

RESTRICTED

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OBSERVER



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The RCAF OBSERVER

Incorporating the RCAF Navigation Bulletin

Founded 1949

This issue of the OBSERVER is given over mainly to topics concerning missiles. Why? To begin with, we are living in a period unparalleled for research and progress in rocket propulsion. Practically every day some new record is set, or another break-through announced. This we cannot ignore, nor can we afford to be content with our knowledge of present aircraft and equipment. These articles, then, are intended to introduce and provide a basic background for the missile and its associated systems.

Articles more closely related to the operational tasks of RCAF observers have been conspicuous by their near-absence in recent issues. This fact, as well as the technical depth of most articles, has aroused considerable criticism from operational units. Considering the whole purpose of the OBSERVER, such criticism is well-justified, and demands consideration.

The RCAF OBSERVER is not intended to be a medium of expression for the staff of Central Navigation School. However, operational units seldom receive condensed, easily-understood accounts of new equipment. CNS staff therefore attempt to write articles for the OBSERVER so that such information may be passed on to observers in the field. Recently, CNS has been forced to produce the OBSERVER almost in entirety, because of the dearth of contributions from other sources; this no doubt contributes to its lack of universal appeal.

No one is more qualified to discuss techniques, suggestions, or problems concerning current observer duties than personnel serving with operational units. In this respect, the OBSERVER is most definitely a medium of expression. If this publication is to improve so that it is of benefit and interest to all observers in the RCAF, it must be given support in the form of article contributions. We shall always welcome constructive criticism in that form!



20 S O R I

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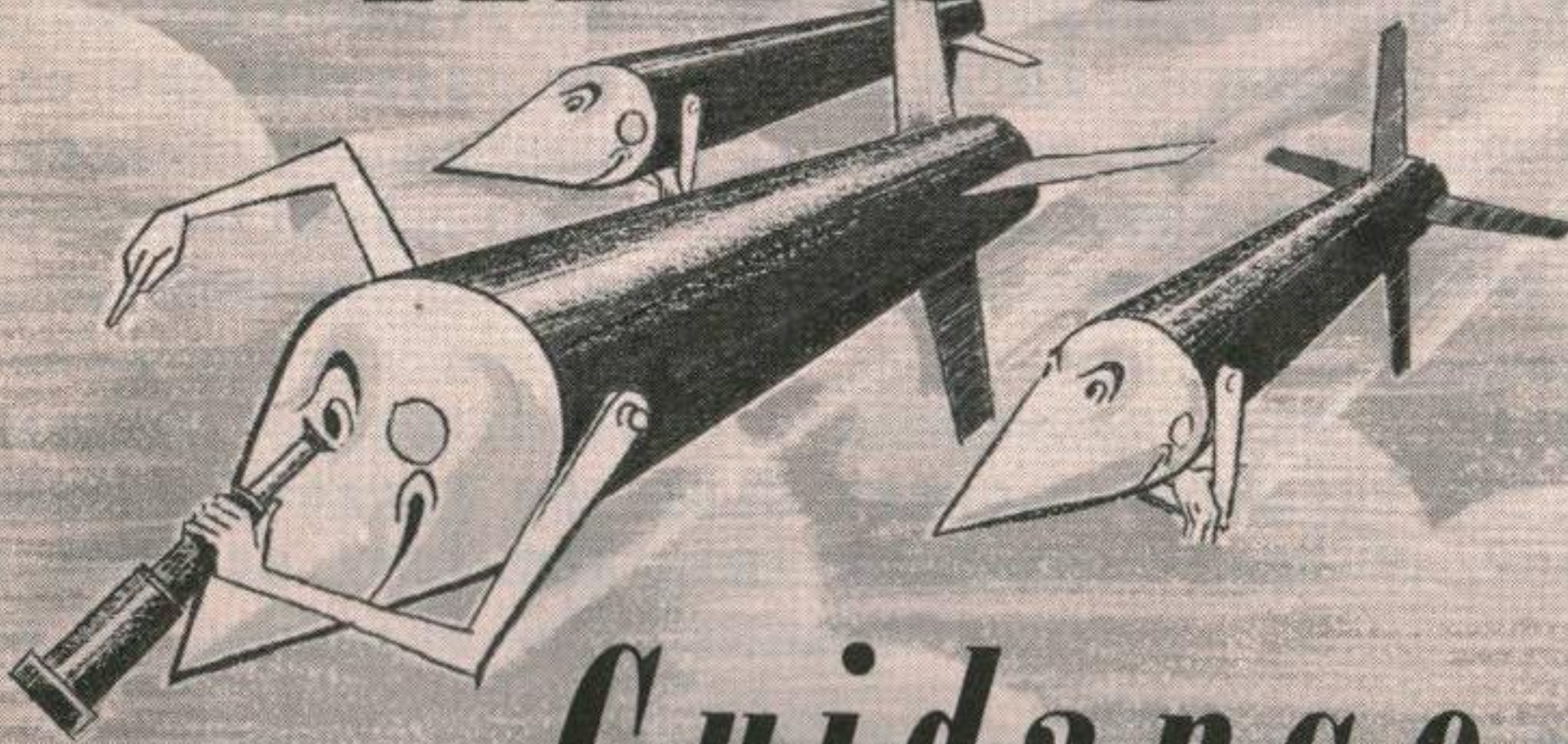
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F/O HR Cutt, F/O JC Girard, F/O RH McPhail, F/O JR Goodwin
F/O RJ Saunders, F/O JP Wilson, F/O GL Lewis, F/O HR Morgan

Front Row

F/O PT Haughn, F/O RM Kaduck, F/L WD Lyall (Course Director),
F/O R Bullough, F/O KR Weaver

missile



Guidance part 1

by Flight Lieutenant G.R. Hunn
3 AW (F) OTU

The guided missile is a recent development in the chain of destructive weapons. Throughout history, man has maintained a never-ending quest for increased range of fire-power, and today he can reach targets across oceans, on other continents. One of the most important current weapons, the guided missile, exists in various forms to fill a variety of needs. Therefore, it is important for the observer to have a general knowledge of the classes of this weapon, its method of guidance, and its capabilities.

Basically, guided missiles can be fired against two types of target: those that are moving, and those that are stationary. This seemingly clear-cut division of targets does not exist in practice, because the factor of range can cause the relative motion of a slow-moving target to be insignificant.

In general, the stationary target exists as a series of co-ordinates in some reference system, and the guidance system is merely required to assess the missile's progress along the trajectory and steer it to the target. The moving target, on the other hand, requires that the missile be provided with directive intelligence obtained from direct observation of the target. The speed of the target is important. As target speed increases, a small error in missile heading will constitute a larger miss distance.

Missile Categories

The definition normally accepted for a guided missile is: "An unmanned, space-traversing vehicle, carrying within itself the means for controlling its flight path". The stipulation that the weapon is unmanned is taken for granted, but readers should remember that missiles such as the Japanese Baka bomb used a human guidance system.

Missiles are categorized according to the medium of launching and the medium containing the target, considering the tactical duty of the missile. The four general categories are:

- Surface-to-Surface
- Surface-to-Air
- Air-to-Surface
- Air-to-Air

These classifications apply to all missiles, guided or unguided, with the exception of underwater weapons such as the homing torpedo. The ICBM (Inter-Continental Ballistic Missile) and IRBM (Intermediate Range Ballistic Missile), as their names imply, follow a ballistic path. Despite the fact that they are guided until rocket shut-off, they are not guided missiles. The method of guiding these weapons while rocket-propelled will, however, be mentioned under the appropriate sections.

FACTORS AFFECTING GUIDANCE

Each of the categories of guided missile is used in a single general field, and each has its own specific problems. Before examining guidance systems in detail, the employment and normal profile of each type should be considered.

Surface-to-Surface Guidance

The surface-to-surface missile is surface-launched and is intended to destroy a target that is also on the earth's surface. This category embraces both land and sea-based launchers using a variety of guidance techniques.

Surface targets are considered to be stationary, because any motion of the target is relatively slight during the missile's time-of-flight. Size can vary considerably from an entire city, a section of a city or a specific building, to a tactical target such as a group of vehicles. The range of the surface-to-surface missile varies from approximately one thousand yards for the short-range, tactical missile to the five thousand miles quoted for the USAF Snark. The size of the surface target tends to increase with range, because it would be both cumbersome and expensive to use a large, long-range missile against a small tactical target. As a result, the absolute accuracy expected of the weapon tends to decrease with range.

The guidance technique used is determined by the role of the missile. Short-range tactical missiles may be controlled using direct observation, in much the same manner as artillery fire is directed. Longer ranges do not permit visual assessment of the missile's trajectory and the requirements of the guidance system are thus increased; also, two major sources of error become evident. If the missile is to be fired between two ground positions, any error in the surveying of either the target or the launch points will introduce error. In addition, failure by the guidance system to assess the actual trajectory accurately will result in a miss. Thus the long range missile presents two major problems:

→ Fixing the launch point and target accurately

→ Fixing the vehicle's position along its trajectory

Obviously the first is purely a question of accurate survey, but the methods of fixing are many and varied.

Surface-to-Air Guidance

The recent discussion concerning the Bomarc anti-aircraft missile has focussed a great deal of attention on ground-to-air missiles. This category is currently concerned with airborne targets such as jet and turbo-propellor aircraft, but the anti-ICBM missile will also fall into this category. In any event the airborne target is relatively small and travels at high speed, thus demanding that the missile sense or "see" the target during its flight.

Various types of missile flight paths exist, depending upon the guidance technique used, but in all types the paramount requirement is to destroy the target before it reaches its weapon release point (Figure 1). The time-delay between the initial sighting and the kill is of extreme importance, as is always the problem in air defence. This factor, coupled with the requirement for accurate target velocity data, is the reason behind the current emphasis on automaticity in the air defence ground environment.

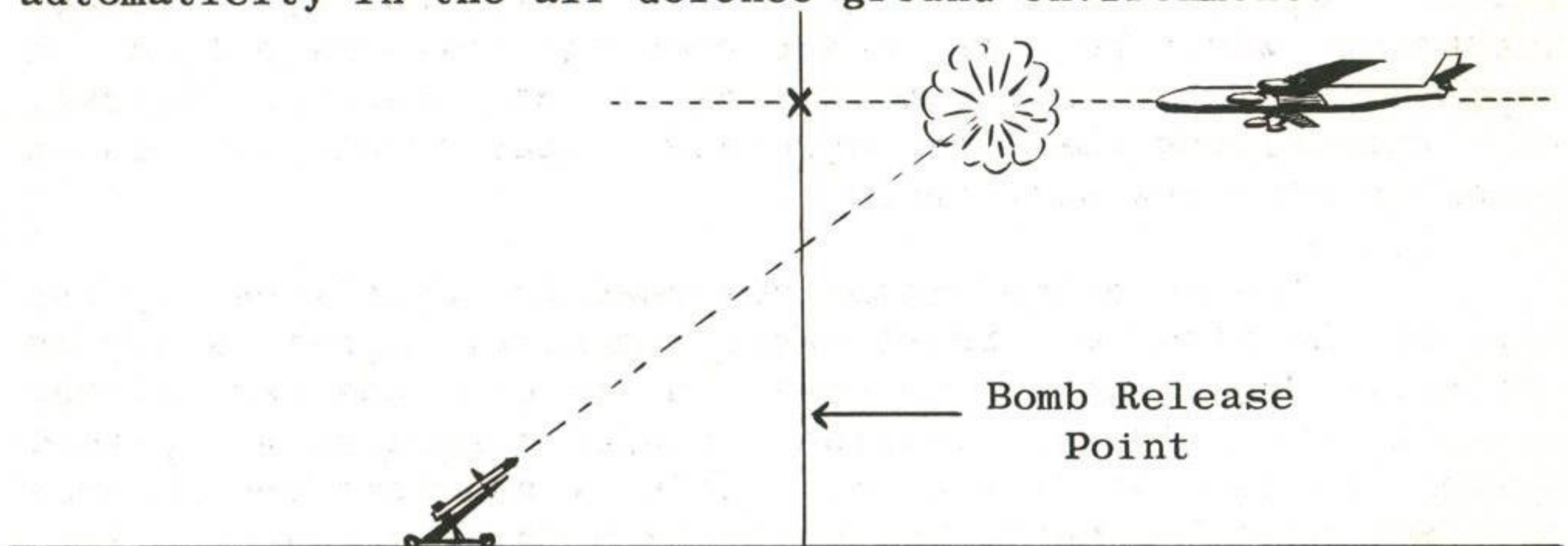


Figure 1 - Surface-to-Air

Air-to-Surface Guidance

The term "air-to-surface" guided missile implies any vehicle air-launched against a surface target. The RAF refers to the weapon as the stand-off bomb because it is launched many miles from the target, permitting the bomber to make an attack without penetrating local defences (Figure 2).

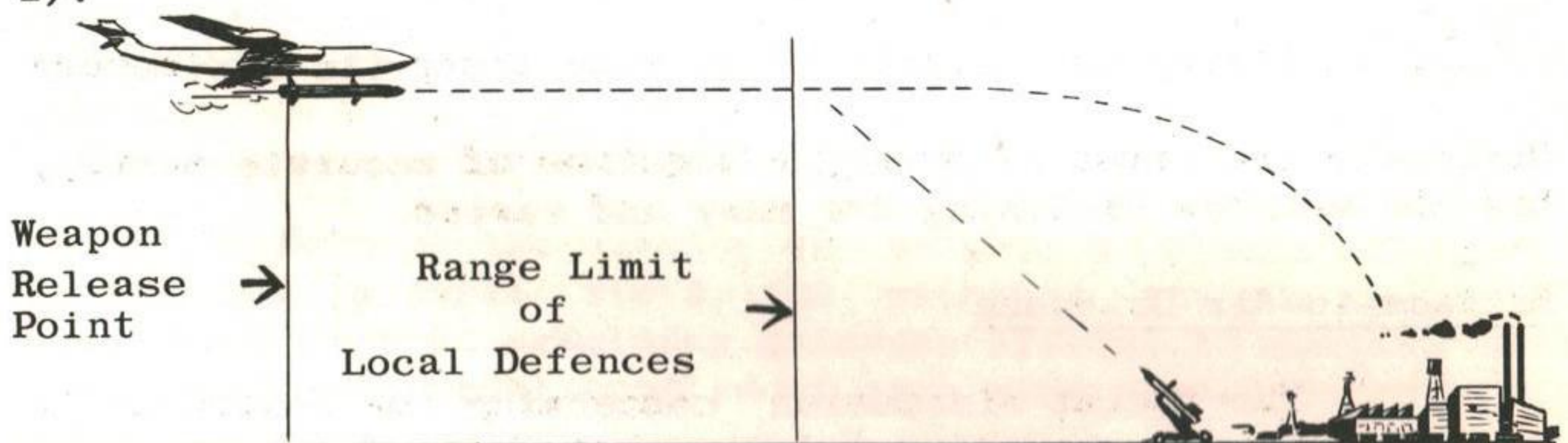


Figure 2 - Air-to-Surface

A variety of techniques exists in this category of guidance, with the range required of the vehicle being the prime factor governing the technique adopted. There is considerable controversy between the proponents of the stand-off bomb and the ballistic missile. The relative merits of

the two weapons can be deduced if each is considered from the limited view of relative cost, accuracy required, ground facilities, and personnel.

Air-to-Air Guidance

Air-to-Air missiles recently have received considerable interest in the national press as a result of the trials of the Sparrow missile, and the success enjoyed by USAF and USN aircraft using the Sidewinder missile in the Far East. Several types of guidance have been used, but the primary consideration is to ensure that the guidance system does not limit the fighter's manoeuvrability.

The guidance system must be able to differentiate between multiple targets, yet the missile itself should be of relatively small size. The size is much larger than for an unguided rocket because in addition to its warhead, the propellant must now carry the sensor components, control actuators and associated machinery to control the flight of the vehicle. Hence, as with other systems, the higher probability-of-kill is bought only at the expense of greater complexity in both the missile and the interceptor.

SURFACE-TO-SURFACE GUIDANCE

It was pointed out earlier in this article that the long-range, surface-to-surface missile is fired against stationary targets. The capabilities of these vehicles were fully realized by the Germans, and before and during World War II they carried out considerable research on all classes of guided missile. However, only surface-to-air and surface-to-surface missiles reached production. The first surface-to-surface missiles made an immediate impression on the Allies when the V-1 buzz-bomb fell on London.

The V-1 guidance system was not as well developed as the vehicle itself, primarily because of the technological problems associated with the production of components. This problem of guidance was solved in the Japanese Baka bomb by the inclusion of a human pilot.

V-1 Guided Bomb

The V-1 guidance system was both simple and effective. It consisted of a barometric altimeter, magnetic compass, directional gyro, rate-gyro, and air mileage counter.

The control surfaces were operated pneumatically through direct loops. The magnetic compass, once set to the desired course, slaved the directional gyroscope to maintain its spin axis along the planned course. Any difference between the orientation of the spin axis and the longitudinal axis of the missile resulted in a signal to the rudder control, through its pneumatic actuator. The elevators were controlled directly from the altimeter. The rate-gyro was included to ensure that the degree of control did not exceed the aerodynamic limits of the vehicle (Figure 3).

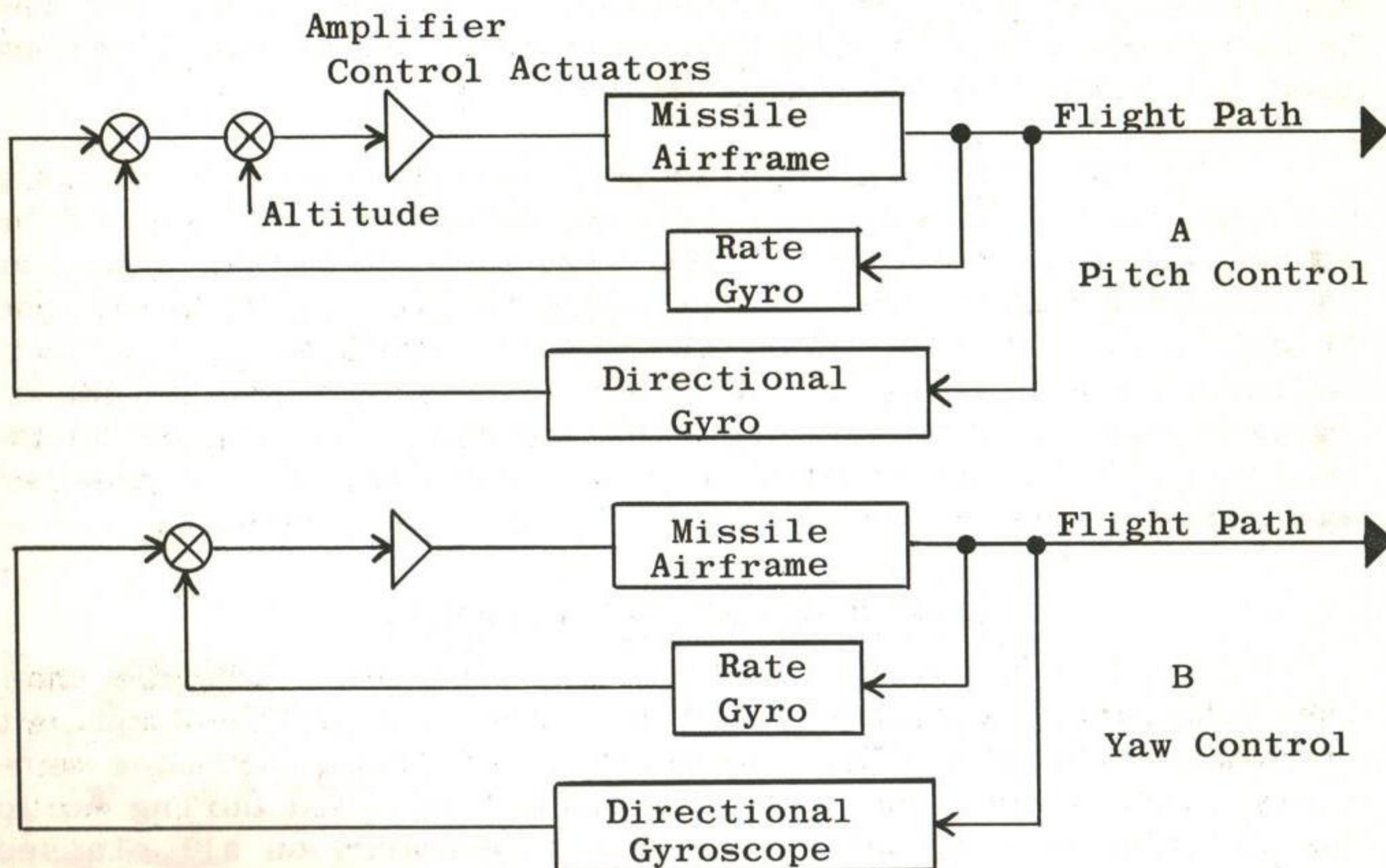


Figure 3 - V-1 Guidance

The air mileage unit was simply a propellor turned by the airstream, similar in effect to a ship's log. When the pre-set air distance had been flown, the control surfaces were locked for the dive. A radio transmitter was also triggered to allow a D/F fix to be taken, so that corrections could be made to successive firings.

Guidance Techniques

As previously stated, the question of guidance is determined primarily by the range desired. For a very long range device, the designer is forced to revert to an essentially gyroscopic-inertial system that may be supplemented by a long-range aid such as celestial, doppler, or other re-

liable fixing. Shorter range vehicles may also use inertial systems, but generally use a radio-fixing or radio-steering technique. The basic factor determining the range is, of course, either area of coverage or the radar line-of-sight.

Inertial Guidance Systems

The inertial guidance systems, particularly the doppler or celestial hybrids, provide the only practical systems for long-range guided missiles. They are independent of both jamming and insufficient coverage by ground-based fixing systems. These inertial systems closely parallel the principles outlined in the articles in previous issues of the RCAF Observer,* but the essential components will be discussed.

As pointed out in the articles on inertial guidance, the heart of the system is a stabilized platform supporting three accelerometers which measure the vertical and

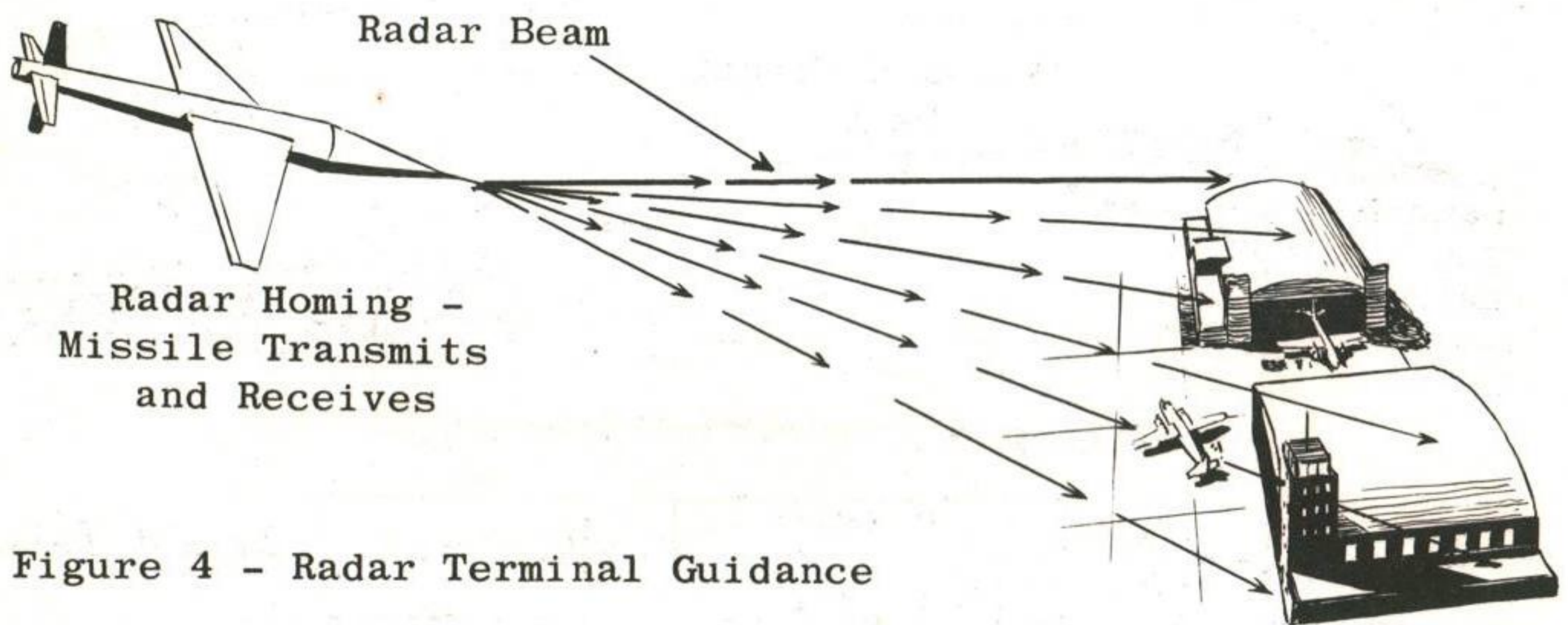


Figure 4 - Radar Terminal Guidance

two horizontal axes of flight. If the horizontal accelerometers are aligned along and across the desired trajectory, the missile will be provided with measurements of distance flown and departure from track. Once the vehicle is at the pre-determined ground position to commence its ballistic dive, the motor can be shut off and the controls locked, or a terminal guidance system could become effective (Figure 4). The terminal guidance system could use infra-red or radar homing onto its target (Figure 5).

* RCAF Observer - Oct 58

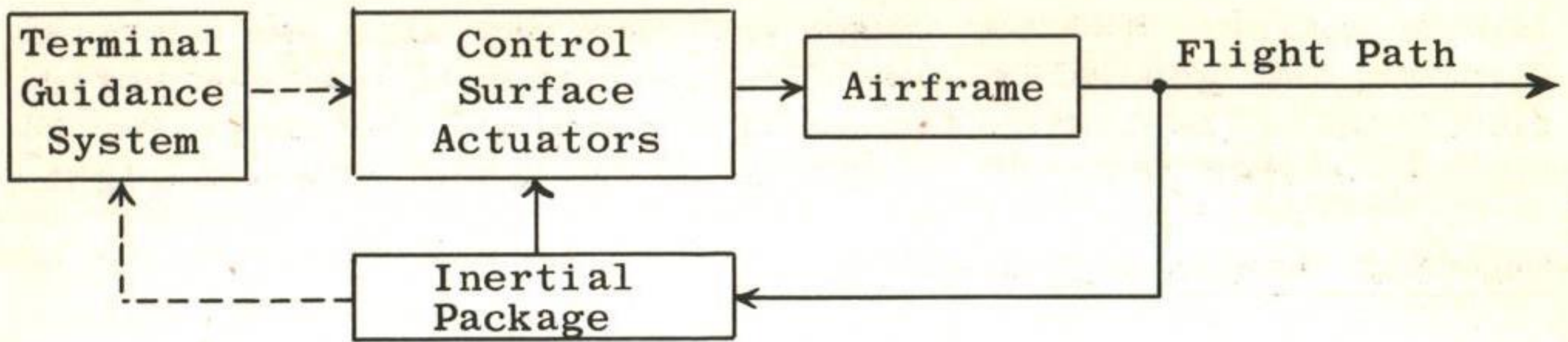


Figure 5 - Terminal Guidance System

The celestial or doppler monitoring of the long-range system would supplement the inertial data, differentiating between course and component errors. The inertial system could be monitored by the outside data, or used to provide the earth horizontal reference for a programmed celestial flight (Figures 6 and 7).

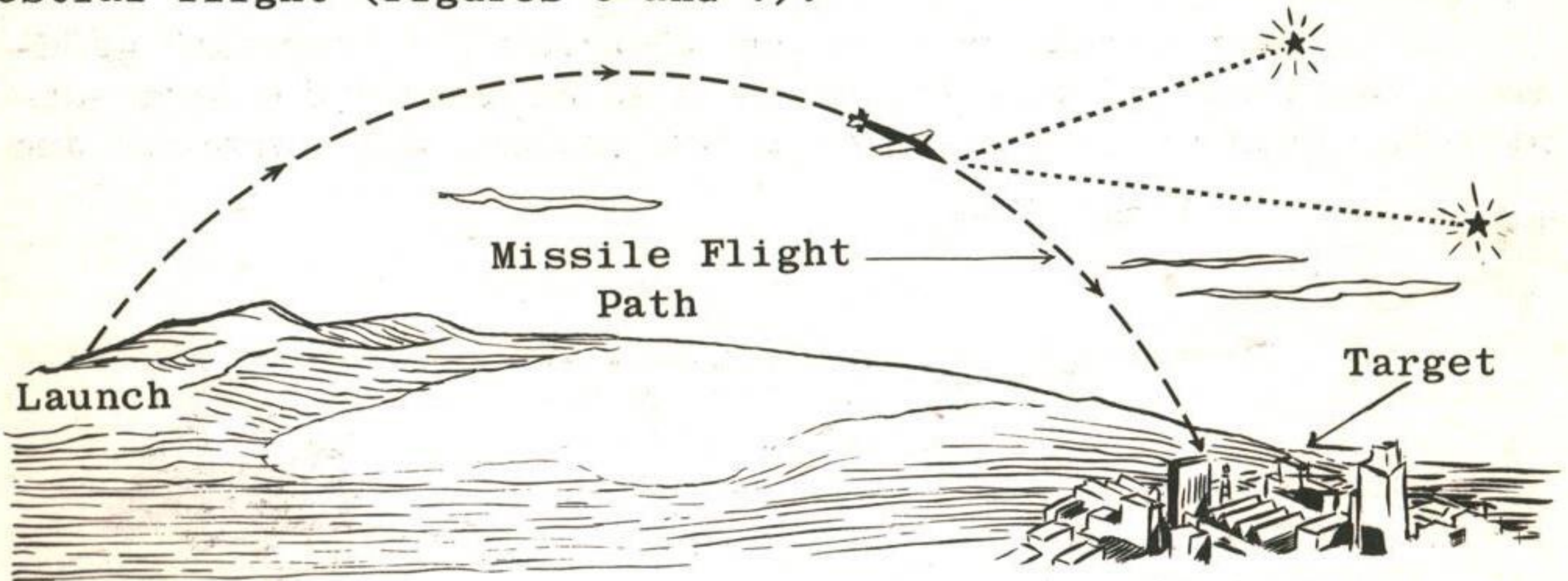


Figure 6 - Celestial Tracking

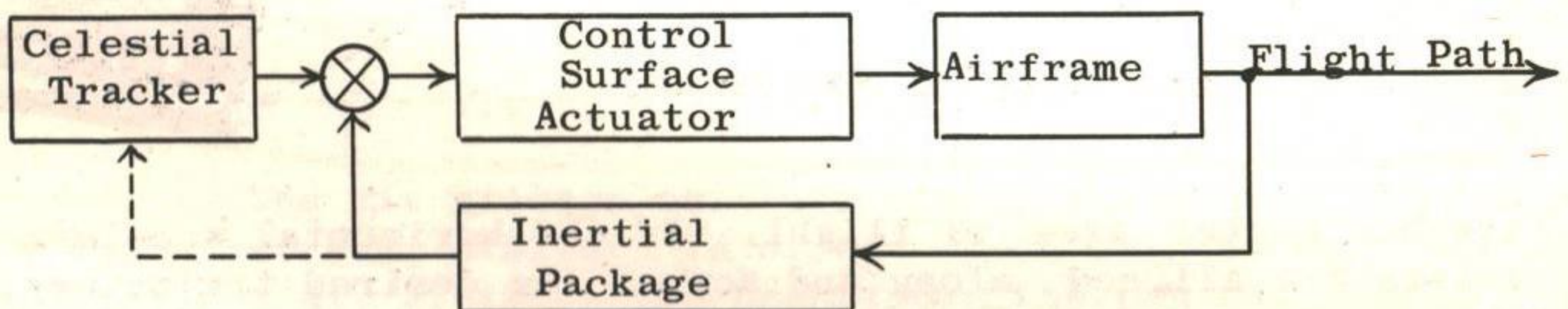


Figure 7 - Celestial-Inertial System

Beam-Rider Missiles

The beam-rider guidance system uses a radar beam directed towards the target. The missile system then detects its position relative to the centre of the beam and rides the centre line. Motor shut-off is achieved by having either the air miles flow or an intersecting cross-beam generate a cut-off signal.

An antenna is placed in the rear of the missile to sense the beam (Figure 8). A coordinator resolves into azimuth and elevation components any departure from beam centre. The azimuth and elevation components actuate the control-surface servos. The system can, in fact, be likened to the automatic target tracking of a fire-control system.

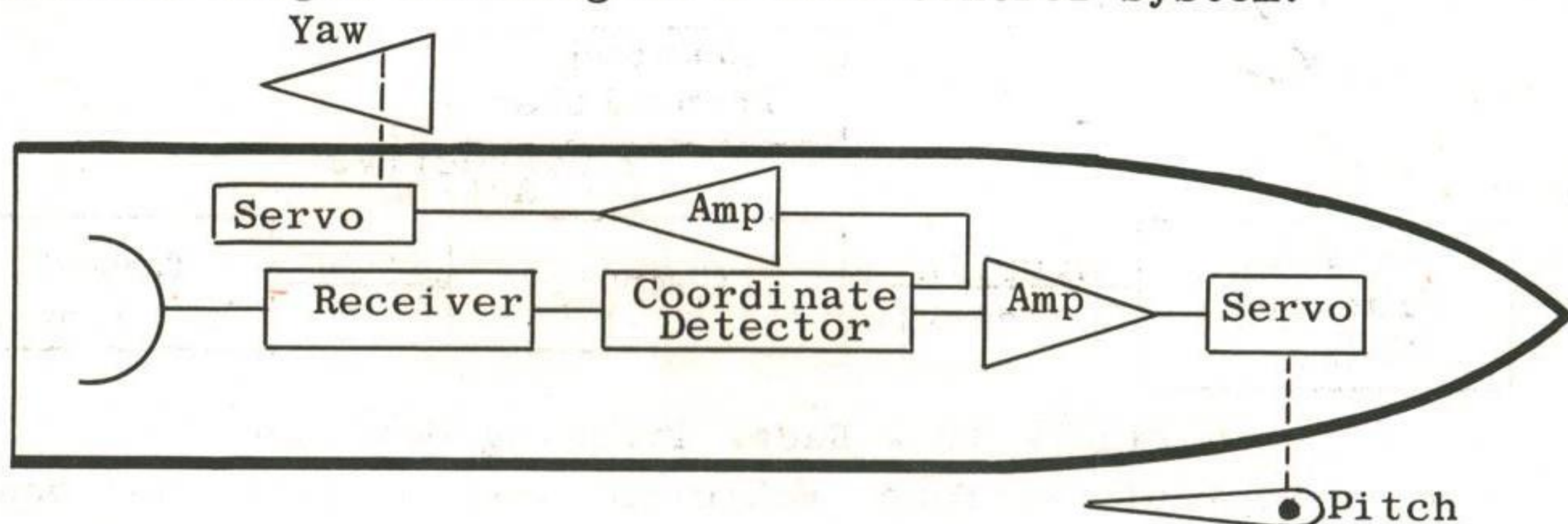


Figure 8 - Beam Rider Guidance

Because errors are corrected by azimuth and elevation signals to vertical and horizontal control surfaces, the missile must be prevented from rotating. If it is not prevented from rotating, the elevators would become rudders, and vice versa. Roll stabilization may be achieved by using either a vertical-axis or a rate gyro (Figure 9).

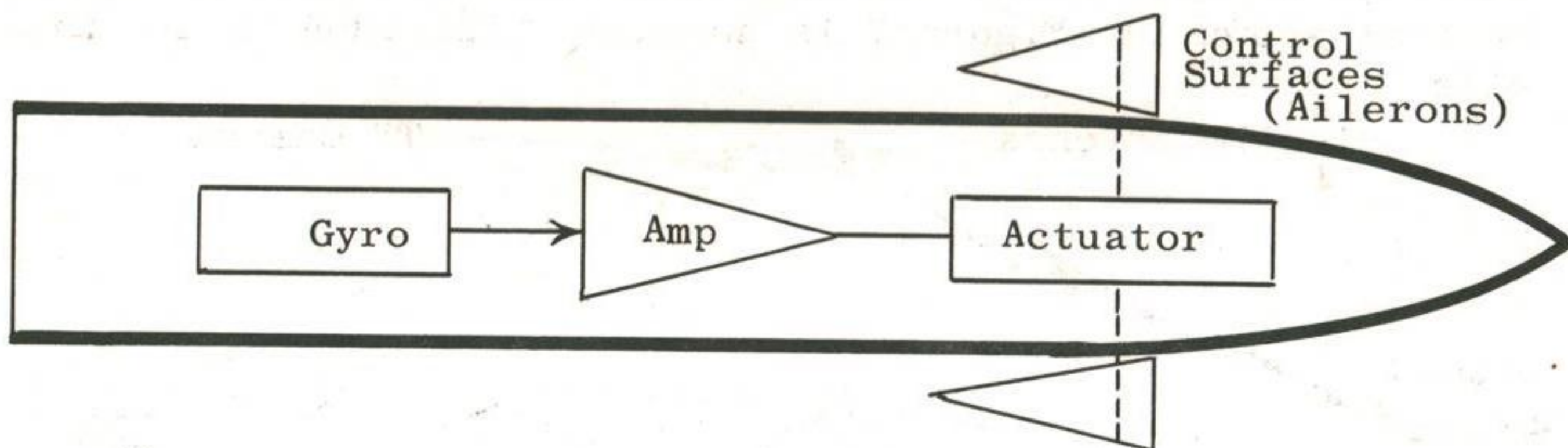


Figure 9 - Roll Stabilization

Command Guidance

In the command guidance system of steering, data is transmitted from an outside source to correct the missile's flight path. The missile is observed, to detect any deviations from its trajectory, and corrective commands are transmitted to revise its flight path.

Command guidance is the simplest system to instrument, because the tracking and computing elements are not installed in the vehicle itself. The technique was first

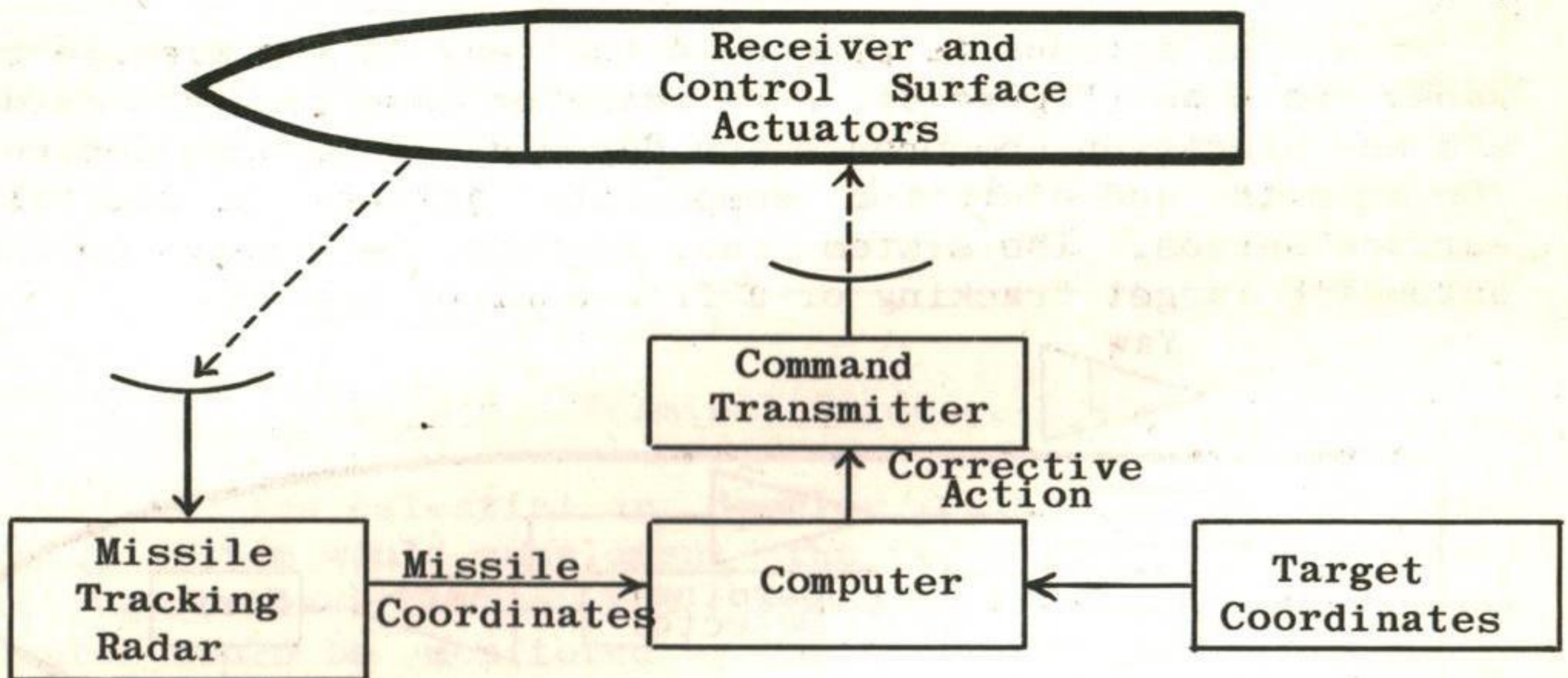


Figure 10 - Radar Tracking Guidance

used to control surface vehicles such as tanks and boats; drone aircraft are an excellent example of its use in the air.

A general flow diagram of a radar-tracking system is shown in Figure 10. If preferred, optical or television tracking (Figure 11) may be used. The radar measures missile position, which is related to the inputs of target coordinates to derive the steering commands. These are then transmitted to the control surface actuators in the missile. While it is not shown, a roll stabilization channel similar to that shown in Figure 7 is normally included in the missile.

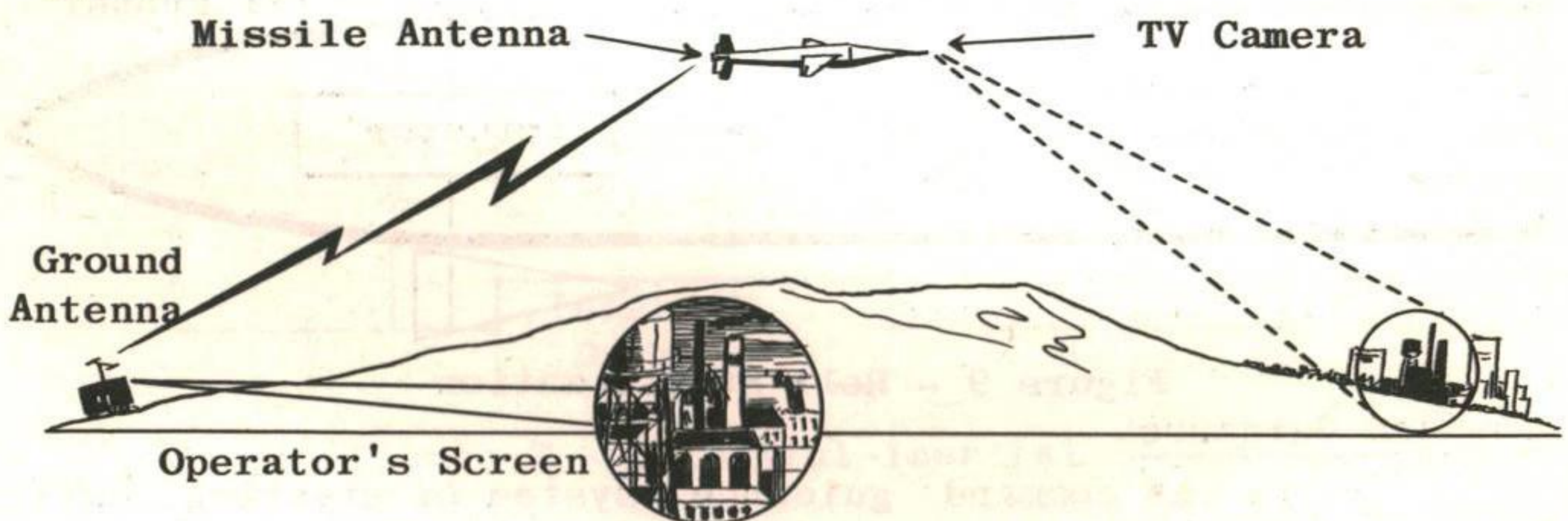


Figure 11 - Television Tracking Guidance

Ballistic Missiles

The ballistic missile can be likened to an artillery shell. The projectile is only guided in its initial rocket-burning phase, which may last from one to three minutes, after which it follows a ballistic path. The analogy

of the artillery shell is not completely true, however, because the vehicle is subjected to aerodynamic forces both during the guidance phase and on re-entering the more dense regions of the earth's atmosphere.

V-2 Rocket

The V-2 rocket, which created such havoc in London prior to the seizure of the Pas de Calais area, was the first true ballistic missile.

To ensure that the V-2 would hit its objective, the missile had to be guided to a point from which the ballistic curve led to the target. As in gunfire, this required that the vehicle be fired at a given azimuth and elevation. Unlike gunfire, a third variable of speed was added.

During the motor-burning period the V-2 was guided by external vanes exerting aerodynamic forces, and also by four carbon vanes in the stream of exhaust gases. The internal and external azimuth control vanes were interlocked, but the pairs of pitch vanes could be operated separately. The basis of the guidance system was two gyros, one controlling both roll and azimuth, and the second controlling pitch. The axis of the pitch gyro was precessed at a constant speed to move the projectile from its vertical launch angle to the desired value. Electrical signals were taken from pick-offs on the gyros and fed to servos which actuated the control vanes.

In early versions of the missile, the velocity was measured by sensing the doppler shift in re-transmitted radio waves, and a shut-off signal transmitted to the motor. This technique was later abandoned in favour of a gyroscope-integrating accelerometer, which cut off the motor once the desired velocity was reached. It is noteworthy that command guidance was also used to correct any azimuth error in the trajectory. A summary of the performance of the V-2 is shown in Figure 12.

Modern Ballistic Missiles

The problem of guiding modern ballistic missiles is essentially the same as those for the V-2; the only difference is that the vast ranges demand much higher perform-

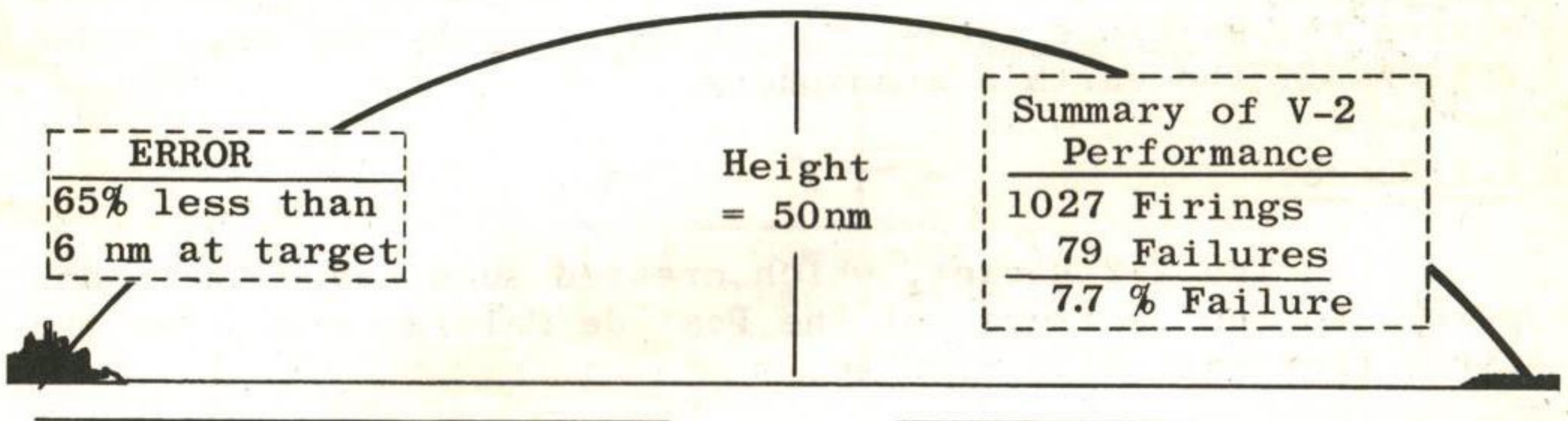


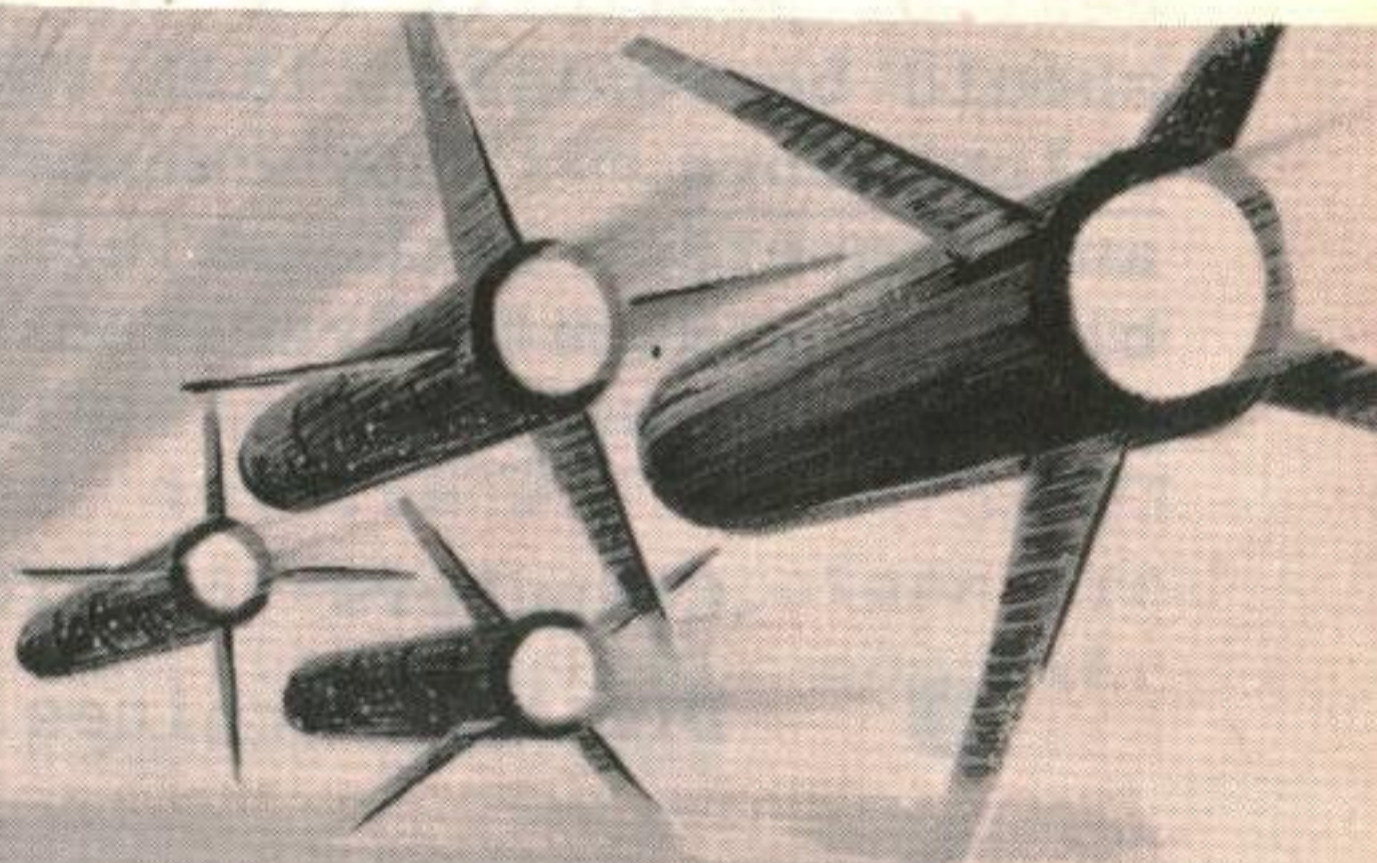
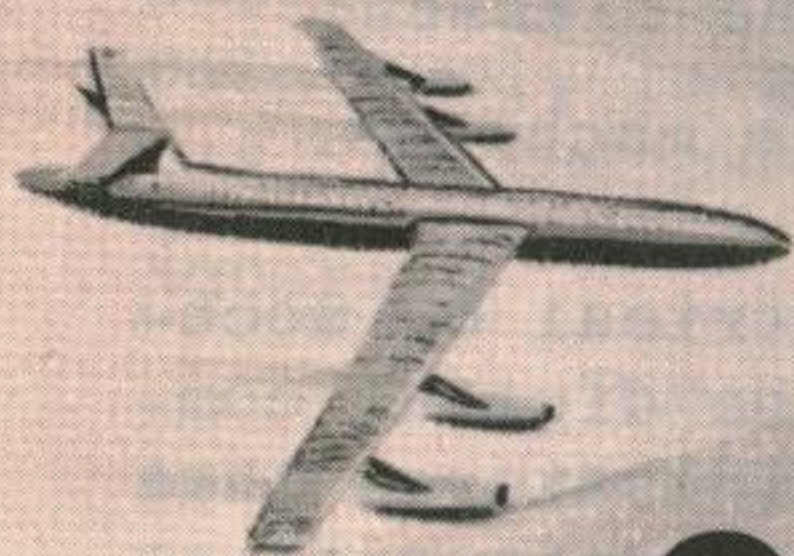
Figure 12 - V-2 Performance

ance from the guidance system. The basic component of the modern guidance system is a stable platform, which in addition to sensing the missile's motion vertically and laterally, also rotates it to the required pitch angle. The guidance system may actuate internal or external vanes, or as in several missiles, move the engine gimbals. Monitoring of the missile, even today, uses the German techniques of command guidance and doppler velocity measurement.

CONCLUSION

This introduction to the surface-to-surface missile has presented the problems associated with missile guidance. It has been in general terms because detailed control techniques differ between manufacturers. In any event, the reader with a sound background in gyroscopic theory and transmission systems should be able to deduce techniques that could be employed. It is hoped that this article has contributed to a fundamental knowledge of guidance techniques, and the problems involved in the design, production, and employment of missiles.

part 1



computers

Repeated references are being made today to different types of computers used in almost every field of activity. Reports are continually appearing about automatic machines being used for weather forecasting, general election predictions, calculating odds in horse races, computing monthly payrolls, and even operating the fully-automatic shopping centres of the future. The greatest growth in the capabilities of automatic computers has been during the past decade, prompted primarily by the needs of the aviation industry. In fact, it has been said that the problems of supersonic flight, missile design, and performance could not have been solved for many years without the aid of the electronic computer.

A computer may be required to solve many types of problems. In the observer specialities, for example, computers are used in navigation, fire-control, bombing, and fuel-control systems. In considering these different machines, the primary factor is whether the equipment must be installed in an aircraft or on the ground, because of the ever-present problems of space and weight. In this and the next issue of the RCAF OBSERVER, the classes of computer will be examined, with a discussion of the techniques and merits of each system, to give the reader a better understanding of computer types and capabilities.

The interest in computers has resulted in a great deal of publicity for the so-called "Electronic Brains". It should be realized that these devices are purely and simply calculators. They cannot do more than solve a problem that any competent mathematician can, but they can solve the problem in a minute fraction of the time.

Classes of Computers

Computers tend to fall into two broad classes:

● Digital machines.

● Analogue machines.

Both classes of computer may use either electrical or mechanical techniques to solve the problem, but the digital computer is normally electric. Both have several features that make them very attractive in certain roles, and in general the two techniques tend to complement rather than oppose one another.

ANALOGUE AND DIGITAL CHARACTERISTICS

Analogue computers vary in size, but have the common feature that all quantities in the problem to be solved are represented by corresponding physical quantities in the machine. Thus in a slide rule, one of the simplest analogue devices, the numbers in the problem are represented by lengths proportional to the logarithms of the numbers. Lengths on the rule are used as the analogue quantities, whatever the nature of the quantities in the problem. In electronic computers, the analogue quantities are normally voltages which correspond to the quantities in the problem according to a fixed scale.

The digital machine solves information in discrete numbers, in contrast to the analogue computer's continuous data. For example, the ordinary desk calculator is a digital machine. The input number and the results of the computations are always exact digital numbers. The accuracy is determined by the size of the number the computer can handle. In electronic machines the input quantities are represented as pulses, with the accuracy determined by the number of pulses (or digits) used. All computations are completed arithmetically, regardless of their type.

Size

Analogue computers can vary in size from tiny hand-held devices, such as the slide rule or navigation computer,

to vast machines occupying many cubic feet of space. The size is determined by the complexity of the problem to be solved. The basic digital computer is the Abacus, still used today in Asia for solving addition, subtraction, and multiplication. Digital desk calculators are relatively portable. The electronic digital computer, however, has a minimum size because of the central pulse-generating component, and because this unit does not increase in size with increased capability of the system, simple electronic computers are relatively large. The result is that the digital computer has, in the past, been limited to complex problems.

Accuracy

The accuracy of analogue machines is generally poor. Errors as small as 0.1% are hard to achieve; errors of 1% are not unusual, and sometimes they are as large as 5%-10%. This characteristic of the system is frequently tolerable because of the inaccuracy of the inputs available (navigation computers or aerodynamic problems). These errors are caused by errors in the measurement of physical quantities, such as voltage, and variations in the characteristics of the electronic components and tubes.

The digital computer is, in theory, perfect in its computing accuracy, but this infinite accuracy is dependent upon an infinite number of digits. In practice, a very large number of pulses can be used, so reducing the error to such a small quantity that it is insignificant.

Speed and Flexibility

Analogue devices are inflexible, being limited in application once they are designed to solve a specific problem. For example, the vector side of the navigation computer has little use for anything other than the solution of the navigation triangle of velocities. In solving its specific type of problem the analogue computer is extremely fast, and electronic analogue devices are frequently three times faster than digital machines when the inputs are varying.

The digital computer, operating on a purely arithmetic basis, is capable of solving any problem that can be reduced to arithmetic. The programming or rearrangement of the input information is the only factor that determines or limits the capabilities of the machine. Because the computer operates using discrete digits, it cannot handle continuously varying inputs exactly, since the number of pulses representing a quantity can change only by one pulse. Calculations involving integration or differentiation must be solved

using calculus of finite differences, but since the effective number of pulses representing a quantity can often be as high as one million, continuous variation can be approximated. The digital machine is generally slower than its analogue counterpart in handling varying inputs, or functions such as sine and cosine, because of its computing technique.

In discussing relative speed, it must be remembered that the automatic digital computer is 20,000 to 30,000 times faster than a man solving the same problem on a desk calculator. Representative times for an airborne digital computer currently under development are: addition, 240 microseconds; multiplication, 4000 microseconds. A large ground computer is considerably faster, with typical speeds as follows:

→ Addition time - 1.2 milliseconds (ms).

→ Multiplication - 2.2 ms.

→ Square roots and reciprocal square roots - 105 ms.

→ Cosines of angles to 11 decimal digits - 80 ms.

→ Reciprocals - 95 ms.

Highly complex problems may take several hours to complete, but manual solution of the same problem could involve years of work. As mentioned earlier, it has been said that the problems connected with rockets and high-speed flight could not have been solved for many years if the giant computers had not been available.

Application of Computers

The analogue computer is ideally suited to computations involving varying inputs. At present, the analogue computer is used for the simulation of dynamic problems in the study of missile system performance, with the computer reproducing the characteristics of the system directly. This is a very economical method of obtaining information without actually flying the aircraft or missile. Analogue devices have also been used exclusively in airborne computers because of the varying quantities to be computed. In fact, the analogue type is the most suitable for any problem that is from simple to medium complexity, but once complex problems are reached the digital device is superior.

Until recently, the digital computer has been applied primarily for the purposes of delayed-action, data-reduction problems, or for specific scientific calculations where long solutions of a repetitive, high-precision nature are necessary. One further advantage of the digital computer that has not been mentioned previously is its "memory" capability. The digital computer can accept inputs from a previously-made punched card, punched tape or magnetic tape, permitting use of problems solved previously to solve further problems. Computers also have storage capabilities permitting immediate automatic location and use of instructions or other problem solutions. Utilization of this "memory" permits "self-checking" action by the computer. Recent developments in miniaturization and sub-miniaturization of components have made the digital computer an attractive device for airborne systems, particularly in those roles where many problems, such as navigation, fire control, and missile control have to be solved. A single digital computer can handle all of these problems, resulting in higher accuracy without an attendant weight penalty.

Functions Solved

The functions normally required in a computer are:

- Addition
- Subtraction
- Division
- Multiplication
- Trigonometrical Functions
- Differentiation
- Integration

The first four are self-evident, but the other functions require more explanation.

Trigonometrical Functions

The presentation of navigational data normally requires that the inputs be converted from heading and air-speed (or track and groundspeed), which are polar coordinates,

into rectangular or cartesian coordinates (miles N/S and E/W). The device which performs this operation is called a Polar/Cartesian Converter.

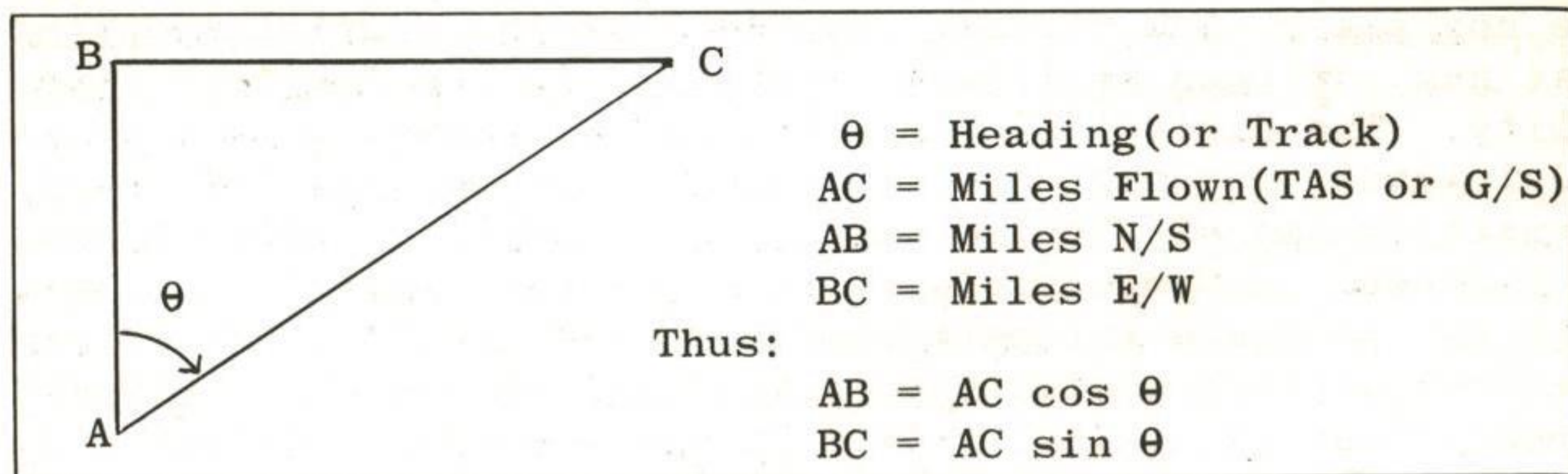


Figure 1 - Polar/Cartesian Conversion

It should be apparent from the example above that the two trigonometrical functions required are SINE and COSINE. Again considering the example above, the east-west component is in miles; to convert this into longitude, the convergency of meridians must be considered, requiring multiplication by the SECANT of the latitude. Thus a third common trigonometrical function must be found.

Differentiation

Differentiation is particularly important in "damping" control systems to prevent over-control. The differentiator provides the rate at which an input is changing, which is vital if stability is to be achieved.

Integrators

The integrator provides an output proportional to time: the altitude mechanism of the Kollsman Periscopic Sextant is an excellent example of this. For example, consider that an integrator has a four-unit output, which was produced by a constant input signal for one minute. If the input signal had lasted only half a minute, the output would be only two units.

Rearrangement of Equations

While the foregoing may have suggested that the solution of the problem is simple, difficulty can be encountered with certain problems. Consider the following division:

$$\frac{x}{y} = z$$

Obviously if y is zero, z must be infinity, which is of course impossible. Even if y is a very small number, considerable difficulty could result. Thus it is often simpler to rearrange the equation, before mechanization, into the form:

$$x = yz$$

This is one isolated example, but there are many more. The main factor is the achievement of simplicity in the actual computation, which is the reason behind all rearrangements.

ANALOGUE COMPUTERS

The analogue computer is the conventional type of machine that has been used in aircraft navigation systems for many years. Examples of automatic or semi-automatic systems are the API, GPI, R0 Computer, and PHI in which the

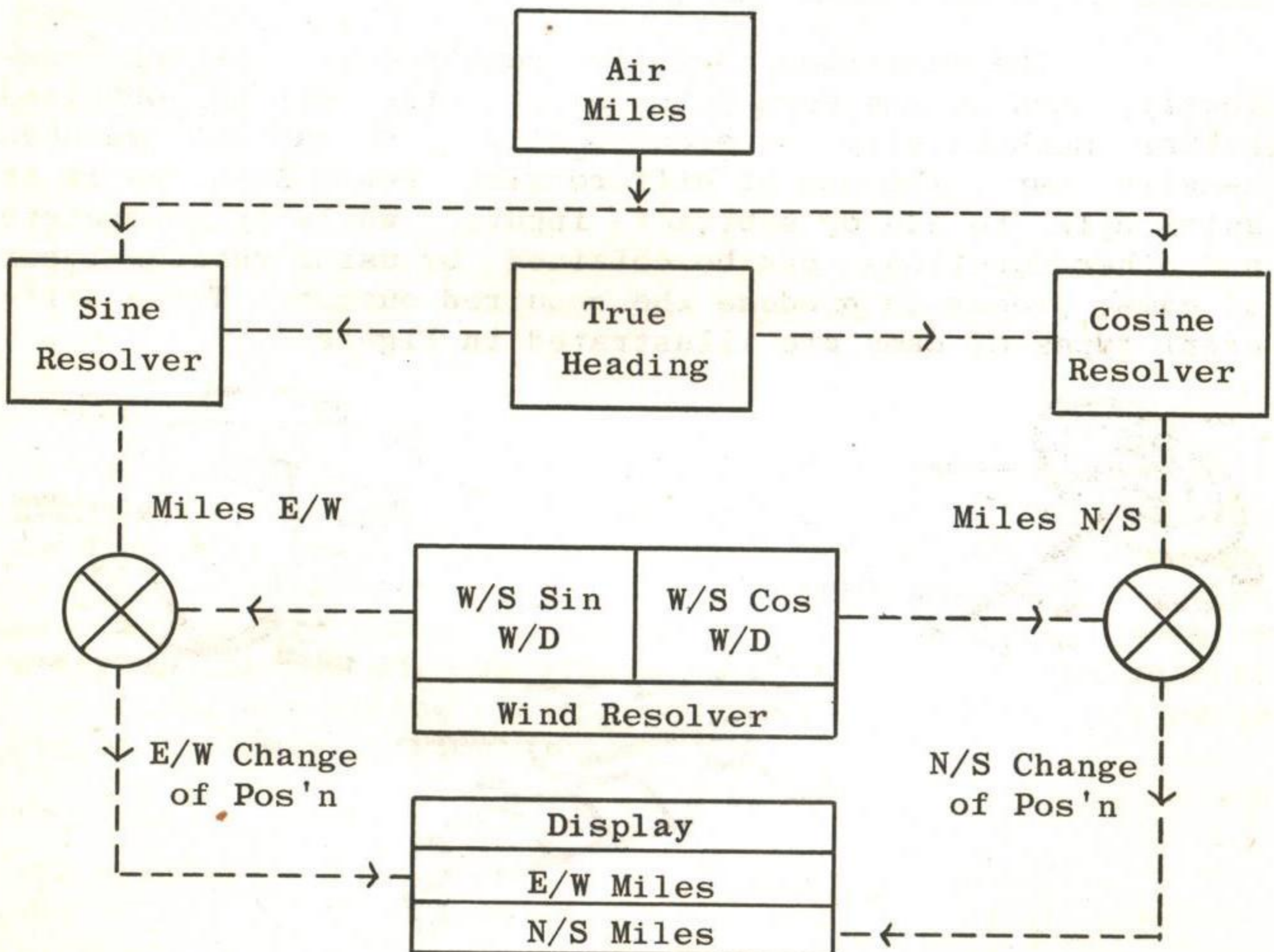


Figure 2 - Navigation Computer

problem is solved using either mechanical or electrical resolvers or a combination of both techniques. It is difficult to generalize on the operation of an analogue device, because of the different problems that they are capable of solving. A typical navigation flow diagram is shown in Figure 2.

In Figure 2, the computer is solving the problem in cartesian coordinates (miles N/S and E/W). Inputs of TAS, True Heading, and W/V are fed in continuously to be resolved into a display in miles N/S and E/W of the datum. Mechanical or electrical sine-cosine resolvers may be used to produce the air and wind miles in their respective components. Transmission can be electrical or mechanical (shaft rotation). Once a given type of input/output has been selected, however, it must be continued, or converted. It should be apparent that the designer can solve the problem using an unlimited selection of techniques; the only common denominator is the general information flow that is mandatory in obtaining the ground position of the aircraft.

Mechanization of Functions

The functions normally required were listed previously, and as has been pointed out, they may be obtained either mechanically or electrically. Mechanical methods usually imply the use of differential gears such as in an automobile to add or subtract inputs, while trigonometric and other functions can be obtained by using various types of cams, precut to produce the required output. Three different types of cams are illustrated in Figure 3.

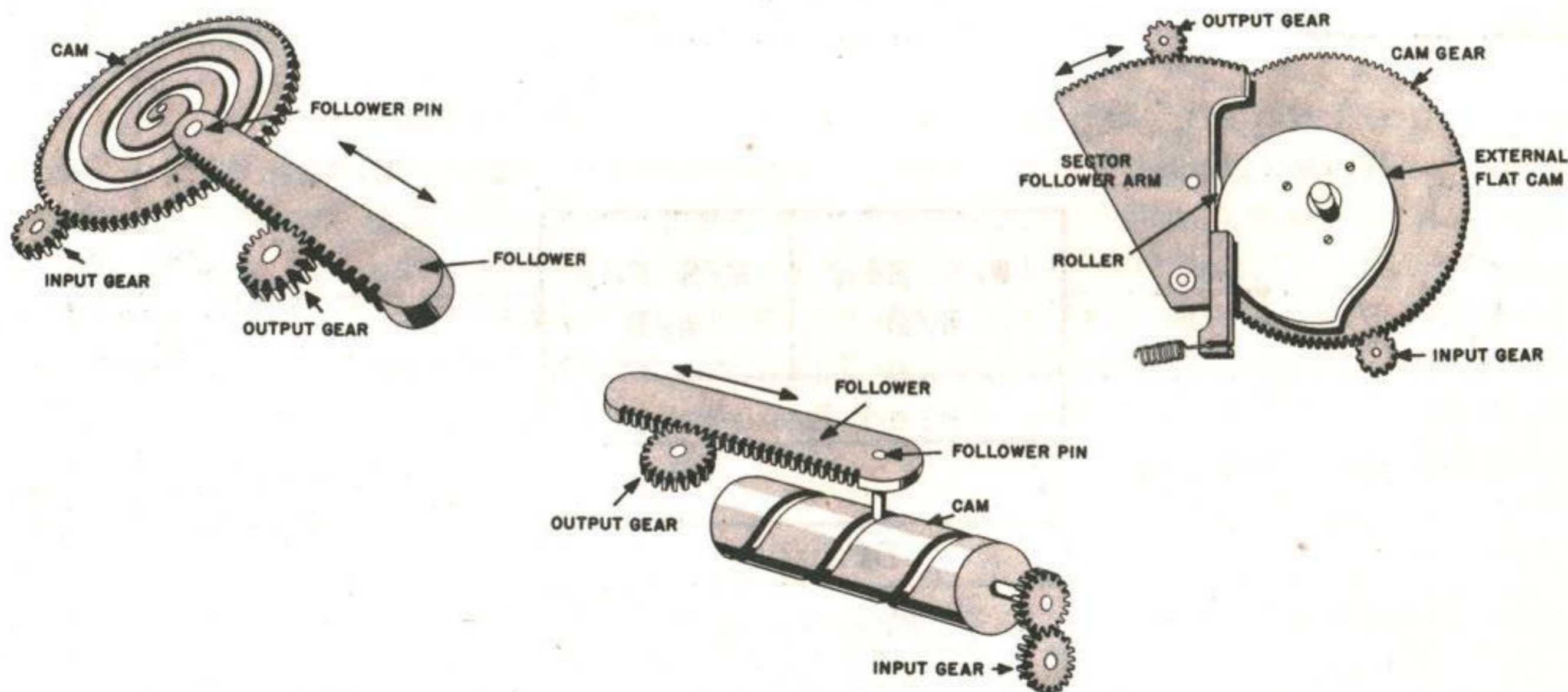


Figure 3 - Computer Cams

Electrical devices depend almost entirely upon the application of Ohm's Law ($E = IR$). By varying the resistance of a potentiometer according to one input, the required function is obtained. For example the flat-card potentiometer consists of a flat, rectangular card wound with thin resistance wire, with the ends connected to equal and opposite potentials. A wiper arm (slider) at the centre is carried on a spindle so that the sine or cosine output depends on the alignment of the wiper with respect to the input datum (Figure 4).

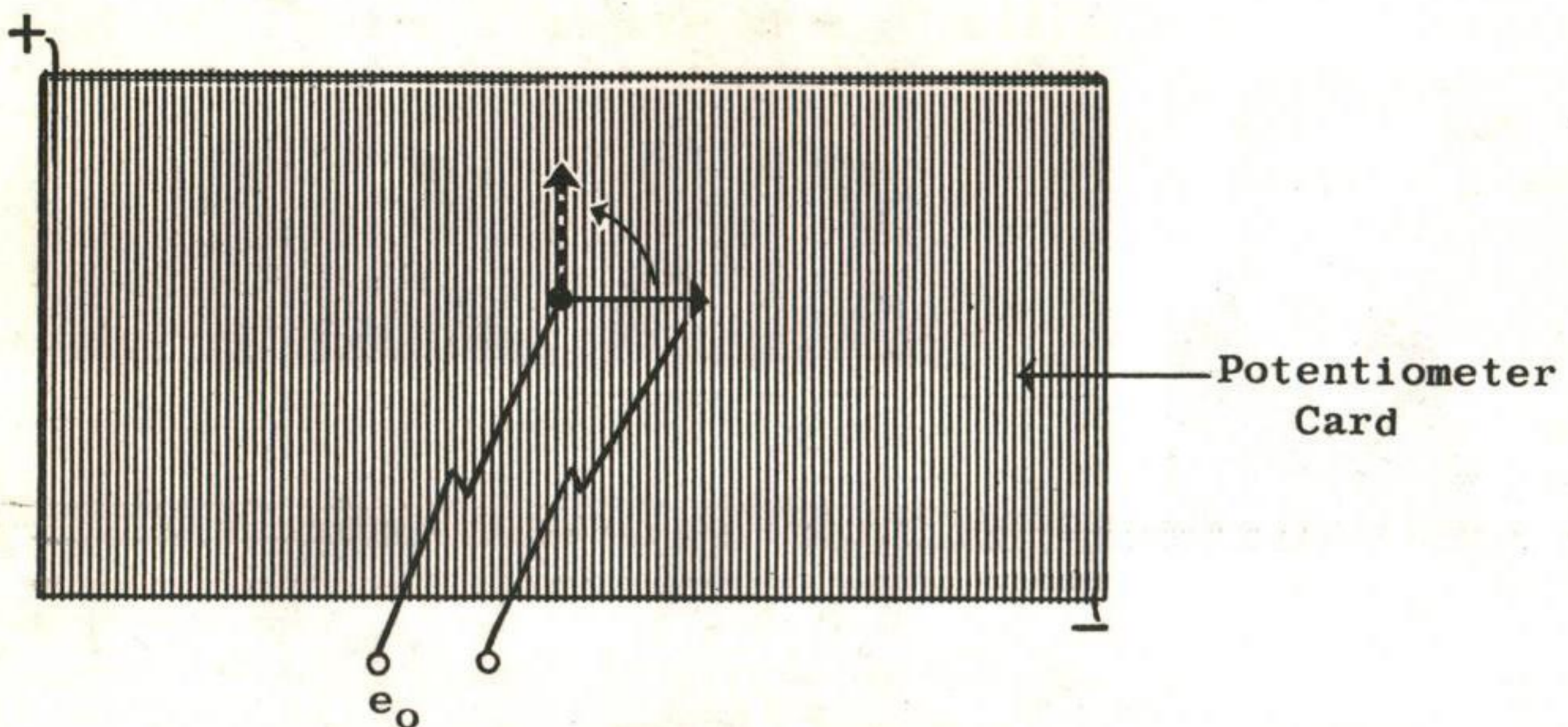


Figure 4 - Flat Card Potentiometer

CONCLUSION

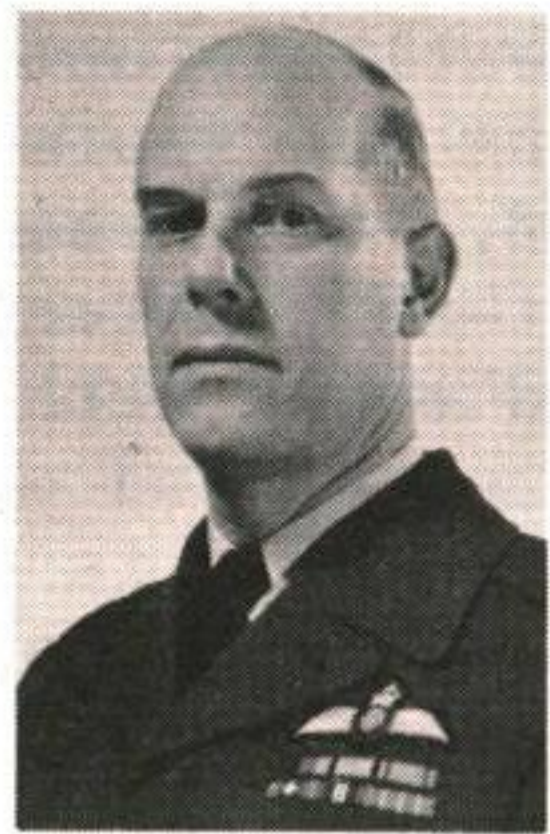
This has been a very brief introduction to computers generally, and to the techniques used in the analogue machine. It has been brief because of the tremendous scope of these instruments, and the wide variety of components that may be utilized. In the next issue the digital machine will be introduced, showing its capabilities and general operation, thus giving a basic understanding of the two techniques that may be encountered.

Central Navigation School



STAFF

1958-9



W/C WF DAVY



S/L EJ HAUGEN



S/L M KAYE



F/L RR BARBER



F/L MS SLEZAK



F/L GW PATRICK



F/L WD LYALL



F/L LJ RUSHCALL



F/L HH ENNS



F/L JW RODGER



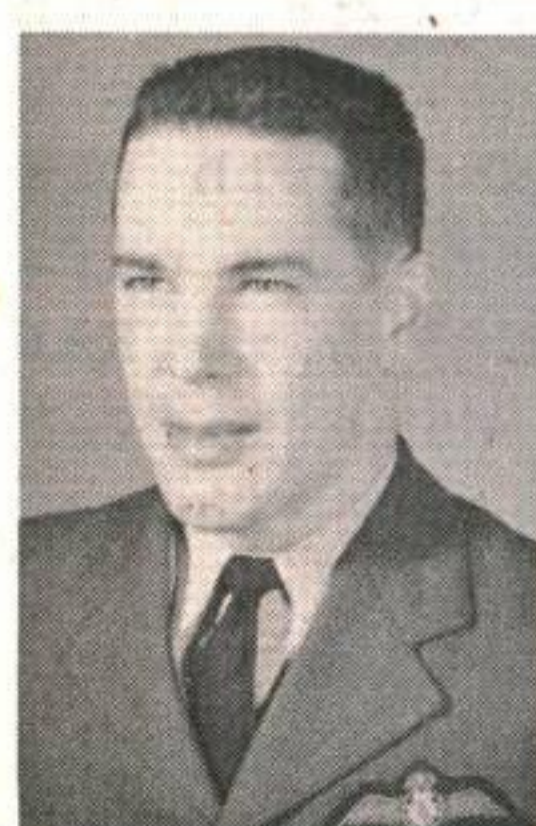
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F/O DK SCHNEIDER



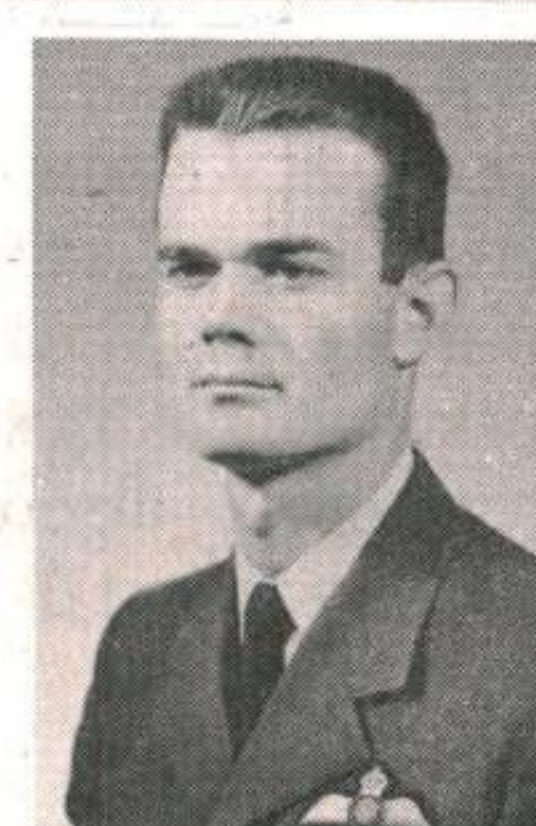
CAPT CE EVANS



F/O RJ PEARCE



F/L JA ROBERTSON



F/L MD GATES



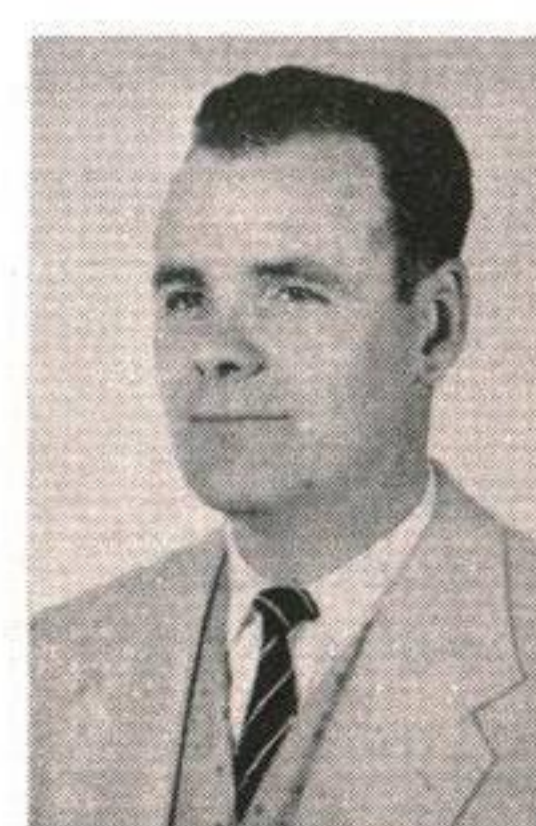
F/L CH NASON



MR LC ODDY



F/O A MCLELLAN



MR JJ MCBAIN

RCAF MPPS

by Squadron Leader R.H. McNichol
2 Air Observer School

Generally speaking, the use of the Most Probable Position (MPP) is confined in the RCAF to transport operations in areas where fixing aids are limited. In the southern areas of Canada, radio aids are readily available, both over land (radio range) and over sea (ground-wave Loran). Therefore, while all RCAF navigators are familiar with the construction of MPPs, they are used only in rather rare circumstances. In the areas of the North Atlantic where RAF Coastal Command operates, fixing aids are more diversified and of varying degrees of accuracy and availability. Therefore it is found necessary to use MPPs frequently.

It is also timely to point out that the RAF have recently brought into operation a new method of constructing MPPs. This system is simpler than that used in the RCAF in that the method is standard for all cases, when using either one or two position lines. This method is shown in the appendix.

General

The more general use of MPPs is found in Coastal Command operations because the range of ground-wave Loran and Consol is reduced at low altitudes. Also, weather conditions either preclude the use of astro, or turbulence reduces the accuracy of the observations. It therefore becomes necessary to make the maximum use of any information obtained, which means that it must be "compromised" with DR navigation.

Loran

There are many areas in the north-eastern Atlantic where Loran fixing is not available; either one position line only is available, or the accuracy of one or more lines may be doubtful. There are two Loran pairs situated with transmitters in northern Scotland, Iceland and the Faeroes. The pairs are oriented so that the best fixing is available on the trans-Atlantic route between Iceland and the UK (Figure 1). The base-line extension areas then lie to the north in the Norwegian Sea. Unfortunately, this is a logical theatre of operations for Coastal Command. Further, the use of Loran in this area is affected by a reduction in range due to magnetic disturbances at the rather high latitude.

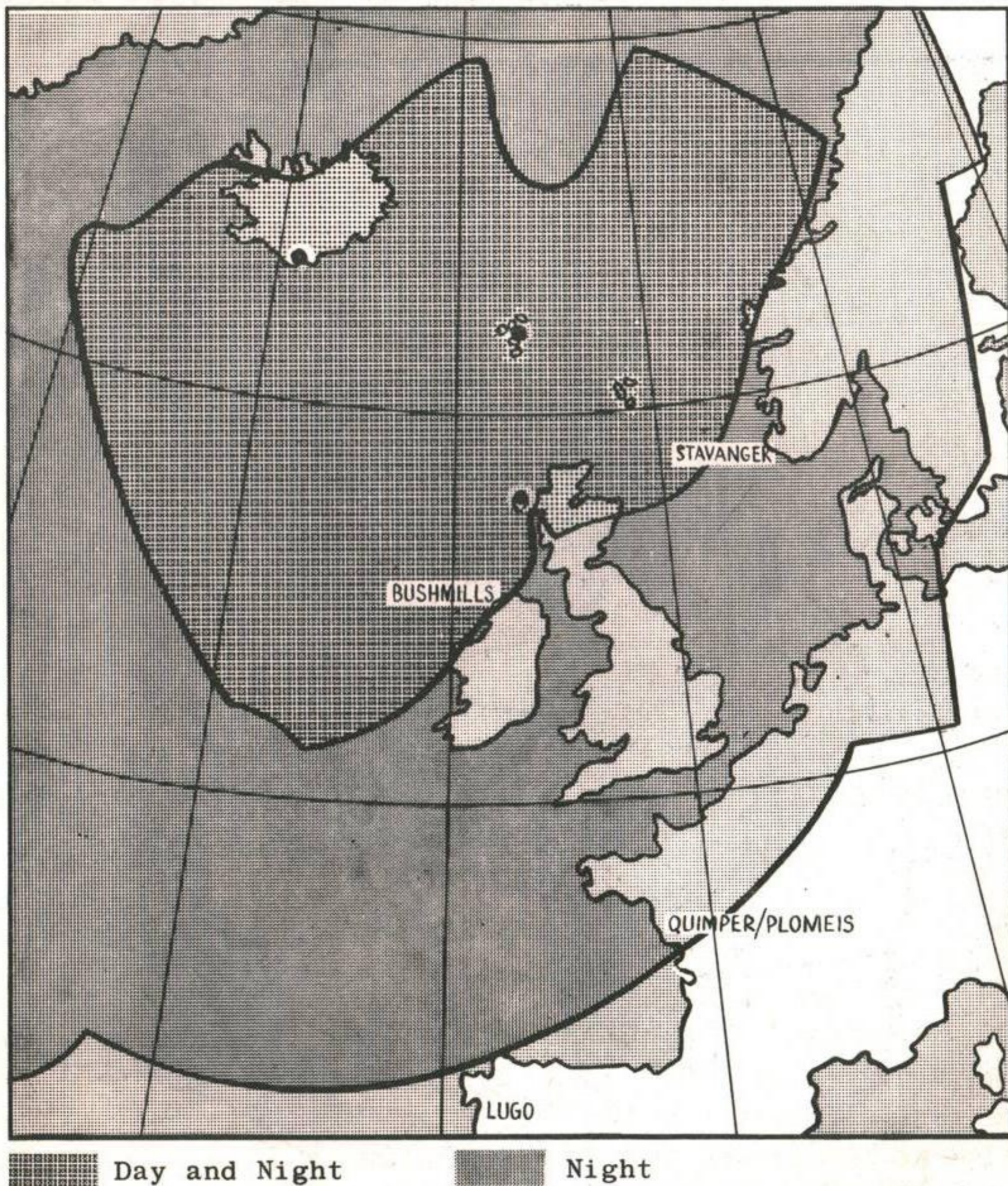


Figure 1 - Loran Coverage

Sky-wave Loran is available at night, but again the accuracy obtained is such that the use of MPPs is recommended. Also, in the summer period there is a short period of darkness when sky waves are available, and a rather long period of twilight during which it is unlikely that any accurate Loran may be obtained.

Consol

The use of Consol poses similar problems. Except for a small area north of Scotland, only one position line is usually available in the Norwegian Sea. Over the North Sea, care must be taken when using Stavanger to avoid plotting position lines in the wrong sector, because the sectors are only 20 to 30 miles in width (Figure 2). There is a large area of relative inaccuracy in the Bay of Biscay con-

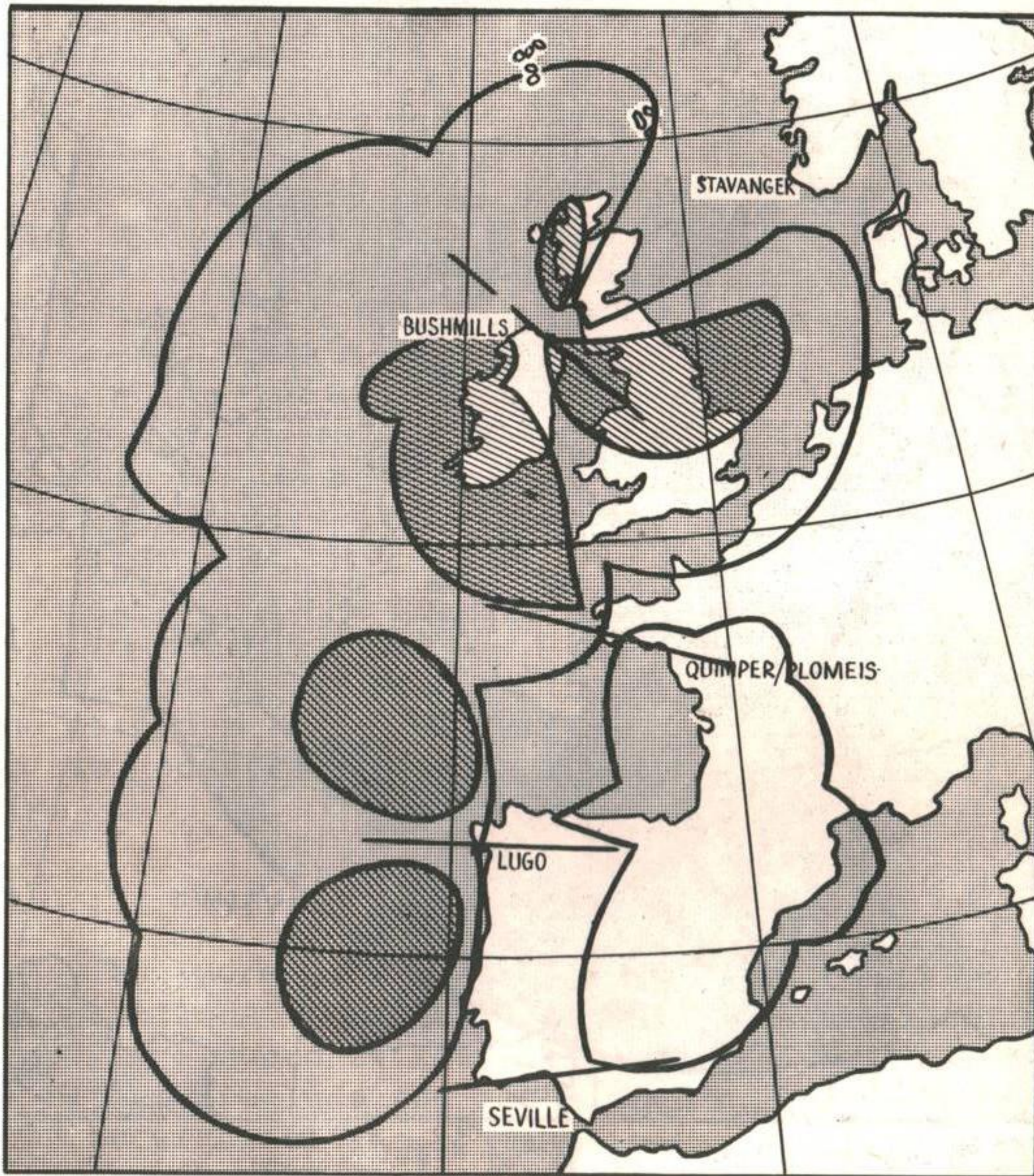


Figure 2 - Day Consol Coverage

nected with the Ploneis station. As can be seen in Figure 2, two-position-line fixes with 5 nm accuracy can be obtained only in limited areas during the day. Figure 3 shows that the accuracy at night is even worse. Thus a very good case can be made for using MPPs with Consol at all times, if the most accurate estimate of the aircraft position is desired.

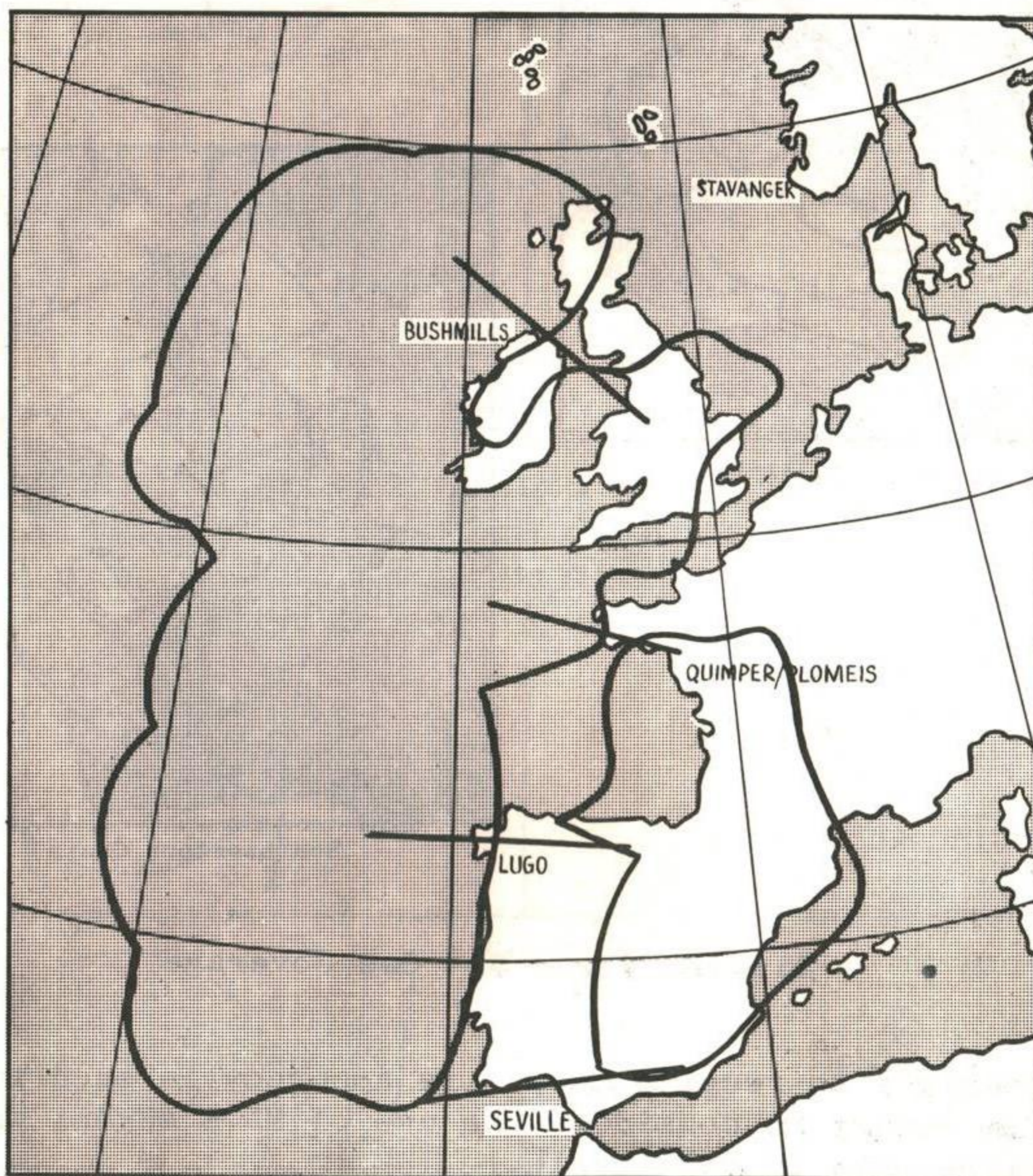
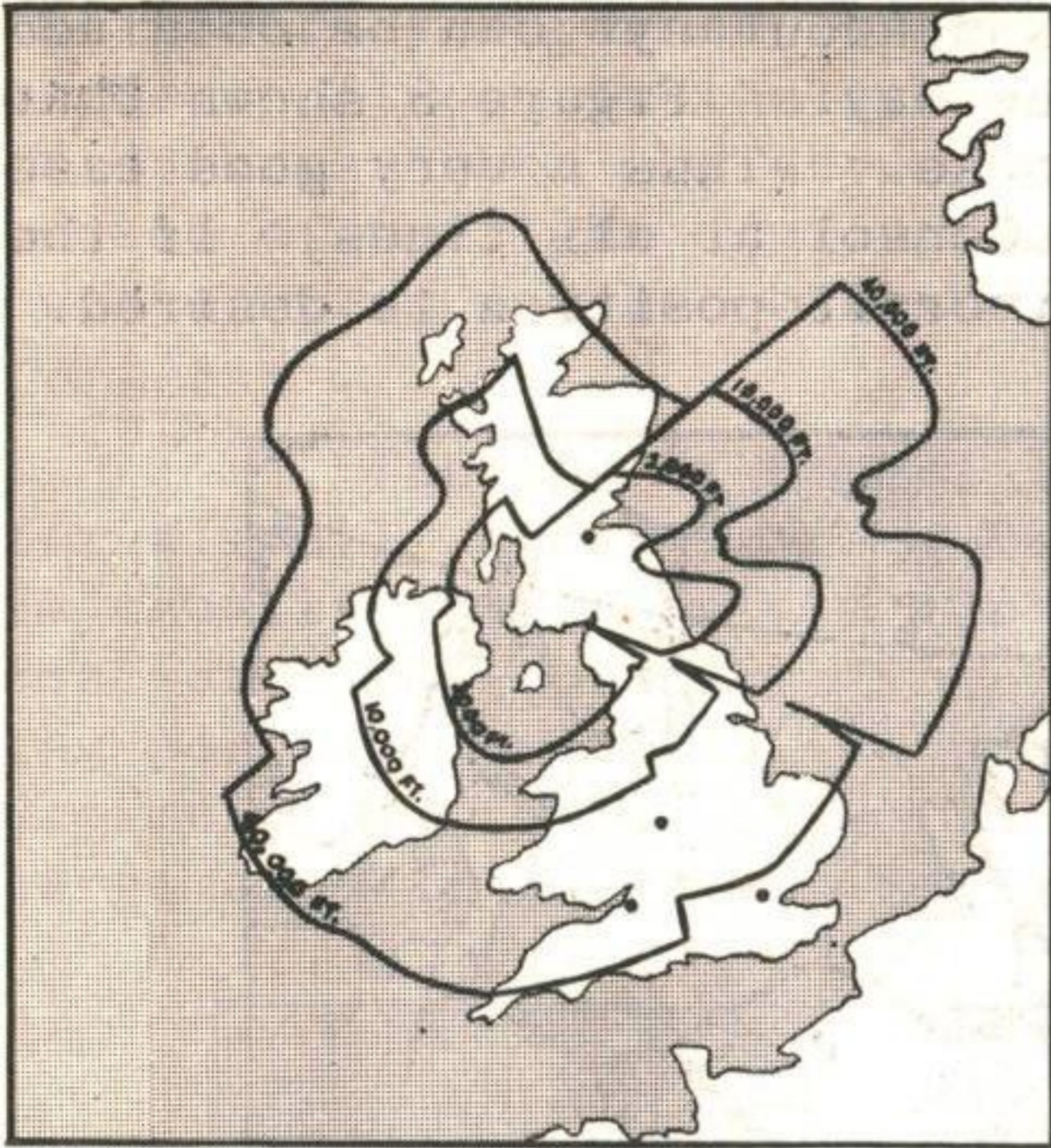


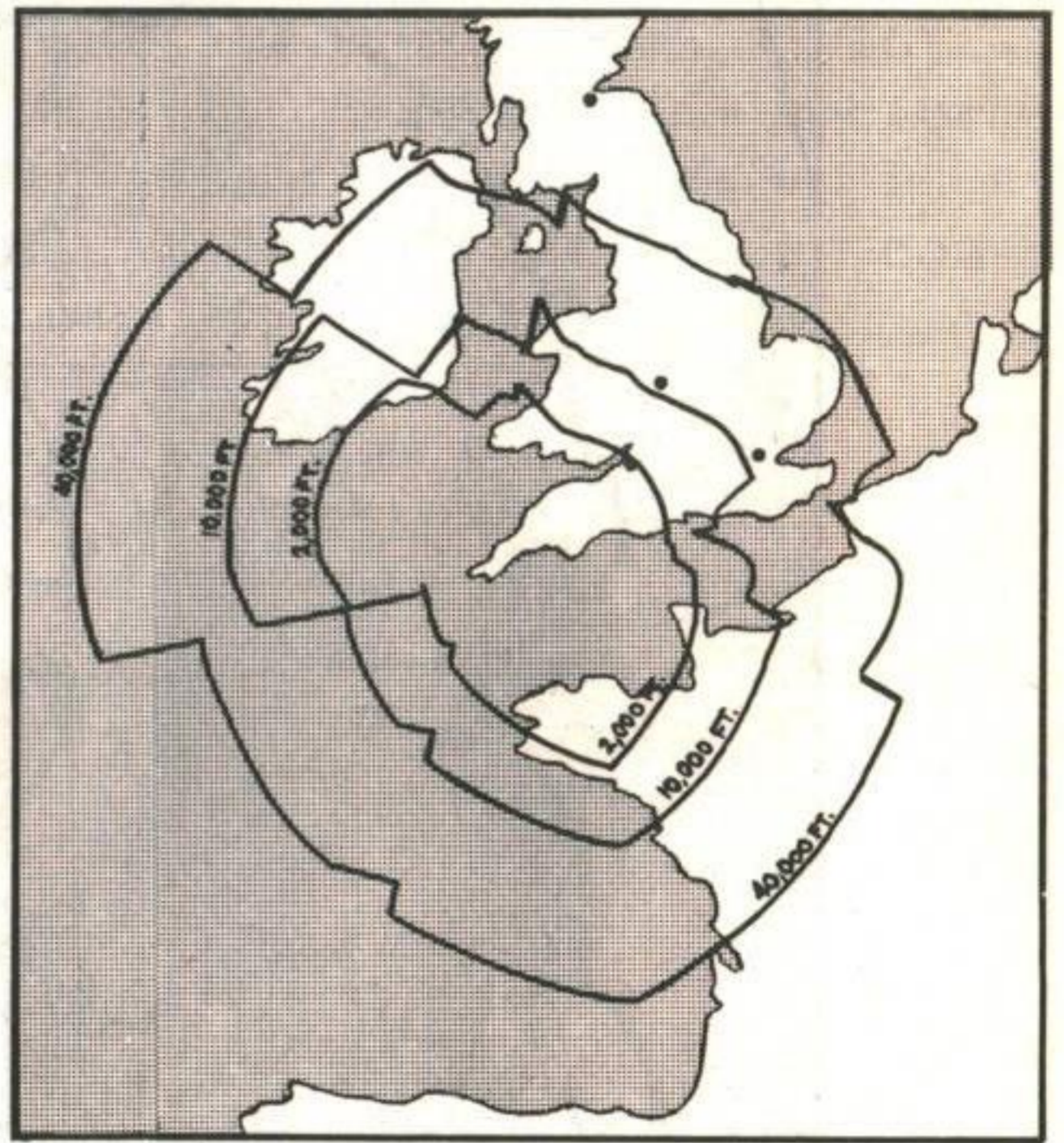
Figure 3 - Night Consol Coverage

Gee

Ex-wartime navigators will be wondering why Gee has not been mentioned as a fixing aid before Loran and Consol. Gee is still used effectively in Europe and is very accurate. It is used in RAF Coastal Command, but only on flights over or near the UK. The range at which Gee can be received is very limited at the heights most frequently flown in Coastal Command operations (Figures 4 and 5). When



Scottish Chain



Southwestern Chain

• Figures 4 and 5 - Gee Coverage

it is possible to receive Gee, its accuracy is such that it is not necessary to consider the use of MPPs except where a single line only is obtainable.

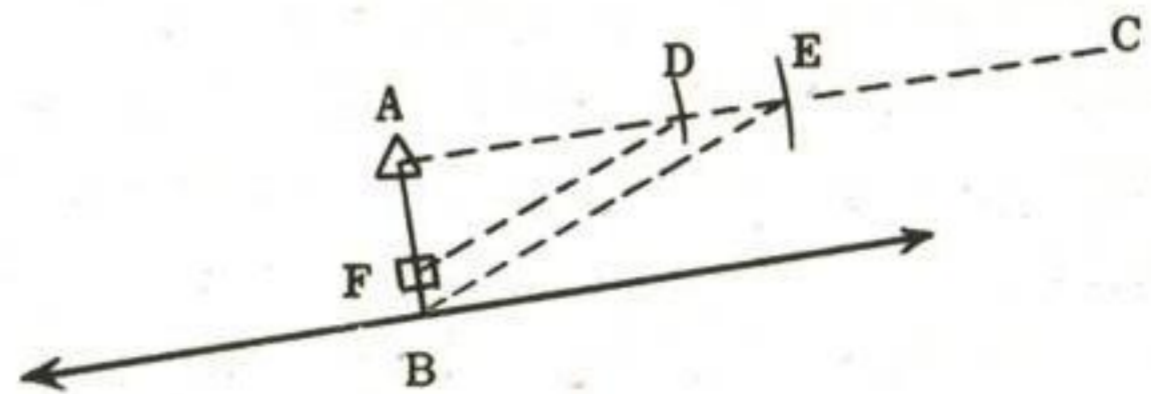
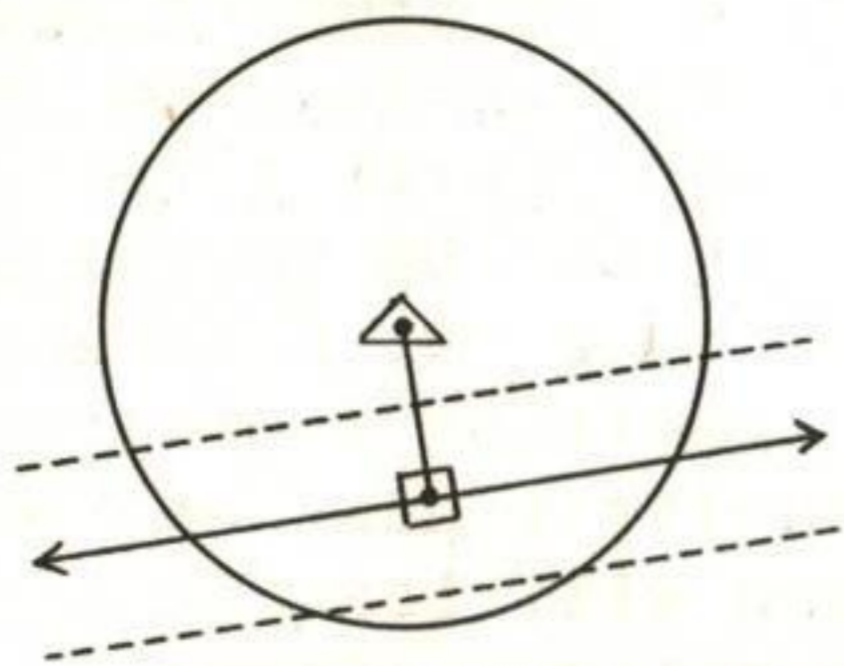
Astro

It is well known that meteorological conditions over the North Atlantic severely limit the use of astro position lines by day or night when flying at low altitudes. When astro is available, it is common practice to construct MPPs from all information other than accurate three-position-line fixes. In many instances, the turbulence at low levels will diminish the accuracy of celestial observations.

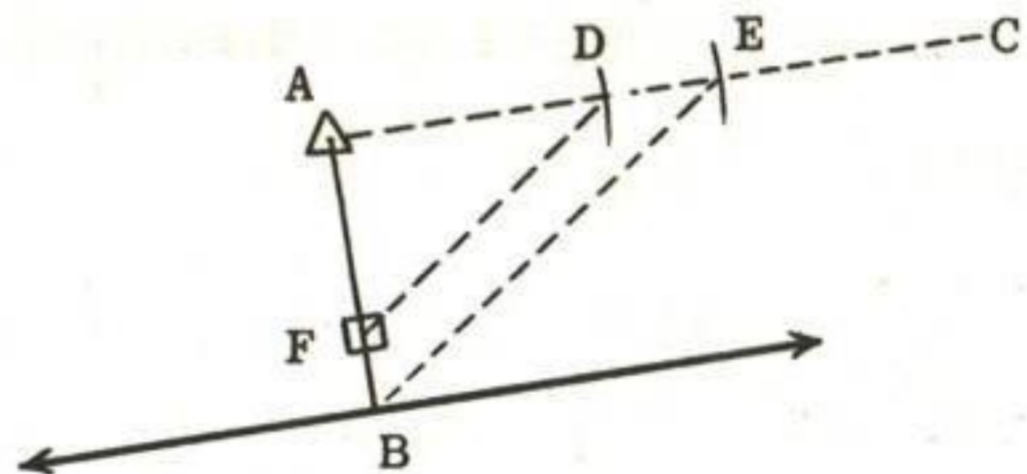
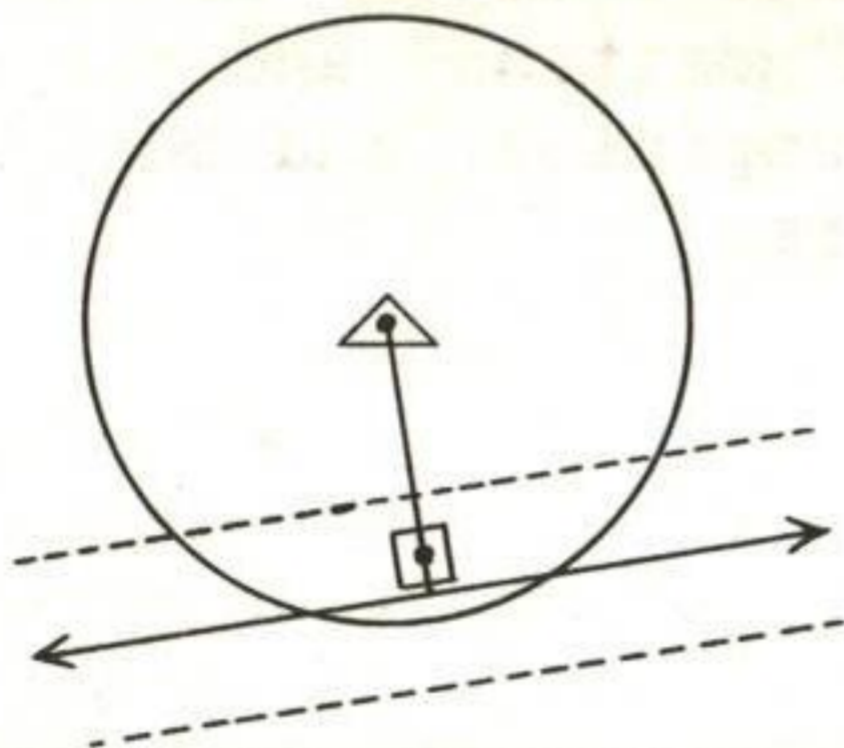
RCAF Method

RAF Method

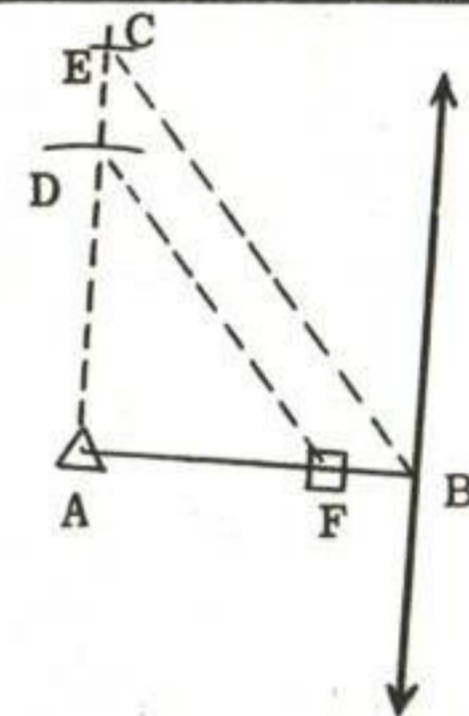
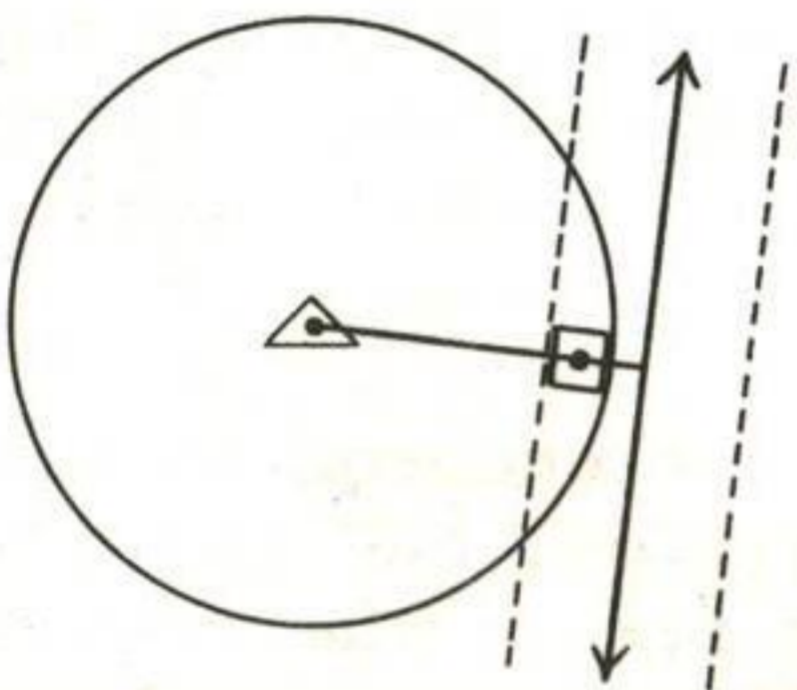
Case 1



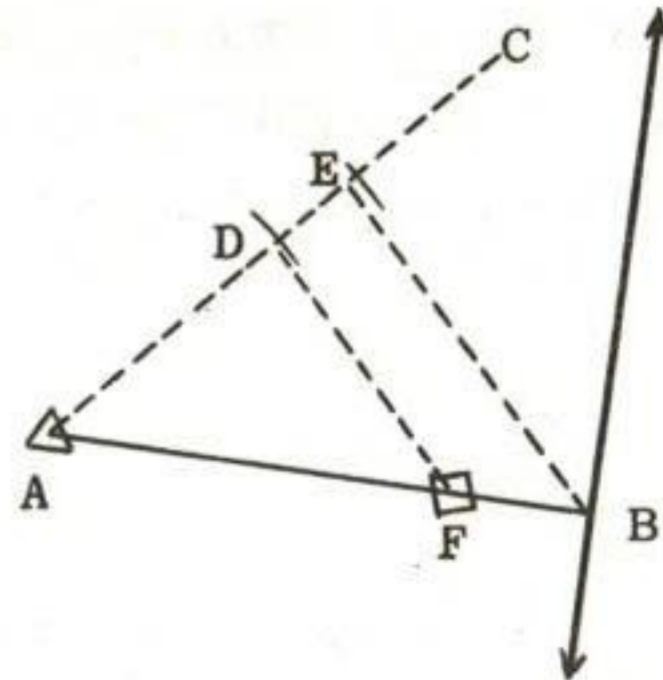
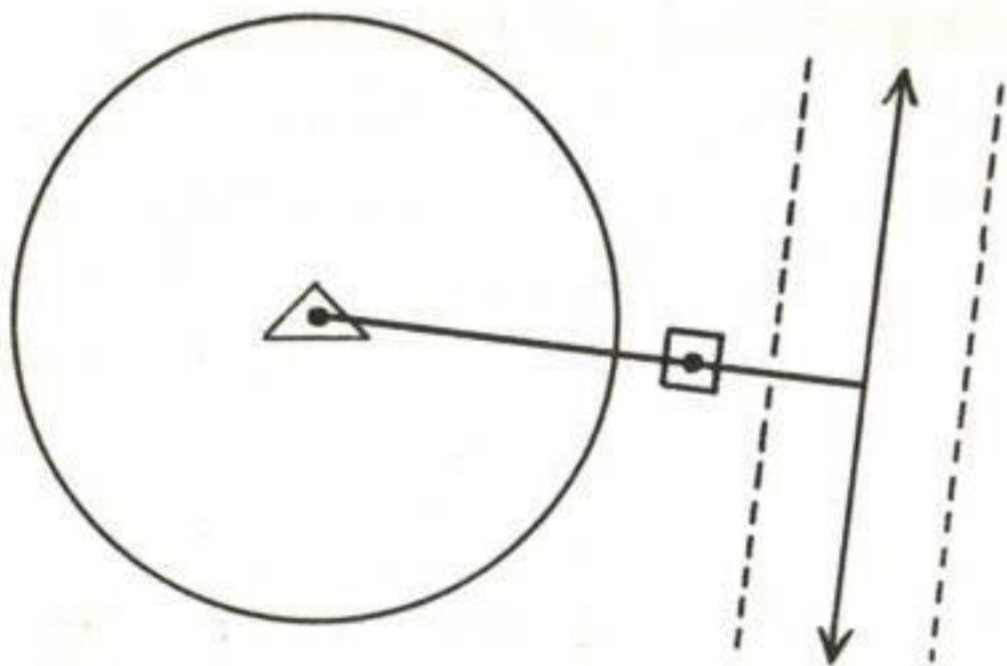
Case 2



Case 3



Case 4



- Draw circle of uncertainty.
- Draw bands of error.
- Construct perpendicular from Δ to position line.
- Locate MPP on perpendicular at mid-point of common area, or at mid-point of area between circle of uncertainty and band of error.

- Draw AB from Δ perpendicular to position line.
- Draw convenient construction line AC.
- On AC, mark off AD = radius of circle of uncertainty, and DE = width of band of probability.
- Join BE, and draw DF parallel to BE, cutting AB at F (MPP).

Table 1 - Single Position Line MPP

Navigation Procedure

When an aircraft is entering an area of accurate fixing aids from an area where aids were inaccurate or not obtainable, it may be wise to use MPPs until a series of fixes either confirm the accuracy of the DR position, or conclusively show the fixes to be accurate. With an accurate compass, in conjunction with an Air Position Indicator, DR navigation over water using multi-drift winds can be very accurate. DR positions thus obtained will lead to accurate MPPs. If fixes are obtained at regular intervals, they should not vary by any large distance from the DR position. Large discrepancies between the DR position and fixing information should be regarded with suspicion, and both DR and fixing information checked for errors.

Summary

The role of Coastal Command is such that it is necessary to know the position of the aircraft as accurately as possible at all times. To achieve this, it is necessary to make the best use of all information available. A method of forming MPPs with fixing information of varying accuracy then becomes invaluable. The MPP improves the accuracy of the DR navigation and fixing information in most cases.

APPENDIX

The Most Probable Position is a compromise between the area of uncertainty about a DR position, and the area of probability about a position line or fix. The methods of MPP construction now taught in the RCAF frequently ignore a correct compromise, with a resultant loss of accuracy. The following comparisons will show that the RAF Coastal Command constructions are simpler, more consistent, and more accurate.

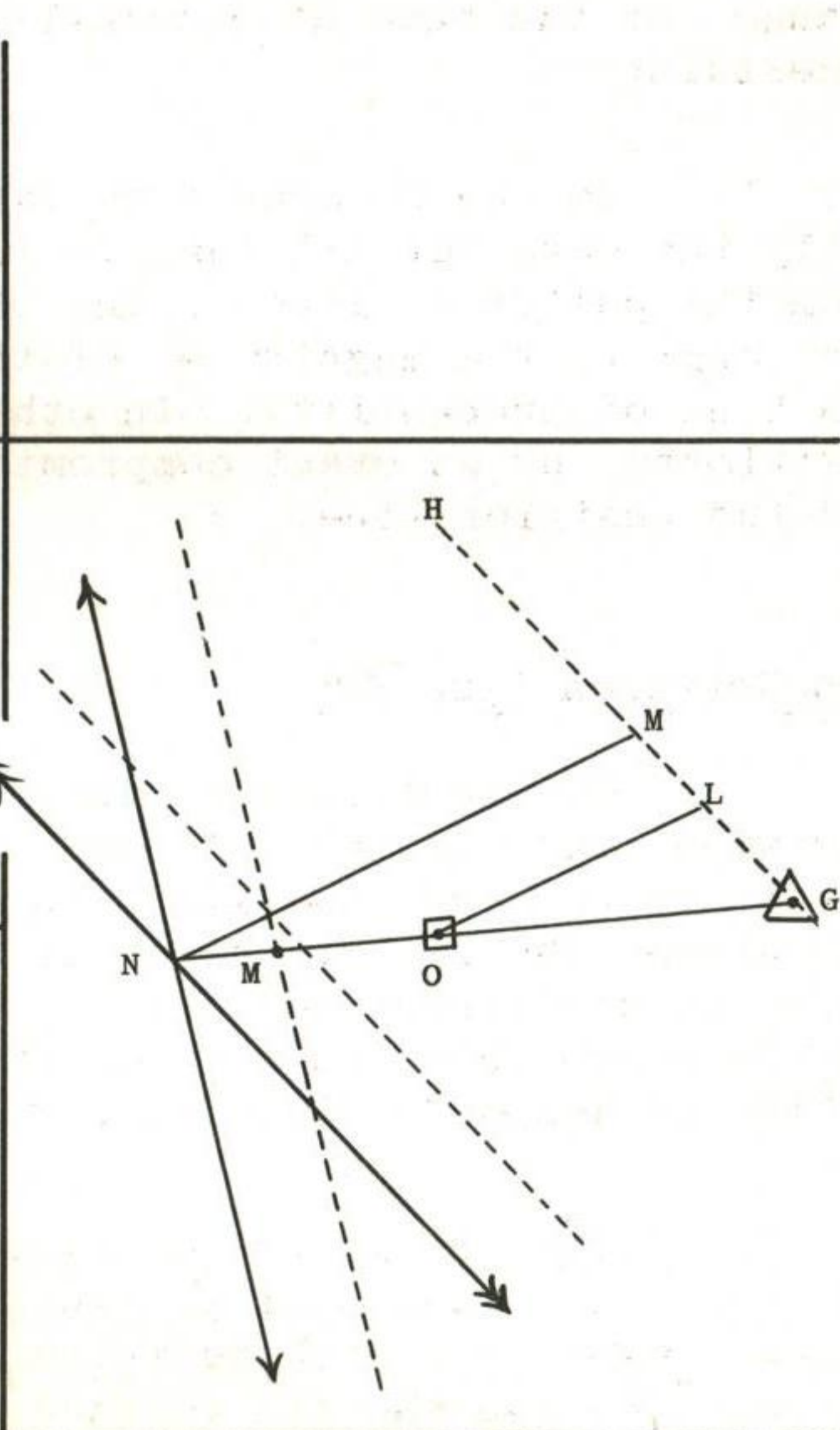
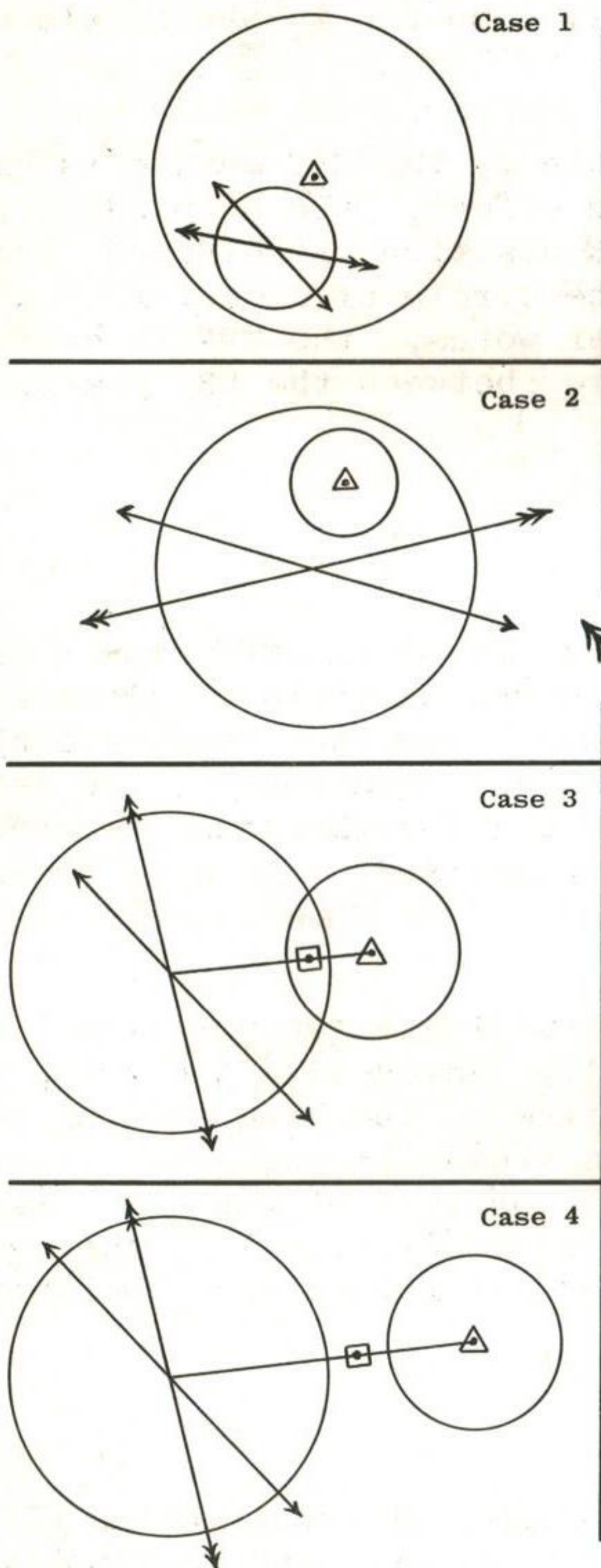
Single Position Line MPP

Table 1 shows the RCAF and RAF methods of constructing a single position line MPP in the four basic cases.

In case 1, the RCAF method assumes the position line to be 100% accurate because the area of probability falls completely within the circle of uncertainty. The DR position is thus completely ignored, and there is no compromise. In the remaining cases, either the center of the common area or the center of the area between the circle of uncertainty and band of probability is used by the RCAF.

RCAF Method

RAF Method



- Draw circle of uncertainty and circle of probability.
- Draw a line from Δ to fix.
- Locate MPP on line joining Δ and fix at center of common area, or center of area between circle of uncertainty and circle of probability.

- Draw NG joining Δ to fix.
- Draw bands of probability on sides of position lines nearest Δ .
- Draw convenient construction line GH.
- On GH mark off $GL =$ radius of circle of uncertainty, and $LM = NM$, that portion of NG common to both bands of probability.
- Join MN, and draw LO parallel to MN, cutting NG at O(MPP).

Table 2 - Two Position Line MPP

Although this is a reasonable practice statistically, there is no allowance made for the possibility of varying rates of change of the band of probability compared to the circle of uncertainty.

As can be seen from Table 1, the RAF method is exactly the same for all cases. In effect, the perpendicular from the position line to the DR position is divided proportional to the magnitude of the circle of uncertainty and the band of probability. In other words, the MPP is always positioned by an exact compromise between the DR position and the position line.

Two Position Line MPP

To simplify the construction of an MPP from a two position line fix, the RCAF has assumed a circle of probability of 10 nm about the fix. In the first two cases in Table 2, either the fix or the DR position is accepted, so that there is no compromise. The third and fourth cases are probably a reasonable compromise when a fixed circle of probability is assumed about the fix.

The RAF method of constructing a two position line MPP still uses bands of probability which vary according to the aid used for each position line. The line joining the DR position and the fix is then divided proportional to the circle of uncertainty and that portion of the same line which is common to both bands of probability. Thus the procedure is similar in all cases, and all information "weights" the location of the MPP.

Conclusion

Obviously, the RCAF methods of constructing MPPs have been modified to gain speed in the air, and to simplify instruction. Their use by experienced navigators is questionable to say the least. The RAF Coastal Command techniques are well worth considering, for they offer uniformity of method, and a far more exact compromise of available information.

ROCKET



by Flight Lieutenant M.D. Gates
Central Navigation School

The complete history of the rocket is lost in antiquity, but some reference is made to it in ancient Chinese chronicles and in the writings of the Arabs. The first crude rockets were powered by black powder, so the rocket may be as old as its fuel, which dates back to 3000 BC. The first recorded use of the rocket was in 1232 AD, when the Chinese used "arrows of flying fire" to repel an attack of Mongols led by the son of Genghis Kahn. The rocket was probably adopted by the Mongols, and later may have had widespread use in the

PROPULSION

conquests of the Kahns and Tamerlane. The Arabs came by its design, either from its use against them or over the caravan routes of Asia, and the information made its way to the then-known Western World.

The dawn of the nineteenth century saw the birth of rocket enthusiasm among Europeans. The father of this rocket era was Hydar Ali, Prince of Mysore, who had a rocket corp of 1200 men in his army. The British suffered badly from the 5000-man rocket corp of Ali's son at Seringapatam in 1792 and 1799. Western military men were moved by this news, and some experimentation was begun. Only one man, Sir William Congreve, was really successful in developing a rocket. Congreve used large sky rockets for early experiments, and improved upon their design considerably. His first rockets were of the incendiary type: they were 40 inches long and 3.5 inches

in diameter. A sixteen-foot stick was fastened to the rocket to provide stability. Later versions of the rocket contained a one-pound warhead or six-pound artillery shell. Congreve's rocket had a range of 3000 yards, thus outdistancing the ponderous mortars of the day by 1000 yards. The rocket bombardment corp was highly mobile, a characteristic which the ten-inch mortar group sadly lacked.

Rockets were used with great effect against the city of Boulogne in 1806; more than half of Cologne was burned in 1807 as a result of a mass raid of 25,000 incendiary rockets. In 1813 the rocket again proved its might by forcing the city of Danzig to surrender after three attacks. The part taken by the British Rocket Corps in the Battle of Leipzig against the Napoleonic armies resulted in the Corp being granted permission to display "Leipzig" on their battle flag. The American National Anthem refers to the rockets which played a large part in the British capture and burning of Washington in 1812. Americans in turn used them in the Mexican War in the late 1840s. The rocket was indeed so successful that most European armies had an integral rocket corp.

By 1850 most armies had abandoned the rocket as a military weapon, and were concentrating on the much-improved artillery. There were a number of reasons for the decline of the rocket. Congreve's rockets used black powder (a mixture of saltpeter, sulphur and powdered charcoal) which had to be pounded into the container. This procedure led to many explosions when the optimum ratio of saltpeter and charcoal was used. The explosions also occurred from clumsy handling of the rocket, especially after long periods of storage. To reduce the manufacturing and handling hazard, the charge was de-sensitized by lowering the ratio of saltpeter to charcoal. This resulted in reduced performance. Even though the long guiding stick had been replaced by vanes in the nozzle, which imparted spin stability, the black powder rocket had reached the peak of its development, and improved artillery once more relegated the rocket to an experimental era.

The part played by rockets during World War I was small indeed. The French used air-to-air rockets to destroy German observation balloons. However, the rocket firing often resulted in the fabric-covered aircraft catching fire from their own rocket's exhaust. The Germans used rockets to propel small boat anchors into barbed wire barriers, which

were then pulled aside by means of a line attached to the anchor, to clear the way for advancing troops. The Americans, under the leadership of Dr. Goddard, carried out many experiments and evolved a number of weapons, one of which was the forerunner of the bazooka. Several days after the trials of these weapons began, the Armistice ended the war and the project was shelved. This occurred in most countries, with the exception of Germany.

Between the wars, experimental rockets were substituted for conventional powerplants. In 1928 an automobile and a railroad car were accelerated to 120 and 175 mph respectively. They were also applied to aircraft with little success. In the early 1930's, rockets were successfully used as power augmentation in the form of Rocket Assisted Take-Off (RATO), a device given limited use by the Germans during World War II.

As early as 1900, the liquid-propelled rocket was being studied. A Peruvian engineer, Paulet, claimed to have constructed and tested a liquid-propelled rocket in 1895. Soon after, a Russian mathematician proposed a rocket-powered space flight and even provided some supporting mathematics. The propellants he suggested are still among the most powerful. In the 1920's, Professor Herman Oberth did much to advance the mathematical theory of rocketry by publishing several volumes on theory and design. In 1926 Dr Goddard's successful flight test of a liquid-propelled rocket probably ended the small-scale experimental era and ushered in a period of extensive experiment by both the American Rocket Society (ARS) and the German Rocket Society.

In 1933 the experimental work of the German Rocket Society was taken over by the German Army. For three years the work was carried on at the original site, and it was here that the idea of the V-2 germinated. Apparently difficulties were encountered and experimental facilities on a larger scale were required. In 1936 the extensive facilities at Peenemunde were set up under the leadership of Von Braun. By 1938 the Germans had produced a rocket motor using liquid oxygen and alcohol that developed 2000 lbs of thrust, a tremendous amount in comparison to the puny, black-powder rockets.

Experiments in the United States were still being carried out, but lack of funds (a factor the Germans were not concerned with in the Hitler regime) and a public lack of

confidence in the rocket kept everything on the experimental basis. In 1941, several members of the ARS formed Reaction Motors, Inc., to develop a successful motor for military application.

At the end of World War II, the Germans had missiles in the hardware stage that were powered by rocket motors: the well-known V-2, an air-to-air missile, and there is also some evidence that surface-to-air missiles were being constructed at the closing stages of the war.

The development of the rocket since the war has been so intense that even a brief resume is impossible. The trend has been to bigger, safer, more compact rockets that will allow space travel, as well as propel intercontinental missiles.

ROCKET THEORY

Until Newton's time, only a few attempts were made to explain how the rocket worked. One attempt was made in 1540 by an Italian who said, "One part of fire takes up as much space as ten parts of air, and one part of air takes up the space of ten parts of water and one part of water as much as ten parts of earth. Now powder is earth, consisting of the four elementary principles, and when the sulphur conducts the fire into the driest part of the powder, fire and air increase; the other elements also gird themselves for battle with each other and the rage of battle is changed by their heat and moisture into a strong wind". It wasn't until 150 years later that Newton's Laws explained how the strong wind powered the rocket.

Newton's second law of motion is concerned with momentum and states, "a force applied to a body will cause the body to accelerate in the direction of the applied force, the acceleration being directly proportional to the applied force and inversely proportional to the mass of the body". Expressed mathematically it is:

$$F = Ma$$

Where:

F = the applied force in lbs

M = the mass in slugs

a = the acceleration in feet per second per second
(ft/sec²)

Thus the exhaust gases of a rocket motor will have a certain amount of force. Newton's third law says that for every action there is an equal and opposite reaction. This is saying, in effect, that the rocket will have a force exerted on it that is equal and opposite to the force of the exhaust gases. This force is called thrust (T).

When weight, the force exerted by a mass being acted upon by a gravitational field, is substituted in the formula for mass, the equation becomes:

$$T = \frac{W}{g} a$$

Where:

T = the thrust in lbs

W = the weight in lbs

g = the acceleration due to gravity

a = the acceleration in ft/sec²

The acceleration (a) may be determined by subtracting the initial velocity (V_1) from the final velocity (V_2) and dividing by the time (t in seconds) over which the velocity change occurs. Thus:

$$a = \frac{V_2 - V_1}{t}$$

and

$$T = \frac{W(V_2 - V_1)}{g t}$$

If a rocket motor burns 18,700 lbs of propellant in 68 seconds, the propellant flow will be 275 lbs per second. To have basic units in the formula, W is divided by t to produce w , the weight rate of propellant flow in lbs per second. Thus:

$$T = \frac{W}{g} (V_2 - V_1)$$

The initial velocity of the propellant in a rocket is always

zero, since it is contained within the rocket itself, so the equation becomes:

$$T = \frac{w}{g} V_e$$

Where:

T = the thrust in lbs

w = the weight rate of propellant flow in lbs/sec

g = the acceleration due to gravity

V_e = the propellant's final velocity (V_2) in ft/sec

The combustion process in the rocket motor increases the pressure of the exhaust gases. The nozzle of the rocket is so designed that the gases expand, with a corresponding increase in velocity, to slightly greater than atmospheric pressure. Once designed, the rocket nozzle will always have the same exhaust pressure. When operating at high altitudes where atmospheric pressure is reduced, a thrust component will be added because of the pressure differential between the nozzle and the atmosphere. Thus a second factor must be added to the thrust formula:

$$T = \frac{w}{g} V_e + (P_e - P_a) A_e$$

Where:

P_e = Pressure exhaust in lbs per square inch

P_a = Pressure of the atmosphere in lbs per square inch

A_e = Area of the exhaust nozzle in square inches

An example calculation of thrust may serve to further illustrate the formula. A rocket motor burns 275 lbs of propellant per second and has an exhaust velocity of 6,560 feet per second when the exhaust nozzle pressure is 20 lbs/in². The area of the nozzle is 660 square inches. The thrust of the rocket at sea level, where the atmospheric pressure is 14.7 lbs/in², is found to be:

$$\begin{aligned}
 T &= \frac{W}{g} V_e + (P_e - P_a) A_e \\
 &= \frac{275}{32.2} \times 6560 + (20 - 14.7) 660 \\
 &= 56,000 + 3,500 \\
 &= 59,500 \text{ lbs}
 \end{aligned}$$

The thrust developed by the same rocket at an altitude of 25 miles, where atmospheric pressure is reduced to .01 lbs/in², will increase:

$$\begin{aligned}
 T &= \frac{W}{g} V_e + (20.0 - .01) 660 \\
 &= 56,000 + 13,193.4 \\
 &= 69,193.4 \text{ lbs}
 \end{aligned}$$

The increase in thrust due to the pressure differential is:

$$\frac{69,193 - 59,500}{59,500} \times 100 = 16.25\%$$

The thrust of modern rocket motors may be increased by 20 to 30 per cent because of the increased pressure differential at higher altitudes. Thus the rocket will produce the greatest amount of thrust for the propellant consumed when it is operated in the upper atmosphere.

Classification of Rockets

The propellant, probably the most important aspect of rockets, is used as a basis for classifying them. Figure 1 shows this classification:

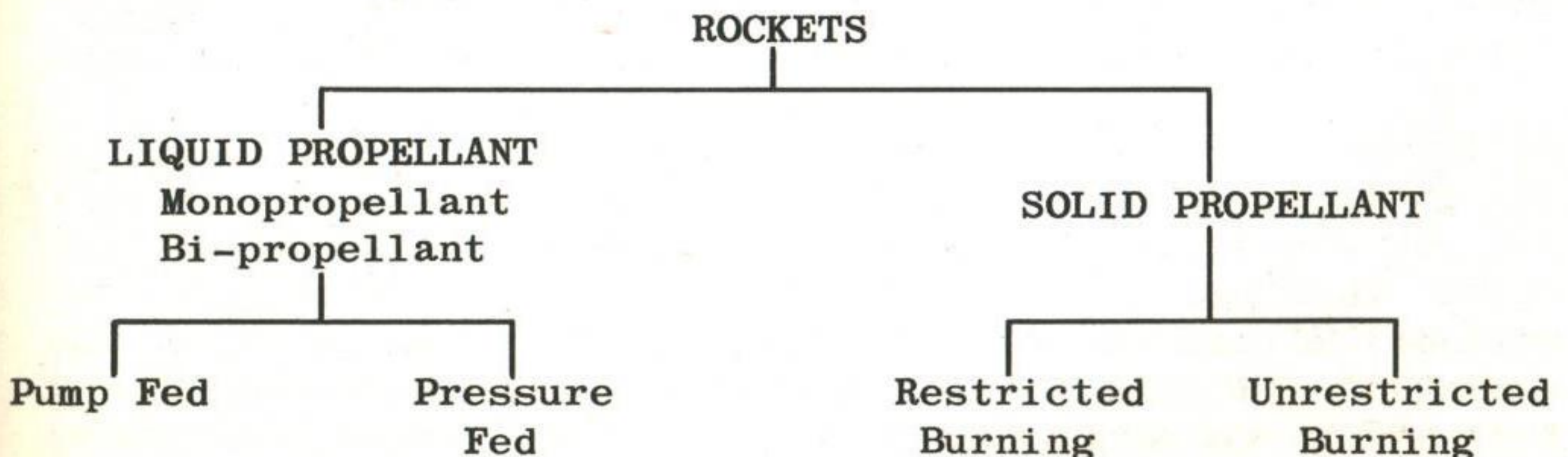


Figure 1 - Classification of Rockets

SOLID-FUEL ROCKETS

Solid-fuel rockets represent the rocket motor in its simplest guise. Fuel in the form of a solid is contained within the combustion chamber, where it is usually ignited by some electrical means. After the fuel has been ignited, the combustion process generates high pressure gases that are accelerated rearward by a nozzle that increases the velocity and reduces the pressure. The illustration in Figure 2 is a schematic of a typical solid-rocket motor.

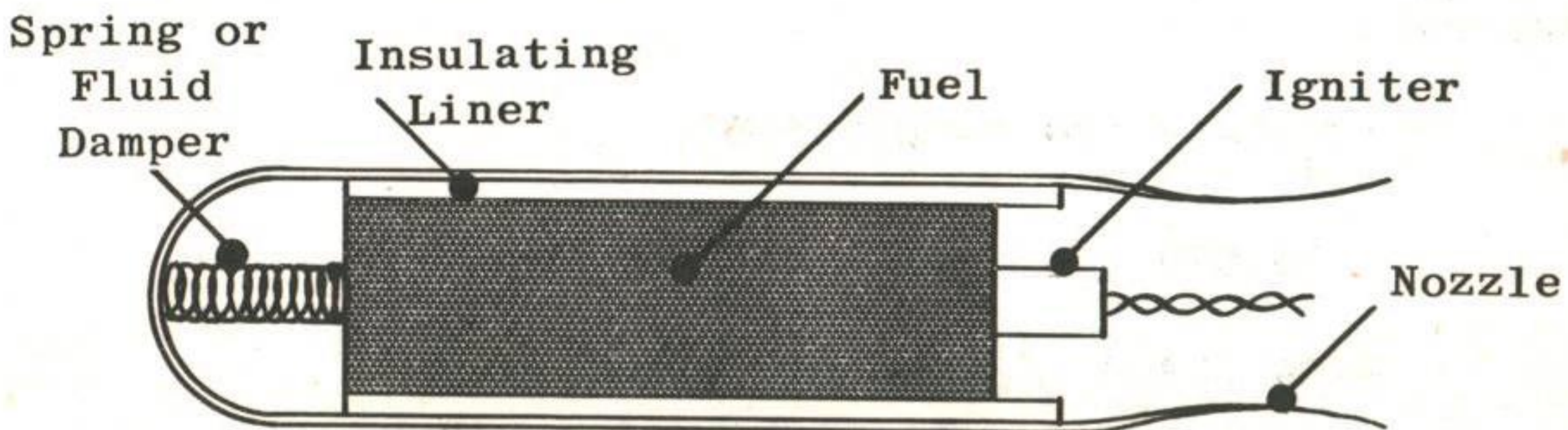


Figure 2 - Solid Fuel Rocket

It is often desirable to control the rate of fuel burning, and hence the thrust output, of a rocket motor. This restriction or programming of the burning rate may be accomplished with a chemical inhibitor or by varying the charge design. Figure 3 shows two of the latter type, which are called restricted-burning rockets. Other charge configur-

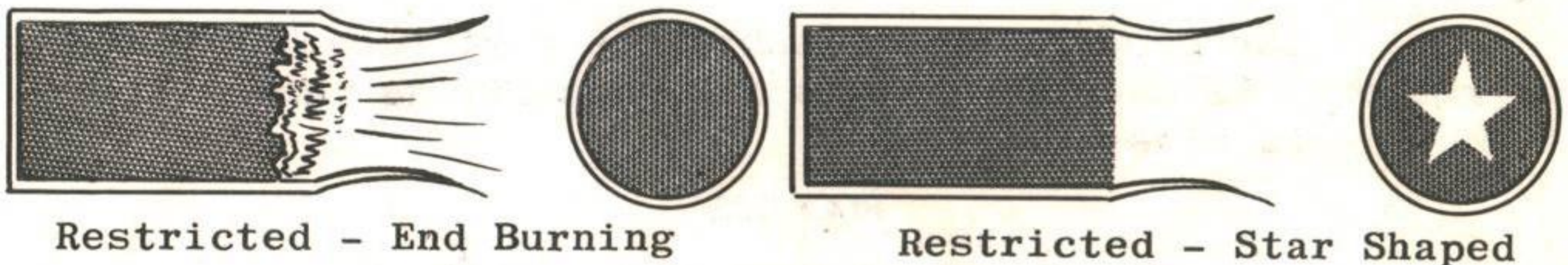


Figure 3 - Restricted Burning Rockets

ations are used in order to program thrust output or accelerations: Figure 4 illustrates some of these charge shapes with plots of their thrust output. The average restricted

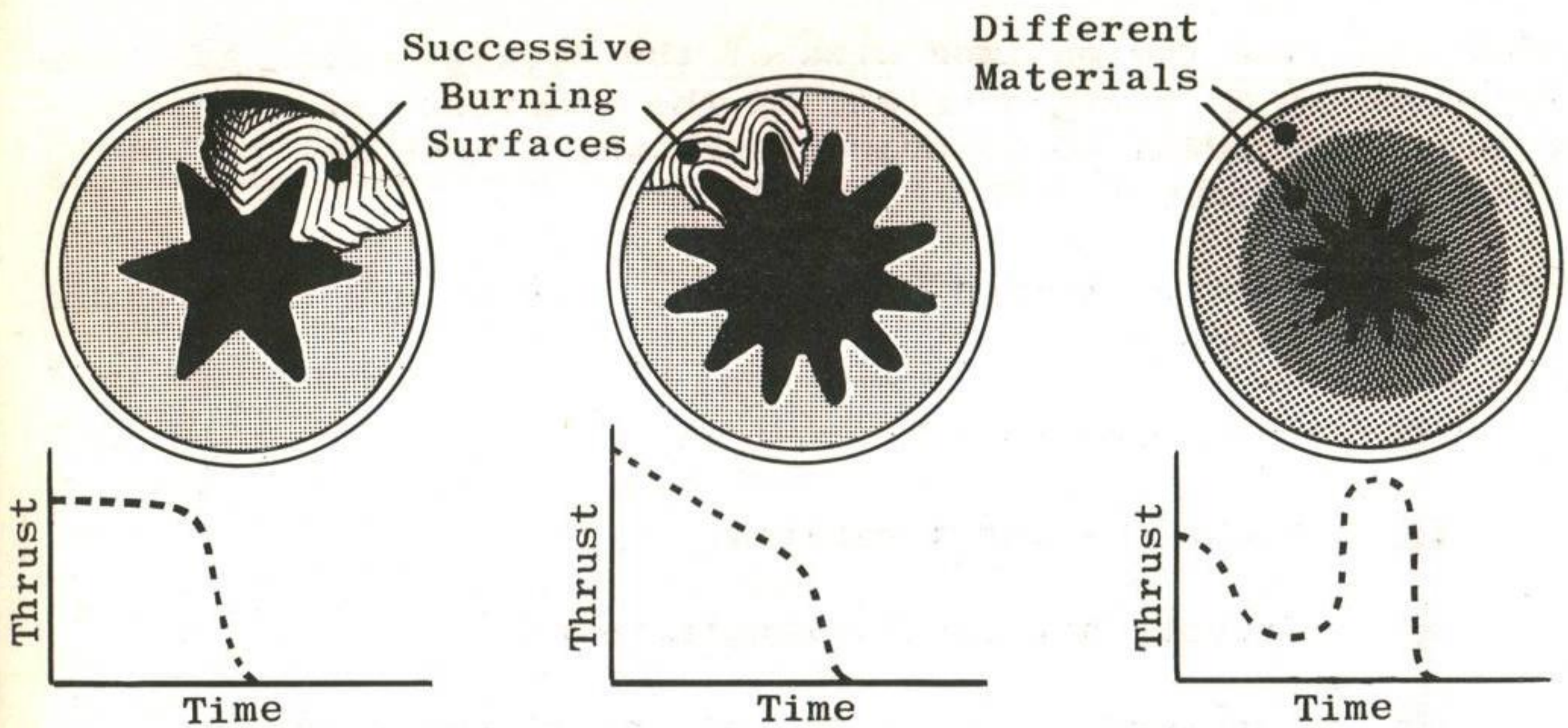


Figure 4 - Thrust Programming

rocket will burn from 3 to 100 seconds. This type of rocket is employed in some missiles but it is used mainly in RATO units.

Unrestricted-burning rockets consume the propellant as rapidly as possible, thus generating maximum mass flow. Some of the charge shapes used to achieve this are shown in Figure 5. The average unrestricted rocket will burn from .05 to 10 seconds. They are used in signal and artillery rockets, and air-to-air guided missiles.

Propellants are the biggest problem in solid rocket design. They are brittle and sensitive to shock, and the ambient temperatures affects the thrust output. Cracks due to temperature changes can cause explosions. The granular nature of the charges results in low structural strength,

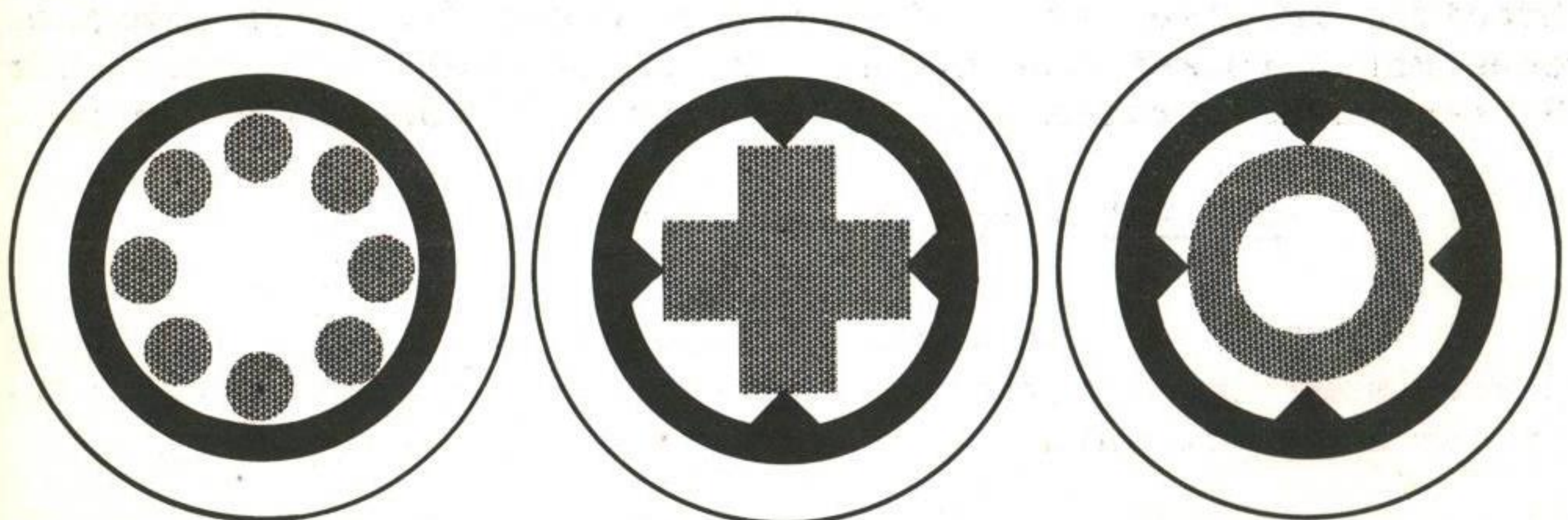


Figure 5 - Unrestricted Burning Rockets

thus limiting the maximum size of the rocket. This has been overcome to a certain extent by the addition of an elastizer. The ideal solid propellant would have the following characteristics:

- Easily stored, stable to shock and temperature changes
- Burn evenly
- Smokeless and flashless
- Cheaply and easily manufactured
- Nonhygroscopic (will not absorb water vapor)
- High Specific Impulse

From the standpoint of performance, it is necessary to have a method of rating the various propellants. In the case of solid propellants, Specific Impulse (Isp) is used. Isp is the amount of impulse produced by one pound of propellant. Expressed mathematically, it is the total impulse (IT) divided by the total weight of the propellant:

$$I_{sp} = \frac{I_T}{W}$$

Where:

I_T = Total thrust in lbs x burning duration in seconds.

W = Weight of propellant in lbs

Specific Impulse, therefore, is in lb-secs/lb. For example, consider a rocket containing 10 lbs of fuel that burns for 5 secs and generates 1000 lbs of thrust. The Isp would be:

$$\frac{1000 \times 5}{10} = 500 \text{ lbs-secs/lb}$$

Some of the fuels in use now are listed in Figure 6 with some characteristics which determine their suitability as a propellant.

Characteristic	Ballistite	NDRC Composite	Galcit
Specific Impulse (lb-secs/lb)	210	160	186
Exhaust Velocity (ft/sec)	6800	5150	5900
Density (lb/ft ³)	101.5	101	110
Temperature Sensitivity	High	Medium	Medium
Temperature Limits (°F)	Restricted Upper Limits	-40 to +140	-9 to +120
Burning Rate (Inches/sec)	1.4	0.25	1.6
Chamber Temp (°F)	5000 - 6000	3000-3500	3000 - 3500

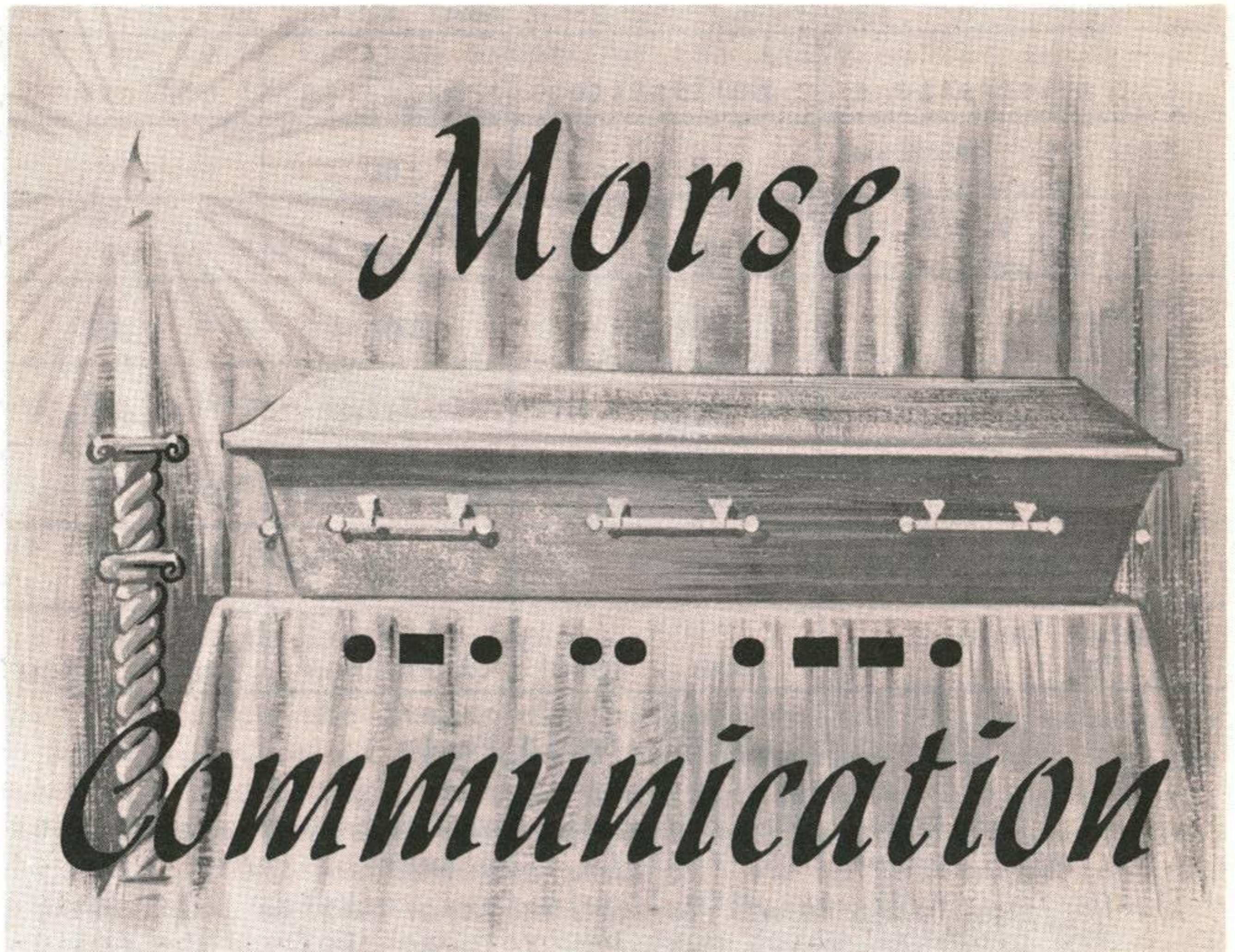
Figure 6 - Solid Fuels

The trend in the missile world is toward greater use of solid-propellant rockets, because of their ease of handling in comparison with liquid-fuel rockets. Obviously, there are problems which must be overcome before the solid-fuel rocket reaches its full potential. Improvements are now being made in the following characteristics:

- Longer and more accurately controlled burning times
- Stability of propellants
- Overcoming the tendency of the nozzles and chambers to burn through at hot spots

CONCLUSION

This article has been a brief introduction to rockets in general, and solid-fuel rockets in particular. The next issue of the OBSERVER will contain the concluding article, which concerns the liquid-fuel rocket.



by S/L C.L. Heide
Air Force Headquarters

It is somewhat discouraging to realize that the RCAF still relies on the "dits" and "dahs" of morse code to provide air-to-ground communication. Aside from sophistication of both ground and air equipments to provide numerous pre-set channels and stable frequency control, this is the same method of communication used eighteen years ago when the trade of Radio Operator was first introduced. This is not really staggering progress. Morse communication has been hard to kill; it has been wounded many times, but the death blow is at hand if we have the initiative to raise the axe. Let us have a look at the axe, which is two-bladed, and the effect it will have on the Obs/Rad if it is wielded.

The first blade is HF Single-Sideband (SSB) voice communication. The transmission of radio signals by a single sideband has the advantage of being able to impart all the transmitted power to the intelligence-carrying sideband, and

the total bandwidth required is only half as great as that of a double-sideband system. This results in a SSB system having a signal-to-noise ratio that is eight times as great as that of a fully-modulated, double-sideband system, for the same peak power. This fact, together with better discriminatory circuits, means that the SSB system now provides reliable voice communications over the same, or even greater, range as our existing HF morse communication system.

SSB equipment is now in production by the Collins Radio Company, and is designated the AN/ARC-58. This is a pilot-operated equipment, which provides 28,000 pre-set channels in the 2 to 30 mcs band. The multiplicity of highly-stable frequencies is provided by a stabilized master oscillator with a stability of one part in one million per month. This equipment is reputed to have 90% reliability on voice communication over a range of 2,500 miles. Recent reports indicate that Strategic Air Command is converting as rapidly as possible to SSB equipment, most likely the ARC-58.

The second blade is airborne radio teletype. This equipment has been in use for years, and was pioneered by Trans-Canada Air Lines; other major airlines are now in the process of procurement. The system is being used for the direct printing of weather information in aircraft flying the North Atlantic route. TCA is using equipment manufactured by Federal Telecommunications Laboratories, working in the 100 kcs band. The ground transmitters are located near Chatham, New Brunswick and Prestwick, Scotland, and have a power output of about 2.5 KW. The predicted reliable range is greater than 1200 nm at night, and between 700 and 900 nm during the day. While satisfactory trans-Atlantic coverage is being maintained at night, few daytime range figures are available. However, an increase in radiated power to 10 KW would likely ensure reliable coverage at any time. In addition, the SSB technique is quite applicable to airborne teletype, and would greatly improve the range of the system.

The total weight of the airborne equipment is about 80 lbs, consisting of receiver, antenna, and teleprinter. The receiver is designed for remote and unattended operation, and no adjustments are required beyond selecting the desired channel. An omni-directional loop antenna is used in the Federal Telecommunications Laboratories system. The teleprinter provides page-printed teletype approximating a standard typewriter, up to a speed of 100 words per minute.

A similar equipment designed for the USAF, designated the AN/AGC-1, is being produced by Kleinschmidt Laboratories Incorporated. Also, British Marconi produce an airborne teletype.

If SSB voice equipment and airborne radio teletype are introduced into the RCAF - and they certainly should be if we wish to take advantage of the tremendous potentialities being offered by these technological improvements to communications - the death of morse communication is certain. After the funeral, what will be the future of the Obs/Rad?

At the moment the Obs/Rad is a pure communicator on the aircraft of all Commands, with the exception of Maritime Air Command. In Maritime aircraft the Obs/Rad is responsible not only for communications, but for many other search and detection equipments. If morse communication is deleted, there will no longer be a requirement for the Obs/Rad as such, but MAC will need what may be called an Air Electronic Officer to operate various electronic equipments.

Under our present training plan, it takes longer to produce an Obs/Rad than either an Obs/AI or an Obs/Nav. More than 75% of the ground and air instructional time on the Applied Radio Course is devoted to morse training to a standard of 20 words per minute, and to the procedures, techniques, and equipments associated with communications by morse code. In less than the time now needed to train an Obs/Rad we could, if morse communication were removed, train an Air Electronic Officer of extremely high calibre for MAC.

Not only would the AEO be a valuable aircrew member, but he could be readily employed in Tech/Tel positions during non-flying tours, where he would bring an operational outlook (sometimes sadly lacking) to bear on decisions affecting electronic air equipments.

The saving to the RCAF by the elimination of the trade of Obs/Rad would more than justify the costs of equipment procurement, and the resulting efficiency in air and ground operations would help to make us an Air Force worthy of the name.

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