HIGH FLYERS

A new take on aircraft development

Other than being famous aircraft, what do the Lear Jet 45, F 22, Euro fighter and Joint Strike Fighter have in common? They all resulted from "integrated product development," a practice that's spreading across the aerospace industry and gradually proving its worth. Here are eight lessons learned from implementing this approach–which can be applied to any industry.

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Integrated product development (IPD) is a management process that integrates all activities from product concept through production and field support. IPD uses a multifunctional team to optimize simultaneously the product and its manufacturing processes to meet cost and performance objectives.

First conceived in the early 1980s, concurrent engineering and IPD practices grew out of the need to minimize time to market and product costs over all other variables in competitive marketplaces. Their use has become widespread among leading-edge companies seeking a competitive advantage. It wasn't until the early 1990s, when U.S. defence budgets were cut dramatically, that aerospace companies began to implement IPD seriously. Affordability and time to market are now the driving forces in product development. Process management and integrated teams are the cornerstones of IPD.

Since 1988, I have been involved in improving engineering processes as a management consultant with the following companies: McDonnell Aircraft St Louis, Boeing deHavilland Toronto, Bombardier Aerospace, Lockheed Martin Tactical Aircraft Fort Worth, British Aerospace and others. Aerospace companies began to adopt IPD and integrated product teams (IPT) between 1988 and 1993.

The new aircraft programs to which aerospace companies applied IPD include the F18, AV8B Harrier, F22, Joint Strike Fighter, European Fighter, Hawk, Dash 8-400, Global Express and Lear 45 Jet. IPD was used in a variety of ways. For example, some programs applied IPD to the entire aircraft throughout its product development lifecycle (the F22); others applied it only to components (the Lear Jet's wing). Regardless, the companies involved experienced similar challenges and learned valuable lessons, as described below.

Lesson 1. Getting Buy-in

Strong upper management commitment is required to drive the implementation of IPD and IPTs in the face of opposition. This must be in the form of hands-on visible support, not just five-minute speeches. And an enterprise-wide framework must be defined that incorporates all "domains of change" in your organization. All employees must be taught how the domains of change interact with one another.

In all of the aerospace companies, some staff resisted the implementation of IPD and IPTs. Before their resistance could be overcome, members of the IPTs needed to understand the concepts, see the benefits of the program, and understand the changes to their role. In other words, most people need to know "what's in it for me" before they will support organizational change. One IPT integration leader stated that everyone supported the new approaches in theory, as long as they weren't going to be personally affected.

There were many instances where leaders avoided or minimized the necessary IPD and IPT changes. This was often due to work pressures to deliver products, uncertainty that the new methods would be as effective as the old ones, and fear that the new methods would undermine management authority. Managers who were used to reviewing and approving all project decisions had to give up some of their authority to empower IPTs.

The aerospace companies also found that their top managers needed to determine how all of the "domains of change" in their enterprises would be affected by IPD. Domains of change are different in each organization, but the core ones common to all organizations are staff/corporate culture, information structure (e.g. data and document management systems), computer systems, business processes and physical structure.

It's important to realize that a change in one domain will affect other ones. For example, if you change your business process workflow, it will impact organizational relationships, resulting in cultural issues. You may also need to reconfigure IT tools and redesign your physical office space. One aerospace company spent about $40 million to redesign its offices to accommodate its new workflow.

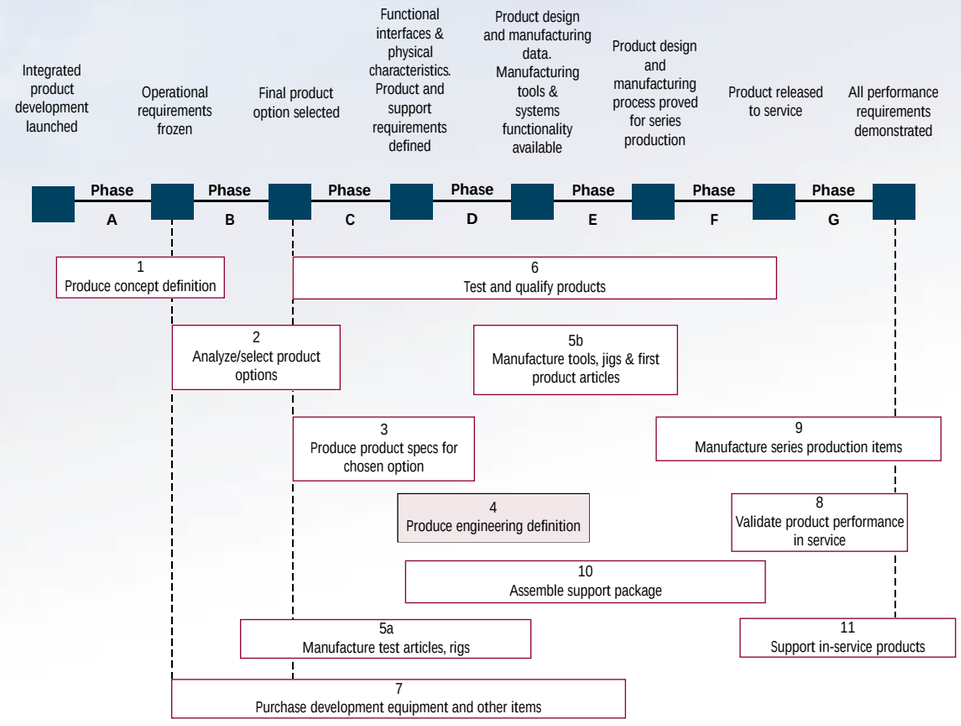
Lesson 2. Leadership

Three to six months after adopting IPD and IPTs, there is a high level of frustration and a desire to revert to familiar approaches. Strong leadership is required to ensure success. This means getting involved hands-on and demonstrating the new behaviours. Formal reinforcement mechanisms should be used.

When the IPD and IPT approaches were first adopted, staff were optimistic. But as everyone began to grasp all the changes required, confusion and doubt developed. People began to ask: "What is my role? Does the IPT have the authority to make decisions or do we need management approval?" In some cases, crises developed as uncertainty grew, and IPTs became focused upon their schedule and products. Some staff advocated going back to the old approach.

The "confusion and doubt stage" is typical in the progression of learning the IPD and IPT approaches. Project leaders need to actively promote and personally use the IPD and IPT approaches, whenever possible. This may involve refusing to review and approve some decisions in order to emphasize the IPT's empowerment, using consensus decision making to demonstrate commitment to IPD, or using other IPD methods. Project leaders need to be role models for the IPD and IPT approaches, because work teams will mirror the behavior of their leadership.

Figure 1. Integrated product development process



Lesson 3. Empowerment

Take the time to define clearly an IPT's purpose, deliverables, customers, process and product measures, resources and team incentives. Encourage IPTs to act

"Empowerment" is more than just a buzz word. An IPT's scope of responsibility/empowerment and resources should be well defined. Within this scope, the team has overall authority and need not seek approval for its actions, allowing product decisions and work to proceed rapidly (see sidebar on p. 32). A process framework must be developed that defines deliverables by phase throughout the lifecycle (see Figure 1 on p. 29).

Lesson 4. Desision Making

Carefully define a consensus decision-making procedure and use it to make some important decisions at all levels of the organization.

Consensus decision making allows all IPT members to contribute to the team's decisions. It is widely accepted that achieving consensus takes longer–particularly until people learn how to use consensus decision-making methods. New skills and considerable practice are required to use consensus decision making effectively. But it ultimately pays off with better decisions.

The aerospace companies experienced similar problems while trying to implement consensus-based decision making. One problem was that IPTs had trouble reaching consensus, because team members had little or no experience with consensus decision making. Most were classically trained mechanical and electrical engineers with little training in applied management skills. They had experience with decision making by majority or by individual, but not by consensus. Many people did not understand that a consensus team decision will usually not be optimal for each individual, but must be workable.

Another problem was that IPTs tried to make every decision by consensus. Some decisions need to be made by an individual, some by small groups, and others by consensus. Decisions should be limited to the smallest group that they affect within an IPT. We found that IPTs can usually agree on which decisions can be made quickly by the IPT leader or sub-team, and which require consensus from all IPT members.

How were barriers to reaching consensus overcome? Two basic decision-making procedures used by one company were "thumb voting" and "multi-voting." Thumb voting allows everyone three alternatives: if you favour the decision, you put your thumb up; if you can live with it, you put your thumb to the side; if you cannot live with it, you put your thumb down. When someone vetoes a decision, the team takes time to understand his or her concerns and arrive at a new alternative that everyone favours or, at least, can live with. Calling for a visible thumb vote ensures an understanding of everyone's viewpoint and builds commitment to the decision.

Multi-voting is used to select and prioritize items from a brainstormed list. Usually, each team member is given a number of votes to identify the items that are most important. The items with the most votes are given top priority by the group. All items from the list are retained. Multi-voting helps teams reach agreement on actions and directions.

Lesson 5. Defining Roles

Make sure that your company's leaders (including all levels of management) and your IPTs define, record and commit to their new roles and responsibilities. Periodically, leaders and IPTs should review and revise their roles and responsibilities. You should also provide training on organizational change management.

We learned that people's roles and responsibilities change with the implementation of IPD and IPTs, which is a difficult process because old roles and responsibilities are deeply ingrained. Unless new roles and responsibilities are defined and documented, each member of the IPT may have a different understanding of what they are.

Consider the role of the team leader. In the past, many decisions were left to the functional manager. A team leader came up with the ideas and recommendations, but the manager often had the final say. The team leader expected the manager to bless a decision before acting on it. In the new environment, the IPT has the final say, but many members of the IPT may still expect a functional manager to approve decisions.

When the people involved become confused about their roles and responsibilities, the risk of abandoning the IPD and IPT approaches is greatest. Some justify doing so on the basis that IPD and IPTs do not work as well in practice as in theory. And this is a critical point. In one case, a company's IPD effort was excellent in the development stage. The theory of IPD was well defined and documented. However, the company ran into difficulties while trying to apply IPD. Why? The IPD effort was being led by people trained only in an engineering discipline, with little understanding of change management.

The discussions that followed on roles and responsibilities allowed everyone to understand the different expectations for a particular role. New expectations for each role were established.

Lesson 6. Communication

Effective and efficient team communication depends upon IPT members recognizing which work is best done by the team, sub-team or individuals.

Communication is more than brochures, posters and get-togethers. For IPD to be successful, effective communication is crucial. A common misconception among IPTs at the aerospace companies was the expectation that most work was now to be done together. Questions and decisions that were addressed by a single person in the past were now discussed by the IPTs. The result was long periods of discussion in which little was accomplished.

We learned that in the IPD and IPT environment, the team should not always work together. Sub-teams and individuals can do some work more efficiently. As part of effective communication and decision making, IPTs need to decide how work should be distributed among IPT members.

When IPTs or sub-teams are doing work, everyone has to be involved in meeting the objectives, controlling diversions and seeking to understand one another's views. A great deal of personal discipline must be exercised by team members to speak only when they have something to add and to relate what they say clearly to the point of discussion.

Lesson 7. Training

Make sure that IPTs are supported with training that defines a core set of engineering discipline, interpersonal, IPT methods and project management skills.

With the formation of IPTs, we encountered four major skill-related difficulties. They were lack of:

- *understanding of other engineering disciplines*. For IPTs to be effective, all team members need to understand a little about the lifecycle steps across all disciplines in the development of deliverables. Cross-discipline training allows IPT members to contribute to each other's work.
- *interpersonal team skills*. Effective communication, listening, encouragement of other members and the suppression of individual egos are examples of some of the skills needed to be an effective member or leader of an IPT. Lack of these skills leads to ineffective decision making, ineffective meetings and inferior IPTs.
- *consistent use of team methods*. Training should allow IPTs to practise team methods (consensus decision making, facilitation, brainstorming, etc.) on real problems. Most people have to see and practise these methods effectively many times before adopting them.
- *basic project management skills*. Cross-discipline cost and schedule estimating and tracking skills are needed.

Lesson 8. Work Sequence

Engineers and managers need to recognize and adopt a different approach to product development workflow to realize the benefits of concurrent engineering. Creative sessions will reduce reviews and rework downstream.

In the past, engineers have developed products through a process of informal consultation and individual creation. Following the initial design stage, the product was subjected to a series of reviews and reworks until the customer accepts it. The views of engineers from different disciplines were often incorporated into the product through repeated reviews. This cycle of review and rework was both costly and time consuming.

In an integrated product development environment, the sequence of engineering product development changes. During creation of the product, engineers from all disciplines necessary to create it are identified and assigned to the project. The product development process involves sub-teams, who create products through continuous review and comment.

During the process, sub-teams use brainstorming, consensus decision making and other techniques that promote creativity. One company used brainstorming to list the design characteristics from all of the relevant engineering disciplines to guide individuals in designing their portions of the work products. Through an interactive process, the sub-teams refined and agreed to the product's content as it was being created. The result was collaboration, with shared ownership of the engineering deliverable.

In essence, the work sequence is reversed, with the review largely occurring prior to detailed design work. The team conducts the creative process collectively and works out the design in a cross-functional way. Individuals then do detailed design after the concepts have been worked out. This avoids rework when other people on the team review the design from a cross-functional point of view. In essence, the cross-functional team can avoid in-depth reviews by ensuring that the design is right the first time.

An IPD environment that provides everyone with immediate access to engineering deliverables as they are being created is required to effectively implement concurrent engineering processes. Enabling technologies, including CAD, modeling and simulation software, allow this process to happen efficiently and speedily.

Putting it all together

Implementing IPD and IPTs requires significant changes in the way we organize, manage and perform work. Strong management commitment is needed to ensure the transition. The new skills require practice and time for the teams to use them effectively.

Often, there is a great deal of optimism when IPD and IPTs are first implemented. But as reality hits, there is a danger of creating frustration and cynicism. To avoid this, IPTs need to assess periodically their progress and plan improvements. Often, an outside team facilitator is needed to assist and advise IPTs. ◆

Author's Bio

Stephen Armstrong is president of AMGI Management Group Inc., a management consulting company based in Toronto. He specializes in operations and strategic management in manufacturing companies that produce highly engineered products. He recently completed a book on engineering management, which will be published by Cambridge University. The company website is at www.interlog.com/~arm/.

Getting set for takeoff

How to build integrated product teams

Getting integrated product teams or IPTs off to the right start can prevent future problems. The following steps should be covered when setting up and leading teams:

- **Develop a product-oriented work breakdown structure.** The process begins with a clear product-oriented work breakdown structure (WBS) for the project. The WBS needs to be closely related to the aircraft system being developed, the end items received by the customer and the overall organizational structure for the product development program. The WBS hierarchy needs to be organized along system, subsystem, sub-subsystem and component lines. Setting up the WBS this way enables IPTs to be established to develop tangible products (see Figure 2, below).

- **Define a clear purpose for your IPT.** The project's IPTs need to be organized around the deliverables of the WBS. The IPT's mission and specific deliverables to be provided to the customer must be clearly specified. The cost, schedule and technical requirements for the team's deliverables must be clearly defined. The relationship of each IPT's deliverables to other deliverables in the system being developed by other IPTs must also be specified. This is often an iterative process among the teams.

Identifying the customers who will receive specific deliverables enables teams to better understand the expectations for deliverables. Here, the term "customer" refers to end users, external customers and internal customers. It also helps to identify points of contact or liaisons needed to complete the team's work.

- **Identify measures of success and incentives.** Each IPT must have an understanding of what constitutes success and how that success will be measured. Detailed business process workflow, as well as product measures, need to be defined. Process and product measures should include costs, schedules and technical measures. Process measures may include schedules for completing tasks versus actual dates of completion, and budgets versus actual costs. Product measures are such things as system failures, specification errors and product costs.

Incentives need to be established that encourage team building. These may include special rewards for when IPT performance exceeds a defined level. Incentives should reward the achievement of measurable goals.

- **Ensure that IPTs comprise cross-functional resources.** IPTs need to comprise all of the engineering disciplines necessary to develop their deliverables. IPTs that include the customer and users are further enhanced. IPTs should assess their needed skill mix and attempt to obtain or develop the skills they lack. It is also important to identify when resources are not needed. This avoids situations in which team members sit around idle.

- **Establish team norms.** Team norms are a set of operating principles, which the IPT's members agree to follow. They include such things as meetings, which should always have agendas and minutes, so that decisions will be recorded and published, and team members will collaborate on, and review, work in progress.

Figure 2. Relationship of work breakdown structure and organizational structure