

MANAGING AEROSPACE PROJECTS IN A MULTI-DISCIPLINARY ENVIRONMENT

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Abstract

In an intensely competitive environment, the challenge for aerospace organisations is not only to advance aerospace science and technology, but to develop world class processes in the application of existing and new technology. Examination of product development processes has yielded significant benefits in cost and timescale reductions of 50-60% through improved multi-functional team working across many of the disciplines required in aeronautics. This paper explores the role of project management in these process improvements. It concludes that for improved competitiveness in aerospace projects, there should be:

- * Multi-functional project teams throughout the project cycle from concept to in-service
- * Team objectives directly aligned to overall project objectives
- * Overall coordination and control by project management
- * Application of basic project management practices by all team members
- * Appropriate training in teambuilding, project management and functional awareness

The paper also suggests that with increasing competition for limited research funds, benefits of cost and timescale reductions with multi-functional teams might also be realised in the research phase.

Introduction

This investigation was initiated following the author's experience of the introduction of Simultaneous Engineering, where the initial stages dramatically improved functional relationships, and the benefits to an aerospace project were seen to be potentially very significant. In discussion with colleagues in other organisations, the answer to the question "Do you apply Simultaneous Engineering?" was met with a range of responses from "Of course, we always have" through "Yes" to "What's that?". Such responses indicated the need for a paper to clarify what is happening in this field.

What Do We Mean by Multi-functional Teamworking?

Multi-functional project teams are not new. They were one of the ways in which the pioneers of aviation were able to achieve their remarkable early success in the marketplace. For example, Paul Smith, the designer of the Moth Minor recalls that DeHavilland set up a team to develop the DH94 Moth Minor in the 1930's. A hangar was rented from the aircraft company (a forerunner of the autonomous business unit of today?), where the whole operation of design, purchasing, manufacture and accounting (a multi-functional project team) was carried out to develop the aircraft against a target selling price of 75% of the Gipsy Moth (benchmarking?).

With the growth of aerospace companies, functional departments were created to establish specialist professional disciplines, such as design. As they grew larger and became more complex, the project management function developed to provide cross functional coordination and control. To provide the balance between projects and functional departments, matrix organisations developed. An uneasy relationship often existed in these matrix organisations between the specialist functions, and between them and the project function responsible for managing the cross functional interfaces.

This was often, (and sometimes still is), exacerbated by poorly defined accountabilities and responsibilities where people felt pulled in different directions, as shown in Fig 1.

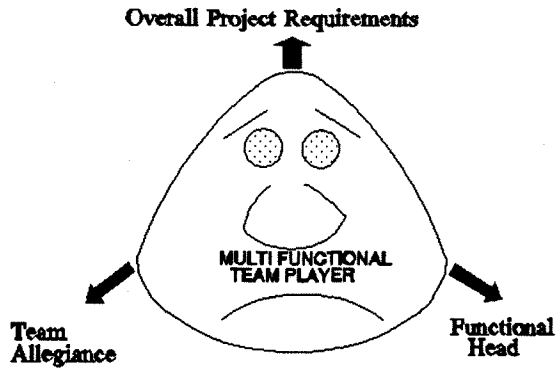


FIG 1 CONFLICTING PRESSURES WHERE ACCOUNTABILITIES NOT CLEARLY DEFINED OR ALIGNED

The relationship has become increasingly strained as the focus has changed from strong functions to strong project teams as the way to improve product development effectiveness (1). If accountabilities are clearly aligned towards a common overall project objective, then the individual working in a matrix organisation is subject to less conflicting pressures (Fig 2).

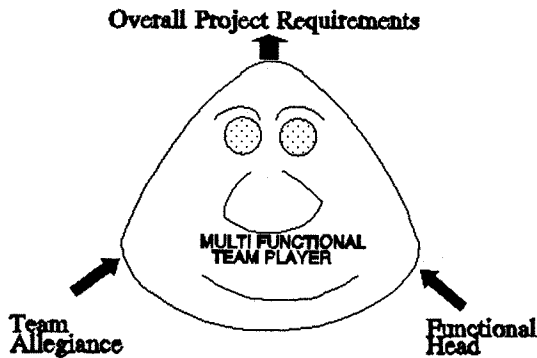


FIG 2 PRESSURES TOWARDS SUCCESS WHERE ACCOUNTABILITIES CLEARLY DEFINED AND ALIGNED

There has been much recent interest in Business Process Re-engineering to improve competitiveness. This has caused many organisations, particularly those in the aerospace sector faced with a major global recession, to challenge the processes involved in developing and

manufacturing aircraft and aerospace products. A common thread emerging has been the recognition that many of these processes involve different functions, such as Engineering or Manufacturing, working in series, and often in conflict when there are overlaps forced due to time constraints (Fig 3).

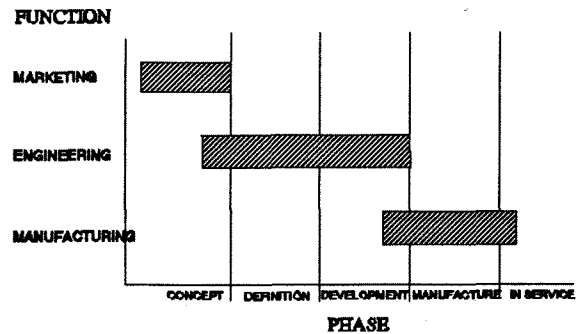


FIG 3 TRADITIONAL PRODUCT DEVELOPMENT FUNCTIONAL ACTIVITY

Improving the way the functions work together so that they can work in parallel (Fig 4) results in a faster time to market at lower cost and higher quality. (2,3).

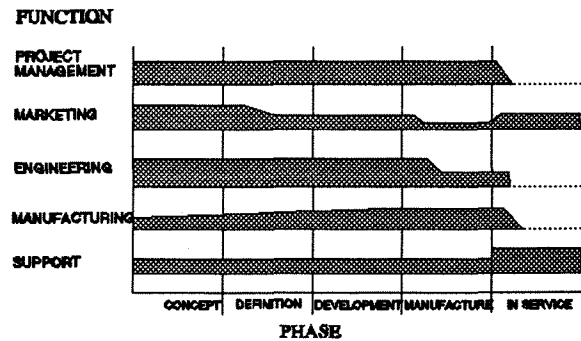


FIG 4 PRODUCT DEVELOPMENT WITH MULTI FUNCTIONAL PROJECT TEAMS

Multi-functional Teams in Industry

Several terms are used which describe cross functional team activity on projects:

- Accelerated Product Development
- Concurrent Engineering
- Design/Build Teams
- Integrated Engineering Teams
- Integrated Project Teams
- Simultaneous Engineering
- Multi-Disciplinary Teams

Essentially these all focus on the bringing together of the functions involved in developing and producing a product with the aim of producing it faster, cheaper and of better quality. In a survey by Engineering, (2), 43% of the companies which implemented concurrent or simultaneous engineering were stated to have achieved business benefits, lower costs, better quality and shorter cycle times. Such improvements have been quantified in a US study (3), which reported timescale reductions of 30-60% and cost reductions of 30-50%.

Accelerated Product Development (4) has been used to describe the process involving teamwork to reduce cycle time.

Concurrent Engineering has recently brought In Service aspects clearly into its scope through the CALS (Computer Aided Logistics Support) initiatives in the Defence sectors. The CALS second phase goal is stated to be reduced lead times and costs for product development using concurrent engineering (5).

Integrated Project Teams, ("Manufacturing, Product Support, Quality Control and Design all working together in the same room") were cited by Cessna (6) as the reason why the prototype Citationjet was an order of magnitude more representative of production than previous Cessnas. This is also the term favoured by Boeing (7).

Simultaneous Engineering (SE), with the general aim to reduce costs and lead times and increase quality, has been defined as

"Large organisations working in the same way small teams always have"

Kumer Battacharyya

This is a useful definition in that it brings out both the team aspect and that the approach is really nothing new.

The generic term Multi-functional Project Teams (MFPT) is the label favoured by the author, since it does not imply a limitation to engineering functions, which might inhibit the opportunities for improvements. Whatever the label used to define the multi-functional team activity, the role of the project management function in such a team is the focus of this investigation.

Multi-functional Teams in Aerospace and Defence

Multi-functional project teams are being used in two main ways in aerospace and defence. Within some organisations, the teams are a fully integral part of the organisation operating across the whole project. These integrated project teams may be linked to the work breakdown structure such that every work package is the responsibility of a team.

Examples of integrated teams are seen in Boeing and in the UK MOD(PE).

Multi-disciplinary Project Teams in Boeing These teams are now a fundamental element of Boeing Programme Management since they are seen as a significant factor in achieving a timely and cost effective process for design, development and production (8). The teams consist of the functions shown in Fig 5, and are also known as product development teams, integrated product teams, or design/build teams. The Programme Manager assesses the type of team structure necessary, with the Work Breakdown Structure defining the team system responsibilities. The 777 used the team concept right from the initial planning (9), including airlines and suppliers. The NATO AWACS also fully implemented Integrated Product Teams as part of a continuous quality improvement initiative, as well as in anticipation of a USAF Requirement (7). The teams are accountable to the Programme Manager with delegated authority to achieve specified deliverables and schedules within a given budget.

Integrated Multi-disciplinary Project Teams in UK MOD (PE) This is an example of a customer recognising the value of the multi-functional team approach. A team of functional specialists from finance, contracts, logistics, quality assurance, technical and programme management areas, together with support from specialists such as reliability, pricing, IPR, legal etc are directly accountable to the Project Manager (10) to achieve the cost, time and performance objectives laid down in the Project Management Plan.

FUNCTION	BAe Cobra SE	BAe Avionics Dev SE	BAe NRA SE	BAe Hawk SE	Boeing 777 Dev IPT	Boeing NATO AWACS IPT
CUSTOMER	✓				✓	✓
PROJECT MNGT		✓	✓	✓	✓	✓
MARKETING			✓			
SALES			✓			
ENGINEERING	✓	✓	✓	✓	✓	✓
MANUFACTURING		✓	✓	✓	✓	✓
PROCUREMENT	✓	✓	✓	✓	✓	✓
CUSTOMER SUPPORT/ LOGISTICS	✓	✓	✓		✓	✓
FINANCE			✓		✓	✓
TEST		✓	✓			✓
SUPPLIERS		✓	✓		✓	✓
QUALITY ASSURANCE				✓		✓
CONTRACTS	✓					✓

✓ - DENOTES INVOLVEMENT AT SOME STAGE

FIG 5 FUNCTIONAL INVOLVEMENT

Other companies have seen the value in using the multi-functional team approach to focus on achieving specific cost or time reduction improvement targets - effectively they act as task forces.

Examples of this were seen in the British Aerospace Airlines Division and Military Aircraft Division.

Simultaneous Engineering in British Aerospace Airlines Division Following a number of very successful initiatives introduced at BAe Hatfield on the BAe 146 aircraft, such as cellular working, network planning, just-in-time procurement, self approval and quality improvement, (which were in effect using multi-functional teams), there were significant reductions in cost and timescale in manufacturing. For example, BAe 146 final assembly was reduced from 31 weeks to 13 weeks. However, the drive for continuous improvement led to the introduction of Simultaneous Engineering to improve still further the engineering processes.

The aim was to minimise throughput time, eliminate unnecessary work and ensure 'right first time' so that engineering efforts were focused on those activities bringing competitive advantage, ie faster and quicker satisfaction of customer needs. (Fig 6)

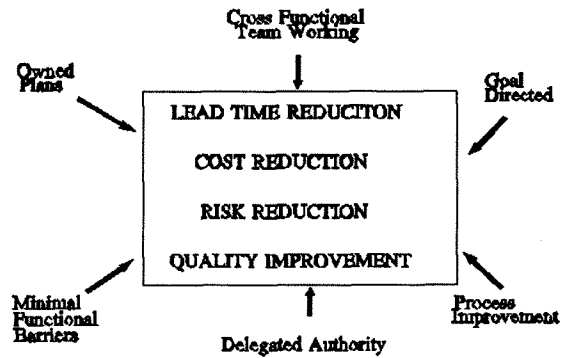


FIG 6 SIMULTANEOUS ENGINEERING IN BAe

An Implementation Steering Group was established at functional head level which, together with consultants, initially targeted eight areas where the greatest potential existed for improved performance. Team members were nominated by their functional heads to join a team on the basis of who could contribute the most to the team at that particular point in time. Fig 5 shows the main functions represented on three of the pilot SE teams. The teams were accountable to the Implementation Steering Group.

Simultaneous Engineering in BAe Military Aircraft The organisation of the BAe Hawk SE team was somewhat different from that of the BAe Airlines Division, even though the 'task force' aims were similar. The Hawk SE aim was to achieve a 9 month cycle time in production. A team of 10 consultants and 10 BAe engineers oversaw some 12 major 'natural work teams' and 36 subteams of operators, supervisors and section heads. The functions covered are shown in Fig 5, and were essentially engineering functions, with some supplier involvement. Whilst one person was selected as team leader, the whole team were accountable for their project.

The Role of Project/Programme Management

The terms project and programme management are sometimes used in different ways in Europe and the USA. For the purposes of this paper, the term 'project management' will be used to denote the process of coordinating and controlling projects, and 'project management function', to denote the specialist staff who report to a Project Manager or Programme Manager responsible for the total or overall project.

Since cross functional coordination affects the way the functions work together, then the cross functional role of project management should be a key driver in identifying and achieving process improvements.

Planning Projects

"The selection and communication of project priorities is the clear responsibility of the Business Managers and Project Manager" This was the guidance from the Managing Director of the BAe Airlines Division when the SE teams were established. The balance between empowerment of the multi-functional project team and direction from the Project Manager needs to be carefully considered to ensure that the plans of the team are focused towards the overall project business results rather than results which appear optimal from the team perspective, but which may be sub optimal for the project. Boeing Integrated Project Team plans are coordinated through the Work Breakdown Structure, with direct accountability to the Programme Manager to ensure alignment of the team and overall project objectives and plans.

A key activity in the planning stage is the development of a Risk Management Plan by project management. The project management function can therefore work closely with or within the MFPT to help ensure that the MFPT carries out an appropriate risk analysis and develops risk management plans.

The lead time reductions on the BAe 146 referred to earlier were, to a large extent, achieved by improved network planning. Process reviews undertaken as part of the SE initiative in BAe Airlines Division also revealed much time wasted in rework due to inadequate planning and communications. The message here is quite clear - a key role of a multi-functional team is to realise the benefits of system level network analysis with optimisation across departments rather than plans for each department, (which result in either complex interface specifications between departments, or in arguments over who is responsible for the failure to deliver).

The Goal Directed Project Management System (GDPM) was introduced by consultants helping to implement the SE programme in BAe Airlines Division. However, it was not linked with the existing project planning and control systems already in place based on work breakdown structures. Since the GDPM approach did not specify lower level activity or plan subsequent milestones, there was less confidence in medium to long term forecasts. Also, since GDPM milestones were not based upon a network analysis, there was no way of knowing whether they represented all the critical path milestones, or whether key activities leading up to the milestone had necessarily been identified.

An important benefit of GDPM was "ownership" of milestones by individuals in the team. This benefit may well have been achieved, without the disadvantages, if basic network analysis itself had been more widely understood and used by all of those involved in the team. Certainly, one of the reasons cited for the success of the BAe Hawk SE team was the involvement of the whole team in developing the project management network.

There has been evidence of significant benefits from multi-functional teamworking as indicated earlier. If it is assumed that a MFPT should achieve reductions of say 40% in time and cost, then a key project management role must be to re-date project plans (11), as indicated in Fig 7. Failure to do so means, in effect, slack targets and the likelihood that the expected improvements will not be achieved.

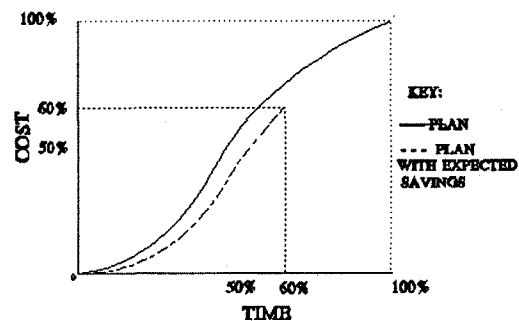


FIG 7 EXPECTED EFFECT OF SIMULTANEOUS ENGINEERING ON PROJECT PLANS

The project management role in the planning stage should therefore be to:

- * Ensure team objectives are consistent with overall project requirements and fully understood by all team members
- * Ensure best project management practice is employed by the team, including network analysis and risk management

Organising Projects

Organisation and Selection of the MFPT The organisation and selection of the multi-functional team is probably the most important element contributing to its success or failure. The project team composition is likely to be from different functions as the project moves through different phases.

Fig 5 shows some of the functions involved in the teams considered in this study which cover feasibility to production stages of projects.

In Boeing, the Programme Manager, in conjunction with relevant functional managers, initiates the organisation of the team by carrying out an organisational analysis to determine the most appropriate team structure. The teams consist of 30 or fewer members, with a core group of 4 to 6 at any one time. (9). On complex projects such as AWACS and the F22 program, two levels of team were employed. An Analysis Integration Team was responsible for system engineering, managing interfaces, configuration control, and also coordinated the technical work of the Integrated Project Teams.

The organisation of multi-functional teams in BAe Airlines Division was driven initially by the Implementation Steering Group. Although the project management function was initially excluded in the belief that "if multi-functional teams work properly there is no need for project management", it was subsequently added when project management joined the Implementation Steering Group and the value of project skills was recognised.

A valuable element in the BAe Airlines Division SE team organisation was the use of a Project Responsibility Chart to communicate the organisational interfaces (Fig 8). This communicated who was responsible for executing the work, who was responsible for taking decisions, and interface involvement such as who should be consulted.

The BAe Hawk SE team consisted of a mixed "overseeing team" of consultants and BAe engineers supervising the major 'natural work teams' with subteams of operators, supervisors and section heads. The nature of the production cycle reduction aim meant that the functions were engineering-related, with some supplier involvement. Each team was accountable for its own project.

Customer/Supplier Involvement If a contract has already been placed for development, the involvement of the customer in the multi-functional project team should help ensure that his/her needs are being correctly interpreted, and possibly help develop the requirement through innovative interaction with the team. There may be constraints with commercial confidentiality, Intellectual Property Rights and making contractor deficiencies visible.

The Boeing 777 has involved potential customers in multi-functional teams from a very early stage (8). It would seem that given the customer interface responsibilities often assigned to the project manager, a valuable role for project management might be to help identify the risk areas and develop risk management plans to maximise participation by customers.

Similar constraints to those related to customer involvement may inhibit the involvement of suppliers. However, Boeing have successfully involved suppliers in their integrated project teams (8, 12). The BAe 146 Project view was that suppliers were key to the development process and therefore should be involved. A plan was developed to introduce them into the Avionics Development Simultaneous Engineering Team after the risk strategy for dealing with confidentiality issues had been decided.

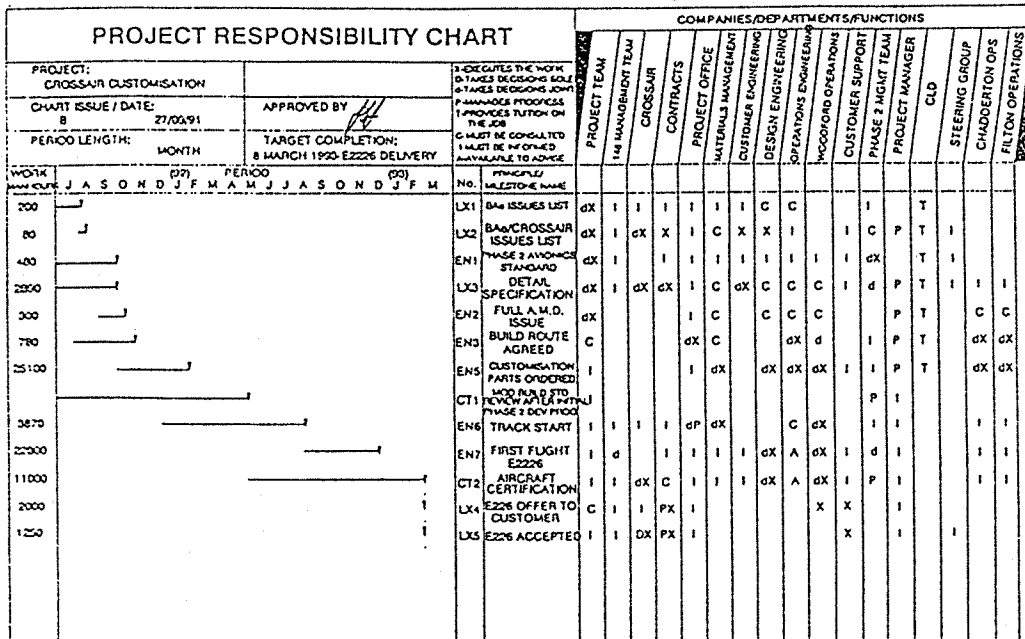


FIG 8 PROJECT RESPONSIBILITY CHART

With increasing sub-contracting of project activity, because it is considered lower price, non core business, or because of offset requirements, the involvement of suppliers may be an increasing feature of multi functional project teams.

The role of project management in the organisation of teams should be to:

- * Establish, in conjunction with functional management, the composition of teams necessary to meet project objectives
- * Ensure all essential processes are covered by either MFPT or functions

Monitoring and Controlling Projects

On the BAe 146 project, there was concern that the individual SE teams might not achieve optimum results for the project unless their activities were coordinated. A Project Review Board was established, led by the Project Director, to review overall progress of the SE teams working within the project, and to understand key risk issues. The Board received presentations from the SE team members, enabling overall project coordination and control towards project objectives to be achieved, as well as resolving resource and priority issues outside the empowerment of the SE team.. In effect, the SE team empowerment was strengthened by 'drawing in' senior management to help resolve problems.

A supervisory team role for coordinating multi-functional project teams is also seen in an academic software development project (13). Whilst not an aerospace example, the approach of creating a 'guidance team' does seem to be relevant. The Guidance Team role was to;

- Identify project goals and write project brief
- Select and assign project team members
- Determine other resources and provide them
- Monitor progress
- Sign off results
- Provide accountability to the rest of the organisation for the work of the project team

The MFPT itself retains responsibility for achieving the agreed results.

A supervisory role was also effected by an IPT Advisory Council on the NATO AWACS which met every two weeks. It was attended by the Programme Manager and the functional managers to review performance and

risks, and to identify where additional support was required to meet IPT objectives.

This meeting was also attended by the USAF/NATO representatives (for other than cost performance discussions since the contract was Fixed Price).

The project role in monitoring and controlling multi-functional teams should be one of:

- * Overall monitoring of progress
- * Delegation to team of detailed monitoring and control of their task
- * Resolution of problems outside the empowerment of the team

Leading Projects

The leadership of the MDPT is clearly very important for success. In most of the cases examined, the team leader was elected from within the project team. Since one of the criteria for selection of project managers is leadership skills, then it is not surprising that this function provided some of the team leaders. However, when the team leader comes from another function, then the project manager can offer a useful training or mentor role for the team leader. Project management can also provide guidance on the leader's task of priority setting within the team.

So *should* project management normally be the team leader? To answer that question in general terms, it is helpful to look at the types of teams suggested by Drucker (14). Drucker used the analogy of soccer and cricket teams for development activity. He suggested that the Japanese began in the 1970's to switch from the 'cricket' team, (where everyone played on the team, but not simultaneously as a team), to the 'soccer' team, (where everyone had a fixed position but worked as a team in a flexible and fast way to score goals). He emphasised that the soccer team was controlled by a coach whose word was law. Developing this analogy for MFPTs, the fixed position equates to a functional specialism. Should project management be the coach, the captain, another player, or outside the team as referee?

As a member of the team, project management will bring a variety of project planning, monitoring and controlling skills and experience to bear on the team activities.

Such project experience is increasingly being developed by functional specialists, but the distinctive added value of project management is the overview to enable effective decision making towards the overall objective.

Should project management therefore provide the captain, or team leader? Possibly, since the captain's role does require good leadership skills as mentioned earlier, but there may be other functional specialists with good leadership skills.

Whilst the role of referee may have been one of the traditional project roles in the past, when the emphasis was on auditing and monitoring, in the lean organisations of today it is more important to achieve results than to obey rules which may have been rendered inappropriate in a rapidly changing world. The referee role is therefore ruled out.

The role of coach would seem to be an appropriate one, with the team benefitting from the strategic project overview and risk appraisal to guide them towards the right tactics. However, there is no room for someone who operates from the sidelines.

The best role for project management would therefore seem to be as player/coach, combining an important position on the team bringing project management skills, with a strategic overview to make sure the team has the right strategy to win not only the game, but the league!

The leadership skills of motivating and inspiring the team should not be learnt for the first time on the project itself, and the selection of a leader from within the team may need guidance from functional management or project management, since it may well be the first time that some of the team have worked together.

The project role in the leadership of multi-functional teams:

- * may be as team leader
- * should always be providing a strategic overview for the team

Training

Some of the problems encountered in operating MFPT in BAe were interface issues which the teams themselves identified as requiring project management training and techniques to overcome.

A common theme in all of the discussions was the need for more training to operate effectively either as a

teamplayer, team leader, or manager of teams. Simply assigning staff from functional departments because they have the functional skills and knowledge is not enough. They need training in teamwork as well as a better appreciation of the roles of others so that they can help maximise the team contribution. This issue has been recognised by the UK MOD(PE) which is now offering teambuilding training for its integrated project teams. A key principle of the University of Portsmouth approach to that team building training is that off the job learning must be transferred to the work situation. A MFPT teambuilding exercise should therefore involve all of the team players working together on project issues rather than attending courses individually. The University initially work with the project manager and several members of the project team to understand the key issues. This is followed by interviews and a questionnaire for all project team members to identify areas preventing closer integration and improved effectiveness. These barriers are then addressed in workshops combining outdoor activity to build personal relationships in the team, with sessions developing action plans on the specific project issues to improve project effectiveness. The team therefore develops ownership of the objectives and plans to achieve them. The project manager of one project team (15) identified the following achievements as a result of their teambuilding programme:

More shared commitment to the project cause

Clearer identification and ownership of common goals

Individual problems brought out into the open

Better awareness of communication problems and a commitment to resolve them.

More harmonious and closer team

The project manager played a key role in this teambuilding, leading the team through a mutual self discovery and learning of how to improve their performance as a team. This suggests that the team leader should be appointed before any teambuilding training, and that if the leadership of the team changes, a teambuilding renewal event should take place to provide the opportunity for continuous improvement of the team.

Areas for Further Work

Whilst much research is carried out in small teams, they are usually from within the same discipline, or from several disciplines sharing a research topic. This may be termed 'horizontally multi-disciplinary'. In view of the benefits achieved downstream in the project cycle with 'vertically multi-disciplinary teams (ie MFPT), there may be an argument for the inclusion of marketing or manufacturing engineering on an occasional basis in research teams to facilitate the more rapid exploitation of pioneering scientific ideas, particularly when funding is very limited.

Summary and Conclusions

Multi-Functional Project Teams (if operating effectively) can provide dramatic reductions of up to 50-60% of project development costs and timescales through people working better together. Management of Multi-functional Project Teams requires a strong effective project management function to ensure that the team efforts are constantly focused towards the overall project objective.

It is concluded that improved competitiveness in aerospace, throughout all phases, from concept to in-service, may be achieved with:

- * Multi-functional project teams for development
- * Team objectives directly aligned to overall project objectives
- * Overall coordination and control by project management
- * Application of basic project management practices by all team members
- * Appropriate training in teambuilding, and project management, with awareness of the roles of other functions .

Finally, in view of the significant benefits of multi-functional teams in development, and the pressures on research funds, it may be worth exploring their value in the research phase.

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