Lighting the way into space

'LINE OF SIGHT' COMMUNICATION IS SET TO TAKE BACK ITS PLACE FROM RADIO WAVES, WRITES **S ANANTHANARAYANAN**

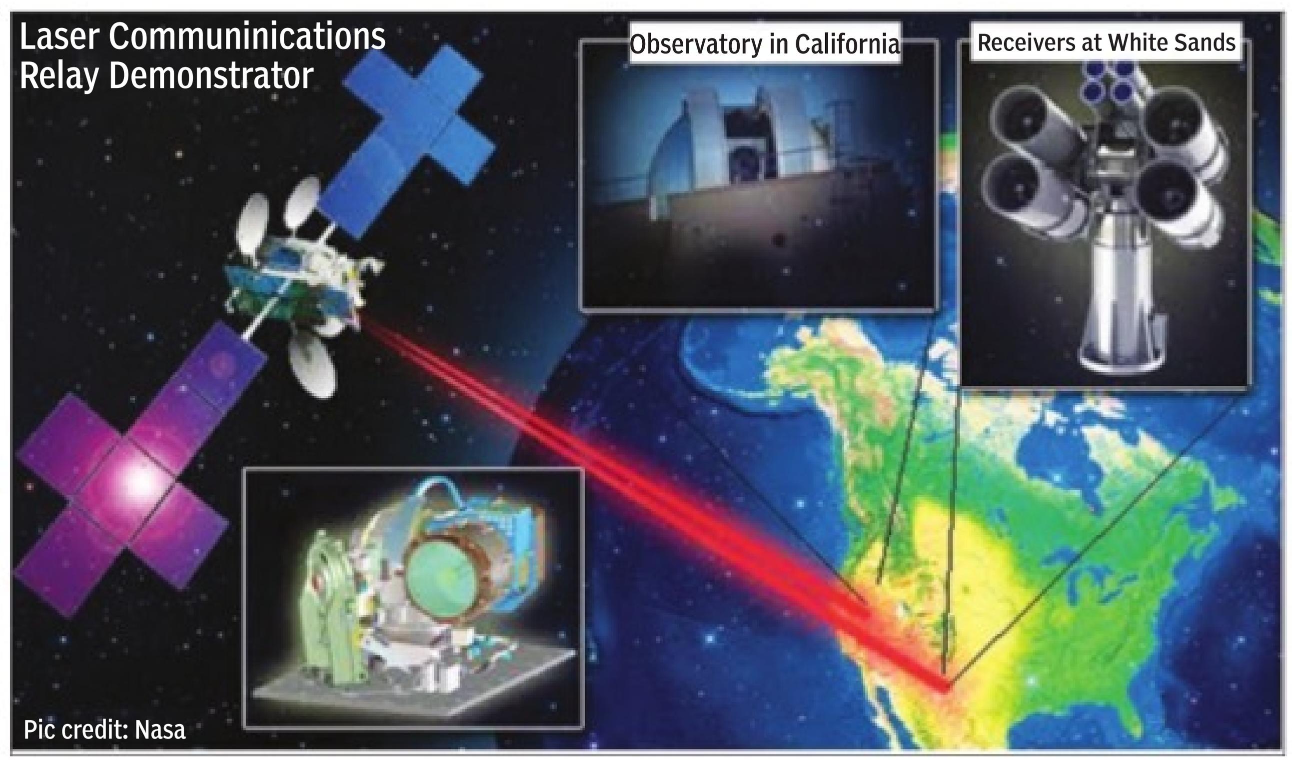
Early communication over a distance was essentially through visible signals. For example, the lighthouse to alert sailing ships, the Morse flasher, the semaphore, from hilltops or even bonfires and smoke signals. The entry of the telephone in 1876 made it possible to "talk around corners" and also over larger distances. Telephony had a long reign and dominated personal communication, but wireless communication also had great range and access. While optical fibre replaced the copper wire carrier in telephony and data transfer, radio waves were the ruling medium for broadcast and communication using satellites, in mobile telephony and for the space programme.

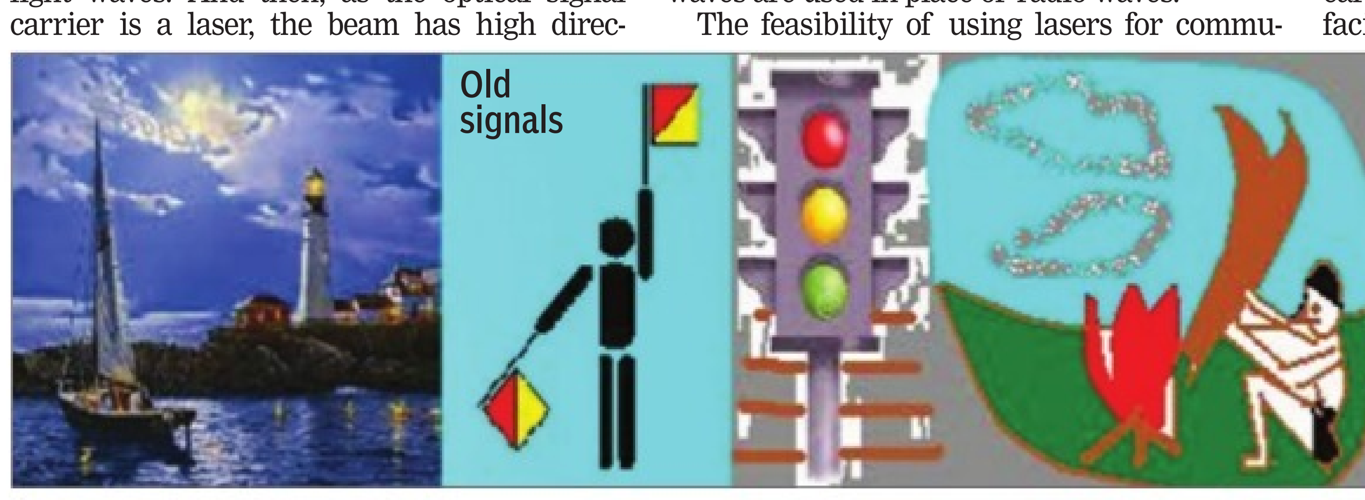
All space exploration by the National Aeronautics and Space Administration since 1958, or by other agencies, has used radio communication to stay in touch with satellites or spacecraft or modules that have landed on bodies in space. There have been great advances in communication equipment and an increase in the extent of data that needs to be sent up to spacecraft as well as sent by the spacecraft to the command station. The need for higher data transfer, in fact, has exploded, with better instrumentation, robotics and ambitious exploration plans. Actual data transfer, however, is still based on waves at radio frequency, and this places a limit on the amount of data that can be handled and, hence, on the benefits of the advances in technology.

Nasa is, hence, in the process of putting together a system of data transfer that has substantially higher capacity, using light waves as the information carrier in place of radio waves. This change would be like what happened with telephony when optical fibres came in. However, as we cannot lay an optical fibre cable out to spacecraft, the communication is by means of laser beams, from the base station to the spacecraft and from the craft to the base station. We can see that this would call for an uninterrupted path from sender to receiver, which means we are back to communication along the "line of sight" and another application of light, the new field of "photonics" (see box).

Benefits of light

The two main limitations of radio waves are that these are low frequency and then spread out when they move over long distances. The low frequency of the waves implies that there is a limit to the quantity of information that can be conveyed with the help of the wave. The second limitation, that the waves spread out, means that the transmission has to be strong, as only a small part would be there at the place where the waves are detected. Optical signals, or light waves, on the other hand, are high frequency waves. Typically, radio waves may have wavelengths in metres, or frequency in millions of cycles per second. In comparison, the wavelength of light waves is in hundreds of a billionth of a metre, or frequency in thousands of billions of cycles a second. A large number of cycles in every second means more opportunity to load data signals on the wave and, hence, the greater data capacity of light waves. And then, as the optical signal carrier is a laser, the beam has high directionality and there is much lesser spread of the energy before the beam reaches the receiver. This allows lower power of transmission and, hence, lesser loads on spacecraft that need to be moved over very large distances.





Another problem with radio signals is that the frequencies used should not clash with the frequencies used for other purposes, like ground or airline communications or broadcast. This constraint disappears when light waves are used in place of radio waves.

The feasibility of using lasers for communication in space applications was first tried out in Nasa's *Lunar Laser Communication Demonstration*, where high throughput, two-way communication with the help of an infra red laser was established between the earth and *the Lunar Atmosphere and Dust Environment Explorer* mission, a robotic spacecraft that orbited the moon and sent back text and image data for 30 days in 2013-14. As the path of the laser beam carrier can sometimes be blocked by cloud formations and so on, the earth link is at three locations, the White Sands facility in New Mexico, the Table Mountain facility in California and the European Space Agency's observatory at Tenerife, Spain. Even orbiting stations to relay data could be considered.

The follow up to LLCD is the *Laser Communications Relay Demonstration*, a two-year long trial of technology that could enable high speed video transmission via laser from spacecraft deep within the solar system. The transmission process, encoding techniques and the tracking process are being refined and would be ground tested in 2017 and tested in space in an orbiting satellite in 2019. The change would be akin to the leap in bandwidth that Internet surfers experienced when we moved from dial-up links to broadband and HDMI cable and researchers would receive streaming visuals from far reaches of the solar system , where they could establish a virtual presence.

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Day of photonics

The European Photonics Industry Consortium, a Brussels-based organisation that seeks to promote the general understanding of the new field of photonics and how it has become integral to all aspects of our lives, celebrated 21 October as the biennial Day of Photonics.

Carlos Lee, secretary general of the consortium, said in an interview that the day was chosen as it was on this day in 1983 that the General Conference on Weights and Measures, in Paris, adopted the speed of light as the basis of defining the length of the standard metre. The consortium thought this day was, hence, technology neutral and also did not represent any country and hence adopted the day for promoting photonics.

Although the word is not so well known as the word "electronics",

for instance, photonics now occurs in almost all the industries and devices that we use, Lee said. Photovoltaic cells, LED lamps, lasers, the Internet, cameras, displays, are all examples of photonics. Solar panels, power satellites, remote hospitals and schools — it could even be loaded on the back of a camel to drive a chiller to preserve medicine the camel was carrying, Lee said. Photonics was enabling industry, 3D printing, the world of medicine in surgery and diagnostics, in agriculture to detect the areas that really needed fertiliser, to sort fruit according to ripeness, and so on.

The consortium organised events in offices, schools, clubs and homes the world over to draw attention to and create awareness of this area of technology and science that underlay almost all the conveniences and essentials of our daily lives, Lee said.

SYNTHESIS BY COLOURS

TAPAN KUMAR MAITRA EXPLAINS A PROCESS BY WHICH THE SEQUENCE OF A DNA STRAND IS DETERMINED

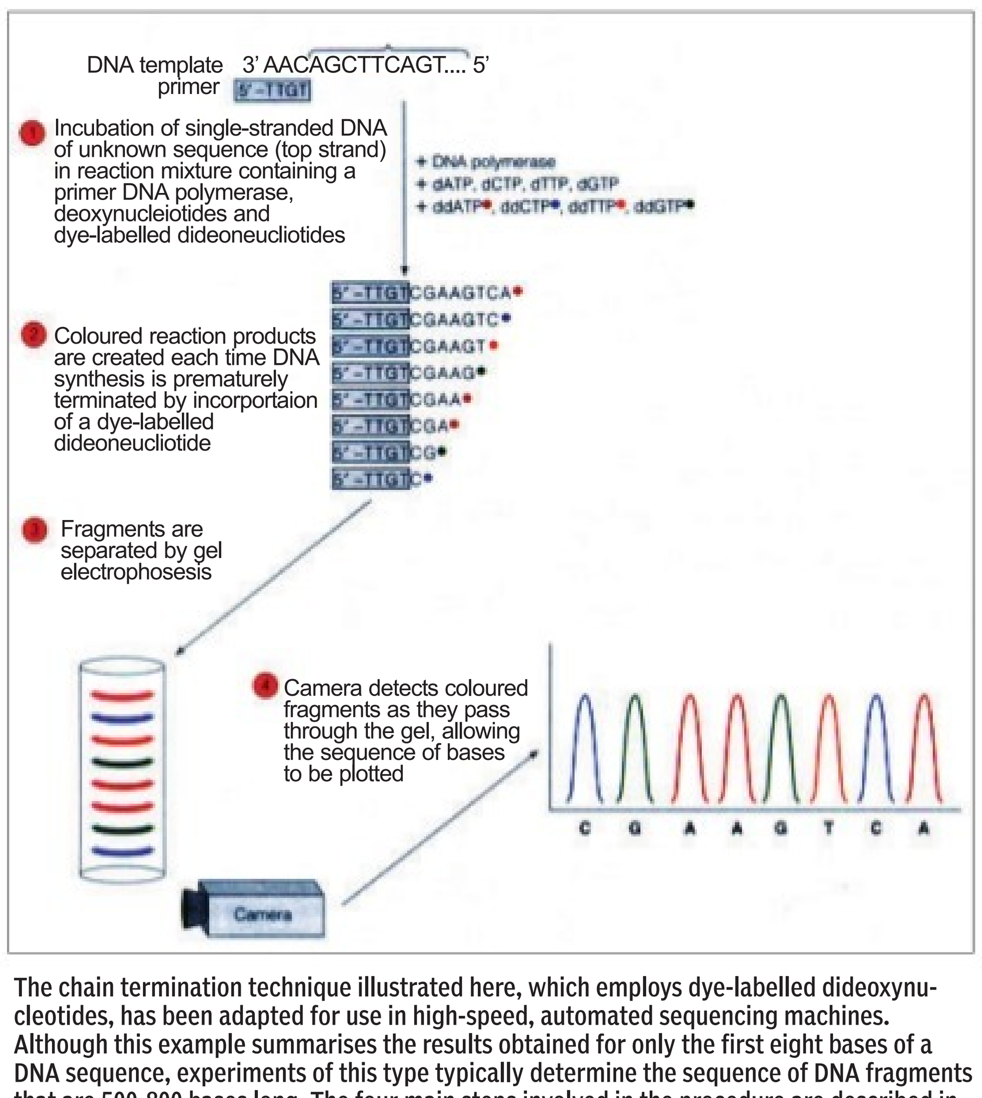
At almost the same time when techniques for preparing restriction fragments were developed, two methods were devised for rapid DNA sequencing — that is, determining the linear order of bases in DNA. One method was devised by Allan Maxam and Walter Gilbert, the other by Frederick Sanger and his colleagues. The Maxam-Gilbert one, called the chemical method, is based on the use of (non-protein) chemicals that cleave a DNA preferentially at specific bases whereas the Sanger procedure, called the chain termination method, utilises dideoxynucleotides (nucleotides lacking a 3'-hydroxyl group) to interfere with the normal enzymatic synthesis of DNA. Let's focus on Sanger's method as it has been adapted for use in automated machines that are now employed for most DNA sequencing tasks.

A single-stranded DNA fragment is employed as a template to guide the synthesis of new complementary strands. Synthesis is carried out in the presence of the deoxynucleotides — dATP, dCTP, dTTP, and dGTP. They are the normal substrates that provide the bases A, C, T, and G to growing DNA chains. Also included, at lower concentrations, are four dye-labelled dideoxynucleotides — ddATP, ddCTP, ddTTP, and ddGTP — which lack the hydroxyl group attached to the 3'-carbon of normal deoxynucleotides. When a dideoxynucleotide is incorporated into a growing DNA chain in place of the normal deoxynucleotide, DNA synthesis is prematurely halted because the absence of a 3'-hydroxyl group makes it impossible to form a bond with the next nucleotide. Hence, a series of incomplete DNA fragments are produced whose sizes provide information concerning the linear sequence of bases.

Let's see how this procedure works. A reaction mixture is assembled that includes the dideoxynucleotides, ddATP, ddCTP, ddTTP, and ddGTP, each labelled with a fluorescent dye of a different colour, for example, ddATP = red, ddCTP = blue, ddTTP = orange, and ddGTP = green.

These coloured dideoxynucleotides are mixed with the normal deoxynucleotide substrates for DNA synthesis along with a single-stranded DNA molecule to be sequenced and a short, single-stranded primer that is complementary to the 3' end of the DNA strand being sequenced. When DNA polymerase is added, it catalyses the attachment of nucleotides, one by one, to the 3' end of the primer, producing a growing DNA strand that is complementary to the template whose sequence is being determined. Most of the nucleotides inserted are the normal deoxynucleotides because they are the preferred substrates for DNA polymerase. However, every so often a coloured dideoxynucleotide is randomly inserted instead of its normal equivalent. Each time a dideoxynucleotide is incorporated, it halts further DNA synthesis for that particular strand. Hence, a mixture of strands of varying lengths is generated, each containing a coloured base at the end where DNA synthesis was prematurely terminated by incorporation of a dideoxynucleotide.

Next, the sample is subjected to electrophoresis in a poly-acrylamide gel, which allows the newly synthesised DNA fragments to be separated from each other because the shorter fragments migrate through the gel more quickly than the longer ones. As they move through the gel, a special camera detects the colours of the various fragments as they pass by. In this particular example, the shortest DNA fragment is blue and the next shortest is green. Since blue and green are the colours of ddCTP and ddGTP, respectively, the first two bases added to the primer must have been C followed by G.



The chain termination technique illustrated here, which employs dye-labelled dideoxynucleotides, has been adapted for use in high-speed, automated sequencing machines. Although this example summarises the results obtained for only the first eight bases of a DNA sequence, experiments of this type typically determine the sequence of DNA fragments that are 500-800 bases long. The four main steps involved in the procedure are described in more detail in the text.

In automatic sequencing machines, such information is collected for hundreds of bases in a row and fed into a computer, allowing the complete sequence of the initial DNA fragment to be quickly determined.

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Messages from the stars

TWO SCIENTISTS FROM LAVAL UNIVERSITY IN QUEBEC, CANADA, HAVE DETECTED STRANGE SIGNALS DURING A SURVEY OF THE SKY. **ANDREW GRIFFIN** REPORTS

Scientists have heard hugely unusual messages from deep in space that they think are coming from aliens. A new analysis of strange modulations in a tiny set of stars appears to indicate that it could be coming from extraterrestrial intelligence that is looking to alert us to their existence.

The new study reports the finding of specific modulations in just 234 out of the 2.5 million stars that have been observed during a survey of the sky. The work found that a tiny fraction of them seemed to be behaving strangely. And there appears to be no obvious explanation for what is going on, leaving the scientists behind the paper to conclude that the messages are coming from aliens.

"We find that the detected signals have exactly the shape of an extraterrestrial intelligence signal predicted in the previous publication and are therefore in agreement with this hypothesis," write EF Borra and E Trottier in a new paper. "The fact that they are only found in a very small fraction of stars within a narrow spectral range centered near the spectral type of the sun is also in agreement with the ETI hypothesis," the two scientists from Laval University in Quebec, Canada, write.

The research has been accepted for publication in the journal *Publications of the Astronomical Society of the Pacific*, under the title "Signals probably from Extraterrestrial Intelligence". But they make clear that further work will need to be done to confirm or deny that hypothesis. That will need to be done is watching for the same signals on different equipment so that all other explanations can be discarded.

Breakthrough Listen — an initiative set up this year to look for alien life and supported by people including Stephen Hawking and Mark Zuckerberg — said that the message was promising. But they said that further work will have to be done before they can be "unequivocally attributed" to aliens. "The one in 10,000 objects with unusual spectra seen by Borra and Trottier are certainly worthy of additional study," the team said in a statement. "However, extraordinary claims require extraordinary evidence. It is too early to unequivocally attribute these purported signals to the activities of extraterrestrial civilisations. Internationally agreed-upon protocols for searches for evidence of advanced life beyond Earth require candidates to be confirmed by independent groups using their own telescopes, and for all natural explanations to be exhausted before invoking extraterrestrial agents as an explanation.

"Careful work must be undertaken to determine false positive rates, to rule out natural and instrumental explanations, and most importantly, to confirm detections using two or more independent telescopes."

THE INDEPENDENT

PLUS POINTS

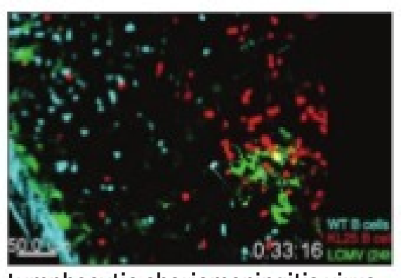
Culprit identified

Most viral infections trigger B cells to produce neutralising antibodies, but for a handful of viruses that cause chronic infections B cells are for some reason unable to do their job. The biggest driver for this suppression, at least for the mouse Lymphocytic Chorio-Meningitis Virus, turns out to be a group of cytokines collectively called type I interferon (IFN-I), according to three independent reports published on 21 October in Science Immunology.

"All of the three papers identified type IFN-I as the culprit," said Matteo Iannacone, an immunologist at the San Raffaele Scientific Institute in Milan, who co-authored one of the studies.

For decades, immunologists have used LCMV as a model system to study T cell-dominant immune responses because B cell production of virus-neutralising antibodies is absent or weak and delayed for several weeks. But because some human viruses, such as HIV and hepatitis B, also fail to induce strong antibody responses, Dorian McGavern, a viral immunologist at the National Institute of Neurological Disorders and Stroke, and others decided to use LCMV to find mechanisms behind B-cell failure.

McGavern's team started by injecting uninfected mice with B cells engineered to recognise LCMV, then exposed them to the virus. Within a week, the injected B cells disappeared from the animals' spleens. If the researchers waited until six days after infection to inject the B cells, however, the cells stuck around. In a separate study, Daniel Pinschewer, a virologist at the University of Basel similarly noticed a three-day "death zone" for LCMV-specific B cells.



Lymphocytic choriomeningitis virus-specific B cells (red) show restricted movement, directionality, and proliferation during chronic infection.

Both teams knew LCMV induces systemic production of high levels of IFN-I during the first few days of infection. "Type I IFN is the most important initiator of the alarm bell," said McGavern. "It is what drives immunity to viruses." But in the case of LCMV, the cytokine seems to have a bad side. When both teams blocked the IFN-I receptor before infection, numbers of LCMV-specific B cells shot up in the spleens of infected mice, allowing the animals to produce significantly higher levels of virus-neutralising antibodies.

To determine what caused the loss of B cells in response to IFN-I signalling, Pinschewer's team infected several types of knockout mice and found that myeloid cells, dendritic cells and T cells were all involved.

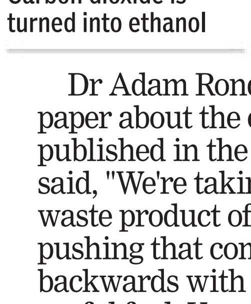
McGavern and his colleagues found that CD8+ T cells responded to IFN-I by killing off LCMV-specific B cells within the first few days of infection. Because CD8+ T cells typically take at least a week to respond to infection, McGavern said it was surprising to see them acting so early, but his team confirmed it by recording interactions between B and T cells in spleens and lymph nodes of the mice. "You have direct visual evidence that cytotoxic T lymphocytes can touch and kill B cells," he said.

According to McGavern's study, the key to losing LCMV-specific B cells is infection through the B cell receptor, which binds and internalizes the virus.

AMANDA B KEENER/THE SCIENTIST

Water into wine?

Scientists have accidentally discovered a way to reverse the combustion process, turning carbon dioxide back into a fuel. Researchers at the Oak Ridge National Laboratory in the USA used complex nanotechnology techniques to turn the dissolved gas into ethanol. Because the materials used are relatively cheap, they believe the process could be used in industrial processes, for example to store excess electricity generated by wind and solar power.



Carbon dioxide is turned into ethanol

The researchers had hoped the technique would turn carbon dioxide into methanol, but ethanol came out instead.

Dr Adam Rondinone, lead author of a paper about the experiment that was published in the journal ChemistrySelect, said, "We're taking carbon dioxide, a waste product of combustion, and we're pushing that combustion reaction backwards with very high selectivity to a useful fuel. You can use it (ethanol) in the current vehicle fleet, right now, with no modifications. Carbon dioxide is a problem right now. If we can use it, then we're preventing it from going into the atmosphere."

The team made a catalyst made from carbon, copper and nitrogen and an electric current was then used to trigger a reaction. They had expected the process to be much more complicated. "We discovered somewhat by accident that this material worked," Dr Rondinone said. "We were trying to study the first step of a proposed reaction when we realised that the catalyst was doing the entire reaction on its own. Ethanol was a surprise. It's extremely difficult to go straight from carbon dioxide to ethanol with a single catalyst."

IAN JOHNSTON/THE INDEPENDENT