Systems Engineering and Project Management, an Ideal Partnership

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Abstract. An effective partnership of the Systems Engineer and the Project Manager on a project will greatly enhance the likelihood that the system will be delivered on schedule and on budget while meeting the needs of the end user. This is a partnership where project leadership is combined, playing to the strengths of each. Systems Engineering and Project Management represent two disciplines fundamental to the underlying success or failure of developing and deploying a complex system. Each of these disciplines has a systematic view of the system, offering each a perspective not afforded to the other development stakeholders. This partnership is paramount on a project of any complexity, how could it be over-looked? Even if these elements alone are brilliant in their own execution, the end result could be a disaster if there is not an alignment and cohesive execution of the two disciplines.

Introduction

Project Management and Systems Engineering are both critical to the success of creating a complex system. Systems Engineering and Project Management are both disciplines that have been well-studied and documented. An effective partnership of the Systems Engineer and the Project Manager on a project will greatly enhance the likelihood that the system will be delivered on schedule and on budget while meeting the needs of the end user. There are numerous books and papers written on both subjects and their many sub-topics individually. In addition, there are numerous papers written about teams, team interactions, and effective leadership. On the other hand, there is little published documentation about the combination of these elements: project management, systems engineering and their combined leadership on a team.

This combination is so critical on a project of any degree of complexity, how could it be over-looked? Even if these elements alone are brilliant in their own execution, the end result could be a disaster if there is not an alignment and cohesive execution of the two disciplines. A cohesive and strategic partnership between Project Management and Systems Engineering can lead to more efficient, effective and successful projects.

To create this paper, numerous Systems Engineers and Project Managers from several medical device companies with established Project Management and Systems Engineering disciplines were interviewed. This informal interview asked these people what kind of Project Management

and Systems Engineering partnerships have they witnessed or been part of that has worked and why. Conversely, they were asked what kind of Project Management and Systems Engineering partnerships have they witnessed or been part of that has not worked and why. From this interview process it became clear that regardless of how a company is structured and what processes were in place, there were similar positive and negative insights that surfaced. These insights gathered from other organizations are included as examples or possible situations and are not attributed directly to a company or organization. In addition to using the observations gathered from various organizations, the model that has been implemented on various projects at Battelle's Medical Device Solutions (MDS) is discussed.

Background. The Project Management Institute (PMI) is the most widely accepted association for the project management profession around the world. The PMI's Project Management Body of Knowledge (PMBOK) defines Project Management as "the application of knowledge, skills, tools and techniques to project activities to meet the project requirements."(PMI, 2004) INCOSE's System Engineering Handbook and ISO 15288:2007 define System Engineering as "an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs."(INCOSE 2008) The objective behind the definitions for these separate disciplines is equivalent. Both discipline's end goal is to achieve the requirements defined for the project. In addition, the tasks that lead up to accomplishing the objective are the same although the role of each discipline would be different. This will be discussed in a latter section in more detail. It would be a natural conclusion then that the most effective affiliation during the course of a project for the Project Manager and Systems Engineer would be a joint partnership.

A stereotypical perspective of what drives a system's development is pictured below in Figure 1. This shows every participant in the process pushing and pulling in a direction that meets their needs or aligns with their point of view. It is joked about and there are cartoons that poke fun at this process. Every person that has delivered a system knows that if the process worked like illustrated below, the system would be a failure and would never meet the needs of all the stakeholders involved.

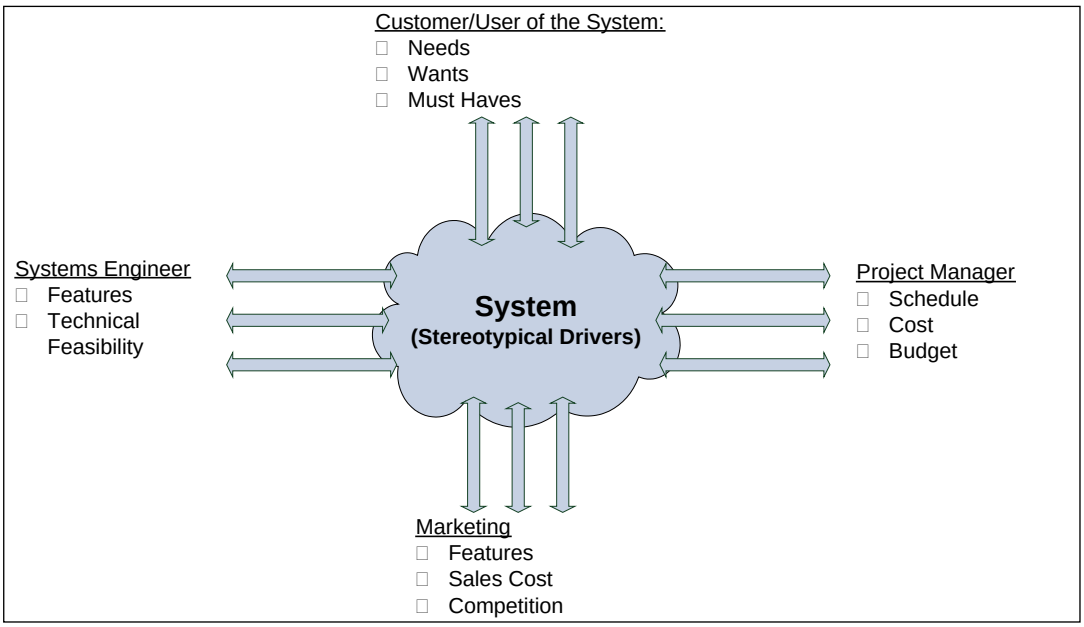

Figure 1 – Stereotypical Drivers

Origin. Battelle's Medical Device Solutions (MDS) team developed this partnership and combined leadership model as part of a project in 1997. This model came about mainly because of the individuals who held the roles of Project Manager and Systems Engineer. The first set of individuals were clearly interested in shared and distributed leadership. Both felt it was critical to be on the same page as each other and accomplished this through constant and quality communication. Each had served as both a Project Manager and as a Systems Engineer on previous projects. Finally, both understood at a high level all the tasks that needed to occur and what their roles were on the tasks to ensure the project was a success for the customer. This model was so effective that it was used on several subsequent projects by the individuals, and thereafter this model was rolled out across the group. The model is shown in Figure 2, Battelle's Medical Device Solutions: Project Accountability Flow.

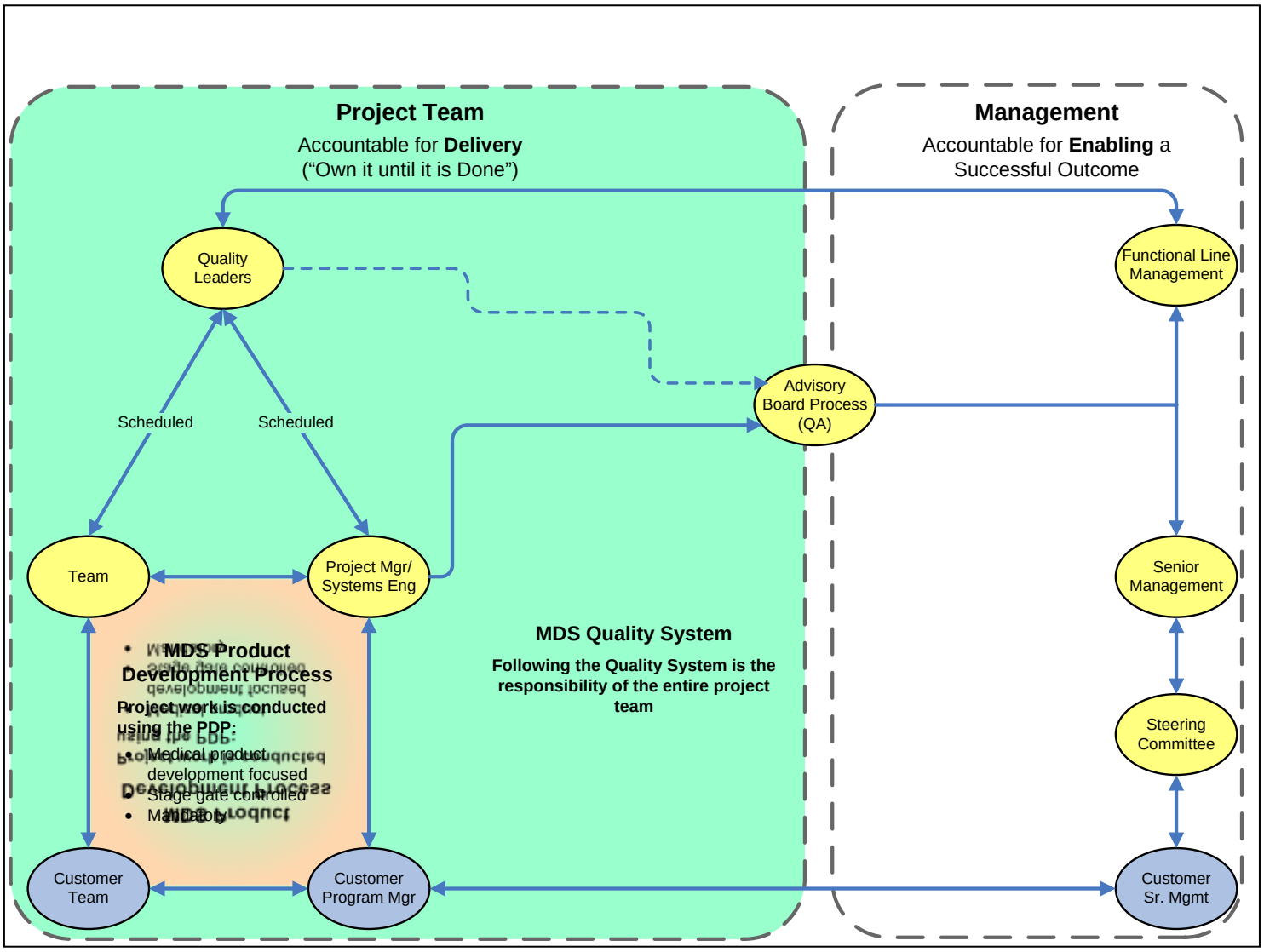

Figure 2 – Battelle's Medical Device Solutions: Project Accountability Flow

The Project Accountability Flow model was developed to capture a process that was individual based, improve upon that process and institutionalize as a process for all.

To understand how this model works, it is important to give background of how these two disciplines are implemented at Battelle MDS. Battelle MDS is a contract medical and product development service provider. The customer is not necessarily the end user or stakeholder, but the company that hired MDS to accomplish their project for them. In MDS, the Project Manager focuses on the customer relationship, helps to provide overall leadership to the project team and has modest depth in the technical space of the project. The Systems Engineer focuses on the interpretation of the customer's needs into the technical design, provides direction and leadership to the team at the system level, and understands how the design fits into the bigger picture. Both the Project Manager and the Systems Engineer are in sync with each other, have the same set of priorities (often are communicated or written to the team) and can "cover" the other. This is represented by the Systems Engineer and Project Manager sharing a common bubble in the model. Even though MDS is a matrix organization, the culture in MDS has been effectively cultivated and developed in such a way that individuals know and understand the importance of being an effective team member when working on a project. To develop a team, MDS co-locates core team members to promote communication and bonding. Teams are encouraged to develop relationships

and trust with each other.

In contrast to this, some matrix organizations keep their discipline teams "siloed." Each discipline would have separate tasks for which they are responsible. For instance, the Systems Engineering group would create a set of requirements which would then be handed over to the design team for design and development. The issue in this example is that the design team likely lacks the knowledge and history of the requirements no matter how well documented or modelled they are. Then when the team reaches the inevitable point when they need to modify a requirement, they may or may not know and understand the implications. Another example is a Project Manager that creates the schedule and drives the team to meet the schedule. Due to this the team might feel pressured to do the "right" thing to meet that schedule; maybe they identify an issue that should be addressed but to meet the schedule they ignore it, or maybe they rush aspects of the design to meet the schedule, or perhaps they ignore the schedule all together. In this case the Project Manager is not leading the project or the team, they are only managing a schedule and the team, separately, is working on their vision of priorities. Another example is a Project Manager focused on the customer, not communicating with the Systems Engineer, and therefore the translation of the customer's needs and expectations is not accurately interpreted by the Systems Engineer and therefore the rest of the team. Here, the design and the system created will probably not meet the needs or expectations of the stakeholders. The "what could go wrong" possibilities are numerous.

The model proposed has the Project Manager and Systems Engineer in leadership positions in the design team. This model is implemented in a manner at some of the companies that were interviewed. A similar model has also been implemented at National Aeronautics and Space Administration (NASA) in their Technical Authority process. In this model the Systems Engineer and Project Manager are separate but equal to ensure safety concerns are not overlooked due to budget. "In February 2006, the agency took a major step and issued an interim policy establishing the organizational independence of technical authority from programs and projects. As a result the lines of technical authority were now independent from, yet equal to, the programmatic lines of authority." (Andary, 2008) This was later codified. In addition to the clear benefit of separate channels to ensure safety needs are met, there are other advantages. These are discussed in latter sections.

For the model proposed herein, the interactions and project activities are outlined in Figures 3 and 4 below. In this model, both the Systems Engineer and the Project Manager are separate leaders of the project development team. The Project Manager working with the Systems Engineer develops the project charter outlining the big picture of what needs to get done but not how to do it. Then, as leaders of the team, they are responsible for carrying out those goals to completion through overseeing the execution and leading the project to its end. The day-to-day intended interaction with the project development stakeholders (Interdisciplinary Team, Quality Oversight, etc.) is based on their roles. However, the Systems Engineer and the Project Manager are aware of each other's current activities and issues. Both are skilled to assist the other in their activities or temporarily manage them. Both are aware of the bigger picture and can make decisions. At the core of the model is constant honest communication and trust in one another.

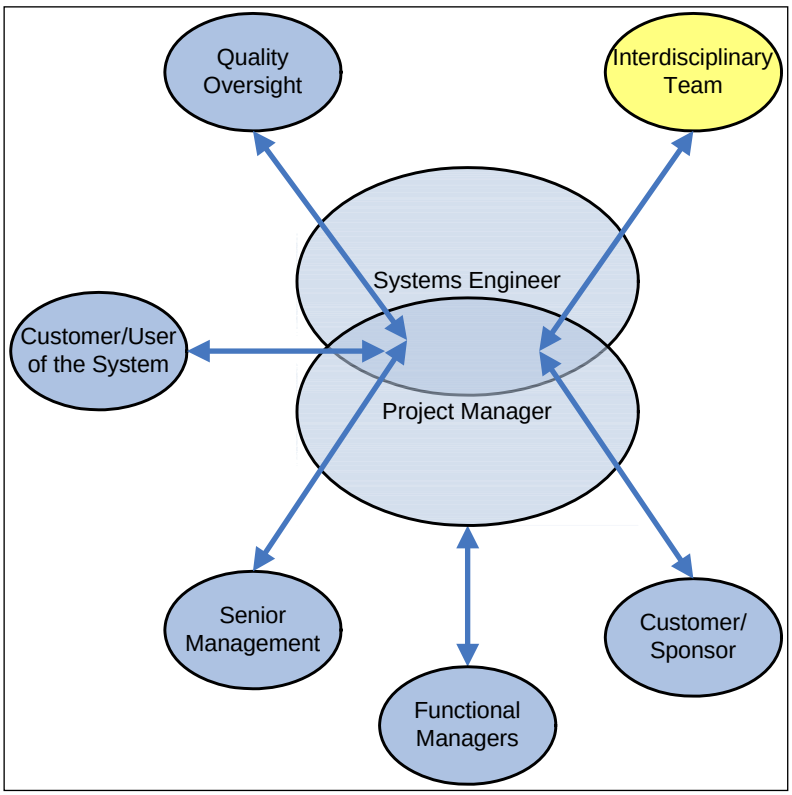

Figure 3 – Leadership Responsibilities of Systems Engineer and Project Manager

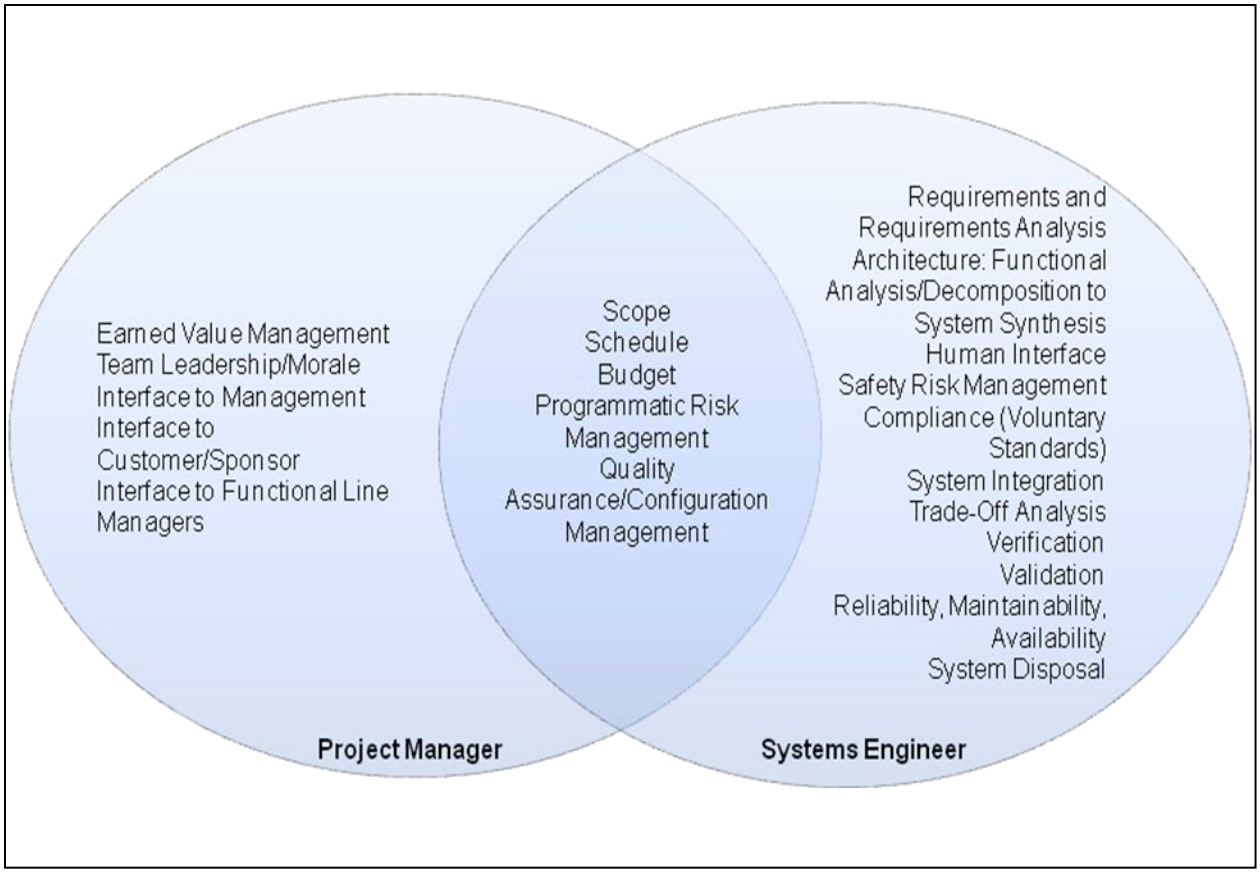

Figure 4 – Systems Engineer and Project Manager Responsibility

Benefits. There are many benefits from having a Systems Engineer and Project Manager partnership. These are summarized and described in detail below:

- Improved Effective and Efficient Project Execution
- Augmented Program Level Coverage
- Distributed Leadership
- Multiple, Capable People to make Program/System Level Decisions
- Broader Perspective
- Shared Defeat for Risky Decisions
- Shared Glory for Risky Decisions
- Inexperience and Shortfalls in an Individual can be Balanced
- Multiple Individuals on Leadership team to Maintain Focus on Project

The greatest benefit is the improvement in effective and efficient project execution. Every benefit that is discussed below contributes to the overall improvement in carrying out any project.

One benefit, stately simply, is that two heads are better than one. The intent of this model is not so the Project Manager is only a domain expert in the program management of the project and the Systems Engineering is only a domain expert in the Systems Engineering tasks of the project. The intent of this model is that both the Systems Engineer and the Project Manager know and understand *enough* about the other's tasks while still being responsible for the completion of their own tasks. So that in the absence of one there is still commonality and confidence in the leadership of the project to the rest of the interdisciplinary team and the customer. The benefit here is to augment program level coverage. For any issue or challenge that arises, there are two sets of eyes and ears in the core leadership of the project, which has the big picture to help the technical team tackle the challenge. For most significant conversations—whether they are with the customer or the technical team—the two are present to help clarify, ask questions, or recall the conversation later.

This benefit can also be called distributed leadership. Both the Systems Engineer and the Project Manager can make decisions, represent the other in a situation, and together, discuss challenges which will lead to an improved and more fully developed resolution. Both comprehend the big picture and are capable of contributing to or making a fully informed program level decision. Why? Because they are in constant communication, they both understand the big picture, the true needs of the customer and the user of the system.

Regardless of who is in each role, both the Project Manager and the Systems Engineer have their own perspective and areas of expertise. This collective broader perspective is of applied benefit to the project. It can be applied to major decisions, technical trade-offs, and programmatic challenges to make the resolution more complete and informed.

Distributed leadership could positively lead to a more aggressive solution in some situations

because the load and the management of the decision can be distributed across two people. This can be the exact factor a project might need to be a success. Regardless of whether a decision is aggressive or conservative, two fully informed people have deliberated and will share the potential risk and reward.

Ideally, every Project Manager or Systems Engineer will be experienced, talented, a clear leader with all of the attributes which are discussed later, but this is not always the case. Systems Engineers and Project Managers are not created with the perfect set of skills and experience for every project. In addition, people are flawed and will have both strengths and weaknesses in their character. A partnership can be setup to balance or reinforce limitation. For example, a newer Systems Engineer can be paired with a more experienced Project Manager or vice versa. A Project Manager who thinks the "glass is half empty" can be paired with a Systems Engineer who thinks the "glass is half full." The benefits of this are clear; of course, there is a negative aspect of this which will be discussed later.

The last benefit is that there are two leaders to keep the project focused and driving to closure. It is so easy, even for project leaders, to be working on a problem or task and to get caught up on aspects that are off track. If one gets off track, the other can bring back the focus to the necessary tasks at hand. The Project Manager and the Systems Engineer are *both* responsible for executing a project to closure. They use the project charter as their roadmap; working together, they lead the project to completion.

Attributes. How can this work? What kind of person should the Project Manager and the Systems Engineer be? Table 1, Key Leadership Attributes outline a description of the key attributes, regardless of the culture of an organization, that are needed for these leadership positions. Thinking through and understanding what these attributes are for a position is crucial to developing and hiring the appropriate talent.

Table 1 – Key Leadership Attributes

Key Leadership Attributes	
Ability to Tack	Leadership
Alliance Management (Client Life Cycle)	Leading through Vision and Values
Assertive Communication	Legal/Contracts
Buffer the Team (Internal and External)	Listening
Building Trust	Management (Numbers)
Carry the Flag	Medical Product Development
Collaboration	Mentoring
Conflict Management (Interpersonal)	Motivating Others

Key Leadership Attributes	
Continuous Learning	Need of Oversight
Crisis Management	Optimism/Inspiration
Customer Service	Ownership
Deal with Ambiguity and Paradox	Preparing for Future (Vision and Management of Vision)
Delegation	Quality Systems
Don't reinvent the wheel; personal and team	Risk Identification and Management
Evaluate and Act (Decisive)	Safety Awareness
Expectation Management	Sales Ability
Experience	Sense of Urgency
Facilitate Change	Set Direction
Influence/Negotiating	Share Key Knowledge
Information Security	Systems Engineering Knowledge
Initiative	Work Standards (High)
Intellectual Property	

Figure 5, Venn Diagram of Overlapping Systems Engineer and Project Manager Attributes, shows those attributes from Table 1 that need to be common between the two. These common attributes have been learned from over 10 years of applying the model in Battelle's MDS team. The common attributes specific to a given organization need to be identified and recognized, then developed and continually nurtured. Hard lessons were learned when this did not occur.

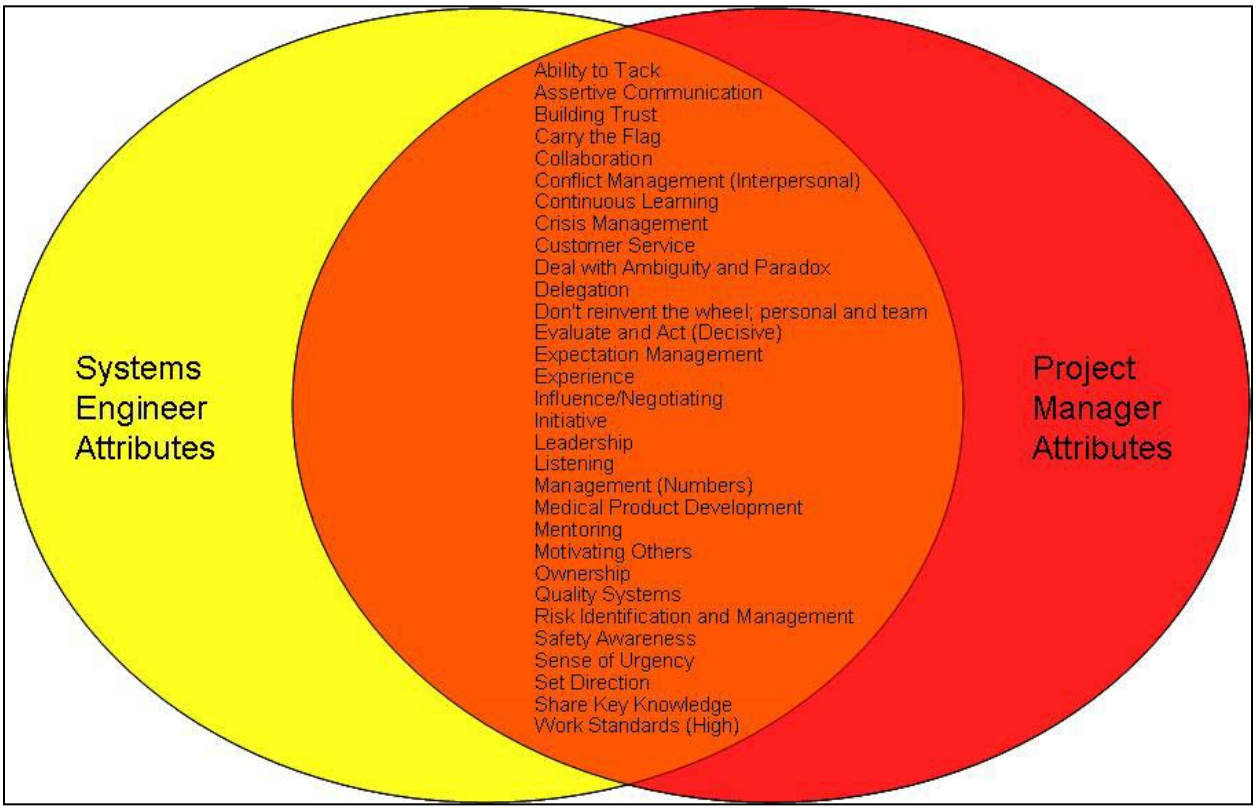

Figure 5 – Venn Diagram of Overlapping Systems Engineer and Project Manager Attributes

Challenges/Struggles. There are challenges to this model (also known as lessons learned). These are summarized and described in detail below:

- Each individual must be vested by senior management on the project.
- Dominant personality of one overpowers the other.
- Two bosses.

One of the challenges is that both the Systems Engineer and Project Manager need to be vested by senior management on project. To be able to effectively maintain awareness of the project, both individuals need to have a majority commitment to the project. The model has not shown to work well when either the Systems Engineer of the Project Manager is less than 50% time on the project. Based on observations it was found that inefficiencies arose because the communications were less direct and non-real time. In addition, the focus of the individual in the <50% role often was to the project with the greater time commitment. The combination of these two observations led to establishment of guidelines for project resource staffing as well as a cognizant awareness by senior management of these assignments.

Distributed leadership requires the personalities of both the Systems Engineer and the Project Manager to be able to share responsibility, communications and the leadership for the program. If

either person has a dictatorial personality then this model will lead to inconsistent decision making, potentially poor and inaccurate inter-team communication, potentially poor and inaccurate communication to the customer, conflict and countless other potential issues.

Another disadvantage to a domineering personality is that the less dominant person might not become engaged in the project. Perhaps the more dominant personality doles out menial tasks instead of challenging and engaging the other team member. In this case, the less dominant personality is disconnected and is not challenged. In this case, they might not care about the success of the project because they don't feel responsible for its outcome. If this is the case, something crucial will most likely be missed and the project could be in trouble.

This challenge has been addressed via the use of personality assessment tools (Meyers-Brigg Type Indicator, Profiler 360°, in-house developed), team building exercises (Forte Communications Style Survey, in-house developed), and relationship counseling for the Systems Engineer and Project Manager. In addition, senior management once again maintains a cognitive awareness of the individuals, their strengths and weaknesses, and their relationship compatibility when making resource staffing assignments for the project leadership.

Another challenge is the possibility of "two bosses". If the Systems Engineer and the Project Manager are not in constant communication, and if clear roles and responsibilities are not defined, then the team can be given conflicting direction and guidance. This leads to confusion, wasted time and energy, irritation and stress on the team, and possibly a bad end result in the project. Communication is the key to utilizing this partnership effectively.

Elements in place to use the model. The benefits of using this model are clear. This next section outlines what must be in place for the model to be implemented.

- Project Manager that believes in Systems Engineering.
- Systems Engineer that believes in Project Management.
- Voices of Equal Weight.
- Shared Vision of the system, execution of the project.
- Balance between a rigid system with clear roles, responsibilities, structure and flexibility to allow forward momentum.
- Open, honest, and constant communication.
- Trust and faith.

First, to implement this model both the Project Manager and the Systems Engineer must understand and believe in each other's discipline. If this is not the case then it will be difficult for either to be effective in their roles. The rest of the team could also perceive this phenomenon and this could influence their perception and lead to ineffective leadership and management of the team.

Second, each must have a voice of equal weight. To realize the benefits from a broader

perspective, augmented project oversight and having multiple people to make project decisions each leader's voice must be heard as much as the other's. Of course, each leader must be capable of listening to each other, putting aside their egos, coming to a consensus decision that is best for the project. Having voices of equal weight will lead to lively discussions, but in the end if each individual remembers that they both want what is best for the project, then the right decisions will most likely be made.

The Project Manager and the Systems Engineer must have the same vision for the project and its execution. This vision needs to be established early on in the project, even prior to the project kick-off. Aspects of their shared vision, once formulated, can become part of the project charter. The charter can be presented at the project kick-off and talked through with the rest of the team so the project starts off on the right step.

When employing this method, clear roles and responsibilities must still be established on the project. For example, the Project Manager is responsible for the schedule and the Systems Engineer is responsible for the product requirements. Neither is created in a vacuum, but clear ownership of the work product has been established. Regardless, there is a balance between ownership and keeping things moving forward. If the Project Manager goes on vacation for two weeks, the Systems Engineer should be capable of managing the team to the schedule and making any adjustments as necessary. This was one of the previously discussed benefits of this model and the project infrastructure should be designed so it allows for this flexibility.

At the core, the model requires open, honest and clear communication between the Systems Engineer and the Project Manager and this requires trust and faith in one another. For each to be capable of making effective decisions they need to be kept informed of each other's activities. To make decisions together, they must be able to speak to each other honestly, with the whole truth. This trust also requires faith in each other's abilities and each other as a person.

Conclusion

A successful project can be accomplished in many ways. However, in the current economic climate and competitive environment, every efficiency that can be gained is a benefit to an organization. The method described in this paper can improve project execution. The benefits of this technique are distributed leadership, it can balance inexperience or weakness, it uses a broader perspective to make decisions, it augments program level coverage and the glory and defeat from risky decisions are shared between the partners. This is accomplished by a Project Manager working in concert with a Systems Engineer. Each leader trusts in the other and remains in sync through constant open and honest communication. This approach can lead to a more effectively managed, cost effective project.

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Biography

David J. Jones is an Engineering Manager with Battelle’s Health & Life Science’s Medical Device Solutions group, where he manages the system, electrical and software engineering staff and processes for medical device development programs. His 29 years of experience in product development includes 17 years as a project manager and systems engineer. He has led the development of a wide variety of electro-mechanical-software medical devices. Mr. Jones received a B.E. in Electrical Engineering from Youngstown State University in 1980. Mr. Jones has been a member of INCOSE since 1994 and is a member of the Regulatory Affairs Professional Society.

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