"LEAN PRODUCTION" AND THE "SKUNK WORKS" APPROACH TO AIRCRAFT DESIGN

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Note – this paper was originally written years ago in support of a production cost estimation project related to the JSF (F-35) program[1]. It was not published or distributed at that time, at least partly because it was felt to be too controversial, even potentially insulting. I think it offers some valid viewpoints concerning the best practices for aircraft concept design development and project management, so it has been made available at www.aircraftdesign.com. It has been slightly updated and edited.

-D. Raymer, Jan. 2008

ABSTRACT: A discussion is offered of the possible misunderstanding and mis-application of some of the principles of "lean production" and other Japanese management techniques in the aircraft design and development world. This is related to the "14 Points" used by Kelly Johnson at the Lockheed Skunk Works.

The well-known book, "The Machine that Changed the World"[2], has become somewhat of a bible for the advocates of "Lean Production", "Re-engineering", and other techniques for improving efficiency in production and, indeed, in all aspects of running a modern corporation. The book is the result of an extensive survey and visitation of numerous automobile factories around the world, performed by the authors, who were part of the MIT International Motor Vehicle Program. Co-author Daniel Roos became the Co-Director of this program, and the Director of the MIT Center for Technology, Policy, and Industrial Development. Furthermore, MIT instituted a major program called the "Lean Aircraft Initiative" ("LAI"), which can be seen as an outgrowth of the research conducted for this book.

The book contrasts "Mass Production" with what the authors termed "Lean Production". Mass Production is described as the "break-it-into-trivial-tasks" production scheme most identified with Henry Ford. The tasks required to produce anything are broken into the smallest possible increments, simplified so that virtually anyone off the streets could be trained to do them, with absolutely no understanding or concern about the totality of the article being produced. Rather than teach people to, say, build and install the doors of a car, one would instead break that overall job into perhaps 50 different steps. A new-hire could be taught to pick up a doorknob from a bin, slip it onto the doorknob post, and tighten a screw. Then, pick up another doorknob from a bin, slip it onto the next car's doorknob post, and...., and continue to do just that simple task, all day, all week, all year. Meanwhile, thousands of equally-isolated tasks are being performed by thousands of other workers, and completed cars are rolling off the production line (rolled off by people who only know how to roll cars off the production line!).

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[1] FYI, this was not written during my time at Lockheed nor is it based on information obtained while there.

[2] Womack, J., Jones, D., and Roos, D., *The Machine that Changed the World*, HarperCollins Publishers, NY, 1990 (available at http://www.aircraftdesign.com/books.html)

While this conjures up images of a boring yet stressful work environment, as epitomized by Charlie Chaplin's "Modern Times", the productivity benefits are clear. Mass production has produced much of the increase in standard of living that we enjoy today compared to 150 years ago. Productivity is improved compared to the prior "craft production" in which skilled workers cluster about a single item being produced, doing a wide and changing variety of tasks as their expertise indicates. Furthermore, the up-front investment in the training of such skilled craftsmen is eliminated, reducing the barriers to the initiation of production. In mass production, the only people requiring broad expertise are the product and production design engineers, who are generally well educated and highly experienced.

In the book, the downsides of mass production are explored and the new alternative, "Lean Production", is introduced. These downsides of mass production include the negative effects on the workers themselves as described above, but go beyond that to include real problems in cost and quality. With the implicit assumption of worker ignorance, and their very-real lack of exposure to the "big picture", the workers have neither the incentive nor the ability to make changes in the way the job is done, and are not even supposed to attempt to solve quality problems as they occur. Instead, any quality problems are left to a post-production rework area, and identification and correction of process-based quality problems are left to the "experts", namely the production line management and the design and production engineers. This tends to lead to poor morale on the part of the workers, but even more important, the problems simply do not get solved until they are major problems, not just "fixable" irregularities. Also, the development engineers tend to become highly specialized and often have little incentive or ability to develop designs with good overall producibility.

In Lean Production, the workers are "empowered" (and in fact required) to identify and solve production problems as they occur. The individual workers can actually stop the entire production line if they encounter a problem that may potentially be producing a succession of bad products. When problems are encountered, the workers act in teams to identify the problem and devise a solution. Eventually, this results in far-fewer bad parts being produced, and a near-elimination of post-production rework.

The book, written in 1990, well-depicts the ongoing transformation in production line operations that is "changing the world", and the principles described in the book are being adopted far beyond the automotive industry. While there are many differences in technology, regulatory climate, production rates, and other factors making applicability to the aerospace industry more difficult, even there the basic principles outlined in the book are taking root. Such applicability is facilitated by the emerging advanced CAD/CAM systems now in widespread usage in aerospace.

However, in this author's opinion there is a tendency to mis-apply some of the principles of the book in certain segments of the aerospace design development process. Specifically, aspects of the book are sometimes read to imply that a strong, knowledgeable, and experienced technical leader is a bad thing, and that a team of equals, with only the faintest form of administrative leadership, is a good thing. This philosophy, which is highly appropriate for the production line "quality teams" alluded to above, seems questionable when it is applied to new product development engineering.

Two interesting quotes follow, depicting the philosophy described in the book:

> *"The first step was to group workers into teams with a team leader rather than a foreman."*

> *"...the better you are at teamwork, the less you may know about a specific, narrow specialty..."*

Two trends in the "re-engineering" of aerospace corporations have been the increased reliance on "Integrated Product Teams (IPT)" for the design of aircraft, and the use of promotion paths based more on managerial team-building skills and less on technical abilities. Both trends seem to be indicated from this book. The overall philosophy of Japanese Lean Production, as described in the book, has entered into the corporate culture to the extent that even a debate of the applicability of the concepts is considered to be an indication that one "isn't a team player."

This contrasts sharply with the situation of 30-40 years ago, when the best or nearly-best technical person was made the boss, and given wide and real powers. Some of these old-time technical leaders, whose names are legend, were so bad at "people skills" that their names became verbs. Engineers, after a chewing-out, would say they had been "(leader's name)-ized"!

Certainly this extreme is also undesirable. But, this author remembers grueling aircraft design reviews in which an unpleasant engineering vice-president, over the course of many hours, personally evaluated every technical aspect of a proposed fighter design with enough technical knowledge to find potential problems in a wide variety of technical areas, from aerodynamics to avionics, resulting in a substantial improvement in the proposed design. Few engineering vice-presidents of today would attempt such hands-on technical involvement. Instead it is left to subordinates and IPT's. The discovery of problems can take much longer, and those familiar with the technical details of any problems uncovered don't have the direct authority to fix them.

Furthermore, most US aircraft companies use a matrix management scheme in which a project leader has rather limited power, and must negotiate and coordinate with functional management to establish work priorities and even to make technical decisions. This is exacerbated by today's teaming between different companies, requiring the project leader to coordinate technical decisions with Chief Engineers and functional management from the other team member companies.

What does this book, so influential in the re-engineering of production lines and production management, have to say about the management of new product development?

"In Western teams, the leader is more properly called a coordinator, whose job it is to convince team members to cooperate" "...the leader really has limited authority." "The (US) team leader is in an extremely weak position to champion a project within the company. It's common...for top management to override the team leader about the specifications...of the product - often repeatedly during the course of development."

"(Japanese Large Project Manager)...was given powers far surpassing any (US Project Manager) ever dreamed of. While (Japanese company) also uses a matrix, ...(manager) was told to borrow appropriate people from each of the relevant departments and transfer them to the ... project for its life. Rather than coordinating, (manager)'s task was, clearly, to manage. He could move the project along rapidly, because all the necessary resources were under his direct control."

"While team members continued to work closely with their functional departments,... (manager) and practically every member of the team continued in their jobs until well after the new model was launched on schedule."

"(Japanese companies) decided early-on that product engineering inherently encompassed both process and industrial engineering. Thus, they formed teams with strong leaders that contained all the relevant expertise."

"In the best Japanese companies the position of (large project manager) carries great power and is, perhaps, the most coveted in the company."

"One might even say that the (large project manager) is the new supercraftsman, directing a process that now requires far too many skills for any one person to master. Oddly, while we're used to thinking of dedicated teamwork as the ultimate sublimation of individuality, new products inside the Japanese auto industry are commonly known by the (large project manager)'s name."

Thus, for new product development, the Japanese companies form dedicated project teams, with all required technical abilities, lead by a strong leader who becomes closely identified with the product, and who has enough real power to direct the outcome and the resources needed to make it happen. While not explicitly stated, it seems obvious from the text that in the Japanese companies, the technical team leaders are drawn from the most able of the technical staff, and that a wide exposure to technical development, production, and customer service is a normal part of the career ladder for these rising technical leaders.

This stands in contrast to the manner in which U.S. companies often operate during new aircraft development. They set up matrixed product development teams, with staff that "rotates" through the project team, and provide little real authority for the project leader (in concrete terms such as hiring, promotion, and firing). This leader is often selected more for team-building and people skills than for directly-applicable technical experience. Upper management tends to overrule the project leader based on non-technical concerns. And, the companies tend to rely on "teamwork" and nearly-leaderless "IPT's" rather than traditional active technical leadership. As shown above, this is *not* how the Japanese companies do it!

Interestingly, the legendary Lockheed "Skunk Works" approach to new aircraft development seems to closely follow the above-described Japanese practice for product development. Kelly Johnson developed such revolutionary aircraft as the P-80, F-104, U-2, C-130, and SR-71, using "14 Points" as described in his autobiography[3]. Many of these 14 Points[4] sound like the "best practices" devised in Japan and described in "The Machine that Changed the World.".

The very first of the 14 Points states that "the Skunk Works manager must be delegated practically complete control of his program in all aspects. He should report to a division president or higher." The second addresses the need for "strong but small" project offices, and the third reinforces this by calling for "a small number of good people." Point number five calls for "a minimum number of (written) reports required", emphasizing the authority of the project manager to get the job done without micromanagement from above. Point number 14 emphasizes the need for people with top technical skills by calling for a way to "reward good performance by pay not based on the number of personnel supervised."

While the "Skunk Works" approach is often held up as the modern ideal for new aircraft development, it seems to be rarely followed in its entirety. Johnson states, "I have been trying to convince others to use our principles and practices for years. ...Very seldom has the formula been followed. Most companies, while desiring the benefits, will not pay the price in revised methods and procedure for setting up a Skunk Works-type of operation. They will not delegate the authority to one individual, as Lockheed did in my case from the very first Skunk Works. It requires management confidence and considerable courage."

He continues this point in another section of the book, stating "the ability to make immediate decisions and put them into rapid effect is basic to our successful operation.." "Without the authority assigned to the Skunk Works by our military customers and the Lockheed corporation, we would not have been able to accomplish many of the things we have done, things about which I felt we could take a risk - and did."

He goes on to suggest (in 1985) that even the Skunk Works itself may become unable to follow his 14 Points, saying, "I fear that the way I like to design and build airplanes one day may no longer be possible. It may be impossible even for the Skunk Works to operate according to its proven rules at some point in the future. I see the strong authority that is absolutely essential to this kind of operation slowly being eroded by committee and conference control from within and without."

In a comment directly applicable to the present discussion, Johnson states "there is a tendency today, which I hate to see, toward design by committee - reviews and recommendations, conferences and consultations, by those not directly doing the job. Nothing very stupid will result, but nothing brilliant either. And it's in the brilliant concept that a major advance is achieved."

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[3] Johnson, C. L., & Smith, M., "More than my Share of It All", Smithsonian Institution, Washington, D.C., 1985 (available at http://www.aircraftdesign.com/books.html)

[4] See them at http://www.lockheedmartin.com/aeronautics/skunkworks/14rules.html

Echoing the Japanese attitude that the position of project manager is “the most coveted in the company”, Johnson relates “three times I was offered a company presidency at Lockheed and three times declined it. To me, there was no better job within the corporation than head of ... the Skunk Works.”

Thus, the legendary “Skunk Works” approach includes a strong technical leader with lots of real authority, a minimum of micromanagement from above, dedicated product teams, and a strict avoidance of “design-by-committee.” All in all, this sounds very much like the Japanese methods for management of new product development as described in “The Machine that Changed the World.” Neither “The Machine...” nor Kelly Johnson’s book describe anything remotely like the nearly-leaderless teams and IPT’s which are sometimes offered as the “new” way for product development.

It is hoped that this brief treatise can stimulate discussion on the best way to manage new product development, and to encourage reconsideration of the interpretation of “Japanese” management techniques as applied to the aircraft development process, more along the lines used by Kelly Johnson’s Skunk Works.

To put it more bluntly, if you want to have a successful project, pick a motivated project leader with top-notch managerial *and* technical[5] skills, give him or her a lot of real authority and a large enough budget, and get the heck out of the way.

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[5] And please, those skills should include experience in the most important aspect of the project. If the project is to design a new airplane from a blank sheet of paper, find someone with that experience. Producing or flying airplanes is not the same skill set as initial design. Or vice versa. And even though I have an MBA, I don’t buy the argument that a good manager can manage anything. I just don’t. Without directly-related experience a person doesn’t develop a “nose” for problems or a sense for what issues need a lot of attention now, and what can wait. Problems fester until anyone can see them, and resources get spent on things that could have waited until later while more-important things were ignored.