Forecasting NRE Cost

and
Delivering Projects Within Budget

Why So Difficult ?

Phil Wardle

Brief Biography

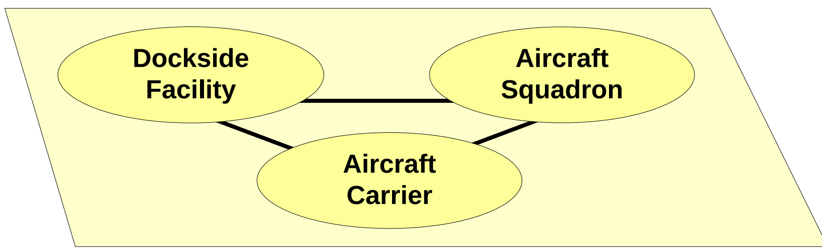
- BSc (Hons) and MSc in Computer Science, University of Manchester
- 35 years experience in oil and gas, telecom, and defence industries – mostly working in Engineering Management
- By way of preparation I've drawn on my own experience of working across these sectors, and more recently, of conducting research with UK and US academia
- Please see my public profile on LinkedIn :- **http://uk.linkedin.com/pub/phil-wardle/13/73/3**

Contents

- The basis of the presentation is to focus on the first five steps of the eight that most practitioners follow when preparing a forecast, discussing some of the issues that can give rise to problems in forecasting Non-Recurring Engineering (NRE) at each step
  - Determine the bounds of the estimate
  - Capture and record the assumptions
  - Develop a cost breakdown structure
  - Identify the best estimating method
  - Collect and analyse historical data
  - Compile and validate the estimate
  - Analyse the uncertainty and risks
  - Deliver estimate in suitable format
- Summary of Challenges
- Questions ?
- Bibliography

Determine the Bounds of the Estimate

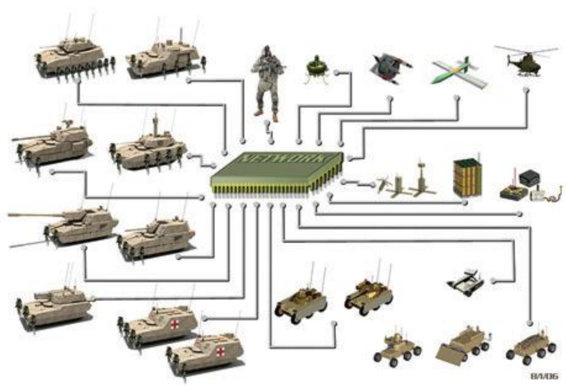
- The CJCSI [1] definition of ***capability*** is: “The ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks”
- Consistent with this there are two widely used views of capability - ***operational*** and ***material***



Operational View of capabilities, roles, missions

e.g. supports the ‘top-table’ discussion between system integrator and the customer

Source: US Army



Material View of systems and people

e.g. supports discussions between system integrator and major subcontractors

Step 1 of 8

[1] CJCSI 3170.01E, Chairman of the Joint Chief of Staff Instruction: *Joint Capabilities Integration and Development System*, 11 May 2005 (USA DoD)

Determine the Bounds of the Estimate

- Which ever view of capability we're taking its clear that we need to be able to put ***boundaries*** around the estimate, i.e. to define with some degree of certainty what is included and what is not
- In the UK defence community it is recognised that capability is achieved by synchronising the eight ***lines of development*** collectively known by the acronym ***TEPIDOIL***; one approach to bounding the estimate is to use these as a checklist, e.g. for each line of development in this list what combination of products and services are needed to sustain it over the CADMID cycle?
  - **T**raining
  - **E**quipment
  - **P**ersonnel
  - **I**nfrastructure
  - **D**octrine
  - **O**rganisation
  - **I**nformation
  - **L**ogistics
- All TEPIDOIL components should be addressed in a through life cost estimate where relevant
- In addition Integration is often added as an overarching theme and cost driver – e.g. this refers to the ability of the UK forces and to train, exercise and operate effectively with forces of other nations

Determine the Bounds of the Estimate

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- Having invested effort in bounding the estimate there may be a reasonable understanding of this on the part of the system integrator and the customer (e.g. defence contractor and UK MoD), but this is easily lost if not captured and recorded

- Examples of cost drivers that might be forgotten if not recorded:-

  - What ordnance is included, what consumption is assumed under various conditions, e.g. during training, in peacetime, in wartime ?

  - What personnel are contributed to in-service support activities by the defence contractor and MoD / forces respectively – how many, what grades, with what expenses overhead?

  - Will there be mid-life upgrades for technology insertion or mitigation of obsolescence?

  - What additional cost might be incurred if deployment is outside the expected theatre, e.g. tanks designed to operate in Europe are have higher support costs when operating in the harsher environment of the Middle East?

- A document or spreadsheet is created to capture the assumptions and data on which an estimate is based, e.g. a ***cost data assumptions list***

Determine the Bounds of the Estimate

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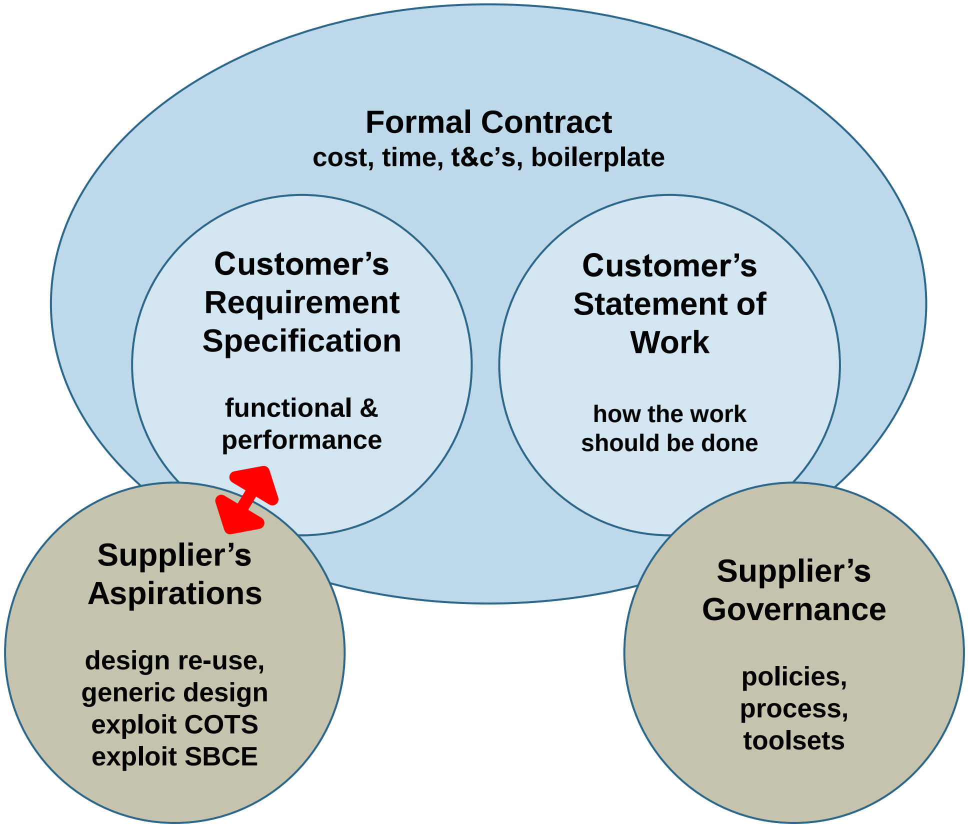
- At this point I'd like to make the proposition using metrics, models and tools to forecast cost and time for a well-defined work package IS NOT our greatest challenge (though we need to work at it, for example to cope with inexorable growth in system complexity)
- In my experience the greatest challenge of all is ***elasticity in the scope of work*** – determining the bounds of NRE content is difficult both in terms of identifying all the tasks and then sizing each task with sufficient confidence
- There are four examples of elasticity on the following slides concerning
  - Bespoke Requirements
  - Prescriptive Process
  - Boilerplate Sell-off
  - Baseline Control

Bespoke Requirements

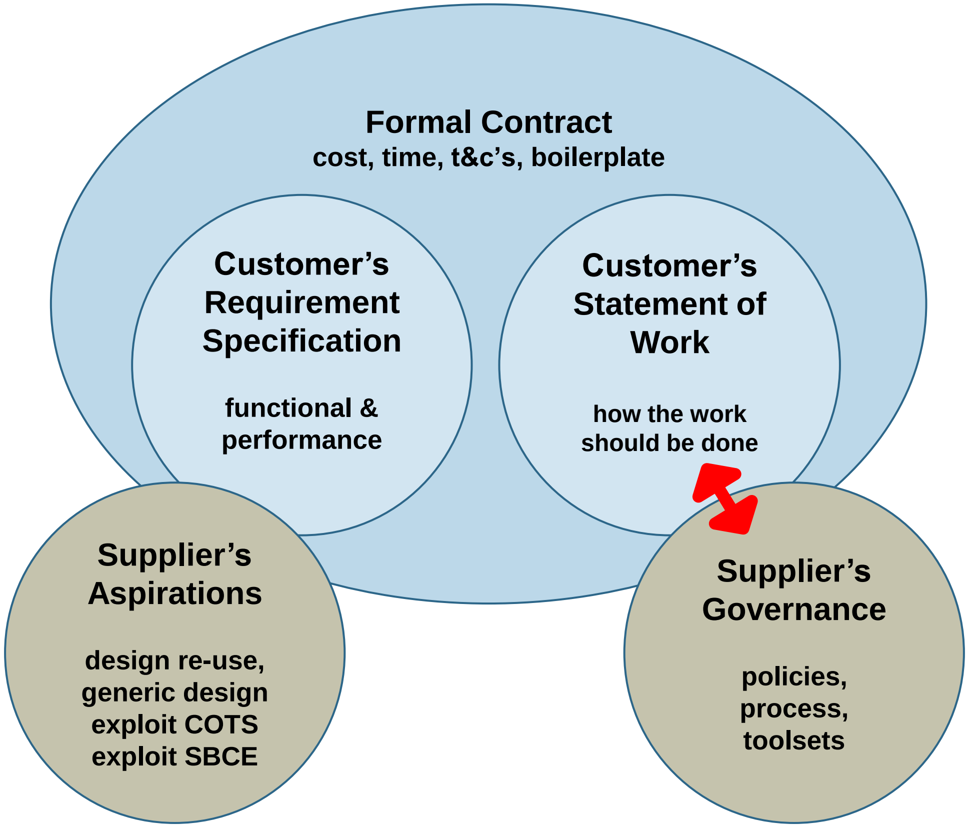
- Historical trend is cost-plus ➔ fixed-price
- Tensions may arise between Customer's requirements as invoked in the Contract (sometimes *arbitrarily* bespoke) and the Supplier's aspirations for design re-use, generic design, and COTS and SBCE [a]
- Bespoke requirements drive uncertainty, e.g. system designs cannot be bottomed out, and subcontracts cannot be scoped or negotiated, prior to submission of bid
- Suppliers will try to build-in cover for this uncertainty in their bid but overspends and delays are still likely to arise
  - Cover is difficult to estimate / justify
- The challenge is to find ways to converge Customer's requirements and Supplier's aspirations during contract negotiations
  - Meet 95% of need at 80% of cost?
  - Re-use h/w, s/w, support solutions?



COTS = Commercial Off The Shelf
SBCE = Set Based Concurrent Eng

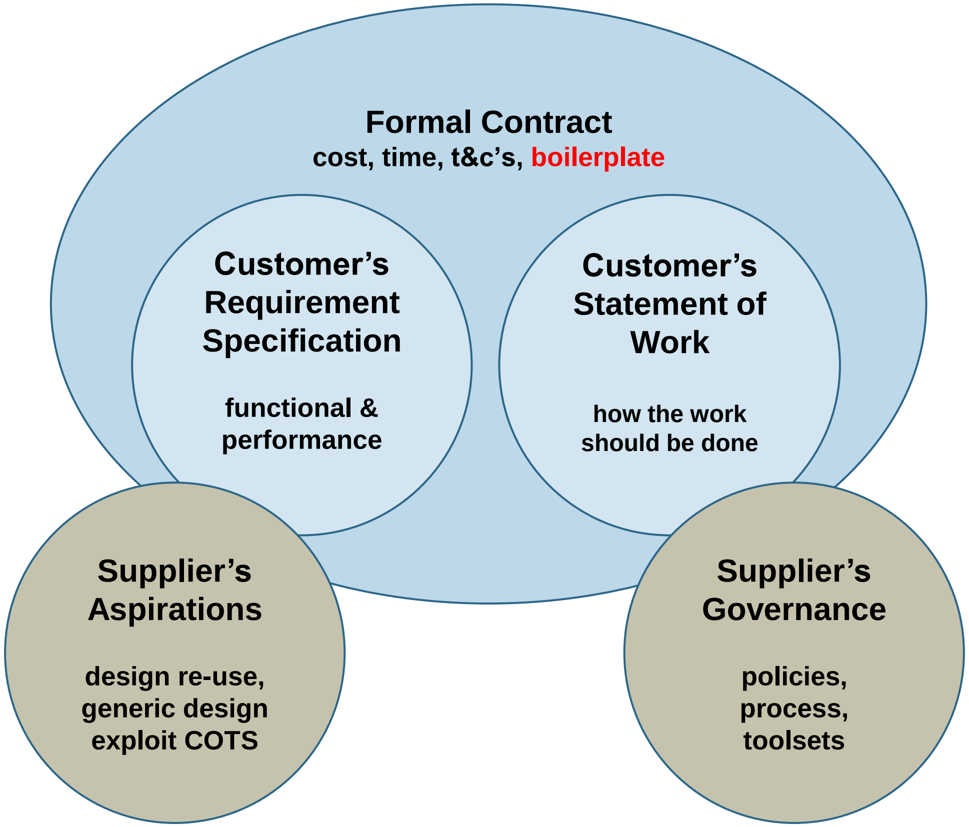
Prescriptive Process

- Historically, the Customer's experience of the Supplier's poor process maturity and lack of visibility of progress encouraged more prescriptive Statements of Work
- Overspends in NRE and delays in formal completion of work packages often arise because sell-off of the Customer's SOW requirements often drags on ("jobs worth" tick-box culture vs. pragmatism) [a]
- Meanwhile, EU and National legislation, and internal initiatives have improved the scope and maturity of Suppliers' internal policies, processes and toolsets
- The challenge is for suppliers to assure customers that it is safe to simplify their SOWs and place greater reliance on the Suppliers' internal governance
- Could perhaps be achieved by increased adoption of open standards and audits [b]



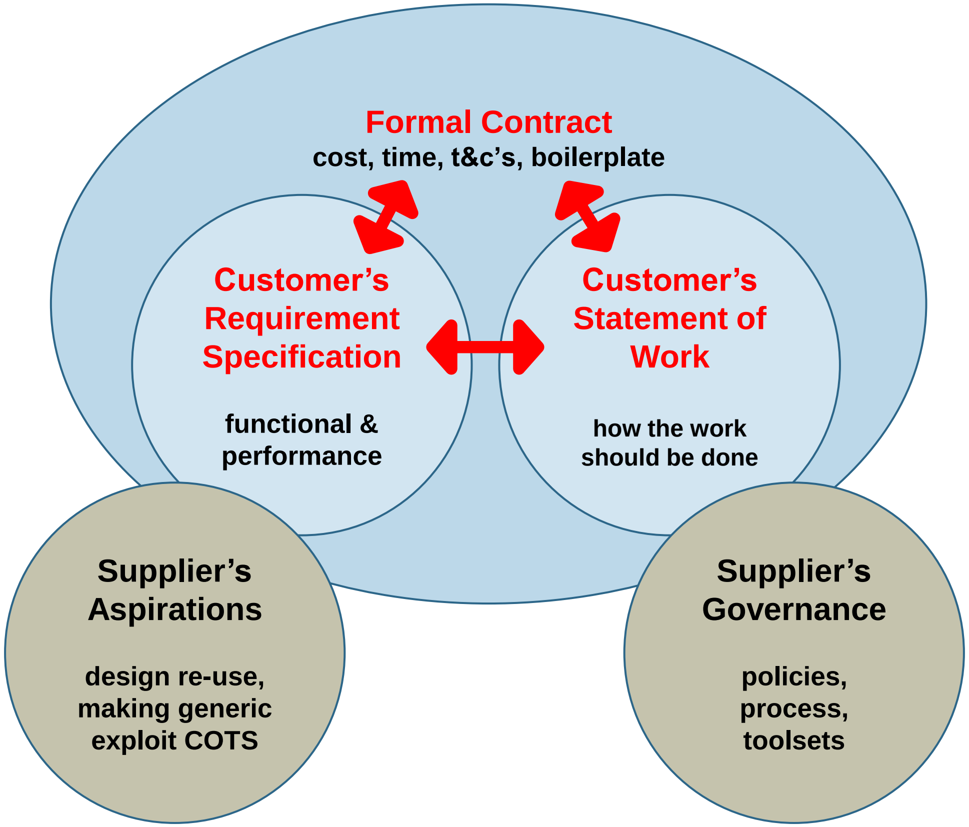
Boilerplate Sell-off

- Customers' own procurement processes may require "boilerplate" requirements to be invoked in the Contract, e.g. as part of a risk reduction strategy for commercial, technical or quality assurance aspects
- This is often a mechanistic process that results in large numbers of requirements that are irrelevant to the project yet they still have to be managed and sold-off [a]
- Overspends in NRE and delays in formal completion of work packages arise when sell-off proves particularly difficult, e.g. Customer and Supplier have a different interpretation
- The challenge is for Customers to be selective when invoking boilerplate, but resource limitations and pressure of time often force their project teams to place too much reliance on checklists



Baseline Control

- As of award of contract the document set is usually complete and consistent, but for perfectly good reasons amendments to this baseline may arise
- Estimates for NRE effort will allow for a reasonable level of change, e.g. to cover re-planning, re-estimating, and re-work of previously competed tasks
- Overspends in NRE and delays in formal completion of work packages arise if the level of changes is higher than allowed for, or the baseline becomes inconsistent
- Changes arising when the design is well advanced have exponential impact on both NRE cost and the ability to deliver on time, e.g. perhaps subcontracts are being negotiated or in progress
- Development lifecycles such as Agile may mitigate the problem but meantime the challenge is to improve baseline control and minimise late changes[a]



Capture and Record the Assumptions

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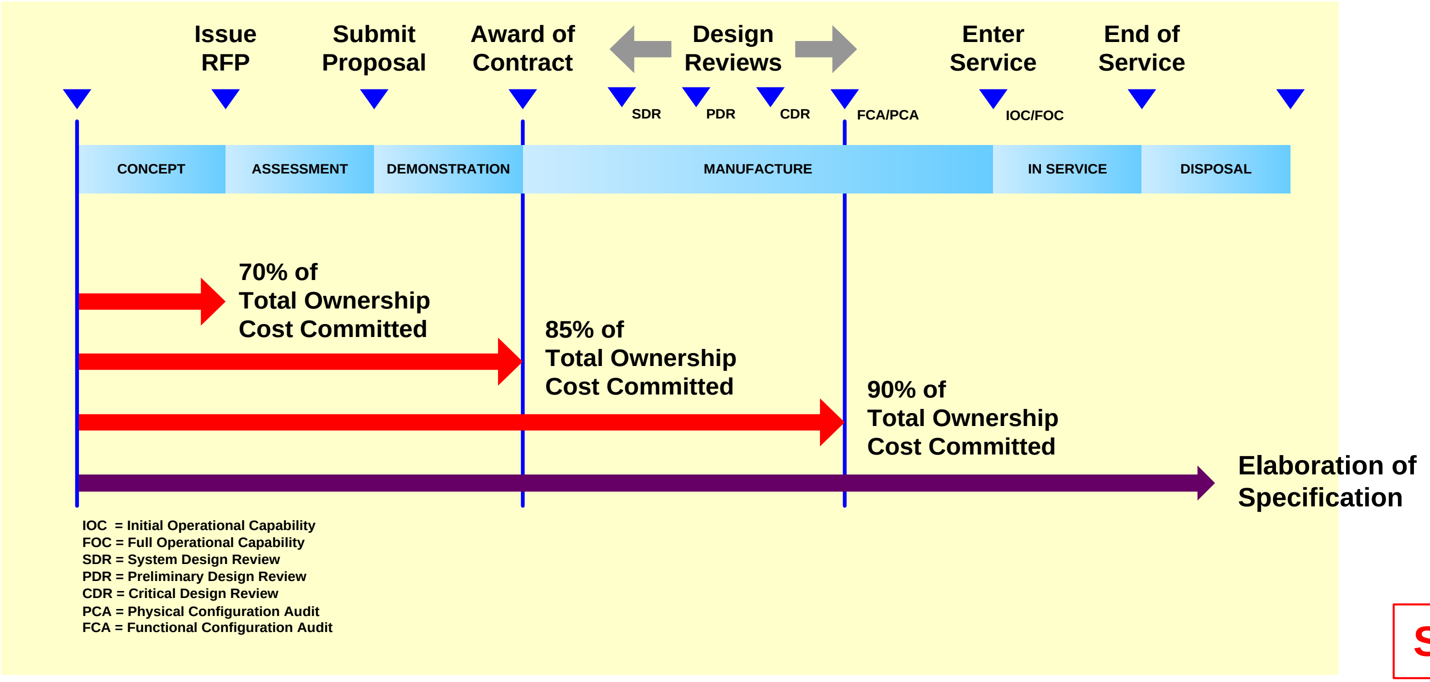
- Some very large, complex, and expensive projects have been kicked-off with nothing much more that a “cardinal points specification” or basic “letter of intent” as the only requirements specification
- Thereafter, both the Customer team and Supplier team are in a catch-up situation to elaborate the specification and formally agree it to the necessary and sufficient level of detail appropriate to the lifecycle stage of the project



Step 2 of 8

Capture and Record the Assumptions

- The Supplier manages catch-up situation is managed by the process of capturing and recording the assumptions so that cost and schedule forecasts can be completed and long-lead technical work (e.g. de-risking, rapid prototyping) and negotiation with subcontractors can continue
- The Supplier has an expectation that the Customer will eventually review the assumptions and incorporate them into the specification baseline
- But if progress on the elaboration of the specification lags too far behind the cost commitment curve the Supplier's estimates for NRE will be increasingly uncertain
  - An increasing proportion of assumptions will be wrong (e.g. assumptions overloaded)
  - Inability to size identified work packages with sufficient confidence (e.g. the number of hardware modules, the number of lines of code, the basis of the support solution)
  - Risk that TBD unspecified functional, performance or operation requirements have not been anticipated by the assumptions process and will drive requirements growth and NRE cost / timescale
- The challenge is to understand the limitations of the assumptions process, however well carried out, and try to left-shift elaboration of the requirements specification such that cost forecasts can be produced with the required level of certainty at each stage of the lifecycle
- Its stating the obvious, but both Customers and Suppliers must adequately resource their teams during in the lifecycle phases prior to contract award in order to ensure good project outcomes

Develop a Cost Breakdown Structure

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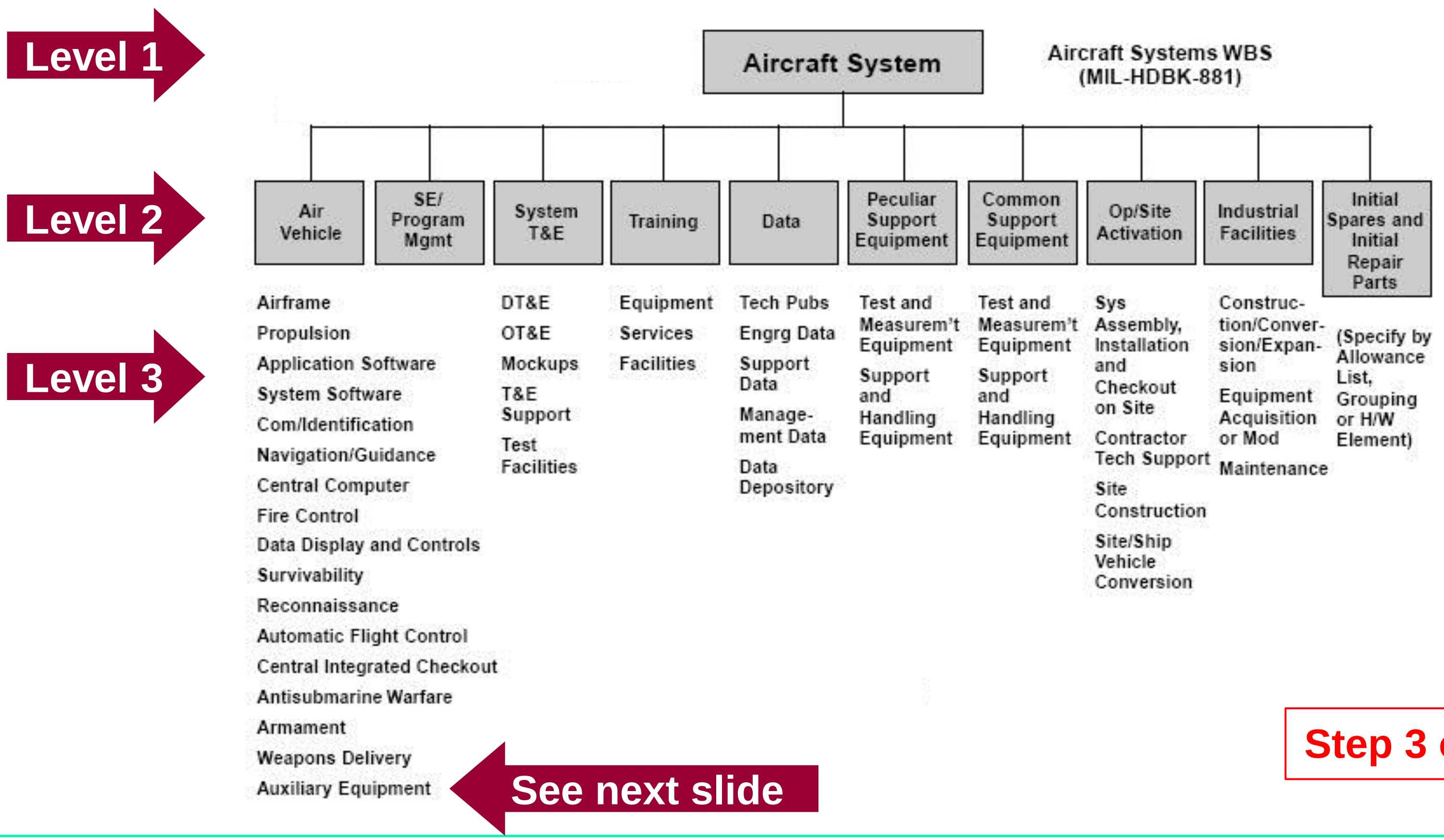
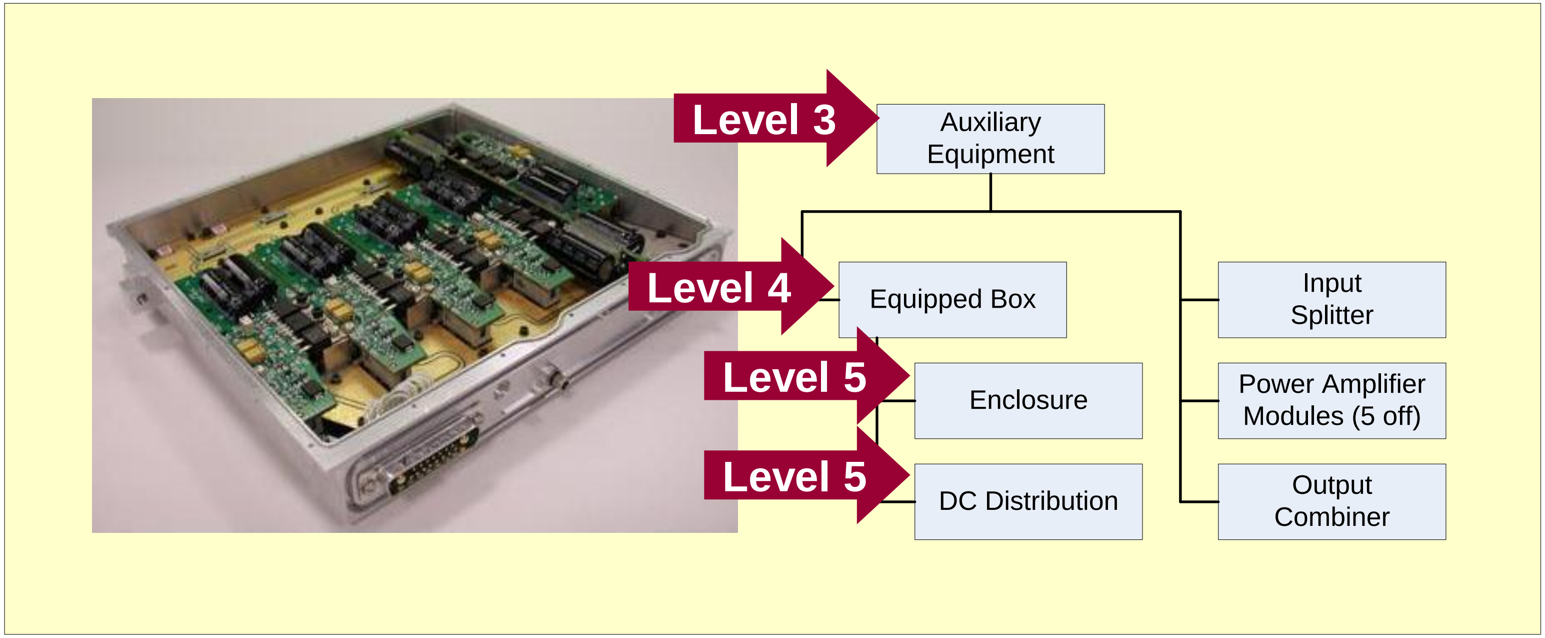
- “Standard” cost breakdown structures serve as a repository for the data, recognising that at the lower levels the structure may be need to be tailored for each class of project; e.g. the US DoD standard *MIL-HDBK-881 Work Breakdown Structure* defines the top three levels only:



Step 3 of 8

Develop a Cost Breakdown Structure

- The Level 3 cost element ***Auxiliary Equipment*** is tailored at Levels 4 and 5 as in this example



- A cost breakdown structure supports the process of collecting, storing, retrieving and analysing the cost outcomes of previous projects in order to calibrate our cost estimating tools – especially for ‘top down’ or ‘parametric’ techniques based on the use of cost estimating relationships (CERs) – and inform estimates made using ‘expert opinion’ or ‘detailed estimating’ that rely on read-across of cost outcomes from earlier similar projects

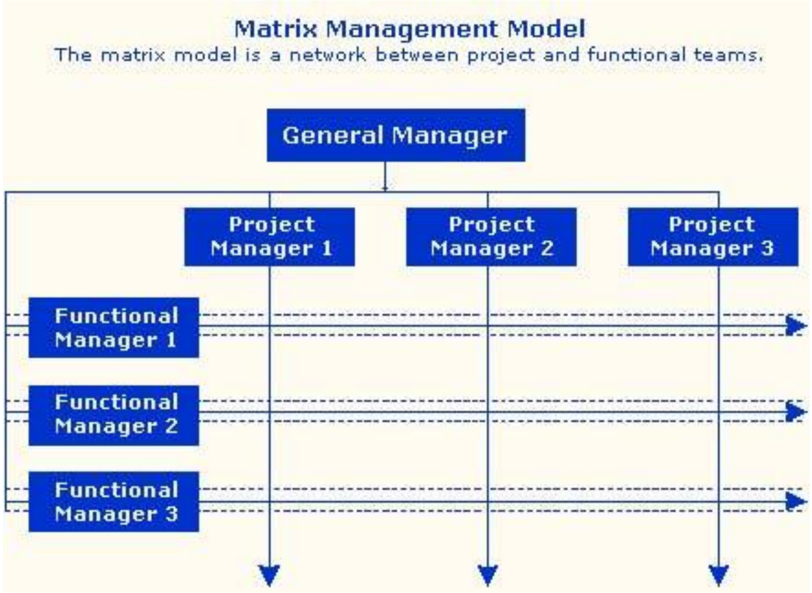
Develop a Cost Breakdown Structure

- Organisations need appropriate governance (i.e. policies and process) such that appropriate 3rd party standards for cost breakdown structures are put in place at (say) Levels 1 to 3; this helps with the exchange and interpretation of of cost data between Customer and Supplie; at the lower levels organisations need to design and calibrate cost breakdown structures appropriate to their business

- The principal difficulty in achieving this is that, in terms of organisational design, emphasis has swung from functions to projects

- The challenge is to provide Functional Managers with the resources to establish and maintain cost breakdown structures on an enduring basis, i.e. they persist from one project to the next

- Functional engineers are more likely to take an altruistic approach to long-term management of the cost breakdown structure



Identify the Best Estimating Method

- Example cost estimate classification matrix for the process industries
- From: AACE International Recommended Practice, No. 18R-97
- AACE = "Association for the Advancement of Cost Engineering"

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

[a] The state of process technology and availability of applicable reference cost data affect the range markedly; the +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope

[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%; estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools

Step 4 of 8

Identify the Best Estimating Method

AACE Class 5
"Concept Screening", Cost-Capability Trade-Off

AACE Class 4
"Study or Feasibility", Parametric Estimate

AACE Class 3
"Budget Authorisation or Control", MoD IG/MG

AACE Class 2
"Control or Bid/Tender" Procurement Should-Cost

AACE Class 1
"Check Estimate or Bid/Tender", EVM

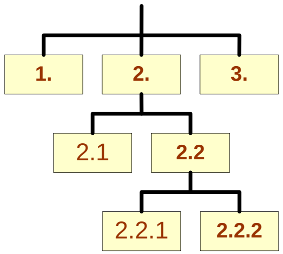
Fuel Consumption ?
CO_2 Emmissions ?
Acceleration 0-60 ?

"Parametric" models calibrated with historical data

"Judgement"

"Analogy"

£ design, produce, operate, dispose



Item	Description	£ design	£ produce	£ operate	£ dispose
1	Chassis				
2	Powertrain				
2.1	Gearbox				
2.2	Engine				
2.2.1	Cyl Head				
2.2.2	Cyl Block				
3	Soft Top				

"Semi-detailed", e.g. to LRU level,
"Detailed", e.g. to component level
Bottom-Up

MoD IG/MG = ***initial gate*** / ***main gate*** approvals
EVM = the ***earned value measurement*** process
LRU = ***line replaceable unit***

Identify the Best Estimating Method

- AACE Class 1, 2 and 3 estimates clearly give the most accurate results and, when the level of specification is sufficiently detailed, can be relied upon with a high degree on confidence
- Class 4 and 5 estimates, which are largely based on a parametric approach, have the potential to cope with some of the problems highlighted above such as incomplete specification and a high level of assumptions
- Unfortunately, in some organisations it has proved very difficult to gain acceptance of parametric techniques: the challenge is that the cost forecasting community needs to devise and articulate a compelling case for parametric estimating as a useful option in the portfolio of available techniques
- In the meantime it is clear that the best estimating method for a given situation isn't being adopted in all circumstances, and opportunities to use alternative methods (e.g. to provide a sanity check) are being missed

Collect and Analyse Historical Data

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Step 5 of 8

Class 5

- 0-2% definition
- L: -20% to -50%; H: +30% to +100%

Class 4

- 1-15% definition
- L: -15% to -30%; H: +20% to +50%

Class 3

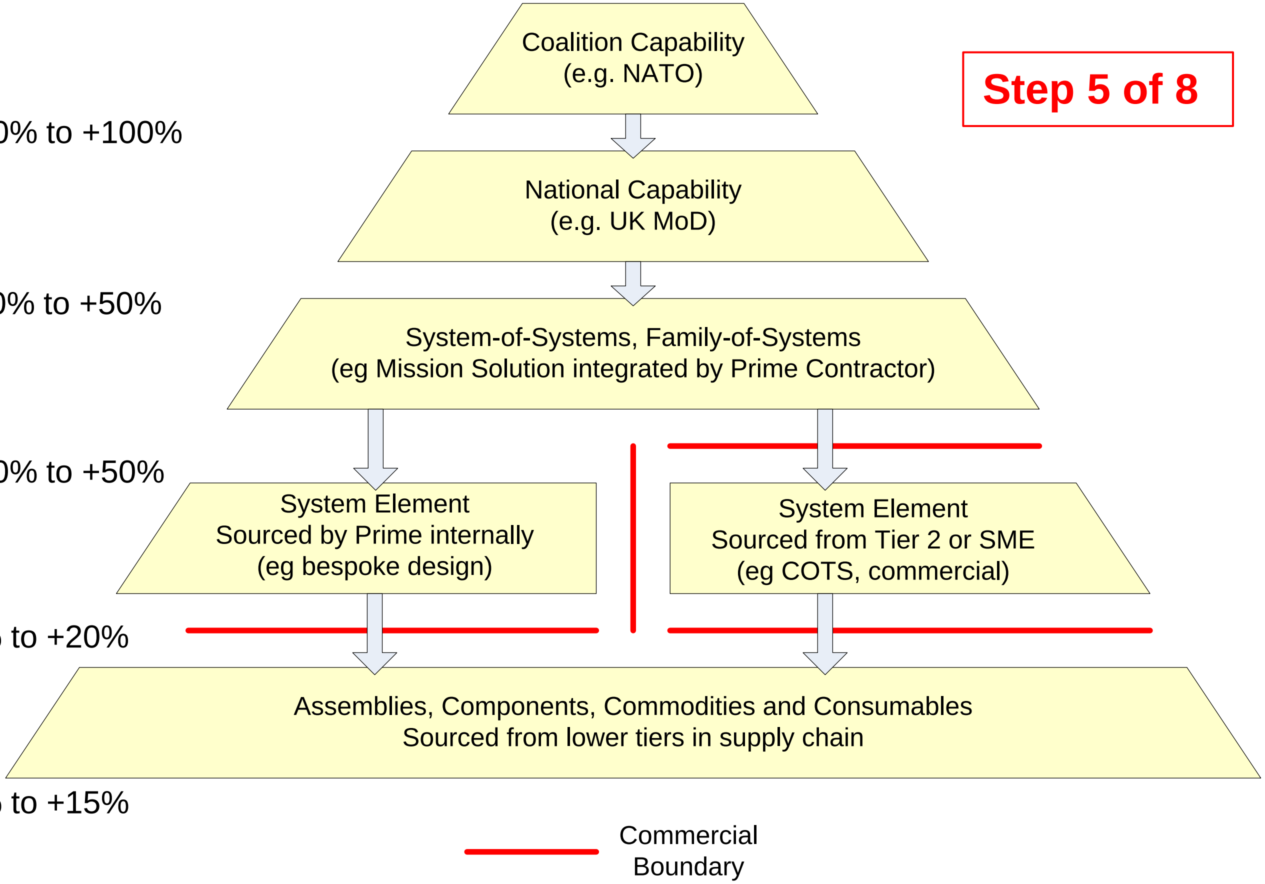
- 10–40% definition
- L: -15% to -30%; H: +20% to +50%

Class 2

- 30–70% definition
- L: -5% to -15%; H: +5% to +20%

Class 1

- 50–100% definition
- L: -3% to -10%; H: +3% to +15%

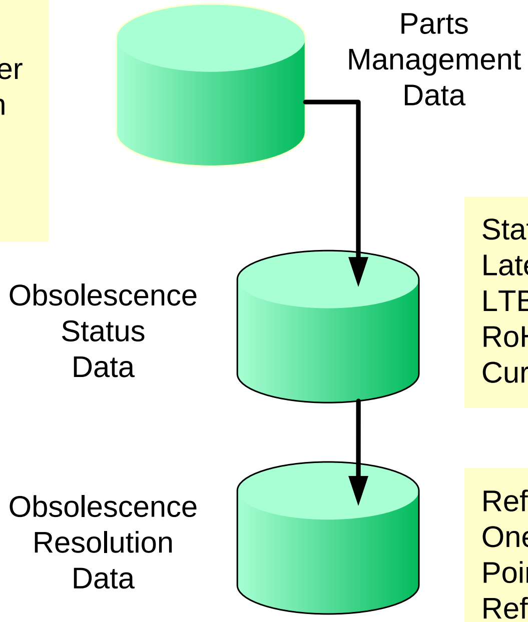


First need to understand what data will be needed for estimates in each class, and where to get it; one challenge is to support the use of open standards for exchange of data between organisations – see obsolescence data example on next two slides (UK MoD "Obsolescence Data Repository")

Collect and Analyse Historical Data

- At the level of individual components (e.g. electrical, electronic and mechanical), obsolescence data is available from specialist companies such as IHS (see http://www.ihs.com) – this gives a prediction of when a given component is likely to become a problem
- An individual company typically uses such services, plus information from its own experience and research with suppliers, to construct an obsolescence database – this example is typical :-

In-house part number
Original manufacturer
Original manufacturer part number
Original manufacturer description
NSN [7] / CAGE [8] code
Projects where applied
Name of tech authority



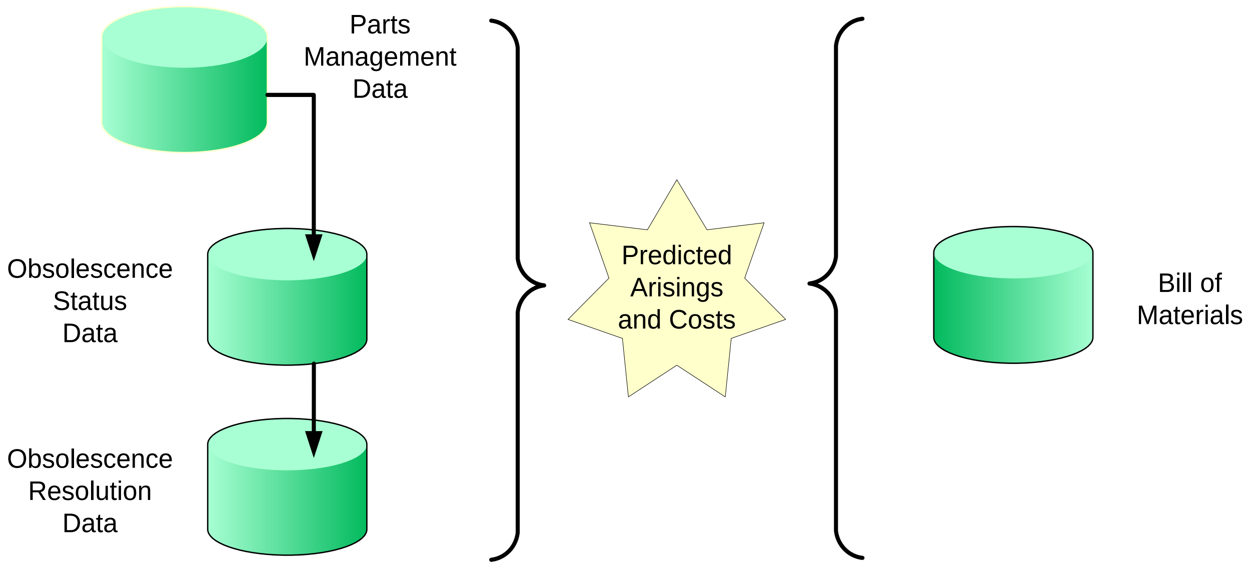
Status – in production, discontinued, etc
Latest prediction of years to end-of-life
LTB [9] date from original manufacturer
RoHS [10] status and RoHS availability
Current stock and anticipated demand

Reference to any known resolution
One-off and recurring cost involved
Point-of-contact for owner of solution
Reference to any alternative F3I [11] part(s)
Reference to any substitute part(s)

[7] NSN = NATO Stock Number
[8] CAGE = Commercial and Government Entity
[9] LTB = Life time buy
[10] RoHS = Restriction of Hazardous Substances Directive
[11] F3I = Form, fit, function and interface

Collect and Analyse Historical Data

- Each component in the “Bill-of-Materials” for an item equipment is looked-up in the Obsolescence Database in order to generate a prediction of arisings and costs over the life time of the equipment



- There is a UK MoD initiative to create a shared “Obsolescence Data Repository” [12] to exchange data on obsolescence status and known resolutions and mitigations but there are both risks and opportunities for the competitive position of individual companies if they decide to participate

[12] The ODR is being developed by the *Joint Obsolescence Management Working Group (JOMWG)* comprising representatives from both the MoD and UK industry. Chaired by Stuart Kelly, Head Obsolescence Management, MoD DE&S Joint Support Chain.

Collect and Analyse Historical Data

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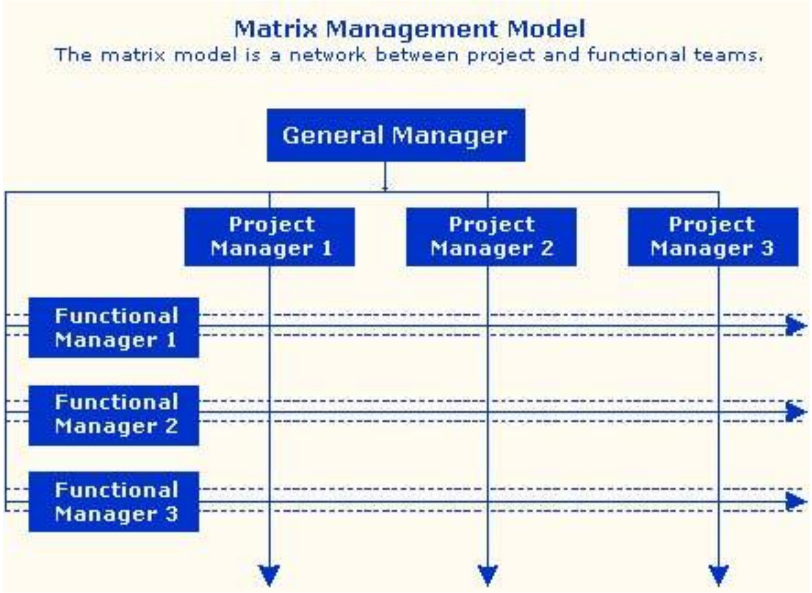
- Similarly to the situation with respect to cost breakdown structures, the emphasis of projects over functions is a challenge to achieving the above - fundamentally, projects are transient and focused on business outcomes whilst functions are enduring and best placed to invest in improved capability, process, and tools
- The challenge is to provide Functional Managers with the resources to establish and maintain data collection and analysis processes on an enduring basis, i.e. they persist from one project to the next
- Functional engineers are more likely to take an altruistic approach to collection and analysis of historical
- Individual engineers often have private information in various formats which is used locally but not widely shared; more investment in knowledge management within an organisation would make the available data more widely accessible and improve the return on investment



Summary of Challenges

- To minimise elasticity in the scope of work
  - Converge Customer’s requirements and Supplier’s aspirations
  - Suppliers to assure Customers that it is safe to simplify SOWs
  - Customers to be selective when invoking boilerplate
  - Improve baseline control and minimise late changes
- On Capturing and recording resolving assumptions
  - Understand the limitations of the assumptions process
  - Left-shift elaboration of the requirements specification
- On cost breakdown structures
  - Establish and maintain cost breakdown structures
- On estimating methods
  - Articulate a compelling case for parametric estimating
- On Collecting and analysing historical data
  - Support the use of open standards for exchange of data
  - Establish and maintain data collection and analysis processes
  - Investment in knowledge management within an organisation

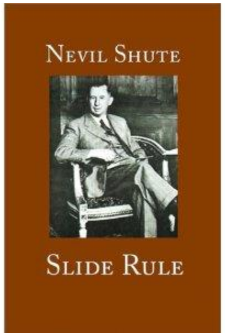
Questions?

Bibliography

- Organised under four broad headings
  - Project Management
  - Politics and Economics
  - Progress in Technology
  - The Industrial Backdrop
  - Milestones in Processes

Project Management

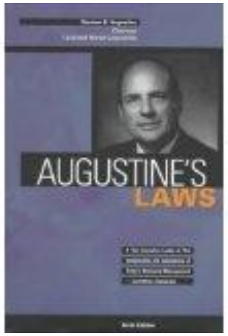
1930 - 1950



[1] Nevil Shute: ***Slide Rule.*** First published 1954. Reprinted 2000. ISBN-10: 1889439185. ISBN-13: 978-1889439181. 268 pp.

Nevil Shute Norway worked as an aeronautical engineer at Vickers before setting up his own airship company. He served in both world wars and was a commander in the Royal Navy Volunteer Reserve in World War II. The parallels between Shute's and his fiction can be seen: airship engineering, the new industry of commercial aircraft and his experience of civil servants and bureaucratic military agencies.

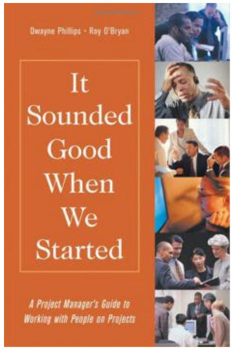
1950 - 1980



[2] Norman R Augustine: ***Augustine's Laws.*** First published 1983. 6th edition 1997. ISBN-10: 1563472392. ISBN-13: 978-1563472398. 395 pp.

This text is a collection of 52 laws comprising an irreverent collection of 52 "Peter Principles" of "What NOT to do" if one wants to become a successful problem-solving manager. Each law formulates a home truth about business life – here's just one example: *if a sufficient number of management layers are superimposed ... it can be assured that disaster is not left to chance.* A number of laws concern cost and time.

1980 - 2000

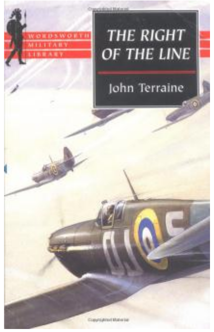


[3] Dwayne Phillips and Roy O'Bryan: ***It Sounded Good When We Started: A Project Manager's Guide to Working with People on Projects.*** Published 2003. ISBN-10: 0471485861. ISBN-13: 978-0471485865. 344 pp.

The authors, both respected project managers with sixty years of experience between them, describe their own mistakes and the valuable lessons they drew from them. They tell the stories derived from a real-world project, providing memorable and practical examples. Provides in-depth insight into Engineering Management issues.

Politics and Economics

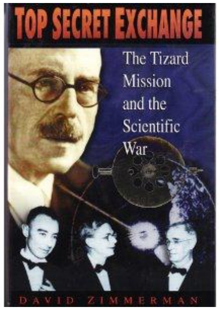
1935 - 1945



[4] John Terraine: ***The Right of the Line.*** New Edition 1988. ISBN-10: 0340419199. ISBN-13: 978-0340419199. 841 pp

As part of the wider story of the RAF in World War II, this definitive account shows how operational, technical, strategic and political requirements of the RAF influenced development of the aviation industry well into the post war era. Gives insight into the way that system engineering trade-offs began to feature in critical decision making.

1940



[5] David Zimmerman: ***Top Secret Exchange: The Tizard Mission and the Scientific War.*** Published 1996. ISBN-10: 0750912421. ISBN-13: 978-0750912426. 224 pp.

The first scholarly study of the British Tizard Technical Mission sent in 1940 to provide the USA and Canada with most of Britain's military and technological secrets, which included radar – specifically the cavity magnetron, which made microwave radar possible. This mission marked the start of lasting Anglo-American co-operation but there always was, and still is, an underlying tension over what intellectual property to protect vs. what to give away. Management of intellectual property (or and the impact of failure to get it right) remains one of the more intractable elements of NRE.

Politics and Economics

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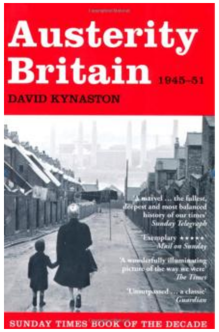
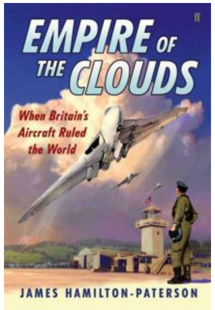
1945 - 1955



[6] David Kynaston: **Austerity Britain 1945-1951**. Published 2008. ISBN-10: 0747599238. ISBN-13: 978-0747599234. 704 pp.

Includes a fascinating account of the political and economic context for the debate on level of defence expenditure in the period leading into the Korean War. In August 1950 the three-year estimate was increased from £2.3 to £3.6 billion, and then to £4.7 billion in January 1951 (around 14% of GDP) despite the balance of trade deficit and exchange rate crisis.

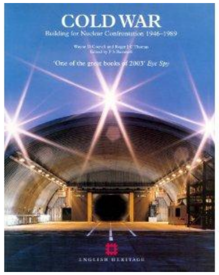
1945 - 1970



[7] James Hamilton-Patterson: ***Empire of the Clouds: When Britain's Aircraft Ruled the World***. Published 2010. ISBN-10: 0571283772. ISBN-13: 978-0571283774. 288 pp.

In 1945 Britain was the world's leading designer and builder of aircraft - a world-class achievement that was not mere rhetoric. Yet this is the story of the failure to build on this leadership position in the 1950's and 60's - for example as a result of allowing domestic customers determine requirements rather than addressing global markets, and prioritising technical performance above operating costs.

1950 - 1980

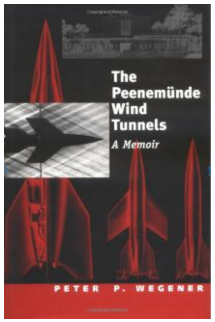


[8] Wayne D Cockroft, Roger J C Thomas, and P S Barnwell: ***Cold War: Building for Nuclear Confrontation 1946-89*.** Published 2005. ISBN-10: 1873592817. ISBN-13: 978-1873592816. 282 pp.

A largely photographic record of the buildings and structures associated with the Cold War of the 1950's and following decades, but with some fascinating supporting narrative. Towards the end of this period many countries including the UK, and notably the former Soviet Union, discovered that the cost of Cold War was becoming unaffordable and a new reality began to emerge.

Progress in Technology

1943 - 1945



[9] Peter P Wegener: ***The Peenemunde Wind Tunnels: A Memoir.*** Published 1996. ISBN-10: 0300063679. ISBN-13: 978-0300063677. 198 pp.

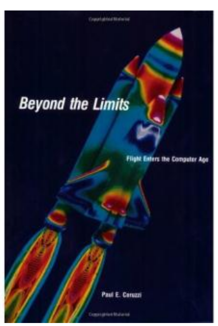
In 1943, on orders from the German Air Ministry, young physicist Peter P. Wegener left the Russian front and reported to the Baltic village of Peenemunde. His assignment was to work at the supersonic wind tunnels of the rocket laboratories of the German Army. The work done there included research on hypersonic flow, i.e. at Mach numbers above 5.0 and aiming for Mach 8.8, but was conducted in horrendous conditions and at great human cost. An extreme example of prioritising achievement of technical objectives above all else.

1945 - 1985

Kenneth P Werrell for the Air University at Maxwell Air Force Base: ***The Evolution of the Cruise Missile****.* Report ADA162646, Air University Press, 1985. 296 pp. Available online – please search for title.

Provides insight into the debate, as of 1985, as to whether the cruise missile would simply become another weapon in the then catalog of aerial munitions, or did it represent a potentially revolutionary class of weapons in its own right? Perhaps an input to DoD trade-studies considering alternative means for the projection of power.

1950 - 1990

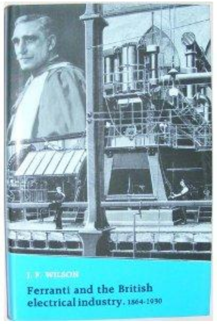


[11] Paul Ceruzzi: ***Beyond the Limits: Flight Enters the Computer Age.*** Published 1989. ISBN-10: 0262530821. ISBN-13: 978-0262530828. 284 pp.

By 1990 progress in aerospace technology had been going on for at least forty years. By then modern flight depended on computers. Spacecraft and fighters make use of leading edge computer technologies in their design, testing manufacture, navigation, operation and crew training. An appendix discusses the role that on-board and ground computers played in the explosion of the space shuttle Challenger, an incident that brought renewed focus on safety-critical systems and NRE policies, processes, and tools involved in their design and validation.

The Industrial Backdrop

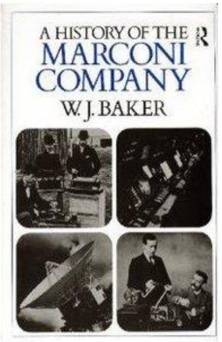
1860 - 1930



[12] J F Wilson: ***Ferranti and the Emergence of the British Electrical Industry, 1864-1930.*** Published 1988. ISBN-10: 0719023688. ISBN-13: 978-0719023682. 197 pp.

Sebastion Ziani de Ferranti's career spanned the period between the emergence of the electrical industry in 1882 and the momentous 1926 Act creating a national electricity supply network. He fought vigorously against the technological, commercial and legal problems this sector had to overcome in its struggle for recognition as a component of the modern economy. He also insisted in investing a high proportion of his company's turnover in ambitious development projects, ensuring that the product range remained competitive in an industry dominated by powerful American and German multinationals.

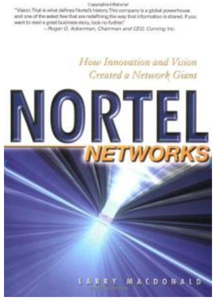
1875 - 1965



[13] W Baker: ***A History of the Marconi Company 1875-1965*****.** Published 1970. ISBN-10: 0415146240. ISBN-13: 978-0415146241. 416 pp.

Describes, in largely non-technical terms, the early scientific discoveries that kicked-off the foundation and development of Marconi. This story is set against the background of successes, setbacks, and commercial "wars". Includes archive photographs.

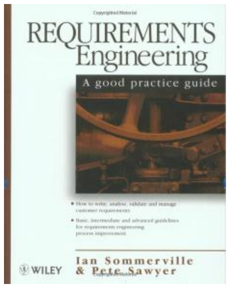
1895 - 2000



[14] Larry MacDonald: ***How Innovation and Vision Created a Network Giant.*** Published 2000. ISBN-10: 0471645427. ISBN-13: 978-0471645429. 286 pp.

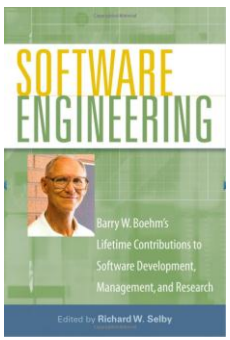
A history of the company whose development was closely associated with that of tele-communications in Canada, wider North America, and eventually the whole planet – but told from the perspective of the period just prior to the "dot-com" collapse and exposure of financial scandals than ended with corporate melt-down.

Milestones in Processes



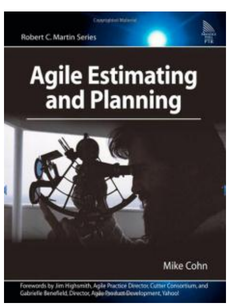
[15] Ian Sommerville and Pete Sawyer: ***Requirements Engineering: A Good Practice Guide*.** Published 1997. ISBN-10: 0471974447. ISBN-13: 978-0471974444. 404 pp.

The goal of requirements engineering is to produce a set of system requirements that, as far as possible, is complete, consistent, relevant and reflects what the customer actually wants. This book presents a set of guidelines that reflect the best practice in requirements engineering. These guidelines are applicable for any type of application and, in general, apply to both systems and software engineering.



[16] Richard W Selby: ***Software Engineering: Barry W. Boehm's Lifetime Contributions to Software Development, Management, and Research*.** Reprint edition 2007. ISBN-10: 047014873X. ISBN-13: 978-0470148730. 832 pp.

This is an authoritative archive of Barry Boehm's contributions to software engineering. Featuring 42 reprinted articles, along with an introduction and chapter summaries to provide context. It serves as a "how–to" reference manual for software engineering best practices. It provides convenient access to Boehm's landmark work on product development and management processes including cost / time forecasting.



[17] Mike Cohn: ***Agile Estimating and Planning*.** Published 2005. ISBN-10: 0131479415. ISBN-13: 978-0131479418. 368 pp.

The push-back on wider adoption of agile or scrum techniques is based, in part, on worries such as how apply to projects that aren't purely software, how to apply to large projects, and how to devise a trusted means of progress reporting. This book claims to have the answers.

- End of Presentation -