Queen Elizabeth Prize for Engineering

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NEWS RELEASE

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Internet and Web pioneers win the inaugural Queen Elizabeth Prize for Engineering

Five engineers who created the Internet and the World Wide Web have together won the inaugural £1 million Queen Elizabeth Prize for Engineering for their innovations, which have revolutionised the way we communicate and enabled the development of whole new industries. Today a third of the world's population use the Internet and it is estimated to carry around 330 Petabytes of data per year, enough to transfer every character ever written in every book ever published 20 times over.

Engineers **Robert Kahn**, **Vinton Cerf**, **Louis Pouzin**, **Tim Berners-Lee** and **Marc Andreessen** were today announced as the winners by Lord Browne of Madingley in the presence of HRH The Princess Royal at the Royal Academy of Engineering, which administers the prize. The winners will come to London in June for the formal presentation of the prize by Her Majesty The Queen.

The art of engineering lies in the efficient combination of technologies to deliver the most meaningful results for society. The international team of judges for the Prize consider that these five outstanding engineers epitomise this approach in the way that they designed and built the Internet and the Web.

Lord Broers, Chair of the Judging Panel for the Queen Elizabeth Prize for Engineering, says: "Engineering is, by its very nature, a collaborative activity and the emergence of the Internet and the Web involved many teams of people all over the world. However, these five visionary engineers, never before honoured together as a group, led the

key developments that shaped the Internet and Web as a coherent system and brought them into public use.

"We had originally planned to award this prize to a team of up to three people. It became apparent during our deliberations that we would have to exceed this limit for such an exceptional group of engineers."

The Internet built on, but significantly extended, the work done on the ARPAnet in the 1960s. Bob Kahn, Vint Cerf and Louis Pouzin made seminal contributions to the design and protocols that together make up the fundamental architecture at the heart of the Internet.

The Internet as a networking infrastructure connects billions of computers together globally. It was Tim Berners-Lee's invention of the World Wide Web – an information-sharing model that is built on top of the Internet – that allows us to use it in the way we do today. The Web vastly extended the use of the Internet beyond email and file transfer. Marc Andreessen wrote the Mosaic browser that made the Web accessible to everyone and triggered a huge number of applications unimagined by the early network pioneers.

The technical prowess of this group of engineers is equalled by their foresight and generosity in sharing their work freely and without restriction. This approach allowed the Internet and the Web to be adopted rapidly around the world and to grow organically thanks to open and universal standards.
Additionally, over the past 30 years, they have served as technical and political stewards of the Internet and the Web as it has grown from its experimental phase to hosting over 50 billion pages of information today.

Prime Minister, the Rt Hon David Cameron MP, said: "It makes me proud that the UK is host to this international prize - the impact of engineering is global and so is the Queen Elizabeth Prize for Engineering. Engineering is about growth and progress for both the economy and society - bringing vast improvements in people's lives. The Internet and the Web are prime examples of this - engineering innovations that have enabled new industries, a huge number of jobs and enabled the world and its people to access education and knowledge as never before"

Support for the Internet and the Web during the nomination process was given by:

Bill Gates, Philanthropist and former CEO of Microsoft: "It would be difficult to point to any significant human endeavour that has not been touched profoundly through the invention and deployment of the Internet. We are living today in only the beginning of the transformations that will come through this enabling technology.

"My principal work since leaving Microsoft has been focused on issues of global health and development as well as on education. The Internet allows us to monitor progress in global health that would be impossible otherwise. It enables faster and more meaningful collaboration among researchers and scientists. It provides access to markets for individuals in the rural developing world. Increasingly, it offers to any student with a connection, access to the best instruction on earth, and entry to a world of information that would have been beyond anyone's imagination just two generations ago. These technologies promote understanding and awareness. They are the enemy of repression and tyranny. And even though their extension to the poor world has far to go, they are critical to expanding well-being of the poor of our world."

Jeff Bezos, Founder and CEO of Amazon.com: "By 'flattening the world' through ubiquitous communication and information flow, the Internet has brought us closer together, increased global understanding, amplified freedom of speech, and served as a strong tonic to totalitarian regimes. It has contributed significantly to economic empowerment in all parts of the world, through disintermediation, specialization, collaboration, and access to markets. One must look to items such as the printing press or widespread electrification to find technologies approaching the Internet's global societal impact."

Al Gore, 45th Vice President of the United States and environmental activist: "Now, for the first time in human history, internet-connected citizens have at their fingertips the sum total of almost all available knowledge of the human experience. Moreover, information has empowered citizens across the globe to challenge and solve some of the world's greatest issues. The development of the internet has, and will continue, to bring about transformational change for mankind."

Professor Dame Wendy Hall, Head of the School of Electronic and Computer Science at the University of Southampton: "The World Wide Web has impacted every aspect of our lives – the way we communicate with each other, the way we work, the way we socialise, the way we shop, the way we find information – enabling us to do things that were impossible before the digital revolution."

Quotes from the Queen Elizabeth Prize for Engineering:

Lord Browne, Chair of the Queen Elizabeth Prize for Engineering Foundation: "Engineering underpins economies, it gives commercial application to scientific discoveries, and it affects every aspect of our daily lives. By laying the foundations for the Internet and the World Wide Web, the five winners have done an extraordinary service for humanity. I am delighted that the Prize can honour the endeavour of these engineers, and make the story of their world-changing innovation known to the public."

Professor Brian Cox, University of Manchester and Judge for the Queen Elizabeth Prize for Engineering: "The Internet and the World Wide Web are prime examples of how engineering enables discovery, generates wealth and changes the world. We could not have imagined, even 20 years ago, having access to so much information. Knowledge is power, and these engineering innovations have empowered over 2 billion people worldwide – and this number is increasing every single day. That is what I call a global benefit to humankind".

Anji Hunter, Director of the Queen Elizabeth Prize for Engineering
"Engineers are often the unsung heroes whose innovations have made phenomenal contributions to society. We need more skilled engineers to solve the world's most pressing problems, which requires not only excellent education and inspirational role models, but more attention focused on highlighting the wonders of modern engineering, wherever they may be. This is what the Queen Elizabeth for Engineering is doing".

Dr Dan Mote, President Elect of the US National Academy of Engineering and Judge for the Queen Elizabeth Prize for Engineering:

"The Cold War direction of the world for security and commercial purposes was based on advantages gained by controlling access to

information and innovation. In the 1990s, controlling access to information became no longer possible, except in increasingly limited circumstances, because of the Internet, the Web and search engines. The defensive Cold War direction collapsed.

By 2000, the 21st Century direction of the world emerged as gaining temporary advantage by accelerating the creation and use of information and innovation through global partnerships. This offensive 21st Century direction, and virtually everything that happens within it, is fundamentally the result of the Internet, the Web and search engines".

Notes

The Queen Elizabeth Prize for Engineering is a £1million global engineering prize designed to reward and celebrate the individuals responsible for a ground-breaking innovation in engineering that has been of global benefit to humanity. Her Majesty the Queen will present the specially designed trophy at the award ceremony held at Buckingham Palace on 25 June 2013.
For more information please visit: www.qeprize.org

The QEPrize is run by an independent trust, called the Queen Elizabeth Prize for Engineering Foundation. The Foundation is chaired by Lord Browne of Madingley, whose fellow trustees are Sir John Parker, President of the Royal Academy of Engineering; Sir Paul Nurse, President of the Royal Society; and Ms Mala Gaonkar, Managing Director of Lone Pine Capital. Professor Sir John Beddington, the Chief Scientific Adviser to the UK Government, is an adviser to the Foundation.

Founding donors to the Foundation include BAE Systems, BG Group, BP, GlaxoSmithKline, Jaguar Land Rover, National Grid, Royal Dutch Shell, Siemens, Sony, Tata Consultancy Services, Tata Steel Europe and Toshiba.

The winners of the prize were selected by an eminent panel of judges from across the world and worked from information in the nominations, comments from referees and any addition required to establish which nomination most fully met the prize criteria. The judging panel for the inaugural cycle comprises: Professor Frances Arnold, Lord Alec Broers (Chair), Professor Brian Cox, Madam Deng Nan, Professor Lynn Gladden, Diane Greene, Professor John Hennessy, Professor Dr Dr h.c. Reinhard

Hüttl, Professor Calestous Juma, Professor Hiroshi Komiyama, Dr Dan Mote, Narayana Murthy, Dr Nathan Myhrvold, Professor Choon Fong Shih and Paul Westbury.

Judges' Citation

The Internet and the Web have revolutionised the way we communicate and enabled the creation of whole new industries. Today a third of the world's population use the Internet and it is estimated that it carries 330 Petabytes of data per year, enough to transfer every character ever written in every book ever published 20 times over. There are about 50 billion pages on the Web. The Internet and the Web have changed the world.

The QE Prize for Engineering is being awarded to five individuals who made major contributions to the Internet and the Web.

Robert Kahn, Vinton Cerf and Louis Pouzin made seminal contributions to the protocols that together make up the fundamental architecture of the Internet.

Tim Berners-Lee created the World Wide Web and thereby vastly extended the use of the Internet beyond email and file transfer.

Marc Andreessen, while a student and working with colleagues, wrote the Mosaic browser that was widely distributed and which made the Web accessible to everyone and triggered a huge number of applications unimagined by the early network pioneers.

While Kahn, Cerf, Pouzin, Berners-Lee and Andreessen made major contributions to the development of the Internet and the Web these systems were the result of collaboration through the use of open standards involving engineers all over the world.

About the innovations: The emergence of a global network

Virtually everything that happens in our 21st century society is touched by the Internet, the worldwide network of interconnected TCP/IP networks supporting innovations like the World Wide Web, search engines and other applications that grow in number every day.

Robert Kahn and **Vinton Cerf** invented the Transmission Control Protocol (TCP) and the Internet protocol (IP) which together make up the fundamental architecture at the heart of the internet and triggered innovations ,including the World Wide Web, which now enable a third of the world's population (over 2.4 billion people) to use the internet.

In 1972, Bob Kahn and colleagues at DARPA (the US Defense Advanced Research Projects Agency) demonstrated that it was possible to connect 20 different computers and send messages between them - in which the messages were broken up into 'packets' of information and reassembled once they reached their destination. The network they had created was called the ARPANET and Bob Kahn described its demonstration as "the watershed event that made people suddenly realise that packet switching was a real technology".

Meanwhile, European researchers were also working on peer-to-peer networks. Developed by a team led by **Louis Pouzin** at the French Delegation a l'Informatique, the CYCLADES network aimed to overcome the limitations of the ARPANET design and was first demonstrated in 1973. CYCLADES was the first network to make the host computers responsible for the reliable delivery of data, rather than the network itself. Pouzin achieved this using datagrams (telegrams of data) that contained all the information needed to route them between two machines, regardless of the path they took. This was combined with an end-to-end protocol defining how the data should be recombined at its destination. These concepts were later used in Kahn and Cerf's Internet protocol. Pouzin has said that he designed CYCLADES "to be connected to other networks — in the future." This released the potential for a distributed global communications network.

The ARPAnet, built in the 1960s, resulted in significant advances in packet-switched, reliable networks. Kahn and Cerf, who had worked on the ARPAnet, and Pouzin, who had interacted with the ARPAnet designers, sought to overcome the cost and scalability limitations of the ARPAnet.

Building on Pouzin's work, Kahn and Cerf came up with the initial idea for what later became the TCP, which defines how electronic devices (like computers)

should be connected to the Internet, and how data should be transmitted between them. Their idea was to hide the differences between network protocols (languages between network devices) by using a common protocol, which made it possible to create a network of networks.

They published their landmark paper, *A protocol for packet network intercommunication*, in 1974. By 1978, the TCP had been separated into two layers, with the most basic functions, such as breaking up data into packets and routing each to the correct destination, forming the Internet protocol (IP). Together, these two protocols, referred to as TCP/IP, are the basis for the modern Internet and Web.

From 1983, the Internet was able to grow organically because of the TCP/IP so anyone who wanted to build a network connected to the Internet could do so – there was no patent agreement for using it and no central control. Kahn and Cerf's desire to encourage the adoption of the technology without profiting directly from it themselves has enabled the Internet to become a truly connected and global communications network.

None of the Internet's developers could have predicted the incredible impact their innovations would have on society, but the Internet protocols were designed to be future-proof in a number of ways. Crucially, the packets do not need to 'know' how they are carried and the network does not need to 'know' what the packets contain; so as new types of communications technology emerge, the basis of the internet will stay the same.

The Internet is a network of networks that connects billions of computers together globally, but it is the World Wide Web – an information-sharing model built on top of the internet – that allows us to use the Internet in the way we do today. **Tim Berners-Lee's** vision for universality enabled the development of a high-level network of content that allows any document to link to any other documents.

Invented by Berners-Lee at CERN, initially to facilitate the exchange of research papers, the World Wide Web is a system of interlinked 'hypertext' documents accessed via the internet; in essence, an information space. Berners-Lee wrote a proposal in 1989, which would become the World Wide Web, and then went on to write the first web browser, server and Web page.

While he did not invent hypertext systems, Berners-Lee proposed using them "to link and access information of various kinds as a web of nodes in which the user can browse at will." His breakthrough was to link hypertext to the Internet and

he developed three technologies to do this: web addresses or a Universal Resource Locator (URL) to reference a web resource; Hypertext Transfer Protocol (HTTP) which is the foundation of data communication for the web and HyperText Markup Language (HTML) which is the main mark-up language for creating web pages and information that can be displayed on a web browser.

As a student at the National Center for Supercomputing Applications (NCSA) at the University of Illinois, **Marc Andreessen** had become familiar with Berners-Lee's open standards for the World Wide Web. Andreessen and colleagues set about creating a user-friendly browser with integrated graphics that would work on a wide range of computers. The resulting code was the Mosaic Web browser – the final piece in the jigsaw that would enable the rapid adoption of the Web by society.

How the Internet differs from the World Wide Web

The World Wide Web (WWW) and the Internet are symbiotic. The Internet itself is a huge network of computers and is built on the Transmission Control Protocol (TCP) and the Internet protocol (IP), which allow the transmission of information between computers on different networks.

The Internet as a networking infrastructure connects billions of computers together globally, but it is the World Wide Web – an information-sharing model built on top of the internet – that allows us to use the 'Internet' in the way we do today. The Web is a collection of multi-media resources or interlinked 'hypertext' documents accessible via the internet.

Timeline

1972 – ARPANET demonstration by DARPA initial development team including Kahn
1973 – CYCLADES developed by Pouzin, Cerf joins ARPANET
1974 – Internet by Kahn and Cerf
1989 – World Wide Web proposal by Tim Berners-Lee
1991 – World Wide Web demonstration by Tim Berners-Lee
1992 – Mosaic Web Browser developed by Marc Andreessen (NCSA student at University of Illinois)
1994 – Navigator browser (developed by Marc Andreessen) released by Netscape

Biographies of the winners

Robert Kahn

Robert (Bob) Kahn, born 23 December 1938, is an American internet pioneer, engineer and computer scientist, who together with Vint Cerf, invented the Transmission Control Protocol (TCP) and the Internet Protocol (IP), which together make up the fundamental architecture at the heart of the internet.

After receiving his degree in electrical engineering at the City College of New York in 1960, Kahn went on to study at Princeton University and completed his PhD in 1964. His first job was at AT&T Bell Laboratories, which he left to complete his doctoral work and then became an Assistant Professor at Massachusetts Institute of Technology (MIT). He took a leave of absence from MIT to join Bolt, Berenek and Newman (BBN), where he was responsible for the system design of ARPANET, the first packet switching network.

However it was his work at the Information Processing Techniques Office (IPTO) within ARPA and the demonstration of ARPANET in 1972 that cemented his place in computer science history. The demo connected several dozen different computers and proved the viability of packet switching. Kahn was responsible for two other packet networks, Packet Radio and Packet Satellite, which raised the issue of connecting multiple packet networks. This, in turn, lead to the development of the TCP/IP protocols for connecting different computer networks; the technology that made the Internet possible.

Kahn became Director of IPTO before starting the US government's billion dollar Strategic Computing Initiative; a massive research and development project into advanced computer hardware and artificial intelligence, funding for which also enabled the nascent Internet to expand significantly.

After 13 years with DARPA, Kahn left to found the Corporation for National Research initiatives (CNRI) in 1986, designed to provide leadership and funding for research and development of the National Information Infrastructure. He has been its Chairman, CEO and President since 1986.

Kahn has received numerous awards including: the ACM Turing Award, National Medal of Technology, Charles Stark Draper Prize, Presidential

Medal of Freedom, Japan Prize and has twice received the Secretary of Defense Civilian Service Award. He has numerous honorary degrees and honorary fellowships.

He is a Fellow of the Institute of Electrical and Electronics Engineers, Computer History Museum, Association for Computing Machinery, and Honorary Fellow of the Society for Technical Communication. He is a member of the National Academy of Engineering and has been inducted into the National Inventors Hall of Fame and Internet Hall of Fame.

Vinton Cerf
Vinton (Vint) Cerf, born 23 June 1943, is an American computer scientist, whom together with Bob Kahn, is considered one of the 'fathers of the internet'.

Having obtained a BSc in Mathematics at Stanford University and a PhD from UCLA in 1972, where he met Bob Kahn and worked on ARPANET, Cerf moved to the US Department of Defense's Advanced Research Projects Agency (DARPA) in 1976, where he stayed until 1982.

Cerf was Vice President of MCI Digital Information Services from 1982 to 1986 and led the engineering of MCI Mail, the first commercial email service to be connected to the Internet. He then became Vice President of the Corporation for National Research Initiatives (CNRI) before rejoining MCI in 1994 as Senior Vice President of Technology Strategy. Cerf was Founding President of the Internet Society between 1992 and 1995 and served as Chair of the Visiting Committee on Advanced Technology of the US National Institute of Standards and Technology in 1996 to this year. He was a member of the US Presidential Information Technology Advisory Committee (PITAC) from 1997 to 2001 and continues to attend several national, state and industry committees focused on cyber-security.

Cerf served as a member of the US Presidential Information Technology Advisory Committee (PITAC) from 1997 to 2001 and still attends several national, state and industry committees focused on cyber-security. Between 2000 and 2007, he was Chairman of the board of the Internet Corporation for Assigned Names and Numbers (ICANN).

In October 2005, Cerf became Vice President and Chief Internet Evangelist for Google. He is President of the Association for Computing Machinery (ACM) and sits on the Board of Directors for the Americas

Registry for Internet Numbers (ARIN), StopBadWare, the Gorilla Foundation, the Marconi Society and the Science Advisory Board for CosmosID. He serves on the Jet Propulsion Laboratory Advisory Committee and is as Distinguished Visiting Scientist there where he is working on the design of an interplanetary Internet. He is Vice Chairman and Treasurer of the National Science & Technology Medals Foundation and was appointed by President Obama to serve on the National Science Board beginning in February 2013.

Cerf is a Fellow of many institutions including the IEEE, ACM, American Association for the Advancement of Science, the International Engineering Consortium and is a member of the US National Academy of Engineering. He is a Distinguished Fellow of the British Computer Society and an Honorary Chairman of the IPv6 Forum, dedicated to raising awareness and speeding introduction of the new Internet protocol. Cerf has been inducted into the National Inventors Hall of Fame, made Eminent Member of the IEEE Eta Kappa Nu (HKN) honor society, received a Lifetime Webby Award, was named a Stanford Engineering School "Hero" for his work on the Internet as well as receiving a lifetime achievement award from the Oxford Internet Institute.

His many awards include the US National Medal of Technology, ACM Alan M. Turing Award, known as the 'Nobel prize of Computer Science,' the Presidential Medal of Freedom, Japan Prize, Charles Stark Draper award of the National Academy of Engineering, the IEEE Alexander Graham Bell Medal, the IEEE Koji Kobayashi Award, the ACM Software and Systems Award and SIGCOMM Award, and the IEEE Third Millennium Medal.

Louis Pouzin
Louis Pouzin, born in 1931, is a French engineer who invented the CYCLADES computer network and its datagram packet switching network, from which TCP/IP was derived.

Having studied at École Polytechnique in Paris, Pouzin worked on the Compatible Time-Sharing System, or CTSS, one of the world's first time-sharing systems at Massachusetts Institute of Technology (MIT) in the mid-1960s. He wrote a programme called RUNCOM, the first operating system "shell"; an idea that lead to the first shell that ran atop UNIX, the operating system that would spread the idea across the computing world. Pouzin joined the Delegation a l'Informatique in 1971 as a researcher for the French government, with the aim of building a national research

network and returned to the US to meet people involved with ARPANET, including Vint Cerf.

In the early 1970s, Pouzin invented the datagram (a data telegram) and CYCLADES, the first network to make the host computers responsible for the reliable delivery of data, rather than the network, in a bid to overcome the limitations of the ARPANET design. He conducted the first demonstration in 1973 and continued to refine the network, which undoubtedly contributed to the way the Internet works today.

Pouzin is currently Project Director with EUROLINC, an association promoting the use of native languages on the Internet.

He has received the ACM SIGCOMM Award for "pioneering work on connectionless packet communication," IFIP Silver Core and IEEE Internet award amongst others and was named a Chevalier of the Légion d'Honneur by the French government. He was inducted into the Internet Hall of Fame in 2012.

Sir Tim Berners-Lee
Sir Timothy (Tim) Berners-Lee, born 8 June 1955, is a British computer scientist and the inventor of the World Wide Web.

Having studied Physics and Queen's College Oxford, graduating in 1976, he worked as an engineer in the telecommunications and microprocessor software industry in Dorset, England.

In 1980, while working as an independent contractor at CERN, Berners-Lee described the concept of a global system based on using hypertext to share information between researchers and built a prototype system called Enquire, which formed the conceptual basis for the World Wide Web.

Back in Dorset, working at Image Computer Systems gave him useful experience in computer protocols and text handling and in 1984 Berners-Lee retuned to CERN, home to a major European Internet node, as Fellow. In 1989 he published his landmark paper, "Information Management: A Proposal" built the first WWW server and web browser "WorldWideWeb.app" and named the World Wide Web.

The Web was first running in CERN in November 1990 and then globally in 1991. He wrote the initial specifications of URLs, HTTP and HTML, and

continued to refine them. In 1994, he founded the World Wide Web Consortium (W3C) and has since served as Director of the standards organization, as a guardian of the Web. He holds the 3Com Founders' chair in Engineering at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL), and also a chair in Computer Science at the School of Electronics and Computer Science, University of Southampton. His research interests include user interface, Linked Data and the Semantic Web.

Sir Tim is an advocate for Internet freedom and open data. In 2009 he founded the World Wide Web Foundation, and in 2012 he co-founded the UK's Open Data Institute (ODI).

Among his many accolades, Berners-Lee was awarded a Knighthood and the Order of Merit, and was the first recipient of Finland's Millennium Technology Prize. He was awarded the Charles Stark Draper Prize, the Mikhail Gorbachev award for "The Man Who Changed the World," and was inducted into the Internet Hall of Fame, to name a few. He has been named among Time Magazine's 100 most important people of the 20th century, was voted among the BBC's Greatest Britons and was ranked joint first in The Telegraph's list of 100 greatest living geniuses.

Marc Andreessen
Marc Andreessen, born 9 July 1971, is an American entrepreneur, investor and software engineer best known for co-authoring the first widely used Web browser, Mosaic, as well as co-founding Netscape Communications and Silicon Valley venture capital firm, Andreessen Horowitz.

As a student studying for a degree in Computer Science at the University of Illinois, Andreessen became a part time assistant at the National Center for Supercomputing Applications (NCSA) where he became familiar with Berners-Lee's open standards for the World Wide Web. Together with Eric Bina and colleagues including Larry Smarr and Joe Hardin, he created a browser with integrated graphics that would work on a range of computers.

Having co-created the influential Mosaic Internet browser, he co-founded Netscape, which later sold to AOL for $4.2 billion. Andreessen then co-founded Loudcloud, which as Opsware sold to Hewlett-Packard for $1.6 billion.

He is now a Co-Founder and Partner at Andreessen Horowitz, a venture capital firm that provides seed, venture and growth-stage funding to technology companies. The firm has $2.7 billion under management across three funds, with portfolio holdings that include Airbnb, Actifio, Box, Fab, Facebook, GitHub, Jawbone, Pinterest, Platfora, Quirky and Twitter.

Andreessen serves on the boards of eBay, Facebook, Glam Media, Hewlett-Packard, Bump, Kno, Rockmelt and TinyCo.