DEFINITIONS AND BASIC CONCEPTS

Lecture Objective: to create a vocabulary with which we can discuss systems and their engineering.

DEFINITION OF A "SYSTEM"

It is important we understand what we are going to be examining in the Unit. So we need a good understanding of what a system is.

Many definitions exist e.g.

"An organised or connected group of objects. A set or assemblage of things connected associated or interdependent so as to form a complex unity; a whole composed of parts in orderly arrangement according to some scheme or plan; rarely applied to a simple or small assemblage of things (nearly = "group" or "set")."

First definition in OED.

A System is a set of interrelated components which interact with one another in an organized fashion toward a common purpose.

NASA Systems Engineering Handbook SP6105

A System is a group of interacting or interrelated entities that form a unified whole.

Wikipedia

A system is an arrangement of parts or elements that together exhibit behaviour or meaning that the individual constituents do not.

INCOSE

The origin of the word: A medieval Latin word term for a musical interval (Note implication of harmony) also used for government, body of ideas, the universe, a body of men etc. Nicked from Greek systema "a whole made of several parts." Used in English from 17th Century

OUR DEFINITION

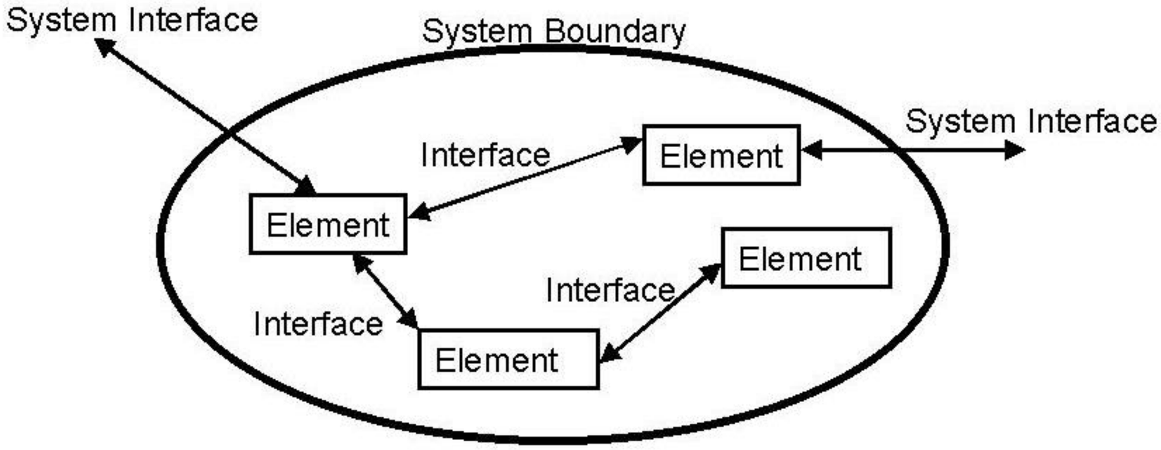
A SYSTEM IS A SET OF ELEMENTS THAT INTERACT WITH EACH OTHER TO CREATE EMERGING PROPERTIES

Consequences:

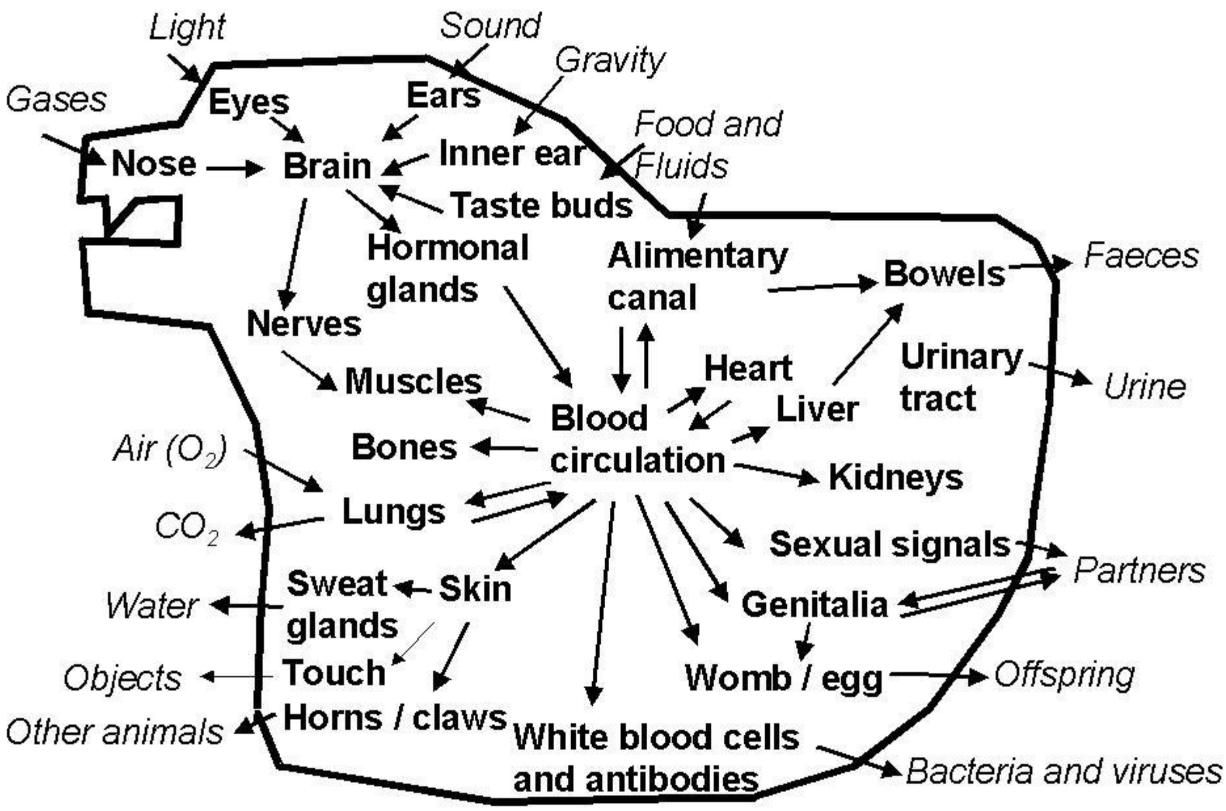
- A system will subdivide into elements
- "Element" is thus formally defined as a component of a system
- Elements must have shared characteristics to interact
- There will be a boundary around the system
- The system will interact outside the boundary (emerging property)

This is nearly a mathematical definition and can be used as the basis for abstract analysis methods that can be used on all systems.

THE SYSTEM MODEL



AN ANIMAL AS A SYSTEM



SYSTEMS IN ENGINEERING

Considering natural processes as systems can be useful both for analysis and as an aid to understanding and thinking: e.g. the "Solar System".

This has proved controversial in some cases (i.e. reaction to Lovelock's Gaia) as it implies natural systems have goals or purpose - which is clearly not true (scientifically, religious views may differ).

Better to think of "natural systems" which do not have purpose but simply exist and "engineering systems" which do have purpose.

An engineered system is designed by a human with a purpose - it has objectives and can be judged on how well it meets these objectives. One of the key purposes of systems engineering is to make sure requirements are both met and met efficiently. Requirements will be a major part of our examination.

Reference "Gaia A New Look at Life on Earth", J.E.Lovelock, Oxford 1979

BOUNDARIES AND ELEMENTS

How are the boundary and the elements of the system determined?

There is no deterministic way to establish these – it is a matter of judgement and convenience.

Elements can be anything (hardware software, activities, concepts, people) but they must form a set; that is there must be a rule that defines what an element of the system under consideration.

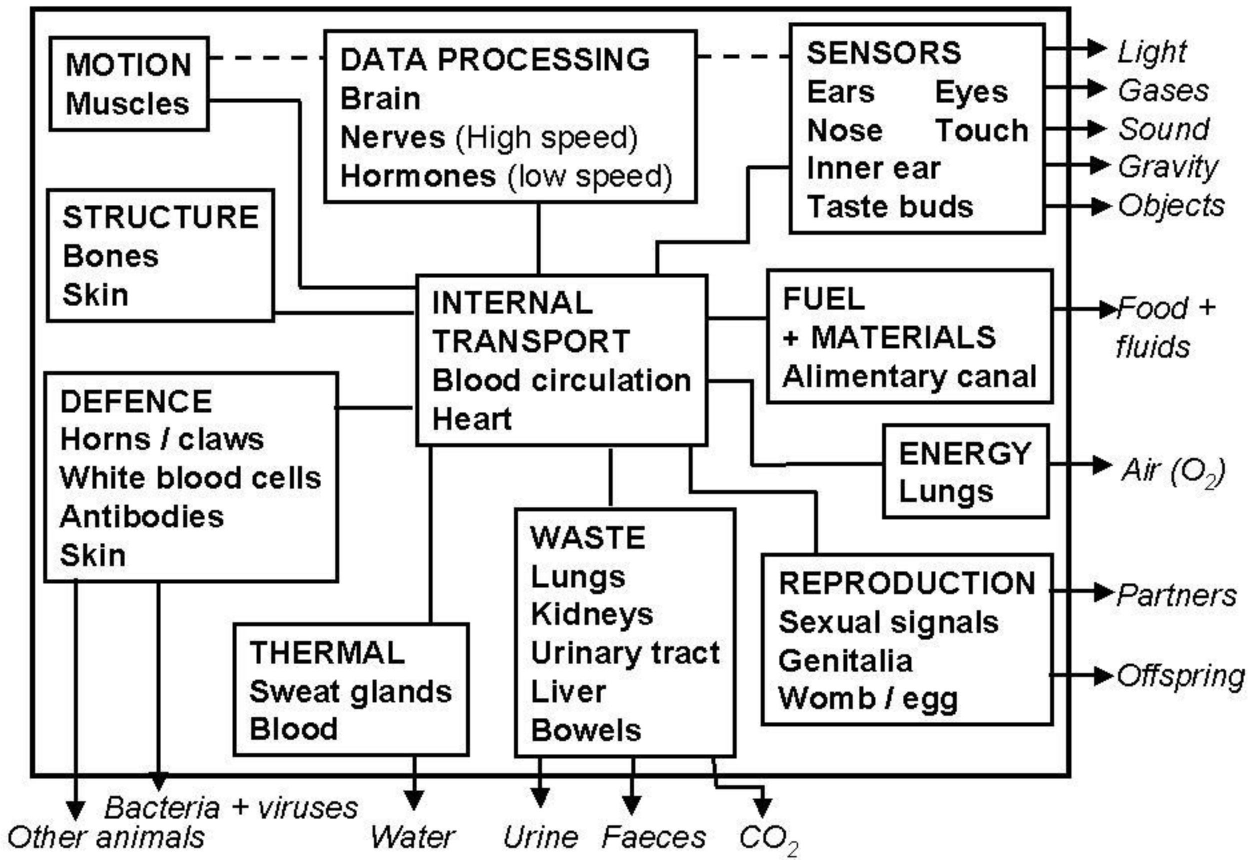
This rule also defines the system as sum of elements that meet this rule

For practical purposes in engineering the basic rule for defining whether an element is in the system or not is: - An element is in the system if it contributes to the deliverable product.

The system boundary is thus determined by the definition of the product.

"A system is whatever the specification says it is" (Hempsell)

ALTERNATIVE ANIMAL AS A SYSTEM



BOUNDARIES AND ELEMENTS IN REAL LIFE

Industries arrive at "standard" solutions to what system they sell and how they should split it up into elements. The process is analogous to natural selection and normally works. However minor differences between companies often exist, beware!

Products can be highly defined within an industry (e.g. classes of car, Hi-Fi boxes)

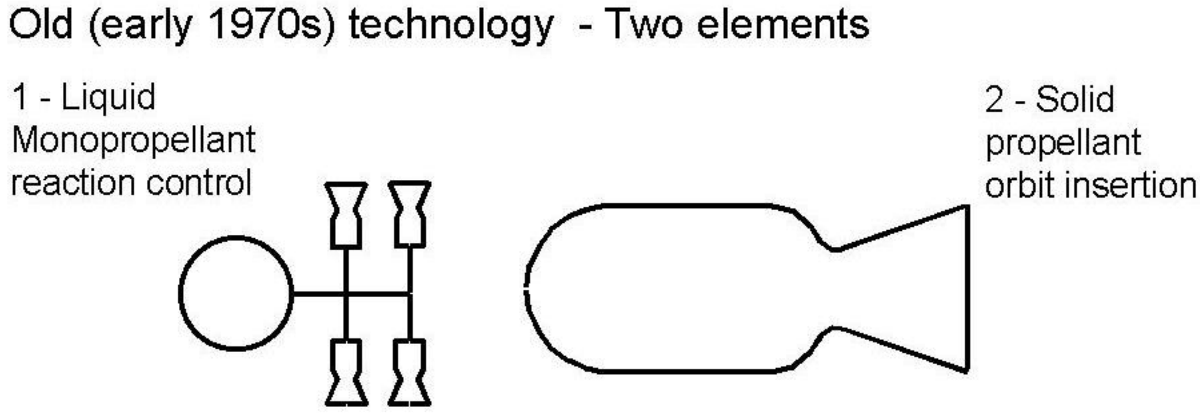
The engineering design organisation of the industries often follows the standard split of the system.

It always a good option to start with the "standard" approach, after all in most cases the industry has considerable success with past practice. But be aware on rare occasions a redefinition of the system boundary or element split may make a better system (better generally being defined by marketability).

This can be particularly true if new technology is available. The impact of new technology is often not the technology's performance but the ability to re-engineer the total system package.

AN EXAMPLE OF CHANGING ELEMENT DEFINITION

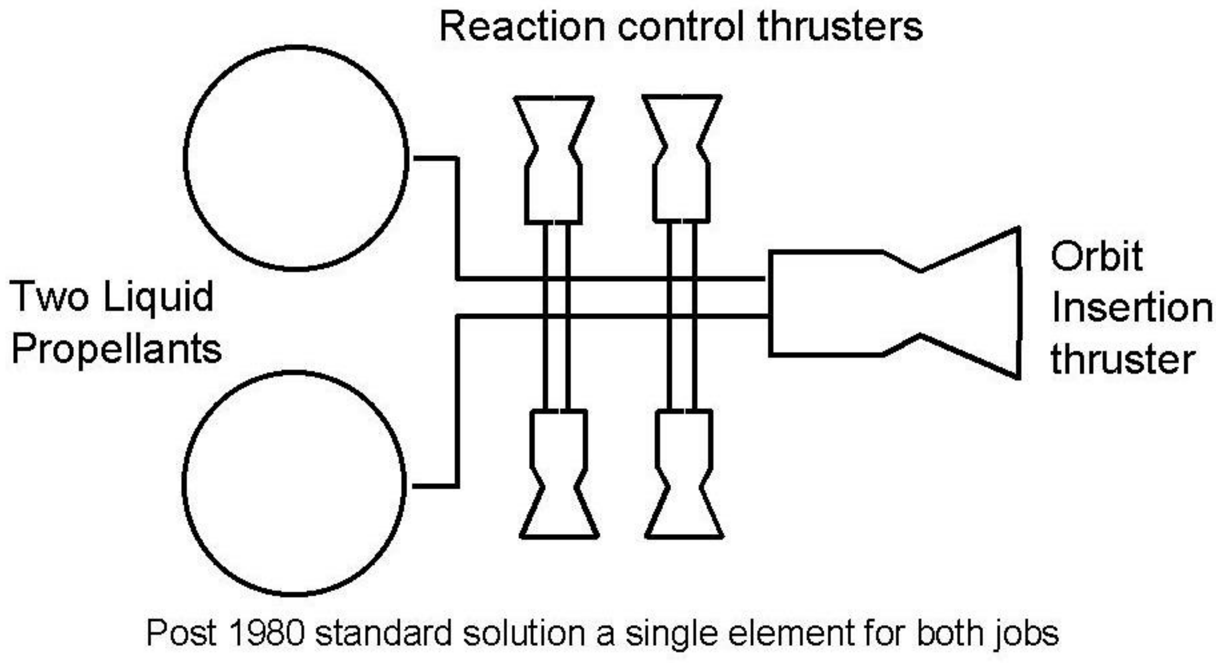
Geostationary satellite propulsion subsystems



New technology small bipropellant propulsion thrusters.
Better performance - How to use it?

Use it for reaction control element?
Uses it for orbit insertion element?
Use it in both elements?

The actual way it was used was to define the elements to form a “combined propulsion system” that did both orbit change and reaction control



INTERFACES

Where an element interacts with another the definition of the interaction is called an "interface".

The definition and control of interfaces is the key to successful systems engineering.

Where the interface crosses the system boundary it is a "system interface".

STANDARDS

In a complex situation, the key to system viability is "standardisation" of system interfaces e.g. power supply (plug, voltage, etc.).

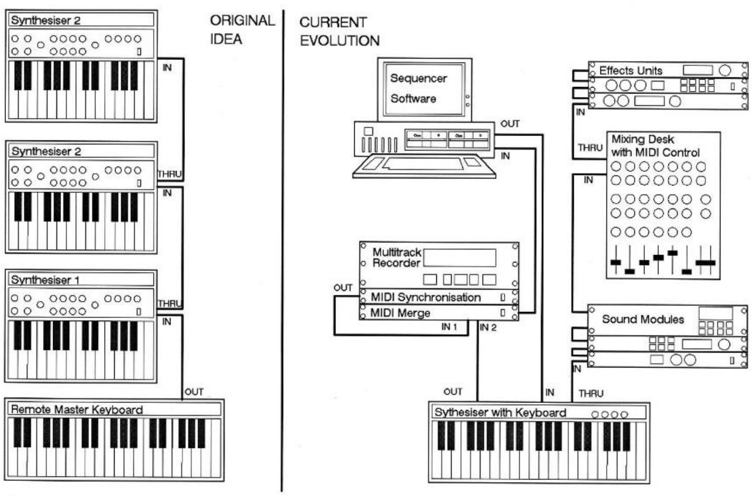
Problem: "Standards are wonderful things that is why we have so many of them"

Although things are getting more organised as the importance of standards is more widely appreciated, most standards are still arrived at through historical chance. Example: 4ft 8.5" railway gauge was set by Stevenson on the Stockton/Darlington line to use up rolling stock he already had from a pony powered railway used in a coal mine. - it became an international standard and is a big problem in producing successful high speed trains.

A GOOD EXAMPLE OF STANDARDS

MIDI = Musical Instrument Digital Interface

Agreed by electronic instrument manufacturers in 1982. It is a standardised code for notes, emphasis, commands etc. and the connection hardware to transmit and receive. It was 0riginally intended to enable a master keyboard to control more than one synthesizer (up to 16).



MIDI opened up a market for synthesizer modules, computer software, automated control. As a result almost every serious electronic musical equipment is MIDI controllable and a massive market in hobby and semi-pro recording has been possible.

Later it was extended to General MIDI which defines sounds - enables electronic music files to be created (like word processor files). General MIDI sound modules are now being incorporated in personal computer sound cards.

Long Term Result: - massive new markets - mass produced cheap products - lots of happy customers - lots of profits for industry.

(Applause - Cheering - Back slapping - etc)

A BAD EXAMPLE OF STANDARDS

ASCII - American Standard Code for Information Interchange

Originally intended to standardise teletype codes so that any make of teleprinter could be used with any make of computer.

It was in practice the standardizing of text into electronic code. It is used by essentially all computers and IT systems. It is the standard!

All big computer companies agreed to it - including IBM. However a flip chart for an internal meeting at this time read shows their real intent:

> **STANDARDS AND THE COMPUTER INDUSTRY**
>
> **THE KEY ISSUE FOR IBM**
>
> **WHICH WILL SHOW BETTER P&L ? (Profit and Loss)**
>
> **- STANDARDISATION TO ACHIEVE AN OVERALL GROWTH OF THE COMPUTER INDUSTRY?**
>
> **- MINIMUM STANDARDISATION IN ORDER TO ACHIEVE COMPETITIVE ADVANTAGE?**

IBM chose the latter and used their own code called EBCDIC thus making their machines incompatible and "locking" the customers into buying IBM.

Long Term Result: - reduction in growth - unnecessary and expensive complexity - less customers and unhappy customers - less money in the industry.

(Boos - Hisses - Cursing - etc)

Reference - "BIG BLUE" Richard Thomas DeLamarter, Dodd Mead 1986
Outlines IBM’s unethical and possibly illegal use of systems engineering to gain competitive advantage.

A COMPARISON OF MIDI AND ASCII

Both are data codes one for text one for music. Also both could be classed as well designed – no obvious lunacy in the encoding arrangements.

MIDI was comprehensive and covered enough information that means no extension have been required.

ASCII only thought American! So important symbols like £, ¥, æ. Stuff like accents needed for foreign languages like Ü, Ø, ¿ also no Greek and no Cyrillic letters. These are added by makers of software as extensions to ASCII but it is not standardised. Hence having to tell the computer what character set you are using, and funny emails with the symbols messed up.

In MIDI all the relevant manufacturers entered the spirit of standardisation and produced products that worked together. With ASCII major players tried to sabotage the standard (without success) but to the detriment of sorting out original weaknesses in a standardised way.

DEFINITION OF SYSTEMS ENGINEERING

Aslaksen and Belcher define it as: *"the art of designing and optimizing systems, starting with an expressed need and ending up with the complete set of specifications for all the system elements"*. This definition highlights the problem with academic consideration of the subject. In real life systems engineers are used through to product delivery and often afterwards as well (e.g. Air traffic accident investigations).

We will use a broader definition of systems engineering as:

"The creation and maintenance of systems to meet defined objectives"

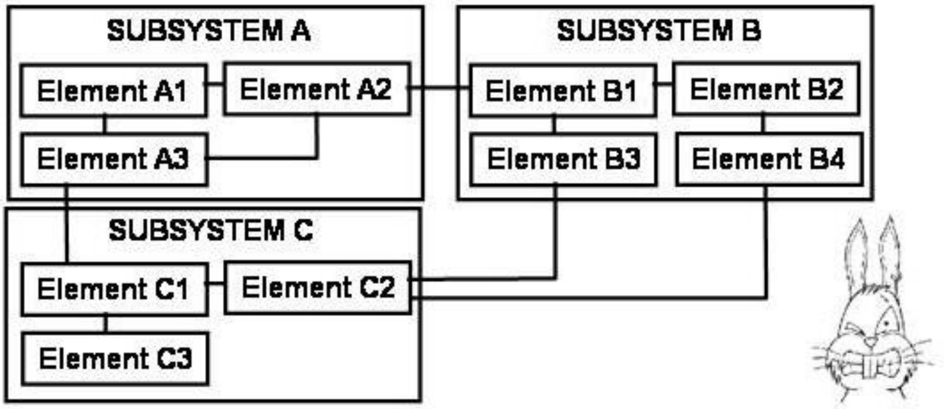
Notes on this definition:
- This meets the objective in the last lecture of matching requirement and product.
- We have a definition of "System" so the definition has meaning
- Meeting objectives makes it engineering (as opposed to natural science)
- It covers the complete product lifecycle (defined next week) - the real life situation
- It has a problem with the interface with other sorts of engineering (an issue in real life too).

SUBSYSTEMS

A "subsystem" is an element of the system that itself is composed of interacting elements. Therefore a subsystem can be treated as a system in its own right.

A hierarchy of systems is useful when designing complex systems. It is almost universal practice in aerospace engineering to divide systems into subsystems.

It is possible to see the redefinition of boundaries in practice. The spacecraft systems engineer will refer to the "Propulsion subsystem", "Power subsystems" etc. The engineers of the subsystem will refer to the "Propulsion system" and "Power systems". Both are valid because, as we have seen, boundaries of a system are flexible and are chosen to aid the analysis and development process.



An Aside - HOLON

The idea of a hierarchy of systems has always been part of systems thinking, but some soft systems thinking adopted the term “Holon” from Arthur Koestler’s book “Ghost in the Machine” *(1967)*.

A “holon”: from the Greek *holos*, which means whole, entire, complete in all its parts' and the suffix -*on* which is its neuter form, cf. prot<u>*on*</u>, neutr<u>*on*</u> and electr<u>*on*</u>.

Essentially a system (as defined by the system model) and a holon are the same thing but Holon is always used in the context of a hierarchy of systems within systems.

SUMMARY

We have introduced and defined the following:

System - A set of elements that interact with each other to create emerging properties.

Subsystem - An element of a system that is itself a set of interacting elements.

Holon – Another word for system but particularly in the context of a hierarchy of systems within systems (more used in soft systems engineering).

Element - A component of system.
(An element is in the system if it contributes to the deliverable product)

Boundary - A definition of what is included within the system.

Interface - The definition of an interaction between elements of a system.

System Interface - The definition of an interaction between an element in the set and an element outside the system (i.e. the interface crosses the system boundary).

Standard - A system interface common to many systems and that is defined prior to system development.

Systems Engineering - The creation and maintenance of systems to meet defined objectives.

CONSEQUENCES OF OUR DEFINITIONS

"System" definition and constraints means:
- We will be looking at complex artefacts that can be usefully divided into interacting elements
- We can derive general analysis methods, techniques etc. applicable to all systems
- We will be concerned with best methods of defining boundaries and interactions
- Much of the material will be concerned with conventions and practice not fundamental "scientific laws"

"Objectives" means:
- We will be dealing with Engineering (i.e. not natural) systems
- An emphasis on requirements of systems
- A "top down" process working from requirements to engineering solutions
- Success is judged by match of product with requirements.