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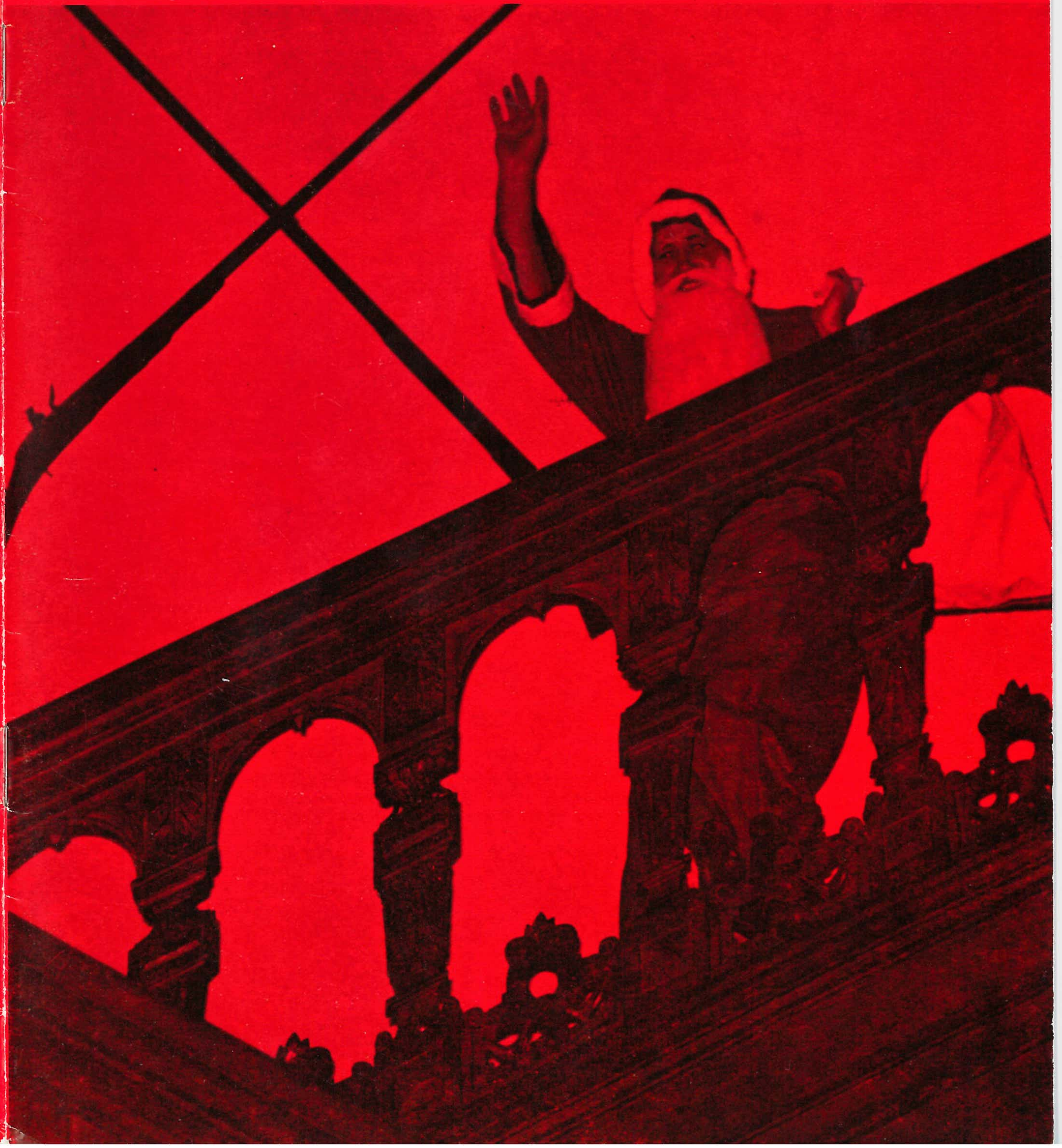

QUEST

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contents

Cover

Father Christmas, making a grand entry along the magnificent staircase at Herstmonceux castle, waves a cheery greeting to the expectant young guests at the annual party. photograph David Calvert

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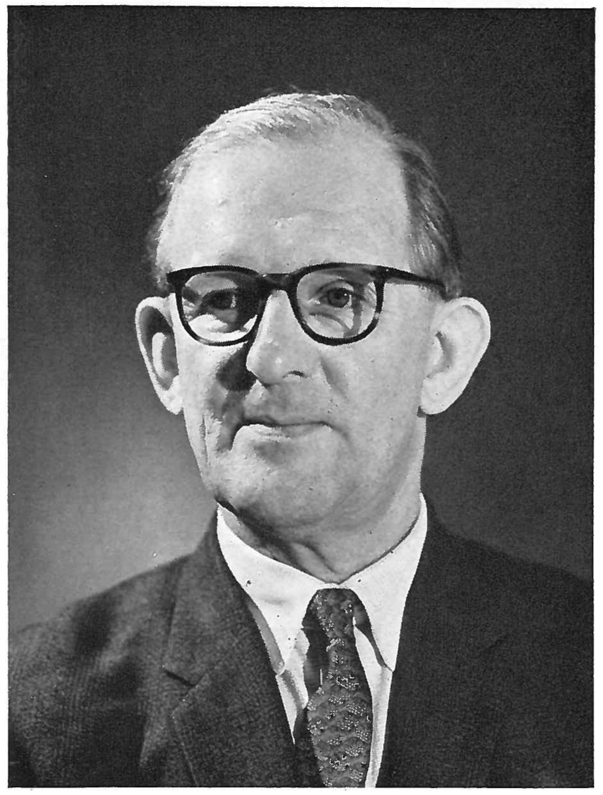
profile



A. F. Wilkins

Deputy Director,
Radio & Space Research Station

Mr. Wilkins retired in December so this is a farewell to a man, who with Watson-Watt and a small group of workers, was responsible for giving us what has often been claimed to be the most important discovery to come out of the Second World War . . . radar. It certainly saved the RAF from being overwhelmed by the Luftwaffe during those fateful days of the Battle of Britain and it paved the way to ultimate victory in 1945.

Born in Manchester in 1907, he was educated, first at Kings School, Chester, then at the City Grammar School where he obtained a Higher School Certificate in Maths, Physics, and Chemistry. He went to Manchester University at the age of seventeen and obtained a BSc in electrical engineering under Professor Miles Walker; then stayed on for another year before going to Cambridge for eighteen months on a research scholarship.

His only experience of private industry was with the Gramophone Company (now EMI) at Hayes, Middlesex in 1930 where he began a research programme on ultra-short waves (VHF) for that company's first venture into television. The programme was short-lived however, because within a matter of weeks, the directors decided to postpone the research in favour of more immediately profitable work.

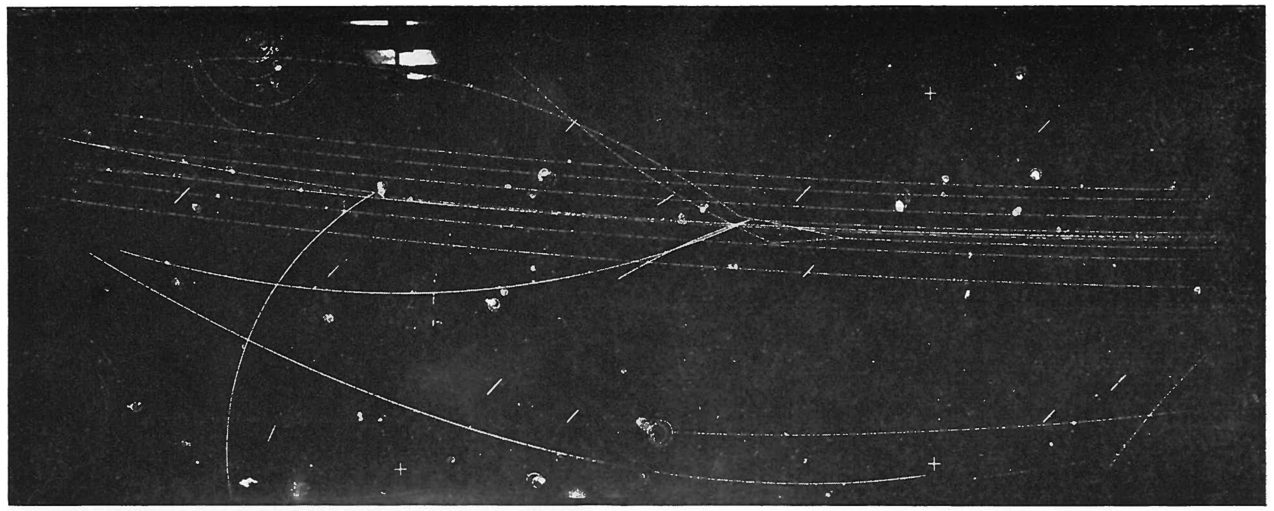
The Radio Research Station at nearby Slough offered the kind of atmosphere he was looking for, but he had to wait until the end of 1930 for a suitable vacancy. The meeting with Watson-Watt is briefly described in the article on page nine, but it must have been a surprise and a disappointment to learn that austerity was not confined only to the private sector. However, he was soon immersed in a study of HF propagation in conjunction with the GPO with apparatus which would soon figure prominently in other, more exciting work.

The highlight of Mr. Wilkins' career was undoubtedly his association with the birth of radar, but it is characteristic of him that in neither the article in this issue or in the previous 'History of the RSRS' in the second issue of Quest, does he amplify his own contributions to the discovery.

It all began when he found a note from Watson-Watt on his desk, written on the back of a desk tear-off calendar (Scotsman Watt didn't believe in wasting anything), which posed the question 'how much radiated energy would be required from a transmitter to raise the temperature of a man's blood to fever heat?' The Quest 2 article deals with the answer to this question, but the idea culminated in the now famous demonstration at Daventry and the eventual isolation in Bawdsey of the team which developed the idea into a workable system which was to be copied throughout the world.

For his part in the discovery of radar, Mr. Wilkins received an inventors award of £12,000.

Mr. Wilkins' hobbies are the study of the German language, metalworking, and gardening, in particular, the growing of cyclamen from seed and the culture of an American strain of tomato which reaches giant proportions and weighs up to about one and a quarter pounds. However, the serious pursuit of these pastimes will have to await the completion of the education of three daughters, until which time he will have to continue to suffer the inclement climate of Slough before he can change it for his beloved Suffolk.



particle physics . . . the ultimate structure of matter

An introduction to high energy physics
for non-scientists

R. E. Rand

Part 1. What is high energy physics?

motivation

Many readers of Quest must have wondered just what goes on in our high energy physics laboratories at Rutherford and Daresbury, and why large sums of money are spent on such apparently obscure research. This and a further article will attempt to answer these questions by giving a simplified account of the subject, but in sufficient detail to enable the reader to appreciate its implications. A typical experiment currently being performed at Daresbury will also be described.

High energy, or particle physics is concerned with the ultimate structure of matter. It is an entirely 'pure' field of research, conducted for the sake of knowledge itself and not for any immediate practical application, military or otherwise. It is true that a certain amount of technological know-how arises as a by-product of the research, but this alone would not justify its cost. The research is carried on nationally and internationally, with a free interchange of results and ideas between physicists of all nations. Such conditions are absolutely essential to the progress of the subject.

To understand why such fundamental research is worthwhile it is helpful to consider the benefits which we now derive from earlier branches of pure research; for example, the discovery of the principle of the electric generator by Faraday in 1832. As well as the obvious practical applications, research into the fundamental nature of electricity also led to the discovery of the electron and eventually to the whole field of electronics. It also contributed to the discovery of the structure of the atom and the subsequent research in atomic physics which produced such vital apparatus as the X-ray machine and more recently the laser, whose potential is only just being realised.

Research into the complexity of the atom led naturally to the discovery of the nucleus. The investigation of nuclear structure was initiated by Rutherford's famous theory of 1911, which was confirmed by the experiments of Geiger and Marsden in 1913. His work was ultimately responsible for the development of nuclear power, radio-isotopes for medical and other purposes, and indirectly for radiation therapy.

Thus we can reasonably expect to benefit eventually from the large amount of research now going on in high energy physics, the descendant of nuclear physics.

The following sections of this article form an introduction to the theoretical aspects of the subject in order that the non-scientist may understand the way in which the experimental research is conducted.

atomic physics

Let us first clarify the branch of physical science with which we are concerned.

All matter is made of submicroscopic particles called molecules and atoms. Molecules are the smallest possible particles of the substances known as compounds (e.g. water, carbon dioxide, plastics, etc.). Molecules are composed of atoms which are the fundamental particles of the elements (e.g. hydrogen, oxygen, carbon, iron, lead, etc.). The study of the interactions of atoms and molecules is called chemistry.

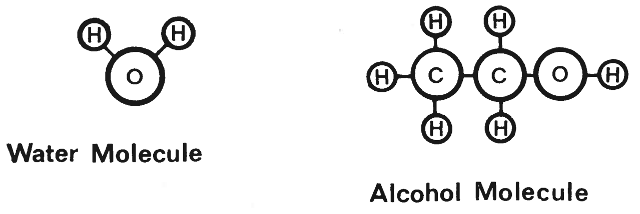


fig. 1 simple molecules

Atoms and simple molecules are approximately one hundredth of a millionth of a cm (10^{-8} cm) across. That is to say a line of atoms 10 cm long would contain 1,000,000,000 (10^9) atoms. If such a line could be magnified to the diameter of the earth (13,000 km), each atom would be about 1 cm in diameter. If we could see molecules with such a high magnification, we should see that they were composed of groups of atoms. For instance, the molecules of water (H_2O) and alcohol (C_2H_5OH) would appear as in fig. 1 where the atoms of hydrogen (H), oxygen (O) and carbon (C) are appropriately labelled.

The study of the structure of atoms is atomic physics. The simplest atom is that of hydrogen. It consists of a central nucleus, which contains most of the atomic mass, orbited by an electron as shown in fig. 2. This diagram is schematic and is not intended to be to scale.

The size of the atomic nucleus is only 1/10,000,000,000,000 (10^{-13}) cm. In order to 'see' it we would have to magnify our '1 cm' atom by a further 100,000 times. The nucleus would then appear to be about 1 cm across. The electron would probably appear to be much smaller. We do not yet know whether it has any size. Experiments of the type done at NINA may eventually settle this question. One can see that atoms and therefore matter itself are composed almost entirely of empty space (a rather surprising fact). The atoms of the elements are distinguished by the number of electrons they contain (e.g. Hydrogen 1, Helium 2, Oxygen 8, Uranium 92, etc.). Atoms are held together by electrical forces. We describe this by assigning to each electron a negative electric charge and to the nucleus a positive charge. The charge on the nucleus must be equal, but opposite in sign (ie, + ve) to the total charge of the electrons since we know that matter in bulk normally exhibits no electrostatic properties. The electrons are held in stable orbits by the electrostatic attraction between them and the nucleus. The interaction between atoms and molecules is also electrical in nature.

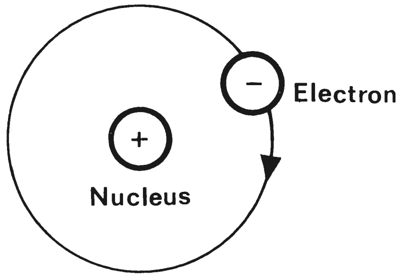


fig. 2 hydrogen atom

nuclear physics

The essential structure of nuclei has been known for about 30 years. The nucleus of hydrogen is a single elementary particle called a proton. It has a positive electric charge equal in magnitude to the electron charge and is 1836 times heavier than the electron. Other nuclei consist of protons plus an approximately equal number of neutrons. Neutrons have the same mass as protons but have no electric charge. Protons and neutrons are held together by 'nuclear' or 'strong' forces about which very little is known in spite of 30 years study. Protons and neutrons are known collectively as nucleons.

Atomic substances whose nuclei have the same number of protons but different numbers of neutrons are called isotopes of each other. For instance, the nuclei of the three isotopes of hydrogen all contain one proton but that of deuterium also has one neutron, while tritium has two neutrons. These varieties of hydrogen, or water made from them cannot be distinguished outside a laboratory.

Some isotopes are unstable and decay spontaneously into simpler nuclei while emitting electrons or other particles. This phenomenon is known as radio-activity. Very heavy nuclei such as uranium when struck by a free neutron or other particle, split up into two approximately equal nuclei, releasing a great amount of energy – the basis of nuclear power. This is known as fission and is distinct from radioactivity although the two are often confused. Note also that the energy of nuclear fission is popularly misnamed 'atomic energy' but actually has nothing to do with atomic structure. The term 'atom smasher' for an accelerator is similarly inaccurate.

high energy physics

The dividing line between nuclear and high energy or particle physics is a nebulous one. Nuclear physics is concerned with the way in which the nucleons are bound together to form nuclei, while high energy physics studies the structure of the nucleons themselves and of other particles which may be produced in high energy collisions, as well as the interactions between these particles. The 'strong' force is thought to be mainly responsible for the behaviour of both systems.

No conceivable microscope could ever 'see' these particles and so their interactions are studied by using accelerators which hurl the particles against each other at very high energies. The high energy physicist is concerned with the apparatus which detects and identifies the particles produced in such collisions and with the interpretation of the data thereby obtained.

forces

It is convenient at this point to consider the various forces known in nature and the laws which describe them.

(a) *gravitation*

The gravitational force is the most familiar in everyday life and surprisingly enough the weakest force known to physicists. For this reason it is very difficult to study experimentally. It is observed as a universal force of attraction between all masses. In the case of objects on the surface of the earth, this force is known as weight. This same force maintains the orbits of the planets around the Sun and of satellites around the Earth. The effects of gravity are generally best observed on an astronomical scale where electrical effects are negligible because of the electrical neutrality of matter in bulk. By studying the planetry orbits, Newton was able to show that gravitation obeyed an 'inverse square law'. This means, for instance, that the force between two objects a certain distance apart becomes four times weaker if the distance between them is doubled. Gravitational forces act between all fundamental particles but, being so much weaker than electrical and strong forces, are never observed in high energy physics.

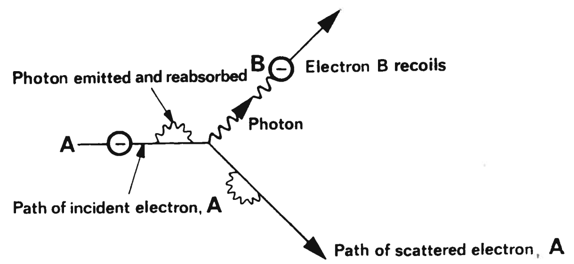


fig. 3 a collision between two electrons

(b) *electro-magnetic forces*

Electrical forces act between electric charges and can be attractive or repulsive. The charges are of two types labelled positive and negative. It is found that the force between similar charges is repulsive and between opposite charges attractive, the forces again obeying an inverse square law. This was originally established by Coulomb as early as 1785 using very simple apparatus by present day standards. As has already been mentioned it is now known that this force is responsible for holding atoms together, the electrons orbiting around the nucleus forming a minute 'solar system'.

The immense superiority of electrical over gravitational forces is illustrated by the fact that the mutual electrostatic repulsion between two protons is 10^{36} times stronger than the gravitational attraction. The electrical charges of most elementary particles, with which high energy physics is concerned, are equal in magnitude, but not necessarily in sign, except of course for neutral particles which have no charge.

Magnetic forces are identical in principle to electrical forces and arise whenever electrical charges are in relative motion.

The study of the spectra of light emitted by excited atoms has confirmed the inverse square law of electrical forces. However a more important result of such studies was the discovery of the quantum theory. Long before this, it was thought that whenever an electric charge underwent acceleration, it emitted light, an electromagnetic radiation. If this were always so, orbiting atomic electrons being in a state of continuous acceleration due to their constantly changing direction of motion would be expected to emit light continuously. Thus the atom would lose energy and collapse. Clearly this did not happen. The situation was clarified by Bohr in 1913, who proposed that atomic electrons could only be found in orbits of certain radii. Intermediate states were forbidden. Light was then emitted by an electron when, for some reason, it jumped from an outer orbit into a smaller one. This light was emitted in the form of a particle or 'photon' having a certain 'quantum' or packet of energy. The concept of the quantum had in fact been suggested earlier by Planck (1900) and by Einstein (1905). The frequency of the light wave was postulated to be directly proportional to the energy of the quantum. This theory as refined by Dirac and others has now been successful in explaining all known facts about the atom.

Thus, when an electron changes its state of motion it can emit a quantum of electromagnetic radiation, which travels at the velocity of light, and depending on the energy lost by the electron the radiation can take the form of a radiowave, light, X-ray or γ-ray (gamma-ray), all of which are identical in nature merely differing in frequency.

This emission of photons is also of great importance in explaining the mutual interaction between electrical charges. So far no explanation has been given of the mechanism by which forces can 'act at a distance'. Clearly some physical explanation is necessary if we are not to regard this as some sort of magic. Let us illustrate this point by considering the force between two electrons. Quantum theory tells us that as a free electron is moving along it is continually emitting and re-absorbing photons. Suppose a fast electron, A, moves close to another electron, B, as shown in fig. 3.

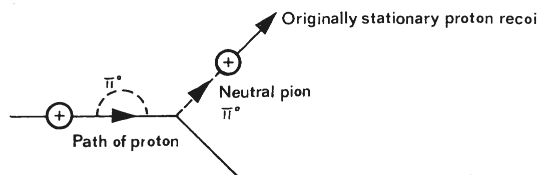
One of the photons emitted by the electron, A, may collide with the other electron, B. The net result of this is that electron A is deviated away from the photon, while the other electron, B, recoils in the direction of the photon, since for both the emission and the collision, the total momenta must remain constant. Thus if we observe only the two electrons they appear to collide and recoil from each other. We may say that this is due to the 'repulsive force' between them but in actual fact the electrons have interacted by 'exchanging' a photon.

(c) *strong or nuclear forces*

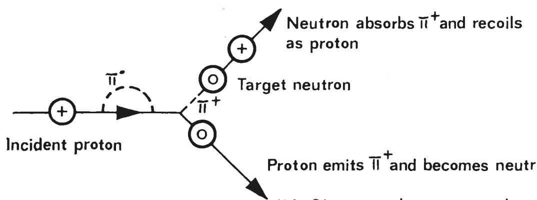
The 'strong' force which holds nuclei together is about 100 times stronger than the electrical force. It bears no similarity to the latter however, being effective only over a very short range of about 10^{-13} cm, the nucleon radius. Also it does not obey any simple law such as the inverse square law.

However, we may think of nuclear forces as being due to an exchange of particles. For the interaction between two nucleons the particle exchanged may be a pion. This particle having a mass about 273 times the electron mass plays a similar role in nuclear forces to that of the photon in the electromagnetic case. Thus a proton as it moves along continually emits and re-absorbs pions. A nearby proton may capture one of these pions and recoil as shown in fig. 4(a). Thus the protons appear to collide. In this case the particle exchanged is a neutral pion, represented by the symbol π°.

Now it is known that electrically charged pions also exist. This leads to an interesting possibility known as 'charge exchange' scattering. An example of this is shown in fig. 4(b) where the moving proton has emitted a positive pion, π^{+}, thus itself becoming a neutron. The π^{+} is absorbed by a neutron, in a nucleus, which now recoils as a proton. The original particles have exchanged their electrical charge.



(a) Proton–Proton scattering



(b) Charge exchange scattering

fig. 4

(d) *weak forces*

A fourth type of force is known in nature. This is the 'weak' force having a strength intermediate between the electrical and gravitational forces. It is responsible for a particular type of radioactivity known as β-decay (beta-decay) in which a nucleus emits an electron. The basic process involved is that a neutron in the nucleus 'decays' into a proton, an electron and a neutrino. The latter is an elusive particle having no mass and no charge and is almost unobservable. It is however of immense importance in high energy physics.

Another example of a weak decay is that of the electrically charged pion. For instance a charged pion can decay into a muon and a neutrino. The muon is a particle with exactly the same properties as the electron except that its mass is about 207 times greater. It is a great mystery why it exists at all as it seems to duplicate the role of the electron in nature. Many experiments in high energy physics are devoted to clarifying this point.

The muon itself is unstable and decays into an electron and two neutrinos. The muon is the chief observable constituent of cosmic rays at sea level. About 1000 muons pass through each of our bodies every minute.

the fundamental particles

High energy physics is the study of fundamental or elementary particles and their interactions. So far we have mentioned just a few of these particles; those which are most abundant in nature. They are the electron, photon, proton, neutron, pion, muon, and neutrino. Many other particles have also been discovered or predicted but there is space here only to mention them briefly. They come under the generic headings of 'mesons' and 'baryons', of which the simplest examples are respectively the pion and the nucleon. There is also the elusive quark, the predicted building block of all strongly interacting particles, but it is yet to be discovered. In addition, every particle is believed to have an 'antiparticle', which exhibits properties generally opposite to those of the particle itself. There are for instance positively charged anti-electrons or positrons and negative antiprotons. If a particle and its antiparticle collide they can annihilate each other, usually with the formation of energetic mesons or photons.

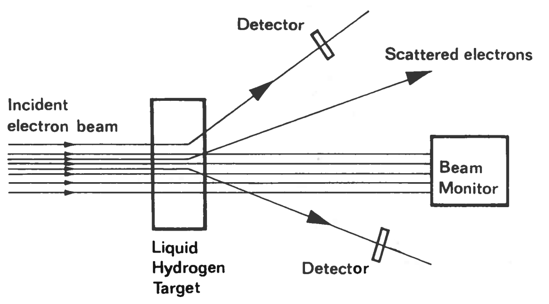


fig. 5 schematic electron scattering experiment

the basic tools of high energy physics

The discussion so far has been entirely abstract and detached from everyday experience. Just how can these particles be observed and studied and why do we need high energy accelerators for this purpose? The second question can be simply answered by an example. We can examine the structure of the proton by bombarding a liquid hydrogen target with a beam of electrons, as illustrated schematically in fig. 5. Most of the electrons will pass straight through the target since as we have seen, matter consists mostly of empty space. Some of the electrons however will scatter from the protons in the hydrogen and some from the electrons. We can distinguish between these two cases by measuring the momenta of the scattered electrons. By observing the angular distribution of the electrons scattered by protons we can deduce such quantities as the radius of the proton. Now in order for this determination to be accurate and sensitive to details of the proton structure, each electron must penetrate well inside a proton before it is scattered as shown in fig. 6. This can only occur if the electrons have sufficient energy. Similar considerations apply to other experiments: the incident particles must be of high energy in order to probe the details of the interaction under investigation.

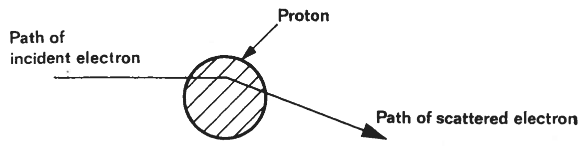


fig. 6 high energy electron scattering from a proton (magnified about 10^{13} times)

How do we detect electrons and other particles? The most common detector in use is the scintillation counter which works in the following manner. Whenever an electrically charged particle passes through matter, it collides with some of the atomic electrons in the material, and these become detached from their atoms. These atoms are said to be 'ionised'. After the passage of the particle, free electrons are recaptured by the 'ions' and in certain substances, known as scintillators, this process is accompanied by the emission of visible light. This light may be detected by an electronic device known as a photomultiplier and thus the passage of the original particle is recorded. By using an array of scintillation counters around a target, the angular distribution of the scattered particles may thus be determined.

The second part of this article will describe in more detail how a high energy physics experiment is devised, organized and conducted, with particular reference to an experiment now being performed at NINA.

stars

G. W. Ricketts

In this traditional season of pantomime, a retired member of the R.G.O. staff recalls how the advance party of staff amused their families (and themselves) twenty years ago when Herstmonceux was not the picture of immaculate orderliness we might know it to be.

Tweedledee falls foul of T'dum's (undercover) trick during the 1943 production of Little Red Riding Hood'. On stage, Mavis Gibson, John Bruce and Keith Jarrett.

For nearly three hundred years since its foundation in 1675, the Royal Greenwich Observatory has been responsible for the discovery and regular observation of the stars, but with the outbreak of war and the bombing of London, observations ceased and the telescopes were dismantled, packed up and put into safe storage.

When the war ended, the long-discussed move to Herstmonceux was put into effect and it is due to the circumstances connected with the removal that I am able to tell how, shortly before Christmas 1949 and for several years afterwards I had the good fortune to discover a number of personal ***'stars'***.

Before the castle and hutted accommodation could be used, much alteration and decoration was necessary, so that the 'Works' Department and Electrical Department, Chatham Dockyard were on the site together with locally recruited building operatives. In the late summer of 1948 the Astronomer Royal and Secretariat moved in followed by the Chronometer Depot to be joined a year later by the Nautical Almanac Office. There was a great shortage of houses and other accommodation and many members of the staff lived in the hostel in the Castle, which is about five miles from Hailsham and Bexhill and thirteen miles from Eastbourne. In order to combat this relative isolation, the Royal Observatory Sports and Social Club was formed to provide outlets for recreation and entertainment for those working at the castle.

In 1949 the club committee proposed that a Christmas party for children should be arranged; the programme to consist of games, tea and an entertainment, and I was asked to organise the entertainment. The average age of the children was such that I thought it would be a good idea to attempt to produce a pantomime. 'Cinderella' was my first choice and the staff were quick to respond so there was nothing for it but write a script, find a stage and scenery, cast the volunteer actors and produce Cinderella in time for the day.

I went into conclave with our typist, and started to dictate the story in the form of dialogue for the respective parts. I then called the first rehearsal in the clubhouse and gave out the scripts, explained that 'the stage is that area chalked out on the floor, the script is not too rigid and I am ready to consider anything that will help the show along'. So we started rehearsals in the hut which was used as the clubhouse. There were Baron Hardup, the Ugly Sisters, Cinderella, Prince Charming, Buttons, Fairy Godmother, Broker's men, Old Retainer (he was the Works dumper driver given the part so that he could recite a monologue), Courtiers and the front and rear parts of the pantomime Horse (on this we proposed to send Cinders to the ball, a coach being too ambitious at this stage of our history).

The next thing was to build a stage and construct sets, it was here that members of 'Works' and Electrical departments gave great help. We were given a double-section of flooring from one of the storage huts but as it was not big enough, the Leading-man of 'Works' told us to take another section, giving a stage of 18ft. by 12ft. A proscenium arch was constructed by the carpenters in their spare time from waste plasterboard and the painters converted the plasterboard into fluted pillars with scrollwork over the top and along the footlights. Electricians, resident in the hostel, employed their leisure making battens, floats and footlights, the reflectors being fashioned from empty fruit and jam tins obtained from the kitchen. They also had to make up a switch panel and wire up the circuits so that the stage lighting could be varied as required. All that was lacking were the curtains and the hostel warden came to our help with the loan of eight single quilts, Admiralty pattern decorated with foul anchor, which were machined together in batches of four, just sufficient to cover the front of the stage.

Rehearsals went ahead with enthusiasm to the accompaniment of a poor piano, backed-up by a piano accordian, but singers sometimes had difficulty in agreeing on a suitable key and maintaining it throughout their number. However we reached the evening fixed for the dress rehearsal and the try-on of hired costumes only to find that the costume for Buttons had not been included. As he had been most self-conscious on stage it was essential that he should be dressed up for the performance. We managed to contact the supplier and arrange for the dresses to be sent to Herstmonceux by bus the next day. They arrived shortly before the show was due to start and it literally ***made*** Buttons and contributed largely to the success of the afternoon.

So ended the first show and it began a tradition that was to improve and continue for some ten years. After Cinderella came Jack and the Beanstalk, Dick Whittington, Aladdin, Babes in the Wood, Red Riding Hood, Robin Hood, Ali Baba and the Forty Thieves, and also Snow-White and the Seven Dwarfs. All these called for better lighting effects, additional props and scenery, seating, and more efficient scene changing and make-up. Willing volunteers came forward for this and also to provide a small orchestra so that the length of the performances grew from the original half-hour to over an hour and a half. A very professional 'lights' outfit was permanently mounted on a platform built over the double doors at the back of the hall which enabled the electricians to make such lighting changes and effects as the script demanded.

Throughout the series the scripts were written at the castle and they followed closely the original stories known to the children, although topical and local material was included. It was essential to find appropriate songs and on one occasion this meant a letter being sent to the BBC to obtain the source of origin of 'Busy doing nothing' and to Charing Cross Road for 'D'you want any dirty work done'. Our principal girls and boys were often as sparkling as professional actors but in the producer's view too bashful until encouraged to 'let their hair down'. The script was always written to include a song which could be sung competitively by separate groups of the audience, but which would first be introduced by the Dame, the Villains or by the Leader of the Slapstick. This, of course, called for frantic urging to greater effort on the part of the audience 'to lift the roof, because the huts have got to come down', and if noise could have done so, the roof would surely have fallen. Sometimes there were places for a few dance steps but this was not considered our strong suit.

We soon appreciated that we were rather selfish in restricting the performances to the children of club members, and so an invitation was addressed to the Headmistress of the village school for the children to attend a special performance after school on the Monday following our own Children's party. The invitation was accepted and an audience of about 170 scholars came each year by public transport and hired coach and, with the addition of Castle staff who stayed after hours to see the show, an enjoyable and noisy time was again spent in the clubhouse.

Thinking of these visits I recall the occasion when a double-decker Southdown bus became stuck under the central-heating supply pipes which crossed the approach road, badly denting the roof of the bus and trapping the vehicle in the South courtyard. Apparently the approach road had been resurfaced during the year and was six inches higher than on previous occasions.

The invitation to the castle pantomime was always awaited with keen anticipation but on our part I must say how we enjoyed reading the tremendous bundle of essays which had been written by the children from five to eleven years of age. The bundle was split up and circulated through the offices and the uninhibited and often amusing comments on every feature connected with the pantomime expressed in word, or in the drawings of the younger ones, were ample reward for the entertainment we had provided.

the birth of radar

A large scale radar 'photoplot' of the Thames estuary

Photograph by courtesy of Kelvin Hughes

some random recollections of
38 years of radio research

A. F. Wilkins

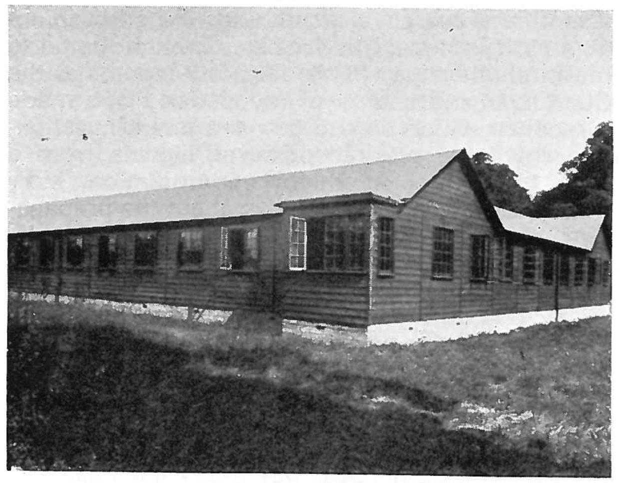
When I reported for duty at the Radio Research Station on 1st January 1931 my first impressions were of austerity, but this was nothing new, for I had experienced shortages of funds in university, and the firm whose research department I had just left was in such low financial water that much of the research, including my own, had been scrapped in favour of more immediately lucrative work.

I found the Superintendent, Mr. Watson-Watt, sitting at his desk in a sparsely furnished office in a big wooden hut which had been built a few years previously to replace earlier buildings destroyed by fire. I discovered subsequently that the hut was not of his choosing; as he said in his note to the Radio Research Board, the life of such buildings was 'only a few years', but the Board had decided on the hut in preference to more expensive alternatives and, moreover they had stipulated that its cost should not be more than £1,700 inclusive of heating and lighting installations. Only one member of that Board survives and he would probably not be very interested to learn that this building is still in good condition and in full use.

I mention all this because it was my introduction to the austerity which then prevailed in Government research establishments, due largely to the serious economic difficulties in which the country found itself but also, no doubt, because scientific research was nothing like so fashionable as it is now. This fact was brought home to me in another way in my first few months at the Station. In the course of my duties I had made a receiver which was to be used in an investigation involving the reception of signals from a VHF transmitter at Rugby radio station. Very little was known in those days about the propagation of such waves. Reception was generally considered to be possible only when there was an optical path to the transmitter and, on two visits to the Rugby area in the Station van with my receiver, this appeared to be the case. On the second visit, however, I thought it might be interesting to carry on from the point at which the signals failed and see what happened. Arriving at Evesham I found it possible to drive up to the top of Bredon Hill and when the gear had been set up, the Rugby signal was audible at good strength. The interesting fact was that the strength diminished in the middle of the day and rose in the evening, even though the transmitter output remained constant, and there were also signs of shorter period fading. On returning to the Station I reported my observations to Watson-Watt and suggested timidly that further investigation of the observations might be worth while. I was surprised to be told that, not only was there not enough money for such an investigation, but the Station could not even afford the cost of another trip to Bredon Hill.

In spite of this shortage of money, life at the Station was very pleasant and some important work was done. The knowledge acquired and techniques developed in those days became of practical value in 1935 onwards during the development of radar. My own part in the experiment which started radar in this country has been described in 'Quest' Vol. 1, No. 2 by G. W. Gardiner. The observations on the Daventry signals must seem footling to present-day television viewers who can witness the same phenomenon every time an aircraft passes overhead. But in those days the effect had not been observed in this country except by Post Office engineers and they just dismissed it as a nuisance. My elementary calculations had shown what to expect and I was naturally delighted to find that they were borne out in practice.

The two or three years which followed this Daventry experiment were some of the happiest of my life. After a few months' preparation at Slough a few of us went away to Orfordness in May 1935 to attempt to demonstrate to the Air Ministry that the proposals made to them by Watson-Watt were really practical ones and not pious hopes. But we had little or no money available for apparatus and the main equipment we took with us included a rudimentary pulse transmitter, one of our 'standard' ionospheric receivers, a cathode-ray oscilloscope, two heterodyne wavemeters and sundry ammeters and voltmeters. Some cast-off instruments were given to us by the Electricity Department of NPL, but they were soon consigned to the mud-flats of the river Ore somewhere near where the avocets started breeding some years ago. Because of this lack of apparatus a good deal of improvisation was necessary and also a good deal of thought to decide what could be done with the available gear. I remember, for example, how keen we were in our first week at Orfordness to discover the resonance frequencies of various aircraft and how I did the job on a Virginia bomber and on the then very hush-hush Sunderland with the aid of the two wavemeters and a pair of headphones.


The wooden hut; the Superintendent's office is the bay windowed room

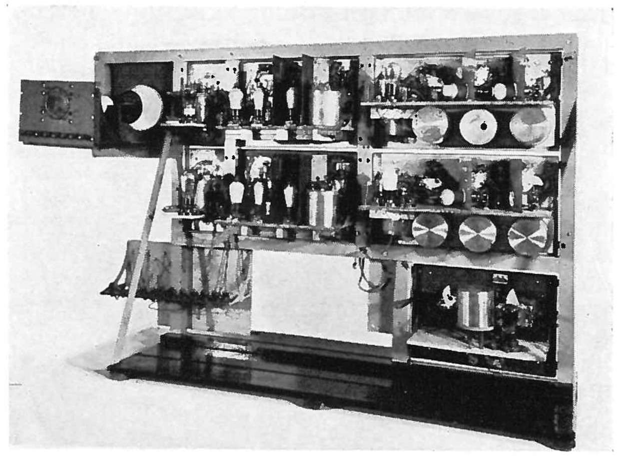
In those days report writing was frowned upon and the only report we produced was a daily statement containing a few words on the day's results which I conveyed to Watson-Watt nightly by telephone in a rather elementary secret code.

In the first few months at Orfordness our main concern was to improve the power output of our transmitter and the performance of our receiver so that aircraft echoes could be obtained at the greatest possible range. To help our researches a standard test flight from Orford to Bircham Newton in Norfolk and back at 15,000 feet was performed for us by the pilots at Martlesham. This was of course, a very boring job for the pilots and one excellent sergeant pilot sitting in his cockpit pondered over the cover story we had given him and his colleagues that we were trying to detect aircraft by picking up the radio interference radiated by their ignition systems. He argued, very sensibly, that so much care had been taken to screen these systems, that he could not hear any interference on his own radio receiver situated only a few feet away, so that either our gear was unusually sensitive or else the official story was bluff – and he leaned towards the latter view. One day when he was fifteen miles from Orford on the return leg of his test flight he switched off his engine and glided as far as he could. On reporting to us, he enquired whether the test had gone well and, on being told that he had done an excellent job he returned immediately to the Sergeants' mess at Martlesham where, with liquid refreshment, his discovery was announced to his colleagues. We did not bother to invent a cover story after that.

During the summer of 1935 we achieved some success with our crude equipment and began to agitate for something better. The Air Ministry was asked for £10,000, a considerable sum in those days and one not readily come by in the financial climate of the time. There was much argument about the wisdom of spending so much money on a defensive device instead of trying to find an offensive weapon, but the money was ultimately given to us and the progress became such that we soon needed larger accommodation. It was then that I suggested to Watson-Watt that he should look at a manor house situated in an isolated position at the mouth of the river Deben and with very useful grounds attached. When a colleague and I had 'discovered' this place in our first week in Suffolk we commented on how suitable it would be for our work. Watson-Watt fell in love with the house on his first visit and, when the 'Works' people subsequently made enquiries they found that the owner was not only willing but anxious to sell, and so we acquired what was, I maintain, the perfect place in which to work. Being situated right on the sea coast and close to Martlesham and Felixstowe air stations which supplied test flights it was ideal for radar purposes (and also for bathing in the lunch hour). The grounds of the manor were excellent for accommodating the various experiments in progress and also for raising fruit and vegetables for use in the mess. Some of us became knowledgeable in the culture, in the large greenhouses, of lemons, nectarines, peaches and grapes, some of which were sold to help the mess funds. Our offices in the manor were of an unusually luxurious kind; Watson-Watt moved from his spartan quarters at Ditton Park into a splendid oak-panelled room with tooled leather-covered walls but furnished somewhat incongruously, with Air Ministry furniture.

By the time we occupied the manor, radar development, although rudimentary, was beginning to arouse great interest among defence chiefs and politicians, and we were constantly being required to stage demonstrations for their benefit. Scores of brass hats, cabinet ministers and very senior civil servants must have studied the face of the cathode ray tube in a room in the stable block with its teak-lined walls still showing signs of the hooves of its former occupants. Many of these visitors were voted a waste of time by most of us, but we had two favourites who were notable exceptions. These were Lord Swinton, the Secretary of State for Air at the time, who had an engineering background and had a lively appreciation of everything we were doing, and Air Chief Marshal Sir Philip Joubert who had profound faith in our work and whose enthusiasm was infectious. Apart from the Tizard Committee very few scientists came our way, indeed discussion of the work outside the manor was forbidden and a breach of this instruction would have landed us smartly in the Tower. I remember the visit of Lord Rutherford in about 1937 because it was he who suggested the use of aerials hung from a captive balloon as a means of testing and calibrating our apparatus. This was found to be an excellent suggestion and up to the outbreak of war we used two balloons towed round the coast by small chartered vessels for calibrating the coastal chain of radar stations.

One of our first successes at the manor was to track a single Hart aircraft flying at 15,000 feet from Bawdsey to Skegness, a distance of about 80 miles. This success was achieved just before the Air Council were due to discuss the desirability of building more of the large concrete coastal sound locators which, although of very poor performance, were the only means of detecting and locating approaching aircraft before the advent of radar. We were very pleased with ourselves when we learnt that our success had caused the Council to drop their proposals and no more of these devices were ever built.


The original radio receiver (rear view).
This is the equipment used by Watson-Watt and Wilkins in the historical experiment on February 26, 1935 which demonstrated that radio echoes of measurable intensity could be received from an aircraft in flight.
Science Museum photograph

Up to the summer of 1936, our work had been mostly successful but in August of that year the first big failure occurred. Radar was needed so badly that we were being continually pressed to undertake new work before the old had been properly consolidated. In late 1935 the Air Council made a decision which, in retrospect, is amazing but which illustrates vividly the urgency of the need for radar. This decision was to build a chain of five stations across the Thames estuary as part of the air defences of London and it was taken before even a prototype station existed; there were, indeed, only the very haziest ideas as to how direction finding was to be done. Bawdsey was to be one station in the chain and I selected the other four between it and Dover with the help of 'Works' people. Arrangements had been made over-optimistically for Bawdsey to take part in the August air exercises of 1936 using new apparatus with aerials built on 240 ft. high wooden towers. The towers were not, in fact, completed by the end of the exercises but it had been possible to instal the aerials while the contractors were at work. No real test of the whole installation had been possible before the exercises began and it was not surprising, therefore, that little or nothing was seen on our cathode ray tubes during the early phases of the exercise. Performance improved in the latter part of the exercise but was not distinguished.

After a severe telling-off from Tizard in which he placed the responsibility for the successful air defence of the country firmly on our shoulders we got down to business in a big way to develop a really good installation at Bawdsey in readiness for another test the following April.

Although the exercises had not gone well, the building up of the research and development staff continued. The original few DSIR workers were invited to transfer to the Air Ministry in 1936 and this we did with considerable reluctance as we appreciated the lack of red tape in the DSIR and our experiences of this phenomenon with the Air Ministry had made us feel anything but happy.

The air exercises of April 1937 redeemed our reputation in quite a big way and the many brass hats who visited Bawdsey were highly pleased with what they saw. Formations of six aircraft making dummy bombing raids on London were located at ranges of up to 100 miles, bearings and heights were measured with good accuracy, and a rudimentary aircraft identification system operated with promise.

I well remember how one young Flight Lieutenant was introduced to the wonders of radar during these exercises. He was a flying boat captain who had been ordered to fly his aircraft on a round-the-lightships trip from Felixstowe so that we could demonstrate to Sir Philip Joubert how clever we had become in locating and plotting aircraft tracks. The Flight Lieutenant had been requested to fly to the North Hinder lightship and turn for home but we strongly suspected that he wanted to get back to the mess early and he was subsequently plotted as turning at the Galloper, a lightship at much shorter range. The dressing down he later received from Joubert, in addition to convincing him of the error of his ways in trying to deceive a very senior officer, resulted in rather better quality service in later test flights, but I did not discover how long it took him to find out how we knew.

While radar research and development at Bawdsey proceeded apace in the years immediately before the outbreak of war, my most important duties concerned the planning and putting into operation of the coastal chain. When Mr. Chamberlain made his well-known 'peace in our time' speech on returning from Munich in 1938 it meant anything but peace for us at Bawdsey. It was obvious that war was imminent and we had to redouble our efforts to have our stations ready in time. We remembered that Tizard had made it clear to us that the Royal Air Force would be outnumbered by the Luftwaffe and must depend for success on the more efficient use of its aircraft; radar would be the means of doing this. I clearly remember him saying after we had once given him a particularly convincing demonstration that, in his view, radar would be equivalent to an increase of five times in the fighter strength of the RAF. We needed no more encouragement to get on with the job.

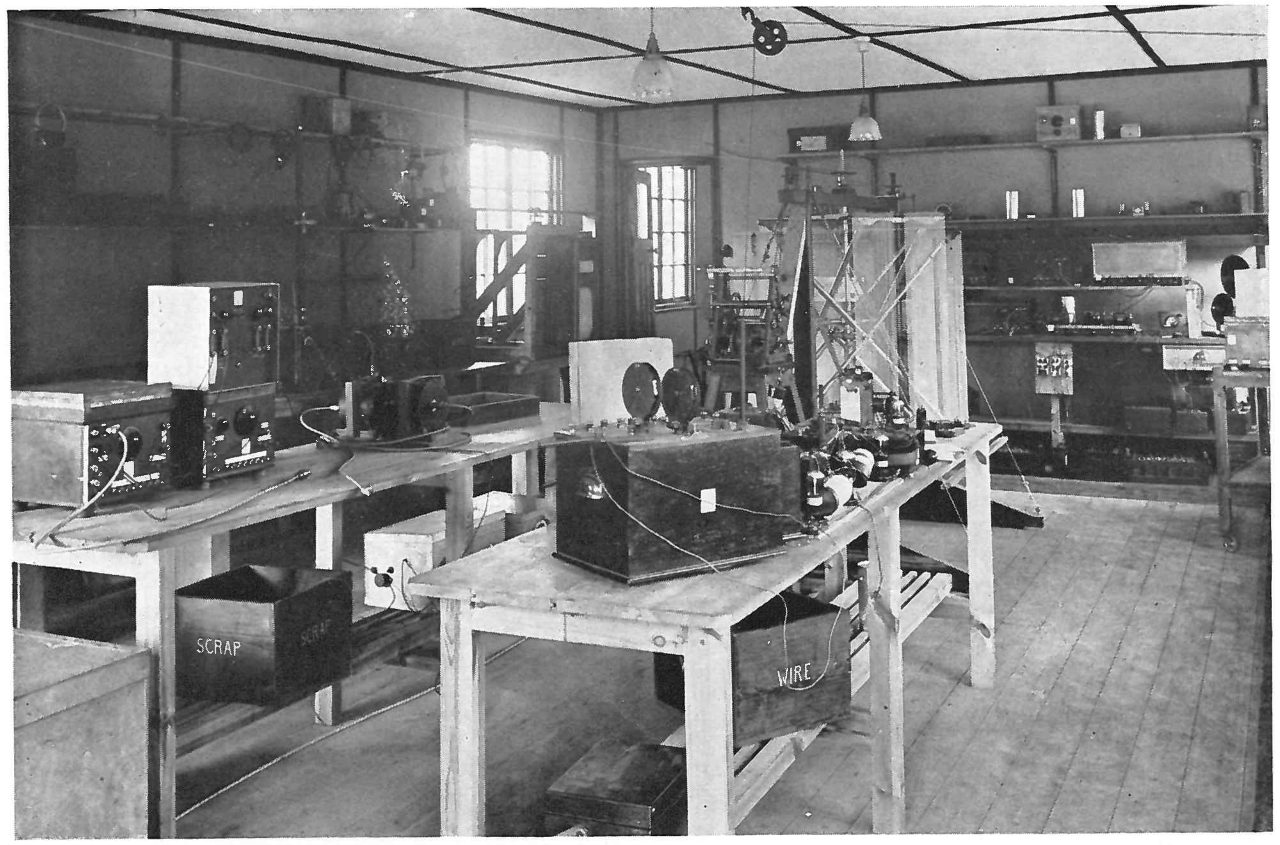
After the excitement of September 1938 had subsided and the hurriedly-built temporary coastal stations had started their 24-hour watch, we returned to the installation of what we optimistically called the 'final chain'. This was incomplete at the outbreak of war but, thanks to the 'phoney war', it was ready in time for the Battle of Britain. For much of the day battles I had a ringside seat because I was making a tour of inspection of the 'chain' at the time and during the night battles I spent a month or so in operating the recently-installed gear at the station at Pevensey, not far from the present home of the Royal Greenwich Observatory. We were doing our best to bring about interceptions of the enemy bombers which crossed the coast overhead each night on their way to London. Although we brought our fighters to the point of opening fire on, I think, two occasions the final result when I left the station was one British fighter lost for no score. These were pioneering efforts at night interception and the radar, both ground and airborne, and the fighters were then quite inadequate.

My experiences during the Battle of Britain demonstrated to me that the study of the problems arising in the use of equipment in the field was of an importance at least as great as that of developing more ironmongery. I was transferred to such work at the beginning of 1941, firstly at the Air Ministry under Watson-Watt, then at Fighter Command Headquarters, and then to Sir Keith Park's headquarters in Ceylon where I was in charge of the Operational Research Section when the war ended. The work we did for Sir Keith Park was nothing if not varied. We investigated such matters as the efficiency of the airlift over 'The Hump' into China; the most effective way of administering napalm to the Japanese troops in their slit trenches; and after the end of the war we even tried to put some science into the process of repatriating the troops through Bombay.

When we heard of the dropping of atomic bombs on Japan, nothing was further from our minds than the ethics of the matter. It only meant that the war would soon be over and we could go home.

I returned home at the end of 1945 by way of Delhi where a pleasant reminder of the happy days at Orfordness was my chance meeting with the sergeant who switched off his engine and glided to a landing. He had risen to the rank of Group Captain and was in command of the air station at which I had landed.

Before going to Ceylon, Sir Edward Appleton had told me of his plans for the expansion of radio research in the DSIR after the war. A new station was to be built and a good deal of new work was to be taken over from other civil departments. The prospect was very exciting and, as by 1945 I had had my fill of military science, I investigated the possibilities of a return to Ditton Park. The machinery in the respective Establishment Offices worked slowly and cautiously and it was not until April 1946 that I once again entered that wooden hut in the park that seemed so peaceful in 1931. But it was rather less peaceful in 1946; housing had spread along the northern and southern boundaries of the land occupied by the station and there were two airfields nearby. The station and the former Wireless Division of NPL had merged in 1933, but they continued to operate as separate entities whilst a search was made to find a suitable site for the new Radio Research Station.



A typical laboratory at the Radio Research Station in the early 1930's

It was ultimately decided to build the new station in Ditton Park, but before building could begin, proposals to build a new housing estate on the western side of the park had to be defeated, as had also a suggestion that the M4 motorway should be run more or less through the centre of the park.

The new buildings were completed in 1956 and, after the cramped quarters of the timber huts, seemed to be exceedingly spacious. This feeling gradually disappeared with the increase of staff until, today, the main station buildings would be bursting at the seams had we not reopened the old hut and built more like it.

The staff is now almost exactly ten times as numerous as in 1931, and the annual expenditure much greater than that. Research as is well known, is a very expensive undertaking and the day is long since past when important results could be obtained with a crude wireless set connected to a galvanometer. Nowadays we seem to require very complex apparatus costing, sometimes, tens of thousands of pounds. We may put it into a satellite which, after a few orbits of the earth, will have produced so many observations that the old slide-rule and pencil analysis is useless and an expensive computer is necessary to unravel them.

Such is progress. I have seen plenty of it during my time at Ditton Park. No one knows what the future will bring, but whatever it is, I trust that the staff of the station will enjoy their work as much as I have done during the past thirty eight years.

science: another bothering year

This is a complete transcription of a document found last week under the back seat of a taxi near St. Pancras. It appears to be an early draft of an annual report by a scientific director and contains some overwritten passages. Unfortunately the name of the institution is not recorded but, since the document appeared to have been in the taxi only a short time, the events presumably relate to the current year.

The first three months of the year under review were devoted to preparing a detailed case to the Book Research Council for the purchase of a book for our library. The application for a grant for this purpose was rejected on the grounds that we already had a book in our library, and that in any case it would duplicate books being read in other institutions. In view of these facts the BRC expressed regret that we should have thought fit to submit this application. It is gratifying to report, however, that the buildings subcommittee of BRC decided to make a grant of £750,000 towards a new library. Almost half this cost is accounted for by a splendid architectural feature comprising three large goldplated balls. These are supported above the roof in a triangular array by means of fibre-reinforced columns so slender that they appear to be floating. This fine example of creative co-operation between architect and engineer dominates the landscape for several miles around, especially when the feature is floodlit at night.

The purchase of a further Nissen hut to house our Plasma Project has unfortunately had to be deferred once again owing to the expense involved, but by installing a second floor in the existing hut and by bending or kneeling when at work the staff have found it perfectly possible to continue.

It has been once again necessary to remind scientific staff that the 17 administrative typists are heavily loaded and cannot be released for other duties. Where reports or papers for publication have to be submitted in typescript, scientists must realise their duty to type these themselves or else have them done privately at their own expense.

It was again necessary to defer the request from Dr. Brown-Jones for a technical assistant. This scientist had complained that his experiments require uninterrupted runs of five days each, and that his health was being affected by the need to stay awake continuously over such periods. Although the need for economy was carefully explained to him, he adopted an uncooperative attitude and it was necessary to allow him to resign. He has since emigrated, and claims that his new employers have built him a computer-controlled apparatus which enables measurements to be made much more quickly and accurately, as well as providing him with a team of five qualified assistants.

It is natural justice, however, that he is, according to reliable reports, having difficulty in maintaining the pH of his swimming-pool within acceptable limits owing to its inordinate size.

Before his departure, Dr. Brown-Jones claimed to be near to an important discovery. To have the best advice, this matter was referred to a leading authority who had laid the foundations of the subject before the 1914–18 war. He immediately discounted Dr. Brown-Jones's claims, pointing out that a more promising line had been suggested by himself as long ago as 1923, and had still not been properly followed up. This authoritative statement should serve to kill, once and for all, the quite unjustified rumours that the value of the work of this member of our scientific staff had not been fully appreciated, and that, as a result, an important breakthrough had been lost to the country.

A number of research projects are continuing satisfactorily along the lines mentioned in last year's report, but the promising special project on hazards to children's health through certain industrial dusts has been terminated because of pressure from the Whitewash Development Authority. *(The last phrase is deleted in pencil and overwritten 'because of pressure of other work'. This is again deleted and replaced by 'because of unsatisfactory results'.)* However, negotiations have now been initiated for a substantial grant towards a project on the behaviour of dust particles in uranium mines, a topic judged to be of greater public interest.

It is gratifying to be able to end this report on a happier note. We have just received confirmation of a grant of £75,000 over three years for research on the effect of British synthetic fibre seam textures on the flight of a cricket ball. Advertisements for a suitable bowler have already appeared, and it is hoped to make an appointment shortly.

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'. . . and there's my daughter at University, please keep her safe. Oh, surely you know what I mean . . .'

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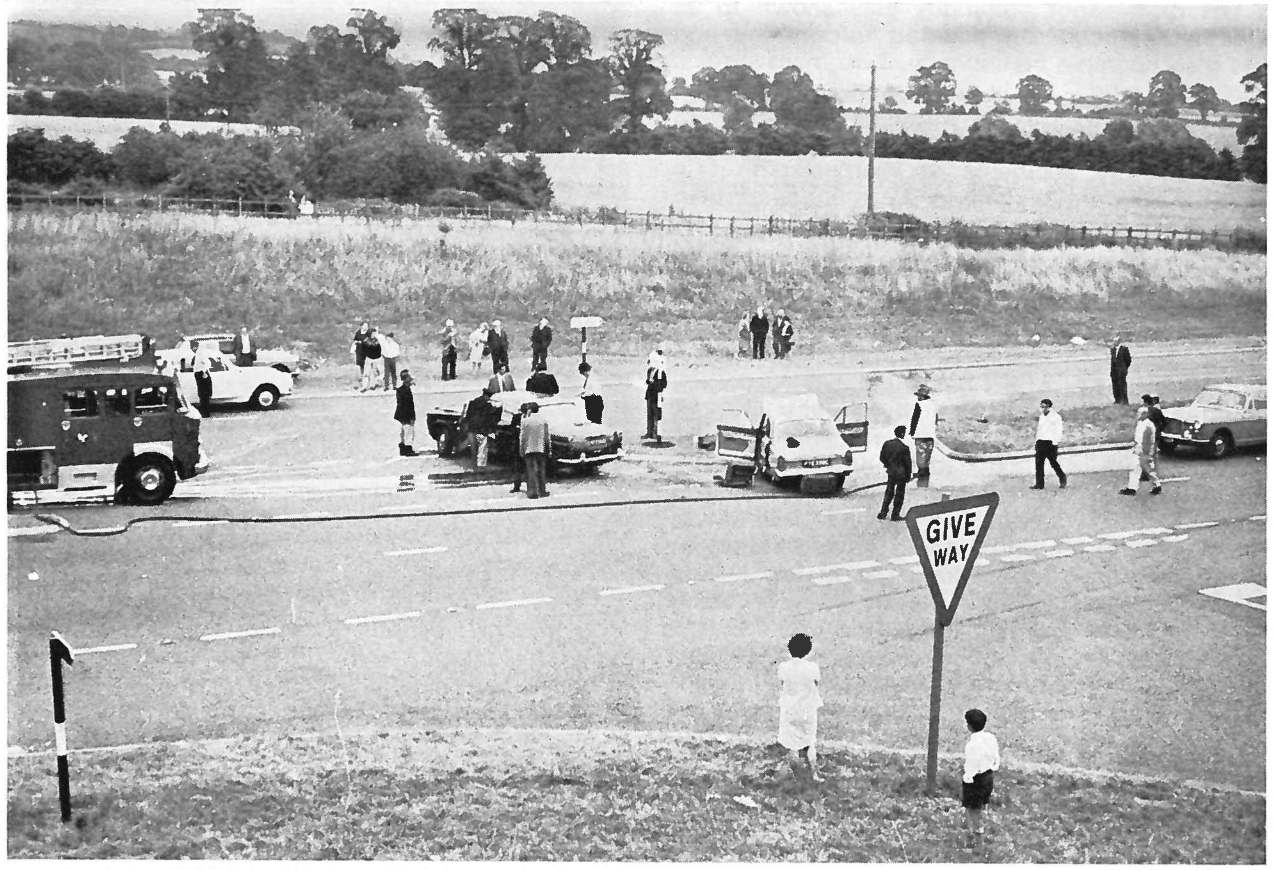


road accident research at Birmingham University

G. M. Mackay, PhD

One of the results of this study by a four-man team of surgeon, psychologist, traffic engineer, and automobile engineer, seems to bear out the commonly held theory that most road accidents are caused by people who drive too quickly and without sufficient concentration.

In 1965 the Science Research Council awarded a grant to the Department of Transportation and Environmental Planning to establish an interdisciplinary team which would examine road accidents in detail. The initial brief was to investigate the possibilities of using an on-the-spot technique in which the research team would go to accidents within a few minutes of their occurrence and collect as much data as possible at first hand. Two main problems had to be overcome; first the team had to be on-the-spot physically within some fifteen to thirty minutes, otherwise post-accident events result in vital information being lost; second, the sample of accidents examined had to be representative statistically of the environment which was being studied.

The first problem was overcome by the outstanding co-operation of the Birmingham City Police and latterly the West Mercia Police when the rural study was undertaken. In spite of the extra work involved, these police forces agreed to inform the author of the occurrence of accidents in a designated area as soon as a '999' call was received. This was done either by special GPO line or over the police radio network – the project car being specially equipped. Thus the research team was able to be at the scene at the same time (and sometimes before) the normal emergency services and to collect all the information at first hand.

The second problem, that of statistical sampling, was overcome by organising a rotating schedule of on-call periods which over the period of the study resulted in equal sampling seven days a week 17 hours a day. The midnight to 7 a.m. period was not sampled because the number of accidents in that time is small and our manpower was better employed examining accidents at busier times. This did result however, in some sample bias.

The on-the-spot technique was shown to be effective in acquiring detailed information and was also operable statistically. Two main studies then developed – firstly an examination of urban accidents in the City of Birmingham; 425 were visited in a two year period, and secondly rural and motorway accidents in Worcestershire; in which 221 were visited in 12 months of field work. Each sample was some 10% of the total number of accidents in the project area.

At the scene the team would examine the vehicles and the location, taking many photographs, particularly of detailed vehicle damage which gives an indication of the sources of injury. Witnesses and involved but uninjured road users would be interviewed informally. Follow up visits by the surgeon to the injured in hospital, by the psychologist to drivers in their homes and by the mechanical engineer to examine the vehicles in detail at garages would then be made, often with return visits to the scene being needed before an accurate reconstruction could be made. It was found necessary to limit the depth with which each accident was investigated in order that a large enough sample of accidents could be examined to be representative of the area studied, although very thorough investigations proved to be of great interest.

The results of these field studies are still being analysed but this article outlines some of the areas of interest.

traffic engineering factors in causation

Road accidents may be considered as arising out of the interaction of a large number of variables which have differing degrees of interdependence. For conceptual convenience these may be grouped under environmental, vehicular and road user areas. The following table shows the relative frequency with which these areas combine together :

causal deficiencies	*%*
Environmental/vehicle/road user factors	16.4
Environmental/vehicle factors	4.8
Environmental/road user factors	48.8
Vehicle/road user factors	7.2
Environmental factors	5.6
Vehicle factors	4.8
Road user factors	12.4
	100.0

Findings to date show that environmental deficiencies play a significant part in causation although often these cannot be assessed independently of road user error. This is particularly so in urban areas where 'background' or 'passive' variables such as poor housing cannot be adequately assessed in a quantitative way.

The traffic engineering analysis has been based primarily on accident location, and design variables associated with different locations have been compared with accepted or defined standards of engineering practice to determine the existence of deficiencies which may or may not be causal.

fig 1 The project vehicle, equipped with radio telephone, cameras, first aid equipment, wrecking gear, special lights and warning strips for night accidents.

In the urban survey particular emphasis has been placed on pedestrian accidents, which constituted some 22% of all the urban accidents, and their relationship to land usage and socio-economic characteristics. The results show that for the under five age group, environment is of major importance – all accidents occurring in low income, high population density areas, although in part this is due to the high density of under fives in those areas. This result is not demonstrated for other age groups where the detailed physical character of the environment plays a more significant role. For all pedestrian accidents the presence of parked vehicles is a main contributing factor (34% of accidents) but in the low income high density areas this again becomes more important – being a factor in 50% of pedestrian accidents in those areas.

Studies of accidents related to pedestrian mobility, expressed by the distance from home to accident site, have shown that for under fives all were injured with 400 yards of home or less. As age increases so too does the proportion of accidents occurring at greater distances from home except for the over 65 age group where the trend is reversed. 60% of all pedestrian accidents occur within half a mile of the pedestrian's home.

The analysis of vehicular accidents complements existing results as far as location is concerned but several causal factors relative to design are emerging which deserve attention. Lack of superelevation (or banking) on urban roads is such an example and this was considered to be of importance in 20% of those accidents occurring at bends. Similarly skid resistance values at traffic signals and pedestrian crossings were found to be extremely low in a number of cases, and whilst in an overall sense this was not significant it is an example of a causal factor which would not be unearthed by other than 'on-site' investigation. Traffic signal locations too showed cause for some concern in cases where timings of phases – particularly amber and red/amber – were below accepted standard levels.

The role of environmental deficiencies in urban accidents is shown to be relevant in 6% of accidents singly and in 70% of accidents in combination with other road user and vehicle causal factors.

road user factors

Information on the road users involved in the accidents was obtained mainly from a post-accident interview, usually in the subject's home. The initial request for an interview was normally made by letter a few days after the accident. Of the subjects approached in this way, 67.2% co-operated. In some cases time or distance prevented a personal interview and a questionnaire was sent by post. Of the questionnaires sent, 52.5% were returned.

At the interview, data were obtained on the accident itself, journey history, driving history, and attitudes towards motoring. The Eysenck Personality Inventory Form A which gave scores on neuroticism-stability and extroversion – introversion was administered. Finally the subject's vision was tested using the Keyston Opthalmic Telebinocular which measured phoria, fusion, monocular and binocular static visual acuity, stereopsis. colour vision and field of vision.

The behaviour of each road user in the accident was assessed to determine if he had made an error that had contributed to the causation of the accident, the criterion for good driving being based on the Highway Code. To produce a logical classification of the errors a model of a three-stage human decision – making process, viz. perception, decision, and implementation was employed. Each major sub-decision was divided into various classes according to the reason for the error.

The following results are based on an analysis of the first 80 accidents, involving 150 road users, studied in the rural project. The table shows the distribution of the types of road users involved.

distribution of road users in the rural sample

category	*No.*	*%*
Saloon	87	58.0
Sports cars	8	5.4
Commercial vehicles under 16 cwt.	18	12.0
Commercial vehicles over 16 cwt.	15	10.0
Motorcycles	10	6.7
Combinations	2	1.3
Mopeds	2	1.3
Bicycles	3	2.0
Scooter	2	1.3
Pedestrians	3	2.0
Total	150	100.0

The low incidence of pedestrians is typical of a predominantly rural area.

The next table shows the distribution of the various types of error within the sample. The 'other error' category refers to the errors which did not fit within the general classification. One was a suicide; the other accident was caused by the road user having an epileptic fit. The two major errors involving a failure to look and excessive speed with regard to the conditions accounted for over half (54.9%) of the known errors committed. The nine cases in which it could not be decided whether or not the road user had committed an error have been omitted from the table.

types of error committed

Error	*No.*	*%*	*% of known error groups (N=62)*
Failure to look	16	11.3	25.9
Misperception of hazard	11	7.8	17.7
Unknown error of perception	4	2.8	6.5
Excessive speed with regard to the conditions	17	12.1	29.0
Other known error of decision	12	8.5	17.7
Errors of implementation	0	0.0	0.0
Other errors	2	1.4	3.2
Unknown errors	22	15.6	—
No error	57	40.5	—
Total	141	100.0	100.0

Details are given of those human factors that contributed to the causation of the 62 known errors. Preoccupation emerged as the major factor mainly because it was frequently associated with the error involving failure to look. This error was significantly associated with riders of two-wheeled vehicles possibly because, not being enclosed in a car, they are more susceptible to environmental distractions. The remaining causal factors played a relatively minor role. Although there were 11 errors involving a misperception of the hazard, only one of these was caused by a visual defect. In several other cases it was apparent that the road users had formed a 'set' or expectancy on the basis of their initial perceptual evidence and rejected any further evidence that was incompatible with the 'set'. If the initial 'set' was incorrect then the error was only realised when the incompatible evidence was overwhelming. By this time, the accident was usually inevitable.

human factors contributing to the errors

factors	*No.*	*%*
Preoccupation	12	19.3
Fatigue	4	6.5
Youth/Inexperience	1	1.6
Emotional Disturbance	2	3.2
Alcohol	3	4.8
Visual defect	1	1.6
Lack of knowledge of road	1	1.6
Lack of driving experience	3	4.8
Illness	1	1.6
None	34	55.0
Total	62	100.0

In over half the errors, no causal factors were established. In many of these cases, the faults were inherent in the usual behaviour of the road user and were not due to any of the relatively immediate factors noted in the analysis.

No significant personality differences have been found between the error sub-groups so far. It was found, however, that the group who made errors involving excessive speed are significantly younger than the non-error group.

vehicle factors

In terms of accident causation, both design and maintenance factors have an influence on vehicle involvement. The following table shows for a sample of cars in the urban project the relative frequency with which deficiencies were present and also causal in the accidents studied:

	deficiency present	*deficiency present and causal*
Forward vision restriction	—	22.6%
Rearward vision restriction	—	3.5%
Deficient lights (including inappropriate use)	10.2%	7.5%
Tyre pressure deficient (10% or greater)	30.1%	4.9%
Tyre treads less than 1/16th inch	25.7%	4.4%
Steering play greater than 7 degrees	20.8%	2.7%
Deficient footbrakes	8.4%	3.5%
Deficient handbrake	1.8%	1.0%

The effect of the new tyre regulations is an example of a maintenance factor which has been monitored during the course of the study. The above table shows that deficient tyres (based on a criterion of 1/16th inch tread) were present on 1 in 4 of all cars in 1966–67. After April 1968 this incidence dropped to 5% in urban areas and 8% in rural areas, there being little difference between accident involved vehicles and a control group.

Vehicle design characteristics influence the course of the accident. For example once an impact occurs the chances of rollover (and subsequently greater injury) are three times greater for three-wheeled cars than for four-wheeled ones.

vehicle and injury factors

In the short term the most important aspect of road accidents is injury causation in relation to vehicle design. The way in which injury comes about can be studied well with the on-the-spot technique, co-ordinated with detailed hospital information. For example the exterior components of cars have been related to pedestrian injury. The following table lists their relative incidence of causing injury:

components	*% of car contact injuries*
Bumpers	29.2
Wings	13.5
Headlights	9.4
Bonnet	8.3
Wheels	7.3
Windscreen	6.3
Windscreen frame	5.2
Grill	4.2
Wing Mirrors	3.1
Doors (including handles)	2.1
Insignia	1.0
Unclassified	10.4
	100.0

The majority of pedestrian impacts are not central but are on the wings, suggesting that changes in the plan view contour of cars might be beneficial. A large number of pedestrians are injured by the secondary impact with the road surface. Most of these impacts however caused minor and moderate injuries; the vehicle causes a significantly greater number of the severe ones as shown below:

source	*minor and mod. injuries*	*severe and very severe*	*total*
Vehicle	64	46	110
Road	117	31	148
Total	181	77	258

Also different models of cars have been shown to have different injury potential, and as the car has been shown to be the main source of serious injury, it would appear that in spite of the large mass differential there is considerable scope for designs which will lead to a reduction of pedestrian injury.

For car occupants, injury patterns are influenced greatly by the crash configuration. The three environments examined show radically different conditions:

	urban	*rural*	*motorway*
Head on	36.3%	39.8%	16.0%
Front corner	24.0	20.4	4.0
Side	20.1	11.8	11.9
Rear end	8.4	4.3	24.1
Rollover (with no primary impacts)	11.2	23.7	44.0
	100.0%	100.0%	100.0%

Of special note is the incidence of head-on impacts. These impacts are to the central two thirds of the front of the car. Few of these impacts are symmetrical however, so that there are sideways vectors which tend to project the occupants into 'A' pillars or the central part of the windscreen. Thus, the symmetrical barrier crash is not a complete or even good simulation of the majority of real collisions. Side impacts in urban areas are of great importance as the majority of casualties occur there.

Rollover becomes increasingly important in the progression from urban to high speed environments with almost half of motorway accidents being single vehicle rollovers.

Detailed descriptions of injuries to car occupants have been made. The patterns are similar, for drivers and nearside front passengers with head injuries accounting for some 40% of the total number of injuries, lower limbs 25%, upper limbs 20%; the remaining injuries are to the central part of the body, the torso and pelvis. This pattern changes considerably however with injury severity, with the head and chest becoming relatively more important in fatal collisions. Expressed differently, overall some 70% of those injured received head injuries.

fig 2 A typical subject for field data collection.

implications of the research

The article outlines the direction of the results of the accident research project at Birmingham University. In the course of the work contacts have been established with a tremendous number of organisations. The car and car component manufacturers, who need particularly field data on the crash performance of their products are most co-operative, as are other research organisations such as MIRA, RRL and RAE Farnborough. After some initial hesitance the police are beginning to see the benefits which come from detailed crash investigation by trained personnel, and already some of their operating procedures have been changed on our advice. In several specific cases the team have been able to help the police in establishing the facts of a collision. The insurance industry has so far only expressed an interest.

The author was called as a technical expert to the trial of the coach driver Philip Dobson in Yugoslavia, and was able to apply some of the experience gained in the Birmingham study. The subsequent six year sentence and then full pardon of Dobson in part reflected the technical inadequacies in the investigation of the accident by the Yugoslav authorities.

In the present legislative climate where car design, particularly in the United States, is being thoroughly reviewed, the present research has shown the need for detailed results from the field before legislation can be introduced rationally. Environments in Britain, the Continent, the United States, Australia and elsewhere are different, as are vehicle designs. Regulations in one country do not necessarily apply with the same force to another. Priorities for improvements are very different. It is felt that this research project has contributed to a better understanding of these factors. Regular monthly meetings take place between members of the research team and representatives of industry to discuss specific problems such as the analysis of vehicle damage, injury classification, injuries from glass, environmental deficiencies and road user behaviour. Thus, it is felt that the findings of the research are being delivered to their potential users, and the research effort has been worthwhile.

tailpiece

SRC decided to support this study because it considered the project to be particularly well suited to universities and that the creation of this multi-discipline team would benefit the postgraduate teaching of the department.

The Aeronautical and Civil Engineering Committee considered eighty-nine grant applications in 1968 and approved fifty-eight awards worth £473,630.

people and their pastimes

bellringing

J. C. Baldwin
Atlas Computer Laboratory

The origin of bells is not known, but they have been used by all races for thousands of years for protection from evil spirits and from bodily harm, and ceremonial bells have been rung for the religious rites of widely varying beliefs. Peruvian aborigines used bells and jingles in addressing their gods, and it is said that in the Mohammedan's paradise, bells hung from the trees to make music for the blessed.

Bells have been associated with sacred rites in christian churches since the fifth century; the Passing Bell called the faithful to pray for the departed soul, and excommunication proceedings called for 'bell, book, and candle'. English church records show the payment of fees to bellringers for services during tempests, and many bells bear the inscription *'Fulgura frango, dissipo ventoss'*, (Lightning and thunder I break asunder, fierce winds I disperse), a reminder of the days when the bells were thought to influence the weather, or the gods who produced it.

Master of the Bristol University Bellringing Society, 1961.

John Baldwin first became involved with bellringing in 1954 when he answered a call for volunteers to ease a shortage of ringers at his home church in Whitstable, Kent. He became genuinely interested in the art when he went up to Bristol University in 1958 and joined the very active University bellringing society. This enthusiastic group met for weekly practices, rang for Sunday services, and held ringing outings to other towers, during which maybe four or five towers would be visited during one afternoon. John became Master of the society in his third year and shortly afterwards married a fellow student and bellringing devotee. He dismisses the legendary powers attributed to bells and claims that bellringers marry other bellringers because only they could possibly tolerate the massive inconvenience. The University of Bristol society even has an official office of Cupid to foster such developments.

After graduating, John spent a year teaching in Shrewsbury and took an active part in the local ringing life, including teaching the art to some of his grammar school pupils. The opportunity of working for a research degree then arose and he went to the Manchester College of Science and Technology where he became a member of the Manchester University Guild of Change Ringers, affectionately known as the MUGs. A memorable occasion of this period was a bellringing tour in Norfolk during which a week was spent cycling and youth hostelling (with an appearance on television news), and a week sailing on the Broads. He recalls a unique experience when he was able to sail up to a church on the Broads for a practice session on its bells. After two years in Manchester he moved with his supervisor to the University of Sussex to complete his research, and played his part in getting the newly-formed ringing society there onto its feet. He is at present the Tower Captain at his home church in Wantage, which boasts a pleasant ring of eight bells with a tenor weighing just over a ton.

One of the activities of bellringers, apart from spending ringing holidays, is peal ringing. A peal involves ringing about five thousand different changes, which usually takes about three hours. In one 'change' each bell sounds once; in 'change ringing' the bells are rung so that they sound in a different order each time. John has rung 140 peals and has rung in over nine hundred of the five thousand towers in this country. (Change ringing in the English style is little practised outside the British Isles.) Ringers tend to remember places they have visited by the characteristics of the bells – for instance Bath is remembered for its unusual anticlockwise ring of ten bells, not for the Roman Baths or Georgian architecture.

what happens in ringing?

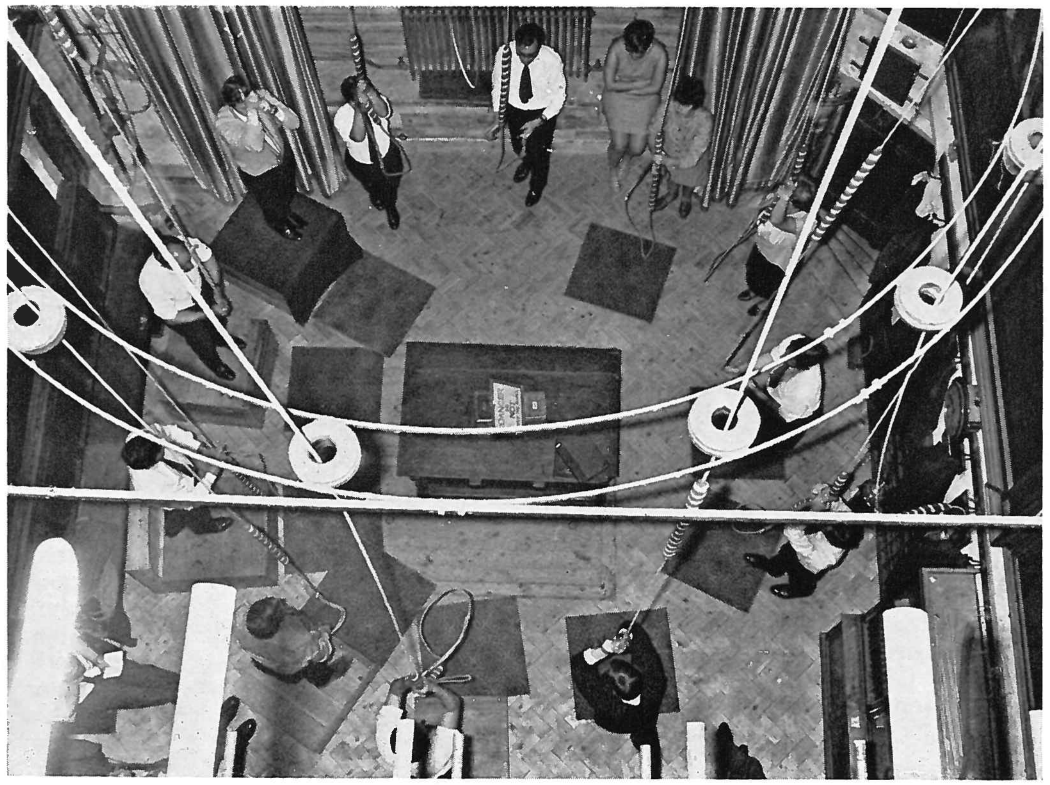
Many people mistakenly think that someone just pulls on the end of a decorated rope so that the clapper strikes the side of the bell. This is not ringing, but chiming, as in a clock movement. A bell hung for ringing is suspended from a wooden or metal headstock which is free to rotate about a horizontal axis. Attached to the headstock is a large wheel, which may be anything up to five feet or more in diameter, to which is fixed a rope. When the rope is tugged, the bell swings slightly and rocks on its bearings. The swing can be gradually increased by pulling at the appropriate time until the bell eventually completes a full circle. A wooden mechanism called a stay and slider prevents the bell overturning completely. The stay is sometimes broken during the learning process and most ringers will confess to having broken at least one.

The bell is left to rest mouth upwards, balancing on the stay and slider, and is then said to be 'up, ready for ringing'. In this position it is obviously dangerous for a non-ringer to pull the rope, and thus set moving a mass of metal weighing anything up to four tons.

Ringing begins when all the bells are 'up', commencing with 'rounds'. That is, sounding one after the other down the scale with the smallest, or treble, ringing first. The order of sounding then changes although no bell moves more than one position at a time. Anything less than five thousand changes is known as a 'touch' and ringers always endeavour not to repeat any more permutations than is absolutely necessary. With five bells only 120 changes are possible (5 x 4 x 3 x 2 x 1), but with eight bells, 40,320 are possible. A peal of this length has actually been rung by eight men at the Loughborough Bell Foundry and it lasted about eighteen hours.

The ringing community is very close-knit and it is no surprise to enter a strange belfry in a distant town and meet there an old friend, acquaintance, or friend of a friend. The weekly journal 'The Ringing World' helps to keep the ringing fraternity in touch, and the 'Ringers Diary' is a mine of useful information. There is a variety of ringing books for the student, the most widely used being Dove's 'Church Bells of Britain', which is now in its fourth edition. This is a directory of all the towers in Britain and lists the number of bells in each, the weight of the heaviest, and the practice night. There are also several gramophone records available, including one of the bells in the new cathedral in Washington, D.C. and the peal that was rung there by English ringers to mark its dedication.

John's hobby is not entirely divorced from his work, because computers also play their part, one of the uses to which they have been put being to check the peal to ensure that no changes are repeated.



Bats-eye view of bellringers in the belfry of St. Peter Mancroft, Norwich.

newsfront

The Editorial Board wish all Quest readers a happy and prosperous New Year

congratulations

The following members of SRC have received awards in the New Year Honours List
D. G. Christopherson, OBE, FRS, member of the Council Knighthood.
J. Howlett, Director, Atlas Computer Laboratory CBE.
Dr. F. B. Bath, Finance Division, London Office, OBE.

In this immediately post-Christmas period, we have resisted the temptation to include photographs of Christmas parties from each of the establishments, because they would appear, in essence, to be the same. We have chosen to use only the photograph from the Greenwich Observatory because the castle is unique and it so easily conjures up pictures of the traditionally English Christmas.

A joint research fellowship has been awarded to Dr. J. W. Elder who is at present working with Prof. G. K. Batchelor in the Department of Applied Mathematics and Theoretical Physics at Cambridge, by the Atlas Computer Laboratory and Churchill College, Cambridge.

Dr. Elder's main interest is the numerical study of the properties of thermal turbulence and during the course of the Fellowship, he is proposing to make an intensive numerical attack on some of the fundamental problems in this field.

Consequent to the recent visit of the Rt. Hon. Edward W. Short, M.P. to Daresbury, the following letter has been received by Professor Merrison.

'May I thank you and your colleagues most warmly for your kind hospitality during my visit, particularly the pleasant and informal dinner on Thursday, and for arranging a programme that I found exceptionally interesting. I was most impressed by the work of your laboratory, and by the calibre and dedication of the staff and research workers. To have established an international reputation in so short a time and to be attracting workers from abroad reflects great credit on the laboratory and on all who are associated with it. I was delighted to learn of the collaboration developing with France and Italy.

I would be grateful if you would convey my appreciation to your Secretary Mr. Rothwell, and to all your staff and research workers for their part in making my visit so memorable. May I offer my best wishes for the future work of the laboratory. I am sure it will accomplish great things.'

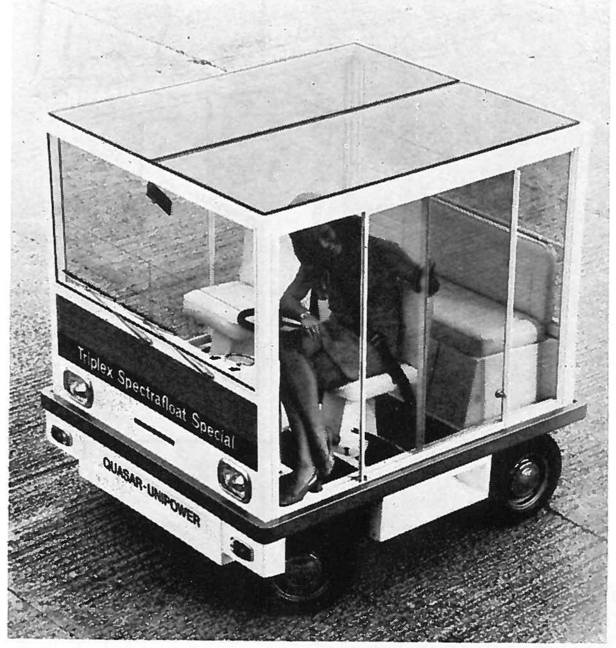
Council Commentary

The Council held a special meeting at the end of September to consider what advice to give to the Government about future participation in ESRO. The position was extremely complicated, with on the one hand sharply increased estimates of the cost of ESRO projects and a reduced scientific content of the ESRO programme, and on the other hand a growing confidence in the ESRO management and a recognition of the wide implications of membership. In the event, the British delegation to the European Space Conference in November was able to say that the UK was willing to pay its share of an ESRO budget growing at 6% p.a., firmly for the years 1969–71 and for planning purposes for the years 1972–74.

At the October meeting the Council discussed plans for the further development of its programme and of the general policies which are summarised for example on pages 2–5 of the current Annual Report. The Boards were invited to bring their programmes up to date and to consider the points of general policy, together with certain other observations and questions from the Council. The consideration of the Board's papers, and of the Council's policy and programme, is to take place in the first five months of 1969. Further items of business in October were the approval of an extension to the computer building at Daresbury, and the approval of grants to develop the cosmic-ray muon studies at Durham and the bubble-chamber film analysis equipment at Oxford.

At the November meeting, Dr. G. G. Macfarlane, Controller of Research at the Ministry of Technology, who is an Assessor to the Council, presented an account of the relationship of the Ministry's work to that of the SRC, and many of the points that he raised were taken up in further discussion. The other major subject was the balance of support of university scientific research from the UGC, Research Councils and other sources. As well as the broad principles, a number of detailed aspects of the question were discussed, including take-over, research training support grants and the need of University Departments for free funds to enable them to initiate new ideas. The Council will be giving further considerations to this whole vital subject at later meetings. The most notable of the remaining items was the recommendation to the DES for approval of a grant of £200,000 to University College, London for the analysis of film from the large heavy liquid bubble chamber 'Gargamelle' at CERN.

Quest has now appeared five times and we are anxious to learn what sort of an impact (if any) it has made, hence the questionnaire included with this issue. We hope that you will complete the form and return it to your local correspondent, because this is the only way in which we can gauge the usefulness of the journal and to plan future issues to appeal to the majority.



Just two issues ago we didn't even know what quasars were, now someone seems to have harnessed one to a most delightful tractive task.

SECRETARY OF STATE FOR E & S AT DARESBURY

The Rt. Hon. Edward Short, M.P. talking to Professor Merrison and the Chairman in the Manchester experimental area, during a recent visit to DNPL. On the extreme left is Professor P. Murphy of Manchester University.

UP UP and AWAY

Not a set for a tv ad, but the inside of a vibration chamber in the new Sound and Vibration lab. at Southampton University. The lab. was built with the aid of a £255,200 SRC grant and was opened in November by Sir Donald Stokes of British Leyland Motor Corporation.

FIRE QUEENS

Hazel Webb (left) and Melanie Gale of the Atlas Computer Laboratory recently won certificates for putting up the fastest time in the fire drill section of the AEA fire brigade competition. Both girls have athletic pastimes, which probably accounts for their speed, Hazel is a keen swimmer, and Melanie is a member of the Girls' Venture Corps and has made a number of parachute jumps.

'If I can't be a kennelmaid, can I be a bunny girl'

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Keeping him in the picture

Dr. Saxton, Director of RSRS presenting a unique desk lamp to Mr. A. F. Wilkins on the occasion of his retirement.

The lamp, which was made in the Workshops, represents the p.p.i. display of the cathode ray tube of the back-scatter experiment with which Mr. Wilkins was closely associated.

The display represents a radar map of several thousand miles radius, centred on Slough, and this is the sort of map which would be used for controlling operational communications circuits.

(see profile and birth of radar)

BEAUTY
WITH THE BRAINS

Miss Evelyn Bambridge
loading a tape into
the 1CT 1905 computer
at RSRS

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contributors

R. E. Rand, Ph.D.
'Particle Physics, the ultimate structure of matter'
Research Associate, DNPL *page 2*

G. W. Ricketts
'Stars'
Senior Experimental Officer, Solar Department, RGO
(Now retired after fifty years service) *page 7*

A. F .Wilkins
'The birth of radar'
Deputy Director (retired) RSRS *page 9*

G. M. Mackay, Ph.D.
'Road accident research at Birmingham University'
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The University of Birmingham. *page 15*