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Development of a Master of Science Programme in Automotive Systems Engineering

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SYNOPSIS

Starting in 1986, in partnership with the Ford Motor Company, Loughborough University has been working closely with the automotive industry in designing, developing and delivering a part-time MSc programme in Advanced Automotive Engineering. Recently the entire programme has been reorganised to incorporate a theme of Systems Engineering. The new course retains a strong automotive engineering content but with an added element of 'top down' design. This paper explains the motivation behind the new course and includes a discussion of recent experience using a newly developed Computer Based Study Support System.

1 INTRODUCTION

The Loughborough MSc programme in Automotive Systems Engineering is aimed at engineers working in the automotive industry, it is not designed to train engineers for their daily job in industry. Rather, it seeks to widen horizons and build confidence, providing a route for MSc graduates to acquire:

- knowledge and technical expertise in a wide range of automotive disciplines
- a systems viewpoint for automotive design and manufacture, with specific skills in formulating automotive engineering systems in terms of their function and performance
- relevant and in-depth knowledge in chosen areas, through elective modules
- the ability to transfer new skills and knowledge to the workplace, via the industry-based MSc project
- a confident and open-minded attitude to exploring new areas of knowledge in the future

The programme is aimed primarily at product development engineers, however, through the correct choice of elective modules the programme offers considerable depth in manufacturing engineering.

In response to industry's need for more work place based study a distance learning element has been introduced into the course. In parallel a computer based study support system has been developed and implemented to assist the student in studying away from the university. This paper includes a description of the support system.

2 AUTOMOTIVE SYSTEMS ENGINEERING

Systems Engineering can mean many different things to many different people. In this MSc programme it is considered to be a pragmatic way of dealing with the complex products, processes and constraints that fill the automotive world. Gone are the days when engineers might seek to build 'good motor vehicles' by the simple strategy of specifying 'good quality components'. Designing and building with confidence involves quantifying the function and performance of systems and sub-systems. 'Good' engineering practice is still needed, but applied in a way that ultimately links the bottom level component design to the top-level objectives such as customer satisfaction and cost effectiveness. No engineer working in the modern automotive industry can afford to ignore this functional approach.

To reflect this, the programme:

- adopts a top-down approach to the delivery of the vehicle engineering topics
- incorporates a 'systems thinking' framework, referring to product lifecycle, target setting, requirements capture and cascade, plus elements of business-related drivers for engineering practice
- includes a very significant level of core technical engineering content
- emphasises the duality of approach to engineering: components and assemblies *versus* functional systems, physical *versus* functional attributes and boundaries, etc., and starts to develop these themes at the vehicle level
- provides clear links between design and manufacture, for example presenting examples where manufacturing capabilities have a large impact on design and system robustness

3 PROGRAMME FORMAT

The MSc comprises 180 modular credits, made up from eight taught modules valued at 15 credits each, plus a Masters Project valued at 60 credits. The programme is designed for part-time study by graduate engineers working in the automotive industry. Of the eight taught modules, four are designated as being 'core' and four more 'electives' are chosen from a list of available options. The core modules are normally studied during the first academic year of the programme, and the electives during the second year. The project is initiated towards the end of the second year, with completion in time for graduation in the summer of the third year. However, in recognition of the sometimes unpredictable demands of the students' work and other commitments, there is considerable flexibility in the time available to complete the programme, and it is usually possible to defer taking any particular module. Table 1 summarises the modular structure of the programme.

Each 15 credit taught module is designed to occupy approximately 10 weeks of part-time study. Central to each module is an intensive week of residential study at Loughborough,. Outside of this, students are expected to work on prepared course materials and assignments, and to do this effectively, they are supported by an on-line delivery system. An interactive

'discussion database' is used to provide additional information and materials, and also to facilitate tutorial-type discussion. This computer based system is password-protected, and accessible by students using a standard web browser such as Netscape.

3.1 The core modules

The Core Modules provide a broad foundation for understanding the wider aspects of automotive engineering. The first two core modules work from a vehicle engineering perspective, developing the relevant engineering fundamentals alongside a top-down review and analysis of the major vehicle systems. This perspective is then widened to deal with more general Systems Engineering concepts and methods. Finally the link to manufacturing and simultaneous engineering is explored. A list of the core modules is given below:

- Engineering Framework
- Vehicle Systems
- Systems Engineering
- Manufacturing Systems

'Engineering Framework' and 'Vehicle Systems' are pitched at the level of vehicle systems and attributes, including elements of the 'top down' focus, particularly in the area of customer and legislative requirements, and how these apply to the major vehicle functions such as straight-line performance, fuel economy or vehicle dynamics. There is also a very strong emphasis on developing the accompanying engineering tools and concepts. The focus is widened in the next two modules 'Systems Engineering' and 'Manufacturing Systems'. These modules address key areas that interface with vehicle design, such as:

- **vehicle life and lifecycle** - where an extended time-line for the vehicle is taken. Thus, issues such as product usability (ergonomics), reliability, recycling, maintainability are dealt with. Also considered is the interaction of vehicle systems with other systems. For example, telematics and highway information systems. An extended list of requirements is thereby generated.
- **vehicle design as a process** - here the methods and procedures relevant to a systems-based vehicle design process are considered. This includes relevant systems engineering tools and methodologies, such as requirements capture and cascade. An overview of CAE testing and sign-off practices also comes under this heading. The link to manufacturing is also explored via issues of simultaneous engineering practice and the need for design for manufacture and design for assembly.
- **vehicle engineering as a business** - the links to commercial and economic factors are briefly explored. This includes cost implications and planning for the design, manufacture, service and disposal phases of the vehicle lifecycle, as well as associated issues of vehicle programme timing. This is an area of common concern for the design and manufacturing areas of the automotive industry.
- **manufacturing systems** - here manufacturing is presented in a way that mirrors the vehicle engineering content of earlier core modules. The emphasis is on manufacturing processes and their organisation, cost, effectiveness, capabilities and limitations.

3.2 The elective modules

In contrast, the remainder of the MSc programme provides an opportunity to add considerable depth, first through the elective modules, and secondly through the MSc project. The electives cover areas such as powertrain design, vehicle dynamics, manufacturing and materials. Though the Systems Engineering aspects are less explicit here, it will always be a priority to highlight the relevance and significance of the technical material covered. A list of the elective modules is given below:

- Powertrain Engineering
- Vehicle Platform Engineering
- Engine Performance and Design
- Vehicle Dynamics
- Vehicle NVH
- Manufacturing and Materials Processing
- Automotive Control
- Design Integrated Manufacture
- Advanced Automotive Materials

3.3 The masters project

Not surprisingly, the project is also expected to provide this same blend of systems engineering framework plus detailed technical engineering content. Typically this is carried out at a company location, under the supervision of a nominated University supervisor, and with the co-operation of a company-based manager or supervisor. The project topic is agreed at an early stage between the student and the academic and industry supervisors, and regular discussions take place. A good project combines the academic rigours of the university with the technical and commercial requirements of the company. Project dissertations can have access restrictions where commercial confidentiality is an issue.

4 MODULE DELIVERY

As mentioned previously, the MSc in Automotive Systems Engineering is aimed primarily at engineers working in industry. In the first year there are four core modules to be studied and in the second year four elective modules. Each of these taught modules occupies a ten week study period centred on a one intensive week of residential study at Loughborough University. The study period begins three weeks prior to the residential week and continues for six weeks after the end of the study at Loughborough. The structure of this study period is shown diagrammatically in Figure 1.

The pre- and post residential study period is supported by the operation of a Computer Based Study Support System (CBSSS). Approximately 6 weeks before the residential week the student receives a mail with brief instructions referring them to the CBSSS. The CBSSS provides a module guide, module overview, key dates, lecture topics, staff contacts, assessment details together with details of the pre-residential study. The nature of the pre-residential study will vary from module to module, but is typically equivalent to nine hours of classroom contact - perhaps 6 lectures and 3 tutorials. It may consist of background reading with structured exercises, computer-based assignments (for example, computer modelling) or whatever the lecturer feels is most appropriate. Required pre-residential study materials are made available at the same time either in electronic form on the CBSSS, or as hard copy printed materials via the normal post.

During the residential week itself there will be a mixture of lectures, tutorials and laboratory sessions. Though the week is quite intense the activities are structured so as to make the time both interesting and challenging. After the residential week there is typically the equivalent of 6 hours of classroom material to be studied as follow-up assignments. There will also be assessed courseworks to complete.

The actual study hours are very hard to quantify, since different people work at different rates and with different levels of commitment, so the numbers given in Figure 1 are intended as an indication of our expectations based on current experience. This might typically be ten hours of personal study per week for the pre-residential study, with 10 hours per week over the following seven weeks being devoted to the post residential study and the coursework assignments. Obviously the workload might not be spread so evenly in practice - some students tend to concentrate their efforts during a shorter period close to the hand-in deadline!

4.1 The computer based study support system

The Computer Based Study Support System (CBSSS) was introduced to assist with the reduction of the residential period at Loughborough from two weeks to one week for each MSc taught module. The main objectives of the CBSSS are:

- to deliver study support material efficiently at a distance
- to provide an effective communication system between the teaching staff at Loughborough University and the students studying at the work place

Several issues were considered in designing and developing the CBSSS. For the University, the system should:

- be easy to develop and to modify
- be cheap to run and maintain
- provide access to students from the UK as well as abroad since the prospective students are local, European and International
- not involve a high level of IT expertise in developing and maintaining

For the users, the system should be:

- efficient and user friendly
- suitable to run on computers with low technical specifications
- easily accessible
- able to run on most available hardware platforms
- able to run with freely available software

It was decided to use the World Wide Web (WWW) as the delivery platform since it is easily available. Lotus Notes R4.5 was chosen as the WWW development software due to its powerful in-built features. Adobe Acrobat Portable Document Format (PDF) was found to be a suitable form to create electronic documents due to its cross platform nature and also due to the compact files generated. PDF documents also maintain the look and the layout of the original documents. In order to read the PDF documents, users need Adobe Acrobat Reader software installed in their machines. Adobe Acrobat Reader software is currently available to download from the Adobe Acrobat Web site free of charge.

4.2 The use of the CBSSS

The CBSSS is a password protected WWW site and it provides information and necessary study support for students studying at the work place. A screen dump of the homepage is shown in Figure 2. The list of available areas in the CBSSS can be seen in Figure 2. Documents under some of these areas are sub-categorised according to appropriate 'Team' names or module names. Each MSc student intake is identified using the 'Team' name. The C Team is this year's intake and the B Team refers to last year's intake. The CBSSS is developed in a way that the new and modified documents can be identified easily by the appearance of the 'New' or 'modified' icons in front of the document title in the content pages. These icons will appear automatically if the document has been created or modified within the last four days.

The first item in the available list, the 'What's New/Modified' hyperlink, shows all the new and modified documents in the CBSSS except in 'Questions & Answers' and 'Chat for Students' areas. The reason that these two areas are excluded is because in these areas students and staff create their own documents. Currently, the time limit for the automatic appearance of the new and modified documents in the 'What's New/Modified' area has been set to two days. This time limit might need to increase after considering the feed back from the staff and students.

The 'Noticeboard' is the area for general information and it contains notices with technical and non-technical matters. 'Library Services' is a hyperlink to the 'University Library Information Services and Resources for Engineering Distance Learners'. The 'Information for Staff' area is only for authorised Loughborough University staff. Students have no access to read documents in this area. Module Leaders post module outline plans for their module in this area prior to the residential week. 'Questions and Answers' is an area where students can ask any general or technical questions which are not directly module related.

The 'Chat for Students' area is a discussion area for students. The lecturing staff have no access to write or read the documents in this area. Students can create their own documents in this area. Once a student has created a document, his or her user name will appear with the title of the document. The aim of this area is to provide a communication facility between fellow students on the course. However, in comparison to the module related discussion areas this area is not extensively used. A possible reason for this is that the current students are all employees of the Ford Motor Company, Jaguar and Aston Martin and therefore communicate at work, either face to face or by other means.

The most active areas of the CBSSS are the 'Study Support Materials' and 'Discussion Forums' areas. Each of these areas have been divided into three categories as seen in Figure 2. Within each category there are sub-categories under the relevant module names. The 'Study Support Materials' areas are used to deliver the pre- and post-residential study support material. Most of documents are distributed as attachments within Lotus Notes documents. The majority of the attachments are in Adobe Acrobat PDF format. The other attachments include Excel data sheets, text files and computer programs written in C, FORTRAN, Matlab and Simulink. Since attachments preserve the formatting of the documents, students can use the data files and computer source codes without having to reformat them. Lecturing staff involved with the MSc course can create documents in the CBSSS with a very little experience in using Lotus Notes.

The 'Discussion Forums' are the most widely used areas in the CBSSS. There are dedicated discussion areas for individual modules. Students and lecturing staff can write in these areas using the edit facility provided within the system. However, since the World Wide Web is being used, there are some limitations. For example, currently, users cannot enter mathematical equations using an Equation Editor or type mathematical expressions with symbols, superscripts and subscripts. Staff and students must express mathematical equations using normal text. However, neither students nor staff criticised this as a problem or a drawback. With future software upgrades this drawback may be overcome. If lecturing staff need to add material with equations and diagrams into the discussion areas, they can use Lotus Notes to edit the relevant discussion area. If necessary, lecturers add explanatory material into the 'Study Support Materials' area and give the document location details in the appropriate discussion area. With the CBSSS, staff can provide effective study support to students at the work place, by communicating with them through the discussion areas and by putting additional study support material onto the system.

The discussion areas are common areas for all students in any particular Team. All the students in that Team can read the entries in the discussion forums. A group of six students who have been using the discussion areas for more than a year were asked if they would use these areas more if the discussion areas were private. They all said it would make no difference to them. They were also asked if there are any features in the CBSSS which could be removed. The overwhelming response was that all features should be retained.

The main drawback of the system is that the WWW can be slow at certain times of the day. To overcome this a new infrastructure was recently introduced which includes the hyperlink 'What's New/Modified'. This eliminates users having to look through all the areas in the CBSSS to find new or modified documents and thus speeds access time. The CBSSS was introduced at the end of 1997 and is still being developed. It is also anticipated that more facilities will be introduced in the future.

5 DISCUSSION

The MSc in Automotive Systems Engineering has now replaced the previously taught MSc in Advanced Automotive Engineering, the aim being to provide a top-down structure for the automotive engineering content, based on such things as system level requirements. Planning these changes has been a joint project between The Ford Motor Company and Loughborough University. Vehicle engineering and manufacturing content both form part of this wider picture, though the emphasis of the programme remains on the vehicle side.

Two years ago there began further discussions with industry representatives aimed at cutting the cost of the course, whilst preserving academic quality and content. One of the main concerns highlighted by the discussions, was the very real cost of engineers spending significant periods of time away from their company. Hence, the decision was taken to reduce the residential time at Loughborough. A number of models were discussed, but it was felt by most people that delivering entire modules by Distance Learning was not desirable. One of the many reasons was that the 'networking' achieved among students via the residential modules was exceptionally valuable, and that the sense of isolation that would be experienced by individuals studying at a distance should be avoided. Hence a plan was introduced which reduced the residential periods to one-week, and supported company based study with an on-line delivery system. This modern flexible/distance learning system is based on Lotus Notes

and the Internet. It is currently being used in the programme to assist student communication with the University and it is being further developed and improved for the future.

Initially there were a number of reservations expressed by staff and students about the new delivery format. The following questions highlight the main concerns expressed about the new programme and format:

- will the depth and quality of the course suffer?
- will lectures be hurried or compressed?
- will students have to study 'distance learning' packages?

First and foremost, Loughborough University will continue to award an MSc degree at the end of the programme, and there is no freedom to downgrade this award, so the depth and quality *cannot* be reduced. The new delivery mechanism ensures that the depth and quality of the course does not suffer. Secondly, the lectures should not be hurried or compressed because the 'equivalent' lecture time is the same, merely the delivery format has changed. Finally, self contained distance learning packages are not used to any great extent. This is a masters level programme and a reasonably high level of maturity is expected of the students. Thus, the use of step-by-step programmed learning methods is considered generally inappropriate. However, some of the early study material in the core modules is covered in this more 'traditional' distance learning approach.

The future structure and delivery of the programme is under a system of continuous improvement. This is embodied in the management of the MSc programme. Of particular importance are regular meetings with an industrial liaison committee - a team of industrial managers and technical experts who works with staff from Loughborough University. This committee helps to steer the MSc in the design, development and management of the programme.

6 ACKNOWLEDGEMENT

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Table 1 Modular structure of the MSc programme

	Assessment		
	Exam	Coursework	MSc Credit
Core Modules			
Engineering Framework	50%	50%	15
Vehicle Systems	50%	50%	15
Systems Engineering	50%	50%	15
Manufacturing Systems	50%	50%	15
Elective Modules (<i>Select Four</i>)			
Vehicle Dynamics	---	100%	15
Manufacturing & Material Processing	---	100%	15
Vehicle NVH	---	100%	15
Powertrain Engineering	---	100%	15
Vehicle Platform Engineering	---	100%	15
Engine Performance & Design	---	100%	15
Design Integrated Manufacture	---	100%	15
Automotive Control	---	100%	15
Advanced Automotive Materials	---	100%	15
MSc Project	---	100%	60

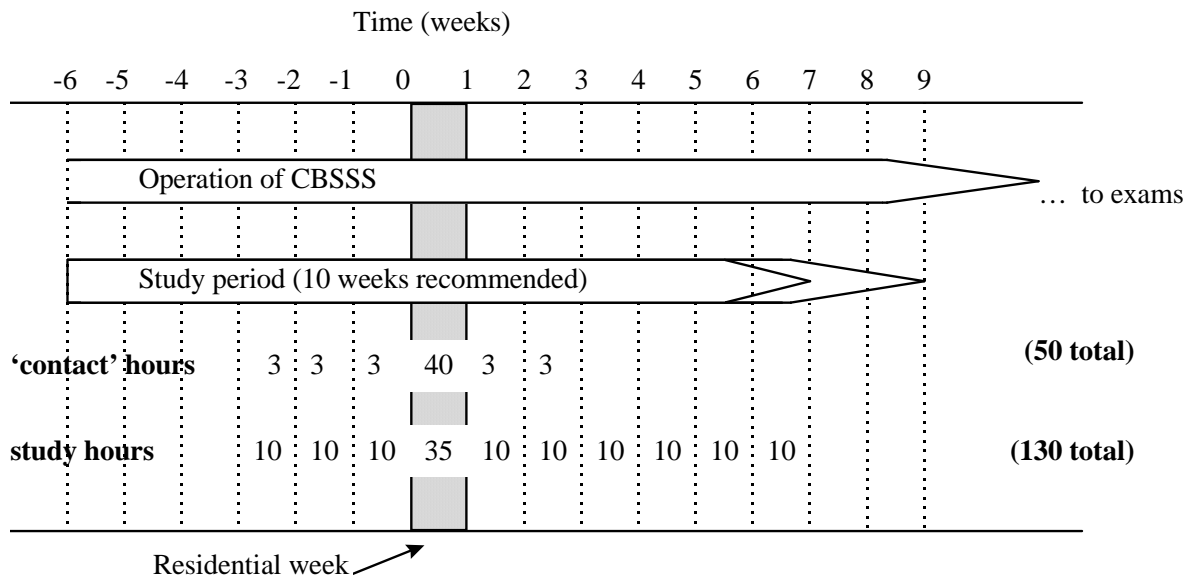


Figure 1 Module delivery format



Figure 2 Screen dump of the MSc homepage