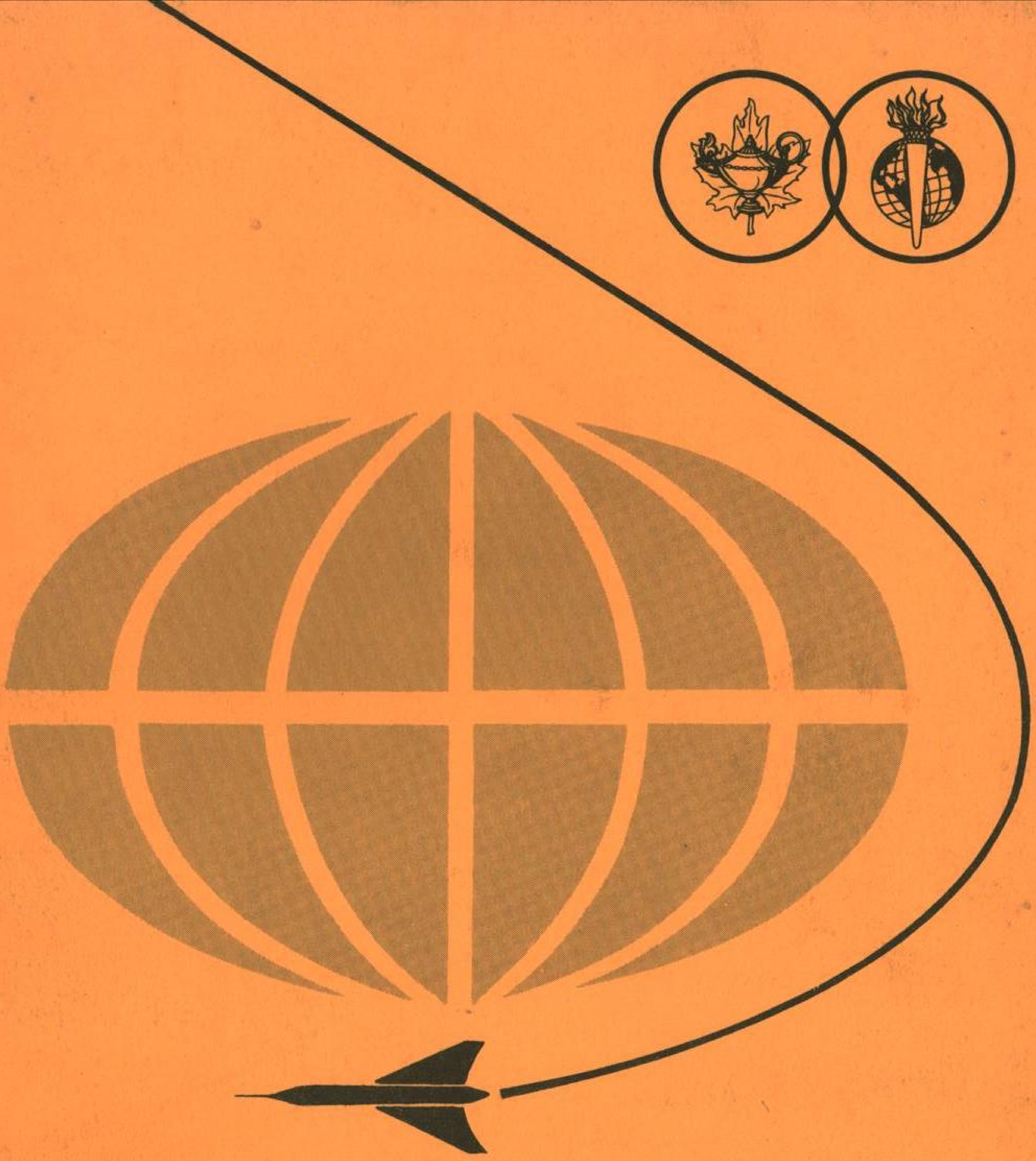

The Canadian Forces

OBSERVER

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EDITOR: F/L J.E. McFadden

CONTENTS

EDITORIAL

CFS + CNS = CFNS ?

Those waves of change which have become so omnipresent to the Canadian Forces during the past few years have finally made inroads on the beaches occupied by the Central Navigation and Central Flying Schools. As a matter of fact, for the past year warning wavelets have been lapping at the castle walls. The seventh wave rolled in during the late summer, bigger than its predecessors and carrying a decisiveness which its minor messengers had lacked. The castles were engulfed, the sands were mingled and when the wave retreated amalgamation was a *fait accompli*.

This is not an epitaph although as separate entities, the two schools no longer exist. The new name after amalgamation is the Central Flying and Navigation School (CFNS). It will be headed by a Commandant of Colonel rank level, (not named at the time of writing). The former CNS Standards have been integrated with CFS Standards. The remaining elements of CNS are now labelled the Aerospace and Advanced Training Branch. There has also been some redesignation of CFS elements and further changes are impending.

Not surprisingly, some alterations to the courses conducted are expected. The Aerospace Systems Course (ASC) will continue. The Advanced Radio Navigator Course (ARNC) is being reviewed with the intent of providing a new course suitable for all air-crew. New courses with the sole purpose of providing instructors for the Air Navigation School are being drafted.

The change may be chaotic but it is not yet calamitous nor need it be. Classes are still conducted. Instructors still instruct. Projects continue to be tackled. As sudden changes are wont to do, there have been repercussions and soul searching and not a little anguish. However, if radio navigators and pilots can team up in the cockpit, then we can find a way to do the same on the ground. We remain shaken, but optimistic still.

Where To From Here ?

Everytime someone suggests that we change the Observer, (and such a suggestion is made at least once after each new issue), we feel obliged to ask ourselves again what it is the Observer is trying to do. Sometimes this self-interrogation reassures us that we are on the right path. Other times it leaves us a little uneasy about the way things are going.

ABOUT THIS ISSUE

That old, controversial topic, in-flight maintenance, finally receives an optimistic treatment in W/C Conway-Brown's article in this issue. The author speaks from experience when he says that in-flight maintenance can and should be done to a greater degree than has been prevalent in our service. During his years, (1962-64), as Exchange Officer with the USAF at Mather AFB, W/C Conway-Brown not only headed up the Nav Bomb Upgrade Training, but also flew with a SAC Wing. The procedures of which he writes have proven time and again that a mission can be successfully completed despite breakdowns in the air. Although he says in his concluding paragraph that the idea is not original, there is no doubt that we in the Canadian Forces have been less than positive in our approach to the problem.

Meanwhile, W/C Conway-Brown, since his tour at Mather, has completed Staff College, became OC CNS, received a promotion, and is now CO of Canadian Forces Station Gypsumville - from California to the Interlake District of Manitoba in a little more than two years. His reaction to the "isolated" posting - "having seen some of the other radar sites, Gypsumville is paradise. Y'all come an' see us, hear!"

Danny Cooper an ex-Flight Lieutenant from CNS, extends a similar invitation, albeit presents a slightly greater problem to get to Edinburgh, Scotland, where he is employed with Ferranti. The author of one of those "fringe" articles (see Editorial), Danny deals with a subject which is of great concern on both sides of the Atlantic: the growing air traffic control problem on our congested trans-oceanic routes. Although he writes now from the viewpoint of civil traffic, he is as aware as we should be that the same facts must be faced by the military users of these air lanes.

Whenever possible, ex-F/L Cooper makes it a point to meet the Aerospace Systems Course on the annual European tour. It was during one of these meetings that he was prevailed upon to produce his timely article.

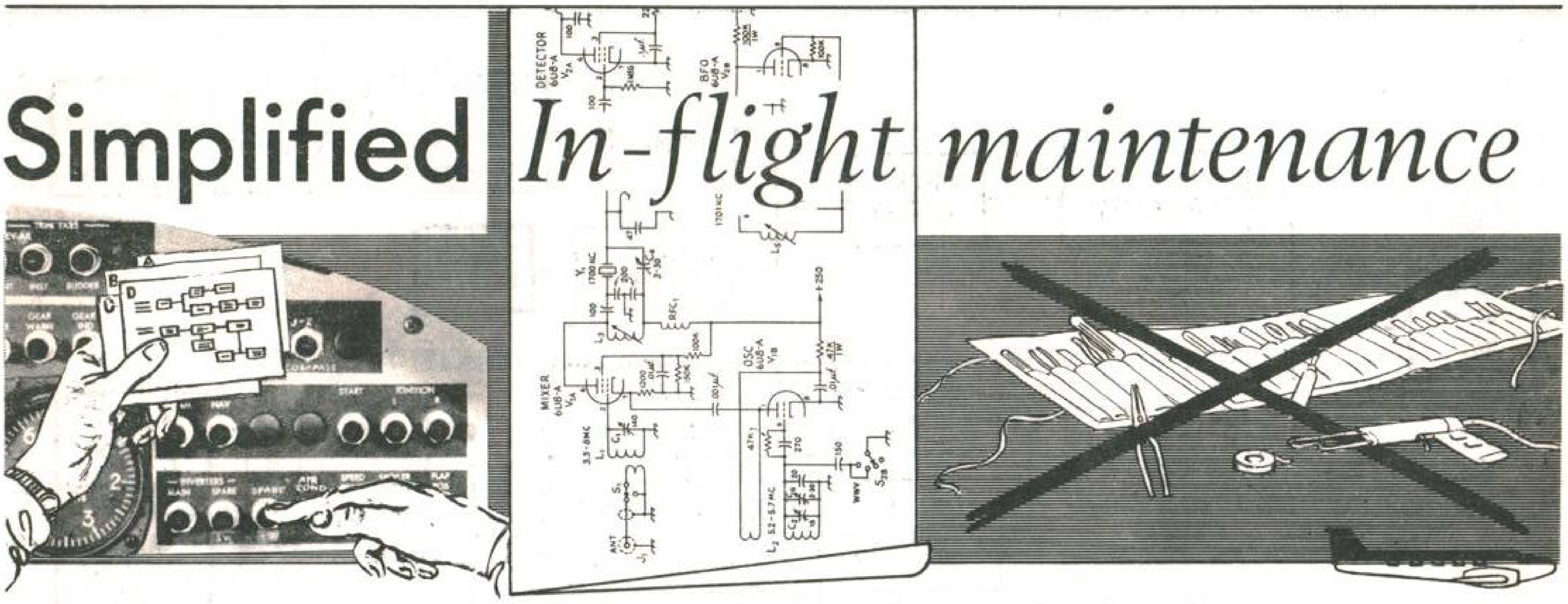
Meeting people on tours and staff visits is one of the best ways to exchange viewpoints and, (as has been unkindly intimitated), trap them into putting their knowledge and opinions in writing. Such was the case when Al Chadwick got together with S/L Geoffrey Wilson of the RAAF in Washington. S/L Wilson did some inveigling of his own and we now have a dissertation on the RAAF School of Air Navigation (SAN). Scale it up slightly and we have a story very similar to the RCAF ANS/CNS except, of course, for the HS 748 which the Australians are getting and which arouses our considerable envy.

To give credit to S/L Wilson, he in turn gives full credit to S/L P.J. Malley, a staff member of SAN in East Sale, Victoria. The article was forwarded addressed to the "RAAF Observer", and S/L Wilson comments, "I am looking forward to receiving the Australian edition of 'The Observer'!"

Closer to home is Brian Sadler who has submitted his views on high speed cruise versus long range cruise. A navigator on 435 Transport Squadron Hercules, F/O Sadler spent several weeks at CNS last Spring on the Advanced Radio Navigator Course and somehow found time to get his article finished before he graduated, (He also found time to organize more parties and diversions for his classmates than any previous course had enjoyed!) In any case, we are grateful, indeed, because it is subjects of this sort that we are always looking for. No matter which technique you use, it is important to be reminded occasionally that there is more than one way to plan and conduct a trip.

The Editor

Simplified *In-flight maintenance*



by Wing Commander G.E. Conway-Brown

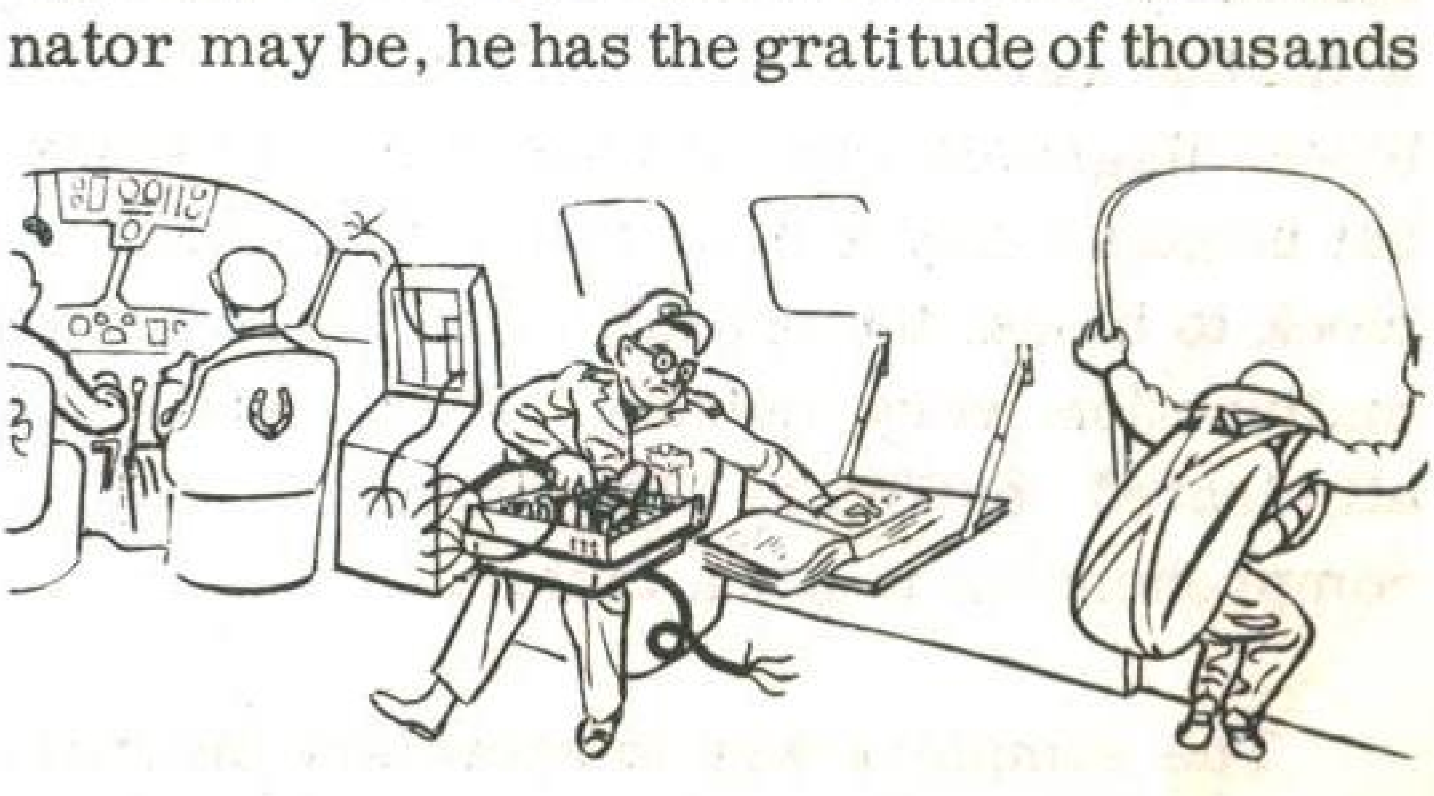
INTRODUCTION

As aircraft systems become increasingly complex, and the performance of one component can have a direct effect on the performance of another, in-flight maintenance is becoming more difficult. Reaction to the problem generally takes one of two forms: to regard in-flight maintenance as impractical; or, to develop complicated check lists and manuals to isolate malfunctions. The author of this article believes that most electronic equipment malfunctions can be repaired in flight if the equipment is accessible to the crew, and that, with a little careful thought, the malfunction isolation procedures can be simplified to a point where almost any crew member can repair equipment in flight.

There are several governing factors which can be used to determine if in-flight maintenance is practical or worthwhile. These include: the importance of the mission; flight duration; repair time; accessibility of equipment; the danger of causing injury to the crew member; the danger of causing further damage to the equipment; and equipment packaging design. In general, in-flight maintenance is practical in bomber, maritime patrol, and transport aircraft, and obviously not very practical in fighter, strike and ground support aircraft. In-flight maintenance practices are currently used most extensively in strategic bombing aircraft where completion of the mission can be so vital that equipment failures must be rectified by the crew members. It is not impossible to visualize vital maritime patrol and transport missions where avionic equipment failures cannot be tolerated and, consequently, in-flight maintenance should be given serious thought in the Canadian Armed Forces.

THE SIMPLIFIED CONCEPT

The basic concept behind the information in this article was developed for the USAF Strategic Air Command some years ago and, with subsequent modifications, the in-flight maintenance manuals for complex bombing-navigation systems in advanced bombers have become extremely simple to use. I am unable to name the originator of the concept outlined below but, according to some sources, an RAF Specialist Navigation Course graduate on exchange duties with the USAF developed the basic idea and it has been refined, (perhaps more correctly - "further simplified"), by many hands ever since. Whoever the originator may be, he has the gratitude of thousands



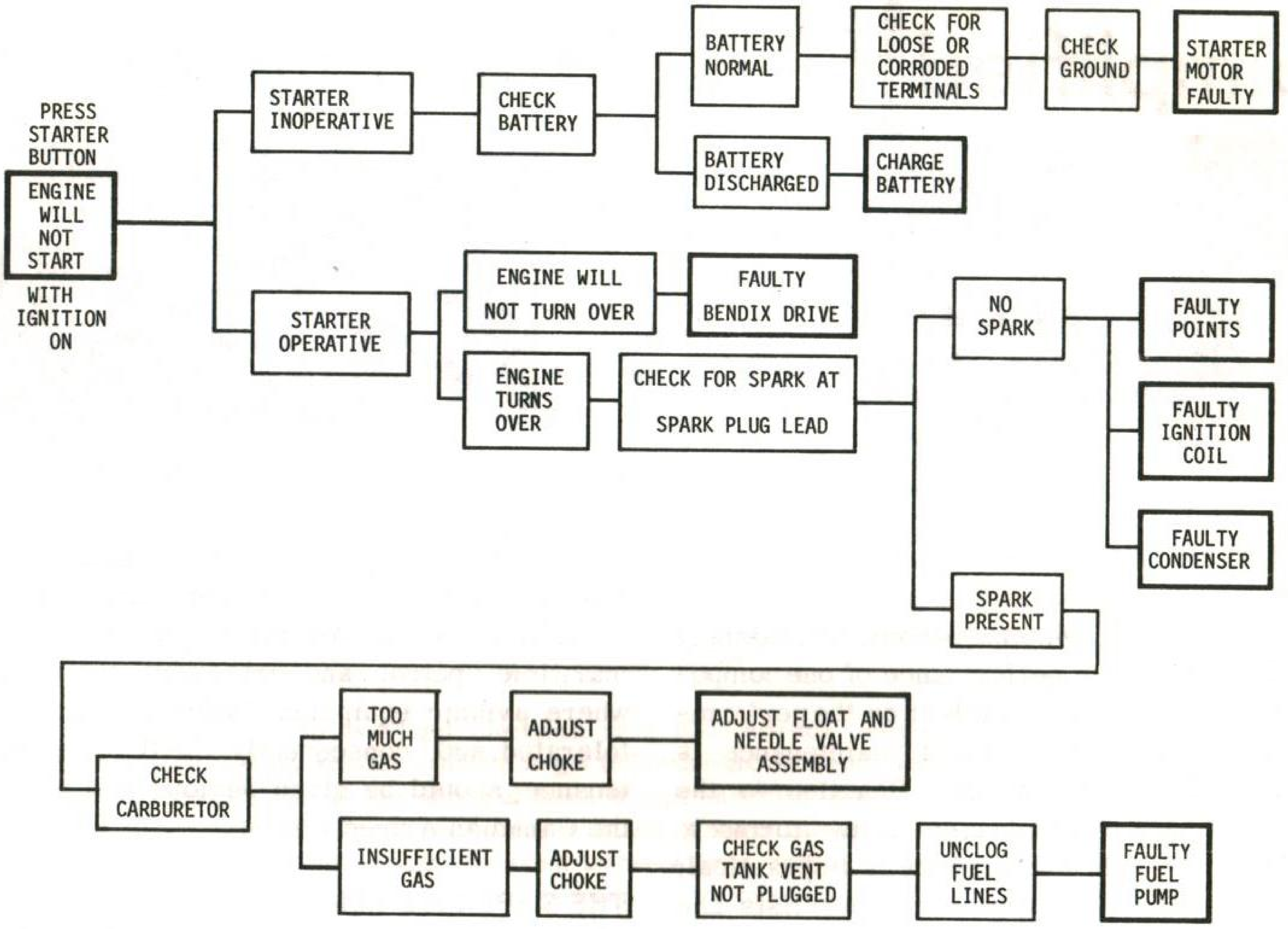


Figure 1

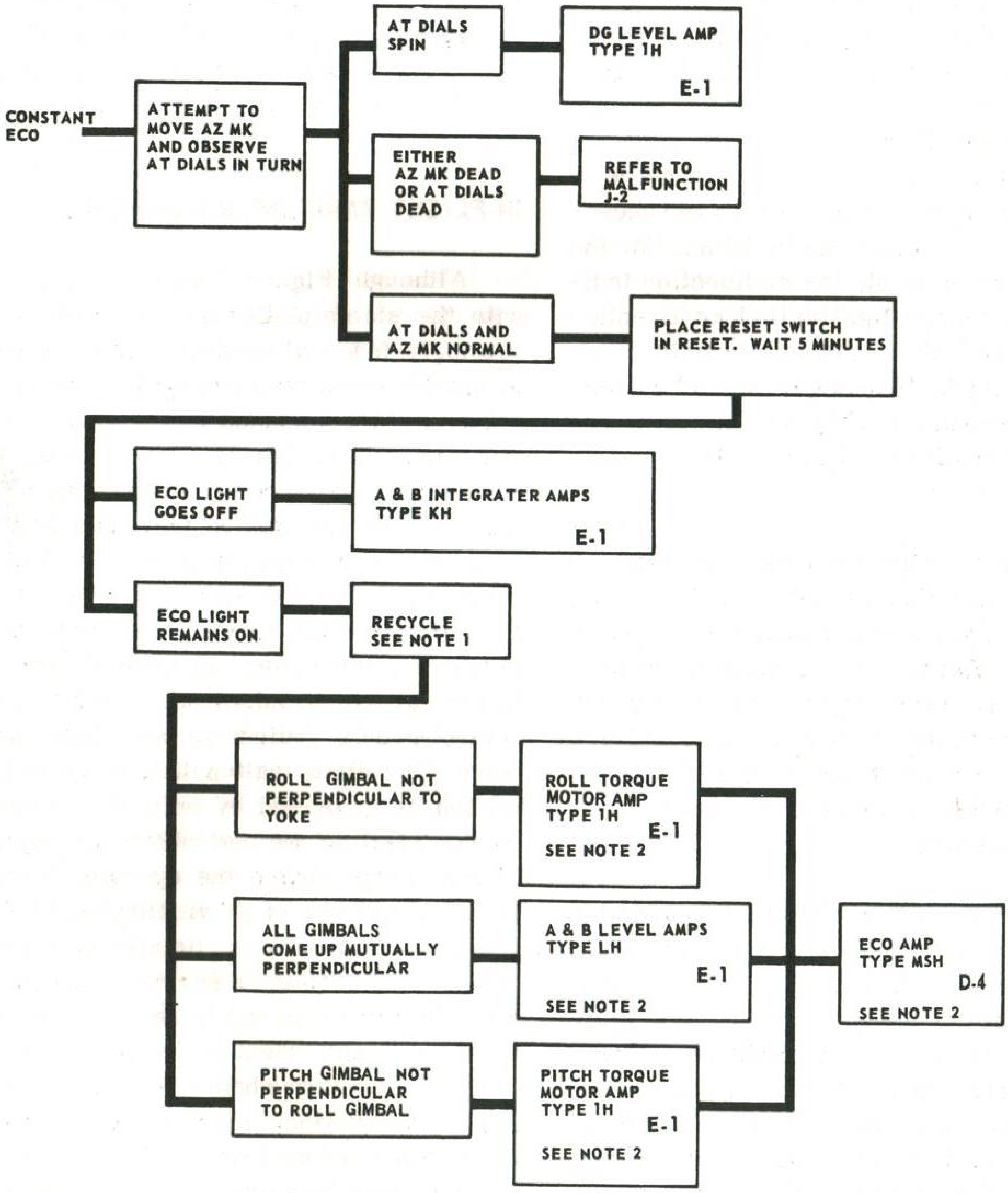
of aircrew officers in the USAF who no longer have to read through masses of information to rectify malfunctions in flight. Repair time is now a fraction of what it was with old in-flight maintenance manuals.

Under the simplified concept, a basic malfunction symptom is presented, and operator actions and equipment reactions are traced out in block diagram form linked together by connecting lines. The resultant "flow" chart can contain blocks in series and/or parallel lines, each line terminating with the cause of the malfunction. These block diagrams can become quite complex, but because they are so simple to follow from block to block, the operator can trace down a malfunction very quickly. False leads are eliminated entirely and technical reading comprehension is not a factor.

The simplest way to show how the malfunction isolation procedure can be portrayed is by example. In Figure 1 a simple problem is presented in which an automobile engine with standard transmission will not start and the operator wishes to determine the cause. Starting at the left of Figure 1, the operator ensures that the ignition is turned on and presses the starter button. Only one of two things can happen - the starter will operate or it will not. Depending upon the starter reaction, the malfunction isolation problem is now narrowed to one of the two initial branches, and the operator need only concern himself with the branch that gave him the reaction. Further checks, actions, and the observance of reactions follow until a line ends at the isolated malfunctioning component. Note the simplicity with which the operator can arrive at the elimination of all ignition and electrical malfunctions and concentrate his attention on fuel malfunctions. Figure 1 is such a common procedure that it warrants no further explanation except to say that it does not represent information flow, but merely malfunction isolation procedures. This point is obvious in the example but it may not be so obvious when applied to complex electronic equipment where, by convention, a block diagram is normally used to present data flow.

G. STABILIZATION

G-1 CONSTANT ECO LIGHT (BLANKING ON PPI)



NOTE 1: TO RECYCLE, PLACE THE FUNCTION SWITCH IN OFF POSITION FOR 1 MINUTE THEN TO STAB.

NOTE 2: EACH TIME AN AMPLIFIER IN THE STAB SYSTEM IS CHANGED THE SYSTEM MUST BE RECYCLED. THE SET WILL BE FULLY OPERATIONAL AT THE END OF 20 MINUTES.

NOTE 3: THE STAB SYSTEM CAN BE CYCLED IN LESS THAN 20 MINUTES BY MANUALLY PUSHING THE HAYDON TIMER (E-1) TO THE THIRD TIMING PERIOD. CARE SHOULD BE TAKEN TO INSURE THAT ALL GIMBALS ARE MUTUALLY PERPENDICULAR.

Figure 2

Now that the basic idea has been presented, let us take an actual case from an obsolescent aircraft system. I chose a common malfunction of a bombing-navigation system that is used for training purposes. As the reader is probably aware, for accurate radar bombing the sighting cross-hairs must be stabilized to eliminate the errors that would otherwise develop from the rolling and pitching movements of the aircraft. A gyro stabilized platform is part of the system to provide this stability and when the platform tilts out of the vertical the operator needs to be informed of this malfunction so that necessary corrective action can be taken. For the system in my example the malfunction indicator is an amber light called an Erection Cut Off (ECO) light. A secondary malfunction indication may be blanking on the radar scope which is also stabilized by the platform. The malfunction isolation diagram is shown in Figure 2.

This malfunction indication can lead the operator to one of eight faulty amplifiers or, depending on his isolation analysis, to one of seven fuses. Each of the components could be changed on a trial and error basis, but through use of the isolation chart in Figure 2, a fraction of the repair time is needed and the operator quickly eliminates all but the faulty system component.

With a constant ECO light, the operator attempts to move the azimuth mark of his cross-hairs by deflecting his hand control, and he observes the true heading (AT) dials while the aircraft is in a slight turn. Three reactions are possible: the AT dials spin; either the azimuth marker or the AT dials do not react; or both indications are normal. Very quickly and simply the operator may have discovered a faulty directional gyro level amplifier (DG LEVEL AMP); he may be led to MALFUNCTION J-2 which reduces the problem to a faulty fuse; or he must take further action to determine which one of the remaining seven amplifiers has failed. As the reader traces Figure 2 through further operator actions, checks, and system reaction indications, it should be readily apparent that with each branching of the diagram, the malfunction problem is narrowed down until eventually there can be only one faulty amplifier. Further explanation of Figure 2 is not necessary to clarify further this concept of in-flight maintenance and it is pointless to enter into detailed discussion of the system itself because it may be unfamiliar to most readers.

IN-FLIGHT MAINTENANCE MANUALS

Although Figure 2 was concerned only with the stable platform of the system, surprisingly few malfunction charts are needed to provide complete coverage for this complex system. Also included are a radar system complicated by having five scopes, three separate analogue computers, a true heading unit, a polar navigation unit, two amplifier units, five power supply units, a modulator, a servo amplifier, two main junction boxes, an amplifier indicator group, an altitude and true airspeed transmitter, an azimuth computer, two radar synchronizer units, and numerous control panels, indicators, and other components. Complete malfunction analysis information is provided by only 56 malfunction charts similar to that shown in Figure 2. These charts enable the operator to isolate the malfunctions of 36 amplifiers, 38 fuses, and 198 vacuum tubes. Relatively few spare components need to be carried in the aircraft because the same value and type of fuses, amplifiers and vacuum tubes are used in many places throughout the system. The in-flight maintenance manual also provides information on apparent malfunctions due to faulty adjustments and the necessary adjustment procedures.

Referring back to Figure 2, it will be noted that in each terminal block where the malfunctioning unit is named there is also some additional coded information. In the first terminal block at the top of Figure 2 where the faulty unit is the DG LEVEL AMPLIFIER, it will be seen that TYPE 1H specifies the type of amplifier needed for replacement. A further code of E-1, given in the bottom corner of the block, indicates the component location within the aircraft. The manual is so simplified that diagrams of the aircraft installation are given to ensure that the operator replaces the correct unit.

Most in flight maintenance manuals which use this simplified concept of malfunction analysis are divided into five sections:

1. A malfunction chart section containing all of the charts similar to the one given in Figure 2, and a cross-referenced index where malfunctions are listed alphabetically and by general problem area.
2. A component location section that illustrates where the unit containing the component is located within the aircraft as well as detailed drawings showing where each fuse, vacuum tube or amplifier is located within the unit itself.
3. A component substitution section that lists amplifiers and vacuum tubes for substitution purposes, showing the effects of cannibalization on various units, sources for cannibalization and vacuum tube interchangeability information.
4. A section outlining alignment and adjustment procedures.
5. An emergency operating procedure section which outlines methods for using system components in a less than fully serviceable state, and the resultant system performance limitations.

DEVELOPING A SIMPLIFIED MANUAL

A simplified in-flight maintenance manual can be adapted from much of the existing material already published in various forms for any avionic system. Engineering Orders provide a wealth of information on malfunction symptoms and remedies in tabular form, and many units already have check lists and repair manuals for operational equipment. These sources, plus common knowledge of malfunction histories, can serve as a starting point.

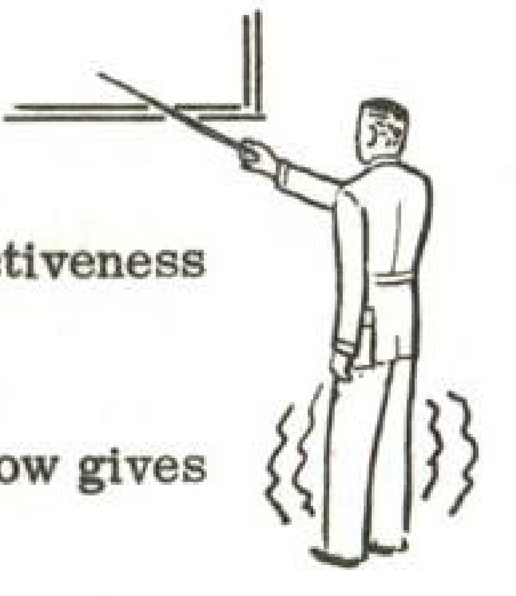
The most useful data for developing the malfunction isolation charts, however is obtained from actual observation of malfunctions as they occur. Most malfunctions can be simulated on the ground with an external power supply providing electrical power to the equipment. The operator merely proceeds to remove each fuse, amplifier, vacuum tube or relay one at a time, and takes notes on all of the equipment reactions and malfunction symptoms that develop Obviously, only components that can be replaced in flight need be tested in this manner. The reader is cautioned that this type of testing procedure should not be undertaken without the approval and supervision of competent technical personnel to avoid damaging the equipment. For some malfunctions which require dynamic observation, the test should be done in flight.

When all necessary malfunction indication data have been gathered, the charts can be drawn. Each chart must start with the most obvious malfunction indication such as a blank radar scope, spinning dials, failure of an indicator to respond to aircraft movement, or an illuminated warning light. Less obvious malfunction indications are normally contained within the chart as reaction branches to some positive action taken by the operator in his isolation procedure. The tricky part in preparing the charts is to combine as many components as possible into the one chart, commencing with a very obvious malfunction indication. Although it is not always possible to avoid charts that show only a malfunction indication and one remedy, oversimplified charts should be avoided. Nothing is to be gained if the block diagram charts replace check lists or tables without reducing the written explanation of malfunction analysis. Figure 2 is an example of a good chart where one obvious malfunction symptom can lead to one of 15 faulty units. In some charts it is impossible to differentiate between possible faulty units and, therefore, the terminal block may contain a series listing of components. Vacuum tube malfunctions often end up as a trial and error solution. However, the operator can isolate the malfunction to one black box of the system and tube replacement is not difficult.

CONCLUSION

Although this article contains nothing original, it explains a concept of in-flight maintenance that may be novel to some Canadian readers. Many aircrew personnel tend to regard in-flight maintenance as an undertaking that should be entered into only with a comprehensive technical knowledge of electronic systems. If this article in some small way dispels that belief, then it will have served its purpose.

BUZZPHRASE GENERATOR



Have you ever felt left out during discussions with systems analysts, cost effectiveness experts, ASC graduates, etc.?

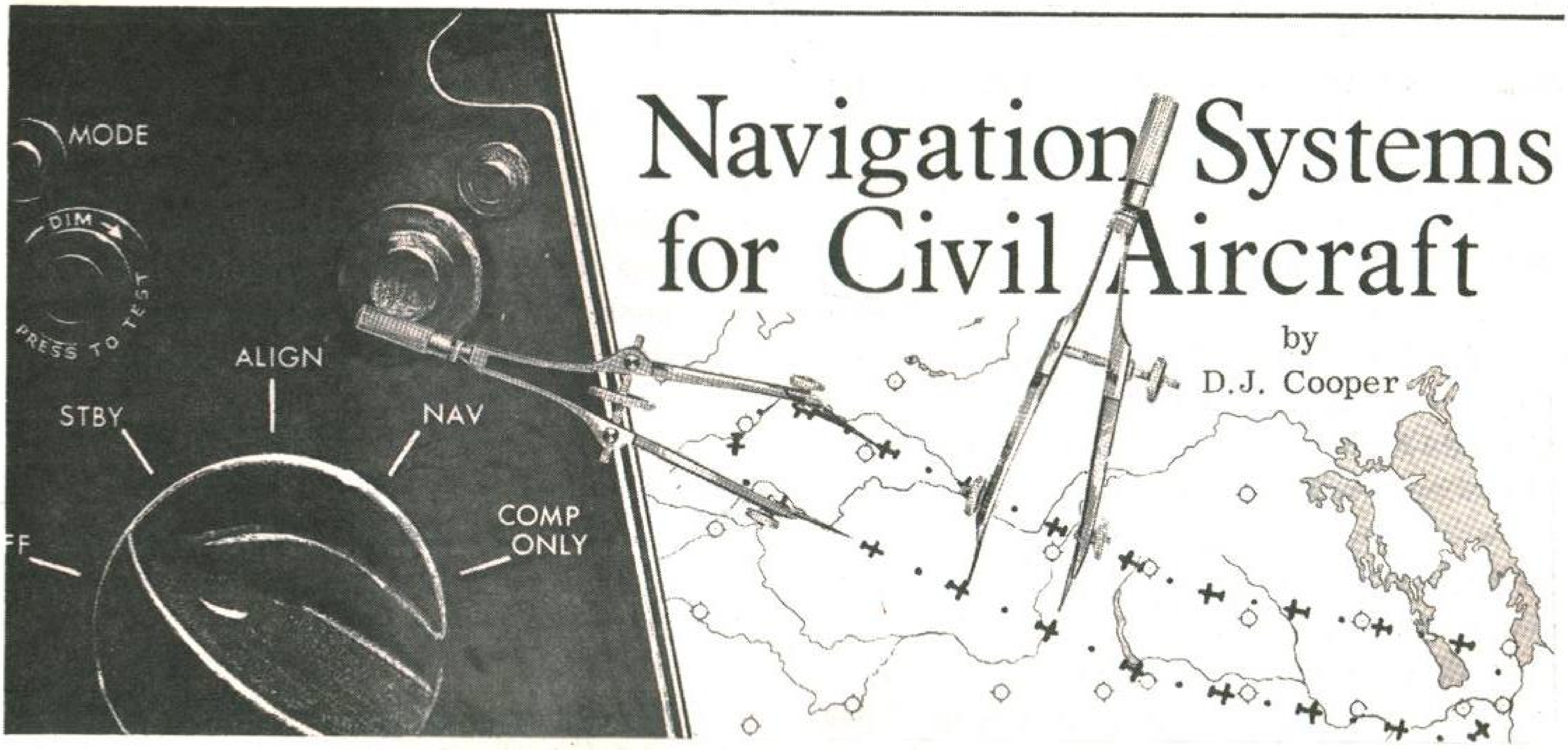
This is no longer necessary. A new invention, the Buzzphrase Generator, now gives its prime practitioners instant expertise on matters pertaining to defence.

The Buzzphrase Generator consists of three columns of buzzwords numbered zero to nine....

COLUMN 1	COLUMN 2	COLUMN 3
0. integrated	0. management	0. option
1. total	1. organizational	1. flexibility
2. systematized	2. monitored	2. capability
3. parallel	3. reciprocal	3. mobility
4. functional	4. digital	4. programming
5. responsive	5. logistical	5. concept
6. optimal	6. transitional	6. time-phase
7. synchronized	7. incremental	7. projection
8. compatible	8. third-generation	8. hardware
9. balanced	9. policy	9. contingency

The procedure is simple. Think of any three-digit number at random. Then select the corresponding buzzword from each column. Put them together and you sound just like you know what you're talking about.

Take for instance the number 257. Take word two from column one, word five from column two and word seven from column three. You now have "systematized logistical projection." You don't know what it means but don't worry, neither do "they".



Navigation Systems for Civil Aircraft

by

D.J. Cooper

THE NAVIGATION DILEMMA

With each passing year the volume of air traffic increases. Air traffic control agencies find it more and more difficult to maintain a safe and orderly flow of traffic without incurring numerous flight delays or issuing flight clearances which are not compatible with the economic operation of modern jet transports. The increased size and passenger carrying capacity of aircraft make the need for improved flight safety more urgent, while at the same time economic considerations and a world shortage of pilots is inducing airlines to operate their aircraft with three-man flight crews in which the two pilots are completely responsible for aircraft navigation. These and other factors are increasing the need and the demand for vastly improved aircraft navigation systems. Once this has been accomplished greater use of the available airspace will be possible, flight safety will be improved, and airline operating costs will be reduced. Benefits will also undoubtedly accrue from a reduction in the number of irate air travellers awaiting late departures in crowded air terminals.

THE NEED FOR SELF-CONTAINED SYSTEMS

The aviation industry is fully aware of the need to improve aircraft navigation and, although opinions vary regarding the most feasible means of accomplishing this aim, it is generally agreed that a self-contained navigation sensor such as Doppler or inertial is required, especially for those aircraft operating on inter-continental routes. This will reduce the aircraft's dependence on ground-based fixing aids and enable a three man crew to navigate effectively in areas where radio aids are non-existent or of questionable accuracy or reliability. Doppler equipment is currently less expensive than inertial, however, its performance is largely dependent upon the quality of the aircraft heading reference, and system accuracy is subsequently inferior to the inertial navigator (which does not require an external source of heading information). In addition to its greater accuracy, the inertial system has the added advantage of providing an accurate heading and attitude reference which is unaffected by acceleration or aircraft manoeuvring. This last feature is of special significance in the case of supersonic transport aircraft in which extended acceleration periods will be an everyday occurrence. Unfortunately, first generation inertial systems were of doubtful reliability and the maintenance costs were prohibitively high in comparison to other systems. However, steady improvements in both system design and manufacturing techniques have increased the performance and reliability of inertial systems to such an extent that they are now an economical proposition.

INERTIAL SYSTEMS

The inertial systems produced by individual companies naturally differ quite considerably in design. The type and number of gyroscopes may differ, the type of accelerometers vary, and either analogue or digital computers may be employed. A wide variety of system configurations has evolved, each possessing specific advantages, however, all systems perform the same basic navigational functions and have certain common characteristics which enable us to discuss them collectively.

1. Inertial navigators consist of an inertial quality platform. a computer, a control and display unit, and the necessary power supply.

2. The systems continually calculate and display present position and steering data to a number of selectable destinations, and provide heading and aircraft attitude angles for utilization by autopilots, radars etc.

3. Provision is normally made to freeze the navigation display so that it may be updated to a position fix obtained from external navigation aids.

4. The errors in pure inertial systems increase as functions of time, and the accuracy of position ranges from an optimistic 1.0nm/hr CEP to a more conservative figure of 3.0nm/hr CEP.

This general inertial system configuration is summarized in Figure 1.

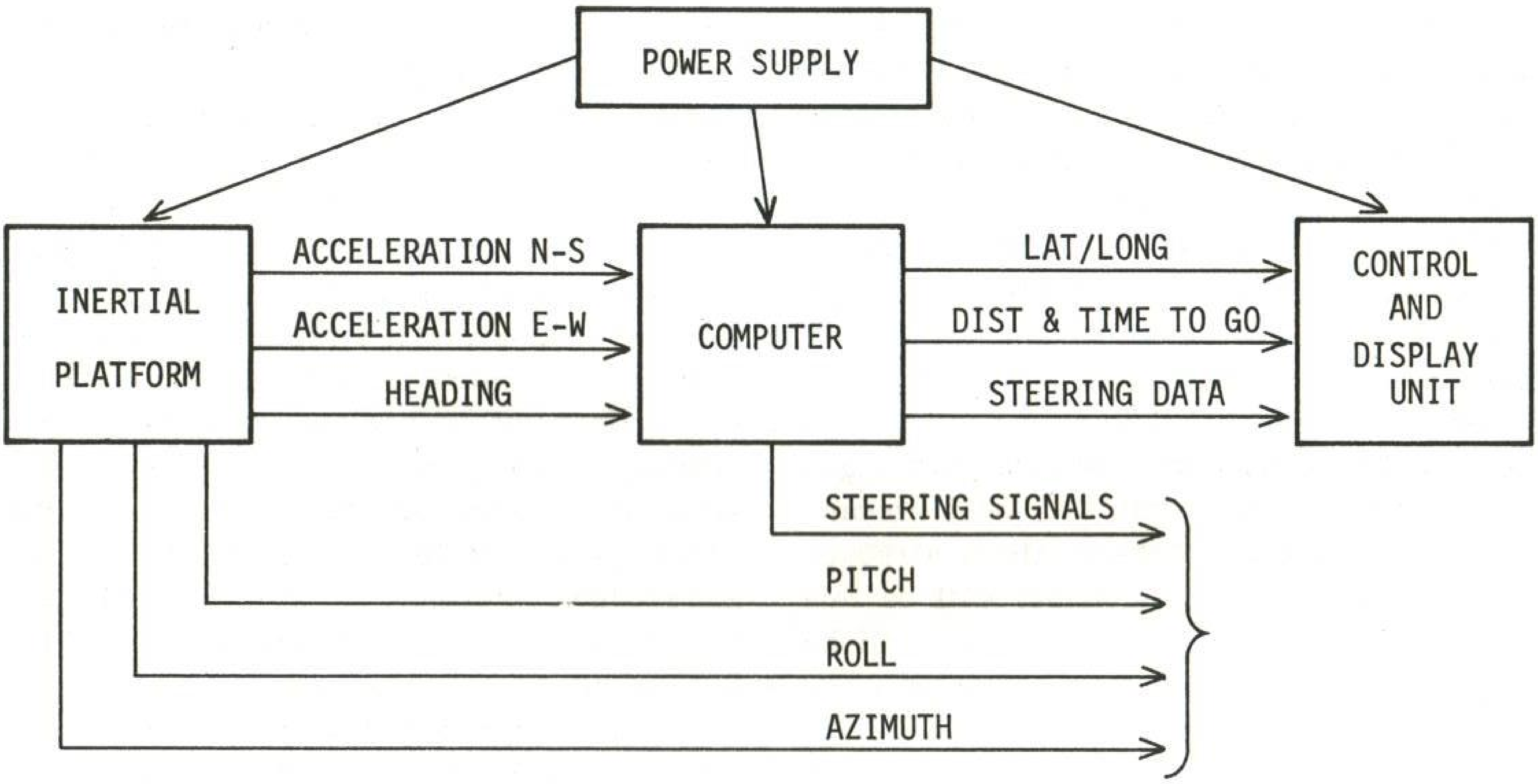


Figure 1: A Typical Inertial Navigator

SYSTEM CONFIGURATIONS

Once concluded that inertial systems are required, it is necessary to consider how the inertial navigator can be best utilized to produce maximum performance and reduction of the crew's inflight work load. The installation of a single inertial system has been considered by manufacturers and operators but this solution has been unacceptable to the majority of airlines since system redundancy is not provided, and the single installation would necessitate frequent cross-checking against position fixes and the pilot's work load would not be substantially reduced.

THE DUAL INERTIAL SYSTEM

Primarily to ensure adequate redundancy the concept of a dual inertial installation has gained favour. In addition to redundancy, the dual inertial system allows the pilot to compare the navigation data from the two systems and if they are in close agreement he can be reasonably confident in the accuracy of his navigation. If the systems should disagree he is immediately aware that an error causing malfunction has occured and he may take action to determine which system is providing erroneous information. In many cases, the faulty equipment will be evidenced by its internal fault detection circuits and the pilot may continue his navigation using the second system.

SOME PROBLEM AREAS

If, however, no fault warnings are present, the pilots will need to assess the system outputs against a position fix in order to determine which inertial navigator is in error. This last process is not as simple as it first appears, since position data is presented to the pilot in different forms by different equipments. Inertial systems use latitude and longitude co-ordinates, VOR/DME employs a rho-theta system, and LORAN uses hyperbolic co-ordinates. These different co-ordinate systems are not compatible and the necessary transformation processes required for system monitoring and cross-checking are laborious and time consuming tasks not easily handled by pilots operating in the confined environment of a high speed jet aircraft.

It is argued in some sectors of the industry that the accuracy and reliability of the dual inertial system should be sufficiently high to allow safe oceanic transit without the need to utilize ground navigation facilities for system cross-checking purposes. This may be true but inertial systems, regardless of reliability or MTBF figures, are subject to unexpected failures and mishandling by flight crew or airline technical personnel. Wide scale experience in the use of inertial systems for long haul operations has not yet been gained, but what experience we do have shows that large navigation errors can occur. The error distribution is not completely gaussian and tails are present in the error analysis. This has instilled a reasonable doubt into the minds of airlines regarding the validity of the two pilot, twin inertial concept. It may well be that the dual system will fail to provide the high order of navigation accuracy demanded for safety in reducing separation standards.

A further shortcoming arises from the display of inertial outputs. Conventional flight instruments and alpha-numeric displays of navigation and steering information do not convey to the pilot a full appreciation of his position relative to the intended flight path, destination, or alternates. This, coupled with the previously mentioned problems associated with inertial monitoring, seriously limits the use of inertial navigators when flying on airways or when transiting from oceanic to airways route structures. These navigation systems' shortcomings need to be overcome and it appears that the solution lies in the more judicious use of ground navigation facilities, and the provision of more meaningful navigation displays.

Considerable time and effort has been devoted to the study of navigation systems which will solve the navigation problems and which will be suitable for initial installation in new aircraft or for the retrofit of existing fleets. It seems fairly apparent that the pro-

vision of adequate navigation facilities depends upon: automatic reduction of fix data derived from any ground based source; the use of this fix information to bound inertial system errors when necessary; and the provision of a more dynamic and meaningful display of navigation and fix data.

With present technology the only feasible means of accomplishing this is through the medium of a powerful digital computer which is capable of accepting inputs in various forms (synchros, voltages, pulses) from all navigation equipments carried in the aircraft. Given these inputs, the computer can employ time sharing techniques to maintain parallel navigation channels, perform the essential co-ordinate transformations required for the reduction of fix data, and supply a suitable display with the information required for navigation and system monitoring functions.

THE NAVIGATION COMPUTING SUB-SYSTEM

To maintain the reliability and redundancy required by modern navigation systems the digital computer must be incorporated into the system in a manner that does not cause associated equipments to be in any way dependent on computer operation. This can be accomplished by allowing the computer to act as an information gathering and correlation centre but preventing it from taking an active part in the operation of individual equipments. It becomes, in effect, a navigation computing sub-system. Figure 2 is a diagrammatic illustration of how this system configuration can be achieved. The inertial systems have retained their own special purpose computers and displays. This provides two important assets. First, a failure of the digital computer does not affect the function-

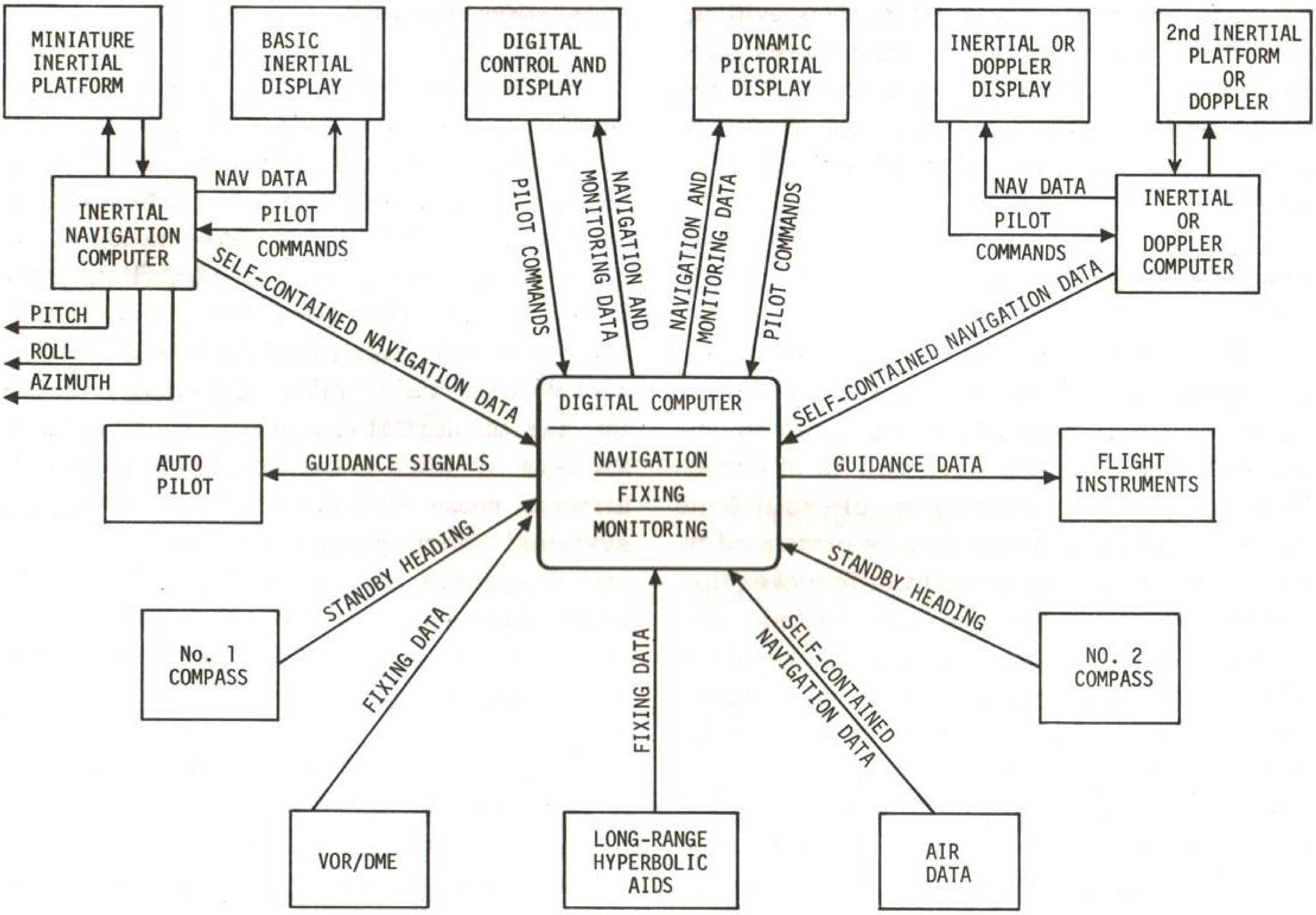


Figure 2: Navigation System Employing a Navigation Computing Sub-System

ing of the inertial systems; and second, the digital computer is not burdened with inertial system calculations and is free to perform a wider range of additional tasks.

PRIMARY COMPUTER FUNCTIONS

The navigation computing sub-system performs three primary functions: guidance and navigation computing; reduction of fixing data; and in-flight system monitoring. In the guidance and navigation function the computer processes inputs from the self-contained sensors (inertial, Doppler, air data) and calculates present position and aircraft progress along its desired route. The use of separate calculations for each sensor establishes individual navigation channels and allows the system to survive sensor failures without jeopardizing operational flexibility.

The capability of the digital computer to establish a position fix from the input of any ground-based navigation aid is probably the most important asset of the navigation computing sub-system. It is this function that greatly reduces the flight-deck work load, and provides the means by which the pilot can assess the performance of individual navigation sensors and update the navigation system when required, thus bounding the errors of the inertial navigator. The navigation outputs of the inertial navigator may be used as a valuable complement to the VOR and VOR/DME systems normally used when flying in the continental airway structure.

The third primary function of the digital computer is to act as an automatic monitor of the navigation system. The computer can check its own operation and that of its input/output equipment by the regular operation of a special test programme. It can check the credibility of various system inputs both preflight and in-flight, and operate a failure warning if limits are transgressed. Finally, the computer can compare navigation information derived from an inertial navigator with information computed from a second inertial system (or Doppler) and air data. Such a comparison enables a warning to be given to the pilot if there is cause to suspect the operation of a self-contained sensor. The pilot is then in a position to inspect the outputs of the various systems more closely and effect a comparison with whatever ground-based information is available. He can then decide which system input is doubtful and which alternate system should be used for the remainder of the flight.

It should be borne in mind that the computer is not intended to perform any decision making functions; these must be left in the hands of the pilot. The computer is a pilot's tool which performs the routine and time consuming tasks of data assimilation and comparison. This integrated data can then be displayed in simple-to-interpret form which allows the pilot to decide the best course of action to follow.

The tasks outlined for the navigation computing sub-system are numerous and complex and one might reasonably expect a computer's capacity to be overloaded. Fortunately, a properly designed modern digital computer is a very powerful instrument, and these tasks are well within its capability. In fact, the modern computer is capable of performing a variety of additional tasks, to name such a few as: the operation of an advanced navigation display; engine monitoring; fuel management; data reduction for accident recording; automatic data link operation and communications control; and airborne maintenance systems.

NAVIGATION DISPLAYS

The digital computer provides a long overdue means of supplying flight crews with a more dynamic and useful display of navigation data. Conventional alphanumeric displays may be improved, but the great advantage lies in the ability to drive symbolic CRT

Figure 3: Argus 400 Digital Computer

displays or pictorial moving chart displays. These displays form an ideal interface between the pilots and the navigation system, and provide features which are impossible using conventional display techniques. For example, a moving map pictorial display operating in conjunction with a digital computer can provide the following facilities.

1. The position of radio navigation aids or alternate routes may be overprinted on the chart and fed back into the computer at will. This reduces computer storage requirements and results in a general decrease of system complexity.
2. Inertially derived position and fix positions may be displayed simultaneously for system monitoring. This same display may be used for updating the navigation system and, since it is done visually, the possibility of human error is greatly reduced.
3. The crew is provided with an instantaneous indication of the changing navigation situation, a feature that eliminates the possibility of disorientation which is possible with conventional displays. This is of special significance in crowded terminal areas.
4. The display can store a wide selection of letdown charts, facility lists, and aircraft check lists, a feature which substantially reduces the pilots cockpit paper-war.

In effect, all the navigation information which is normally scattered around the cockpit, on different instruments and in different forms, is integrated and presented to the pilot on a single comprehensive display.

CONCLUSION

Inertial navigation, digital computing, and advanced pictorial displays appear to be the key to a true improvement in aircraft navigation. The full potential of inertial navigators can be utilized from take-off to touchdown; radio navigation aids can be used with greater efficiency; and the numerous tasks associated with navigation today can be reduced to a few simple operating routines which will allow safe and accurate navigation by a crew of two pilots, even in substantially reduced aircraft separation standards.

WORTH OBSERVING

The following remarks were made by Richard Holloway of Boeing's Wichita Division during a talk with engineering students at Wichita State University and the University of Kansas in late 1966. It doesn't take much imagination to extend their application to many other walks of life which could use a little deflating. This excerpt was reprinted courtesy of Boeing Magazine.

An engineer who cannot communicate is a technician . . . . I've known a chief engineer who quite often asked for one-minute lectures on fairly complex subjects and if the expositor couldn't provide a lecture to explain to the chief what he was talking about, the chief's comment was, "Well, evidently you do not understand it very well yourself." . . . For better or for worse, the flip chart has become a way of life in most engineering organizations.

Engineering is a science of approximation. Don't be misled by digital computer answers out to the 10th decimal place. Never forget that the computer answer is only as good as the computer input. If you put trash in, you get trash out. Never use a complex method to get an answer if a simple one will do and don't expect a precise answer to every problem.

Continued on page 110

The RAAF School of Air Navigation

S/L P.J. Malley

INTRODUCTION

The past twenty years have seen a steady evolution of navigation training in the RAAF and a gradual refinement and improvement of training standards and capability. The output of the School of Air Navigation (SAN), while not large by the standards of bigger air forces, nevertheless represents a considerable achievement on the part of the staff of the School, particularly in earlier years when the facilities available were very limited indeed. Since 1947, the SAN has graduated eight specialist navigators, 160 advanced navigators and 310 navigators as well as some 100 graduates of various other courses such as senior weapons, Antartic navigation, and so on. Aircraft operated by the SAN staff have operated over a wide area of Australia, Australian Territories and New Zealand, from Port Moresby in New Guinea to Pearce in Western Australia.

The RAAF School of Air Navigation (SAN) was established at RAAF Station (as it was then called) East Sale on 5th February 1946 and given the task of conducting all navigation training in the RAAF. This function had been the responsibility of a variety of units such as air observer, air navigation, bombing and gunnery, and astro navigation schools which were established as part of the Empire Air Training Scheme in the Second World War 1939 - 45. With the establishment of SAN the RAAF had for the first time centralized navigation training at the one unit.

The implementation of this task at SAN has changed in detail over the years and has reflected the changing requirements of the RAAF. Until 1961, in addition to basic, advanced and specialist navigation courses, there was a requirement for refresher navigation and astro navigation conversion courses, dictated by the necessity of bringing wartime-trained navigators to a common standard. From 1956 to 1960, SAN conducted Antarctic navigation courses for members of RAAF Antarctic Flights and civilian aircrew of the Australian National Antarctic Research Expeditions. When the Air Armament School, which also was located at East Sale, was disbanded in 1958, SAN inherited some of that unit's tasks and conducted senior weapons officer and explosive examiner courses between 1959 and 1963. Between 1956 and 1960 SAN conducted fighter squadron navigation officers courses but this requirement is now being met from the advanced navigation course.

Currently, SAN is committed annually to one advanced navigation and two navigator courses and the initial phase of one air electronics officer (AEO) course. From January 1969, after re-equipment is completed, the complete AEO course will be held at SAN.

GEOGRAPHY

The School of Air Navigation is one of the units located at RAAF Base East Sale Victoria. East Sale was originally established in 1943 as an operational training unit equipped with Hudson and Beaufort aircraft. The Base has been continually responsible for training functions ever since, and the SAN now shares the facilities with the Central Flying School, School of Photography, and their supporting Base and Maintenance Squadrons.

Located approximately 140 miles east of Melbourne on the flat coastal plain near Bass Strait, East Sale is reasonably well situated for the navigation training task. The area immediately around the base is free from restrictions caused by civilian controlled airspace, firing ranges, and built up areas. At the same time, the rise of the Great Dividing Range to the north ensures that the students develop an awareness of safety height and the necessity to navigate an aircraft in the vertical as well as the horizontal plane. There are few air traffic restrictions on navigation exercises in Dakota aircraft, although the higher cruising altitude of the HS 748, which will replace the Dakota by the end of 1968, combined with anticipated expansion of controlled airspace to the north-west, may produce some routing problems through air routes.

Suitable areas for all types of navigation exercises are convenient to the Base. Overwater flights are conducted over Bass Strait and the Tasman Sea to the south and east, while other exercises to the north-west cover most types of Australian terrain from rugged mountains to featureless semi-desert. Practice in air route techniques is given in the route between Melbourne and Canberra.

NAVIGATOR COURSES

The primary task of the SAN is to graduate navigators with the basic skills and knowledge essential for ready conversion to operational aircraft. To achieve this primary aim, the SAN follows the normal sequence of instruction in theory, plots, synthetic exercises, and air exercises. In common with other Commonwealth air forces, the RAAF holds firmly to the principle that a student cannot learn to navigate unless he is given the responsibility in the aerial environment. In accordance with this principle, all exercises are flown with two students, with each one being responsible for navigation for half the flight. During the other half of the flight, the other student is fully occupied practising equipment operation and procedures which will be needed for future exercises. In this way, the students are able to build up their navigation experience and develop the essential decision-making capability and, at the same time, become proficient in the operation of all equipment as required by the syllabus. This attitude to navigation training will be maintained when the HS 748 enters service in 1969. Flying classrooms as operated by the USAF have never been used by the SAN and the limited use they would have does not justify the cost.

Within this basic philosophy, there have been changes to the navigator course syllabus dictated by changing operational requirements and SAN capability. For example, students initially were required to be trained as bomb aimers as well as navigators before receiving their wings. This phase of training, using Lincoln bombers, was discontinued when the Lincolns were withdrawn from operational squadrons. Bombing training is now a function of the bomber operational conversion unit and SAN teaches weapons theory only. Another fundamental change took place in 1958. Before this time, all students were trainee aircrew while on course and graduated as sergeant navigators. When the decision was made that all pilots and navigators should be commissioned, it became necessary to include in the syllabus sufficient extra training to enable the graduate to become a pilot officer in the General Duties Branch. Today, students are enlisted as cadet aircrew and graduate with a short service commission of eight years. Subsequently almost all are offered either permanent commissions or extensions to their short service commissions.

The type of training aircraft provided naturally has dictated the breadth of practical training given to students. In the early 1950s, for instance, all graduates were trained as navigators and bomb aimers on Dakotas and Lincolns. Since the majority of navigators were posted to units flying these aircraft, they were already well on their way to conversion when they started their first posting. However, by the late 1950s, when the operational squadrons had been re-equipped with such aircraft as Canberras, Neptunes, or Hercules, this fortunate situation no longer existed. Not only were the operational aircraft flying at speeds and heights which could not be attained by the Dakota, but the wide variety of navigation aids and techniques used could not all be taught at SAN. The result, of course, is that the graduates now require much longer conversion courses at their operational units than they did in the past. This unsatisfactory situation will be improved when the Dakota is replaced by the HS 748. In addition to having a performance envelope more typical of operational aircraft, the HS 748 will be equipped with a far more comprehensive and sophisticated navigation system, which will enable the SAN to provide that instruction in operational navigation techniques which is impossible at the moment.

The navigator course comprises 51 instructional weeks each of 38 instructional periods over an elapsed time of 54 or 55 weeks. There are intakes of twelve students each January and June. Each graduate flies approximately 200 hours in Dakota trainer aircraft, of which nearly half is as first navigator. The air training syllabus is divided into manual airplot, automatic airplot, limited aids and astro stages, and there is also some time devoted to practical aerial photography and air route flying. The introduction of the HS 748 must, of course, be accompanied by a revised syllabus and the draft revision is being prepared now. The air exercise programme will require significant alteration to allow the inclusion of such techniques as Doppler trackplot and radar map reading, neither of which is possible on Dakotas. It is hoped that the introduction of a new synthetic navigation trainer will allow the additional techniques to be adequately covered within the existing allocation of aircraft hours per student and that the course will not have to be extended. The syllabus of ground training also will be revised to meet the new course training standard.

AIR ELECTRONICS OFFICER COURSES

In 1965, the RAAF's first AEO course commenced training at the SAN. At present, the SAN is responsible only for the initial three months of this course, and the emphasis is on officer training subjects and an introduction to navigation, airmanship, meteorology, instruments, and similar subjects. The AEO students do not begin their specialist subjects until they start the next stage of their course at the School of Radio, RAAF Base, Laverton, Victoria.

The AEO category was introduced when it became apparent that the term "signaller" did not completely describe the duties and functions of the graduates of the old signaller course. The traditional task of the signaller, that is, communication, now occupies a comparatively small percentage of his airborne time. In the maritime reconnaissance squadrons the operation and interpretation of the various ASW sensors is assuming more and more inportance. The name of air electronics officer was selected to describe this third aircrew category as in the RAF, but in the RAAF AEOs generally are only employed operationally in maritime reconnaissance squadrons. In RAAF bomber and transport aircraft all aircrew duties are performed by pilots or navigators.

When the term AEO was introduced, it was decided that AEOs should have the same career prospects as pilots and navigators. Signallers graduated as sergeants, but AEOs are enlisted as cadet aircrew and graduate as pilot officers with short service commissions in the General Duties Branch in exactly the same way as pilots and navigators.

The AEO course lasts for 59 instructional weeks, with one intake each January of up to 16 cadets. There is greater emphasis on ground training than in the navigator course with students flying some 85 hours - again in Dakota aircraft. The HS 748 will also be used for AEO training, but in this case the aircraft performance will have little bearing on the efficiency and applicability of air instruction. AEO cadets will, however, be trained in radar scope interpretation, and the operation of teletype equipment. This is not possible in the present training aircraft.

The AEO Course will become the complete responsibility of the SAN in January, 1969. Since much of the course training standard for the AEO course is identical with that of the navigator course, there is considerable scope for identical syllabi in certain subjects. The general service subjects, which comprise about one third of the syllabus time for the navigator course, are common to the two courses. Thus there is an excellent opportunity to economize on instructor man-hours by programming a navigator and an AEO course simultaneously. Also, the present system of splitting the two phases of training between two schools results in some wasteful duplication of certain topics. Finally, the experience of the first two AEO courses has suggested amendments to their syllabus. For these reasons, the AEO course syllabus is also being amended so that, wherever possible, periods are identical with those of the navigator course. No doubt with the passage of time the two courses will have an increasing common content. Ideally, the two courses should be the same length, so that all initial training and final graduation activities can be conducted simultaneously. Whether this will be practicable remains to be seen.

ADVANCED NAVIGATION COURSES

The advanced navigation course is the only post-graduate navigation training course conducted by the RAAF. One specialist navigation course was held in 1947, but the requirement for Spec N graduates in the RAAF is so small that this training is more economically conducted on the RAF specialist navigation course.

The aim of the advanced navigation course is to train qualified aircrew to fill the posts of navigation instructor, unit navigation officer, navigation staff officer and research and development officer. The course is not limited to navigators and there are usually one or two pilots on every course. In 1966 for the first time an observer of the Royal Australian Navy completed the course and more are expected on future courses. Only experienced aircrew are accepted and the required qualifications include a minimum of 1000 hours flying, a complete squadron tour, and recent squadron experience.

The course lasts for 18 instructional weeks and is held once a year for up to 12 students. Ground training, including instructional technique, receives the most emphasis and there are only 45 hours of flying programmed. The bulk of the flying is combined into an exercise to New Zealand via RAAF Base Amberley, Queensland, and Norfolk Island, and students practice astro, limited aids, and gyro-grid techniques.

The syllabus for this course has already been drastically revised to make it appropriate for the new generation of aircraft expected in the RAAF in the next few years. Such aspects as inertial navigation, terrain-following radar and computers were, until recently, briefly discussed under the general title of "Future Developments". These and similar topics now receive much more detailed treatment and current graduates, although they may lack practical experience of these modern navigation aids, are sufficiently trained in the theoretical aspects to facilitate the practical assimilation of the techniques and equipments used in new aircraft such as the Orion (P3) and the F-111C.

TRAINING AIDS

The SAN is equipped with the usual range of training and demonstration equipment which needs no further description here. The most valuable item, and one which deserves a more detailed description is the Dead Reckoning Trainer (DRT). The DRT is a most effective device for practising procedures, plotting, and calculation in a realistic real-time situation. It cannot, of course, completely replace air training and it is not completely representative of the airborne environment, but it does keep to a minimum the number of flying hours required for the course, and enables the student to be better prepared for his air exercises. The value of the DRT may be gauged from the fact that students complete approximately 170 hours of synthetic exercises, which is only 30 hours less than the flying syllabus.

The DRT was produced on the Base in 1957. It consists of six pairs of cubicles containing Nav 1 and Nav 2 stations. Each Nav 1 station is fitted with an API Mk 1 and a Variation Setting Control while the main item in the Nav 2 station is the associated GPI Mk 1. Compressed air and power is supplied to all cubicles and the entire unit is controlled from an instructor console.

Nav 1, of course, acts as the navigator for each synthetic exercise and is able to complete his log and chart exactly as he would in flight. Nav 2 is the source of fixing information for Nav 1. Using the GPI, Nav 2 is able to extract pinpoints, measure radio bearings and ranges and calculate intercepts on selected stars and pass the information by intercom to Nav 1 when required. One immediately obvious disadvantage of this system is that apart from the API, Nav 1 does not receive any practice in equipment operation and interpretation. Another limitation is that the time spent as Nav 2 is relatively unproductive and has limited training value. Apart from these inherent shortcomings, the DRT incorporates many obsolete or obsolescent components which are nearing the end of their useful life and a replacement trainer is necessary.

In any case, its replacement would still be essential when the HS 748 enters service. The DRT cannot simulate the performance of the new training aircraft and it is impossible for the present system to give a realistic portrayal of the operation of the new navigation equipments. Accordingly, an air staff requirement for a new synthetic navigation trainer has been published and the trainer is planned to be in operation in 1969.

The new trainer will be a vast improvement on the present DRT. The requirement is for twelve cubicles, each representing as far as possible the Nav 1 station of the HS 748. The entire system will be computer controlled, with capacity for expansion to 20 cubicles if necessary. Different meteorological situations and radio aids environments can be set up for different exercises and there will be a recording system which will allow a rapid post-exercise comparison to be made between the student's plot and the actual aircraft position at all stages of the exercise. The operation and interpretation of all navigation aids will be the responsibility of Nav 1, and there will be no Nav 2 required at all. Individual cubicles can be stopped and started at any time without affecting other cubicles. Although the operation of equipment will not be completely realistic in all cases, (for example, astro information will be provided by an automatic readout of Hs) the interpretation and presentation generally will be realistic and typical random errors and equipment malfunctions can be injected as required.

It is apparent that the new trainer will eliminate many of the limitations associated with the present DRT. Apart from providing a realistic performance envelope and practice in the use of new navigation aids and techniques, all the time spent in the trainer by students will be fully productive and more typical of an actual exercise. The ability to compare the actual plot with the student's plot almost immediately after an exercise will permit more effective debriefing and the "exercise stop" facility will allow supervising instructors to correct mistakes as they occur.

One serious limitation in the School's training capability for some time has been the lack of radar training aids. The Dakota trainer is not fitted with PPI radar and the SAN does not have any radar simulator. At present, the graduate receives no practical radar training until he reaches his squadron and, if he is posted to an aircraft such as the Canberra, which has no PPI radar either, it may be years before he receives any practical radar experience at all. The AEO students who will be flying with the navigators also will require radar experience.

The HS 748 will be fitted with cloud warning radar with a ground mapping capability; however the limited training that this will provide will not fully meet the graduation requirement and an air staff requirement has been raised for a radar scope interpretation trainer to complement the airborne training. This trainer will not be representative of any particular radar equipment, but will provide realistic practice in scope interpretation of typical terrain and shipping targets, and demonstrate the effect of the variation of radar parameters such as beam width and pulse length. It is hoped that it will also be in service in 1969.

TRAINING AIRCRAFT

The training aircraft in use has, of course, a considerable influence on the course syllabus and the standard of the graduates. Ideally, a navigation training aircraft should be capable of a performance similar to that of operational aircraft and be equipped with comparable navigation aids. Financial limitations do not always allow this ideal situation to be achieved and the training aircraft used by the SAN have not always met this requirement.

The first aircraft used by SAN was the Avro Anson, which was retired in 1951. The performance and aids available in this aircraft were very limited, but the experience of students was broadened by some flying in Lincoln bombers. A number of Lincolns were based at East Sale for navigation and weapons training. Indeed, one aircraft was specially modified for navigation training in 1947. This aircraft was christened "Nyhuan", an aboriginal word meaning "Pathfinder", on 28th May 1947 and, in common with other Lincolns, saw considerable service until they were retired in 1958. The Lincolns were extremely valuable as training aircraft because, at the time that they were in use at East Sale, they were still in use as bomber and, in a modified form, maritime reconnaissance aircraft.

However, it is the ubiquitous Dakota which has provided most SAN students with

Hawker Siddeley 748

Equipment	Dakota	HS 748
Main compass	Kelvin Hughes G3	Sperry CL-11 (twin fit)
Standby compass	Pioneer B-16	E2-B
Sextants	Kollsman periscopic. Mk 9AM hand held	Kollsman periscopic (twin fit)
Drift meters	Mk 2 drift recorder Pioneer B3	Kollsman B6
Radio compass	AN/ARN-7	Bendix DFA-73A (twin fit)
DME	AWA VAN-4	AWA VAN-4
TACAN	Nil	AN/ARN-52
SAR homing	SARAH	AN/ARA-50 UDF homer
Radar	Nil	AN/APN-158
Doppler	Nil	AN/APN-153(V)(N)
Navigation computer system	API Mk 1, GPI Mk 1, and WFA Mk 1	GPI Mk 7
Radar altimeter	AN/APN-1	AN/APN-141
ILS/VAR/VOR	ARI 18011	Collins 51-RV-1
IFF	Nil	Yes

Table: COMPARISON OF DAKOTA AND HS 748 NAVIGATION EQUIPMENT their initial flying experience. The first Dakotas appeared at East Sale in 1951 and they have continued to give valuable service ever since. Originally, the aircraft were operated in the standard freighter configuration but were later extensively modified internally for the navigation and photographic training roles. The forward section of the freight compartment was equipped with separate plotting tables for two student navigators and an instructor. A complete ADRIS system comprising API, GPI, and WFA was included and a Kollsman periscopic sextant, DME, and a B3 driftmeter have been added to the aircraft's original equipment. There is no doubt that in its time the Dakota navigation trainer has been a most effective aircraft for its task. Now, of course, the Dakota has serious limitations for the navigation training role. It cannot fly fast enough or high enough to provide students with experience of the conditions they will meet in operational squadrons or of the navigation aids in use, and hence the techniques which can be taught are not representative of those in service. For example, almost all multi-engined operational aircraft of the RAAF are fitted with Doppler without a corresponding training capability being available at the ab initio navigation training level. Recognizing this deficiency the RAAF has ordered eight HS 748 aircraft as replacements.

The HS 748 trainer for the RAAF has been specifically designed as a navigator/AEO training aircraft and its arrival at East Sale is being keenly anticipated. Typically, it will operate at approximately 220 knots TAS and 25,000 feet instead of the Dakota's 140 knots TAS and 10,000 feet. Its endurance at height and low level should be sufficient to conduct the six hour navigation exercises which are standard at the moment. The extra height capability will be a particular advantage, since the HS 748 will be able to fly above much of the weather which now forces the cancellation of certain navigation exercises, such as astro, in the Dakota.

The HS 748 will be fitted with stations for one navigation instructor, two student navigators, one AEO instructor and two student AEOs with one further station as yet uncommitted. The air training of navigators and AEOs can therefore be conducted concurrently. Another advantage will accrue from the more comfortable crew environment of the HS 748, i.e., the students will be less susceptible to fatigue and air sickness. A slightly lowered suspension rate might also result from this advantage.

Probably, however, the greatest advantage will accrue from the very comprehensive range of navigation and communication equipments. The Doppler, GPI, TACAN, radar, twin ADF and twin sextant installations will vastly increase the variety and productivity of the air training at the SAN. In many cases, the equipment fitted is identical with that used in operational units. The Doppler, for example, is AN/APN-153, which will also be fitted to a number of the new aircraft for Operational Command. The future graduate of the SAN will not only be experienced in a more realistic environment and in current techniques, but in many cases he will already be able to operate the navigation aids he will find on his new aircraft. The table of comparison between the equipments fitted in the Dakota and in the HS 748 gives a clear idea of the tremendous improvement offered by the new aircraft.

FUTURE DEVELOPMENTS

The next two years hold many exciting and interesting developments for the SAN. The biggest operation will be the acceptance and delivery of the new aircraft. SAN crews will ferry the aircraft from the United Kingdom to Australia in groups of two, beginning in August 1968. The last two of the complete batch of eight are due to reach East Sale in December 1968.

AEO training becomes the complete responsibility of the SAN from January 1969. At the same time the present annual intake of navigator cadets is planned to increase from 24 to 30 The cadet population of the school will increase from its present maximum of about 40 to over 60. To accommodate this number, a new self contained Cadet's Mess has been designed and should be finished during 1968.

Allied with the introduction of the new aircraft and the increased training commitment is the introduction of new training aids. In addition to the synthetic navigation trainer and the radar scope interpretation trainer already mentioned, a complete range of equipment will be installed specifically for the AEO students, including a HF procedure trainer, ASW demonstration equipment, and a HF air/ground station.

This unprecedented re-equipment and expansion programme of SAN requires a considerable amount of preparatory work. Syllabi are being re-written around the new aircraft, the required domestic and training accommodation and training aids are being planned for completion before the first courses start training on the new aircraft, and the instructors and crews must be converted to the new aircraft. In addition, the intake of courses in 1967-68 has been adjusted so that there will be the minimum of disruption to programmes and reduction in output of graduates during the re-equipment period.

SAN was twenty one years old this year. Although the birthday presents will be some twelve months late, it is true to say that the School has reached maturity and is about to embark on a phase of increased productivity, with its capability vastly improved by the introduction of new aircraft and training aids. ☐

WORTH OBSERVING continued....

Many people (usually mathematicians) claim that mathematics is the language of engineering. But in most cases the results of mathematical manipulation are presented as graphs. Hence, graphs may be considered the language of engineering. Graphs on which the words are typed are merely an indication that the engineer who drew them can't letter.

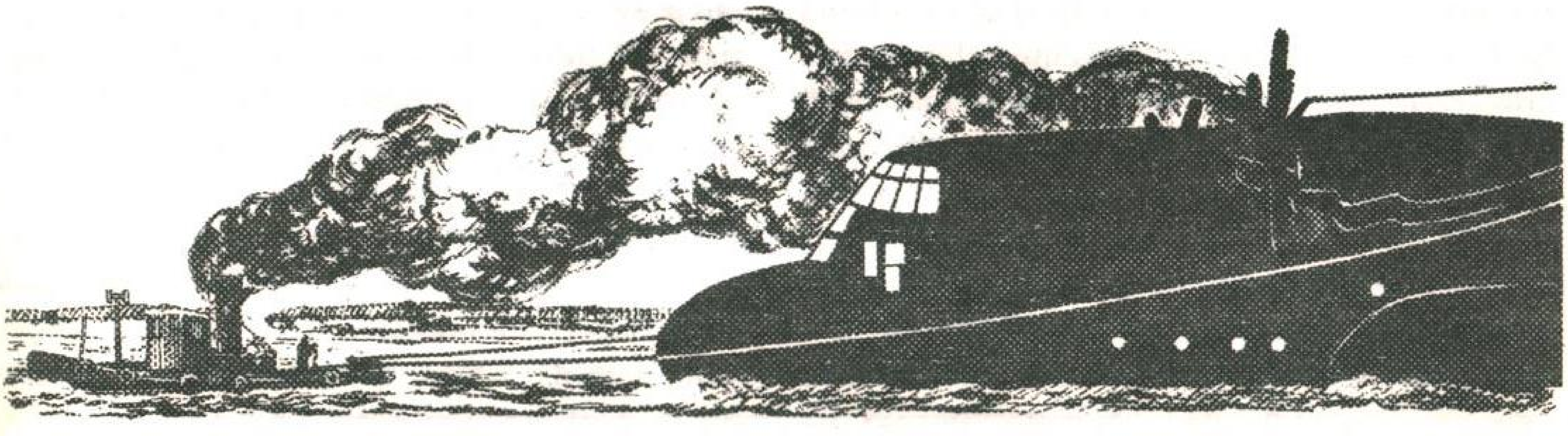
One of my pet peeves is the introduction of fancy nomenclature and acronyms. Sometimes I think programs have been sold mainly on the basis of having a clever catch title rather than on having any valid technical content.

There are nearly always several satisfactory answers to every problem and the choice . . .often depends on things beyond the control of the engineer, such as cost or timing. Practically every engineering problem today must be presented in terms of alternatives.

I recall a study we were doing once using a DC-3. We were using the airplane for low speed, single-engine flight and, in order to conduct an analog computer study to supplement the flight test work, we needed the stability derivatives of the DC-3. We called up an engineer at the Douglas Company and asked him if we could have a set of stability derivatives for the DC-3. He told us, "Sonny, when the DC-3 was built, stability derivatives had not even been invented." This is just another example of the fact that you can build a pretty good flying machine with very little complex theory, and I sometimes wonder today if we aren't making a 100 by 100 matrix analysis an end in itself rather than a tool of engineering.

Responsibility is made up of many small things which used to be called a "gentleman's characteristics. . . ." It is easy to say "It's not my job to worry about that." It may not be-but it is your responsibility to make sure that someone is worrying about it.

THE MERITS OF THE HIGH-SPEED CRUISE



by F/O B.K. Sadler

The days of the C-119 Flying Boxcar are more than two years past now and the Hercules that replaced the Boxcar has stood up very well in the tasks of a greatly expanded role, one that has become literally world-wide. The aircraft has been called, by the crews that fly her, both simple and complex, depending, we can assume, on whether or not they are experienced in the Command. To a freshman navigator who has just graduated from ANS, the OTU at Trenton gives him his first look at the "one-thirty".

Fixing oneself, the function which he learned at Winnipeg, loses its dominance of his time and he must begin to share his concentration with such inherent problems as high-level meteorological phenomena, fuel management, and over-all flight profiles. I don't think that anyone will disagree that this must present an awesome environment within which the new navigator must learn to live and function. Hence, we hear the aircraft and its role described as complex. But to the old salt who had been flying for years, the Hercules and its flight profile presented relatively fewer new problems of adjustment, and he quickly mastered his new function. Now, after two or more years on the aircraft, everything seems simple again due to his experience. In this article I would like to point out something which the experienced navigator may have overlooked, due to oversimplification in his handling of the aircraft and its function, and which the novice may not realize due to his preoccupation with the basics.

Efficiency is defined by Webster as the production of the desired result with a minimum of effort, expense and/or waste. Related to the operation of the Hercules, (or Transport Command as a whole for that matter), this can be expressed in terms of carrying the maximum payload across a given distance in a minimum time with a minimum effort. What I propose to show is that navigators can programme the Hercules more efficiently by using the almost forgotten High-Speed Cruise (referred to as HSC) in place of the standard Long-Range Cruise (LRC), when such a cruise technique is compatible with the flight characteristics, as on the scheduled flights across the Atlantic to and from No. 1 Air Division.

If we look at various conditions of operation we can, with the aid of our Fuel Prediction Chart for the Hercules, come up with a comparison of the two types of cruises with respect to engine time, payload capability, fuel required and total crew day. The charts are duplicated in Figures 1 and 2. However, before we delve into specifics, a few generalities that pertain to present scheduled flights must be explained. For example, in Table 1, I have used a reasonable basic weight for the C-130E of 76,000 lbs, and an all-up weight of 155,000 lbs, which leaves a total of 79,000 lbs to be shared between fuel required and payload carried. In the distance column, 3600 nms represents the approximate distance from Trenton to Lahr, Germany, via Route 2 (which follows a composite Great Circle across Goose Bay and 57N). The execution of the HSC requires a fuel stop and for this purpose, Goose Bay has been chosen, although most of the other eastern seaboard airfields could be used in actual practice as well. Subsequently the distance of 2700 nms represents

Table 1: HSC - LRC Comparison

Example	Temp Dev'n	Distance	Dir'n W/C	Time	% Gain	Fuel Req'd	Payload Capacity	% Gain	Crew Day	% Lost
1 LRC	-15	3600	East	11+45	5%	58900	20100	24%	14+45	1%
HSC		2700	+30	11+10		54000	25000		14+55	
2 LRC	ISA	3600	East	11+50	3.5%	59300	19700	32%	14+50	2%
HSC		2700	+30	11+25		53000	26000		15+10	
3 LRC	+15	3600	East	11+50	nil	61000	18000	50%	14+50	5%
HSC		2700	+30	11+50		52000	27000		15+35	
4 LRC	-15	3100	West	12+35	6.5%	61600	17400	30%	15+35	nil
HSC		2200	-30	11+45		56400	22600		15+30	
5 LRC	ISA	3100	West	12+35	5%	62300	16700	44%	15+35	nil
HSC		2200	-30	11+55		55000	24000		15+40	
6 LRC	+15	3100	West	12+40	3%	63700	16000	53%	15+40	2%
HSC		2200	-30	12+15		54500	24500		16+00	
7 LRC	+15	3100	West	11+55	3%	61300	17700	51%	14+55	3%
HSC		2200	-15	11+35		52100	26900		15+20	
8 LRC	-15	3100	West	11+55	5%	59200	19800	24%	14+55	1%
HSC		2200	-15	11+20		54500	24500		15+05	
9 LRC	+15	3100	Either	11+15	1.5%	58500	20500	38%	14+15	4%
HSC		2200	0	11+05		50700	28300		14+50	
10 LRC	ISA	3100	Either	11+10	5%	57000	22000	27%	14+10	1%
HSC		2200	0	10+35		51000	28000		14+20	

These examples illustrate general trends found in familiar circumstances. A Navigator can, with the aid of his Fuel Prediction Chart, ascertain the advantages pertaining to any flight under any particular set of circumstances with which he is confronted.

the leg from Goose Bay to Lahr, and Westbound, the distance of 2200 nms represents the distance from Gatwick to Goose Bay, with 3100 nms the distance from Gatwick to Trenton. Needless to say, the 900 nms between Goose Bay and Trenton pose no problems regarding range or fuel.

The columns depicting Temperature Deviation and Wind Component are self-explanatory and, I think, a fair representation of those found on the North Atlantic. There are others both outside and within those I have set down but I don't think they need be brought in to make the point any more clear. The Time column figure is extracted from the chart (added to which is a block time for the airways leg, plus twenty additional minutes for the letdown and take-off at the fuel stop required in the HSC) In the Fuel Required column, the figure represents the total flight plan fuel comprised of estimated burn-off (from the prediction chart), the 5% en route reserve, holding reserve of 3300 lbs, and the fuel required to alternate. In the latter case, I have adopted a standard fuel figure of 5600 lbs, except for the westbound HSC where, because Goose Bay is the destination, I have assumed a more reasonable figure of 8000 lbs. The payload figure is attained by subtracting the basic weight and fuel required from the maximum permissible take-off weight of 155,000 lbs. As far as the Crew Day column is concerned, the time consists of the en route time plus three additional hours of crew duties both pre- and post-flight. In the case of the HSC, an additional 45 mins is included for the ground time consumed in the fuel stop. All in all, I think one would agree that these figures are very reasonable and unbiased.

If we follow through the Comparison Table, and the Fuel Prediction Chart, doing a couple of examples, then the point of the HSC will become evident and the other examples will become self-explanatory. For instance, examples numbered 4 and 6 are concerned with opposite extremes in temperature and a wind component found not infrequently on a westbound flight. In example 4, we enter the Fuel Prediction Chart for LRC with the ground distance of 3100 nms, and proceed straight up to the reference line, then follow the curves until we arrive at the Wind Component (in this case, minus 30). Straight up brings us to the en route time, determined by the Temp Dev'n: here, a dev'n of minus 15 gives us a time of 12+35. Extending our line straight up once again, we arrive at the reference line for Fuel then follow the curves to the Temp Dev'n (minus 15) and finally continue upward, past the section concerned with All-Up Weight (we are using the standard of 155,000 lbs), to the top line where we find our predicted burn-off is 50,200 lbs. To this sum we add our 5% reserve of 2510 lbs, our holding reserve of 3300 lbs, and our fuel to alternate of 5600 lbs, giving us a total Fuel Required (to the nearest 100 lbs) of 61,600 lbs. This figure, combined with the aircraft's weight gives us in this instance a Payload Capability of 17,400 lbs. By adding three hours to the en route time we can estimate that this flight will be accomplished in a Crew Day of 15+35 duration.

Turning to Figure 2, the Fuel Prediction Chart for HSC, and following the same procedure, (but with a distance of 2200 nms), we finish with a time of 11+45 comprised of the following: 8+05 from the chart, 20 mins for the letdown and take-off at the fuel stop, and a block time of 3+20 for the airways leg of Goose to Trenton. Fuel Required out of Gatwick is 56,400 lbs and, therefore, the Payload Capability becomes 22,600 lbs. Adding a total of 3+45 to the en route time we can estimate that this type of cruise will accomplish the flight within a Crew Day of 15+30. In the columns concerning the percentage lost or gained, we find that the HSC carries out the same flight requirements but in 6.5% less engine time, with a 30% increase in payload capability and with nil increase in the crew day.

In Example 6, with the temperature at the opposite extreme (ISA +15), and with the same component of minus 30, the HSC comes out ahead again with a 3% decrease in engine time and a whopping 53% increase in payload capability for only a 2% increase in the crew day. An additional interesting note is that the LRC requires 63,700 lbs of fuel which is 800 lbs above the total fuel capacity (62,900 lbs) of the aircraft! These are but two examples, and naturally the figures fluctuate depending upon the circumstances involved.

However, careful perusal of the Comparison Table will enable us to see a few apparent trends. Foremost is the substantial increase in payload capability that the HSC affords the Hercules. Indubitably, there will be some who argue that the aircraft will be bulked out (that is, will run out of cubic feet capacity before actual weight capability), but if this occurs, then you have even more fuel to fly the HSC and save engine time. This brings us to the second advantage of the Low and Fast method, and that is the saving in engine time. Obviously, extra fuel burned is more than offset by the man-hours saved by increasing the calendar time between major overhauls. On the third subject of crew day increases, may I first say that the increases are small and are concerned only with that particular crew, whereas the engine time saved is accumulative over a period of months. Secondly, I think that all navigators will agree that with the double positions of pilots and engineers and their rotational policies during the over-water portion of flight, there is hardly room for any complaints over an increase of 0 to 5% in their crew day. On the contrary, from their conversations, I gather that most pilots will be pleased to get another landing in, not to mention the brief respite on the ground which serves to break up the flight.

Another trend that becomes visible is the type of advantage inherent in a particular change of circumstances. If we look at the temperature we find that with a cold extreme the HSC offers its greatest decrease in engine time and yet still maintains a substantial increase in payload capability. With a warm extreme in temperature, this type of cruise loses its advantage concerning engine time but offers fantastic increases in payload capability with possibilities upwards of 53%! Not to be forgotten is the fact that you may not make it all the way home even with the LRC if the temperature is warm enough, as we saw in example 6!

An argument against the use of the HSC, especially eastbound, is that it is more favourable to climb to maximum height to take advantage of maximum winds and increase the Specific Ground Range (expressed in nautical miles per 1000 lbs of fuel burned) With this idea I must agree although the figures in the Comparison Table (eastbound) give us food for thought even in this area. However, the advantages of the HSC do become indisputable on westbound flights with negative wind components, and it is here, as we can see in the table, that they may be exploited to their fullest.

If any navigators reading this are interested in practicing this type of cruise, may I express a few words of caution. Most important is that in utilizing an HSC, one must conduct fuel management with care because you can no longer just drop in for more fuel " once you reach land" as often happens with the Long-Range Cruise. Your destination is the other side and there is no fuel bowser half-way there! Even the idea of just popping up a couple of thousand feet to reduce your fuel consumption does not always work as the winds (westbound) at that higher altitude may keep your Specific Ground Range at the same value and, in fact, may reduce it further. Secondly, for those who haven't practiced this type of cruise even sporadically, it would be advisable to solicit the opinions and policies of your respective Sqn Nav Officer. Last but not least, it would be only fair, not to mention safe practice, to keep that much-maligned soul in the left seat, the Captain, informed of what you are intending or would like to do. Regardless of what he does or doesn't get paid, if anything goes wrong, he still carries the can!

EXAMPLE

TEMP: ISA-15
DIST: 4270
WIND COMP: -30K
T/O WT: 145,000
THEN
TIME: 17:12
FUEL: 61,400

LONG RANGE (99%) CRUISE

PRE-FLIGHT PLANNING GRAPH
INCLUDES INITIAL & ENROUTE CLIMB-NO RESERVE INCLUDED

GUIDE TO INITIAL CRUISING ALTITUDES

2000' STEPS AT APPROX 2 1/2 HOUR INTERVALS

WT \ TEMP DEV	+15	+10	+5	ISA	-7½	-15
155000	17.0	18.0	20.0	21.0	22.0	23.0
145000	19.0	20.0	22.0	23.0	24.0	25.0
135000	22.0	23.0	24.0	25.0	26.0	27.0
125000	24.0	25.0	26.0	27.0	28.0	29.0

C130E
WITH
PYLON TANKS
4 ENGINES
@ 895°C TIT

ISSUED 1 APR 66

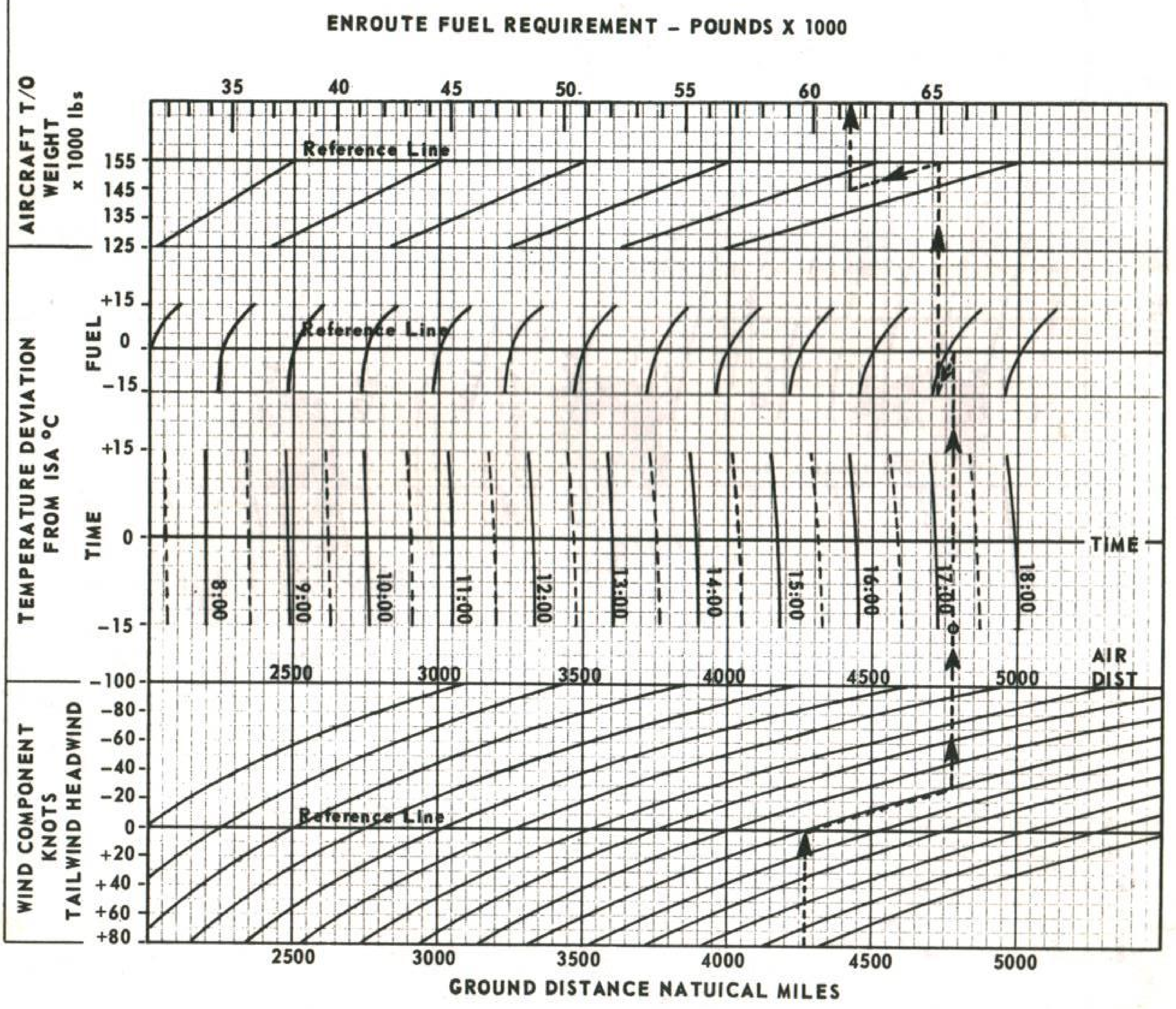


Figure 1

HIGH SPEED CRUISE

EXAMPLE

TEMP: ISA–15
DIST: 3550
WIND COMP: +30K
T/O WEIGHT: 145000
THEN
TIME: 10:34
FUEL: 53,100

PRE–FLIGHT PLANNING GRAPH

INITIAL & ENROUTE CLIMBS INCLUDED–NO RESERVE INCLUDED

GUIDE TO INITIAL CRUISING ALTITUDE

2000' STEPS AT APPROX 3 HR INTERVALS

TEMP DEV / WT	+15	+10	+5	ISA	–7½	–15
155000	14.0	14.0	15.0	15.0	16.0	16.0
145000	16.0	16.0	17.0	17.0	18.0	18.0
135000	18.0	18.0	18.0	19.0	19.0	19.0
125000	20.0	20.0	20.0	20.0	20.0	20.0

C130E

WITH

PYLON TANKS

4 ENGINES

@ 895°C TIT

ISSUED 1 APR 66

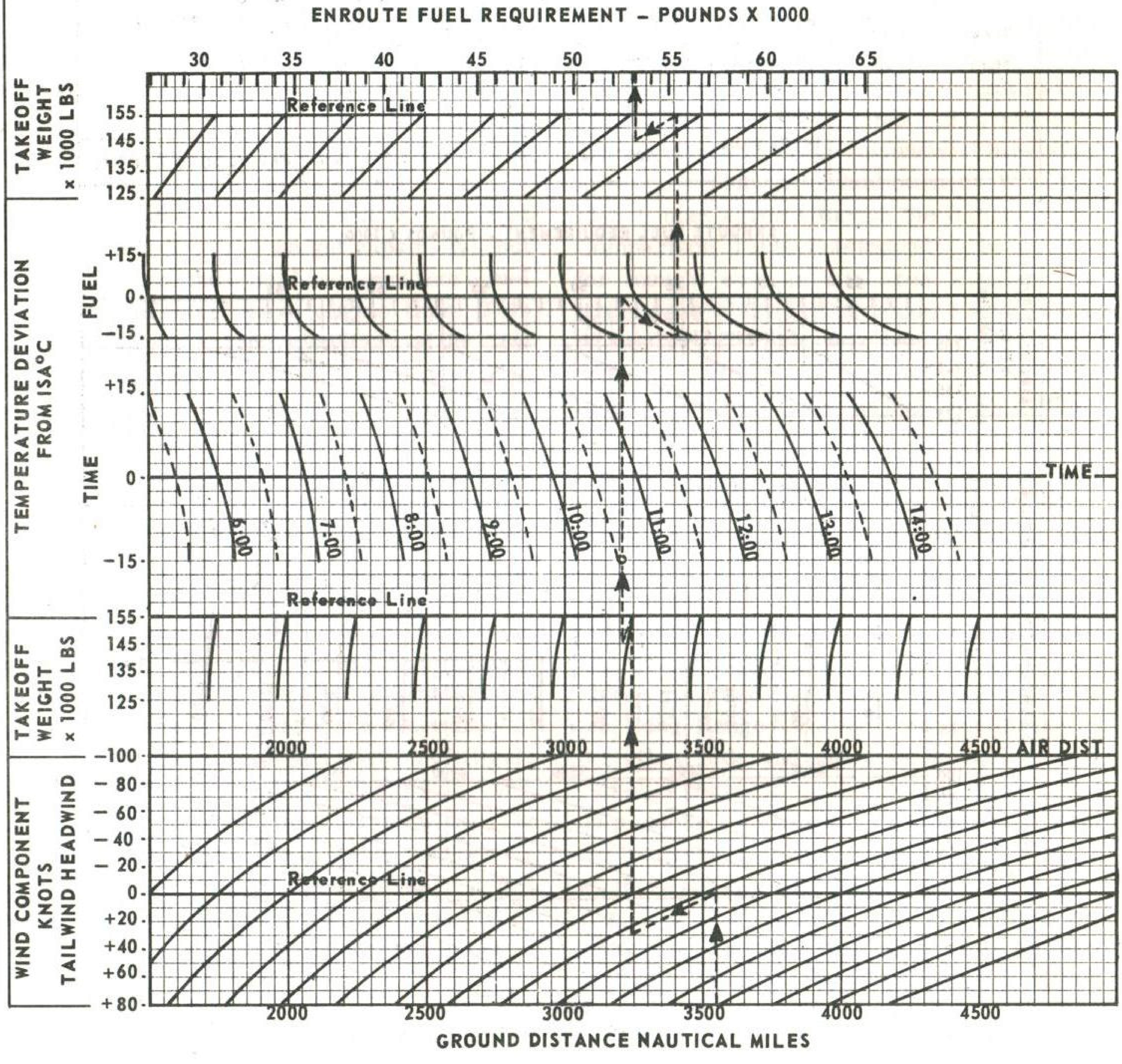


Figure 2

F/L J.B. SINGLETON
435 (T) SQN

F/L J. TANCHAK
405 (MP) SQN

F/L A. BIASON
404 (MP) SQN

F/L J.A. TUSTIN
4(T) OTU

F/L J.E. PILON
CFB GREENWOOD

F/L J.D. FRENETTE
CFB SUMMERSIDE

F/O R.R. BUJOLD
4 (T) OTU

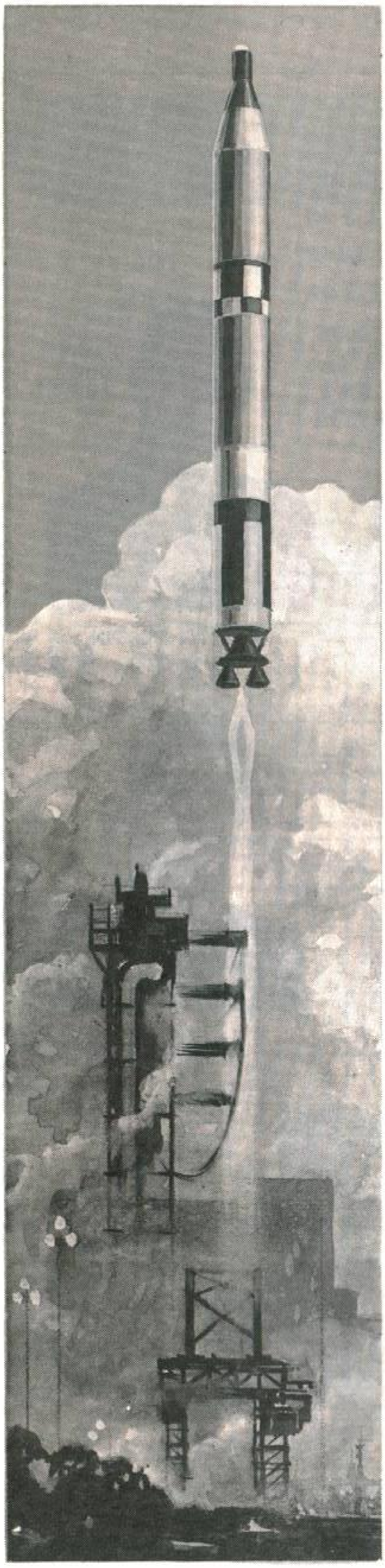
F/L R.L. GAEDE
2(M) OTU

F/L J.C. SLATER
407 (MP) SQN

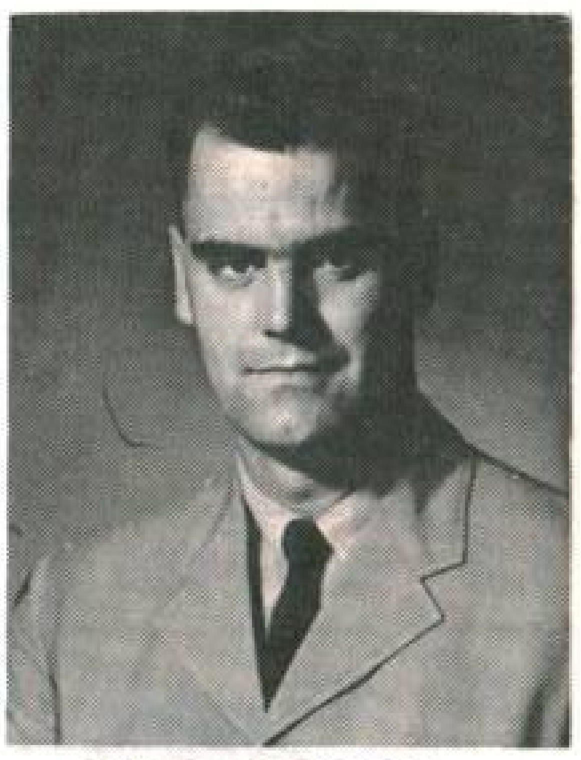
F/L G.R. BURGE
103 RESCUE UNIT

F/O M.R. SITKO
111 KU

Advanced Radio Navigator Course 6703



F/L K.H. PAULS
AIR/RN/RO



F/L D. BATTYE
TECH/TEL

F/L R.W. KUNTZ
AIR/RN/LR

F/L G.E. GILLESPIE
AIR/P

F/L B.C. HEPWORTH
AIR/RN/RO

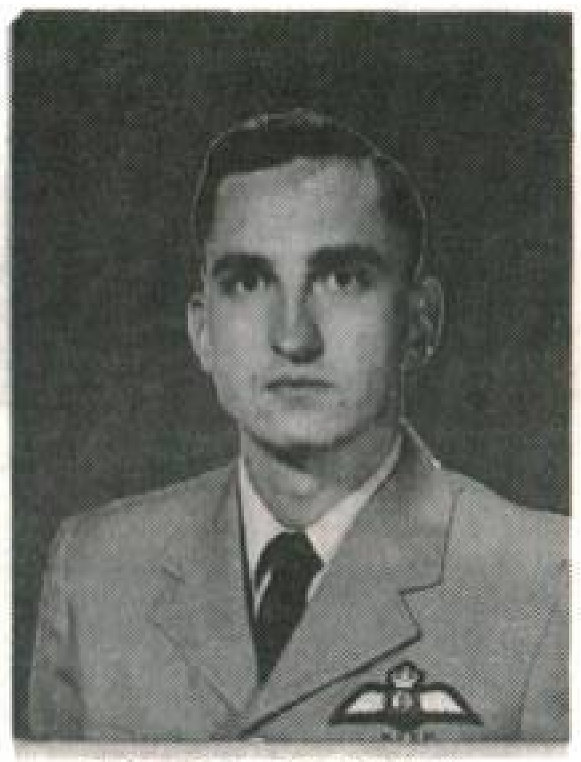
F/L H.A. BREEN
AIR/P

F/L S.A. JAKNUNAS
AIR/P

CAPT L.C. LEE
NAV (USAF)

LT. A.G. SINCLAIR
RCN (WEAPONS)

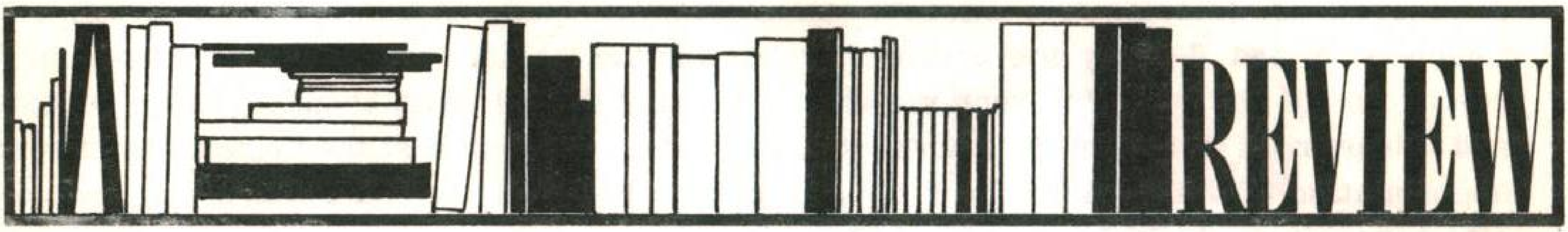
LT. A.M. BINGLEY
RCN (AIR/P)



F/L G.D. LESLIE
AIR/RN/LR

F/L D. ANDERSON
AIR/RN/LR

Aerospace Systems Course No. 20



"AERODYNAMICS OF V/STOL FLIGHT"

Author: Barnes W. McCormick, Jr.,
Pennsylvania State University
(Copyright 1967) 321 pp

Publishers: Academic Press Inc.,
New York (London)

Price: $15.63

V/STOL is a combination of two abbreviations, VTOL and STOL, which stand for "vertical take-off and landing" and "short take-off and landing". Thus, V/STOL aerodynamics is that part of aerodynamics which deals primarily with the theories and the devices which enter into the design of aircraft having vertical take-off and landing or short take off and landing capabilities. V/STOL aerodynamics has been receiving great emphasis as demonstrated by the recent rapid development of aircraft with exceptional take-off and landing performance. Because many V/STOLS have direct application in military fields V/STOL aerodynamics should be of interest to all of us.

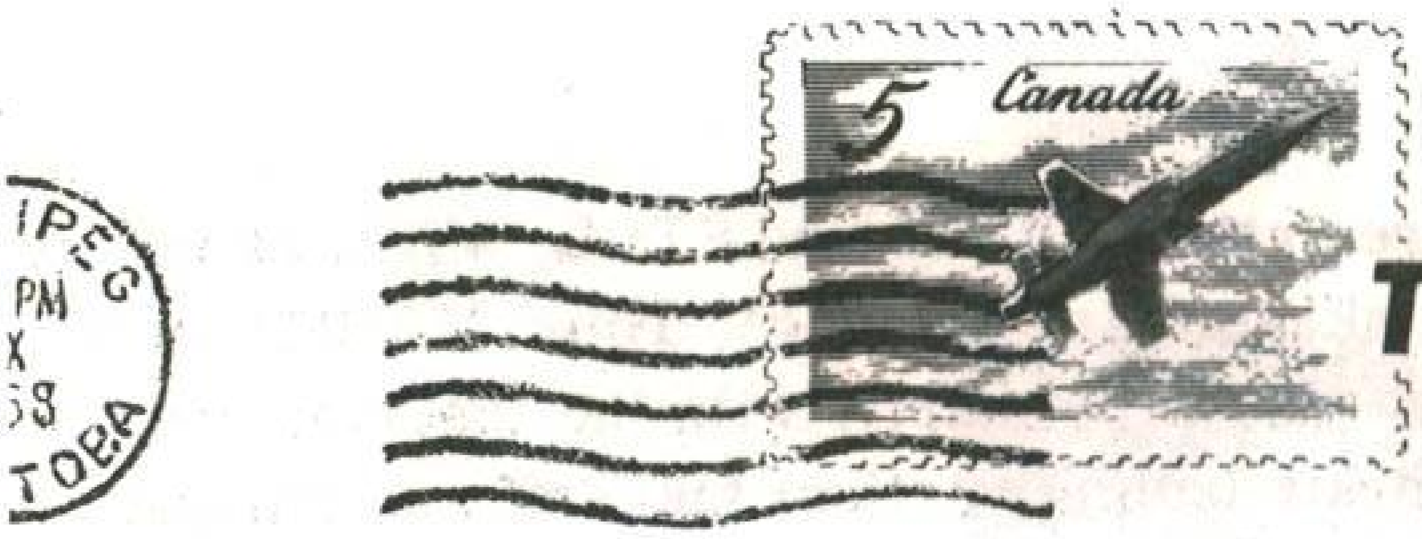
This book, by Barnes W. McCormick, Jr., was written primarily as a textbook for senior level undergraduates or graduates in either V/STOL or low speed aerodynamics. It is not concerned with the operational aspects of V/STOL aerodynamics; it deals with the development of aerodynamic theories and the application of these theories for production of "lift" at low aircraft forward velocities. In this book "lift" means all the vertical forces which sustain an aircraft in flight. They may include the usual lift from a lifting surface as well as the vertical force produced by some form of directed engine thrust. Complete understanding of the mathematical development demands a fair knowledge in advanced mathematics. However, the reader who is familiar with aerodynamics but only mildly with mathematics will still gain from this book; the author always tries to stress the practical aspects and practical results of his analysis either by graphical presentation or short summary at the end of each section and chapter.

The book is divided into 12 chapters, and logically the first is devoted to a short history of current V/STOL vehicles. The first part of chapter two is made up of the mathematical presentation of the fundamental relationships of fluid mechanics upon which future mathematical developments are based. The last part of the chapter presents a very understandable explanation of the interrelation of boundary layer, drag, lift, Reynolds number and flow separation. Chapters four, eight and nine cover the aerodynamics of propeller, of wings in propeller slipstream and of directed propeller and fan-in-wing configurations. Chapter five offers a comprehensive study of helicopter aerodynamics. Chapters 6 and 7 study the unpowered flap and the jet flap, especially the variation of coefficient of lift with different variables. Chapter 10 deals with boundary layer control and Chapter 11 with thrust augmentation and deflection of jets; the principle of thrust augmentation is well explained and is used to further explain some aspects of the ground-effect machines which are described in Chapter 12.

"Aerodynamics of V/STOL Flight", being primarily a textbook for advanced students, is heavy with mathematical development but it also contains concise and easily understood written arguments stressing the conclusions derived from the mathematical analysis. The author has also included a substantial list of references, as many as nineteen per chapter, to help the reader find more information on any particular topic.

Central Flying and
Navigation School
CFB Winnipeg

JFY Sorel
Squadron Leader



TO THE EDITOR

Dear Sir,

I am writing to you to obtain permission to reprint, from the "RCAF Observer" Vol. 13 No. 2 1967, Flight Lieutenant E.R. Lypchuk's star identification charts in the next IANC newsletter. The intention would be to reproduce them in cut out form in a similar manner used in the 'Observer', that is with the instructions on one side and the charts on the other.

These charts concern a problem which all practising navigators know exists, but about which little has been done. They very adequately fill a need in the navigators 'tools of trade' and, I think, will be of great interest to airline navigators throughout the world. Please pass my regards to Flight Lieutenant Lypchuk for sorting out a formidable technical problem of this nature.

In closing I should like to thank you for your excellent publication, which provides much interesting reading and from which, in the future, I would like to reprint more technical articles.

Yours faithfully,

C.H. Gullen,
Exec. Sec.
International Airline Navigators Council

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