involved in the approval process will be modeled in future, and therefore ability for different submodels to represent the system was important. Overall structure of the model is given in Figure 2.

7 SIMULATION STUDY OUTCOME

The system was a non-terminating system and the batch means approach was used to establish the run length and the confidence intervals. Using the SIMAN Output Processor, it was determined that, that to obtain a relative error of around 2% at a 95% confidence level, 10 batches of 240 observations each was required. This translated to 14,081 days of simulated time, with statistics cleared at 1200 days to remove start-up bias. The simulation output was validated by consulting with experts and also comparing the overall flow times with the available data. This particular simulation study resulted in a critical examination of the activities the different engineering design change groups were involved in. The immediate outcome was in confirming the delays that take place in the engineering change approval process. One of the obvious things were the delays in routing the ECR packages between engineering groups. This could be attributed to the fact that packages were routed manually, by an individual taking it to the next group or by sending it through the company mailing system. This study resulted in justifying the management decision to introduce an electronic data transfer facility to reduce administrative delays. The simulation analysis highlighted some of the areas where a more detailed analysis of operations was required so that delays can be further reduced.

8 CONCLUSIONS

The simulation study of the engineering design change approval process was a result of an effort by a major commercial aircraft company, to go beyond shop floor simulation and develop factory wide simulation capability. As the engineering change process involves almost all components of a manufacturing system, it was felt that an analysis of this process would provide a good insight into the interactions among the various groups of the company. As is the case in many non-traditional applications of simulation, the biggest problem was lack of information. Considerable amount of interviewing, data collection, and cooperation from the groups involved was required before the information flow and relevant data became available. One immediate benefit of this study, was a better understanding of the information flow by the individual groups. The other benefit was that this model forms the basis for simulation studies of the individual components of the decision process. The interest showed by the management has resulted in the intiation of a more detailed study of the role of the manufacturing engineering group in the engineering design change approval process.

REFERENCES

UNIFIT II User's Manual. 1991. Averill Law & Associates, Tuscon, AZ.

Pegden, C. D., R. E. Shannon, and R. Sadowski. 1991. *Introduction to Simulation Using SIMAN.* McGraw Hill, New York.

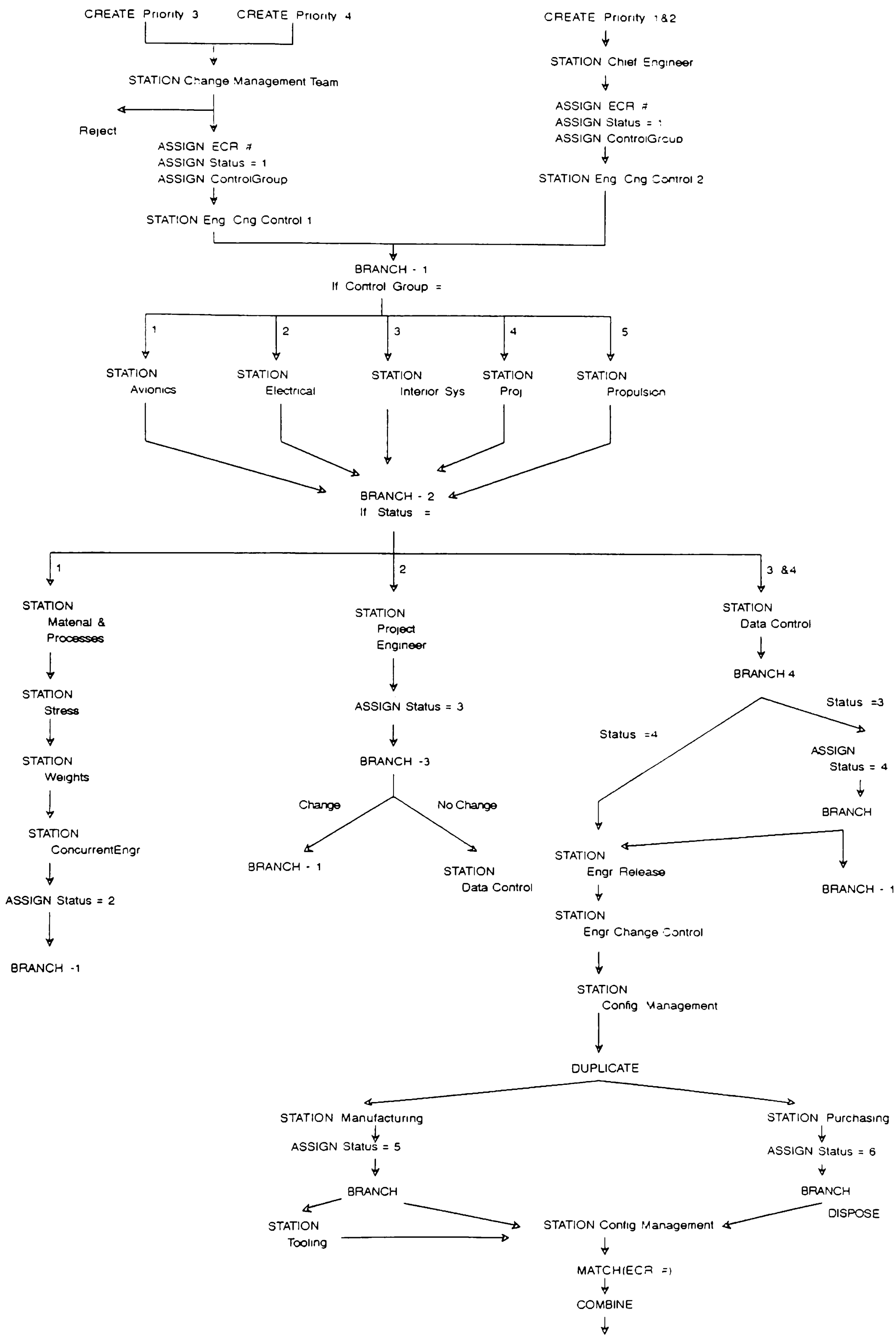

Figure 2 : Simulation Program Structure

AUTHOR BIOGRAPHIES

SUBRAMANIAN PRAKASH is an Assistant Professor of Industrial Engineering at The Wichita State University. He obtained his PhD from Texas A&M University. His interests are in Simulation Applications in Manufacturing, Goal Directed Simulation Systems, Factory Wide Simulation, and Development of Integrated Modeling Environments.

JOEL SCHLOTTHAUER is a Graduate Student in Industrial Engineering at The Wichita State University. He is Group Leader, Aircraft Systems Engineering with a leading business jet manufacturer. He has a BS in Mechanical Engineering from Oklahoma State University, and has six years of aerospace design experience. His interests are in Object Oriented Simulation, Operations Research applications in Manufacturing and CAD systems.