PROJECT MANAGEMENT

SUCCESSFUL MANAGEMENT OF A LARGE PROJECT

The key to successfully managing a large project (which nearly all aerospace projects are) is to have organisation, procedures and management practices that tie the systems engineering processes and project management processes together.

That is why the technical organisation of major system houses often reflect the way the system is broken down with departments for each of the sub-systems.

For this lecture we will look at:

- Task breakdown
- Management organisations
- Document Control

Blanchard and Fabrycky has a reasonable chapter on System Management.

HOW A PROJECT GETS STARTED

Typical aerospace practice for a government funded project is for the customer to issue a "Request For Proposal" (RFP). This is the form used when the product is not fully defined which by definition must apply if a new system design is required. (There are also "Requests for Tenders" (RFTs) which are used when the product or service is well defined). An RFP will typically contain:

- The Requirement Specification
- A contractual agreement
- Instructions for bidding
- A Statement of Work (SOW)

A "Statement of Work" (SOW) defines the work to be done. The basic principles of what constitutes a good SOW are the same as for a good Requirement Specification.

If the RFP is for a study or support work rather than a system then a Requirement Specification is probably not relevant. Only the SOW will exist in this case. In some system developments the SOW may not exist and the work done implied by the request for the system.

To win contracts bidders must prove two things.

1. They offer the best technical solution (i.e. lowest cost) to meet the specification.
2. They have a credible organisation within which to do the work.

Which brings us to management and the link with systems engineering.

BASIC TASK DEFINITION (WORK BREAKDOWN)

This uses essentially the same tools etc. as are used for breaking down and analysing the system itself. After all the management and the project development process is a system in its own right.

We saw an example of work breakdown in the lecture on Networks and Diagrams. It is a good idea to follow the guidelines for function breakdowns - logically it the same basic technique. In real life people tend to be "sloppier" about task breakdowns and will have many more than 7 "daughters" from one "mother."

The objective of breaking down a project into elements is to reach manageable units that can be controlled. As the tasks in each element are performed they should all contribute towards the eventual completion of the system interfaces (normally in the form of documents and drawings) both into and out of the element should also be tracked.

With development costs in order of $10 billion that is in the order of 100,000 people-years of effort with at peak tens of thousands of people working on the project.

Compare this with the ideal size unit for monitoring and control which is 5 – 10 people. The aim is to get task broken down in a hierarchical manner to 5 - 10 people units that a single person can manage.

WORK PACKAGES

The end product of breaking the tasks down is to define work packages which constitute the elements of the project management system (we have already seen work package breakdowns).

The work packages are normally described in a document called a Work Package Description (surprise, surprise). These are often supplied to the customer in aerospace government sponsored projects and define the work to be done. These Work Package Descriptions respond to the statement of work in the same way a Design Specification responds to a requirement specification.

A Work Package Description defines the interfaces in terms of inputs to the work package required to do the work and outputs from the work package (often an input to another work package). It also defines the tasks to be performed to get the required outputs.

Detailed costing of projects is normally based upon estimates of the cost of each work package. The ideal cost of a work package is typically $100,000 to $500,000 on larger projects, but can be around $10,000 on small studies.

<table>
<tr><td colspan="2">Guest Associates (Europe)</td><td colspan="2">Project</td><td colspan="4">Necropolis</td></tr>
<tr><td>Work Package</td><td>2.6</td><td colspan="5">Scout Concept Design</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Organisation</td><td colspan="2">Hempsell Astronautics</td><td>Manager</td><td colspan="3">Mark Hempsell</td></tr>
<tr><td>Time</td><td>Start</td><td colspan="2">Month 4 (Concept Review)</td><td>End</td><td colspan="2">Month 8</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Objective</td><td colspan="6">To produce an independent assessment of the Mission design</td></tr>
<tr><td>Inputs</td><td colspan="6">• Initial Requirement Specification
• QinetiQ Input</td></tr>
<tr><td>Tasks</td><td colspan="6">• Produce a concept System Architecture for the Scout for Parametric Costing
• Produce preliminary system Budgets
• Produce 3D CAD model
• Produce concept design report</td></tr>
<tr><td>Outputs</td><td colspan="6">• Preliminary Concept Design description for Mid Term Review
• Final Concept Design description
• CAD Model</td></tr>
<tr><td>Supporting Info.</td><td colspan="6">System design - 18 days
CAD model - 5 days
Report Writing - 7 days</td></tr>
<tr><td rowspan="3">Cost Estimate</td><td colspan="2">Effort (Work Days)</td><td>30</td><td>Rate</td><td>£***</td><td>Cost</td><td>£******</td></tr>
<tr><td colspan="2">Direct costs £</td><td></td><td colspan="4"></td></tr>
<tr><td>Notes</td><td colspan="6"></td></tr>
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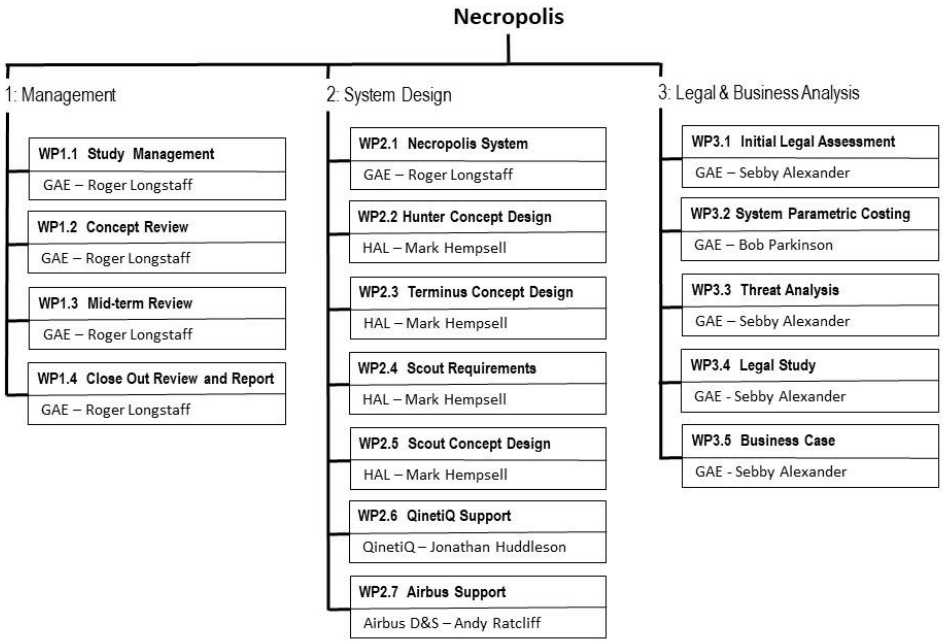
The example shown here is based on the ESA standard format for a work package description. Other organisations and customers will have something similar.

Putting the cost estimate in with the Work Package descriptions is very unusual and definitely not in the ESA standard. Cost are normally attached to Work Package as a separate exercise given this is commercially sensitive data, but I find when pulling a proposal together it is easier to have the cost and the work together. If the customer requires you to submit the WP descriptions the cost estimate would be removed.

Outside ESA my experience has been that a customer will require a Work Package breakdown and a one line description of the work and who is going to do it not all the full descriptions.

BREAKING A PROJECT DOWN

We have already seen the use of networks as a tool to examine work, tasks and management planning issues. To illustrate the Work breakdown a family tree is often employed.



The management system is often more complex than the system it is developing and more people are involved in the process so organised and formal methods become more important. Most companies will have standard ways of dealing with this.

The two key issues are:-

1 - to ensure that the interface between different work elements are all covered and well defined. That is the work done by one person really is what is required by the next person in line.

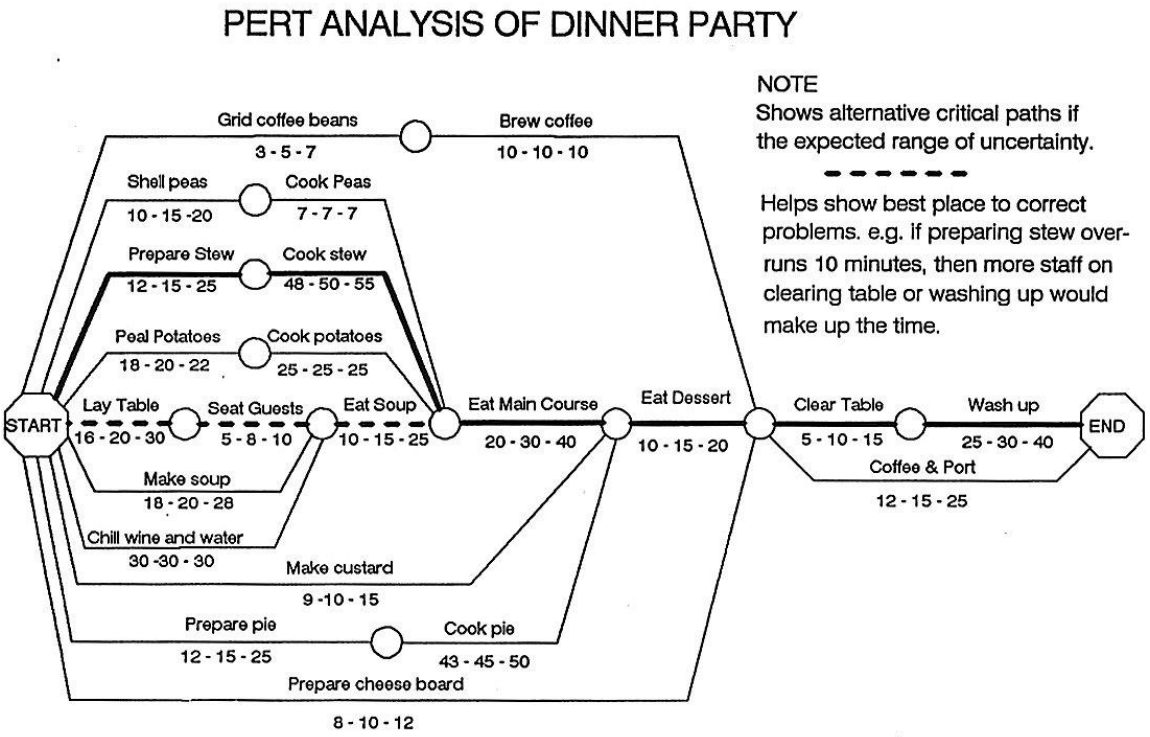
2 - To enable detailed and accurate costing of the project firstly to set the price and secondly to monitor progress.

In the development stages of a project and in many case later on as well the main interfaces are documents of one form or another.

During production the outputs are various hardware and software components and assemblies.

WORK PACKAGE NETWORKS

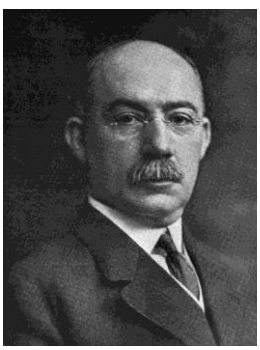
There are two common ways Critical Path/PERT and Gantt of diagrammatically showing Work Packages - We have already met Critical Path/PERT



GANTT CHARTS

Another way to network the work breakdown this time to show the relation of work to the calendar. Also called Milestone charts.

Named after Henry Gantt (1861 -1919) who invented the chart in the 1910s (but there were very similar things already in circulation).



Very commonly used in Project Management and in my experience always asked for customers in proposals.

It places the work packages as bars along a calendar axis so it is easy to see when packages start and finish and also what work should be being undertaken at any point in time

WP	Title	1	2	3	4	5	6	7	8	9	10	11	12
1	Management	1.1 General Management											
		1.2 Concept Review					1.3 Mid term Review				1.4 Close Out Review and Report		
2	System Engineering		2.1 System Level Analysis										
			2.2 Hunter										
			2.3 Terminus										
				2.4 Scout Requirements		2.5 Scout Concept							
			2.6 QinetiQ Support										
			2.7 Airbus Support										
3	Business Case	3.1 Initial Legal Assessment								3.2 Costing			
			3.3 Threat Analysis										
			3.4 Legal Study										
									3.5 Business Study				

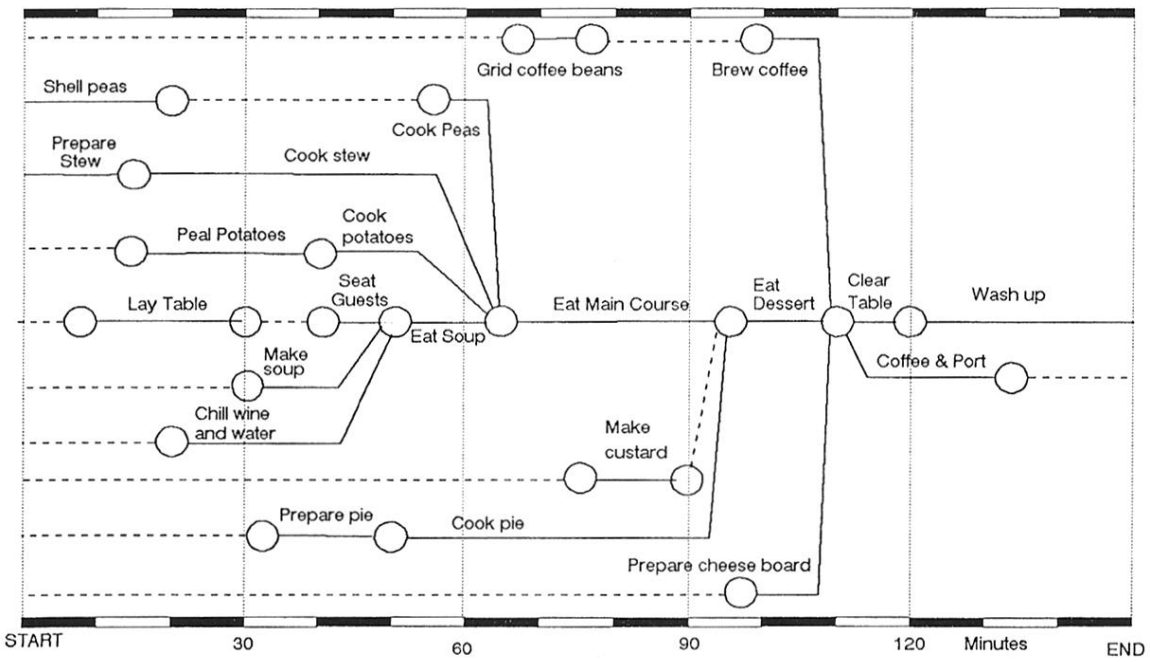
Concept Review — Mid Term Review — Business Case Review

Q1 Payment ▲ Q2 Payment ▲ Q3 Payment ▲ Final Payment ▲

This is not only useful for knowing what is going on. As you should have staff effort and costs associated with each Work package you can easily determine the staffing and cost profiles over time. I normally have a version of the GANTT in Excel to do this but there are specialist programs based around Gantt charts including: Microsoft Project, Project Manager, Smartsheet, Monday, Proggio,

NAUGHTY BUT NICE - MIXING CPA AND GANTT CHARTS

Not in any textbook or company procedure but can be very effective as a planning tool. After you have done the Critical Path or PERT analysis transfer the logic onto a time related milestone chart.



MANAGEMENT STRUCTURES

There are two main types of management structure used in engineering industries. These are:

Project Organisation
Matrix Organisation

PROJECT ORGANISATION

Project organisation split the work force into projects and everybody is assigned to one of these projects. There is one line of management and the project teams are multi-disciplinary. Potential problems with the approach are:

- Project teams are limited to product lifetime, leading to constant reorganisation.
- Company skills and work loading more difficult to spread among projects.
- Management balancing of cost/schedule Vs quality/standards relies on individual judgement.

Chief Engineer					
PROJECT A Project A Manager		PROJECT B Project B Manager		PROJECT C Project C Manager	
Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)	Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)	Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)
Engineer		Engineer		Engineer	
Engineer		Engineer		Engineer	
Engineer		Engineer		Engineer	
Engineer		Engineer		Engineer	
	Engineer		Engineer		Engineer
	Engineer		Engineer		Engineer
	Engineer		Engineer		Engineer
	Engineer		Engineer		Engineer

MATRIX MANAGEMENT

This approach organises the workforce along the same divisions as the system that is to be developed. They are placed in specialist engineering departments (sometimes called "Line" Departments). These then allocate engineers to projects.

Projects have their own management but the engineering work force comes from the line departments. Thus every engineer has two management structures over him or her.

1. "Line" or "Departmental" responsible for specialist engineering issues and overall workforce deployment.
2. "Project" responsible for system engineering and task allocations within the project

SIMPLE EXAMPLE OF MATRIX MANAGEMENT

		Project Director					
		PROJECT A Project Manager		PROJECT B Project Manager		PROJECT C Project Manager	
		Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)	Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)	Assistant Proj. Mang. (mechanical)	Assistant Proj. Mang. (electrical)
Chief Engineer — Chief Designer (mechanical)	Head of Structures	Engineer		Engineer		Engineer	
	Head of Thermal	Engineer		Engineer		Engineer	
	Head of Propulsion	Engineer		Engineer		Engineer	
	Head of Mechanisms	Engineer		Engineer		Engineer	
Chief Engineer — Chief Designer (electrical)	Head of Power Systems		Engineer		Engineer		Engineer
	Head of Data Handling		Engineer		Engineer		Engineer
	Head of Communications		Engineer		Engineer		Engineer
	Head of Control		Engineer		Engineer		Engineer

PROBLEMS WITH MATRIX MANAGEMENT

Matric management is the most widely used management organisation in large aerospace companies but it is not perfect.

- It only works for large organisations involved with many projects.
- It can lead to tensions between engineering department concerned with engineering quality and project management concerned with schedule and cost.
- Project "team spirit" not always established.
- Tends to be a higher cost way for working - probably as a result of the other problems.

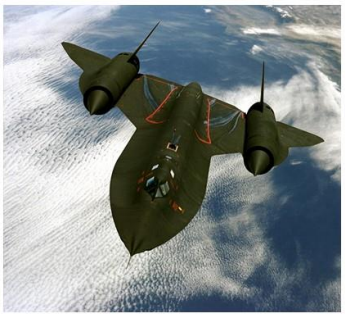
"SKUNK" WORKING

In 1943 Lockheed founded the Advanced Development Project group under Clarence "Kelly" Johnson for the development of the Shooting Star fighter. It became known as the "Skunk Works".

It has been responsible for some spectacular aircraft e.g. F104 Starfighter, U2, SR71 Blackbird, Fl17 Stealth Fighter

F104
Starfighter

U2
Dragon Lady



SR-71
Blackbird

F117
Nighthawk

- it has also produced some turkeys but people tend to forget about them.

It not only produce spectacular aircraft it brings them in at about half the cost -so not surprisingly the group is much admired. Imitators often refer to "Skunk Working" - At least they did until Lockheed made it a trade mark.

Basically it uses a project organisation structure but operated special "rules". During 1950's Kelly Johnson outlined the 14 "rules" that made the Skunk Work management style successful.

UK industry is often a little cool about "Skunk Working" as the small company structure in the 1950's and 60's meant many of the basic ideas were applied throughout the UK industry.

Reference: "The Skunk Works Management Style - It's No Secret" Ben R Rich, Aerospace, March 1989

SKUNK WORKS - KELLY JOHNSON'S 14 RULES

1 - The project manager is in complete control.
2 - Keep the project office small.
3 - Minimise the people involved - essential team members only.
4 - Use a simple drawing control system.
5 - Minimise reporting to essentials.
6 - Monthly cost reviews
7 - Contractor controls subcontractors.
8 - Use contractor's quality system.
9 - Contractor has flight test authority.
10 - Frozen specifications before contract signing.
11 - Adequate and consistent funding from customer.
12 - Mutual trust between contractor and customer.
13 - Strict control on outside contacts.
14 - Reward employee's engineering value.

WHAT' S WRONG WITH SKUNK WORKING

If Lockheed have been so successful with it why doesn't everybody do it.

- It splits the company resource base. The "Skunk Works" takes the finest engineers the company has leaving only the mediocre in other company divisions.
- It only works for demonstrators, prototypes, and small production runs (below 50).
- Large projects exceeding a $ billion or two need larger management structures.
- It produces variable quality of output. Yes it has the freedom to produce the genius but also the freedom to produce a turkey (although on balance, over several projects, the customer does gain significantly).
- (Related to above) If a turkey is produced and the project is government funded the political fall out can be a problem. A lot of the micro-management by politicians and civil servants is to protect against embarrassment. Note that almost all of the Skunk works projects are in the "black world".
- Small teams, working in semi-secrecy, with trust between the paymasters (who do not see much of what is going on) and the team are all important factors to success but not always realistic in the real world.

DOCUMENT CONTROL

Within a development project the main interface between work packages are documents of various sorts. Because of their importance documents are formally control by a document control system. This means assigning unique identities (numbers) recording issue status, recording changes made with each issue, and having an authorising path to give them legal status. A formal document should always have the following

- Title: Obviously
- Address: of the organisation that produced it. Many firms also assert their copyright but even it you don't there should always be a record of where a document comes from.
- Document number: According to a document control system.
- Issue: Again controlled by the document control procedure. Normally a document has an issue history with it as well.
- Date: Not to be forgotten
- Signatories: typically:
  Written by: the person who did the work
  Checked by: somebody else never the person who did the work (who should have checked it anyway.
  Approved by: somebody high up in the line management (chief designer or equivalent) approving the engineering content of the document.
  Authorised by: The person in the project management organisation responsible for the relevant work package. This says the company accepts the cost and schedule implications of the document
  (sometimes) the safety officer is added where safety issues are involved.

(Engineering Drawings are controlled in a very similar way although older companies may have some additional boxes on drawings like "traced by" signature which are now obsolete. In aerospace companies "stress and weights" will also have a signature.)

SOME POINTS ON DOCUMENTS

- Sometimes it is desirable to circulate a document in draft form before formal issue. These draft issues can go through several versions and are sometimes given draft issue letters "A", "B" etc. before issue 1 the first signed up formal issue
- There is a tendency to use the formal document control for quite unimportant or simply record documents. This can get expensive, either people should be encouraged not to use it or there should be a second level document control system with much less formality.
- Remember taking out a number does not necessarily mean you have to produce the document. Numbers are cheap and in limitless supply.
- Having longer numbers with project bits in etc can also prove advantageous as projects can then operate document control more independently while staying within the company system.