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An Analysis of Computer Aided Design (CAD) Packages Used at MSFC for the Recent Initiative to Integrate Engineering Activities

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Abstract

This paper analyzes the use of Computer Aided Design (CAD) packages at NASA's Marshall Space Flight Center (MSFC). It examines the effectiveness of recent efforts to standardize CAD practices across MSFC engineering activities. An assessment of the roles played by management, designers, analysts, and manufacturers in this initiative will be explored. Finally, solutions are presented for better integration of CAD across MSFC in the future.

1.0 Introduction

1.1 Background

"NASA's missions include science and exploration that's never been done before." [3] Accomplishing these challenges requires the design, manufacturing, and use of complex systems like shuttles, space stations, satellites, probes, and more. Building hardware for these systems requires the integration of numerous complex subsystems and "understanding every aspect of the product to the tiniest detail." [3]

In 1997, management in the Structures and Dynamics Lab at MSFC proposed a series of lab process improvement initiatives, one of which was the Multidisciplinary Design and Analysis (MDA). This initiative involved defining the design process and proposing solutions to better integrate the lab's engineering processes. The idea of having an "integrated" engineering solution caught management's attention at the Engineering Directorate level. The initiative was elevated to the directorate level for implementation in all engineering activities at the Engineering Directorate at MSFC.

A team from the Engineering Directorate was assembled in 1999 to support the MDA initiative and investigate how to improve the CAD design process and reduce design time and cost. The team reviewed CAD packages and tools for data management of design information. The data management tool was needed to capture all new and changed data, provide configuration management of the data, and provide access to the data by others in the design process.

The review team consisted of CAD modelers, testers from structural dynamics and stress analysis teams, manufacturing personnel, assembly and mass properties product designers, and expert CAD developers with expertise in various CAD packages. It's worth noting that management had decided prior to the study that the solution would include a single CAD package for MSFC.

Prior to the study, the primary CAD systems used at MSFC were evenly split between Pro Engineering (Pro/E) and Unigraphics (UG). The benefits of using a single CAD system include simpler administration, seamless CAD model integration, efficiency increases in analysis and manufacturing and simpler product data management. However, using a single CAD system limits a design organization in selecting the best tool for their task. Management believed that the benefits outweighed the drawbacks.

The team made the following recommendations for the Engineering Directorate:

1. Use a single CAD package to provide seamless information flow through design, test, and manufacturing.
2. Use a product data manager (PDM) tool to provide the CAD data management solution as well as a data manager for all non-CAD engineering data produced and evaluated at MSFC.

The group recommended UG for use at MSFC from an assessment of the CAD technology with respect to modeling, assembly, drafting, routing, manufacturing, analysis, translating, and administration. The UG package was quickly adopted and implemented by the Engineering Directorate's mechanical group. The electronics group had heavily used Pro/E for their design work. Therefore, the electronics group postponed the transition to UG since it felt that UG did not provide the all needed capabilities and received a waiver from the director of Engineering.

In early 2002, the electrical group made the decision to move to a CAD package (SolidEdge) known to be compatible with UG. During the same time period, the Integrated Engineering Capability (IEC) office selected the Windchill software for the PDM. Windchill is a Parametric Technology Corporation (PTC) software package and is the parent to Pro/E CAD package. The electrical group reversed their earlier decision to move to a UG CAD package since a lot of functionality would be lost and decided to stay with Pro/E. The PDM will add even more functionality to the Pro/E CAD package to enhance their design process. This decision halted the seamless one CAD package integration envisioned by management and the team in 1999 to improve the design process.

1.2 Problem

Over the 3 year history of the MDA implementation, the design to manufacturing processes at MSFC still have deficiencies in technology areas and interrelationships across the design activities. Some processes do not flow smoothly from one step to another, and some activities continue to use old technology including the use of non-automated procedures. These deficiencies cause schedule slippages and budget overruns in MSFC. Management has proposed solutions in the past (single CAD package, for example) that have either not been implemented or not had management's commitment to ensure implementation.

1.3 Why is this So Important?

MSFC is currently the system integrator of the Space Launch Initiative (SLI) program which has the potential for funding upwards of $4.85 billion over the next five years [2] if all options are exercised. The SLI Program Office in conjunction with the Engineering Directorate at MSFC and other NASA centers will examine proposed designs made by the SLI contractors for feasibility. Design ideas and proposed solutions will often be offered to NASA for evaluation as CAD models. The information must be made accessible and configuration managed throughout the design and analysis process. The degree to which MSFC is able to realize MDA's original goals will considerably impact MSFC's success on the SLI program and the success of the program as a whole.

1.4 Master Model Concept

The mechanical group during the MDA initiative effort proposed and adopted the CAD master model concept. "The idea of the master model is that you have one master driving model which contains the full product definition. Everything else is derivative information which relates to, and is dynamically associated back to, the master model."[3] The information contained in the master model is an input to all the analysis, manufacturing, testing, and operations. Configuration management (CM) provides the rules and processes applied to the product definition so that changes can be traced and the CAD master model is baselined. The CAD master model is used throughout the design processes and is vital to establish CM controls on the designs.

1.5 CAD Use by Design Analysts

Early in the design process, the CAD model definition is sent to structural and dynamic analysts for an assessment of the preliminary design. The results may show a need to change some of the input parameters to improve the design or to fix problem areas. The time lag in getting changes back through the designers creates problems in finishing the analysis especially when multiple iterations are needed. Analysts will make parameter changes or redo the model themselves in order to perform testing in a timely manner. This results in a loss of control of the design by the designer and problems with CM, since the Master Model Concept has been broken.

1.6 Manufacturing Use of CAD Models

If manufacturing is to be performed in-house, the released design is sent to the manufacturing department for machining, electrical work, and other activities to produce the part. A CAD model is not used during in-house manufacturing. The Computer and Numerical Control (CNC) manufacturing group who machine the parts using either computerized or manual machining tools is not set up to use CAD packages. The CAD models could be translated into the current machining software but much information would be lost. Therefore, the CNC group chooses to reenter design information into the system. After the information is coded for use by the CNC machines, it is copied onto those machines using a 3-½ inch floppy. Paper products are being used by the machinists for the manual machines. The CAD models do not provide all the necessary information such as tolerance levels that the machinists require to build the part and the machinists use a paper 2D drawing to access all the needed information.

The inspection department uses paper products to verify part quality. The electrical packaging department and the sheet metal manufacturing department also use paper products that are provided by the designers or printed from a CAD model. These departments are not set up for CAD packages since they do not possess the technology to use CAD. The CNC manufacturing group has plans to transition to the UG CAD manufacturing package for compatibility with the mechanical group's CAD models. The Engineering Directorate management wants all manufacturing activities automated from production to delivery of the completed part.

1.7 Data Repository of CAD Models

The data repository receives part designs in 2D paper formats. Currently, the Federal Repository which dictates deliverable requirements, requires 2D drawings. The in-house designers desire is to work with and release 3D models. New programs or upgrades to existing systems will often use previous designs as a starting point. If the designs are in a format that makes them easy to change, this would save time and cost rather than starting from scratch. However, even if all the required software were also saved with the 3D model (correct version of CAD software and all associated tools), the correct hardware to read and run the software would also be needed.

1.8 CAD Use by Contractors

MSFC programs employing contractors receive the CAD information in various formats from those contractors. Some contracts currently in place stipulate design delivery in paper format only. The manufacturing group estimated a 90% paper copy delivery from contractors of designed parts. The CAD models are usually converted from scratch by the mechanical and electrical departments into the MSFC CAD package if they're not delivered in UG or Pro/E format. Translators are sometimes used but require additional effort for model clean up and input of lost model information. Cleaning up a CAD model can take as long as to redo an identical model and check it for consistency.

2.0 Case studies in Literature

2.1 CAD Implementation

2.1.1 Herman Miller

Herman Miller, a producer of interior furnishings, implemented a system to integrate their database and CAD tools and automate their maintenance and work request process. Prior to implementing their computer-aided facilities management (CAFM) system, the company used three different processes to manage facilities information. None of the systems could talk to one another and much of the information had to be duplicated in each system. After integrating all of the facilities management processes, Herman Miller has enjoyed "enormous savings in time and effort and increases in profitability". [4] There has also been a "vast improvement in the accuracy of the facility information." [4] This improvement has "diverted substantial property taxes by the accurate reporting of reduced occupancy to local government authorities" [4] that directly resulted from the integration and improved capabilities of the CAFM.

2.1.2 Rolls Royce

Rolls-Royce and Bentley Motor Cars, a manufacturer of luxury motor cars, wanted to better exploit the CAD models it had developed. "Rather than using CAD as just another service into the product development process, the CAD environment could be enhanced to become an integral part of a development process that was integrated across the whole design function and beyond. Every activity involved with product development could be related back to the base information in the [CAD] models, which would provide a single source of all new product information."[7] A manufacturing planning environment was also implemented to supplement the development process in the engineering environment.

A single CAD package was adopted at Rolls Royce. All suppliers were required to deliver their products using the same CAD package so that the CAD model would not need to be translated. The new development process allows Roll Royce to reduce the number of prototypes since the CAD package allows for detailed viewing of the designed system. The better design results and reduction of late design changes have resulted in financial savings due to "vehicle product development times [have been reduced] by about 25 per cent."[7] The new development process also allows for greater customization of features in a cost effective manner. Another financial benefit was a reduction in the cost of components from suppliers due to a lower percentage of late design changes.

2.1.3. General Motors

General Motors's North American Operations (GM) began a corporate-wide technology effort to implement a common software system and methodology for all GM facilities management locations. The CAD standards included "specific CAD drawing requirements, procedures, and best practices. Utilities were developed to simplify the process and increase compliance."[2] Benefits included: annual savings between $20,000 and $50,000 per CAD user, improved communication, and consistent drawings.

2.2 Industry CAD Issues

2.2.1 Design Process Difficulties

Although "CAD has done a great deal to improve design and manufacturing, [often] very little communication exists between design engineering and manufacturing. Engineering designs the product and then throws the drawing over the wall for manufacturing to make the product." [1] For CAD to succeed, the data products must be able to move between all stages of the design process from engineering to manufacturing. "In many cases, CAD has been implemented in just one, or in a limited number of these stages (e.g., in design engineering but not in manufacturing engineering), or in the 'proposals' drawing office but not in the 'production' drawing office. Partial implementation of this sort can only be successful on a very limited scale." [14]

Most manufacturing organizations do not have a product development environment that operates with a single CAD system. "Getting one program to work with another is one of the biggest problems companies have with computer software. This lack of compatibility of CAD software costs manufacturers in the automotive industry alone $1 billion a year" [14] One supplier to the automotive industry has stated that his company would save $235,000 annually if he could just have one CAD system instead of 19 different licenses from 13 different systems. [14]

2.2.2 Solutions implemented

2.2.2.1 One System Implementation

The automotive industry Original Equipment Manufacturers (OEMs) require the use of one CAD system for their products. This provides the OEMs a seamless integration of supplied products. "The only successful integration is with companies using a single CAD system" [6] The strategy of a single CAD system adds cost to the project from the added expense when using the preferred CAD model. However, according to Ford Motor Company, " We believe that by enforcing a single system policy, we are lowering our engineering costs.." [14]

2.2.2.2 Exchange

2.2.2.2.1 CAD Standards and Translators

"The neutral CAD format is a data output option on virtually all CAD systems, and serves as an intermediary language that virtually all CAD systems can likewise understand." [15] The Initial Graphic Exchange Standard (IGES) was developed in 1979 and was mostly used in the United States. The International Standards Organization (ISO) began developing a universal translation language in the form of the Standard for the Exchange of Product Model Data (STEP) in 1983. STEP is a "comprehensive ISO standard (ISO 10303) that describes how to represent and exchange digital product information. The STEP describes the geometry, topology, tolerances, relationships, attributes, assemblies, and configuration." [13] The STEP standard is gaining popularity and most high-end CAD packages provide this capability. The data is the geometric representation of the CAD model. [10]

The use of translators can create the need for a lot of cleanup work and reengineering. Ford Motor Company is investigating a translation tool to help to exchange data with Volvo (a recent acquisition) that operates in a different CAD package. CAD standards and translators have the problem of not providing the required design information including features, history, and constraints to the translated CAD model. However, recent improvements in some high-end CAD packages allow for a limited ability to graphically input parametric data once a file has been translated using the STEP standard and thus reducing the reengineering effort. This allows for design changes in the translated file that previously could not be done or was more difficult to perform.

2.2.2.2.2 Visualization Tools

There are CAD data products currently available that provide a visualization tool which is CAD file format independent data. One example is a ".jt" file. "A .jt file is a lightweight converted version of a CAD file that allows users to view product images online. The lightweight file has no design history nor can the file be modified for design changes. The .jt file can be converted from several file types such as UG, CATIA, I-DEAS, and Pro/E." [1] The .jt files are native to one CAD vendor while another provides a similar lightweight file called .ol. There are many CAD data products that provide the environment for .jt or .ol files for a designer to perform design analysis such as fit checks from CAD models produced in multiple formats.

2.2.3 Heterogeneous CAD Infrastructure

"Manufacturers that supply to the entire automotive industry must purchase, maintain and staff three separate product development teams, one for each CAD system." [14] Outsourcing can provide access to CAD systems not developed in-house but required by the customer. Outsourcing can cost $25 to $30 more per hour than in-house development. [11] "A heterogeneous CAD infrastructure and staff allow for a supplier to deliver required native information to multiple OEMs." [14] This approach results in a costly infrastructure and a manpower balancing problem.

2.2.4 Re-do CAD files

Some designers initially develop the product in the designer's preferred CAD system and then re-do the CAD models from scratch in the customer's required format for delivery. Re-doing a CAD model is estimated to "cost between $500 and $5000 per part (depending on part complexity and size), and far more for assemblies." [14]

2.3 Manufacturing Improvements

Hamilton Standard Electronic Manufacturing Center has implemented several initiatives in the 1990s that have improved their manufacturing capabilities. In the overall manufacturing process at their Farmington, CT factory, "teams were formed consisting of assemblers, technicians, production control planners, engineers, and supervisors."[5] These teams reviewed every process to determine areas that could be improved by eliminating non-value added operations. Through the review process, equipment improvements were identified and implemented. The need for inspection has been minimized and cycle time and rework have been reduced by as much as 50%.[13]

Producibility guidelines have been implemented "resulting in cycle time reductions and reductions in scrap, rework, and repair." [5] Multiple design and manufacturing disciplines have been brought together through [PDM] software to integrate product design data and information. "Cycle times reductions of nearly 50% have resulted because the various efforts can be performed concurrently rather than sequentially."[5]

Hamilton Standard uses concurrent engineering to integrate product development processes to "connect initial product concept, design, and related processes to manufacturing and support. [Concurrent engineering] is implemented through the detailed procedures and guidelines that provide a structured methodology for the formation, function, and operation of the process as a whole..".[5] The objectives of the guideline include improve product quality, minimizing cost of design, development and manufacturing, and improving the transition from engineering to manufacturing. [5]

3.0 Assessment of MSFC Design Process

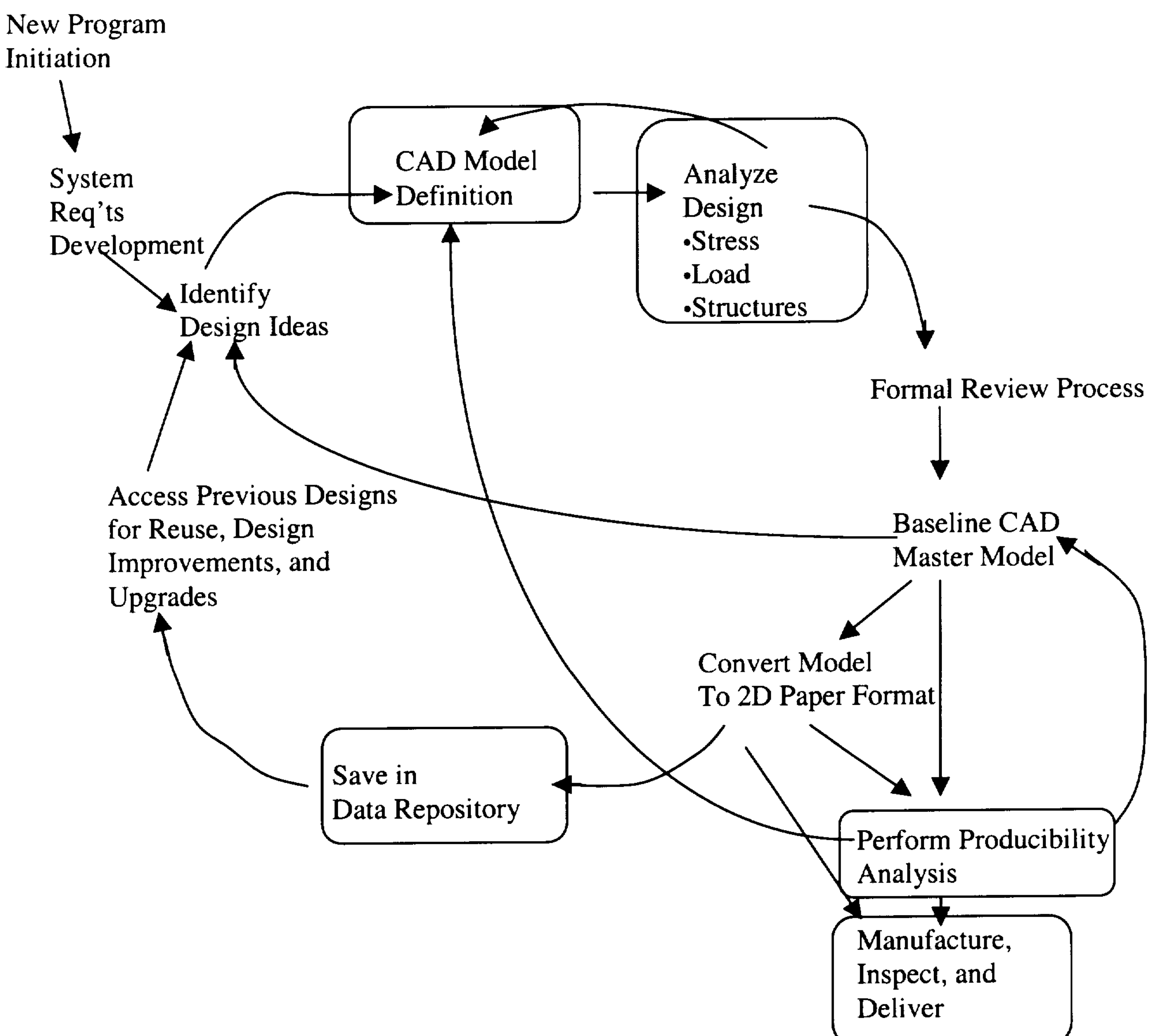
The problem areas in the engineering design process using CAD packages are summarized below.

1. Multiple CAD Use: MSFC uses multiple CAD packages. Other NASA centers have their own CAD packages which may or may not be the same as those used at MSFC. Contractors usually provide their designs in a different CAD format. At a minimum, a single CAD package needs to be agreed upon within a functional area of a project or system. Interoperating between CAD packages requires translators, use of standards, or redoing the models, which all require additional resources.
2. Design Analysis: During testing for stress, structures, loads, etc. the analyst may need to change the parameters to improve or correct a design. The analysts may change parameters in the CAD models themselves during their testing. This results in CM issues and loss of control over the design by the designer.
3. Producability Analysis: Manufacturing does not review in detail the design until after the design has been baselined and is ready to be manufactured. This can result in late design changes that add cost and schedule to the project.
4. Manufacturing Through Delivery Activities: Manufacturing through delivery activities do not exploit CAD package capabilities. CAD use is in limited areas with most activities still using the 2D paper format of the designs.
5. Data Repository: The CAD master models are saved in the data repository as 2D drawings or scanned files of the 2D drawings. These methods are not in a format that lends itself to easily making design changes or inputs to a new design.

4.0 Analysis of Problem Areas

4.1 Systems Diagram

The design process is a series of relationships between different activities. The interactions of any one activity affects the entire process and depends on what at least one other activity is doing. By identifying work flows, problems areas can better be examined. The current design process is shown below using a systems diagram.



Systems Diagram of Current Design Process

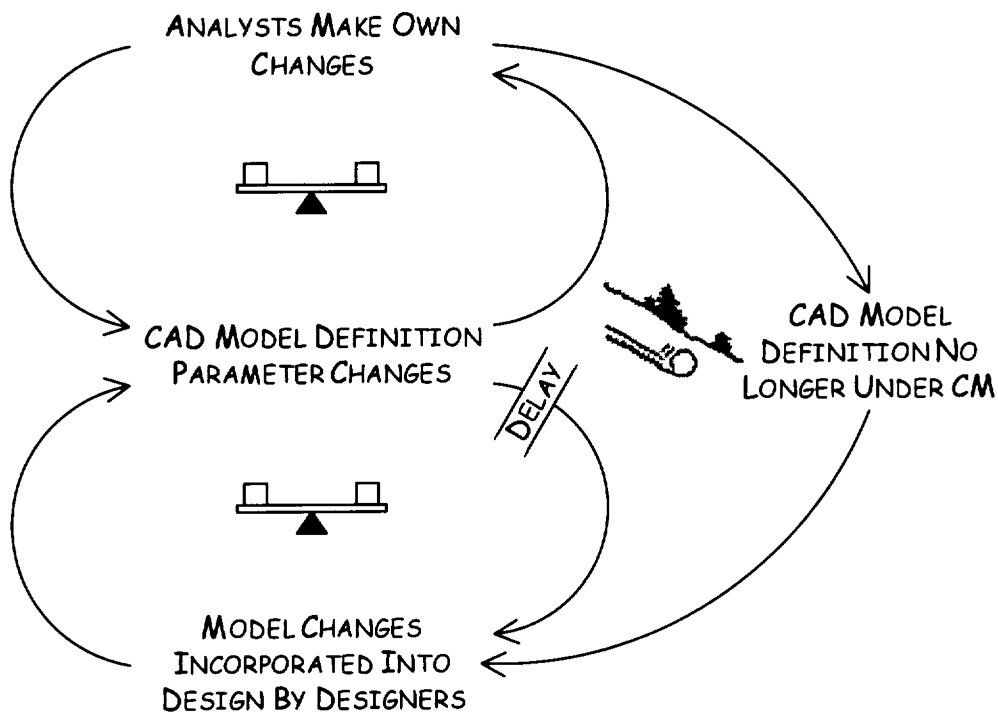
4.2 Multi CAD Use

Management's initial idea was to integrate the engineering processes by using a single CAD package at MSFC. The relationships involved with CAD model design involve more than just MSFC. Management's desire for a single CAD package while proven in industry to resolve interoperability issues, will not work while other NASA centers and contractors continue to use different CAD packages. Improving the interactions between personnel in the activities of creating a design with a CAD package also provides a means for integrating the overall design process. Focus should be placed on how to incorporate the many different formats and not on a solution that has not been successfully enforced at MSFC and cannot be enforced with all participants.

The CAD master model can be a conglomeration of many different CAD packages merged into one product description. Designers should be concerned with seamless sharing of CAD data only where needed in defining the master model. Industry has provided solutions in the forms of standards, translators, and lightweight files. An assessment of current technology and near-term technology show that CAD package developers are addressing these issues and offering more compatibility with each new software release. For example, version 18 of UG now offers the ability to add parametric information graphically from translated files in Pro/E.

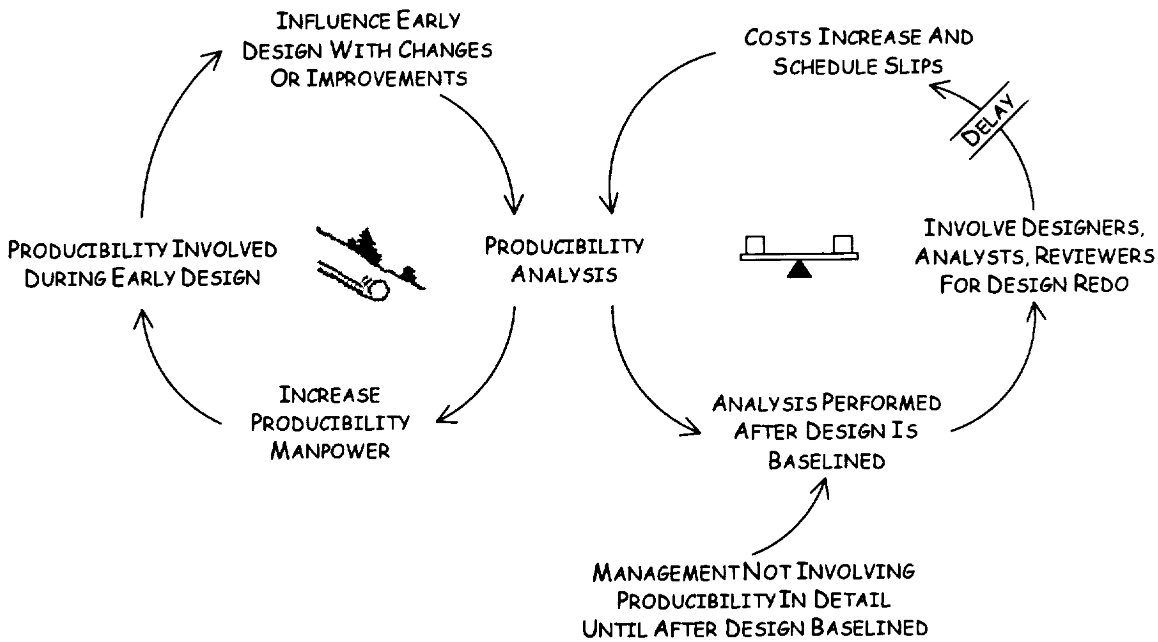
4.3 Shifting the Burden in the Design Analysis

The following shifting the burden diagram [12] shows a problem with the design analysis. Both the designers and analysts are trying to create a product description that meets the system requirements. Changes to the parameters may need to be made for the analysts to complete their testing. When parameter changes are needed in the design there may be a delay in the designers incorporating the change and providing the new design back to the analysts. The analysts will often make the changes themselves to the design. The CAD/design procedures for identifying rules and responsibilities at MSFC is an informal and inconsistent arrangement between the designers and analysts.



4.4 Limits of Growth for the Producibility Analysis

The following limits to growth diagram [12] shows where the real costs and schedule delays are with the producibility issue. Management is assuming that there will be few, if any, problems with manufacturing and does not invest in the manpower to do detailed producibility analysis early in the design where problems can more easily be corrected. Many problems are not caught until manufacturing is set to begin. If a producibility problem is discovered just before manufacturing is set to begin then it will require changing the design and going back through the previous steps including analysis and review. Management, by not providing for and recognizing the needs of producibility, can cause added costs and schedule slippages in the design process.



4.3 Management's Contribution to CAD use in Manufacturing

Management's strategic policies have determined the technological state of the manufacturing activities. Neglect at improvements cannot be corrected by merely investing large sums of money in the problem. "It normally takes several years of disciplined effort to transform manufacturing weaknesses into strengths. It can take several years to break the habit of "working around" limitations of the manufacturing operation."[8] Management must decide what roles in their business policy manufacturing will play and provide investments to accomplish this goal. There are four stages of manufacturing's strategic role. [8] Each stage is determined by manufacturing's position in the overall business policies. Stages cannot be skipped but must be taken sequentially in order to reach a higher state of ability.

Stage 1 is an internally neutral role and has little influence on the organization's overall strategic policies. Safe and proven technologies are used and are purchased from the outside and not developed within the organization. Management minimizes their involvement in Stage 1 manufacturing departments. Stage 2 is an externally neutral role. A stage 2 manufacturing organization follows normal industry practices regarding work force, equipment purchases and adding any capacity additions. The introduction of major changes is avoided when possible. Some in-house development is used. Stages 3 and 4 look to manufacturing as an important aspect of the overall organization. Manufacturing actively supports the organization's strategic position. Management "seeks out carefully thought out sequence of investments and systems changes over time" [8] and formulates a manufacturing strategy. Stage 4 continues by anticipating new manufacturing practices and technologies and seeks to acquire expertise long before they are an industry standard.

MSFC falls at Stage 1. New technology does not become incorporated into the manufacturing processes unless workarounds are not providing products in a timely and cost-efficient manner. The type of manufacturing system that MSFC is envisioning is a Stage 3 organization where investments and overall system changes will significantly impact business policy.

Using a CAD model throughout manufacturing (i.e. paperless manufacturing) is only now getting MSFC's attention when industry has tackled this problem many years earlier. The automated means for manufacturing can bring the organization up to a stage 2 level. If management desires an integrated engineering capability with manufacturing, then manufacturing will need to play an equal role in developing products as design and analysis. This is at a stage 3 level and will require more than technology improvements. It will require management's commitment in terms of strategic planning, manpower, and financial resources to bring the manufacturing organization up to this level. If a Stage 3 organization is not the goal, then workarounds can be implemented where little payback exists for improving the design processes.

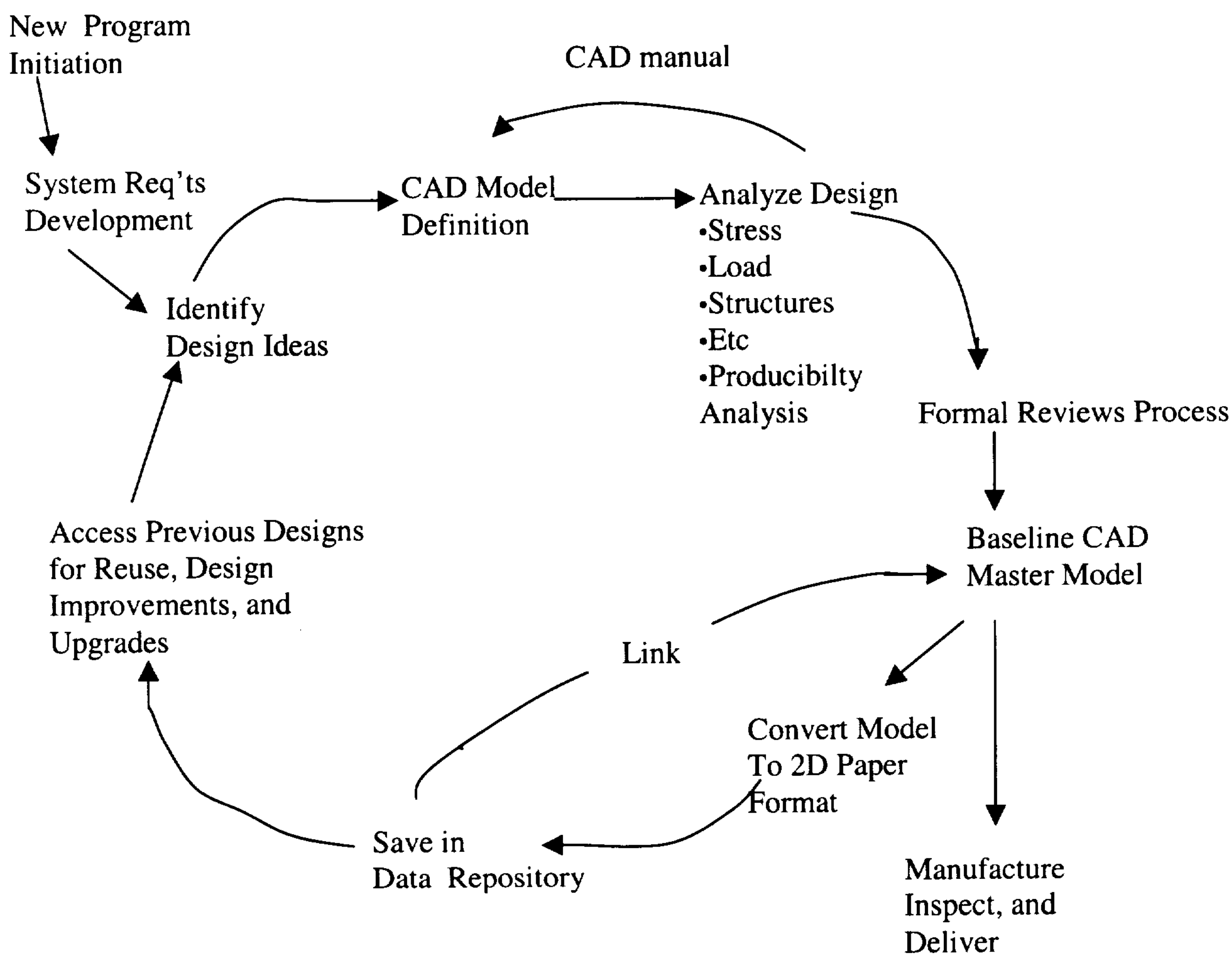
4.5 Technology Implementation for Data Repository Issue

The data repository issue of requiring paper drawings is a result of federal laws based on old technology. NASA needs in its strategic plan a 3D CAD model release process. This process would need to include all the information required to access a

CAD model rather than a sheet of paper or a scanned in drawing. Technology exists today that allows for links to databases for viewing of information.

5.0 Recommendations and Summary

Proposed Systems Diagram after Implementing Solutions



Systems Diagram of Proposed Design Process

Resource requirements for proposed solutions:

	Personnel Interactions	Manpower	New Technology	Discontinuous Innovation	Continuous Innovation	Cost
Multiple CAD Use	•		•		•	$
Design Analysis	•	•			•	$
Producibility	•	•			•	$$$
Manufacturing	•	•	•	•		$$$$$$
Data Repository			•		•	$$

5.1 Proposed Solutions

Recommend MSFC management taking lessons learned from the MDA effort so far and initiating a second phase to address the problems in integrating the engineering processes. Management should present their goals better to front-line designers and manufacturers at a (sub)system integration level of detail. MSFC needs to use an industry standard CAD data format such as STEP for CAD models. This will make the system integration job smoother allowing MSFC to deliver its systems more reliably. The CAD packages should not be mandated at the level of the internal systems. However, designers and their subsystem manufacturers need to use the same CAD packages since they must share detailed subsystem information. Acquire buy-in to the second phase of the MDA by demonstrating success across several projects instead of at the center or directorate level.

Technology implementation is needed to improve the design process for multiple CAD use, manufacturing to delivery activities, and the data repository issues. Current technology provides most of the solutions needed for these issues. Short-term workarounds can be used where solutions provide only partial successful implementations. CAD interoperability has the biggest shortfall in technological solutions. Manufacturing to delivery activities and the data repository issues have proven solutions in industry.

CAD interoperability is a problem felt by many in the industry. With the increased reliability in translators and standards, interoperability is quickly being resolved. Management may want to have a single CAD package at the MSFC level as a long-term plan if the standards and translator technology levels out in the next few years without providing a consistent and reliable solution. The CAD model designers currently use workarounds that allow various CAD model packages to either be integrated together or have scheduled time for the redo of delivered CAD model designs into the current MSFC CAD package.

The manufacturing to delivery activities needs new technology to bring these activities at the same level of many organizations in industry. The new technology will provide a discontinuous innovation, i.e. one that incorporates a change of behavior and a modification of the products and services needed to perform the job. Successfully implementing the discontinuous innovations should be well planned and phased in over a several year time period. Changes should be phased in from those involving the least amount of impact to those changes incorporating a new way to perform job duties and access information. Communication, training, and employee involvement are key areas for successful implementation.

There are various proven processes available to bring MSFC up to the desired technological levels. A review of best practices in industry is a first step. These changes should be viewed as bringing the manufacturing organization up to a stage 2 level. A stage 3 level needs a change in the current strategic outlook of manufacturing at MSFC before the high resource requirements (financial and manpower) are used to reach and sustain the stage 3 level. Management should revisit MSFC's strategic role for manufacturing to ensure it is compatible with MSFC's overall business policies and use this as a basis for needed improvements.

The data repository issues can be solved by linking the 2D design in paper or electronic format back to the CAD master model through the use of the PDM. The IEC office can provide this as a new data product. It is important to have this link be as transparent as possible to the user so that only a few new or additional steps have to be taken. The new PDM can make this happen will little impact to the user except to provide the information the user needs in a form that will be easier to use. The PDM can help specify allowable users to the information and their privileges to the CAD master model to maintain CM and security. A clone of the CAD master model can be used by the designers for reuse and improvements when appropriate allowing the CAD master model to remain unchanged.

The design analysis can be corrected if management focuses on the relationships of the participants and their needs. A set of CAD practices should be implemented. A CAD manual would contain those bits of information that make the flow and iterations between the designers and analysts work more productively. It would be developed by the designers and analysts to resolve the issues each has with the current modes of operation. Sections of the manual would include responsibility issues, method of parameter changes, acceptable time delays and what to do when too much time has passed, and how CM will play into the interactions. Control and oversight are included as well as information flow. The CAD practices will be successful only if they are easier to use than to ignore.

Similarly as with the design analysis, the producibility analysis will be corrected once the relationships between the designers and producibility personnel are established. The producibility analysis will need earlier design information to affect the design sooner and at a time where changes are less costly. Management should provide the manpower needed in the model definition phase. Long-term this will decrease the overall cost of a design when there are fewer late design changes.

5.2 Summary

The MDA initiative has been a starting point to integrate the engineering activities at MSFC. A second phase to this initiative can bring about the original goal of integration across the engineering activities. Use of the PDM tool can provide access to information needed by all participants in the design process and enhance CM by tracking revisions and baselined designs. The CAD issues are primarily centered around interrelationships of the players in producing a design to delivery process. Technology is useful in automating and improving the engineering concepts however it is the communication and relationships between all the activities that will improve the integration of the engineering activities.

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