ASEAN J. Sci. Technol. Develop. 4 (2) (1987) 1–7

SYSTEMS ENGINEERING - IS IT RELEVANT TO BRUNEI ?

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ABSTRACT

The concept of "Systems Engineering" is a powerful approach to meet the needs of a technical environment which is getting progressively more complex. This is particularly true in the case of Brunei Darussalam which makes extensive use of hi-tech systems. With "Systems Engineering" emphasis is shifted from a knowledge of the parts alone to an understanding of how the parts fit together to make a dynamic system. With this approach we study and learn to apply a branch of knowledge only if it is relevant to the analysis, design, implementation and maintenance of an engineering system.

This paper highlights the concept of Systems Engineering, changes taking place in engineering technology and the impact of the new technological developments on educational strategies. This paper provides strong evidence that Brunei Darussalam will gain significant benefits by adopting a systems approach for tertiary/degree programmes in engineering.

INTRODUCTION

The Institut Teknologi Brunei was started in January 1986 to meet the technical manpower requirements of Brunei Darussalam. As part of an Academic Programme Development 1986–1995[1], work has now started on the development of a Bachelor of Engineering (B. Eng.) programme in the Department of Electrical & Electronic Engineering.

This paper, which attempts to summarize some of the available literature in the area of "Systems Engineering", was written in response to a brief from the Departmental "Degree Course Development Committee".

The committee has responded to this paper by adopting a "Systems Engineering" approach when implementing the new degree programme.

In this paper it is intended to highlight :

The concept of Systems Engineering

Changes taking place in engineering technology

The impact of the new technological developments on educational strategies

Relevance of Systems Engineering in the Brunei context

SYSTEMS ENGINEERING

The "Systems Engineering" approach has already been adopted in numerous professions. Users of "Systems Engineering" under various guises include mathematicians, computer analysts, economists, social scientists and engineers.

A recent colloquium jointly sponsored by several of the professional engineering institutions in London, England addressed the nature and scope of the term "Systems Engineering". Following are some of the distinguishing characteristics that were identified :[2]

- Many systems are so complex that just finding a systematic way of handling all the variables and their interactions can become the most important problem.

- Certain parts of the system as well as some of the external interactions cannot be characterized in electrical terms at all. For example, one part of a system may be a human being.

- The need which is to be fulfilled is most often not expressed in engineering terms. Therefore "design" must be preceded by "definition".

In an engineering sense a system can be considered as a set of related components required to perform a specific task. "Systems Engineering is the art of designing and optimizing such a system".[3] In this process the following phases can be clearly identified.

Analysis	A comprehensive system specification is produced after analysis of user requirements.
Design	The main task is divided into sub tasks. Interaction among modules are clearly defined.
Implementation	The system is physically created.
Maintenance	Any previously undetected errors are corrected. The system is kept at a functionally acceptable level. Also any minor changes in user needs are accounted for.

A degree programme that focuses on systems engineering will expose the undergraduates to the above concepts earlier in the programme. The different subjects are taught with the view of giving the students both the knowledge and the skills to perform the above phases of system development. Therefore in addition to the vertical development of individual subject material, there are strong horizontal links at every stage of the programme of study, thus resulting in a coherent programme.

To meet the new requirements some changes to the curricula are necessary. In a traditional course emphasis is on understanding working principles, design manufacture and trouble shooting at a component level. This should now be changed to an approach which starts at the system level but does not exclude the need to know about individual component performance characteristics as this knowledge is essential to system simulation, design and optimisation.

Earlier in the programme modules of systems are introduced; end to end specifications and inter-modular protocols are defined.

The principle subjects are taught in parallel to provide the necessary theoretical background. These principle subjects are taught with the primary objective of meeting the requirements of Systems Engineering rather than the acquisition of knowledge for its own sake.

Some changes to the order in which subject material is presented may become necessary.[4] The curriculum development process may well result in material being presented to students in a changed sequence. For example in Engineering Mathematics, set theory and logic may well be taught at an earlier stage than high level language and number theory followed possibly by Fourier Analysis and Differential Equations.

The implementation phase can be treated in two ways :-

1. In a society where there is an electrical and electronic manufacturing industry the emphasis should be on design and construction.
2. If a manufacturing base is absent and technology is imported then emphasis should be on

   Drawing up specifications

   Tendering

   Installation

   Approval testing at system and sub-system level

Treatment of fault location strategies, selecting a suitable servicing policy i.e. preventative maintenance versus replacement at breakdown, inventory control, system updates etc. are required to accomplish the maintenance phase.

Most present day systems consist of not just hardware but also software. Therefore Software Engineering is an integral part of such a degree programme.

IMPACT OF TECHNOLOGICAL DEVELOPMENTS

At present we can observe a rapid growth of semiconductor technology. The advent of Large Scale Integrated Circuit Technology offers systems of amazing diversity and complexity at unbelievably low prices. Part of this diversity includes the extensive use of microprocessors to provide system automation and some degree of machine "intelligence".

The effect this growth of semiconductor technology has on our day to day life, either at home or at our place of work is dramatic. The way we process information is now completely revolutionized. We take for granted the facilities offered by word processors, data bases and electronic mail. Home banking and shopping by computer are just round the corner. One can book an airline seat for anywhere in the world in just a few minutes.

In the service industry Computer Aided System Design and Computer Aided System Testing are emerging as powerful tools for progress. These tools release the engineer from detailed routine tasks so that he can concentrate on optimizing overall system performance.

With the introduction of Integrated Services Digital Networks (ISDN) techniques for transmission of a combination of voice, images and data over a national or international telephone network became a practical possibility.

To optimize the benefits from this rapid growth of technology it has become necessary to integrate a wide range of disciplines which were previously treated in isolation. A good example is the development of the humble car. Until recently to design a car knowledge of elementary thermodynamics, simple chemistry and traditional mechanical engineering was sufficient. It was within the capabilities of a traditional mechanic to repair it.

Now the latest "hi-tech" cars require a design or service engineer who is, in addition to the above disciplines, familiar with microprocessor technology, control engineering, instrumentation technology, communications engineering, acoustics technology and power electronics. Also with increased system complexity and the presence of feedback control systems, fault finding and repair becomes a premium skill requiring an in-depth understanding of the dynamics of the whole system.

The need for the integration of different disciplines and associated educational challenge is further highlighted by the following statement by Professor W. Gosling[5]; in particular about information engineering.

> "In our industry we need many information engineers of different colour. Let me spell it out a little. The disciplines split many ways: between hardware and software, digital and analogue, devices and systems, sensors and processing.

None of these categories is negligible or unimportant, nor is it useful to gain mastery of one without at least an insight into the others".

GLOBAL ADJUSTMENTS IN ENGINEERING EDUCATION

About ten years ago, Gordon Moore, the founder and president of Intel Corporation, made an observation about the history of technology which he dubbed "Moore's Law".[4] The law states

> "Whenever there is an order of magnitude change in a parameter of technology, ten times faster or cheaper or smaller etc: there is an accompanying qualitative change in the exploitation of that technology".

Gordon Moore was referring to semiconductor technology which was, at that time, being exploited using classical design techniques and product concepts. Today, as predicted, there is an acute shortage of people capable of exploiting this new technology, as is evident from international advertisements for employment in the expanding hi-tech areas.

To face this challenge the initial response from educational establishments was to amalgamate elements of existing courses - computer science, electrical and electronic engineering etc. This resulted in a bewildering mixture of concepts, theories, models, tools and techniques, drawn from disparate disciplines. These courses lacked common themes or any grand unifying principles.

A further problem facing educational institutes was institutional accreditation-- the relevant institutions such as I.E.E. have themselves yet to come to terms with the new technological order.[4]

1986 saw the start of a change. Many international tertiary education establishments implemented revised degree programmes. Most of these new courses have very successfully integrated the relevant disciplines using a "SYSTEMS" theme. Examples include

- Electrical and Information Science Tripos (EIST) at University of Cambridge
- Computer Systems Engineering at N.S.W.I.T., Australia [6]
- Bachelor of Engineering at City Polytechnic, Hong Kong.[7]

IS IT APPLICABLE TO BRUNEI DARUSSALAM ?

Brunei Darussalam currently has no electrical or electronic manufacturing industry; but uses many systems; some of which belongs to the latest hi-tech category. Thus our graduates are more likely to be working at a systems level.

Examples of these systems include :

- CAT scan at the RIPAS hospital
- Missile systems used by Brunei Armed Forces
- I.S.D.N. communications systems
- Process Control Systems at Brunei Shell
- Airline reservation system at Royal Brunei Airlines
- Power Generation and Distribution System of Jabatan Lectric
- Broadcasting Systems at Radio Television Brunei
- Computer Systems in various organisations.

The direct applicability of the Systems Engineering approach can best be demonstrated by an example - Brunei Darussalam will commence a Data Communications Network, DCN, in two years time as the first step towards providing an Integrated Services Digital Network.

During the analysis phase a survey has to be done among potential users of the system to determine their current and projected data communications requirements for both local and international traffic.

These requirements are translated into detailed system specifications during the design phase. It is essential for the engineers involved with this phase to understand the system in its totality and be able to intelligently apply the relevant analysis and project planning tools such as cost-reliability curves and PERT charts.

Often in the past system design and system operation were not integrated. The design engineer had only a rudimentary understanding of system operational problems and procedures. Thus the design although functional was often not optimised for maintenance. This problem can now be overcome using an integrated systems engineering approach where the design team have a total understanding of system operation and maintenance requirements. The design engineer must realise for instance the importance of incorporating sophisticated monitoring and analysis capabilities, such as Nodal Bit Error Rate monitoring, into the total system specification.

During the implementation phase of the project, the complete system will need careful engineering management to minimise installation costs, delays and disruptions to existing services. Also acceptance tests, mainly of the end to end type needed for total system and sub system validation need to be done with great precision.

Once the system is operational a maintenance programme to achieve an acceptable grade of service and system life is implemented. A global system perspective which accommodates the changing needs and habits of the system user is necessary to optimize system performance during the lifetime of the system.

A graduate coming from a traditional engineering course will need many year of on-the-job training to see a system as a single entity. This is not only a waste of resources but also a major problem for countries like Brunei Darussalam where there is a shortage of suitable manpower. On the other hand a graduate educated with a Systems Engineering approach can meet the above requirements with a minimal amount of further training.

To conclude this paper the following extract from Mead's Report[1] is thought appropriate.

> "Integrated with these provisions is the need for a professional engineering qualification to satisfy the career needs for the executive staffing of various enterprises. Initially it is envisaged that such staff would be involved predominately in the conceptual design, specification and operation of engineering systems purchased from external sources, and as such their education should be rather more broadly based than the classical subdivision of engineering degrees. Accordingly, the Higher Diploma developments will be complemented by an engineering degree covering a wide range of cross disciplinary skills commensurate with the concept of Systems Engineering".

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