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NEW WAYS OF DOING BUSINESS (NWODB) COST QUANTIFICATION ANALYSIS

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Introduction

The cost of designing, producing and operating typical aerospace flight hardware is necessarily more expensive than most other human endeavors. Because of the more stringent environment of space, hardware designed to operate there will probably always be more expensive than similar hardware which is designed for less taxing environments. It is the thesis of this study that there are very significant improvements that can be made in the cost of aerospace flight hardware.

NASA, and its aerospace contractor community essentially set the mold for the culture of the civil aerospace business in the 1960's during the manned Mercury, Gemini and Apollo programs and with the unmanned satellites and launch vehicles that were developed at the same time. Especially in the early days of space flight, building flight hardware to operate in the unfamiliar environment of space was a challenge that required solutions that were extremely conservative in terms of risk. A culture was put in place that worked--but it was also a culture that was very costly. Several attempts have been made over the years to introduce a more cost effective culture into the way NASA does business. At the outset of development, the Shuttle was believed to offer improved cost due to reusability, routine operations, low cost per flight and low cost payloads. Likewise, the Space Station hoped to save cost through commonality of systems, international contributions, a sophisticated management information system, the implementation of design-to-cost, etc. In fact, neither of these programs were very successful in lowering the historical cost trends of the agency. Currently, the National Launch System and the Space Exploration Initiative are basing some of their cost projections on similar culture changes.

Budget

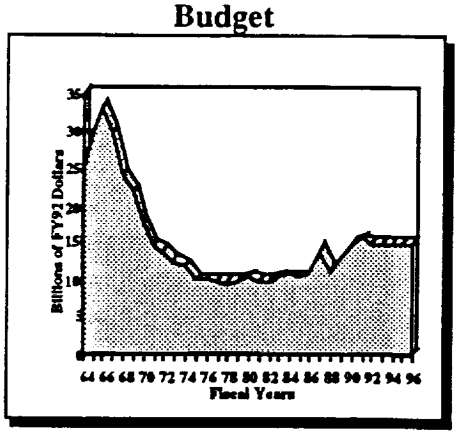

Figure 1

Cost

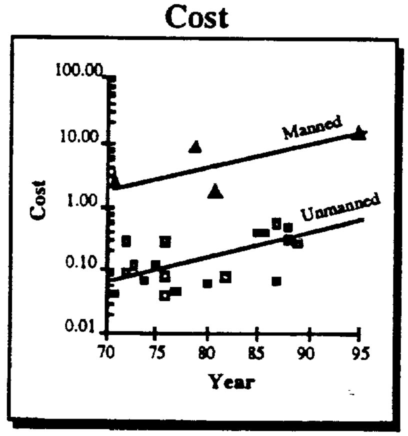

Figure 2

Schedule

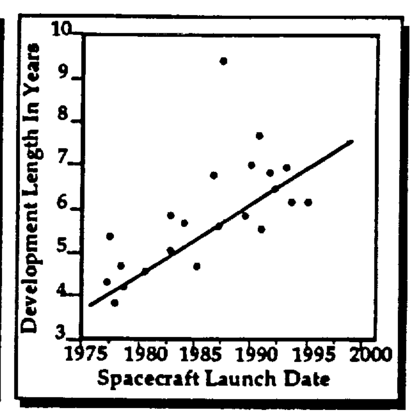

Figure 3

Today the NASA budget (Figure 1) is perceived by most observers to likely be relatively flat over the near term (in constant dollars). At the same time, the cost (Figure 2) and schedule (Figure 3) of typical NASA projects are generally perceived to be rising due to growing performance requirements, more complex organizational and integration circumstances, changing requirements, budget problems and other reasons. Obviously, constant budgets and rising costs are not compatible with plans for a sustainable or growing space program. This study was undertaken with the goal of determining if there are changes which could be implemented in the way NASA and its contractors do business that could result in lower cost.

Such studies are not an original idea. A number of past efforts have dealt with quite similar questions and there are a number of current analyses going on within the aerospace community which are developing data regarding "new ways of doing business". This study has participated in or at least reviewed many of these past and current activities and has attempted to incorporate their key findings into this analysis. Several common observations can be made that have emerged from this review of new ways of doing business. First, at its most basic, all cost reductions stem from doing the job with fewer people. Secondly, because NASA projects are dominated by labor cost, there is basically no way to significantly reduce cost other than finding ways to be more efficient in the utilization of labor. However, new ways of doing business do not necessarily mean employing fewer NASA and contractor personnel-- it can instead be thought of as enabling the accomplishment of more projects for a given budget. Thirdly, any cost credits hypothesized for new ways of doing business are not capable of being substantiated with 100% certainly-- the belief that cost can be lowered will remain a leap of faith until new projects have had a chance to prove out the reasonableness of the new recommendations to be made. Finally, this study generated few, if any, new ideas. The principles have been known for years. Implementation is everything.

In addition to formulating recommendations concerning new ways of doing business, this study focused on quantifying the likely cost benefits that might accrue if the suggested improvements were implemented. The specific approach utilized by the study team was a Continuous Improvement method called Quality Function Deployment. The QFD process is a structured approach to problem solving. Originally developed by the Japanese, the QFD process has been used by a number of American companies with good results. In this case the QFD was directed toward the development of a model of an improved process by which NASA conducts projects. In the QFD process "wants" (i.e. desirable end results) are correlated with "hows" (how a want is to be implemented) in a QFD matrix. Other steps in the QFD are establishing the strengths of the relationships between the hows and wants, performing competitive assessments of the process being analyzed in comparison to other competing processes (i.e. other ways of doing business) and rating the importance of features of the final process. Once the features of the new way of doing business model had been identified and the benefits quantified, the overall study results were briefed to NASA managers. The feedback gained through the briefing process turned out to be a major source of new ideas regarding ways to improve the current project process. All of these ideas were then synthesized into the study recommendations.

In summary, the findings of the study were that numerous recommendations exist from past and current studies which, if implemented, could result in significant cost savings. The particular quantitative findings of this study (which will be examined in detail below) are that something on the order of a 25% cost credit is appropriate to reflect the likely savings associated with new way of doing business. The study team recommends that an average reserve level of around 15% should be adequate (as compared to the historical practice of about 30%) due to the expectation that the improved process should, if implemented successfully, reduce downstream "unknowns" in the form of requirements changes, technical rework, external impacts, schedule rephrasing, etc. that have traditionally consumed reserves. Finally, the implementation of new ways of doing business should lower the Program Support requirements for new programs from 10%-15% to around 5%-10%. Program Support includes costs that the government incurs beyond the scope of the prime contractor (i.e. miscellaneous supporting contracts).

NWODB Benefits Areas

The study identified general NWODB benefits in six broad areas. These were:

1. More Extensive Prephase C/D Investment.
2. Multi-year Funding Stability.
3. Improved Quality And Management Processes
4. Improved Procurement Processes.
5. Advanced Design Methods.
6. Advanced Production Methods.

More Extensive Prephase C/D

The first of the NWODB recommendations is in a category called More Extensive Prephase C/D. A number of previous studies have recommended that NASA should provide a more ample upfront definition of its projects. The statistical history of NASA programs show that those programs that invest as much as 5% to

10% of their ultimate cost in the prephase C/D studies, advanced development, and technology areas ultimately are the most cost effective. The High Energy Astronomical Observatory (HEAO) is an excellent example of a program which invested in excess of 5% prior to start, which resulted in a cost effective project that experienced little cost growth.

In this upfront Pre-Phase C/D period, the focus needs to be on requirements and user needs. A majority of resources should be applied after final concept selection to avoid wasting resources on the wrong concepts. The maturity in the Phase B studies should be advanced more to a level normally found at the preliminary requirements review and the preliminary design review levels. The preliminary design should be conservative with realistic margins and realistic cost estimates. The Prephase C/D period should utilize prototyping and test beds in parallel with paper studies to reduce risk and validate the selected concepts. The Advanced Development and SRT activities should be used to mature the selected required technologies before the competition ends and before Phase C/D begins. To the extent possible, each project should maximize its use of off-the-shelf hardware and use commercial parts. Formal design reviews should be de-emphasized and replaced with a continuous review process. This would alleviate the need for large preliminary requirements review and preliminary design review meetings in which hundreds of people are involved and replace it with a continuous review process at the product development level. After authority to proceed, (APT) the review item discrepancy or RID process should be confined, to the extent possible, to design topics as opposed to requirements changes. Finally, Pre-ATP funding for long-lead high risk parts should be pursued much as the Astronomical X-ray Astrophysics Facility (AXAF) did with its mirrors.

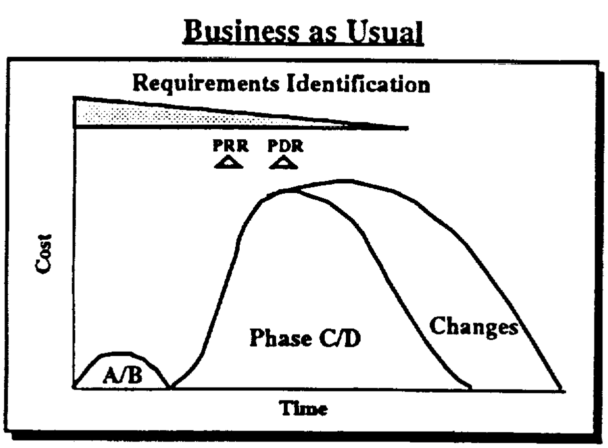

Figure 4

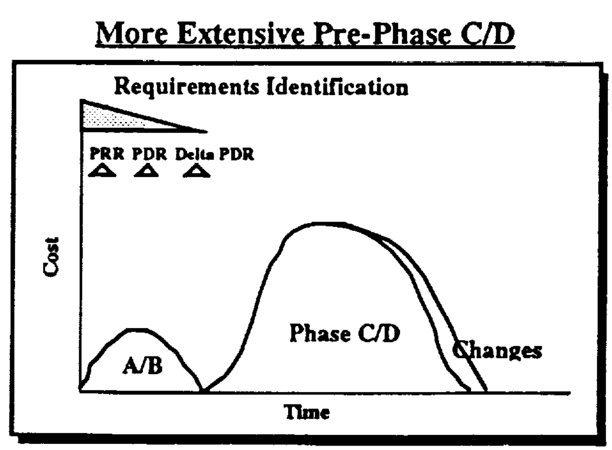

Figure 5

Figures 4 and 5 illustrate these ideas using both the Business As Usual and a

NWODB NASA projects formats respectively. In the business as usual approach, a modest Phase A/B investment is made and the requirements identification process spills over into the Phase C/D time frame. This leads to a relatively high Phase C/D cost and a large magnitude of change traffic, which adds to cost. The NWODB approach in which a more extensive Phase C/D investment is made and the Requirements Identification process is completed prior to ATP would lead to a relatively lower Phase C/D cost and a much lower cost associated with change traffic which can be seen in figure 5.

Multi-Year Project Funding Stability

The second NWODB category is Multi-Year Project Funding Stability. This section obviously requires Congressional support but, it also requires a more realistic new start wedge budget planning process by NASA in which the temptation to start more projects than can be realistically funded in the out years is averted. Multi-year project funding stability would eliminate, to a large degree, the replanning and rephasing cost associated with today's typical project. It would promote more efficient schedules, reduce the fixed cost, allow NASA to pursue large lot buys, and promote the development of operationally efficient designs. The adoption of a no-year funding approach would enhance budgeting flexibility by allowing NASA to use funds over more than a two year period. The effects can be visualized in figures 6 & 7. Figure 6 depicts a business as usual NASA project in which the planned project budget is not obtained in the early years. The results are a highly erratic budget which

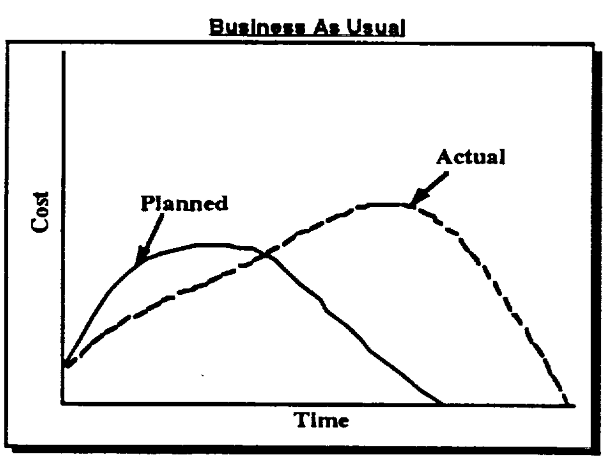

Figure 6

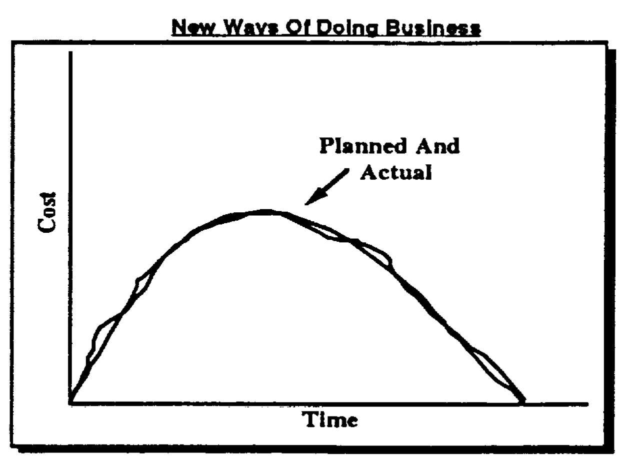

Figure 7

leads to cost growth down stream and schedule slips. In the NWODB approach (figure 7) a multi-year project with stable and predictable funding is shown. The result is a project that would more nearly match its budget and contain costs.

Improved Quality and Management Processes

The third category addresses improved management, and enhanced quality. In a broad sense, this NWODB is defined as pursuing improvements in every process through the integrated efforts of all members in an organization. This improvement requires that a strong continuous improvement philosophy be instilled in the work force. It also assumes the heavy utilization of simultaneous engineering (alternately called concurrent engineering, design build teams or product development teams). It assumes that the normally heavy integration activities required for a typical NASA project can be reduced by driving the integration function to lower levels within the concurrent engineering teams. It is also recommended that a strong design-to-cost approach be utilized, in which cost goals are distributed to the product development teams and the designs are iterated until the cost goals are achieved. By implementing these items, savings can result in a variety of areas including decreased test requirements, identification and elimination of overlapping or redundant capabilities, reduction of product cost, increased quality, and production and user satisfaction. Concurrent Engineering and Design to Cost are discussed below.

Traditionally, in the business as usual (BAU) approach, organizations are segregated according to function (design, manufacturing, test or operations, etc.) This is a typical, historical way of organizing a NASA project, which can be graphically observed in Figure 8 (using a launch vehicle project as an example). In this business as usual approach, the flight hardware is designed and then sequentially passed on to manufacturing, test, and operations. Such a process leads to a high level of change traffic and redesign effort to correct problems associated with design which makes manufacturing, test and operations more difficult. A more efficient way of managing a project is by employing concurrent engineering. As seen in Figure 9, a concurrent engineering project is divided into design build or product development teams (PDTs). The concurrent engineering approach utilizes product development teams which include representatives from design, manufacturing, test, operations, cost estimating, and all the other disciplines required so that the resulting design is capable of being efficiently manufactured, tested, and operated. The concurrent engineering process has a foundation of strong design-to-cost and continuous improvement philosophy. As opposed to the BAU approach, concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal including quality, cost, schedule and user requirements. It is assumed

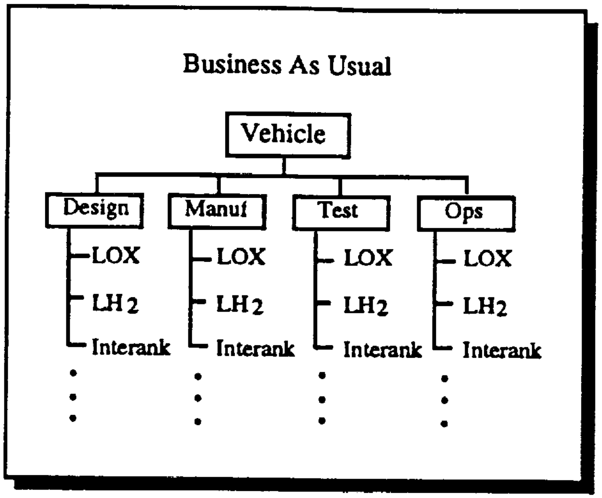

Figure 8

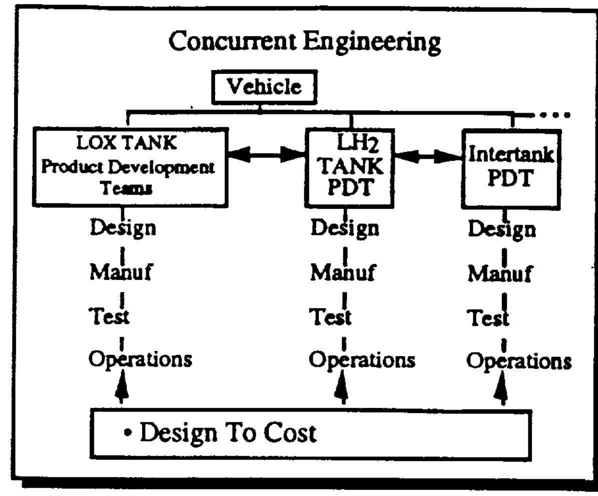

Figure 9

that concurrent engineering techniques permeate throughout PDTs and serve as a viable foundation for these design build or product development teams. Concurrent engineering utilizes small hierarchical teams in two areas: a core team comprised of design engineers, manufacturing engineers, quality engineers and procurement specialists and support teams composed of cost analysts, schedule analysts, systems engineers, tool designers, and suppliers. These design-build teams focus on minimizing life cycle costs, and enhancing risk mitigation.

Another of the major elements in this category is Design to cost (DTC). This process is a method of controlling cost by establishing cost goals at specified levels of a work breakdown structure and then requiring the project to make trades which will ensure that the system built will meet those cost goals. DTC encompasses acceptable performance at fixed costs and employs an iteration of conceptual design against DTC goals. In this regard, DTC requires a DTC manager responsible for aggregate cost performance, who establishes challenging but achievable cost goals. Then the manager names individuals responsible for each element and establishes organization/employee motivation plans, which include award fee incentive and value engineering. From a time standpoint, design to cost should be implemented in Phase A/B and then continued in Phase C/D. Additional characteristics of design to cost include a focus on improvement over invention, the specifications in the request for proposals of requirements/functions, as approved by design solutions, and the iteration of conceptual designs against design-to-cost goals.

Several other ideas essential in the Improved Quality and Management category include maintaining the continuity of the teams from Phase B to Phase C/D, the use of contractor reporting systems, the minimization of Data Requirements

Documents and CDRL's, the use of grandfather clauses to exempt on-going projects from new emerging reporting requirements, the avoidance of multi-center projects and the integration of the R&D and C of F budget processes.

Improved Procurement Processes

Category four includes ideas to change the procurement system. The purpose of focusing on procurement methods is to achieve greater efficiency in the system mechanics and greater program success in terms of accomplishing contract objectives. In addition, an improved acquisition process can diminish cost overruns and schedule slippages.

The most important aspect of improving the procurement process is streamlining acquisition organizations and procedures. Additionally, procurement methods can be enhanced by expanding the use of commercial products and increasing competition. Also improving the quality of acquisition personnel and improving the capability for industrial mobilization are two methods that need to be utilized. Incentivizing cost controls and penalizing overruns is also crucial.

Many of the recommendations involving the procurement process have to do with reducing the procurement cycle to make it easier to maintain stable contractor teams between Phase B and Phase C/D The current way of doing business is contrasted with the NWODB in figure 10 and 11. In the current way of doing business, parallel Phase B studies are completed and followed by a long period of time in which the RFP is prepared and released and proposals are prepared by the contractors.

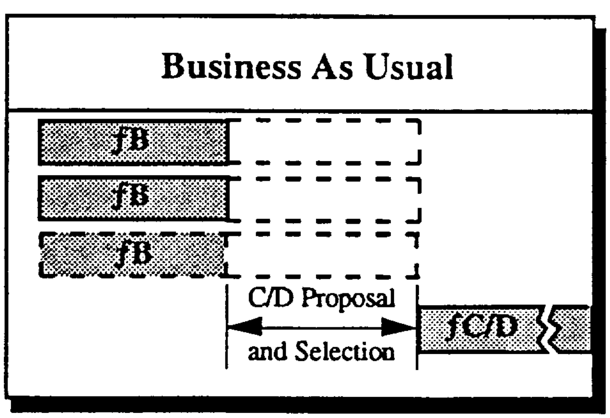

Figure 10

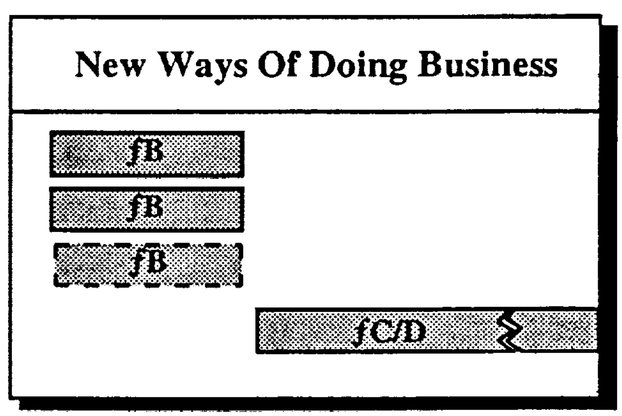

Figure 11

This leads to a large gap between Phase B and Phase C/D and large expenses associated with maintaining the continuity of the teams during this down time. In the NWODB approach the Phase C/D proposal is solicited during Phase B. This requires that the level of funding provided to the contractors in Phase B is consistent with that required for generating the Phase C/D concept, but should lead to a dramatically shortened time between these two Phases of a typical NASA project. Other Procurement Process recommendations include the possible elimination of the Best and Final Proposal process, the streamlining of the RFP Boiler Plate to eliminate untailored specifications, the use of the NASA Research Announcement process, and the elimination of cost as a selection factor during the Source Evaluation Board with the substitution of cost realism as an evaluation criteria in order to obtain more realistic contractor bids (It should be noted that the recommendation related here were generally favored by a majority of the QFD team members and management reviewers. Unanimity was not reached, however, on all recommendations. This is especially true of those recommendation regarding the elimination of best and final and the elimination cost as a selection criterion.) The use of Fixed Price Contracts should be considered where possible. NASA should consider the use of the same contractor for the entire project cycle, from design through production and operations as opposed to the more normal habit of using different contractors for these three phases. A large number of recommendations involved more efficient incentives and penalties associated with cost control and overruns. It was recommended that the FAR be revised to allow more reasonable profit margins for Aerospace contractors in excess of 15%. Another recommendation was the qualification of multiple vendors for critical parts, which of course would need to be traded against the economies associated with lot buys. A cash awards system should be established for value engineering proposals. Finally it was recommended that budget reserves should be saved and applied after projected funding of the project and that reserves should be used for technical problems and not budget cuts.

Advanced Design Methods

The fifth NWODB recommendation is in the area of Advanced Design Methods. Many advances in the specific ideas, tools and equipment for space system design have taken place over the past 10 to 15 years. These advances have enabled NASA and its contractors to produce fast, better and more cost effective space system designs.

Discussions in the available literature and with our QFD team suggested that NASA and the Aerospace contractor community could achieve increased cost saving with greater implementation of current and advanced design methods when compared with the expected cost predicted by historical based cost estimating techniques. The use of Computer Aid Design, Computer Aided Manufacturing, and Computer Aided

Software Engineering tools have not reached their full potential and uniform implementation. Specifically many subcontractors to the major NASA prime contractors do not rely on CAD, CAM or CASE systems. The uniform implementation of these Advanced Design Systems have good potential for cost savings. Figure 12

	BAU		NWODB
	Very Low	Nominal	Very High
Use of Design Tools Such as Computer Aided Design	None	Non-Standard Tools, No Previous Experience	Extensive Use Mature Tools
Generation of Schematics	No Automation	No Automation	Fully Automated
Production Planning	No Automation	No Automation	Fully Automated
Configuration Control	No Automation	New or Non-Standard System	Electronic Link To Design Tools
Program Control	No Automation	New or Non-Standard System	Fully Integrated

Figure 12

shows BAU verses NWODB in the implementation of Advanced Design Methods. It illustrates that the present BAU approach uses low to nominal level of Advanced Design Systems and the NWODB approach would be to more full implement those systems. The QFD Team recommended that NASA implement an automated capability for the generation of schematics, production planning data, configuration control, and program control. Also NASA and its contractors should implement paperless management systems, and should design for manufacturing and assembly. Through more extensive use of these mature tools and a more fully automated electronic environment cost effectiveness would improve compared to historical NASA projects. These savings would not only be within the design stage of the program but production and operations stages as well. Specifically, a better designed product is easer and cheaper to produce in production as well as more reliable in operations.

Advanced Production Methods

The sixth and final NWODB category is the utilization of advanced production methods. These include, but are not limited to, quick change tool, robotics systems, MRP systems, just-in-time inventory, and a number of other technical improvements in production methods. The goal of these manufacturing processes techniques is to reduce cost. The processes and techniques identified by our QFD team all provide some cost savings. They achieve their savings through increased productivity,

	BAU		NWODB
	Very Low	Nominal	Very High
Automated Machining And Assembly Operations	None	Some Use On Product Dedicated Production Lines, Comp Controlled Machinery	Full Use Of Flexible Machining Centers Computer Controlled Machinery
Automated Production Routing And Activity Control	None	Generated For Some Operations	Linked With CAD, Prod Plnng For All Operations
Links To Suppliers And Subcontractors	No Electronic Links	Links With Major Suppliers	Links With All Suppliers Automated
Work In Process Inventory	Extensive, Initiated On An Order Push Basis	Some Inventory On Long Lead Items	Virtually None In Storage, JIT Environment

Figure 13

reduced down time, reduced scrap, increased quality, reduced touch labor, and increased reliability. Figure 13 shows the current implementation status of a few advanced manufacturing processes. It shows BAU verses NWODB in the implementation of advanced production methods. It illustrates that our present BAU approach uses low to nominal levels of advanced production systems and the NWODB approach would be to more fully implement those systems. One problem with the implementation of advanced production methods is the initial capital cost. While a higher cost will likely be experienced in the DDT&E phase, a payback will be achieved in the production and operations phases. As similarly stated in the advanced design section, the use of these advanced tools have not reached their full potential and uniform implementation. Specifically many subcontractors to the major NASA prime contractors do not rely on automated machining, and production systems. The uniform implementation of these Advanced Design Systems have good potential for cost saving.

NWODB Cost Quantification

After these NWODB were identified, the team used four methods to quantify the potential cost benefits. These methods included a (1) literature survey & historical analysis quantification, (2) a programmatic effects analysis, (3) a parametric model analysis, and (4) an industry survey. The findings indicated that as much as a 50% cost credit could be applied to the business as usual cost estimates. More reasonably, it is expected that only 10% to 35% credit would accrue to the typical NASA project.

Summary Literature Survey and Historical Data Analysis

As previously discussed, six areas of NWODB were addressed. To reiterate, they are: 1) More Extensive Pre-phase C/D; 2) Multi-year Funding Stability; 3) Improved Quality and Management, Processes, 4) Improved Procurement Processes, 5) Advanced Design Methods; 6) Advanced Production Methods. Literature searches and various data analysis techniques were used to attempt to quantify potential cost savings due to these NWODB. Published articles and data on cost reduction techniques were researched, categorized and assessed as to applicability. Non-aerospace data points were qualitatively adjusted to the aerospace environment. Savings in specific subtotal areas were adjusted to the total non-recurring and recurring level. Engineering judgment, weighting factors and subjective analysis were applied to logical groupings of related cost savings approaches to establish likely potential savings if approaches were successfully implemented. Source material for the literature searches included technical journals, scientific periodicals, current texts, and other sources.

More Extensive Pre-Phase C/D

This category was quantified by analyzing past NASA programs and looking at the relationship between the Prephase C/D investment that was made in these historical programs and their downstream cost effectiveness. By doing this the team was able to determine that if a project invested between 8% and 10% of its ultimate cost prior to entering Phase C/D that substantial savings could accrue. These savings were estimated to be around 25% to 30% in the DDT&E phase and 5% in production phase. These results based on 25 NASA program data points are graphically illustrated in figure 14.

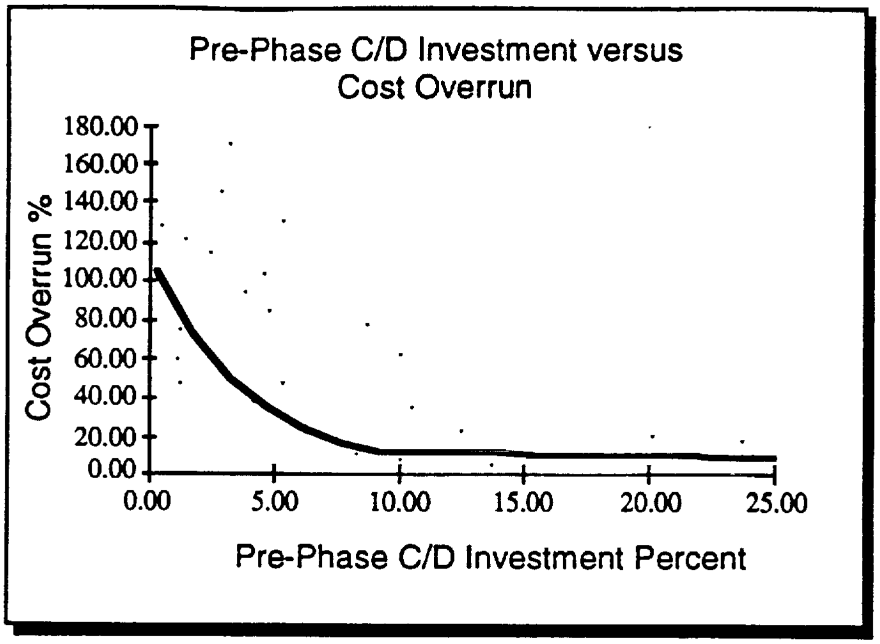

Figure 14

Multi-Year Funding Stability

The second NWODB idea, Multi-year Funding Stability, was also quantified by analyzing past data, and past programs. In this analysis a number of programs such as Cosmic background Explorer (COBE) and the Orbital Maneuvering Vehicle (OMV) were evaluated. These programs did not experience funding stability but conversely had the reverse situation, lack of funding stability. The programs were analyzed to determine the magnitude of the cost associated with this lack of funding stability. On the average it was determined that programs that have lacked multi-year funding stability have costed about 15% more cost in the DDT&E phase and 5% more cost in the production phase due to lack of multi-year funding stability. Therefore savings of this magnitude could be expected for those programs which did have multi-year funding stability.

Improved Quality and Management Processes

The third NWODB category, Improved Quality and Management Processes, was quantified by examining the literature associated with these types of quality and management improvements. An example is concurrent engineering, which involves the integration of design, manufacturing, and product support to shorten the product life cycle.

The cost quantification of this category is based on literature and data base searches. The literature suggests that approximately 30% could be saved in the

DDT&E phase and nearly as much 25% in production phase if the suggested management and quality improvements were implemented.

Improved Procurement Processes

In the fourth area the literature also has shown that improvements in procurement processes can reduce cost. A recent U.S. Senate task force is urging congress to "place greater emphasis on multi-year procurement." and to "simplify procurement regulations." The saving estimated in the literature is about 5% in the DDT&E and 5% in the production phase.

Advanced Design Methods

The implementation of new design methods can cause reductions in inspectors, scrap, rework, touch rate and engineering changes, and new and revised documentation . The cost quantification is based on literature and data base searches. It was found that approximately 5% savings could be accrued in both the development and production phases of the program if these methods were used.

Advanced Production Methods

The sixth and final NWODB Category is Advanced Production Methods, It was also quantified by literature surveys. The literature findings indicated that due to the required investment in more sophisticated tooling and equipment a net cost increase of around 5% in the DDT&E phase would be realized. In addition it was estimated that a 10% savings could follow in the production phase.

Summary

The total savings due to the six selected NWODB areas is shown in figure 15 and represent a composite (multiplicative) savings, not the sum of percentages. As seen on the figure, the methodology is based on the cost saving percentages and the cascade effect based on previous NWODB cost reduction factors. The literature and historical data analysis approach has suggested savings of up to 55% could be obtained in the DDT&E phase and 40% in the production phase. Because of the lack of preciseness in the quantification analysis implicit in the literature and historical data analysis approach, the team decided to attempt to verify the benefits of NWODB by other approaches.

Summary of Literature and Historical Data Analysis Approach Savings

NWODB Benefit Areas	Basis	DDT&E	Production	Operations
1. More Extensive Pre-Phase C/D	Data Analysis	20%	5%	TBD
2. Multi-Year Funding Stability	Data Analysis	15%	5%	TBD
3. Improved Quality And Management Processes	Literature*	20%	15%	TBD
4. Improved Procurement Processes	Literature*	5%	5%	TBD
5. Advanced Design Methods	Literature*	5%	5%	TBD
6. Advanced Production Methods	Literature*	-5%	10%	TBD
Total Cost Savings**		50%	40%	TBD

* Composite Findings From a Number of Studies and Documented Company Experiences

** Total Savings represent composite (multiplicative) savings - not sum of percentages

Figure 15

Programmatic Effects Analysis

The second of the four quantitative methods to determine NWODB cost saving measures is the programmatic effects analysis. In this analysis it was assumed that the NWODB would be manifested as improved cost effectiveness in three broad areas. These were 1) improvements in labor utilization, especially improvements in the nontouch to touch labor ratio; 2) reduced change traffic (especially requirements changes and some make-it-work change reductions as well) and; 3) reduced external impacts and schedule rephasing.

The first step in programmatic effects analysis quantification was to assemble the cost of the typical BAU NASA program which is depicted in Figure 16. The DDT&E and First Production Unit is comprised of four cost aspects - the base program, requirements changes, make-it-work changes, and schedule rephasing. The total DDT&E and first unit production cost of this typical NASA program is set at an arbitrary 160 units of money. Of this 160 units of money, the typical NASA program has a ratio corresponding to 128 units of money for DDT&E and 32 units of money for the first production unit. Other characteristics which are typical of NASA programs include a heavy contribution to cost by change traffic which can be divided into three general areas: requirements changes, which account for 27 units of money; make-it-work changes, which account for 18 units of money; and schedule re-phasing which account for 15 units of money in the DDT&E phase.Similar ratios are seen

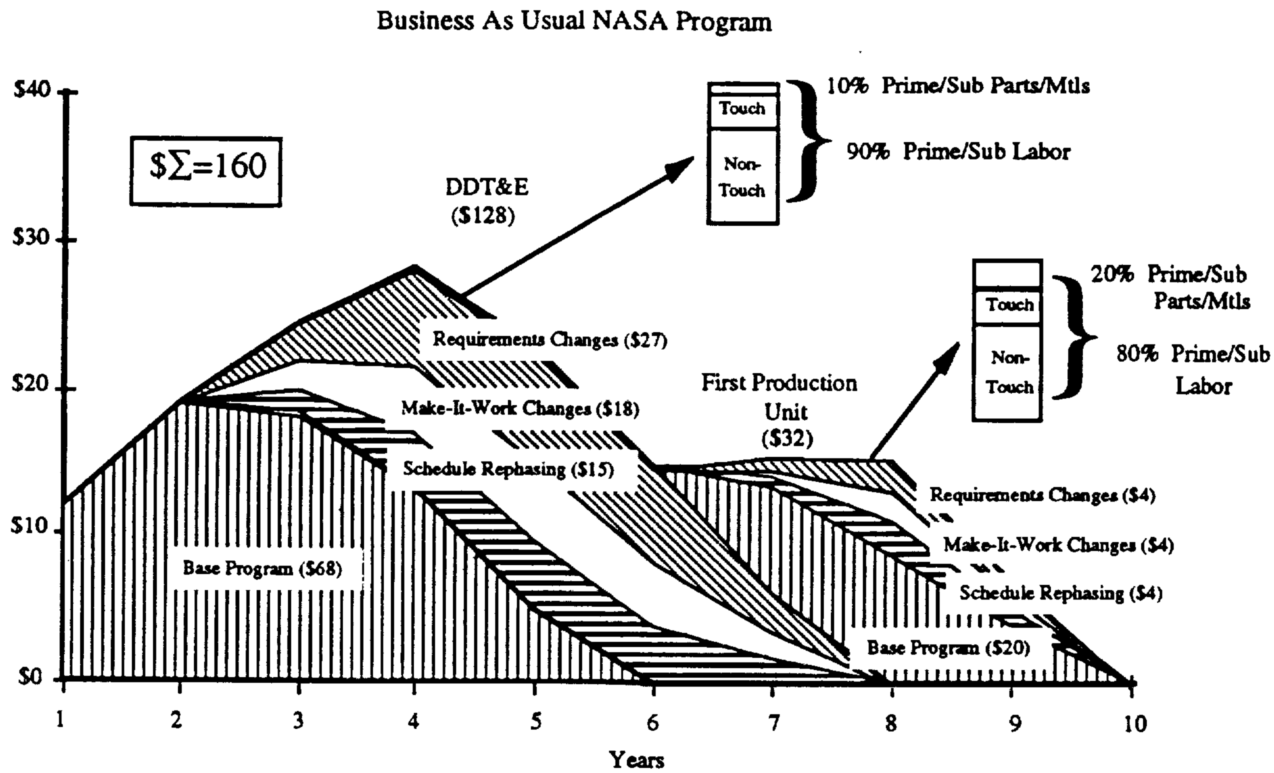

Figure 16

in the first unit production costs as well. Another characteristic evident in typical NASA programs is a large labor component of the total cost, upwards of 90% labor in the DDT&E and about 80% labor in the first production unit cost. This high labor component can be further subdivided into non-touch and touch and the average NASA program seems to have about a six to one non-touch to touch labor ratio.

To arrive at programmatic savings of 55% and 47% for DDT&E and Production respectively, a three step process is initiated on the BAU NASA program. Figures 17,18 & 19 examines the effects to this typical NASA program cost profile if the three programmatic effects changed were implemented. First it was assumed that an improvement can be made in the nontouch to touch labor ratio. The team determined that a one third improvement in the nontouch to touch labor ratio was reasonable due to improved management quality and procurement processes and advanced design and production methods. If this improvement could be made the cost of the NASA program set at 160 units of money, would be reduced through this one improvement to 120 units of money.(see figure 17 below) Figure 18 depicts the improvement

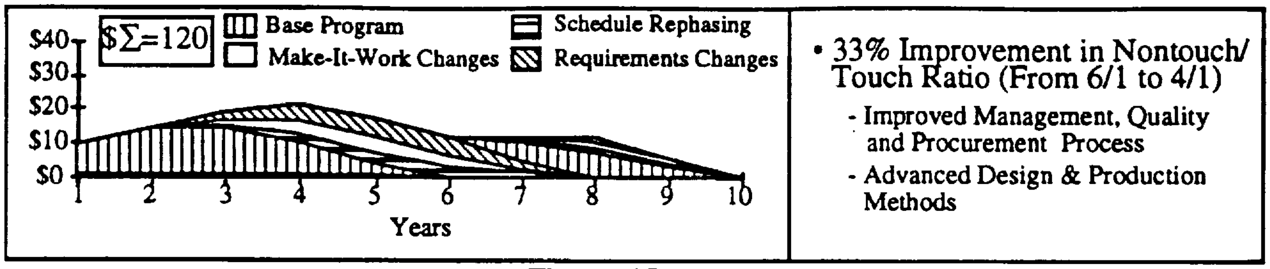

Figure 17

that would accrue if requirements changes could be eliminated all together, and a reduction in make-it-work changes of about 50% could be implemented due to more extensive prephase C/D, improve management, quality, and procurement processes and advanced design and production methods. Implementing these changes would bring the cost down from 120 units of money to 89 units of money.

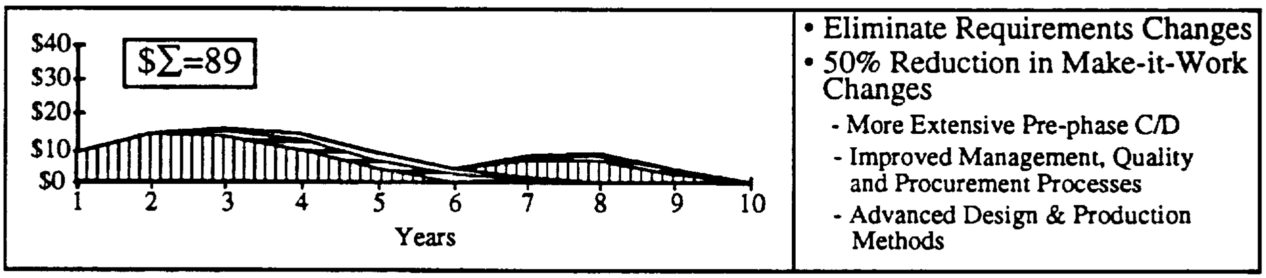

Figure 18

Finally, Figure 19 examines the benefits that could be associated with eliminating schedule re-phasing and bringing the development schedule down from seven years to five and the production schedule down from three years to two. This would further reduce the cost from 89 units of money down to 74 units of money.

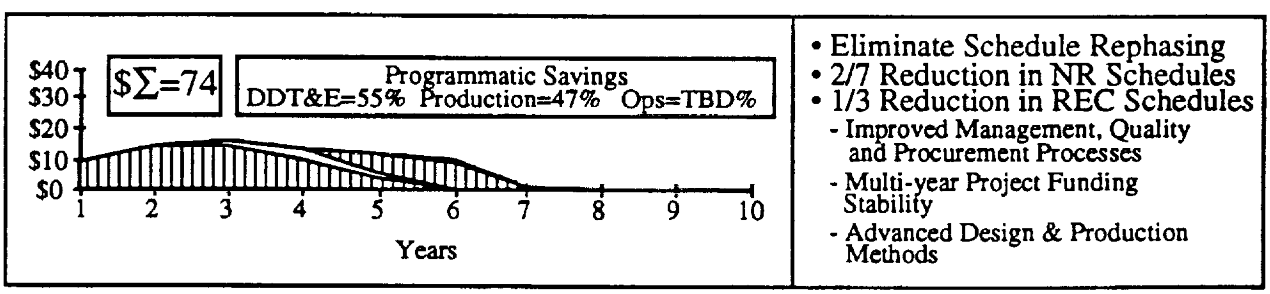

Figure 19

In summary the programmatic effects analysis suggested that the total savings due to NWODB would be on the order of 55% for DDT&E and 47% for production. Figures which closely correspond to results obtained from the previous literature survey and database analysis technique.

Parametric Modeling Analysis

The third method used to verify the NWODB cost savings was parametric modeling. Two commercial parametric cost models which are in use within NASA were used to estimate NWODB cost savings by varying model input parameters. The SEER-H and PRICE-H cost models were the models utilized in this study. Both of these models were calibrated to the NASA business as usual approach and the model parameters were reset to reflect the NWODB using cost analyst judgment. In the SEER-H model there are 11 benchmark criteria to determine NWODB cost saving measures. These are: requirements volatility, development tools, production tools, new design, material type, tolerance, number of prototypes, parts certification level - mechanical and electronic, constant process, circuit composition, and integrated circuit technology. The setting or calibration of these benchmarks is the technique used to adjust parameters. For example the SEER H model includes a parameter which measures requirements violability. To calibrated to the NASA business as usual approach the parameter was to be set to the high end of the range. To model the cost savings associated with less requirements violability in the NWODB

Summary Of Parametric Modeling Analysis

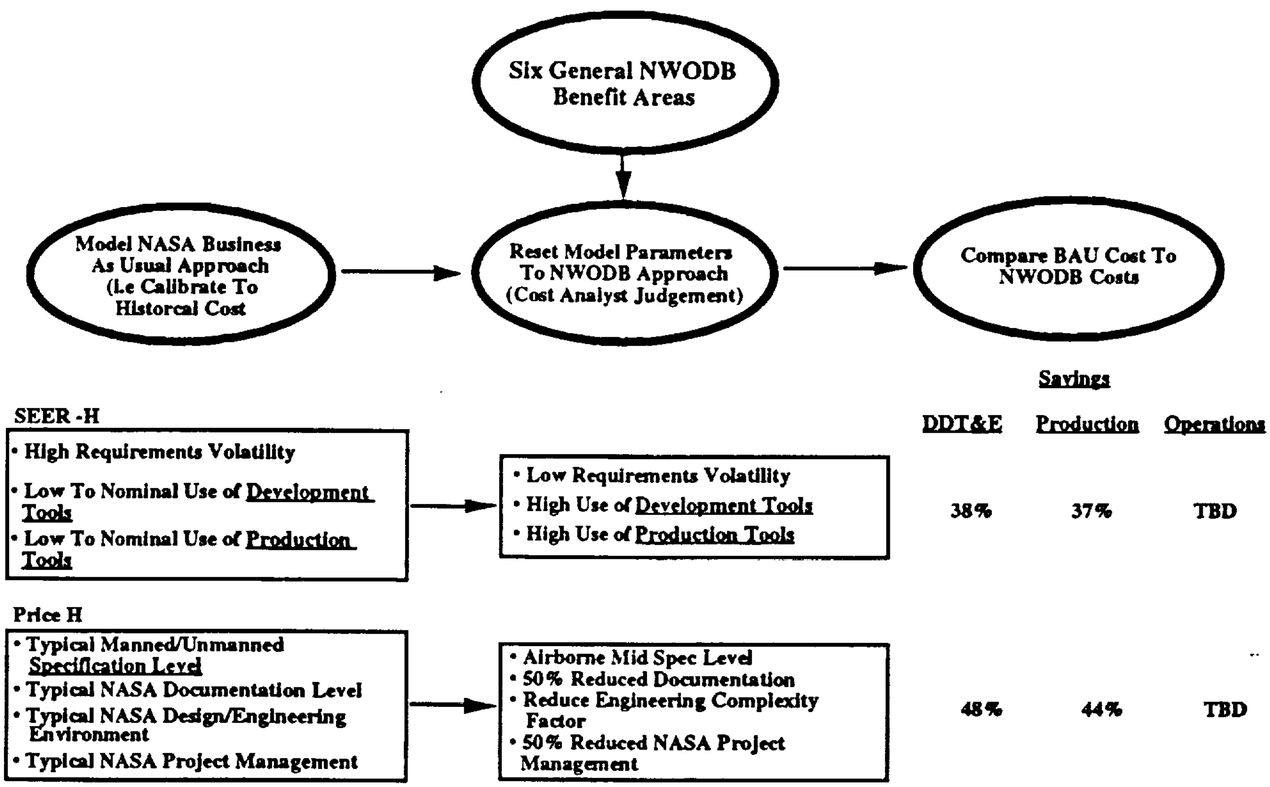

Figure 20

environment this parameter was reset to low requirements violability range and the reduced cost noted. The SEER H model also includes a parameter which measures the degree to which development and production tools are being used by the contractor development team. For the business as usual approach these model parameters were set to low to nominal which best model NASA historical cost. They were then reset to reflect a high use of development and production tools to model the new ways of doing business approach and again the cost savings were noted. A similar process was used for other parameters in the PRICE H model and the results of the analysis in aggregate suggested that for the SEER H model 38% and 37% savings could be achieved in the DDT&E and production phases respectively and for the PRICE-H model 48% and 44% savings could be achieved in the DDT&E and production phases respectively. All of these results agree fairly well with the results obtained from the previous two methods. The data for this analysis is shown in figure 20.

NWODB Industrial Survey Cost Savings Summary

The final analysis to assist in cost quantification was the use of an industry survey. At the beginning of June 1992 an industry survey was developed using five NWODB areas.(Quality,Management & Procurement had been combined at this point in the study) The survey listed the NWODB main topics and gave several examples for each. The survey participants were asked to rate the five general categories of NWODB using a rating scale that ranged from 2.00 (twice as costly) to .25 (25% as costly or 75% savings.) They were asked to rate the five NWODB within the three phases of Development, Production and Operations. In additions these areas were

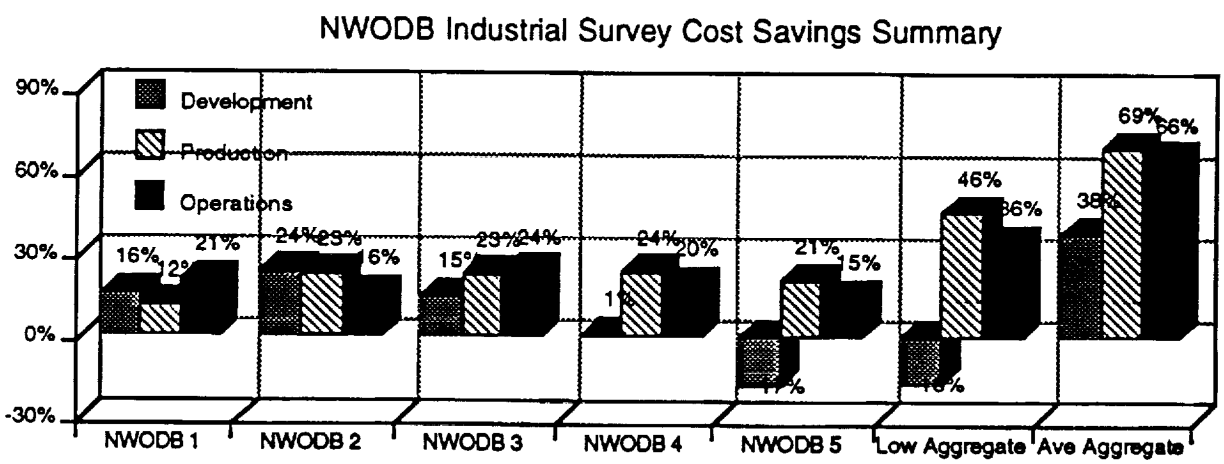

Figure 21

rated twice, first for *structural/mechanical* and second for *Electrical/Electronics*. Thirty people were identified as survey recipients and a survey was sent to them. Of the thirty surveys, nineteen were received and the data tabulated and analyzed. Figure 21 shows the mean scores from a 95% confidence interval of combined data for the five areas of NWODB. The aggregate columns illustrate cost saving at their highest potential. It should be kept in mind that these maximum costs savings if all NWODB changes are made. Because it is unlikely that any project can fully implement all of the NWODB ideas the team findings reflect the more probable savings range is in the 20% to 30% percent range.

NWODB Cost Savings Summary

The literature survey & historical data analysis, the programmatic effects analysis, the parametric model analysis, and the industry survey are all within the same ranges. It should be kept in mind that these are maximum costs savings (see Figure 22) if all NWODB changes are made. Because it is unlikely that any project can fully implement all of the NWODB ideas the team findings reflect the more probable savings range is in the 20% to 30% percent range.

NWODB Cost Savings Summary

MAXIMUM SAVINGS POTENTIAL

Six General Benefit Elements

	DDT&E	Production	Ops
Literature Survey and Historical Data Analysis	55%	40%	TBD
Programmatic Effects Analysis	53%	43%	TBD
Parametric Model Analysis			
SEER-H Model	38%	37%	TBD
PRICE-H Model	48%	44%	TBD

More Probable Savings Range*
20% - 30%

*** To Be Determined On A Project By Project Basis**

Figure 22

Implementation

As stated throughout this paper implementation is everything! As part of this project the QFD team developed an NWODB Implementation Matrix (Figure 23). This matrix identifies crucial departments or personnel within the government and NASA who should have the responsibility for NWODB implementation. The QFD team rated each departments or personnel impact to NWODB using two identifiers, S for Strong Impact in Implementing and M for Medium/ minor Impact in Implementing.

In addition there were some final recommendations of the NWODB study team. The first recommendation was to continue the study of NWODB to validate the proposed culture changes, and expand the list of proposed culture changes. Also the cost and schedule benefits that have been suggested by the study need to be validated. All of this is a Center-wide and Agency-wide responsibility. It was further suggested by the team that for the foreseeable future both BAU and NWODB cost estimates need to be developed for all future projects to give management the information they need to choose between the two approaches. The team also suggested that the NWODB approaches should be implemented on selected future programs. For example, LUTE, the Lunar Ultraviolet Telescope Experiment, and NLS the National Launch System.

NWODB Implementation Matrix

	Congress	NASA Administrator	Assoc. Administrator	Program Managers	Center Director	Project Manager	Chief Engineer	Concurrent Eng. Team	SRM&QA	Procurement	Comptroller	Legal
1) More Extensive Pre-Phase C/D	M	M	M	M	M	S	S	S	-	-	M	-
2) Multi-Year Funding Stability	S	S	S	M	M	-	-	-	-	-	M	-
3) Improved Quality & Management Processes	-	M	M	M	S	S	S	S	S	M	M	M
4) Improved Procurement Processes	S	S	M	M	M	M	M	M	-	S	M	S
5) Advanced Design Methods	-	-	-	-	-	M	S	S	M	-	-	-
6) Advanced Production Methods	-	-	-	-	-	M	S	S	M	-	-	-

S = Will Have Strong Impact In mplementing NWODB
M = Will Have A Medium/Minor Impact In Implementing NWODB

Figure 23

Conclusion

The team recommended that the changes if proven to be beneficial should be implemented into the NASA culture starting at the top with Program Managers at NASA Headquarters down through Center Management, Project Management, Chief Engineers, Institutional Managers, the Contractor Teams, and the Design Build Teams.

Finally the team noted that taking cost reduction credits without implementing the associated culture changes is obviously inappropriate in that the cost analysis community can participate in new ways of doing business but implementation is an Agency-wide responsibility.

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Appendix A

NEW WAYS OF DOING BUSINESS COST IMPACT CHECK SHEET

New Ways of Doing Business

System:	Structural/Mechanical			Electrical/Electronics		
Phase:	Development	Production	Operations	Development	Production	Operations

1. More Extensive Pre-Phase C/D & E

- •Establish Realistic Cost Baseline
- •Focus on Requirements and user Needs
- •Ample Definition Funding (5% - 10%)
- •Advance PRR and PDR Maturity into Phase B
- •Perform Extensive Cost Trades and Sensitivities
- •Maximize Off-The-Shelf Hardware Where Applicable
- •Develop Conservative Preliminary Design with Margins
- •Provide Pre-ATP Funding for Long Lead - High Risk Parts
- •De-emphasize Design Review: Emphasive Continuous Review
- •Confine Review Item Discrepancies (RIDs) to Design Topics, Not Requirements
- •Utilize Advanced Development/SRT to Mature Selected Technologies Before Competition

Comments: ____________________

System:	Structural/Mechanical			Electrical/Electronics		
Phase:	Development	Production	Operations	Development	Production	Operations

2. Multi-year Funding Stability

- Use No Year Fund Approach
- Requires Congressional Support
- Allows Efficient Use of Manpower
- Eliminate Replanning/Rephasing
- Promotes Efficient Schedules (Reduces Fixed Costs)
- Permits Flexibility to Adjust Schedules, Priorities, Etc.
- Requires Realistic New Start Wedge Budget Planning by NASA
- Allow Long Lead Procurement, Large Lot Buys, Adequate Early Test Programs, Operationally Efficient Design

Comments: ____________________

Typical Rating Factor:

2.00--twice as costly	.75--75% as costly
1.75--75% more costly	.50--50% as costly
1.50--50% more costly	.25--25% as costly
1.25--25% more costly	NA--Not Applicable
1.00--No effect on cost	

NEW WAYS OF DOING BUSINESS COST IMPACT CHECK SHEET

System:	Structural/Mechanical			Electrical/Electronics		
Phase:	Development	Production	Operations	Development	Production	Operations

3. Improved Management, Quality & Procurement Processes

- Utilize Design to Cost
- Reduce Levels of Management
- Minimize Multi-Center Projects
- Eliminate Best and Final Proposal
- Insist More Realistic Contractor Bids
- Solicit Phase C/D Proposal in Phase B
- Establish Petty Cash Fund to Save Schedule
- Incentivize Cost Control/ Penalize Overruns
- Instill Continuous Improvement (CI) Philosophy
- Budget Reserves After Projected Peak Funding
- Consider Fixed Price Contracts Where Possible
- Establish Employee Rotation To Generalize Skills
- Intergrate Project R & D and C of F Budget Processes
- Establish Cash Awards For Value Engineering Proposals
- FAR Revisions to Allow More Reasonable Profit Margins
- Maintain Continuity of Team From Phase B to Phace C/D
- Eliminate Cost as a selection factor - Evaluate Cost Realism
- Use Same Contractor For Design, Production and Operations
- Reduce Procurement Cycle to Facilitate Stable Contractor Team
- Qualify Two Vendors For Critical Parts (Trade Against Lost Buys)
- Streamline RFP Boilerplate to Eliminate Untailored Specifications
- Minimize DR's/CDRL's, Maximize Use Of Contractor's Reporting System
- Drive Integration Fuction to Lower Levels through Concurrent Engineering
- Use Grandfather Clause to Exempt On-going Projects From New Reporting Requirements
- Utilize Concurrent Engineering / Design Build Teams / Product Development Teams (PDTs)
- Use NASA Research Announcements (NRA) Process to Accelerate Non Development Procurements
- Reserves To Be Controlled By Project Manager and Applied To Technical Problems, Not Budget Cuts

Comments: ______________________________

Typical Rating Factor:
2.00-- twice as costly
1.75-- 75% more costly
1.50 --50% more costly
1.00--No effect on cost
.75 -- 75% as costly
.50 -- 50% as costly
.25 -- 25% as costly
NA -- Not Applicable

NEW WAYS OF DOING BUSINESS COST IMPACT CHECK SHEET

System:	Structural/Mechanical			Electrical/Electronics		
Phase:	Development	Production	Operations	Development	Production	Operations
4. Advanced Design Methods						

- Use CAD/CAM/CASE Systems
- Integrate Product and Process Design
- Design for Manufacturing and Assembly
- Design For Process/Design for Automation
- Impliment Automated Generation of Schematics, Production Planning Configuration Control

Comments:

System:	Structural/Mechanical			Electrical/Electronics		
Phase:	Development	Production	Operations	Development	Production	Operations
5. Advanced Production Methods						

- Robotics
- Use CAE/CAM/CNC-Systems
- Use CIM-Computer Integrated Manufacturing Susterns
- Use FMS-Flexible Manufacturing Systems
- Paperless Manufacturing System
- MRP-II Material Requirements Planning
- JIT-Just In Time Manufacturing
- Inventory Bar coding
- Quick Change Tooling
- Statistical Process Control
- Automated Spray Techniques
- Chemical Machining Process
- LASER Drilling
- Water Jet Cutting
- Super Plastic Forming
- VPPS Variable Polarity Plasma System
- Impliment Near Net Shape Casting Techniques

Comments:

Typical Rating Factor:	1.00--No effect on cost
2.00--twice as costly	.75--75% as costly
1.75--75% more costly	.50--50% as costly
1.50--50% more costly	.25--25% as costly
1.25--25% more costly	NA--Not Applicable

NASA Marshall Space Flight Center Engineering Cost Group