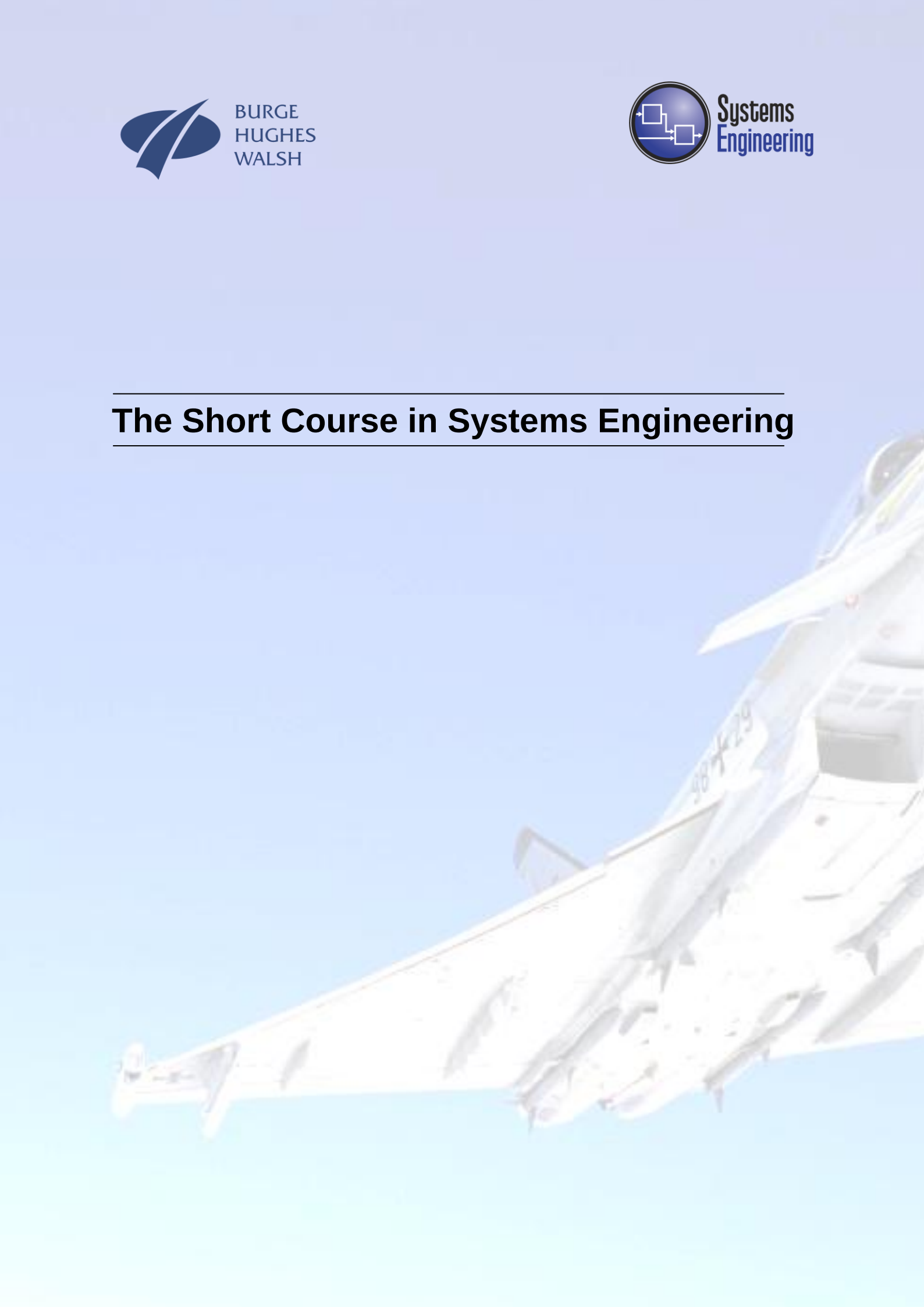
BURGE
HUGHES
WALSH

Systems
Engineering

The Short Course in Systems Engineering



1.0 Introduction and Background

As the world becomes more complex, Systems Engineering has become seen as the approach to handling that complexity and associated risks. Applied correctly System Engineering will dramatically

- reduce introduction times through:
  - reduced design lead time
  - reduction in number of design changes
  - reduction in production or delivery errors
- improve the quality through
  - better product or process in the hands of the customer
  - improved reliability
- reduce costs through
  - reduced introduction costs
  - reduced warranty claims
    reduced Through-life cost

Applying System Engineering correctly, however, requires not only skills and knowledge but also a profound understanding of the underlying systems principles. Systems Engineering is as much about mind-set as is it is about process and tools. Education and training are therefore critical to the development of an organizational capability in Systems Engineering.

The short course in Systems Engineering aims to educate and train participants in how to practically apply systems thinking to the creation, development and delivery of complex systems. It is specifically for those people who are involved in new system introduction from marketing through to system support.

The focus on 'doing systems engineering' makes it unique and perhaps why a derivative of the course is the backbone of engineering training for BAE SYSTEMS. Other customers in include Roll-Royce, MBDA, SELEX sensors and airborne systems, dstl, Qinetiq, Bookham Technology and E2V.

2.0 Course Objectives and Content

The objectives and outcomes of the short course in Systems Engineering are defined in the following quad of aims:

Purpose • To provide delegates with the understanding, overview and specific knowledge of Systems Engineering concepts, principles and practice.	**Customers and Benefits** • Delegates: greater expertise in Systems Engineering • Company: greater in-house capability to practise a systems approach to the design of complex systems
Deliverables At the end of the course delegates will have • A greater understanding of systems concepts and thinking • An appreciation of the systems engineering process • Improved knowledge and skill in applying systems engineering tools and techniques	**Measures of Success** • Delegates recognise the need for, and adopt, a systems approach to engineering propulsion systems • Begin to apply the principles and tools in their work

The content of the one-week Systems Engineering Short Course is shown in Figure 1.

3.0 Course Philosophy and Approach

The course philosophy is for a one-week tutor-led course that can be run “on-site” or at any suitable off-site venue. The course follows a typical system lifecycle but emphasises the critical early phases of requirements engineering, system conceptual and architectural design and system optimisation. The course has a flexible structure to take into account local working hours and practices. However, the course does require a minimum of 37 hours and the daily finish time may have to be extended if an early finish on Friday is desirable. If required it can also includes an element of company specific input.

The course approach is based on the Kolb learning cycle with a significant proportion of the course set aside for exercises to reinforce the learning. Indeed, many of the small group exercises involve a case study which provides a practical focus for the course and enables the delegates to practise the tools and techniques presented. This case study culminates with a “design review” on the last day where the participants present their system concept solution.

The case study can be tailored to product oriented systems or service oriented systems. If need be, a hybrid exists that requires the simultaneous development of a product and service based system as a system of systems.

4.0 Who is it for and Numbers?

The short course in Systems Engineering is aimed at all personnel involved in the new system introduction and product support. Indeed, wherever possible having a mix of engineers, marketing, project managers, and customer support engineers is most beneficial in terms of deploying and adopting a systems approach.

The course has been designed for a maximum of 16 participants.

5.0 Delivery Requirements

The delivery of the Systems Engineering short course requires a principal lecture room to accommodate maximum numbers and two tutors at any one time, plus two additional syndicate rooms which can accommodate about one-third of the cohort size working informally. The principal room should have LCD projection facilities, white boards and flip chart, the syndicate rooms also having white boards and flipchart.

	8.45	9.00 - 10.00	10.00 -11.00		11.00 - 12.00		13.00 - 14.00	14.00 -15.00		15.00 - 16.00	16.00 -17.00
Monday	ARRIVAL	Introduction to Course, Ice Breaker and Course Aims & Expectations	Introduction to Systems	BREAK	Customer Specific Introduction	LUNCH	Introduction to Systems Engineering	Systems Thinking using Diagrams	BREAK	Systems Diagramming Exercise	Eliciting Customer Needs
Tuesday	REVIEW	Define Requirements: Understanding Customer Needs		BREAK	Textual Analysis and Exercise	LUNCH	Viewpoint Analysis	Viewpoint Analysis Exercise	BREAK	Functional Modelling	Functional Modelling Exercise
Wednesday	REVIEW	Functional Modelling Exercise	Sensitivity & Failure Analysis	BREAK	Sensitivity & Failure Analysis Exercise	LUNCH	Verifying Technical Requirements meet Customer Requirements using QFD 1	Quality Function Deployment Exercise	BREAK	Design System Concept	Concept Generation Exercise
Thursday	REVIEW	Concept Generation Exercise		BREAK	Concept Integration and Selection	LUNCH	Concept Integration and Selection Exercise		BREAK	Life Cycle Engineering	Detailed Design and Optimisation/ Robust Design
Friday	REVIEW	System Optimisation and Sensitivity Analysis		BREAK	System Optimisation and Sensitivity Analysis	LUNCH	Integrating Group Mini-Project	Presentations of results from Mini-Projects	BREAK	Presentations of results from Mini-Projects	DEPART

Figure 1: Systems Engineering Short Course Content

Appendix A: Course Session Purpose and Outcomes

Session	Purpose	Outcomes
Introduction to Course, Ice Breaker and Course Aims & Objectives	Introduce course aims and objectives and introduce delegates to each other	Participants: • are told the course aims and objectives • know more about fellow delegates
Systems, Systems Thinking and Systems Engineering	To provide the theoretical underpinning of systems concepts, systems thinking and systems engineering	Participants: • know the difference between systems thinking, systems approach and systems engineering • know the system properties and what constitutes a system. • recognise the importance of the system boundary and environment and how it can influence system behaviour • have had explained the concepts of systems thinking
Company Introduction to Systems Engineering	To provide the Rolls-Royce view and motivation for adopting and practising Systems Engineering	Participants understand the company's reasons for adopting Systems Engineering and the benefits it will bring the company.
Systems Thinking with Diagrams and Exercise	To demonstrate how systems thinking can be aided and supported through simple diagramming tools. To illustrate the systems meta-approach of divergent and convergent thinking	Participants: • are shown how diagramming can help in applying the systems thinking concepts of holism, structuralism and abstraction. • have undertaken an exercise to demonstrated divergent and convergent thinking and the use of diagramming to convey complex information
Introduction to Systems Engineering	To show that output of systems engineering is information and that it is used to manage risk on the business. To demonstrate that good systems engineering requires the balance of: • process • people • tools • Infrastructure	Participants: • understand the role of systems engineering in managing risk • recognise the key ingredients to successful systems engineering • know the four phases of the Systems Engineering process: o Define Requirements o Create Solution o Optimise Solution o Verify Solution
Define Requirements	To define the purpose of the Define Requirements phase and its key activities and tools	Participants: • know the purpose of the Define Requirements phase • know the key process steps and what type of tools are appropriate
Understanding Customer Needs	To give an understanding of the nature and origin of customer requirements. To define the Holistic Requirements Model To demonstrate the importance of system functionality	Participants: • realise the common and specific features of requirements • know and can apply the requirement categories of the Holistic Requirements Model • understand the importance of system functionality as a system invariant and the basis for systems design

Systemic Textual Analysis and Exercise	To introduce the Systemic Textual Analysis tool as a way of analysing written/expressed customer requirements to help identify/derive missing requirements	Participants have successfully applied Systemic Textual Analysis to the case study problem
Viewpoint Analysis and Exercise	To introduce the Viewpoint Analysis as a tool for determining a systems functional requirements	Participants have successfully conducted Systemic Viewpoint Analysis on the case study problem and seen real examples
Functional Modelling and Exercise	To introduce Functional Modelling as a tool for modelling the requirements of a system to generate a simple behavioural/operational model of the proposed system	Participants: • recognise the need for functional/behavioural modelling • have successfully generated a functional model for aspects of the case study problem • seen real examples
Sensitivity and Failure Analysis	To provide the theoretical basis for understanding system sensitivity and emergent behaviour To provide tools that allow for an early assessment of system sensitivity from the requirements analysis	Participants: • recognise the dangers of emergent behaviour in complex systems particularly system sensitivity and functional failures • appreciate the need for sensitivity analysis tools • practise using Functional Failure Model And effects Analysis
Verifying Technical Requirements Meet Customer Requirements using QFD 1	To provide practical experience of verifying the completeness and consistency of a requirements set though QFD 1 To show how QFD 1 helps define a PRD	Participants: • are introduced to Quality Function Deployment as a tool for managing requirements during new system introduction • experience using QFD I as a tool for assuring compliance, completeness and consistency of customer and derived technical requirements • seen real examples
Create System Concept	To provide an overview of the Create System Concept phase of Systems Engineering how it relates to the meta-process of divergent and convergent thinking.	Participants: • know the purpose and objectives of the Create Solution Concept Phase • know the key process steps and what type of tools are appropriate
Concept Generation and Exercises	To develop skills in team based creativity methods as applied to system design	Participants are able to use a number of simple creative thinking tools to generate alternative system solutions in structure and logical fashion for the case study problem using Function Means Analysis
Concept Integration and Selection – and Exercises	To develop skills in integrating functional solutions into complete system concepts To evaluate complete system concepts	Participants: • understand the need for design integration and are able to apply the approach to the case study problem • Can evaluate complete system concepts using simple Decision/ Pugh matrices
Verifying Solution Concepts Meet Technical Requirements using QFD 2 and Exercises	To show how QFD 2 can check that the selected system concept meets the technical requirements and helps develop SSRDs	Participants: • understand how QFD 2 can check that the selected design concept meets the technical requirements • understand how QFD 2 can help flow down requirements to sub-system level and ultimately component level • experience using QFD 2

System Architecting	To introduce the principles of system architecting and why it is important To introduce the system concepts of cohesion binding and coupling. Show how tools such as N^2 can help identify the "best" logical architecture	Participants: • have an understanding of the importance of architectural design • Understand the key principles • are aware of tools such as N2 analysis to select appropriate architectures • seen real examples
Optimise Solution and Detailed Design	To provide an overview of the Optimise Solution and Detailed Design phase of Systems Engineering	Participants: • know the purpose and objectives of the Optimise Solution and Detailed Design Phase • know the key process steps and what type of tools are appropriate
The Principles of Robust design	To provide an introduction to Robust Design	Participants appreciate the power and purpose of robust design in particular the principles behind parameter design and tolerance design
Searching the Design Space using Designed Experiments	To introduce the methodology of "Designed Experiments" as the systematic approach to search the design space to find the robust optimum	Participants: Understand the failing of one-factor at a time search methods Recognise the power of Designed Experiments Conduct a simple exercise
Preparation of Case Study Presentations	To review the course through the preparation of a presentation of their case study system solution	Participants review the system engineering approach and summarise the key aspects in a short presentation
Case Study Presentations	To present the case study	Participants deliver their system solution
Summary and close	To provide an overall summary of the course and elicit delegate feedback	