SOUE News

Issue 4 **Summer 2005**

Society of Oxford University Engineers

Welcome to the fourth issue of SOUE News

We first draw attention to the enclosed circular inviting you to the next Jenkin Meeting. The Jenkin Lecturer on 1 October will be John F Coates OBE, who was the naval architect behind the remarkable reconstruction of a Greek trireme, the 170-oared ramming warship of 2500 years ago. The Greeks optimised their design by trial and error over a century or so. John did not have that luxury — there was money to build ONE. Come and hear whether he got it right. And there is a dinner in Somerville the evening before.

In this issue, apart from the usual news items, we have articles by Alistair Borthwick on the unhappy state of the Yellow River in China, which most of the time barely makes it to the sea; Paul Newman on mobile robots which, like 18/19th century explorers, find their own way around and make a map while doing so; and Paul Taylor on John Wallis's 17th century design for building a flat roof out of timbers barely long enough to reach 30% of the way across (working out the forces had Wallis solving 25 simultaneous equations). The fourth-year project mentioned by Paul was reported on in the first issue of SOUE News.

Almost stop-press was the death of Ewan Corlett, widely acclaimed for his part in bringing Brunel's Great Britain back from a sandbank in the Falklands and in the restoration of this classic ship in Bristol, where all can see her. An interesting coincidence is that he and our Jenkin Lecturer overlapped at Queen's in the 1940s, and both went in for naval architecture.

We draw your attention to the note on the back page, asking for contributions to SOUE News from members outside the Department.

David Witt (Magdalen 1959), Simon Turner (Lincoln 1987)

In This Issue

Head of Department's Report to SOUE 2004 – 2005

Richard Darton

Introduction

Rodney Eatock Taylor demitted office as Head of Department on 30 June 2004, having been head for five very successful years from 1999. These years saw the Department obtain a top ranking in the 2001 Research Assessment Exercise, the retirement and recruitment of many staff, and the initiation of some exciting projects, many of which are ongoing. The Department is very grateful to Rodney for his leadership.

The next Research Assessment Exercise will cover the period 2001–2007 inclusive, and a survey of research activity in the summer of 2004 showed that we are in good shape. Annual research income to the Department from all sources is around £7 million, which supports a wide range of activity. Our top research rating is not only a huge reputational benefit to the Department, it also brings about £4 million of extra government funding annually — it is essential that we maintain or improve on the position. (Improvement is possible, since next time there will be a rating profile, rather than a single number.)

Teaching is the other major activity of the Department and in the summer of 2004 the Quality Assurance Agency published its Institutional Review Report on the University of Oxford. Engineering Science had been one of the five departments subject to detailed scrutiny, and received a highly satisfactory report. On the other hand, in the Guardian 2005 University Guide, although Oxford is rated best University overall, we are pipped to the top position in General Engineering by Cambridge, who score an extra point in the metric "job prospects". Members of SOUE might have a view on this!

Awards

At the 2004 SET event at the House of Commons, Dr Mark Kendall was named one of the country's top young researchers for his work on needle-free drug and vaccine delivery, and Moira Smith (JES), a final year student supervised by Dr Constantin Coussios, won a commendation. Sach Mukherjee, a third-year DPhil student supervised by Professor Stephen Roberts won the prestigious Fulbright AstraZeneca Fellowship for 2005–06 to work at the University of California, Berkeley on computational and statistical aspects of cancer systems biology. Michael Schwertner, a DPhil student working with Professor Tony Wilson won the Mathematics and Physical Sciences division prize for his work on adaptive optics. Dr Daniele Dini, a former research student and now post-doc in Solid Mechanics was awarded the IMechE bronze medal in tribology.

The Royal Academy of Engineering made Leadership Awards to four of our undergraduates, recognising their very high potential: James Hume (BAL), Anna Lea (WAD), Christopher Pritchard (ORL) and Matthew Scott (TRI). Mark Hunter (PBK) was a finalist in the Higher Education Academy — Engineering Subject Centre Student Awards 2004–2005, having written an essay addressing the question "What makes the best learning experience for an engineering student?".

Nor have marks of distinction been restricted to youth: Professor Eatock Taylor was made 28th Georg Weinblum Memorial Lecturer in recognition of his many outstanding contributions to the field of ship hydrodynamics; Professor Sir Mike Brady has won the Henry Dale prize of the Royal Institution for his outstanding work; Professor Richard Darton was awarded the Institution of Chemical Engineers' Council Medal. Professor Lionel Tarassenko and his research group and e-San, an associated spin-out company, won an E-Health Innovation Award 2005 for their mobile phone technology for monitoring diabetes.

In the Recognition of Distinction Exercise 2003–4 the title of Professor was conferred on Dr Peter Ireland, Dr David Nowell and Dr Steve Roberts, and the title of Reader was conferred on Dr Steve Duncan, Dr Alex Korsunsky and Dr Martin Williams.

Academic Staff Movements

Two new lecturers in mechanical engineering were appointed: Dr Tom Povey, and Dr John Huber; a Departmental Lecturership in Chemical Engineering was filled by Dr Peter Martin. An election was made to a new Chair in Materials Engineering: Professor Alan Cocks, currently head of Engineering at the University of Leicester, who will take up his post in January 2006.

One retirement took place during the year, of Terry Jones, who had been Donald Schultz Professor of Turbomachinery since 1988, and a member of the Department since 1960.

Other news

Dr Paul Newman, Departmental Lecturer, was one of the presenters of the IEE Faraday Lecture *"Control Freaks? — how robots affect our world"* which was delivered and simultaneously webcast in February 2005.

The Oxford Centre for Tissue Engineering and Bioprocessing was initiated, under the leadership of Professor Zhanfeng Cui. Professor Cui spent part of 2004/5 at the University of Minnesota, where he was 2002 J S Braun/Braun Intertec Visiting Professor.

The Royal Society published a memoir (Biogr Mems Fell Roy Soc Lond **50** 47–59 2004) of Sir Derman Christopherson FRS who died in 2000. He took a first in engineering at Oxford in 1941 and later obtained a DPhil, having worked as an assistant to Sir Richard Southwell on relaxation methods.

Development and fund-raising

In December 2004 Lord Sainsbury opened the new Information Engineering Building (IEB), fronting on Banbury Road (see SOUE News Issue 3 for picture and description). This £12.7 million project, completed on time, now provides accommodation for around 100 staff and students. It is an architectural link between several previously separate buildings on the Keble Road Triangle, and a magnificent extension to the complex of buildings on this site. That opening ceremony can be regarded as marking the first step in our current development campaign. The IEB was made possible by a substantial award from the Government's Science Research Infrastructure Fund, and also a generous benefaction (£1.5 million) from the Wolfson Foundation for the Wolfson Medical Vision Laboratory. The balance (£1.7 million) was provided by the Department's share of money accruing to the University from the spin-out of two very successful companies, Powderject and Mirada Solutions. These were founded by Professor Brian Bellhouse, and Professor Sir Mike Brady.

The Bellhouse Foundation has made two significant gifts to the Department, to enable us to expand teaching and research in biomedical engineering. As a result, Dr Fred Cornhill, Director of the Institute of Biomedical Engineering (IBME), has now been joined by a full-time fund-raiser (Ms Molly Dixon), who is working jointly for us and for the Department of Clinical Pharmacology. Further developments enabled by these gifts will be announced soon.

Our two immediate fund-raising goals are, first, to raise some £25 million for the IBME project, which includes around £16 million for the building and fit-out, and some £9 million for posts. The IBME will be located at the medical campus in Headington.

Our other major priority is to raise funds for graduate scholarships. It remains a sad fact that every year, very able students who would benefit greatly from post-graduate training here, and whom we are keen to accept, fail to obtain funding from the scarce and fickle sources available to graduates, and must abandon their plans to study at Oxford. Once again, substantial sums are necessary if we are to find a long-term solution to this problem.

Our Advisory Board (Gordon Campbell, Professor Will Stewart, Professor Sir John Taylor, Dr John Forrest and Phil Ruffles) has been encouraging us to develop a plan for our long-term future, and to adopt coherent policies to realise it. Fund-raising is a key to this. Our experience with the IBME has shown that we cannot simply wait for Government or University to divert scarce resources to us — we have to be more pro-active at fund-raising ourselves. In

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Head of Department's Report to SOUE 2004 – 2005 cont.

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this regard I am very pleased to be able to report a recent bequest to Engineering Science of £200,000 — from a history graduate! Over the next few years we will be developing our plan, and enlisting the support of our friends and alumni in helping us to realise it.

Is the Lower Yellow River Sustainable?

Alistair Borthwick

For almost ten years, the Department of Engineering Science has undertaken collaborative research with the Institute of Environmental Engineering, Peking University, and the Yellow River Conservancy Commission, China, on the sustainable management of water resources in the Lower Yellow River. By interpreting hydrological data, we have found that the Lower Yellow River is unable to meet its primary requirements for sustainability.

Figure 1: The Lower Yellow River downstream of Sanmenxia to the Bohai Sea

The Yellow River is over 5000 km long, and flows from the Qinghai-Tibetan Plateau to Bohai Bay (Figure 1). Its catchment area occupies the arid and semi-arid North China Plain, which is composed of land recovered from an earlier epicontinental basin that became filled with sediment. Until dykes and levees were constructed, the river was free to find its way to the sea, and often migrated, leading to an enormous alluvial area along China's eastern seaboard. The annual runoff in the Yellow River has a mean volume of about 58 billion m^3, and varies from 14 to 86 billion m^3. The river transports a mean annual load of about 1.6 billion tons of fine yellow sediment that originates mainly from the Loess Plateau (Figure 2) in Shanxi and Shaanxi Provinces. The Loess Plateau has a total area of 640,000 km^2, of which more than 70% is eroding. Geological uplift driven by neo-tectonic movement is promoting extensive gravitational erosion, partly by rockfalls and landslides. Further man-made erosion is occurring as an indirect consequence of regional development. As a result, the tributaries feeding the Middle Yellow River contain hyper-concentrated levels of suspended sediment. Downstream of Sanmenxia, the sediment-laden Lower Yellow River meanders eastwards past the major cities of Zhengzhou and Kaifeng, through Shandong Province, until reaching the Bohai Sea.

Due to the river slowing and depositing sediment, the bed of the Lower Yellow River has risen to a level that is about 5 m on average higher than that of the land outside its dykes. This phenomenon is often referred to as the "hanging river". At Kaifeng and Xinxiang, the riverbed is respectively 13 and 20 m higher than street level. Worse still, as the breadth of the Lower Yellow river converges from 24 km to 0.3 km so does its local flow capacity, which

Figure 2: Loess region: Middle Yellow River

falls from 22,000 m^3/s to 11,000 m^3/s in its lower reaches. Over the centuries, the Lower Yellow River has gained an awesome reputation for disastrous floods and for changing course. Extensive flood control works have been constructed, protecting an area of about 120,000 km^2. Even so, more than 50 major floods, 1500 dyke breaks, and 20 changes of course have been recorded in a period of about 2500 years. In one flood in 1642, more than three hundred thousand people died at Kaifeng. Analysis of the historical data has shown that the river breaches can be classified as follows: dyke overtopping; scour caused by the river main channel being directed against the dyke walls; dyke collapse due to piping, seepage and leakage; ice-jam breaches affected by freezing and thawing of the river water; and man-made breaches (such as in 1938 when the dyke at Huayuankou was destroyed and 890,000 people perished, in an attempt to prevent Japanese occupation). After the founding of the People's Republic of China in 1949, all the dykes of the Lower Yellow River have been strengthened and had their crest elevations raised a total of four times. Even so, although the dykes are reasonably safe against overtopping and ice-jam breaching, they require further renovation to prevent scour or collapse-induced breaches.

Over the past few decades, the Lower Yellow River has begun to lose its vitality. Runoff into the river has decreased due to water storage and sedimentation of upstream reservoirs, changes in land-use, and warming of the central Asian climate. There may also be a contributory effect from a combination of uplift of the Qinghai-Tibetan Plateau and a lowering of the water table. Meanwhile agricultural, domestic and industrial water consumption has more than doubled, in step with socio-

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Is the Lower Yellow River Sustainable? cont.

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economic development. The river flow has reduced so much that no-flow and nearly no-flow events occur frequently. To date, the worst year for no-flow events was 1997, during which no water flowed into the sea for 330 days. That year, the maximum no-flow river length was 700 km, almost equal to the entire length of the Lower Yellow River. Low flows cause water shortages, and increase sedimentation, thus raising the riverbed level and bringing about an increased risk of flooding. The rapidly changing behaviour of the river makes it impossible to use past hydrological data to predict flood discharges sensibly. For example, a flood event that ten years ago had a one-in-a-hundred-year return period may now have a one-in-two-year likelihood of occurrence. High levels of effluent discharge into the Lower Yellow River combined with its reduced flow discharge have caused the water quality to deteriorate, and the eco-system to degrade. Desertification is taking place near the river mouth, where the exposed bed has become arid and wind-driven erosion is starting to occur. The coastal zone has also been severely affected, to the extent that previously offshore oilfields are now located inland.

Water resources management and flood control of the Yellow River are the responsibility of the Yellow River Conservancy Commission, which in turn reports to the Ministry of Water Resources and thence to the Central Government of China. After 1949 a flood control system was established with dams storing water in the upstream reaches and more than 1000 km of dykes reinforced along the lower reaches. Soil and water conservation measures were implemented, including the construction of 112,000 warping dams (to trap sediment) and more than four million water retaining structures. This brought about a decrease of about 300 million tons per annum of sediment entering the river. Recently, the Ministry of Water Resources altered the management framework from one of water conservancy to one of sustainability. Wang Shucheng, Minister of Water Resources stated the following four objectives for the Lower Yellow River: (1) the dykes should not be breached; (2) the river should not experience zero flows; (3) water quality should meet the required standard; and (4) the riverbed should not rise further. As a result, the Yellow River Conservancy Commission is presently developing a long-term strategy for the sustainable management of the Yellow River, supported by scientific, engineering, socio-economic, legal, and political inputs. A unified approach is being taken to water resource management, allowing for the fact that the river passes through several provinces. Countermeasures such as variable water pricing, restrictions on water consumption, engineering works such as the flood control and sediment flushing system at Xiaolangdi reservoir, dyke strengthening, additional sediment check dams, river training works, and flood warning systems are being implemented in the context of a sustainable water management system for the Lower Yellow River. But are these sufficient? In China, a huge effort has been directed towards understanding and mitigating the problems of the Yellow River. People have begun to debate whether the no-flow phenomenon is a sign that the river is unsustainable, or even dying. The Yellow River Conservancy Commission estimates that by 2010, the total water consumption may reach 52 billion m^3 per annum, leading to a shortfall of more than 10 billion m^3, given 42 billion m^3 available for supply in a moderately dry year. With this in mind, the Yellow River Conservancy Commission has developed a three-pronged approach to managing the Yellow River, where the prongs are the river itself, a digital model, and physical model studies of the Loess Plateau, Xiaolangdi and Sanmenxia reservoirs, main channel and estuary.

Joint research is being carried out between the Institute of Environmental Engineering at Peking University, the Yellow River Conservancy Commission, and the Department of Engineering Science at Oxford University to assess the overall sustainability of the Lower Yellow River. To this end, we propose the following diagnostic tools: the concepts of minimum water demand for river sustainability (i.e. the minimum flow rate needed for the river ecosystem to flourish), functional no-flow events (flows that are too weak to sustain the ecosystem), river resource functions (that classify the flow into functional headings such as water available to the ecosystem, water required for socio-economic purposes, and excess flood water), and an integrated river health index. These tools have been applied to the Lower Yellow River using flow discharge data from four hydrological stations. In particular, the integrated river health index attempts to take account of the major factors that affect the condition of the river, including the annual functional no-flow river length (a parameter that reflects the relative severity of no-flow events), annual sediment carrying capacity, water available for the ecosystem, and water demand for socio-economic purposes. Interpreting the data, we found that, on average, ever since 1990 the minimum water demand for river sustainability has not been satisfied along at least half of the Lower Yellow River.

Figure 3 gives a plot of the number of functional no-flow days per annum recorded in four reaches of the Lower Yellow River in the years from 1964 to 2001. There is a noticeable upward trend in the number after 1985, particularly for the Aishan-Lijin reach closest to the mouth of the Yellow River. It appears there is a possibility that the Yellow river could become permanently disconnected from the sea. By converting river discharges into river resource functions, we find that the river was no longer capable of supporting further regional development after the 1980s and as a consequence the condition of its ecosystem had weakened significantly. By 1990, the water demand essential for the river ecosystem could not be satisfied even if the water resources were distributed evenly during the whole year and there was no water loss due to floods. However, extreme flood events have

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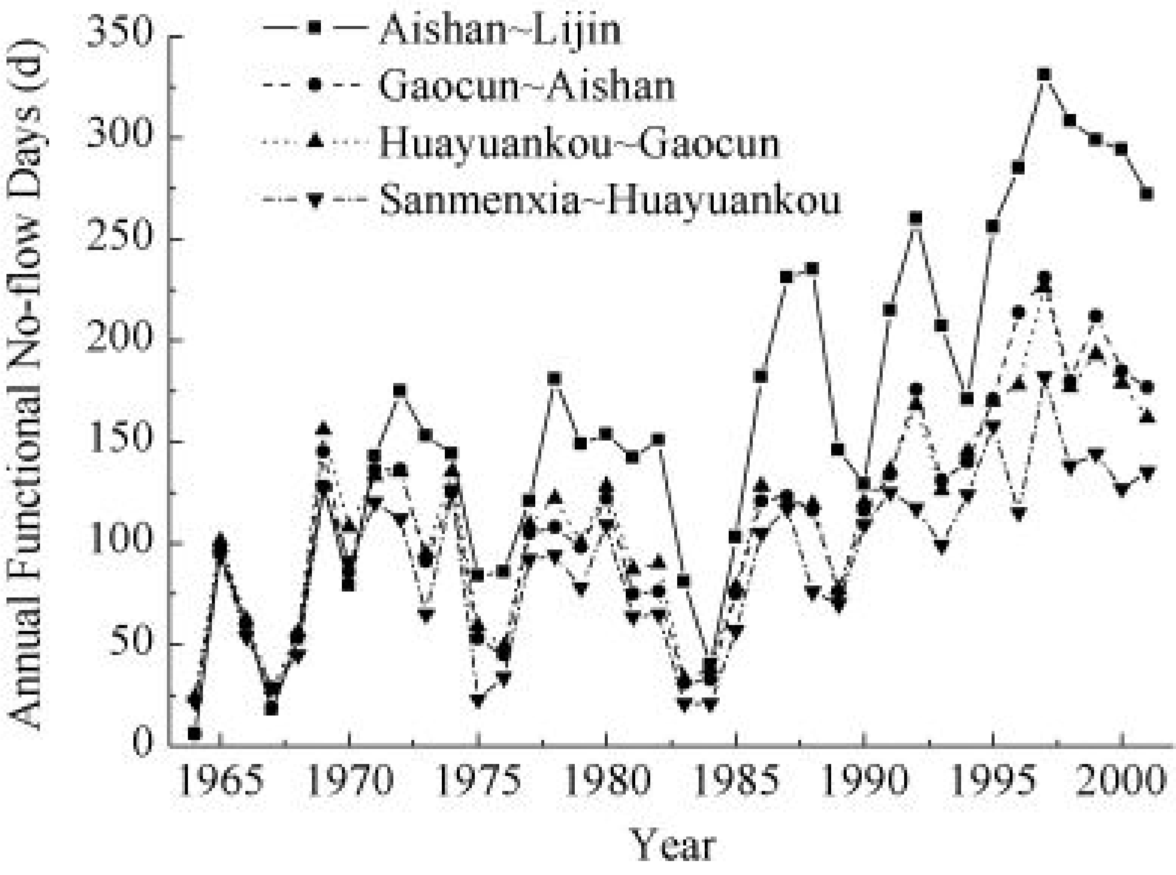

Figure 3: Annual functional no-flow days: 1964–2001

Is the Lower Yellow River Sustainable? cont.

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continued unabated, even though runoff has sharply decreased, indicating that the normal river functions have been severely impaired. Figure 4 shows the behaviour of the river health index in the period from 1964 to 2001. For the river to be sustainable, the index must have a value of at least unity. It is obvious that the condition of the Lower Yellow River has declined drastically since the 1960s. After 1970, the river health index is generally below 0.5, and only sporadically reaches the 1950s standard. After 1990, the river system is in a dreadful condition. The lowest point occurs in 1997, when runoff was the lowest recorded, no-flow events were most prevalent, water shortage caused large economic losses, and the ecosystem suffered great damage. In 2001, the upstream dam at Xiaolangdi became operational, and considerably improved the water and sediment conditions in the Lower Yellow River. However, although no zero-discharge events have occurred after 1999, the evidence from Figure 4 is that the river health index has remained at a very low level since then. It appears that the Lower Yellow River's ability to meet its eco-system and socio-economic requirements is exhausted.

In conclusion, our results confirm that the Lower Yellow River is not sustainable at the level it had in the 1950s, and has declined to the point that it is unable to meet any of its primary functional requirements even after the implementation of recent countermeasures.

In the future, it may be possible to store water in Dongpinghu Lake (to the south of the Lower Yellow River) for release in times of drought. Additional water could be supplied from the western route of the South-to-North Water Transfer Project. Groundwater may also be abstracted in dry years, provided it is replenished in wet years. By changing agricultural practice, the demand for irrigation water could be reduced. Selective discharges from proposed upstream reservoirs at Qikou, Gu'xun, and either Dalishu or Xiaoguanyin could control the ratio of water to sediment in the river and so help prevent sedimentation. By means of flow diversion, it may also be possible to scour the riverbed near the estuary. Further levees and warping dams may be constructed to counteract the sediment supply from the Loess Plateau. To this end China's Ministry of Water Resources has proposed the construction of 60,000 warping dams by 2010, a monumental task. Finally, to improve water quality, limits must be placed on the total effluent discharge into the river from each province, backed up by proper monitoring and effective legal measures. Further research will be undertaken to ascertain whether these are likely to achieve their aim.

The author would like to thank Professor Jinren Ni of Peking University and Professor Guoying Li of the Yellow River Conservancy Commission for their input with regard to this article.

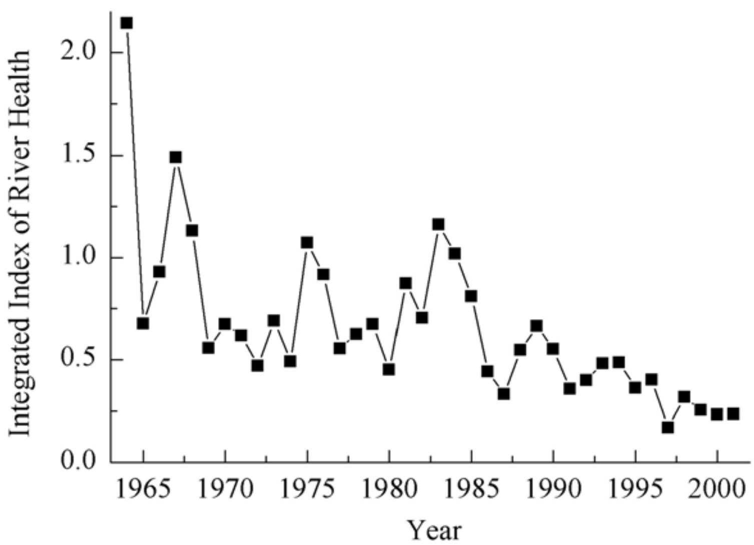

Figure 4: Integrated River Health Index for the Lower Yellow River since 1964

The 17th Jenkin Lecture, 23 October 2004: Bubbles

Dr David Kenning — report by David Witt

Almost the first point in David's lecture was that there were really two quite different sorts of bubbles. To the layman, the image first suggested by the word may be the spherical object floating in the air above the sink when someone has been having fun and games with the detergent. Such a bubble is of course a quantity of air enclosed within a much larger volume of air by a thin film of liquid. For it to be stable, the liquid has to be a mixture, e.g. of water and soap or detergent. The principal engineering significance of such bubbles is when they congregate in large numbers to make "foams".

The other sort of bubble is a quantity of gas or vapour inside a larger volume of liquid, as seen for example when the top is taken off a lemonade bottle, or in a boiling kettle. It was the particular role of bubbles in the boiling process that had been the subject of David's research for many years, and it was two aspects of this that formed the main topics of his lecture:

1. better methods for cooling electronic equipment;
2. the role of micro-bubbles in steam explosions in nuclear reactors.

But first we were given a short exposition of the "physics of bubbles". The balance of forces across the surface of a bubble is such that it is in equilibrium when the surface tension of the liquid balances the pressure difference between the vapour inside and the liquid outside. In "nucleate boiling", the most commonly occurring form, bubbles of vapour form on the heated surface, preferentially at small cavities. Vaporisation occurs mainly on the "triple contact line", where the vapour-liquid interface meets the heated solid surface. If the surface is easily "wetted" by the liquid, the bubbles tend to leave when they are quite small. On a poorly wetted surface, which "prefers to be dry", the bubbles cling on until they are much bigger, and the surface under them may overheat.

Electronic equipment dissipates heat, which has to be got rid of. In modern equipment the heat dissipation per unit area is getting rather large, whether in high-power semiconductors (diodes, gate-turn-off thyristors etc.), or in the central processors of computers as they get faster and faster. It is a question of removing heat continuously from a very intense source, and disposing of it to a diffuse sink, usually the atmosphere. So far, the heat has usually been removed by air convection, either natural or forced with a fan, but this technology is approaching its limits. And for some applications, the power required to drive the fan, or the noise it makes, are major drawbacks. David threw out a target of 2 MW/m^2 (or 2 W/mm^2)[1] for rate of heat removal from a semiconductor at 125°C, and started to investigate whether it might be got with boiling heat transfer.

"Heat pipes" are an existing form of this technology, currently used in lap-top computers. The liquid in the pipe is evaporated at one end and condensed at the other, then returns by capillary action via a wick on the wall of the duct.

But it is possible to do without the wick, which is a rather slow way of moving liquid. The geometry first considered was a rectangular channel of cross-section 1 mm x 2 mm, heated at one end and cooled at the other. Bubbles of steam, separated by "slugs" of water, move in one direction, and water gets back again by flowing past the bubbles in a thin film on the walls. With a heat flux of 2 MW/m^2, it is fairly easy to calculate that the depth of the water film in the heated section will be decreased by evaporation at a rate of about 0.8 mm/s, if not topped up in some way. But it was predicted that the film under the bubbles would only be about 7 μm thick at the most anyway, so if not "topped up" would disappear completely in about 9 ms. So things have to happen quite fast. There will be very rapid accelerations and high transient pressure fluctuations.

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[1] Around an order of magnitude more than one gets in an electric kettle

The 17th Jenkin Lecture, 23 October 2004: Bubbles cont.

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The process is not yet well understood, and there are many design variables to be selected, so a combination of computer modelling and experimentation is under way in many places, sometimes with channels much smaller than the 1 mm x 2 mm just considered. The results of computer modelling do not yet match experiment as well as could be hoped, so the models are clearly in need of improvement. But the target of 2 MW/m^2 looks as if it may be achievable.

David then went on to consider his number two topic: what happens when one very hot liquid suddenly mixes with another cold, volatile, liquid. This can occur under extreme fault conditions in a nuclear reactor (and did at Chernobyl). Less serious incidents can happen in a chip pan, and more serious ones in volcanoes, such as Krakatoa in 1883[2].

Consider the case of very hot molten metal falling into water. If the metal stays in fairly large drops, say 10 mm or so in diameter, then the heat transfer is by "film boiling", in which an unbroken vapour layer forms around the drop. Heat transfer across this layer is quite slow, and thermal equilibrium will be reached in a reasonably "controlled" manner. But if some disturbance breaks up this film, the boiling rate increases dramatically. The resulting pressure pulse can break up the drop into numerous smaller drops, thus greatly increasing the surface area and boiling rate. If the disturbance then breaks up neighbouring drops in a chain reaction, then there can be a "steam explosion".

In an experiment with a hot sphere in water at 100°C, it was found that film boiling occurred if the sphere was hotter than 300°C, and nucleate boiling (the faster version) if it was cooler than 150°C. In between was transitional. So most of the heat in very hot metal would come out fairly slowly. But if the bulk temperature of the water was lower, e.g. 50–70°C, then a different phenomenon appeared, "micro-bubble boiling". Small bubbles appeared on the surface of the hot sphere, but did not coalesce. Instead they floated away and condensed in the surrounding water, thus giving rapid heat transfer, even from very hot metal.

The lecture concluded with a brief look at some medical and biological applications of bubbles. One of these, "lithotripsy", the fracturing of kidney stones with collapsing bubbles generated by focussed ultrasound, is already in use. Other applications are perhaps around the corner.

David Kenning spent 40 years (1963–2003) on the academic staff of the department, most of them also as engineering tutor at Lincoln. He is continuing active research in his retirement, at Brunel University.

The Jenkin Lecture (and the Society's AGM) were preceded by two half-hour talks given by relatively recent graduates, both of the 1995–9 vintage and both from St Catherine's.

Claire Edwards (née Lewis) went to work at a Corus steelworks in South Wales after graduating, until recently, when she moved to pharmaceuticals at Glaxo-SmithKline in Kent ("from one production line to another" as she put it). In "Developing the Engineer" she talked of her experiences, and of the need to keep learning, and not just about technical matters! She made the point that people at all technical and professional levels were necessary for the successful functioning of any industrial activity, and expressed the view that to create artificial distinctions between different levels was misguided. Engineering Institutions please note! (Universities too perhaps?)

Gemma Long has recently been training as a patent attorney (like a rather surprising number of our graduates over the years), and spoke about "The Law of Invention", with which she is rapidly becoming acquainted. How inventive

[2] It is thought that sea-water got into the magma chamber. Six cubic *miles* of island were blown away, and the explosion was heard 2000 miles away in Perth, Australia

does an invention have to be? And who is the "skilled man", to whom a new idea may, or may not, be immediately obvious? She followed up this look at the law by entertaining us with an account of some remarkably curious inventions that have been patented, or at least offered for that purpose, over the decades.

Personalia

Rod Eddington (Lincoln) was given a knighthood in the Queen's Birthday Honours in June, for "services to civil aviation". He has been Chief Executive of British Airways since 2000, following some years with Cathay Pacific Airways. He came from Australia to do a DPhil here with David Kenning in the late 1970s. He has announced his intention of leaving British Airways soon. In view of recent events, he is probably looking forward to it!

George Whitby (Wadham 1931–4) died on 16 April 2005, aged 92. He spent most of his career with ICI, apart from a secondment to the Ministry of Munitions during World War Two. One of his early contributions at ICI was as engineering manager for the construction of plants to make the polyester fibre Terylene. The first plant was built on Tees-side in 1951–4, but several others followed to satisfy the rapidly growing demand. They were built both here and in the US, the latter in cooperation with American Celanese.

He was made chairman of ICI Fibres Division in 1961, and by 1963 was on the main board. In the early 70s, before his retirement in 1974, he directed a substantial expansion of ICI in North America. For ten years after retirement he worked as a consultant.

His wartime work for the Ministry of Munitions was initially on the development and production of an effective new anti-tank shell, which came into use after D-Day, and then on the study of intelligence reports about the V2 rockets then being developed in Germany. For his war work he was awarded an OBE, and in 1982 he was elected Fellow of the Royal Academy of Engineering.

[based on the Times obituary of 23 May 2005]

Martins Scholarship at Pembroke

As announced in our last issue, Paul Martins (Pembroke 1972–5), who gave the Jenkin Lecture in 2003, died tragically in a swimming accident while on holiday with his family in Devon in August 2004.

Paul had worked for BP since 1982, and in 1992 he received the Royal Academy of Engineering's MacRobert Award for outstanding engineering achievement. This was for his work on increasing the productivity of oil and gas wells by "hydraulic fracturing", thereby greatly reducing the number of wells needed to tap a particular field. At the time of his death he was "Head of Discipline for Wells and Completions".

BP has now endowed an engineering scholarship in his memory at Pembroke, which will be worth £4500 to whoever performs best in each year's Part 1 examination.

Mrs Charlotte Martins told Pembroke that Paul had very positive memories of his time there, and it had been an ambition of his to do something for Pembroke engineers, so the BP-endowed scholarship would have given him particular pleasure.

We foresee some intense competition for it among Pembroke third-years!

John Wallis and the Roof of the Sheldonian Theatre — Structural Engineering in Oxford in the 17th Century

Paul H Taylor
[Originally published in a Keble journal]

John Wallis was the Savilian Professor of Geometry in Oxford for just over 50 years around the second half of the 17th century. He was a most remarkable figure — probably the leading English mathematician of that era apart from Newton. His appointment to the Savilian Chair may have come about as a reward for deciphering intercepted Royalist dispatches during the Civil War. After the Restoration this work apparently continued. His Royal Society biography describes him as "decipherer to William III", making him an early predecessor of GCHQ. Like his modern day counterparts, he also complained about his role becoming widely known — governmental leaks were a problem then as now!

Whatever the reason for his arrival in Oxford, Wallis became a leading mathematician and corresponded with scholars throughout Europe including Fermat, most famous for his Last Theorem only proved in 1995. Wallis worked extensively in geometry and calculus, publicising both his own work and also that of others including Pell and Newton, each notoriously reluctant to publish anything. In much of his mathematical work, one can detect his interest in patterns of both symbols and numbers — with echoes of his skill as a decipherer. This interest in patterns is obvious in his single foray into structural engineering.

Wallis tackled a practical problem — how to provide a flat structure such as a roof to span a large square open space, using only wooden beams much shorter than the required span and only supported around the edges. He devised a repeating pattern of short but interlocking beams, which could be extended to span any sized space. Each beam within the body of the pattern is supported at its ends by other beams, and provides end supports for two other beams. All these internal beams are identical. The whole pattern is only supported around the periphery. The edge beams are shorter and each rest on an external support only at their outside end. Individually, these edge beams are also supported by the internal array at their inner ends. They themselves support the array at their centres. Overall, this is a clever but somewhat confusing arrangement of short interleaved structural elements, making up a repeating pattern. A 1 m square model of the pattern of beams is shown below.

To the modern engineer, what is perhaps most remarkable about Wallis's structure is that it requires no glue or screws at the joints — in modern engineering parlance, only simple vertical forces are transmitted at the contact points between the beams. The structurally awkward problem of transmitting bending and twisting moments through connections is eliminated by clever design. Wallis worked out the mathematics of how such a structure carries load — what a modern engineer would recognise as structural analysis. This required the solution of a set of 25x25 simultaneous equations with a repeating pattern, the mathematics reflecting the geometry of the array. These he solved exactly by hand, an impressive achievement as the forces transmitted from each beam to the next involve ratios such as 3088694/340167. This was as far as Wallis got with his structural analysis. However, these results are essential for deciding what cross-section would be required for each beam. Given the technical knowledge of the middle 17th century, could Wallis have estimated the required size of each beam for a given structural load?

In 1638 Galileo presented a discussion of the length of a cantilever beam able to support its own weight. This combined the theory of structures with the strength of materials, a combination still reflected in engineering teaching today. Although not correct in the details, Galileo's results reflect enough of the actual physics to allow the use of scale-models to correctly size the beams in a practical application of Wallis's design. So, Wallis could have sized his beams for an actual building. Could he also have solved the more difficult problem of predicting the deflection of his structure under load? The answer this time is no. This requires the linear elastic theory of beam bending — a problem not solved until many years after Wallis's time.

There is an intriguing further connection between Wallis as the Savilian Professor, his structural design and the visitors' Oxford of today. Christopher Wren came to Oxford as a student in 1649, the same year as Wallis was appointed Savilian Professor, so presumably Wallis taught him. Certainly they knew each other and were both members of the group whose meetings triggered the foundation of the Royal Society. Wren is most famous as an architect but he was also a distinguished mathematician. Perhaps, even more than Wallis, he should also be regarded as a structural engineer, as is clear from his ingenious design for the magnificent dome of St. Paul's Cathedral. One of his more modest achievements was the design of the Sheldonian Theatre. Here he aimed for a flat ceiling without any internal supporting columns. Such columns would have interfered with the use of the building as a venue for dancing!

There is documentary evidence in Wren's family papers that he had seen and admired Wallis's design and that he seriously considered it for the roof of the Sheldonian Theatre. Unfortunately, it was never actually built: Wren designed a type of composite roof truss that was used instead, although there is perhaps an echo of Wallis's overlapping beams in some of the lead work in the windows.

At this point, I should perhaps explain the origin of my interest in John Wallis. Robin Wilson, a colleague of mine at Keble, has recently co-authored a book on the history of mathematics in Oxford[1] which contains a drawing of Wallis's design. It struck me that a structural analysis of the design using modern methods would make an interesting and unusual final year undergraduate project. This project also involved constructing probably only the third model of Wallis's structure ever made. Wallis himself instructed carpenters to make two small models, the second one he presented to King Charles II, "who was well pleased with it".

Structural analysis of Wallis's structure highlights some interesting subtleties in the way it carries loads. With the simple joints between the beams only transmitting vertical forces, there is a smooth distribution of supporting reactions around the periphery. In contrast, had the beams been rigidly connected to transmit bending and torsion moments as well, the distribution of edge reactions would be quite different, with the largest edge reaction being almost doubled and the edge force for the beam closest to the each corner being inverted. This somewhat counter-intuitive behaviour is related to significant torsion or twisting of the beams, which only occurs with rigid connections at the internal joints. For a given load, Wallis's structure will deflect more than an orthodox rigidly connected array of beams — known as a grillage to modern engineers. However, the smooth distribution of edge reactions would be much easier to provide on the top of brick or stone walls — with advantages for the design of the rest of the structure. Perhaps, his design is cleverer than even Wallis realised, and Wren did miss an opportunity with the roof structure of the Sheldonian Theatre.

In conclusion, modern engineers can greatly admire the work of the famous Oxford mathematician John Wallis. He produced a beautiful and sophisticated structural design, with engineering calculations, approximately 250 years before the University recognised engineering as an academic discipline.

[1] *Oxford Figures: 800 Years of the Mathematical Sciences*. Edited by John Fauvel, Raymond Flood, and Robin Wilson. Oxford University Press, Oxford, 2000.

Research in Mobile Robotics

Paul Newman and the Oxford Mobile Robotics Research Group

I research robotics. What do you imagine that means? Do I spend time attending a babbling, annoying, shiny-gold humanoid? No, that is the stuff of science fiction. Perhaps I'm concerned with a "River Dance" troop of robot arms as they perform their synchronised assembly of a car? No, this is a well-understood area — witnessed by industrial adoption of the technology. In fact I'm concerned with a problem for which the robot mechanism (body) is largely irrelevant. The problem on which I work is equally central to the future of robots operating on Mars, the ocean floor, in nuclear facilities, in your living room, down mines and inside B&Q warehouses. The problem is this: how does a mobile robot know where it is?

Having a machine answer "where am I?" is an information engineering problem that has been at the heart of mobile robotics research for over two decades, and while fine progress has been made, we still do not possess the machines we thought were just "around the corner" in the early 1980s. We still hope to build autonomous mobile robots that operate in both "everyday" and exotic locations. We need robots to explore places we as humans can't reach or are unwilling to work in (and that includes economic as well as safety reasons). Not getting lost requires answering "where am I?" at all times. But how can robots do this without a map? Can they make one for themselves? — Yes, but as yet, not reliably.

But let's back up, why would they need to make a map in the first place? Why not use GPS or "tell" the machines in advance what the operating region looks like — i.e. give them the map? Well, for one thing GPS doesn't work sub-sea, underground, in buildings or on Mars and it is pretty flaky in built up areas so we can discount that. It is true that in some situations we could (and do) provide the vehicle with an *a priori* map often in the form of laser-reflective strips or beacons stuck at known locations around a factory, port or hospital. The problem is that it is not always possible, let alone

Figure 1: "Marge" — an all terrain autonomous vehicle with 2D and 3D laser scanners. Her partner, "Homer", is not shown. The cube near the front bumper is the 2D laser scanner used to build the basement map in Figure 2. The second cube is mounted on a "nodder" and allows the vehicle to scan its environment in 3D.

convenient or cheap, to install this infrastructure, and once installed it is inflexible and imposes unnatural constraints on the workspace. You don't want a pallet delivery system to fail simply because someone obscured a few patches on a wall. Imagine the increase in autonomy that would result from being able to place a machine in an *a priori* unknown environment and have it learn a map of its environment as it moves around. It could then use this map to answer the "where am I?" question — to localise. This is called the Simultaneous Localisation and Mapping (SLAM) problem and is stated as follows:

> "How can a mobile robot operate in an *a priori* unknown environment and use only onboard sensors to simultaneously build a map of its workspace and use it to navigate?"

The tricky part is that this is a chicken and egg problem: to build a map you need to know where you (the observer) are but at the same time you need a map to figure out where you are. The simplicity of the SLAM problem statement is beguiling. It is after all something that we humans, with varying degrees of success, do naturally — for example when

Figure 2: A SLAM-built map of the Information Engineering Building at Oxford. The small triangles on the grey trace mark the path of the robot around the building. The map is built from scratch and develops as the vehicle moves. The same map is used for navigation.

stepping out of a hotel foyer in a new city. Yet SLAM in particular is a topic that has challenged the robotics research community for over a decade.

There is a strong commercial incentive to use SLAM in sectors already well populated with mobile robotics. The number of service robots in commercial use is substantial and growing fast. They appear in a multitude of guises around the world — hospital courier systems, warehouse and port management, manufacturing and security to name but a few. The United Nations Economic Commission for Europe (UNECE) predicts expenditure on personal and service robotics will grow from $660m US in 2002 to over $5b US in 2005[1] (excluding military expenditure which is a vast sector in itself). However, almost without exception, and as I've already mentioned, present day service robots require costly and inconvenient installation procedures and are intolerant of changes in the workspace. SLAM offers a viable way to entirely circumvent these issues and further fuel the commercial exploitation and development of mobile robotics.

From an information engineering perspective the difficulties arise from two sources — uncertainty management and perception. Sensors are noisy and physical motion models are incomplete. The combination of uncertain

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[1] UNECE United Nations Economic Commission for Europe World Robotics Report 2003 http://www.unece.org/press/pr2003/03stat_p01e.pdf

Research in Mobile Robotics cont.

(Continued from page 15)

motion and uncertain sensing leads inevitably to uncertain maps. A key challenge is how to manage this pervasive uncertainty in a principled fashion and, most importantly, in real-time. There is then the issue of suitable perception for SLAM — what aspects of the robot's workspace should be sensed and used to build the map with which to localise? How should they be sensed and what is the interplay between sensing and map representation? These are some of the questions that the Mobile Robotics Research Group is trying to answer.

Figure 2 is a map of the Information Engineering Building basement at Oxford built using a SLAM algorithm. The vehicle started in the top right hand corner and drove around the building entering each room sequentially. (The path planning was done by a human in this case although we do have autonomous path planners/explorers.) A key point is that the size of the map grows with time, as can be seen by the video at the web address given below[2]. The basement contained piles of builder's rubble and sundry non-regular equipment all of which was mapped precisely. This map was built with a 2D laser scanner mounted on our robot "Marge" shown in Figure 1. We are now looking beyond 2D-only mapping to building full 3D maps using combinations of laser, camera and radar data. Figure 3 shows a rendering of a map built of part of the exterior of the Thom building. In our very latest work, "Marge" has mapped the whole Keble triangle.

So what are the open questions? If it is now possible to build these maps on-the-fly and have machines use them to navigate, then what is left to do? Well, there is a problem with robustness. The machines may work for an hour or so but then things tend to go horribly wrong. A particular problem is correct "loop-closing" — recognising that the vehicle has

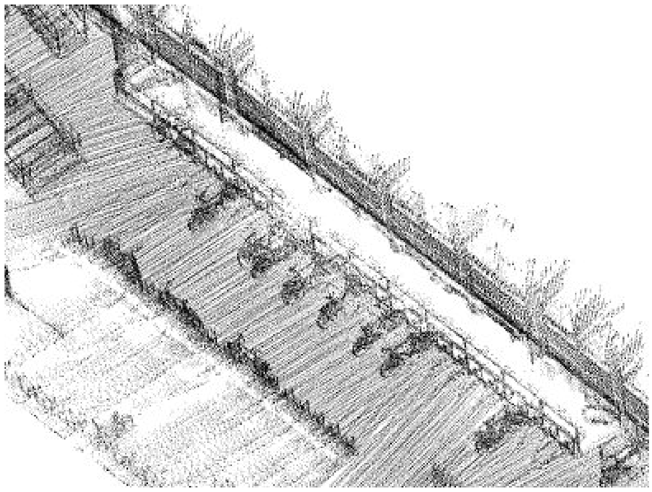


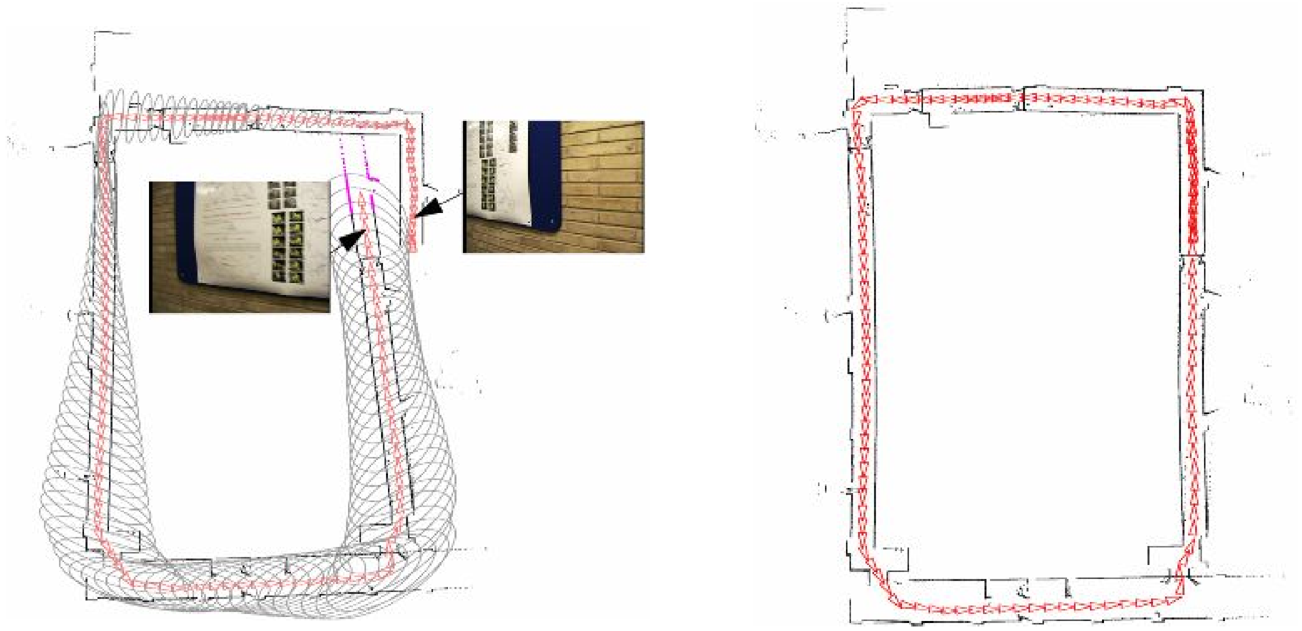
Figure 3: A section of a 3D SLAM map — the bicycle racks of the Thom building

returned to a previously visited (mapped) location.

Central to our approach is local scene saliency detection — finding what is interesting and "stands out" in a particular block of 3D laser data or what is remarkable about a given camera image. Intuitively, if we build a database consisting of "interesting" things and the times they were observed we could query the database with the current scene; if positive matches are returned then there is a good chance we have been here before. As always the devil is in the detail. It is unlikely that exactly the same place is revisited and so onboard sensors will present a different view of the same place the second time round. Now, we as humans are pretty clever at understanding multiple views of the same scene — it isn't so easy to endow a machine with the same ability.

In one approach we are combining sensed geometry, resulting from 2D and 3D laser scanners with texture and pattern information from cameras, to build a database of complex, high-dimensional scene descriptors. We use these rich descriptors to disambiguate the loop-closing problem. One can think of this as loop-closing by "recognising" a previously visited location because of how it looks, how it appears. This is in contrast to having the robot blindly believe an internal idea (estimate) of

[2] A video of the SLAM algorithm building the map above can be found at http://www.robots.ox.ac.uk/~pnewman/videos/IEB/IEBBasement.mpg



Figures 4a and b: The effect of using visual saliency in autonomous mapping. Two views of the same poster are detected and used to suggest a "loop closing event"

position and only entertaining the possibility of loop closure when this estimate coincides with a previously mapped area.

To illustrate, Figures 4a and b above show a map of a looping corridor about 100 m long. The left hand figure shows the map built using geometrical mapping alone — clearly it has missed the loop closure event. (The ellipses represent estimated three-sigma bounds on vehicle location.) The problem was caused by a small angular error while coming through some swing doors on the bottom right. The map on the right of the figure is produced when the algorithm is presented with sequential views from an onboard camera. Without prompting, it spots the similarity between two posters (interesting texture in the context of the rest of the wall). The fact that the images have vastly different time-stamps suggests the vehicle is revisiting an already mapped area. The validity of this tentative loop closure is checked and accepted by the SLAM algorithm, which then modifies the map and vehicle location to produce the crisp, correct map on the right. Importantly, and in contrast to the status quo in SLAM, the possibility of loop closure is deduced without reference to location or map estimates. Were this not so we would be using a potentially flawed map and position estimate to make decisions about data interpretation — hardly a robust approach!

Alas, there is not space to describe the other approaches we are taking to increase robustness in mobile robot navigation. Suffice it to say it is a fascinating area in which to be working and indeed one that has seen a resurgence of both research and industrial interest in the UK and internationally of late. High profile events like the Darpa Grand Challenge (in which autonomous machines are required to navigate the Mojave desert), Martian rovers, deep-sea rescue and oil surveying are never far away from the science press. But if these machines are really to fulfil their potential for improving our lives, scientific knowledge and operational reach, they can't get lost. They have to operate for weeks and months not hours and minutes. This is not simply a matter of better software, better hardware or better sensors. It comes down to smarter perception and smarter information engineering. That is what we are working on.

The 31st Lubbock Lecture, 13 May 2005: Less Incrementalism and More Breakthroughs

The 31st Maurice Lubbock Memorial Lecture was given on 13 May 2005 by Dr Robin Batterham FREng FIChemE, entitled:

"Less Incrementalism and More Breakthroughs — thoughts on avoiding the collision between sustainability and our response to climate change"

Dr Batterham is Chief Technologist of the mining company Rio Tinto Ltd, and also Chief Scientist to the Australian Government. He started by pointing out the rapid rate of recent progress in certain technologies, particularly those involving applications of electronics on the one hand, and the science of DNA on the other. He then went on to consider the world's likely future demand for energy. One estimate is that demand will virtually double from 2000 to 2030, but that nearly all of it will still come from fossil fuel sources: coal, oil and gas. Most of the increased consumption is expected to be in developing countries, which indeed will largely take over its supply.

Such an increase in fossil fuel consumption, if allowed to happen, would lead to unacceptable global warming and climate change, and it did not appear that the adoption of known technologies either for increasing the efficiency of energy use, or for non-fossil generation, were likely to do more than slow the rate at which climate deterioration would happen. Quoting from the *Economist* "those grand aspirations [of the Rio summit] have fallen flat in the decade since the summit. Little headway has been made with ... climate change or loss of biodiversity", Dr Batterham concluded that incremental improvements are not enough. Breakthroughs are needed.

As an example of a relevant breakthrough in his own industry, he described a new way of smelting iron ore, "HiSmelt Technology", which reduced the emission of CO_2 to 1 tonne per tonne of steel produced, compared with 1.9 to 3 tonnes using standard blast furnaces. Iron ore and coal in powdered form were injected into a hot (1200°C) blast of air. Droplets of molten iron were thrown on to the walls of the furnace, and ran down into a bath below.

Completely new ideas like this were called for, to get carbon emissions down rather than just rising a little less than they might otherwise do, and it was engineering science that would have to come up with them, and make them work.

The main lecture was preceded by two shorter talks by members of the Department on sustainability issues:

Guy Houlsby on *"Offshore Wind Power"*, and

Alistair Borthwick on *"Is the Lower Yellow River Sustainable?"* [See Alistair's article in this issue, which of course cannot include the remarkable film he showed of the river starting to flow again after a no-flow period: a cascade of rapidly-moving yellow water with the consistency of liquid concrete!]

Lubbock Day Project Exhibition 2005

The exhibition took a new turn this year, because Sharp Laboratories of Europe (based in Oxford Science Park) gave us an extra £1000 for prize money, of which £500 was to swell the general prize fund, and £500 was to be a prize for the best electronic exhibit. This offer came out of the blue when we invited Sunay Shah, a Keble engineer now working for Sharp, to be one of the judges, and it was most welcome. Probably as a result, we got more entries than ever before, and only just managed to fit them all into Lecture Room 3. Prizes were awarded as on the following page:

Hardware Section: Manish Pindoria and Nick Woolley, both of Pembroke, for their joint exhibit "Seeing with Sound", £200 between them.

Poster Section: Andrew Moxon, Keble, "High-frequency flow behaviour in a choked nozzle", and Moira Smith, Jesus, "Improving cancer treatment with ultrasound", £150 each.

Sharp £500 prize for the best electronic exhibit: Mike Coulson, Keble, "Hydro-acoustic positioning system".

Other prizes went to:

Ross Turnbull, Lincoln, "Inertial Navigation System"

Nicholas Cole, Lincoln, "Deployable Cylinders"

Mohamad Jamaluddin, Worcester, "Low-cost stereoscopic display system"

Simon Chadwick, Lincoln, "Robot controller"

Ga Lok Chung, Pembroke, "Analysis of bird behaviour from video sequences"

Murray Forsyth, Pembroke, "Environmental monitor buoy"

Annabel Jenkins, Somerville, "Wound closures"

Ben Whitaker, Worcester, "Lightweight robot arm"

Our thanks to the judges, who were:

David Currie, St John's 1994–8, now with IBM, Winchester

Richard Hartshorn, Somerville 1995–9, now with Goodwin Hartshorn, London

Elizabeth Padmos, St Anne's 1990–4, now with BP, Aberdeen

Sunay Shah, Keble 1994–8, now with Sharp, Oxford

and of course to Sharp Laboratories of Europe for their generous contribution to the prizes.

Another Successful Spin-off

Oxonica, a spin-off from the Engineering Science Department formed in August 1999, was floated on the AIM (Alternative Investment Market) in July. It was founded by Professor Peter Dobson and Dr Gareth Wakefield. The flotation follows its growth on the Begbroke Science Park and the development of two successful products that are generating revenues:

Envirox is a nanoparticle diesel fuel additive based on cerium oxide and it is being supplied to the Stagecoach bus fleet and is on sale at pumps in the Phillipines. This additive greatly reduces carbon particulates in the exhaust, reduces nitrous oxides and gives an increase in fuel efficiency of around 10%.

Optisol is a nanoparticle-doped titanium oxide product that is used in sunscreens. In addition to shielding the skin from harmful ultra-violet radiation it also protects the skin by eliminating the free radical production that is commonplace in most sunscreens. Boots are currently using this product in their Soltan range.

The company is extending its activities based on these products and also hopes to launch some new nanoparticle-based medical/biological diagnostic products shortly.

Ewan Corlett, 1923–2005

Ewan Corlett will be long remembered for his part in the rescue of Brunel's pioneer steamship, *The Great Britain*, from a sandbank in the Falklands, and her subsequent restoration at Bristol.

He read Engineering Science at Queen's, 1941–4, in the middle of World War Two, and then went to work for the Naval Construction Department of the Admiralty in Bath. After the war he did a PhD in naval architecture at Durham. From 1952 onwards he was with Burness, Corlett & Partners, Naval Architects and Marine Consultants, and was their Managing Director from 1955.

It was in 1967 that he wrote a letter to The Times pointing out that this historic ship, "the first iron built ocean-going steamship and the first such ship to be driven entirely by a propeller", was lying, an abandoned and broken hulk, on a sandbank in the Falkland Islands, and suggesting that she at least be surveyed, and if possible brought back and restored. The proposal attracted wide support, and after a trip to the Falklands in 1968 to survey her, the rescue was planned and funded. In 1970 the 3000-ton vessel was patched up, floated, loaded on to a pontoon, towed across the Atlantic and put into the very dock at Bristol where she had originally been built. Since then she has been substantially restored, and has become a major visitor attraction in Bristol. Corlett's book *The Iron Ship* (1975) tells the story both of *The Great Britain* herself, her construction and voyages, and of her dramatic rescue.

From 1974 Corlett was appointed a trustee of the National Maritime Museum at Greenwich. He was subsequently made OBE, a Fellow of the Royal Academy of Engineering, and given other honours.

In 1990 he attended the annual dinner of the SOUE, and made a memorable after-dinner speech, of which, as luck would have it, the transcript is in our files.

For those who did not hear it then we have re-printed it below.

He died in the Isle of Man, where his home was, in August this year.

Ewan Corlett's after-dinner speech at the 1990 SOUE Dinner:

> I think it was James Duport who said "whom God would destroy He first sends mad". When I first wrote to the Times suggesting that something should be done about THE GREAT BRITAIN — and got an overwhelming response — quite a few people, including I fear, my wife, thought I had gone mad. The ship was 8000 nautical miles away, virtually in the Antarctic, was a wreck and 123 years old at the time! Well that was 23 years ago and I am reassured. The ship has been restored and I am demonstrably here and undestroyed. Perhaps, then, I was not mad — but then who am I to say.
>
> Joking apart, though, for a serious modern engineer to contemplate such a thing must have raised, quite reasonably, some doubts as to judgement. It seems less strange today because rescuing old ships has become quite an "in" thing but really it was, and indeed is, only justifiable on very special grounds. Well the grounds were there. Isambard Kingdom Brunel C.E. was one of the most remarkable engineers that Britain or indeed the world has ever produced. His energy, vision and engineering genius must excite the admiration of any engineer — it certainly did mine. This was his ship and what a ship, the progenitor of all modern ships. So, between admiration for Brunel and a growing awareness of the sheer importance of this particular ship I plead grounds for a verdict of sanity and dismissal of the charge of madness.
>
> In Brunel's day all engineers were "civil", with the initials C.E. While today C.Eng. means something different, the wheel has in a way turned full circle as the term encompasses all qualified engineers as did C.E. in Brunel's time. That reminds me of a young acquaintance who had just achieved

the professional status of Chartered Engineer. His family were obviously very impressed, as that evening, when saying her prayers, his four year old daughter was heard to start the Lord's Prayer with "Our Father Chartered in Heaven"! I doubt that any of us would claim that degree of professional standing — but if any engineer could, I suspect that it would be friend Isambard! Actually, it's rather like the parson who heard his children burying their dead hamster in the garden, to the invocation "In the name of the Father and of the Son and into the hole he goes!"

Enough of such levity. Let me adopt a lofty attitude. Most engineering disciplines deal with mere machinery, bridge structures, aircraft, vehicles and so on. Naval architects deal with ships. Ships are different, they have personalities — sometimes very cussed ones — maybe that is why we refer to a ship as she. You can build two identical sister ships and one will be a bitch all her life, apparently justifying the aphorism that the goal of all inanimate objects is to resist man and ultimately defeat him. Yet the sister ship can be the exact opposite, living out her life with the affection of all who have to do with her.

Oh, I know what you are thinking — I am being a sentimental old salt and not a scientific engineer, but a long career has left me quite convinced. THE GREAT BRITAIN is just such a ship, kind, cooperative and never giving trouble. Her career from her launch in 1843 to her hulking at Stanley in 1886 repeatedly showed this. Two examples; the ship was designed for a load draft of 17 feet. When on the Australian route she was loaded to 21 feet and when she finished up as a sailing ship she was loaded down to 25 feet — an enormous increase over her design. Yet she was not overdesigned structurally. Out of interest I converted her structural scantlings from iron into their steel equivalent and her rivetted construction into welded. The disposition of material in her hull girder and the total weight of equivalent steel were almost identical to those taken from today's Lloyds Small Ship Rules.

Yet Dupuy du Lome the French Naval Constructor in Chief commented, after seeing her under construction, that she was flimsy. Wrong; she never gave any structural trouble at all in her service life. When we came to salvage her in 1970 she was broken in two, right down the starboard side to the keel — not her fault as the gunwale had been brutally cut away to make an entry port when hulked in Stanley. When scuttled in Sparrow Cove the scour under her bow and stern had left a considerable hogging moment amidships as the ends were unsupported. However I was able to dive through sand tunnels under her port side and check that she was intact right to the keel. The holes in her hull were plugged and the Great Britain was floated. When we lifted her out of the water onto a pontoon, the bow had to lift first and an enormous sagging moment was imposed amidships. Hinging on the port side structure, this should close the twist and the two foot gap at the top of the break. At least that was the theory and with some ships it would have been most unwise to rely on it and the scanty data available.

With the G.B. I truly did not worry. We had done all we could and I knew in my bones that the old girl would play ball, and she did. With a loud report, the 48 in wide by 1 in thick steel stringer plates we had fitted at various deck levels buckled, the ship straightened and the gap completely closed. You can see this today. Of course we had left the straps unstiffened over a fair span so that their critical buckling stress was low. But just think how easily it could have gone wrong. We never had any real worries in that salvage. When she first floated a force 11 storm blew up immediately. Her rudder which had been jammed hard over, came free and we were able to ride it out at anchor using the rudder to keep her head to the wind. Everything went to schedule and the

(Continued on page 22)

Ewan Corlett, 1923–2005 cont.

(Continued from page 21)

crowning blessing was that she docked at Avonmouth about £500 inside budget estimates. When one thinks how many things could have gone wrong, it is hair raising, or would be if one had enough hair to raise. Some of you may think "the old boy is in his dotage" when I say that somehow that ship inspired confidence that things would not go wrong — and they did not.

Well, there she is in Bristol, in her original building dock. We have the VICTORY, of enormous historical importance, CUTTY SARK, epitome of the beautiful age of commercial sail, WARRIOR, the first modern warship and THE GREAT BRITAIN, the forerunner of all modern merchant ships. She represents all that has been best in British Engineering. Built with great courage, way ahead of the practice of her time, she incorporated a host of original features that were highly successful and pointed the way for the next half century; we are incredibly lucky that this particular ship has survived. I have spent my working life at the sharp end of the modern marine industry but am completely unrepentant over the time and effort that I and many others have put into the ship.

Having said that I detect a disturbing tendency for the old ship/old industrial equipment bandwagon to roll faster and faster. We must not allow Britain to become a theme park for historical engineering but must keep our eyes as a nation on the future, just as did Brunel. THE GREAT BRITAIN is one of the few real specials and we should restrict ourselves to preserving those. You see, THE GREAT BRITAIN was built — and nobly — in the days before engineers lost their national charisma, something that has only begun to return in recent years. When I.K.B. swallowed half a guinea doing conjuring tricks for his children it lodged in his gullet. There was widespread concern in the country. Eventually it came out with him upside down on a frame of his own devising. Such was his standing that the business of the House of Commons was interrupted for the Prime Minister to announce the fact. That, ladies and gentlemen, is the exposure and standing that professional engineers in this country must aim for and attain in the future — they deserve it on their achievements.

Finals Prizes Awarded 2005

The Examiners recommended the following awards in respect of Final Honour Schools in 2005:

Engineering Science Part 2

Maurice Lubbock Prize for best performance:

Michael P Coulson, Keble

Edgell Sheppee Prize for excellent performance:

Nicholas Barlow, Trinity

Edgell Sheppee Prize for Laboratory or Drawing Office Work:

Moira Jane Smith, Jesus

ICE Prize for best performance in Civil Engineering:

Thomas A Adcock, St Peter's

IMechE Certificate for the best student in Mechanical Engineering, and nomination to the Frederic Barnes Waldron Prize:

William R Sweeney, Jesus

IEE Prize for best performance in Electrical Engineering:

Sinead Anne Williamson, St Catherine's

IChemE Prize for best performance in Chemical Engineering:

Matthew Swain, Somerville

IEE Manufacturing Engineering (Unipart Industries) Prize:

Annabel Ka Lai Jenkins, Somerville

Babtie Prize for best project in Civil Engineering:

Nicholas CH Cole, Lincoln (on multi-configuration deployable structures)

IMechE Prize for best project in Mechanical Engineering:

Daniel J Payen, St Peter's (on stresses in a Formula 1 front suspension)

Motz Prize for best project in Electrical Engineering:

J Marc Thomas, Wadham (on a fluorescence lifetime imaging system)

Ronald Victor Janson Prize for best project in Electronic Communications:

Nicholas JT Taylor, Worcester (on digital filters for modelling gain in semiconductor lasers)

Worshipful Company of Scientific Instrument Makers Project Prize:

Rossini T Hayward, St Anne's (on high-resolution stereo microscopy)

Royal Academy of Engineering Prize for excellent design in a project:

Michael P Coulson, Keble (on a hydro-acoustic positioning system)

Rolls-Royce Prize for an outstanding project displaying innovation:

Mark R Austin, Worcester (on associating names and faces in the news)

Engineering Science Part 1

Gibbs Prize for best Part 1 project:

Jane Buckroyd, Jesus; Thomas Makin, Wadham; Thomas Pearson, Queen's; Michael Reed, Queen's (on the design of a demountable exhibition and administrative building for an archaeological site)

Royal Academy of Engineering Prize for best treatment of sustainability in a third-year design project, jointly to:

(1st) Neil Bianchi, Somerville; Cheuk-Yin Chui, Exeter; Andrew Fawcett, Balliol; Steven Holmes, New; Stephen Marshall, Magdalen; Adam White, St John's (on a battery-driven rickshaw for Mumbai, with solar-powered recharging stations)

(2nd) Matthew Arthington, Christ Church; Peter De Blacquiere-Clarkson, Somerville; Alexander Critien, Corpus; Robert Gauldie, St Catherine's; Juliana Meyer, St John's (on design of an offshore wind-farm)

Engineering, Economics and Management Part 2

Maurice Lubbock Prize for best performance:

Nicholas J Christie, New

Edgell Sheppee Prize for best performance in an Engineering Part 2 Project:

Andrew M Wood, Somerville (on designing cam profiles for variable valve actuation)

IMechE Certificate for an outstanding project in Mechanical Engineering:

Andrew M Wood, Somerville (as above)

Engineering and Computing Science Part 2

Maurice Lubbock Prize for best performance:

Mark JP Cummins, Balliol

Let's Hear From You!

Too much of this newsletter is being written within the Department — we would like more material from the Society's members at large. We are sure that many of you have interesting stories to tell, whether full-blown articles, short anecdotes or just personal news which other members might find interesting (the Personalia section is currently fairly short, and is mostly filled with information that the editors discover themselves — if something interesting or noteworthy has happened to you, or another Oxford engineer that you know, tell us about it!)

Please send articles, stories, notes, news etc. to the postal address below, or via e-mail to the editors:
Simon Turner at souenews@soue.org.uk or David Witt at david.witt@eng.ox.ac.uk.

"All that education, and she's gone to work in the steel mill!"

As reported by Claire Edwards in her talk to the SOUE last October, being what her grandmother said when, after reading Engineering Science at St Catherine's, Claire took a post with Corus in a South Wales steel-works near her home.

SOUE News

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