

Olcott Memorial Oration 2005

New frontiers of engineering

The Olcott Memorial Oration 2005 delivered by Old Anandian Professor Nimal Rajapakse, Professor of Mechanical Engineering University of British Columbia, Canada.

Venerable Maha Sangha, Principal of Ananda College, Past Principals, Past and Present Teachers of Ananda, Distinguished Invitees, Fellow Anandians, Ladies and Gentlemen.

It is indeed a great honour for me to deliver the 2005 Olcott Oration, and I am most grateful to the President and the Executive Committee of the Old Boys' Association for giving me this opportunity.

Thirty-three years have passed since I left Ananda College after completing Grade 12. Four generations of my family studied at Ananda. My late grandfather, Don Elias Rajapakse, studied at Ananda and gained admission to the Ceylon Medical College. My late father, my uncles, my bother, my nephew and cousins also studied at Ananda. I came to Ananda College in Grade 3 after spending a year at a school in my village near Attanagalla and another year at Olcott College which was then amalgamated into Ananda College in 1962.

This oration is held in memory of a great man, Colonel Henry Steele Olcott, who played a leading role in establishing Ananda College and laid the foundation for developing many other leading schools in Sri Lanka. While preparing for this oration, I decided to refresh my memory of Colonel Olcott's life. Colonel Olcott was the President, Founder of the Theosophical Society in America.

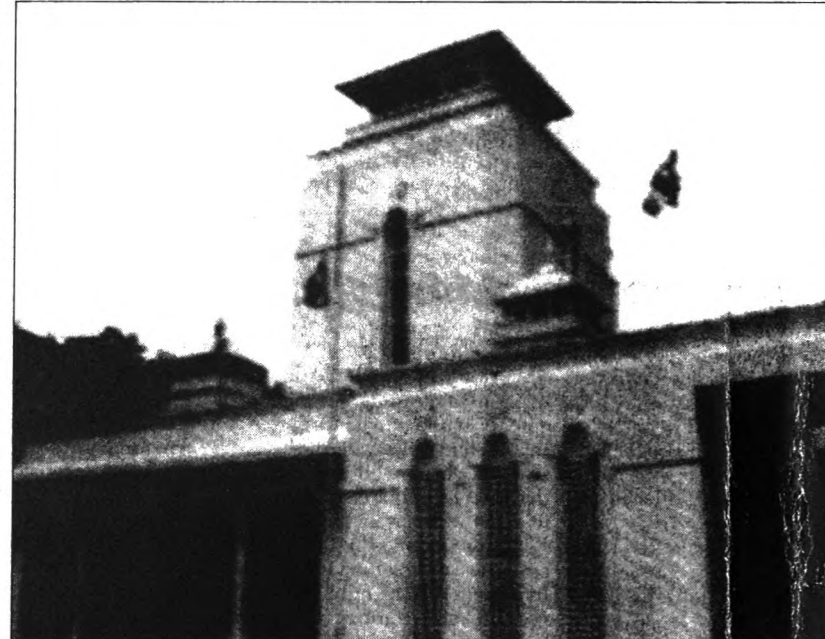
He came to know of Sri Lanka (called Ceylon at that time) after reading an article published in the *Ceylon Times* about the famous debate of Ven. Gunananda Thera held in Panadura. Colonel Olcott and Madam H.P.

Blavatsky (Co-founder of the Theosophical Society) arrived in Galle on May 17, 1880. Colonel Olcott undertook a concerted effort to revive the Buddhist culture in Sri Lanka and to build a network of schools to provide education to Sri Lankan children who had very limited access to education at that time. As a result of his efforts, the Buddhist English School was established on November 1, 1886 at 61, Maliban Street, Pettah, renamed Ananda College in 1895. Although founded under the patronage of Buddhist men and women, Ananda's doors have always been open to students and teachers from other religions. The school has maintained an educational environment built on strong discipline, academic excellence, mutual respect, religious harmony, openness and inclusiveness for nearly 120 years. Ananda College is a symbol of the qualities and vision of great men like Colonel Olcott. Many of us gathered here today are truly indebted to Colonel Olcott and his team for the superior education provided by Ananda College and other BTS schools in Sri Lanka.

When the organisers of this oration invited me to speak, I decided to talk about engineering for two reasons.

The first is obvious, as engineering is my chosen profession. The second reason is that Ananda College has arguably the best record, among all schools in Sri Lanka, of nurturing young Sri Lankans to become engineers. Old Anandians have made significant contributions to the practice and teaching of engineering in Sri Lanka and around the world. There are many distinguished engineers who studied at Ananda.

It is difficult to mention everyone by name but I would like to talk about a few. The pioneer of hydroelectricity development in Sri Lanka the late Mr. D.J. Wimalasuren-



dra, C. Eng., studied at Ananda. Mr. Wimalasurendra was the first Sri Lankan to recognise the vast amount of hydroelectric power that could be harnessed from the country's rivers. In 1918, he prepared a seminal paper summarising his ideas for the development of hydroelectric power. His ideas were not well received by the Government of Ceylon and he retired from government service in 1930. The importance of hydroelectric power was recognised after Sri Lanka gained independence. Today we see the benefits of Wimalasurendra's vision throughout the country.

The late Dr. B.M.A. Balasuriya, arguably the best structural engineer Sri Lanka ever had studied at Ananda. He was also my teacher at the University of Moratuwa. I would also like to recognise two leading engineering educators who studied at Ananda. They are Prof. M.P. Ranaweera, former Dean of Engineering of the University of Peradeniya and Prof. K.K.Y.W. Perera, former Dean of Engineering of the University of Moratuwa. Mr. H.B. Jayasekera, former Chairman of the Central Engineering and Consultancy Bureau, is another distin-

guished engineer who studied at Ananda. Many Old Anandians have settled abroad and enjoy distinguished careers in engineering. I would like to mention Dr. Chandana Wirasinghe, who is currently the Dean of Engineering of the University of Calgary, as an example.

Why has Ananda College been so successful in nurturing future engineers? I think it is because of outstanding teachers and mentors who encouraged many of us to study Mathematics and pursue a career in engineering. I would like to pay special tribute to our great mathematics teacher and mentor, the late Mr. C.M. Weeraratne, who was an Old Anandian himself. He had a distinguished teaching career at Ananda and served the school for nearly forty years. I am glad that Mr. Weeraratne's daughter, Kusum, is in the audience and that she is also an old Anandian.

Ladies and Gentlemen, Let me now turn to the new frontiers of engineering. Engineering is a marvellous discipline to study, research and practice. It is about great innovations, and has had a tremendous impact on modern society and our quality of life. There are

many new frontiers of engineering and I do not have the time to talk about all of them. Even in the few I am interested in, I have a lot to learn. I will talk about two frontiers that will have a significant impact on modern society and quality of life.

Colonel Olcott undertook a concerted effort to revive the Buddhist culture in Sri Lanka and to build a network of schools to provide education to Sri Lankan children who had very limited access to education at that time. As a result of his efforts, the Buddhist English School was established on November 1, 1886 at 61, Maliban Street, Pettah, renamed Ananda College in 1895.

Technological development will continue to accelerate at a rapid speed in this century, following the great strides made in the nineteenth and twentieth centuries. The frontiers of engineering are advancing on many unexplored territories. In the 19th and 20th centuries, we were driven by the desire to go big. We have seen giant skyscrapers, suspension bridges, aircraft, chemical processing plants, etc. Such developments significantly improved our standards of living. The rise and fall of various technology sec-

tors constitute a normal development cycle and will continue to happen in the future. For example, railroad building in the western world peaked during 1845-1900 and died down several decades later. The aviation industry peaked in the 1970s and thereafter reached a steady state. The same is true of the information technology industry which peaked during the last two decades of the 20th century and has seen a gradual downturn over the past five years.

Micro Electro Mechanical Systems (MEMS) and Nanotechnology

We have gone through four waves of technological advances over the past three centuries and are now in the fifth one. The fifth wave corresponds to MEMS and Nanotechnology.

In contrast to the technological goals of the 19th and 20th century to make things bigger, the fifth wave of technology

winner in Physics, the late Prof. Richard Feynman, who taught at the California Institute of Technology, Prof. Feynman was a visionary who predicted the fifth wave of technology in a talk given in 1959 at the annual meeting of the American Physical Society. The title of Prof. Feynman's talk was "There is Plenty of Room at the Bottom" and he repeatedly emphasized the word 'Plenty' during his talk. Twenty-four years later (i.e. 1983), Prof. Feynman gave another fascinating talk at the Jet Propulsion Laboratory in Pasadena, California. The title of the talk was "Infinitesimal machinery". The Journal of Microelectro Mechanical Systems published the texts of these two talks in 1992 and 1993.

In these talks, Prof. Feynman planted the seeds of MEMS and Nanotechnology. He asked, Why can't we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin? He

takes us in the opposite direction to analyse, design, build and manipulate objects that are too small to see with the naked eye. The MEMS technology involves objects with dimensions ranging from few millimetres to micrometres whereas Nanotechnology involves objects with dimensions ranging from one to one hundred nanometres. Before I proceed to give some examples of new engineering developments related to the fifth technology wave, it is appropriate to talk about a Nobel Prize

examined biological systems at the cellular and molecular levels and contemplated building mobile micro-robots for surgery. He speculated about one of the most intense research areas for engineers and scientists working on Nanotechnology today building devices at the atomic and molecular levels! He went on to talk about the possibility of another current hot research area in Computer Engineering and Physics quantum computing.

The fifth wave of technology, which we are rid-

ing today, is about Prof. Feynman's ideas and vision. Many things he mentioned have become possible in recent years or will become possible over the next few decades. Let me highlight some recent advances and future directions in MEMS and Nanotechnology.

MEMS technology came to the forefront of engineering in the early 1990s although some applications existed before that.

It is a technology similar to that used for making computer chips. Today a computer chip, the size of your thumb can perform 10 billion operations per second. Advances in semi-conductor technology for more than a decade have enabled building very small-scale mechanical devices and objects such as beams, plates, gears, motors, actuators, etc. Could we build a micro-robot that navigates through blood vessels using bio-sensors to reach the site of a cancer for controlled delivery of a drug?

This would be a much more effective way to treat cancer patients than current approaches such as radiation therapy.

Research is under way to use MEMS technology to restore vision to people suffering from certain types of blindness. According to an article published in the Mechanical Engineering magazine of ASME, a group of engineers from several leading laboratories in the United States is working together to design and build a microelectro mechanical device that can be implanted on the surface of the retina. In this article retina, a microelectrode array will perform the function of normal photoreceptor cells, to restore vision for people whose photoreceptors cells have been damaged. The goal is to build an array of 1,000 electrodes, with each electrode having a diameter of 50 um.

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The 100-electrode array, according to the researchers, will deliver enough optical resolution for patients to read and recognise fine shapes. Another interesting application of MEMS technology under development is an implantable device for monitoring blood glucose, oxygen, acidity or other chemicals. My colleague, Prof. Mu Chiao, who holds a Canada Research Chair in MEMS and Nanotechnology in the Department of Mechanical Engineering, does this work. The proposed device is a square silicon chip, half a millimetre thick and two millimetres wide. It will have a self-contained power source and work by allowing chemicals in the blood to follow through it.

A sensor measures chemical concentrations then sends this information to a tiny processor, which transmit the information to a receiver.

A major challenge in implantable biomedical device technology is the power source. Lithium batteries have long been used to power implantable devices such as pacemakers and spinal-cord stimulators. According to Prof. Chiao, MEMS-based implantable biosensors can become viable if a power source can be built using MEMS technology.

To meet this need, Dr. Chiao teamed up with other researchers to build a micro-battery that runs on glucose from body fluids. He has applied for a US patent for this new battery.

While MEMS researchers are searching for revolutionary new applications and MEMS technology rapidly advances towards mass production of micro devices for various applications, a new area of research that takes us deeper Prof. Feynman's infinitesimal world has emerged. This is Nanotechnology. Feynman speculated about Nanotechnology nearly fifty years ago. Advances in Nanotechnology are expected to yield significant benefits in areas as diverse as advanced materials, water treatment, information and communication technology, computer technology and medicine. According to The Royal Academy of Engineering, Nanotechnologies are the design, characterisation, production and application of structures, devices and systems by controlling shape and size at a nanometric scale. The length scale of interest is typically one to one hundred nanometres. Ground breaking research is under way in leading laboratories in North America, Europe and Japan. The United States Government has allocated 3.7 billion dollars for Nanotechnology R&D during 2005-08. Japan now spends a billion dollars per year on Nanotechnology R&D. Asian countries such as India, Singapore, Thailand and China are also making significant investments in Nanotechnology research.

Advanced materials have played a critical role in technological advances over the past four to five decades. Today we have composite materials that are not only much lighter than steel but several times stronger. Nanotechnology would allow us to build, starting at the atomic and molecular levels, new materials that have novel properties, functions and applications. Carbon Nano Tubes (CNT) are an important class of nanomaterials in the development of this new generation of materials. There are two types of carbon nanotubes: single-walled or multi-walled. The diameter of a carbon nanotube is only a few nanometres and the length varies between a few micrometres to centimetres. Carbon nanotubes are not only extremely stiff and as strong as diamonds, they can also conduct electricity extremely well. Current R&D efforts are focusing on the application of CNTs in reinforced composites, sensors and nanoelectronic devices. In addition, some nanomaterials, such as nanocrystal line ceramics, have properties that may result in superior quality medical implants. Nanotechnology could be used one day to build a new generation of smart materials that possess the ability to sense, actuate and perform self-repair.

There will be many exciting applications of Nanotechnology in medicine. One of the most exciting areas is in drug and gene delivery. The challenge is to build a nanoparticle with an on-board sensor that can destroy specific diseased cells by using controlled delivery of drug molecules or introduce new, stronger, DNA molecules to repair damaged cells. This dream may not be realised for another 20-30 years but the ground work is being laid today in leading laboratories. According to an article published in the Mechanical Engineering Magazine of ASME, another exciting area for Nanotechnology is the creation of a neurochip for the brain. The human nervous system is composed of special cells known as neurons. The neurons form complex networks that are the basis of the brain circuitry that gives us our intelligence and a host of other abilities, including motor control and sensing. It is envisioned that Nanotechnology would open the door to design and fabricate transistors that can mimic individual neurons. A neuro-biochip is a device containing many such transistors to simulate the function of part of the brain neurons. Such devices could open up new treatment methods for people suffering from brain diseases such as Alzheimer's and other neurological diseases.

Let me take a minute to explain why I am interested in MEMS and Nanotechnology. My area of specialisation is Solid Mechanics, which deals with the mechanical behaviour of materials, and forces and

deformations in structures and devices under various types of loading. Now think about the structures and devices encountered in MEMS and Nanotechnology. Consider a practical example of a MEMS device where a crack could grow at a rate of less than one micron per day. How do we model and understand fracture at that scale to ensure reliability of MEMS devices? Another good example is in biomedical applications where nano-scale holes are created in a plate device to allow transfer of cells and fluids.

Civil and Mechanical Engineers have studied stress concentration around notches and holes in plates for a long-time. Could we use such solutions at the nano-scale? At the nano-scale, surface energy and quantum effects play a dominant role. What happens when a fluid flows through a micro or nano-scale channel? Research shows that modelling of devices at the nano-scale cannot be done by classical continuum mechanics or fluid mechanics. New theories accounting for surface energy and quantum effects have to be developed. I am therefore interested in developing new theories and computational

techniques to study the mechanics of nano-scale and micro-scale objects.

Hydrogen technology

Let me now talk about another new frontier of engineering. A major challenge facing the world today is the pollution caused by fossil fuels. Fossil fuels produce several harmful gases when they are burned. Motor vehicles and electric power generators are the prime sources of carbon monoxide and carbon dioxide in the atmosphere, which contribute to global warming and climate change. Motor vehicles also emit nitrogen oxides, sulphur and carbon particulates (or soot) which cause serious health problems in humans. Around the world today, billions of dollars are spent on research and development programs in the area of clean energy technology.

Alternative fuels such as natural gas, ethanol, methanol, etc. have been studied for many decades. It is well known that electric vehicles have many advantages over conventional vehicles run by internal combustion engines. The main advantages are efficiency, no pollution and low

mechanical wear and tear due to fewer moving parts.

I would like to talk about a new frontier of engineering that would make cars powered by a device analogue to a conventional battery viable and efficient. The device is powered by hydrogen and research is underway in leading industrial and government laboratories around the world. The Clean Energy Research Centre at the University of British Columbia (UBC) and the Institute for Fuel Cell Innovation of the National Research Council of Canada located at UBC are leading Canadian centres for hydrogen-based clean energy technology. Hydrogen is the most abundant chemical element in the universe. Think of the abundant amount of water and plant life on earth as sources of hydrogen. Hydrogen can be considered the ideal fuel because of its inexhaustibility and compatibility with nature. How do we use hydrogen to run a car or produce electricity for an industrial plant? The answer is a device called a fuel cell. A Swedish scientist first introduced the concept of a fuel cell in 1838. A fuel cell is similar to a conventional battery. It is an electrochemical device,

which uses hydrogen and oxygen as the reactants. Hydrogen and oxygen are fed to a fuel cell from an external supply. The reactants are therefore continuously supplied, unlike in the case of a traditional battery. A continuous supply of reactants allows for continuous long-term operation of fuel cells. The only by-product of a hydrogen fuel cell is water vapour.

I am sure you have an obvious question for me. Why are we still running cars and power generators on petrol and diesel instead of using fuel cells? Although hydrogen-based fuel cell technology looks very attractive from a pollution point of view, there are significant technological challenges in getting our cars and other equipment run by fuel cells.

What are these challenges?

The main challenges are economical production, storage and distribution of hydrogen. Hydrogen can be obtained from water by the process of electrolysis - splitting water molecules using electricity. Energy is therefore required to produce hydrogen and has to be obtained in a clean and efficient manner.

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Over 75 per cent of hydrogen produced today comes from natural gas (methane) reforming (about 23 per cent is produced from petroleum). Another issue is storage of hydrogen either in liquefied or compressed (high pressure) form. It is also necessary to develop a network of refueling stations similar to current petrol stations, where automobiles can be refueled. The first hydrogen refueling station was opened in Iceland in 2003. There are also issues

in the design and manufacturing of fuel cells with respect to materials, water management and temperature. Major auto and electric power industries are investing substantial resources (multi-millions of dollars) to address these key technological barriers. Research is also underway to replace batteries used in many industrial equipment and consumer electronic products by fuel cell powered batteries. There are already demonstration cars and buses in operation. A hydrogen

highway is planned from Vancouver to Whistler in Canada. It is expected that most major technological challenges will be addressed over the next two decades and that hydrogen-based clean energy technology will be implemented by automobile and other industries. Applications with power demands below 1 kW constitute a potential market niche for fuel cells. Examples of these applications include communication systems, power tools, portable electronics, sensors for remote locations and a large number of recreational appliances. Small-scale power plants (1 to 50 kW) for residential and commercial applications (e.g. restaurants, hospitals, and hotels) are another areas with significant potential. Large-scale power generation (100 kW - 2 MW) from fuel cells is also under consideration.

Impact on engineering education

The new frontiers of engineering that I touched on today and other new frontiers have a significant impact on engineering education. It is important to examine and debate the future directions of engineering education. I have been an engineering educator for over twenty years.

I have served as Head of a Civil Engineering Department and am currently serving as Head of a Mechanical Engineering Department. My area of specialisation, Solid Mechanics, is core to both Civil and Mechanical Engineering, and the fundamentals are based in Physics and Applied Mathematics. This breadth has helped me to think more

broadly about engineering education.

In order to meet the challenges of the new frontiers of engineering and the needs of the 21st century, it is important to educate engineers to think across different subject areas. As you can see, many of the new frontiers involve a high degree of interdisciplinarity and require a strong engineering science foundation. The new areas such as Nanotechnology require engineers with strong skills in basic sciences, engineering sciences and engineering design. In the last 2-3 decades of the 20th century, engineering programs around the world became too specialised and many 'soft' engineering subjects were added. Engineering programs became too compartmentalised and students today have difficulty in seeing interconnections between core subjects. Such approaches to engineering education discourage interdisciplinary and produces engineers with poor system integration skills.

One of the greatest strengths of my training as a civil engineer at the University of Moratuwa is that I had to take second-year courses in Thermodynamics, Electrical Engineering and the Theory of Machines in addition to a strong foundation in Mathematics, Physics and Chemistry. Today many universities graduate civil engineers with practically no knowledge of Thermodynamics. Theory of Machines, Electronics and Instrumentation. How can we expect these engineers to design buildings that conserve energy or apply modern concepts such as structural health monitoring, smart HVAC systems, smart materials, etc? Similarly, Electrical Engineering programs contain no elements of Thermal Sciences

or Advanced Mechanics, even though most modern day electronic devices have a moving part and heat generation is a critical design issue.

Another issue to note is the emergence of Biology as a core discipline of engineering in the 21st century. This is a challenge because biology has never been a part of the engineering core. However, think about emerging areas such as Nanotechnology, tissue engineering, bio-electronics and the vast opportunities in the health and communication technology sectors. In these areas, great inventions will be made based on biological systems. We therefore need to think seriously about including core elements of biology in relevant engineering curricula. In my opinion, there is strong merit in having a common curriculum, based on core engineering sciences, design, mathematics and basic sciences for the first two years of undergraduate engineering programs. Sufficient specialisation can be achieved in the remaining two years, and postgraduate studies should be the avenue for further specialisation. Some of the world-renowned institutions such as Harvard University have a strong component of core engineering sciences and integration of Biology in the undergraduate engineering programs.

Undergraduate programs in areas such as Mechatronics (integration of Mechanical, Electrical and Computer Engineering), Engineering Sciences and Biological Engineering will become very popular in the 21st century. The graduates from Mechatronics and Engineering Science programs are often employed by high-tech industry. According to my knowledge, Sri Lankan universities do not offer undergraduate programs in

Engineering Science. Both Mechatronics and Engineering Science undergraduate programs are aimed at training engineers with strong system integration skills.

The new frontiers of engineering could also have a significant impact on engineering practice. According to an editorial in Engineering Trends Newsletter, "The convergence of scientific and engineering disciplines is also rapidly changing the practice of engineering in industry, and the manner in which engineers in industry function. In the past, engineers in industry frequently worked alone or with other engineers, usually from the same discipline, to design products or processes. Today, engineers in industry increasingly work in multidisciplinary product design teams that may include team members with backgrounds in business, marketing, sales and other areas, in addition to science and engineering."

Experience has shown that diverse, multidisciplinary design teams create better technical solutions. To insure that these teams function effectively, industry needs engineering graduates with strong communication and teamwork skills." Two weeks ago, I had lunch with a former CEO of a Canadian advanced technology company.

According to him we need only two types of engineers to drive the knowledge-based economy of the 21st century. One is an engineer with strong system integration skills to create the inventions, and the other is an engineer with strong product management skills to generate value out of these inventions. I think that is an important message for engineering educators around the world.

Ladies and gentlemen, I am now near the end of my speech.

I have a brief message to all students of Ananda. You belong to a highly privileged group of Sri Lankan students and the education you receive from your school is first class by any international standard. I urge you to think broadly when you study, participate in extra curricular activities, volunteer your time for a good cause, have some free time to pursue things that interest you, read about the world, enjoy art and music and take every opportunity to learn about different cultures, religions, languages and be proud of your own roots. Being an outstanding student means much more than achieving straight as in national exams. It means becoming a well-rounded person with excellent academic, communication, leadership and social skills. Follow in the footsteps of Colonel H. S. Olcott, Mr. C. W. Leadbeater, Sir D. B. Jayatilake, Mr. P. D. de S. Kularathne, Mr. G. P. Malalasekera, Mr. L. H. Mettananda, Engineer Wimalasurendra, Senator Amarasuriya, Prof. Rajasuriya and other great men and make a difference.

Finally, it is time to thank. In my opinion, a great school gives its students two important things: excellent education and life-long friends. Ananda blessed me with both. I am truly grateful for the excellent education and great friends Ananda gave me. Many of my former classmates are in the audience. I want to thank them for their friendship. All my former teachers deserved my sincere thank. I also want to thank my family members, especially my mother and two sons, for their love and encouragement.