CASE STUDY ON THE STRATEGIES OF SYSTEMS ENGINEERING

by

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ABSTRACT

Systems Engineering, in this thesis, is defined as a formal process for the development of a complex system that is driven by a set of established requirements through its life cycle. The objective of this thesis is to analyze the effectiveness of implementing systems engineering using a division of a major automotive manufacturer as the subject of the analysis.

A key individual within systems engineering is the system engineer. Different strategies were used in selecting and assigning responsibilities to the system engineers. Hypotheses are formulated based on these different strategies.

The research method consisted of questionnaires administered either in a structured interview that concluded with an open discussion, or in a survey. Both system engineers and customers of systems engineers were included in the analysis. The data were transformed numerically and then analyzed for statistical significance to determine support or lack of support for each hypothesis. The results were then utilized as the basis for suggested improvements in the implementation strategy for systems engineering at this major automotive manufacturer.

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Finally, my wife and children, who helped focus me on completing this thesis, deserve a warm round of applause.

CHAPTER ONE

INTRODUCTION

As companies move forward into the 1990s, they have realized the value of teamwork in improving their effectiveness. Many companies started the teamwork concept on the production floor with Quality Circles or within their staff areas with Simultaneous Engineering. Quality circles are focused on involving the production workers in continuous improvement of the manufacturing process. Simultaneous engineering is focused on involving staff functions in the solving of current problems and improving designs and processes of future products through multi-functional teams.

A new process being started in some companies is Systems Engineering, which is focused on involving departments within the product engineering function in the coordination of specific components into a system before that system is integrated into the final product.

OBJECTIVE

The objective of this thesis is to analyze the effectiveness of implementing Systems Engineering using a division of a major automotive manufacturer as the subject of the analysis. The approach taken concentrates on capturing the current status of various systems and then analyzing this information for strengths and weaknesses. The goal is to make recommendations based on this analysis which would improve the implementation of system engineering across all systems.

BACKGROUND

The division being analyzed is part of a major automotive manufacturer, and the division began simultaneous engineering in 1986. This transformation was from an individual functional focus to a team multi-functional focus. Simultaneous engineering evolved into Simultaneous Management since it included all levels and functional groups of the organization.

One shortcoming that became apparent as multi-functional teams worked on a specific product was lack of coordination within the Product Engineering group. This lack of coordination resulted in interface problems between Simultaneous Engineering teams that should have been solved functionally within Product Engineering. To improve the Simultaneous Engineering process, a new process within Product Engineering was started in 1990 called Systems Engineering (SE). Their definition of SE is:

> ...a formal process for the development of a complex system that is driven by a set of established requirements through its life cycle. It involves the application of scientific and engineering efforts to transform an operational need into requirements.[1]

The controls and display System Engineer's responsibility demonstrates this process. The instrument panel has a variety of button controls, i.e., radio, HVAC, and fuel data center, that are engineered and designed (released) by separate engineers but are viewed as a system by the customer. The System Engineer's role is to coordinate the appearance, feel, and lighting of the buttons to give a consistent and perceived image of high quality to the customer.

The System Engineering process implemented has several characteristics that include Requirements Engineering, Tradeoff Studies, Design Reviews, Work Breakdown Structure, Statements of Work, Risk Management, Configuration Management, Engineering Notebook, Program Notebook, and Platform Database. The next sections are overviews of these characteristics including their associated outputs. The Requirements Engineering section contains additional details since it is the key characteristic for this division at this point of implementation of Systems Engineering.

REQUIREMENTS ENGINEERING

Requirements Engineering (RE) is the backbone of Systems Engineering since it aligns a product program, maintains this alignment over the product cycle, and ensures that the final product meets the original requirements. The key elements of RE are:

(1) identify critical customer requirements using the Quality Function Deployment (QFD) process;

(2) capture and communicate these requirements through technical specifications; and

(3) ensure product conformance through validation plans.

QFD is a specific methodology for translating the voice of the customer into technical requirements that impact product design and its associated manufacturing and assembly processes.[2,3] The concept of the voice of the customer goes beyond the voice of the final customer to include voices of the direct customer, i.e., the dealer; service, i.e., independent garage, engineer, assembler, supplier, manufacturer, management, governments, competitor; the press; non-customer, and other applicable voices.

Marketing leads the process in collecting the voice of the customer data through marketing clinics and nationwide surveys. Product Engineering leads the process in translating the subjective voice of the customer data into objective requirements that will drive the product and process design.

The QFD process employs a series of interlocking matrices designed to facilitate this translation which is referred to as a "House of Quality." QFD has several process steps for determining target values to attain customer requirements. The three outputs of the QFD process are vehicle level requirements which include:

(1) the "whats" -- the voice of the customer data;

(2) the "hows" -- product characteristics; and

(3) the "how much" -- target values.

Once customer voices are translated into requirements, they must be communicated through documents called Technical Specifications. There are three key technical specifications documents, i.e., the Vehicle Technical Specification (VTS), the System Technical Specification (STS), and the Component Technical Specification (CTS). The VTS are used to establish and communicate the requirements that Product Engineering needs to design, test, and validate the vehicle, provide the basis for contracts between customers and suppliers of specific products and/or processes, and provides a basis for tradeoff studies. The requirements included should be complete and not open to interpretation. A VTS template is used to facilitate the preparation of a program-specific VTS, to act as a checklist, and to provide consistency in communication between program and technical staffs. Finally, validation plans confirm that the vehicle or manufacturing process meets its technical specification requirements as shown through test, demonstration, inspection, and/or analysis.

Once vehicle-level product and process requirements are identified, balanced, and documented in the VTS, then these requirements are allocated to vehicle systems. A system is a major division of the vehicle based on the criteria of similar levels of complexity and minimizing functional interfaces. As with the vehicle, there are systems QFD which include Voice of the Customer data and a House of Quality.

These system requirements are documented in a System Technical Specification (STS). The STS includes appropriate requirements and validation information from the VTS with additional detail as required, requirements derived from integration areas, and defines interfaces. An integration area is created when vehicle requirements are allocated to multiple systems. An interface is the physical or functional mating of two different systems.

System Block Diagrams are a tool used by the systems engineers to add further detail to vehicle integration and interfaces. The System Block Diagrams contain the subject system with appropriate components within the center block. The subject system block is enclosed with a department block that contains systems that interact with the subject system. Finally, the outermost block contains the vehicle systems that interact with the subject system. These system block diagrams are developed by the systems engineers and are included in the VTS and STS.

A System Validation Plan is developed for each system. These validation plans specify the plans and procedures that will be used to confirm that the systems meet their specified requirements.

In a similar rolldown, system requirements are allocated to a component level. A component is a lower level, discrete division of a system. There is a component QFD matrix with appropriate Voice of the Customer data, a Component Technical Specification containing component requirements, and a Component Validation Plan.

The net result of Requirements Engineering is a design process that has defined and balanced requirements at all levels, i.e., Vehicle, System, and Component. This should assure the best vehicle to the final customer with proper optimization of each system and its appropriate interactions.

TRADEOFF STUDIES AND DESIGN REVIEWS

Tradeoff studies are structured analytical methods using the requirements from QFD to identify, define, and evaluate alternatives. The benefits expected are to force the design to the requirements through objective evaluations which provide sufficient information to choose the "best" alternative. A tradeoff study is a seven-step process consisting of:

1) obtaining all pertinent requirements;

2) identifying alternatives;

3) establishing the decision criteria via "musts" and "wants" with appropriate weights for want criteria;

4) scoring the alternative by ensuring that it meets each "must" criterion and ranking it on each "want" criterion;

5) assessing the sensitivity of the weights of wants and rankings;

6) considering the consequences (weaknesses) of the chosen alternative and analyzing how to minimize the risk; and

7) documenting the tradeoff study.[4]

The product "musts" and "wants" developed not only include the final customer requirements obtained in the QFD process, but also the internal customer requirements of "stakeholder" functional groups. The ultimate desired result is a robust design that can be manufactured, assembled, and which meets the customers' requirements within the total vehicle.

The tradeoff studies are the basis for a design review which is "a technical forum for communicating design intent between a design activity and a panel of technical specialists."[5] The intent is to improve and agree on the optimum design that meets the requirements. The four steps followed in the process are:

1) ensure requirements are valid;

2) communicate design intent;

3) identify potential design problems; and

4) review lessons learned.

There are two types of design reviews: formal and informal. The **informal** design reviews are working meetings initiated by the responsible engineer to obtain technical input from peers on the proposed design as it is evolving throughout the entire design process. The **formal** design review is larger in scope since it includes a review board of experts who can be from other divisions or departments and an audience of interested parties. The objective is to review the production intent design using the four steps outlined above before final release. These formal design reviews are scheduled meetings held at specific benchmarks throughout the product program. The benefits of obtaining mutual agreement on the optimal design are improved quality, improved coordination, and reduced rework.[6]

WORK BREAKDOWN STRUCTURE/STATEMENT OF WORK

The Work Breakdown Structure (WBS) is a graphical representation of the project consisting of the major tasks required to deliver the product and related tasks to support each major task. The Statement of Work (SOW) is a narrative description of a portion of the work required for the project. A SOW contains the following information:

1) project title and author;
2) purpose;
3) deliverables identified and connected to an internal customer;
4) timing and resources required including manpower, computer, and/or material;

5) inputs required and the associated source identified; and

6) a methodology description of how the task is to be accomplished.

Also provided is a SOW process model which defines specific tasks and responsibilities in initiating and completing a SOW.[7]

RISK MANAGEMENT

Risk Management is the "process of identifying, assessing, quantifying, monitoring, handling, and documenting risk."[8] The Risk Management process as described allows for two key benefits: early identification and planning on high-risk areas. It allows management to be part of the risk analysis rather than placing the entire burden of "meeting a program objective" on the actual workers. Two important stages are the Monitor and Handle Risk stages which include specific triggering events, appropriate status reports, identification of responsible individuals, and avoidance or modification plans.

CONFIGURATION MANAGEMENT

Configuration Management identifies the functional and physical characteristics of any item in the program and then controls, communicates, and audits changes to those characteristics. The benefits are to establish a baseline for the program and then to provide formal reviews with proper documentation for communication of any changes to that baseline. Once a baseline has been established, a Change Control process which involves a multifunctional Change Review Board is initiated. This Change Control process consists of evaluating the effect and scope of a proposed change, having the Review Board decide if the change should be implemented, and then distributing a change notice to the organization.[9]

ENGINEERING NOTEBOOK/PROGRAM NOTEBOOK AND PLATFORM DATABASE

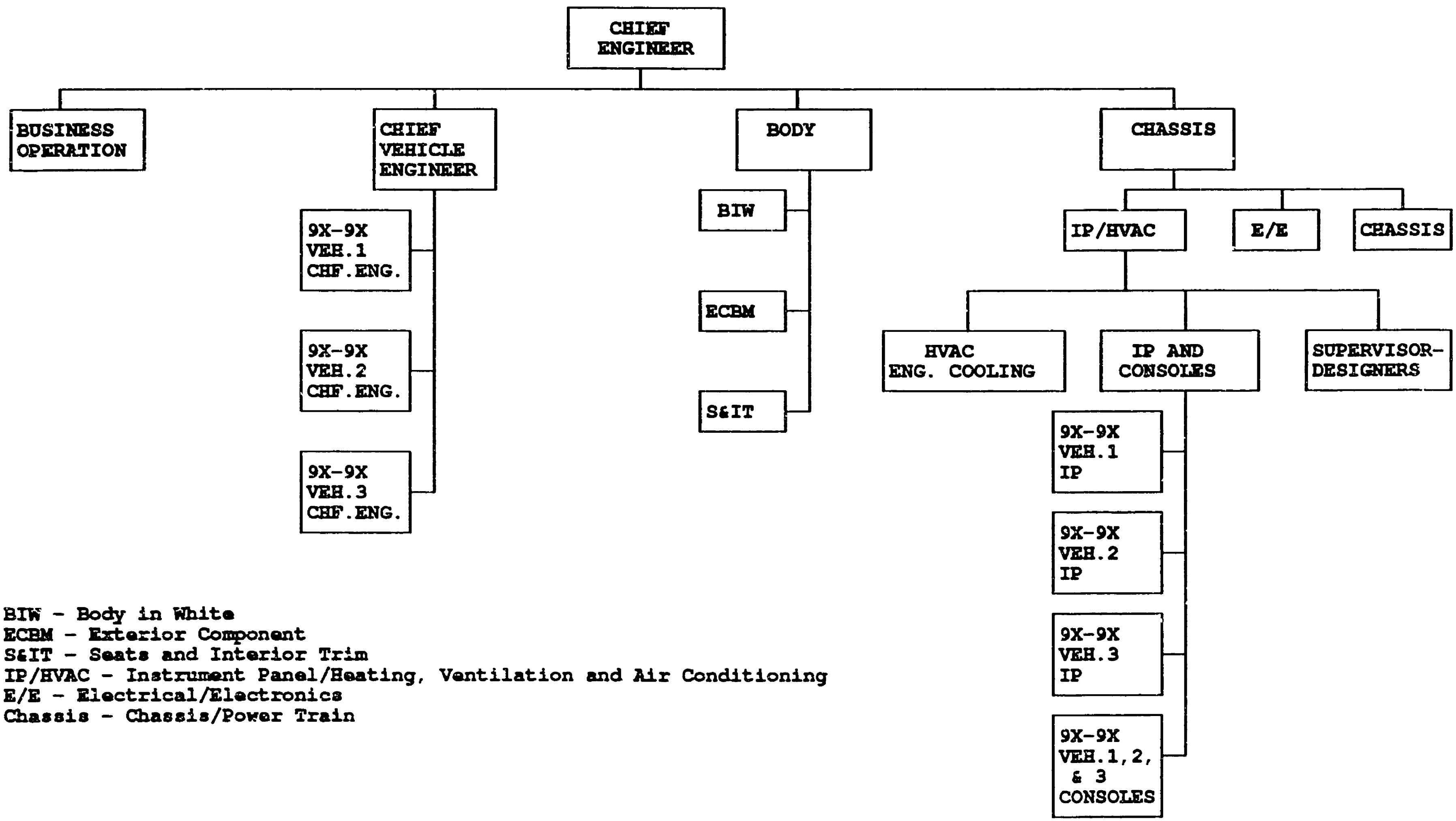
The Engineering Notebook (ENB)/Program Notebook (PNB) is a library of engineering and program information that is produced with completed cover pages, an appropriate index, and then made available to the organization. The benefits derived from and ENB/PNB are a written record providing a means of disseminating information, a method of training people, and a source for future projects complete with information and lessons learned. A specific structure for the ENB/PNB identifies format, information to be recorded, and a process flow that includes individual responsibilities. The cover sheet on all documents includes a title, an abstract, and key words that can be used for computer searches. The process requires an administrator with specific functions.[1]

The Platform Database is a computer tool to assist in managing the large amounts of information in a program. Selected information (e.g., Product Planning Matrix or Vehicle Technical Specifications) is collected, updated, and shared across platform functions. In addition to successfully managing information, another benefit is capturing this historical data for use on future programs.[11]

ORGANIZATION STRUCTURE

In order to implement Systems Engineering, the division had to develop a specific structure within Product Engineering to support the process. The Product Engineering Group is divided into four major sections: Business Operations, Chief Vehicle Engineer, Body, and Chassis. The Chief Engineer and the heads of these four groups are called the Vehicle Engineering Team (VET) staff. The Chief Vehicle Engineering Group has Vehicle Chief Engineers with appropriate support who are responsible for engineering coordination of the total vehicle as sold directly to a customer in the marketplace. The Body and Chassis sections have departments organized around six major vehicle systems: Body-in-White (BIW); Exterior Components and Body Mechanical (ECBM); Seats and Interior Trim (S&IT); Instrument Panel/Heating, Ventilation, and Air Conditioning (IP/HVAC); Electrical/Electronics (E/E); and Chassis/Power Train (Chassis). Each of the six departments is headed by a staff engineer. The staff engineer has several assistant staff engineers reporting to him, with the actual number depending on total vehicle content. Assistant staff engineers have reporting to them several release engineers whose responsibility is to engineer, design, and then release into the part specification system specific components to specific vehicles. A representative organizational chart showing these various relationships may be found in Figure 1.1.

FIGURE 1.1
Organizational Structure of Division Studied



BIW - Body in White
ECBM - Exterior Component
S&IT - Seats and Interior Trim
IP/HVAC - Instrument Panel/Heating, Ventilation and Air Conditioning
E/E - Electrical/Electronics
Chassis - Chassis/Power Train

Also, specific vehicle integration areas are assigned to a department. These vehicle integration assignments are not shown as part of the representative organizational chart since they are specific to a department. These vehicle integration individuals or groups have responsibilities that require a specific expertise and coordination throughout the total vehicle. The nine vehicle integration areas are:

(1) underhood packaging

(2) ride and handling

(3) vehicle structure

(4) mass

(5) squeaks, rattles, acoustics and windnoise

(6) crash worthiness

(7) corrosion

(8) human factors

(9) vehicle architecture.

As you can see, these vehicle integration groups work with several system engineers on total car issues.

Based on their vehicle responsibilities, each of the six departments are organized differently in order to best support Systems Engineering. Two key organizational differences resulted, i.e., having a dedicated system engineer versus having a shared system engineer/release engineer or system engineer/assistant staff engineer. A dedicated system engineer is a full-time system engineer with only Systems Engineering responsibilities. A shared system/release engineer or a shared system/assistant staff engineer has not only a future focus on systems, but also a today focus on parts release or administration. This dual responsibility has the potential of resulting in present and future task priority conflicts.

The basis for a dedicated or shared Systems Engineering responsibility centered on the system's scope and impact on the vehicle. The scope of a system included the number of components within the system and the number of interfaces with other systems. A system engineer or system engineer/release engineer reports to an assistant staff engineer.

The specific responsibilities for each role had to be developed based on the implementation of systems engineering. The responsibilities within Systems Engineering for each role is as follows (note that this does not represent the total responsibility for each job description):

<u>Responsibilities Within Systems Engineering: Vehicle Engineer</u>

- Translate requirements from Marketing to the Vehicle Technical Specification (VTS) with assistance from the systems engineers in alignment with the program requirements.
- Allocate technical requirements to systems through functional staffs.
- Manage system interfaces at the vehicle design to vehicle requirements.
- Manage resolution of complex technical issues affecting your vehicle.
- Administer the Program Notebook.

<u>Responsibilities within Systems Engineering: Assistant Staff Engineer</u>

- Assure necessary coordination between your activity and all other related activities.

- Facilitate formal design reviews; participate in informal design reviews.

- Lead employees in the timely completion of system/component designs and/or development activities.
  * define, maintain, and improve the technical process
  * integrate the systems under your control
  * allocate requirements from "staff requirements" to systems
  * coordinate system technology rollout plans within your group
  * provide change control for all system/component revisions which impact program requirements.

Responsibilities Within Systems Engineering: System Engineer

- Ensure that your system(s) work within and meet the requirements of the vehicle.

- Provide technical leadership and system integration for your system(s).
- Assist Vehicle Engineers in creation of VTSs.

- Translate requirements from the VTS into the STS with assistance from the Vehicle Engineer and Release Engineers in alignment with the program requirements.

- Allocate requirements to components.

- Facilitate informal design reviews as appropriate.

- Manage component interfaces at the system level. Resolve interface issues with other systems. Assist Vehicle Engineer with system interfaces to vehicle.

- Resolve system cross carline issues.

- Manage the development and validation of the system design to system requirements.

- Manage resolution of complex technical issues affecting your system(s).

- Ensure engineering changes meet system requirements.

- Lead system competitive benchmarking process.

- Lead systems rollout planning for all carlines.

- Initiate system advance/technology projects.

Responsibilities Within Systems Engineering: Release Engineer

- Ensure that your components work within and meet the requirements of the systems.

- Translate requirements from the System Technical Specification (STS) into the Component Technical Specification (CTS) with assistance from the System Engineer and suppliers in alignment with the program requirements.

- Assist System Engineers in creation of STSs.

- Design and release components that meet requirements. Allocate requirements to parts.

- Resolve interface issues with other components/parts. Assist System Engineer with component interfaces to system.

- Manage the development and validation of the component/part design to component requirements.

This background information with more details on Systems Engineering, the organizational structure, and specific roles and responsibilities were the center of a two-day training that all impacted individuals participated in at the start of Systems Engineering implementation about 18 months before this thesis. The information was developed by the Chief Engineer and his direct reports, piloted with a focus group consisting of individuals from each role, modified based on focus group feedback, and then rolled out to other impacted individuals.

FOOTNOTES

1. Company X Systems Engineering User's Workbook, 1990, pp. 3-1 to 3-9.

2. Sullivan, L.P., "Quality Function Deployment," Quality Progress, June 1986, p. 39-50.

3. Hauser, J.R. and Clausing, D., "The House of Quality," Harvard Business Review, May-June 1988, pp. 63-73.

4. Company X Workbook, p. 2-39 to 2-43.

5. Ibid., p. 3-25.

6. Ibid., pp. 3-25 to 3-32.

7. Ibid., pp. 3-2 to 3-4, and Appendix D.

8. Ibid., p. 3-5.

9. Ibid., pp. 3-8 to 3-13.

10. Ibid., pp. 3-14 to 3-21.

11. Ibid., pp. 3-22 to 3-24.

CHAPTER TWO

HYPOTHESES

DEDICATED vs SHARED SYSTEM ENGINEERING RESPONSIBILITIES

As stated in the Organization Structure section, Systems Engineering was implemented within each department from two basic approaches, i.e., as a dedicated or shared responsibility. A dedicated system engineer is a full-time system engineer with only Systems Engineering responsibility. A shared system engineer has not only the future focus on systems, but also a today focus on parts release or administration. If this dual responsibility and workload is properly assigned, then both present and future task priorities can be accomplished. If, however, the workload is too high, individuals have a tendency to give present tasks higher priority due to organizational pressures at the expense of future tasks.

This prioritization problem should manifest itself in several ways when contrasting a dedicated and a shared system engineer. First, a dedicated system engineer should have more time to become familiar with and understand the systems engineering tools. This dedicated individual therefore should perceive himself as having a high understanding of the tools and be further along in actual implementation of the tools. Also, these same individuals should be perceived by their organizational customers as being further along in terms of meeting system engineering objectives.

Also, in studying the dedicated and shared issue across departments, it was discovered that in general both strategies had been employed in each department. Since each department had the same training, it can be assumed that any difference in the implementation of systems engineering can be explained by this shared or dedicated issue.

H-1: When we compare Systems Engineers who have dedicated responsibilities to those who have shared responsibilities, the following will result:

1: Dedicated system engineers will have a better understanding and implementation of the system engineering tools;

2: Dedicated system engineers will have a perceived higher value by their organizational customers in meeting system engineering objectives; and

3: Overall department variation on perceived value by organizational customers can be explained by the percentage of dedicated system engineers to the total.

FORMAL EDUCATION IMPACT

The implementation of systems engineering goes beyond understanding and implementing a uniform set of tools. It also involves a cultural change in the basic approach to design and engineering. The approach shifts from a "cut and try" experience-based approach. This analytical approach is forced through the requirements engineering tool and resulting formal technical specifications at various design levels, i.e., VTS, STS, and CTS.

The ability of an engineer to make this transition when assigned system engineering responsibilities could be influenced by his familiarity and past experiences with analytical techniques. One indicator of this difference in background could be whether an engineer did or did not have a formal engineering degree.

> H-2 Due to the analytical nature of requirements engineering tool, system engineers who have analytical, technical backgrounds as indicated by an engineering degree will be more successful in meeting system engineering objectives.

IMPACT ON PRODUCT DESIGN

As indicated above, systems engineering is a cultural change for the organization. Cultural changes take time to implement and often real benefits are several years into the future. This division's own experience with simultaneous engineering indicates that it took three years to show some major improvements from simultaneous engineering and that it took five years to become part of the divisional culture. Therefore, the impact after 18 months of systems engineering on the anticipated major improvement, i.e., product design, is expected to be minimal at this time. The customers of the system engineers who can best assess this issue are the release engineers. Release engineers have responsibility to engineer, design, and then release into the part specification system specific components to specific vehicles.

> H-3 Progress in implementing Systems Engineering, as seen by release engineers, is inadequate to impact product design.

TODAY VERSUS FUTURE VALUE

Continuing to build on the above, for a new process to develop to its full potential, it must be accepted and believed in by the individuals who are key stakeholders. In this case, the attitude of the system engineers toward the current and future value of the process could indicate long-term success. If the current and future values of systems engineering are seen as the same by the systems engineers, and if Hypothesis 3 is correct, then the long-term future of systems engineering is in jeopardy. Based on this organization's past success in implementing the simultaneous engineering culture, it could be assumed that they will successfully implement systems engineering.

> H-4 The future value of systems engineering as perceived by the system engineers will be greater than its current value.

VALUE TO THE INDIVIDUAL

This acceptance and belief in the process could also affect a systems engineer's current effort in implementing the systems engineering objectives. Those individuals who feel they have derived high value from the systems engineering principles could be putting more effort into their implementation. If this is true, the effort should be perceived positively by the organization. This is in contrast to systems engineers who, in their minds, have not derived a benefit to date.

H-5 Systems engineers who believe they have derived a high value from the systems engineering principles in pursuing their own work will be perceived highly by the organization, in meeting the systems engineering objectives.

CHAPTER THREE

RESEARCH METHOD

This study was conducted among the technical staff members in a specific division of a major automobile manufacturer. As previously described, the Product Engineering Group that was studied is divided into six departments. Data were collected from two different groups, i.e., System Engineers and customers of System Engineers. System Engineers are the newly created positions within each department with responsibilities as previously described (see Chapter One for details). Customers of System Engineers included management peers and other co-workers.

Data were gathered using one of two methods. An individual was either included in a structured interview that concluded with an open discussion, or in a survey. The structured interview and survey were connected by a common questionnaire for each target group (see Appendix 1 and 2 for samples of the questionnaires used). Although it has been shown that the face-to-face structured interview is a preferred method for this type of research,[1] both methods had to be used due to individual and author scheduling and availability. Each questionnaire contained closed-end or fixed choice questions that could be quantified for statistical analysis.[2]

SYSTEM ENGINEERS

Data were obtained from 31 of the 34 system engineers within the organization. The structured interview included 27 of the system engineers, with only four completing the questionnaire on their own.

The seven-point questionnaire had specific closed-end questions covering several broad categories, including:

(1) understanding of Systems Engineering tools;

(2) implementation of Systems Engineering tools;

(3) understanding of specific formal documents of Systems Engineering, i.e., Vehicle Technical Specification (VTS), System Technical Specification (STS), and Validation Plans;

(4) completeness of the VTS, STS, and Validation Plans from a requirements perspective;

(5) an individual's attitude toward Systems Engineering.

The open discussion held after completing the questionnaire centered on the strengths and weaknesses of Systems Engineering, additional comments on the individual's attitude toward it, discussion of a specific tool recently completed (i.e., block diagrams), and management support of the process.

CUSTOMERS OF SYSTEM ENGINEERS

The customers of System Engineers were divided into five classifications. The classifications and the number of individuals included in a structured interview or survey are as follows:

Number of Individuals

CATEGORY	STRUCTURED INTERVIEW	SURVEY	NO RESPONSE	TOTAL
VET Staff	4	0	1	5
Staff Engineer	5	1	0	6
Assistant Staff	9	1	1	11
Vehicle Integration*	8	3	1	12
Release Engineer	1	22	9	32
TOTAL	27	27	12	66

* Includes vehicle engineers

All of the above classifications have been discussed in the Organization Structure section on pages 16 through 21.

The five-point questionnaire centered on a single question, as follows (see Appendix 1 for actual example):

> For each system, please indicate your response to the following question: To what degree has the effort on this system met your expectations in terms of Systems Engineering objectives?

If an individual was not familiar with a specific system, then he was asked to check "Not Applicable." The questionnaire listed the system and referenced the System Engineer. The open discussions held after completing the questionnaire centered on the strengths and weaknesses of Systems Engineering and any ideas for improvements to the process.

FOOTNOTES

1. Singleton, R., Straits, B.C., Straits, M.M., and McAllister, R.J., Approach to Social Research. New York: Oxford University Press, 1988, pp. 235-236 and 243-248.

2. Ibid., pp. 265-269.

CHAPTER FOUR

RESULTS

In this chapter, I will present the results of my research as it applies to each of the hypotheses given in Chapter Two. The goal of the research was to consider each hypothesis in the light of the information gained from the interviews and questionnaires. This information was transformed numerically and then analyzed for statistical significance to determine support or lack of support for each hypothesis. Below I have presented each hypothesis followed by the corresponding research outcomes.

HYPOTHESIS ONE: DEDICATED vs. SHARED ENGINEERING RESPONSIBILITIES

The first subset of Hypothesis One focuses on the influence of a System Engineer (SE) having either dedicated or shared responsibilities and its impact on their understanding or implementation of the Systems Engineering tools. Examining their responses to a series of questions related to the tools of Systems Engineering, one does not find many statistically significant differences between dedicated and shared SEs. Of these twenty questions, only two questions indicated a difference in mean response rate that could be considered statistically significant. Both of the questions dealt with familiarity a SE has with a specific document, i.e., the 199X

Vehicle Technical Specification (VTS) and their System Technical Specification (STS). In both cases, the responses of the dedicated SEs indicate a much higher mean than the responses of the shared SEs.

For the VTS familiarity question, the dedicated group had a mean which is significantly higher than that of the shared group (ρ=0.007)(see Table 4.1). (Reminder: the numbers in parentheses are the probabilities that the difference found in the means might have resulted from chance along, i.e., the lower the probability, the higher the confidence that the reported finding is real. The accepted standard is that the ρ value should be 0.05 or less for a comparison to be considered statistically significant.) For the STS familiarity question, the mean of the dedicated group is significantly higher than the shared group (ρ=0.029)(see Table 4.2).

The above data is not strong evidence supporting the first subset of Hypothesis One. Since all mean scores are relatively high, the data appears to only indicate a higher priority and additional time spent by dedicated SEs on familiarizing themselves with two new Systems Engineering documents. Since the other eighteen questions did not indicate any significant mean response difference, the conclusion must be that the organizational structure choice of having either dedicated or shared responsibilities for an SE has not had a significant impact on the understanding or implementation of the Systems Engineering tools to date.

The second subset of Hypothesis One focuses on perceived value of the organizational customers in dedicated versus shared SEs meeting Systems Engineering objectives. This analysis was divided into two separate categories: Non-Release Engineers and Release Engineers. The Non-Release Engineers (NRE) are

<TABLE 4.1>

Comparison of Dedicated and Shared System Engineers' Response to Question 10*

Status of System Engineer	Response based on a 7-point scale
Dedicated	6.60
Shared	5.47
τ	2.94
ρ	0.007

*Question 10: "Are you familiar with the Vehicle Technical Specification (VTS) for the 199X car body?" (specific year and model named in actual questionnaire).

<TABLE 4.2>

Comparison of Dedicated and Shared System Engineers' Response to Question 13*

Status of System Engineer	Response based on a 7-point scale
Dedicated	5.93
Shared	4.47
τ	2.30
ρ	0.029

*Question 13: "Are you familiar with the System Technical Specification (STS) for the systems(s) you are involved in?

mainly indirect customers of the SEs and include all management and peer customers, i.e., VET staff, staff engineer, assistant staff engineer, and vehicle integration personnel. The Release Engineers (RE) are direct customers of the SEs since the specific output of SEs should directly impact the design and engineering responsibilities of a RE. (Additional organizational details can be found on pages 16 to 21.) These two separate categories will be used again in other hypotheses analysis.

The NREs had a positive statistically significant difference in their mean perception of dedicated versus shared SEs ($\rho = 0.05$) (see Table 4.3).

The REs had a negative statistically significant difference in their mean perception of dedicated versus shared SEs ($\rho = 0.001$) (see Table 4.3). Therefore, in contrast to the NREs, the REs perceived the shared SEs as doing a better job than the dedicated SEs. This reversal in perception could be attributed to the fact that most shared SEs also have RE responsibility and therefore may better understand the needs of a RE. This conflicting data is evidence that there is <u>not</u> a perceived higher value by the organizational customers for dedicated SEs in meeting Systems Engineering objectives.

The third subset of Hypothesis One focuses on the overall departmental variation on perceived value being attributed to having 100% dedicated or 100% shared SEs. Only three of the six departments met this analysis criterion. Body-in-White (BIW) and Seat and Interior Trim (SIT) departments have 100% dedicated SEs, whereas Electrical/Electronics (EE) has 100% shared SEs. The other three departments have a mixture of both therefore cannot be included in the analysis. The

<TABLE 4.3>

Comparison of Dedicated and Shared System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Dedicated	3.51	2.48
Shared	3.33	3.12
τ	1.92	-3.34
ρ	0.05	0.001

analysis was accomplished by comparing the data for all dedicated or shared SEs minus the departmental SEs to the data for all departmental SEs for both NRE and RE categories. Each department is analyzed separately.

The NREs perceive the dedicated SEs outside of BIW as performing better than the BIW SEs ($\rho = 0.01$) (see Table 4.4). Based on the hypothesis, this was not the expected result since the data as analyzed should not have given statistically significant difference in results.

The REs did not perceive a difference between the dedicated SEs outside of BIW and BIW SEs ($\rho = 0.15$) (see Table 4.4).

<TABLE 4.4>

Comparison of Dedicated and Body-in-White Department System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Dedicated	3.62	2.59
Body in White	3.20	2.21
τ	2.60	1.46
ρ	0.01	0.15

Neither the NREs nor the REs perceived a difference between the dedicated SEs outside of SIT and the SIT SEs ($\rho = 0.13$ and 0.69, respectively) (see Table 4.5).

The NREs did perceive a difference between the shared SEs outside of EE and the EE SEs ($\rho < 0.001$) (see Table 4.6). As with the BIW department, this is not the expected result based on the hypothesis. Also, the EE SEs are perceived higher than would be predicted based on 100% shared SEs, whereas the BIW SEs are perceived lower than would be predicted based on 100% dedicated SEs.

Finally, the REs did not perceive a difference between the shared SEs outside of EE and the EE SEs ($\rho = 0.08$) (see Table 4.6).

<TABLE 4.5>

Comparison of Dedicated and Seat & Interior Trim Department System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Dedicated	3.59	2.52
Seat & Interior Trim	3.35	2.41
τ	1.54	0.40
ρ	0.13	0.69

<TABLE 4.6>

Comparison of Shared and Electrical/Electronic Department System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Dedicated	3.12	2.97
Electrical/Electronics	3.65	3.48
τ	-4.16	-1.77
ρ	< 0.001	0.08

This contradicting departmental data analysis indicates that other factors can override the dedicated versus shared status of SEs. Therefore, the data does not support this third subset of Hypothesis One.

HYPOTHESIS TWO: FORMAL EDUCATION IMPACT

Hypothesis Two focuses on the impact of an analytical technical background, as indicated by an engineering degree, on the perceived success of meeting Systems Engineering objectives. This analysis is divided into two categories, as in Hypothesis One, i.e. examining the perceptions of Non-Release Engineers (NRE) and Release Engineers (RE). Of the 34 System Engineers (SE), only 23 were included in the analysis. The other 11 SEs were not included since they had been assigned as a SE for less than twelve months and therefore had insufficient time to show an impact on the job. Of those included, 17 had an engineering degree, while 6 did not. The time factor was not an issue in the dedicated versus shared analysis since being dedicated or shared is a job characteristic whereas college or no college is an individual characteristic.

Both REs and NREs see SEs with a college degree as outperforming their non-degreed colleagues by a significant margin ($\rho < 0.001$ and $\rho=0.004$, respectively) (see Table 4.7).

The above analysis indicates strong evidence that an analytical, technical background as indicated by an engineering degree is a major factor in the perceived success of a SE in meeting the Systems Engineering objectives.

Based on the above research findings, another analysis of the second subset of Hypothesis One can be done. In this analysis, the impact of dedicated versus shared SEs with a technical college degree can be examined. There are 8 dedicated and 9 shared SEs, both groups with technical college degrees.

<TABLE 4.7>

Comparison of Technical College Degree and No Technical College Degree System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Technical College Degree	3.70	3.00
No Technical College Degree	3.11	2.30
τ	4.77	2.94
ρ	<0.001	0.004

The NREs did not perceive any difference in the performance of dedicated and shared SEs with technical college degrees ($\rho = 0.77$) (see Table 4.8).

On the other hand, REs do see that among degreed SEs, those who are shared outperform those who are dedicated ($\rho = 0.03$) (see Table 4.8). This difference is about the same as seen in the original analysis completed on subset two of Hypothesis One. Therefore, this additional analysis is consistent with the previous analysis and does not change the conclusion of the data not supporting Subset Two of Hypothesis One.

An analysis could not be done on non-degreed, dedicated SEs and non-degreed shared SEs because there is only one person in the non-degreed, shared SE group.

<TABLE 4.8>

Comparison of Technical College Degree Dedicated and Technical College Degree Shared System Engineers' Performance in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
Technical College Degree, Dedicated	3.73	2.69
Technical College Degree, Shared	3.69	3.33
τ	0.29	-2.21
ρ	0.77	0.03

HYPOTHESIS THREE: IMPACT ON PRODUCT DESIGN

Hypothesis Three focuses on the progress in implementating Systems Engineering, as indicated by Release Engineers (RE), being inadequate to impact product design. The analysis is performed by calculating the mean score given for all System Engineers (SE) by REs. There is no statistical comparison since the other reference point is time zero with mean score of zero. The data indicate a mean score of 2.75 with a standard deviation of 1.26 on a 5-point scale. Since the main objective of Systems Engineering from an RE's perspective is its impact on product design, this score relative to what was expected presents evidence not supporting this hypothesis. The expected low value is based on comments made by SEs and Non-Release Engineers (NRE) during the interview process. Additional data must be collected in the future to further analyze the validity of this hypothesis.

HYPOTHESIS FOUR: TODAY VERSUS FUTURE VALUE

Hypothesis Four focuses on the future value of Systems Engineering as perceived by the System Engineers (SE) being greater than its current value. The data were obtained directly by comparing responses in Question 21 in the Systems Engineering questionnaire.

The SEs are very optimistic about the future value of Systems Engineering ($\rho < 0.001$) (see Table 4.9). This significant increase in mean value for the future is strong evidence supporting the long-term value of Systems Engineering from a SE's perspective.

<TABLE 4.9>

Comparison of Today's Value and Future Value of the Implementation of Systems Engineering to the Company From a System Engineer's Perspective

State of Systems Engineering	System Engineer's Perception of Value of Systems Engineering to Company (7-point scale)
Today	3.03
Future	5.91
τ	-8.57
ρ	<0.001

HYPOTHESIS FIVE: VALUE TO THE INDIVIDUAL

Hypothesis Five focuses on how System Engineers (SE) who believe they have derived a high value from the System Engineering principles in pursuing their own work will be perceived highly by the organization in meeting Systems Engineering objectives. The data were obtained by creating two groups of SEs based on their response to Question 22 in the Systems Engineering questionnaire: "How much value have you derived from the Systems Engineering principles in pursuing your own work?" The high-value group consists of SEs who responded with a 6 or 7 rating, versus the low-value group consisting of SEs who responded with a 1 or 2 on the 7-point rating scale. The SEs who responded with a 4 rating were not included in either group because they are at the midpoint of the rating scale which is considered neutral. The SEs who responded with a 3 or 5 rating were not included in either the low-value or high-value group because they are close to the midpoint of the rating scale. The addition of these people to both groups does not affect the analysis.

The high-value group has 9 SEs and the low-value group has 7 SEs. This analysis was divided into two separate categories: Non-Release Engineers (NRE) and Release Engineers (RE), as done in previous analyses.

The NREs did perceive a difference between the high-value SE group and the low-value SE group ($\rho = 0.01$) (see Table 4.10). The REs did not perceive a difference between the high-value SE group versus the low-value SE group ($\rho = 0.08$) (see Table 4.10).

This contradicting evidence requires a modification of the hypothesis to limit its scope in order to be supported.

MODIFIED HYPOTHESIS FIVE

H-5	Systems engineers who believe they have derived a high value from the Systems Engineering principles in pursuing their own work will be perceived highly by the **non-release** organization in meeting the Systems Engineering objectives.

<TABLE 4.10>

Comparison of High Individual Value and Low Individual Value of Systems Engineering to Systems Engineers' Performances in Meeting Systems Engineering Objectives From a Customer's Perspective

Status of System Engineer	Customer Perception of Degree System Engineering Objectives Met (5-point scale)	
	Non-Release Engineer	Release Engineer
High Individual Value	3.46	3.00
Low Individual Value	3.06	2.40
τ	2.56	1.78
ρ	0.01	0.08

CHAPTER FIVE

DISCUSSION

The research findings indicate that the dedicated versus shared status of System Engineers (SE) is not a major factor in either their understanding and application of the Systems Engineering tools or in customers' perception of the degree to which they meet Systems Engineering objectives. This finding was not expected since both SEs and their management (VET staff, staff engineers, and assistant staff engineers) indicated during interviews that dedicated SEs have advantages over shared SEs. The advantages mentioned were having adequate time to learn and do the new process, and a lack of priority conflicts between the SE responsibilities and the shared responsibilities. Most individuals indicated that shared responsibilities are more short-term (today) priorities versus SE responsibilities that are more long-term (future) priorities.

A possible explanation for this is that overall workload may be more important than being dedicated or shared. If a dedicated SE has more than one system, as is true with several individuals, or the number of interfaces required with other systems is above the mean, then a dedicated SE's total workload may be equivalent to that of a shared SE. This equivalent workload most likely results in similar time and priority problems.

The other responses in the Systems Engineering questionnaire indicate discussion points separate from the hypotheses. First, the Systems Engineering tools appear to be understood by all (Tables 11, 17, 20, and 26 in Appendix) but the tools are not being used extensively (Tables 12, 16, 21, 22, 27, 28, and 29 in Appendix).

One specific weak area appears to be in the understanding and application of Quality Function Deployment (QFD) (Tables 13 and 14 in Appendix). Only eleven SEs have been involved in a House of Quality process. Although not statistically significant due to small number of data points, those dedicated SEs that have been involved have a mean score in actually applying their involvement which is 2.2 scale points higher than the shared SEs (Table 16 in Appendix 3). Also, the data indicate that Simultaneous Engineering is impacting Voice of the Customer (VOC) information more than QFD. The weighted average mean of VOC information from Simultaneous Engineering is 3.75, whereas the weighted average mean of VOC information from QFD is 2.83 (Table 15 and 14, respectively).

Two other weak areas in the requirements engineering concept is in the lack of a connection between requirements and VOC and in the incompleteness of requirements. The weighted average mean of 3.7 for the connection between requirements and VOC and the weighted average mean of 4.2 for the completeness of requirements appear to be low for the requirements engineering concept (Tables 19 and 23, respectively).

Requirements Engineering is the cornerstone of Systems Engineering. Therefore, Requirements Engineering has been the major focus during the initial implementation of Systems Engineering. Management (VET staff, staff engineers, and assistant staff engineers) indicated during interviews their expectation that Requirements Engineering has made significant progress within Systems Engineering.

The customers' perception of a department not correlating to its organizational structure of either dedicated or shared SEs requires additional discussion. Several other factors, such as having a college degree, departmental leadership, and departmental workload could be possible reasons for this lack of correlation. The analysis for Hypothesis Two suggests that the number of SEs with technical college degrees should influence the customers' perception of a department. The emphasis on Systems Engineering by departmental leadership in comparison to the other departmental assignments could influence the effectiveness of SEs and resulting customers' perception. Currently, Systems Engineering lacks metrics that can be used by the SEs and management to measure the progress and emphasis of Systems Engineering.

Finally, the departmental workload, which fluctuates with the product content in each car program, could impact the priority of SEs. Pilot and start-of-production problems, coupled with high product content, can result in these issues taking priority over other departmental assignments. This was the case for the Body-in-White department included in the analysis. Since Systems Engineering is more future-oriented, the process will never "naturally" have top departmental priority.

The research findings indicating the positive impact of a technical college degree on a customer's perception of SEs meeting Systems Engineering objectives was not expected. Only one staff engineer mentioned this as a potential factor during the interviews. The selection criterion for the initial launch of Systems

Engineering had a technical college degree as a minor factor. The critical selection criterion was based on management's evaluation of an individual's background, experience, and performance. The individuals considered were restricted to those currently within a department. The conclusion from Hypothesis Two is that an improvement in the selection process would be to require a technical college degree.

The low value of Systems Engineering to REs was supported by the SEs themselves. The SEs responded to questions 16 and 17 in the Systems Engineering questionnaire which dealt with requirements and System Technical Specifications (STS) influence on product design. The relatively low weighted average means of 3.9 and 3.2, respectively (Tables 24 and 25 in Appendix) indicate their feeling, as expressed in the interviews, that it is "too soon" for Systems Engineering to impact the REs.

There is high potential for success of the long-term cultural change required for Systems Engineering based on the perceived high future value analyzed in Hypothesis Four. The SEs' interviews indicated an additional two to three years is required to get the real value of Systems Engineering. Management commitment to Systems Engineering over this timeframe will be essential in reaching this potential. Even though the research findings do not indicate success of a dedicated over a shared SE, the organizational perception revealed in interviews is that management commitment to Systems Engineering is linked to dedicated resources. Management must maintain and enhance their perceived commitment to Systems Engineering if it is to be successful in spite of external pressures to reduce costs and headcount.

The research findings indicate the importance of SEs deriving value from Systems Engineering in pursuing their own work (Hypothesis Five). Management needs to discuss this issue with each individual SE in order to better coach them on the personal value of the process. Also, management should seek out individual success stories and publicize them. This would create an awareness of the individual value of Systems Engineering and, hopefully, inspire individuals to have their own success stories.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be made based on this research project:

1) A dedicated System Engineer does not have an advantage over a shared System Engineer. The total workload of each engineer must be understood and allocated properly to best ensure a successful System Engineer.

2) Quality Function Deployment (QFD) is still not fully understood nor fully used by System Engineers. Additional training in QFD is needed and should include a major section on linking Voice of the Customer (VOC) input to requirements.

3) Organizational structure within a department is not the sole criterion for predicting the success of the System Engineers within the department. Specific Systems Engineering metrics are needed to assist both management and System Engineers in assessing the progress of Systems Engineering.

4) System Engineers with technical college degrees can be expected to be more successful than Systems Engineers without a technical college degree. A technical college degree should be a major criterion in selecting future System Engineers.

5) The value of Systems Engineering to the Release Engineers has not yet been realized. Specific metrics to obtain feedback from the Release Engineers on this issue is required.

6) The long-term success of Systems Engineering exists in the minds of the System Engineers. Management commitment to Systems Engineering, as indicated by priority and workload assignments, is required in order to develop this potential success.

7) System Engineers who see the value of Systems Engineering to themselves are viewed as more successful by management than their counterparts who do not see this value. Management should determine and publicize individual success stories in order to enhance the overall image of Systems Engineering.

APPENDIX 1

Systems Engineering Questionnaire

Massachusetts Institute of Technology
Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts 02139

SYSTEMS ENGINEERING - QUESTIONNAIRE

NOTE: VALUES IN BOXES ARE NUMBERS OF RESPONSES

For each of the questions that follow, please indicate your response on the scale below each question.

1. To what degree does the term "Voice of the Customer" (VOC) have a precise meaning for you?

Not at all — Somewhat — Very Much

0	0	0	3	3	14	11

2. To what extent do you think the VOC impacts the product system(s) you are involved with?

Not at all — To a Great Extent

2	1	4	6	10	3	5

3. To what degree does the term "Quality Function Deployment" (QFD) have a precise meaning for you?

Not at all — Somewhat — Very Much

2	2	3	5	5	8	6

4. To what extent did you obtain VOC information through the QFD process?

Not at all — To a Great Extent

12	7	3	1	4	2	2

5. To what extent did you obtain VOC information through your involvement in simultaneous engineering teams?

Not at all — To a Great Extent

5	5	4	4	7	4	2

6. Have you used a formal "House of Quality" procedure to determine VOC information?

__10__ YES __21__ NO

If YES, to what degree did you use it?

Very Roughly — Completely

1	3	0	1	3	1	1

7. Do you have a clear understanding of the meaning of Requirements?

Not at all — Excellent Understanding

2	3	1	3	10	8	2

8. Choose a feature of your system which you believe would have an impact on the customer's long-term evaluation of product quality.

____

For this feature, how do you operationally define it:

____

9. To what extent have requirements been the result of any VOC information on the product system(s) you are involved with?

Not at all — To a Great Extent

9	4	2	3	6	2	5

10. Are you familiar with the Vehicle Technical Specifications (VTS) for the 19xx car program? (specific car program used in actual questionnaire)

Not at all — Very Familiar

0	1	1	0	7	7	15

11. To what extent are the system(s) you are involved in included in the VTS?

Not included — Partially — All Inclusive

1	3	2	5	7	8	5

12. To what extent have requirements been included in the VTS?

Not included — Partially — All Inclusive

6	5	3	5	3	6	2

13. Are you familiar with the System Technical Specifications (STS) for the system(s) you are involved in?

Not at all — Very Familiar

3	2	1	2	7	6	10

14. To what extent have requirements been included in the STS for the system(s) you are involved in?

Not at all — To a Great Extent

3	6	2	4	6	8	1

15. How complete are the requirements for the system(s) you are involved in?

Very Incomplete — Very Complete

4	4	4	4	4	8	2

16. To what extent have the requirements been of value in the execution of the component designs within the systems you are involved in?

No Value — High Value

4	4	5	4	4	8	1

17. To what extent have the STS been of value in the execution of the component designs within the systems you are involved in?

Not at all — To a Great Extent

6	6	7	5	3	2	2

18. Are you familiar with the Validation Plans for the systems you are involved in?

Not at all						Very Familiar
1	1	4	2	1	13	9

19. To what extent have the requirements been of value in the creation of the Validation Plans for the systems you are involved in?

Not at all						To a Great Extent
3	5	4	3	9	2	3

20. To what extent have the STS been of value in the creation of the Validation Plans for the systems you are involved in?

Not at all						To a Great Extent
9	5	4	5	4	2	1

21. How much value would you say that the introduction of systems engineering principles has been for the company?

None			Some			A Great Deal
5	8	5	7	4	1	0

TODAY

None			Some			A Great Deal
5	8	5	7	4	1	0

FUTURE

22. How much value have you derived from the systems engineering principles in pursuing your own work?

None			Some			A Great Deal
1	6	2	4	10	5	3

23. Interview Question: Based on your experience with block diagrams, how valuable do you think they will be to you? (Author's numerical assessment based on verbal response)

None			Some			A Great Deal
0	3	2	11	0	3	0

APPENDIX 2

Customers of Systems Engineers Questionnaire

CUSTOMERS OF SYSTEMS ENGINEERS

QUESTIONNAIRE SUMMARY FOR NON-RELEASE ENGINEERS

<u>4</u> VET Staff
<u>6</u> Staff Engineer
<u>9</u> Assistant Staff
<u>11</u> Vehicle Integration
<u>30</u> Total

<u>Question:</u> To what degree has the effort on this system met your expectations in terms of systems engineering objectives?

(Note: N/A--Not Applicable checked for unfamiliar systems)

Values in boxes are:

<u>Percent</u> of Responses OR <u>Number</u> of:

	Not at all		Somewhat		Very Much	System Eng.*	Responses	N/A
BIW	7	23	32	24	14	4	62	58
ECBM	9	26	29	21	15	6	68	112
S&IT	3	16	37	27	16	5	92	58
IP/ HVAC	1	13	26	39	21	4	90	40
EE	5	4	37	30	24	8	114	126
CHAS-SIS	0	23	30	23	23	7	111	99
TOTAL	4	16	32	28	20	34	527	495

* Number of System Engineers within a department

Note: The following equation is implicit in above:
(Number of SEs) x 30 = (No. of Responses) + (No. of N/A)

CUSTOMERS OF SYSTEMS ENGINEERS

QUESTIONNAIRE SUMMARY FOR RELEASE ENGINEERS

Number of Release Engineers responding: 23

Question: To what degree has the effort on this system met your expectations in terms of systems engineering objectives?

(Note: N/A--Not Applicable checked for unfamiliar systems)

Values in boxes are:

Percent of Responses OR Number of:

	Not at all		Somewhat		Very Much	System Eng.*	Responses	N/A
BIW	32	32	25	7	4	4	28	64
ECBM	42	25	17	17	0	6	12	126
S&IT	31	31	9	22	6	5	32	83
IP/ HVAC	10	15	60	10	5	4	20	72
EE	0	37	13	20	30	8	30	154
CHAS-SIS	18	12	29	35	6	7	17	144
TOTAL	21	27	24	18	10	34	139	643

* Number of System Engineers within a department

Note: The following equation is implicit in above:
(Number of SEs) x 23 = (No. of Responses) + (No. of N/A)

APPENDIX 3

Tables Comparing Dedicated and Shared System Engineers' Responses to Questionnaire

<TABLE 11>

Comparison of Dedicated and Shared System Engineers' Response to Question 1*

Status of System Engineer	Response based on a 7-point scale
Dedicated	6.20
Shared	5.94
τ	0.80
ρ	0.43

*Question 1: "To what degree does the term 'Voice of the Customer' (VOC) have a precise meaning for you?"

<TABLE 12>

Comparison of Dedicated and Shared System Engineers' Response to Question 2*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.87
Shared	4.47
τ	0.67
ρ	0.51

*Question 2: "To what degree do you think the VOC impacts the product system(s) you are involved with?"

<TABLE 13>

Comparison of Dedicated and Shared System Engineers' Response to Question 3*

Status of System Engineer	Response based on a 7-point scale
Dedicated	5.13
Shared	4.65
τ	0.75
ρ	0.48

*Question 3: "To what degree does the term 'Quality Function Deployment' (QFD) have a precise meaning for you?"

<TABLE 14>

Comparison of Dedicated and Shared System Engineers' Response to Question 4*

Status of System Engineer	Response based on a 7-point scale
Dedicated	3.00
Shared	2.65
τ	0.48
ρ	0.63

*Question 4: "To what extent did you obtain VOC information through the QRD process?

<TABLE 15>

Comparison of Dedicated and Shared System Engineers' Response to Question 5*

Status of System Engineer	Response based on a 7-point scale
Dedicated	3.93
Shared	3.59
τ	0.52
ρ	0.61

*Question 5: "To what extent did you obtain VOC information through your involvement in Simultaneous Engineering teams?"

<TABLE 16>

Comparison of Dedicated and Shared System Engineers' Response to Question 6*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.71
Shared	2.50
τ	2.09
ρ	0.08

*Question 6: "If yes, to what degree did you use IT (a formal "House of Quality")?

<TABLE 17>

Comparison of Dedicated and Shared System Engineers' Response to Question 7*

Status of System Engineer	Response based on a 7-point scale
Dedicated	5.07
Shared	4.53
τ	0.95
ρ	0.35

*Question 7: "Do you have a clear understanding of the meaning of a requirement?"

<TABLE 18>

Comparison of Dedicated and Shared System Engineers' Response to Question 8*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.79
Shared	4.00
τ	1.37
ρ	0.18

*Question 8: "Choose a feature of your system and then write a requirement for it. Authors personal assessment on quantitative number."

<TABLE 19>

Comparison of Dedicated and Shared System Engineers' Response to Question 9*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.07
Shared	3.35
τ	0.89
ρ	0.38

*Question 9: "To what extent have requirements been the result of any VOC information on the product system(s) you are involved with?"

<TABLE 20>

Comparison of Dedicated and Shared System Engineers' Response to Question 11*

Status of System Engineer	Response based on a 7-point scale
Dedicated	5.40
Shared	4.47
τ	1.68
ρ	0.11

*Question 11: "To what extent are the system(s) you are involved in included in the VTS?"

<TABLE 21>

Comparison of Dedicated and Shared System Engineers' Response to Question 12*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.20
Shared	3.31
τ	1.23
ρ	0.23

*Question 12: "To what extent have requirements been included in the VTS?"

<TABLE 22>

Comparison of Dedicated and Shared System Engineers' Response to Question 14*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.60
Shared	3.75
τ	1.30
ρ	0.20

*Question 14: "To what extent have requirements been included in the STS for the system(s) you are involved in?"

<TABLE 23>

Comparison of Dedicated and Shared System Engineers' Response to Question 15*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.13
Shared	4.25
τ	-0.170
ρ	0.87

*Question 15: "How complete are the requirements for the system(s) you are involved in?"

<TABLE 24>

Comparison of Dedicated and Shared System Engineers' Response to Question 16*

Status of System Engineer	Response based on a 7-point scale
Dedicated	4.07
Shared	3.69
τ	0.56
ρ	0.58

*Question 16: "To what extent have the requirements been of value on the execution of the component designs within the systems you are involved in?"

<TABLE 25>

Comparison of Dedicated and Shared System Engineers' Response to Question 17*

Status of System Engineer	Response based on a 7-point scale
Dedicated	3.20
Shared	3.18
τ	0.04
ρ	0.97

*Question 17: "To what extent have the STS been of value in the execution of the component designs within the systems you are involved in?"

<TABLE 26>

Comparison of Dedicated and Shared System Engineers' Response to Question 18*

Status of System Engineer	Response based on a 7-point scale
Dedicated	5.87
Shared	5.06
τ	1.36
ρ	0.19

* Question 18: "Are you familiar with the Validation Plans for the systems you are involved in?"

<TABLE 27>

Comparison of Dedicated and Shared System Engineers' Response to Question 19*

Status of System Engineer	Response based on a 7-point scale
Dedicated	3.93
Shared	4.07
τ	-0.20
ρ	0.85

*Question 19: "To what extent have the requirements been of value in the creation of the Validation Plans for the systems you involved in?"

<TABLE 28>

Comparison of Dedicated and Shared System Engineers' Response to Question 20*

Status of System Engineer	Response based on a 7-point scale
Dedicated	3.60
Shared	2.50
τ	1.76
ρ	0.09

*Question 20: "To what extent have the STS been of value in the creation of the Validation Plans for the Systems you are involved in?"

<TABLE 29>

Comparison of Dedicated and Shared System Engineers' Response to an Interview Question*

Status of System Engineer	Authors' Assessment of Response based on a 7-point scale
Dedicated	4.10
Shared	3.75
τ	0.44
ρ	0.66

*<u>Interview Question</u>: "What value to you are the block diagrams you created?"

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