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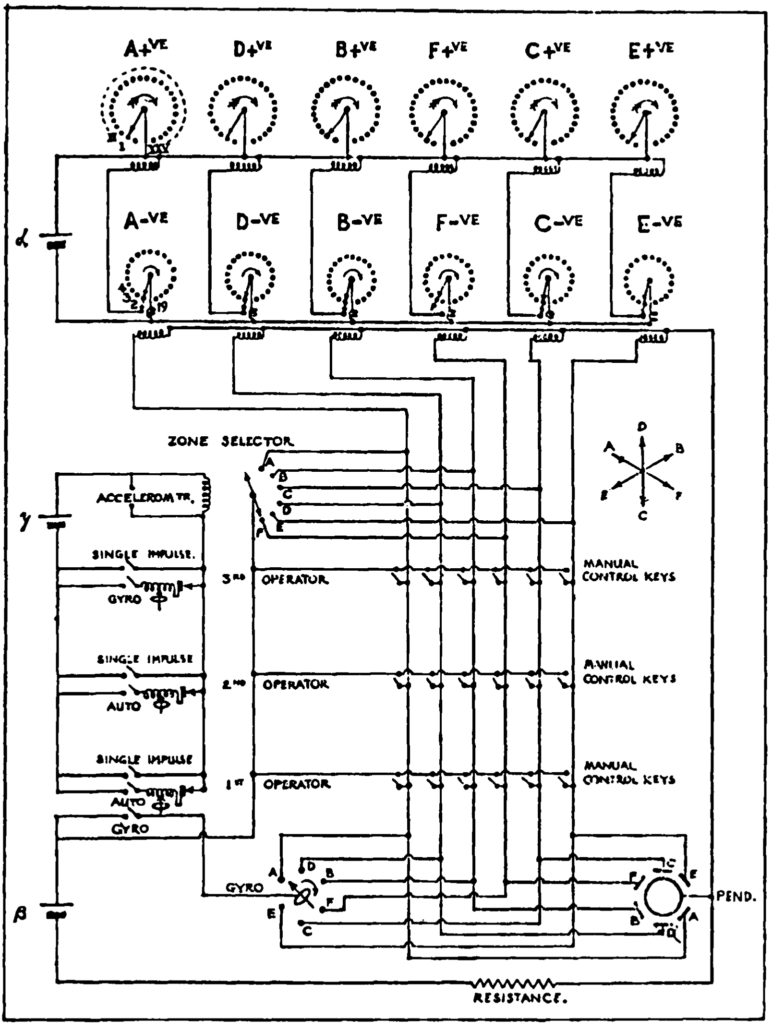

Automatic Firing Control of Lunar Spaceship. *See article page 4*

THE BRITISH INTERPLANETARY SOCIETY

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The Research Fund has been established for the purpose of financing rocket and other astronautical research in the British Isles. All contributions should be sent to the Treasurer, and requests for further particulars from the Hon. Secretary.

ON THE COVER OF THIS ISSUE

is a simplified wiring diagram of the automatic control system devised to fire the motors of the Lunar Spaceship designed by the B.I.S. and described in the last issue of the JOURNAL, For explanation, see page 4.

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EDITORIAL

It is six months since the last **Journal** was published, and they have been six months of progress for the B.I.S.—largely because of the last **Journal.**

That **Journal,** which contained the outline of the first spaceship seriously designed, was used by the Publicity Department to good effect. It was sent, mostly with covering letters, to all famous personages who have ever at any time evinced any interest in the possibility of interplanetary travel, to well-known scientists, and to numerous journals, magazines, and newspapers. The results were immediate. National newspapers from **The Times** to the **Daily Express** (or *vice versa,* if you wish) reviewed the **Journal**—emphasising its sensational aspects and largely ignoring its serious content, certainly, but nevertheless arousing public interest in the subject, which was the object of the Publicity Department.

Reporters came to interview us, and though most of them recorded us reasonably accurately, some went away to pen the most garbled accounts imaginable. Technical journals, however, published more sober articles, treating us fairly and open-mindedly. The article in **The Model Engineer,** dated April 13th, is an example of this agreeable attitude.

Once we won the cover of a well-known journal, and saw the B.I.S. space-ship displayed on all the bookstalls, shooting colourfully to the Moon. Once we stole half the photo-news page of a national Sunday newspaper from Herr Hitler (in the week-end of the Czechoslovakian crisis) with plans and drawings of the spaceship. Once we had the pleasure of hearing ourselves described on the air from one of the B.B.C. Regional Stations. And once we answered all criticism from intelligent readers of **The Listener** for thirteen consecutive weeks in the correspondence columns, and finished triumphantly with our critics tamed or converted.

The backwash of this publicity splash still breaks upon us, with cuttings coming in from provincial papers and from America, Australia, South Africa, India, and more remote corners of the world.

The effort has produced one real effect : there is a noticeable difference in the public attitude towards the proposition of a voyage to the Moon by rocket. People are beginning to accept the fact that a rocket could accomplish that voyage. The question they ask now is changing from " How ? " to " Why ? " Why do we want to go to the Moon ? For anyone who feels anything of the spirit of science, the question is unnecessary. For anyone who has nothing of the thirst for new knowledge in him, the answer is incommunicable. We can only reply : " Why not ? "

But publicity is only part of our progress. In these pages you will read of the activities of the Technical Committee, the construction of models to prove the practicability of certain of our theories, and the facing and solution of new problems as they present themselves. And all the time, research continues.

THE FIRING CONTROL OF THE B.I.S. LUNAR SPACESHIP

By J. H. Edwards and H. E. Ross

The preceding Journal contained general particulars of the British Interplanetary Society's Lunar Spaceship, and on the cover of this issue is reproduced the electrical circuit used to fire the motor tubes.

Certain factors have led the designers to introduce automatic control for most stages of the flight. It is realised that the acceleration employed (lg, working up to 4g), though not excessively high, and well within the limits of human endurance, is bound to restrict physical movement and may temporarily impair mental activity, so that swift reaction to unforeseen circumstances might be more or less seriously curtailed. It is therefore thought advisable to relieve the crew of as much work as possible during thrusting periods, even at the expense of carrying some additional weight, such as cannot be avoided when an automatic pilot is provided. Furthermore, it must be remembered that on the first crossing of Space every effort should be made to maintain a maximum reserve of fuel to meet unexpected contingencies and also that the Spaceship will be projected on a definite course (i.e., an interplanetary orbit) from which no great deviation can be allowed. In other words, the transit orbit of the Spaceship can be pre-determined at least as exactly as the trajectory of a shell fired from a gun, and so the number, the rate of firing and the times of firing of motor tubes can be forecast with considerable accuracy over the major portion of the flight. This latter being the case, the adoption of a selector system becomes possible, and since such equipment can be made to ensure maintenance of direction (thereby conserving fuel) and arranged to assist in stabilising the vessel, automatic control is preferable to wholly manual operation . . . . Incidentally, it should be mentioned that the large number of tubes used is a formidable obstacle to manual control, since disastrous mistakes in the selection of tubes might easily occur. Moreover, the rapid firing rate called for is such that the keys could not be manipulated quickly enough by hand alone.

Manual control is not, however, entirely abandoned. The delicacy required in handling the ship at certain stages of the flight (particularly when nearing Earth and Moon) is outside the scope of automatic control, and so provision is made for firing tubes by hand at the will of the pilot, who can either accelerate the ignition rate, retard it, or make the firing occur spasmodically.

Excluding the few motors used for fine landing manœuvres and the tangential artificial gravitation jets, some of which use liquid fuel, the total number of tubes needed is 2,250. These range in size from 7cms. to 28cms. lip diameter, the largest being used for ascent from Earth, and the fuel they contain is graded according to the thrust requirements at individual stages of the flight. The tubes are not ignited directly from the firing battery, for the power needed to start them is considerable, and direct ignition would demand a very bulky power unit. An intermediate " detonating " head is therefore fixed to each tube, and a moderate current is employed to ignite the material it contains, chemical reaction generating the high temperature of combustion required to ignite the fuel.

In all 6 steps are provided ; every step being a cellular formation (honeycomb) of tube units. Step numbers 1 to 5 (inclusive) each comprise 168 large tubes (or cells), all of which are used for release from Earth. No. 6 step consists of 45 medium tubes in the outer rings, with a double bank of 1200 small ones inside. All the medium tubes and the lower half of the small are used for descent upon Moon, and the remainder of the step supplies power for reascent from the Satellite and deceleration on approach to Earth. In No. 1 of the 5 large-tube steps 126 are wired in parallel and ignited simultaneously by a single impulse from a separate firing control (see note at end of article). This initial burst supplies the high power needed to start the ship away from rest on the earth. The other 42 tubes in this step (those in the outer ring) are wired for individual manual firing. (The circuit for this is not shown because of the additional complications it introduces). These 42 tubes are used to enhance and correct the initial thrust supplied by the first 126 tubes. Subsequent tubes in all the other steps are fired individually. Tubes that fail to ignite drop off automatically as soon as the previous tube finishes firing.

Surrounding each step is a separate light metal sheath. This is used to keep the tubes in place until they are ready to be discarded and also helps to reduce air-turbulence while the vessel is passing through the atmosphere. The lower end of each of these **sheaths** is joined to a perforated **web** interposed between adjacent **steps**. These **webs** distribute the weight evenly and help to retain the tubes in position. **Sheath** and **web** are automatically jettisoned directly after the last tubes in the preceding **step** have fired—being blown off by the blast from tubes above. Figure 1 shows the disposition of **zones** in a **step.** Each **step** is divided into 6 **zones,** A B C D E F, and one tube per **zone** is ignited in that order. This " jumping " sequence has been adopted to ensure that successive impulses are distributed evenly over the firing area of the **step,** thereby maintaining co-axial thrust. Parts of two adjacent **steps** may be in action simultaneously. When the outer rows of the lower **step** have been fired and the inner tubes are working, ignition begins in the outer tubes of the **step** above. In the case of **step** No. 1, where 126 tubes are ignited simultaneously and the remaining 42 tubes are fired manually, firing of No. 2 **step** is instituted immediately the desired thrust corrections have been made. It is at this juncture, therefore, that the automatic firing control is put into operation.

The Automatic Pilot.

The automatic pilot consists essentially of a trigger vibrator unit which delivers a series of electrical impulses to a bank of selectors, causing their arms to move and complete tube firing circuits. Three of these units are shown, one for each of the crew ; the object being that an instantaneous transfer of control can thus be carried out in times of emergency. For sake of simplicity, the actual switching employed for this change-over is not depicted, but it can be mentioned that it is similar to that used in house-wiring for the control of a lighting-point from any of several switches.

The rate of firing of tubes is controlled by the frequency of the pulses, which may be varied at will within a limited range by altering the position of a copper lagging "slug" incorporated in the trigger unit. Each selector consists of an energising coil, an armature joined to a ratchet which engages on a toothed wheel, a contact arm attached to this wheel, and a series of stationary contacts over which the moving arm passes. In all 13 selectors are used. The primary or **zone** selector, which is energised by the trigger mechanism, selects the **zone** in which a tube is to be fired, and it therefore has 6 contact positions corresponding to A B C D E F. The other 12 selectors " pick out " tubes for firing. Half of these selectors have 20 positions, and are wired to the **negative** of the tube ignition battery (gamma). These are henceforth referred to in the text as the **negative selectors.** The other 6 selectors have 26 positions, and are wired to the **positive** of the tube ignition battery (gamma). These are henceforth referred to in the text as the **positive selectors.** The **positive** and **negative** selectors are arranged in pairs, one **positive** selector and one **negative** selector being inter-connected to receive impulses from an individual **zone** line. All the selectors move on **make** current. A **negative** selector moves one position for every impulse from the **zone** selector ; a **positive** selector moves one position only on completion of each round of its companion **negative** selector—**i.e.,** when the latter passes from its 20th contact to its first again.

The arrangement of the system can now be examined.

When the main switch of the automatic system (**auto**) is closed the armature of the trigger unit begins to vibrate, making and breaking the **zone** selector circuit. This sets up a pulsating current in the **zone** selector coil, operating the ratchet mechanism and causing the contact arm to move. (There is a space between each selector position, so that two lines are never in circuit together). As contact is established to each position in turn an impulse is sent through the appropriate circuit to the energising coil of the selected **negative** tube selector . . . A B C D E or F according to the position reached. Circuits are thus closed to individual tubes, which then fire.

At " **Pend** " is represented the automatic stability control. This consists of a metallic pendulum suitably suspended on the major axis of the ship. Around it and separated from it by a small space are arranged 6 **contact segments,** so oriented that their respective positions correspond with the **zones** they control. Each segment is wired to the line of a Zone. The housing of this unit is fixed to the vessel itself and a **resistance** is inserted in the line so that the battery is not shorted during operation of the device. If from any cause the thrust developed by the motors does not remain co-axial, then the pendulum lies over on one side and short circuits a certain **zone** of tubes. So long as this short persists no firing takes place in the corresponding **zone,** and the vessel tends to return to its original thrust line. It should be noted that prior to ascent from Earth the ship will be inclined at an angle of 1 in about 15 from vertical—which means that the pendulum will be lying over to one side and touching a segment. This being so, it may appear at first sight that when the ship begins to rise it will automatically assume vertical ascent—but such is not the case. The group firing of 126 tubes constitutes the initial impulse, and the acceleration derived from these immediately causes the pendulum to pull over into line with the major axis of the ship, so that the temporary short is removed before individual tubes commence to fire. The vessel therefore continues to rise in the line of initial projection, and is maintained automatically in this line by the pendulum control until navigation corrections are needed.

Since this automatic stabilisation is additional to that provided by the firing order of the **zones**, the alternate clockwise and anti-clockwise ignition of rows of tubes (refer to fig. 1, zone key), and the rotation of the vessel itself, a high degree of stability is ensured. (The Spaceship is rotated by the launching equipment before starting from Earth, its rate of spin thereafter being varied as desired by tangential tubes). It has been calculated that by using these precautionary measures 10% of all the tubes on one side of the ship could remain unfired and the vessel still be stable.

Unfortunately the many precautions taken to keep the vessel stable make it very difficult to deflect it if desired—and it will be necessary to do so when undertaking navigational manœuvres. To obviate this difficulty a gyro destabilizer is incorporated, for the suggestion of which we have to thank Mr. J. W. Campbell, Junior, the Editor of **Astounding Science-Fiction.** The gyro, holding the same direction in space, fires tubes round the ring synchronously with the rotation. By this method it is possible to deflect the ship about 3° a second if desired. This makes it possible manually to control stability as well as acceleration if need be.

Referring again to the trigger mechanism, it will be seen that a switch (**single impulse**) is connected across the battery **Alpha** and the **zone** selector coil. This is the **main manual control switch.** Normally it is kept open by a spring, and when depressed it shorts out the vibrator and thus **halts firing.** By alternately depressing and releasing this key the tubes can be ignited in bursts of any desired duration, thus giving manœuvring control.

In addition, the **6 keys (manual control keys)** control the **zones** by hand as desired. Manipulation of these keys, which are normally sprung open, increases the rate of firing of tubes by allowing the introduction of auxilliary impulses.

Two leads are taken from across the **zone** selector energising coil to the **accelerometer,** where short-circuiting contacts are provided. If at any time the g rises to a dangerously high value, these contacts short out the **zone** selector and further firing ceases.

A more detailed explanation of the operation of the system can now be given.

The batteries are connected up in the order **Gamma, Beta, Alpha.** When battery **Gamma** is connected nothing occurs. When battery **Beta** is connected the F selector of the **negative** selector bank moves on one stud. Owing to the liability of the selectors to move when connecting the batteries, after **Beta** battery is connected and before **Alpha** battery is connected it is necessary to set back **negative** F selector to stud No. 1. When the **Alpha** battery is connected the **positive** selectors all move forward from stud O to stud I, the first operating position.

Owing to the fact that the **negative** and **positive** selectors are in positions 1 and I respectively, no tubes are connected to the

1.I. positions, otherwise tubes would immediately fire. At the pre-determined moment of starting a large quick-make switch (not shown) throws a separate source of power on to the first 126 tubes. These tubes have a range of firing rates, so that the outer ones finish first, allowing the automatic control to put in fresh tubes to maintain the initial thrust uniformly. The main switch of the auto pilot is thrown in when the outermost of the first batch has reached the end of their firing and when the remaining 42 tubes of step 1 have been fired manually to conform with thrust requirements.

The closing of the main switch allows current to pass from battery Gamma through the zone selector, causing it to move to position A. This changes the current from battery Beta from the negative selector F to negative selector A, making the latter move to stud 2, thus completing the circuit of battery Alpha through the negative selector A contact 2 and the positive selector A contact I to the negative and positive poles respectively of tube A.I.2. It will be noticed that the current to operate the zone selector passes through the vibrator coil, setting this unit in action and thus giving a series of impulses to the zone selector, moving it onwards through contacts B.C.D.E., etc. As each of these positions are brought into circuit the corresponding negative selector moves on to stud 2, thereby completing the circuits to fire tubes B.I.2., C.I.2., D.I.2., etc. This continues until the zone selector reaches position F, after which the next move brings the other end of its wiper on to A. This passes a second impulse through the negative selector A, causing it to move to position 3, thereby firing tube A.I.3. The next impulse brings the zone selector to B again, moves negative selector B to position 3, firing tube B.I.3. This process continues to F.I.3., then the A system operates again with A.I.4 and so on until the negative selectors have completed their round and all the I tubes in all the zones have been fired. After the negative selectors have reached position 20 the next impulse moves negative selector A to position 1 again. In this position it establishes once more the connection to the auxiliary stud leading to the energising coil of positive selector A, so that this in its turn immediately moves to its position II, firing tube A.II.1. Likewise, negative selector B, when next arriving at its first position again, operates its positive selector. Thus the entire sequence of operation is now repeated, firing tubes A.II.1, B.II.1, to F.II.1, A.II.2, B.II.2, etc., until all the II tubes have been fired, when the negative selectors will again reach studs 1 and the positive selectors stud III, and so on until the entire system has been operated. If the automatic stability pendulum unit has delayed the operation of the selectors in any zone, their own sequence of operation is continued quite independently of the selectors of the other zones.

Considerations of space do not allow us to reproduce here the full details of all the tube connections, but the following is an example of the wiring of a zone.

CONNECTIONS TO TUBES OF ZONE A.

Step	Tubes	+VE Connection	—VE Connection
1.	1 to 7	A.I.	A.2 to A.8
	8 to 28	MAIN	MAIN
2.	1 to 12	A.I.	A.9 to A.20
	13 to 28	A.II.	A.1 to A.16
3.	1 to 4	A.II.	A.17 to A.20
	5 to 24	A.III.	A.1 to A.20
	25 to 28	A.IV.	A.1 to A.4
4.	1 to 16	A.IV.	A.5 to A.20
	17 to 28	A.V.	A.1 to A.12
5.	1 to 8	A.V.	A.13 to A.20
	9 to 28	A.VI.	A.1 to A.20
6.	1 to 20	A.VII.	A.1 to A.20
Medium	2 to 40	A.VIII.	A.1 to A.20
	4 to 60	A.IX.	A.1 to A.20
	6 to 75	A.X.	A.1 to A.15
6. Lower	1 to 5	A.X	A.16 to A.20
--small	6 to 145	A.XI. to A.XVII.	A.1 to A.20 seven times
	146 to 152	A.XVIII.	A.1 to A.7
6.	1 to 13	A.XVIII.	A.8 to A.20
Upper —small	14 to 133	A.XIX. to A.XXV.	A.1 to A.20 six times
	134 to 152	A.XXVI.	A.1 to A.19

The other zones are connected in the same way to their respective selectors.

The steps 1 to 5 (inclusive) are connected across the top of the step to busbars which run down the central tubular conduit as far as the top of the first step.

The tubes in the 6th step are connected directly to the selectors, without passing down the tubular conduit.

The central conduit tube in the 1st step is occupied by a dynamo, which is run from the accumulators until it has sufficient momentum to fire the initial 126 tubes—when the battery is switched off and the dynamo is thrown on to the 126 tube group. This is done in order to reduce strain on the ship's batteries, which are therefore not subjected to a sudden overload many times their normal functioning current.

The outer ring of the 1st step consists of extra fast tubes, so that they can be held back to adjust stability if needed, but will still finish before the next row. They are rigidly attached to the next row.

The detonator circuits are not completed until the tube immediately below has dropped off. This prevents explosion. To avoid the selectors moving ahead in such a case, a pawl moves into

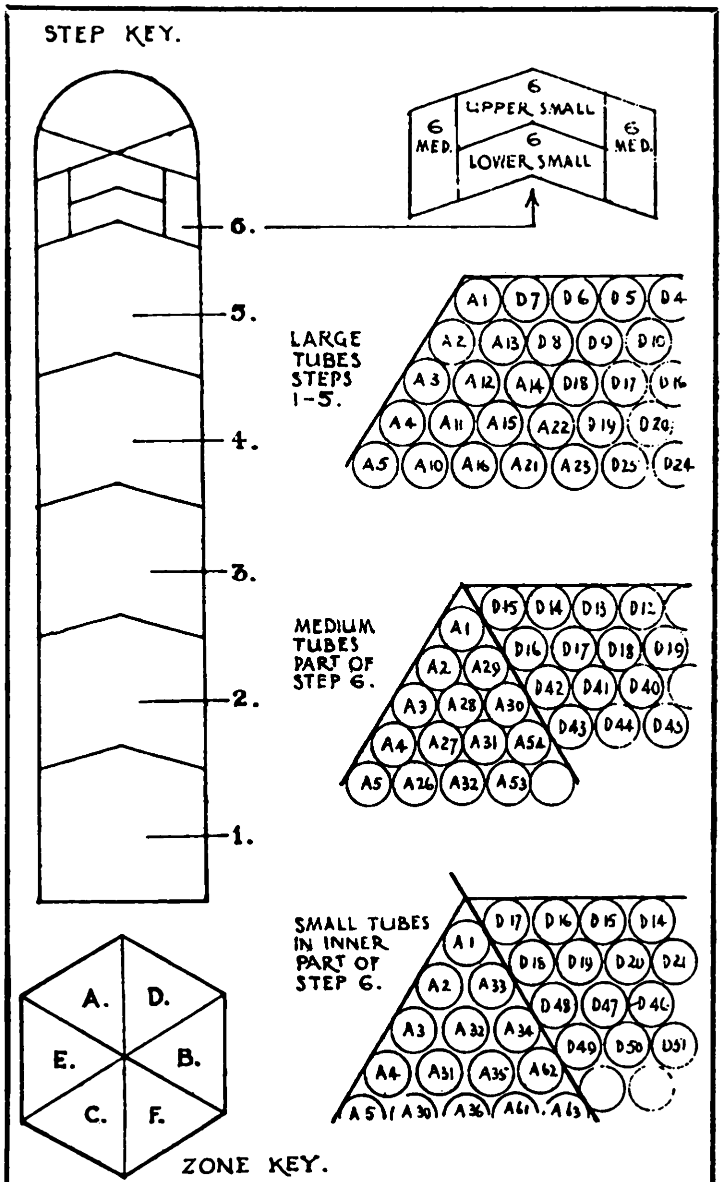

STEP KEY.
6 UPPER SMALL
6 LOWER SMALL
6 MED.
6 MED.
6.
5.
4.
3.
2.
1.
LARGE TUBES STEPS 1-5.
MEDIUM TUBES PART OF STEP 6.
SMALL TUBES IN INNER PART OF STEP 6.
A. D. E. B. C. F.
ZONE KEY.

Figure I

position on the **negative** selector ; this prevents the selector moving again until the current flows. The pawl is released by the small coil shown below the selector arm. The pawl can be released by hand in the case of a faulty circuit. Liquid fuel tubes are essentially for use when manual control is required, and so are not connected to the robot pilot.

....

To the uninitiated the system may seem very complex, but it is one that ensures a high degree of reliability combined with swift and easy control—conditions of operation that must be satisfied. No new principle is embodied, and most of the apparatus used is similar to that operating daily in automatic telephone exchanges. Furthermore, the equipment can be tested thoroughly before it is layed out for final design, and opportunity is thus provided for training purposes. Practice " flights " (replicas of the Lunar voyage) can be made by setting the apparatus to certain requirements, and trials can be made of the ability of the pilot and navigator to meet unexpected contingencies . . . Hence when the first voyage is undertaken there is little likelihood that circumstances will arise that are entirely foreign to the experience of the crew.

FUTURE PROGRESS IN ASTRONAUTICS.

by Arthur V. Cleaver.

As its name signifies, the B.I.S. is primarily interested in the achievement of interplanetary travel and to the furtherance of that aim all its activities are directed. However, the question has often been asked as to whether any of our work could have more immediate practical applications, for the most optimistic of us admit that space travel is not likely to be achieved for many years.

In this stimulating article, Mr. A. V. Cleaver, who incidentally is not a member of any of the B.I.S. Committees, makes some suggestions regarding our most suitable policy. Though we are not in agreement with all of Mr. Cleaver's points (some of which are dealt with in the Technical Report) he raises several questions which will have to be considered in framing our research programme.

The Technical Committee has already gone into most of these matters (particularly the question of sounding rockets and rocket aeroplanes) in considerable detail, and if Mr. Cleaver's article arouses sufficient interest a report on the whole subject will be given in the next **Journal.**

EDITOR.

The B.I.S. Technical Committee have now completed a provisional design for a lunar space-ship more detailed than any previous effort along these lines. They have even incorporated designs for instruments by means of which the speed, altitude, and surroundings of the vessel may be observed and have made demonstration models of these instruments. They have considered carefully the questions involved in taking off, navigating and landing the ship, and in providing for the stay of the expedition on the surface of the Moon and their safe return to Earth.

After all this, they have concluded that there would be no insuperable difficulties in building such a craft with existing materials, to use existing fuels. It is not suggested for one moment, of course, that the present design is finalised ; there is not a fraction available yet of the vast amount of experimental data necessary before such a claim could be made. The B.I.S., fully realising this, hopes to play its part in amassing some of this data, and is, in fact, already on the point of making a start on the job as far as its meagre financial and other facilities permit. However, it is suggested that if some ten to fifteen years could be spent on ground experiments, with all the necessary money, personnel, and apparatus for these provided by some scientific fairy godmother, then the construction of a space-ship, based on the present design but modified in detail in the light of these experiments, could be undertaken with complete confidence.

The writer of the present article, who claims to have just as much faith in the ultimate achievement and value of space flight as any other member of the B.I.S., nevertheless wishes to raise the question of whether it will be achieved in quite this sudden and dramatic manner, or whether, indeed, this is quite the best manner in which even to hope it will be attempted.

The cost of the first space-ship would be, to quote from the recent B.I.S. pamphlet, "no more than that of a single destroyer." While endorsing the implied views of the authors of that remark as to the superior intrinsic value of the space-ship to the warship, it must be pointed out that such an outlay nevertheless represents a huge sum to be raised for a project which the majority of people are likely to regard for a long time to come as extremely visionary. The task of finding this money would be made easier if some intermediate achievements of the rocket could be pointed out as a guarantee of the success of the final scheme. Further, it will be admitted that the failure of the first space-ship, after the expenditure of hundreds of thousands of pounds on its construction and many years of experiments, would be a catastrophic blow to the development of astronautics, whereas the failure of any less ambitious preliminary schemes would not be so serious.

The reply sometimes made to the above arguments is that any "half way" applications of the rocket, while perhaps useful in themselves, would be of little technical assistance in the development of the true space-ship. Since the publicity value of such experiments (if they are successful !) is not usually questioned, the charge is sometimes added that they would be mere stunts.

I personally can see little justice in this latter charge, always assuming that the experiments were deliberately made with the object of providing new data and not merely as spectacular displays. It might be added that, as the B.I.S. has always recognised, publicity of the right sort is not by any means to be despised.

It is undeniable that a laboratory is the only place where the effects of independent variables can be isolated and studied one at a time ; it is therefore the ideal place for obtaining accurate quantitative data. But field experiments can supply information of another kind, which, though cruder, is none the less equally essential.

For example, the flight of a sounding rocket to an altitude of a few hundred miles from the earth's surface would provide incontrovertible evidence that the tubes propelling it would work satisfactorily under conditions approximating more closely to those obtained in space flights than any which could be reproduced in a laboratory. Experiments with proving stands, pressure chambers, and so forth, would have been an essential preliminary to the construction of the sounding rocket, but only the flight itself could prove that the data gained in these experiments had been sufficiently well understood and applied to encourage us to proceed one step further towards the construction of a space-ship. Any engineer will understand the force of the above arguments ; as a rough analogy, the increasingly common practice of building large flying scale models of projected aircraft, in addition to making wind tunnel tests, may be mentioned. The two techniques are essentially complementary, and are in no sense alternatives.

Aeronautics provides us with another argument in favour of making haste slowly. If the present B.I.S. design for a space-ship proves to be as amazingly accurate an anticipation of the machine which makes the first Moon trip as was Henson's " Aerial Steam Carriage " of 1843 of the modern aeroplane, then all concerned will deserve the congratulations of posterity. The design of Henson's followed from the theoretical work of Cayley much in the same way as the B.I.S. design does from that of Oberth, Esnault-Pelterie, and others. The continuous development of the aeroplane can be traced, after Cayley's speculations and experiments and the design and model work of Henson and Stringfellow, through the gliding experiments of the Lilienthals to the first powered flights by the Brothers Wright. Ground experiments with primitive wind tunnels and whirling arm apparatus proceeded the whole time, being conducted by many other experimenters in addition to those mentioned.

Incidentally, those who believe space flight is still centuries off might ponder the fact that only sixty years separated Henson and Stringfellow from the Wright aeroplane. However, the point which it is desired to stress here is the very gradual nature of the development of aviation, in the sense that the aeroplane is not the outcome of the work of solely one experimenter, or group of experimenters. Also, it is extremely noticeable that those researchers who, like Langley, Maxim and Ader, attempted to apply the results of their very valuable ground experiments directly to the construction of large scale flying machines succeeded in producing only very spectacular failures.

It has been suggested that rocket aeroplanes may play much the same part in developing the space-ship as the glider did in the history of the aeroplane, that we shall learn the technique of building and operating them first, that they will gradually increase in size and power, flying faster and higher until they leave the atmosphere behind and make short hops into space itself. This idea does not bear very serious examination as long as by " rocket aeroplane " is meant a craft more or less orthodox except for its means of propulsion—that is, a machine depending on aerodynamic means for its normal lift and control. Whether terrestrial transport by pure projectiles will ever become practical is entirely another story, but the development of jet-propelled aircraft seems inevitable if the present trend towards higher and still higher speeds continues, owing to the increasingly poor efficiency of the airscrew at forward speeds above 500 to 600 m.p.h.

Such rocket aircraft as have been envisaged by aerodynamical engineers would not be projectiles in the sense that a space-ship would be, and would, indeed, have little in common with it apart from the fact that both were propelled by the reaction from a stream of hot gases produced in a combustion chamber. The motor design would be quite different ; the first essential of an aeroplane jet propulsion motor would be that it should aspirate the external air, otherwise the weight of fuel to be lifted for any reasonable range would be prohibitive. Also, since the exhaust speed of the gases would inevitably be much higher than the maximum speed of the aircraft, some device for capturing even more air than was required for combustion purposes alone and of using this for thrust augmentation, would be desirable, otherwise the propulsive efficiency of the system, especially during climb, would be very low.

Thus the " rocket motors " of the space-ship may ultimately be simple tubes of solid fuel, and those of the aircraft very complicated petrol-air burning devices incorporating gas turbines driven blowers. Reference 1 contains an interesting discussion of most of the jet propulsion schemes which have been put forward for aircraft.

The field in which this application of reaction propulsion is most likely to provide valuable data for the construction of space-ships is the design of the life container, which will probably be no small problem in itself.

Turning now to sounding rockets, it will be remembered that Mr. Truax told us last year that the American Rocket Society now regarded the construction of a successful one as its immediate aim. Dr. Goddard has for many years also directed his researches along these lines, and the work of the "Galcit" group at the California Institute of Technology should also be mentioned. Reference 2 contains a description of their experimental apparatus, while references 3 and 4, which have been commented on by Mr Edwards in our own Bulletin, contain an account of their preliminary theoretical investigations. These last two articles offer considerable hope for the future of the sounding rocket. The criticism that the rocket's flight would be too short for scientific instruments to obtain accurate readings might be met by designing a parachute giving the rocket a very low sinking speed and taking the readings on the way down, as far as meteorological readings were concerned. Alternatively, as the A.R.S. have suggested, completely new types of instruments might be developed. Certainly a sounding rocket could be built to fly much higher than any balloon, and while small rockets ascending only a mile or two would be of little use for any purpose, immediately their ceiling exceeded, say fifty to a hundred miles, they would be of real interest.

It is suggested, therefore, that a report by the B.I.S. Technical Committee on the possibilities and limitations of sounding rockets would be of real value at the present stage in the development of astronautics. From a study of the conclusions reached by others, it seems likely that they will provide a valuable link between ground experiments and the design of the first space-ship.

References.

1. " Aircraft Engineering," September, 1936.

2. " Astronautics," July, 1938.

3. " Journal of the Aeronautical Sciences," March, 1938.

4. " Journal of the Aeronautical Sciences," December, 1938.

REPORT OF THE TECHNICAL COMMITTEE.

Since the last report the Technical Committee has been largely occupied with checking up on details of the Space ship and its voyage. A large number of queries and suggestions have come in and have had to be carefully considered, and certain points which were only generally considered in preparing the design have had to be considered in detail. The robot pilot has been designed and certain points have arisen in connection therewith that are being forwarded to the Experimental Committee for practical tests, if financially possible.

The weakest point in the proposition of a Lunar voyage is the problem of landing (both on the Earth and Moon). The method employed in the published design is power-on landing with shock absorbers. This appears satisfactory as regards the Moon landing, except that we are not satisfied that we have achieved the best possible design for shock absorbers. Helico vanes and parachutes have been considered for the Earth end and, without as yet definitely committing ourselves, parachutes are favoured. The design of these calls for a specialist, and Squadron Leader D. Ross Shore's kind offer to do this for us has been accepted.

Any suggestions re the design of shock absorbers would be most welcome. They are required to bring gently to rest a body weighing 20 tonnes, travelling downwards at more than 5mts/sec. and possibly having a sideways motion of 1 mts/sec. and/or being tipped 10 degrees. These latter points make it very difficult to design shock absorbers which will not dig into the ground and snap off, or buckle under the vessel, etc. Make your suggestions as detailed as possible—your main idea might not satisfy all the requirements, but some of the details might form the basis of a solution.

The Committee has also studied high altitude rockets and jet propelled aircraft, to determine to what extent they might supply information of value to us. In the case of high altitude rockets it was decided that the load put on the motors would be so low that they would be effectively " running light " throughout and consequently they could give no useful information of the nature of a working condition test for space-ship motors. In the case of jet propelled aircraft the smallest size of motor used in the B.I.S. Space-ship design would be almost fully loaded by an aeroplane travelling at very high speeds and comparatively low altitudes. If any difficulty arose over the high temperature of the gases it could be avoided by the use of lower grade fuel and still leave ample power for the propulsion of the aeroplane. It was therefore decided that there would be technical justifications for the inclusion of jet propelled aircraft in our programme provided that they were essentially **very high speed planes.**

The following is a list of answers to the queries that have been raised and appear to be of general interest. Considerations of space make the explanations only very brief.

The use of a strong detachable carapace and a light plastic dome for the life container was dictated by considerations of weight. The nose has to stand up to enormous heat and pressure while going out through the atmosphere. The weight needed to withstand this would reduce the load ratio from 1,000 to 300 if it were carried to the end, and as it serves no useful purpose once the atmosphere is left behind it is jettisoned. This construction also protects the life container from frictional heat by providing a vacuum flask.

The cellules are only held on to the ship by their own thrust and thus fall away as soon as they have finished firing. Any form of release by the pilot or the auto-pilot would be too dangerous, for, if a cellule failed to release, the one behind would most likely explode and thereby damage or remove a large number of the other cellules in its immediate vicinity.

The Space-ship is steered by liquid fuel jets. Inertia wheels were originally suggested, but as they are not capable of overcoming any serious errors in the line of thrust the liquid fuel jets would have to be provided as well. So it was felt that the extra weight of the inertia wheels was not justified.

It has been suggested that fins should be used for stability and control in the air. Fins have, it is true, a tendency to hold the ship on the same course, but they have also a tendency to turn the ship nose down. So long as the ship was exactly vertical they would be an advantage, but once any appreciable error did develop, the tendency to nose down would become dominant with catastrophic effect.

The use of pendulum instead of gyro-automatic stabilising has been criticised. It should be borne in mind that the ship is itself rotating and that under these conditions gyros and pendulums largely exchange their functions. The rotation of the ship prevents divergence from the course—the purpose of the pendulum being to damp out wobble.

There are several misapprehensions in the matter of stability. Having a very low c.g. on an aeroplane makes it self-stable, but only because the centre of weight is below the centre of air reaction, and both are external forces, whose direction is fixed in the first case relative to the direction of the Earth and in the second case relative to the direction of motion. In the rocket ship, however, the inertial reaction and thrust substantially dominate over all other forces, and these two forces are both fixed relative to the vessel. The consequence of this is that it makes no difference where the centres of application of these forces lie, but only where the lines of application lie, and thus there is no decrease in stability by having a high c.g. and a low centre of thrust.

The inertia instruments, the altimeter, speedometer, impulse-meter and accelerometer have been selected after a careful consideration of radio and optical instruments. The latter are used while coasting but they are no use while driving, partly because of lack of information about the visible size of the Earth, partly because of the exhaust gases, and partly because corrections have to be made within ¼ sec. of observations, which does not give time for the calculations involved. Owing to the varying conditions of propagation of radio waves in the vicinity of the Earth and the entirely unknown conditions of propagation in the vicinity of the Moon, radio instruments do not provide sufficient accuracy at any stage.

It has been pointed out that climbing vertically for a short distance and then flattening out gives a lower gravitation loss than an entirely vertical climb. This is certainly a fact, but the difficulties and losses of the manœuvring make it rather uncertain in practice. Furthermore, a loss of unknown magnitude would be considerably worse than a much larger loss of exactly known magnitude. The gravitation loss is in any case only about half of what is generally assumed : the loss is approximately proportional to the firing time, but the altitude is also approximately proportional to this. Since the higher the altitude the lower the release velocity, about half the gravitation loss is recovered by this increase in altitude.

We now come to the vexed question of solid and liquid fuels. We chose to use principally solid fuels because the aggregate weight of fuel, motor and accessories is considerably less for solid than for liquid fuels. There is also an advantage in that strength of the fuel augments that of the ship.

Furthermore, we know of no stable liquid fuel of sufficient power. Substances such as liquid oxygen can be used for rocket fuels, but they are unsatisfactory as Space-ship fuels owing to evaporation. For life container use, where the quantity is not critical, we may use liquid oxygen during the earlier part of the voyage, but even for that purpose it could not be considered satisfactory for the whole period.

We have been criticised for carrying stores of water and oxygen instead of reclaiming them from the atmosphere. We are not against partial reclamation if it can be done without excessively weighty apparatus, but it would only be an auxiliary method, as to put our entire faith in any such apparatus would be to reduce the extremely high factor of reliability to which we have worked throughout.

There have been numerous outcries against the use of batteries instead of generators, but we must point out that besides the enormous weight of a generator it has to be driven. When the total mixture taken into the cylinders is considered, an ordinary internal combustion engine works out at about .02 Kcals/g. We do not expect rocket motor efficiencies, but we must get a higher figure than this. If, however, we put rocket fuel into a mechanical motor it would burn out. Thus we considered batteries, which can use Mg-HCl, which is practically a rocket fuel, and use it at a much higher efficiency than any mechanical motor. We require 3 K.W. for the initial firing, and after that, about 1,200 watts. for firing and control. Another 3 K.W. was required for the steam jets and 10 K.W. for heating, but it has now been decided to use steam heating from direct chemical reaction, to use small liquid fuel jets instead of steam jets for steering, and to use a motor generator in (and detached with) the bottom step to fire the initial 126 tubes. The reliability of this does not matter, as failure would simply mean a non-start. It is driven by the batteries but accumulates energy by its inertia, and thus the battery requirements are reduced to 1,200 watts.

EXPERIMENTAL SECTION.

The Experimental Section has dealt very largely with the altimeter. This has given a great deal of trouble. It was originally tried with solid bearings and a clock spring. It was found that the friction was too great in proportion to the power of the spring. Those who studied the formulae in the last Journal will realise that the accuracy is dependent on the losses being negligible as compared with the spring power. It was next tried with ball-bearings and a gramophone spring. The bearings were carefully tested before use and were found to have a co-efficient of friction of .02 against the makers' rating of .001. It was calculated that they should still be just about good enough. It was now found, however, that the chains tended to ride the sprocket teeth and thus introduce losses. Belts could not be used as any slip would give a major error. The arrangement was tried of hanging the weight on a thin thread and winding the latter on a drum. This introduced some minor errors but cured the loss. It was now found that the gramophone spring was unsuitable, as it only returned about 75% of the energy put into it. Better ball races and more accurate drums are now being obtained, and the instrument has been redesigned to use a helical spring.

The speedometer and impulse-meter, which are subject to the same losses and difficulties as the altimeter, are being held up until these problems have been solved for the altimeter.

The original design of the battery was entirely unsuccessful, owing to the text book laws, upon which the design was based, proving entirely erroneous. Both voltage and current were found to be higher than theory indicated, but this was offset by the reaction being so violent that it was completely unmanageable. The text book laws are being carefully checked and it is hoped that further progress will be possible when this work is completed.

The coelostat has given least trouble of the experimental matters. Some difficulty was experienced in lining it up, but once this was solved the first model was able to give a satisfactory demonstration. Full details are given elsewhere in this issue.

The pressure tank being still beyond our resources, and the earlier parts of the programme being well under way, it was decided to go ahead with the proving stand, which would, at least, enable us to test commercial rockets and thus determine their faults in order to avoid making the same mistakes ourselves. The proving stand has therefore been designed and constructed, and calibration is proceeding. It is not possible to say at this stage whether it will be satisfactory.

There has been some criticism of the whole idea of designing the Space-ship before doing the experimental work. We are glad to say this has been almost entirely from non-members, so that presumably the majority of the members understand and approve our programme. Perhaps it is advisable, however, to reiterate, that, as the other societies do not seem to have got far towards solving the problem of space flight by experimenting before they decided what they were trying to learn, we decided that we must first try to design a satisfactory Space-ship from existing knowledge, in order to determine what experiments were needed. The design is being modified as experimental results become available, although, from our studies of the subject so far, it is not expected that any major alteration will be necessary. J.H.E.

ANNOUNCEMENTS.

We are pleased to be able to record that a Fellowship of the British Interplanetary Society has been conferred on Dr. Otto Steinitz in recognition of his contributions to the science of astronautics.

The B.I.S. wishes to announce its gratitude to Mr. Charles Bein, who very generously contributed half the sum needed towards the cost of the recent publicity pamphlet issued by the Society.

THE B.I.S. COELOSTAT

By R. A. Smith.

In the design for a Space-ship recently published in the **Journal**, it was assumed that the ship would rotate. There are two reasons for this : to give longitudinal stability in vacuo ; and to produce an effect of artificial gravity by the effect of centrifugal force, thus avoiding the possibility of the crew being overcome by vertigo during the power-off periods of the voyage.

Whilst a satisfactory solution is thus provided to these two problems, it gives rise in its turn to new difficulties of its own.

It will obviously become necessary, at certain stages of the flight, for the crew to make navigational observations. As the ship will be rotating, the occupants will see their surroundings apparently spinning about a point in the axis of rotation of the ship, and there can be no doubt that accurate observations would be impossible under these conditions.

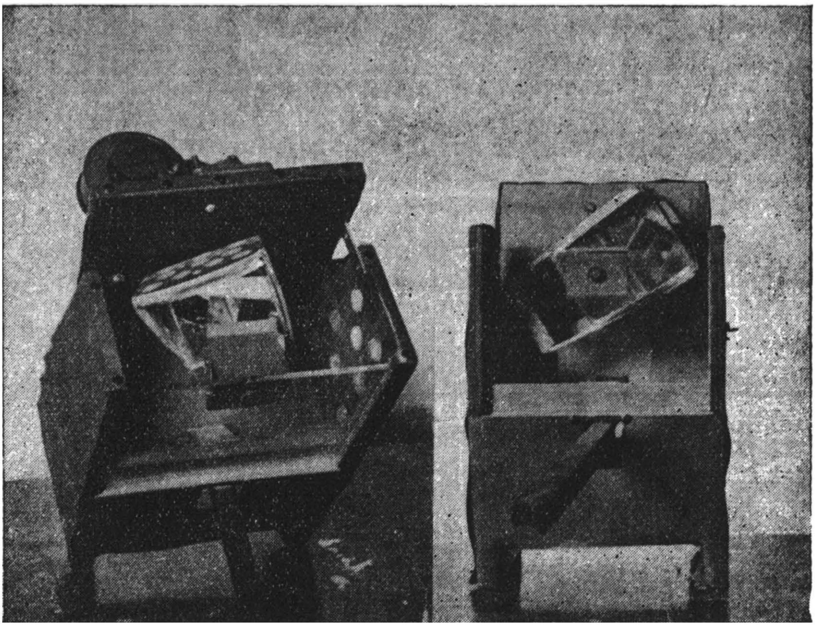
It was decided that some means of presenting an appearance of a stationary field of vision must be devised, and the Technical Committee undertook the investigation of the various possibilities that presented themselves.

The suggestion that the scene should be scanned by an electron camera, and the picture elements projected on to an internal viewing screen after having been suitably re-assembled to present the desired stationary appearance, by means of suitable electrical circuits in the scanning control, was dismissed in consideration of the great weight required for the amplifier and the complexity of the circuits involved. Other suggestions examined were abandoned because they involved the necessity of a part or the whole of the observer remaining stationary, thus nullifying the effect of rotation.

It was finally decided that it should be possible to devise a system of moving mirrors which should produce the desired effect, and investigation was made along these lines.

Designs finally emerged which seemed theoretically satisfactory, and it was thought best to construct a model to discover whether there were any hidden flaws in the scheme in practice, as there appears to be no record of any attempt having been made previously to obtain this effect. An estimate of the cost of constructing a demonstration model was arrived at, the anticipated cost was submitted to a meeting called to consider the development of the experimental programme, and a provisional sum was agreed. As the work proceeded and the minor technical difficulties were overcome, it was decided to give a demonstration of the model at one of the public meetings of the Society.

It was decided to have a disc, rotated by a gramophone motor,



(*Photographs by* *R. Church.*)

Figure 1 - Tilted forward to show details. Figure 2 - Front view.

to represent the rotating field of vision. It was found that the motor would have to rotate the disc in the opposite way to the normal direction of a gramophone turntable, and would therefore have to be specially adapted to this purpose. The construction of this part of the apparatus was left to an experienced engineer, in order to save time.

Before continuing further with the description of the experiments, it would be as well to consider the conditions of operation it was intended to demonstrate.

In flight it will be necessary to provide observation in three different directions at various stages of the journey :—

(A) Axially, away from the firing face. For this purpose three ports are provided, close to the apex of the life-container shell.

(B) Axially, towards the firing face, for which windows are provided in the space where the circular life-container floor overhangs the hexagonal main body of the ship.

(C) Radially, for which twelve ports are provided in the shell of the life-container, circumferentially, at 30° separation all round.

Although opposiee in direction, the conditions for (A) and (B) are fundamentally the same, so far as the coelostat is concerned. The field of vision will appear to be rotating about the axis of the ship ; whilst for condition (C) the scene will appear to be sweeping past angularly, or equatorially, as the astronomers would have it, thus requiring different treatment from the other two cases.

As this condition can be dealt with quite simply, by rotating a double-sided mirror before each port at half speed of revolution and about the same axis as the ship, by means of synchronous electrical motors, it was decided not to prepare a demonstration of the coelostats for this position. The model demonstrated (shown in Figs. 1 and 2) is, therefore, intended for coping with conditions (A) and (B) only, and although operating on the same principles as those for use in the ship, was actually constructed rather differently, omitting the points of finer adjustment which would be necessary in the finished instrument. The difference will be readily appreciated after a study of the sketch of the finished apparatus shown in Fig.3.

In view of the several important omissions from the demonstration model, and the fact that it was operating under conditions which presented its shortcomings in their very worst light, owing to the necessarily close range of indoor operation, it is surprising that it was possible to obtain the degree of steadiness that was achieved. Its performance leaves no room for doubt that it will be quite satisfactory in actual operation.

Fundamentally, the coelostat consists of two revolving mirrors A and B, and two stationary mirrors C and D.

The mirror D, into which the observer looks, is the smallest of the series, the others being progressively enlarged to obtain as wide a field angle as possible—the maximum obtainable without the use of lenses being 16°. This mirror is fixed to the rim of the port so that it does not obstruct any of the field. Its face is inclined at an angle of 45° to the main axis of the ship, and on looking into it along a line parallel to the main axis, a view of the second fixed mirror, C, is obtained. This is fixed centrally in the port, being attached to the material of the port itself, its face also at an angle of 45° to the main axis of the ship and at right-angles to that of D.

In it is seen a view of B, one of the rotating mirrors A and B, which are fixed together along one edge, with their faces at right-angles to one another and at 45° to the main axis, and are rotated about an axis parallel to the main axis passing through the centres of C and D. They are held in a shoe specially counterbalanced to compensate for the fact that they are eccentrically mounted about their axis of rotation. This shoe is fixed to the spindle of a synchronous motor, held in a frame secured to the rim of the port, at a speed, controlled by the master gyro, of half that of the ship. This

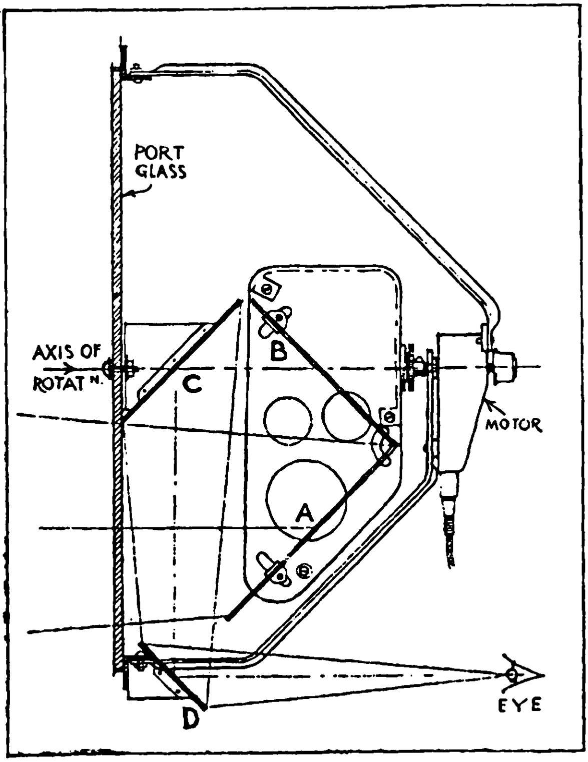


Figure 3 - The optical system of the Coelostat.

pair of mirrors are so positioned and shaped at their opposite ends that they clear the line of sight through the instrument, and avoid clashing with the stationary mirrors.

The faces of the two fixed mirrors C and D are inclined away from the port, whereas the faces of the revolving mirrors A and B are inclined towards it, so that the light falling on the outer rotor mirror from the scene is reflected on to the inner rotor mirror B, thence on to the central fixed mirror C, then on to the viewing mirror D, and then via a suitable eyepiece to the eye of the observer.

The rotation of the scene is actually done by the revolving mirrors, the whole purpose of the stationary mirrors being solely to act as a periscope, conducting the light to the eye of the observer. As they rotate the scene through twice the angle through which they themselves revolve, it is necessary to rotate them at half the speed of the ship so that the scene appears to remain stationary. The method by which they do this is best illustrated by an imaginary experiment.

It will be observed that by holding a mirror vertically in front of one's face, and rotating it through an angle of 45° about a vertical axis, the scene will appear to rotate to twice that extent. Holding the mirror above one's head, at an angle of 45° to the vertical, and rotating it about a vertical axis, it will be observed that the walls of the room appear to be spinning round as before.

Now, by adding a second mirror fixed to the first along one edge so that their faces are at right-angles, and rotating them together about the same axis, it will be seen that a view of the floor is obtained, still spinning as before, with the head and shoulders in the foreground, obscuring part of the view.

If one imagines a small periscope to be placed in the position the head occupied, so inclined that by looking into it along a horizontal line from one side a view is obtained of the scene as reflected in the mirrors, obviously the same view of a spinning floor will be obtained. By placing another mirror in this last position, suitably inclined, it is obvious that a view can still be obtained of the floor spinning as before whilst looking into it in a direction towards the floor.

This is in effect the set up of the coelostat, the floor representing the field of view.

There is no reason why the weight of such apparatus need be very considerable if care is taken in design ; and there is no theoretical limit to the accuracy of the instrument, providing the mirrors are optically true and accurately placed. It would be an advantage to use surface polished mirrors, to avoid double reflection and polarisation, although there was no indication in the model's performance of any trouble arising from this source.

The slight wobble shown in the demonstration from time to time was due to the faulty alignment of the coelostat with the centre of rotation of the disc. It was also found that the inclination of the first revolving mirror had to be altered to suit the distance of the object when it was at a short distance, such as was the case for the demonstration. This is caused by the fact that the viewing mirror in revolving changes its angle slightly in relation to the centre of rotation. This effect would not occur obviously where the object was at any considerable distance, because the angle subtended from its two opposite positions of the revolution would become very small.

This machine holds one rather interesting possibility of development, at least, apart from its space-ship application. With suitable adjustment it could be used as a slow-motion stroboscope.

The reader is probably aware that the stroboscope makes use of the peculiarity of the eye referred to as retentivity of vision in much the same way as in the cinematograph, and is for this reason applicable for use only in cases where the speed of revolution is sufficiently fast to provide sufficiently rapid repetitions of position; speeds below this produce blurring.

In the case of our principle, however, there is no lower limit, but a top limit instead : when the parts fly apart under the effect of centrifugal force. As this would not be likely to occur under speeds of less than 500-600 R.P.M., and the machine has to revolve at half the speed of revolution of the object, it could therefore deal with objects revolving at speeds up to 10C0-1200 R.P.M. Should this prove to have any commercial value, it will once again prove that experiments designed to investigate one line of research may often yield facts of wider interest . . . . I hope so for the sake of the B.I.S. Research Fund, but I need hardly add that we are not placing too much dependence on the materialisation of this happy possibility.

MATERIALS FOR THE SPACE-SHIP

By Arthur Janser, F.C.S., F.C.I.S., F.R.S.A., Research Chemist.

The last few months have seen the creation of the design of the Lunar Space-ship, which has been worked out and calculated in considerable detail.

Great attention has also been devoted to the problem of the material which is to be used for the construction of the Space-ship and its different parts, and a considerable number of experiments have been conducted, of which a brief report is given in the following lines :—

Summarizing the results obtained so far, it can be stated that synthetic plastics are to be used prevalently and in preference to metals for constructional parts. Their outstanding advantage is that, while having a mechanical strength equalling that of metals, and in addition thermic and electric insulating power, they possess extremely low specific gravities compared with metals, viz., between 1.00 and 1.50.

Plastics of this nature, in particular the polymerisation products of compounds containing the CH_2: CH—group, are too expensive to find general use for the construction of aircraft, but their use for the Space-ship is fully warranted.

Considering the application of plastics more in detail, the Space-ship is fitted with a protective outer hull made of glass-like fused Aluminiumoxide, which is produced by a special Thermite process in a furnace ; the inner hull, which harbours the life container, is made of several layers of strong linen fabric, stretched over a light frame and bonded together with a compound of chlorinated rubber and a resin made from chlorinated substituted Diphenyl, which I have recently synthesised.

A constructional material for instruments and interior equipment of particular usefulness is Balsa wood, treated with Hard Lac Resin. This is of extremely light weight and yet strong and sturdy. I achieved also the production of a shellac modified Urea—Formaldehyde Resin in a spongy form, which has a specific gravity of .60 and a horny resilience reminiscent of ivory, which might be used alternatively.

For optical instruments and mirrors (not forgetting the Coelostat) a Poly-Methyl-Methacrylate-Resin will be used, which has a transparency and refraction co-efficient similar to glass and is unbreakable. Its use for portholes is also considered.

For electric purposes Eu-Poly-Styrene will be used exclusively. This resin is also glass clear and quite outstanding in dielectric and mechanical strength. Flexible tubing will not be made in rubber, but in Poly-Vinyl-Chloride, which is indefinitely flexible and non-elastic.

Liquids, in particular the Hydrogene-peroxide which is proposed to be taken for water and oxygen supplies, are to be kept in strengthened plastic containers made of Ethyl Cellulose with a protective coating of a Vinyl-Acetylene Resin inside.

Special attention has been paid to the adjustable easy chairs, on which the crew of three will have to spend practically the whole time while the intervening space between Earth and Moon is crossed. A closely interwoven fabric of phosphorbronze and horsehair is impregnated in rubber solution and vulcanized. This material possesses a degree of resilience and elastic recovery which makes it suitable for supporting the bodies of the crew against the pressure of acceleration and absorbing the thrust.

The clothing for the crew will be woven especially from a yarn with a high silk content, in a manner similar to the "Aertex" fabrics. It is also proposed to wear a tight-fitting interlock weave garment of elastic threads for the purpose of controlling the blood-pressure in view of the considerable changes of gravity to which the crew will be subjected.

Great advances have been made with the firing tubes. Research work is now being conducted with inorganic bonding materials of great mechanical strength and heat resistance. Firing tubes will be constructed by bonding abestos cloth in a mould with the described material and cementing the shaped body into metal tubes, which will be comparatively light in weight.

From these promising beginnings it is expected that a considerable saving of weight will be effected in the end, which will lead to a very advantageous reconsideration of the mass-ratio originally envisaged.

All this work contributes to render the construction of the Lunar Ship a practical proposition, worthy of the serious consideration of scientific bodies.