Inherent Discipline Required in Large System Change

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ABSTRACT

Recent electrical architectures of land vehicles have shown a marked increase in networking and integration of electronic controls into traditionally electro-mechanical devices, which results in complex functional interactions throughout the electrical system. This trend often drives a large system change that modifies the engineering roles of the component level engineer and also creates a need for an evolution to a vehicle level systems engineering approach.

In this paper, a claim was put forth that without a certain level of inherent discipline in place and functional, no successful large system change can occur. Inherent discipline was decomposed into three parts: process, personal, and organizational disciplines. Each of these was described and relationships between them were investigated. The correlation between parenting and organizational discipline was explored.

A case for the business value of inherent discipline was made by examining two examples; one of organizational progress and one of manufacturing progress. Then a case study of an emerging large system change, feature ownership, was presented. Details on the engineering roles required for feature based development at each of the hierarchical levels of the electrical system were presented. Using the Design Structure Matrix as a tool, the interactions of the development process used for implementing distributed features were analyzed.

Elements of inherent discipline required for a successful implementation of feature ownership were identified, as well as feedback from engineers in the organization implementing this large system change. The criticality of organizational discipline, in particular, to the feature ownership change initiative was emphasized. Recommended next steps for process, personal, and organizational discipline were detailed and possible effects of lack of discipline on feature ownership were postulated. The three types of discipline form a balance for the large system change initiative. The absence of any of the three can have a detrimental effect on the progress and effectiveness of the change, leading to poor quality, application or implementation of the change.

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1 Motivation for "Inherent Discipline Required in Large System Change"

Recent electrical architectures of land vehicles have shown a marked increase in networking and integration of electronic controls into traditionally electro-mechanical devices. With the increase in networking in vehicles, there has been a corresponding increase in the amount of distributed control of software enabled features. The distribution of control logic across multiple electronic control modules (ECUs) increases the implementation complexity of the distributed feature as it creates interactions between the ECUs and possibly across organizational boundaries (as a different organization may have design responsibility for each of the ECUs). On the other hand, integration of electronic control into traditionally electro-mechanical devices (e.g. smart motors) decreases the amount of system level interactions but increases the skill set needed by the engineer responsible for the design of this device. Not only do they require mechanical and electrical design skills, but they also require skills regarding functional and logical control design practices.

Each of these examples not only modifies the roles and responsibilities of the component level engineer, but also creates a need for an evolution to a vehicle level systems engineering approach to ensure the successful implementation of a feature. There must be a feature based perspective that is taken at each of the hierarchical levels of the vehicle under development. Such implementations put a greater emphasis on "who owns what" with respect to defining, developing, implementing, and verifying these features for the vehicle program. As such, this concept of feature ownership can be thought of as an enabler for this evolution (i.e. large system change) to a more vehicle level systems engineering approach and specific details on the resultant roles at each of the hierarchical levels need to be outlined. The complexity of the resultant development process lends itself to analysis using the Design Structure Matrix (DSM) [1]. One complexity is the functional interactions of a distributed feature. Another complexity is the organizational interactions required to implement a cross-functional distributed feature. Such an analysis can provide deeper understanding of these interactions and provide a framework from which this evolution to a more vehicle level systems engineering approach can be based.

As an SDM project, the author examined an unsuccessful large system change initiative to discover the causes of the failure. Two resources, <u>Managing for the future: organizational</u>

behavior & processes [2] and True Change: how outsiders on the inside get things done in organizations [3] provided much insight into the reasons why a successful change did not take place. When the author was pressed by their advisor what was the "one thing" (as Curly put it in the movie "City Slickers") that was the root cause of the failure, lack of discipline was the author's conclusion. Part of the basis for this conclusion was that throughout the discussion on how to pull change in an organization, Klein [3] mentioned elements of discipline as an enabler. In the context of transitioning to lean manufacturing principles, Klein stressed that modifying behavior to enable such a change "requires an immense degree of discipline by the entire organization" [3, page 41] and that one key factor was "introducing the idea of discipline as an alternative approach" to the current practice of process workarounds. The organizational analysis tool of Three Lenses [2] also contained many concepts that can be traced as the basis for the inherent disciplines theory presented herein. Some of the questions used in such an analysis are:

- Is there the right skill mix?
- Who is accountable?
- What is the reward system?
- Is the initiative consistent with the strategy of the company?
- Was the workforce consulted in the design of the process and resultant work tasks?
- Who has the power to make decisions?
- How is information shared?
- Who benefits in any productivity gains?
- Do the employees feel like part of the team?
- Is progress charted and displayed?
- How are conflicts settled?
- How is the initiative communicated?

For an organization to be successful in a change initiative, it must have a disciplined answer to all these questions.

There have been many books written and studies conducted on instituting change in organizations; whether it be driving management initiatives, technical evolutions (or revolutions), reorganizations, or acquisitions one necessary piece of the puzzle is discipline. It is often taken for granted, sometimes discounted, and even disguised, during the planning phases of the change initiative. Often is it mentioned after the fact, when the initiative is struggling, as something that needs to be addressed. During a long career in any product development field, an experienced engineer will see many of these initiatives come and go. It is my claim the one of the enablers that must be in place for any initiative to truly succeed is a certain level of inherent discipline. This paper will examine this claim in two ways. After a description of inherent discipline, the value of inherent discipline will be examined by looking at two well known theories on successful large system change. Then an emerging large system change taking place while this thesis is being written (feature ownership) will be described (with engineering roles outlined) and analyzed to determine which of elements of inherent discipline are required for the large system change to be successful. Once this examination is complete, recommendations will be outlined on the vital steps which should be taken to increase the chance of a success for feature ownership initiative.

1.1 Types and levels of inherent discipline

When one says the word discipline in an engineering organization, two thoughts often come to mind. The first is the type of engineering work that is being referred to, i.e. electrical, mechanical, software, reliability, logistics, etc... This comes from the definition of discipline that states: "a field of study" [4, page 330]. The second is the type that brings back memories from childhood. Its definition states: "orderly or prescribed conduct or pattern of behavior" [4, page 330]. This type is similar to the concept of moral values in that it tends to be obvious to a given observer in that they know what it looks like when they see it, but the steps to instill such an attribute are varied and controversial. In fact each observer really has their own variation of what discipline (just like morality) truly is. This paper will look at this second, more elusive, type of discipline.

As with other complex systems, the change "system" is a complex set of interactions which must be made simpler to allow analysis. The concept of inherent discipline presented herein will be decomposed into three parts: Process discipline, Personal discipline, and Organizational discipline. Process discipline deals following the various process steps defined for any engineering effort. Personal discipline deals with an individual's actions when performing any engineering effort. Organizational discipline deals with the actions of the management and social structure that forms the environment in which engineering effort takes place.

1.2 Without discipline

It is this paper's contention that without a certain level of all three of these disciplines in place and functional (as opposed to dysfunctional), no successful large system change can occur, and in the case detailed within, no true feature ownership can take place. While a subsequent section will describe what is meant by feature ownership, this section will briefly discuss what is meant by in place and functional. One of the first steps of discipline being in place is the awareness and understanding that discipline indeed plays a part in the success of the initiative. After this occurs, acceptance of the mores associated with the aspects of discipline must occur. For the discipline to be functional there needs to be a consistency and alignment of the resultant disciplined actions. The functional effectiveness is partially a numbers game where the higher the percentage of the organization that is acting in a disciplined fashion, the more effective the engineering effort will be. Consistency over time is another important factor. Omission of any of these pieces will cause any large system change to suffer.

2 Types and levels of inherent discipline

To understand the system of discipline required to successfully implement large system change, a decomposition of the concept of inherent discipline is warranted. As stated earlier, one way to do this decomposition at the first level is to segment it into Process, Personal, and Organizational. While each of these types can be thought of independently, the interactions between them truly make it a system of discipline. Each is required for large system change initiative such as feature ownership to be successful. In the next few sections, an explanation of each of these inherent discipline types will be given, along with a discussion of their interactively.

2.1 Process Discipline

Process, "a series of actions or operations conducing to an end" [4, page 929], discipline speaks to the consistent implementation of the engineering actions necessary to produce an engineering outcome. One of the first aspects of process discipline is whether the process is <u>defined</u>. After a process is defined, the next natural step is to <u>document</u> the process so that others can be aware that it exists and what it is. For a process to be effective, it must have sufficient <u>detail</u> in order to produce repeatable results. Only when these elements are in can the process be followed by individuals other that those who where involved with the process development. Measurements on the process can then be taken to gain understanding in the effectiveness of the process. The effectiveness metrics of the process can then be reviewed to gain confidence in the process and provide alerts to errors in the process. Identified errors must be fixed and the process updated to progress the engineering organization. The underlined words can be used as checklist items in an analysis of process discipline.

2.1.1 Defined

The first step in creating process discipline is the definition (i.e. creation) of the processes which the workforce is going to follow in the first place. This definition can be planned and coordinated by a formal process group or it can evolve from the best practices of the organization. The key here is that there is awareness and acceptance that there is a right way to do things. This definition of the process creates a roadmap to the large system change desired.

2.1.2 Documented

After the process is defined, then next step is to document the process. This documentation allows two vital activities to follow: process consistency and process improvement. The consistent execution of the process will enable a repeatable and predictable series of work products from the organization in question. Once this consistency is achieved, improvements to the process will naturally follow. It will be the nature of the engineering community to optimize the workflow described in the process and will give the work force a feeling of ownership of the process itself, once the individuals have been able to place their stamp on it. The way in which the process is documented should be a natural language for the executors of the process. This documentation should be available to those which it serves to guide. The documenting of the process provides an artifact for the engineering community to refer to not only during the process of implementing the large system change, but also when the change has take place (so that the organization does not revert back to the old way of doing business).

2.1.3 Detailed

As with any technical documentation, the level of detail to which it goes into is a key determinant to its effectiveness. This level is detail is dictated by the desires of the process definition team. What specifically is the goal that is trying to be accomplished? Is it to have the same sequence of steps? To have same information used and / or delivered in the creation of an engineering deliverable? To ensure the same engineering rigor be used? The level of detail contained in the documentation of the process will not only create a baseline of understanding of the process itself, but also act to deter the creativity of the executor of the process. This placement of constraints on the engineering community can decrease the level of optimization which can take place on the process over time and as such is not something which should be taken lightly. Thus the process must contain enough detail to simply and completely outline the required work tasks, including any sequence of steps, but not so detailed to inhibit or deter the natural evolution of the process to a more optimized and efficient state. These specific details are required to ensure a consistent level of understanding of the process across all parts of the organization involved with the large system change.

2.1.4 Followed

The effort of defining, documenting, and detailing a process can be all for naught if no one follows the process. A valid question is why should the process be followed? There should be value associated with the proper execution of the process. If this value is fully understood, the rationale for following the process is easily communicated. This question of following the process is a good example of the interrelations of the three disciplines: process, personal, and organizational. Why should one follow the process? From a personal discipline perspective (we will discuss this in more detail later), one should follow the process because that is their job. From a process discipline perspective, the process should be one that it can be followed and will provide value if it is followed. From an organizational discipline (this is also be discussed in more detail later), there should be incentives for the employees to follow the process and the actions of the management team should be consistent with a desire for following the process. All effected parties must follow the defined process in order for the large system change to be complete.

2.1.5 Measured

Assuming that the process should indeed be followed, then how does one actually know if and how well it is being followed and thus progressing? This desire should lead to some type of measures being defined and put in place to give an indication regarding how faithfully the process is being followed, and the results which are being gained. Again, remember that the process was put in place to facilitate the accomplishment of a set of goals. These goals are the yardstick which the process results are measured against. The old adage, be careful what you measure, comes into play here. The inclination is to create process metrics around elements which are easiest to measure. This will allow measurements to occur, but may cause optimization of the process to get good measurements which will not lead to accomplishing the goals which led to the creation of the process in the first place. An effective set of process measurements will provide insight to the progress of the large system change.

2.1.6 Reviewed

Once measurements are being taken, the next step is to analyze the measurements. This analysis should be done with the goal to gain a better understanding of the process results as a whole. The timeliness and periodicity of this analysis will be dictated by the nature of the process, the previous analysis results, and any discrepancies between the perceived present state and the desired future state. These analyses should be reviewed by the process stakeholders and actions should be taken to improve any process deficiencies identified by the process measurements. Lack of reviews (or subsequent actions from the reviews) is a signal to the process executors that the value of the process is not as critical as they may have been told it was. Review of the process measures provides an opportunity to perform any needed midcourse corrections to the large system change.

2.1.7 Updated

Any actions identified in the process reviews which can be attributed to a process deficiency should lead to the update of the deficient process. This update should follow a defined revision process and be enacted with the concurrence of all involved stakeholders. Any acknowledged outdated process will lead to a general decrease in process discipline because it will be looked upon as an indication that the value of the process is not worth the effort to update it. This also motivates the process executors to deviate from the documented processes, as they are known to be deficient and the workforce justify not following the process as just trying to do what's right for the company. Updating the process will allow the large system change to evolve and continuously improve in the future instead of being a one shot deal which should be discarded at the first sign of difficulty.

2.2 Relationship between Personal and Organizational Discipline

Before detailing what is personal and organizational discipline, a discussion on the relationship between the two is warranted. One reason for this is to set the stage between the delineation of the two. A second reason is to introduce the dependences of one to another. While this discussion could be placed after the concepts of personal and organizational discipline were describe, placing it prior allows the proper context of each discipline to be better understood. At first blush, one can think of organizational discipline as the collective set of personal discipline exhibited by all those in a position of power in the organization. This is the driver for organizational discipline elements described later as "consistent" and "aligned". Simply put, if the organization's management team does not exhibit personal discipline in their collective execution of the policies and procedures in place, the organization does not have a high level of organizational discipline.

The dependencies between the two disciplines are, as described by Klein [5] a paradox "between the need for operating discipline and employee empowerment over operating decisions" [5, page 179]. This confusing relationship is one reason that consistency is an element of both personal and organizational discipline. Consistent behavior at both the personal and organizational level reduces this confusion's effect on the workforce by filling in the unwritten details of corporate policies and procedures through learned behaviors. Some of this is based on relationships between engineer and supervisor, because as Klein puts it "the vast majority of American workers are quite skeptical of top management's motivations" [5, page 184]. Some is based on relationships between the engineers themselves (i.e. peer pressure). This dependency is also illustrated in the relationship between a person being committed and an organization rewarding such commitment. While some of the level of commitment a person has is affected by their societal culture, most is the result (and in reaction to) their perception of the organization's discipline. Klein writes "employees feel a sense of commitment when they have an opportunity to personally influence or contribute to job-related outcomes" [5, page 182]. This can be directly tied to the empowerment element of organizational discipline. Another factor on personal commitment that can be tied to organizational discipline is the trust employees have in the organization. This trust is built from the organization showing a high level of discipline regarding the reward structures in place for employees and how much training is made available to employees in order to enable them to become more successful and valuable to the organization over time. The following sections continue this discussion by detailing some of the particulars of personal and organizational discipline.

2.3 Personal Discipline

Personal, "relating to an individual or an individual's character, conduct, motives" [4, page 867], discipline speaks to the engineers who are following the process in order to produce the desired set of engineering deliverables. One interesting aspect of this is that not only is there discipline required in what the engineer is doing (conduct), but also what the engineer is thinking (motive). Klein described the need for this type of discipline in reducing process variability in that "This requires employee acceptance and conformance to established standards or procedures, which may not be of a particular employee's choice" [5, page 182]. One example of this span between both doing and thinking is whether the engineer is committed to performing the job assignments given to them. Another example is whether the engineer is ethical their daily efforts. Honesty is another element of personal discipline. The technical capability of the engineering community is often tied to the commitment to education of the individual engineers; this commitment is a form of personal discipline. The consistent execution of the required tasks is an inherent trait of someone who has personal discipline. The effort one puts into communication has a direct effect on the success of an initiative and can also be binned under personal discipline. One thing to notice is that each of these concepts requires time and energy on the part of the engineer. If the engineer is operating in a stressful environment that overloads or overburdens them, there is a very high certainty that engineer will not be able or willing exert the energy it takes to exhibit a high level of personal discipline. This is often perplexing to the management team (who have a direct impact on an engineer's workload), as a once highly disciplined engineer can "all of a sudden" become an inconsistent and poor performer. Again, the underlined words will form the basis for a checklist which can be used for analyzing personal discipline.

2.3.1 Committed

Commitment is an attitude to conform to what must be done as defined in an organization's processes to the best of an employee's ability. This commitment forms, as Klein puts it, a "psychological contract toward work"[5, page 182]. This commitment is based on the loyalty felt by the employee, the relationships the employee has with their management and peers, and their attitude about the work tasks they are performing [5]. In today's business environment everyone has too much work assigned to them. A committed engineer will work to understand the priorities of their work assignments, gain agreement from their management team regarding acceptable and achievable schedules for completion of their work assignments, and then work to their utmost ability to meet the schedule. A non-committed engineer will play one task against another, not giving full effort to any task they are not committed to execute. There is always a built in excuse for the non-committed engineer that there is too much work to be done, so this is as good as I could do with the time I have. An employee's level of commitment is an indication of the amount of personal discipline they have and is an enabler for accurate process measurement regarding how good the existing process is and how effective any subsequent improvement actions are. An employee's specific drive to get the job done comes from their commitment. A high level of commitment is needed in the often stressful environment that accompanies any large system change.

2.3.2 Ethical

There are many concepts of ethics being discussed in the workforce today. For the purpose of this paper, we will say that an ethical worker is one that follows the code of conduct defined by the company in which they work. One reason to take this tack is that what is defined as ethical in one type of business may not be allowed in another. The other reason is that this code of conduct is often explicitly defined for the engineer, updated as appropriate, and any deviations from it may result in disciplinary actions (including termination and criminal prosecution). This being said, how ethical a person is determines the quality of relationships they have with their peers and their supervision. This is both on a perceived and actual level. If perception is that a person is not ethical, time and effort is wasted by those who interact with that person in order to check on the veracity of the information and efforts given by the non-ethical person. This reduces the productivity of all those involved. If a person's actions are truly not ethical, the quality and completeness of there efforts is questionable, again decreasing the productivity of the organization. This individual will play the system by not holding themselves accountable for their own actions, not admitting their mistakes, and perhaps follow the letter but not the intention of a given process. All of these actions will make the large system change effort and continuous improvement of the organization much more difficult.

2.3.3 Honest

As with the discussion in the preceding paragraph on ethics, this paper does not try to define moral standards in the discussion of personal discipline but rather place it in the context of today's business environment. Honesty also fits into this type of discussion. An honest employee is one that does not purposely deceive others for their own gain and to the determent of their company. This can be linked to a person's integrity, but again encompasses both their intentions and actions. From an intention viewpoint, a person with a high level of personal discipline will demand the truth of themselves. They feel responsible for any agreements made between themselves and others, both within and outside their specific organization. From an actions perspective, an honest individual communicates their actual intentions and provides not only actual information, but also clearly offers up all assumptions and associated circumstances needed for the correct interpretation of the data. The personal discipline element of honestly has great effect on the efficiency of an organization. Purposely dishonest actions can lead to additional cost to a product development process and a breakdown of trust within an organization, decreasing the quality of personal interactions. A person who has dishonest intentions not only contributes to the inefficiency of the organization, but also decreases their own efficiency with the time lost contemplating inappropriate actions and the effort required to cover up these actions. These inefficiencies linked to a lack of honesty can cause the large system change to fail, even when all other required pieces are in place.

2.3.4 Educated

The amount of education which an individual requires for their work assignment is a difficult thing to measure. Part of the difficulty comes from the varied ways in which an engineer can gain this education; universities, technical seminars, independent study, mentoring, and on the job experience / training are the most common ways identified. Formal education is often used as a ticket for entry into an organization, but is not a true indicator of engineering ability. Recently, in some industries (such as the automotive industry) the technical maturity of a given individual for their specific work assignment is gaining favor as a measure of the engineer's applicable education. The main way of measurement is a self assessment by the engineer in question. This self assessment is a formalized way in that the engineer indicates whether they feel they have the necessary education and work experience to perform their job duties. Engineers which do not have the technical competence to perform the duties assigned to them will produce deliverables of low quality and take longer in doing so. A highly disciplined engineer would use this technique (or others) to identify any technical gaps and then act to close those gaps as appropriate. These actions could not only be used to fill any competency gaps for their current job tasks, but also those in the near future (increasing their ability to meet development schedules). Increasing one's technical competence also increases their value to the organization as a whole. Engineers who are competent in more than one area provide flexibility for the organization to move them into several roles without decreasing the quality and efficiency of the engineering effort.

While the discussion thus far has been focused on the technical side of education, the business side is important also. Understanding what it takes to move the organization forward, what are the key business drivers and knowledge of cross functional interactions are also valuable both to the individual and the organization. If employees have the ability to affect changes in procedures, a fundamental understanding of the business side of the organization is important. One caution for the employee is to not get so wrapped up in learning ancillary aspects of their job that they lose focus on their main job function. Learning more about the organization may increase the chances of this occurring, but must be tempered with the increased value to the company of employees knowing the business basics essential to facilitate more effective change. This is because the more knowledgeable an employee is, the more effective they are in breaking down any bureaucratic barriers hindering organizational progress. Education is important to the success of any large system change because, by definition, the change will include new ways of doing engineering tasks which will require new skills from the affected engineering community.

2.3.5 Consistent

There are two ways in which an individual can be consistent. They both can be derived from the definition "free from irregularity, variation, or contradiction" [6, page 239]. The first way is in the individual's performance on their work deliverables. What was accomplished in a certain timeframe, using a certain method, with a certain outcome which will be replicated in a similar fashion with similar results each time that task is performed. This type of consistency is often described with metrics and statistics. The other way for an individual can be consistent relates to their character. The manner in which an individual interacts with others while carrying out their daily duties is also a measure of consistent behavior. Whether it is the individual's mood, tone, mannerisms, attentiveness, or timeliness, this type of consistency is not one which can be easily quantified, but rather one that affects the desire of others to interact with the individual and the acceptance of that individual's work products.

Both types of consistent behavior are the basis in which expectations are formed. Examples of these expectations are delivery dates, work product content and quality, and personal interaction dynamics. The more consistent one is, the more easily an expectation of delivery is created, the less of a perceived risk is associated with the accomplishment of that particular deliverable, and the more drastic the response if the expectation is not fulfilled. As discussed earlier, inconsistency introduces variation into the development process. Without the personal discipline element of consistency in place, large system change and a continuous improvement process cannot be realized for the individual or the organization. This discipline enables the concept Klein described this as *Dynamic Taylorism* where "standardized work is based on stabilizing the procedure so it can then be improved upon"[5, page 187].

2.3.6 Communication

The discipline of an individual's communication is similar to the discipline of being consistent in that there are two aspects to it. The first is the information being communicated and the second is the manner is which the communication takes place. The information being conveyed should be of a format and content level which meets the uses of the person it is being delivered to. Often it is easier to provide information in a raw, unprocessed format which may not be suitable for others to use. This requires the recipient of the information to perform some post-delivery processing of the data prior to using it. This delays any discussion on if the data is understandable, usable or correct until after it is in the hands of the customer.

The way information is communicated affects the acceptance of the data. A disciplined person will help create an environment that enables open and free discussion to take place. Such an environment improves the diversity of ideas considered, allows consensus to be reached, and reduces what Klein discussed as "'group think', where individual ideas are lost" [5, page 189]. Three metrics on the manner of communication are the openness, timeliness, and effectiveness of the communication. Of the three, timeliness is the easiest to measure. If the information is communicated when (or prior to) the time the recipient needs it, the communication was indeed timely. Openness and effectiveness of the communication is in the eye of the beholder. Regardless of how vital the information is, if the recipient cannot understand or believe the data, the data may be regarded as useless. While good communication is a two-way street, the amount of effort and care used by the communicator is a good indicator of that individual's communication discipline. Taking responsibility to ensure that any form of communication is effective improves the quality of the communication content, reduces miscommunication and thus increases the communication process efficiency. This increase of communication efficiency increases the chances of the large system change to be successful.

2.4 Organizational Discipline

Organizational, relating to an administrative and functional structure [4], discipline speaks to the culture that exists in the engineering environment. At first glance, one might call this management discipline, but it really extends beyond the discipline of the current management team (though it includes this) to the discipline of the company past, present, and future. There are many similarities to this and how a parent interacts with their children. The messages and actions a parent takes with a child should be consistent so that the child can have an understanding as to the expectations placed on them. These messages and actions should be aligned with each other (get exercise and don't eat junk food) and should be aligned with the other parent. Desired behavior should be rewarded and undesired behavior should not. The parent should provide appropriate training and ensure that the child is learning the needed skills. The child needs to feel empowered to make age appropriate decisions without the parent undermining the child's confidence. The parent provides appropriate governance to guide the child's development. Like the parent who must be able to provide these actions to multiple children in the presence of uncontrollable outside influences, an organization must accommodate numerous types of employees and an uncertain and ever changing business and economic climate.

2.4.1 Consistent

This is the organizational equivalent to the consistent element made above regarding the personal discipline. While all of the topics discussed earlier apply here, the scope of this section is much larger, as it describes the entire organization. It also speaks to both the actions which affect the organization as well as those with affect the organization's interface to the rest of society. One aspect that should be highlighted here is the breadth of which this consistency is measured. How consistent an organization can be thought of is determined within a department, across departments, across divisions, and across its interface to society as a whole.

In fact, the discipline of organizational consistency will drive how corporate policies and practices are viewed, both within and outside the organization. If a company consistently understates quarterly financials, only to perform fourth quarter miracles, Wall Street analysts will consider this a lapse in financial discipline. If the treatment, compensation, and consideration of employees, suppliers, or customers are uneven, the organization cannot be thought of as a single entity, but rather a loosely bound set of activities, without a single culture. Operating at a high level of discipline regarding consistency is the foundation for trust. This trust is the enabler for employees to feel confident in the future and exhibit a high level of personal discipline, which will be a foundation on which the large system change can be anchored to.

2.4.2 Aligned

While consistent behavior is admirable, it cannot be thought of as effective unless it is aligned. The baseline of this alignment needs to be with regards to the corporate policies and practices in place. Actions of all individuals within an organization must be aligned, thus creating the need of these corporate policies and practices. Each of these policies and practices should not conflict, but rather compliment each other. The revision history of these policies and practices are often an indicator of this alignment. Well aligned policies will not need to be updated because they will minimize operational conflicts due to misalignment.

Another aspect of alignment is again across the organization, but relates to what is being done (not how as discussed above). If one part of the organization is striving to reduce software complexity, while another is trying to provide flexible hardware, conflict due to misalignment is experienced. The concept of the balanced scorecard was developed to facilitate this type of alignment. While there are many implementations of this concept, the key idea is that for a given period (usually once a year) the organization will create goals and objectives (with measurable metrics) which provide hierarchical and cross-organizational alignment. Organizational interfaces to achieve the stated goals are identified in order to allow alignment of action to occur.

One reason alignment is such a critical element of organizational discipline is because of employee cynicism. If there is a belief that the organization has got its act together, the employees will believe that it has their best interests in mind when changes occur in the workplace. Being able to see alignment of procedures and the resultant continuous improvement across the organization allows process change to occur at a quicker pace by reducing the internal resistance to change and increasing employee's commitment to the specific change initiative.

2.4.3 Rewarded

Regardless of the type of business the organization is in, one of the goals of the organization and the individuals working for it is to be successful. One measure of success is the rewards garnered during the execution of the actions associated with the running of the business. Each individual is performing their job function in order to be rewarded. For more philanthropic individuals, the reward may be in the sense of accomplishment of a deed well done. For most individuals however, the rewards desired are more tangible. How an organization rewards its employees is a main contributor in defining how it wants its employees to carry on their duties. Klein states the employees "will strive to improve their output if they perceive a direct link between their job performance and their compensation or future promotion"[5, page 181]. Regardless of published policies on behavior, the actions which are perceived by the workforce as the drivers for higher rewards will be the ones which are most commonly demonstrated. The pattern of promotion of an organization is a true indication of what is rewarded (and thus truly valued). The attributes which form the basis of the promotion decision must be those which the organization wants to promote as being valuable.

One common example of this is fire fighting [7] vs. performing preventive action. In many organizations, the act of putting out fires (regardless of who set them) is rewarded handsomely at performance review time. Part of the reason is the visibility the fire fighter gets during the battle and the ability of the organization to quantify the actions taken (i.e. the fire being put out). Those individuals who are actively preventing the fires from occurring are often overlooked because of the inability to quantify how many fires were prevented and at what cost savings. When this is demonstrated by an organization, the employees soon learn that greater rewards are given (and thus greater effort should be given) for getting out of trouble instead of preventing it. The more capable workers are likely to flock those "hero" type positions, leaving less capable workers actually preventing issues from occurring (or those positions being left unfilled).

Another common lapse in the rewards aspect of organizational discipline is the team player vs. the individual contributor. Every organization espouses the desire for its employees to be team players, but will reserve the highest rewards to those who have great individual accomplishments. An issue here is again one of quantification. How does one quantify how well a worker participates in a team environment? In this case, negative rewards (disciplinary actions) often result from the lack of desired behavior. This example illustrates the need for the rewards (both positive and negative) to be identified and open for review and evaluation. Most organizations delineate negative rewards much more clearly and succinctly than the positive ones (due to litigation risks). Regardless of the type, appropriate rewards must be in place in order to motivate the work force in acting is a manner consistent with the goals of the large system change.

2.4.4 Training / Learning

The organization needs to provide training opportunities to their workforce and create a culture that encourages learning. This is especially important when trying to implement some type of change. One indicator of how important a change initiative is to an organization is the amount of information and training is put in place prior to a change initiative being kicked off. The prioritization of needed training and the amount of resources allocated to educate the organization regarding the desired change provides not only skills required to succeed, but also signals the workforce on the seriousness of the organization to follow through with the implementation of the change. A highly disciplined organization will not attempt a large system change without ensuring that the learning resources are in place to enable success.

The training opportunities given to employees instill a level of confidence that the organization is committed in increasing that individual's value and future earning potential, instilling a measure of loyalty to the organization. It also provides a more flexible workforce which can more easily adapt to changes in the future. This enables a high level of discipline regarding an individual's personal education and is the only way for employees to get the job and business related skills specific to a given organizational position, which is vital if that individual has the discretion (or responsibility) to modify existing work practices.

2.4.5 Empowered

The definition of empower, "to give official authority" [6, page 370] provides great insight to the confidence an organization has in not only it's workforce's technical capabilities, but also it's decision making ability. The more disciplined the organization, the less likely it is to revisit decisions made by its empowered employees. The more frequently this revisiting of decisions occurs, the less empowered the workforce feels and thus becomes. One key point is that the degree of authority given must be clearly understood. Decisions being made by employees who are not empowered are not true decisions and decisions not being made by those who have been empowered to make them cause confusion to the workforce and a resultant lack of confidence in the organization's ability to make decisions as a whole.

The level of empowerment given to employees increases their feelings of ownership in the results of their work products and "a sense of ownership leads to commitment" [5, page 182]. Klein [5] identifies autonomy, voice in decision making, creatorship, and gainsharing as proxies for ownership. Each of these proxies provides the organization an opportunity to prove its discipline regarding empowerment to its employees. Allowing employees' autonomy in the scheduling and determination of task specific engineering methods increases the personal responsibility the individual has in their work deliverable's quality and timeliness. Giving engineers a voice in decisions affecting their duties increases their ownership in the resultant outcomes of those decisions. Creatorship is the concept of having employees participate in the creation of the work environment and gainsharing is the compensating of employees for productivity improvements. These each provide additional incentives to the engineers and increase their confidence that the organization is looking out for their best interests. A high level of organizational discipline regarding empowerment increases employee motivation to perform at a high level of personal discipline, which will enable a more successful large system change to take place.

2.4.6 Governance (Governed)

Again, the definition provides great insight. Governance, authoritative direction and control [6], requires both the existence and organizational understanding of the source of the direction and control. The much used phrase who, what, when, why, and how has great bearing on this aspect of organizational discipline. Who is providing direction and control (and why them)? What is being directed and controlled (and why not others)? When are these actions occurring (and why then)? Why are they needed (and what would happen if they didn't exist)? How are they being communicated (and what tracking mechanisms and control actions are in place)? If any of these are missing, effective governance cannot occur.

Governance is needed to ensure, as Klein puts it "Employee discretion over work methods... must fall within the boundaries of standardized work methods" [5, page 187].

Regardless of the culture of the organization, the governance element of organizational discipline provides the structure for compliance to the corporation's policies, with associated consequences for deviations to them. An organization without strong governance is like specifying a requirement without verifying that it has been implemented (or telling a child to clean their room without showing them what "to clean a room" means and not checking on the results), you get what you get and you won't know what that is until it is too late to change what you got. Large system change cannot be left to chance. Strong governance is required to steer the ship and provide course corrections as necessary.

2.5 Was Dr. Spock really talking about organizational discipline?

In his many works, Dr. Benjamin Spock provided trusted guidance to America's parents. Many of the concepts he discussed related to the inherent disciplines being discussed. One can think of the organization as being the parent and the employee in the role of the child. Much of the advice he gives to parents can be used as good (with a little modification to the context) behaviors for an organization that has strong organizational discipline.

In one of his later works, Dr. Spock on Parenting [8], Spock relates discipline to what he calls "child management". This discipline is in the sense of the "to train or develop by instruction and exercise" definition [6, page 322]. In this child management, he saw 3 pairs of opposites that had a great effect on the child's behavior: Lenient vs. Strict; Authoritarian vs. Democratic; Imposed vs. Inner Discipline. In the case of Lenient vs. Strict, domineering parents use fear to get the desired behavior out of their children. They believe that is more effective (or perhaps easier) than "the power of love, of the wish to imitate, to achieve, to please, to take responsibility, to grow up" [8, page 135]. Submissive parents always give in because they are the ones afraid; Afraid that their children will resent or not love them. The outcome of this is that the children are not taught how to respect others and often do not respect themselves.

The authoritarian manner of parenting is often characterized as the parent being mistrustful of the child. The basic assumption of an authoritarian is that children are naturally bad and are in need of constant supervision (and correction). Democratic parenting allows the child to be involved with the decision making process, but must provide firm guidance. Parents who do not provide firm leadership and let their children make decisions that they are incapable of (or too immature to) will find themselves with offspring who are "obnoxious tyrants" [8, page 139].

The last pair of opposites comes down to a manner of trust regarding the child. Imposed discipline provides the child with few, if any, options in what and how tasks are accomplished. The parent provides leadership by dictating the actions to be taken and the manner in which the actions should be performed. Inner discipline is a result of a gradual process of increased trust by the parent in the decision making capability of the child. The increasing levels of responsibility given to the child foster the growth of self-trust and initiative in the child.

By replacing the role of the parent with the role of the manager and the role of the child with the role of the employee, one can see that perhaps Dr. Spock was really a managerial behaviors expert as well as a child rearing expert. In fact, he also saw the relationship when he wrote "At the office or shop, the manager who is not satisfied with the way a new worker is doing his job doesn't rush in and give him a swat on the behind. He or she explains what change in performance is needed – more than once, if necessary. Ideally, the same should be true of the way we handle our children" [8, page 149]. In fact one can look at how the treatment of workers and the treatment of children have evolved over the ages and see similarities. Prior to unions, workers were indiscriminately mistreated and abused. Prior to social service agencies, children were indiscriminately mistreated and abused. The number of management theories (and books) and the cyclic nature in which today's genius and innovation becomes tomorrow's quack and overused faddish cliché, only to resurface in another form in 20-30 years parallels that of the parenting (and educational) theories.

When looking at the inherent disciplines outlined previously, one can see that strong organizational discipline is an enabler for strong personal discipline to be exhibited in the workplace and a successful employee, just as strong parental discipline leads to strong inner discipline in a child and success in later life. Employees should be assumed to be well intentioned and self motivated. Organizational processes should treat employees with respect, and like a good parenting team, the management team should treat each other with respect and support one another. Inexperience should be met with training, supervision and strong guidance. Looking again at the traits of the inherent disciplines, several analogies to parenting can be made. Through the organizational discipline that empowers employees, their decision making skills will develop, just like those in a child that is treated with respect in a more democratic environment. Consistent and aligned management direction reduces confusion, just like parents being supportive and not contradicting each other's directions. Providing training and encouraging learning shows trust in the ability of the employee to progress, just like taking an active role in a child's education. Providing firm governance needs to give clear directions and guidance without seeming submissive or overbearingly authoritarian, just like parenting needs to make sure that a child understands their boundaries. These direct ties give an indication why indeed these disciplines are inherent and required for any large system change.

3 Business Value of Discipline – Two success stories

One question that needs to be raised is one of value. What is the business value of discipline? Anecdotally, the case for discipline is often made by evoking the phrase "having everyone on the same page", but what does this mean? Striving towards the same goals. Valuing the same things. Creating confidence in decisions made. Being able to predict the outcomes of planned actions. All of these speak to indications that the organization is performing at a high level. As with many things, the effects of types of discipline discussed are hard to specifically quantify.

Because of this, two different analyses will be discussed in order to justify the business value of the disciplines outlined above. Each looks at the relation discipline has with an existing study of business success in the context of a large scale change. The first is an analysis of organizational progress over time. It uses the book Good to great: why some companies make the leap ... and others don't [9] as the basis of analysis. The second is an analysis of manufacturing capability progress. It uses the Toyota production system as the basis of the analysis. The concepts of discipline discussed above are evident and an integral part of the successes described in the scenarios presented. Because of this, any lack of discipline would have a detrimental effect on the successes and thus provide evidence of the business value of the disciplines outlined above.

3.1 Organizational Progress – Transitioning to greatness

This analysis makes the case of the value of exhibiting the inherent disciplines by looking at an organization's evolution (and hopefully progress) towards greater success over time. The concepts of inherent discipline presented above have many similarities to the case made by Collins [9] regarding what are the characteristics inherent in companies as they evolve from good to great companies. In his study of over 1400 companies, 11 of which were deemed as having evolved from good to great, Collins found that this evolution occurs in two stages: the buildup and the breakthrough. In describing the transition from good to great, Collins created a framework of concepts whose foundation consisted of three arenas of discipline: Disciplined People, Disciplined Thought, and Disciplined Actions. The analysis in this section will contain a discussion of the framework that Collins created and provide comparisons on his arenas of discipline and the inherent disciplines described above. These comparisons are given to provide insight that, while they may be renamed and presented in a different manner, the inherent disciplines are present for the large system change of transitioning a company from good to great according to Collins' framework. A brief description of the framework created by Collins will be given next, followed by a comparison of Collins' identified elements of discipline and the elements of inherent discipline.

The figure below is a diagram used by Collins to provide a visual overview of the path from a good company to a great one.

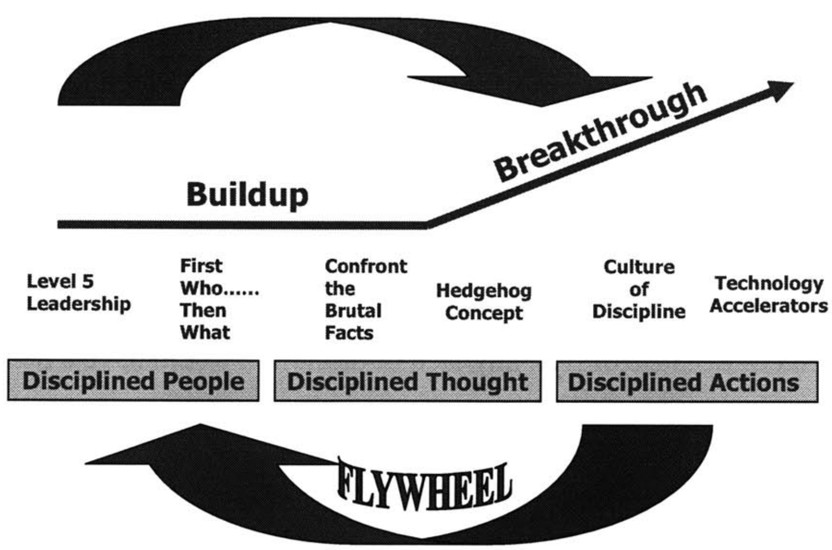

Figure 3-1 Good to Great [9, page 12]

The buildup, or creating the foundation needed for greatness to occur, requires the right leadership, the right people, and the right frame of mind (or as the warden said to Cool Hand Luke "get your mind right"). As depicted above, the arena of disciplined people includes two aspects, leadership and who the people should be. Leadership can be looked upon as an enabler for the transition to greatness. Attributes of the leadership needed included personal humility, professional will, the willingness to create a foundation which would enable their successors to achieve greater success and personal responsibility. This type of leadership is described by "leaders look out the window to attribute success to factors other than themselves. When things go poorly, however, they look in the mirror and blame themselves, taking full responsibility" [9, page 39]. The right people not only entail having the right individuals but also putting those people in the right place.

The last part of the buildup, confront the brutal facts, is gaining the realization of the true realities of the organizations situation, good or bad, and having confidence that the organization can overcome any of the roadblocks that stand in the way of greatness. Once this foundation is in place, the breakthrough towards greatness can begin. Again, Collins states that disciplined thought is needed, in this case, the hedgehog concept. This concept is simply the understanding of what the organization's core business is and what it should be. A disciplined culture provides the environment where the right people can perform up to their capabilities. One can see where this environment would have to be quite different if the wrong people were in the organization. With the right people, the culture can be one that enables greatness, with the wrong people; it has to be one that enforces policies. The last piece of Collins' puzzle it the appropriate use of technology to accelerate the organization's growth. This is not technology for technology sake, or as he puts it "never use technology as the primary means of igniting a transformation...they are the pioneers in the application of carefully selected technologies" [9, Page 13]. The flywheel concept completes the discussion on this evolution to greatness. This is simply a metaphor for the building up and sustaining of momentum. This is the meeting of *success breeds success* and *Rome was not built in a day*. In an organization's evolution to greatness, there was no single event or silver bullet that made it turn the corner, just a considerable amount of disciplined people, thought, and actions.

The next few sections will discuss the correlation to the "Good to Great" framework and the inherent disciplines outlined earlier. The discussion's organization is aligned with Collins' framework of three successive arenas of discipline with correlations to the inherent disciplines provided to each of these arenas: disciplined people, disciplined thought, and disciplined action.

3.1.1 Disciplined People

3.1.1.1 Leadership

In the discussion of leadership, Collins described 5 levels of leadership and stated the "Every good-to-great company had Level 5 leadership during the pivotal transition years" [9, page 39]. These leadership levels are diagrammed in the figure below. With this in mind, an analysis of how our inherent disciplines relates to the Level 5 leader is warranted. The most obvious correlation is to our Personal Discipline concept. The Level 5 leader must have a strong awareness and be a role model for all the personal discipline traits described earlier.

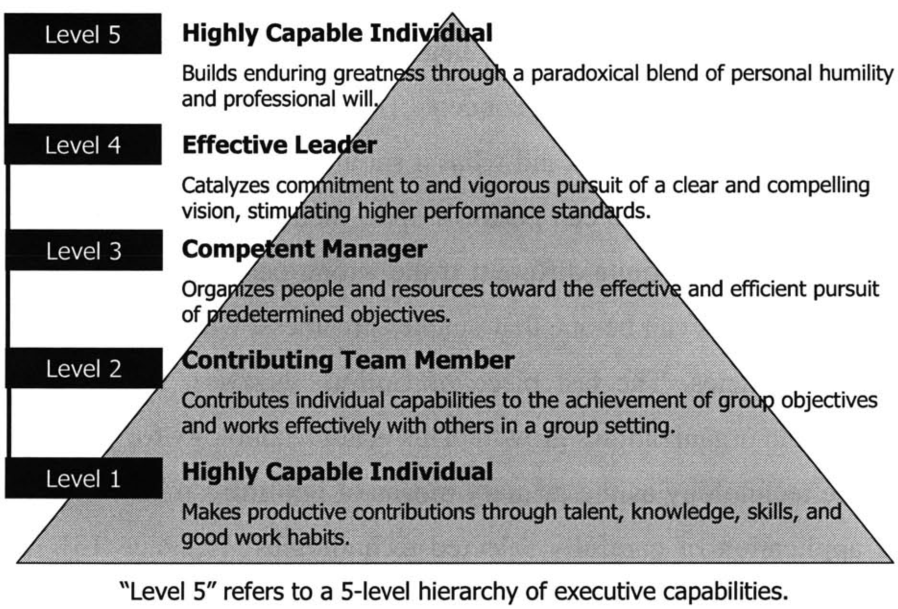

Figure 3-2 Leadership Levels [9, page 20]

One of the distinguishing differences between a Level 5 and Level 4 leader is the commitment they have to the organization. While both are driven to succeed personally, only the Level 5 shows the commitment to the company to ensure that their successor will also succeed. To enlist the right people, the leadership must display ethical, honest and consistent behavior. To successfully employ the right technology accelerators, the leaders must constantly update their education. The leader's ability to communicate effectively will enable the company to confront the brutal facts and provide the lubrication necessary to keep the flywheel's momentum running smoothly. Thus a Level 5 leader exhibits an extremely high level of personal discipline.

The leadership team must exhibit high levels of organizational discipline. One prime example of this is instilling and enabling the culture of discipline. Excessive controls and obtrusive bureaucracy with unnecessary levels of hierarchy will reduce the organization's effectiveness. The direction and authority given to the employees will determine this culture of discipline. Rewards should be given those whose actions are in line with the company's hedgehog concept.

The leadership must also drive for process discipline. Without a defined process giving adequate metrics, the ability to compile the brutal facts, let alone react to them will be severely hampered. The review of process metrics also plays a vital role in providing the data needed to keep the flywheel spinning.

3.1.1.2 The Right People

As with the leadership, the Collins concept of the right people is highly correlated to personal discipline. The right people will have the attributes described by this inherent discipline. The lack of any of these will turn the right person into the wrong person. Collins highlights a strong interaction between personal discipline and organizational discipline (rewarded) regarding the right people when he states "The purpose of a compensation system should not be to get the right behaviors from the wrong people, but to get the right people on the bus in the first place, and to keep them there" [9, page 50].

Another aspect of organizational discipline touched on regarding the right people is one of consistent and aligned behavior. It is suggested that "A company should limit its growth based on its ability to attract enough of the right people" [9, page 63]. This sounds like some type of corporate heresy, to deliberately reduce the growth of a company because it cannot find an appropriate match. Why not just hire the best available and train that person the needed skills? Well, what this seems to suggest is that personal discipline forms a behavior baseline which enables the company to have confidence that the individual will be able to progress as the company progresses. It also suggests that organizational discipline must be in place to ensure the acquisition and retention of the right people.

3.1.2 Disciplined Thought

The two elements of Collins' disciplined thought come together to begin the ascension of the company towards greatness. The realization of the true realities of the organization's situation (confront the brutal facts) is the initial step. There must be process discipline exhibited to come to this realization. How will this information be collected and who will compile and distribute the information (process discipline - defined)? Who will interpret the information and how will conclusions / decisions be reached (process discipline - reviewed)? Over what time frame will this realization take place (process discipline - updated)?

Because the facts may indeed be "brutal", there must be *personal discipline* in place. The effort must be done in as *ethical* a manner as possible in order not to influence the information, and thus the results, in any particular way. The effort in the collection and presentation of information should be of *consistent* detail and done *honestly* to enable confidence in the subsequent steps taken with the data. The organization must be disciplined enough to instill confidence that the facts will indeed be used in the right fashion to make the right decisions (organizational discipline - consistent and aligned) and that the individuals compiling and presenting the facts are submitted to the "killing the messenger" syndrome, (organizational discipline - rewarded). The response to the facts is the critical element that begins the ascent to greatness, the controls put in place to direct this ascension (organizational discipline - governance) will give the management team the dials necessary to make any future adjustments. Collins describes these last two points as "Conduct autopsies, without blame" and "Build red flag mechanisms that turn information into information that cannot be ignored" [9, page 88].

The second portion of Collins' arena of disciplined thought is the focus on the organization's core business, the hedgehog concept. This focus needs to be determined by: what is the organization capable of being the best at, what can the organization be passionate about, and what are the measures that are the key determinate on how the organization business plan should be driven. This again requires extreme organizational discipline to keep the focus sharp and ensuring that all activities of the company support the core business (consistent and aligned). There needs to be process discipline regarding the development of the key economic drivers and the consistent monitoring of them (defined, documented, measured, and reviewed). Another key process discipline aspect of this disciplined thought is the understanding that this is indeed and iterative process (updated). In fact, Collins had an unexpected finding that "It took four years on average for the good-to-great companies to get a Hedgehog Concept" [9, page 119].

3.1.3 Disciplined Action

Collins' final arena of discipline needed for a company's breakthrough to greatness is that of disciplined action. At this point in the change process as described by Collins, things are in place and a focus exists; now all that remains is the execution.

3.1.3.1 Culture of Discipline

For this execution to take place, Collins believes that a culture of discipline must be in place. This enables the right people to do the right thing without undue bureaucracy, but also requires the people to act in an appropriate (i.e. disciplined) manner. Collins describes it in this way, " A culture of discipline is ... about getting disciplined *people* who engage in disciplined *thought* and who *then* take disciplined action." [9, page 142]. This aligns very well with the inherent disciplines of personal and process discipline. In this culture of discipline, one of the most important facets is what Collins calls the *fanatical adherence* to the focus of the hedgehog concept. This requires the organization to not spend time or resources on things not core to the business. This adherence is a type of *organizational discipline* that *consistently* keeps tasks *aligned* with the organizational goals and objectives. The employees must be *trained* in order to understand the rationale and the nuances of the adherence and should be *rewarded* accordingly.

3.1.3.2 Technology Accelerators

The last segment in Collins' path of organizational progress is how organizations should react to and use technology in their road to greatness. This is an *organizational discipline* that requires *alignment* of the use of new and existing technology to accelerate the change. With a focus on the hedgehog concept for the organization, "good-to-great organizations avoid technology fads and bandwagons, yet they become pioneers in the application of *carefully selected* technologies" [9, page 162]. This alignment of the application of technology enables the implementation the organization's processes and must be used effectively by the employees to complete their duties.

3.1.4 Momentum

The metaphor of a flywheel is used by Collins to stress the need for the continual application of these disciplines to drive organizational progress. The flywheel represents the effort to keep pressure on the organization to move in a "consistent direction" [9, page 166]. This is an example of the *organizational discipline* that is needed to sustain the momentum on the large system change initiative. *Consistent* direction that is *aligned* with the organization's goals that have effective *governance* in place will keep the flywheel spinning. Collins sums it up this way, "the good-to-great companies did get incredible commitment and alignment – they artfully managed change". [9, page 176].

One can see how the inherent disciplines identified earlier play an integral part in the organizational progress concepts outlined in Good to great: why some companies make the leap … and others don't [9]. These concepts have been identified as key attributes of great companies which have distinguished themselves from their good competitors. If one believes in the distinctions made by Collins regarding the good from the great, then one must give credence to the supposition that indeed there are inherent disciplines required for a company to become great, and thus create the business value that the inherent disciplines have regarding the progress of an organization. The table below shows the relationships between the inherent disciplines and those described in Good to great: why some companies make the leap … and others don't [9].

	Correlations Legend: H - High M - Medium L - Low		Inherent Disciplines		
			Process	Personal	Organizational
Good to Great	Disciplined People	Leadership	L	H	M
		Right People	L	H	M
	Disciplined Thought	Brutal Facts	H	M	M
		Hedgehog Concept	H	L	H
	Disciplined Actions	Culture of Discipline	L	M	H
		Technology Accelerators	L	L	H

Correlations Matrix - Inherent to Good to Great disciplines

Figure 3-3 Correlations Matrix

The high degree of correlation of the required arenas of discipline called out by Collins to the inherent disciplines show how integral these inherent disciplines are to the large system change of transitioning a good company to greatness. Because of this, a case can be made for the high value these disciplines have for a company to follow (if there wish is to progress to being great).

3.2 Manufacturing Progress – Transition to Lean Principles

In many of the instances already discussed, one can see that the outcome of poor discipline is variability. Poor process discipline will cause variations in the usage of the process throughout the organization. Poor personal discipline will cause variations in the quality of the individual's deliverables. Poor organizational discipline will cause variations in the objectives and goals across the organization. When one thinks of variation within an engineering organization, the manufacturing process immediately comes to mind. And when one thinks of successful large system change in the manufacturing process, the Toyota production system comes to mind. This section will look at some of the discipline concepts which are evident in the Toyota production system. Why? Just as we stipulated that one business value of discipline can be seen in the evolution of a company, another business value of discipline is the reduction of variation in the output of an engineering organization. This section will first discuss some of the factors of the Toyota production system which have been linked to its success, followed by an analysis of how the elements of inherent discipline are evident in these factors. The argument being that for a production facility to successfully change to a more "Toyota-like" facility, the inherent disciplines are required. And because they are required to enable such a successful change, they have a certain level (albeit hard to measure) business value to those organizations which exhibit them.

3.2.1 Success of the Lean Production System

There is universal acceptance of the success of the Toyota Production System. This success is measured not only in consumer acceptance of the product, but also in productivity and quality metrics. As well documented in the book, The machine that changed the world: the story of lean production [10], the Toyota Production System is an evolution of the Henry Ford mass production system. The Toyota Production System is the foundation upon which the concept of lean production is built. Despite popular belief that plant location is a leading indicator of performance, studies [11] have shown that the management philosophies (manufacturing and human resource) in the plant are the true indicator. Krafcik stated the thesis "that corporate culture has a strong influence on plant performance" [11, page 47]. He found as one company "has implemented more and more lean production management policies...altering its own corporate culture... it has experienced a remarkable coincident increase in productivity performance" [11, page 49].

Many of the particulars of these successful management philosophies have roots back to the inherent disciplines identified earlier. Span of worker control, worker responsibility for quality control, autonomous work teams, flexibility in worker assignments, and emphasis on continuous process and worker capability improvement are all lean production concepts whose success are directly correlated to the inherent disciplines. One interesting note is that Krafcik had similar findings to Collins regarding technology. High levels of automation on the production floor was not required for high productivity, but rather appropriate usage of automation by a skilled workforce with flexible processes led to high levels of productivity.

There are two features exhibited by lean manufacturing facilities [10, page 99]. The first deals with flexible responsibility and the second deals with measurable accountability. This flexible responsibility "transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car" [10, page 99]. There are many elements that enable this type of responsibility. The workers must have or acquire a diverse set of skills to allow them to be rotated into several different job duties. Workers must be able to operate in autonomous teams responsible for maintenance and quality control as well as production duties.

The measurable accountability "has in place a system for detecting defects that quickly traces every problem, once discovered, to its ultimate cause" [10, page 99]. The elements that enable this type of accountability include: providing information critical to identifying productivity and defect targets, an effective issue resolution process, and a workforce that feels comfortable enough in the workplace environment to solve problems instead of covering them up.

While studying the success of New United Motor Manufacturing (NUMMI), the joint venture of Toyota and GM, Wilms, et al. [12] found that the organizational culture acted as an enabler for the productivity gains seen at NUMMI. They "discovered that the company's transformation stemmed largely from its ability to create a new "third" culture, a hybrid of the best of its American and Japanese parentage" [12, page 100]. These and other similar findings identify the elements which enable the Toyota Production System to be so successful. There are two arenas of discipline that seem to exist in these studies. The first is one of disciplined action on the factory floor and the other is one of a disciplined attitude (or as Collins [9] called it, disciplined thought) that pervades the factory culture. The next few sections will discuss each of these arenas.

3.2.2 Discipline on the Lean Factory Floor

Krafcik identified a metric, "management index" [11, page 52] which could be used as a predictor to the performance of a plant as it transitioned to lean principles. This index consisted of four components: teamwork, visual control, unscheduled absenteeism, and percentage of floorspace dedicated to repair facilities. The more the workers acted as a team, the higher the teamwork, the more capable the workforce is as a whole. The personal discipline elements of commitment, honesty, consistency, and communication are needed for great teamwork to exist. The organization discipline elements that enable this sense of teamwork to exist include rewarding teamwork and aligning each worker's objectives to foster cooperation on the factory floor. This high level of teamwork enables the worker rotation that is a vital element of the TPS.

The visual control component serves as a measure of the span of control that each worker has in the factory. This is one indication of how flexible the workers are. A strong level of process discipline must be in place in order for this visual control to exist. The process steps must be understood by each worker that performs an interfacing action in order to achieve the desired effect. The workers must have personal discipline in order to keep educated on these interactions and the company must have the organizational discipline of empowerment which will give these workers the motivation to become the flexible workforce needed for the TPS to run efficiently. Another aspect regarding visibility identified by Womack; et al. [10] is that on the lean production floor each worker's contribution to the value of the car is visible. This result in a reduction in the number of indirect (overhead) workers and the increase of the number of tasks (including maintenance and quality control) expected of the line worker. The fact that extra space is eliminated in the TPS increases the worker visibility to other line workers, increasing communication and providing a on the job training ground regarding interfacing work steps. Unscheduled absenteeism can be directly tied to the personal disciple of acting in an ethical manner. Organizational reward systems must discourage unscheduled absenteeism in order to reduce the worker buffer needed in order to keep the plant running on any given day.

The last of Krafcik's component of the management index, percentage of floorspace dedicated to repair facilities, has a few inherent discipline tails associated with it. The process discipline must be such that continuous improvements are possible. This dictates the need to quickly being able to update existing processes in order to reduce the time that the line is stopped. Personal discipline is required in that the workers must be committed to not allowing defective parts to proceed down the line. For this commitment to exist, the organization must have discipline in empowering the workers to indeed stop the line and be consistent in their commitment to first pass quality instead of pushing to meet production targets regardless of any indicated quality issues. Training must be made available which supports the problem solving skills required in this environment of continuous improvement.

3.2.3 Discipline in the Lean Culture

The cultural transition that Wilms et al. [12] observed at NUMMI can be characterized as an evolution of confidence. The union workers gained confidence that the management would evolve to treating them "fairly and equitably" [12, page 105]. The management team gained confidence that the union would evolve to be cooperative and flexible. As this confidence grew, mutual trust was created. A sense of security was needed in the lean culture in order for the workers to feel valued. This security was codified (process disciple) in a no layoff policy, but this did not become part of the culture until the policy was tested and the company had the organizational discipline of acting consistent with the policy (in fact, they provided training to the idle workers in order to increase their value).

Fairness was another element of the evolution of the culture. One of the most evident indicators on the fairness of an environment is how problems are handled. In the lean culture, the management focus is on the problem, not the culprit. There is an underlying assumption that the workers are performing at their ability (assumption that the workers have a high level of personal disciple) and that the process or design must be improved to solve the problem. This assumption requires that a high level of process discipline as a baseline. Consistent organizational actions in the face of problems allowed NUMMI to make fairness a part of there cultural evolution. An example of one such consistent action described by Womack et al. was the Toyota practice of asking "the five why's" [10, page 79].

The reward system is a more tangible part of the lean culture. To increase worker flexibility, a reduction in job classifications is warranted. This results in a flat wage scale. Bonuses must benefit all workers equally. In order for this to be accepted, there must be organizational discipline in rewarding workers by, as Wilms et al. put it, "tying the company's success, and the success of the individual, to things they can control" [12, page 106].

Perhaps the largest "shock" to the organizational discipline in place at NUMMI initially was empowering each and every worker to stop the line. The culture of mass production prefers the line never stop. The TPS foundation on continuous improvement relies on the line being stopped in order to create the improvement opportunities. This empowerment needs to be supported by strong process discipline in accurately measuring the production process in sufficient detail to identify these improvement opportunities. The ability to stop the line puts a constant tension on the workers, the management, and the process. Wilms et al. found something that the previous discussion on Spock touched on in that "When a manager gives in to pressure, however, and turns authoritarian, he or she usually gets an angry response that distances team members and diminishes trust" [12, page 107].

Once this Lean Culture is in place, workers show, as Womack et al. puts it, "initiative and responsibility to continually improve the system" [10, page 103].

The Toyota Production System has at it's foundation a high level of discipline, thus proving the value of the inherent disciplines in the production world and as such, these inherent disciplines enable the large system change to a more lean manufacturing system. At NUMMI, Wilms et al. found that "though some team members complain about the system's demands for discipline, most agree that, under GM, discipline had become too lax" [12, page 109].

4 Case Study of an emerging large system change

This section will investigate an emerging large system change, feature ownership, and how the inherent disciplines relate to it. This large system change is a change initiative presently occurring in a product development organization whose mission is to deliver world class electrical systems to land vehicles. This organization provides design and release engineering for several electrical and electronic components within the vehicle's electrical system, delivers the electrical harnesses to the vehicle program, and performs integration of the electrical system into the vehicle. It does not produce (i.e. have any manufacturing plants) any components and does not write any of the software which resides in the vehicle. For purposes of simplicity, this organization shall be referred to as Electrical Systems Integration (ESI) throughout the rest of this paper.

The study will begin with background on feature ownership, describing topics such as its scope, system elements and functional organization, an example from a sample system (power liftgate system) and the development organizational structure. This will be followed by a discussion of the inherent discipline elements required for this large system change to take place.

4.1 Feature Ownership

Feature – a prominent part or characteristic; something offered to the public or advertised as particularly attractive [4, page 426]

Ownership – the state, relation, or fact of having power over (control) [4, page 831]

The advent of networked vehicles with distributed feature control and systems modeling has put new emphasis on "who owns what" with respect to defining, developing, implementing, and verifying electrical features for vehicle programs. This is the genesis of the feature owner concept.

The term ***feature owner*** has different interpretations, depending on the organizational perspective of the observer. Why "feature"? Feature is the term used within ESI when listing software implemented control functions. Why "owner"? Owner is the individual who will own and resolve any related issues as the program travels along the systems engineering "V". The vehicle program team perspective links the feature owner to one who delivers that feature to the program. The cross vehicle perspective links the feature owner to one who is the Subject Matter Expert (SME) on the feature's specifics.

Why was this getting to be a problem? In the context of electro-mechanical systems, the development process complexity increases dramatically when embedded software is introduced. Many historically mechanical systems, like closures, were transitioning to electrically assisted operation and in some cases (e.g. a power liftgate) totally autonomous operation. Due to the nature of the transition and the expertise within the various organizations of the typical vehicle development company, many of the higher vehicle and system level requirements were left to the lower level (typically software) requirements author to define. This resulted in an inefficient development process that led to integration issues in the later phases of the program. Some of the problems encountered included:

- Inadequate interface definition
- Inadequate or undefined requirements and/or targets
- Inadequate verification and validation

Besides taking a vehicle level view of strategic functionality, there are several additional underlying concerns that ESI felt feature ownership would help. Having a single point of contact for feature definition would enable more formal governance and change control on the vehicle's operational characteristics. It would also enable software process improvements, more consistent interfaces across suppliers and programs, requirement traceability throughout the various levels of system hierarchy, and support an evolving model based systems engineering capability. At the electrical system level, goals of the feature ownership initiative included complete roles and responsibility coverage throughout the product development community, complete requirement and interface definition, paired with associated integration and verification testing. At the lower subsystem level, the goals included development of a complete specification suite with reusable requirement and design verification elements.

ESI identified several principles regarding the feature ownership initiative. The focus is on feature operation, basically information flow and control flow. Due to how the organization is structured and vehicle programs are managed, three roles were identified in the implementation of a feature: Feature Owner, Feature Integrator, and Feature Application engineer. The feature owner defines and controls the end to end operational characteristics of the feature. The feature integrator owns resultant interactions due to feature partitioning decisions. The feature application engineer owns the implementation of the feature on the vehicle program. In ESI job position terms, the feature owner is a core engineering function, the feature integrator is an EE systems engineering function, and the feature application engineer performs the design and release function. The following figure depicts the interaction between the single instance (cross vehicle role) of the feature owner and the multiple instances (program specific role) of the feature integration and application engineers. The knowledge base provides the reusable assets desired and the past program implementations (along with their associated lessons learned) provide feedback to the feature owner to enable continuous improvement on the various elements of feature ownership. The figure also provides a list of engineering deliverables required by each role as defined in ESI's development process.

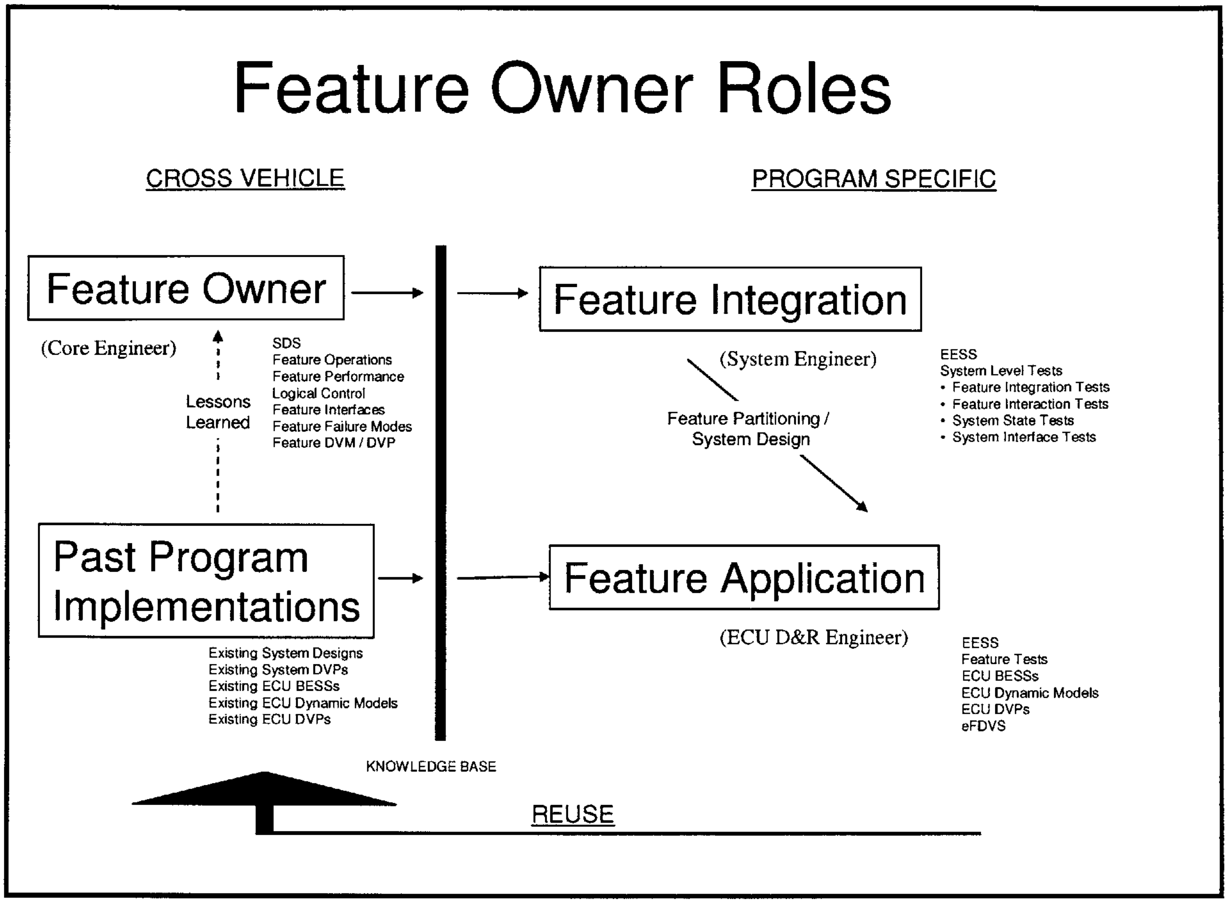

Figure 4-1 Feature Owner Lifecycle

4.1.1 Feature Owner System Scope

As a result, the feature ownership concept has to include all systems that have a role in the feature's functionality. The system that this paper examines is really a functional system that is overlaid upon a physical system. This is very analogous to Hatley's [13] Requirements Model being implemented on his Architecture Model. In fact, the existing functional requirements development methodology and notation used throughout ESI was derived from the work of Hatley and Pirbhai [13]. The focus of this effort is the vehicle functionality whose operation and/or logical control are typically implemented in software. Why select this focus? This is because of the tremendous amount of information coordination which must occur to ensure flawless execution of such a feature. Simple truth tables given to a component designer are no longer enough when allocating logical control across a distributed architecture, being implemented with components designed by different suppliers whose contracts (and contacts) are with different organizations within the typical vehicle development company.

Another aspect of the system under consideration is that the focus will be on vehicle functionality that the typical customer is aware of and places some value in. Cross organizational functions which, albeit complex, do not come into direct contact with the customer are a subset of the system under consideration herein. This customer interface creates complexities not seen with hidden functions. Esthetics, ease of understanding feature operation, and ergonomic factors are examples of additional design considerations when a system's inputs or outputs interact with the end customer.

A simple view of this type of system can be seen in the figure below. This depicts the power windows function from the customer's perspective.

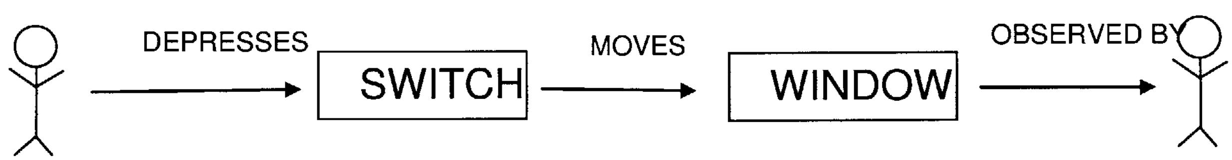

Figure 4-2 Simple Power Window Function

The actual implementation of such a system is somewhat more complex. Not only are there more components involved than just a switch and a piece of glass, there are also two organizations (Electrical Engineering and Body Engineering) within the typical vehicle development company which must interact appropriately to ensure proper operation. In the figure below, a more detailed view of the power window system is shown (from the electrical perspective).

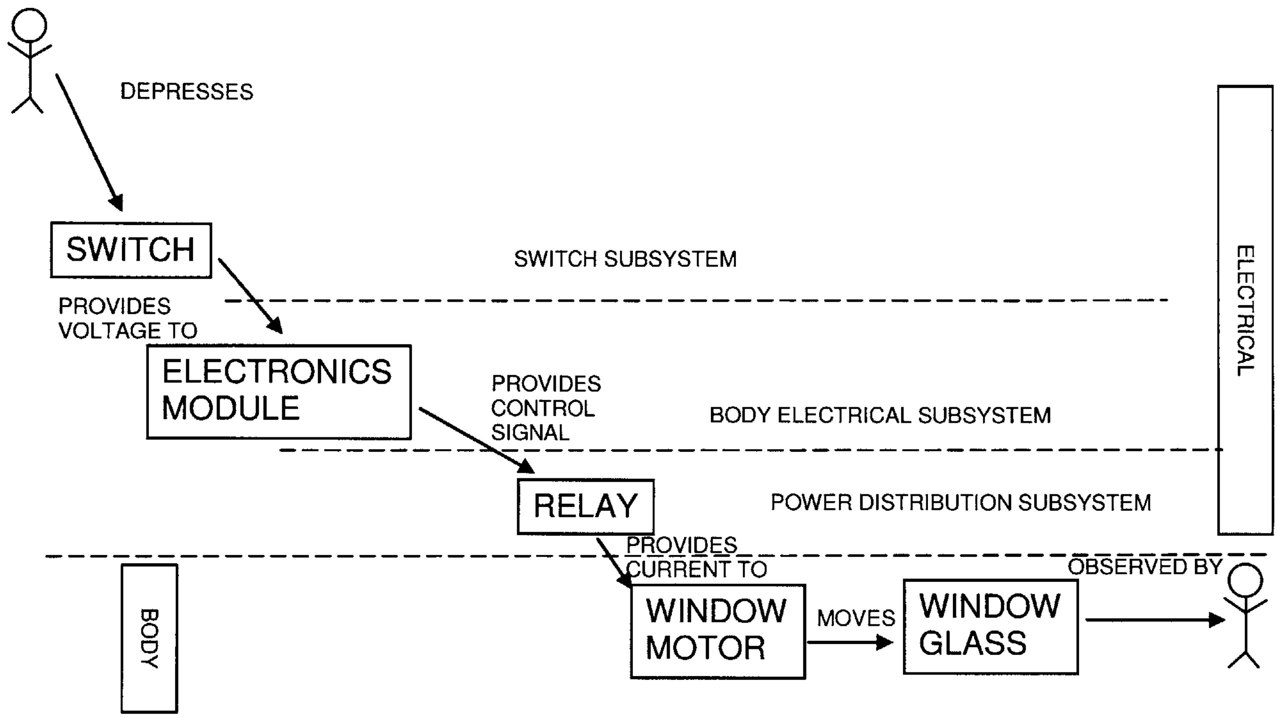

Figure 4-3 Detailed Power Window Function

4.1.2 Generic Feature operation system elements

Generically, many features can be implemented with the following system elements: customer input (switch), customer output (actuator), state indicator (sensor), processing unit (module), and communication media (network). Each of these elements contributes several functions to the overall operation of a given feature. The question is how to create a process that defines then allocates functional requirements to various system elements? After that allocation, what interactions must be taken into account to ensure the feature at the vehicle level meets the customer's (and company's) expectations?

The feature as a whole also can be decomposed into several functions which need to be considered. From a hierarchal perspective, one can think of the feature operational requirements at a vehicle level, implemented at a component level with these generic elements. Each of these elements contributes certain feature operational design parameters necessary to implement the desired feature. Some of these design parameters (functions) are the result of the feature's requirements, while others are the result of the chosen implementation's physical embodiment (e.g. If a networked design is used, each component on the network has an additional functional requirement to communicate on the network).

The following table itemizes the functions required by each of the generic system elements and the feature at the vehicle level to successfully implement a feature with an embedded controller. The overall feature operation (can be thought of as the vehicle level feature system) is called out as a system element. This is done for two reasons. The first is that this is the object that the customer actually purchases. The issue under consideration is the development of the feature as a whole and while one could argue that the system is comprised of the various parts, the value (and the development issues) arises in the development of the feature requirement, not the component requirements. Each of the other system elements shown are themselves systems where the delineation of the feature from these elements is justified by the fact that each one of the common functions listed below can indeed be different and still have an acceptable feature implementation (i.e. Power Moding, the feature may only be active in run, but the switch may be active during accessory, run and start).

The second reason stems from the principles in creating requirements from the Hatley-Pirbhai [13] method. The functional model is first created. This model forms the basis of the feature requirements. The input / output processes are added when the template is overlaid on the functional model. When the architecture is created and these features are allocated (super-bubbled) to the components shown on the architecture model, a new template must be overlaid on each component's allocated portion of the feature. This will define new I/O and must then be integrated with the other functional requirements of that component. This integration can augment or modify the allocated requirements. This is one type of interaction needed between the component system elements and the feature operation itself.

Getting back to the table, the first column shows the breakdown of the system into elements. The second column shows the breakdown of that element's functions that affect the feature's operation. These will be used as the tasks needed to be performed in the development process. Please note that this is a very feature centric view. This view is taken because that is where the issue lies. There are owners of each component, but who / how is the feature owned is the issue at hand. The last column just provides descriptions of functions where needed.

SYSTEM ELEMENT	FUNCTION	DESCRIPTION
FEATURE OPERATION	POWER MODING	Ignition states and wake/sleep
	OPERATIONAL DELAY	From input to output
	OPERATIONAL LOGIC	Customer Perceived, Manual vs. Auto, lockouts
	MOTION STRATEGY	How fast, smooth, etc.
	CUSTOMER INTERFACE	How many, where, feedback, location
	INTRA-FEATURE COORDINATION	Interactions with other features
SWITCH	ILLUMINATION	What, when and how much
	FEEL	Force, tactile feedback
	STYLING	
	LOGIC	
	CURRENT MODE	High current vs. Low current
	LOCATION	
	COMMAND CONTENTION	Multiple requests at the same time
	POWER MODING	
	FAILURE MGMT	
	DELAY	Event to output
SENSOR	POWER MODING	
	ACCURACY	
	SPEED	Change in input to change in output
	OUTPUT INFORMATION	Physics to enumeration
	FAILURE MGMT	How it fails, what it means
	CONTROL LOGIC	May be in HW or SW
	DELAY	Event to output
ACTUATOR	POWER MODING	
	SPEED	
	SMOOTHNESS	
	FAILURE MGMT	
	INPUT INFORMATION	Enumeration to Physics
	TOLERANCE	Output vs. Input variance
	FEEDBACK	May be viewed as a sensor
	CONTROL LOGIC	May be in HW or SW
	DELAY	
MODULE	POWER MODING	
	INPUT PROCESSING	Filtering, contentions, failure mgmt
	OUTPUT PROCESSING	Failure mgmt, arbitration
	FAILURE MGMT	States go to outputs when module failed
	ECM BASED CONTROL LOGIC	May be in HW or SW
	INTRA-FEATURE COORDINATION	Interactions with other features
	INTER-FEATURE COORDINATION	Feature fail mgmt, mode/states of feature, logic conflicts
	DELAY	Input to Output
NETWORK	DELAY	Queueing, Contention, Transport time
	FAILURE MGMT	
	INFORMATION CONTENT	
	SPEED	Periodic

Figure 4-4 Generic System Functional Elements

In the table above, each function is with respect to that system element's contribution to the feature operation. In other words, the delay of the network is the feature delays attributable to the network, while the delay of the module is the feature delays attributable to the module.

4.1.3 Generic Feature Operation DSM

To model the process of developing a feature, a Design Structure Matrix (DSM) was used. DSMs are used to model and analyze the information flow of the product development effort [1]. The tasks (the function column of the preceding table) needed to complete a project are listed as both rows and columns (in the same order). Then the body of the matrix is filled in by consideration of a row at a time. An X is placed in the matrix if that row's task needs information from that column. The DSM shows design iterations and can be optimized to improve information flow. Rearrangement of tasks on the matrix can lead to reduction of information exchange, which is usually accomplished by changes in task organization (and perhaps changes in the company's organization). The rearrangement of tasks can be done via several mathematical algorithms and essential strive to eliminate X's above the matrix's diagonal.

Once the tasks have been sufficiently reordered, the resultant matrix is visually inspected to group tasks that are coupled. These couplings often lead to changes in the development approach to reduce information exchanges.

When one uses these system elements, identified above, to create a generic feature, one resultant DSM looks like the following figure. Keep in mind, this shows a generic system with one system element each (which in practice would never probably happen as you would want two modules before creating an architecture with a network). The initial entries of this DSM are shown in black, subsequent additions from experts within ESI are shown in red.

			FEATURE						SWITCH										SENSOR							ACTUATOR									MODULE								NETWORK			
			POWER MODING	OPERATIONAL DELAY	OPERATIONAL LOGIC	MOTION STRATEGY	CUSTOMER INTERFACE	INTRA-FEATURE COORDINAT	ILLUMINATION	FEEL	STYLING	LOGIC	CURRENT MODE	LOCATION	COMMAND CONTENTION	POWER MODING	FAILURE MGMT	DELAY	POWER MODING	ACCURACY	SPEED	OUTPUT INFORMATION	FAILURE MGMT	CONTROL LOGIC	DELAY	POWER MODING	SPEED	SMOOTHNESS	FAILURE MGMT	INPUT INFORMATION	TOLERANCE	FEEDBACK	CONTROL LOGIC	DELAY	POWER MODING	INPUT PROCESSING	OUTPUT PROCESSING	FAILURE MGMT	ECM BASED CONTROL LOGIC	INTRA-FEATURE COORDINAT	INTER-FEATURE COORDINAT	DELAY	DELAY	FAILURE MGMT	INFORMATION CONTENT	SPEED
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	II	JJ	KK	MM	NN	OO	PP	QQ	RR	SS
FEATURE	POWER MODING	A			X			X								X			X							X									X											
	OPERATIONAL DELAY	B	X															X							X									X								X	X			X
	OPERATIONAL LOGIC	C	X					X				X			X		X					X	X	X	X				X	X		X	X			X	X	X	X		X			X	X	
	MOTION STRATEGY	D			X															X	X	X					X	X			X		X													
	CUSTOMER INTERFACE	E		X	X	X			X	X	X	X		X				X						X	X						X										X	X	X	X			
	INTRA-FEATURE COORDINATION	F	X		X		X								X																										X						X
SWITCH	ILLUMINATION	G	X				X									X																														
	FEEL	H					X					X		X																																
	STYLING	I					X			X				X																																
	LOGIC	J					X				X					X																														
	CURRENT MODE	K										X																											X							
	LOCATION	L					X				X																																			
	COMMAND CONTENTION	M					X					X																																		
	POWER MODING	N	X		X																																									
	FAILURE MGMT	O	X		X		X	X				X				X																														
	DELAY	P										X																																		
SENSOR	POWER MODING	Q	X		X																	X																								
	ACCURACY	R			X																X	X																								
	SPEED	S			X	X														X				X																						
	OUTPUT INFORMATION	T			X	X														X	X			X																						
	FAILURE MGMT	U	X		X			X											X					X																						
	CONTROL LOGIC	V			X	X													X				X																							
	DELAY	W		X	X															X	X	X	X	X																						
ACTUATOR	POWER MODING	X	X			X																					X						X													
	SPEED	Y				X																						X		X			X													
	SMOOTHNESS	Z				X																								X	X		X	X												
	FAILURE MGMT	AA																												X	X	X	X													
	INPUT INFORMATION	BB																									X	X	X		X	X	X					X								
	TOLERANCE	CC																									X	X		X		X	X													
	FEEDBACK	DD				X																					X	X	X	X	X		X	X								X				
	CONTROL LOGIC	EE			X																						X	X	X	X	X	X		X												
	DELAY	FF		X																							X			X		X	X													
MODULE	POWER MODING	GG	X			X										X			X							X										X	X		X	X	X					
	INPUT PROCESSING	HH					X	X				X	X		X	X	X	X	X	X	X	X	X	X	X							X			X				X	X	X		X	X	X	X
	OUTPUT PROCESSING	II				X		X	X																	X	X	X	X	X	X		X	X	X			X	X	X	X		X	X	X	X
	FAILURE MGMT	JJ						X									X						X					X	X		X	X	X		X	X	X		X	X	X			X	X	X
	ECM BASED CONTROL LOGIC	KK			X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X
	INTRA-FEATURE COORDINATION	MM					X	X									X	X							X										X	X	X	X	X		X		X	X	X	X
	INTER-FEATURE COORDINATION	NN				X	X	X							X		X	X			X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
	DELAY	OO		X								X	X			X		X	X		X			X	X	X	X	X		X		X				X	X		X	X	X				X	X
NETWORK	DELAY	PP	X	X																	X						X	X														X			X	X
	FAILURE MGMT	QQ	X		X	X																													X			X				X			X	X
	INFORMATION CONTENT	RR	X		X	X		X				X					X			X		X	X	X				X	X	X	X	X	X		X		X	X	X	X	X			X		X
	SPEED	SS						X													X						X	X		X		X	X				X		X	X	X	X	X	X	X	

Figure 4-5 Generic Feature DSM

Keep in mind that the tasks shown in the matrix is the actual definition / development of the specific functions needed to implement a vehicle level feature. The system elements are included to provide easier understanding of the matrix as a whole. This DSM is different from those typically done from the perspective of scope. Usually DSMs are used to show high level tasks, like casing design or wiring layout. With the scope of this paper being the tasks necessary to define a feature's operation that will ultimately reside in software, the tasks are at a much lower level. While this level may seem too low (too detailed), it is an appropriate level to fully model the different tasks actually needed for a vehicle level feature.

Upon examination of this generic DSM, one can combine the functions contained in one system element. This is what would be traditionally the starting point of a DSM, however the specifics are then hidden. This simplifies any organizational analysis done with the DSM, but caution must be used when doing this. The following enhanced DSM places shaded boxes around all the functions of a given system element. The expertise that the D&R engineer responsible for the component needs to include the items shaded for each element. This means that if an engineer is responsible for D&R of a smart window motor, they must be able to fully design and validate the logical control of that component as well as the electro-mechanical aspects of it (This is the type of information that is hidden if a traditional DSM would have been used initially in this study). This is a key point with regards to a typical vehicle development company's product development area. When electrical / electronic control is integrated into traditionally mechanical components, the skill set of the component D&R engineer must be expanded to include this. If this is not done and an electrical expert is expected to assist the D&R engineer the information exchange (as shown by the DSM) would be very high.

Further enhancements to the DSM are the annotation of the yellow and red portions. The yellow portion shows the interaction needed for implementing a network on a vehicle. This justifies the current ESI practice of creating a Network Program Action Team, PAT, to facilitate the design and testing of vehicle level communication. The red portion shows a need for vehicle level coordination. The enhanced DSM clearly depicts a coordination effort of an integrator needed to develop robust solutions for these cross functional features.

			FEATURE						SWITCH									
			POWER MODING	OPERATIONAL DELAY	OPERATIONAL LOGIC	MOTION STRATEGY	CUSTOMER INTERFACE	INTRA-FEATURE COORDINAT	ILLUMINATION	FEEL	STYLING	LOGIC	CURRENT MODE	LOCATION	COMMAND CONTENTION	POWER MODING	FAILURE MGMT	DELAY
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
FEATURE	POWER MODING	A			X			X								X		
	OPERATIONAL DELAY	B	X															X
	OPERATIONAL LOGIC	C	X					X				X			X		X	
	MOTION STRATEGY	D			X													
	CUSTOMER INTERFACE	E		X	X	X			X	X	X	X		X				X
	INTRA-FEATURE COORDINATION	F	X		X		X								X			
SWITCH	ILLUMINATION	G	X				X									X		
	FEEL	H					X					X		X				
	STYLING	I					X			X				X				
	LOGIC	J					X				X					X		
	CURRENT MODE	K										X						
	LOCATION	L					X				X							
	COMMAND CONTENTION	M					X					X						
	POWER MODING	N	X		X													
	FAILURE MGMT	O	X		X		X	X				X				X		
	DELAY	P										X						
SENSOR	POWER MODING	Q	X		X													
	ACCURACY	R			X													
	SPEED	S			X	X												
	OUTPUT INFORMATION	T			X	X												
	FAILURE MGMT	U	X		X			X										
	CONTROL LOGIC	V			X	X												
	DELAY	W		X	X													
ACTUATOR	POWER MODING	X	X			X												
	SPEED	Y				X												
	SMOOTHNESS	Z				X												
	FAILURE MGMT	AA																
	INPUT INFORMATION	BB																
	TOLERANCE	CC																
	FEEDBACK	DD				X												
	CONTROL LOGIC	EE			X													
	DELAY	FF		X														
MODULE	POWER MODING	GG	X			X										X		
	INPUT PROCESSING	HH					X	X				X	X		X	X	X	X
	OUTPUT PROCESSING	II				X		X	X									
	FAILURE MGMT	JJ						X									X	
	ECM BASED CONTROL LOGIC	KK			X	X	X	X	X			X	X		X	X	X	X
	INTRA-FEATURE COORDINATION	MM					X	X									X	X
	INTER-FEATURE COORDINATION	NN				X	X	X							X		X	X
	DELAY	OO		X								X	X			X		X
NETWORK	DELAY	PP	X	X														
	FAILURE MGMT	QQ	X		X	X												
	INFORMATION CONTENT	RR	X		X	X		X				X					X	
	SPEED	SS						X										

			SENSOR							ACTUATOR								
			POWER MODING	ACCURACY	SPEED	OUTPUT INFORMATION	FAILURE MGMT	CONTROL LOGIC	DELAY	POWER MODING	SPEED	SMOOTHNESS	FAILURE MGMT	INPUT INFORMATION	TOLERANCE	FEEDBACK	CONTROL LOGIC	DELAY
			Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF
FEATURE	POWER MODING	A	X							X								
	OPERATIONAL DELAY	B							X									X
	OPERATIONAL LOGIC	C				X	X	X	X				X	X		X	X	
	MOTION STRATEGY	D		X	X	X					X	X			X		X	
	CUSTOMER INTERFACE	E						X	X						X			
	INTRA-FEATURE COORDINATION	F																
SWITCH	ILLUMINATION	G																
	FEEL	H																
	STYLING	I																
	LOGIC	J																
	CURRENT MODE	K																
	LOCATION	L																
	COMMAND CONTENTION	M																
	POWER MODING	N																
	FAILURE MGMT	O																
	DELAY	P																
SENSOR	POWER MODING	Q				X												
	ACCURACY	R			X	X												
	SPEED	S		X				X										
	OUTPUT INFORMATION	T		X	X			X										
	FAILURE MGMT	U	X					X										
	CONTROL LOGIC	V	X				X											
	DELAY	W		X	X	X	X	X										
ACTUATOR	POWER MODING	X									X						X	
	SPEED	Y										X		X			X	
	SMOOTHNESS	Z												X	X		X	X
	FAILURE MGMT	AA												X	X	X	X	
	INPUT INFORMATION	BB									X	X	X		X	X	X	
	TOLERANCE	CC									X	X		X		X	X	
	FEEDBACK	DD									X	X	X	X	X		X	X
	CONTROL LOGIC	EE									X	X	X	X	X	X		X
	DELAY	FF									X			X		X	X	
MODULE	POWER MODING	GG	X							X								
	INPUT PROCESSING	HH	X	X	X	X	X	X	X							X		
	OUTPUT PROCESSING	II								X	X	X	X	X	X		X	X
	FAILURE MGMT	JJ					X					X	X		X	X	X	
	ECM BASED CONTROL LOGIC	KK	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	INTRA-FEATURE COORDINATION	MM							X									
	INTER-FEATURE COORDINATION	NN			X	X	X		X		X	X	X	X	X	X	X	X
	DELAY	OO	X		X			X	X	X	X	X		X		X		
NETWORK	DELAY	PP			X						X	X						
	FAILURE MGMT	QQ																
	INFORMATION CONTENT	RR		X		X	X	X				X	X	X	X	X	X	
	SPEED	SS			X						X	X		X		X	X	

			MODULE								NETWORK			
			POWER MODING	INPUT PROCESSING	OUTPUT PROCESSING	FAILURE MGMT	ECM BASED CONTROL LOGIC	INTRA-FEATURE COORDINAT	INTER-FEATURE COORDINAT	DELAY	DELAY	FAILURE MGMT	INFORMATION CONTENT	SPEED
			GG	HH	II	JJ	KK	MM	NN	OO	PP	QQ	RR	SS
FEATURE	POWER MODING	A	X											
	OPERATIONAL DELAY	B								X	X			X
	OPERATIONAL LOGIC	C		X	X	X	X		X			X	X	
	MOTION STRATEGY	D												
	CUSTOMER INTERFACE	E						X	X	X	X			
	INTRA-FEATURE COORDINATION	F						X						X
SWITCH	ILLUMINATION	G												
	FEEL	H												
	STYLING	I												
	LOGIC	J												
	CURRENT MODE	K					X							
	LOCATION	L												
	COMMAND CONTENTION	M												
	POWER MODING	N												
	FAILURE MGMT	O												
	DELAY	P												
SENSOR	POWER MODING	Q												
	ACCURACY	R												
	SPEED	S												
	OUTPUT INFORMATION	T												
	FAILURE MGMT	U												
	CONTROL LOGIC	V												
	DELAY	W												
ACTUATOR	POWER MODING	X												
	SPEED	Y												
	SMOOTHNESS	Z												
	FAILURE MGMT	AA												
	INPUT INFORMATION	BB				X								
	TOLERANCE	CC												
	FEEDBACK	DD								X				
	CONTROL LOGIC	EE												
	DELAY	FF												
MODULE	POWER MODING	GG		X	X		X	X	X					
	INPUT PROCESSING	HH	X				X	X	X		X	X	X	X
	OUTPUT PROCESSING	II	X			X	X	X	X		X	X	X	X
	FAILURE MGMT	JJ	X	X	X		X	X	X			X	X	X
	ECM BASED CONTROL LOGIC	KK	X	X	X	X		X	X		X	X	X	X
	INTRA-FEATURE COORDINATION	MM	X	X	X	X	X		X		X	X	X	X
	INTER-FEATURE COORDINATION	NN	X	X	X	X	X	X			X	X	X	X
	DELAY	OO		X	X		X	X	X				X	X
NETWORK	DELAY	PP								X			X	X
	FAILURE MGMT	QQ	X			X				X			X	X
	INFORMATION CONTENT	RR	X		X	X	X	X	X			X		X
	SPEED	SS			X		X	X	X	X	X	X	X	

Figure 4-6 Enhanced view of Generic Feature DSM

If such a feature integrator role was implemented (they would provide the coordination needed to eliminate the 3 remaining X's above the diagonal) and each one of the component D&R engineers had the necessary functional expertise, the generic feature DSM could be simplified to the following.

	FEATURE	SENSOR	ACTUATOR	SWITCH	MODULE	NETWORK
FEATURE	X	X	X	X	X	X
SENSOR	X	X				
ACTUATOR	X		X			
SWITCH	X			X		
MODULE	X	X	X	X	X	X
NETWORK	X	X	X	X	X	X

Figure 4-7 Simplified Generic Feature DSM

We will now examine an actual feature using the concepts developed thus far. The feature will be a power liftgate.

4.1.4 Power Liftgate Example

4.1.4.1 Power Liftgate Feature Description

Following is a brief description of the Power Liftgate Feature, similar to the source materials used in creating the operational manual for a vehicle. *The Power Liftgate Feature automatically opens and closes the liftgate upon operator request. The Power Liftgate Feature will begin opening the liftgate when the customer presses the key fob, front switch, rear switch, or unlatches the liftgate. This motion will only occur if the liftgate feature is not inhibited and the vehicle is stopped. The Power Liftgate Feature will also begin opening the liftgate if it is in the process of closing and it hits an obstacle or the customer reverses the motion by pressing one of the activation switches. This opening motion is stopped when the customer presses one of the activation switches, the liftgate hits an obstacle, or the liftgate becomes fully opened. Motion is suspended while the vehicle is starting.*

The Power Liftgate Feature will begin closing the liftgate when the customer presses the key fob, front switch, rear switch, or unlatches the liftgate. This motion will only occur if the liftgate feature is not inhibited and the vehicle is stopped. The Power Liftgate Feature will also begin closing the liftgate if it is in the process of opening and it hits an obstacle or the customer reverses the motion by pressing one of the activation switches. This closing motion is stopped when the customer presses one of the activation switches, the liftgate hits an obstacle, or the liftgate becomes fully closed. Motion is suspended while the vehicle is starting. Prior to starting *the closing motion, there is an audible warning that sounds and continues until the closing motion has stopped.*

4.1.4.2 Power Liftgate Feature Diagrams

The diagrams below are included to give aid the reader in understanding the Power Liftgate system. The first is a subsystem block diagram that shows the subsystems involved in the Power Liftgate and the physical interfaces. The second is a block diagram from the customer's view, showing the components that the typical customer is aware of regarding the Power Liftgate. The third diagram shows the feature functions that were developed for the Power Liftgate. These are some actual examples of the "generic tasks" that were shown in the generic feature DSM.

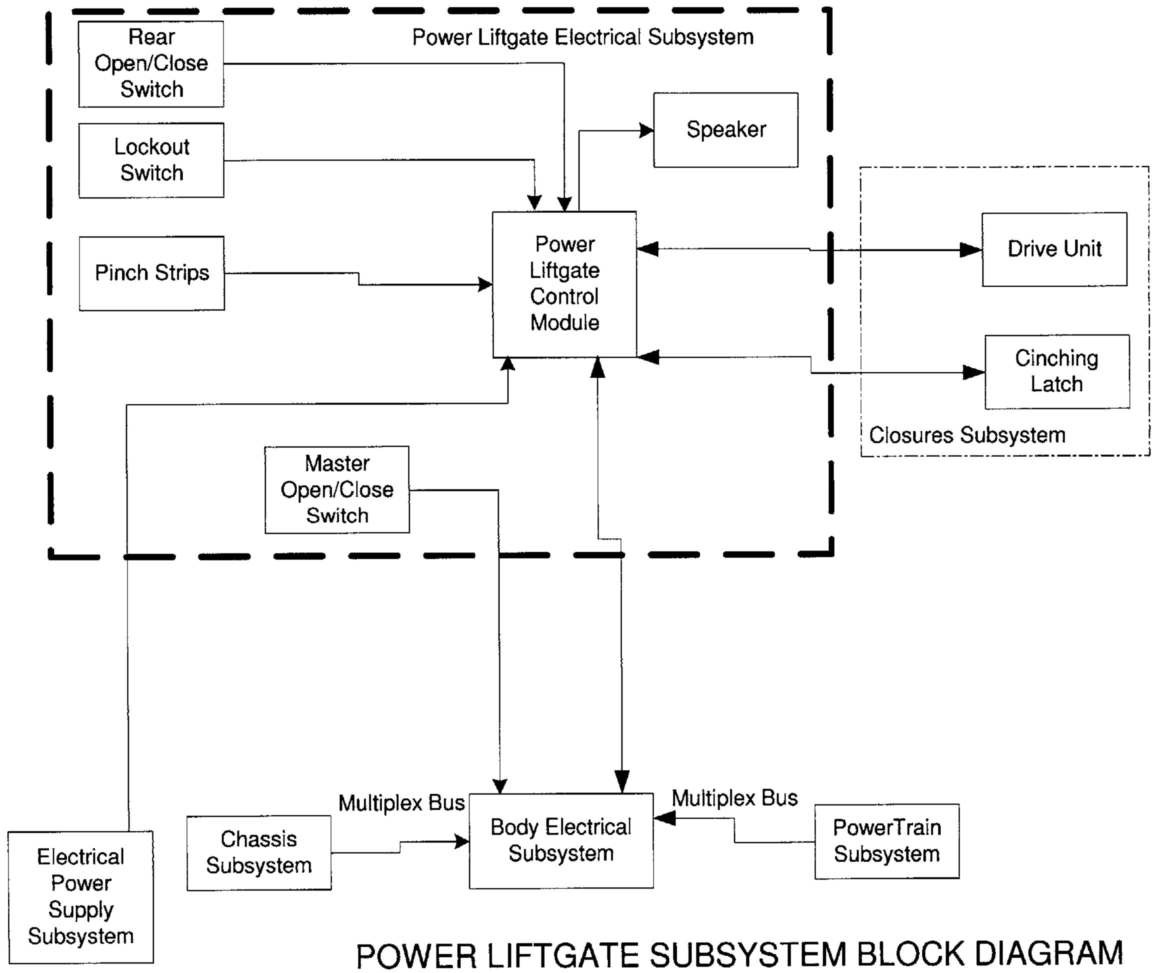

Figure 4-8 Power Liftgate Subsystem Block Diagram

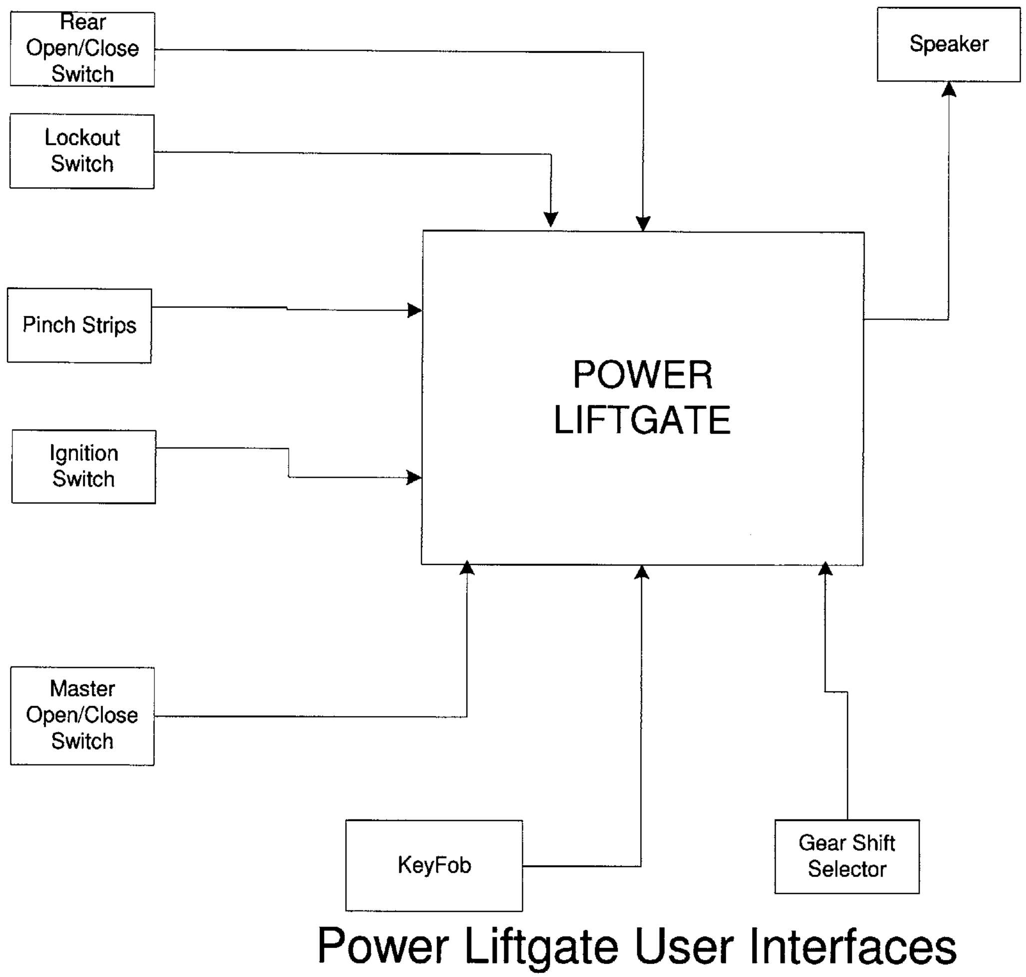

Figure 4-9 Power Liftgate User Interfaces

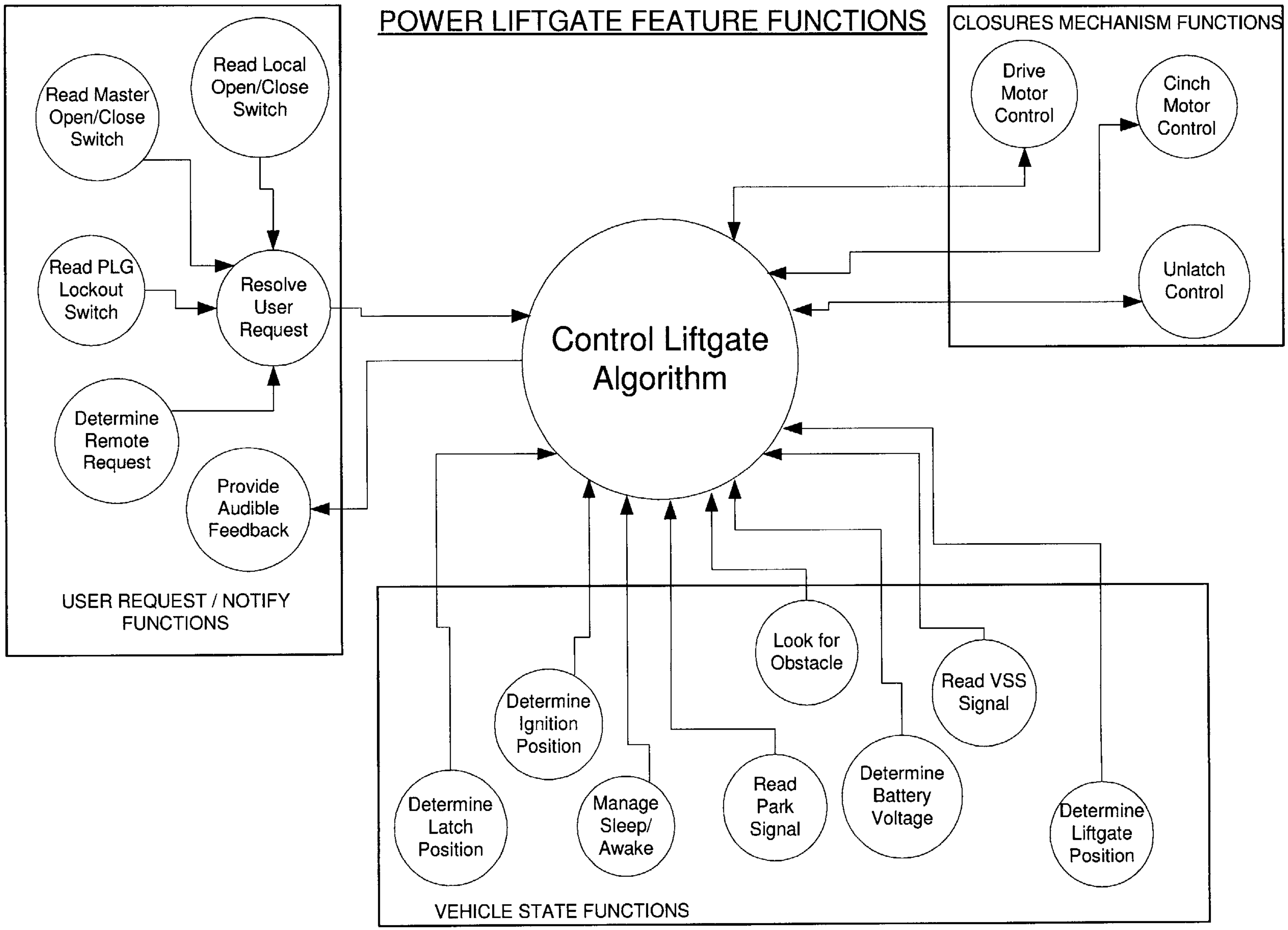

Figure 4-10 Power Liftgate Functions

The preceding design was analyzed using the same DSM technique used for the generic closures feature. Please note that the starting point for this DSM was the simplified generic feature DSM. Again one can see the need for a vehicle level feature (Power Liftgate) role regarding the design of the feature operation as a whole. Other items of interest include the blue area. Notice that this implementation is not a fully distributed over the network. The power liftgate module is hardwired to the body hardware but is not connected on the vehicle network and must get the vehicle state information from a hardwired connection to the body control module. This illustrates the issue of having the engineer responsible for the module containing the feature's control logic being the feature owner. This engineer does not have visibility of the entire feature implementation and is removed from most of the feature's inputs by another electronics module. One can also see that with additional modules on the network, the role of the network PAT is even more vital.

	Feature Owner / Integrator	Clinching Latch	Drive Unit	Pinch Strips	Speaker	Customer Switches	Key Fob	Network	PC Module	ABS Module	SJB Module	PLG Module
Feature Owner / Integrator		X	X	X	X	X	X	X	X	X	X	X
Clinching Latch	X											
Drive Unit	X											
Pinch Strips	X											
Speaker	X											
Customer Switches	X											
Key Fob	X											
Network	X								X	X	X	X
PC Module	X							X			X	
ABS Module	X							X			X	
SJB Module	X					X	X	X	X	X		X
PLG Module	X	X	X	X	X	X					X	

THIS AREA IS ONE REASON THAT THE PLG MODULE ENGINEER SHOULDN'T BE THE FEATURE OWNER-IF THE FEATURE IS PARTIALLY HARDWIRED AND PARTIALLY MUXED, THE IMPLEMENTATION IS OUT OF THERE SCOPE

THIS AREA REINFORCES THE NEED FOR A MUX PAT TO COORDINATE THE NETWORK. THE NETWORK WAS MOVED UP IN THE MATRIX BECAUSE THE FEATURE WAS NOT FULLY DISTRIBUTED, ie MOST OF THE I/O WAS HARDWIRED

THIS AREA REINFORCES THE NEED FOR THE FEATURE OWNER TO BE AT LEAST AT A SYSTEM LEVEL WITH INTERFACES TO OTHER PMTs

Figure 4-11 Power Liftgate DSM

While this analysis clearly shows the need and roles of the integrator and application engineer in implementing a feature, where the role of the feature owner stops and the implementation team begins is dependent on what is desired to be consistent and reused (i.e. what is contained in the knowledge base. The following diagram of the system V shows that the feature owner (green text) is involved at the vehicle and early system level of the development process. They also provide value in the middle portion of the V, with requirement verification and verification planning services. Note that two additional roles are shown on this V. The first is that of the core subsystem engineering function. This function serves to define the feature implementation roadmap across all vehicle programs. The second is that of the architecture engineering function. This function serves to ensure architectural consistency across all vehicle programs.

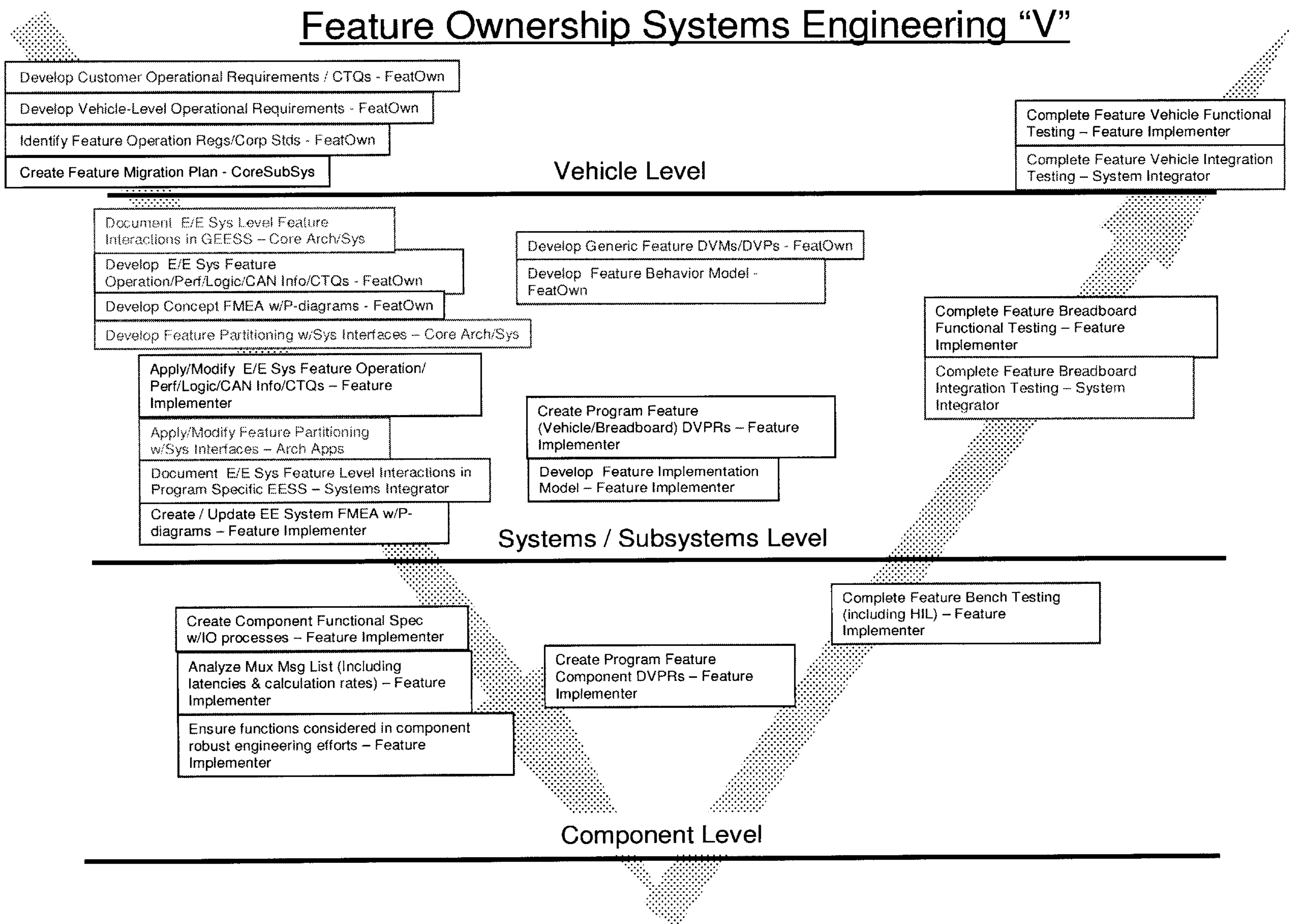

Figure 4-12 Feature Ownership Systems "V"

4.1.5 Organizational Structures

In a company as large as typical vehicle development companies there are many different views one can take when looking at the organizational structure. From a vehicle program's perspective, the structure is based on Program Management Teams (PMTs). A PMT is typically formed to manage the development of a major vehicle system. Examples of these are the Power Train PMT and the Electrical PMT. The figure below depicts an example of the hierarchical organizational structure which the PMTs reside in.

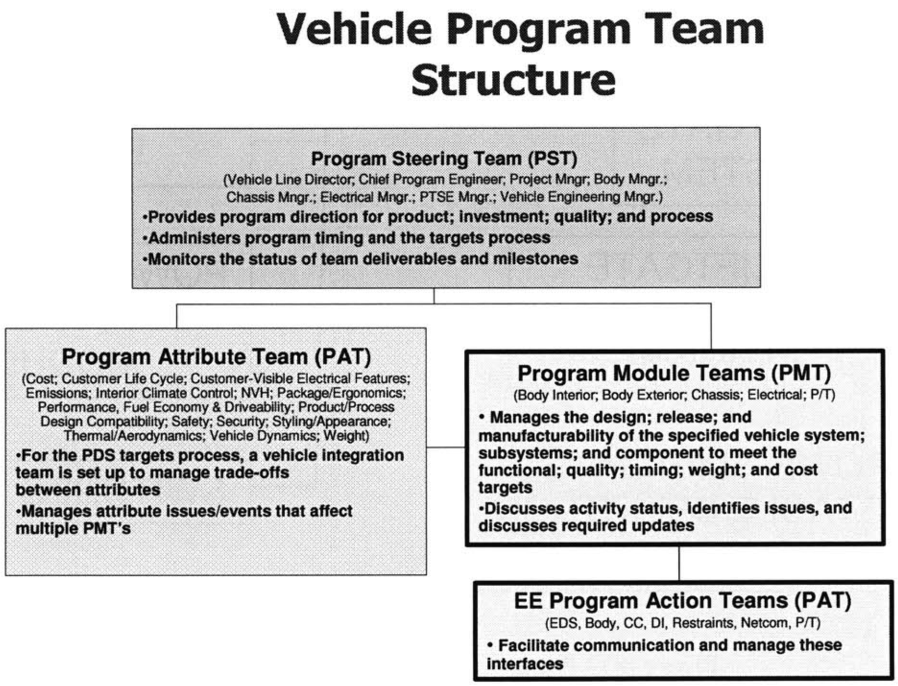

Figure 4-13 Vehicle Program Team Structure

Each PMT is comprised of several Design Verification Plan (DVP) teams. Typically these DVP teams coordinate the allocation and verification of the requirements for a particular subsystem or component. Program status for DVP teams is reported through the PMT to the vehicle program. This is the perspective that we will discuss in this section.

4.1.5.1 Current Organizational Structure

The DVP team is a key organizational element for the vehicle program. It is the unit where standards and requirements are allocated to, new requirements are created, requirement interfaces and interactions are formalized, and testing is planned and conducted. For one vehicle program, the DVP team structure dealing with a power liftgate is shown below.

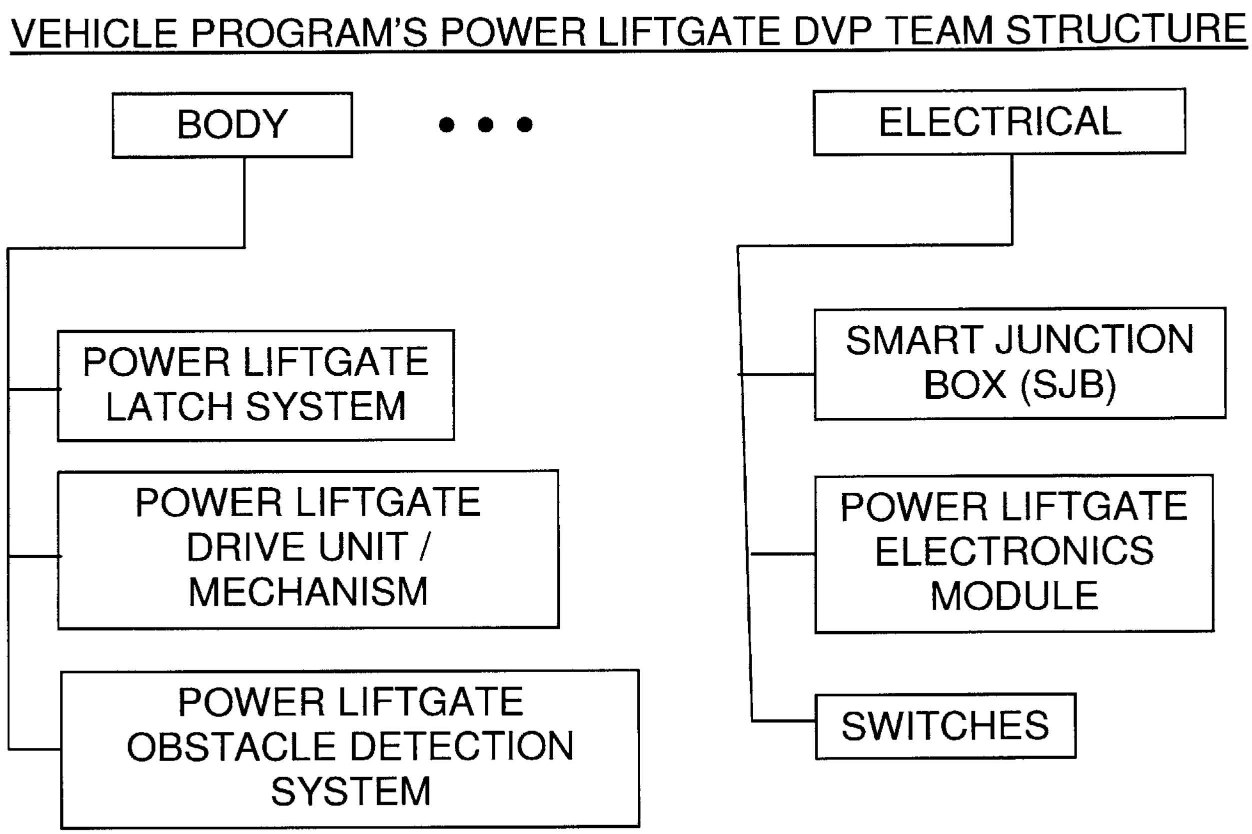

Figure 4-14 Power Liftgate DVP Team Structure

One can see that the interactions between the different DVP teams are crucial in the successful development of the power liftgate system. This is especially true when one considers that each of the components allocated to each DVP team is probably produced by a different supplier and has a different D&R engineer supporting its development. One can also see that any cross system verification must be done at least at the PMT level. A key decision is the determination of which PMT performs what functions.

Look at the interactions which occur regarding the Electrical Program Module Team (EPMT) for a typical vehicle program. What makes the EPMT unique is that it provides three functions to the vehicle. These can be thought of in generic terms as providing electrical power and distribution (batteries, wiring, alternator), providing functionality (radio, instrument cluster), and electrical design expertise (electronic control modules, switches, connectors). This can be explained by looking at the hierarchy of the vehicle functionality. In the most straight forward case the vehicle is composed of systems which are composed of subsystems which are composed of components. The Electrical PMT provides services at each of these levels. At the vehicle level, it is responsible to ensure robustness regarding Electromagnetic Compatibility (EMC). At the system level, it integrates the entire electrical system of the vehicle. At the subsystem level, it delivers the multimedia, driver information, and power supply functionality. And at the component level, it designs and releases (D&R) components for its subsystems and others (such as body, chassis, and climate control).

When one looks at how a vehicle team allocates requirements, this too is a hierarchical structure. There is a vehicle team which is composed of Program Attribute Teams (PATs). These PATs provide targets to the PMTs (of which one is Electrical). Each PMT receives targets and system level requirements. The PMTs are decomposed into various Design Verification Teams (DVPs) which receive requirements cascaded from the PMTs and from other sources, depending on the scope of the DVP team.

Electrical PMT roles and responsibility include:

- Manage design & release of EDS system
- Manage vehicle specific architecture design
- Manage development of E/E System
- Manage collocated/dedicated Electrical PMT resources
- Manage deliverables of E/E Subsystems
- Lead and coordinate E/E system trade studies and interface problem resolution
- Lead E/E System and EDS Technical Design Reviews, support E/E Subsystem TDRs
- Lead and coordinate engineering sign-off to vehicle program
- Provide on-site E/E system engineering and EDS support at assembly plant (PVT, launch)
- Support delivery of all Vehicle Attributes
- Manage EPMT Timing, EPMT Cost (variable and tooling), EPMT Resource Needs, EPMT deliverables to support program

DVP Team roles and responsibilities include:

- Create complete requirements listing
- Define what vehicle or system / subsystem configurations should be used to verify each requirement
- Select design verification methods to be used
- Create a Design Verification Plan
- Record verification results and assess program risks

The following figure shows the typical DVP team hierarchy at the vehicle level regarding electrical content.

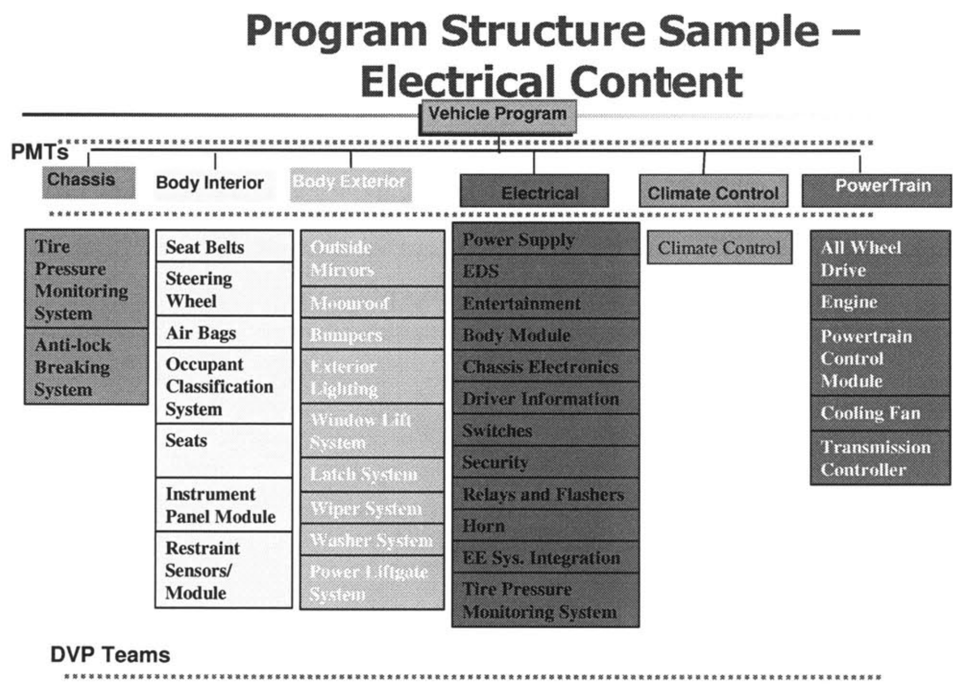

Figure 4-15 Program DVP Team Structure

Because of varying services the EPMT provides, there are typically many complex interactions which take place, which need to be correctly and consistently managed. Often, the EPMT will create Project Action Teams (PATs) to facilitate communication and manage these interfaces. These PATs have the responsibility to ensure that the requirements and testing is coordinated across the electrical DVP teams to ensure proper, robust implementation of a feature such as power lift gate. A survey of a number of ESI vehicle programs shows that the typical

Project Action Teams (PATs) which are used by the EPMT to coordinate the various interactions are:

- Electrical Distribution System
- Powertrain
- Climate Control
- Driver Information
- Restraints
- Body
- Network Communications

PAT Meetings are held periodically to manage the interactions and each PAT leader in turn attends the PMT meeting for the higher level coordination. The DSM methodology will allow us to determine the "best" PAT structure is and show weak interactions (share *physical* interfaces, marked with an "x") vs. strong interactions (share *functional* interfaces, marked with an "F"). These functional interfaces are the key organizational interfaces that the feature owner process must work to optimize. The figure below shows the initial DSM structure created to show the interactions between the various DVP teams which are of interest to the EPMT. A DSM of a larger scope would provide greater insight to the vehicle teams, but looking at the interactions from an EPMT perspective might provide more actionable results for how the EPMT manages its complex interactions regarding feature ownership.

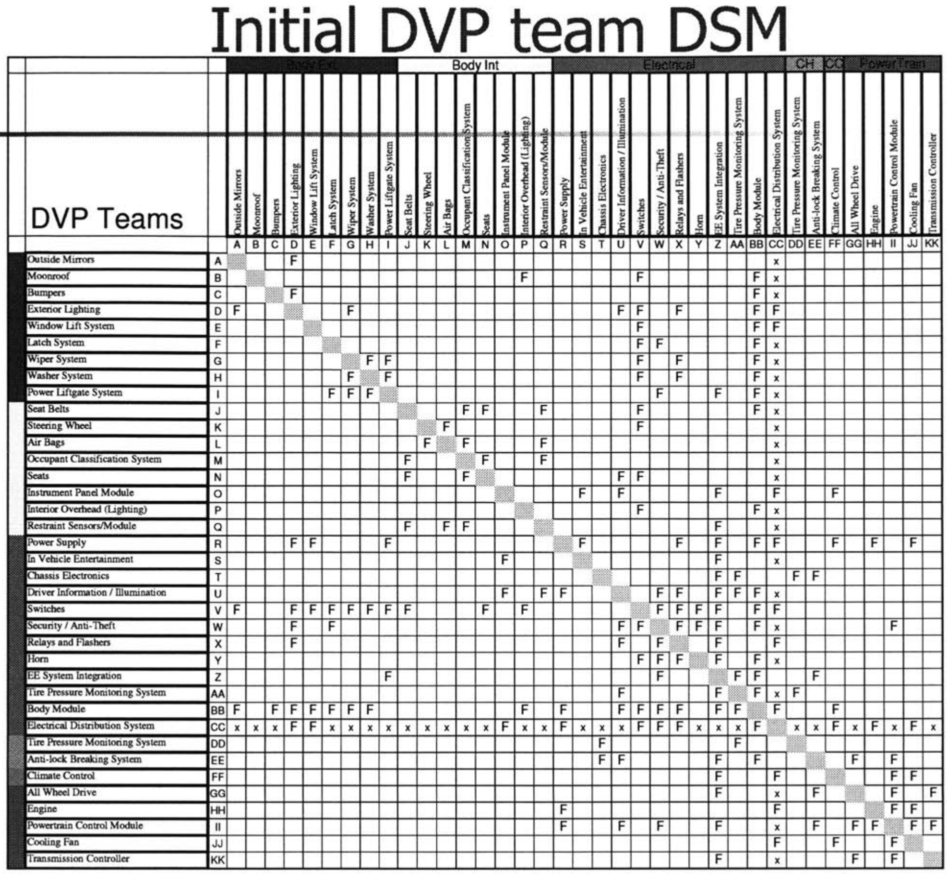

Figure 4-16 Initial DVP Team DSM

Manipulation of the DSM to group the interactions the DVP team organizational interfaces creates the DSM depicted below. Analysis of this DSM shows a possible new set of PATs for the electrical PMT that would reduce the cross functional PAT interactions required to deliver a feature to the vehicle. The Exterior Lighting and Visibility PAT teams would consist of electrical and body exterior DVP teams. The Restraints PAT team would consist of body interior and electrical DVP teams. The Electrical PAT would consist of entirely electrical DVP teams, while the IP Center stack, vehicle dynamics, and TPMS teams would be more cross functional with 3 or more PMT's DVP team being required membership. Again there is shown a need for an EE systems integration PAT to coordinate across all this electrical. One key item in the DSM reduction is that there is a separate electrical PAT to the EE systems integration PAT. This will reduce the amount of time required for the non-electrical engineers to be tied up in meetings discussing items that are not of interest to them.

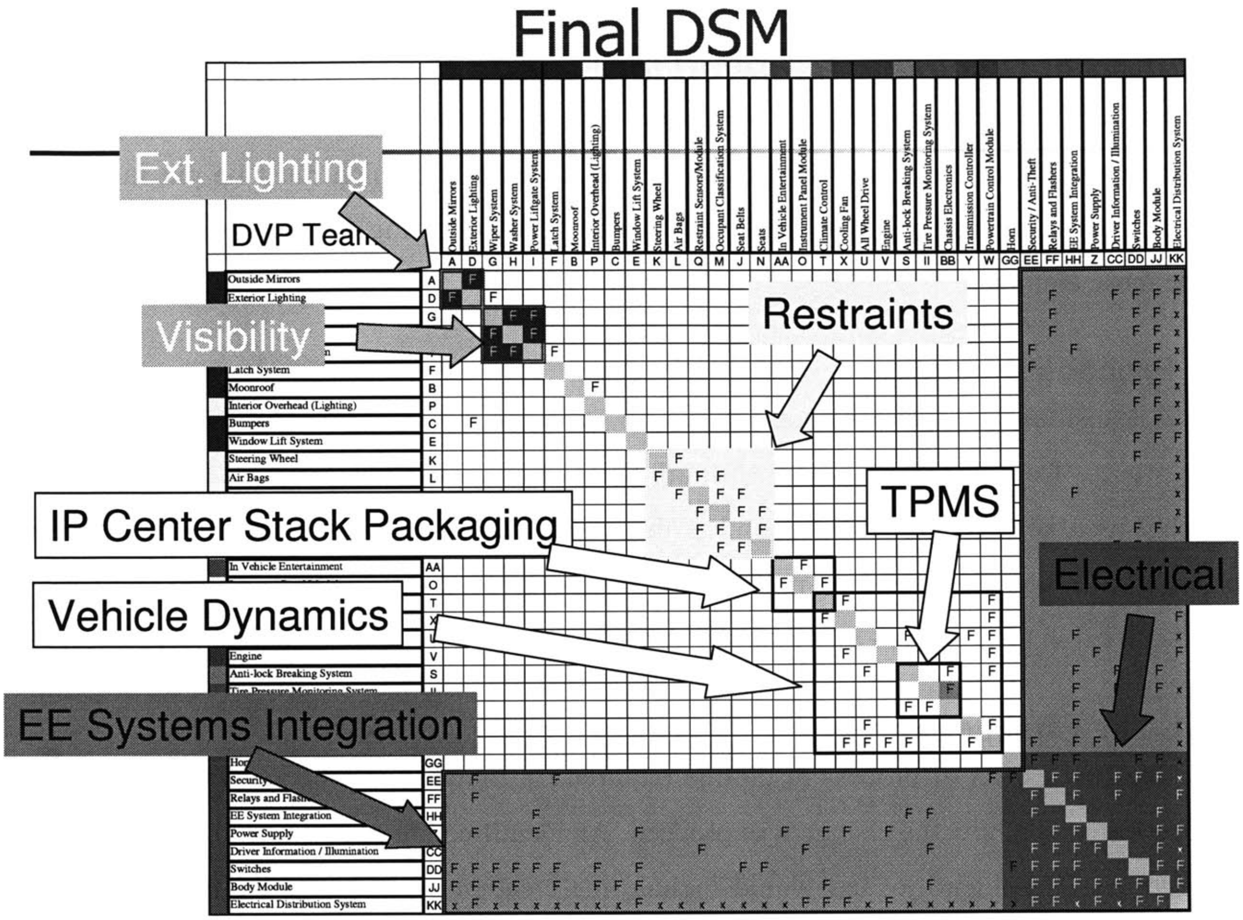

Figure 4-17 Final DVP Team DSM

4.1.5.2 The Organizational DSM lessons applied to the Power Liftgate

When reflecting on the results of the DSM analysis and the DVP team structure two things are clear. The Switch DVP team would need to perform those tasks grouped to the switch system element; the SJB DVP team would do those tasks associated with the SJB element, etc. Who would the feature integration tasks be allocated to? One option would be to split the tasks between the Body and Electrical PMTs. This would result in many information exchanges and iterations, which seems to be an undesirable alternative. Another option would be to allocate the feature integration to one of the PMTs. This seems like a better option than splitting the tasks. A third option would be to create another DVP team to perform these integration tasks. This team would require representation from the EE systems integration DVP team and the corresponding body systems integration DVP team.

4.2 Inherent Discipline Required for Feature Ownership

For ESI to transition to an organization that provides the feature ownership roles identified above there are many elements of inherent discipline which must be put in place to enable a successful change initiative to take place. The following sections will identify and describe these elements.

4.2.1 Process Discipline

A transition to feature ownership can be decomposed into two facets. The first is the change process from the existing way of doing business to the new way, which includes feature ownership as a key element. The second is the steady state process of operating in a manner consistent with the roles identified regarding feature ownership (i.e. performing the engineering steps identified in the Feature Ownership Systems Engineering "V").

4.2.1.1 The Change Process

The first aspect of process discipline required for the change process is that of defining the process steps on how the change will proceed. An identification of features to be owned must be performed. This identification would include the creation of a feature listing. This feature listing should be overlaid on a feature hierarchy, which would provide a framework for feature / function decomposition and be used to identify and define interactions between features. Once this listing is created, owners for each feature need to be assigned. Feature ownership best practices (requirements, implementations, verification tests, etc.) should then be identified for existing features and developed for new or modified features. A clear definition of the various feature ownership roles and responsibilities as they apply for each feature should be defined, documented, with appropriate organizational consensus.

When these feature ownership assets are in place, an assessment on the quality and coverage of the assets should be conducted. An example of the assessment of the quality of the functional requirements for a feature would include requirement content, method, and attribute. The following table provides a listing of a minimal content set for a feature / functional requirements document.

Feature/Functional Requirements Content List

- Purpose
  - Introduction
  - Constraints
    - Environmental
    - Business / General
    - Safety / Regulatory
  - Higher Level Functional Requirements
    - Allocated
    - Derived / Interfaced
- Design
  - Description
    - Block Diagram / Decomposition
    - Operation
  - Interactions
    - HMI
    - Higher level
    - Peer
    - Decomposed
  - Performance Requirements
  - Diagnostics / Service Requirements
  - Configurations / Variations
- Behavioral
  - Operator Assumptions / Tasks
  - Interfaces
    - HMI
    - Communication buses
    - Hardwired
    - External / Environmental
    - Data Models / Definitions
  - Functional Modes
    - Operational Behavior
    - Diagnostic / Service Behavior
    - Assembly Behavior
- Physical Implementation
  - HMI
  - Sensing
  - Acuation
  - Performance
  - Package
  - Robustness
- Verification / Validation
  - Simulations
  - Experiments
  - Methods
  - Traceability
  - Reporting

Figure 4-18 Feature/Functional Requirements Contents List

Each of the requirements listed above should have certain attributes to ensure their quality. These attributes include: correctness, unambiguous, completeness, verifiable, consistent, traceable, modifiable, concise, organized and annotated. The representation of the requirements should be defined, and thus evaluated, by the method chosen by the organization. Notation and style used in the representation of the requirements documentation must be consistent from feature to feature.

Feature coverage is a measure of how many of the features (and resultant interactions) has been listed, owned, etc. With the scope defined by feature ownership, all features contained in the electrical system that are software enabled should be the baseline on which the coverage is compared. A plan for the development of missing feature assets should be created to gain an acceptable level of feature coverage, with a goal of 100% of all existing and planned features.

A disciplined change process would include the measurement of the progress of the change. Metrics to drive and monitor the change should be created, measured, and reviewed on a defined cadence. One method of this is the concept of a dashboard. A dashboard provides a high level, one page report on the key metrics of interest to the reviewing community. The figure below is an example of a dashboard which could be used to monitor the progress of the change process.

FEATURE OWNER DASHBOARD

OVERALL METRICS

# of Features Identified			% of Features Owners Identified			% of Best Practices Identified			% High Quality Specs		
Initial	17-Jun	5-Aug	Initial	17-Jun	5-Aug	Initial	17-Jun	5-Aug	Initial	17-Jun	5-Aug

DETAILS ON EFFORT REMAINING

Feature Owners Missing			Best Practices Missing			Specification Updates Required		
	17-Jun	5-Aug		17-Jun	5-Aug		17-Jun	5-Aug
Body			Body			Body		
Chassis			Chassis			Chassis		
PT			PT			PT		
EE			EE			EE		

Figure 4-19 Feature Owner Dashboard

4.2.1.2 The Steady State Operational Process

Once the change process has sufficiently progressed, the process discipline of the steady state operational process should begin. The steady state operational process is the new way of doing business. Again, one can use the inherent process discipline elements as a blueprint on how to proceed. In the definition of the operational process should include the two views of the feature lifecycle shown in Feature Owner Roles diagram, cross vehicle and program specific.

The cross vehicle role is often referred to as the core or generic role, as its intention is to create feature artifacts which can either be used as a starting point for multiple program specific implementations or be reused across multiple programs. These artifacts, or assets, are looked upon as corporate standards whose deviations are to be governed. Processes need to be developed for the creation and maintenance of these standards. Any deviations to these standards required by a program should be reviewed and a decision made as to whether an update is required. Artifacts which are not used for several program cycles should be reviewed for applicability in the current business / product environment and designated as obsolete if the artifacts are of no future value. Because of the rigor of this operational process, an approval process for the creation and revision of the assets should be developed which includes the eventual users (program specific implementers) in order to reduce the generation of assets which require extensive modification by the program teams in order to make them applicable for the given vehicle program.

Processes to outline how and when to use the feature owner cross vehicle assets also need to be developed. The when is often shown on a program work plan and facilitated by the program management area of the organization. The how should be described in sufficient detail as to enable reproducible efforts across programs and documented in process sheets linked to the program work plan. The terminology in the process sheets should such that they are understandable to the executor of the work task. The measure and review of progress against the work plan will form the basis of the organization's product development quality operating system.

One aspect of this operational process that should not be overlooked is that of designating a process owner. The process owner is analogous to the feature owner and should maintain the process assets over time. Changes in organizational structure, project management tools, and product cycles would cause a need for the process particulars to be reevaluated for appropriateness. The attributes of a good functional requirement are also applicable for a good process requirement. The format and content of the process deliverables should provide the work task executor with the same amount of direction as the functional requirements specification provides the feature implementer.

4.2.1.3 Engineering Process

An overlooked portion of product development process discipline is that of engineering processes. These processes are essentially the "how to" guide for the engineering day to day tasks. These tasks are often not identified on work plans, but rather, can be thought of as application notes to the engineer on how to perform a specific task. Tasks which it is desired by the organization to be done to a given quality level using a given method (and / or tool) to ensure reproducible results are candidates for inherent process discipline described herein. There was mention earlier regarding an example of this, feature / function requirements development. Another example of this type of process which is desired for feature ownership is verification. In the process of developing and implementing a feature in an electrical system there are two prominent areas of verification. The first is the verification that the requirements are correct. The second is that the implementation (components working in the system) is correct, per what is documented in the feature requirement documents. Again, the inherent process discipline elements of: defined, documented, sufficient detail, followed, measured, reviewed, and updated; form a framework to ensure a certain level of success in the execution and quality in the results of these verification efforts.

4.2.2 Personal Discipline

As with any product development process, feature ownership is dependent on the individuals performing the specific work tasks. The inherent personal discipline of committed is vital for the success of the feature ownership. Each individual engineer must make a commitment to understand the process and perform all the steps outlined in the process. Two key pieces of this process which enable success over time are a commitment to connect with the operator (customer) of the vehicle and the commitment to perform all the robust engineering processes during the product development cycle. Connection to the customer is needed in order to have the feature's operation fulfill the needs and expectations of the vehicle operator. Many times the engineering community believes that it knows how the consumer will operate the vehicle and what parameters of the feature operation are critical for customer satisfaction. Unfortunately, engineers often have group think in that they come from similar backgrounds, talk the same language, and like the same things, which is representative of a very small portion of the consumer base. While increasing the diversity of the engineering staff helps this, only the commitment of the feature owner to conduct a thorough customer requirements elicitation will ensure that the features operation will result in a low number of "things gone wrong" and perhaps even some surprise and delights.

The concept of robust engineering is one that uses cross functional teams to develop product requirements, evaluate design alternatives and critical design parameters, and taking an active role in the prevention of mistakes during the development process. Robust engineering processes for the feature owner process include tasks such as: Create component based functional specification with Input / Output processes, Create program specific feature / function design verification plan, analyze network message latency requirements and calculation rates, ensure functions contained in component level DFMEAs, develop feature failure management and diagnostics, develop vehicle assembly and service feature requirements, and analyze feature/function requirements with functional simulation models. Each of these tasks is a preventative measure which reduces program risk, but is labor intensive. A high level of personal commitment is needed to motivate the engineer through to completion of these tasks, as there is often not a right or wrong answer which comes out of these processes.

From the discussion on what feature ownership is and the associated tasks, several skills are required of the engineers doing the feature ownership roles. Essentially, the engineers need to be able to effectively carry out the tasks outlined in the DSMs presented earlier. Some of these skills include: the ability to identify corporate, customer, and industry requirements and translate them into a hierarchical system-to-component functional design; understand how architectural constraints affect the feature; be able to select functional parameters which allow for desired operation across the operational profile; apply robust engineering methods; plan, perform, and analyze functional testing; identify manufacturing derived functional requirements; be able to apply the defined methods/tools in process documentation; define data communication schemes; understand electrical interface effects on functional operation; and be able to evaluate functional compatibility of resultant interactions. As introduced earlier, the engineers must have the personal discipline to honestly evaluate their own competency in each of these skills and create a plan to gain the needed education to close any gaps that they have. The many interactions required to successfully implement a feature create the vital need for all of these skills to be effectively brought to bear in the feature development process. Inexperienced engineers must have the confidence in their peers to ask for help when it is needed and the experienced engineers must be ethical enough to provide the needed mentoring in order that the organization can put out a quality product.

Engineers are notorious for their lack of communication skills. Whether this be a product of their personality, up bringing, or current environment does not matter. As the DSM analysis shows, the interactions required among engineering groups (and thus engineers) require effective communications to occur. One aspect of communication is the effort required to prepare the communication, whether written or oral. Personal commitment by the engineer to spend the energy to prepare the information in an acceptable format, with verbiage friendly to the audience, is a form of personal discipline that is must be done at a high level. Energy is also required to ensure that the audience is interpreting the information correctly.

Another aspect of communication is that of being proactive. While some may say that this is a form of effort, it is really an attitude similar to the prevention of mistakes attitude of robust engineering. Anticipating that others may need recently acquired information may not be a "pull" type effort (i.e. waiting for others to ask for information), but it provides information to others who may not be knowledgeable enough to ask for it and creates an environment which encourages information exchange (instead of information extraction). A common part of the development process where this proactive communication is vital is when it has to do with changes to the feature. Whether it is a requirements change, a design change or a test procedure change; the diverse interactions between the design components and between the design organizations demand even the prospect of a change being communicated to all those interfacing entities. Changing a door ajar switch from a normally open to a normally closed can cause a safety issue if the power liftgate thinks it is closed when it is really open (especially when the vehicle is going down the highway). As soon as an engineer believes a change is necessary, the scope of the change and the accompanying rationale and justification must be divulged through the defined change management process to reduce the effect of the change to the development work plan. Again, this type of behavior is the result of a high level of personal discipline. Many engineers want to wait until they have all the nuances of the change all figured out, but this could be disastrous in today's ever decreasing product cycle time.

The consistent outward display of high personal discipline is often shown by individuals identified as role models within the organization. They are said to walk the walk. Their disciplined behavior creates expectations on the entire team's behavior through peer pressure.

This can be used by the leaders in each of the areas contributing to feature ownership to increase the collective personal discipline of the program as a whole. If the electrical team leader proactively communicates with the body interiors team leader, being honest and upfront on issues and concerns, the rest of the electrical team will follow suit with their interdisciplinary counterparts. Any unethical behavior on the part of the team leader will undercut their reputations and color their interactions with others on the team. Because of this, the more interactive the work tasks, the more vital personal discipline is, i.e. the larger the system change, the more emphasis should be placed on getting people with high levels of personal discipline involved.

4.2.3 Organizational Discipline

The collective management team of ESI must exhibit a high level of organizational discipline in order to realize its desired goals for the feature ownership effort. This is due to the high amount of organizational interactions required for successful implementation of distributed features. In modern electrical systems, the implementation of distributed electro-mechanical, software enabled features cannot be done in a vacuum by one person. The following sections will describe some aspects of organizational discipline regarding consistency, alignment, rewards, training, empowerment and governance required for feature ownership.

4.2.3.1 Consistency

The hallmark element of organizational discipline is consistency. Without consistency, the engineering community does not know what to expect and how to act. Without consistency, the customers of the deliverables from the organization do not have a high level of confidence in the quality of the deliverables. One aspect of consistency that often comes into play in large system change and is which is applicable to the feature ownership concept is that of resources. Simply put, if engineering effort is expected then resources should be allocated. If resources are not allocated, then the work must not be important. As mentioned above, the change process of transitioning to feature ownership should not be overlooked. It should be resourced appropriately. Engineers performing tasks for the first time take longer to complete these tasks. Additional resources should be put in place to manage the change process and create the required process artifacts. Managing the change process cannot be a side job for those responsible for the program deliverables because when times start getting tough, the engineers will focus on getting the product out the door, regardless of the process. Once the steady state operation process is in effect, a process owner should be resourced, along with appropriate staff to manage the quality operating system. The DSM analyses identified the need of a feature integration role. This role should be resourced appropriately to ensure the interactions are handled and not left to chance by expecting component engineers to pick up this responsibility. While the discussion on resources has focused on appropriate levels of staffing, time and money are other forms of resources. Organizations with high levels of discipline ensure that adequate time is allocated for the completion of each engineering task. Nine women cannot have a baby in 1 month and 2000 permutations of feature inputs cannot be manually tested in half a day. Many of the feature ownership tasks can be more efficiently done with computer aided and model based design practices. Providing proper resources in the terms of simulation, requirements management, process management, and configuration management tools also show a consistency that increases the chances of a successful change initiative.

Another way in that the organization must show discipline regarding consistency for feature ownership is how the feature operates (i.e. the specific functional requirement suite). A consistency in the operation of the feature from a customer perspective is vital for the success of the feature ownership change initiative. One reason for this is to be able to realize the value of reusable engineering assets over time. If the organization allows or encourages individual programs to specialize feature operation without an identified customer want to differentiate one feature implementation from another, why have a single point of contact for a feature at all? All the cross vehicle work will have to be redone and if that is the case, there is not reason to expend the resources (engineering, process, and infrastructure costs) to create assets before it is known if the individual programs will adopt them.

Another reason for the organizational consistency around feature operation is to show the engineering community that it is indeed serious about the "control" portion of the ownership duties. What is the motivation for the feature owner to go through each of the engineering disciplines if someone is going to redo the effort later? At each level of the feature ownership system hierarchy, ESI must be consistent in how it chooses to control the given feature engineering deliverables. The figure below depicts the increasing levels of control which must be chosen along with an associated delivery mechanism to document (document type in parenthesis) their intentions. One can use a distributed feature as an explanation tool for this concept. If consistent customer operation is desired, commonality can be accomplished through a documented, ESI-wide strategy paper. If ESI wants to control the interface types of the distributed feature, the structure should be documented in a design guideline. If ESI wishes to control the correctness of the feature implementation, an integrated (optimized design for a particular implementation) approach that documents the detailed requirements is necessary. The highest level of control ESI can have over a feature (keeping in mind that ESI does not have a component manufacturing facility) is that of having a coherent strategy over time and across programs. These assets would become corporate standards and thus cross vehicle requirements.

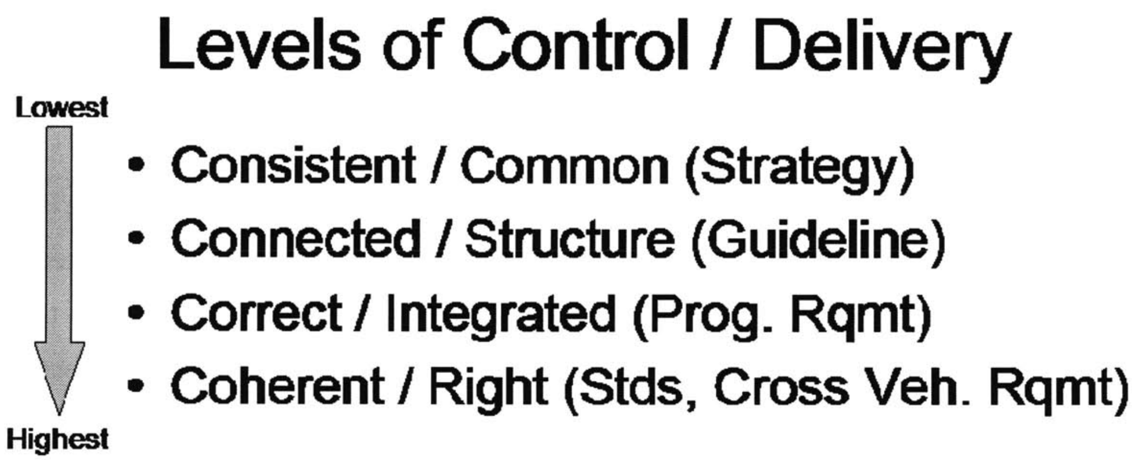

Figure 4-20 Levels of Control / Delivery

One can see the importance of ESI being consistent regarding the levels of control exercised for feature ownership. If at the vehicle level a feature is a strategy but an interacting feature is a cross vehicle requirement, such a difference must be thoroughly understood as the cross vehicle requirement's interaction becomes a constraint on the strategy, thus limiting the strategy owner's design flexibility. The increasing levels of desired control increases the development time and corresponding organizational overhead required to ensure such control is accomplished. Thus ESI cannot state it wants a particular feature implementation to be a corporate standard and not give the feature owner enough time or product direction visibility to make sound engineering judgment regarding cross vehicle program implications of the implementation.

4.2.3.2 Alignment and Rewards

A disciplined approach to alignment of efforts and rewarding successful completion of those efforts will be a key enabler for feature ownership. It was illustrated during the DSM discussion that there are numerous interactions between components and development organizations for successful implementation of features. Team structures should be aligned to reduce redundancies and organizational interfaces. Product architectures should be aligned across vehicles and over time to reduce engineering effort and product cycle time. Alignment of responsibilities around the system hierarchy will ensure the proper emphasis is placed on the integration tasks, apart from the component design tasks. Proper alignment of feature allocation to organization is needed to assure the proper skill set is available to accomplish all the required engineering tasks. Proper alignment of technology support functions, such as network communications and simulation modeling, will reduce the number of design errors made by more generalist D&R engineers.

Alignment of product strategies across vehicle program time frames is required. Scheduling a new feature on a particular program cannot be done unless the feature technology is sufficiently ready for production. Features which need other features present for their proper operation (power liftgate requiring remote entry) must be planned in appropriate feature bundle sets. Feature implementations designed with reuse as a determining factor in their business case must have those features contained in the program assumptions.

Discussions of organizations aligning their actions often end up on the subject of aligning the reward system to the behaviors desired in the workers. Feature ownership entails considerable amounts of up front definition and robust design to eliminate the amount of error correction that occurs later in the product development cycle. In order to reward this failure prevention, engineers objectives should be aligned to metrics that measure successful feature owner task completion. Amount of reuse and number of standard interfaces are two such metrics which would align with the principles of feature ownership. Rewarding an engineer for fixing an issue that they should have caught using defined engineering disciplines (i.e. showing a high level of personal discipline) is not aligned with good feature ownership organizational discipline.

Another reward that is often overlooked, but essential with a process such as feature ownership is the documentation of lessons learned and the incorporation of them into the existing reusable assets. Engineers are often transitioned off programs as they are going through production launch and then assigned to another program. They are not given time or rewarded for this generation and incorporation of lessons experienced on their program. This step is vital in the continuous improvement of the feature owner assets and the actions of the organization in regards to time allocated at the end of a program and subsequent rewards for these improvement efforts must be aligned.

4.2.3.3 Training, Empowerment, and Governance

The steps necessary to roll out the feature ownership process form a sequence for this next portion on the discussion of organizational discipline needed. Training on the feature owner process steps, the various roles, and the specific skills need to be provided to not only those who are asked to complete tasks associated with feature ownership, but also to those who will interface with them. Once the engineers are trained on the process and possess the skills needed to succeed in feature ownership tasks assigned to them, they will begin to feel confident, which is an enabler for being empowered. Any new tools or methods defined or developed as part of the feature ownership engineering process should also have an adequate level of training and support services provided.

ESI must communicate to the engineering community the level of control each individual is expected to exert over their "owned" assets. Once this is communicated, the actions of the organization must show that the engineers are truly empowered to make the daily decisions necessary to gain that level on control over the assets. One example of an organization showing a high level of discipline regarding this empowerment is not allowing feature operational details (such as how long the lights stay on when the power liftgate is closed) to be changed on a particular program without the feature owner's concurrence. If this level of empowerment is not given to the feature owner and is instead kept at a higher management level, then it is really that management level that is the feature owner? Another example of the right level of empowerment has to do with the roles and responsibilities given to the engineers. If an engineer is made responsible for an outcome over which they have not control (i.e. not empowered to make it happen), there exists a lack of organizational discipline and the engineer is really set up to be a scapegoat if failures occur. This type of "dis-empowerment" often happens when an engineer from one organization is asked by their management to ensure that an engineer from another organization completes their tasks (i.e. the software engineer is responsible to ensure that vehicle level feature requirements are developed).

Empowerment should not be confused governance. For an organization to have alignment the actions of empowered engineers need to be monitored and there needs to be a higher authority in case of disputes that cannot be resolved, for whatever reason, at the engineering level. Governance ensures that individual and department efforts are compatible with efforts which are not in the span of control of those individuals and departments. Governance also acts as a check to ensure that any planned changes to a feature asset is coordinated with other changes, either as a result of the first change or dictated by an associated change in product strategy. One example of this would be coordinating a new key fob enabled function (power liftgate) with a redesign of the key fob due to new FCC regulations. Again, governance does not necessarily take away from an individual's empowerment, but rather looks that the issue at a higher level with a larger view of the organizational implications. In this way it is similar to the deliberation process used in many public policy decision making processes. An organization with a high level of discipline will make the governance policies known and follow them with a defined cadence and membership team.

4.3 Feedback on Feature Ownership

As part of ESI's rollout of feature ownership, an awareness session was given to individuals identified as probable feature owners, feature integrators and feature application engineers. Slides from the presentation are included in the appendix. Prior to the presentation, the audience was given a feedback sheet and asked to provide comments on the presentation content, concerns with the feature owner process as presented, and the discipline (process, personal, and organizational) required for feature ownership to be successful. Because these terms of discipline could be foreign to some in the audience, each was described with one sentence. These description were: Process discipline deals with following the various process steps defined for any engineering effort; Personal discipline deals with an individual's actions when performing any engineering effort; Organizational discipline deals with the actions of the management and social structure that forms the environment in which engineering effort takes place.

Forty three people attended the awareness session (which lasted one and a half hours and included extensive Q&A). Thirteen feedback sheets were returned. Regarding "Concerns with the feature owner process as presented" item, the responses centered around: lack of engineering resources required to implement the process; lack of compliance of feature owner defined operations by the feature application engineers; the business value of following this specific process, variability (based on the feature) in how the roles are allocated to specific parts of the ESI organizational structure; and who would "own" interactions that are shared by multiple features.

The following listing summarizes the responses received for what is required, by each discipline type, for feature ownership to be successful. Please note that the responses are shown in the discipline type identified by the respondent. Incorrect binning of the response may be an indication that the descriptive sentence provided on the feedback sheet was unclear.

- Process Discipline –
  - Provide process differences based on module and supplier
  - Process must be clear and simple
  - Process must be consistent with program specific development process
  - Feature owner must define all hardware design specific interactions that affect input filtering, output conditioning, and communication bus parameters
  - Identify, document and provide access to who the feature owners are
  - Provide a feature owner process "owner" to maintain the listing of features and owners
  - Ensure that a feature is not scheduled for implementation until the feature ownership deliverables have been completed
- Personal Discipline –
  - Provide training
  - Ensure adequate review of deliverables is done
  - Ensure that feature is fully defined prior to application on a program
  - Ensure that the feature owner is responsible for directing all areas affected by the implementation of the feature
  - There must be a willingness by the engineers to adopt this approach to engineering a feature
  - There must be a continued sense of urgency to ensure the rollout of this process
  - Ensure that the specification quality is high

- Organizational Discipline –
  - Ensure access to the feature listing is provided
  - Create clear set of roles and responsibilities for feature owner engineering tasks, including identification of all stakeholders for each feature
  - Create a clear governance process and ensure all programs are aware of it
  - Provide ample resources and tools for verification effort
  - Reorganize away from a component based organization to a system or feature based structure
  - Ensure that the feature owner is in the same organization as the feature application engineer
  - Ensure that the proper tools, training, time and personnel are allocated to the effort
  - Ensure that each role is being effectively executed
  - Ensure that governance decisions are data driven

It is my belief that the comments given on the feedback sheet provide a window into some of the difficulties (and frustrations) that the engineers in the audience feel during the execution of their daily duties (i.e. what the current culture of ESI is). A cursory analysis of the feedback shows that a couple of themes emerge regarding what is needed for this particular large system change to be successful. Resources, be it people, tools, training, or time, must be allocated to the effort. This seems to indicate that the engineering community does not have confidence in the process and organizational discipline of ESI. Decision making processes and authority must be clearly defined and understood throughout the organization. This seems to indicate that confusion or disagreement exists in the current culture regarding how and who really makes feature implementation decisions within ESI, i.e. lack of organizational discipline. Alignment of roles and responsibilities, feature ownership listings, and specification quality measures across the organization must be ensured. This also seems to indicate a lack of confidence in the organization's discipline of dealing with cross functional items.

It is interesting to note that there seems to be confidence by the engineers in their own ability to understand and implement the change successfully. Only the "There must be a willingness by the engineers to adopt this approach to engineering a feature" entry of the feedback given shows any lack of confidence in the current capability of the engineering community. This may be a case of engineers pointing fingers at others or it may be an indication at the current source of frustrations that many of them feel.

5 Recommendations

The three types of discipline form a balance for the large system change initiative. The absence of any of the three can have a detrimental effect on the progress and effectiveness of the change. The following table shows effects of the absence of one of these discipline types.

EFFECT OF DISCIPLINES ON CHANGE

PROCESS DISCIPLINE	PERSONAL DISCIPLINE	ORGANIZATIONAL DISCIPLINE	EFFECT ON CHANGE
PRESENT	PRESENT	PRESENT	SUCCESSFUL CHANGE
ABSENT	PRESENT	PRESENT	POOR IMPLEMENTATION
PRESENT	ABSENT	PRESENT	POOR QUALITY
PRESENT	PRESENT	ABSENT	POOR APPLICATION

Figure 5-1 Effect of Disciplines on Change

The absence of process discipline will lead to a poor implementation of the initiative. This can be due to the lack of a defined process or the inconsistent / incomplete following of process steps. The resultant, subsequent implementation instances that occur over time will be inherently different, as the set of development steps undertaken differ, leading to an inconsistent result. This will act to slow the progress of the change by causing confusion as to what the proper scope and meaning of the initiative really was.

The absence of personal discipline will lead to poor quality of the engineering deliverables required of the initiative. Incomplete and inconsistent performance of the tasks required of the engineer will lead to future defects in the product and higher resource costs. These substandard work products may go undiscovered as the root cause of the defects, which may lead to unnecessary effort to instill more steps into the current process. This type of lack of discipline will result in a distrust of the initiative due to the resultant poor outcomes of the initiative.

The absence of organizational discipline will lead to poor application of the initiative throughout the organization, across projects and over time. Inconsistent expectations on the engineering community by the management team will lead to variations of the initiative being carried out. This will cause inaccurate assessments to the success, value, and progress of the initiative and make any attempt to improve, evolve, and update the initiative principles and subsequent details futile.

When reviewing the concept of feature ownership, several specific recommendations can be made to increase ESI's chance of successfully implementing this large system change.

5.1 Process Discipline Recommended Next Steps

One of the first items that must be completed is an initiative change process that has gained consensus amongst all affected stakeholders. Once this is finalized, the steady state feature owner process should be defined and embedded into ESI's procedures and program work plans. Specific methods for critical engineering processes should be identified and codified into process sheets. Finally, a cadence of review for the change process and the steady state process should be established. The measurements collected in preparation of these reviews should be true indicators of the progress of the principles of the feature ownership concept. Number of feature owners identified and number of approved feature assets are two examples of appropriate metrics for the change process. Number of programs using approved features and number of lessons learned incorporated into the feature knowledge base are two examples of appropriate metrics for the steady state process.

5.2 Personal Discipline Recommended Next Steps

The most obvious step that must be taken by the ESI engineering community regarding personal discipline involves becoming educated on the feature ownership concept. Feature owners, integrators and application engineers must learn the skills required for them to fulfill their roles in the feature ownership process. They must also gain understanding on the process itself and show commitment to perform the duties required of those in their positions. Those engineers who are stakeholders in the lifecycle of the feature (as defined by the feature ownership process) must be proactive in their communication with engineers of interfacing organizations. Examples of this proactive communication are: feature owners alerting others when a feature asset is created or modified; feature integrators providing active facilitation of compatibility reviews; feature application engineers identifying lessons learned which should be incorporated into the feature knowledge base.

5.3 Organizational Discipline Recommended Next Steps

The responses from the feature owner awareness session indicate that this is the area that requires the greatest amount of focus for ESI. Proper allocation of resources should be the first priority for the ESI management team. The effort must be fully funded with regards to engineering resources. Engineers who have been assigned the various feature lifecycle roles should be given adequate time to perform the required duties and the necessary training to successfully complete the assigned tasks. A process owner should be appointed to ensure proper development and maintenance of the process artifacts and feature owner listings. The process owner should provide status reports to the appropriate governing body. Another aspect of funding that needs to be addressed is that of tools. The acquisition and deployment of tools for the management of feature assets, for improving efficiency of executing defined engineering methods, and for increasing feature simulation and verification capability are examples of Collins' technology accelerators for the feature ownership process.

Restructuring of the organization to accommodate the interactions required for the successful implementation of the feature owner process is also required. Parts of the organization responsible for the creation of the cross vehicle feature assets should be structured to reduce department interactions and redundant skill allocation. Features should be allocated to organizations according to whether the feature is part of that department's hedgehog concept (i.e. brake features should be allocated to the brake department and chassis features should be allocated to the chassis department). The vehicle programs should organize their PAT structure to facilitate DVP team interactions and to ensure that all feature stakeholders are included in any program specific feature decisions.

One final element of organizational discipline that should be considered immediately by ESI is that of rewards. Personal and organizational objectives with associated metrics should be created and included as part of the performance review process. Successful completion of these objectives should result in higher compensation, while poor quality engineering deliverables and ignoring defined processes should not result in fire fighting accolades when the deficiencies are corrected.

5.4 Possible effects of Lack of Discipline

While success is never guaranteed, there are several scenarios which will result in probable failure of feature ownership if there is a lack of the inherent disciplines described herein. If the change initiative champion leaves their position, the initiative will fade into the background as unimportant. If engineering resources are not allocated, the process will be discredited. If tools are not deployed, the engineering methods will go unexecuted. If objectives are not aligned across organizations, interactions will be ignored. If training is not provided, the engineering efforts will become ad-hoc. If the process and deliverables are not reviewed and updated, the feature assets will become obsolete.

6 Summary

6.1 Why we began and what we found

The impetus of this work was to gain an understanding of how a needed large system change to implement ownership of distributed software enabled features in new electrical architectures of land vehicles could be implemented more successfully if certain, inherent discipline was present. This inherent discipline was decomposed into three parts: process discipline, personal discipline, and organizational discipline. It was the intention of this work to make the case that without a certain level of all three of these disciplines in place and functional, no successful large system change (such as feature ownership) can take place.

The three parts of inherent discipline were described. Relationships between personal and organization discipline, and parenting and organizational discipline were discussed. The business value of inherent discipline was examined using two cases. The first case was one of how organizations progress from being a good company to being a great one. The second case was one of how manufacturing facilities progress by transitioning to lean principles. The concept of feature ownership was introduced and the elements of inherent discipline required for successfully implementing this large system change were identified. Feedback received by a group of prospective feature owners was introduced and recommendations were given regarding how to move forward on the implementation of feature ownership.

The findings of this work were diverse in nature, ranging from the relationships between the inherent disciplines to specific actions which should be taken by ESI to improve their transition to feature ownership. We found that each process discipline element seemed to build upon the previous element in sequential fashion. We found that several elements of organizational discipline were the compilation of the management team's personal discipline and that consistency was an element of both personal and organizational discipline and was needed to gain committed behavior. We found that while required discipline was described with different terms, the inherent disciplines were indeed evident in organizations' transition to becoming a great company with the highest correlation being that of organizational discipline. We found that inherent disciplines were present not only on the factory floor, but also in the culture of those who transition to lean production principles.

We found an effective allocation of engineering tasks to three primary feature ownership roles: Feature Owner, Feature Integrator, and Feature Application. We found that for distributed features, an integrator role was vital for efficient development to occur. We found that a cross organizational design verification team was needed to effectively manage the implementation of distributed features. We found that the transition to feature ownership consisted of three distinct process pieces: the change process, the steady state operational process and the engineering process; each of which needed high levels of process discipline in order to succeed. We found that while learning and communication were key personal discipline elements for feature ownership, commitment was the most vital for success. We found that without the consistency element of organizational discipline there would be confusion across the organization regarding the engineering roles and the management commitment of feature ownership. We found that the engineering community which would be most greatly affected by feature ownership expressed a lack of confidence in ESI's current level of organizational discipline. Finally, we found that the absence of any of the parts of inherent discipline could lead to poor implementation, poor quality, or poor application of a large system change such as feature ownership.

6.2 Applicability to other industries

While the primary context of this work was on large system change affecting land vehicle development in general and software enabled features in particular, the inherent disciplines are applicable for large system change in other industries. A software development organization's progress up the CMM levels [14] must be accompanied by increased levels of the inherent disciplines. Distributed features whose implementation is primarily mechanical instead of electronic would benefit by exhibiting the feature ownership principles and corresponding inherent disciplines described herein, regardless of the end product.

Several of the recommendations offered to ESI have merit outside organizations involved with the development of land vehicles. A clear delineation between the change process and the steady state operational process has widespread applicability to any large system change initiative. A plan should be developed for each, with a clear understanding of the end goals driving the steady state operational process. A cadence for review of appropriate metrics which give a true indication of the progress of each of these processes will allow for midcourse corrections, with the review frequency being dependent on the urgency of the change. Any large system change which requires their workforce to add to their existing skill set requires the workers to be committed to learning the required skills and the organization to make those learning interventions available in a timely fashion. In industries which utilize cross-functional teams and employ robust engineering philosophy need an engineering community that is proactive in their communication. This proactive behavior is consistent and complimentary with defect prevention actions used in robust engineering development efforts.

Any large system change effort, regardless of industry type or organizational size, must be fully funded to enable success. If adequate funds are lacking, the effort should be delayed or broken down into a series of smaller efforts, sized in accordance with available funds. All large system change efforts need a process owner to ensure not only complete process definition but also maintenance of process artifacts. Personal and organizational objectives must be accompanied by metrics which promote desired outcomes. Accomplishment of those objectives must be rewarded accordingly. This again is applicable to all organizations undertaking large system change.

6.3 Further areas of study

With this thesis, as is the case with most, there are several areas which could be investigated at a deeper level if more time was available. One such area is creation of quantifiable levels for each of the inherent discipline types. This would be similar to the CMM levels for software organizations [14] where, for example, the first level of process discipline would be a defined and documented process and the second level would be a detailed and followed process. Another area of study would be the sequence relationship of which elements of inherent discipline are required before others are possible. We alluded to this in the discussion that one aspect of organizational discipline is that it is the result of the personal discipline of each member of the management team. One last area of further study which is worth mentioning is a prioritization of which elements of inherent disciplines are of most value to different types of large system change environments. For example, is process discipline a higher priority for a mature company while personal discipline is a higher priority for a startup company?

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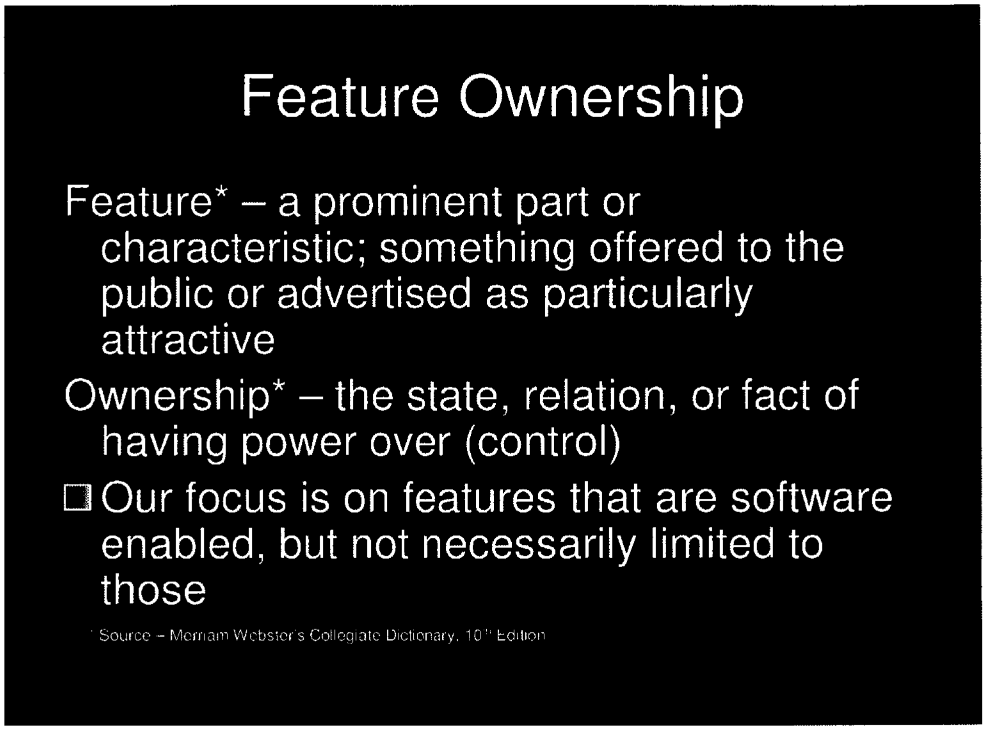
8 Appendix – Slides from the Feature Owner Awareness Session



Feature Ownership Goals

- SUBSYSTEM SPECIFIC GOALS
  - complete specification suite
  - reusable requirement and DV elements
- SYSTEM GOALS including INTERFACING ORGANIZATIONS
  - complete R&R coverage
  - complete requirement and interface definition
  - complete integration and verification testing
- Governance on Feature Implementations with associated metrics

Feature Owner Principles

- Focus is on feature operation – information flow and control flow
- 3 roles in implementing feature – Feature Owner, Feature Integrator, Feature Application
- Feature Owner owns end to end operational characteristics of the feature
- Feature Integrator owns resultant feature interactions due to partitioning decisions
- Feature Application owns implementation of the feature on the vehicle program

Feature Owner Complexities

- Levels of feature definition and ESI ownership – vehicle level: Audio, E/E Subsystem: Body (lighting), E/E Component: Chassis
- Feature ownership is a support function (skill set required) to the Subsystem Owner (resp. for schematics, HW rqmts, costs, weight, subsystem FMEA, etc)
- Existing features based on current best practices vs. new features being developed per Arch. Group's new feature process
- Distributed and Cross-organizational feature interactions need system level stewardship (core and program)

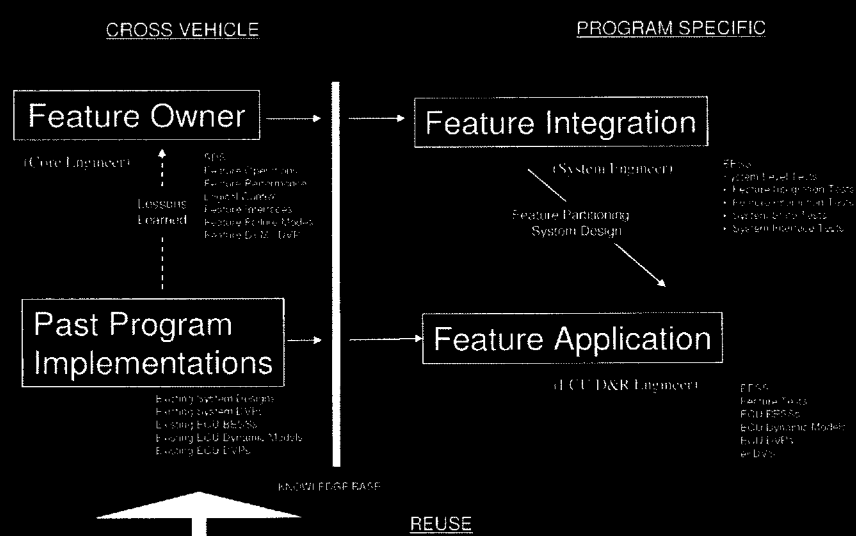
Examples of ESI Feature Ownership Levels (not exhaustive)

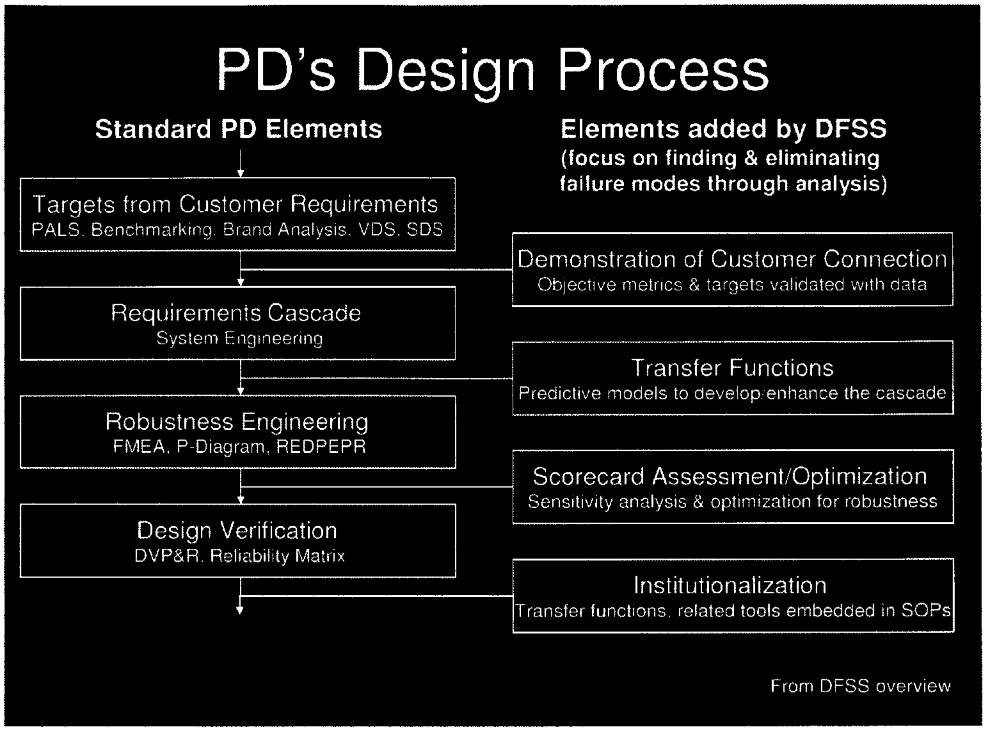
- Vehicle Level Features Owned by ESI
  - Audio, Family Entertainment, TPMS, Navigation, Electric Power Management
- EE System Level Features Owned by ESI
  - Exterior Lighting, Interior Lighting, Climate Control, Warning Chimes, Heated Glass, Power Windows, Power Seats, Power Closures, Power Column, Power Pedals
- EE Component Level Features Implemented by ESI
  - Steering, Suspension, Gauges, Warnings Indicators, Message Center, ACC

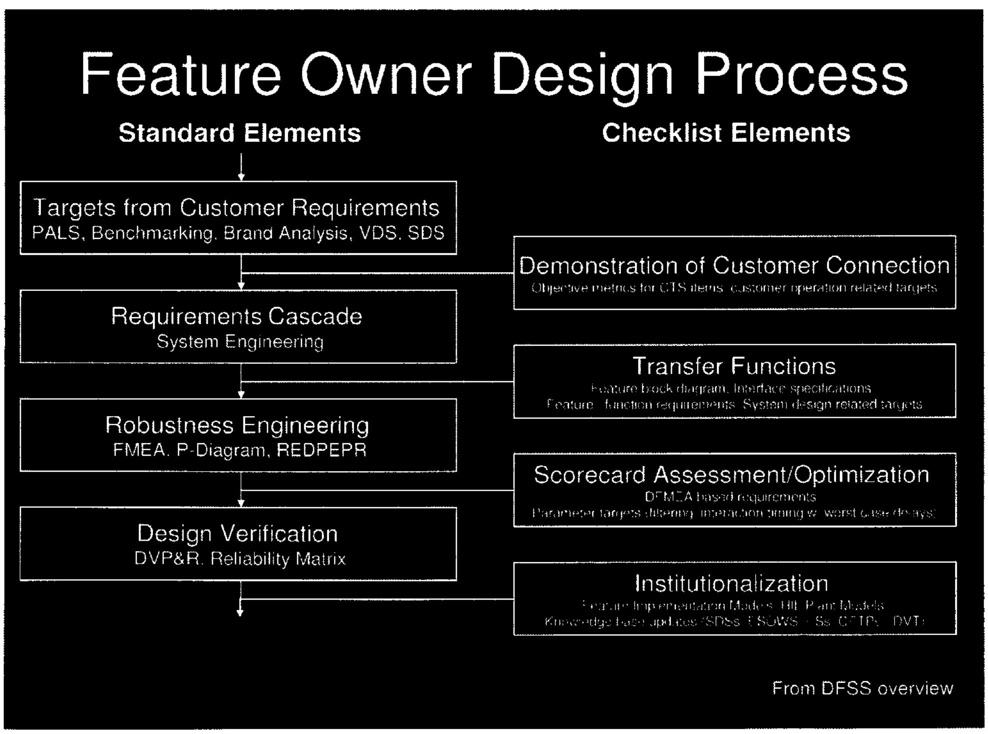
Ownership Level Determines

- Feature target setting process
- Level and detail of ESI specification and testing at vehicle, EE System, and Component level
- Organizational interfaces
- Level of Core and Program ESI effort

Generic Feature Owner Roles




PD's Design Process
Standard PD Elements
Targets from Customer Requirements
PALS, Benchmarking, Brand Analysis, VDS, SDS
Requirements Cascade
System Engineering
Robustness Engineering
FMEA, P-Diagram, REDPEPR
Design Verification
DVP&R, Reliability Matrix
Elements added by DFSS
(focus on finding & eliminating failure modes through analysis)
Demonstration of Customer Connection
Objective metrics & targets validated with data
Transfer Functions
Predictive models to develop/enhance the cascade
Scorecard Assessment/Optimization
Sensitivity analysis & optimization for robustness
Institutionalization
Transfer functions, related tools embedded in SOPs
From DFSS overview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Robustness Engineering
FMEA, P-Diagram, REDPEPR
Design Verification
DVP&R, Reliability Matrix
Checklist Elements
Demonstration of Customer Connection
Objective metrics for CTS items, customer operation related targets
Transfer Functions
Feature block diagram, Interface specifications
Feature / function requirements, System design related targets
Scorecard Assessment/Optimization
DFMEA based requirements
Parameter targets (filtering, interaction timing w/ worst case delays)
Institutionalization
From DFSS overview

Feature Owner Process Steps (1)

- Customer Requirements
  - Develop customer operation related satisfaction characteristics, targets, and specification
  - Identify operation related regulatory, ARL and SDS requirements
  - Leads to Vehicle Level feature operation requirements
  - Tools include:
    - Benchmarking, QFDs, Quality History, SETk/eFDVs, Customer (or surrogate) Clinics, Market Research, HMI simulation
  - Checklist Elements:
    - Critical to satisfaction items, objective metrics for CTS items, customer operation related specifications w/targets

Feature Owner Process Steps (2)

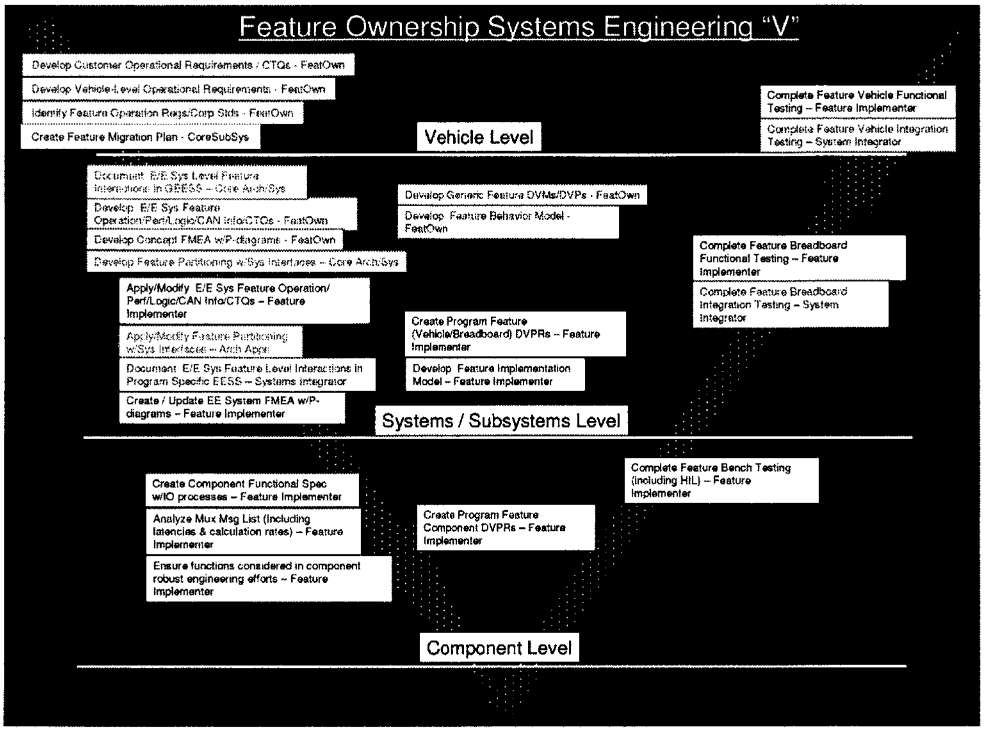
- Requirements Cascade
  - Create feature operation system design (overlay information and control flow on system architecture) w/ functional allocation and boundary diagrams – Interactive with architecture team and SCTs
  - Identify and specify feature interfaces
  - Create functional requirements (transfer functions) w/ associated models
  - Create Concept FMEA w/P-diagrams
  - Specify critical to quality parameters (response times, resolution, sequence)
  - Tools include:
    - Existing design documentation, Block diagrams, Requirements Capture / Traceability Tools, Functional Modeling (Matlab/Simulink), REDPEPR, eRoom
  - Checklist elements:
    - Feature block diagram, Interface specifications, Feature / function requirements, concept FMEA, P-diagram, System design related targets

Feature Owner Process Steps (3)

- Robust Engineering
  - Create Component based functional specification w/IO Process requirements (filtering parameters)
  - Create feature / function DVP
  - Ensure functions appropriately captured in FMEA
  - Develop feature failure management and diagnostics
  - Analyze / update / enhance functional models
  - Tools include:
    - Parameter Design, Tolerance Design, Functional Modeling (Matlab/Simulink), FMEA methods
  - Checklist elements:
    - Component based functional specifications, DFMEA, Parameter targets (filtering, interaction timing w/ worst case delays), DVPs

Feature Owner Process Steps (4)

- Design Verification
  - Complete Bench based testing
  - Complete Breadboard based testing (functional and integration)
  - Complete Vehicle based testing (functional and integration)
  - Develop and Complete VO support testing
  - Calibration process confirmed
  - Tools include:
    - HIL, Equipment identified in DVTs, Breadboard Process, eFDVS, Requirements Capture / Traceability Tools.
  - Checklist elements:
    - Test results, knowledge base updates (SDSs, ESOWS, ESs, CETPs / DVT)



Maturity of Feature – 2 Workflows

- Existing Feature
  - Identify feature owner and best practice
  - Evolve / improve design documentation for subsequent applications
  - Focus robust engineering methods on feature changes / issues
- New Feature
  - Follow new feature definition process (governed by Architecture Group)
  - Use Technology Development process for new features resulting from new technology (governed by Technology Development group)

Feature Owner RASIC (1)

		Cross Vehicle			Program		
Design Phase (from DFSS)	Feature Ownership Task	Feature Owner	Core Arch / Systems	Core Subsystems	Systems Integrator	Feature Implementor	Architecture Applications
Targets from Customer							
	Develop Customer operation related satisfaction characteristic and targets	R	S	A	I	I	I
	Develop Customer operation related specification	R	S	A	I	I	I
	Identify operation related regulatory requirements	R	S	A	I	I	I
	Identify / develop operation related ARL / SDS requirements	R	S	A	I	I	I
	Develop Vehicle Level feature operational requirements	R	S	A	I	I	I
	Create Feature Migration Plan	S	A	R	I	I	I

RASIC Legend

R - Responsible for Deliverable / Action. Has authority

A - Approves of action and/or sign-off

S - Supports the completion of Deliverable / Action

I - Inform - Needs to know of action completed

C - Consult - A stakeholder of the Deliverable / Action

Feature Owner RASIC (2)

		Cross Vehicle			Program		
Design Phase (from DFSS)	Feature Ownership Task	Feature Owner	Core Arch / Systems	Core Subsystems	Systems Integrator	Feature Implementor	Architecture Applications
Requirements Cascade							
	Develop NEW feature operation system design with functional allocation.	R	S	A	I	I	I
	Feature Definition	R	S	A	I	I	I
	Feature Functional Performance	R	S	A	I	I	I
	Feature Partitioning (functional decomposition)	S	R	A	I	I	I
	Operating Modes and Interactions	R	S	S	I	I	I
	Control Logic & Event Triggers	R	S	S	I	I	I
	Specify NEW feature system interfaces	S	R	A	I	I	I
	Specify Feature CAN Information	R	S	S	I	I	I
	Specify Feature Hardwire Interfaces	S	R	A	I	I	I
	Create Concept FMEA w/P-diagrams	R	S	S	I	I	I
	Specify critical to quality parameters (including response times, resolution, and sequence)	R	S	A	I	I	I
	Create Generic DVMs / DVPs (including SETk)	R	S	A	I	I	I
	Document E/E Sys Level Feature Interactions in GEESS	S	R	S	I	I	I
	Apply / Modify EXISTING feature operation system design with functional allocation.	I / A	I / A	I / A	A	R	S
	Feature Definition	I / A	I / A	I / A	A	R	S
	Feature Functional Performance	I / A	I / A	I / A	A	R	S
	Feature Partitioning (physical allocation)	I / S	I / A	I / A	A	S	R
	Operating Modes and Interactions	I / A	I / A	I / S	S	R	S
	Control Logic & Event Triggers	I / A	I / A	I / S	S	R	S
	Specify / Modify EXISTING feature system interfaces	I / S	I / A	I / A	R	S	S
	Specify Feature CAN Information	I / A	I / A	I / S	S	R	S
	Specify Feature Hardwire Interfaces	I / S	I / A	I / A	R	S	S
	Create / Update System FMEA w/P-diagrams	I / A	I / I	I / S	R	S	S
	Analyze / Modify critical to quality parameters (including response times, resolution, and sequence)	I / A	I / I	I / A	A	R	S
	Identify Current DVMs / DVPs (including SETk)	S	S	S	A	R	S

Feature Owner RASIC (3)

Design Phase (from DFSS)	Feature Ownership Task	Feature Owner	Core Arch / Systems	Core Subsystems	Systems Integrator	Feature Implementor	Architecture Applications
Robust Engineering							
	Create component based functional spec. w/ IO processes	S	S	S	S	R	
	Create NEW Feature Behavior Model	R	S	A	S	I	
	Create EXISTING Feature Implementation Model	S		A	S	R	
	Create PROGRAM feature / function DVP (including eFDVS)	I		I	A	R	
	Analyze Mux Msg latency rqmts & calculation rates	S		S	A	R	
	Ensure functions contained in DFMEAs				A	R	
	Develop feature failure management and diagnostics	S		S	A	R	
	Develop VO and Service feature requirements	S		S	A	R	
	Analyze feature/function with functional models	S		S	I	R	
Design Verification							
	Complete feature bench testing (including HIL)	S			A	R	
	Complete feature breadboard functional testing	S			A	R	
	Complete feature breadboard integration testing	S			R	S	
	Complete feature vehicle functional testing	S			A	R	
	Complete feature vehicle integration testing	S			R	S	
	Support VO testing	S					
	Update Feature Knowledge Base	R	S	A	S	S	
	GEESS	S	R	A	S	S	
	SDS	R	S	A	S	S	
	Feature Behavior Models	R		A	S	S	
	Feature Spec. Best Practices	R		A	S	S	
	Feature DVP Best Practices	R		A	S	S	

Feature Owner Process Status

- Feature Asset Identification – Documenting feature owners and best practices
- Feature List Consolidation – mapping of feature partitioning, common schematics, GEESS and feature owner lists
- GEESS Update – Detailing feature operation, partitioning, and interfaces
- Common EE Sys DVP being developed – Feature integration and interaction tests identified and DVTs to be written by Sys. Eng's
- Feature Owner Process Framework developed