Boeing Dreamliner:
A Project Management Study

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Abstract

The 787 Dreamliner aircraft project required not only the application and integration of new construction materials, it also required new project management techniques for Boeing. By outsourcing most of the aircraft fabrication, Boeing's primary role changed from designer and manufacturer to system integrator. Hindsight shows that more preparation and planning was needed for this transition. This case study review of the Boeing Dreamliner examines the project management techniques actually employed during the initiation and execution phases of the project. Techniques evolved from the start of the project to what is used currently. Best practices and recommendations for how a large-scale outsourced project could be managed are described. During the initiation phase, Boeing decided to outsource both design and manufacturing. Outsourcing core competencies is a risk to the main contractor's design and manufacturing edge. The authors recommend selecting those subcontractors with a five step plan, based on selection criteria and culminating with clearly defined expectations. Boeing's selection was strongly based on cost and market access, and the subcontractor understanding of work expectations initially differed from Boeing's. It is important to work closely with subcontractors when advanced technology and key components are at stake. Boeing is doing this now, more effectively than at the start. Regular monitoring and control has improved as the project has progressed. Finally, delays and issues show after the fact that Boeing's early work would have benefited from more robust risk management methods. Risk management techniques are discussed as are improvements Boeing has implemented currently.

Introduction

Objectives and Approach

The authors examine project management (PM) practices for subcontracting in large, complex, multiple subcontractor projects. The Boeing Dreamliner is the case study for this analysis. The paper looks at initial and current Boeing Dreamliner PM subcontracting methods, and makes recommendations for best practices to improve success. The authors studied sources from literature and their interview with John Phillips, Deputy Chief Engineer for Flight Test and Lab Test 787-9. Practices are examined by stages of the project life cycle as described below.

Project Phases

This project life cycle model has three phases, as modified from references [1] and [2] and shown in Figure 1 below:

- Phase 1: Initiation
- Phase 2: Execution
- Phase 3: Evaluation and Termination.

In this initiation phase, the idea for the project is conceived, the project is selected to fit in with the strategy of the company and with the company's portfolio of projects, and planning occurs. The original project conception is outside of the scope here. Some insight into project selection is below in the Dreamliner background. Planning and other aspects of initiation relative to subcontracting are the focus in the report's Phase 1 section. In certain models, planning is a member of the next phase of the project, execution. Phase 2 here covers monitoring and control of the project. Risk management is part of the Phase 2 discussion though it also has planning aspects. Evaluation of the completed project's success and termination procedures are the final, third, phase. This last phase is not yet applicable for the Dreamliner.

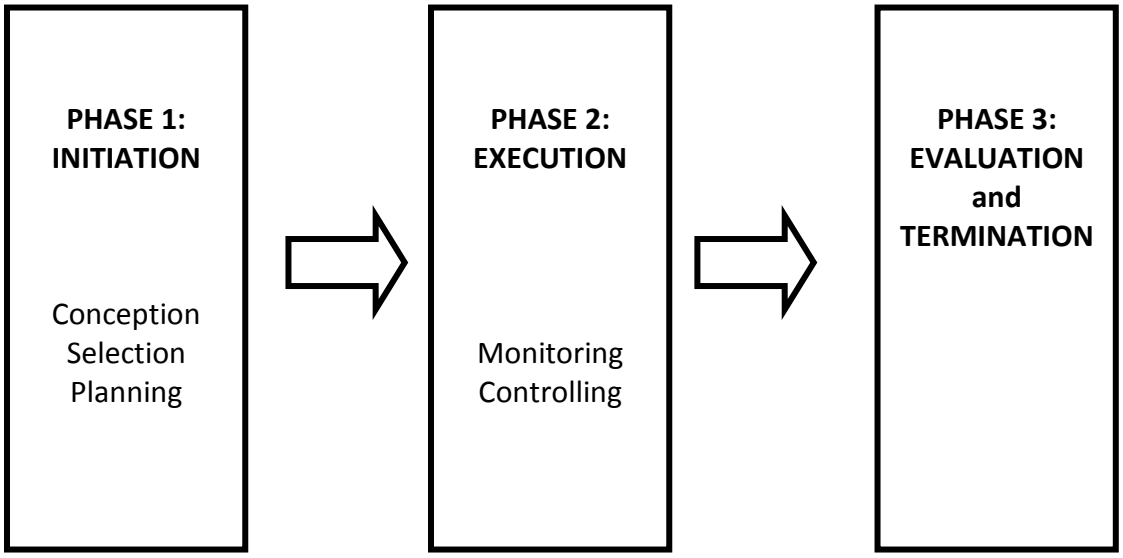

Figure 1: Life Cycle Phases of a Project.

Dreamliner Background

The Dreamliner was selected to give Boeing a significant technological edge in the marketplace to regain market share vs. its rival, Airbus [3]. The Dreamliner will be "the first passenger plane to be made mainly with light plastic composites" [3] instead of the usual aluminum.

This aircraft not only departed from traditional commercial plane building materials, but also introduced a new way in which the aircraft would be built. Previously, Boeing did most of the engineering design and relied on multiple subcontractors to build parts. These parts would all be assembled in the company's manufacturing headquarters in Washington State. To reduce risk [3], cost, and assembly time, the Dreamliner relied on over 900 subcontractors [4] not just to supply parts, but also to perform some of the aircraft's design and assembly. Boeing positioned itself as a large-scale system integrator [Appendix].

Originally heralded as an intelligent move, the result of this plan has resulted in long delays for the yet unreleased aircraft. Announced schedule delays became ongoing starting in January 2008, shown in Figure 2. Currently, the initial flight delays of the Dreamliner are 28 months behind schedule with an estimated project cost overrun of $2.5 billion [5]. At the same time, the Dreamliner is still the most successful plane to date in terms of its approximately 850 advance orders [3].

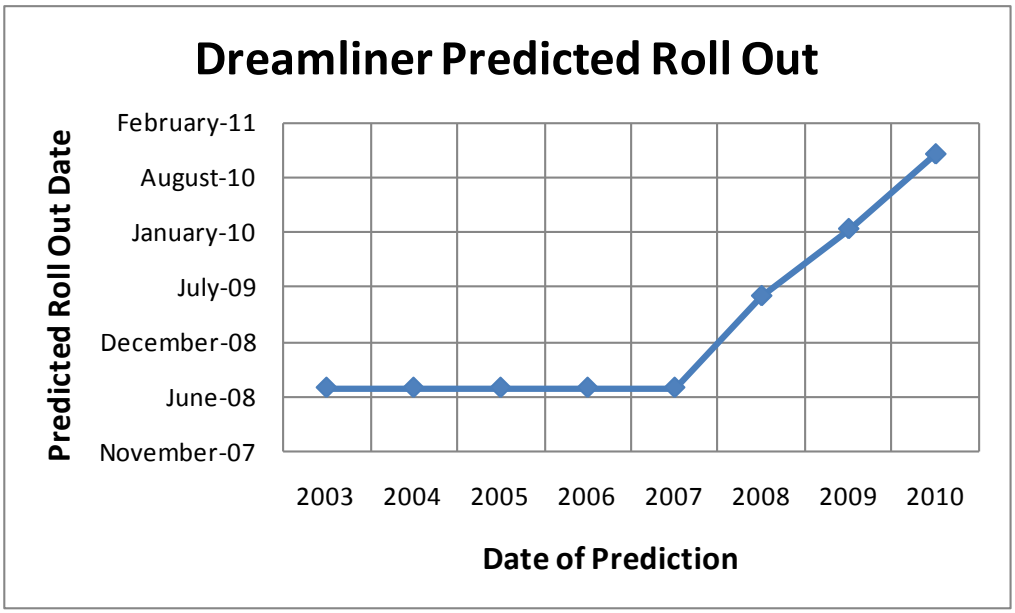

Figure 2: Dreamliner Predicted Roll Out vs. Date of Prediction from [6-13].

Boeing's Reasons for Outsourcing

The common driver for outsourcing manufacturing is to reduce operating costs, such as with the Boeing Dreamliner case. The cost of designing and building the aircraft was estimated to be in the billions of dollars. But the reasons for outsourcing go beyond the savings of operating costs. They include: introduction into new markets, sharing product development risks and leveraging technology competencies to gain competitive advantages.

First, in order to sell the Dreamliner in new global markets, Boeing would need to have a presence in those countries. Boeing had originally outsourced some of the development of the

767 to Japan in order to gain market access. This trend continued for the development of the 777 and the Dreamliner. Boeing's project plan for the Dreamliner includes the entire wing structure for the aircraft to be built by Japanese companies [14].

Second, when outsourcing certain activities, the risk associated with those tasks are shared. In some cases, a company that does not have experience in a certain activity can alleviate their risk by outsourcing to a subcontractor that specializes in the field. Not only are the development risks transferred to the outsourcing subcontractor, but the development risk is marginalized.

Third, the Dreamliner aircraft was designed to use composite materials which would make the plane lighter and more fuel efficient. Boeing did not have the manufacturing expertise in-house to build the parts and outsourced in order to quickly gain these manufacturing technologies without increasing their own research and development costs [15]. The downside to acquiring technology using this strategy is Boeing never actually controls the competency unless it eventually buys the company. This makes Boeing dependent on their outsourcing companies in order to develop their core company goal – the manufacture of aircraft.

Ultimately, it is important for a company to focus on their core competencies and whatever helps them gain a competitive advantage in their marketplace. Activities not directly tied to the company's core competencies can be outsourced to specialized subcontractors who have gained competitive advantage for those activities [16]. This result should be a product that has greater quality, innovation and value to the customer [15].

Phase 1: Project Initiation

Introduction

Three aspects of this complex project relative to the initial phase are discussed and evaluated below. First, Boeing made a trade off by outsourcing some of its manufacturing core

competencies. Second, selecting subcontractors is vitally important when a project is heavily reliant on them. Third, issues of planning with subcontractors are examined.

Outsourcing Manufacturing Core Competencies

When outsourcing manufacturing, access to manufacturing knowledge, fabrication techniques and material expertise by product designers will be more difficult resulting in designs for less producible products [16]. This is especially the case when processing and new types of materials and their application is concerned, as with Boeing's Dreamliner.

Design for manufacturability (DfM) or Design for Assembly (DfA) recommends that there be partnership between the product development team and the manufacturing team [16]. Complex products rarely go through a single design iteration, as manufacturing and material constraints introduce design tradeoffs. The recommended process entails the cooperation and input from the two teams until a feasible design is drafted as shown in Figure 3. This cooperation is best facilitated through a partnership.

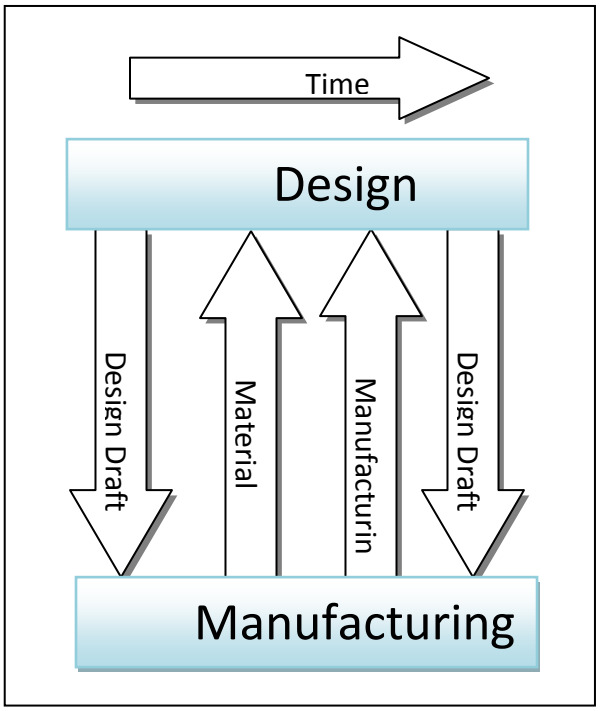

Figure 3: Interactions between design and manufacturing.

As described in this paper, the aspects of a company that establish its competitive advantage are its core competencies. So when outsourcing manufacturing, it can no longer be considered a core competency because it is being completed outside of the company. In addition, that beneficial relationship between manufacturing and design is lost. This is particularly important for products representing a significant step in technology due to the uncertainties involved. Dankbar states that "outsourcing of manufacturing is not an option if a company is planning to remain actively engaged in more than just incremental product development." [16]

Recommendations

Boeing has outsourced 80% of the manufacturing of the Dreamliner [17] and with that goes the manufacturing knowledge that is required to design and build aircraft. By giving up these core competencies Boeing is moving from being an aircraft builder to being a systems integrator, which shifts the design and manufacturing knowledge to companies outside of Boeing and the United States where they may be helping other companies into their competitive market [14]. It is important for Boeing to outsource aspects of the Dreamliner project to other companies for reasons detailed in the previous sections, but Boeing is doing so at the risk of losing competitive advantage in the marketplace.

Maintaining a greater share of the manufacturing of the aircraft, Boeing will retain the manufacturing know-how and gain experience working with the new materials that will be crucial for future aircraft designs. Likewise, this know-how will increase the level of manufacturability in their designs thus providing better input to their outsourcing subcontractors while retaining their core competencies and their competitive advantage in the marketplace.

Subcontractor Selection

The beginning of any outsourcing endeavor begins with the selection of a subcontractor. Often, this selection process has put too much emphasis on reducing operating expenses and costs [16], but other aspects including the subcontractor's reputation in the industry, alignment of strategic goals, and quality controls are necessary to be successful [16][18]. Such a relationship requires investigation and due diligence before making the decision on whether or not to outsource. Before entering into such arrangement, some suggest answering the following questions [15]:

- What is the problem that we are trying to solve?
- What is our long term strategy?
- What are our alternative solutions
- Why is outsourcing good for the company?
- What is the level of maturity or experience of our company in regards to outsourcing? Is the company risk averse?

The importance of choosing the appropriate subcontractor is paramount to the company. The decision makers must also take into account the aspects of the business that will be outsourced and how it impacts the core competency of the company. Once deciding to outsource an activity, it is very difficult to reverse that decision because the costs of regaining that competency are extremely high [16]. The loss of competency might also affect the company's competitive advantage in the market place and introduce a reliance on a third party that may reduce the company's bargaining power [15].

A company has an organizational mission and goal that drives it in a certain direction. When outsourcing an activity of the company, it is important that the partner shares these

same goals [16]. Both companies within the partnership will then share the same position in a competitive market and the success of one company will help the success of the other.

Next, when selecting a subcontractor, a company can also decrease the overall subcontractor costs by choosing one that shares a strategic goal. This has a two-fold impact on the relationship. First, the outsourced subcontractor will not have to re-tool or re-configure their processes to align themselves with the company which will reduce integration time within the execution phase of an outsourcing relationship. Second, choosing from multiple subcontractors that work within a specific market creates a competitive environment from which the company can evaluate the different subcontractors, hopefully concluding in a more cost effective solution.

Recommendation: VENDOR Selection Approach

One process for subcontractor selection is the VENDOR approach [18]. This approach separates the subcontractor selection activity into five different stages shown in the "Partnership Pyramid" shown in figure 4. This structure allows the decision makers to go through the process of identifying the problem, evaluating the options and executing on the decision to ensure that the best possible decision is made.

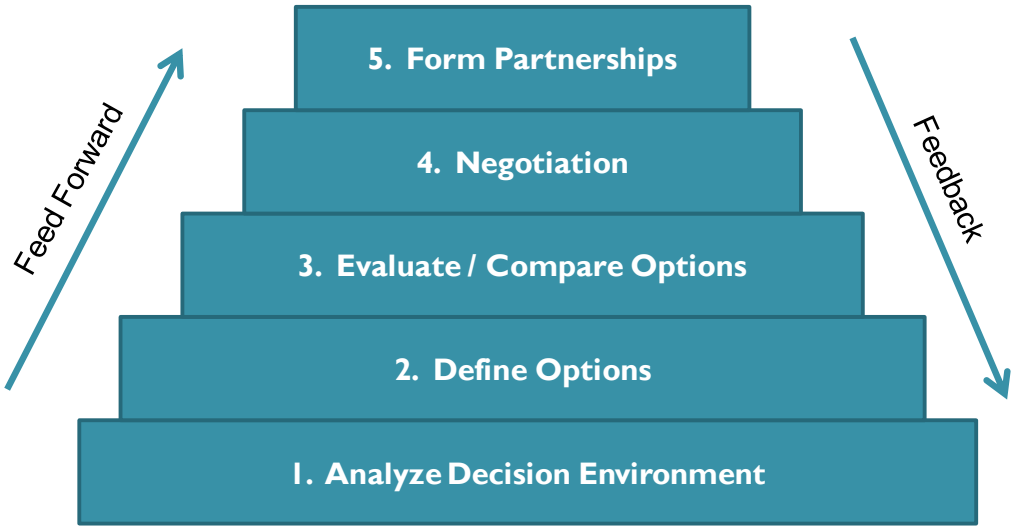

Figure 4: Stages of the VENDOR approach.

Another aspect of the "Partnership Pyramid" is the inclusion of feedback and feed-forward. Each stage is dependent on the preceding one and the information gathered in one stage can be used to revisit the previous stages or be used to drive the processes defined for the next stage.

Boeing's actual subcontractor selection criteria considered cost, technical expertise, and geographic area [Appendix]. That is, a lower cost subcontractor and one in a geographic area where Boeing hoped to gain a share of the market was desirable. Judging by the technical problems experienced with many subcontractors, technical expertise does not seem to have been heavily weighted in the selection process. A more robust method such as the VENDOR approach may have resulted in better overall selection.

Stage 1: Analyze Decision Environment

In the first stage, the company considering outsourcing work needs to understand the internal and external environments for which their decision will be a part. Defining the internal environments entails identifying the stakeholders, understanding the demand for the services, define quality and performance standards and finally specify the selection criteria. To understand the external environment for the decision, the company must understand the legal and regulatory constraints that exist, the capabilities of the possible subcontractors and how the subcontractors will be rated per the defined selection criteria. The criteria and importance of this stage is described in the subcontractor selection section above.

Stage 2: Identify Options

It is suggested that the data gathered during Stage 1 be fed forward to help identify which of the subcontractors in the market may be able to meet the company's needs. Operational Research techniques are recommended, such as linear and multi-objective programming in order to determine the feasible options. The results of such computations not only frame the decision problem and criteria, but also provide sensitivity and "what-if" analysis.

Stage 3: Evaluate and Compare Options

This is the most difficult of the stages due to a possibly high number of stakeholders and opinions that may be involved in the decision process. Using models and tools during this stage

can help to minimize gut feeling and emotional decisions. It is recommended that using tools such as Data Envelop Analysis (DEA), Decision Support Systems (DSS) and SWOT analysis help to analyze and compare the options [15]. It is important to note that using such decision tools suggests that there is more to making the decision than choosing the lowest cost solution. In order to create a successful relationship the decision criteria defined in the first stage need to be addressed.

Stage 4: Negotiation

Negotiation is an important step to not only reduce costs, but also to help align the subcontractor and the company to a singular goal. A subcontractor that may not have addressed the company's needs may be willing to change their processes or vary their performance to better meet the decision criteria specified in stage 1. This step may involve sending out Request for Proposals (RFPs) to the available subcontractor options to be reviewed by the stakeholders [15]. Once negotiation is complete, the company may revisit one of the earlier stages to update their decision criteria or re-evaluate now that the different subcontractor options may have become a more or less attractive option compared to the other options.

Stage 5: Form Partnerships

After going through the VENDOR process, the result is a decision based on clearly identifying the needs of the company and the performance and capability of the subcontractor providing a win-win situation. One key point is that the result of this stage is a partnership, not the acquisition of a client.

The basis for forming a partnership with the selected subcontractor is the Service Level Agreement (SLA). An SLA goes beyond a contract by identifying measurable activities and metrics, documenting expectations, workflow processes, communication exchange and the process for reporting and resolving issues [19]. This stage is explored in more detail in the section below.

Planning for Manufacturing Partnerships

Initially, Boeing's subcontractors received a statement of work (SOW) with minimal thought to whether or not it was understood by the subcontractor or to subcontractor management. Boeing was not used to having to define requirements in as much detail as needed for subcontractors. When engineering and manufacturing were in-house the relationship was more of a partnership, since both groups were part of Boeing and both were aligned to a specific goal. Requirements could be less well-defined due to a built-in safety net. That is, design engineers and builders were in close physical proximity which provided easy methods for information exchange. [Appendix]

For the Dreamliner project, manufacturing was outsourced initially without much thought of the communication needed between design and manufacturing. Many of these relationships were expected to operate in a "throw it over the fence" method: meaning that once a design was completed, the expectations were that designs would be given to a subcontractor who would eventually deliver the final part which would then be integrated [Appendix]. When entering an outsourcing relationship, there are different types for each type of subcontractor.

Relationship Levels When Outsourcing

Applying supplier management practices, when outsourcing, may not be applicable in all situations. How closely an outsourced subcontractor's output aligns with the company's core competency dictates the level of trust and responsibility shared within the relationship. These levels of interactions can be organized into three zones: Partnerships, Network Member and Market Supplier [20]. Figure 5 shows that depending on the outsourced subcontractor's contribution to the core competencies of the company, the level of interaction and focus on knowledge sharing changes.

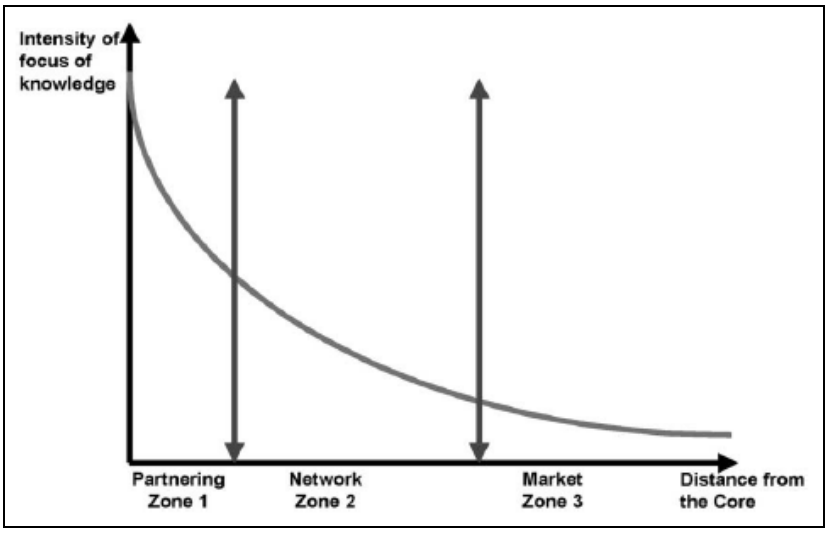

Figure 5: Relationships with outsourced subcontractors change with the distance from the company's core competencies [20].

The first zone represents relationships where the outsourced subcontractor supplies key, high-value components for the company. For the Dreamliner, Boeing outsourced many large components, such as the wing and fuselage sections of the airplane to be developed by other companies. These items are clearly high-value components and their design is closely aligned with the core competitive advantages of Boeing's marketplace. In a partnership, the two companies share capital expenditures, transfer of personnel and investments in research and development [18].

The Networking zone is employed when a company needs to acquire a technical expertise that is not already in-house. This type of relationship still requires interaction between the two companies, but not at the level described for the Partnering zone. While technical knowledge is shared between the two companies, there is an understanding that each company has the goal of extending their technical expertise in their specific area to generate greater innovation and competitive advantage in their space, resulting is a better final product.

The Market zone describes the basic supplier relationship and the outsourced company does not have any needed specific technical knowledge. This relationship is commonly used to

acquire standardized products and is usually formed through a contract. Little or no technology transfer occurs in such a case.

Recommendations

At the beginning of the project, Boeing's management of outsourcing subcontractors was simply to draw up designs for the different components and give them to the subcontractor. The overall plan was for Boeing to take the role of a product integrator, leveraging the expertise of the outsourced companies to apply their best practices in regards to completing the design and delivering the product. The problem with such an application is that the high-value components and level of complexity lends itself to needed a partnership, though Boeing was treating the interaction as a supplier relationship.

As the Dreamliner project was delayed, and inefficiencies and issues with the delivered products became obvious, Boeing understood a different level of interaction was required. They realized that their outsourced subcontractors needed to be treated as partners instead of suppliers and made an effort to improve the technology transfer and communication. Such was the case when Boeing purchased Vought Aircraft, which was responsible for the development of parts of the fuselage [17]. Vought Aircraft was one of the bottlenecks in the development of the Dreamliner and resulted in Boeing taking back some of the essential manufacturing work.

Also, Boeing learned as the project went along to improve communication on the SOW and to implement risk planning. Now, Boeing reviews subcontractor plans and comes to agreement with them on the work that needs to be done.

Phase 2: Execution

Introduction

The execution section considers monitoring and controlling of the project. Based on information from monitoring, the project can be controlled to keep on schedule, within budget, and to meet performance requirements. Clearly, good practices in this area are crucial.

Relative to the Dreamliner case, a discussion of these subjects and recommendations are given below.

Monitoring and Controlling

At Boeing, subcontractor work was not monitored carefully at first. Upper management believed that subcontractors were fully in charge of their own work. That is, subcontractors needed virtually no supervision to fulfill the requirements and that requirements specified by Boeing were sufficient to obtain what was needed. Unfortunately, the work may have been new to the subcontractor and the Boeing requirements were not clear enough or stable enough to obtain needed performance as originally given [Appendix].

The project management plan is the ideal baseline from which to build monitoring and controlling methods for the project. The objective is to evaluate how well the project is doing relative to key performance issues with enough time to have the ability to make needed adjustments. Keep in mind that each project management plan differs depending on the status, degree of risk, size and complexity of the project. The Boeing Dreamliner 787 is a large and complex project that needs to have a very detailed and well-thought-out project management plan. As given in [2], the monitor and control project work process includes:

- Comparison of "the actual project performance against the project management plan."
- Continuous performance assessment to identify which "actions are indicated and then recommending those actions as necessary".
- Monitoring and evaluating project risks to insure the risks are indicated, reported, and a suitable risk action plans are being executed.
- "Maintaining an accurate, timely, information base" regarding the "projects' product(s) and their associated documentation" throughout the project.

- Giving the appropriate information that "support status reporting, progress measurement, and forecasting"
- Assisting in updating the "current cost and current schedule information" by providing appropriate forecasts.
- "Monitoring implementation of approved changes" as needed [2].

Reference [21] advises spelling out monitoring and controlling expectations in the subcontractor SOW. Methods may include "regular conference calls, regular progress reports, on-site meetings at the subcontractor's facility", and problem reporting where status differs from plan [21].

Recommendations

As above, the authors also recommend specifying monitoring and controlling methods in the initial SOW. Both the type and frequency of measurements should be stated. These would need to cover measures for schedule, cost, and performance measures which are examined at high enough frequency to correct problems. Regular meetings to discuss status and additional on-site meetings should be covered. Processes to tag problems and bring them to the main contractor attention should be included. Although not done with the initial SOW, Boeing's later subcontractor strategy meets these requirements.

Boeing learned as the project progressed to improve its review of subcontractor execution. Now, the company makes site visits to examine the work [Appendix]. In fact, in 2007, "Boeing says it recently added additional project engineers, who were brought from other divisions of the company and will be responsible for specific parts of the airplane, such as its structure, computers and electrical systems" [15]. More project managers meant it was possible to improve monitoring. And, in fact, status reviews became more consistent [Appendix].

Accurate information in status reviews had been hindered, to some extent, by a reluctance to ask upper management for help when needed. There is now a formal process to bring need for help to the attention of upper management [Appendix].

Another monitoring improvement was Boeing's change to use one integrated Dreamliner schedule instead of a schedule for each individual area [Appendix]. This makes the interconnections of work effort clearer. Monitoring is easier and more accurate.

Earned value analysis (EVA) came into use at Boeing during this time and enhanced monitoring of subcontractors. EVA gives a more accurate view of schedule status, providing a measure of how much work is actually accomplished vs. the original plan. It also gives a better check on cost, showing how much was expended vs. how much expenditures were originally planned for the work accomplished.

Boeing CEO Mr. McNerney, stated in September 2009 that "Boeing…intends to retain a greater share of the engineering on future project and monitor its partners' work much more closely" [3]. The company learned the need for greater technical control and subcontractor supervision.

Risk Management

Risk management is important in all phases of a project. It is not sufficient to identify and mitigate risk in the monitor and control phase it is also important to make it part of the planning phase. In order for a project to successfully meet schedule, cost and performance goals it is important that risk management methodologies be embedded in the project management methodology.

Based on the delays to the project it is clear that Boeing did not do a sufficiently good job in identifying risk and of putting mitigation plans in place. That is not to say that Boeing did not recognize risk in this project. In fact, Boeing's shift from being an airplane manufacturer to

a large-scale systems integrator was part of a financial risk mitigation plan. Boeing's historical business model had suppliers build components to print to having partners. The new Boeing model shares the risk of design, development and delivery of large sections of the airplane [22,14] with subcontractors. Similarly, Boeing took actions to mitigate against what it saw as a labor risk in Everett, Washington by opening an assembly plant in Charleston, South Carolina [23]. However, the 787 project has experienced significant delays due actualization of risks in delivery schedules and technical performance. While it may be possible that the delays to the program would not be avoided through risk management, it has been reported that, for example, Boeing knew about potential performance issues with the wing stringers but did not have a plan to address the technical risk [24].

Risk is present in all projects and judging by the issues and delays the Boeing 787 Dreamliner project is no exception. The Project Management Institute's Body of Knowledge (PMBOK) describes risk as an uncertain event that, if it occurs, will have an effect on at least one project goal [2]. Risk to a project can be broken down into three broad categories: schedule risk, technical risk, and financial risk. Examples of each category can be found in the 787 project and will be discussed in this section. Additionally, some methods to identify and mitigate risk will be described and finally some recommendations will be made.

Virtually everyone will agree that as a project becomes larger and more complex the risks increase. As more subprojects, subcontractors, partners and suppliers become involved the higher the chances of unplanned events. Because events that may occur with a component being delivered by a partner may affect other partners and the overall schedule, communication of the risks throughout the organization becomes particularly important [25].

During his interview, John Phillips of Boeing provided an example of this type of risk. He suggested one of the challenges to the new business model where design, testing and delivery responsibility has been passed down to partner subcontractors is changes in design. When all the design responsibility was controlled within Boeing, changes could be addressed by an

engineer walking down the hall to meet with those responsible for manufacturing the components. In the new paradigm, changes in design are much more complicated due to the physical distribution of the facilities involved as well as the fact they are not all the same organization. There is now a need for formal communication with partners and suppliers before changes can be incorporated. This is a form of risk because design changes to address technical issues may cause schedule delays. The delays would be extensive without an easy but formal procedure, particularly if the risk associated with the issue is not visible to all organizations involved. In this example, changes in design would need to be identified as a risk and the mitigation plan would include a formal system to resolve the changes quickly regardless of the organizations involved.

As was described in the last example, risk identification is an important part of risk management. Anderson, in an article for the Project Management Institute (PMI, suggests that recognizing risk and addressing it is critical to success of any project. He further suggests that large projects should be broken down into small pieces so that risks at each level can be identified. Additionally, internal and external risk should be considered [26]. This all rings true for Boeing on the 787 as the project is extremely large so its risk must be broken down to the component or even the task level. The recommendation that both internal and external risks be identified is particularly important for the project where Boeing shared the design and build responsibilities with outside partners to an unprecedented level.

There are many different methods that can be used to identify risk. Some typical ways methods will be discussed briefly. Historical data is perhaps one of the best ways to find potential issues. That is, compare a project (and its component parts) to similar work that has gone on previously. However, as was discussed previously, the 787 project is the first of its kind for Boeing in two important ways: first in the level of design outsourcing, and second in the use of composites in the airplane structure. Therefore, history would not be a good guide.

Another method that is used commonly in small projects is simple brainstorming. It is not possible to identify risks for a project by brainstorming at one level for the whole project. For example it is unlikely that at the project management level high stress areas in the stress model for the wing stringers would be identified as a risk. However, brainstorming can be a good tool to identify risks if used at the each level of a project, at the subproject or task levels. Once identified this risk then need to be ranked and recorded as will be discussed below.

A technique similar to brainstorming, but with slightly more structure, such as "cause and effect" or Ishikawa diagrams is also a common technique. In this method, main sources of risk are identified such as resources, planning, and performance. Then, the factors that contribute risk to these categories are added as branches to a diagram [27]. These diagrams are also called "fish bone" diagrams because they resemble a fish skeleton when completed. The benefit of this type of method is that it visually represents the potential contributions to risk in a way that is easy for all the organizations to understand. While many techniques are available to identify risks, the most important factor is that they be used as a standard part of an organizations methodology and that they be updated regularly.

Once potential risks have been identified, by whatever method the organization adopts as part of their methodology, those risks must be assessed in terms of their potential impact on the overall program. A commonly applied method is to use a failure mode and effects analysis (FMEA) [26,28,29]. This method is currently incorporated into part of ISO-9000 and QS-9000 quality certification levels. The standard FMEA technique is to give risks on a risk probability number (RPN) based on potential occurrence, severity, and probability of detection as shown in equation below [28]. It is possible to score risks against different

RPN = Probability of occurrence x Level of severity x Effectiveness of detection

project objectives such as cost, schedule of performance. Once RPN scores are created for each risk it is possible to use a Pareto analysis to decide which risks should be addressed first.

Additionally, it is typical to use a threshold RPN score above which all risks require mitigation plans. Based on the way the RPN is calculated the mitigation plan could address anyone of the three factors used in its calculation.

In terms of risk management, identifying and prioritizing risks alone is not sufficient to promote a successful project, monitoring and communicating risks is also important. Some type of risk register should be used to capture and communicate risks throughout the organization. This type of risk database should be used to monitor and track risks and mitigation plans. In a paper about a NASA risk register database system, Perera and Holsomback suggest that a risk database should be a day-to-day tool for organizations to manage risk. They also recommend that each risk be assigned a specific owner who is then responsible for generating and managing an associated mitigation plan [29]. Patterson and Nealiley also recommend a risk register system to aid management of project risk. They maintain that the risk register is an important tool that allows risk to be evaluated, recorded and managed across a project irrespective of geographic location [30].

The description of risk identification, prioritization and the recording of risk mitigation plans in a risk register could be misinterpreted to suggest these activities occur once during the project planning phase; this is not the case. All of the activities described thus far should be done continuously throughout the project [25,29-31]. Risks change as projects develop. Some risks do not occur while new ones appear. Plans must be adjusted to address these changes. Risk planning and review should be embedded in the project management methodology and should be managed throughout the project lifecycle.

In addition to continuous risk assessments, project planning is a key predictor of project success. Zwikael and Sadh argue that planning is an effective risk management tool. They compared the outcomes of projects that had a high level or risk at the beginning of the project to projects that had a low level of risk at the beginning. What they found was that the risk itself was not a good predictor of success but that the project planning played a larger roll [31]. This

emphasizes that risk management needs to be embedded in the project management methodology. It suggests that if risks are identified and communicated, and that if mitigation plans are developed and managed, risky projects can be successful.

Recommendations

It is difficult to tell from the short interview with John Phillips all the details of Boeing's risk identification and mitigation methods. It is clear, however, that during the 787 project a number of risks were not resolved without having an impact on the project goals. During the interview, Mr. Phillips indicated that Boeing is now using a software system called BORIS (Boeing Opportunities and Risk Identification System) which is similar to a risk register described above. The system is used to identify and record risks so that they can be shared across the organization. Each risk is then assigned to an owner who is responsible for a mitigation plan. This system is apparently very similar to or is based on a commercially available system called "Risk Radar" produced by American systems of Chatilly, Virgina. The Risk Radar mantra is "Identify, Analyze, Track, Mitigate, Control" and the details of the system show that it has all the features discussed in this section. At this point it is not clear if Boeing had BORIS during the early stages of the 787 project or if it was simply not embedded in the project management methodology or if the risks were simply not foreseen.

Currently, Boeing monitors weekly reports internally on current and potential problems. In a change since the beginning of the project, Boeing reviews problems regularly with subcontractors. The focus is on what must be done in the future instead of catching up on past problems. The idea is that focusing on the future will be more effective in overcoming problems [Appendix].

Any project where an organization departs from historical business models the way Boeing did has a large amount of risk. It emphasizes the need for a formal risk management system to avoid large failures in terms of project outcomes. Furthermore, this risk management methodology should be done ongoing at every level of the organization if the goal is a successful project.

Conclusions:

The Boeing 787 Dreamliner project continues to present Boeing with a number of challenges. For the first time, Boeing is building a passenger plane from composite material and is doing so by using an unprecedented amount of outsourcing and partnerships. This paper discussed how Boeing placed much of the design and build work, that had to date been considered its core competencies, with outside subcontractors, which may entail a risk to the company. It is believed that Boeing used cost and market access as the primary criteria to make the subcontractor selections with less emphasis on technical ability. Some recommendations were made for the subcontractor selection process, including clearly defining scope of work and ensuring subcontractor's goals are aligned with Boeing's goals. The authors proposed working alongside the subcontractors, improving the SOW and reviewing plans with subcontractors for better performance, steps which were implemented more effectively later for the Dreamliner.

In the execution phase of the Dreamliner project, Boeing has continued to face challenges due to the changes in their business model. This paper reviewed methods for control and monitoring the project. On this front, Boeing's monitoring of project partners has increased significantly. There is also a formal process to ask for help.

Finally, this paper discussed risk management. Risk should be considered throughout the project lifecycle. Risk management should be embedded in the project management methodology and should be done at every level continuously throughout the project life cycle in order for a project to be successful. Boeing has incorporated a risk register system to help with this endeavor. Additionally, Boeing has made risk mitigation planning a key part of the project with risks being assigned an owner and being a standard part of the project reporting.

Bibliography

[1] Meredith, Jack R. and Mantel, Samuel J. Jr., *Project Management: A Managerial Approach*, Hoboken, NJ: John Wiley & Sons, Inc., 2009.

[2] Project Management Institute and PMI Standards Committee, *A Guide to the Project Management Body of Knowledge: PMBOK Guide*, Newtown Square, Pa: Project Management Institute, 2004.

[3] C. Drew, "A Dream Interrupted at Boeing," *NY Times*, Sep. 2009.

[4] P. Hise, "The remarkable story of Boeing's 787:
The Dreamliner, the fastest-selling commercial plane in history, rolled out Sunda," *CNN Money*, Jul. 2007.

[5] D. Gates, "Boeing still sure delayed 787 will be profitable," *Seattle Times, The (WA)*, 2009.

[6] "The Boeing Company 2002 Annual Report," 2003.

[7] "The Boeing Company 2003 Annual Report," 2004.

[8] "The Boeing Company 2004 Annual Report," 2005.

[9] "The Boeing Company 2005 Annual Report," 2006.

[10] "The Boeing Company 2006 Annual Report," 2007.

[11] "The Boeing Company 2007 Annual Report," 2008.

[12] "The Boeing Company 2008 Annual Report," 2009.

[13] "Boeing 2009 Third-Quarter Financial Results," Oct. 2009.

[14] A. MacPherson and D. Pritchard, "Boeing's Diffusion of Commercial Aircraft Technology to Japan: Surrendering the U.S. Industry for Foreign Financial Support," *Journal of Labor Research*, vol. 28, 2007, pp. 552-566.

[15] S. Kumar, E.C. Aquino, and E. Anderson, "Application of a process methodology and a strategic decision model for business process outsourcing," *Information Knowledge Systems Management*, vol. 6, 2007, pp. 323-342.

[16] B. Dankbaar, "Global Sourceing and Innovation: The Consequences of Losing both Organizational and Geographical Proximity," *European Planning Studies*, vol. 15, pp. 271-288.

[17] S. Holmes, "Boeing's Global Strategy Takes Off:
The aerospace titan is taking a measured approach to outsourcing, with help from local teams," *Business Week*, Jan. 2006.

[18] C. Weber, J.R. Current, and A. Desai, "VENDOR: A STRUCTURED APPROACH TO VENDOR SELECTION AND NEGOTIATION," *Journal of Business Logistics*, vol. 21, 2000, pp. 135-167.

[19] J. Yallof and C. Morgan, "Beyond Performance Standards: How to Get the Most From Your Outsourcing Relationship," *Benefits Quarterly*, 2003, pp. 17-22.

[20] F. Amesse and P. Cohendet, "Technology transfer revisited from the perspective of the knowledge-based economy," *Research Policy*, vol. 30, 2001, pp. 1459-1478.

[21] Michael D. Taylor, "How to Manage Outsourced Projects: Practical "How To" Ways for Managing Today's Challenging Projects," c. 2003. 2009.

[22] T. Williams, R. Maull, and B. Ellis, "Demand chain management theory: constraints and development from global aerospace supply webs," *Journal of Operations Management*, vol. 20, 2002, pp. 691–706.

[23] T. Reed, "Boeing Rolls the Dice with New 787 Plant," *TheStreet.com*, Oct. 2009.
[24] D. Gates, "Boeing 787 may not fly this year.," *The Seattle Times.*, Jul. 2009.
[25] T. Williams, "Risk-management infrastructures," *International Journal of Project Management*, vol. 11, Feb. 1993, pp. 5-10.
[26] S. Anderson, "Risk identification and assessment," 2009.
[27] R. Jen, "Visual Ishikawa Risk Technique (VIRT)-An Approach to Risk Management," 2009.
[28] T.A. Carbone and D.D. Tippett, "Project Risk management Using the Project Risk FMEA," *Engineering Management Journal*, vol. 16, Dec. 2004, pp. 28-35.
[29] J. Perera and J. Holsomback, "An integrated risk management tool and process," *Aerospace Conference, 2005 IEEE*, 2005, pp. 129-136.
[30] F.D. Patterson and K. Neailey, "A Risk Register Database System to aid the management of project risk," *International Journal of Project Management*, vol. 20, Jul. 2002, pp. 365-374.
[31] O. Zwikael and A. Sadeh, "Planning effort as an effective risk management tool," *Journal of Operations Management*, vol. 25, Jun. 2007, pp. 755-767.

Appendix A

Boeing Dreamliner Manager Interview Script

Introduction

We are graduate students at Portland State University in the Engineering and Technology Management Department. We are doing a term project for our Project Management class.

We are investigating risk management strategies for cost, schedule, and performance on the Dreamliner, focusing on risk management of subcontracting and outsourcing. We would like to come out with an understanding of the actual situation, what worked well, and what could have been changed for greater success in this and similar projects.

Thank you for agreeing to talk with us.

[Each interviewer tell their name and a little about themselves.]

We would like to speak with you for about 45 minutes. Is this a good time?

Do you have any questions?

Can you give us a little background on yourself?

What is your position in the Dreamliner project?

Questions

Background of Dreamliner Project Management

1. How is the Dreamliner Project organized?
2. What is different about the Dreamliner Project? Why?
3. What are the project management successes of the Dreamliner? Why are they successes?
4. What are the project management challenges of the Dreamliner? Why are they challenges?
5. If you could do it all over again, what would you change in terms of project management? Why?
6. How did the project make its original estimates for cost, schedule, and performance? Why?
7. What project management practices were used in terms of managing (and why?):

   a. Cost
   b. Schedule
   c. Performance
8. What were the strengths and weaknesses of your project management practices? Why?
9. What is in place to manage risk? Why?
   a. How did you determine what the risks were?
   b. How did you determine which risks to address?
   c. How did you address risk?
   d. How did you check up on risk status?
   e. How did you keep track of costs?
   f. How did you take care of scope creep?
   g. Did you use particular tools?
10. Did your risk management change over time? How? Why?
11. What were the strengths and weaknesses of your risk management practices?
12. Do you have methods in place to make changes in project management during the project?
13. Did you feel you had top management support? Why?
14. Was there a team orientation within Boeing?
15. Do you feel there was a team orientation considering both Boeing and subcontractors?
16. How did cultural differences between Boeing and subcontractors affect the project? Why?

Management Strategies for Outsourcing and Subcontractors

1. What were your thoughts about the subcontracting strategy? Why?
2. Can you describe the relationships and the level of communication between Boeing and the subcontractors?
3. Did you have specific agreements between your company and the subcontractors? Why?
4. What was the main success in terms of using subcontractors and outsourcing for Boeing? Why?
5. What was the main problem in these terms? Why?
6. What do you think would increase success the most for management of subcontractor and outsourcing? Why?
7. How did you monitor subcontractor progress?
8. How was subcontractor/outsource performance insured and evaluated? (MM p. 82)
9. How were subcontractors and outsourcing risks handled?
10. Did this change over time? Why?
11. How did you handle change orders?
12. What were the strengths and weaknesses of the methods used? Why?

To Keep the Conversation Going

Tell me about

Why?
How?
Tell me more
Reflect questions back
Clarify and verify responses
Describe
Most people would say….How do you feel about this?

Closure

Thank you very much for your time.
This was helpful and insightful.

Would you care to receive a copy of our completed report?
Where may we send it?

Afterwards

Send a thank you e-mail

Appendix B

Interview Notes: John Phillips 10/21/2009

Interviewers: Wendy Peterman, Noah Third, Tom Torres

Background

- John has spent five years on the Dreamliner program so far.
- He was Deputy Chief Engineer on the 787-8 for four years.
- Last year he was Deputy Chief Engineer for Flight Test and Lab Test on the 787-9.
    - John has no direct reports
    - John's organization is responsible for flight test for the 787 and all other programs. There are about 7,500 staff in this area.

- Manager of the entire 787-9: Scott Thatcher
    - Under Scott: Dan Mooney Overall PM 787-8, Mark Jenks Overall PM 787-9
        - Under Mark: Design Teams by Airplane Section such as Forward, Mid, Aft, Interior, as well as Test and Airplane Level Integration ***(Airplane Level Integration coordinates across teams, works on common core practices and does risk management)***
- Boeing is a matrix organization
- Team definition for these notes: flight test would be a team

What is different about the Dreamliner?

- Historically, Boeing aircraft were made out of aluminum and all built in-house. Boeing designed and built the aircraft.
- With the Dreamliner, Boeing is the large-scale systems integrator.
    - Partners share in the design work
    - Boeing is responsible for systems integration
- Partners and testing with the Dreamliner:
    - Suppliers (partners) are responsible for all qualifications testing
    - Partners are responsible for instrumentation systems to test their part.
    - There are over 65,000 parameters to measure
    - Boeing does all major airframe testing
- Partners and suppliers across the world share the risk of building an airplane.
    - For example, one section is built in Italy, there are three Japanese partners, Hamilton Sundstrand is doing the power systems, a company in England has responsibility for the flight deck
- It costs over $10B to develop a new airplane, too much risk for one company.
- Quality testing has had significant challenges
- Historical development changes

- In-house
  - designers would sit next to builders
  - requirements did not need to be as stringent
- Now
  - Boeing did not do a good job of defining a stable, clear, concise set of requirements
  - Hard to manage change

How did subcontractor management change?

- Four years ago on the Dreamliner project
  - Upper management told John "They [subcontractors] are truly our partners. We don't have to manage the SOW because they [subcontractors] won't make money until we sell the airplane"
- As time progressed, Boeing found
  - Most partners had not done the assigned work before
  - Partners did not know what they should do
  - Boeing did not have good measure in place to look at subcontractor performance
  - Boeing's look at performance was:
    - Have you started your work?
    - What part are you working on now?
- Now
  - Detailed measures in place (for performance?)
  - Subcontractors review their build plan with Boeing
  - Boeing goes on site to check (performance?)
- Fastener Example
  - The first delay was due to fastener issues
  - Boeing knows that there may be significant lead time to order fasteners
  - Partners did not know about the lead time and ordered fasteners too late

How did you choose partners?

John did not do this personally

Choice was on

- Cost
- Perception of technical expertise
- Geographical area
  - This was sometimes the most important.
  - The idea is to build relationships where Boeing can sell the planes.

Mistakes

One of the mistakes Boeing made was almost all of the technology is new for the Dreamliner. The use of composite material for larger, higher volume, aircraft is new. Partners had to build new factories and hire new people.

Changes in monitoring the iron triangle and risk management

- Start of project
  - Almost no monitoring
  - We just need to know when you get it [just need to know when the part is available]
- Now
  - Boeing management goes on site to help partners achieve goals
  - There are more regular status reviews with each partner and supplier
    - Boeing and subcontractor have regular status meetings where issues and staffing (for example) are discussed
  - There are consistent tools across the enterprise to manage risk
    - Boeing uses BORIS (Boeing Opportunity Risk Issue System)
  - Boeing uses project management best practices
- Current risk management
  - Individual teams have to identify risk, including financial risk, and develop mitigation plans
  - Opportunities are what we could do better
  - BORIS is a software program used for risk management
  - Likelihood, consequence, team affected, owner team, owner of risk, and mitigation plans are included
    - Likelihood is measured on a 1-5 scale
  - Lower level and program level risk meetings are held
  - Stop light (red, yellow, green) status is given [for issues?]
    - Stop light rating is on performance to the plan
  - Risks included are schedule, technical, and cost
  - Risks are hierarchical
    - There are about 15 program level risks
    - Teams (under them, such as flight test) have their risks
    - Team group levels have their own risks
  - Risk identification
    - Some top down risk identification: Leadership team on the program can identify a risk and assign it to the team, partner, or supplier
    - Most risk identification comes from the bottom up, from people working on the Dreamliner
      - Start with a candidate risk
      - Go up through the organization approval meeting and work through the process until the risk is closed
    - Most risks come from the second level management team (managers of 100 to 200 people)
    - Suppliers can also identify risks
  - Boeing adopted earned value in the past five years (this aids in risk management-WLP)
  - See also “What are Boeing PM Best Practices”

Communication between Boeing and subcontractors

- Most people feel they are a team
- At the company level there is a more adversarial relationship
    - Partners want to be compensated for the extra work they have done over the past 2 ½ years
    - Boeing feels this is part of the original SOW
    - One solution: Vought was a major partner and Boeing bought them
- Boeing did have specific agreements with partners at the start
    - Original contract might be (eg flight test): as part of your section you will support flight test activities –and that's it
- Current agreements are more specific
    - Continuing above example—for every bracket that holds a wire Boeing asks the supplier their design, fab, planning, and installation plans and an identification of who does what
- The change in this agreement type for testing came about in June 2006

Successes

- Better integration of the build plan
- Boeing and subcontractors are involved in having discussions about when specifically install parts
- There are upfront negotiations, etc.

If I had to do it over again

We have implemented these changes in the 787-9 based on 787-8 experience

- Instead of negotiating a year before testing, Boeing is already starting negotiations with partners for the 787-9 due out in 2013.
    - Partners want to build airplanes and get to a production cycle where there are standard flows and all are well understood. Only the first six aircraft are the flight test ones. Partners view the SOW as an irritant to getting to the streamlined production cycle.
- Engage design engineering community and have ONE Boeing Sow. Not one SOW to build and one SOW to test
- Partner focals (person who deals with each individual partner for each team) for each partner section is upfront in building relationships with partners
- We're here to work together—what is the best way to do it?
    - Previously—here's what you need to do
    - Now build relationships with partners and mutually agree on what they are doing

Is subcontracting like the Dreamliner the new paradigm?

- Probably will be the new paradigm because it costs so much to develop a new airplane
    - All new airplanes will be built out of composites
- Modification of existing airplanes is a different story
    - For example, the -10 will have most work in house

- Boeing will do most of design work
- May also utilize partner's expertise for some parts

Is any specific PM training provided to Boeing team members?

- For every supervisory group there are cost account leaders for each second level manager in the organization
- These cost account leaders were trained in earned value and critical path analysis

What are Boeing PM best practices?

- Using earned values
- Risk and issues management
- Help needed
  - Teams are reluctant to ask for help from upper level management
  - There is a chart for help needed wherein
    - If you have issues, they are identified
    - Who you need help from is identified
    - When you need help is given
- Issues management system
  - That is, software tools to track and manage financial, technical, and performance issues
- Integrated Schedules, called horizontal integration
  - Going through team by team they cover
    - Major events for the next year
    - A milestone definition for each of the above
    - Identification of every teams need (for the milestone) from other teams (predecessors) and when your team supplies outputs to other teams (successors)
    - Make sure have a single integrated schedule (such as for the 787 program)
  - Near-term look-ahead reports given weekly (to John, for example)
    - These cover 30(?), 60, 90 day and delinquent items. Each team reviews each of these activities
- Focus in the last two years on:
  - Here's what's in front of us
  - Here's what's due
  - What can we do to honor our commitments to the other teams
  - If can't honor them, go into BORIS
  - Background
    - Previously had 3 to 4 sets of upper level management changes as the program slid
    - Boeing realized that even at upper level management each time got
      - Here's the status
      - Here's what we're behind on
      - Focus then was to fix what we're behind on

- Many people in Boeing are now going through the process to get their PMP, it is now a "very big deal at Boeing"
    - Boeing pays for the training
    - John says about 10% of the people he know are working on their PMP
    - John says "project management classes are well worth the time"