# Aerospace Systems Engineering
# 2019

Unit Code: AENG30009

As the sophistication of engineering systems grows they develop into ever more complex mixtures of mechanical, electrical, electronic and software engineering. Systems engineering is a discipline widely used within aerospace and other industries to dealing with such large and complex projects. It is considered a very important discipline. A decade ago, just after it changed its name from “British Aerospace” to “BAE Systems”, the company when responding to the systems engineering course proposal, said that systems engineering **"has been identified as a so called 'core competence' of British Aerospace, being central and critical to the business".**

Government's Defence and Aerospace Foresight Panel produced a report on the importance of systems engineering said - **"This report shows that the principles embodied in the Systems Engineering discipline must be applied to manage highly complex inter-relationships, both technical and financial, if cost effective solutions which truly meet customer needs are to keep this sector of industry successful and competitive into the 21st Century".**

The course aims to introduce practical systems engineering with an emphasis on the methodology used in the aerospace industry. The syllabus covers both the theoretical aspects of systems and systems modelling, and more practical conventions and practice in industry. It is based about lectures and background reading.

**Course Structure:** 20 lectures
Set and general background reading
Project activity

## Reference Books

"Systems Engineering - Coping With Complexity" by Stevens, Brook, Jackson and Arnold, Prentice Hall 1998
"Systems Engineering and Analysis" by Blanchard and Fabrycky, Prentice Hall
"Systems Engineering" by Aslaksen and Belcher Prentice Hall 1992
"Systems Engineering: An Introduction" by Boardman, Prentice Hall
“Systems Design and Management” by Bob Parkinson – **Coming soon**

**Unit Director**: Mark Hempsell:
email – TBD (To Be Determined)

# Lecture Timetable

| Week | Date | Time | No | Lecture |
|---|---|---|---|---|
| 1 | 30th Sept (Mon) | 11:00 | 1 | Introduction to the unit |
| | | 12:00 | 2 | What is a system? |
| | 4th Oct (Fri) | 14:00 | 3 | System lifecycle |
| | | 15:00 | 4 | Requirement generation |
| 2 | 7th Oct (Mon) | 11:00 | 5 | Requirement capture |
| | | 12:00 | 6 | Trade offs |
| | 11th Oct (Fri) | 14:00 | 7 | Budgets |
| | | 15:00 | 8 | System diagrams |
| 3 | 14th Oct (Mon) | 11:00 | 9 | Project management |
| | | 12:00 | 10 | Human factors |
| | 18th Oct (Fri) | | | NO LECTURES |
| 4 | 25th Oct (Fri) | | | NO LECTURES |
| 5 | 1st Nov (Fri) | 14:00 | 11 | Reliability |
| | | 15:00 | 12 | Safety |
| 6 | 8th Nov (Fri) | 14:00 | 13 | Maintenance |
| | | 15:00 | 14 | Quality & verification |
| 7 | 15th Nov (Fri) | | | NO LECTURES |
| 8 | 22nd Nov (Fri) | | | READING WEEK |
| 9 | 29th Nov (Fri) | 14:00 | 15 | Soft systems |
| | | 15:00 | 16 | Systems modelling |
| 10 | 6th Dec (Fri) | 14:00 | 17 | Parametric analysis |
| | | 15:00 | 18 | Systems models |
| 11 | 13th Dec (Fri) | 14:00 | 19 | Stochastic models |
| | | 15:00 | 20 | Summary |
| 12 | 20th Dec (Fri) | | | READING WEEK |

# Project Dates

| Stage | Task | Date Set | Submission |
|---|---|---|---|
| 1 | Write a Requirement Specification | 4th Oct | 1st Nov |
| 2 | Select a compliant product | 8th Nov | 6th Dec |

# Planned Student Workload

| Activity | Hours | Basis |
|---|---|---|
| Lecture attendance | 20 | 20 one hour lectures |
| Essay research and preparation | 54 | 3 hours per 18 substantive lectures |
| General research | 6 | 2 -3 Books |
| Project stage 1 | 10 | |
| Project stage 2 | 2 | |
| Revision | 6 | |
| Taking the exam | 2 | |

# Assessment

**Project 15%**

A two stage individual exercise

Stage 1 – Write a requirement specification
Stage 2 – Selecting a compliant solution for someone else's requirements

**2 hour exam 85%**

The exam is an essay exam – asking questions related to the various lectures. You are assumed to have read beyond each lecture. The rough marking structure is
About 70% for material in the lectures
About 30% for material from external sources

So if you just throw my lectures back at me in it not possible to get a first class mark. Historically the Unit has proved to have a low failure rate (but each year one or two bozos managed it) but also had a very low first class mark rate because most students showed absolutely no evidence of outside reading, or original thinking.

| Class | Level | Classic Maths question | Essay Equivalent |
|---|---|---|---|
| 2:2 | Can remember the stuff | What's the formula (with proof)? | What was in the lectures? |
| 2.1 | Understands the stuff | Put numbers in and get an answer. | Arrange to show understanding, i.e. it is not just a memory dump. |
| 1st | Can create with the stuff | Handle the problem with changed parameters. | Is new material added showing complexities and subtleties can be handled. |





Hand Tools Armour Dug-out House Bicycle

What do these have in common?

…………………………………………………………………………………………





Mary Rose Spitfire Pyramids Car

What do these have in common?

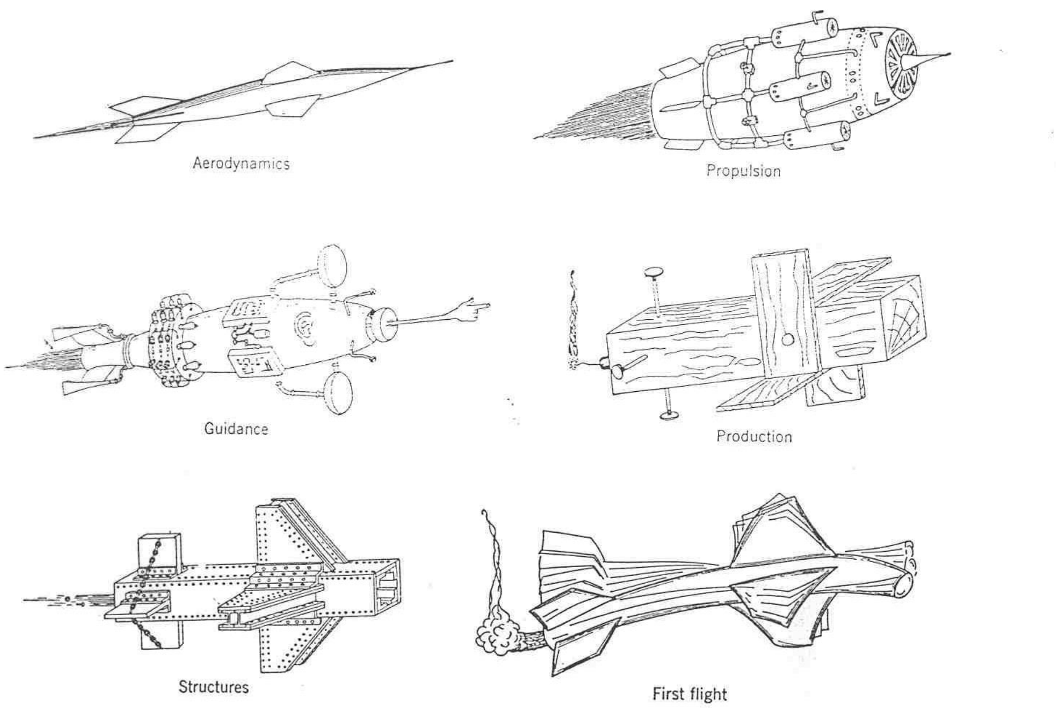
…………………………………………………………………………………………




Modern Fighter Saturn/Apollo Lloyds Building Ark Royal

What do these have in common?

…………………………………………………………………………………………




Conflicting Design Drivers!

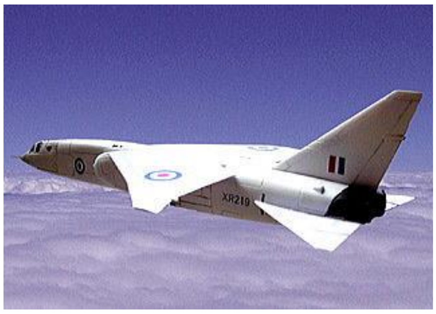
## SYSTEMS ENGINEERING

Engineered products have reached a “complexity barrier” where no one person can comprehend the whole thing in enough detail to design or make it. Systems engineering is a methodology that enables higher level engineering decisions to be passed on to lower level specialist engineering sign and manufacture in way such that ensures when all the specialist components are put together they make a product that works.

It is a way of approaching, modelling and organising the development of complex engineering artefacts.

It is somewhat different from other types of engineering in that it is related to management, organisation, paperwork - i.e. more human orientated and less the applied science sort of activity. It also is where much of the creativity and design innovation on complex products takes place.

So why did it evolved? And why in aeronautics and computing?



A4/V2 Polaris TSR2

Systems engineering is a discipline that has arisen since the Second World War, primarily in the Aeronautics and the early computing industries. During World War 2 military aircraft and electronic products grew in complexity such that it was no longer possible for a single engineer to understand the whole product. These were the first products to meet this complexity barrier

A World War invention "Operations Research" introduced a concentration on the objective of the equipment (or combination of equipment) rather that the engineering solution and this formed the basis of what became systems engineering.

## WHAT HAPPENED NEXT?

Systems engineering becomes the standard approach to all aerospace and military systems. 20% - 30% of all engineers working in aerospace are systems engineers and the rest work within a systems engineering framework.

Academic interest starts up – their work is not at first very relevant to real life but some new concepts emerge particularly "soft systems engineering."

Other industries with large projects adopt some or all of systems engineering approaches - particularly civil engineering – but with their own emphasis.

The last point is important. There is no one "systems engineering" applied to every situation. Nations, industries, even companies, differ in the detail of how they implement it. Be alert for differences in terminology, procedure, even the approach. But you will find that fundamentally what going on is the same.

1990 what is now the "International Council of Systems Engineering" was formed.

## WHAT IS SYSTEMS ENGINEERING?

It is a "tool kit" of various techniques in

Requirement generation
Analysis
Modelling
Project Management

It is based on two fundamental principles.

1) That the approach to product development should be "TOP DOWN" from the purpose of the product through analysis of the resulting technical requirements to engineering design of the product.

2) The concept of a "system model" – that is a picture of what a system is.

These approaches could be applied to almost anything but in practice they take a lot of work (especially paperwork) so only make sense for engineering products that are beyond the "complexity barrier."

**WARNING 1:** Unlike most of engineering disciplines we teach, systems engineering is not an applied science, based on empirical study of the outside world. It is a human construct to aid the engineering process through the "complexity barrier". If the course starts to appear a little wafflely and frothy, I suggest try reading about real system's developments and hopefully the value will become clearer.

**WARNING 2:** There are no right answers, no perfect systems *. A 100% optimised system is neither possible nor financially viable

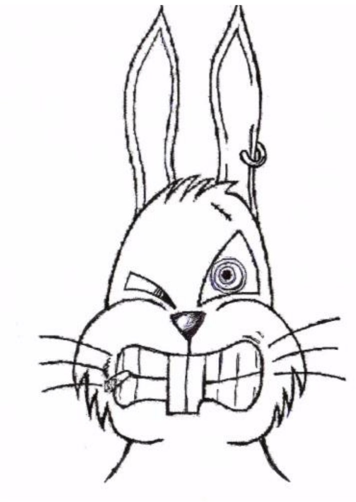
**WARNING 3:** It is claimed by some systems engineering experts that all a practitioner needs to know is the systems engineering basics and he/she will be able to apply it to any product without any real knowledge of the product.

**- This is rubbish! –**

Systems engineering (like maths) is a general tool that has wide applicability but to use it effectively you must be knowledgeable about what you are applying it to. Many fine aircraft have been produced by engineers who knew nothing of systems engineering – BUT no good aircraft has ever been produced by a systems engineer who was not also an expert on aircraft.

(* Although systems designed by M.Hempsell esq. MSc ARCS FBIS get very close. Available at reasonable hourly rates)

**WARNING 4 – *THE KILLER BUNNY!***



In Monty Python and the Holy Grail, King Arthur and his knights face the apparently fluffy cute white "Rabbit of Caerbannog", which kills three of them before they realise its dangerous nature.

From past experience on this course some concepts in systems engineering look easy and straight forward at first sight but are actually difficult and complex and catch students out.  So to help out; I will mark such deceptive bits with a "Killer Bunny" logo

## SOME POINTS ON THE UNIT

This unit is only an introduction to systems engineering and it covers the subject in a rather simplistic way. It is enough to help you understand the process you are in should you be involved in a large complex project. It is not intended to turn you into a full blown Systems Engineer.

We are mostly covering "hard systems" with only a taster of "soft systems". This is because you need to understand "hard systems" before you can tackle "soft systems". Different industries have different balances between these approaches. As a comparison:

> **Aerospace -** tends to use "hard systems", which is better when the purpose is simple and the complexity is in the engineering;
>
> **Civil Engineering -** tends to use "soft systems", which is better when the complexity is in the purpose and the engineering itself can be quite simple.

Because in real life (by definition) Systems Engineering is used in very complex situations, I cannot often use real life examples to show detail of the processes, but have to look at artificial simple cases during the lectures, which can look a little silly. You should use your background reading to explore the principles in real projects.