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BREAKING THE AIR TRAFFIC JAM

Traffic Control and Navigation in The Jet

INTRODUCTION

When commercial aviation entered the era of jet flight, it also created new problems for an already overloaded air traffic control system.

Two symptoms of this situation have alerted the flying public. One is the increasing number of delays experienced by airline flights—delays that force discomforts on passengers and cost the airlines millions of dollars a year. The other is the increasing number of reported "near misses" and the threat of mid-air collisions.

These are the problems most familiar to air travelers, but they are merely manifestations of the great change taking place in conditions of flight. Airspace is becoming an increasingly traveled avenue of transportation; business, general and commercial aviation activity is growing and air speeds have long since outmoded the "see and avoid" era.

Commercial fleets of jets are now operating at altitudes formerly traveled only by military aircraft. These aircraft close at such a high rate of speed that man can no longer count on his physical resources to avoid accident. In air traffic control, using the so-called ANC (Air Force, Navy, Civil) criteria, up to 100 miles of space must be clear between aircraft to maintain the minimum separation of 10 minutes.

All this does *not* mean that flying today is hazardous—scheduled flying is still many times safer than traveling equivalent distances in the family automobile.

However, safety has been accomplished by compromising the efficiency of aircraft operations, because the *system* for air traffic control—a system that is almost entirely manual—has nearly reached the limit of its capability to accept additional increases in traffic volume.

To overcome traffic problems in the jet age, human resources must be augmented by advanced technologies that are already helping to solve complex problems in defense and industry. In the United States, a central organization, the Federal Aviation Agency, has been activated to plan, develop and place into operation new tools for increasing the safety and expeditiousness of flight.

The present manual air traffic control system is being replaced by a semi-automatic one; developments are being pressed forward that will enable pilots to navigate their aircraft with greater precision; airports are being modernized to handle more traffic more efficiently; communications systems are being improved to speed up the process and, in some cases, make it almost completely automatic; information is being collected that will provide for further improvements in the traffic control system as they become necessary.

This booklet attempts to summarize progress now being made in the first two key areas: in the program to modernize data handling in the nation's air traffic control system; and in the advancement toward more precise air navigation. The companies of General Precision Equipment Corporation are playing very important roles in both of these areas.

Busy nighttime traffic pencils the pattern of lights shown below in only 30 minutes at Washington airport.

THE U.S. AIR TRAFFIC CONTROL SYSTEM AND ITS MODERNIZATION

The Growth of Air Traffic in the United States

GROWING ACTIVITY AT AIRPORTS:

In the year 1958, airport control towers reported a total of 26,599,719 aircraft operations. This is 67% more than in 1950 when the figure was 15,971,152, and 189% more than in 1942 when it was 9,208,776.

GROWING TRAFFIC BETWEEN AIRPORTS:

In the same year, enroute control centers reported 31,799,000 "fix postings" (reports on aircraft positions). In 1948, only 8,599,444 of these position fixes were reported.

GROWING NUMBERS OF AIRCRAFT:

Today there are 109,000 aircraft using the airspace over the United States. In 1938, there were only 22,000.

Experts estimate that by 1975 air traffic in the U. S. will be double what it is today, and the demand for traffic control services among aircraft flying by instrument flight rules is expected to increase 10 times.

Air traffic control is based on three factors: *accurate navigation* of the individual aircraft in flight; *communication* between aircraft and the ground-based control organization; and *coordination* of aircraft movements so the aircraft can be operated efficiently and safely.

The navigation function is, of course, performed in the aircraft by the pilot or navigator. Although it is not technically a function of traffic control, precise navigation is vital to the efficiency of any system for handling air traffic.

Communication and coordination functions are a major concern of the Federal Aviation Agency. All major airports are connected through a vast telephone and Teletype network. The ground network in turn connects to ground-air-ground radio communication stations. Altogether there are approximately 36 air route traffic control centers, 249 airport traffic control towers and 347 air traffic communication stations.

The system begins operating when the pilot makes up his flight plan and it is filed at the appropriate air route traffic control center. The flight plan includes the type of aircraft, its identification number, its destination, speed, desired altitude, route and expected departure time. This information is first used to probe for potential conflicts. If there is a potential conflict, the cognizant controller advises a change in the flight plan to comply with established separation criteria.

Each aircraft in the system, except when radar procedures are being used, is cleared between successive pairs of predesignated geographic points. These points are, in fact, areas, since the route width takes into account navigational error (an aircraft is assumed to occupy a 10-mile width at conventional altitudes and a 32-mile width at high altitudes). Each area is under the cognizance of a specific controller. The flight is handed from one controller's cognizance to the next through each regime of flight, in accordance with an active flight plan updated to correct for changes in winds aloft, cruising speed and other factors.

When aircraft are under control using radar procedures, such as in a transition or terminal area, the number per controller is considerably less because each aircraft is given instructions more frequently. The availability of radar data through the Federal Aviation Agency's current long-range radar program is a most significant step toward solving the problem of more efficient

One of 249 airport traffic control towers across the country that guide local traffic visually and direct arriving and departing planes within the "terminal area" (up to about 30 miles from the airport).

Air Route Traffic Control Center controls enroute traffic within its area.

use of airspace since it permits greatly reduced separation standards. This is the only tool currently available in the air traffic control system that allows this reduction. The high-powered radars are capable of detecting aircraft up to 200 miles in range and 60,000 feet in altitude. They are being located in the vicinity of busy terminals and in the extended area around airports where severe problems associated with the climb and descent of aircraft are encountered. FAA, cooperating closely with the military services in the installation of these radars, plans to provide long-range radar coverage throughout the airspace above 15,000 feet over most of the domestic U. S. and to lower altitudes on high density routes. FAA also operates airport surveillance radars that can detect aircraft within a 50-60 mile radius and up to altitudes of 25,000 feet from the antenna. Located at major terminals, these radars have permitted a considerable reduction in the interval between successive landings and departures.

Information on a flight is recorded on flight progress strips. It is also communicated verbally to all appropriate controllers along the route of flight. The flight progress strip, which is a valuable permanent record as well as an aid to control, is kept up to date by similar communication between the cognizant controllers and the pilot as he reports his position along the way.

The System's Shortcomings

The present air traffic control system has evolved gradually from early beginnings more than 30 years ago.

While there have been certain improvements in the system over the years—the use of radar since World War II, for example, has helped immeasurably—its basic form has remained substantially the same for the last 20 years. It has remained essentially a *manual* system, in which flight progress strips are made out by hand; postings are manual; communications are by voice, interphone and radio, performed by individuals; flight plans and flight progress are analyzed by the controllers and computations are made manually.

With increasing air traffic, the system has become burdened by its own excessive detail. The reason for traffic congestion and delay is often simply that the controller is so busy with clerical duties that he lacks time for his important job of *controlling* traffic. Beset by the repetitive tasks of doing everything manually, he must think first of safety, and must, therefore, refuse to grant clearances to aircraft until his handling of data assures him that safety criteria have been met.

This problem is becoming more acute every day. In addition to the naturally increasing traffic load, more and more aircraft that have been flying under visual flight rules (VFR) are being brought under control of the system because of the growing hazard of "see and be seen" procedures.

Since only flights under instrument flight rules can be in the system (under "positive control" by ground controllers for safe separation), FAA is attempting to increase the proportion of flights under IFR. As quickly as possible the agency has been setting up "superskyways" in which only IFR traffic is allowed. All airline and many military flights today above 10,000 feet are voluntarily under IFR, but as yet there is no requirement for any aircraft other than civil jet transports to fly IFR except in bad weather or when operating in a positive control airway.

Government Action

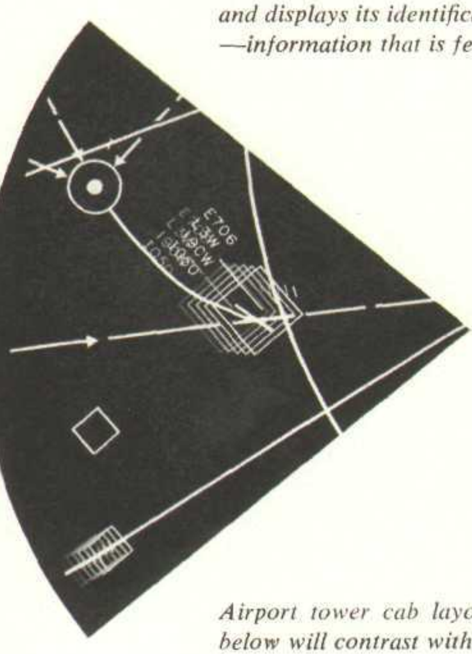
The federal government has for some years been alert to this situation. In February 1956, President Eisenhower appointed Edward P. Curtis as Special Assistant for Aviation Facilities Planning. Mr. Curtis was asked to conduct a study of the nation's long-range requirements for aviation facilities, and to prepare a plan for meeting these requirements. He was also asked to recommend appropriate legislation and executive organization within the government to carry out the plan.

The Curtis report delivered in May 1957 contained a comprehensive analysis of the nation's air traffic problem, as well as many recommendations for action. A key recommendation proposed establishment of an interim research and development organization, the Airways Modernization Board (AMB), to provide the necessary communications, navigational aids and control needed to accommodate future air traffic in the U. S.

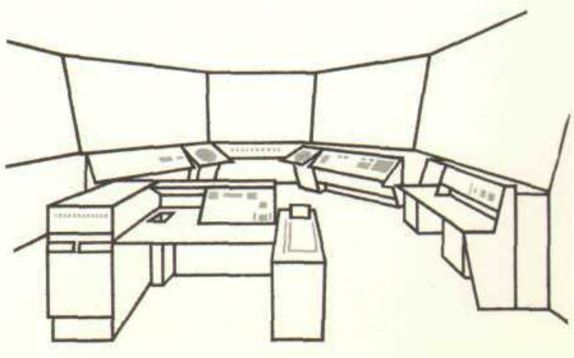
Also proposed was the establishment of the Federal Aviation Agency, which would consolidate the government's activities in connection with air traffic control and the requisite facilities for its improvement. By the time the new agency was established, the AMB—now the FAA's Bureau

THE TRAFFIC CONTROLLER'S TOOLS in the past have consisted mostly of his pencil and his voice. Data on each instrument flight—position, speed, altitude, heading and the like—must be relayed by voice. The controller writes this information on "flight progress strips" and posts them manually on his board. This slow-paced system was originally designed to handle only bad weather operations.

IN THE OLD SYSTEM (above), controllers have had to follow aircraft blips on radar scopes by pushing around manually little plastic markers called "shrimp boats." Rooms are darkened to make aircraft paths visible. IN THE NEW SYSTEM (below), a tracker visible in daylight automatically follows the aircraft and displays its identification, altitude and landing slot —information that is fed to it by the computer.



Airport tower cab layout with new consoles shown below will contrast with visual and manual operations in towers today.



of Research and Development—had already initiated programs to modernize U. S. aviation facilities: as of October 31, 1958, more than 100 research and development projects were actively being pursued under this program.

Of these projects, the keystone effort in the initial program is the Data Processing Central. This project is being carried forward for the FAA by General Precision Laboratory (GPL), a subsidiary of General Precision Equipment Corporaiton. Two other subsidiaries, Librascope, Incorporated, and Link Aviation, Inc., are also working under GPL, as are other associate contractors—chief among them Tasker Instrument Corporation and Stromberg-Carlson Company.

The GPL Contracts

GPL received its assignment in the spring of 1958. The project constituted an attack on the cumbersome, outdated techniques for manual handling of flight data, and an effort to give controllers modern tools for traffic analysis.

Most urgent of the many challenging problems to be solved in achieving smooth and efficient flow of air traffic is that of improving coordination between the many controllers who sequentially share responsibility for each flight. A great decrease in the amount of manual effort required to assemble, store, process, distribute and display flight data is a first priority step to progress.

The data processing system now being specially designed by GPL will automate these data handling functions and permit the controller to rely on electronic equipment to process and display information on aircraft within the traffic control system. He will thus have greater freedom for decision-making functions.

What the New Data Processing Central Will Do

The new equipment will relieve the controller of all routine functions except communicating with the pilot (and FAA has a program for automating this function, too) and inserting information into the system through keyboards. He will also still have the important job of making decisions. Everything else—all calculations, printing and distributing of flight progress strips, updating of strips, conflict prediction, transfer of data—will be performed automatically.

The Data Processing Central will provide up-to-date information on all aircraft within the control system to all cognizant controllers—in the enroute, transition and terminal traffic areas. And it will communicate this information automatically, according to plans set up ahead of time.

Moreover, the system will assist the controller in handling unexpected developments such as might occur in any flight—missed approaches, overtaking aircraft, radar obscuration, unusual weather, changes in flight plans and military "scrambles" through airways.

The system will increase the controller's effectiveness in other ways besides mere automation of present clerical functions. One example: the automatic analysis of a mass of information about aircraft flights too complex for quick handling by the human brain, with presentation of possible flight conflicts on electronic displays.

How the Data Processing Central Will Work

The new system for processing and displaying flight data has been designed to evolve naturally from the old. However, while it will operate on the same basic principles, the whole process will be radically changed and speeded up because the data-handling function will be semi-automatic.

The reasons for developing an automated system using the basic principles of the system now in use are convincing: The FAA must "phase in" new equipment as it becomes available without disrupting the system's operation. Also, in the event of a power failure or equipment breakdown, it would be possible to fall back on manual techniques and keep the system functioning. Not the least of the reasons is the fact that the principles of the system now in use have been developed and proven by years of trial.

It is easiest to visualize how the Data Processing Central will work by following its handling of information on a routine airline flight:

Pre-Takeoff

Before takeoff, the pilot will file his flight plan just as he does now. The information on his plan—the type and identification of the aircraft, its route, estimated time of departure, cruising altitudes and speeds—will then be inserted in proper code format into the enroute computer in the air route traffic control center.

At a preset time before scheduled takeoff, the computer will automatically activate the plan. This means a series of flight progress strips will be automatically printed and distributed to control positions having jurisdiction over the flight. Controllers at these positions will mount the strips on the displays of their consoles.

Takeoff

When the pilot is ready to take off and requests taxi clearance from the ground controller in the tower, his request is relayed to the center. A center controller will insert the estimated departure time directly into the computer by means of a keyboard at his fingertips. The computer will then probe its memory to see if there is a conflict or violation of the criteria for safe separation between this flight and any other, up to the point of the flight's first fix enroute to its destination.

If there is no such conflict, the computer will send an automatic signal back to the tower and the local controller in the tower will clear the aircraft for takeoff. If there is a conflict, it will be displayed to the controller along with alternatives, and he will send to the computer a new clearance that will simultaneously be displayed in the tower.

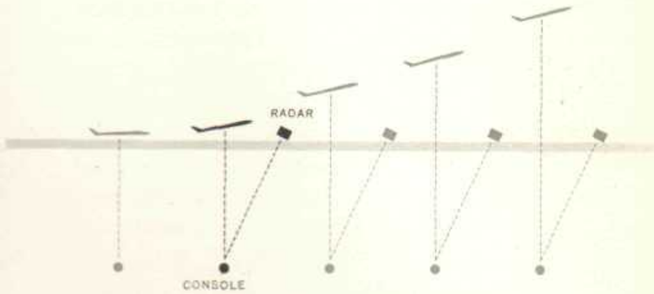
Airborne

At takeoff the local controller, using his keyboard, enters clock time into the computer. The computer then activates the flight plan information, computes estimated times to check points along the route and causes punch and print units to prepare flight progress strips for cognizant control sectors within the center.

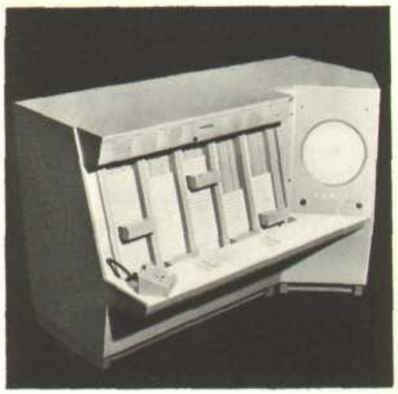
A short while later, the flight plan controller sends appropriate flight plan information to the next adjacent air traffic control center along the route of flight. Each center on the route of the flight in turn processes and distributes appropriately punched and printed flight strips for each cognizant control position, updating information as necessary upon receipt of enroute fix reports from the aircraft.

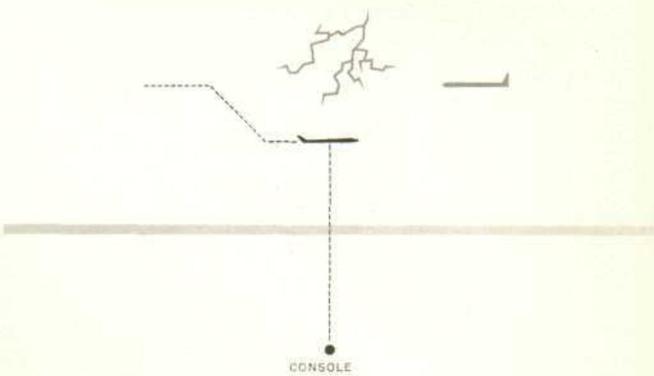
At the consoles where controllers have posted

When aircraft takes off in the new system, its flight plan is entered into the computer, which automatically prints a flight progress strip for all cognizant controllers. After local controller authorizes takeoff, an approach/departure controller assumes control as soon as he sees the plane on the screen of the Approach/Departure Console (at right).

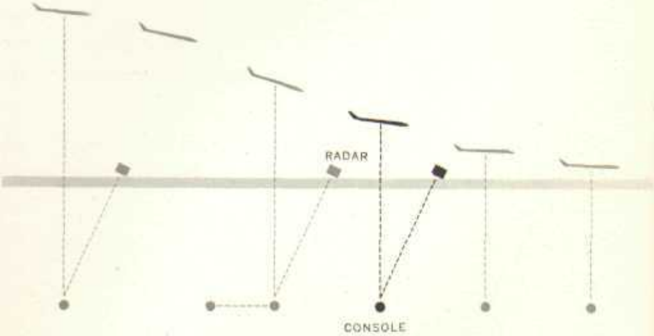


A potential conflict may occur when an unpredicted storm causes an aircraft to slow down. The computer will then alert the controller at the Enroute Sector Console (at right) by lights and printed warnings and the computer, through a special display, will help the controller select the best alternate flight plan.





Information on the relationship of an aircraft to other aircraft approaching a terminal is displayed on a Sequence Console (at right) to the landing sequence controller, who makes landing assignments. An approach/departure controller monitors the aircraft on radar until the tower controller takes over.



the flight progress strips, an automatic printing machine moves up and down keeping strips updated with new flight data as it is punched on a keyboard by the controller. Lights beside each strip signal to call the controller's attention to new information or a potential conflict discovered by the computer.

If two or more flights are expected to transit a fix at the same altitude with less than the stated separation criteria (presently 10 minutes), the computer presents the information on a pictorial display. The cognizant controller inspects the conflict data and changes the clearance of one or more of the aircraft. Using his keyboard, he enters new clearance data into the computer. He may quickly probe to determine whether a new conflict is created in his or the adjacent sector.

Transition Control

Near the end of the enroute portion of the flight, jurisdiction is transferred to transition control, and radar procedures are instituted using "track-while-scan" elements that feed the aircraft's position directly into the computer.

On a pre-programmed basis the computer continually calculates time to touchdown, using appropriate distance/altitude information for the type of aircraft involved, and automatically makes up the landing sequence.

Assignment of the runway time slot is made by the cognizant controller, after which the computer and its associated consoles and displays help the controller provide instructions for path-stretching and speed adjustment enabling the pilot to make good his assigned landing time. Control becomes increasingly tighter as the aircraft approaches the terminal area. At predesignated locations along high density airways, transition radar control—using long-range radar—passes jurisdiction to terminal control where airport surveillance radar is utilized.

Terminal Area

When the aircraft arrives in the terminal area, jurisdiction is passed to the approach controller and finally to the local controller, who monitors the aircraft's progress to touchdown. The local controller uses an electro-mechanical display showing the last five sequence positions prior to the touchdown, as well as the last aircraft that has made its landing.

Fast Coordination of Information

Measured by the quantity of data it will handle and the speed with which it will communicate, the new GPL equipment will perform a prodigious job. For example, the proposed New York area test system will:

Receive 735 flight plans per hour;
Store 1,100 flight plans simultaneously;
Print and distribute 2,665 flight progress strips every hour;
Update 10,000 strips per hour;
Transmit 368 flight plans and 2,168 updates per hour to adjacent centers.

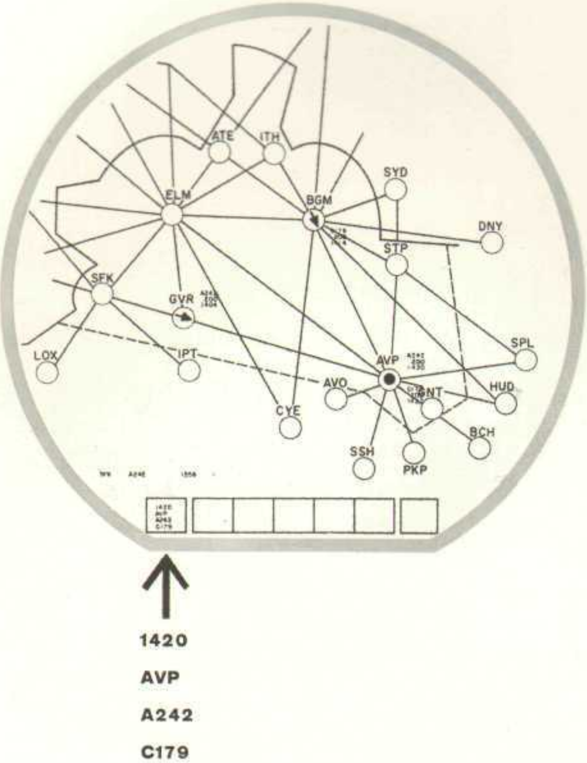
This is several times the maximum present data-handling capability of the New York center, with a comparable number of personnel. A larger or smaller increase at New York or any other center can easily be achieved since the new system has been designed on a "building block" basis.

The data processor, which will serve as the heart of this system, was designed and constructed by Librascope, using the latest solid state (transistors and diodes) techniques with magnetic core high-speed internal memory and large capacity dual drums for storage. The system communicates directly to nearby control consoles and uses a high-speed input/output buffer system for communicating with remote locations.

The data processor's features include a unique file system with variable key addressing to make most efficient use of storage, and unusual reliability resulting from the use of twin memory drums, dual arithmetic units and parity checking on all data transfers. The computer provides about 100 times the file search speed and 20 times the computation speed of computers now in limited service for air traffic control.

In practical terms, the job of *coordinating* air traffic will be enormously improved, and useful information will be quickly and automatically available to traffic controllers at all positions where needed. The communications block that has long existed between centers will be eliminated and controllers will be freed from clerical duties to concentrate on decision-making tasks—a job for which they are extremely well qualified.

CONFLICT DISPLAY is one of the new tools controllers will have in the new system. After warning lights signal a conflict, controller presses button on conflict display which (below) indicates conflict at fix AVP between flights A 242 and C 179. Previous fixes of these aircraft and direction of movement are also shown.



The first elements of the FAA-GPL system, including the complete data processor, will be operating experimentally in early 1960 at FAA's National Aviation Facilities Experimental Center in Atlantic City, New Jersey. Similar equipment will be installed later for operation in the New York area—chosen because of the huge volume of civil and military air traffic concentrated there. The FAA program is expected to provide a significant improvement in air traffic control operations in the United States by 1963.

Beyond 1975—Toward Full Automation

Greater use of airspace by a growing population—in new types of aircraft traveling up to two or three times the speed of sound and in mushrooming thousands of private and business aircraft—will multiply the problems of traffic control in the latter part of this century.

New solutions to these problems are already on the way—from the planning of government experts and from the laboratories of modern industry. To a large extent, they will evolve from progress being made today in systems engineering and in assigning ever-increasing tasks to modern computers.

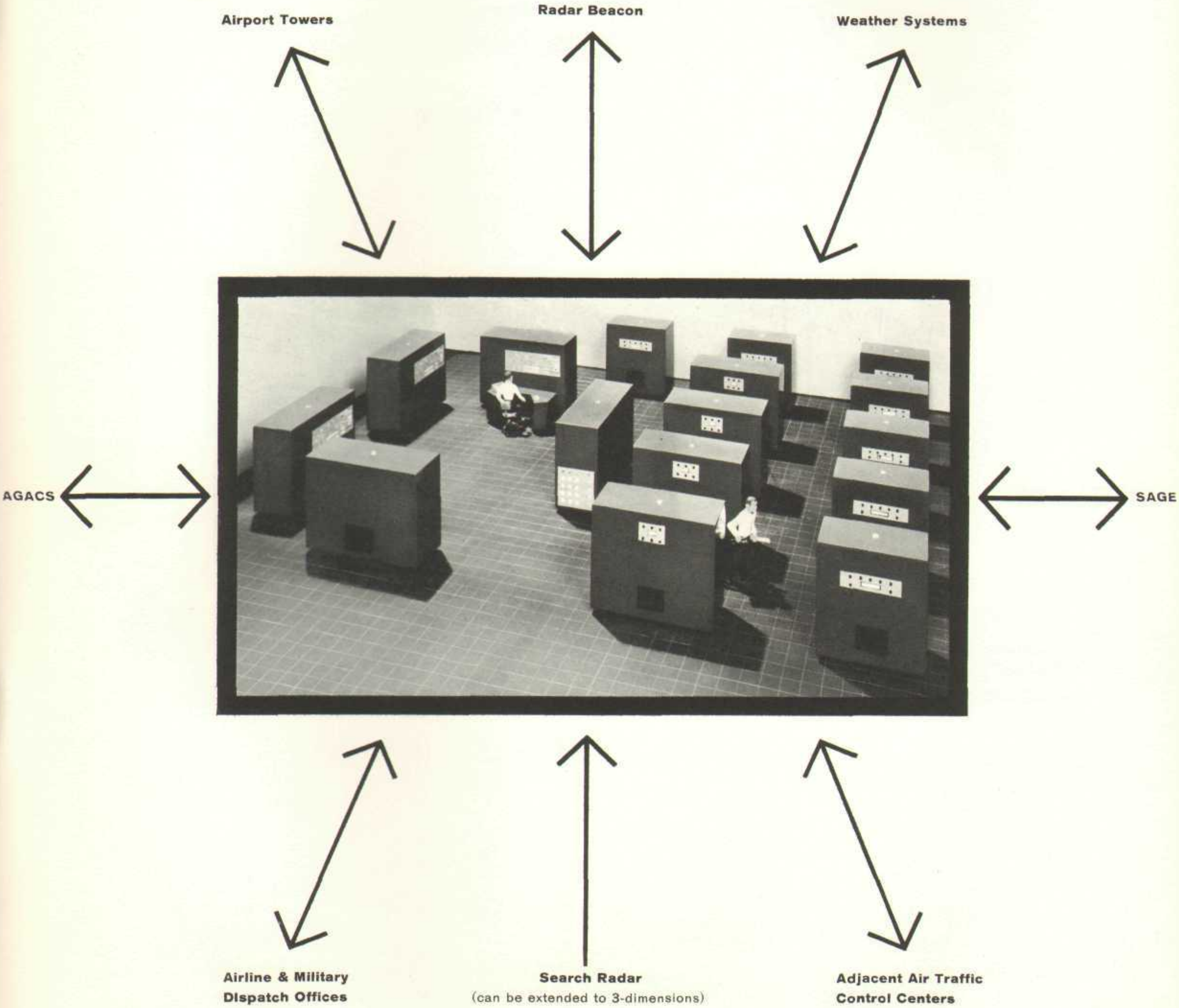
It is quite conceivable, for example, that an electronic airspace inventory and reservation system will one day make space available automatically according to standardized flight priorities. Air traffic control and weather data will be processed by a ground network of computers, which will also be linked to computers in aircraft. Accurate navigation data therefore will be utilized in obtaining automatically and continuously optimum routes and speeds for pilots.

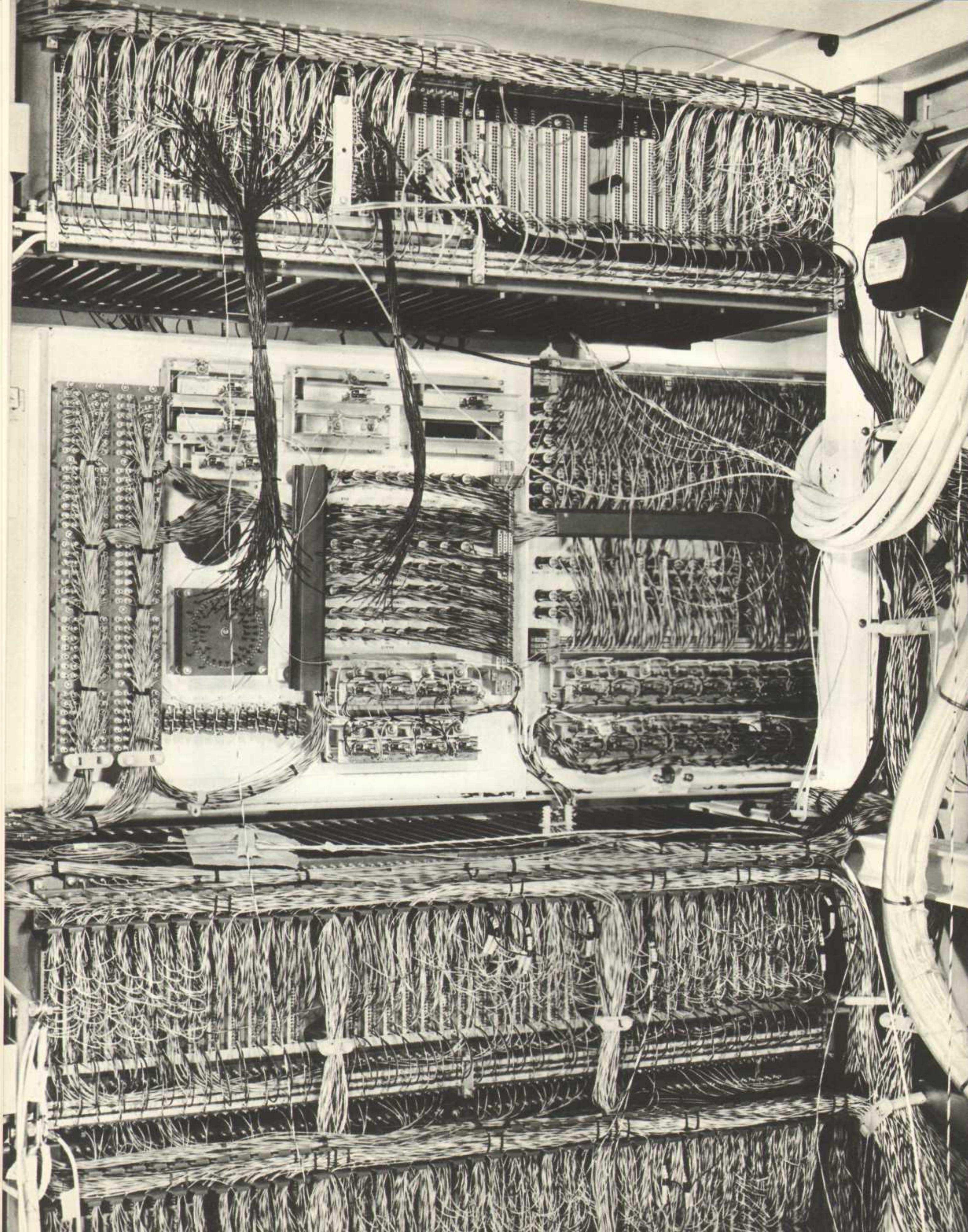
In this world of tomorrow, pilots will probably file by automatic data entry devices or telephone such basic information as proposed departure time and place, and destination. Computers will analyze the flight, considering all factors such as weather, other traffic, separation rules and airport facilities, and will automatically propose a flight plan for the pilot.

There will still be people making key decisions—in the cockpits and on the ground. But the computing machines, by performing tasks more complex than any they are handling today, will radically simplify the human function.

THE DATA PROCESSOR IS THE HEART OF THE NEW TRAFFIC CONTROL SYSTEM

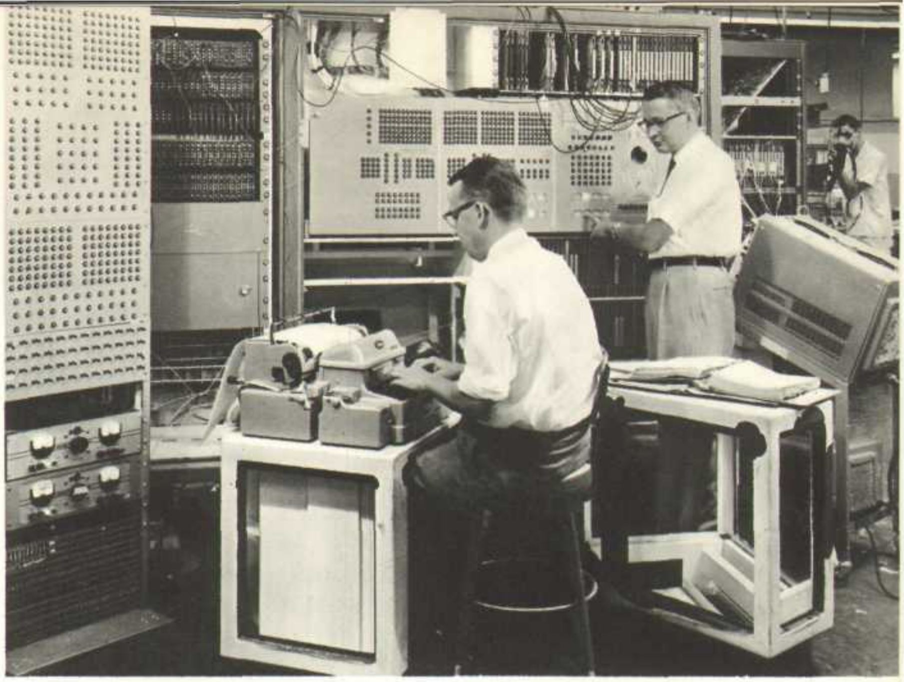
Receiving, processing and communicating a vast quantity of information, the data processor (computer and file system) is the heart of all the major facilities and systems related to air traffic control.

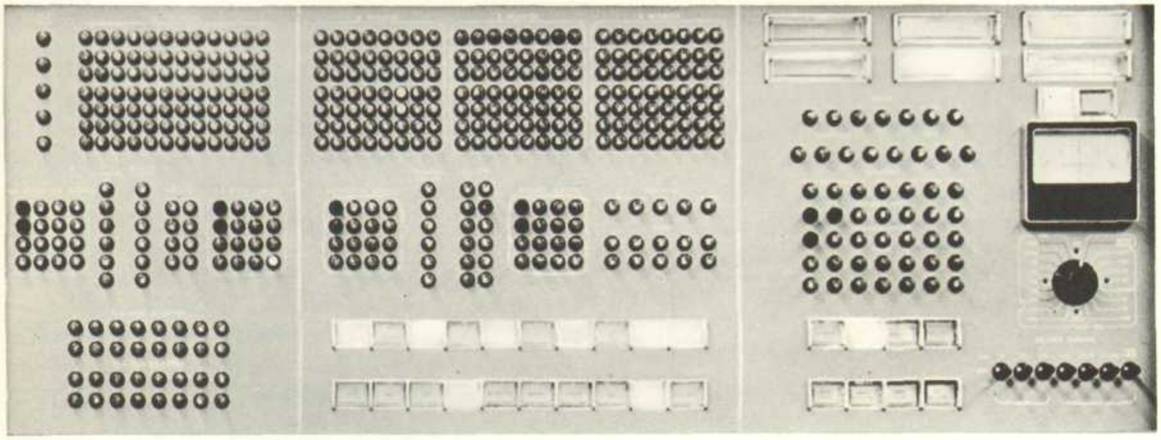


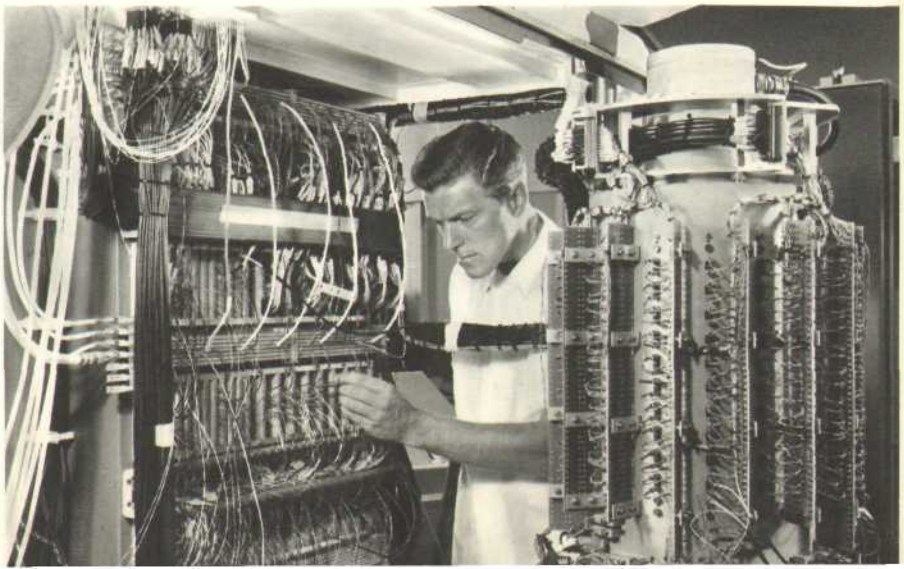


View of wiring inside the computer console.

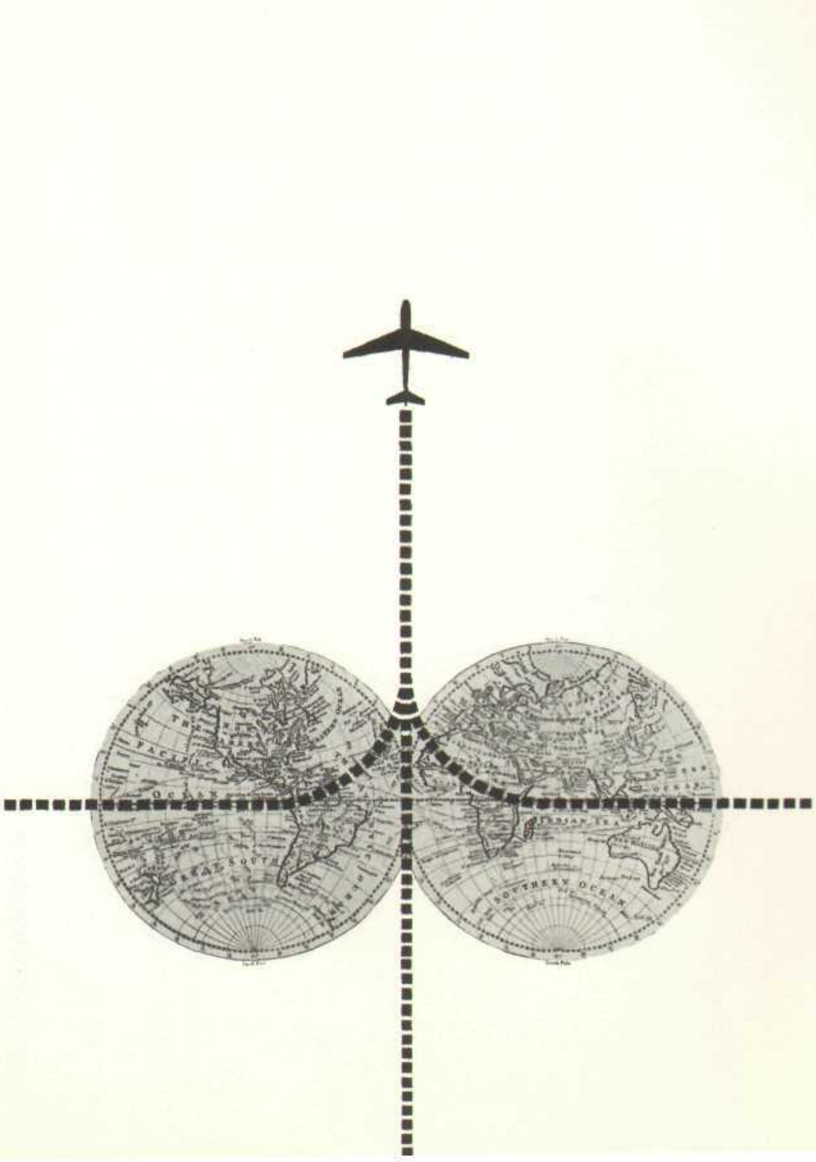
Computer check-out: Operator seated at programming console tests input/output device. Control panel above operator and display panel at left are for testing only.
Actual display panel is shown below.
Bottom photo: File drum unit checkout. Each drum holds 16,000 words in storage—including a great variety of information such as type, speed and altitude of aircraft, airline, wind, estimated departure and arrival times.







PRECISION AIR NAVIGATION



New Progress Toward an Important Goal

Air navigation has come a long way since the days of following railroad tracks, highways and rivers.

The speed of flight, high altitude operation and instrument conditions all require the pilot of a modern aircraft to place complete reliance on radio aids for knowledge of his position. His accuracy of navigation, therefore, is only as good as the system he uses.

Navigation precision is important to the aircraft operator for two reasons:

If aircraft navigation is perfect, the air traffic control problem is simply one of scheduling flight according to time. This means the pilot will be able to fly from one place to another with a minimum of delay. Also, better airspace utilization could be achieved through a reduction in lateral separation standards.

Even more important, accurate navigation enables the operator to increase his efficiency—an urgent need in view of the high cost of all aircraft operation today. With precise navigation, the pilot can fly accurately from point to point over long distances; he can find helpful jetstream tailwinds and avoid headwinds; he can accurately follow changes in his routing; and he can manage his fuel consumption better. He can do all this with a reduced workload. For the military, of course, precise navigation is essential for rendezvous or arrival "on target," as well as for efficiency of operations.

The Navigation Problem: Standard Techniques

The basic problem in air navigation is finding *position in relation to the ground and speed of progress*. For an aircraft in flight, navigation is a continual problem, since position is constantly changing and is affected by winds that may shift abruptly in force or direction.

A technique widely used especially by U.S. civil aviation for short-range air navigation (under 200 miles) involves the use of cooperating elements of electronic equipment, one in the aircraft and the other on the ground.

The basic component in this navigation aid system is VOR (VHF Omnidirectional Range). This is an electronic system that gives a pilot his line of position with respect to a VHF (very high frequency) radio signal sent out from a ground station. Fixes from such ground-based VOR signals, figured with the time between them, can give a pilot a good approximation of his direction and ground speed.

By the end of 1959, there should be about 670 of these VOR stations operating in the U. S., and by 1965, a total of more than 1,000. There are already many thousands of aircraft carrying the airborne VOR equipment.

In addition, VOR ground stations in the U. S. are being converted to include TACAN, a device first developed as a classified project for the U. S. military services, which gives properly equipped aircraft both bearing and distance from a ground station. This means a pilot can fix his position along a bearing line to only one ground station.

The TACAN-augmented VOR stations are called VORTACs. As yet there are only a limited number of fully commissioned VORTAC stations in the U. S., although a larger number are operating on a test basis as the conversion program moves forward. It costs the government about $70,000 to install a typical VOR station; about $187,000 to convert a VOR station to VORTAC; and about $45,000 a year to maintain the whole installation after conversion.

In mid-1959 there were 258 VORTAC facilities in operation or in the process of being commissioned. FAA's plans call for increasing the number of VORTAC's to 345 by mid-1960 and to about 1,000 complete VORTAC facilities by 1965.

In early March 1959, the International Civil Aviation Organization (ICAO) officially adopted the distance-measuring portion of TACAN for world-wide use. This equipment is called DME-T (distance measuring equipment-TACAN), and will be added to certain VOR stations outside the U. S.

These stations will differ from U. S. VORTACs only in that they will not necessarily have the bearing portion of TACAN as will the U. S. stations.

A large number of ground stations is needed because the radio signals are limited by "line of sight." For aircraft at lower altitudes, the stations must be within 90 miles of each other to provide continuous coverage. For long-range flights across oceans, pilots rely on old-time dead reckoning, corrected intermittently by celestial navigation ("shooting the stars" to get fixes), and on longer-range electronic aids that are still ground-based.

Self-Contained Navigation Equipment

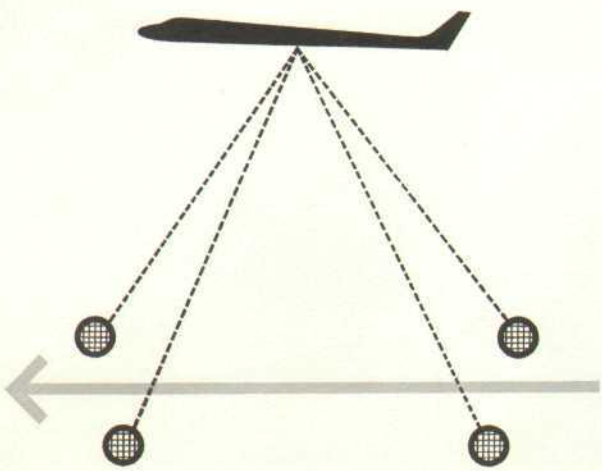
Any navigation system based on ground aids is, of course, a dependent system: the aircraft can navigate only where there are such aids. For this reason, the development in recent years of self-contained navigation systems, where all the navigation equipment is contained in the aircraft itself, has been closely watched by aircraft operators.

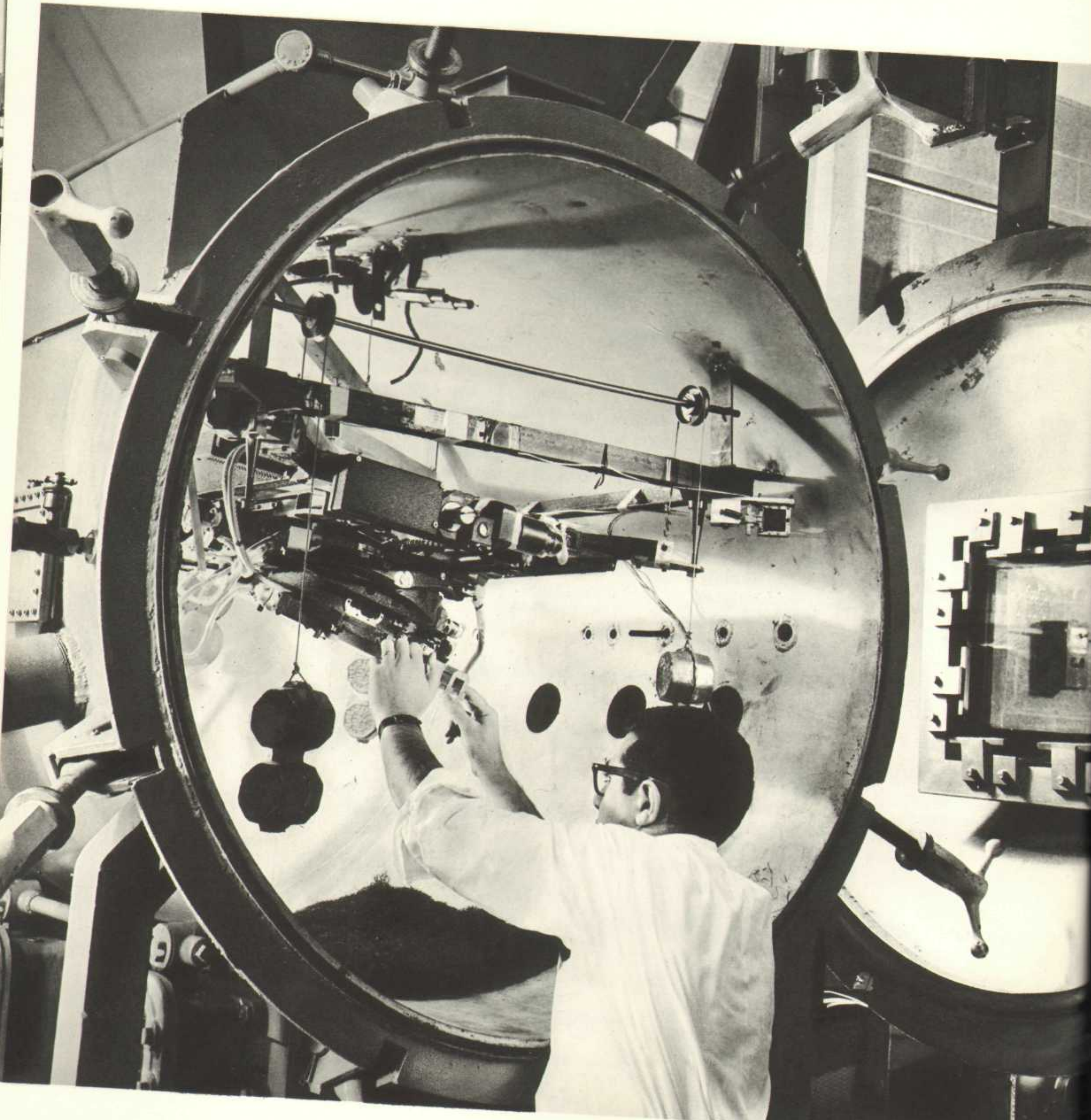
One important indication of progress has been with a system based on wave-motion principles first described in 1842 by Christian J. Doppler. Doppler noted that if a moving source emits a sound, the pitch of the sound becomes higher as it approaches a stationary listener and lower as it moves away. (Anyone who has stood on a railway platform while a train whistles through the station has noticed the Doppler effect: the pitch of the train's whistle lowers after the train has passed.)

Shortly after World War II, a group of scientists from Massachusetts Institute of Technology designed an air navigation system based on the Doppler effect and using waves transmitted by radar. With these people General Precision formed GPL, which then started work on a classified Air Force contract.

The First Doppler Equipment

The work at GPL resulted in the first successful flight test of Doppler navigation equipment, and





Engineer prepares GPL navigation system for test in special environmental chamber.

during 1948 the equipment became the first to measure automatically ground speed and drift angle. It also became the first self-contained equipment ever to navigate a transcontinental flight, as well as the first to navigate automatically flights over the pole and over both the Atlantic and Pacific Oceans.

In 1957, the GPL equipment was declassified by the government and became available to civil aviation under the trademark RADAN® (RAdar Doppler Auto-Navigator). Meanwhile, military aircraft continue to be fitted with the equipment because of its many extraordinary advantages. Over 1,500 military aircraft are now flying with Air Force versions of GPL Doppler systems.

How the RADAN System Works and What It Does

The basic Doppler equipment bounces four beams of radar microwaves off the ground and receives their echoes back in the aircraft. By measuring differences in receipt of these echoes (the Doppler shift), the equipment can tell two things essential to solving the navigation problem: first, the aircraft's ground speed; and, second, its drift angle–the difference between where the plane is pointing and where it is actually going. The pilot then has in front of him on a special display a continuous indication of his ground speed and his drift.

In the RADAN system, a precise heading indicator, or compass, is added as well as a computer. By calculating the aircraft's track over the ground (which it figures from the heading and drift angle) and its ground speed, the RADAN system can give a pilot such information as his present position, the distance to his destination, his course to destination, and the distance he has flown—continuously and automatically, without aid of ground facilities.

Moreover, RADAN systems can operate in any weather, over any terrain, at any time and at all operational flight altitudes. Accuracies exceed those of old-time dead reckoning techniques by as much as 25 times. In many hundreds of long-distance flights with this equipment, ground speed accuracy over oceans and continents has been figured at an average of 0.2 percent of ground speed, and drift accuracy of 0.15 degrees of drift angle—very high orders of precision.

The Important Time Factor: HIDAN*

While solving the basic navigation problems of *speed* and *direction* is, of course, vital, the element of *time* is of key importance in flight situations.

Time is important to commercial airlines, which must constantly improve schedules and keep to them. It is important to the military, for rendezvous in time as well as position—whether for refueling or for coordination of maneuvers.

To avoid collision hazards, any effective traffic control system also must separate aircraft in *time* as well as position.

The U.S. air traffic control system is based on the flight plan—on the pilot's plan to be at a certain point at a certain time. As traffic grows and aircraft speeds increase, the *precision* and *automation* of accounting for time at every instant will become increasingly critical factors in flight.

With these requirements in mind, GPL developed a self-contained navigation system called HIDAN, which automatically gives the pilot an indication of his performance with respect to time. (HIDAN stands for HIgh Density Air Navigation.)

In effect, a HIDAN system is RADAN plus an automatic, continuous accounting for time. In a HIDAN-equipped aircraft, the pilot will therefore be able to tell not only what his position is and the distance he has flown and has yet to go to his destination; he will also see whether he is behind or ahead of time, and he can adjust the speed of his aircraft accordingly.

Advantages In Air Traffic Control

Any system for managing air traffic works best when aircraft are navigated with on-time precision.

First and most important, the pilot navigating with such a precision airborne system can more easily make good his flight plan: if the system tells the pilot he is behind time, he can increase his speed, within the limits of aircraft capability, as much as he needs to make up the lost time and arrive at his destination on schedule. This "controlled time of arrival" could make possible an on-time aircraft capability that would enormously increase efficiency.

Such a system can give the pilot all the information he needs to make prompt decisions while in flight: decisions to speed up, slow down, hold, proceed or file a new flight plan. Since the system can deliver more accurate information on performance to the pilot and, through him, to the traffic control centers, it would increase traffic control efficiency. The centers could work more reliably, since their

The pilot of the X-15 rocket ship will use GPL Doppler in a B-52 launching plane to calibrate and zero in his inertial guidance instruments.

Air Force jet with GPL Doppler system carried Vice President Nixon to Moscow in less than 10 hours flying time. GPL systems have been instrumental in record-breaking cross-country and transatlantic flights.

information would be better, and the workload of the traffic controllers would be proportionately reduced. In sum, these systems can give pilots and traffic controllers *precision flexibility;* the accuracy of their information is greatly sharpened, but they are still free to use it as they see best.

Another very important advantage of precision navigation systems to air traffic control relates to safe separation of aircraft. The control system now reserves a block of airspace for each aircraft in the system as a safety measure. For a 600-mile-an-hour aircraft at cruising altitudes without radar control, this moving block of air is 10 minutes, or 100 miles long, 32 miles wide and 2,000 feet deep.

This safety factor is set up to overcome the deficiencies in present data handling and communication within the traffic control system.

When the efficiency of these functions is improved, as it will be with equipment now being developed, the need for accurate navigation of aircraft will mount greatly. The precision of the control system will exceed the precision of present air navigation techniques. New techniques will be required to make possible shorter separation criteria for aircraft—possibly reducing the time separation from ten to five minutes or less between aircraft. This would have the effect of more than doubling an airway's traffic capacity.

Another way in which precise navigation could eventually increase traffic capacity of the air is by reducing the need for ground-based navigation aids. It should be possible to establish new airways, with widely separated ground navigation aids, in which basic reliance would be placed on self-contained navigation equipment. This would relieve the taxpayer of the cost of establishing and maintaining a fully-equipped new airway, and yet open up additional airspace for travel.

Precision airborne navigation systems offer a number of additional advantages in an air traffic control environment, such as:

Closer control over flight along ascent and descent paths;

More accurate routing of aircraft through crowded terminal areas;

More accurate "holding patterns" for aircraft waiting to land;

Increased accuracy in maneuvers such as overtaking, path-stretching and missed approaches;

Reduced pilot workload in fewer demands for communicating over many different frequencies;

Generally, closer sequencing of aircraft for landings, better use of airport facilities and fewer delays for everyone.

For all of these reasons, the Federal Aviation Agency may soon conduct extensive evaluations of "self-contained autonavigator systems" as they might be expected to operate in an air traffic control environment.

Other Advantages of RADAN and HIDAN

RADAN and HIDAN navigation systems also offer many other advantages of particular importance to aircraft operators.

The first of these is in over-ocean flying, or in any long-range route structure (such as polar flying) where ground navigation aids are not available. Precise navigation with these systems enables the pilot to fly from point to point with greater accuracy. Since airline executives report it costs up to $1,600 per flying hour to operate a jet transport, the need is clear to improve precision of "straight" or optimum track flying.

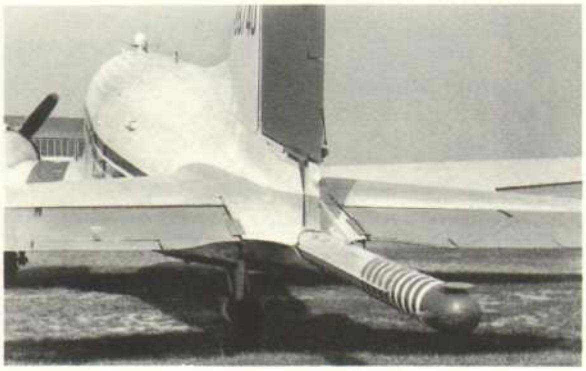
In addition, these systems give a continuous indication of wind conditions. This means the pilot can promptly seek out helpful jetstream tailwinds and avoid costly headwinds. By communicating the wind information he encounters aloft, the pilot can also help in the planning of routes and altitudes for other flights.

Implicit in all of this is a key advantage to every airline or aircraft operator: navigation with such a high order of accuracy provides the means for much more economical aircraft operation. Among other things, fuel management becomes far more efficient, a vital consideration with jet aircraft.

The new navigation systems also are important to aerial exploration of remote or featureless areas of the earth. GPL equipment has dramatically improved efficiency of such operations by guiding survey planes over jungle, desert, muskeg or water without aid from ground stations.

A RADAN or HIDAN system is not a single piece of "hardware." It is a system involving the assembly of a number of components to meet many requirements. The basic components are available now. At GPL, planning is going forward on a number of refinements—such as an "autopilot coupler," a device whereby navigation information would automatically be fed to an autopilot that would then make necessary adjustments in the control of the aircraft without any need for pilot action.

GPL Doppler systems in Hurricane Hunter aircraft made possible first precise and instantaneous measurement of hurricane wind speed and direction.



DC-3 used by Aero Service for oil exploration has "stinger" on its tail containing magnetometer, and a small, lightweight GPL Doppler system in front to provide precise position data.

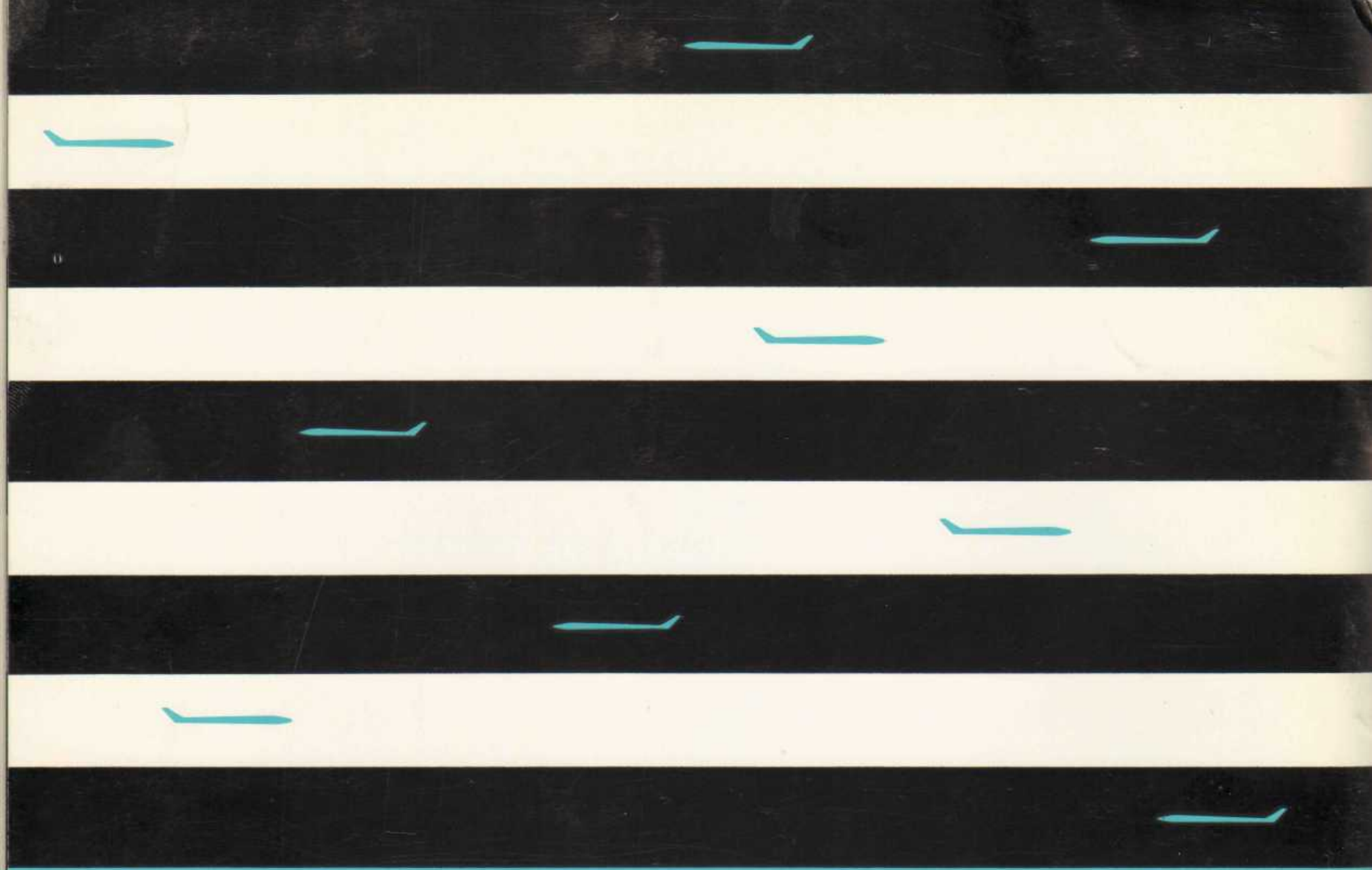
By use of Doppler airborne navigation systems, planes surveying remote areas can be navigated without requiring ground stations such as the one shown here.

THE BROAD FRONT OF AIRWAYS MODERNIZATION

The subjects discussed in this booklet are among many that concern aviation today. The connected problems of air traffic control and precision air navigation have been examined here because they are critical, and because General Precision companies are applying their unusual experience in advanced technologies to the development of equipment that will help solve them.

To forestall the traffic jam into which aviation seems to be headed as commercial jets enter the scene, solutions must be found to a number of other problems of airways modernization. These solutions will also come from the combined energies and skills of people in the federal government, in aircraft manufacturing, in the airlines and in the research and development laboratories of organizations such as General Precision working on the frontiers of applied science.

There is every reason to expect that this network of creative and resourceful individuals will provide the public with ever safer, more efficient air travel.



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